



Carpentry Skills

for Certificate III

2e

BONNICI | FORD | HICK



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Preface

This text covers all core units and major elective units for the Certificate III in Carpentry CPC30220. It also addresses the major learning areas and topics covered in:

- Certificate III in Joinery CPC31920
- Certificate II in Construction Pathways CPC20220
- Certificate II in Building and Construction Pre-apprenticeship 22338VIC
- Certificate I in Construction CPC10120.

The text, in line with Australian Standards and national building codes, is designed to teach the underpinning knowledge and skills that are required to work effectively in the construction industry. The student can then apply and adapt these skills to current workplace practices. Out in the workplace, techniques will vary as a result of an employer's preference or building philosophy; however, the core skills remain the same. The text aims to support students as they practise and refine their own techniques in an ever-changing workplace.

As a teaching resource, this publication covers all skills and knowledge required by apprentice carpenters in the domestic and industrial sectors. It will assist in the teaching of hand and power tools, plan reading, work health and safety, and sustainability. Each chapter is aligned to units of competency to aid trainers in their planning and delivery. All chapters have worksheet questions that reinforce the content covered, as well as student research tasks and end-of-chapter activities. Plan reading is integrated into most chapters and refers to the set of plans located in the Appendix of this book.

With clear step-by-step instructions and up-to-date content, this publication will become a valuable part of an apprentice's toolkit.

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About the authors

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Daniel currently teaches Carpentry and Design Technology at Bayside P–12 college (Paisley campus, Newport) in their Technical Trades Centre. Prior to this, Daniel was employed at Victoria University (TAFE), where he was the VET in Schools' (VETiS) coordinator for carpentry, bricklaying, furnishing, construction trade taster and school-based carpentry apprentices. Daniel taught in the areas of VETiS and apprenticeship carpentry.

Daniel has worked in Australia and the United Kingdom as a carpenter in the domestic, industrial and commercial sectors. His qualifications include:

- Certificate III in Carpentry—industrial broad stream
- Diploma of Vocational Education and Training
- Certificate IV in Workplace Assessment (TAE)
- Graduate Certificate in Leadership in Education and Training
- Certificate IV in Building
- Graduate Diploma in Technology Education.

Daniel currently chairs the Victorian Carpentry Teachers Network, which has representatives from all Victorian TAFEs. He has contributed to the Victorian Certificate II in Building & Construction for the past 15 years as a subject matter expert and project steering committee member. In 2017 Daniel was appointed to the carpentry Technical Advisory Group (TAG) advising on the redevelopment of the Certificate III in Carpentry CPC30220, Certificate II in Construction pathways CPC20220 and Certificate I in Construction CPC10120.

In 2007 Daniel was recognised for his work in the VET in schools carpentry area and awarded:

- Australian Trade Teacher of the Year in General Construction 2007 (Institute for Trade Skills Excellence)
- Victoria University Vice Chancellor Peak Award for Excellence in Teaching and Learning 2007
- Victoria University Vice Chancellor Citation for Excellence in Teaching and Learning for the Faculty of Technical and Trades Innovation 2007.

Daniel is an avid supporter of WorldSkills Australia and has been a convenor and judge for VETiS construction and Open carpentry at regional and state competitions for the past 15 years. He was chief judge in the category of VETiS construction at the last four national competitions.

ALISTER FORD

Alister commenced his carpentry and joinery apprenticeship in June 1979 at the age of 15 and completed in June 1983.

He then worked on some very large commercial and industrial construction sites around Melbourne, before relocating to country Victoria in 1990 and starting his own carpentry and joinery business that operated for 15 years.

His qualifications include:

- Certificate III in Carpentry & Joinery (Trade Qualification)
- Certificate IV in Training & Assessment
- Diploma of Vocational Education and Training.

In 2002 Alister commenced teaching Carpentry Certificate II and III part-time at the University of Ballarat TAFE division while still running his own business.

In 2005 Alister commenced full-time teaching in carpentry at the UB TAFE and also held the position of Program Coordinator for the Building & Construction Department that oversaw the running of the carpentry, joinery, furniture-making, cabinet-making, painting and decorating, bricklaying/blocklaying and design/drafting programs.

In 2010 Alister transferred his employment as a building and construction teacher to the East Gippsland TAFE, now TAFE Gippsland, based at the Bairnsdale Trade Centre campus, to teach Certificate II and III in Carpentry.

Alister has also been a WorldSkills judge several times.

MICHAEL HICK

Michael Hick has over 20 years' experience as a carpenter and joiner. He is an experienced Carpentry and Joinery teacher, currently teaching in the Secondary School system.

Michael is very passionate about his teaching and trade and continues to be active in the industry through his family's staircase business. He has previously taught at Victoria University (TAFE) for 10 years, teaching Carpentry and Joinery Certificate II and III. Michael has also worked as an International Skills Assessor for Carpentry and Joinery for 13 years.

Michael's qualifications include:

- Carpentry and Joinery Apprenticeship: Certificate III – Building and Construction (Finish and Fit out) (Carpentry and Joinery)
- Certificate IV in Workplace Training and Assessment (TAE)
- Diploma in Vocational Education and Training Practice
- Graduate Diploma in Technology Education.

Further Trade Qualifications:

- CPC30211 Certificate III in Carpentry
- CPC32008 Certificate III in Carpentry and Joinery
- CPC31912 Certificate III in Joinery
- LMF30502 Certificate III in Cabinet Making (Wood Machinist stream).

Competency mapping

	CPC30220	CPC31920	CPC20220	22338VIC	CPC10120
Chapter	Certificate III in Carpentry	Certificate III in Joinery	Certificate II in Construction Pathways	Certificate II in Building and Construction—Carpentry	Certificate I in Construction
1 Work health and safety	CPCCWHS2001	CPCCWHS2001	CPCCWHS2001	CPCCOHS2001A	CPCCWHS2001
2 Construction work hazards and risk control strategies	CPCWHS3001	CPCWHS3001			
3 Workplace communication	CPCCOM1014	CPCCOM1014		CPCCOM1014A	CPCCOM1014
4 Trade calculations and measurements	CPCCOM1015	CPCCOM1015	CPCCOM1015	CPCCOM1015A	CPCCOM1015
5 Trade drawings	CPCCCA3025	CPCCOM2001		VU22015	CPCCOM1017 CPCCOM2001
6 Working effectively and sustainably within the construction industry	CPCCOM1012	CPCCOM1012	CPCCOM1012	CPCCOM1012A	CPCCOM1012
7 Carpentry hand tools	CPCCCA2002	CPCCCA2002	CPCCCA2002	VU22023	CPCCCM2005
8 Timber joints	It is important for students who want to become carpenters within the building industry to understand the content in Chapter 8, even though it is not explicitly covered by units of competency.				
9 Construction fastening and adhesives	It is important for students who want to become carpenters within the building industry to understand the content in Chapter 9, even though it is not explicitly covered by units of competency.				
10 Carpentry power tools	CPCCCA2002	CPCCCA2002	CPCCCA2002	VU22023	CPCCCM2005
11 Static machines	CPCCJN3100	CPCCJN3100			
12 Handle carpentry materials	CPCCCA2011	CPCCCA2011	CPCCCM2004		CPCCCM2004
13 Site setting out and basic levelling	CPCCCA3002 CPCCCM2006	CPCCCM2006	CPCCCM2006	CPCCCM2006 VU22023	CPCCCM2006
14 Advanced levelling operations	CPCCOM3006 CPCCCM2006				
15 Carry out excavation	CPCCCM2002			VU22031	
16 Construction calculations in carpentry work	CPCCOM3001	CPCCOM3001	CPCCCM1011		CPCCCM1011

	CPC30220	CPC31920	CPC20220	22338VIC	CPC10120
Chapter	Certificate III in Carpentry	Certificate III in Joinery	Certificate II in Construction Pathways	Certificate II in Building and Construction—Carpentry	Certificate I in Construction
17 Subfloor and flooring	CPCCCA3003	CPCCCA3003		VU22024	
18 Wall framing	CPCCCA3004	CPCCCA3004		VU22025	
19 Wet areas	CPCCCA3012	CPCCCA3012			
20 Ceiling framing	CPCCCA3005			VU22026	
21 Pitched roofing	CPCCCA3007			VU22026	
22 Advanced roofing	CPCCCA3009				
23 Erect roof trusses	CPCCCA3006	CPCCCA3006			
24 Construct eaves	CPCCCA3008			VU22026	
25 Work safely at heights	CPCCCM2012 CPCCCM2008	CPCCCM2012	CPCCCM2012	VU22016	
26 Restricted height scaffolding and work platforms	CPCCCM2008 CPCCCM2012			VU22016	
27 External cladding	CPCCCA3017			VU22027	
28 Installation of windows and doors	CPCCCA3010 CPCCCA3024	CPCCCA3010 CPCCCA3024		VU22028 VU22029	
29 Internal linings and fixings	CPCCCA3024 CPCCCA3010	CPCCCA3010 CPCCCA3024		VU22028 VU22029	
30 Erect and dismantle formwork for footings and slabs on the ground	CPCCCA3028 CPCCCM2002			VU22031	
31 Concreting to simple forms	CPCCCM2012 CPCCCM2002		CPCCCM2012	VU22031	
32 Formwork for stairs and ramps	CPCCCA3018				
33 Construct timber external stairs	CPCCCA3016	CPCCCA3016			
34 Carry out demolition	CPCCCA3001	CPCCCA3001	CPCCCM2009	VU22030	
35 Plan and organise work		CPCCOM1013	CPCCOM1013		CPCCOM1013

Chapter 1

Work health and safety

Learning Objectives

- LO 1.1 Train to survive your first day at work**
- LO 1.2 Know about duty of care: PPE, safety signage and personal wellbeing**
- LO 1.3 Avoid construction industry injuries**
- LO 1.4 Identify major health and safety risks**
- LO 1.5 Deal with emergencies on construction sites**
- LO 1.6 Know about Australian work health and safety legislation, regulations and codes of practice**
- LO 1.7 Analyse workplace hazards**
- LO 1.8 Prepare safe work method statements and job safety analysis**
- LO 1.9 Formulate work health and safety management plans**

Introduction

The building and construction industry covers a wide range of workplaces. These workplaces are among the most dangerous of any Australian working environments—by comparison, others appear far less hazardous. Hundreds of thousands of Australian construction workers go to work each day with the belief and expectation that they will return home safely after completing a hard day's work. This chapter will focus on construction worksites related to residential construction.

The federal legislation that addresses workplace health and safety in Australia is the *Work Health and Safety Act 2011*, compilation number 9: 1 July 2019, which is underpinned by the Work Health and Safety Regulations of individual Australian states and territories. This legislation has been adopted by the majority of Australian states and territories.

Residential building worksites, such as those for the construction, extension, renovation or demolition of a house, are not commonly considered dangerous workplaces, but many workers are exposed to hazards every day without realising it. Many Australian building workers are either seriously injured or die each year because they are involved in work accidents, or are exposed to hazardous substances on residential building worksites they believed were reasonably safe.

Among these workers are young people in their first job, learning new skills and trying hard to fit into a foreign environment where the majority of people they are working with have much greater work and life experience. All around them, they are exposed to hazards that older and more experienced workers have learnt to deal with over many years.

In this chapter, as a continuation of your previous workplace induction training (Construction Induction White Card), you will learn about all aspects of working safely in the construction industry. You will learn about being aware of your own safety at all times, about having a duty of care to your fellow workers, and about Australian work health and safety laws, regulations and codes of practice.

You will read about personal protective equipment (PPE), how to select the correct equipment, how to wear or use it properly and how to identify situations where other workers, although not involved in the particular task, will need to use PPE as well.

Workplace signage will also be explained in this chapter. It is important to be able to identify the different types of signs and understand their specific meanings.

In addition, you will learn how to identify workplace hazards and risks and how to document them in a job safety analysis (JSA) or in a safe work method statement (SWMS), as well as how to formulate strategies to control or eliminate these hazards and risks. You will also learn about workplace health and safety plans, which you will put into practice almost every day on a construction site.

Additionally, you will learn about the accidents, injuries and incidents that could occur and how best to deal with such emergency situations should they take place.

WORKPLACE SCENARIO

Search the Australian or your state's WorkSafe website and you will find articles and stories documenting incidents that have occurred in the Australian construction industry involving the collapse or failure of scaffolding systems.

At worst, these incidents can be fatal to the workers on the construction site and even members of the public who may be nearby. Such incidents can sometimes thankfully result in only minor injuries, but in most cases the cost can be enormous, with lives lost, people badly injured and an enormous amount of damage to property.

One such incident that I recall happening in the Melbourne suburb of Prahran in 2009 could potentially have claimed many lives, but miraculously no one was killed and only three workers were injured.

A scaffolding was constructed to the height of six stories, across the front facade of a building in Commercial Road, Prahran. Approximately 50 workers were on this construction site and, luckily, at the time of collapse, it was morning teatime and most of the workers were in the site sheds having a work break.

However, three workers were on the scaffolding when it collapsed. Emergency workers said they were amazed that no one was killed—neither site workers nor the general public. The scaffolding collapsed onto Commercial Road, crushing seven cars parked along the road outside the construction site. It also brought down powerlines and tram lines, and nearby buildings had to be evacuated. Of the three workers who were on the scaffolding at the time of the collapse, one man escaped with a broken finger and cuts and scrapes, another man suffered broken ribs and back injuries and a third man suffered cuts and scrapes to his arms and legs. These men were treated by emergency personnel and transported to the hospital. One of them had jumped off the scaffolding as it started to collapse, and the other two men had 'ridden' it to the ground. It was extremely fortunate that there were no pedestrians walking along the footpath below at the time, or any people in the parked cars.

After this incident occurred, the worksite was closed by the WorkSafe authority while investigations took place, and the road was closed for some time so that the area could be cleared, and the power and tram lines restored. An incident like this has the potential to claim many lives, but luckily most of the workers were not on the scaffolding at the time, and no members of the public were in the vicinity. The material cost of this incident would have been enormous, but it would have been much higher if lives had been lost.

A simple Google search will allow you to access and read all of the details of this scaffolding collapse incident.

1.1 Train to survive your first day at work

Before starting work in the construction industry all workers must undertake compulsory safety training, but to be successful workers must be prepared for lifelong training. Training and skills development is the best defence against workplace accidents on your first day of work and for every working day that follows.

1.1.1 Mandatory construction induction training

In all Australian states and territories, it is mandatory for all construction workers to undertake general induction training *before they commence work on a construction worksite*. This is particularly important for young construction industry workers, as over recent years there have been cases of young workers who did not undertake this training and were fatally injured on their first day of work.

On completion of the **mandatory construction induction training**, an identification card is issued to the successful participant. This card must be carried by workers at all times while they are undertaking building and construction work. Each state or territory is responsible for both regulating the training and issuing of these cards (see Fig. 1.1).

Regardless of the state or territory the card is issued in, they are **mutually recognised** by all other states and territories. Before working in Victoria, it is recommended that workers from another state or territory confirm that their construction induction card will be recognised.

1.1.2 Site-specific induction training

It is also compulsory for workers to undertake **site-specific induction training** before they enter any new worksite. This is particularly important for young workers. This training identifies all hazards specific to that particular worksite and is normally provided by a representative of the employer or the builder in control of the site (e.g. the site manager or safety officer). For example, if there is an area where excavation is being carried out, workers will be warned of this hazard and, most likely, be told not to enter that area unless authorised.

Site-specific induction training is also an opportunity for the employer or the site manager to:

- sight and confirm that the worker has completed their general induction training and record the details of their general induction card
- explain the safety rules that apply to that worksite
- explain site emergency procedures and the location of the emergency assembly area
- provide the location of first-aid stations and where site amenities are located.

On completion of this training, the site manager will record the workers who undertook the training and, on some projects, issue a card or sticker to indicate their participation and that their site induction training is up to date or current (see Fig. 1.2).

Fig. 1.1 (a–d) Sample construction induction cards for some states—each state and territory has its own card

(a) **NEW SOUTH WALES**

		WORK HEALTH AND SAFETY GENERAL CONSTRUCTION INDUCTION
John James Citizen		Date of Birth 01/01/1987
100001 Card No.	12345 RTO No.	Date of Issue 01/06/2019

(b) **WESTERN AUSTRALIA**

		OCCUPATIONAL HEALTH AND SAFETY CONSTRUCTION INDUCTION
Issued to		Issue Date
Custom White Signature Panel		
Card No 000000		

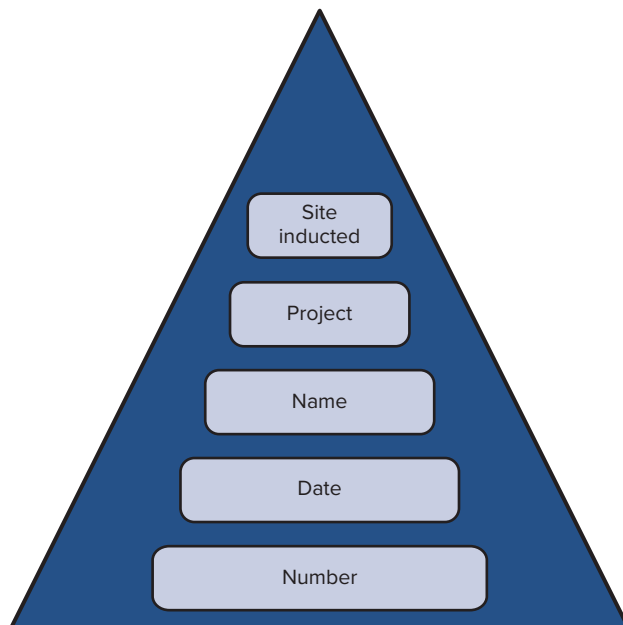
(c) **TASMANIA**

		WORK HEALTH AND SAFETY GENERAL CONSTRUCTION INDUCTION
Date of Birth		
Issue Date		
Card No		

(d) **QUEENSLAND**

		OCCUPATIONAL HEALTH AND SAFETY CONSTRUCTION INDUCTION
Cardholder's name		Date of birth / /
RTO No.		Issue date / /
Card No.		

Source: (a) Image supplied by SafeWork NSW; (b) WorkSafe Western Australia (DMIRS); (c) WorkSafe Tasmania; (d) Office of Industrial Relations, Queensland

Fig. 1.2 Site induction hard hat sticker

hazardous task where all risks are identified and evaluated, and appropriate controls are put in place. The employer will ensure that all workers have read and understood the information provided before they can commence work.

1.1.3 Other training

1.1.3.1 Work activity training

Where there is a new work situation that requires workers to carry out work in which they have no experience, employers must provide appropriate **work activity training** to ensure that those workers can undertake the work safely. Often this type of training is conducted informally on-site as a **toolbox meeting** and workers are given an opportunity to participate in a risk assessment process that identifies any possible risks and how these can be managed or controlled.

If the work is of a high-risk or hazardous nature, the employer will provide workers with a copy of a **safe work method statement**. Safe work method statements provide a step-by-step approach to a

For young workers and any workers with no previous construction experience, this is especially important. Until a worker can undertake work competently, they must be properly supervised by a person who is authorised by the employer to supervise their work and carry out that same work in a competent manner.

Work classified as high risk includes that which involves:

- a risk of falling more than 2 metres
- work carried out on a telecommunication tower
- the demolition of load-bearing elements of a structure
- the disturbance of asbestos
- work requiring temporary support of structural components
- a confined space
- excavation greater than 1.5 metres deep
- tunnelling
- the use of explosives
- work near pressurised gas mains or pipes
- work on or near chemical, fuel or refrigerant lines
- work near energised electrical installations/services
- a potentially contaminated or flammable atmosphere
- tilt-up or pre-cast concrete construction
- a location on, in or adjacent to a road, railway, shipping lane or other traffic corridor that is in use by traffic
- a location near a powered mobile plant
- artificial extremes of temperature
- a location near water or other liquid that involves a risk of drowning
- diving.

1.1.3.2 Nationally accredited training

Formal off-job training in a specific occupation or skill combined with on-job training and supervision by a qualified and competent person is a pathway to a safe workplace for all workers. Some examples of Australian national construction qualifications are shown in Table 1.1.

Table 1.1 Australian national construction qualifications

Certificate I in Construction	Certificate III in Paving
Certificate II in Construction	Certificate III in Post-tensioning
Certificate II in Construction Pathways	Certificate III in Rigging
Certificate II in Building and Construction (Victoria)	Certificate III in Roof tiling
Certificate III in Bricklaying/Blocklaying	Certificate III in Scaffolding
Certificate III in Carpentry	Certificate III in Shopfitting
Certificate III in Concreting	Certificate III in Signage
Certificate III in Construction waterproofing	Certificate III in Solid plastering
Certificate III in Demolition	Certificate III in Steelfixing
Certificate III in Dogging	Certificate III in Stonemasonry (monumental/installation)
Certificate III in Joinery	Certificate III in Wall and Ceiling lining
Certificate III in Painting and Decorating	Certificate III in Wall and Floor tiling

More information on these qualifications can be found at www.training.gov.au.

Traditional apprenticeships and entry-level vocational training that result in a national qualification under the Australian Qualifications Framework will provide specific trade training combined with **safe operating procedures** to safely carry out specific trade work (Fig. 1.3).

Fig. 1.3 Safe operating procedures

SAFETY OPERATING PROCEDURES
Power tools

 Safety glasses must be worn at all times when using power tools.	 Long and loose hair must be contained.
 Safety footwear must be worn at all times when using power tools.	 Protective clothing must be worn.
 Loose jewellery must not be worn.	 Hearing protection must be used when using power tools.
 Dust mask may be needed for this tool.	 Ensure loose clothing is contained or removed.

PRE-OPERATIONAL SAFETY CHECKS

1. Check workspaces and walkways to ensure no slip/trip hazards are present.
2. Read manufacturer's instructions and familiarise yourself with the tool.
3. Ensure all guards and safety shields are in position before starting the power tool. Faulty equipment must not be used. Immediately report any suspect machinery.
4. Ensure the power tool and leads have been checked and the electrical safety tag is current.
5. Check the power tool's lead and plug for cuts or exposed wires.
6. Locate and ensure you are familiar with the operation of the ON/OFF starter.
7. Ensure the power supply has an RCD (safety switch) installed. If in doubt use a portable RCD.

OPERATIONAL SAFETY CHECKS

1. Ensure the work area is stable and level and that the power tool is set up appropriately.
2. Ensure power leads are kept off the ground.
3. Small objects must not be held by hand.
4. Never leave the machine running unattended.
5. Do not bend down near the machine while it is running.
6. Never force the power tool to do its job.
7. Ensure you have a firm grip on the power tool.
8. Slowly move the power tool across the item in a uniform manner.

HOUSEKEEPING

1. Switch off the power tool.
2. Leave the machine in a safe, clean and tidy state.
3. Ensure all off cuts are disposed of in an appropriate receptacle.
4. Ensure any sawdust is swept up.

POTENTIAL POWER TOOL HAZARDS

■ Hot metal	■ Sparks	■ Noise	■ Sharp edges	■ Electrocution
■ Entanglement	■ Dust	■ Eye injuries	■ Splinters	■ Kick back

This SOP does not necessarily cover all possible hazards associated with the machine and should be used in conjunction with other references (SWMS and manufacturer's instructions). It is designed to be used as an adjunct to teaching Safety Procedures and to act as a reminder to users prior to machine use

1.2 Know about duty of care: PPE, safety signage and personal wellbeing

1.2.1 Personal protective equipment

Together with training, personal protective equipment (PPE) provides the most essential and basic form of protection for all workers. All workers are required by law to use PPE in accordance with:

- safe operating procedures required by their employer and authorities
- any training they receive
- work method statements they must follow.

Where there is a potential risk of injury, employers must supply PPE and ensure that their employees correctly use any PPE they provide (Fig.1.4).

PPE provided by employers could include such items as:

- safety glasses, goggles or face shields
- overalls or workpants
- high-visibility clothing
- high-visibility reflective vests
- jackets
- steel-capped boots
- rubber boots
- earplugs or earmuffs
- gloves—leather or rubber
- respirators or dust masks
- hard hats
- caps or hair nets
- wide-brimmed hats
- UV protective sunscreen or clothing
- knee pads
- arm guards
- aprons.

Fig. 1.4 Personal protective equipment (PPE)



Courtesy of Alister Ford

1.2.2 Safety signage

A range of safety signage is used on construction worksites. For large worksites where there are many workers undertaking a wide range of work activities, there are many different safety signs. On smaller residential building sites, there are fewer and less varied signs.

There can never be 'too many' signs if they prevent injury and save lives!

It is important to take notice of all signage on a worksite and make every effort to read and understand the safety warnings, instructions or information they provide.

Fig. 1.5 Mandatory action signs



Courtesy of Alister Ford

A range of designs and colours are used for signs depending on the information that the sign is conveying.

Blue signs on a white background often with black lettering will tell you that the action you see is mandatory (Fig. 1.5). Generally, these signs will show or give instructions about the type of PPE that you must wear when in the designated area.

A white sign often with black lettering or figures with a red circle and line tell you that the action depicted on the sign is prohibited. This can include such things as No Smoking (Fig. 1.6), No Entry, No Mobile Phones and No Pedestrian Access.

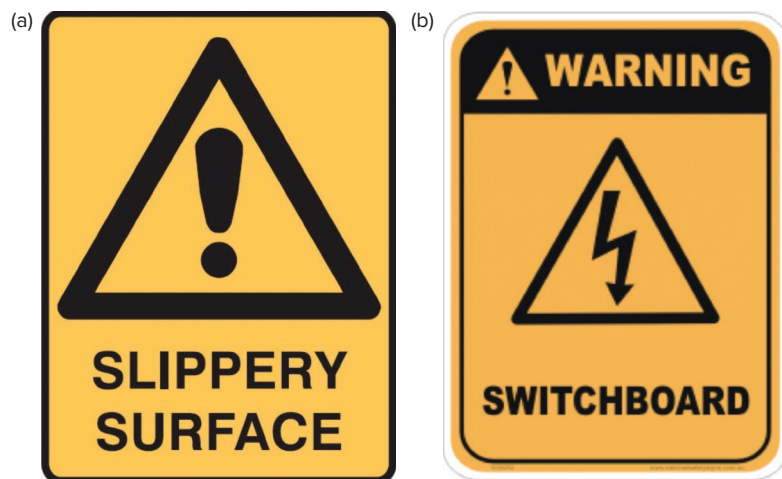
Warning signs are generally yellow with black lettering and a hazard symbol inside a black triangle (Fig. 1.7). The hazard may not be life-threatening but may indicate an activity where extreme caution must still be exercised.

Fig. 1.6 Prohibited action signs



Courtesy of Alister Ford

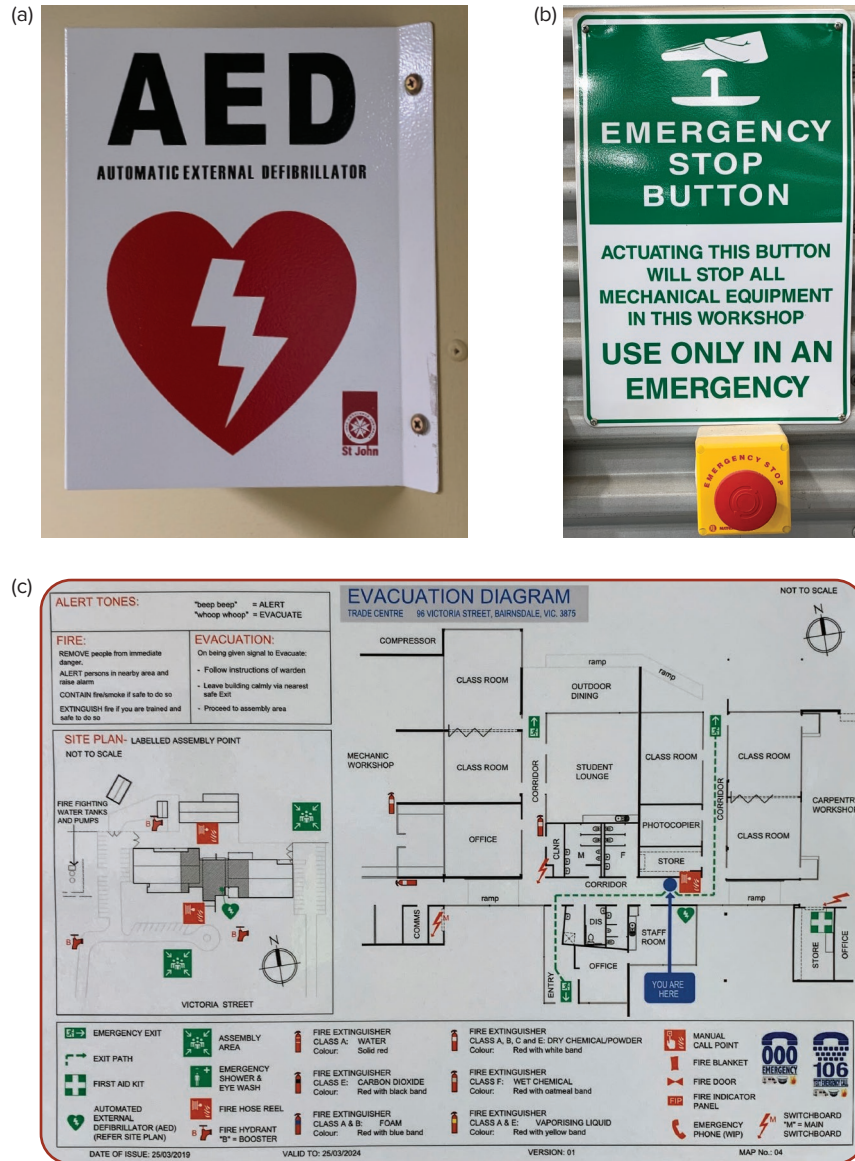
Fig. 1.7 (a) and (b) Warning signs



Courtesy of Alister Ford

Emergency information signs consist of a white symbol, lettering or both, often on a green background. Information can include the siting of emergency exits and assembly points, first-aid stations or kits, emergency eye wash or showers and safety equipment (Fig. 1.8).

Fig. 1.8 (a–c) Emergency information signs



Courtesy of Alister Ford

1.2.3 Personal wellbeing

Every day when you go to work, you and all other workers have the right to a safe environment, both physically and mentally. You have the right to be able to safely carry out all of your tasks for the day, then return home.

1.2.3.1 Drugs and alcohol

Drugs and alcohol should not be used or consumed by anyone on any building site at any time. Anyone presenting for work under the influence of alcohol or drugs should be removed from the workplace

Fig. 1.9 Site safety signs

Courtesy of Alister Ford

If you are a smoker, you must not smoke anywhere on the building site except in these designated areas. Any no-smoking signage must be noted and adhered to.

1.2.3.3 Bullying, harassment and discrimination

Bullying

Any form of bullying, be it intentional or unintentional, on the construction site is totally unacceptable. Sometimes a person may unknowingly bully someone, thinking it is just a harmless joke or part of an initiation. Any behaviour of this type needs to cease the moment it is identified and reported if required.

Forms of bullying may include:

- verbal abuse, insulting remarks, teasing, mocking, threats or unwarranted criticism
- physical intimidation
- violence
- deliberate exclusion
- tampering with, or deliberate damage to personal property, tools or work being undertaken.

Sexual harassment

Sexual harassment is against the law, meaning it is a criminal offence. No one in the workplace should be subjected to sexual harassment of any type at any time. Sexual harassment is generally looked upon as being a deliberate or premeditated act.

Forms of sexual harassment can include:

- whistling
- comments of a sexual nature
- uninvited physical contact
- offensive messaging or commenting via social media

immediately and appropriate arrangements made for them to be transported home or to a medical facility if required.

Every worker now also needs to be vigilant for discarded syringes and needles left on worksites. These can be thrown in from the street, over neighbouring fences or left by users after they have entered the worksite illegally for the night seeking shelter.

This is becoming a more common occurrence on building sites. If you do acquire a needlestick injury, remain calm. If there is a first aider on-site, report to them immediately—if not, see your supervisor. Wash the wound thoroughly with soap and water then report it to your doctor as soon as possible for a follow-up consultation.

1.2.3.2 Smoking in the workplace

Smoking is not an illegal activity, but many construction sites are now smoke-free or have designated areas or site sheds where smoking is allowed.

- subjecting someone to offensive material
- taunting or making comments about a person's presumed sexuality or private life.

Discrimination

Employers are now subject to all federal anti-discrimination laws, meaning that everyone has an equal opportunity to apply for and be given due consideration for any job that may be available to be filled. In other words, everyone gets a 'fair go'.

Some of the major discrimination acts include:

- *Australian Human Rights Commission Act 1986*
- *Disability Discrimination Act 1992*
- *Racial Discrimination Act 1975*
- *Sex Discrimination Act 1984*
- *Age Discrimination Act 2004*.

If you feel you are being bullied, harassed or discriminated against at any time, do not just try to ignore it, hoping it will go away.

It may be a very awkward or difficult thing to do, but you need to take action by talking to your employer or the correct authority and explaining the situation with a view to having it rectified.

Also document any incidents with the date and time with a description of what has occurred.

CHECK YOUR UNDERSTANDING

1. List five items of personal protective equipment (PPE).
2. Obtain approximate costs for a set of PPE that is suitable for your occupational area of interest.

1.3 Avoid construction industry injuries

1.3.1 Fatal injuries

From the beginning of 2014 until the end of 2018, a total of 156 workers in the Australian construction industry lost their lives while at work.

The construction services sector accounted for 92 of these fatalities, the building and construction sector for 42, and the heavy and civil engineering construction sector for 22.

Of the 42 fatalities in the building and construction sector, 23 occurred in the residential building construction area and 19 were in the non-residential building construction area.

These figures have been taken from Safe Work Australia's 'Work-related traumatic injury fatalities Australia 2018' report released on 18 November 2019, Section 1.5.3, Priority Industry: Construction. See Table 1.2 in this chapter.

1.3.2 Injuries

In 2017-18, the number of serious injury claims (13,855) in the construction industry was at its highest for the past 19 years, rising by 7% in total from 2000-01 until the end of 2018.

Of the 19 listed industry divisions, the construction industry is one of only five industry divisions to record a rise in serious claims.

These figures have been taken from Safe Work Australia's 'Australian Workers' Compensation Statistics 2017-18' report released on 10 January 2020, Section 2.4, Industry. See Table 1.3 in this chapter.

Table 1.2 Worker fatalities: Construction industry subdivisions by mechanism of incident, 2014 to 2018 (combined)

Construction subdivision and mechanism	No. of fatalities	% of fatalities
Construction services	92	59%
Falls from a height	31	20%
Vehicle collision*	15	10%
Being hit by falling objects	11	7%
Contact with electricity	10	6%
Being trapped between stationary and moving objects	7	4%
Being hit by moving objects	6	4%
Being trapped by moving machinery	4	3%
Slide or cave-in	3	2%
Rollover of non-road vehicle	2	1%
Other mechanisms	3	2%
Building construction	42	27%
Falls from a height	18	12%
Being hit by falling objects	9	6%
Being hit by moving objects	5	3%
Contact with electricity	3	2%
Vehicle collision*	2	1%
Being trapped between stationary and moving objects	2	1%
Other mechanisms	3	2%
Heavy and civil engineering construction	22	14%
Being hit by moving objects	9	6%
Vehicle collision*	3	2%
Being trapped between stationary and moving objects	2	1%
Falls from a height	2	1%
Being hit by falling objects	2	1%
Other mechanisms	4	3%
Construction 5-year total	156	100%

* Vehicle collisions include fatalities that occurred as a direct result of a vehicle crash. Vehicles include not only road vehicles such as cars and trucks, but also machines such as aircraft, boats, loaders, tractors and quad bikes.

Note: The percentages shown in this table have been rounded to the nearest whole number; therefore the sum of percentage figures for each column may not equal the total.

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Table 1.3 Number of serious claims by industry, 2000–01 and 2012–13 to 2017–18

Industry	2000–01	2012–13	2013–14	2014–15	2015–16	2016–17	% chg	2017–18
Health care and social assistance	15 315	18 725	17 325	17 010	16 350	16 910	10%	17 345
Construction	12 295	12 000	12 280	12 590	13 055	13 115	7%	13 855
Manufacturing	27 025	15 315	14 120	13 960	13 190	13 050	–52%	12 925
Transport, postal and warehousing	11 555	9985	9425	8950	8350	8485	–27%	8515
Road transport	5260	4605	4400	4245	4075	4175	–21%	4165
Public administration and safety	8120	10 715	9970	9240	8510	8420	4%	8305
Retail trade	11 895	9030	8970	8910	8755	8350	–30%	8190

Industry	2000–01	2012–13	2013–14	2014–15	2015–16	2016–17	% chg	2017–18
Education and training	6100	6480	6275	6515	6385	6670	9%	6685
Accommodation and food services	7400	6650	6295	6310	6300	6110	–17%	5985
Administrative and support services	6265	4540	4145	3855	4240	4710	–25%	4880
Wholesale trade	5910	4855	4640	4690	4605	4450	–25%	4660
Agriculture, forestry and fishing	5455	3635	3490	3440	3620	3700	–32%	3560
Agriculture	4155	2840	2655	2635	2820	2835	–32%	2730
Other services	4270	3550	3430	3050	2850	2975	–30%	2890
Mining	1905	3025	2850	2220	2145	2110	11%	2140
Arts and recreation services	2320	2065	2210	2195	2125	2185	–6%	2120
Professional, scientific and technical services	2110	1755	1760	1830	1735	1790	–15%	1905
Electricity, gas, water and waste services	1415	1315	1270	1220	1150	1190	–16%	1120
Rental, hiring and real estate services	1030	1115	1105	1085	1020	1015	–1%	1050
Financial and insurance services	1310	845	800	765	690	605	–54%	655
Information media and telecommunications	1220	700	685	630	545	590	–52%	470
Total	133 040	117 045	111 525	108 685	105 725	106 510	–20%	107 335

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WORKPLACE SCENARIO

A young construction worker fell backwards into an unguarded drill hole 2.4 m deep. He fell to the bottom of the narrow hole with his feet sticking up above his head, squeezed into a sitting position. He was conscious, his head and hands were free, but he couldn't move. Other workers were prevented from digging him out because of site emergency procedures.

Soil had already fallen on top of him and rescuers couldn't come too close to the edge, concerned with disturbing the loose soil and burying him alive. A few days before the accident another worker had complained that the site was unsafe because of the poor quality of backfill.

An experienced ambulance officer tried to be lowered head-first into the hole to attach ropes to pull him out, but this was considered too dangerous.

Confident that the rescue would be successful, a video was recorded for training purposes. At the Coroner's inquest, the video shows a conversation between the young worker and rescuers in which he expresses his fear of the water rising around his head.

The rescue lasted over two hours. For at least five minutes before he was removed from the drill hole, his head was covered by mud and water. He lived for another five days in hospital before dying. The cause of death was drowning.

1.4 Identify major health and safety risks

1.4.1 Working at heights

Table 1.4 Worker fatalities: Construction industry, falls from a height fatalities by breakdown agency, 2014 to 2018 (combined)

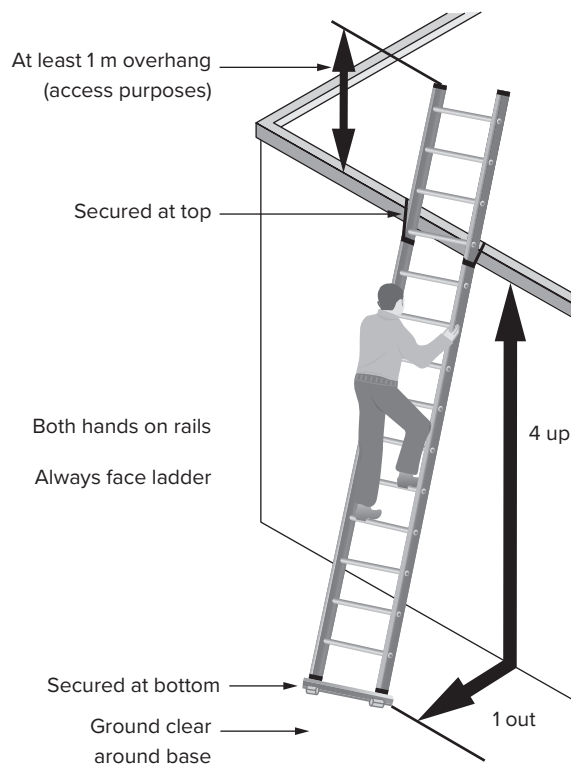
Falls from a height: breakdown agency	No. of fatalities	% of fatalities
Buildings and other structures	18	35%
Ladders	9	18%
Openings in floors, walls or ceilings	4	8%
Scaffolding	3	6%
Doors and windows	3	6%
Other agencies	14	27%
Construction 5-year total—falls from a height	51	100%

Note: The percentages shown in this table have been rounded to the nearest whole number; therefore, the sum of percentage figures for each column may not equal the total.

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1.4.1.1 Ladders

Fig. 1.10 Correct ladder use



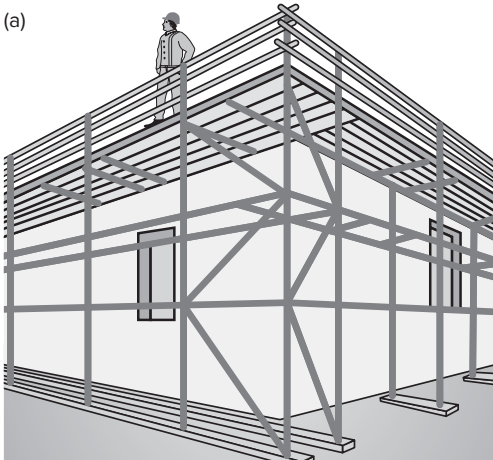
SAFETY TIPS Safe work on ladders

- Ladders should be rated at 150 kg for industrial use.
- Ensure ladder is long enough to extend to a height of 1 metre above a roof.
- Ladders must extend at least 1 metre above the highest rung being stood on or as far as possible above the level where work is being carried out.
- Set up on a solid and stable surface.
- Place ladder at a slope of 4:1.
- Secure top and bottom of ladder to stop slipping.
- Ensure the ladder is in good condition—inspect it.
- Use a tool belt to carry materials and tools.
- Maintain three points of contact when climbing or working from a ladder.
- Wear covered slip-resistant shoes.
- Only one person on a ladder at any time.
- Always face the ladder when ascending or descending.
- Do not climb higher than the third rung from the top of the ladder.

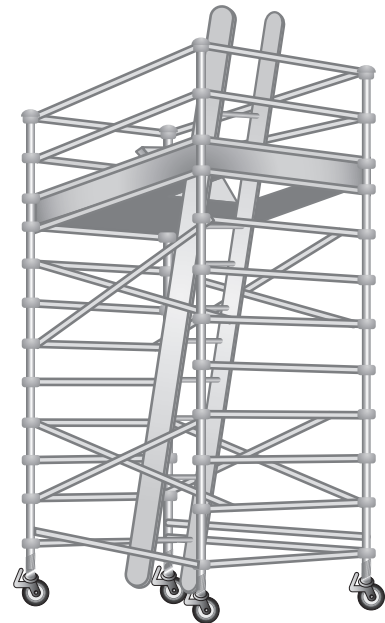
1.4.1.2 Scaffolding

Fig. 1.11 (a) Perimeter scaffold with a fully decked working platform, guardrails and toeboards; (b) mobile scaffold with an access ladder and trapdoor

(a)



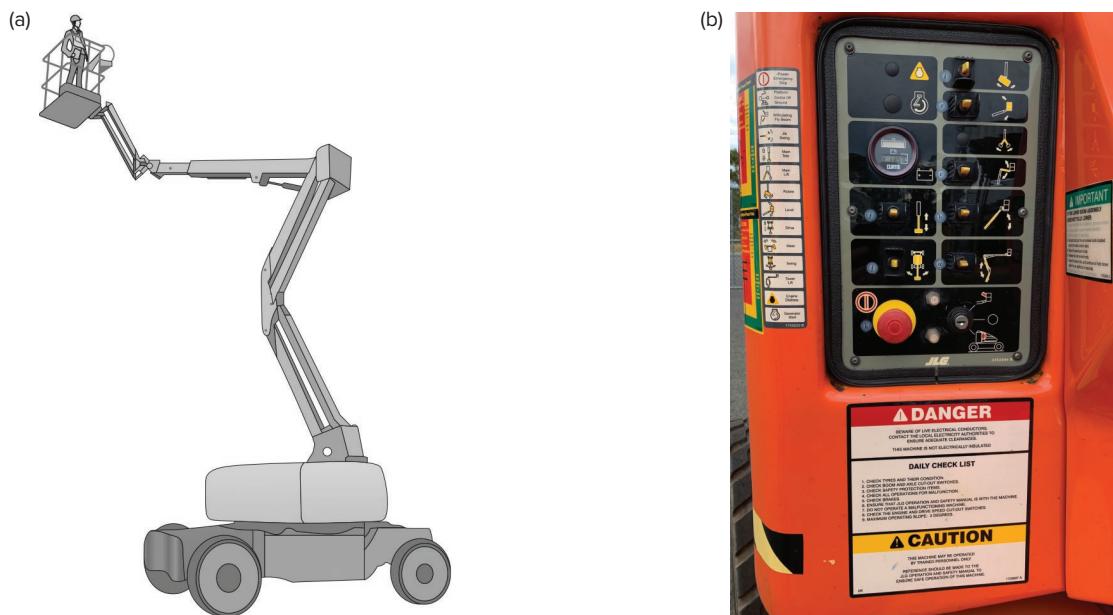
(b)

**SAFETY TIPS** Safe work on scaffolding

- Check the scaffolding for faults before using it and when you first get on it.
- Enter or exit the scaffolding via designated ladder bays or stair bays only.
- Scaffolding should be kept clear of powerlines.
- Do not overload scaffolding.
- Do not alter the scaffolding unless you are authorised and qualified.
- Keep the scaffolding clear of debris and obstructions.

SAFETY TIPS Safe work on mobile scaffolding

- Keep mobile scaffolding level and vertical—not leaning.
- Keep clear of powerlines, open floor edges and penetrations.
- Lock castor wheels before using the scaffolding.
- Do not move mobile scaffolding while anyone is still on it.
- Do not climb the scaffolding to access it—an internal ladder must be used.

1.4.1.3 Elevated work platforms**Fig. 1.12** (a) Boom-type elevated work platform; (b) control panel

Courtesy of Alister Ford

SAFETY TIPS Safe work on elevated work platforms

- Operators need to be trained to operate an elevated work platform (EWP), including the safe use of fall arrest equipment and emergency rescue procedures.
- Platforms must be used only on a solid, level surface free of obstructions and depressions or holes.
- Safety harnesses must be worn by anyone using an EWP.
- Operators of boom-type EWPs must be licensed if the EWP has a working height of 11 m or more.

1.4.2 Falling objects

Anyone working in the construction industry will at times be faced with the hazard of work being carried out overhead. Normally there will be barriers and signs to prevent anyone from passing through or working in such a hazardous area, or there will be protective hoardings to protect passers-by or anyone working below an active work area.

A major concern, however, is the potential for a falling object to land outside a restricted area or to oversail a protective hoarding. Hard hats must be worn when working in or walking through any areas adjacent to work that is being carried out overhead (Fig. 1.13).

When materials or equipment are being transferred from the ground level to a higher level by cranes or hoists:

- do not work or walk directly under the equipment or materials as they are raised
- stay outside any barricaded area beneath a crane or hoist
- if there are no barricades, don't go near any area under the crane or hoist
- take into account the height the materials or equipment will be raised to and the type of materials or equipment being raised (Fig. 1.14).

Equipment such as steel scaffolding tubes, planks, bricks or bags of materials will be scattered outwards if a chain or wire rope breaks suddenly. The higher the materials or equipment are above the ground, the greater the distance they will be spread across below.

Normally there will be a **crane chaser** or **dogman** on the ground to direct workers and passers-by a safe distance away from the hazardous area, but it is far better to avoid such hazardous areas altogether until the materials and equipment have been moved.

Fig. 1.13 Hard hats must be worn in 'hard hat areas'



Courtesy of Alister Ford

Fig. 1.14 Materials being raised by a crane



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WORKPLACE SCENARIO

A construction worker narrowly avoided death when a stack of concrete sheets hit him after they fell two stories. The man worked as a 'dogman' on the site, a job that requires guiding a crane operator as they move a load. The crane swung into a metal loading platform, which dislodged the concrete.

Paramedics worked to free the man from the rubble before he was taken to hospital with injuries believed to include fractured vertebrae. There were concerns that rules demanding 'exclusion zones' beneath the cranes had not been enforced.

1.4.3 Trucks, excavators, bobcats, backhoes and forklifts

1.4.3.1 Delivery vehicles

Construction sites can receive deliveries of building materials or equipment at any time. The drivers of large, heavy trucks delivering building materials or equipment such as prefabricated wall framing, roof trusses, timber, steel, concrete, bricks, plasterboard, roof tiles, concrete or scaffolding often struggle to find a suitable location to set down the load, or they try to enter or leave a construction site that has restricted access. If they are operating a small hoist, they will be carrying or moving an elevated load of materials or equipment that may partly obscure their line of sight.

SAFETY TIPS Safe work for deliveries

- Never assume that the driver can see you.
- Do not walk behind reversing trucks.
- Be alert and make sure you can hear and see delivery vehicles on-site.
- Never allow yourself to be trapped between a delivery vehicle and any immovable objects such as stockpiled materials, scaffolding or walls.
- Do not stand behind a tipper as it unloads sand or other bulk materials—stand well clear and to one side so that the driver can see you.
- Always have a prepared area where materials or equipment can be safely unloaded and stored to specifications without risk to any workers or the environment.

Fig. 1.15 Worker in front of an excavator wearing high-visibility clothing



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If you are close by any heavy mobile plant, ensure the plant operator is aware of your presence and can see you. When working near any heavy mobile plant, wear high-visibility clothing (Fig. 1.15) and work only in an area protected by barricades between the operating plant and workers and where they can see you.

An excavator bucket moving with a sideways swing or the swinging end of a concrete boom pump (Fig. 1.16) will cause a serious, if not fatal, injury.

1.4.3.2 Excavation plant and other vehicles

Excavators, bobcats, backhoes, forklifts, concrete boom pumps and cranes are heavy and noisy machinery. The operators are focused on making sure that they:

- do not damage any services, including underground natural gas, power, sewer and water
- never hit any overhead electrical or telephone lines, trees, buildings, scaffolding or other stationary items
- are operating their machine effectively at all times.

The operator will not always see or hear anyone beside them or behind them when they are operating an excavator, crane, boom pump or forklift.

Fig. 1.16 (a) and (b) (a) Concreters working with a concrete boom; (b) pumping concrete



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WORKPLACE SCENARIO

Never underestimate or take anything for granted in the construction industry.

In 40 years of working in this great industry I have seen some accidents that should never have happened and some near misses that potentially could have ended in tragedy.

I've seen things as simple as forgetting to wear the correct PPE, as well as power tool and equipment accidents and structure collapse. I've also seen things on other building sites where I was not working myself that left me wondering, 'What are these workers even thinking?'

It was on one such occasion some 30 years ago that I felt I could not just keep going and ignore what I had seen. I was living and working as a self-employed builder in rural Victoria and was travelling home one evening after my workday had finished.

Driving into the town where I lived, I had to pass the local golf course. The golf course water supply was a series of dams that was an actual water course, sited along the fence line about 20 metres from the road. The golf course had engaged an earth-moving contractor to dig trenches between the roadside table-drain to the top dam and then more trenches between the four dams.

These trenches were for piping to be laid down, and a new pumping station was to be constructed and installed as well.

As I drove past, I noticed that the excavator was operating and had created a deep trench from the roadside to another larger excavation further off the road.

The excavation was so deep, all I could see in there was the top of the excavator's assistant's hard hat. I estimated the trench to be approximately 1.8 metres deep. I couldn't believe what I had just seen. I pulled over and off the road and quickly made my way back to the excavation site, signalling to the operator to cease before assisting the worker in the trench to get clear—there was no way out for him but at the end of the trench some 5 or 6 metres away.

I explained to these guys about the nature of the ground they were working on and that any excavation should be correctly shored up to stop the risk of a collapse and someone being buried alive. They told me that they were ahead of schedule and had started the excavation late that afternoon rather than waiting until the next day. They could get the job finished quickly and would install the trench shoring when it arrived the following day.

That would have been too late if someone had been buried alive that day. The ground was wet, and this could easily have happened.

The excavation workers stopped work for the day and assured me that the shoring would be installed the next day. They were grateful that someone had stopped and called them out. Complacency can be a major contributing factor to workplace accidents or incidents.

So, I went on my way, glad that I had stopped and done something.

The next morning when heading off to work I drove past again. The excavation crew were there on the site, standing outside the barriers they had erected the previous evening before leaving for the day.

They were looking at the trench they had excavated the previous day, but there was a major change: the trench had collapsed and caved in overnight. These workers had had a lucky escape. It was a near miss that could so easily have ended in tragic circumstances.

1.4.3.3 Passing traffic

Often, it may be necessary to leave the confines of the construction site to assist with delivery vehicles delivering such things as pre-fabricated wall frames or roof trusses, timber packs, concrete, plant or machinery. These vehicles often need to reverse into the site.

In this situation, the general public will continue to use the road outside the site. It may be necessary to temporarily stop local traffic so that the delivery vehicle can enter the site safely.

Correct reflective hi-vis clothing must be worn and every precaution taken to alert passing traffic in plenty of time as to whether they need to stop or slow down. A stop/slow bat operated by someone who has been properly trained in traffic control is the most effective method for this. If not, good clear, concise hand signals should be employed.

1.4.4 Manual handling

Manual handling of materials and equipment is still the number one cause of non-fatal work-related injuries in the construction industry. Any manual handling tasks need to be carefully planned and organised to ensure the task is carried out safely. Correct lifting and carrying and setting-down procedures should always be observed.

Different building materials and equipment will all have different characteristics and may even have manual handling instructions included in the manufacturer's instructions or the material safety data sheet.

Injuries that could occur from manual handling can include:

- back injury
- hernia
- muscle tear or sprain
- ligament tear or sprain
- lacerations
- cuts
- puncture wounds
- fractures.

These injuries are usually caused by incorrect lifting, carrying and setting-down procedures, sharp edges or protrusions, incorrect assessment of the load and trying to lift too much.

1.4.4.1 Preparation for lifting

- Decide how far the load will be moved once it is lifted and how it will be moved.
- Perhaps the load can be rolled rather than lifted?
- Can it be moved onto a trolley?
- Is a crowbar needed to dislodge the load?
- Can it be placed into a wheelbarrow and wheeled to the final location?
- Determine if you have a suitable mechanical device to lift the load.
- Before lifting the load, determine the weight and decide if two people are needed to lift it.

1.4.4.2 Lifting a load

- Stand as close to the load as you can.
- Place your feet apart with one foot alongside the load to create a stable base.
- Bend your knees and keep your back and body upright and straight as you squat down.
- Adjust your feet to maintain balance.
- Your front foot should still be next to the load and facing the direction you plan to go in.

- Make sure your feet are firmly in position.
- Grasp the load firmly with both arms close to your body and straighten your legs slowly.
- Lift the load with your legs and arms, keeping your body and back straight.
- Keep the load close to your body and don't twist your body on your legs as this twisting movement can damage your knees or cause muscle strains!
- Keep your legs slightly bent and free as you walk. *Don't lock your knees!*

Use the same procedure in reverse when you have moved the load to the new location.

If the load is too heavy, immediately reverse the procedure and place the load back down.

Fig. 1.17 (a–d) Shovelling loose materials such as sand or dirt: (a) keep the legs apart with one foot in front and close to the end of the shovel; (b) put weight on front foot, place both hands on the shovel with each hand resting against a leg, and bend legs and push forward using body weight to push the shovel; (c) step back onto back foot with loaded shovel and keep the load close to your body; (d) step and turn feet and body in the direction of where the material needs to be placed. Keeping the load close to your body, roll your forearms, wrists and hands to dislodge material



Courtesy of Alister Ford

1.4.4.3 Moving loads using a wheelbarrow

- Load the wheelbarrow evenly so that it is balanced sideways.
- Place the majority of the load forward and balanced over the wheel.
- Make additional trips rather than overloading.
- Load it facing in the direction you want to wheel it.
- Use your legs, not your back to lift the wheelbarrow.
- Use your normal walking pace.
- Cross all bumps or ridges at 90° to the wheel.
- Keep tyres hard and properly inflated.
- Make sure the pathway is clear of debris.
- Use the legs when travelling downhill to brake the wheelbarrow by lowering them to skid on the ground.

1.4.5 Hazardous substances

1.4.5.1 Asbestos

Asbestos is considered a hazardous substance and is also **carcinogenic**. Diseases such as **mesothelioma** and **asbestosis**, which are associated with asbestos exposure, were responsible for 90 fatalities in the construction industry over the six-year period from 2005–06 to 2010–11.

Asbestos cement, or 'fibro', was used until the late 1980s. It was commonly used in residential construction for wet area linings in bathrooms and laundries, for the eaves lining on brick veneer cottages and for a variety of external cladding profiles, including smooth sheeting on timber-framed cottages (Fig. 1.18).

It is difficult to correctly identify bonded asbestos cement compared to modern fibre cement products. Any material that resembles fibre cement sheeting found when renovating a home built before 1990 should be considered as hazardous asbestos cement until confirmed otherwise.

Immediate exposure to bonded asbestos alone is not a hazard unless there is an attempt to remove it during renovations and demolition.

Fig. 1.18 Post-war fibro home with external asbestos cement sheeting



Courtesy of Alister Ford

Bonded asbestos can be damaged by:

- high-pressure water cleaners
- grinding
- saw cutting
- drilling
- snapping or breaking up
- compressed air
- abrasive blasting
- abrasive power tools
- pneumatic tools.

The asbestos fibres can be exposed (Fig. 1.19) and become airborne and also collect among other debris that has to be removed. When undertaking any demolition, it is recommended that a P1 or P2 mask or respirator be worn as these are designed to protect

the wearer against a range of fine particles including asbestos (Fig. 1.20). However, they do not provide protection against toxic fumes or gases. Cheap dust masks for protection against 'nuisance dusts' are completely unsuitable for any construction work and offer little protection against any fine particles.

Asbestos is removed by specialist licensed contractors who are trained and qualified.

Fig. 1.19 Damaged bonded asbestos with asbestos fibres exposed



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Fig. 1.20 Disposable respirator with valve (note coding below valve)



Courtesy of Alister Ford

TIP Normally the builder (the head contractor) who is contracted to renovate a home would investigate the presence of bonded asbestos and arrange for suspect materials to be tested and, if necessary, removed by a specialist asbestos removal contractor before construction work commences.

1.4.5.2 Crystalline silica

What is crystalline silica?

Crystalline silica is a naturally occurring mineral found in many types of rock or soil, which, when used in the construction industry, can be found in products such as:

- concrete and associated aggregates
- cement
- mortar
- sand
- stone
- composite or engineered stone
- bricks/blocks (clay or cement)
- autoclaved aerated concrete
- grout
- ceramic tiles
- natural sandstone
- granite
- asphalt.

The dust generated when working with these products, commonly known as *silica dust*, can be extremely harmful if inhaled into the lungs, and can cause silicosis, along with other illnesses and diseases, including lung cancer, emphysema, bronchitis and kidney disease.

Workers using any of the products listed above, or any other silica-containing materials, and carrying out work on these products, such as:

- grinding
- cutting

- drilling
- sanding
- polishing
- abrasive blasting
- demolishing
- crushing
- jackhammering
- transporting (loading, unloading)
- dry sweeping.

Need to be especially vigilant in following the instructions laid out in the **material safety data sheet (MSDS)** for the product, including wearing the correct PPE and protective clothing, and using the correct safe work methods and associated tools and equipment.

Even just working in the vicinity of any of these activities being carried out on silica-containing building products can be dangerous to your health, and all safety requirements should be observed.

The amount of crystalline silica present in different products used in the construction industry can vary greatly. Examples of the typical concentration of crystalline silica in some products can be seen in Table 1.5.

Table 1.5 Typical silica content of some building products

Construction/building product	Product silica content %
Concrete and associated aggregates	30%
Composite/engineered stone	90%
Bricks	5–15%
Natural sandstone	67%
Ceramic tiles	5–45%
Autoclave aerated concrete	20–40%
Granite	25–40%
Demolition dust	3–4%

What is silicosis?

Silicosis is an incurable disease with symptoms that include repeated coughing, shortness of breath and chronic fatigue.

Silica dust particles, which may be so small they are impossible to see, cannot be broken down by the human body when they enter the lungs. The dust will cause inflammation if it lodges deep in the lungs, resulting in scarring of the lung tissue.

Irreparable damage to the lungs caused by acute silicosis can necessitate a lung transplant and, in the most extreme cases, can cause death.

Silicosis can develop rapidly, moderately or slowly. It may take only a matter of weeks to present or many years, depending on the amount of silica dust, the time frame of exposure and the metabolism of the individual and how the person's body reacts to the exposure.

Rapid development is known as *acute silicosis*. This means the exposure has been at extremely high levels for a short period of time, possibly resulting in inflammation of, and fluid in, the lungs, shortness of breath, low blood oxygen levels, coughing, fatigue, acute chest pain and weight loss. This can all happen within only a few weeks or may take a few years of exposure to inhaled silica dust.

Chronic silicosis can appear after 10 years, and anywhere up to 30 years, of exposure to silica dust. In such cases, the person may not have been exposed to extremely large amounts of silica at any one

time, but the exposure may have been constant over many years. It often affects the upper lung area, possibly resulting in extensive scarring; swelling may also occur in the lungs and chest lymph nodes. This is known as progressive massive fibrosis.

Accelerated silicosis can occur after high levels of exposure to silica dust in any time frame up to 10 years. Progressing more rapidly than *chronic silicosis*, the swelling of the lungs and the associated symptoms will occur much more quickly.

Typically, there will be no symptoms of silicosis in the early stages. It may be detected only using CT scans or chest X-rays. It is vitally important that anyone working in a silica dust-affected area at any time who has any symptoms such as coughing, wheezing, chest pain or breathing difficulties consults a doctor immediately.

Workers constantly carrying out tasks in an area that may have silica dust present should always be vigilant and have regular health checks with their doctor.

Managing the hazards and risks of exposure to silica dust

The hazards and associated risks of working with crystalline silica-containing building materials, and the silica dust that will be created, vary depending on the specific task being carried out.

External or internal work both have different environmental issues. The materials being used to achieve different outcomes will determine the work methods to be used, the tools and equipment that will be required, and the number of workers needed to carry out the job safely.

As with many other construction tasks, working in an environment where silica dust is present will require a hazard audit followed by a risk assessment. A safe work method statement (SWMS) should then be formulated.

The identified risks associated with the task can be managed by implementing measures using the hierarchy of hazard control.

Analysing workplace hazards and using the hierarchy of hazard control are discussed in section 1.7 of this chapter.

Because of the danger of silica dust and the high probability of it being present in many construction materials that being used at the worksite each day, the hierarchy of hazard control specifically for working with silica-containing materials is discussed here.

A range of control measures may be required to create a safe work process for some tasks. This will depend on the risk of exposure while carrying out the specific task.

The hierarchy of hazard control for silica-related tasks includes the six levels listed in order in Table 1.6, from most effective, number 1, to the last resort, number 6.

Table 1.6 Hierarchy of hazard control for silica-related tasks

LEVEL 1	Elimination
LEVEL 2	Substitution
LEVEL 3	Isolation
LEVEL 4	Engineering controls
LEVEL 5	Administrative controls
LEVEL 6	Personal protective equipment (PPE)

Level 1: Elimination

Elimination is the total removal of the hazard from the workplace. This is generally not practicable as silica dust will naturally occur in the workplace, purely through the products and materials being used. Silica dust can be eliminated at the source by changing or removing the dust-generating processes.

For example:

- a wet method of working on silica-containing material will most likely generate less dust than a dry method
- capturing dust at the position of generation
- using dust-suppression methods such as a water spray, local exhaust ventilation and vacuums.

Level 2: Substitution

This involves replacing the construction material or product with another that is less hazardous. Like elimination, substitution may not be a viable option in terms of the finished product that has been ordered and needs to be delivered at the completion of the job.

Substitution can include using:

- silica-containing products that do not require cutting, grinding or polishing
- products that contain less silica
- silica-free products.

Level 3: Isolation

Placing barriers around hazards, creating no-go zones, and creating distance between hazards and workers are all particularly effective ways to isolate workers from the hazard. It is not possible to isolate all workers, though, as some will still need to carry out the required work.

Isolation controls could include:

- creating a restricted access area to isolate dust-generating tasks
- having the work carried out off-site
- exclusion zones
- physical barriers (temporary walls, plastic sheeting)
- closing nearby work areas for the duration of the present task.

Level 4: Engineering controls

Engineering controls change the way a task is carried out in a physical sense. It is important to be aware that using engineering controls can also introduce other hazards such as noise, water, electricity, vibration, compressed air or fuel into the workplace.

Engineering controls for silica dust can include:

- using automatic equipment when cutting, drilling, grinding, routing or polishing
- using wet cutting or grinding methods
- using cutting, drilling, grinding, routing and polishing equipment fitted out with H-class local exhaust ventilation and water attachment for the suppression of dust
- using ventilation/dust extraction systems that are professionally designed for any specific work area
- ensuring vacuum cleaners are rated as M- or H-class
- using sacrificial backing boards.

All engineering control methods are susceptible to wear and damage as silica dust is very abrasive. Regular maintenance is vital to keep all equipment in good working order. Equipment should be cleaned and checked for any damage each time it is used.

Things to check for include:

- wear and tear of any moving parts
- corrosion
- damaged parts
- air or water leaks
- dust extraction equipment being well cleared
- guards and flaps containing water spray being in good working order.

Level 5: Administrative controls

Administrative controls will not physically eliminate the hazard. They are generally used in conjunction with any substitution, isolation or engineering controls that have been implemented.

The actions of the workers will determine how effective any administrative controls are. Training and supervision are important in providing a total understanding of any administrative policies in place.

Precise planning also needs to be undertaken, so that any administrative controls fully complement any other existing controls.

Administrative controls for silica dust can include:

- safe work method statement (SWMS)
- safe operating procedures (SOP) that give the correct instructions for the operation of tools, plant and equipment, including pre-operational safety checks, operational safety checks and housekeeping
- dust hazard signage (Fig. 1.21)
- documented clean-up procedures
- maintenance schedules for equipment and PPE
- job rotation schedules so that workers are not continually exposed to silica
- restricted areas for work to be carried out on silica-containing materials
- planning of cutting, grinding and polishing tasks to keep such activities to a minimum.

Administrative controls for work on products containing silica include:

- rotation of workers' shifts to keep exposure to a minimum
- laundry services for workwear and PPE to ensure contaminated workwear and PPE is not taken home
- cleaning, maintenance and storage policies for tools, equipment and PPE, including cleaning areas and sealed storage units or bags.

Training of workers must include:

- specific training for workers who will be handling and working with products containing silica
- training during site induction and also when the characteristics of the workplace change, due to work progressing
- educating workers about silica dust and the effects it can have on their health
- explaining the controls that can be put in place for their own protection
- information about how bad work practices can put them at risk of exposure
- procedures to be undertaken if they feel workplace practices are unsafe
- how to report hazards immediately if they see them, and also if they feel unwell.

Housekeeping:

- Reduced exposure to, or the elimination of, silica dust can be attributed to good housekeeping.
- Displaying policies and procedures in the workplace is an excellent way to keep workers constantly aware of the health and safety requirements.

Fig. 1.21 Silica dust hazard warning signs



Source: WorkSafe Victoria

Decontamination:

- Silica dust on work clothes and PPE can expose other workers who have not been in the vicinity of the work taking place.
- H-Class vacuum cleaners can be used to remove dust from work clothes, and policies should be in place to ensure workers carry out this task before leaving the work area.
- Washing hands, arms, faces and even hair is particularly important, and an area for this to take place should be provided.

Level 6: Personal protective equipment (PPE)

PPE is the last resort on the hierarchy of control. Before PPE is considered, all other controls should be fully assessed and put in place where practicable. PPE should be used only to supplement higher-level controls or when no other means of control is viable.

Any PPE must be of the standard required as written down in the MSDS if one is available; if not, PPE must be appropriate for the job at hand as discussed and documented in the SWMS. All PPE must be in good condition and fitted correctly.

PPE used when working with silica-containing products, and the associated silica dust, can include:

- respiratory protective equipment (RPE)
- eye protection
- hearing protection
- hand and arm protection
- protective clothing
- aprons
- rubber boots
- steel-capped boots
- hard hats.

Reviewing workplace health and safety hazards and risk controls

As with any construction progresses, reviews on control measures should be carried out regularly as the workplace changes. Do not wait for something to happen before reviews take place as by then it could be too late. Use the same process of review as you did when first conducting the hazard and risk audit. If new hazards or risks are identified, a review of all work practices, work areas and construction materials should take place and any changes to current controls should be documented and communicated to all workers involved.

1.4.5.3 Dry powder building products

Cement, lime, fireclay, tile adhesives or any combination of these materials in a packaged form are considered to be hazardous substances until they have been mixed and placed.

1.4.5.4 Processed timber products

Processed timber products such as **medium-density fibreboard** (MDF), treated pine, plywood and materials made with recycled timber and plastics contain materials that in a dust form can be very harmful. P1 or P2 respirators or dust masks must be worn when cutting these products.

1.4.5.5 Fibre cement board

These products are used for cladding, internal wet area linings and as external and internal wet area flooring. The dust generated by cutting these materials is hazardous.

1.4.5.6 Insulation materials

The most common insulation materials that you will encounter on a domestic building site will be the fibreglass insulation batts that are fitted into wall frames or roof spaces.

Table 1.7 Recommended RPE for working with engineered stone

PAPR loose fitting helmet High level of protection		• Positive pressure reduces fatigue • Can be worn with facial hair • Does not require fit testing • Can be heavy, depending on the unit
PAPR loose fitting hood High level of protection		• Positive pressure reduces fatigue • Can be worn with facial hair • Does not require fit testing
Half face powered air-purifying respirator Medium level of protection		• Does not impair vision or mobility • More comfortable over longer periods • Positive air pressure reduces fatigue • Cannot be worn with facial hair • Requires fit testing • Needs to be fit checked with each wear

Source: WorkSafe Victoria

The fibres from these batts can cause severe irritation to the skin, eyes and lungs, so the correct clothing, eye protection and respirators should be used to ensure you are well protected.

Alternative insulation materials may be wool, paper or foam-based, and the correct PPE must be used according to the manufacturer's instructions.

1.4.5.7 Protective dust masks or respirators

Any worker using the products listed above must ensure that they do not breathe fine dust particles from these materials into their lungs. They may have to wear protective P1 or P2 dust masks to prevent this occurrence. Such dusts can cause **pneumoconiosis**, a chronic disease of the lungs that can result in tightness of the chest, difficulty in breathing, chronic coughing, bronchitis and emphysema. Although diseases such as pneumoconiosis are not cancers, they can still result in a fatality at worst or at best long-term disability that stops a worker from continuing in their career.

1.4.5.8 Solvents, pesticides, acids, adhesives, gases, alkaline and petroleum products

Any products containing chemicals or gases have the potential to damage your skin, eyes and lungs. Before using any unknown chemical or gaseous product on a construction site, it must be identified and a materials safety data sheet must be available to explain what the product contains, what injuries or illnesses it may cause, how these can be treated and what form of PPE must be used by any worker required to use such products on a construction site.

Chemicals must not be mixed under any circumstances unless the directions clearly state that it is a requirement and safe to do so. Risks include causing an explosion or fire, or emitting poisonous fumes. Any mixing of substances must be done strictly according to the product manufacturer's instructions and material safety data sheet, using the correct mixing equipment and PPE.

If you fail to comply, and an incident occurs, many people could be affected—and not just those in the immediate vicinity.

Examples of commonly used products that may contain hazardous chemicals or gases are paints, sealants, adhesives, cleaners, oxyacetylene, waterproofing and fireproofing products.

These may be supplied in many types of tins, drums, plastic containers, glass containers, cylinders or pressurised containers. The material safety data sheet will also give detailed instructions on how any spills or leaks must be contained and cleaned up.

The required equipment detailed must be prepared and be readily available in case such an emergency occurs.

All materials used on any construction site must by law be accompanied by a materials safety data sheet. This requirement includes common construction materials such as cement, bricks, lime, fibre cement board, treated pine and other processed timber products.

1.4.6 Electrical hazards

Electricians are exposed to the danger of electrocution every day. Any building worker may be exposed to an electrical hazard at any time while at work. There are two main controls that are used to protect workers against electrocution.

1.4.6.1 Remove the risk

Electricians do this by turning off the power when they are working with live wiring. The same control can be applied by all workers. If you are in doubt about the condition of any electrical wiring (e.g. in a renovation project), turn the power off and use rechargeable battery-powered tools, a portable generator and other petrol-powered equipment, or use the power available from a neighbour.

TIP Rechargeable battery-powered tools remove the risk of electrocution due to faulty electric tools.

1.4.6.2 Earth leakage circuit breakers and residual current detectors

Both devices switch off power and are extensively used in the construction industry to protect workers. The earth leakage circuit breaker (ELCB) detects any leakage of power into the ground, while the residual current detector (RCD) detects any imbalance of power in the circuit (Fig. 1.22).

These devices are mandatory on all construction sites where electrical power is used. Normally an electrical lead is plugged into a source of power and the ELCB or RCD is connected at the end closest to where electric power tools are being used. The power tools are plugged directly into the ELCB or RCD.

1.4.7 Extreme working conditions

If working in extreme conditions, whether it is a hot or cold environment, correct procedures must be taken to ensure the health and safety of yourself and your fellow workmates. Sunburn, dehydration and heat stroke can occur if working outside in the typically hot and sunny Australian conditions.

Every effort must be taken to cover up and protect your skin to avoid sunburn and complications in later years such as skin cancers. Long-sleeved shirts, wide-brimmed hats and sunscreen will give you good protection on hot sunny days. Drink plenty of water, sipping frequently to reduce thirst. A few simple precautions such as these can prevent what may become a traumatic time if ignored.

Extreme conditions may also be encountered if working in environments where humidity levels, radiant heat and temperatures, whether hot or cold, are regulated to a non-natural temperature, or unregulated and at an unknown level.

These could be places such as:

- cool rooms
- cold stores
- boiler houses
- foundries
- industrial kitchens
- factories
- workshops
- subfloor spaces
- roof spaces.

Working conditions in any of these extreme environments must be closely monitored, as well as the physical wellbeing of each worker. Issues such as heat exhaustion and hypothermia can strike quickly and without warning.

Detailed information regarding hot or cold workplace conditions and personal safety can be found in the Safe Work Australia 'Code of Practice: Managing the work environment and facilities', December 2011, Section 2: The work environment, Part 2.8: Heat and cold.

Fig. 1.22 Residual current detector



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

3. List, in order of risk, the three work activities responsible for the highest numbers of fatalities in the construction industry.
4. Name the two different devices that must be attached to a power source to protect workers from electrocution.
5. Name two classifications of respirators that are suitable for use in asbestos removal.

1.5 Deal with emergencies on construction sites

All construction sites, including residential building sites, must have a site safety plan. The site safety plan has an evacuation plan that must be followed in the event of evacuation of the site.

There should also be designated site personnel (e.g. area chief warden) to take charge of the building site and the evacuation process if such an event occurs. Any instructions issued by these persons must be carried out as directed.

If an emergency occurs, or a situation arises on a construction site, remember to remain calm and work in unison with other workers to carry out the correct procedures as outlined in the site safety and management or evacuation plan. Others may need to rely on you for assistance or guidance at any time, whatever the situation.

There should also be an approved first-aid kit available on any construction site.

1.5.1 Emergency evacuation

The main reasons for evacuation of a residential site could be a bomb hoax, fire, earthquake, flash flooding, gas leak, chemical leak, building or partial building collapse, the threat of violence or any other uncontrolled event or incident. Each site has a designated assembly area that all site workers must go to in the event of an emergency evacuation so that they can be signed off as present. Otherwise, other people may have to return to the site and try to account for anyone who is missing.

1.5.2 Emergency firefighting equipment

With a large fire, the best course of action is to isolate the fire if safe to do so, sound the fire alarm, whether it is a site siren or a break glass alarm, and then evacuate the worksite, moving everyone to the designated emergency assembly area. Call 000 and accurately relay any information for the fire brigade to arrive at the correct place in the minimum amount of time. The fire brigade is best equipped to tackle any large fires with their trucks, hydrants, hoses, reels and breathing apparatus.

For smaller fires, a portable fire extinguisher or fire blanket can be used to prevent the fire spreading. Portable fire extinguishers contain a range of different types of extinguishing agents designed to extinguish specific types of fires (Fig. 1.23).

1.5.3 Medical emergency

A medical emergency on a construction site normally occurs when there has been an accident and a worker is seriously injured. If an accident occurs, other workers have an obligation to respond and assist the injured worker as best they can.

Workers who have been injured may need emergency first aid. On smaller residential construction sites, there may not be a qualified first-aid officer available, but the other workers should have a basic knowledge of first-aid procedures and know how to keep the injured worker safe and comfortable until the trained emergency workers arrive.

The **site safety management plan** should have the contact details for the closest hospital and medical centre or general surgery, including the opening hours.

First-aid kits should be available on-site for the treatment of minor injuries, but they must be properly maintained. Typically, minor injuries on a residential construction site will involve cuts or lacerations. This means there will be blood present. If you are assisting a fellow worker who has had an accident and there is blood present, you should first put on a pair of disposable gloves, which should be found in the first-aid kit. This will give you, as the assisting worker, some protection from any blood-borne diseases that may be present. The main blood-borne infections are hepatitis B, hepatitis C and HIV/AIDS. A simple precaution like this can give you every confidence to assist an injured coworker.

Fig. 1.23 Types of fires and suitable extinguishers

Class and type of fire		A	B	C	D	E	F	
Type of extinguisher	Colours	Wood, paper, plastic	Flammable and combustible liquids	Flammable gases	Combustible metals	Electrically-energised equipment	Cooking oils and fats	
Water		Yes	No	No	No	No	No	Dangerous if used on flammable liquid, energised electrical equipment and cooking oil/fat fires.
Carbon dioxide (CO2)		Limited	Limited	No	No	Yes	No	Not suitable for outdoor use or large class A fires.
Dry chemical powder (ABE/BE)		Yes AB(E) No B(E)	Yes	Yes	No	Yes	No AB(E) Yes B(E)	Look carefully at the extinguisher to determine if it is a BE or ABE unit.
Foam		Yes	Yes	No	No	No	Limited	Dangerous if used on energised electrical equipment.
Wet chemical		Yes	No	No	No	No	Yes	Dangerous if used on energised electrical equipment.
Fire blanket		Limited	Limited	No	No	No	Yes	Fire blankets are effective for oil and fat fires within saucepans and for extinguishing clothes that catch on fire. (Ensure you replace after every use.)
Fire hose reel		Yes	No	No	No	No	No	Dangerous if used on flammable liquid energised electrical equipment and cooking oil/fat fires.

Any injury, no matter how minor, must be correctly documented in case of any later complications arising from the injury, and also to assist in the planning of future tasks to stop any similar incident occurring. This also applies to any near miss, where injury is luckily avoided. If you are working on a residential construction site, it is important to be familiar with the site safety management plan as it may save your life or the life of a fellow worker.

1.6 Know about Australian work health and safety legislation, regulations and codes of practice

The model national legislation that addresses workplace health and safety is called the *Work Health and Safety Act 2011* (Cth) (WHS Act). The implementation of this legislation is supported by the *Work Health and Safety Regulations 2019* (Cth) (WHS Regulations) together with national

Fig. 1.24 Fire blanket

Courtesy of Alister Ford

standards and codes of practice. Under this model, all workers and employers have shared roles and responsibilities to ensure that construction worksites are safe. These shared responsibilities mean that individual workers must at times participate in the assessment of risks associated with the tasks they undertake.

Most Australian states and territories have now adopted the model safety legislation of the federal government. An immediate benefit has been the mutual recognition of qualifications for mandatory general induction training and the adoption of common codes of practice. The 'harmonisation' of safety requirements across all Australian states and territories not only reduces red tape but also makes the management and implementation of workplace safety more consistent and consequently more effective than it has been in previous years.

There is broad mutual recognition of construction induction White Cards across all state and territory authorities, but interstate workers should check with local authorities to confirm acceptance of the card they hold. A construction induction card will not be accepted if it does not have all of the details required by the local authorities or is out of date.

1.6.1 *Work Health and Safety Act 2011 (Cth)*

The following information from the *Guide to the model Work Health and Safety Act* (Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>) details the main purpose and aim of the *Work Health and Safety Act 2011 (Cth)*:

The WHS Act provides a framework to protect the health, safety and welfare of all workers at work and of other people who might be affected by the work.

The WHS Act aims to:

- protect the health and safety of workers and other people by eliminating or minimising risks arising from work or workplaces
- ensure fair and effective representation, consultation and cooperation to address and resolve health and safety issues in the workplace
- encourage unions and employer organisations to take a constructive role in improving WHS practices
- assist businesses and workers to achieve a healthier and safer working environment
- promote information, education and training on work health and safety
- provide effective compliance and enforcement measures, and
- deliver continuous improvement and progressively higher standards of work health and safety.

In furthering these aims, there must be regard for the principle that workers and other persons should be given the highest level of protection against harm to their health, safety and welfare from hazards and risks arising from work as is reasonably practicable.

For these purposes 'health' includes psychological health as well as physical health.

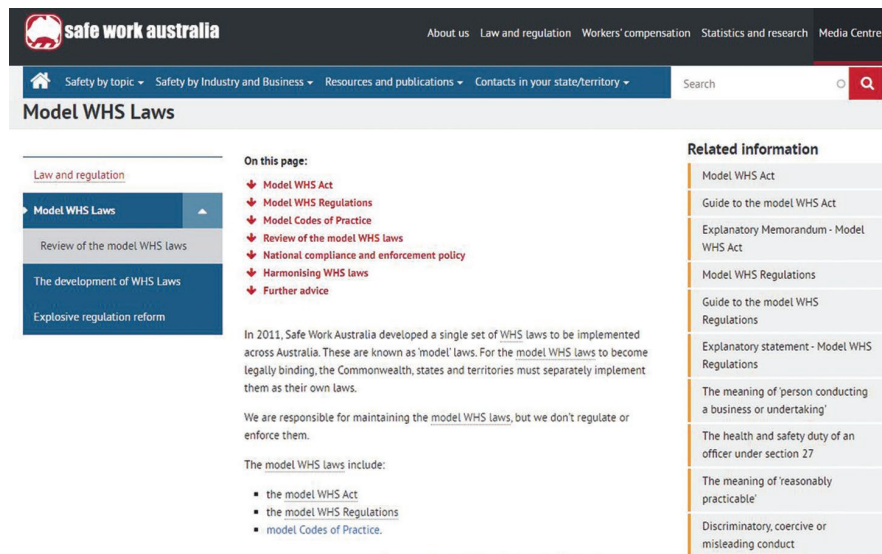
A full copy of the Act can be downloaded from www.comlaw.gov.au. The *Guide to the Work Health and Safety Act* can be downloaded from www.safeworkaustralia.gov.au (Fig. 1.25).

1.6.2 *Work Health and Safety Regulations 2019 (Cth)*

The Work Health and Safety Regulations 2019 (Cth) (WHS Regulations) complement and support the general duties under the WHS Act and support it by setting out mandatory obligations on specific matters. You can access the comprehensive 600-page WHS Regulations document at the Safe Work Australia website (www.safeworkaustralia.gov.au) (Fig. 1.26).

Fig. 1.25 *Work Health and Safety Act 2011 (Cth)*

Sourced from the Federal Register of Legislation at 8 July 2021. For the latest information on Australian Government law, please go to <https://www.legislation.gov.au>; <https://creativecommons.org/licenses/by/4.0>

Fig. 1.26 *Work Health and Safety Regulations 2019 (Cth)*

Courtesy of Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>

The Regulations impose 'duties' (see note on 'duty of care') on people who have a role in undertaking construction work, including:

- the person who commissions the construction work must consult with the designer of the structure on matters relating to health and safety during construction work and provide a health and safety report by the structure designer to the principal contractor
- the designer of the structure must provide a written health and safety report to the person who commissioned the project
- the principal contractor is responsible for the overall management and control of site health and safety, including collecting work method statements for high-risk construction work, providing and maintaining an WHS management plan and informing all workers of the content of the WHS management plan
- workers must comply with the WHS management plan and have their general induction training card available.

The term *duty of care* refers to a requirement to exercise due diligence in performing a WHS duty and to act proactively to ensure health and safety at work. It is applied to all people, regardless of the level of responsibility they have in undertaking construction work.

1.6.3 The meaning of construction work

The WHS Regulations (Part 6.1 Preliminary, 289, p. 277) define construction work as follows (Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>):

- (1) . . . **construction work** means any work carried out in connection with the construction, alteration, conversion, fitting-out, commissioning, renovation, repair, maintenance, refurbishment, demolition, decommissioning or dismantling of a structure.
- (2) . . . **construction work** includes the following:
 - (a) any installation or testing carried out in connection with an activity referred to in subregulation (1);
 - (b) the removal from the workplace of any product or waste resulting from demolition;
 - (c) the prefabrication or testing of elements, at a place specifically established for the construction work, for use in construction work;
 - (d) the assembly of prefabricated elements to form a structure, or the disassembly of prefabricated elements forming part of a structure;
 - (e) the installation, testing or maintenance of an essential service in relation to a structure;
 - (f) any work connected with an excavation;
 - (g) any work connected with any preparatory work or site preparation (including landscaping as part of site preparation) carried out in connection with an activity referred to in subregulation (1);
 - (h) an activity referred to in subregulation (1), that is carried out on, under or near water, including work on buoys and obstructions to navigation.

For any construction worker who has responsibility for the actions of other workers in relation to safety, see the comprehensive details in Chapters 18–19 of the Regulations.

1.6.4 Codes of practice

Codes of practice provide guidelines for meeting the requirements of the WHS Act and the WHS Regulations and may be used in a court of law as evidence to prove compliance with the WHS legislation (Fig. 1.27). Construction sites that are not operating safely will often be referred to a copy of a code of practice by WHS inspectors to demonstrate why their work procedures have failed to comply with WHS legislation.

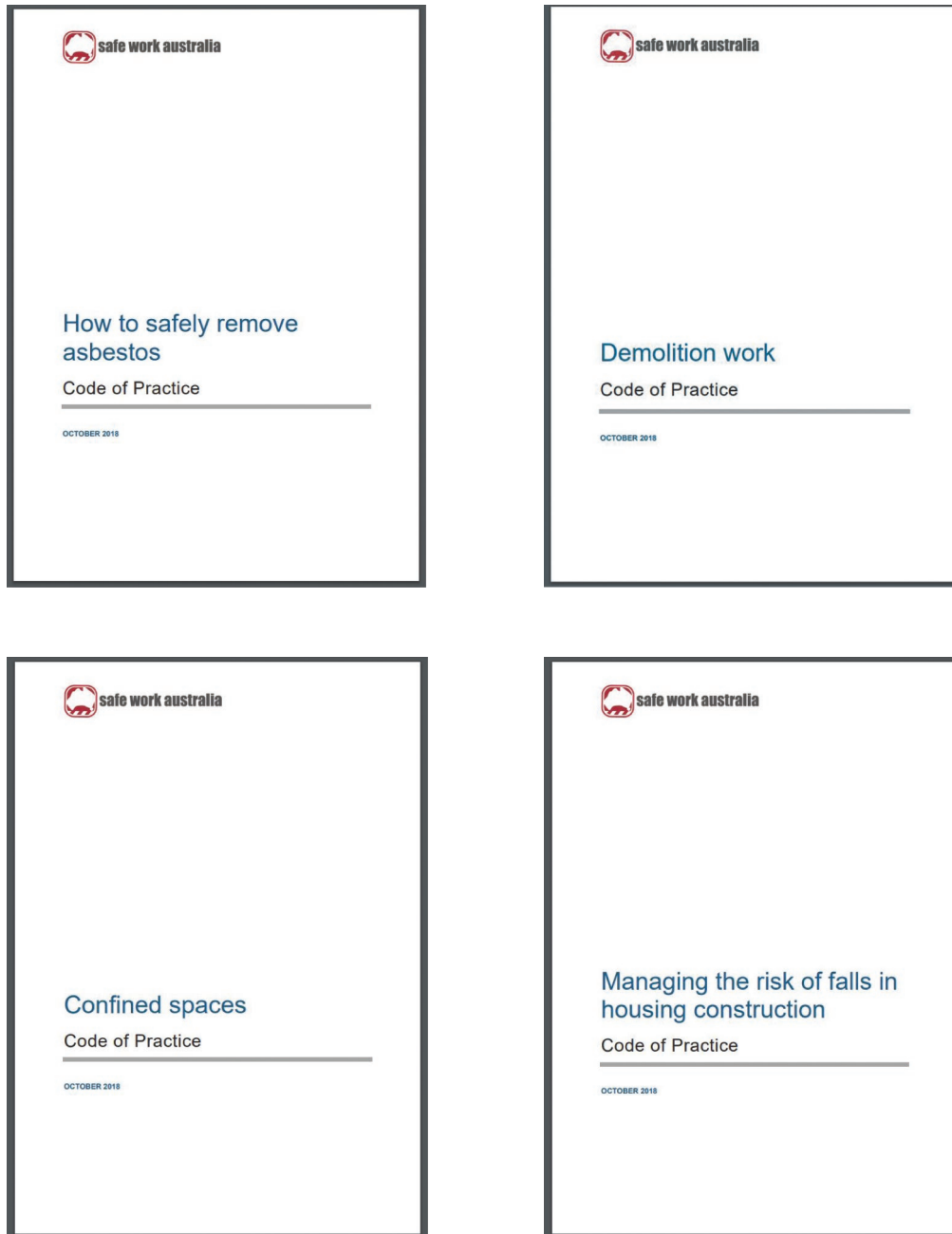
Compliance with codes of practice is not mandatory. In some cases, it may be better to use another method or system of work that results in improved outcomes when compared to the outcomes of a model code of practice. However, all responsibility is on the person using an alternative to a code of practice to prove that it is at least equally safe to use and provides an equivalent or higher standard of WHS than suggested by the code of practice.

A comprehensive register of model codes of practice is available for download at www.safeworkaustralia.gov.au.

Relevant state and territory authorities also have a range of codes of practice related to the construction industry.

CHECK YOUR UNDERSTANDING

6. Name the two pieces of Australian legislation that address workplace safety.
7. List the three different types of compulsory training that all workers must undertake before commencing any construction work.
8. List your state and name the state authority in it that regulates work health and safety.

Fig. 1.27 Codes of practice for high-risk construction work

Courtesy of Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>

1.7 Analyse workplace hazards

The process of analysing workplace hazards would normally commence with a site safety audit or safety inspection. Any worker on site can be called up to assist a safety officer to undertake a safety audit. On larger construction sites, a site safety audit should be undertaken by at least two people to ensure that all hazards are identified. Depending on the level of risk, these may be undertaken every day.

Figure 1.28 shows the front page of a sample site safety checklist to which other items may be added. A very simple handwritten list of risks may also be used in this process provided it is properly signed and dated. Normally the audit report will include recommendations or comments from the person undertaking the safety audit and a date when previous safety issues have been resolved.

Fig. 1.28 Sample front page of a site safety checklist

SITE SAFETY CHECKLIST

Site address			
Contact name			
Contact number			
Date			
Fax number			
Email address			
Prepared by			
SUMMARY OF INSPECTION AND SITE DESCRIPTION			
Comments, additional safety issues and site-specific hazards			
List of issues or hazards that require attention or corrective action			
REQUIREMENT	YES/NO	COMMENT/ACTION REQUIRED	DATE COMPLETE
Safety management Documented WHS management system Workers inducted to site and record kept			
Site safety signs and notices Construction site safety signs displayed			
Site security/public protection Safeguard for public and after hours (e.g. locked plant and switchboards, barricaded trenches, etc.)			
Site amenities Toilets and handwashing facilities Meals area and drinking water			
First aid and emergencies First-aid kit and contact for first-aid assistance Emergency procedure and contact numbers Register of injuries			
Risk assessments and WMS/JSAs Risks assessed for all activities including work at heights, trenching, working near powerlines, etc.			

The site safety audit can then also be used to assist with writing the following documents:

- safe work method statements
- job safety analysis
- health and safety management plans
- work plans
- work schedules.

After completion, the checklist is filed for future reference as evidence that a risk analysis has been carried out.

1.7.1 Risk categories

Once the risks have been identified, each must then be analysed and a 'risk category' determined. A typical risk assessment matrix used in the construction industry is shown in Figure 1.29. The likelihood of occurrence is first identified in the far left-hand column. The consequence is then estimated and from this the category of risk is classified as follows:

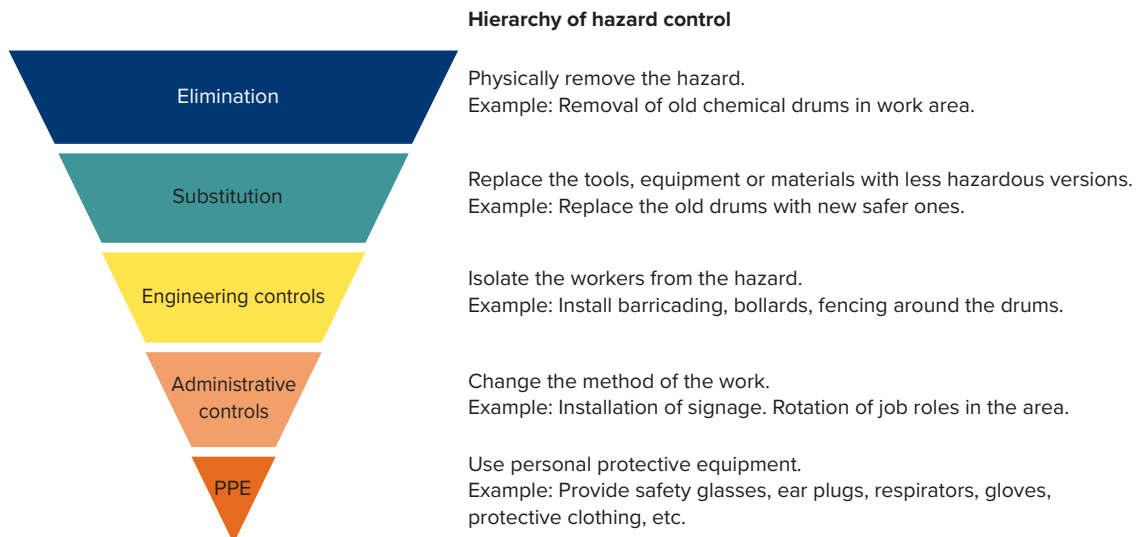
- E–Extreme risk: death or permanent disability
- H–High risk: long-term or serious injury
- M–Moderate risk: lost time
- L–Low risk: first-aid treatment.

Fig. 1.29 Risk assessment matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	M	H	H	E	E
Likely	M	M	H	H	E
Possible	L	M	M	H	E
Unlikely	L	M	M	M	H
Rare	L	L	M	M	H

Where the work undertaken is considered to be a 'high-risk construction activity', a safe work method statement must be developed, identifying an appropriate way—using a hierarchy of hazard control (Fig. 1.30)—to either remove the risk altogether, if feasible, or control the risk to a point where the consequence is either moderate or low.

Fig. 1.30 Hierarchy of hazard control



1.8 Prepare safe work method statements and job safety analysis

A safe work method statement (SWMS) is a simple document that outlines the logical steps required to successfully and safely complete a task. When completed, it should be readily accessible and understandable to workers who use it. According to current legislation, an SWMS must be used to remove or minimise risk when people undertake high-risk construction work. On construction sites valued at more than \$250 000, it is the responsibility of the principal contractor to ensure that all trade contractors provide an SWMS before they undertake high-risk work. Alternatively, a job safety analysis (JSA) may also be utilised. A JSA is a form of risk assessment that includes step-by-step details of how the task is to be carried out safely. It is broken down into three components—basic steps, hazards and procedure. (See here: <https://content.api.worksafe.vic.gov.au/sites/default/files/2018-11/ISBN-Safe-work-method-statements-2018-11.pdf>.)

The Work Health and Safety Regulations 2011 (Cth) state the following requirements for an SWMS (Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>):

Regulation 299 Safe work method statement required for high-risk construction work

- (2) A safe work method statement must:
 - (a) identify the work that is high-risk construction work; and
 - (b) specify hazards relating to the high-risk construction work and risks to health and safety associated with those hazards; and
 - (c) describe the measures to be implemented to control the risks; and
 - (d) describe how the control measures are to be implemented, monitored and reviewed.
- (3) A safe work method statement must:
 - (a) be prepared taking into account all relevant matters, including:
 - (i) circumstances at the workplace that may affect the way in which the high-risk construction work is carried out; and
 - (ii) if the high-risk construction work is carried out in connection with a construction project—the OHS management plan that has been prepared for the workplace; and
 - (b) be set out and expressed in a way that is readily accessible and understandable to persons who use it.

WorkSafe Victoria, the Victorian workplace safety authority, recommends following these five steps when creating a JSA (WorkSafe Victoria, 'Advice for managing major events safely', April 2006, p. 50, <https://www.worksafe.vic.gov.au/resources/advice-managing-major-events-safely>):

- (1) **Document the activity:** Assemble those involved in the activity and then, using the JSA worksheet, write down the tasks that make up the activity, step by step.
- (2) **Identify the hazards:** Next to each task, identify what part of the task may cause injury to those doing the work or to anyone else nearby.
- (3) **Document the control measures:** For each identified hazard, list the measures that need to be put in place to eliminate or minimise any likely risk of injury to those involved.
- (4) **Identify who is responsible:** Document the name of the person responsible for implementing the control measure.
- (5) **Monitor and review:** Make sure the activity is supervised to ensure the documented process is being followed. The JSA should be reviewed whenever a documented activity changes, when there is a change of personnel or after an appropriate length of time.

JSAs and SWMSs are identical in concept but there is no prescriptive or mandated layout. Either document can be designed to achieve the outcomes required under national WHS legislation.

CHECK YOUR UNDERSTANDING

9. List three items of information provided in a safe work method statement.

1.9 Formulate work health and safety management plans

The principal contractor must prepare a WHS management plan before construction work commences. Where the value of the construction work is \$250 000 or more, a WHS management plan is required by law. The principal contractor has a duty to make the WHS management plan accessible for all workers and to review the plan regularly and advise all workers of any changes to the plan.

The size and complexity of WHS management plans for construction sites varies with the size of the job and the number of workers on-site at any time and the number of high-risk construction activities taking place. So certain jobs will have a highly complex, comprehensive and lengthy document comprising several lever-arch files or volumes; larger projects will also include a separate demolition management plan and traffic control plan. For a small trade contractor or a smaller project, a less complex plan is needed.

The WHS Regulations describe the minimum requirements for an WHS management plan. It must include the following in relation to a construction project:

- the names, positions and responsibilities of all persons at the workplace whose positions or roles involve specific health and safety responsibilities
- how persons conducting a business or undertaking at the workplace will undertake consultation, cooperation and the coordination of activities under their duty to comply with the Act and Regulations
- the arrangements for managing any work health and safety incidents that occur
- any site-specific health and safety rules, and arrangements for ensuring that everyone at the workplace is informed of these rules
- the arrangements for the collection, assessment, monitoring and review of the SWMS.

In practice, an WHS site safety management plan can become a much larger overall safety management system by providing additional guidance and information required under WHS legislation, such as:

- evacuation plan
- contact details for the principal contractor and other key safety personnel such as the first-aid officers and safety officers
- site map of first-aid stations and emergency telephones
- register of all general construction induction card holders working on-site
- register of workers who have undertaken site-specific safety training or induction
- register of major plant maintenance schedules
- schedule of all high-risk construction work, including dates, location and who is undertaking the work
- demolition plan
- traffic control plan
- recycling and waste disposal plan
- asbestos removal plan
- silica dust plan
- register of incidents/accidents/near misses
- safety committee details
- worker facilities and amenities available on-site
- location and contact details of closest hospital and medical centres
- register of hazardous substances and materials safety data sheets (MSDS)
- register of required signage.

Student research

1. Review the codes of practice available at Safe Work Australia (www.safeworkaustralia.gov.au) and determine which of these are specific to the construction industry.
2. On the internet, locate a model safe work method statement that applies to your occupation or vocational area of study.

End-of-chapter activities

1. Using AS 1319 safety signs for the occupational environment as a reference, sketch and label the colouring for two signs from each of the following categories:
 - (a) mandatory signs
 - (b) prohibition signs
 - (c) hazard signs
 - (d) emergency information signs.
2. Refer to Safe Work Australia, 'Code of Practice: Managing the work environment and facilities', December 2011, Section 2: The work environment, Part 2.8 Heat and cold and list the following:
 - (a) six ways to minimise the risk of heat strain or exhaustion if it is not possible to eliminate the risk
 - (b) five ways to minimise the risk of exposure to extreme cold if it is not possible to totally eliminate the risk
 - (c) five warning signs of hypothermia to look out for in any of the workers on a particular job.
3. Identify the six levels of the hierarchy of control for working with silica dust-producing construction materials. Then research and report extensively on each level of silica dust safe work practices.
4. Create a safe work method statement for the use of carpentry hand tools required for basic chiselling, sawing, hammering and planing while working at a carpenter's work bench.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1319—
1994
(reconfirmed 2018)
Safety signs for
the occupational
environment

Safe Work
Australia,
Code of Practice:
Managing the work
environment and
facilities

Chapter 2

Construction work hazards and risk control strategies

Learning Objectives

LO 2.1 Plan and prepare for construction work

LO 2.2 Prepare and implement a job safety analysis (JSA)

LO 2.3 Prepare and implement a safe work method statement (SWMS) for high-risk work

Introduction

Job safety analysis (JSA), job safety and environmental analysis (JSEA), job hazard analysis (JHA), safe work method statement (SWMS)—which one do I use?

Confusion often surrounds which document needs to be used for specific construction tasks.

- Should you use a JSA or a SWMS for demolition work?
- Should you use a JSEA or a JHA for work involving flammable adhesives?
- Which document should you use when constructing and erecting wall frames?
- Which document should you use if erecting roof trusses?

All of these are legitimate questions, but they will often receive different answers.

In this chapter you will learn about both the SWMS and JSA so that you know which document to use for specific tasks. We also look at how they often overlap each other as they are very similar in layout and content. We will discuss how you can break down construction tasks into manageable steps, allowing you to identify, assess and manage the hazards and risks associated with each step in relation to the job environment. Ultimately, you will learn how to provide a well-managed and safe workplace for all workers, whether they are directly or indirectly involved in the task.

2.1 Plan and prepare for construction work

2.1.1 National, state and territory work health and safety authorities

The Australian government statutory body that was established in 2008 to develop and evaluate national policy relating to work health and safety (WHS) and workers' compensation is known as 'Safe Work Australia'.

Safe Work Australia is jointly funded via an intergovernmental agreement by the Commonwealth, state and territory governments. Safe Work Australia performs its functions in accordance with its Corporate Plan and Operational Plan. These plans are agreed upon annually by the various state and territory ministers for WHS.

Safe Work Australia is an inclusive body that works in partnership with state and territory governments, employers and employees to drive national policy development on WHS, as well as workers' compensation matters. It works to:

- develop and evaluate national policy and strategies
- develop and evaluate the model work health and safety legislative framework
- undertake research
- collect, analyse and report data.

As a national policy body, Safe Work Australia does not regulate work health and safety laws. Instead, the Commonwealth, states and territories have responsibility for regulating and enforcing WHS laws in their own jurisdictions.

This means that whichever state or territory you are working in, you will need to be familiar with the laws and regulations that have been put in place for that jurisdiction.

For example, a construction company may be based in Albury, New South Wales, and carry out most of its work in and around that city. But if the company is called on to carry out works in Wodonga, which is situated across the border in Victoria, it would have to ensure it complied with any WorkSafe Victoria laws and regulations, which may differ slightly from those in New South Wales.

The individual state and territory work health and safety authorities are listed below:

- New South Wales: SafeWork NSW
- Queensland: Workplace Health and Safety Queensland
- Victoria: WorkSafe Victoria
- Tasmania: WorkSafe Tasmania
- South Australia: SafeWork SA
- Western Australia: WorkSafe WA
- Northern Territory: NT WorkSafe
- Australian Capital Territory: WorkSafe ACT.

2.1.2 Safe Work Australia 'Model Code of Practice: Construction work'—correct use and application

Codes of practice provide practical guidance on meeting the requirements of the *Work Health and Safety Act 2011* (Cth) (WHS Act) and the Work Health and Safety Regulations 2019 (WHS Regulations) they may be used in a court of law as evidence to prove compliance with WHS legislation. Codes of practice also provide practical guidance on how to effectively identify hazards and manage risks in the workplace.

Codes of practice are available, free of charge, to download and use as required from Safe Work Australia or from any individual state or territory work health and safety authority.

Construction sites that are not operating safely will often be referred to a code of practice by WHS inspectors and asked to demonstrate why their work procedures have failed to comply with WHS

legislation. Compliance with codes of practice is not mandatory. In some cases, it may be better to use another method or system of work that results in improved outcomes compared to the outcomes of a model code of practice. However, all responsibility is then on the person using an alternative to a code of practice to prove that it is at least equally as safe to use and provides an equivalent or higher standard of WHS than suggested by the code of practice.

The Safe Work Australia 'Code of Practice: Construction work', May 2018, is an approved code of practice under Section 274 of the *Work Health and Safety Act 2011* (WHS ACT).

This code of practice should be used in conjunction with other codes of practice specific to the tasks being carried out.

For example, for the specific task of erecting roof trusses, you could also use the Work Safe Australia 'Code of Practice: Managing the risk of falls in housing construction', October 2018.

Information contained in the Code of Practice for construction work (Fig. 2.1) includes:

Section 1—Introduction, including the definitions of:

- construction work
- high-risk construction work
- construction projects
- structures
- health and safety responsibilities
- risk management procedures.

Section 2—Construction work-specific duties pertaining to (and with roles and responsibilities explained):

- persons conducting a business or undertaking (PCBU)
- officers
- workers
- other persons.

Section 3—The process of risk management, including:

- hazard identification
- risk assessment
- risk control
- review and maintenance of control measures.

Section 4—Safe work method statements (SWMS):

- definitions
- preparation
- implementation
- reviewing and revision.

Section 5—Work health and safety (WHS) plans:

- definitions
- contents
- preparation
- communicating the plan to others
- reviewing and revision
- correct storage/availability.

Section 6—Requirements for information, training, instruction and supervision, including:

- general construction induction card (CIC/White Card)
- specific workplace induction training
- other required training
- supervision.

Section 7—General workplace management arrangements, including:

- Appendices A to K, giving examples and templates for all information mentioned in sections 1–6
- construction workplace facility requirements
- current code of practice amendments to the current version, 2018.

The Safe Work Australia Model Code of Practice can be accessed and downloaded from www.safeworkaustralia.gov.au.

2.1.3 Construction terminology relevant to hazard identification and control strategies

Construction industry terminology covers every aspect of the construction industry.

No matter the task, specific terminology will have to be learned in relation to it.

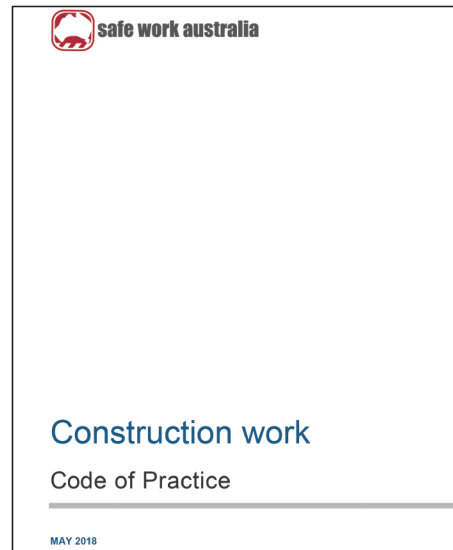
The glossary of terms in Appendix A of the Safe Work Australia 'Code of Practice: Construction work' provides terms and descriptions relevant to the writing of a JSA or SWMS.

Formulating these safe work method documents will be a lot easier if you have a good understanding of the terms and descriptions, as they are a requirement of the health and safety process.

Some important terms and definitions you will need to know to create a JSA or SWMS include, but are not limited to, the following:

- **Control measure:** an action taken, in conjunction with the use of a hierarchy of control as set out in the WHS regulations, to as far as is reasonably practicable eliminate or minimise health and safety risks. A control measure can also be referred to as a risk control measure or a risk control.
- **Hazard:** anything that has the potential to cause harm to a person. This could be a physical hazard, such as machinery, tools and chemicals, or a situation which might include bullying, physical violence or repetitive work.
- **Hierarchy of control:** a system of controls written in descending order and used to minimise or eliminate exposure to hazards. It commences with the most effective control, elimination, followed in descending order by substitution, isolation, engineering controls, administration controls and personal protective equipment (PPE).
- **Managing risk:** a process set out in WHS regulations to eliminate health and safety risks as far as is reasonably practicable. If this is not possible, then the aim is to minimise the risk as much as possible. Managing risk also includes hazard identification, assessment and implementation of control measures and the ongoing review of these measures.
- **May:** notes an optional course of action.
- **Must:** notes that a legal requirement exists that has to be observed.
- **Person conducting a business or undertaking (PCBU):** can include a company, unincorporated body or association, sole trader or self-employed person.
- **Risk:** the possibility that harm (death, injury or illness) may occur when exposed to a hazard.
- **Should:** notes a recommended action.

Fig. 2.1 Code of Practice for construction work



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2.1.4 Worksite inspections and identifying hazards, risks and potential causes of incidents and near-misses

The specific steps associated with safely carrying out a construction task should not be the only things you consider when formulating a JSA or SWMS. The entire worksite—including the personnel who come and go, the placement of construction materials, the plant and equipment and the physical changes in the building as construction progresses—needs to be considered.

Every building site has an ever-changing environment. The process of analysing workplace hazards would normally commence with a site safety audit or safety inspection.

Using a site safety action plan (see WorkSafe Victoria—Safety action plan at www.worksafe.vic.gov.au and a site safety checklist (see Fig. 1.28 ‘Sample front page of a site safety checklist’) can help the site audit process as any identified potential hazards or risks can instantly be classified and documented for immediate action, while specific required items that should already be in place such as signage, barricading, first-aid equipment and facilities can also be checked off on the site safety checklist.

Domestic building sites such as housing construction or renovations can be assessed by the builder and apprentice. It takes just a little time to look around and identify and note any potential hazards that may present themselves during the day’s work. These might include the fact that subcontractors are arriving periodically to carry out specific work tasks, that building materials may be scheduled for delivery, that homeowners may be scheduled for a walk-through, or that building inspections may be booked and inspectors will be on-site. These can all be documented for later inclusion in a JSA or SWMS when required.

On large commercial or industrial building sites, there may be a more diverse range of personnel involved in a site safety audit walk-through, depending on the scope of the work being undertaken at the time.

These personnel may at times include:

- structural engineers
- civil engineers
- project managers
- site managers/foremen or women
- OH&S officers or representatives
- union representatives
- leading hand tradespersons
- tradespersons
- apprentices.

Due to the ever-changing nature of the workplace on a building or construction site, it will be necessary to conduct a site safety audit whenever major changes to the work environment occur. This could involve a walk-through at least once or several times a week or, if required, at the start of each workday.

The site safety audit can then also be used to assist with writing the following documents:

- SWMS
- JSA
- health and safety management plans
- work plans
- work schedules.

On completion, the checklist can then be stored electronically or filed and stored as paper-based documents for future reference as evidence that a risk analysis has been carried out.

CHECK YOUR UNDERSTANDING

1. Go to the following web link and watch the three short videos relating to site inspections, then answer the following questions: <https://www.worksafe.vic.gov.au/do-your-own-inspection>.

Video 1: Find the hazards in your workplace

- (a) What would be the first action taken during an inspection of the workplace?
- (b) How would you define a hazard?
- (c) Name two hazards in the workplace that may be harder to identify.
- (d) What would be a good way to identify hazards that regularly affect your workplace?

Video 2: Assess the risks

- (a) What needs to be done immediately after any hazards have been identified and listed?
- (b) Which hazards need to be the first to have risk control measures implemented around them?
- (c) What needs to happen when new tasks are introduced into the workplace?

Video 3: Fix the problems

- (a) Who often gives the best suggestions for dealing with hazards and risks, and why?
- (b) What is the first aim of controlling a hazard and the associated risks?

2.1.5 Identifying risk management strategies for the task

2.1.5.1 Work health and safety management plan

After carrying out worksite inspections for hazards and potential risks, risk management strategies need to be identified so they can then be used in formulating the JSA or SWMS.

The work health and safety management plan for the construction site can be an extremely useful reference document if you need to find specific information regarding the site.

The principal contractor must prepare a work health and safety (WHS) management plan before construction work commences. Where the value of the construction work is \$250 000 or more, a WHS management plan is required by law. The principal contractor has a duty to make the WHS management plan accessible to all workers and to review the plan regularly and advise all workers of any changes to the plan. The size and complexity of WHS management plans for construction sites vary with the size of the job, the number of workers on-site at any time and the number of high-risk construction activities taking place. So, certain jobs will have a complex, comprehensive and lengthy document comprising several lever-arch files or volumes; larger projects will also include a separate demolition management plan and traffic control plan. For a small trade contractor or a smaller project, a less complex plan is needed. The WHS Regulations describe the minimum requirements for a WHS management plan, which must include the following in relation to a construction project:

- the names, positions and responsibilities of everyone at the workplace with positions or roles that involve specific health and safety responsibilities
- how people conducting a business or undertaking at the workplace will carry out the appropriate consultation, cooperation and coordination of activities under their duty in compliance with the Act and regulations
- the arrangements for managing any work health and safety incidents that occur
- any site-specific health and safety rules, and arrangements for ensuring that everyone at the workplace is informed of these rules
- arrangements for the collection, assessment, monitoring and review of the SWMS.

In practice, a WHS site safety management plan can become a much larger overall safety management system by providing additional guidance and information required under WHS legislation, such as the:

- evacuation plan
- contact details for the principal contractor and other key safety personnel such as the first-aid officers and safety officers
- site map of first-aid stations and emergency telephones
- register of all general construction induction card holders working on-site
- register of workers who have undertaken site-specific safety training or induction
- register of major plant maintenance schedules
- schedule of all high-risk construction work, including dates, locations and details about who is undertaking the work
- demolition plan
- traffic control plan
- recycling and waste disposal plan
- asbestos removal plan
- register of incidents/accidents/near-misses
- safety committee details
- worker facilities and amenities available on-site
- location and contact details of the closest hospital and medical centres
- register of hazardous substances and material safety data sheets (MSDS)
- register of required signage.

2.1.5.2 Risk categories

Once the risks have been identified, each must then be analysed and a 'risk category' determined. This would be a typical risk assessment matrix used in the construction industry.

The likelihood of occurrence is first identified in the far left-hand column. The severity of consequence is then estimated and from this the category of risk is classified as follows:

- E–Extreme risk: death or permanent disability
- H–High risk: long-term or serious injury
- M–Moderate risk: lost time
- L–Low risk: first-aid treatment.

Where the work undertaken is considered to be a 'high-risk construction activity', a SWMS must be developed, identifying an appropriate way—using a hierarchy of hazard control (see Fig. 1.30 'Hierarchy of hazard control')—to either remove the risk altogether, if feasible, or control the risk to a point where the consequence is either moderate or low.

2.1.5.3 Hierarchy of control

The purpose of a hierarchy of control is to determine which hazard or risk control measures will best help eliminate or minimise each identified hazard or risk.

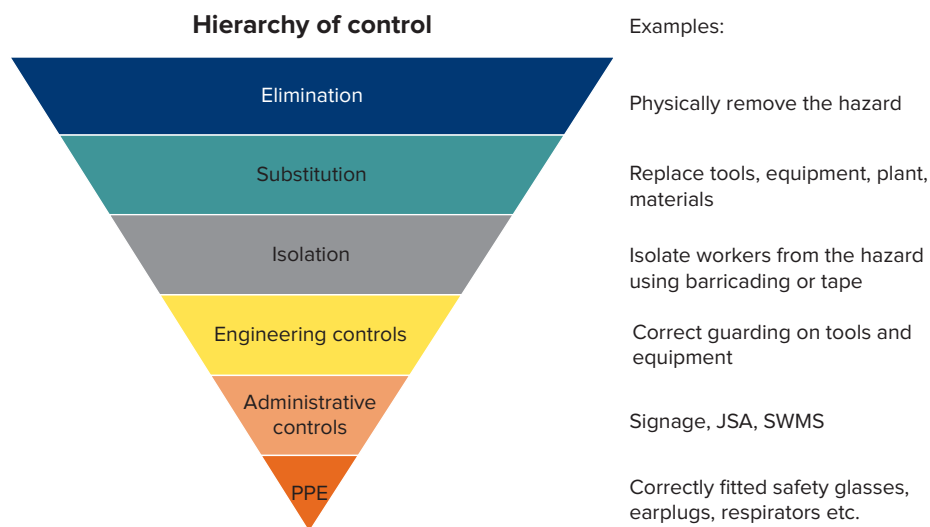
Generally, there are five or six levels in the hierarchy of control used in the construction industry. If a five-level hierarchy of control is used, the isolation and engineering control levels will generally be combined.

The following section lists six levels of control. To effectively eliminate or control any hazard or risk, the highest control level possible should be employed.

These include, in order from the highest to lowest levels (Fig. 2.2):

- **Elimination:** the top level of control needs to be the first consideration. Can the hazard or risk be eliminated or removed from the workplace completely? An example of elimination could be to backfill and compact any open trenches immediately after work has been completed rather than leaving them open for a period.
- **Substitution:** minimise the hazard or risk by substituting one work practice with a safer practice. An example of substitution could be setting up safe work platforms or scaffolding to install roof trusses rather than walking the top plates.
- **Isolation:** an example of this could be setting up barricading to stop workers or the general public from entering specific work areas.
- **Engineering controls:** these could include practices such as installing shoring to excavations to prevent the collapse of the excavation, trapping workers.
- **Administrative controls:** examples include using signage to give information, directions or warnings regarding workplace procedures. The JSA and SWMS are each considered to be administrative controls. So too are work schedules, training programs, safe operating procedures (SOP), manufacturer's instructions and material safety data sheets (MSDS).
- **PPE:** this is the last resort. When all other control measures can only reduce but not fully eliminate the hazard or risk, PPE should be considered to complement the other implemented control measures. PPE must be correctly fitted and used to maximise its effectiveness.

Fig. 2.2 Hierarchy of control



With all of the information now collected from the previous sections of this chapter, we are ready to proceed with formulating a JSA or SWMS.

2.2 Prepare and implement a job safety analysis (JSA)

2.2.1 What is a JSA?

The JSA has been used in the Australian construction industry for many years now.

This is a document that outlines the steps required to safely complete a specific work task on a given day or days, as long as the task is not classed as high-risk work.

The JSA is a live document and will need to be amended and updated if work conditions change. This could include such factors as changes in the weather or changes to the work environment—for example, building material deliveries and new plant or subcontractors arriving on-site.

The JSA will often be formulated by the worker or workers who are going to carry out the task. These workers will need to have been correctly trained in all aspects of preparing a JSA.

The JSA will consider the personnel on the job site, the tools and equipment to be used, the building materials and accessories to be used, the required PPE and the workplace environment.

It will include step-by-step details of how the task is to be safely carried out, such as:

- hazard and risk identification, for each step
- control measures for the identified hazards and risks
- the person or persons who will be responsible for each step of the task being carried out in a safe manner.

2.2.2 Preparing and implementing a JSA

WorkSafe Victoria, the Victorian workplace safety authority, recommends following these five steps when creating a JSA (courtesy of WorkSafe Victoria):

1. Document the activity: assemble those involved in the activity and then, using the JSA worksheet, write down the tasks that make up the activity, step by step.
2. Identify the hazards: next to each task, identify what part of the task may cause injury to those doing the work or to anyone else nearby.
3. Document the control measures: for each identified hazard, list the measures that need to be put in place to eliminate or minimise any likely risk of injury to those involved.
4. Identify who is responsible: document the name of the person responsible for implementing the control measures.
5. Monitor and review: make sure the activity is supervised to ensure the documented process is being followed. The JSA should be reviewed whenever a documented activity changes, if there is a change of personnel or after an appropriate period of time.

In summary, the JSA:

- provides a written record of the process to be used to undertake a task. As it is a record that can be used in court, it should be signed off by the parties who have responsibility for the tasks.
- is only a written record. Management processes must be in place to ensure workers have the skills to complete the job and that there is a required level of supervision to ensure the tasks are completed as documented.
- should be developed in consultation with all employees who may undertake the task, not just the principal contractor or supervisor. The JSA must be kept on-site in a prominent position for easy access.

2.3 Prepare and implement a safe work method statement (SWMS) for high-risk work

The Safe Work Australia 'Safe work method statement for high-risk construction work' information sheet gives clear guidance on the content of the SWMS and the responsibilities of the workers involved with implementing it for high-risk work.

2.3.1 What is a SWMS?

The SWMS has been adopted by the construction industry as an administrative control document that identifies and outlines the steps required to successfully and safely complete **high-risk** construction work activities.

According to current legislation, a SWMS must be fully completed and in place before workers undertake any high-risk construction work.

It can also be used in place of a JSA for everyday work tasks that are not considered high risk.

For this reason, it is now more likely that a SWMS will be used for most tasks (both high- or low-risk work) that take place on a building site.

2.3.2 Preparing and implementing a SWMS

A SWMS can be used for multiple high-risk tasks undertaken over the total course of a construction project. Like a JSA, it will need to be reviewed and amended if the work conditions change.

A SWMS for high-risk work must be prepared by the persons conducting a business or undertaking (PCBU), or the PCBU must ensure that a SWMS has been prepared by the builder or subcontractor for themselves and their workers.

The SWMS will identify the nature of the high-risk work to be carried out. Like a JSA, it will break down the task(s) into logical steps. It will:

- identify the hazards and associated risks involved in carrying out the task(s)
- include the control measures for the identified hazards and risks
- identify the person(s) responsible for each step of the task being carried out in a safe manner.

When completed, the SWMS or JSA may be distributed electronically or printed out and handed to all involved personnel.

The SWMS or JSA can be stored on-site as paper-based documents or on any electronic devices and programs being used to coordinate the construction project. They should always be readily accessible via these mediums if reviews or amendments are required and should be written so they are understandable to all workers who use them.

Safe Work Australia states in its 'Safe work method statement for high-risk construction work' information sheet that a SWMS **must**:

- identify work that is high-risk construction work
- specify the hazards relating to the high-risk construction work and the risks to health and safety
- describe the measures to be implemented to control the risks
- describe how the control measures are to be implemented, monitored and reviewed.

A SWMS should also be short and focused on describing any specific hazards identified for the high-risk construction work that is to be undertaken. It should describe the control measures that are to be put in place so that the high-risk work can be carried out safely. A SWMS that is long and overly detailed can lead to confusion as it may be difficult to follow, hard to apply in the high-risk workplace and difficult to monitor or review.

The SWMS must be easy for all workers to understand–remember, not all workers will be from English-speaking backgrounds. Pictures, drawings, sketches or diagrams may be a more effective way of communicating the required information.

There are other legislative requirements regarding the assurance of health and safety such as controlling exposure to noise, dust or other hazardous materials, but these hazard and risk controls do not need to be included in detail in the SWMS.

If the SWMS is written along with a workplace-specific risk assessment, evidence of this risk assessment may need to be provided to the regulator or for auditing purposes if required, but this information does not need to be written up in detail in the SWMS.

Student research

1. Print out the safety action plan from the earlier link and do an inspection of your worksite or trade school live work area. Identify any hazards and list them in order of priority from high to low. Add any required actions, responsibilities and timelines.
2. Visit the following SafeWork SA web link and download a copy of the Hazard list and risk assessment register: https://www.safework.sa.gov.au/__data/assets/word_doc/0010/143785/Simple-Steps-Hazard-and-Risk-Register.docx.
Using this document and the risk level analysis chart shown in Chapter 1, Figure 1.30, complete a risk level analysis of the hazards you identified in your safety action plan from the earlier worksite inspection section.
3. Download the JSA template from the following link and fill out all of the sections for a work-related task that is not considered high risk: <https://www.commerce.wa.gov.au/publications/job-safety-analysis-jsa>.
Some examples could be: carrying out the building set-out, standing prefabricated wall frames, installing door jambs and hanging doors.

End-of-chapter activity

Use the following link to download the 'Subbypack' attachment as provided: <https://www.commerce.wa.gov.au/publications/ohse-subbypack>. Using the 'Subbypack', Sections 2–7, complete the required forms and develop a SWMS for a high-risk construction project you are working on or have worked on, including the development and writing of the SWMS.

Example: The demolition of an old unused brick veneer house; the erection of roof trusses on a two-storey house; or cutting and pitching a roof for a house (working at height).

Sections to be completed include:

- Section 002: Project details and introduction
- Section 005: Hazard categories
- Section 007: Safe work method statement (SWMS).

Sections 3, 4 and 6 are to be used as references for the completion of these listed sections.

The SWMS should be carefully planned and all sections filled out in detail.

AUSTRALIAN BUILDING CODES AND STANDARDS

A circular graphic with a light blue border. Inside the circle, the text "Safe Work Australia, Code of Practice: Construction work, May 2018" is written in a dark blue, sans-serif font, centered and arranged in four lines.

Safe Work
Australia, Code
of Practice:
Construction work,
May 2018

Chapter 3

Workplace communication

Learning Objectives

LO 3.1 Understand important forms of communication for construction workers

LO 3.2 Communicate in work teams

LO 3.3 Communicate with employers and supervisors

LO 3.4 Resolve disputes

Introduction

Australia's building and construction industry now offers remarkably diverse employment opportunities. People with varying physical and mental abilities and a range of cultural and ethnic backgrounds are employed in many different roles on building sites across the country every day. Ultimately, they all contribute to one common goal: to communicate and work together and get the job done to the required national standards and quality levels.

In the building and construction industry, many different languages are used every day across numerous worksites. The mixture of ethnic backgrounds and different languages, combined with a noisy work environment, can sometimes make communication difficult. In addition, common construction terms are meaningless to someone who has never worked in the construction industry before, so there is the need to learn a new workplace language, as well as understand the different forms of communication. Plus, not all workers on a construction site will have a complete understanding of the next worker's role. Communication is thus an important factor in achieving a safe work environment and conveying the specific roles of other workers.

When starting a new job, it is important to first introduce yourself and let others know what your role involves, as well as asking questions about what they are doing so you can engage in conversation. Doing this, you will soon gain a better understanding of the many tasks being carried out around you, and you will get to know the people you are working with, and learn how best to communicate with them.

You will need to understand the different types of communication skills required to work effectively and cohesively with others in the construction industry. Some workers may not speak English very

well, others may have hearing or eyesight problems, while some may have a poor grasp of the use of electronic communication devices such as mobile phones, tablets or computers. But effective communication needs to take place nonetheless.

The communication skills that you will learn will give you the confidence to conduct face-to-face, visual, electronic and written communication with your employers, supervisors, work team members, other construction site workers and members of the public. But how does a newly recruited construction worker with little industry experience effectively communicate with the other workers they interact with every day? To be an effective communicator, you need to consider some important points to ensure the information you are providing or receiving is understood by the many different people you will be working alongside. With your new skills you will be able to clearly gather, deliver, receive and clarify information using the correct means of communication.

Additionally, workplace meetings occur regularly on construction sites, for various reasons ranging from toolbox meetings to dispute resolution. The ability to participate in and contribute to workplace meetings, or to conduct yourself professionally if you are involved in any type of workplace dispute, is a particularly important communication skill to learn.

TIP The mix of different languages, occupations, age groups and levels of work experience on a worksite can create barriers to communication between construction workers. Other barriers include a noisy workplace, misunderstandings that lead to arguments and mistakes, and impoliteness. However, most of these barriers can be overcome by clearly and effectively using the correct communication techniques explained in this chapter.

3.1 Understand important forms of communication for construction workers

Direct communication with another worker is the main form of communication on construction worksites. However, effective communication involves far more than being able to speak with another person in the same language. There are other equally important visual forms of communication.

3.1.1 Direct communication

A face-to-face discussion, a telephone conversation, radio communication, hand signals and gestures are all direct methods of communication between individuals or a number of workers.

3.1.1.1 Face-to-face verbal communication

Face-to-face verbal communication is probably the most used form of communication on construction worksites. For this to be effective, you must speak clearly and loudly enough to be heard. Remember that older construction workers may have hearing damage. Softly or quietly spoken words are difficult to hear and can be misunderstood.

If you are uncertain about whether your message has been heard clearly, ask the person if they understood you. For example, you could say, 'Did I make sense?' or 'Did I explain that properly?' Don't say, 'Didn't you understand me?' or 'Do I need to say that again?' as some workers may interpret this as suggesting they don't understand English or they are not intelligent.

Pay attention to what others are telling you and face them when they communicate with you. If you can't hear very well because of background noise, read their lips and watch their expressions as well as trying to listen to what they say. Move to a quieter work area if necessary.

Do not pretend to understand what has been said! Ask politely for the information to be repeated and ask any related questions to ensure that you understand what has been said to you. Experienced workers appreciate honesty, and good supervisors will know that you take your job seriously rather than pretending to understand.

SAFETY TIPS Noisy work areas

- When wearing hearing protection, don't remove the protection in a noisy work area to speak.
- Stand closely to the worker you wish to speak to and speak loudly or shout and read their lips. They should be able to hear and understand.
- Move to a less noisy work area if necessary.

3.1.1.2 Telephone, radio, mobile phone

If you are using a mobile phone or radio to communicate with another worker, make sure you speak clearly and use these devices only where background noise is low and the person listening can hear you (Fig. 3.1). Alternatively, use text messages and include a related image in the message.

Two-way radios are also commonly used on construction worksites, but you must follow the correct two-way radio procedure to ensure that the communication is understood.

TIPS Using a two-way radio

- Turn your microphone on when speaking and off when listening.
- Establish radio contact first by identifying and calling the name or call sign of the person you are communicating with. Then identify yourself.
- Sign off each time you have finished speaking using the term 'over'.
- End the communication by saying 'out'.
- Do not communicate any information that you do not want others to hear. There is no privacy with two-way radio conversations.

Fig. 3.1 Two-way radio communication



Courtesy of Alister Ford

3.1.1.3 Gestures and hand signals

When communicating directly with other workers using gestures such as nodding 'yes', shaking your head 'no' or shrugging that you don't know, make sure the worker you are communicating with is watching you and mouth the words so that they can read your lips if you are in a noisy work area.

Hand signals play an important role in communicating directly with other workers. When using hand signals such as an upright arm with the palm of your hand facing a person to signal 'stop', keep giving that signal until they stop (see Fig. 3.2). Do not assume they have seen your hand signal until they respond by stopping.

3.1.2 Visual communication

Visual communication on construction sites plays an equally important role as direct communication and is a method used to convey official site requirements and rules.

3.1.2.1 Building plans and specifications

Building drawings, or plans, together with **engineer's detailed drawings** and **specifications** are the principle method of communicating how a building is to be constructed. The ability to read and interpret plans is an essential skill for all construction workers.

Tradespeople are expected to be able to read and interpret the scope and detail of work that they are required to carry out as part of their contribution to the overall construction of a building.

A site manager is expected to be able to read and interpret all aspects of a building plan and to then communicate the requirements of that plan to individual trades. Building plans are the common line of communication between the building designer and those who will construct the building.

An important part of early plan reading is the ability to locate the correct building site if it is in a new estate or a remote location. The site plan will contain details of the suburbs, towns, localities, lot numbers and street names, but the ability to find the correct location via electronic or paper-based maps is especially important. No one wants or needs to be driving around looking for the correct building site.

On larger commercial and industrial construction sites and now on some domestic building sites, communication regarding plans and specifications is being carried out totally via cloud-based apps, programs and platforms. Refer to Chapter 5, Trade drawings, section 5.2.5, Specifications, for more information regarding these latest trends in construction communication methods.

Fig. 3.2 Traffic control: signalling 'Stop!'



Courtesy of Alister Ford



INTERPRETING PLANS

Review the housing plans in the Appendix. From drawing 01, identify and answer the following:

1. What is the address of the building allotment for the proposed new residence?
2. Who is the client?
3. What is the current status of the adjoining lots 8, 10 and 11?
4. What is the difference in height between the floor level and the excavation level?
5. What is the distance between the front and rear boundary of the building site?
6. How wide is the building site?
7. The site has a fall or downward slope. Is the fall from front to back or back to front?
8. What is the soil type (classification) for the building site?
9. What is the wind classification for the building site?
10. What is the BAL (Bushfire Attack Level) rating for the building site?

3.1.2.2 Communication using mobile phones, tablets, personal computers, apps, emails, copier/scanners

Communication using electronic devices has come a long way in recent years and now, at the click of a button or the touch of a screen, you can access any number of installed communication apps and have a video or voice conversation with almost anyone just about anywhere. Again, good communication skills—such as speaking clearly, listening attentively and trying not to speak over the other person—are needed.

This type of communication is especially useful on a building site as not only can a conversation take place, but viewing the matter at hand can now be done in real time. So it may be the case that a company supervisor or director, a building materials supplier or a sub-contractor can have a direct view of the situation and be able to make on-the-spot decisions while on another building site or in an off-site office, allowing the job to progress without delay. The time and date of the conversation will also be automatically recorded.

These modern communications devices provide ways to communicate with construction workers that can be included with other forms of communication or used alone. For example:

- construction site issues such as building plan errors, mismatched building finishes, defective building work and unsafe work areas can be photographed and sent via text message or app on a mobile phone or tablet, or as an attachment with an email
- a handwritten order can be photographed and sent as an email attachment via mobile phone or tablet, or alternatively an order can be typed as a text message and forwarded to a supplier
- if a copier/scanner is available, many of these machines now have a scan-and-send email application. You can send a hand-drawn sketch, handwritten message or any other relevant document, which will be delivered immediately to the structural engineer via the scan-and-send email feature.

3.1.2.3 Hand-drawn sketches

The simple sketching of on-site construction details, together with other direct communication, including speech, can overcome many barriers to effective communication. Different languages, occupations and levels of work experience create barriers to communication that can be overcome by including sketches as part of the process of communicating and receiving facts and ideas (see Fig. 3.3).

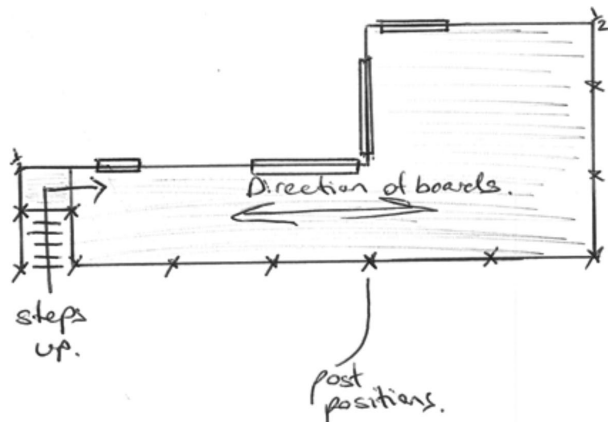
3.1.2.4 Written communication and site documents

Written communication in the form of handwritten or typed documents is commonly used with construction work. However, to deal with this type of communication you must be able to read or write a range of different documents. The ability to read correctly and understand what is written and the ability to write by hand or type or enter text into a mobile phone are extremely important skills widely used in the construction industry.

Examples of relevant documents include:

- *Site safety plans, safe work method statements, safe operating procedures and accident reports* (refer to Chapter 1, Work health and safety).
- *Material labels and material safety data sheets (MSDS)*. For safety reasons it is very important that you know how to access, read and understand the MSDS or material labels for any products or materials

Fig. 3.3 Sketched layout of decking and posts



in the building industry. The information on these documents also needs to be communicated to other workers on the job site so they are aware of any substances or materials that may be harmful to health if they are improperly exposed to the product. Anyone working on the site should be aware of important points such as material handling and working procedures, required personal protective equipment (PPE), spills or leakage actions and clean-up, emergency medical procedures, and manufacturer and supplier information before the work starts. Information

on understanding safety data sheets can be downloaded from www.safeworkaustralia.gov.au.

- *Company policies, procedures, regulations and quality requirements.* These items may be written into your contract of employment, giving a clear indication of the company's expectations of you. They can also be used in a broader sense to cover the expectations and quality requirements of all employees in the many job roles over the many different job sites in regard to work practices and finished products. All of these policies, procedures, regulations and requirements must be followed to maintain a safe and harmonious workplace and to uphold the standards of professionalism, workmanship and product quality that the company requires.
- *Work bulletins, site notices, memos, work instructions (including specifications and requirements), work plans and work schedules.* Depending on the worksite, any of these documents could be displayed on a noticeboard in or outside the site office or plan room, or even in the employee break room. These documents may also be sent to individuals or work teams electronically. Another method of distribution is to provide handouts to all team members at toolbox meetings before work commences. However you receive these documents, you must read them carefully and understand what is required of you with regard to the mentioned work. If at any stage you are unsure of what is required, it is important to ask your supervisor to clarify these points to avoid risking any mistakes or accidents.
- *Time sheets, pay dockets (Fig. 3.4), claim forms.* It is especially important that you know how to fill out your time sheets clearly and correctly, whether by hand or electronically. Any mistakes on your

Fig. 3.4 Example of a pay docket

Pay advice: Pro-Build Constructions ABN: 76 872 932 179 Name: Phillip McNeight Award: Building & Construction General On-Site Award—Carpenter Date of payment: 26-11-2020. Pay period: 19-11-2020 to 25-11-2020 Hourly rate: \$32.00 Annual salary: \$63,332.00 Bank details: CBA. BSB 1234 A/C 567890 Leave accrual as at 25-11-2020 Annual leave: 114 Hours Personal/carer's leave: 45.6 Hours LSL: 68.4 Hours.			
Entitlements	Unit	Rate	Total
Wages for ordinary hours worked	40 hours	\$32.00	\$1280.00
Travel allowance	5 days	\$15.00	\$75.00
Minus RTO accrual	2 hours	\$32.00	-\$64.00
Leave taken during the pay period	00 hours	\$00.00	\$00.00
TOTAL ORDINARY HOURS PAID = 38 hours			
TOTAL RTO HOURS ACCRUED = 6			
OT × 1.5	00 hours	\$00.00	\$00.00
OT × 2	00 hours	\$00.00	\$00.00
Gross payment			\$1291.00
Deductions			
Taxation			\$330.00-
Union fees			\$9.80-
Total deductions			\$339.80-
Net payment			\$951.20
Employer superannuation contribution—12%			
BUS			
Contribution			\$154.92

time sheet could mean a delay in your wages being paid. Always check your pay slips. Learn how to read them properly. Do not just take it for granted that your wages will be correct every time. Mistakes do sometimes get made. Your pay slip will contain a lot of information with which you need to keep up to date, such as your pay scale or hourly rate, the amount of tax you pay, how much is being contributed to your superannuation account, how much sick leave you have, how much annual leave you are entitled to and how much long service leave you are entitled to. If at any time you are unsure of the information on your pay slip, talk to your employer. They will explain it to you and the information you take on board from this one simple act of communication will help you in times to come.

- *Orders (Fig. 3.5), delivery dockets and invoices (Figs 3.6 and 3.7).* It is crucial to understand these particularly important documents. If you are signing for a delivery, you must know how to check that you are receiving the correct materials, tools or equipment, in terms of both quality and quantity. You must also be able to give clear directions regarding distribution, stacking or storage of the items around the worksite according to the given workplans. Sign for the delivery only when you are sure that all of the items on the delivery docket have been delivered and are undamaged. If you believe that any items are missing or have been damaged during transportation, you should not sign as you may put yourself in a compromised position, and some of the blame may be apportioned back to you. Instead, bring the problem to the attention of your supervisor so that it can be sorted out promptly and effectively with the company providing the goods.

Fig. 3.5 Example of a purchase order

Pro-Build Construction 575453 ABN: 78 872 932 179		Purchase Order	
18–28 South Road		ORDER NO.	170474D
City West, Victoria 3006		DATE	15-12-2020
(03) 987 654 3211		CUSTOMER ID	Premier Building Supplies
TO	David Thompson		
	Premier Building Supplies. 6-18 Princes Highway, City West. Vic. 3006		
Quantity	Description	Unit price	Total
415.00	L/M 90 × 20 Merbau Decking	4.50	1867.50
4.80	L/M H3 Treated Pine 290 × 45 F7	14.20	68.16
14.70	L/M H3 Treated Pine 190 × 45 F7	9.50	139.65
39.60	L/M H3 Treated Pine 140 × 45 F7	7.15	283.14
15.00	L/M H3 Treated Pine 90 × 35	4.10	61.50
15.00	L/M H3 Treated Pine 50 × 35	2.50	37.50
18.00	L/M Dressed Hardwood Posts 90 × 90	23.50	423.00
27.00	L/M H3 Treated Pine 140 × 35	5.50	148.50
33.00	L/M 90 × 35 Treated Pine—'Terminator'	4.00	132.00
4.00	Secura FC Interior 2.7 × 0.6 Sheets	100.00	400.00
20.00	Galvanised Post Holders 90 × 90	8.00	160.00
1.00	Box Galvanised 65 mm Coach Screws	25.00	25.00
		Subtotal	\$3745.95
		GST	374.60
		Total	\$4120.55

Fig. 3.6 Example of a delivery docket

DELIVERY DOCKET			
TJ HARDWARE PTY LTD 367 CHAMBER RD WYOMING			
DELIVERY NO	070513/05	ORDER NO.	170474D
DATE	20 December 2020	DATE	15 December 2020
DRIVER	Henderson	CUSTOMER ID	David Thompson
TO		David Thompson Premier Building Supplies. 6-18 Princes Highway, City West. Vic. 3006	
THE FOLLOWING ITEMS IN GOOD ORDER AND CONDITION			
Quantity	Description		
415.00	L/M 90 × 20 Merbau Decking		
4.80	L/M H3 Treated Pine 290 × 45 F7		
14.70	L/M H3 Treated Pine 190 × 45 F7		
39.60	L/M H3 Treated Pine 140 × 45 F7		
15.00	L/M H3 Treated Pine 90 × 35		
15.00	L/M H3 Treated Pine 50 × 35		
18.00	L/M Dressed Hardwood Posts 90 × 90		
27.00	L/M H3 Treated Pine 140 × 35		
33.00	L/M 90 × 35 Treated Pine—'Terminator'		
4.00	Secura FC Interior 2.7 × 0.6 Sheets		
20.00	Galvanised Post Holders 90 × 90		
1.00	Box Galvanised 65 mm Coach Screws		
SUPPLIER SIGNATURE		RECIPIENT SIGNATURE	
TERMS 7 DAYS FOR ANY CLAIMS			

Fig. 3.7 Example of a tax invoice

TJ HARDWARE ABN: 72 534 801 766			INVOICE	
18–28 South Road		TAX INVOICE	170474D	
City West, Victoria 3006		DATE	15-12-2020	
(03) 987 654 3211		CUSTOMER ID	David Thompson	
TO	David Thompson Premier Building Supplies. 6-18 Princes Highway, City West. Vic. 3006			
Quantity	Description	Unit price	Total	
415.00	L/M 90 × 20 Merbau Decking	4.50	1867.50	
4.80	L/M H3 Treated Pine 290 × 45 F7	14.20	68.16	
14.70	L/M H3 Treated Pine 190 × 45 F7	9.50	139.65	
39.60	L/M H3 Treated Pine 140 × 45 F7	7.15	283.14	
15.00	L/M H3 Treated Pine 90 × 35	4.10	61.50	
15.00	L/M H3 Treated Pine 50 × 35	2.50	37.50	
18.00	L/M Dressed Hardwood Posts 90 × 90	23.50	423.00	
27.00	L/M H3 Treated Pine 140 × 35	5.50	148.50	
33.00	L/M 90 × 35 Treated Pine—'Terminator'	4.00	132.00	
4.00	Secura FC Interior 2.7 × 0.6 Sheets	100.00	400.00	
20.00	Galvanised Post Holders 90 × 90	8.00	160.00	
1.00	Box Galvanised 65 mm Coach Screws	25.00	25.00	
		SUBTOTAL	\$3745.95	
		GST	374.60	
		TOTAL	\$4120.55	
TERMS 30 DAYS—THANK YOU FOR YOUR BUSINESS!				

Fig. 3.8 Licence to perform high-risk work

Courtesy of Alister Ford

3.1.2.5 Mandatory licences and qualifications

Mandatory licences are used to communicate to others that a builder, tradesperson or construction worker has the authority to carry out specific building or construction work. Some tradespeople are licensed to work in just that trade.

Plumbers and electricians must be licensed, whether they are employed or work as contractors.

All construction workers must undertake general induction training before working on a construction site. On completion they are issued

with a card to carry at all times as proof that they have undertaken the training.

Hoist operators, crane operators, forklift drivers and workers carrying out scaffolding, dogging and rigging must have a 'National licence to perform high-risk work' (Fig. 3.8).

3.1.2.6 Construction site signs

Construction site signs include safety and warning signs (Fig. 3.9), direction signs (Fig. 3.10) and information signs (Fig. 3.11). Signs play a critical role by:

- reminding workers to use their personal protective equipment (PPE) and avoid unsafe work practices
- warning workers that they must be cautious when entering a dangerous work area
- directing workers to a specific location on-site or directing them away from areas they are unauthorised to enter
- providing advice and information about the worksite, including the safety rules they must obey.

CHECK YOUR UNDERSTANDING

1. List 10 different types of visual communication used in the construction industry.
2. List five points that must be considered when using two-way radio communication.
3. How would you go about communicating with another worker who has a severe hearing impairment?
4. How would you let someone in a noisy work environment know they are doing a good job? Assume you and the other worker are wearing hearing protection and that you can't leave the work area.

Fig. 3.9 (a) and (b) Safety and warning signs

Courtesy of Alister Ford



Courtesy of Alister Ford

Fig. 3.10 Direction sign



Courtesy of Alister Ford

Fig. 3.11 Information sign



Courtesy of Alister Ford

3.2 Communicate in work teams

In today's workplace, all workers have a responsibility to maintain worksite communication with their colleagues. Workers should place a high level of importance on all interactions with their fellow workers, including social aspects.

Once you have a job, how you communicate with your employer, supervisor and your fellow employees will play a major role in whether you have a great job or an ordinary job. You will spend a lot of time during your life at work so make it count!

Good-quality communication between yourself and your colleagues will make your time at work worthwhile, and your working day will go more quickly, regardless of how hard the work may be.

3.2.1 Communicating with other workers

To work effectively with others, you must be able to communicate with them. This means being able to discuss matters not strictly related to work, being honest and friendly, and showing some interest in what they do on-site and off-site.

An ability to interact with other workers is essential. From a safety and productivity perspective, the effectiveness of work teams depends on all members of the team being able to communicate and work together.

For new workers with little industry experience, it is absolutely essential to be able to communicate with more experienced workers. Apprentices and trainees must be able to ask questions and receive and understand both positive and critical feedback in relation to the work they perform.

Older, veteran workers must have the confidence to pass on the knowledge they have acquired over their many years of work. However, they can be confident about passing on their knowledge only if younger, less experienced workers listen and apply that information.

Equally important is non-verbal communication between workers, which plays a vital role in the effectiveness of work teams. Individual team members need to encourage and support other team

Fig. 3.12 Thumbs up!

© Fluid Shutter/Shutterstock

members by acknowledging good work practices with, say, a 'thumbs up' gesture (Fig. 3.12) or a nod of the head together with a smile.

Through their own actions, every worker conveys information to other workers. Actions that benefit both individuals and the work team include the following:

- Treating other workers politely and greeting them in the morning and saying 'see you later' when leaving work to go home sets the scene for cooperation in the workplace.
- Having skilled workers with high work standards ensures that the work team maintains a good standard of work.
- Ensuring one work member regularly wears PPE signals to all other workers, including those outside of their team, that workplace safety is an important issue.
- Making sure the tools of the trade are well-maintained and cleaned and stored away at the end of each day sends a strong visual message that demonstrates each worker's personal values and responsibility.
- Maintaining a clean and tidy work area is a strong visual message to other workers that encourages safety, high work standards and professionalism.
- Encouraging workers to be diligent and methodical promotes a strong work ethic among all team members.

3.2.2 On-site meetings

On-site meetings may be called for a range of reasons including industrial or safety issues, the use of a new material that requires training, or an employer wishing to make an announcement or issue special work instructions. These meetings are often called **toolbox meetings**.

Meetings on worksites are generally short, as most workers are keen to get back and finish what they were doing before the meeting commenced. If you participate in an on-site meeting, try to obtain as much information as possible from the meeting.

Do the following when participating in meetings:

- If you are late, try not to disturb other workers.
- Be quiet when others are speaking.
- If a show of hands is requested to vote at a meeting, make your intention clear.
- If you have a question or would like to make a proposal to the meeting, raise your hand and address your question to the person running the meeting.
- If you would like to make a proposal to the meeting, write down what you would like to propose and read it out, making sure you can be heard and understood.
- If the meeting is important, make brief notes during the meeting or after it finishes.

CHECK YOUR UNDERSTANDING

5. Toolbox meetings can be called at any time on construction sites for all the workers on the job or just for a specific work group. List three reasons why a toolbox meeting may be called at short notice.
6. Besides providing individual protection for the wearer, how does the use of PPE by one worker benefit other workers?
7. Explain how you would demonstrate to other workers that you have a strong work ethic, without actually telling them so.

3.2.3 Communicating with the public

In the construction industry you will often be required to communicate with the general public. This may be the case if someone enters the building site mistakenly or if they are an expected visitor but are unsure who, or where, to report to. Always greet any visitors politely and ask clearly if you can be of any assistance in directing them to where they need to be.

It may be that the person they wish to see isn't on-site at that time—if so, clearly write down the visitor's details and pass this on to the person concerned so that the visitor may be contacted at a later time.

Alternatively, you may need to communicate with the general public if some of the work takes place outside of the worksite boundaries—for instance, if concrete trucks are arriving for a pour or building material delivery trucks need access to the job site to unload. Note that in such cases, traffic and pedestrians may need to be halted for a period of time. If you are involved, you must ensure that you communicate clearly with any pedestrians, drivers, delivery truck drivers and fellow workers and that they have understood you.

Remember that drivers or pedestrians may not be able to hear you. Make sure that any sign you may be operating, such as a stop/slow bat, is clearly displayed and visible to any members of the public who are affected.

Also ensure that any hand signals you may use in conjunction with the sign are clear and concise.

WORKPLACE SCENARIO

Communication is important at all times. I recall once when I was working as a carpenter for a major Melbourne construction company. We had just commenced work on a vacant site in Dunlop Road, Mulgrave. The datum for the job site needed to be obtained and marked for the building site excavations and setting up for construction to begin.

The datum height was noted on the building plans, but the levels needed to be obtained from a surveying marker located in the middle of the intersection of Springvale Road and Ferntree Gully Road. The company surveyor was contacted and soon arrived on-site to set the correct datum for us. I was assigned to assist, so we introduced ourselves and then the surveyor explained to me how the job would be done. There were no electronic measuring devices at that time, so the levels would be shot using an automatic level and staff. Readings would be transferred to a booking sheet and later the calculations would be made, and the site datum marked for work to proceed further. The surveyor explained the whole process to me, so I understood exactly what we needed to achieve in this job. He explained all of the hand signals that we would use as we would be approximately 80 to 100 m apart at all reading points and change of stations and this would be our

only means of communication. We made our way to the 1.5 km intersection and set up the instrument for the first reading.

The surveyor gave me a small orange flag. These were the days before hi-vis work clothes, and it was 8.30 am on a busy Melbourne weekday. There was traffic everywhere. I soon found out what the orange flag was for as I stood in the middle of the intersection holding the staff. It was my only means of communication with the car and truck drivers who passed through that intersection as I stood out there.

I made it safely back to the footpath after the first reading was taken, then, with a series of levels taken using the hand signals as our means of communication, we worked our way back along Springvale Road to the job site. After the calculations were completed, we were able to establish the correct datum for the job and the work on-site was able to proceed. This was the first time I had ever worked with a surveyor, so I made sure I engaged in conversation with him and asked questions about all aspects of the job. I learned a lot that day about surveying and worksite communication that I still put into practice to this day.

3.2.4 Communicating with trainers

1. People often commence employment in the construction industry as an apprentice or trainee.
2. A mandatory component of an apprenticeship or traineeship is to undertake off-site training and even some on-site training, although not under the direction of your immediate supervisor.
3. Whichever training organisation you enrol with will assign a trainer to you, and if you attend off-site training you will most likely be in a class with other students enrolled in the same qualification. Any on-site training would be conducted in a one-on-one situation unless your employer has more than one apprentice or trainee at the same level.
4. Effective communication with your trainer is vitally important. A lack of communication could be the cause of you failing enrolled subjects, which essentially costs your training organisation, your employer and yourself, time and money.
5. All parties involved should discuss and clearly record the details of your training plan requirements, your enrolment, study times and progress.

3.3 Communicate with employers and supervisors

It is extremely important to be able to speak directly to your employer or supervisor about all aspects of your work and your work role.

At your first contact with a potential employer or supervisor, and in any later interactions, make sure they understand you are a productive worker willing to be part of a work team—even if the team is just the two of you!

3.3.1 Face-to-face communication with employers and supervisors

Always greet your supervisor or employer at the start of work and say goodbye when you leave work. This will demonstrate that you enjoy working with them and like your job; it also encourages fair treatment by your employer or supervisor.

Work-related problems are best dealt with by speaking to your employer or supervisor privately. It is best to be upfront and honest about any work issues you may have.

A common problem for many young employees is their understanding of *what* they are actually paid and their conditions of employment. If these conditions were not established at the time of applying for the job, it is appropriate for you to ask what they are. An open and honest employer will appreciate you coming to them directly rather than asking someone else.

TIP As a new worker you must first build trust in other workers before discussing work-related problems.

3.3.2 Non-verbal communication

As discussed earlier, non-verbal communication between you and your employer or supervisor includes a range of documents that you may be required to use, signs that you must comply with, and the use of gestures and sketches.

Other elements of non-verbal communication you must be aware of include:

- *Wearing required PPE.* Employers and supervisors become very agitated when workers fail to wear PPE because if there is an accident, they will share responsibility and may be fined because you did not comply with work instructions. By not wearing PPE you are demonstrating disregard for your safety and the maintenance of a safe workplace for all workers. Most employers and supervisors are genuinely concerned about your safety and health. Ignoring their concerns is a strong message to them that you do not appreciate their concern for your welfare.
- *Maintaining a good personal appearance, speaking clearly and working diligently.* These all convey the message to your employer that you want to achieve the best possible work performance.
- *Maintaining your tools.* This demonstrates to your employer that you want to achieve good-quality workmanship and that you understand the importance of good workmanship for the success of the business.
- *Constructing or building to standards required by your employer or supervisor.* This conveys your acceptance and adoption of the standard of quality that your employer or supervisor has set and wants to achieve.
- *Using correct trade terminology.* This prevents misunderstandings and demonstrates a desire to be understood and to be acknowledged as a person with a good knowledge of the technical aspects of your trade—in other words, 'Being seen as acting in a professional or tradelike manner'.

3.4 Resolve disputes

Disputes on building sites are generally the result of poor communication. The best way to prevent disputes is to maintain communication at all times. Misunderstandings should be corrected immediately.

If you have an argument with your employer or supervisor or another worker, continue to maintain a polite relationship. Keep saying good morning when you arrive for work and good afternoon when you leave, otherwise you may have to leave a job you really like.

Arguments are generally resolved with time. Just keep talking and keep on smiling! In most cases both parties will eventually apologise to each other, and it is often better to be the first to apologise so that everyone can move on.

If your attempts to resolve a dispute fail, make enquiries outside of your workplace, such as through employer or employee organisations or relevant government agencies. If you discover you have not been treated fairly, discuss the matter again with your employer or your supervisor. If the problem is not resolved as a result of this, you may have to apply for another job or take the matter further.

TIP It is far easier to apply for another job while you have a job. If you plan to resign from a job, get your next job organised first.

CHECK YOUR UNDERSTANDING

8. A worker accuses you of ridiculing them after you attempt to help them complete a task because you believed they needed assistance. How would you remedy this situation?
9. What would you do in the future to prevent such a misunderstanding?
10. You have made a mistake and think you may have to pull down work you have just completed after working on that job for four hours. Select one of the three options below and explain why you have selected it.
 - a. Tell your supervisor immediately.
 - b. Not tell your supervisor and instead immediately start to make good the defective work.
 - c. Pull the work down and start another job.

Student research

1. Do an online search for 'Australian construction terminology' and list and define 10 new construction terms with which you are not familiar.
2. Visit Safe Work Australia: www.safeworkaustralia.gov.au. Visit the Resources and Publications section. From the list, select 'Model Codes of Practice', then select 'Construction Work' from the listed codes. Identify who has health and safety duties relating to construction work.

End-of-chapter activity

Look around your worksite or training facility and see how many signs you can locate; list them and what they are communicating.

Divide them into categories of:

- safety signs
- warning signs
- direction signs
- information signs.

Note the colours of the signs and the writing. Can you spot any trends in terms of the colours and the categories in which you have placed them?

AUSTRALIAN BUILDING CODES AND STANDARDS



Safe Work
Australia,
Construction work,
Code of Practice,
May 2018

Tradie talk—Let's ask the supervisor for his or her opinion
—We need to check this against the plans

Chapter 4

Trade calculations and measurements

Learning Objectives

LO 4.1 Understand metric units

LO 4.2 Use an electronic calculator

LO 4.3 Perform calculations using plane geometry

LO 4.4 Calculate the volume of solid figures

LO 4.5 Calculate and order materials

Introduction

The carpenter who is active in the trade will need to make calculations daily. These can include simple additions or subtractions of lengths, or they may involve calculations of geometrical areas and volumes. The carpenter may also be required to work out the quantities of material required to complete the job at hand, as well as calculating the costing of these materials.

In this chapter you will learn how to perform some basic calculations and will be shown how to calculate the area, volume and perimeter of various shapes. You will also learn basic calculator procedures and how to tabulate and order materials.

4.1 Understand metric units

Metric units are used throughout the building industry. They include the units shown in Table 4.1. Note that small letters are used for all symbols except where the unit is derived from a proper name, such as newton (N) and ampere (A), or where the value is over one million, such as the megapascal (MPa).

Table 4.1 Common units in the construction industry

Unit	Physical function	Symbol
Metre	unit of length	m
Millimetre	1000 millimetres = 1 metre	mm
Kilometre	1000 metres = 1 kilometre	km
Square metre	unit of area (m × m)	m ²
Square millimetre	unit of area (mm × mm)	mm ²
Hectare	unit of area (10 000 m ²)	ha
Cubic metre	unit of volume (m × m × m)	m ³
Litre	unit of volume or capacity	L
	(100 mm × 100 mm × 100 mm)	
	1000 litres = 1 m ³	
	1 litre of water = 1 kg	
Kilogram	unit of mass	kg
Gram	1000 grams = 1 kilogram	g
Tonne	1000 kilograms = 1 tonne	t
Newton	unit of force	N
Pascal	unit of pressure = 1 N/m ²	Pa
Kilopascal	1000 pascals	kPa
Megapascal	1 000 000 pascals	MPa
Volt	electrical potential	V
Ampere	electric current	A
Watt	unit of power = V × A	W

It is important that tradespeople working in the construction industry are able to read and record measurements accurately to the nearest millimetre. Measuring equipment used on a building site can include:

- laser measuring equipment (Fig. 4.1)
- one-metre folding rulers
- retractable steel tape measures
- trundle wheels
- levelling devices
- straight edges and squares.

Laser measuring equipment is becoming more popular in the building industry, and is used especially when a tradesperson is doing a quote and needs to measure up a job—for example, building partition walls in an open office space. Such tasks would normally take two people to measure up using a long tape. With a laser device, however, the device is set down against one wall, and it calculates the distance by firing a laser beam across the floor until it hits another wall. Then, the electronic display shows the length. The device speeds up the task and is extremely accurate.

It is essential to take care of measuring equipment. A tape should be wiped clean occasionally, especially if it gets wet, as the metal will rust. If it does get wet, a clean rag with some oil on it will help stop any corrosion.

Fig. 4.1 Laser measuring device

© AlexLMX/Shutterstock

For most other equipment, avoid dropping it and ensure batteries are charged if present. If it comes in a case, keep it in that case, so that the equipment is protected and remains accurate. Calibration of some equipment is required periodically, so please read the manufacturer's instructions prior to its first use.

The metric units used in the building industry for linear measurements are metres and millimetres, where one metre (m) = 1000 millimetres (mm). Usually, dimensions on building plans are given in millimetres, but on some large site plans they may be given in metres. This system eliminates the possibility of making errors in reading any dimension, as the decimal point can go in only one place. Plus, plans can often be kept in a dirty environment and it can be difficult to see if it's a dot or a spec of dirt. If there is no decimal point shown in a figure, it must be in millimetres. For example, a dimension of 3648 is in millimetres and no symbol of 'mm' is necessary to indicate this fact.

If a decimal point is shown, and the figure is written to three decimal places, then all of the figures before the point are metres and all after the point are millimetres. For example, a dimension of 27.632 is 27 m and 632 mm and, again, no symbol is necessary to indicate this on the plan.

4.1.1 Converting millimetres to metres

To convert millimetres to metres, divide the figure by 1000 (e.g. 3648 mm divided by 1000 = 3.648 m). The easy way to divide by 1000 is to move the decimal point three places to the left, adding zeros to make up the three places if necessary. For example:

$$\begin{aligned} 3648 \text{ mm} &= 3.648 \text{ m} \\ 17846 \text{ mm} &= 17.846 \text{ m} \\ 5 \text{ mm} &= 0.005 \text{ m} \\ 75 \text{ mm} &= 0.075 \text{ m} \end{aligned}$$

Note that a zero is placed before the decimal point if there is no significant full figure. With practice, dividing by 10, 100 or 1000 becomes a procedure of mental arithmetic. For example:

- To divide by 10, move one place to the left.
- To divide by 100, move two places to the left.
- To divide by 1000, move three places to the left.
- To multiply by 10, move one place to the right.
- To multiply by 100, move two places to the right.
- To multiply by 1000, move three places to the right.

If necessary, add zeros to the right; for example, 306 multiplied by 10 equals 3060.

4.1.2 Adding metric units

To add metric units, write the quantities in a column with the decimal points aligned, then add up the columns; the decimal point in the answer will be aligned with those above it. For example, to add the dimensions 6.372 m, 4.021 m, 50 mm, 120 mm and 6 mm:

	6.372
	4.021
	0.050
	0.120
	0.006
Total	10.569 m

4.1.3 Subtracting metric units

To subtract metric units, write down the quantities—the smaller figure under the larger figure—and, with the decimal points aligned, subtract. For example, subtract 3.645 m from 12.429 m:

$$\begin{array}{r} 12.429 - \\ 3.645 \\ \hline \end{array}$$

Total 8.784 m

or subtract 28 mm from 3.620 m:

$$\begin{array}{r} 3.620 - \\ 0.028 \\ \hline \end{array}$$

Total 3.592 m

4.1.4 Multiplying metric units

To multiply metric units, multiply in the normal manner and, counting from the right-hand side of the final figure, place the same number of decimal points in the answer as there are in total in the two numbers being multiplied together. For example, multiply 2.632 m by 6.3 m:

$$\begin{array}{r} 2.632 \times \\ 6.3 \\ \hline 7896 \\ 15792 \\ \hline \end{array}$$

Total 16 5816

Then count back four decimal points, so the answer is 16.5816 m².

4.1.5 Dividing metric units

To divide metric units, divide the dividend by the divisor, and the decimal point in the quotient should be over the decimal point in the dividend. For example, divide 39.392 by 8:

$$\begin{array}{r} 4.924 \\ 8 \overline{)39.392} \\ 32 \\ 73 \\ 72 \\ 19 \\ 16 \\ 32 \end{array}$$

or

to divide 39.392 by 2.5, first move the decimal point in both the dividend and the divisor one position to the right:

$$\begin{array}{r} 15.757 \\ 25 \overline{)393.920} \\ 25 \\ 143 \\ 125 \\ 189 \\ 175 \\ 142 \\ 125 \\ 170 \end{array}$$

Answer = 15.757, to three decimal places.

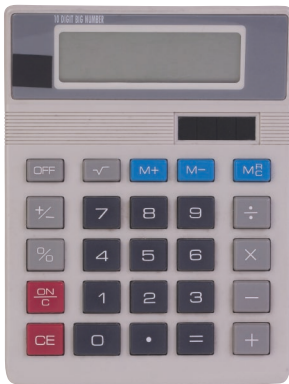
TIP The common metric units used in the building industry for linear measurements are metres and millimetres.

CHECK YOUR UNDERSTANDING

1. Which metric units of length are used in the building industry?

4.2 Use an electronic calculator

Fig. 4.2 Basic calculator keyboard



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It should be mentioned from the outset that the calculator is regarded as one of the most valuable tools of the trade—and probably one of the cheapest. The keyboard of the basic calculator is shown in Figure 4.2, with examples of how to use the calculator following. It is assumed that the calculator will be used wherever possible throughout this book, and solutions have been arranged in such a way that the figures can be entered and the problems solved using the calculator.

A useful hint when using a calculator is to make a rough estimate of what the answer should be, then to check the magnitude of the number. This is just in case a mistake was made in entering the number, which often puts the result out by a factor of ten or more.

Most calculators are similar in operation, but the order in which some of the function keys are pressed may vary from brand to brand. Check the operating instructions supplied with the calculator.

4.2.1 Addition

Units must be entered in the same units; for example, either metres or millimetres only, in one calculation.

To add 23.5 m to 87.45 m on a calculator enter:

$\boxed{C} \boxed{2} \boxed{3} \boxed{.} \boxed{5} \boxed{+} \boxed{8} \boxed{7} \boxed{.} \boxed{4} \boxed{5} \boxed{=}$

This displays the answer 110.95 (m).

Where mixed units are to be added, they must all be converted to the same unit. For example, add 9.38 m, 0.09 m, 125 mm and 84 mm.

1. Convert all units to metres:

$$= 9.38 + 0.09 + 0.125 + 0.084$$

On a calculator enter:

$\boxed{C} \boxed{9} \boxed{.} \boxed{3} \boxed{8} \boxed{+} \boxed{.} \boxed{0} \boxed{9} \boxed{+}$
 $\boxed{.} \boxed{1} \boxed{2} \boxed{5} \boxed{+} \boxed{.} \boxed{0} \boxed{8} \boxed{4} \boxed{=}$

This displays 9.679 (m).

2. Convert all units to millimetres:

$$= 9380 + 90 + 125 + 84$$

$$\boxed{C} \boxed{9} \boxed{3} \boxed{8} \boxed{0} \boxed{+} \boxed{9} \boxed{0} \boxed{+} \boxed{1} \boxed{2} \boxed{5} \boxed{+} \boxed{8} \boxed{4} \boxed{=}$$

This displays 9679 (mm).

4.2.2 Subtraction

Units subtracted must also be in the same units. For example, subtract 23.5 m from 87.45 m:

$$\boxed{C} \boxed{8} \boxed{7} \boxed{.} \boxed{4} \boxed{5} \boxed{-} \boxed{2} \boxed{3} \boxed{.} \boxed{5} \boxed{=}$$

This displays the answer 63.95 (m).

4.2.3 Multiplication

Measurements may be multiplied as measurement by measurement for areas, or by a factor to increase the number. For example, multiply 2.4 m by 3.6 m:

$$\boxed{C} \boxed{2} \boxed{.} \boxed{4} \boxed{\times} \boxed{3} \boxed{.} \boxed{6} \boxed{=}$$

This displays the answer 8.64 (m²).

Multiply 2.456 m by 6:

$$\boxed{C} \boxed{2} \boxed{.} \boxed{4} \boxed{5} \boxed{6} \boxed{\times} \boxed{6} \boxed{=}$$

This displays the answer 14.736 (linear metres).

4.2.4 Division

Measurements may be divided by similar units or by a factor to decrease the number. For example, divide 72.8 by 34:

$$\boxed{C} \boxed{7} \boxed{2} \boxed{.} \boxed{8} \boxed{\div} \boxed{3} \boxed{4} \boxed{=}$$

This displays the answer 2.141.

4.2.5 Squaring a number

To square a number is to multiply it by itself. For example:

$$\begin{aligned} 4^2 &= 4 \times 4 \\ &= 16 \end{aligned}$$

Some calculators have a function key marked x^2 that, when pressed, will square any number that has been entered.

$$\boxed{C} \boxed{1} \boxed{2} \boxed{x^2} \text{ displays the result } 144.$$

If there is no squaring function on the calculator, the entry should be as follows:

$$\boxed{C} \boxed{1} \boxed{2} \boxed{\times} \boxed{1} \boxed{2} \boxed{=} \text{ also displays } 144.$$

Some calculators may function automatically by multiplying by the last number entered when the $\times$ button is pressed, if no further entry is made:

$$\boxed{C} \boxed{1} \boxed{2} \boxed{\times} \boxed{=} \text{ displays } 144.$$

4.2.6 The square root of a number

The square root of a number is the reverse of the square of a number. The square root of a number is that figure which, when multiplied by itself, will result in the given number.

For example, $4 \times 4 = 16$, so $\sqrt{16} = 4$.

This can be done on a calculator that has a square root function key. The alternative is to look at a set of tables, or to derive the answer by trial and error:

$\square \square 1 \square 6 \square \sqrt{x} \square \square$ displays the answer 4.

4.2.7 Percentage calculations

Percentage calculations (symbol %) convert fractions into units per 100 units and are commonly used as a basis for calculating such things as discounts on accounts or allowances for adding waste to various quantities. Percentage calculation can also be used to establish a profit margin when costing a job.

Percentages commonly found and their equivalent fractions are:

$$5\% = 5/100 = 1/20$$

$$10\% = 10/100 = 1/10$$

$$20\% = 20/100 = 1/5$$

$$50\% = 50/100 = 1/2$$

$$12.5\% = 1/8$$

$$33.33\% = 1/3$$

$$66.66\% = 2/3$$

$$16.66\% = 1/6$$

For example, $7\% \text{ of } \$36.25 = (36.25 \times 7)/100$
 $= \$2.54$

Some calculators have a percentage key marked with the symbol %, which carries out this calculation when the numbers are entered and the percentage key pressed. For example:

$\square \square 3 \square 6 \square . \square 2 \square 5 \square \times \square 7 \square \% \square$

This displays the answer 2.5375 (\$2.54).

4.2.8 Memory keys

Memory keys are available on most calculators and enable the operator to memorise several minor calculations and bring them together as a whole. The relevant keys are:

$\square \text{CM} \square$ clear memory

$\square \text{MR} \square$ memory recall

$\square \text{M}- \square$ subtract from memory or memory minus

$\square \text{M}+ \square$ add to memory or memory plus.

The result is finally given when the recall button is used.

Calculate 7 articles at \$6.25

plus 4 articles at \$0.62

plus 14 articles at \$13.40

$\square \square \text{CM} \square 7 \square \times \square 6 \square . \square 2 \square 5 \square \square \text{M}+ \square \dots 43.75$

$\square 4 \square \times \square . \square 6 \square 2 \square \square \text{M}+ \square \dots 2.48$

$\square 1 \square 4 \square \times \square 1 \square 3 \square . \square 4 \square \square \text{M}+ \square \dots 187.60$

Then press the memory recall $\square \text{MR} \square$ and the answer 233.83 (\$233.83) will be displayed.

4.2.9 Ratios and proportions

Sometimes problems can be solved quickly by using proportions. For example:

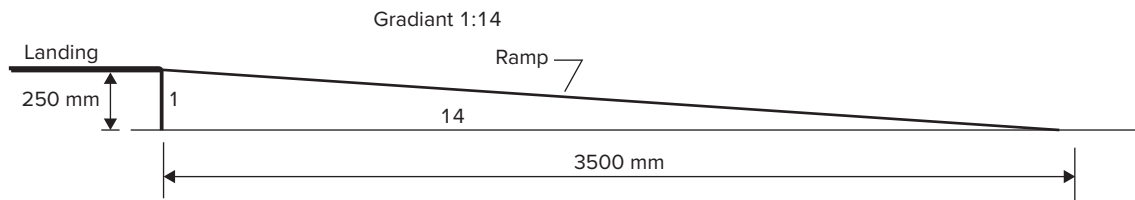
A plot is 8.25 m long by 2.5 m wide. If the width were to be increased to 3.5 m, what will the length be if it is to preserve the same proportions? The ratio of 8.25:2.5 must be maintained, so the new ratio will be $x:3.5$.

$$\begin{aligned}\text{Therefore, } x/3.5 &= 8.25/2.5 \\ x &= (8.25 \times 3.5)/2.5 \\ &= 11.55 \text{ m}\end{aligned}$$

The following shows an example of how the use of ratios and proportions are put into practice on a building site when designing and constructing an access ramp.

An access ramp is to be built with a maximum gradient of 1:14 as determined by the Building Code of Australia. The height of the ramp is to finish 250 mm above ground level. Therefore, the horizontal length of the ramp will need to be a minimum of 3500 mm so that it complies with the design ratio, i.e. $14 \times 250 \text{ mm} = 3500 \text{ mm}$ (Fig. 4.3).

Fig. 4.3 Ratios and proportions



4.2.10 Parentheses

When some quantities are shown in parentheses, it means that this part of the problem must be treated as a complete unit and must be calculated first. For example:

$$\begin{aligned}(4 \times 2) + (3 \times 8) &= 8 + 24 \\ &= 32\end{aligned}$$

If no parentheses are present, the calculations may be confusing. Mathematical conventions dictate that the multiplications should be carried out first.

CHECK YOUR UNDERSTANDING

2. Add together the following units: 6.3 m, 2673 mm, 0.050 m, 18 mm and 24.050 m.

4.3 Perform calculations using plane geometry

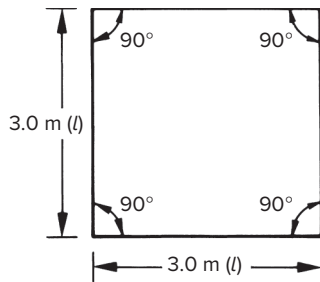
A *plane surface* is a flat surface and a *plane figure* is a figure that lies wholly on a plane surface. The *perimeter* of a plane figure is the distance around the sides of the figure. A plane figure has dimensions in two directions only and has area only. The measurement of plane figures in various combinations is an important part of the carpentry trade.

4.3.1 Quadrilaterals

Quadrilaterals are plane figures bounded by four straight sides; they contain four angles that together add up to 360° .

A particular group of quadrilaterals are called *parallelograms*, which can be defined as plane figures having two pairs of equal and parallel sides. There are four types of parallelograms: a square, a rectangle, an L-shaped figure and a rhombus.

Fig. 4.4 Square

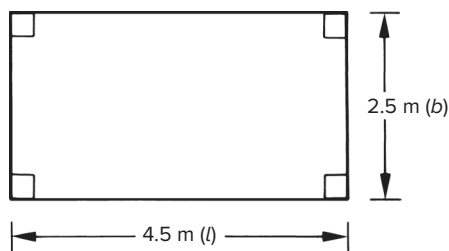


4.3.1.1 Square

A square is a plane figure having four equal sides and four equal angles (Fig. 4.4). Each angle is 90° .

$$\begin{aligned}\text{Perimeter} &= 4 \times l \\ &= 4 \times 3 \\ &= 12 \text{ m} \\ \text{Area} &= l^2 \\ &= 3^2 \\ &= 9 \text{ m}^2\end{aligned}$$

Fig. 4.5 Rectangle



4.3.1.2 Rectangle

A rectangle is a plane figure having two pairs of equal and parallel sides and four equal angles, each of 90° (Fig. 4.5). A rectangle has length (l) and breadth (b) or width (w).

$$\begin{aligned}\text{Perimeter} &= (2 \times l) + (2 \times b) \\ &= (2 \times 4.5) + (2 \times 2.5) \\ &= 9 + 5 \\ &= 14 \text{ m} \\ \text{Area} &= l \times b \\ &= 4.5 \times 2.5 \\ &= 11.25 \text{ m}^2\end{aligned}$$

4.3.1.3 L-shaped figure

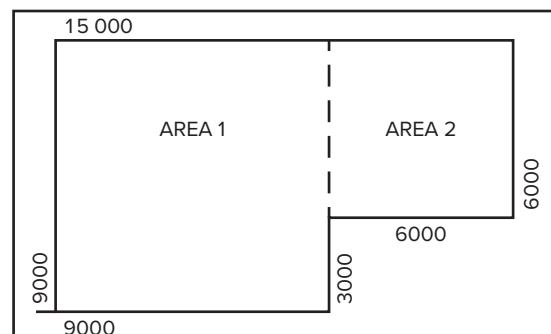
An L-shaped figure is the extension of a square or rectangular-shaped figure (Fig. 4.6).

$$\begin{aligned}\text{Perimeter} &= 15 \text{ m} + 6 \text{ m} + 6 \text{ m} + 3 \text{ m} + 9 \text{ m} + 9 \text{ m} = 48 \text{ m}, \text{ or} \\ \text{Perimeter} &= (2 + l) + (2 \times w) \\ &= (2 \times 15) + (2 \times 9) \\ &= 30 + 18 \\ &= 48 \text{ m}\end{aligned}$$

To calculate the total surface area of the L-shaped figure, you will need to first divide it into two separate areas (note the broken line).

$$\begin{aligned}\text{Area 1} &= 9.0 \times 9.0 = 81 \text{ m}^2 \\ \text{Area 2} &= 6.0 \times 6.0 = 36 \text{ m}^2 \\ \text{Total area} &= 117 \text{ m}^2\end{aligned}$$

Fig. 4.6 L-shaped building



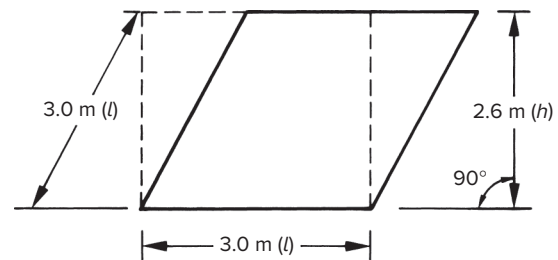
TIP For best practice when working out surface area, it is always easier if you convert the dimensions to metres prior to calculating as area is normally expressed in m².

4.3.1.4 Rhombus

A rhombus is a plane figure having four equal sides, with two sets of dissimilar angles (Fig. 4.7). The base of any rhombus figure is the side on which it is shown to be standing—any side can become the base. The perpendicular height (h) of a figure is the height of the figure measured at 90° to the base.

$$\begin{aligned}\text{Perimeter} &= 4 \times l \\ &= 4 \times 3 \\ &= 12 \text{ m} \\ \text{Area} &= l \times h \\ &= 3.0 \times 2.6 \\ &= 7.8 \text{ m}^2\end{aligned}$$

Fig. 4.7 Rhombus

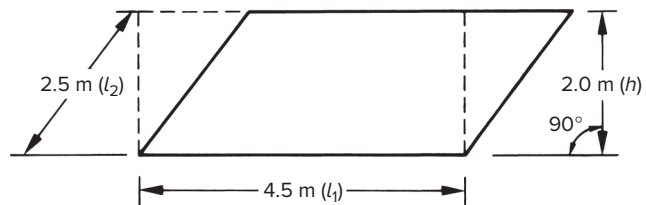


4.3.1.5 Parallelogram (rhomboid)

This is a plane figure having two pairs of equal and parallel sides, with two sets of dissimilar angles (Fig. 4.8).

$$\begin{aligned}\text{Perimeter} &= (2 \times l_1) + (2 \times l_2) \\ &= (2 \times 4.5) + (2 \times 2.5) \\ &= 14 \\ \text{Area} &= l_1 \times h \\ &= 4.5 \times 2.0 \\ &= 9 \text{ m}^2\end{aligned}$$

Fig. 4.8 Parallelogram

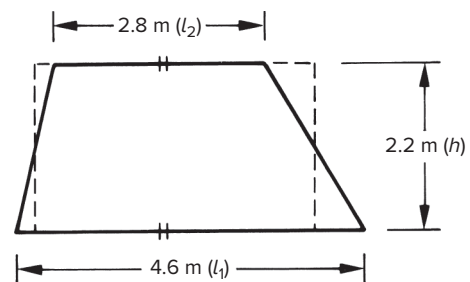


4.3.1.6 Trapezoid or trapezium

This is a plane figure, not a parallelogram, bounded on four sides, two of which are parallel (Fig. 4.9).

$$\begin{aligned}\text{Area} &= \frac{l_1 + l_2}{2} \times h \\ &= ((4.6 + 2.8)/2) \times 2.2 \\ &= 7.4/2 \times 2.2 \\ &= 8.14 \text{ m}^2\end{aligned}$$

Fig. 4.9 Trapezium



CHECK YOUR UNDERSTANDING

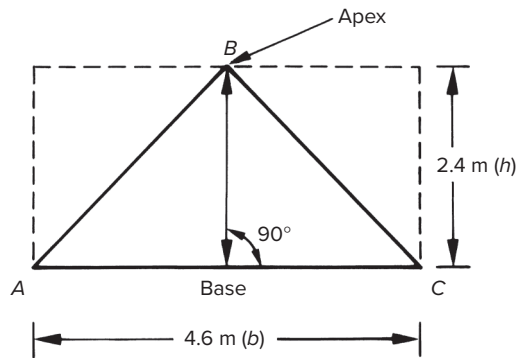
3. Calculate the perimeter of a rectangular block of land that measures 43 m × 26 m.

4.3.2 Triangles

Triangles are plane figures bounded by three straight sides (Fig. 4.10). Triangles have the following properties:

1. Any two sides added together are greater than the third side.
2. The sum of the included angles equals 180° .
3. The exterior angle is equal to the sum of the two opposite interior angles.

Fig. 4.10 Triangle

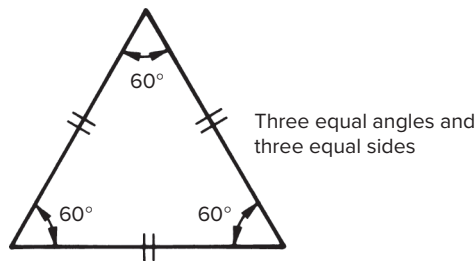


Triangles are identified by indicating the corner points with an uppercase letter and the side opposite the corner with the same letter in lowercase. The side on which the triangle stands is the base and the perpendicular height is the distance from the base to the apex, measured at 90° .

$$\begin{aligned}\text{Area} &= \frac{b \times h}{2} \\ &= \frac{4.6 \times 2.4}{2} \\ &= 5.52 \text{ m}^2\end{aligned}$$

There are six types of triangles: equilateral, isosceles, scalene, right angle, obtuse and acute. In this chapter, we will discuss equilateral, isosceles, scalene and right-angled triangles.

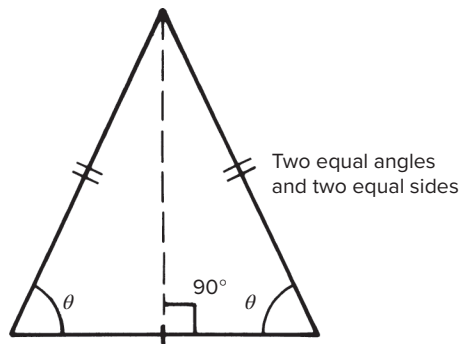
Fig. 4.11 Equilateral triangle



4.3.2.1 Equilateral triangle

An equilateral triangle is a triangle with three equal sides and therefore three equal angles (Fig. 4.11).

Fig. 4.12 Isosceles triangle



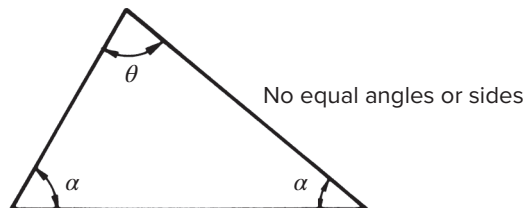
4.3.2.2 Isosceles triangle

An isosceles triangle has two equal sides and therefore two equal angles (Fig. 4.12). A perpendicular line drawn from the apex to the base will bisect the base.

4.3.2.3 Scalene triangle

A scalene triangle has no equal sides and no equal angles, but each single angle is less than 90° (Fig. 4.13).

Fig. 4.13 Scalene triangle

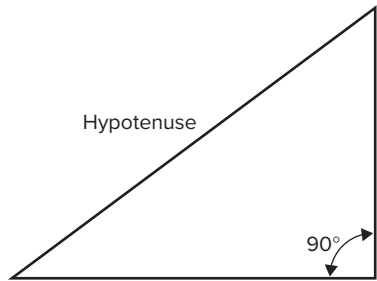


4.3.3 Right-angled triangles

These are triangles in which one of the included angles is a right angle (90°) (Fig. 4.14). The side opposite the right angle is called the *hypotenuse*.

The right-angled triangle is most valuable for solving various problems that confront the carpenter, such as setting out right angles and calculating the lengths of roof rafters using *Pythagoras' theorem*. This theorem states: 'In a right-angled triangle, the square on the hypotenuse equals the sum of the squares on the other two sides.'

Fig. 4.14 Right-angled triangle



The most readily adaptable right-angled triangle is one with sides in the proportions 3 to 4 to 5 (Fig. 4.15). We can prove the theorem in the following way:

$$a = 3$$

$$b = 4$$

$$c = 5$$

$$c^2 = a^2 + b^2$$

$$25 = 9 + 16$$

Using this theorem, if any two sides of a right-angled triangle are known, the third can be calculated (Fig. 4.16):

$$c^2 = a^2 + b^2$$

$$c^2 = 2.3^2 + 6.4^2$$

$$\text{Therefore, } c = \sqrt{(5.29 + 40.96)}$$

$$= \sqrt{46.25}$$

$$= 6.8 \text{ m}$$

Fig. 4.15 3, 4, 5 triangle

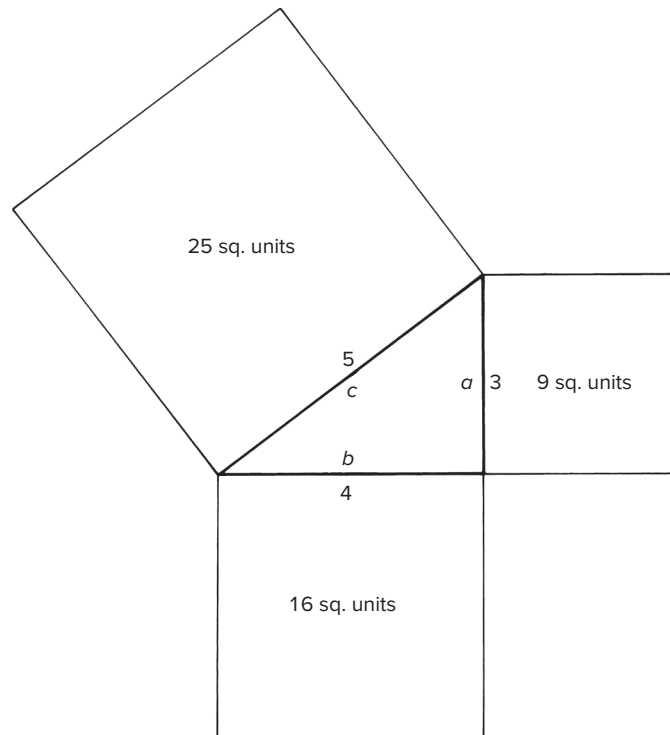
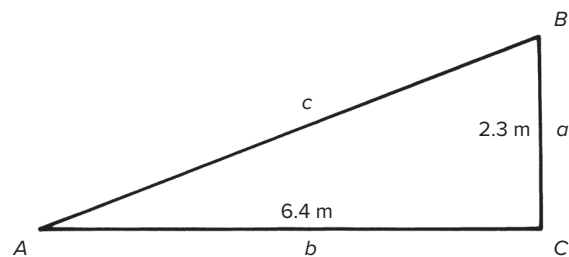


Fig. 4.16 Triangle problem



4.3.4 Circles

Circles are plane figures, bounded by a line traced out by a point moving at a fixed constant distance from another given fixed point (Fig. 4.17).

- The **circumference** of the circle is the length of the line traced out by the moving point, to again reach its starting point (the distance around the outside of the circle).
- The **centre** is the fixed point.
- The **diameter (symbol d)** is a straight line drawn through the centre and terminated at each end by the circumference.
- The **radius (symbol r)** is a straight line drawn from the centre of the circle to the circumference, its length being half the diameter.

In any circle, there is always a fixed ratio between the length of the circumference and the diameter. This ratio is termed pi (π) and has a value of 3.142 (to three decimal places). That is, the circumference of a circle is always 3.142 times the length of the diameter.

If the diameter is 2.8 m, then:

$$\begin{aligned}\text{Circumference of circle} &= \pi \times d \\ &= 3.142 \times 2.8 \\ &= 8.797 \text{ m}\end{aligned}$$

Some calculators have a π key, which when pressed will automatically display the value of π . In this problem, the solution would be:

$\boxed{\pi} \boxed{\times} \boxed{2.8} \boxed{=} \boxed{8.7964}$

This displays 8.7964.

If the π key is not available, then the value of π can simply be entered in the usual way.

The area of a circle can be calculated as follows:

$$\begin{aligned}\text{Area of circle} &= \pi r^2 \\ r &= 1.4 \text{ m} \\ \text{Area} &= 3.142 \times 1.4 \times 1.4 \text{ m}^2 \\ &= 6.158 \text{ m}^2\end{aligned}$$

4.3.4.1 Parts of a circle

As shown in Figure 4.18, the parts of a circle are as follows:

- An **arc** is any part of the circumference.
- A **semi-circle** is half a circle bounded by half the circumference and the diameter (d).
- A **quadrant** is one-quarter of a circle bounded by two radii at 90° , and one-quarter of the circumference.
- A **sector** is part of a circle bounded by two radii and the arc between them.

Fig. 4.17 Circle

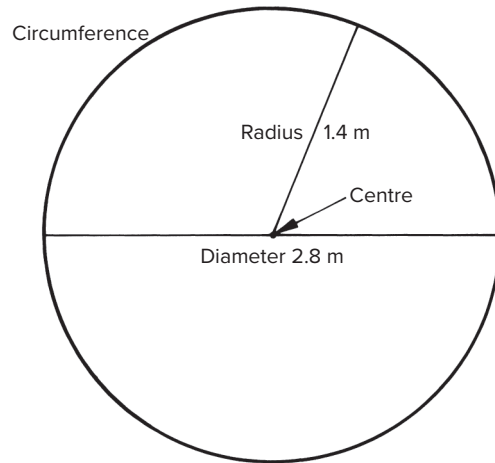
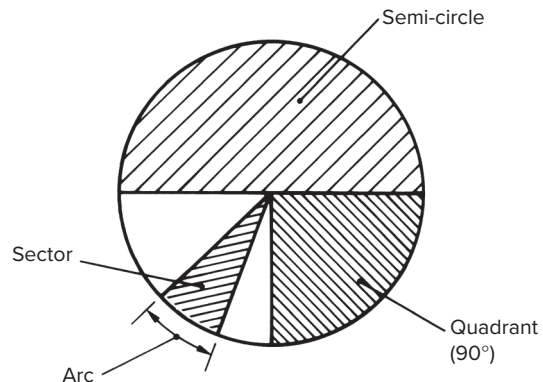


Fig. 4.18 Parts of a circle



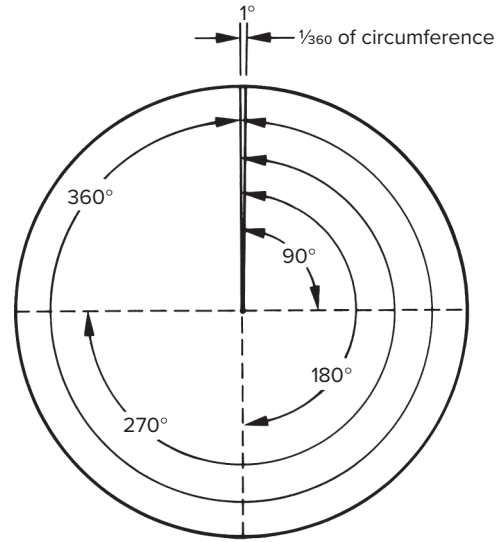
4.3.4.2 Degree

When a radius of a circle rotates through $1/360^{\text{th}}$ part of the circumference it forms an angle and the angle is termed 1° . Therefore:

- $\frac{1}{4}$ circle = 90° , or one right angle
- $\frac{1}{2}$ circle = 180° , or two right angles
- Full circle = 360° , or four right angles, as shown in Figure 4.19.

Parts of a degree are called minutes (') and seconds ("), where one degree equals 60' and one minute equals 60". Degrees are the usual way to measure angles.

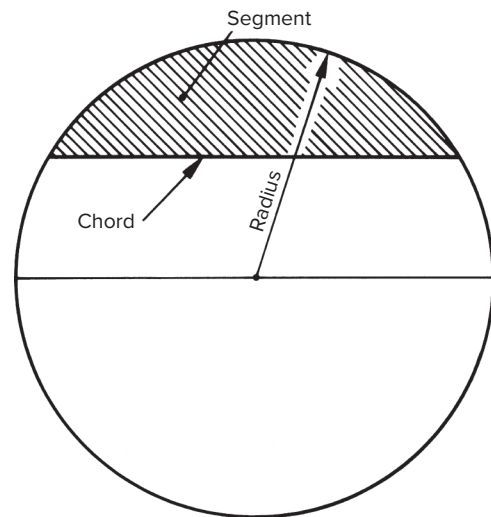
Fig. 4.19 Degree increments of the circle



4.3.4.3 Chord

A *chord* is a straight line joining any two points on the circumference other than the diameter; a *segment* is the part of a circle bounded by a chord and its arc (Fig. 4.20).

Fig. 4.20 Chord, segment and radius



4.3.5 Polygons

There are many polygons (i.e. plane figures having more than four sides), but the two most likely to be encountered are the hexagon and the octagon.

4.3.5.1 Hexagon

The regular hexagon is a plane figure bounded by six equal sides, each side at 120° to the one adjacent (Fig. 4.21). A hexagon can be thought of as six equilateral triangles grouped around a central point. The perimeter of a hexagon is equal to the length of a side multiplied by six.

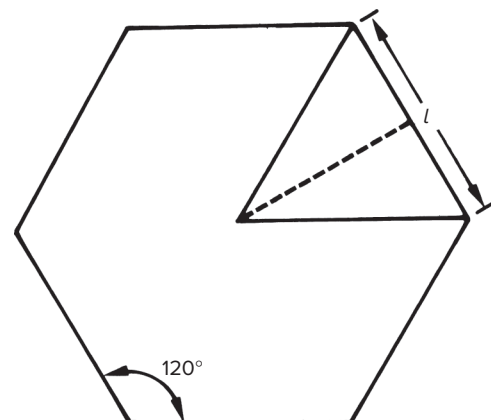
The area of a hexagon is equal to the area of the equilateral triangle formed by joining two adjacent corners to the centre of the figure, multiplied by six. Therefore, using the formula for the area of triangles, the area of the regular hexagon will equal the shortest distance from the perimeter to the centre, multiplied by half of one side, multiplied by six.

$$\begin{aligned}\text{Area} &= \frac{l}{2} \times \text{shortest distance to centre} \times 6 \\ &= l \times \text{shortest distance to centre} \times 3\end{aligned}$$

If the distance to the centre is not known, it can be calculated by trigonometrical methods, and will be found to be a constant ratio with the sides of the regular hexagon. Using this method, the area of a hexagon will be:

$$\text{Area} = l^2 \times 2.598$$

Fig. 4.21 Hexagon



4.3.5.2 Octagon

The regular octagon is a plane figure bounded by eight equal sides, each side at 135° to the one adjacent (Fig. 4.22). The perimeter of a regular octagon is calculated by taking the length of one side and multiplying by eight, while the area of a regular octagon can be calculated by two methods:

1. A similar method to the hexagon can be used, where the area of the isosceles triangle bound by two adjacent corners and the centre of the figure can be calculated and multiplied by eight. This can be represented as:

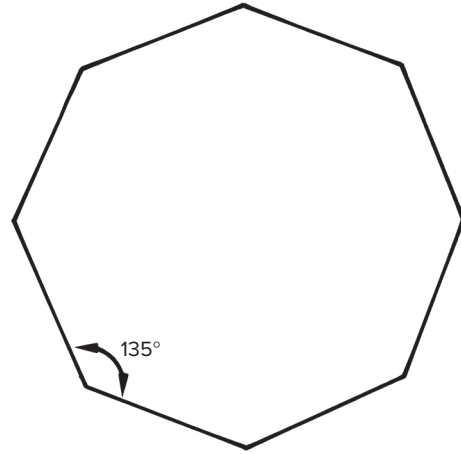
$$\begin{aligned}\text{Area} &= \frac{l}{2} \times \text{shortest distance to centre} \times 8 \\ &= l \times \text{shortest distance to centre} \times 4\end{aligned}$$

Once again there is a constant relationship between the length of a side and the distance to the centre of a regular octagon, giving the simple formula:

$$\text{Area} = l^2 \times 4.8284$$

2. Another method is to take the area of the square that would just encompass the octagon and to subtract the area of the four small triangles at each corner of the square. This will be useful if calculating areas of non-regular octagons.

Fig. 4.22 Octagon



CHECK YOUR UNDERSTANDING

4. What is the area of a rectangular figure $4.6 \text{ m} \times 450 \text{ mm}$? Show the formula used and all workings.
5. Calculate the area of a circle with a diameter of 8.360 m . Show the formula used and all workings.

4.4 Calculate the volume of solid figures

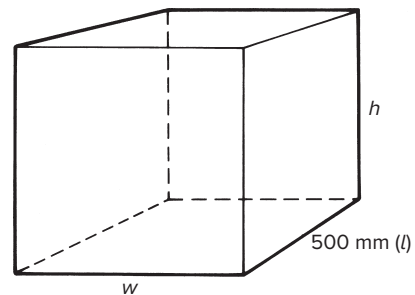
Solid figures are those that occupy space, and the amount of space is called their 'volume'. Solid figures have three dimensions—length, breadth and height.

4.4.1 Cube

This is a solid figure contained by six square faces. It has length, width and height, which are all equal (Fig. 4.23).

$$\begin{aligned}\text{Volume} &= l \times l \times l, \text{ or } l^3 \\ &= 0.5 \times 0.5 \times 0.5 \\ &= 0.125 \text{ m}^3\end{aligned}$$

Fig. 4.23 Cube



4.4.2 Prism

A prism is a solid figure with two equal and parallel ends and straight parallel sides, which are parallelograms. Prisms are named according to the shape of the end faces.

The *axis* is an imaginary line joining the centres of the end faces. When the axis is at right angles to the end faces, it is termed a *rectangular or right prism* (Fig. 4.24). Otherwise they are called *oblique prisms* (Fig. 4.25).

$$\text{Volume of rectangular prism} = l \times b \times h$$

$$= 0.7 \times 0.5 \times 2.5$$

$$= 0.875 \text{ m}^3$$

Fig. 4.24 Rectangular or right prism

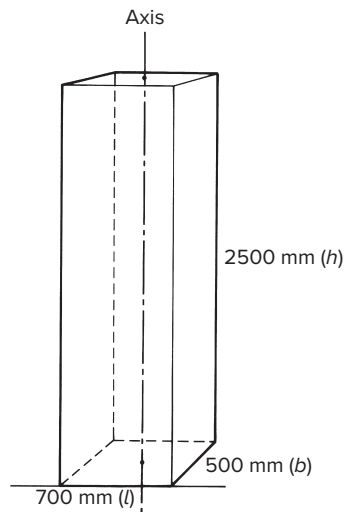
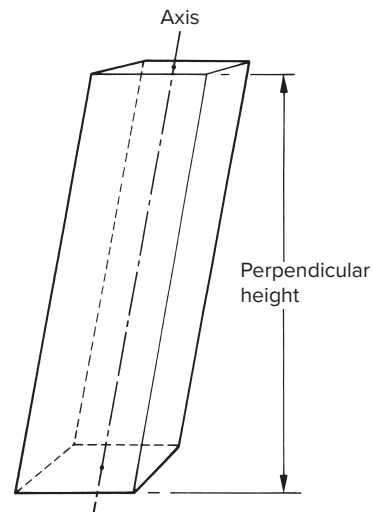


Fig. 4.25 Oblique prism



Prisms are often found lying on their side, such as in a concrete beam (e.g. Fig. 4.26) and the formula for the volume can be modified to:

$$\text{Volume} = \text{area of end} \times l$$

$$\text{Volume of square prism} = w^2 \times l$$

$$= 0.3 \times 0.3 \times 4.6$$

$$= 0.414 \text{ m}^3$$

$$\text{Volume of triangular prism} = (b \times Ph)/2 \times l$$

$$= (1.5 \times 0.6)/2 \times 3.8$$

$$= 1.71 \text{ m}^3$$

Fig. 4.26 (a) Triangular prism; (b) square prism

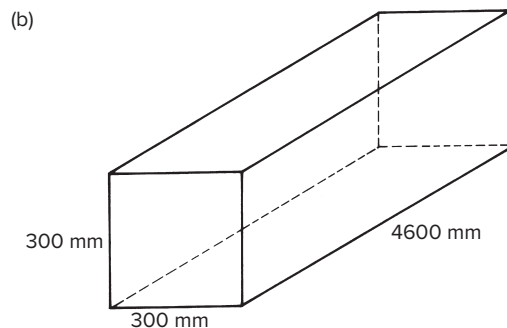
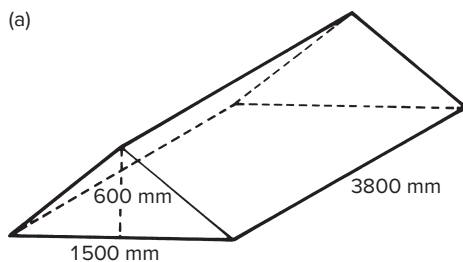


Fig. 4.27 Cylinder

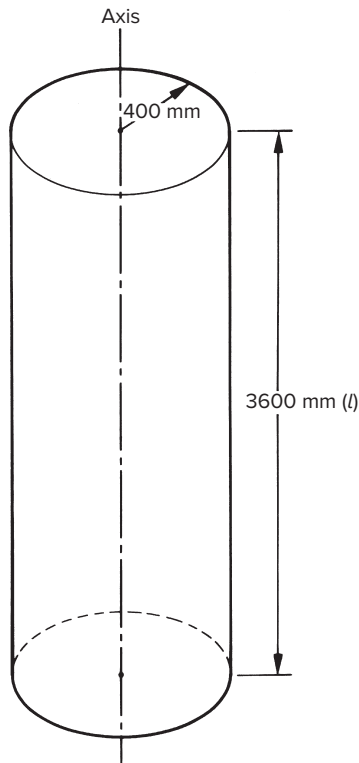
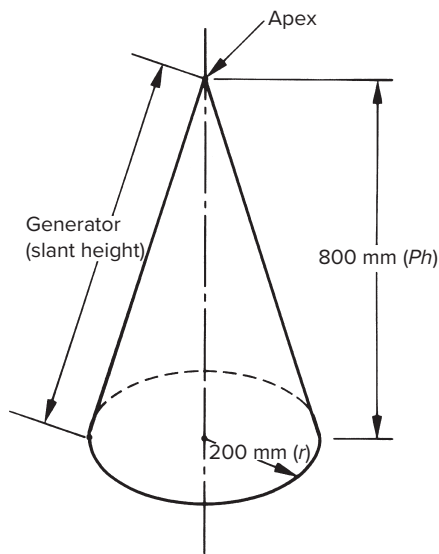


Fig. 4.28 Cone



4.4.3 Cylinder

A cylinder is a solid figure having two circular ends and straight parallel sides (Fig. 4.27).

$$\begin{aligned}\text{Volume} &= \text{area of end} \times h \\ &= \pi r^2 \times h\end{aligned}$$

For example, calculate the volume of a cylinder with a diameter of 800 and a height of 3600.

$$\begin{aligned}\text{Volume} &= \pi r^2 \times h \\ &= 3.142 \times 0.4 \times 0.4 \times 3.6 \\ &= 1.81 \text{ m}^3\end{aligned}$$

4.4.4 Cone

A cone is a solid figure with a circular base and straight sloping sides meeting at an apex (Fig. 4.28). The *generator* is a straight line joining any point on the circumference with the apex. The *slant height* is the length of the side along the generator, and the *perpendicular height* is the distance from the base to the apex measured along the axis.

The volume of a cone is equal to the area of the base times one-third of the perpendicular height (Ph). For example, the volume of a cone with a radius of 200 mm and a perpendicular height of 800 mm is:

$$\begin{aligned}\text{Volume} &= \pi r^2 \times 1/3 \times Ph \\ &= 3.142 \times 0.2 \times 0.2 \times 0.8/3 \\ &= 0.0335 \text{ m}^3\end{aligned}$$

4.4.5 Pyramid

A pyramid is a solid figure standing on a geometrical base with straight sides sloping to an apex. Pyramids are named according to the shape of their base—square (Fig. 4.29), rectangular, hexagonal, etc. The volume of a pyramid is equal to the area of the base $\times 1/3 \times Ph$. For example:

$$\begin{aligned}\text{Volume of a pyramid} &= \text{area of base} \times 1/3 \times Ph \\ &= (0.3 \times 0.3 \times 1.2)/3 \\ &= 0.036 \text{ m}^3\end{aligned}$$

CHECK YOUR UNDERSTANDING

6. A concrete path measures 22 m in length $\times$ 1600 mm in width $\times$ 100 mm in depth.
 - a. Calculate how many cubic metres of concrete will be required to pour that path (show the correct formula and workings).
 - b. What would be the total cost of the pour if the cost of ready-mix concrete is \$165.00 per cubic metre? Note: when ordering ready-mix concrete, the company will supply only in increments of 0.2 cubic metres. Therefore, when placing an order and costing, you will need to round up your order to the next 0.2 of a cubic metre.

4.4.6 Weight/mass

Weight/mass is important for a number of activities in the building industry. For instance, it needs to be known when calculating roof members for a timber roof, as the mass of the roof covering needs to be determined so that the appropriate size of the member can be calculated.

It would also need to be known when picking up materials such as crushed rock from a garden supplies centre using a trailer. For loose materials such as crushed rock, sand and concrete, the volume is generally calculated and expressed in cubic metres (as mentioned earlier in this chapter). However, the weight also needs to be known so that the trailer is not overloaded. All trailers, utes and trucks have a maximum weight rating, and it is against the law to exceed that rating—it is also dangerous. The weight of loose material can vary depending on its water content. For instance, 1 square metre of sand can have different weights depending on how much moisture is present, although the volume doesn't vary. The company selling the product will generally know the weight of a cubic metre of that material, so it is important to ask the question prior to loading.

Alternatively, a weighbridge could be used to work out how much the loaded material weighs. The trailer would first need to be weighed empty and then again once loaded. However, this is not really practical and would be time-consuming and costly. The weight of the products would be stated in either kilograms or fractions of a tonne.

4.4.7 Tolerances

Knowing what tolerance is being worked to will ensure that the work being carried out is completed to the desired standard. For example, when setting out a rectangular house, it is important to check that it is square once set out. So, the two diagonal measurements would be measured to see if they were the same. A difference of 5 mm in the two diagonal measurements would be deemed acceptable. But if the difference was 50 mm, this would be considered to be outside the acceptable tolerance of error. The house would therefore need to be set out again.

Tolerances can also be used when teaching apprentices about the expected quality when completing certain tasks. For example, as an apprentice I was taught the acceptable gap in a mitered joint when installing the architraves around a door, was the thickness of a cigarette paper. This was a way of gauging what standard of work was acceptable rather than providing a measurement.

4.5 Calculate and order materials

Table 4.2 is an example of how a carpenter would record what materials are required for the arbour in Figure 4.30. It's important that the notes on the table are clear and concise so that the company supplying the materials understands what the carpenter wants, but also so that at a later date the carpenter does not have to rely on memory alone for the finer details of the project and does not need to recall what the original thinking was when working out the quantities.

Fig. 4.29 Square pyramid

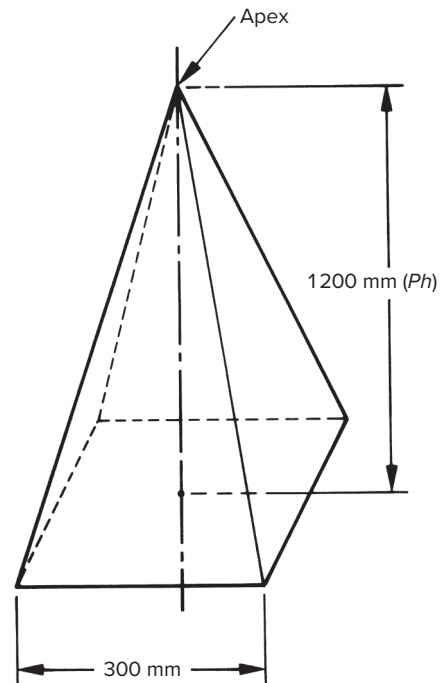
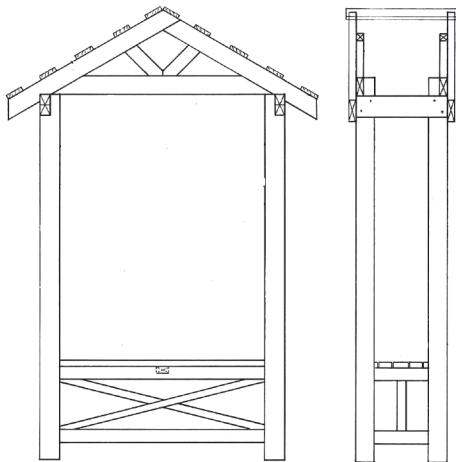


Table 4.2 Arbour material list

Item	Part	Timber species	Quantity required	Length	Width	Thickness	Remarks
1	Posts	Oregon	4	2.4 m	90 mm	90 mm	
2	Roof members	Hoop pine	2	2.4 m	90 mm	45 mm	Rafters
3			1	2.1 m	70 mm	35 mm	Battens
4			2	1.5 m	90 mm	45 mm	Fascia beam
5	Seat members	Hoop pine	1	1.8 m	70 mm	45 mm	Top and bottom back rail
6			1	2.4 m	70 mm	45 mm	Top and bottom front rail
7			1	2.4 m	70 mm	45 mm	Seat supports
8			1	1.8 m	70 mm	45 mm	Side
9	Seat slats	Jarraah	3	2.7 m	90 mm	19 mm	
10	Seat brace	Hoop pine	1	2.4 m	70 mm	35 mm	

Courtesy of WorldSkills Australia

Fig. 4.30 Timber arbour with seat

Courtesy of WorldSkills Australia

Table 4.2 can be adapted to use for ordering any construction materials. The key is to be clear with the information being recorded and to include enough information so that people can make sense of it.

This table can be drawn by hand or created on a computer-based spreadsheet program. The advantages of using a digital table are that once the table is created, it can be used multiple times for different projects. The functions within the spreadsheet mean you can create rules/formulas to calculate the total material amounts and material costs, add wastage etc., without having to calculate this manually. All you are doing is inputting data. The table is easy to send via email and can be amended with ease without having to redo it from scratch—as you would have to do if it was handwritten.

WORKPLACE SCENARIO

When I was a third-year apprentice, we were working on my boss's house. One day we were installing the stumps for the subfloor. The concrete truck was there and we were barrowing the concrete to each hole ready for the stumps to go in. It was a blistering hot day, about 36 degrees, so the concrete was going off quickly and we were working as fast as possible to get the concrete poured and the stumps in place. We were also looking forward to finishing for the day, but as we finished placing concrete into the last hole, my boss yelled out that the next concrete truck would be arriving in 15 minutes. 'Oh?' we said. 'Another truck?' Guess who had doubled the concrete order by mistake! There was no way of returning it, so needless to say, by 9 pm that night we had also poured blind concrete for the patio, and all of the external steps for the house had been poured, too!

Chapter 5

Trade drawings

Learning Objectives

LO 5.1 Locate, access and verify plans and specifications

LO 5.2 Identify and interpret types of construction plans and drawings and their features

LO 5.3 Recognise commonly used symbols and abbreviations

LO 5.4 Locate and identify key features on building plans

LO 5.5 Use drawing programs and tools and determine project requirements

Introduction

The ideas and construction methods used to produce buildings are set down in the form of drawings and building specifications. These allow different trades to understand the work that needs to be done without referring to one specific person. All architectural drawings and specifications are produced using a specific language. It is necessary to understand how the information is conveyed by architects and draughtspersons in order to read the drawings and specifications and then build the planned structure as intended by the designer.

In this chapter you will learn how to access, identify and verify version currency and read basic building plans and documents. This will include elements such as the different plans, elevations and sectional views associated with working drawings in the building trade.

You will learn how to identify and read aspects such as title panels, specifications, amendments, abbreviations, symbols and scales. You will then produce some working sketches and drawings of your own using the drawing equipment discussed in the chapter.

5.1 Locate, access and verify plans and specifications

5.1.1 Paper-based plans and specifications

Walk onto any domestic construction site where a new house is being constructed or home extensions or renovations are taking place around Australia, and the work crew carrying out the construction work will most likely be working from a paper-based set of house plans and specifications that have been drawn up to accommodate all of the trades involved in the construction process.

The workers on-site will all have their own set of plans supplied to them by the builder, so they have access to any information required as the work progresses.

These plans would have been developed by an architect or draughtsperson on behalf of the client, or by the construction company if the building being constructed is one that is unique to that company.

These plans and specifications are usually discussed and finalised by the builder and the client, with a construction contract being signed. Then, any changes to the plans or specifications during the course of the construction will be discussed by both parties and any amendments signed and dated.

These amended plans and specifications will then be distributed to the relevant trades to be verified and used for the remainder of the project.

Any engineered items, such as prefabricated wall frames and roof trusses will be delivered onto the construction site with their own set of plans showing the configuration and the tie-down and bracing requirements.

5.1.2 Electronic plans and specifications

More and more these days, the project plans and specifications, as well as many other facets of construction work, are being developed and managed electronically by all parties involved. This is especially so for major commercial and industrial construction sites, although some domestic building companies are moving to totally electronic management of their housing construction projects as well.

Apps programmed with cloud-based platforms for data that can be immediately accessed via computers, tablets, Ipads and phones are now available.

It is no longer necessary to print out plans and specifications in sheet or book form or store them electronically in Word documents or on spreadsheets. The process of physically adjusting and making changes to plans, then reissuing them to every trade person or associate by email or fax, or hand-delivering paperwork, is becoming a thing of the past, especially on major construction projects. With these new programs becoming more commonplace in the construction industry, any adjustment to a plan or specification, no matter how major or minor, can be communicated to every party involved in the project within seconds.

Major contractors—who would generally control the data, in consultation with architects, engineers and clients, right through to the subcontractors and suppliers—can now make adjustments or changes, known as amendments, to the plans or specifications and have them uploaded to selected parties registered to the specific construction project on the program. Notifications are sent to the recipients, so they are made aware immediately of any amendments that have been made. As soon as the program refreshes on the device, the amendments are there to be viewed and used. This means that everyone involved receives the same amended information at the same time.

As well as making updated data readily available to all parties, this removes the chance of costly mistakes or confusion surrounding specific construction methods or details that may have been conveyed to one contractor within a certain period of time, but not another. The companies that develop, sell, then host these apps will provide all of the technical and background support needed to run the software and make sure all of the data storage is secure.

One such platform is **Procore Construction Management**, which offers complete management of specific construction stages such as:

- tendering
- project management
- quality control
- workplace safety

- plans and specifications
- building information modelling (BIM)
- equipment management
- project financials
- invoice management
- accounting integrations.

Procore is cloud-based, and information about the specific construction project being undertaken can be shared within seconds with other parties involved. Larger commercial or industrial construction companies are more likely to be using management platforms such as Procore due to the enormous capabilities of the platform.

5.2 Identify and interpret types of construction plans and drawings and their features

There are basically two levels of drawings:

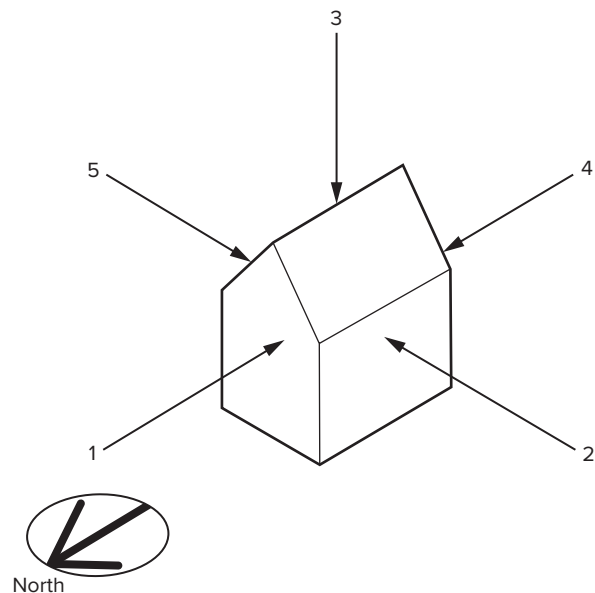
1. **Design drawings**, where the ideas on relationships, sizes and stylistic treatment of rooms are explored. These drawings allow the architect and the client to agree about what is to be done.
2. **Building or working drawings**, which set down the finalised design. These, together with the job specification document, provide all of the information the builder and tradesperson need for construction work to take place.

The information conveyed in all types of architectural drawings is standardised so that people in different places and from different backgrounds can understand the construction of the building.

The basic form of drawing is called *orthographic* projection and consists of a series of related views of the building, which, when looked at in conjunction with each other, allow a complete understanding of the building (Figs 5.1–5.4).

The three main types of ‘view’ of a building are the plan, elevation and section.

Fig. 5.1 Naming views on an orthographic drawing



5.2.1 The plan view

The plan view shows the layout or arrangement of parts of a building when seen from above (bird's eye view) such as the rooms in the building. There are many types of plan view, for example:

1. site plan
2. floor plan
3. roof plan
4. footing plan.

Naming or numbering of views	
View 1 or Elevation 1	North elevation
View 2 or Elevation 2	West elevation
View 3 or Plan	Plan
View 4 or Elevation 3	South elevation
View 5 or Elevation 4	East elevation

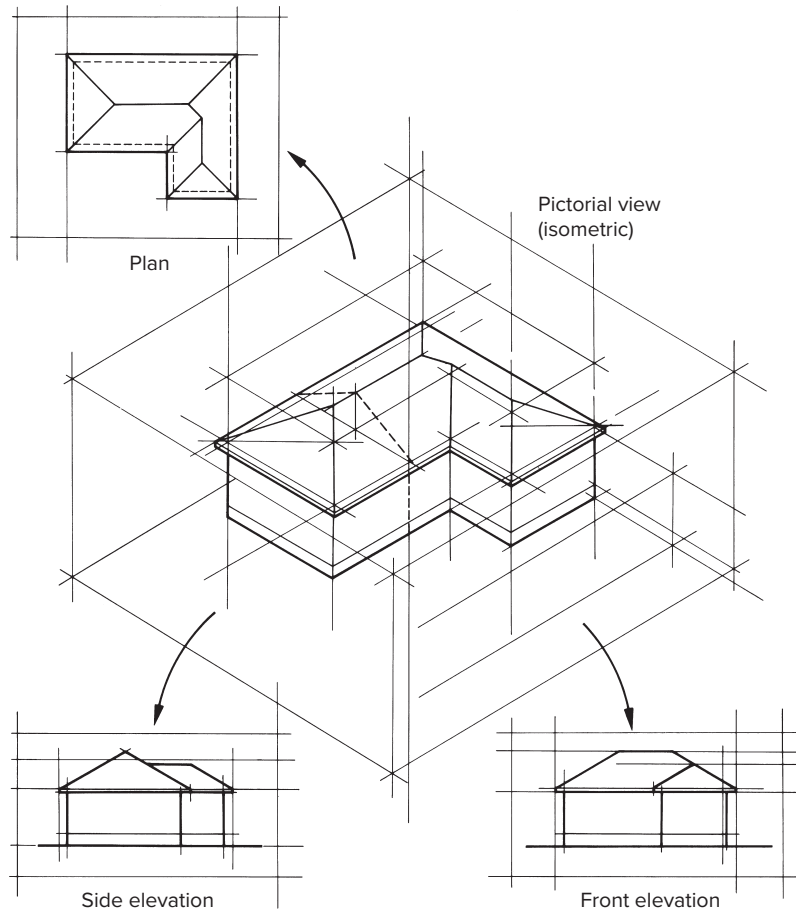
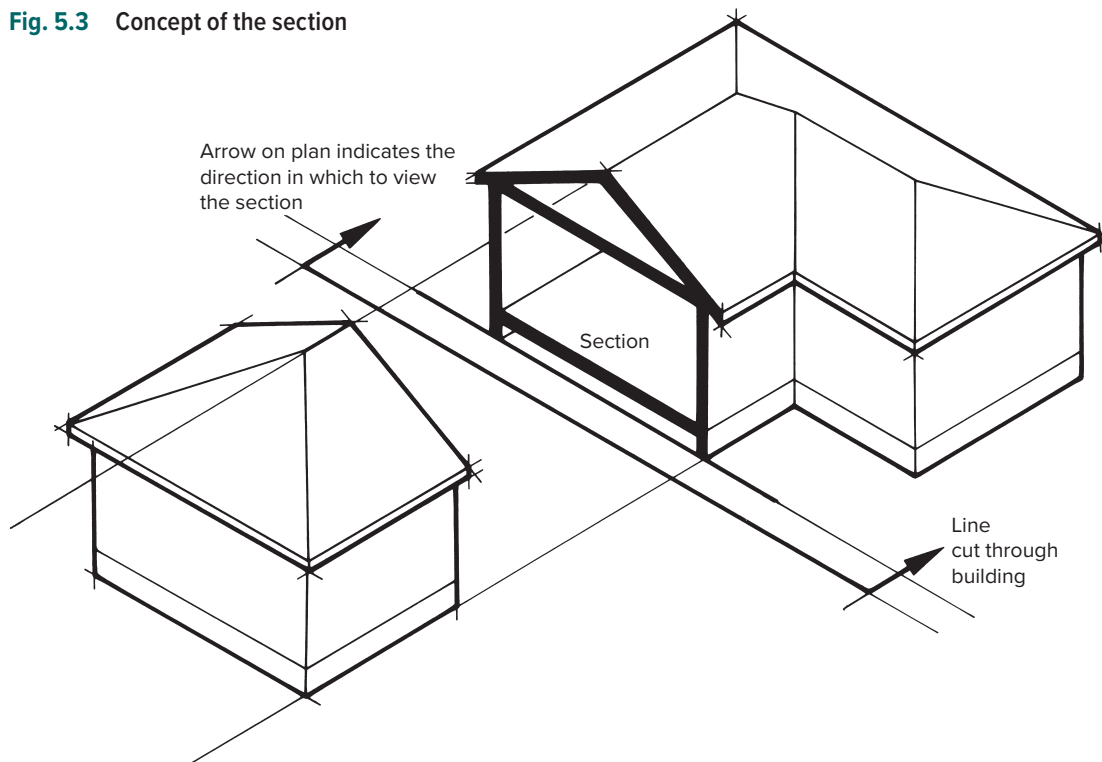
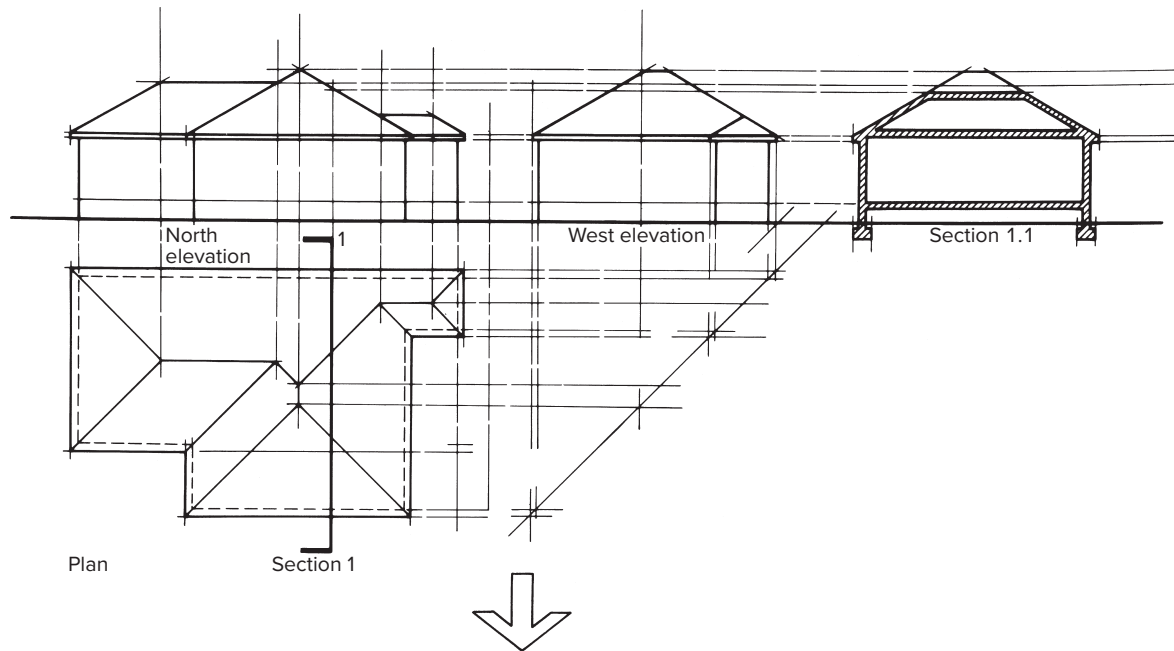
Fig. 5.2 Orthographic drawing—concept**Fig. 5.3** Concept of the section

Fig. 5.4 Arrangement of orthographic views on a drawing

5.2.2 The elevation view

This is a view of a side of a building, facing it squarely. For a building with four sides, the architectural drawings will show four elevation views. To avoid confusion between the elevation views, we name each elevation according to what direction it faces on the compass, for example, the south elevation.

5.2.3 The sectional view

This is like a vertical plan view; just as a floor plan is a view of the walls as if the roof of a building had been removed, so a section is a side view as if an exterior wall had been removed. More correctly it is a 'cut' through a building at a certain point. It shows heights and internal structures that are not evident in the plan or elevation views.

5.2.4 Understanding scaling

The architectural information comes in many varied forms, and is set out on single or multiple sheets of paper, often referred to as the 'drawings' or 'plans' of the building.

The process of drawing large objects such as buildings or parts of buildings to a proportionate size that can be fitted on to paper is called *drawing to scale*. The scale is, in effect, a reduction of the full-sized object to a small picture—like a reproduction that exactly represents the real thing. For example, instead of drawing a window that is 900 mm long, it is drawn at a reduced scale, say, 1/50th of its full size. This enables all of the orthographic views to be reduced and placed on handy-sized sheets.

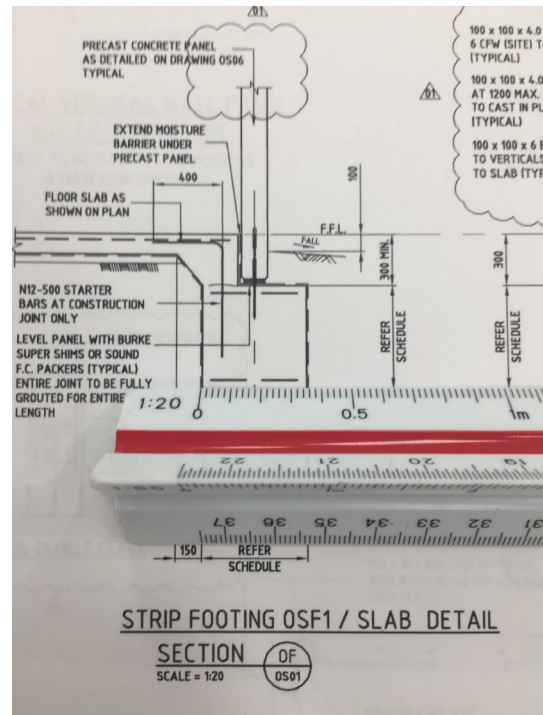
The most common scales used in construction practice are:

- site plans—1:500, 1:200, 1:100
- plan views—1:200, 1:100, 1:50, 1:20
- elevations—1:200, 1:100, 1:50, 1:20
- sections—1:200, 1:100, 1:50, 1:20
- construction details—1:10, 1:5, 1:2, 1:1 (full size).

A simple way to understand how scaling works is to measure between the dimension lines and multiply by the scale to which the plan has been drawn (Fig. 5.5). This may need to happen if the dimension has been missed and not recorded.

If plans need to be produced from preliminary sketches that have dimensions jotted in, simply divide the measurement by the scale to which the plan will be drawn to get the correct measurement for drawing.

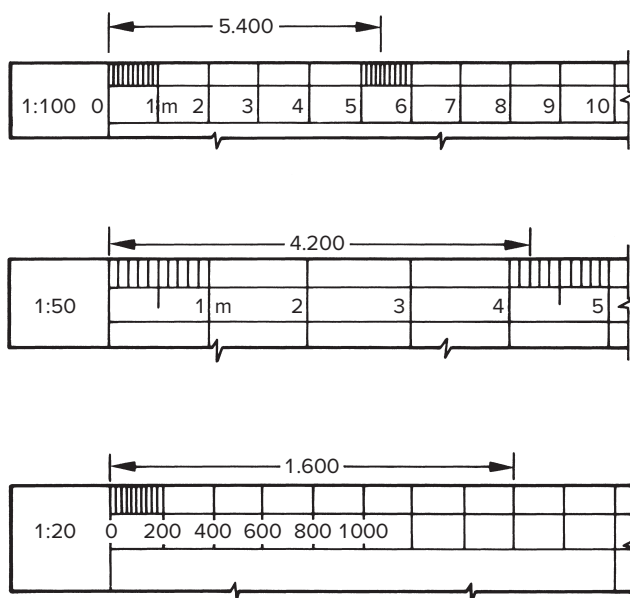
Fig. 5.5 A 350 mm wide strip footing shown at scale 1:20 by scale rule



Courtesy of Alister Ford

TIP The measurements on architectural working drawings will always take precedence over a scaled measurement.

Fig. 5.6 Reduction scales



Put simply, true length divided by scale = plan length. Or plan length multiplied by scale = true length.

For domestic constructions, the most common scales of drawings are 1:100 and 1:50 (Fig. 5.6). This is because domestic construction practice has become relatively standardised and there is no need to show details that are common knowledge throughout the industry. In order to represent this common construction practice at reduced scales, a symbolised code for building elements (e.g. windows and doors) has evolved. A sample of these conventions displaying the symbols for materials is shown in Figure 5.7.

These symbols in fact comprise the 'language' of building drawing and it is necessary for carpenters to familiarise

themselves with them in order to interpret construction drawings. The symbols appear on plans, elevations and in sections at various scales. On some types of drawing (notably restorations and extensions to existing buildings), the symbols are coloured in order to distinguish new work from the existing structure.

Fig. 5.7 Architectural information—symbols for materials

Material	General location drawings (section) Scale: 1:50 or less	Large-scale drawings (section)
Brickwork		
Cement render, plaster	Too fine to hatch	
Concrete		
Concrete block		
Cut stone masonry		
Earth		
Fill		
Glass	Too fine to hatch	
Hardcore		
Insulation		
Partition block		
Rock		
Structural steel		
Stud walls		
Timber	Usually too fine to hatch	Sawn
		Dressed

WORKPLACE SCENARIO

I can recall a day early in my career as a qualified carpenter and joiner. I had finished my apprenticeship in a carpentry/joinery workshop environment and had now commenced a new full-time job with a major construction company in Melbourne.

I was sent to a building site in the city and when I arrived, I reported to my foreman. This site was the construction of a multistorey building well in excess of 30 floors high. The foreman showed me around and introduced me to some of my new work colleagues then told me which job he needed me to do.

The work is comprised of some framing and formwork that needed to be set up on one of the floors so that we could then proceed further with that job. I asked for some plans and specifications, so off we went to the shed that was specifically allocated to housing all of the building plans and documents.

When we walked into the shed there were racks and benches along each wall totally covered with folders full of plans and documents. I had no idea where to look. I had never seen anything like this before. I was totally overwhelmed with the enormity of it all. I told the foreman that I had no idea what to do in regards to obtaining plans for the job at hand, so he showed me how to reference all of the plans and specifications.

After that I spent a lot of my spare time in the plan shed teaching myself how everything worked on a major job site such as this one.

5.2.5 Specifications

A specification is the extension of the working drawings and contains additional written instructions that complement the working drawings. While the working drawings contain written details, their main purpose is to show information relating to the shape, location and dimensions of the building. Additional information on the quality of the work, materials, fabrication sizes, colour and finishes of the building project are contained within the written specification document. Information that is not found in one document should in most instances be found within the other.

Specifications for an extremely large construction such as a multistorey building may be provided via apps for electronic devices, as previously mentioned in this chapter, or electronically via computer Excel spreadsheets or in book form, sometimes being provided in multiple volumes. For smaller construction jobs there may only be a smaller booklet. Sometimes the specifications may be included on the working drawings.

A standard specification will include information for the builder and various tradespeople working on the specific project and is provided under headings such as concreter, bricklayer, carpenter, plumber, electrician, etc.

When the specification is read in conjunction with the working drawings, sufficient information will be available for the builder and contractors to submit accurate tenders, sign contracts and engage in the construction of the building.

NATSPEC Construction Information is an impartial, national, not-for-profit organisation. It is not involved in advocacy or policy development and is owned by the Australian government and the Australian design, building, construction and property industry. One of its partners is the Master Builders Association of Australia.

The organisation, which has been in operation for more than 40 years, has the objective of improving the construction, productivity and quality of the Australian built environment, through delivering the country's national, comprehensive construction specification system.

Specifications from the largest construction projects through to domestic jobs can be developed using the NATSPEC (National Building Specification) tools available on the organisation's site.

It provides comprehensive templates—all that is needed is to select the items required to be in the specification. These items are then automatically loaded into the document and all information regarding the product and the Australian Standards that need to be met are included.

NATSPEC is available for use by professionals such as building designers, architects, structural engineers, construction companies, landscape architects or designers, interior designers and service engineers through to domestic owners/builders. It is also the body responsible for overseeing the National BIM Guide and all associated documents.

There are many NATSPEC sources, but they include:

- Australian Building Codes Board (ABCB)
- Australian Construction Industry Forum (ACIF)
- Cement, Concrete and Aggregates Australia (CCAA)
- Concrete Institute of Australia (CIA)
- Forest and Wood Products Australia (FWPA)
- Glue Laminated Timber Association of Australia (GLTAA)
- Green Building Council of Australia (GBCA)
- National Association of Steel-Framed Housing (NASH)
- National Occupational Health and Safety Commission (NOHSC)
- Safe Work Australia
- Standards Australia
- State WorkSafe departments
- Victorian Building Authority (VBA).

Many more sources of construction industry information are available on the NATSPEC website. However, those listed above are the ones you are most likely to encounter during your time as an apprentice carpenter, as you will at times need to reference information from some of these organisations in regards to the work you are carrying out.

5.2.6 Amendments

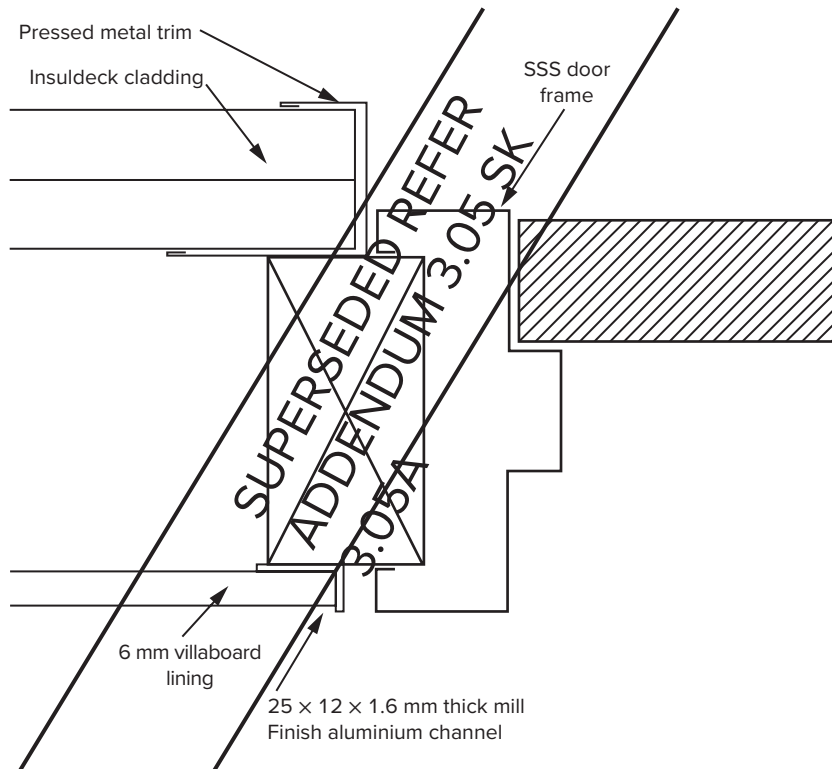
If a change is decided upon during the construction of the building, the plans and specifications will need to be changed and approved. This is called an amendment, or a minor variation, depending on the size and scope of the change (Fig. 5.8). Amendments need to be shown on the most recent set of plans. This can be confirmed by cross referencing the dates of the working drawings being used and also the set of specifications being referenced to make certain both documents are up to date. Any amendments made must also be signed and dated by the client and builder so there is no chance of confusion between any of the parties involved with the build.

Amendments can be shown on the working drawings and also noted in the plan title panels. If there are changes to the specifications of the finished job, the amendment may need to be noted in the job specifications as well.

Most amendments will occur when the client decides to make some changes or if any specific building materials or items are no longer available after the plans have all been approved and work has commenced.

Some common changes include the resizing of rooms, requirements for walls to be constructed in a different position, a window being repositioned or made bigger, and bathroom or kitchen alterations or redesigns.

Amendments to the plans on large-scale construction jobs will often be marked on the plan with a direction to check the addendum for more information. This will usually be a specific book or document that accompanies the plans and specifications.

Fig. 5.8 An amended plan referring to the addendum for more detail

TYPICAL EXTERNAL TIMBER DOOR FRAME

Courtesy of Alister Ford

As mentioned earlier in this chapter, amendments to plans and specifications can now be made available to all concerned as soon as they are made, confirmed and uploaded via cloud based platforms where all the information is stored by the host and managed by the builder principal.

The size or scope of the alteration doesn't matter—it is always best to have the amendments approved by the relevant authorities and the plans altered by the architect or draughtsperson.

5.3 Recognise commonly used symbols and abbreviations

5.3.1 Abbreviations

Using abbreviations is a way to show summarised written details—shortened or abbreviated names for appliances, fixtures and other items—on a plan without deliberately overcrowding or cluttering up the document.

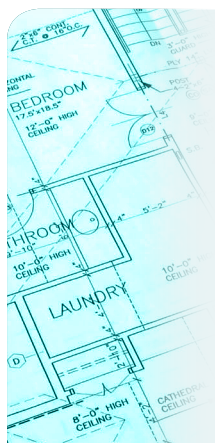
The most common abbreviations used are compiled in a list; a small sample of these is shown in Table 5.1. A more comprehensive list is available in Australian Standard AS 1100 Technical drawing, Part 301 Architectural drawing (AS 1100.301–2008).

Table 5.1 Interpretation of abbreviations used in construction

Abbreviation	Word(s)	Abbreviation	Word(s)
AHD	Australian height datum	FW	Floor waste
AJ	Articulated joint	G	Gas
AL	Aluminium	HW	Hot water unit
AS	Australian Standard	NCC	National Construction Code
B	Basin	P	Pier
BCA	Building Code of Australia	PBD	Plasterboard
BDYL	Boundary line	PCC	Pre-cast concrete
BL	Building line	PF	Pad footing
BT	Brick	PG	Plate glass
BV	Brick veneer	RSJ	Rolled steel joist
BWK	Brick work	S	Sink
C	Cooker	SA	Smoke alarm
CF	Concrete floor	SD	Sewer drain
CL	Centre line	SHR	Shower
COL	Column	SWBD	Switchboard
CONC	Concrete	SWD	Stormwater drain
CR	Cement render	T	Truss
CTR	Contour	TBM	Temporary bench mark
CW	Cavity wall	TM	Trench mesh
D	Door	TRH	Trough
DGE	Drainage	UNO	Unless noted otherwise
DP	Downpipe	V	Vent
FCL	Finished ceiling level	W	Window
FFL	Finished floor level	WC	Water closet
FHT	Floor height		

5.3.2 Contents of drawings

Refer to Figures 5.9-5.11 and the sample working drawings located in the Appendix for examples of drawing types.



INTERPRETING PLANS

Refer to drawing 05 in the Appendix.

Identify, sketch and label the symbols for the following items:

- double power point
- light point
- manhole (ceiling access point)
- exhaust fan
- hot water service
- smoke detector.

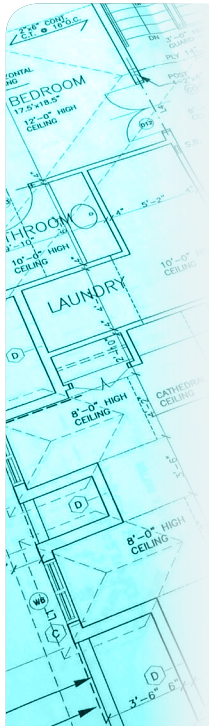
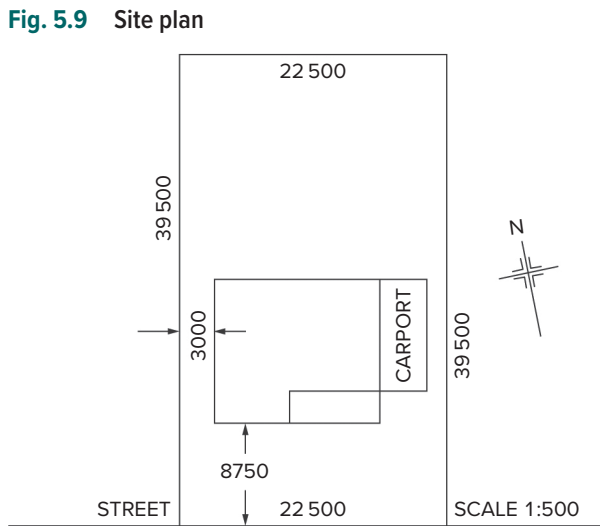
5.4 Locate and identify key features on building plans

5.4.1 Site plan

Refer to Figure 5.9 and drawing 01 in the Appendix.

Information found on a site plan can include:

1. site boundaries and dimensions
2. contours of the block of land
3. location of the proposed building
4. roads and pathways
5. soil and surface water drains
6. location of services—electricity, gas, sewer, water
7. service runs from mains to building
8. site datum point
9. earthworks—banks or excavations
10. landscaping
11. existing trees
12. direction of north
13. location of easements.



INTERPRETING PLANS

Refer to the site plan view, notes and regulations in drawing 01 in the Appendix and obtain the following information:

- size of the building block
- width of the service easement
- distance set back from the street alignment to the front building line
- scale that the site plan is drawn to
- street name and lot number of the building site
- number of downpipe outlets required for connection to stormwater drainage
- BAL (bushfire attack level) rating for the site, and the referenced Australian Standard
- height of the proposed residence
- what must be checked by the builder prior to the start of construction
- maximum gradient of the driveway should not exceed a slope ratio of . . ?
- established fencing arrangements for the south, east and west boundaries of the site
- current date of the plan version if no amendments have been made.

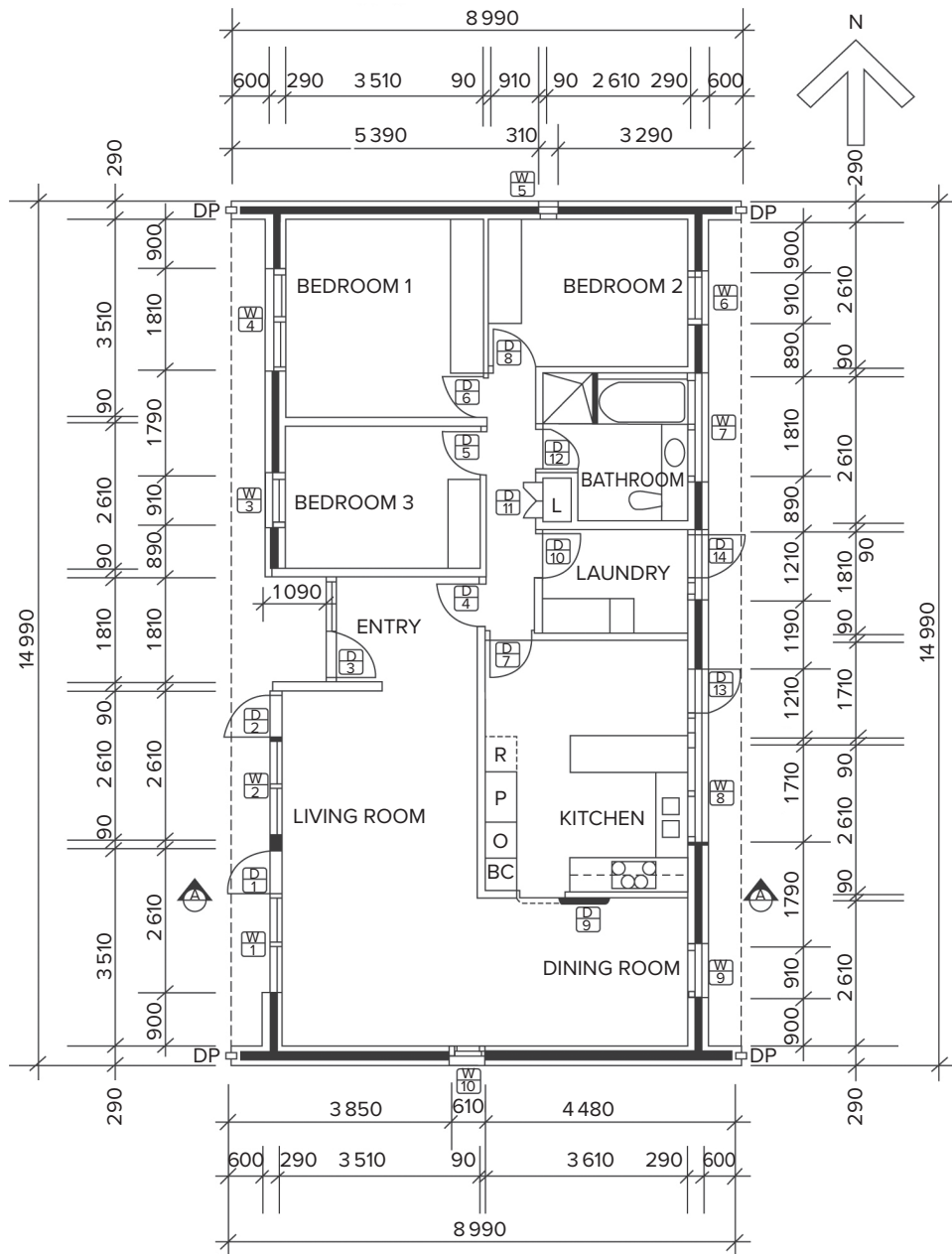
The direction north should always be indicated on the site plan.

5.4.2 Floor plan

Refer to Figure 5.10 and drawing 02 in the Appendix.

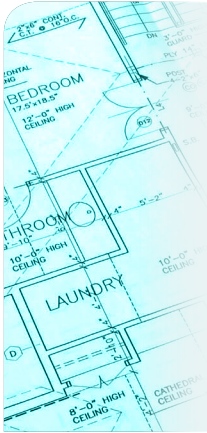
Floor plan details can show:

1. internal and external walls
2. overall building dimensions

Fig. 5.10 Floor plan

3. internal dimensions
4. openings in walls—doors and windows
5. wall thicknesses
6. location of fittings and fixtures
7. names of rooms
8. floor finish materials
9. location of stairs and number of treads
10. location of sections.
11. wind classification for the site
12. type of glass to be installed in the bathroom and en-suite windows

13. the total accumulated internal measurement from the south wall of bedroom 3 to the north wall of bedroom 2
14. the number of vinyl planks required to cover the floor of hall 1 and hall 2, including the linen cupboard. Add 10% to cover doorways and waste
15. the type of roof to be constructed on this dwelling
16. the total accumulated internal measurement from the east wall of the bathroom to the west wall of hallway 1.



INTERPRETING PLANS

Refer to the floor plan view in drawing 02 in the Appendix and obtain the following information:

- overall length and width of the building
- internal dimensions of the garage
- smoke alarm points
- type of floor covering installed in the laundry
- the Australian Standard to which all pre-fabricated wall framing must comply
- the number of vertical construction joints to be included in the building.

5.4.3 Footing plans

The footing plan will show the:

1. location of the footing system
2. width and depth of footings
3. location and levels of drains.

5.4.4 Roof plans

This plan is often superimposed on the floor plan and can include:

1. shape of roof
2. slope of roof (pitch)
3. gutters, downpipes and sometimes levels
4. type of roof cover
5. roof penetrations—chimney, roof lights
6. type of construction (if applicable).

5.4.5 Services plans

Refer to drawing 05 in the Appendix.

These are normally superimposed on floor plans in domestic building plans and can show, for example:

1. electrical layout
2. plumbing and drainage layout
3. air conditioning.

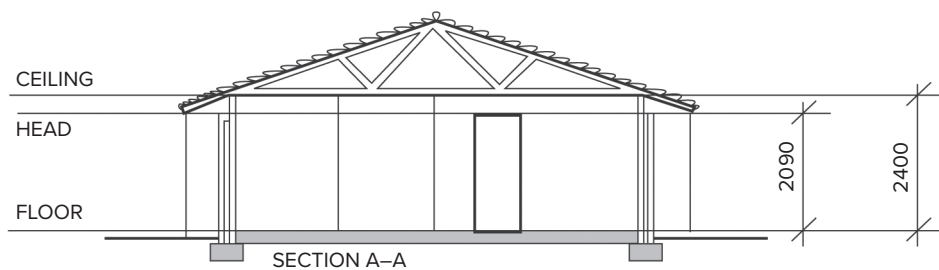
5.4.6 Sections

Refer to Figure 5.11 and drawing 04 in the Appendix.

Section details can include:

1. new and old ground levels
2. heights above ground of rooms and roof
3. construction and thickness of floors, walls, roofs
4. internal and external walls
5. openings in walls
6. location of fittings and fixtures
7. names of rooms
8. slope of roof.

Fig. 5.11 Section



INTERPRETING PLANS

Interpreting sectional views and details

Refer to the section and detail views, and information in drawing 04 in the Appendix, and identify the following:

- type of slab design
- overall height of the walls
- the Australian/New Zealand Standard that must be followed when installing all flashing
- two current documents that all timber framing must comply with
- the minimum height for the installation of ceramic wall tiles on shower walls
- type of material from which eave lining is constructed, and the type of coating used to finish it
- where to find energy rating information on wall and ceiling insulation
- scale to which typical eaves detail is drawn.

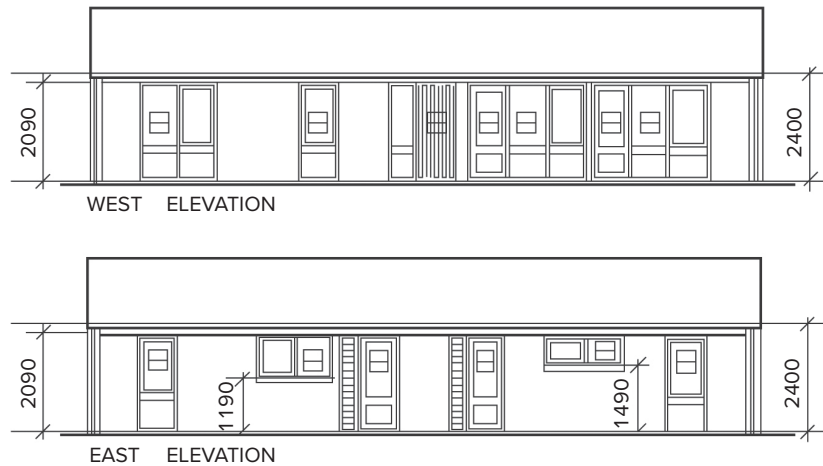
5.4.7 Elevations

Refer to Figure 5.12 and drawings 03 and 04 in the Appendix.

Elevation drawings will show:

1. size and shape of external walls
2. size and shape of openings
3. external finishes
4. new and old ground levels

5. floor and ceiling levels
6. roof shape and slope.
7. window (joinery) height.

Fig. 5.12 Elevation

INTERPRETING PLANS

Interpreting elevation views

Refer to the elevation views and information in drawing 03 in the Appendix and identify the following:

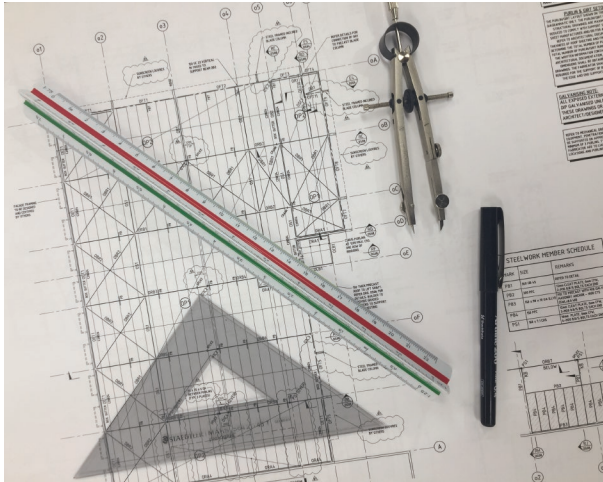
- pitch of the roof
- roof covering
- type of windows
- floor-to-ceiling height
- draft or issue number of the elevation plans
- the Australian Standards in accordance with which vertical construction joints must be constructed
- position of weep holes, and the maximum spacing
- number of construction joints to be placed in the wall of the west elevation
- difference in height between the FFL and the garage FL.
- the type of glass to be installed in the front door frame assembly and door.

CHECK YOUR UNDERSTANDING

1. Which plan view will give you the position of a building on an allotment?
2. How are elevations identified on a working drawing to avoid confusion?
3. List five items of information that can be found on the elevation view.
4. List the most common scales used in the following drawings:
 - a. site plans
 - b. plan views
 - c. elevations
 - d. sections.

5.5 Use drawing programs and tools and determine project requirements

Fig. 5.13 Drawing tools on a plan—compass, scale rule, set square and drawing pen



Courtesy of Alister Ford

The tools used to produce working drawings and plans have come a long way over recent years, with the development of many computer-aided design (CAD) programs and more recently building information modelling (BIM). You can now produce drawings, both two-dimensional and three-dimensional of the highest quality very quickly on a computer at the click of a mouse.

However, there will still be times when a builder may need to produce their own working drawings and plans for the purposes of quoting or presenting ideas to the client as specified in preliminary discussions on the building project.

Plans and drawings are not just for the construction of new buildings. The builder

may also produce their own plans for the manufacturing of smaller items in the workshop such as cupboards and cabinetry, furniture, staircases, windows and doors.

The builder can do this quickly and accurately using traditional drawing methods (Fig. 5.13). Some items may be drawn to scale, while others may be drawn to full size.

Drawing tools include:

- drawing board
- T-square
- set squares
- scale rule
- ruler
- compass
- protractor
- eraser
- pencils
- retractable pencils
- drawing pens
- drawing paper
- graph paper.

5.5.1 Computer-aided design (CAD)

The term 'CAD' or 'computer-aided design' in the building and construction industry refers to using computer programs to design whole buildings, the individual rooms or the areas within, as well as any of the fitments to be installed in the building.

CAD can be used to create both two-dimensional (2D) and three-dimensional (3D) views. It can be used to create images and information relating to the structural aspects of the house or building, such as the foundations and footings, flooring systems and wall framing, as well as the roof construction. It can also be used for finishing components such as the windows, doors, external cladding finishes, roof

and eaves, and for barge finishes and interior fit-out such as internal wall linings and trims, kitchens, bathrooms, en-suites, laundries etc.

Practically everything to be included in a domestic house build can be designed using a CAD program.

As the design takes shape, aspects such as standards and codes, specifications, dimensions, product information, building materials, component descriptions and any other required supplementary information can be included for reference alongside the finished plans.

Some of the added benefits of using a CAD program to generate plans and illustrations can include:

- faster turnaround times of plans being produced
- accuracy in plan production as errors will automatically be flagged
- consistent plan quality
- images can be generated during plan production and immediate changes, if required, can be made
- plans can be rescaled during production for a complete overview or to focus on specific details
- information can be easily stored for re-use or amendment.

CAD has advanced even more recently, with three-dimensional printing being available.

5.5.2 Building information modelling (BIM)

There are many building information modelling (BIM) platforms and programs available for use in the construction industry.

BIM enables a virtual information model by digitally representing the physical and functional characteristics of a building and allowing them to be shared by all involved in the project—from the earliest conception through to the design and construction, and continuing throughout the life of the building until demolition, when the building is no longer sustainably viable for its intended use.

BIM also has the ability to automatically generate the quantities required for construction, costing estimates, ordering information and delivery tracking information.

The BIM program would be used by all involved—from the team of designers to all those who work physically on the construction of the project, including:

- architects
- draughtspeople
- Engineers, including structural, civil and building services
- landscape designers
- interior designers
- surveyors
- principal contractor
- subcontractors
- owner/operators.

Building information modelling uses three-dimensional representations electronically on screen, rather than the traditional two-dimensional paper-based plans, which would include plan, elevation, and sectional views.

BIM programs can view the projected building from any desired position. Projections can be sliced through to determine internal views, and from this, floor plans, elevations and sectional views of any part of the building can be produced. These can include plan views of the entire building site, the physical building itself in its entirety, through to the finest detail of any particular section or room in the building, and then right down to the finished fitments of the building.

TIPS

- An important point to remember: always treat your drawing equipment the same as you would your tools of trade.
- Keep everything clean and in good order so that when you need to use them, they will not let you down.

Student research

Visit the NATSPEC BIM website: <https://bim.natspec.org/>. Go to the resource dropdown menu, and open the 'Introduction to BIM' link. Next, scroll down to 'The benefits of using BIM' section and list the seven benefits of using BIM.

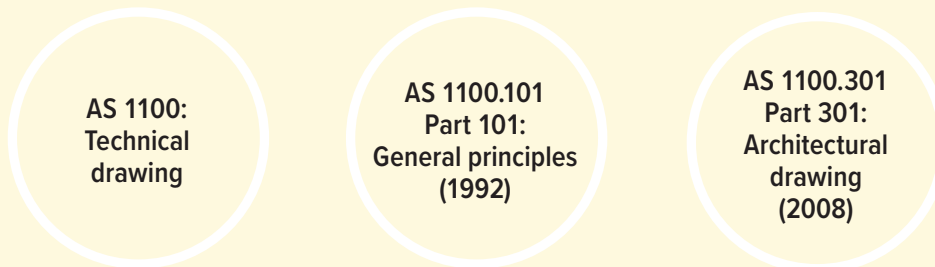
Using the information supplied for each of these seven benefits, provide a handwritten or Word document report, in your own words, that addresses each benefit in approximately 40–60 words per benefit.

End-of-chapter activity

Using the drawing tools discussed in section 5.5, neatly draw the following three types of plans to the specifications provided. Sketch some preliminary drawings for reference if required.

1. A site plan, drawn to scale, of your house and the land that it occupies.
 - Include your house, out-buildings, driveway, entrance, easements and any trees.
 - The plan should show all dimension lines.
 - Try to visualise the size and shape of the block of land and position the house and out-buildings correctly so you have a realistic interpretation.
2. A simple floor plan, drawn to scale, of your own house.
 - Include all the rooms in the house as well as all windows and doors.
 - The plans should have all dimension lines included.
 - Try to visualise the size of the rooms in relation to each other and draw them accordingly so that this preliminary plan of your house is realistic.
3. Using the site plan and floor plan that you have produced of your own house, add a room extension to the ground floor of your house including:
 - the extension drawn to scale in plan view on the site plan, showing any trees to be removed or alterations to any outbuildings
 - the extension floor plan drawn to scale, showing dimension lines, external cladding, door and window positions, internal walls and any fitments
 - an elevation view drawn to scale of the area of demolition required to accommodate and allow access to the new extension
 - three elevation views drawn to scale; one elevation of each of the three new extension walls, showing external cladding, roof details, windows and doors and subfloor if applicable.

AUSTRALIAN BUILDING CODES AND STANDARDS



Tradie talk—Knock up a sketch showing what is required for this part of the job

Chapter 6

Working effectively and sustainably within the construction industry

Learning Objectives

LO 6.1 Know about the Australian construction industry

LO 6.2 Understand the various occupations, job roles and working conditions within the construction industry

LO 6.3 Accept responsibility for your work duties and workload

LO 6.4 Work within a team

LO 6.5 Identify personal development needs

LO 6.6 Identify current resource use and implement resource improvements

LO 6.7 Comply with sustainability and environmental regulations in the construction industry

Introduction

This chapter will give you the knowledge and understanding of the Australian construction industry you need to become an effective contributor, while carrying out sustainable work practices, individually or as a member of a team, within the industry.

You will learn about:

- the structure of the Australian construction industry and the opportunities that lie within it for employment, as well as the specific occupations and job roles, and the associated conditions
- your responsibilities to yourself and your fellow workmates while working within a team, and how to be an effective contributor to the everyday functioning of the job site
- identifying and carrying out safe work methods and practices that meet the standards of national and state legislation
- identifying your own professional development needs, and the steps required to gain the necessary skills and knowledge for future advancement within the construction industry

- dealing with disharmony or disputes within the team effectively before they escalate
- identifying the current resources that are used within your own work role and the opportunities to improve the efficiency of these resources
- environmental regulation compliance and the procedures that must be followed with the correct reporting of breaches or potential breaches.

6.1 Know about the Australian construction industry

The construction industry is one of the largest industries in Australia and it continues to grow as every year passes. It encompasses all areas of construction, from the average family home to the tallest skyscrapers in major cities.

In fact, the construction industry is Australia's largest non-service industry.

6.1.1 Population growth and the construction industry

Australia continues to experience a steady population growth (Fig. 6.1), which is why the construction industry also continues to grow—more people means there is more need for housing and the infrastructure that goes with it, such as shopping centres, hospitals, schools, transport, roads, railway stations, airports and recreational facilities. The list is endless. Everything you see about you that provides shelter, protection and services can in some way be attributed to the construction industry.

As our major cities continue to grow, both in terms of population and area, so too does domestic housing continue to sprawl further and further.

New suburbs are being created and existing suburbs are filling quickly as vacant land is purchased so that new dwellings can be constructed.

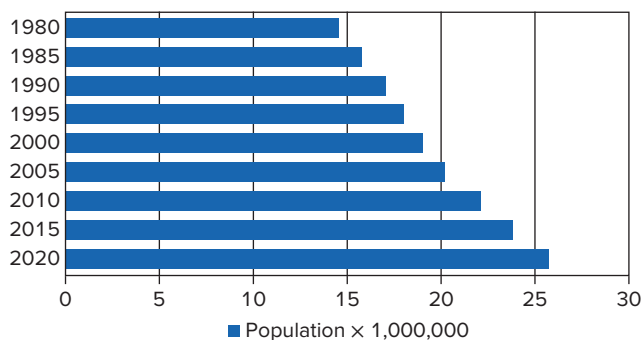
In inner-city suburbs, new apartment blocks are being constructed and older manufacturing buildings are being transformed into apartments for more condensed living.

Rural cities and towns are also growing larger as the construction of infrastructure makes the daily commute to work in the city so much easier. This means that everyday living services in these towns and cities need to be catered for, and so new schools, medical centres, hospitals, shopping precincts and recreational facilities are also being constructed.

In June 2020, Australia's 12 major cities contained just over 78% of the country's population of approximately 25.75 million people. This means that just over 20 million people live in the eight capital cities and four next largest cities combined (Fig. 6.2).

With this type of population growth, it is easy to see why major cities and the surrounding areas are the hotspots for employment in the construction industry.

Fig. 6.1 Australian population growth since 1981



Currently there are approximately 1.15 million people employed in the Australian construction industry. Taking into account the population growth figures in Figure 6.1, there will continue to be sustained growth in the construction industry as new technologies, new construction materials and modernised construction methods are introduced on a regular basis.

6.1.2 Construction industry sectors

The Australian construction industry can be divided into different sectors depending on the type of work being carried out.

From the perspective of carpentry work, the industry can simply be divided into three sectors:

- residential/domestic sector
- commercial sector
- industrial sector.

These three sectors are generally where someone would enter the construction industry as an apprentice, gain a trade qualification over the designated time of the apprenticeship and then look to pursue employment in any chosen vocation within the industry.

Often, further training will then be undertaken to gain the required qualifications for advancement within the industry.

This could mean being self-employed and taking out registration as a builder or working for a larger company and undertaking training to be able to fill specialist roles within that company's framework.

Residential/domestic construction may consist of buildings such as:

- houses
- townhouses
- flats
- bungalows
- out-buildings associated with the above.

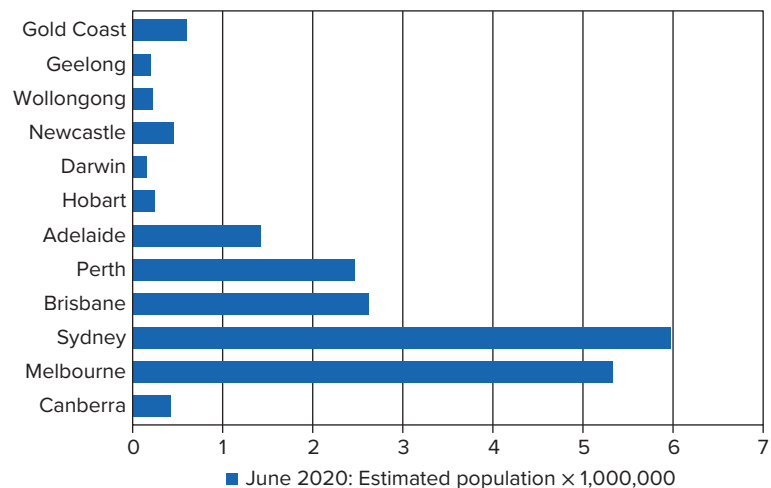
Commercial construction may consist of buildings for the following uses:

- shopping centres
- retail stores
- hospitals
- medical centres
- serviced offices
- nursing homes
- restaurants
- cafes
- hotels
- motels
- sporting/recreational facilities
- police/fire/ambulance stations.

Industrial construction may consist of buildings or structures for the following uses:

- refineries
- bridges
- power stations
- warehouses
- factories
- airports
- railway stations
- desalination plants
- skyscrapers
- damming and hydro plants.

Fig. 6.2 Population of Australia's 12 major cities



It doesn't matter which construction sector you look at, planning, demolition, construction, renovation, repairs and maintenance work will always be needed; this also extends to other sectors, which may work alongside all three of the major sectors previously listed. For instance:

- site and building surveying sector: surveying, subdividing parcels of land, determining site boundaries, setting required levels, map distances, heights, slopes and land contours
- site development and preparation sector: subdividing land, constructing roads and services, preparing individual building blocks
- general construction and demolition sector: residential and non-residential construction, including carrying out alterations, renovations and additions to existing structures
- building structure sector: bricklaying/blocklaying, concreting, roofing (concrete or terracotta tiles, metal, slate, shingles), steelwork
- installation services sector: plumbing (hot/cold-water supply and systems, gas supply and systems, sewer lines and septic tanks, drainage), electrical (power supply, lighting), telecommunications (phone lines, media, television), fire services, air conditioning, heating, refrigeration, security systems
- building completion sector: glazing, carpentry, plastering, tiling, painting and decorating
- specialist construction sector: waterproofing, scaffolding, rigging, swimming pools, spas, landscaping, fencing, crane operation, dogging, formwork, post-tensioning, pre-tensioning.

6.2 Understand the various occupations, job roles and working conditions within the construction industry

6.2.1 Trade occupations and job roles

There are many different career opportunities within the Australian building and construction industry—many begin with someone undertaking and completing an apprenticeship.

It is important to research the industry and learn about each trade area and the tasks that each of these trades perform. This can be done through career study classes at school, trying out specific trade-related subjects at school, attending trade expos, coordinated work experience through school, seminars, workshops, after-hours work or holiday work.

It is important to talk to people who work in the industry. They may be immediate family members, other relatives, family friends or a friend's family members. Seek out as much information as possible. This will help you to decide on a specific trade career path.

If you have already decided on the specific trade that interests you, there may also be the option of undertaking a pre-apprenticeship course in that specific trade. Successful completion of a pre-apprenticeship at Certificate II level is an advantage when applying for an apprenticeship, as the prospective employer will see that you, the applicant, are keen on that specific career path. Also, the experience gained on the pre-apprenticeship course, plus the qualifications that come with that course—for example, on completing the Construction Industry Induction Training, you will be issued with a Construction Industry Card (CIC)—mean you will be work-ready.

The Australian Apprenticeships Pathways websites, www.australianapprenticeships.gov.au and www.aapathways.com.au, provide information and guidance to assist those who wish to pursue a career in the construction industry.

Qualifications gained by completing an apprenticeship or completing specific training in the building and construction industry can include:

- carpentry
- joinery

- carpentry and joinery
- shop-fitting
- stair-building
- plumbing
- electrical work
- bricklaying/blocklaying
- wall and ceiling lining
- painting and decorating
- solid plastering
- floor and wall tiling
- concreting
- demolition
- glazing
- stonemasonry
- dogging
- formwork and falsework
- rigging
- roof tiling
- scaffolding
- steel fixing
- waterproofing.

Further advancement within the industry can be even more far-reaching if you are able to complete your apprenticeship training then continue with specific job role training to gain even more qualifications. This training can be done through registered training organisations, which may include industry groups and educational institutes.

Future roles can include:

- management
- supervision
- estimating
- drafting
- surveying
- company representation
- machine and plant operation
- sales and service
- business ownership
- combining trades.

From directly working in a specific job role for a construction company—which means being paid every week or fortnight, accruing sick leave, annual leave, long service leave and having superannuation contributions made on your behalf by your employer—to being self-employed and indirectly working as a sub-contractor for different companies—meaning that all the leave entitlements and contributions would be made by yourself—the range of work is vast, but all of these roles need to be filled if the building and construction industry is to remain vibrant and self-sustaining.

6.2.2 Technology trends

Technology in the construction industry is forever evolving, which in turn means that the employment opportunities are forever evolving as well. Not only are the methods used to carry out many construction tasks being made easier, with tasks now able to be completed by qualified tradespeople in

a much quicker time frame than previously, but the employment opportunities within the design and manufacturing processes are also adapting as the technology and materials change.

Examples of such change are the use of high-level electronic technology utilising computer design programs such as BIM (building information modelling) or CAD (computer aided design) to engineer, design and plan modern structures, coupled with modern computer-aided machinery to build pre-fabricated construction items such as wall frames and roof trusses from either timber or steel. These structures are then delivered to a building site to be erected on-site in a fraction of the time it used to take using hand and power tools.

This is just one example of the many pre-fabricated job options available in the construction industry. Another area offering employment opportunities within the industry relates to the packaging and transport requirements of pre-fabricated construction items.

Building materials are always changing with new technology and trends. For instance, composite materials are being produced more often and being used for more applications.

Tools and equipment are also constantly being improved by power tool manufacturers. Battery-powered tools are now being used on construction sites for most tasks. From battery drills to table saws, every conceivable power tool can now be battery powered and fast charged, which avoids the need to run power leads around construction sites.

Another important area is the development of more environmentally friendly construction machinery used with batteries rather than relying on liquid fuel as the power source. Items such as earth-moving equipment, cranes and larger mobile safe working platforms are now being seen more often on construction sites.

6.2.3 Employment conditions

Employment within the construction industry, whether full time or part time, means being employed under a contract of some description. A contract of employment will outline both the legal and the organisation's requirements in relation to such things as the duties, responsibilities and expectations of both the employer and the employee. It will also include company policies and procedures, as well as employment conditions and entitlements, including but not limited to hours of work, rates of pay, penalty rates, leave entitlements and expected employee behaviour.

If at any time you need to clarify anything regarding your contract of employment, speak to your employer. If you do not receive the required information, you can seek it out from other sources. Industry bodies such as building associations and unions can give you advice through their specific newsletters, bulletins, publications and websites. Some can even assist with access to legal advice or representation if required.

Industry awards and wage scales can be accessed through www.fairwork.gov.au.

The website also includes information on subjects such as:

- workplace agreements
- industrial agreements
- enterprise agreements
- access and equity principles and practice
- anti-discrimination and related policies
- dismissal laws.

6.2.4 Safe work methods and practices

Every worker has the right to a safe workplace. It should be the highest priority for all employers and employees to ensure that everyone can carry out all of their daily work tasks safely and efficiently, free from any physical or mental stresses, then return home to their family after the day's work.

All companies within all sectors of the construction industry are subject to federal and state and territory work health and safety laws, regulations and legislation and the conditions within them. This means that everyone employed by the company is also subject to these conditions and must always follow and uphold them.

The *Work Health and Safety Act 2011* is an especially important legal document, which outlines the safe work practices that need to be adhered to.

Employees must make every effort and take reasonable care to ensure the wellbeing and safety of themselves as well as any coworkers.

They must cooperate with their employer to assist in complying with all requirements of the *Work Health and Safety Act* and while at work they must not interfere with or misuse either recklessly or intentionally anything provided for health, welfare or safety.

Employers must provide for the safety and wellbeing of all employees in a way that is free of risk.

Duties of employers to employees to achieve this include:

- provision and maintenance of plant and work systems that are safe, practical and pose no risk to health
- planning and organising for the safe use, handling, storage or transport of plant or substances
- making safe, monitoring, maintaining and keeping risk free any places of work under their control
- providing facilities that are adequate for the welfare of any employees at any workplace under their control
- providing information, instruction, supervision or any required training to any employees to ensure that they can perform their roles in a safe manner without risk to their health.

By putting these points from the *Work Health and Safety Act* into an easier-to-understand form, the following points are some important construction site safe work practices and methods that the employer would be expected to ensure:

- access to clean, well-maintained site amenities such as toilets, eating areas, first-aid kit/area and drinking water
- WHS policies and procedures observed and maintained on a day-to-day basis
- training in the correct selection, fitting and use of personal protective equipment (PPE) and clothing
- training given for the safe operation of plant and equipment
- training for emergency procedures, including the use of firefighting equipment
- good housekeeping practices to ensure the work area is kept clean, tidy and safe
- training in risk assessment to ensure all workers can contribute to safe work plans
- waste and debris storage procedures and disposal plans, established in accordance with environmental and safe work procedures
- prevention of bullying and harassment of any employee
- establishment of designated smoking areas
- zero tolerance to drugs and alcohol in the workplace.

All of the above points can be covered and checked off when undertaking site-specific induction. See Figure 6.3, Sample checklist for site induction.

For further information on the 'Workplace Induction for Construction Workplaces Information Sheet', visit www.safeworkaustralia.gov.au.

6.2.5 Drugs and alcohol in the workplace

Drugs and alcohol must not be used or consumed in the workplace under any circumstances. Full reference to this topic can be found in Chapter 1, Work health and safety.

Fig. 6.3 Sample checklist for site induction

WORK INDUCTION FOR CONSTRUCTION
WORKPLACES INFORMATION SHEET

3

APPENDIX A - WORKPLACE SPECIFIC INDUCTION CHECKLIST

This checklist provides examples of what could be covered in workplace specific induction training for workers.

No	Items covered	Yes	No	N/A
1.	Have you checked the competencies and qualifications of inductees?			
2.	Have you discussed and clearly stated the procedures for reporting incidents, injuries and hazards?			
3.	Have you discussed the workplace safety rules?			
4.	Has the person been taken through relevant safe work method statements for the tasks to be performed?			
5.	Is specialised equipment required and have they been trained to use the equipment?			
6.	Do people have the correct PPE available e.g. ■ hard hat ■ safety glasses ■ safety boots ■ long sleeve shirt, and ■ high visibility vest?			
7.	Have you shown the person what to do in an emergency and identified the location of the: ■ assembly point and evacuation route ■ closest medical facility ■ contact details of emergency services, and ■ provisions for emergency communications?			
8.	Have you shown the person where all relevant firefighting equipment is located, for example fire extinguishers and hose reels?			
9.	Have you shown the person: ■ the location of the first aid facilities and kits, and ■ who the first aiders are and how to obtain treatment?			
10.	Have you shown the person where all the facilities are located including: ■ crib sheds ■ toilets, and ■ drinking water?			
11.	Have you explained the workplace security procedures?			
12.	Have you introduced the person to the Health and Safety Representative?			
13.	Do they have any further questions or need clarification on any points or topics?			

NOVEMBER 2014

6.2.6 Smoking in the workplace

Although not illegal, many construction sites are now run as smoke-free. Full reference to this topic can be found in Chapter 1.

6.2.7 Bullying, harassment and discrimination in the workplace

These actions, whether intentional or not, are now illegal and punishable by law. Full reference to this topic can be found in Chapter 1.

6.2.7.1 Discrimination

Employers are now subject to all federal anti-discrimination laws, meaning that everyone has an equal opportunity to apply for and be given due consideration for any job that may be available to be filled. In other words, everyone gets a 'fair go'. Full reference to this topic can be found in Chapter 1.

CHECK YOUR UNDERSTANDING

1. List the three main sectors of the Australian construction industry.
2. Give three examples where technology advancements have enhanced productivity in the construction industry.
3. Identify and list five situations or actions that may be construed as workplace bullying.

6.3 Accept responsibility for your work duties and workload

Your duties and the accompanying workload in your chosen career pathway will be established in consultation with your employer, taking into consideration your qualifications, experience and employment status.

An overview of your duties and workload will be documented in your individual job description.

Specific tasks will be allocated to you as they are required to be carried out, and careful planning and scheduling should go into any task to ensure safe and efficient work practices are employed to complete the given task to the required quality and standards by the agreed deadline.

Sometimes, the tasks and completion timelines will be affected by different factors that may be uncontrollable. These include the weather, delays in the delivery of materials, substandard materials needing replacement, equipment breakdown, servicing or unavailability, or the non-attendance at work of team members through illness or personal matters. No matter what the reason for the delay, re-planning should be done and the delays should be communicated to your supervisor as soon as possible.

If at any time you are unsure about what to do, stop and ask. Do not take any short cuts. Speak to your supervisor. It may be the case that more training in specific areas or work processes is required, such as new building materials, machinery operation, tools, plant, equipment or personal protective equipment. Or it may even be necessary to have workers with expertise in specific areas join the team to ensure the tasks are carried out safely and correctly to the required quality and standards.

An excellent format for planning construction tasks is the Gantt chart (Fig. 6.4).

This system of planning was invented in the early 1900s by a man named Henry Gantt.

Fig. 6.4 Gantt chart

PRO-BUILD CONSTRUCTIONS			18-28 South Road City West, Victoria 3006			Phone (03)987 654 3211 email: probuild@construction.com.au					
Construction Schedule: Steel portal framed garage/workshop											
Activity	WEEK 1					WEEK 2					Sub-contractors register
	1	2	3	4	5	6	7	8	9	10	
Site establishment and scrape	■										City West Excavations Contact: Jim. 4344 472 837
Building set out	■										
Excavate and prepare for footings and slab		■									No Leaks Plumbing Contact: Rick. 5425 488 663
Plumbing and electrical services		■									
Set up formwork, reinforcement			■								Shocking Electrical Contact: Robert. 5444 843 787
Set up cast ins for portal frame			■								
Pour and finish concrete				■							Concreting Contact: Val. 5442 579 633
Construct portal frame				■							
Erect portal frame					■						Steel supplies Contact: Rod. 9353 464 486
Fit roofing and flashings						■					
Fit window and door frames and flashings						■					Roller door Contact: David. 7526 377 488
Fit wall cladding and flashings						■	■				
Fit roller door							■				
Rain headers, guttering and downpipes								■			
Plumbing fit out								■			
Electrical switchboard and fit out									■		
Carpentry fit out									■		
Building clean										■	
Site clean										■	
Hand over										■	

Courtesy of Alister Ford

Effectively, a Gantt chart is a bar chart that lists the activities and stages of any construction project vertically in the correct order of them happening, with the time frames for each activity listed horizontally, usually in weekly blocks divided into the working days of the week.

These charts can be filled out by hand and displayed on any construction site noticeboard for any of the workers to see.

Gantt charts can also now be developed electronically on spreadsheets and printed out for display or forwarded on to workers via electronic devices. There are also excellent templates available for download on the internet. These can then be automatically updated at any time if the schedule of work changes for any reason.

This is an excellent way for sub-contractors to be kept up to date with the work scheduled for them as it nears commencement time and for any delays to be communicated to all workers.

Such charts are generally formulated by the project supervisors as they know the specific time frames for jobs and the organisation of other trades and materials, etc. However, there is no reason why you cannot, individually, jot down your own schedule for your designated tasks using this system. It does not matter whether it is an hourly plan for a single day or a daily plan for a week. If you can be organised in terms of your workload time frames, you will work more effectively, be more productive and produce a higher-quality product for your employer or client.

CHECK YOUR UNDERSTANDING

- How would you ensure that safe and efficient work practices are employed to complete the given task by the agreed deadline?
- Which work-team members need to be actively involved in the planning of any tasks to be carried out?

6.4 Work within a team

Work teams, work crews, work gangs—these are all common construction industry terms for a group that works together to get the job done safely and efficiently. A work team generally consists of the supervisors and workers employed by the construction company, but others can come and go from the team as different tasks need to be performed.

This can include personnel such as:

- subcontractors
- health and safety representatives
- union representatives
- delivery drivers and assistants
- crane operators and dog-men
- materials, and equipment supply company representatives
- specific labour hire as required.

As a team member, you should be actively involved in the planning of any tasks to be completed, in consultation with supervisors, WHS representatives and other team members, including any temporary team members, to ensure that all safety aspects are addressed.

Safety matters can include:

- site safety inspections
- hazard identification and reporting
- identification of high-risk work
- the formulation of safe work method statements (SWMS) or job safety analyses (JSA)
- the safe use of all tools and equipment while adhering to the standard operating procedures (SOP)
- the correct selection, fitting and wearing of personal protective equipment (PPE)
- safe manual handling and use of building and construction materials according to the manufacturer or supplier's instructions, and/or any material safety data sheets (MSDS) supplied with the product.

Agreed timelines for the completed construction stages and final completion, including handover, can be set by work teams as required. These can also include reporting systems for any delays, as well as the quality control requirements for the finished product.

These points must also be reviewed by members of the entire team at designated times, and can include details about when:

- new workers arrive on site and need to be inducted and included in a specific work team
- existing team members finish their particular part of the job, then leave the worksite
- specific work conditions change so that all workers are aware of any changes to the systems of work
- physical changes to the workplace have occurred.

All work team members need to be clear about their and other team members' individual roles, responsibilities and allocated tasks within the team. They must be able to follow any instructions, directions and guidelines that will contribute towards the team goals and objectives being fulfilled, as designated specifically by supervisors or team leaders. These should be confirmed with fellow team members so that each individual can assist others when required. Looking out for each other on a construction site can be hugely beneficial to the progression of the overall job and the personal safety of all team members. Knowing that someone has 'got your back' can be a great motivator for aiming to achieve the best quality of work in the safest manner. Being appreciated by other team members because you look out for them and assist them when required—and knowing in turn that when you need assistance, all you need to do is ask—will bring harmony to the work group and create a high-quality work environment.

Any confusion may lead to disharmony within the team, accidents or altercations occurring, building materials being damaged and rendered unusable, or tools, plant or equipment being badly damaged.

Such incidents will be costly—whether in terms of lost time through personal injury, or the damaging effects of witnessing a colleague being severely injured, time lost waiting for new construction materials, tools, plant or equipment to be delivered, plus any specific training or instruction required to safely use the new products, as well as time lost while management, supervisors and team members work to resolve disputes.

Any identified problems should be addressed openly and honestly immediately so they are identified and not left to fester—which could lead to severe disharmony among team members.

Reviewing all of the above points on a regular basis as a team, on the other hand, will contribute greatly to all aspects of the job running more smoothly, leading to team harmony and cohesion, and an understanding of the roles and responsibilities within the team. This will result in everyone working well together with one common goal of safely and effectively producing and handing over a quality product.

6.5 Identify personal development needs

The construction industry is forever evolving. Changes are being made rapidly to accommodate new construction materials, work systems and technologies. With these changes come changing job roles. It is important to be able to identify such changes and keep up to date with any new systems so that your employer sees you as an asset to the advancement and future success of the company.

Identifying training and professional development opportunities in these areas can lead to you gaining new qualifications that keep your knowledge base of new industry trends up to date, as well as equipping you with the practical skills required to implement such changes.

Talk to your supervisors and employers about any opportunities that you identify. It may be something that they have not considered but, when brought to their attention, they may see it as an opportunity for one of their employees to learn new skills that will help them advance in the industry as well as becoming an extra asset to the company.

Many construction material, work system and technological changes that occur in the construction industry workplace come with training provided in that specific area. Employers will select those they feel would be best suited to participate in any required training. It is important to always be enthusiastic about the chance to further your knowledge and skills so that when such opportunities arise you will be considered for inclusion.

Not everyone can do every training, so there will be times when others get an opportunity, but you do not. This is a chance for you to keep on working enthusiastically to company requirements and standards, but also to communicate with those supervisors and workers who completed the training to see what they have learned. You can learn from everyone.

As well as learning new skills associated with new construction systems and materials, this is also a chance for you to develop and enhance other skills, such as the communication skills needed to explain about and instruct others in what you have learned and the organisational skills required to plan and carry out the work, whether individually or within a work team.

With regard to the technology required to correctly explain construction procedures, this could include the use of computers and associated programs or tablet and phone apps.

Not all training and professional development opportunities have to be associated with new technologies and systems in the industry, however.

There are many opportunities to train and gain qualifications in traditional construction practices. Ticketed courses such as traffic management control, scaffolding, rigging, dogging, forklift, elevated work platforms or skid steer can enhance your employment opportunities.

Having a test and tag licence can be advantageous as an employer can then have someone within the company carry out this work as required rather than bring in an outside contractor.

There can also be training opportunities to become involved in the WHS aspects of the building industry, such as becoming an WHS representative or officer.

Additionally, there may be opportunities to further your current qualifications. If you are an apprentice, you will be completing your Certificate III studies as required as a component of your apprenticeship. When you complete your allocated trade school studies you can then consider undertaking the certificate IV course. This can lead to you gaining your registered building licence or to progress to another vocation within the construction industry such as staff and site management roles, costing and quoting or even branching into areas such as drafting or surveying.

The training opportunities for furthering your career in the construction industry are many and varied.

CHECK YOUR UNDERSTANDING

6. What could be the advantage of bringing training opportunities you have identified for your personal development to the attention of your employer?

6.6 Identify current resource use and implement resource improvements

The resources that you use in the construction industry will differ from one construction site to the next. These differences may be very minimal, or they could be major.

The term *resources* includes the building materials and all of the associated sundries that are used in the construction that is taking place. Correctly calculating the construction materials, ordering them and organising delivery and storage are all very important factors to be considered as any mistakes can be very costly, requiring new materials and leading to associated job delays.

Other resources may include the tools and equipment that you require, including the means of maintaining and transporting all of your gear.

Additional required resources such as electricity, water, gas, fuel, chemicals, adhesives or paints need to be organised well in advance of the required time of usage. In some cases, specific storage requirements will need to be met.

Having a good knowledge of all of the required resources for the job is vital.

It is also especially important to ensure that anything related to construction resources is well documented.

Companies will have specific reporting systems. For example:

- building material stock lists
- building sundries stock lists
- chemical registers (MSDS—material safety data sheet)
- plant and equipment booking systems
- vehicle booking systems
- employee training and qualification registers.

Such documents must be used correctly and kept up to date. These are some points to bear in mind:

- If building materials or building sundries are running low, they need to be ordered to replenish supplies.

- Failure to update chemical registers can have catastrophic consequences in the event of an emergency.
- Emergency services personnel need to know immediately upon arrival of any potential hazards they may encounter.
- Plant and equipment should be clearly booked for use and logbooks maintained for servicing and maintenance purposes.
- Company vehicles need to be clearly booked for use and used at the required time.
- Employee qualification and training registers need to be kept up to date for all personnel on-site.

If a specific task arises, it is then easy to establish if anyone on-site has the correct qualification or training to carry out the task. For example, traffic management may be required so that delivery trucks or cranes may enter or leave the construction site. The properly trained employee can then be designated to carry out this task.

A great tip for anyone starting a career in the construction industry is to keep your own work journal. This does not need to be a day-to-day diary documenting every task that you do. Use it instead as a journal, in which you document all of the important things you learn from talking to others and watching how others go about their everyday tasks on the building site. Include details of how to correctly carry out specific tasks, whether related to your own specific trade skills, work health and safety, hazard identification and reporting, communication, job site organisation, planning procedures, site meetings—including details of how you actively participated in such meetings to give your opinion, advise others or make suggestions for resource or work procedure improvements—other trade workers or sub-contractors, emergency procedures, first-aid procedures and environmental practices. There are so many new skills to learn and knowledge to be gained. One thing is guaranteed: you will never stop learning while employed in the construction industry.

WORKPLACE SCENARIO

One of the things that frustrates me a lot nowadays is that we live in a throwaway society, and this mentality is slowly creeping into the construction industry.

Throwaway building materials.

Throwaway material and equipment packaging.

Throwaway containers.

Throwaway tools.

The convenience of it all adds up to a quicker completion time and handover of the finished job.

I recall when I commenced my apprenticeship in 1979. One of the first things that my new boss did was sit down in the carpentry/joinery workshop with me and formulate a list of tools that I would need to purchase over the four years of my apprenticeship so that I would be work-ready as a qualified tradesman when the time came.

He told me to buy quality, explaining that it may cost a bit more, but that these tools will serve you well and will last for your entire working life and beyond.

From my very first pay cheque, I started to put this kit of tools together. I still have most of these tools in my toolbox in the shed, all sharp and well maintained, ready to be used when needed.

Part of this kit comprises three high-quality steel hand saws with solid timber handles—not the type you buy today that are chemically sharpened and with a plastic handle, so that the first nail you hit renders it useless. So, you throw it in the bin and go and buy another one.

As soon as I purchased these new hand saws my boss said, 'Well, now you need to learn how to breast, set and sharpen them, but a lot of practice will be required.' I really had no idea about any of this, but I said I was willing to learn a new skill.

The first thing I had to do was build a set of saw chops (a timber construction in the form of a clamp to hold the saw blade while you sharpen it). Now I was ready to sharpen my saws as required.

After setting the saw into the chops I was shown how to breast it. This meant running a flat file lengthways along all of the saw teeth to bring them all back to the same height.

Then I needed to set the saw. This was done with a small setting tool, which, when squeezed shut, pushed a single saw tooth across to the desired position so that the cut would be wider than the thickness of the steel blade and the saw wouldn't jam up during cutting. Every tooth on the saw had to be individually set—every second tooth down one side and then every second tooth back up the opposite side.

Then the saw was ready to be sharpened, using a small triangular-shaped file held at the correct angle to sharpen each tooth of the saw individually.

When finished, these saws would always be as sharp as they were on the day I purchased them, and they never let me down in terms of the quality of work, whether I was required to produce everything from framing construction to fine joinery work.

After I had completed two years of my apprenticeship an opportunity arose that meant transferring my apprenticeship from the country town where I lived to Melbourne.

I went from a workshop environment with one carpenter and two apprentices to another workshop in the city with three carpenters and I was to be the fourth apprentice—a daunting experience for a second-year apprentice who was still not old enough to get a driver's licence.

Anyway, I had not been there long and was learning a lot more about trade, communication and teamwork skills, along with being kept very busy with all of the tasks assigned to me on each day's workshop plan.

I was surprised to walk into the workshop not long after commencing my job and there were probably five or six hand saws, a few portable power saw blades and some of the blades from the large rip saw and planer laid out on one of the work benches. My boss asked me if my hand saws needed sharpening and to put them with the other saws so they could go to the saw-sharpening service to be sharpened. 'Only \$5 per saw, great value,' he told me. I did some quick maths in my head: three saws, \$5 each, total \$15—nearly 20% of my week's wage gone on saw-sharpening costs. I told my boss, 'Thanks for the offer but it's OK, I'll sharpen them myself.' Everyone stared in disbelief. None of them, tradesmen or apprentices, knew how to sharpen a saw. They said, 'Well, we have to see this.'

So, I built a new set of saw chops. And then in half an hour I had my rip saw and panel saw breasted, set and sharpened. Luckily, they were still fairly sharp, and I didn't need to hit them too hard with the file.

By the end of the day I had one saw from each of my workmates on my workbench. Everyone wanted to learn how to sharpen their own saws. I did not mind, I was happy to show them, so I taught all of my new workmates how to sharpen their own hand saws.

Over the years I have saved a lot of money by spending 10 or 15 minutes of a lunchbreak once or twice a week maintaining and sharpening my saws. And I still do. I do not need to buy throwaway saws.

6.7 Comply with sustainability and environmental regulations in the construction industry

6.7.1 Sustainability in construction

Sustainable building is the term commonly used to describe the activity of building design and construction carried out according to sound environmental principles. This includes the effect of construction and building on the environment during all building phases—from the amount of energy used in the production of building materials and the waste produced during construction to the use of ecologically non-toxic substances and the eventual demolition of the building and the recycling of its materials. Sustainability in the built environment must also be taken into account during the planning of new developments, the extent of land exploited in development areas and the number of roads and amount of transportation needed to service the development.

Not every new building needs to be designed by an architect or be high-tech to be classified as sustainable. It is by being guided by the simple ideas and basic principles of building design and construction that we can ensure that environmentally friendly buildings become the norm. A building ‘consumes’ energy (Fig. 6.5).

Fig. 6.5 Sustainable buildings—built with the environment in mind



Courtesy of Alister Ford

6.7.1.1 Strategies for sustainability

All types of construction have positive and negative aspects. For example, a timber building is easier to insulate but a masonry building is better suited to utilising passive solar gain; a timber building can be built from locally grown materials, but one built from bricks could be recycled and used again. The choice of design, construction methods and systems and materials must by necessity be related and based on environmentally sound principles for it to be classified as sustainable.

Strategies for energy efficiency include:

- designing for low-energy use by utilising superinsulation, airtightness and ventilation control; active and passive solar energy; day-lighting and solar control; efficient cooling and heating systems; and efficient lighting and appliances
- using low-embodied energy materials, preferably those sourced locally, relatively unprocessed and originating from a renewable resource, and limiting the use of high-energy materials.

Strategies for material use include:

- using unprocessed materials in the first instance such as solid timbers and natural stone, earth, clay and fibres and using local materials, if available
- using materials that can be re-used such as soft mortars for bricks and blocks, screw fixings, and limiting glues and composite materials

- minimising the use of new materials by revamping buildings for new uses, refurbishing whole buildings or building components and using recycled materials, if feasible
- using materials that will form a healthy interior environment, such as organic surface coatings, natural fibres, and not using formaldehyde glues in sheet products.

The energy consumption of buildings is our most significant issue if we are to reduce their environmental impact. Close to 20% of all energy used in Australia is done so in the construction and operation of buildings. As much as 60–70% of this energy could be saved by energy conservation strategies such as bulk insulation, energy-efficient glazing, airtightness in specific climatic zones, use of passive design approaches, efficient heating and cooling systems (active systems), efficient appliances and landscaping to provide shade or wind protection appropriate to our different climatic zones.

Conservation strategies adopted by governments have been introduced through the following:

- building and design standards (e.g. BCA, Building Code of Australia; BASIX, Building Sustainability Index)
- certification of trades processes and labelling programs (e.g. the Green Star program; WERS, the Windows Energy Rating Scheme)
- taxation incentives (e.g. insulation subsidies).

Energy conservation is as much about choosing the appropriate energy source as it is about saving that energy. In modern buildings, energy usually takes the form of electricity, predominantly supplied by the national grid and generated from fossil fuel combustion (coal or gas), hydropower or gas supplied from a natural reserve or as a product of fossil fuel combustion (coal gas).

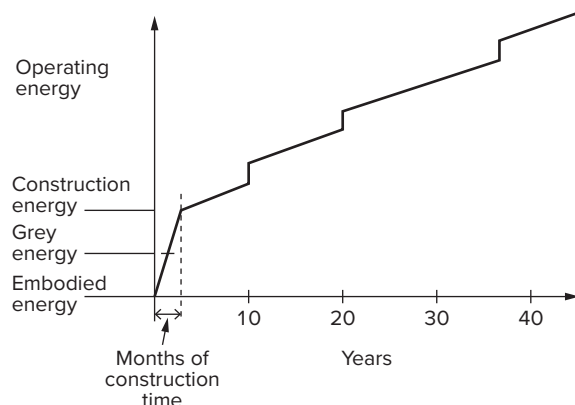
A building 'consumes' energy (Fig. 6.6):

- through the manufacture of building materials and components (embodied energy)
- in the distribution and transportation of building materials and components to the construction site (grey energy)
- in the construction of the building itself (construction energy)
- in the operation of the building, its systems and appliances each year (operating energy).

These types of energy are defined below:

- *Embodied energy* is the amount of energy used to extract and process a building material. It is expressed by the amount of carbon released into the atmosphere by the manufacturing process. The objective of a sustainable approach to building is to select materials and components that minimise this type of energy. The most straightforward way of doing this is to select materials that are used in their raw state (timber, stone, compacted earth), recycled (steel, crushed brick and concrete) or processed close to the building site.
- *Grey energy* is that energy consumed in transporting building materials from the manufacturer or quarry to the construction site. By supporting local industry and using local materials, this energy can be minimised. Where the building site is at a distance from the supply sources, the energy cost will be higher. This type of energy is termed as 'grey' because it is usually not seen or accounted for.
- *Construction energy* is the energy used in the construction of the building itself and is the smallest energy component used in the overall building process. Like grey energy, it

Fig. 6.6 Average embodied and operating energy usage for a house



Data from Your Home, 2013, Embodied energy, www.yourhome.gov.au/materials/embodied-energy; CSIRO

is often overlooked; however, this energy is important for running a construction site, avoiding waste generated by poor building procedures and the uneconomic use of water and irresponsible disposal of demolished or unused materials, along with general health and safety measures.

- *Operating energy* is the energy used in the operation of the completed building, along with its systems and appliances. This is the greatest amount of energy consumed and occurs after the building is handed over to the owner. This energy use receives the most attention by energy conservation measures such as building design strategies, the selection of materials and efficient heating and cooling systems, lighting and appliances. Operating energy is closely tied to the climatic zone in which the building is built, and the response to design and construction taken to minimise energy consumption will vary from climatic zone to climatic zone; however, generally every building will require some seasonal heating or cooling and day-to-night ventilation.

6.7.1.2 Making buildings low energy

Low-energy buildings usually refers to a building's operating costs, that is, the amount of energy and the cost of it for heating or cooling a building to a comfortable temperature for human habitation. A low-energy building needs to be matched to the climatic zone in which it is built and requires sufficient thermal insulation to prevent heat gain or loss through the building envelope. Table 6.1 shows a comparison, by building element, between the approximate heat loss/gain for a traditional and a low-energy house in Sydney. As you can see, low-energy design practices save a large amount of energy.

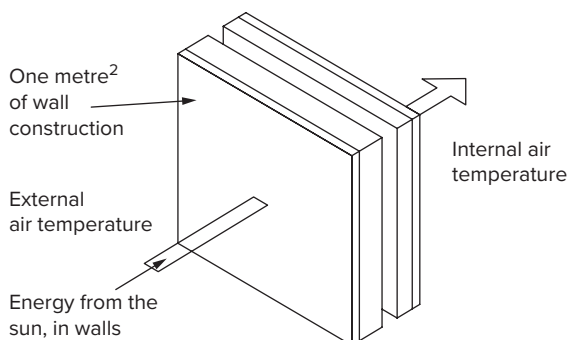
Table 6.1 Approximate heat loss/gain for a house (Sydney)

External envelope elements	Traditional house	Low-energy house
Air movement/leakage	25%	15%
Floor	10%	2%
Roof	15%	6%
Walls	25%	15%
Windows	25%	13%

Every construction material has some ability to conduct heat. This thermal conduction value is called its *U-value* (sometimes expressed as an R-value, which is a reciprocal of the U-value, or $U = 1/R$). The U-value describes the flow of heat (usually air) passing through a one-square-metre part of the external envelope of the building, for example, a wall constructed in the brick veneer (Fig. 6.7).

The lower the U-value (or higher the R-value), the less the heat gain or loss moving through the wall from outside to inside. In order to achieve a particular interior thermal comfort level, the thickness

Fig. 6.7 U-value—the flow of heat through the external envelope



of the wall would be increased as needed. In practice, this does not happen, but a combination of different materials and bulk insulation is used in the construction of the wall to achieve the comfort level.

The greatest heat gains or losses are usually caused through air leakage of the external envelope. In traditional buildings this was usually through poor-fitting windows and doors and uninsulated walls, roofs and floors. In a low-energy building, greater attention is paid to the airtightness of the external envelope, which can reduce heating and

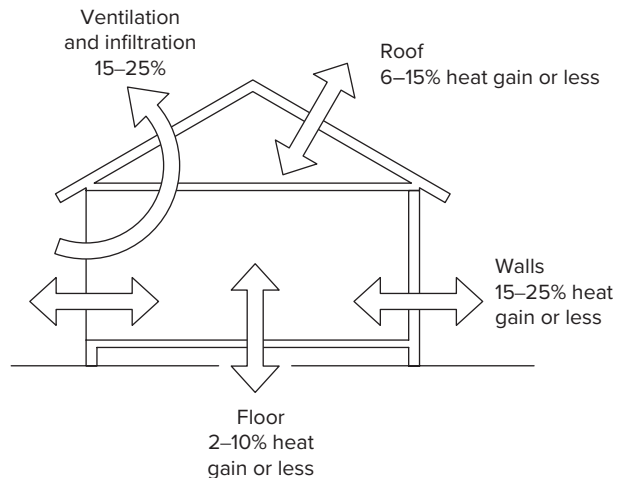
cooling bills by increasing the efficiency of the insulation. An insulation layer is only as effective as its airtight sealing.

Airtightness is a 'barrier' (a vapour barrier) made up of the combination of interconnected materials, sealed joints and components in the building envelope to provide a barrier against air leakage from outside to inside and vice versa. Air leakage through the building envelope accounts for up to one-third of heat gain and loss in modern buildings (Fig. 6.8). In humid environments, air leakage of warm air causes condensation to occur within the building envelope, leading to mould growth in structural members, particularly in lightweight construction.

Energy conservation at all stages gives the greatest reduction of the impact of a building on the environment. The most important energy measures for achieving low operating energy are:

- using efficient thermal insulation on the external envelope of the building—the roof, walls, windows and floor; use either reflective foil or bulk insulation depending on the climatic zone
- ensuring that thermal or heat bridges are eliminated
- depending on the climatic zone (see the National Construction Code), to construct either an open external envelope or an airtight external envelope, using a design that minimises heat gain or loss through its orientation and through natural or mechanical ventilation
- using energy-efficient windows and glazing
- installing efficient heating and cooling systems that have the lowest energy consumption
- using thermal mass in the colder climatic zones.

Fig. 6.8 Heat gained or lost through the building envelope



CHECK YOUR UNDERSTANDING

7. List and describe the four types of energy that a building consumes.

6.7.2 Legislation and sustainability

State and territory governments in Australia, along with building industry agencies, have taken steps to address the major impacts of waste on the environment and the overuse of resources in construction through enacting legal frameworks, regulations and practices to govern sustainability on building sites. The commonwealth legal framework is that of the overall country, ensuring protection of the natural (land protection, water resources, biodiversity) and cultural (Indigenous culture, heritage works) environments. In addition, the Commonwealth provides advisory information and assessment tools for all those in the construction industry. These include:

- the National Construction Code incorporating the Building Code of Australia
- Standards for the use and composition of materials and practices (e.g. AS 1684 Residential timber-framed construction)
- energy efficiency guides
- waste management handling guides
- voluntary accreditation schemes, such as NABERS (the National Australian Built Environment Rating System) and Green Star.

State governments provide practical legal regulations for the building industry in each state, such as:

- applicable building standards
- health, sanitary and workplace safety standards
- environmental protection, for example, environmental protection Acts such as the *Environmental Protection Act 2017* (Vic)
- specific state and territory regulations, for example, ACTHERS (the ACT House Energy Rating Scheme), BASIX (the Building Sustainability Index, NSW) and 5 Star Plus (WA).

The local government focus for buildings is:

- planning and building permits to undertake works
- waste disposal and recycling of materials
- the provision of utility services such as water and sewerage.

Other bodies that operate within the building industry offer training, accreditation and information guides on procedures for sustainable practices for tradespersons and builders. These include:

- state and territory Master Builders Associations (e.g. the Master Builders Association of Victoria: www.mbav.com.au)
- the Master Plumbers' and Mechanical Services Association of Australia: www.plumber.com.au
- the National Electrical and Communications Association: www.neca.asn.au
- Housing Industry Association Ltd: www.hia.com.au
- Safe Work Australia: www.safeworkaustralia.gov.au
- Keep Australia Beautiful: www.kab.org.au
- Ecospecifier Global: www.ecospecifier.com.au
- Good Environmental Choice Australia (GECA): www.geca.eco
- Sustainable Choice: www.lgp.org.au/sustainable-choice.

6.7.3 Sustainability practices on the building site

6.7.3.1 Storage of materials

Many materials are delivered to a building site during the construction phase. On a large building or multi-housing development, the amount of materials to be handled can be extremely large. Thus, the sensible placement and secure storage of materials until they are needed is critical. The construction sequence of the project is aided by the logical placement of materials, which eliminates the double handling of materials and improves the efficiency of the workflow (Fig. 6.9).

Fig. 6.9 Logical placement of building materials



Courtesy of Alister Ford

Good storage decisions are crucial to reduce material wastage due to loss or damage. These include the following considerations:

- placing a waterproof cover over materials to protect them from the weather
- separating materials into different groups relevant for each trade
- establishing enclosed storage areas (e.g. wire cages) to reduce accidental physical damage to materials; protect delicate and fragile materials; and contain loose materials, for example, sawdust, sand and gravels
- providing a support structure for relevant materials to prevent distortions such as the warping, bowing and twisting of timber
- establishing a safety enclosure for hazardous materials and substances and ensuring PPE and related safety data sheets are available
- erecting barriers during the construction phase to prevent heavy downpours washing away loose material and waste and stopping polluted run-off entering the stormwater system.

6.7.3.2 Conservation of energy

The amount of energy used on a building site during construction is called *construction energy*, as mentioned earlier. While small in comparison to the operating energy used over the building's life, it still counts for the builder during construction. The main energy source for construction sites is electricity, which in remote locations is generated via diesel or petrol from a generator.

Sources of energy waste are commonly:

- the use of old or inefficient equipment
- leakage from compressed air and LPG equipment that has been left on
- electricity from equipment being left on when not in use, including work lights, computers, air conditioning and vacuum equipment
- blunt equipment such as power saws, routers, drills, cutters, etc.

6.7.3.3 Dealing with waste materials

A distinction needs to be highlighted between waste materials and site rubbish. Waste on a building site usually comprises timber offcuts, sawdust, plastic packaging materials, metal trimmings and broken glass. Site rubbish comprises domestic rubbish, paper wrapping, plastic cups, empty bottles and the like.

Table 6.2 lists the most common waste on building sites. The builder or site supervisor is responsible for waste materials and site rubbish. The separation of these rubbish types is an important part of good site management (Fig. 6.10).

Table 6.2 Common waste on building sites

Liquid waste	Solvents; contaminated water from the wash-down of equipment; rainwater run-off; any other liquid
Metal	Offcuts, nails, straps, paint canisters, cans
Paper	Cardboard, packaging, boxes, documents
Plastics	Packaging and wrap, straps, Pownail strips, bottles, solid foams, Corflute sheets
Solid waste	Concrete, bricks, tiles, ceramics, plaster, render, sand
Timber	Off-cuts, sawdust, MDF, plywood protection sheets

Fig. 6.10 Building waste and site rubbish should be separated



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

8. Explain the difference between waste and rubbish on a building site.

6.7.3.4 Site management

Across Australia, state and local laws require that a building site be clean and in good order to both protect the environment and the workers on-site. On-the-spot fines for site litter and larger fines for waste material and pollution from a site into the immediate environment can be issued by local governments and state agencies. Any breaches or potential breaches must be reported to the relevant authorities immediately. Good site management can prevent this occurring and produce a professional image for the building industry.

Environmental protection options on a building site can include:

- sediment control fencing correctly installed along the low boundaries of the building site
- using sediment logs around storm water entry points
- stockpiling sand or soil up the slope from the sediment control fence, and covering it with tarps if it would otherwise be exposed to the elements for any period of time
- installing shakedown boards across the site entry and large crushed rocks on designated roadways on site to prevent mud being taken out onto the road via vehicle tyres
- containing on-site litter with the use of wire waste cages or covered skip bins.

Other positive outcomes of good site management include the following:

- a well-organised and clean site is a safer workplace
- clients will equate an efficient site with good workmanship
- a clean and efficient site will save money for the client, the builder and each individual tradesperson by minimising material damage and site accidents.

6.7.4 Sustainability terminology

It is important to identify, source and use environmentally and socially responsible materials and products. Table 6.3 lists common sustainability terms to assist with this goal.

Table 6.3 Common sustainability terms

Access	Inclusive design principles should be used to cater for all people with disabilities and all those with specific needs
Biodiversity	The variety of all living things; the different plants, animals and micro-organisms, the genetic information they contain and the ecosystems they form
Carbon dioxide (CO ₂)	A greenhouse gas that is colourless and non-toxic; a product of burning fossil fuels and the main contributor to climate change
Climate change adaptation and mitigation	Commonly thought of as extreme weather events such as drought, storms, cyclones, heavy rains and floods caused by the increase in greenhouse gases in the atmosphere brought about by the burning of fossil fuels
Conservation	Preserving the resources we have and using them in a cautious manner that does not deplete them for future generations
Ecological footprint	A measure of human demand on the earth's ecosystems
Ecosystem	An area of natural habitat that contains living organisms. One ecosystem interacts with another, so a disturbance in one will affect another
Embodied energy	The amount of energy used to manufacture and process a building material; measured by the amount of CO ₂ released by the process to extract it and manufacture the material
Embodied water	The volume of fresh water used to produce a particular product, measured at the place where it was produced
Energy	Energy comes in many forms and can be converted from one form to another. Energy is always conserved, as governed by thermodynamic laws
Environment	All that surrounds us: air, earth, water, vegetation
Environmental management	The strategic arrangements made to reduce the environmental impacts of a development or an organisation's operations
Environmental site analysis	An assessment of a building site for its vulnerability to flooding, rainfall run-off, bushfire, habitat contamination and endangered species
Fossil fuel	A naturally occurring substance created over millions of years that is used as a fuel
Greenhouse gases	Natural and human-made gases that absorb and re-emit infrared radiation. The main gases are water vapour, carbon dioxide, methane, nitrous oxide and hydrofluorocarbons
Health and wellbeing	Buildings should promote healthy environments and lifestyles for users. This includes workplace health and safety for all site workers and the promotion of healthy lifestyles through eliminating hazardous substances, health checks and extended education programs
Job safety analysis	An assessment of a building site to identify hazards and risks to workers' health
Life cycle	A series of changes in the life of a material or building component or system. Included is the cost of acquiring the product, installing the product, operating it, repairing it over its useful life and disposing of it
Natural materials	Materials of zero-embodied energy found in nature requiring no processing. These include tree trunks and branches, tree bark, tree wattles, and mud, clays, stones and grasses
Natural resources	Raw materials available for human activities, e.g. forests are a resource for timber
Pollution	Contamination of the environment or an ecosystem by substances that are harmful to living organisms
Processed materials	Materials subjected to high-energy or chemical processes, such as reconstituted timber products including hardboards and chipboards; manufactured bricks, including clay, concrete and silica lime products; roofing tiles including terracotta clay-based tiles; and concrete/cement products
Supporting communities	Consideration of the effect of a building development on the local community. The building industry needs to become involved and establish how development will improve an area
Sustainability	The ability to continue activities without exhausting the available resources or degrading the environment. This includes economic, social and natural aspects
Sustainable development	A development or building project that meets the needs of the present without adversely affecting the ability of future generations to meet their needs
Synthetic materials	Materials (usually of high-embodied energy) that have little or no natural content. These include the category loosely called plastics

(continued)

Table 6.3 Common sustainability terms (continued)

Trade and labour standards	Consider if clients, contractors and supply chains are meeting accepted labour standards. Ensure there is no exploitation of cheap labour and that acceptable working conditions are provided
Transport and mobility	Consider opportunities for sustainable transport of workers and materials throughout the building phase. Priority of walking, cycling and public transport should be emphasised
Waste	Materials that are surplus to those needed for a project. These need to be minimised by re-using, recycling and recovering throughout the construction phase and across the supply chain
Worked natural materials	Materials (of low embodied energy) that occur naturally but are mechanically worked to make them more useful in building, such as split and sawn timber, dressed timber, slates, dressed stone, lime and gypsum
VOC	Volatile organic compounds. These compounds become a colourless and pungent gas at room temperature, which causes watery eyes and nausea, skin irritations and difficulty in breathing

6.7.5 Sustainability and suppliers

It is important that the suppliers you use act in a sustainable manner and meet the basic standards of environmental performance. Just as you are applying sustainability principles to your trade, you should expect that others in the supply chain do the same. Most of the highest environmental impact occurs in the supply chain beyond your control.

Recommended sustainability expectations for suppliers; they:

- are proactive in improving the sustainability aspects of their products
- comply with relevant Australian Government policies and standards
- look to reduce the environmental and social impacts associated with the use of their products
- are innovative and constantly seek out areas of improvement for the sustainability of their products
- are interested in improving sustainability in the supply chain of their products
- are responsive to your questions on sustainability

Student research

1. Visit the Australian Apprenticeships Pathways website: www.australianapprenticeships.gov.au. Download a copy of the National Code of Good Practice for Australian Apprenticeships. Read the document and discuss the following points in written form.
 - (a) Why has this code of practice been developed?
 - (b) Who should keep a copy of the code of practice in their records at all times?
 - (c) What are the five major points in the code of practice that the employer and apprentice will work together to achieve and maintain?
 - (d) List the five items regarding the responsibilities and obligations of the employer. Discuss in detailed written form the requirements mentioned in these five items.
 - (e) List the two items regarding the responsibilities and obligations of the apprentice. Discuss in detailed written form the requirements mentioned in these two items.
2. Visit the Australian Apprenticeships Pathways website: www.aapathways.com.au. Download a copy of the jobs pathways chart, Construction, Plumbing and Services.
 - (a) List each of the five study stream levels available in the Carpentry sector of the construction industry.
 - (b) List the job roles that come under each of these five stream levels.

End-of-chapter activity

Using Microsoft Excel or Word, create a Gantt chart for a construction project that you have recently worked on with your employer or while participating in any construction training. Print the document as if it were to be displayed so that all workers on-site could refer to it.

AUSTRALIAN BUILDING CODES AND STANDARDS

National
Construction
Code (NCC)

AS 1684—2010
Residential
timber-framed
construction

Tradie talk—The three Rs: reduce, re-use, recycle

Chapter 7

Carpentry hand tools

Learning Objectives

- LO 7.1 Understand the uses of personal protective equipment**
- LO 7.2 Identify and use measuring and marking equipment**
- LO 7.3 Identify and use hand saws**
- LO 7.4 Identify and use chisels**
- LO 7.5 Construct basic timber joints**
- LO 7.6 Identify and use hammers**
- LO 7.7 Identify and use bench planes**
- LO 7.8 Understand workbench equipment and its uses**
- LO 7.9 Identify and use cramps**
- LO 7.10 Identify and use other hand tools**

Introduction

Hand tools are a basic necessity for any good tradesperson. Learning how to identify and use hand tools properly and confidently will aid any tradesperson in their day-to-day work. The ability to use hand tools properly will provide the skills and knowledge for the proficient use of hand-held power tools.

In this chapter you will learn how to identify common timber joints and construct these joints using the tools outlined in this chapter. You will be able to tell when your hand-tool techniques are improving because the quality of the joints will improve. You will also learn how to sharpen chisels, hand-plane blades and hand saws.

7.1 Understand the uses of personal protective equipment

Personal protective equipment (PPE) is the most important 'tool' a tradesperson will use. It will help keep you safe and protect you from being injured while you work by minimising risks to your health

and safety. This section lists the essential forms of PPE you will need when working. Always look for the Australian Standard logo so you know the item of PPE meets the relevant Standard.

7.1.1 Clothing

Protective clothing includes overalls, work pants, work shorts, high-visibility shirts, jackets and hats specifically designed to be used while working in the building industry. These are made of materials that won't burn or melt, can't be easily ripped and provide protection from UV radiation. Essentially, they are much more durable than normal clothing and are designed to protect or shield your body from workplace hazards and injury.

7.1.2 Work boots/shoes

Safety footwear is designed to protect your feet from getting injured and support your body so you can work effectively. They come in many shapes and sizes with different levels of protection offered for the building industry. This includes various grades of toe cap, reinforcement that provides built-in protection at the front of the boot/shoe. There is a huge range of designs available, some looking like regular runners or traditional leather boots.

7.1.3 Eye protection

Eye protection for the building industry is designed to protect you from hazards such as flying particles, dust and harmful gases. A range of eye protection is available, including goggles and safety spectacles, some with the appearance of designer sunglasses. Made of materials that don't shatter or break easily, all eye protection must be manufactured to the relevant Australian Standard. Eye protection is designed to be close fitting so there are no large gaps between the eyewear and the face to prevent objects from getting in.

7.1.4 Ear protection

In the building industry, ear protection is necessary when working in or near a noisy environment. The most common protection devices are earmuffs that cover the entire ear or plugs that are inserted into the ear canal. Both are designed to dampen down loud noises so your hearing isn't damaged. The better the quality of the device, the better the protection.

7.2 Identify and use measuring and marking equipment

7.2.1 Four-fold rule

The four-fold rule (or carpenter's rule) is made of boxwood or plastic and is for general use, especially benchwork. It is one metre in length and marked in millimetres. For accurate measuring, hold the rule on edge so that the markings will be in contact with the timber (Fig. 7.1b).

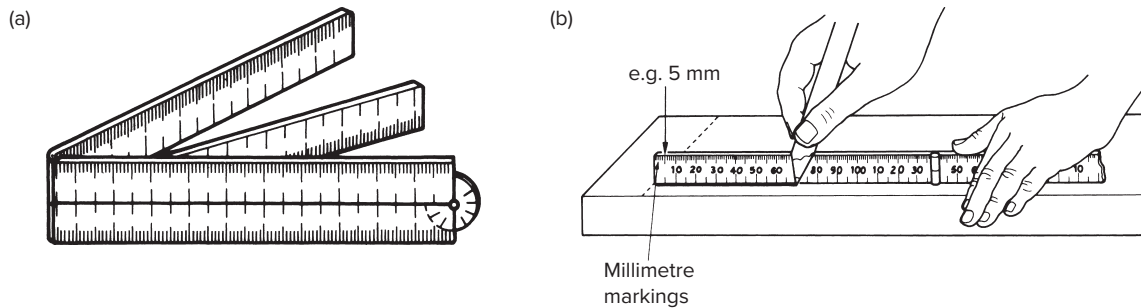
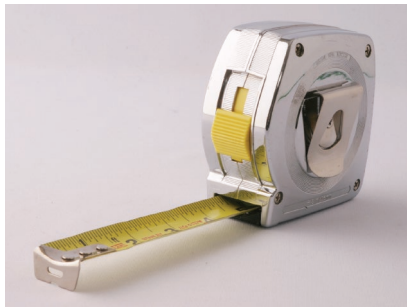
TIP The four-fold rule can be used for more than just measuring. It can also be used to gauge lines on timber and to determine the size of a gap. For example, the thickness of the rule when folded up is generally 10 mm, which is the same thickness as the plasterboard found on most house walls.

7.2.2 Retractable measuring tapes

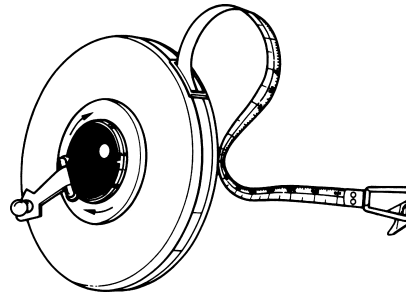
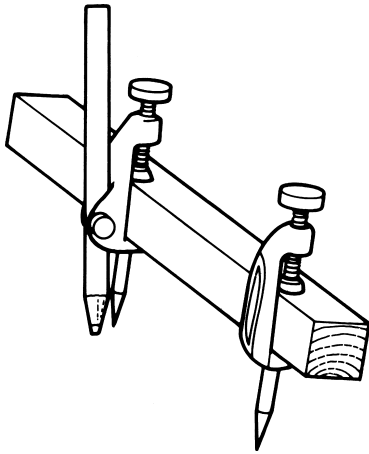
Retractable tapes are available in lengths from 2 m to 8 m and are particularly useful for construction work.

7.2.3 Long fibreglass/steel tapes

Long fibreglass/steel tapes are available in lengths of 20 m and 30 m and are used for measuring on-site, setting out and large construction work (Figs 7.2 and 7.3).

Fig. 7.1 Four-fold rule: (a) general view; (b) holding and measuring**Fig. 7.2** Retractable measuring tape

© McGraw Hill Education/DAL

Fig. 7.3 30 m tape**Fig. 7.4** Trammel points

7.2.4 Trammel points

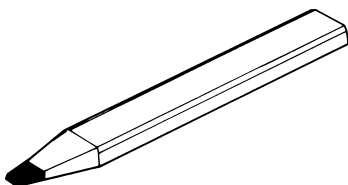
Trammel points can be attached to a wooden bar to form a pair of dividers and are used for stepping off large distances or marking out circles (Fig. 7.4).

7.2.5 Carpenter's pencil and crayons

A carpenter's pencil has a large flat lead, which stays sharp for longer, especially when working with rough-sawn timber (Fig. 7.5). The pencil is available in soft, medium or hard grades. Medium is suitable for most purposes.

TIP Generally, carpenter's pencils are red in colour (medium grade) and bricklayer's pencils are green (hard grade). Bricklayer's pencils would not really mark timber but would rather dent it because they are so hard.

Lumber crayons are variously coloured markers used for conspicuous marking on rough-sawn timber surfaces.

Fig. 7.5 Carpenter's pencil

7.2.6 Try square

A try square is used for marking lines at right angles to a face or edge and for checking that timber is square (Fig. 7.6). It consists of a stock and a blade, which is permanently fixed at 90° to the stock. The size of the square is determined by the length of the blade, which can vary from 100 mm to 300 mm.

For accuracy, try squares must be checked from time to time (Fig. 7.7). This is done by selecting a board with a straight edge and using the try square to mark off a line at right angles. Reverse the square, and if the blade of the square coincides with the line, it is accurate.

Fig. 7.6 Try square

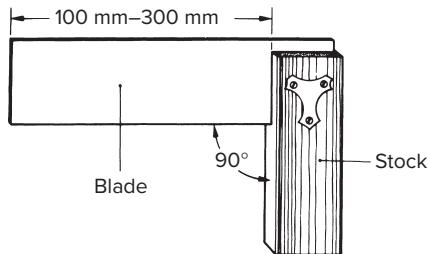
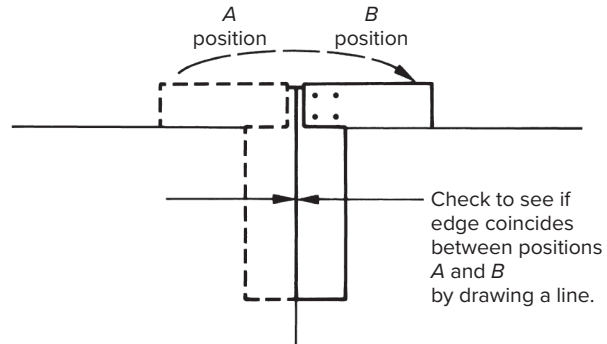


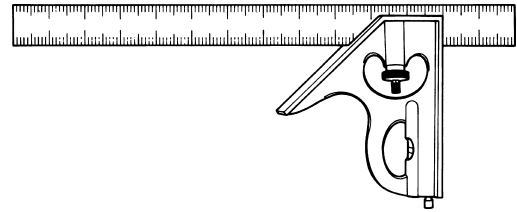
Fig. 7.7 Checking a try square



7.2.7 Combination square

A combination square can be used to set lines at 90° and 45° (Fig. 7.8). The blade is 300 mm long and is adjustable on the stock, which allows it to be used to gauge lines parallel to an edge. Sometimes a level bubble is built into the stock.

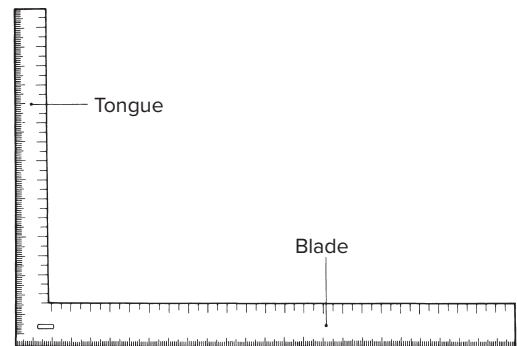
Fig. 7.8 Combination square



7.2.8 Steel carpenter's square

The carpenter's square is used for squaring large sheets of material and for setting out in roofing and stair construction (Fig. 7.9). It has a tongue and a blade, usually 400 mm × 600 mm, marked in millimetres.

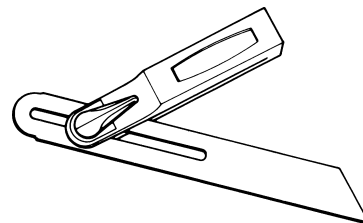
Fig. 7.9 Steel carpenter's square



7.2.9 Sliding bevel

A sliding bevel is used to set various angles (Fig. 7.10). The blade is adjustable to the stock.

Fig. 7.10 Sliding bevel



7.2.10 Marking gauges

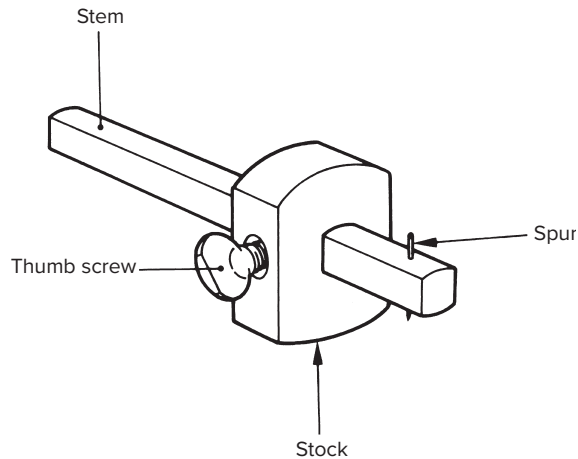
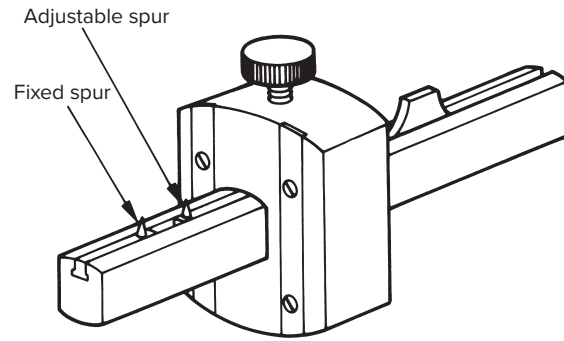
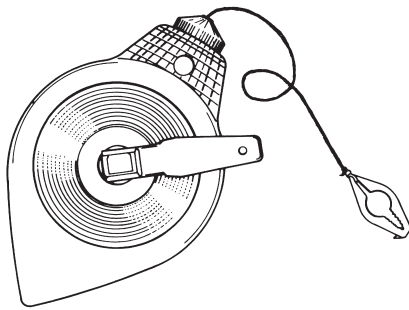
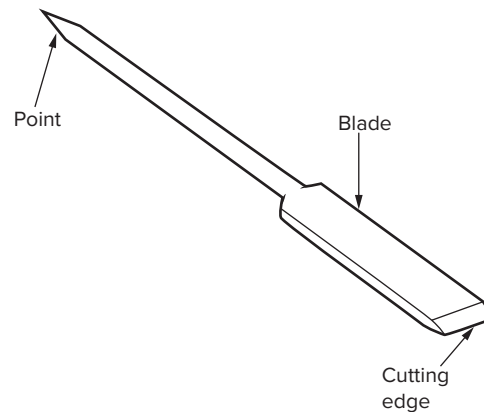
Marking gauges are a group of tools used for marking lines parallel to an edge or a face (Fig. 7.11). The gauge is usually made of beech wood and the stock is adjustable on the stem.

7.2.11 Mortise gauge

A mortise gauge has two spurs, one of which is movable (Fig. 7.12). It gauges two lines at once and is used mainly in marking out mortise-and-tenon joints, slip tongues and in similar situations.

7.2.12 Chalk line reels

Chalk line reels are a convenient way to mark straight lines, mainly on construction work (Fig. 7.13). The string is dusted with chalk, and stretched between two given points. It is then flicked to produce a visual straight line.

Fig. 7.11 Marking gauge**Fig. 7.12** Mortise gauge**Fig. 7.13** Chalk line reel**Fig. 7.14** Marking knife

7.2.13 Marking knife

This is used as an alternative to a pencil. It has a sharp blade used to mark accurate lines, where a saw or chisel is to be used. It is ideal for marking shoulders of tenons (Fig. 7.14).

SAFETY TIP Always make sure the hand tools you are using are sharp—a sharp tool is far safer than a blunt tool.

CHECK YOUR UNDERSTANDING

1. How long is a carpenter's four-fold rule? In what units is it marked?
2. What tool in the carpenter's kit could be used to mark off angles at 35°?
3. What is the purpose of a marking gauge?

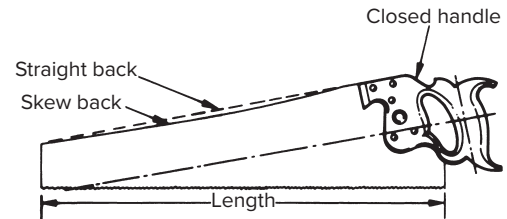
7.3 Identify and use hand saws

Woodworking hand saws are manufactured from high-quality steel, specially formulated and tempered to provide the right degree of hardness and flexibility so that the teeth will maintain their sharp edge but will not break off while in use or when being set and sharpened (Fig. 7.15). A good-quality saw, when held by the handle and tip, should bend into a uniform curve and return to a straight line when released. The handle is made of wood or plastic moulded to fit the hand comfortably. The best guide to quality is undoubtedly the reputation of the manufacturer and the price. Saws suitable for professional use may not always be the cheapest initially, but in skilled hands they will give many years of faithful service.

In recent years, a number of new types of saws have come onto the market to meet the changing needs of the trade; for instance, saws not only for use in timber but also for plastic, metal and other sheet materials.

Teeth are formed on the cutting edge of the saw and are shaped according to the purpose of the saw.

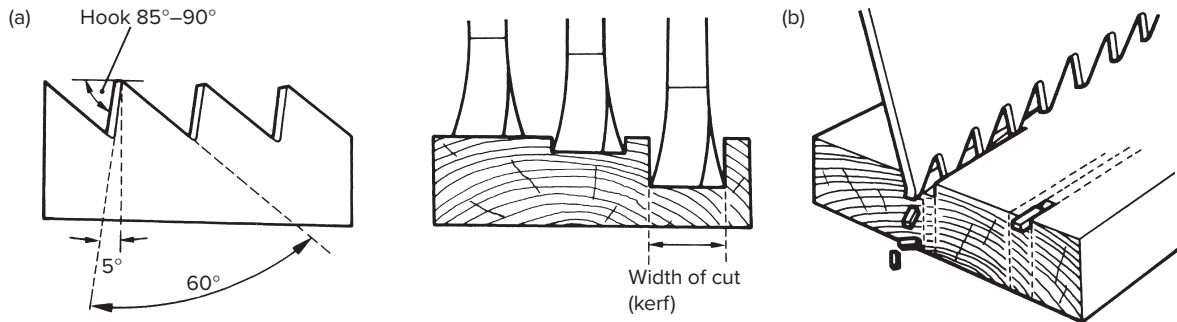
Fig. 7.15 Typical hand saw



7.3.1 Shape of saw teeth

Timber is composed of wood fibres overlapping and lying in the direction of the grain. The saw teeth must sever the fibres cleanly and remove the waste from the saw cut. *Rip saws* are designed to cut in the direction of the grain; the teeth form a series of chisel points that sever the fibres and the wood crumbles away in front of the teeth in the form of sawdust (Fig. 7.16).

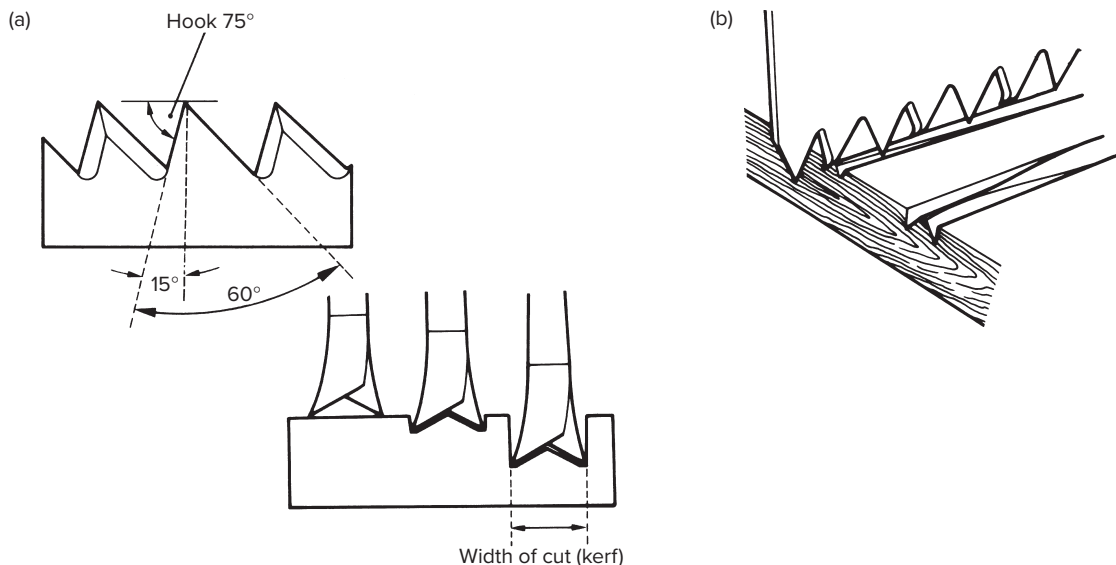
Fig. 7.16 (a) Rip saw teeth; (b) cutting action



Saws designed to cut across the grain of the timber are shaped like a series of knife edges that sever the fibres in two places; again, the wood crumbles away between the cuts. These are called cross-cut saws (Fig. 7.17).

The angle formed between the face of the teeth and the length of the blade is referred to as the *hook* and is important to the performance of the saw. With a large angle of hook—up to 90° for rip saws—the

Fig. 7.17 (a) Cross-cut teeth; (b) cutting action



saw will cut more quickly, but the cutting will be harsh and absorb more power. If the face of the tooth is laid back by only a few degrees, the cut will be smoother and require less effort.

7.3.2 Clearance to the saw blade

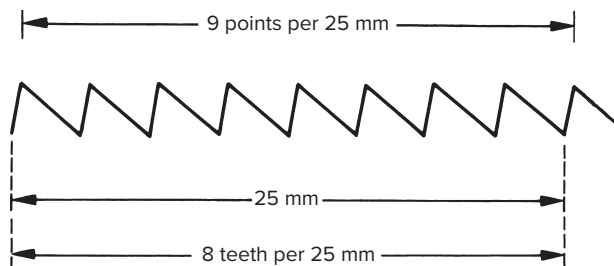
So that the blade will not bind in the saw cut, or **kerf**, the teeth of the saw are *set*. This is the practice of bending the top half of each tooth in opposite directions, so that the saw kerf will be approximately 1.5 times the thickness of the blade. Soft green timber will require more set than hard dry timber.

Good-quality saws are also *taper ground*, which means that the back of the saw blade is thinner than the cutting edge, thus also providing clearance in the cut.

7.3.3 Size of saw teeth

The size of the teeth is expressed as the number of teeth to 25 mm (Fig. 7.18). Sometimes the term 'points per 25 mm' is used, which includes the point at the start and finish of the 25 mm so that eight teeth per 25 mm (8 TP 25 mm) equals nine points per 25 mm (9 PP 25 mm).

Fig. 7.18 Size of saw teeth



7.3.4 Using hand saws

The correct grip for all saws is shown in Figure 7.19(a). This helps to relax the hand muscles and gives direction to the saw blade. Timber should be supported on saw stools and the correct stance adopted (Fig. 7.19b). Notice how the saw, the forearm and the shoulder are in a straight line. Commence with the saw at a low angle, in line with the direction of the cut, and use short, light strokes. Guide the saw with the thumb of the other hand. Gradually increase the angle to approximately 45° when **cross-cutting**, and 60° when **ripping** (Fig. 7.20).

7.3.5 Hand saws in general use

Without putting any downward pressure on the saw blade, maintain the stance and continue the cut using the full length of the blade, with the arm swinging freely in line

Fig. 7.19 (a) Saw grip; (b) stance; (c) supporting the end

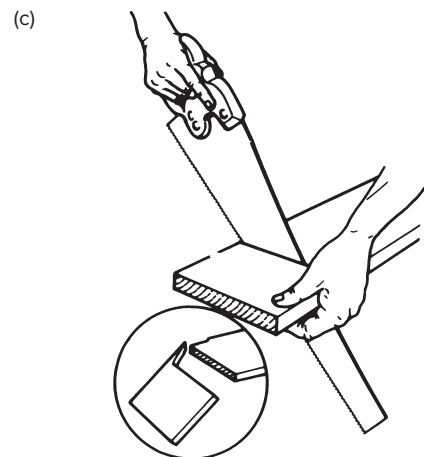
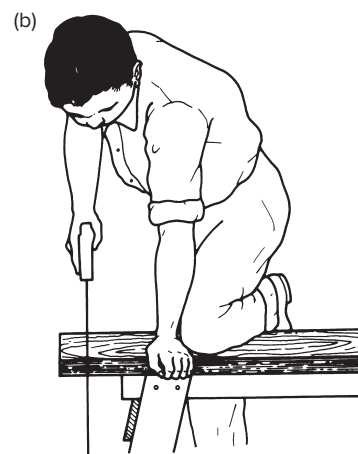
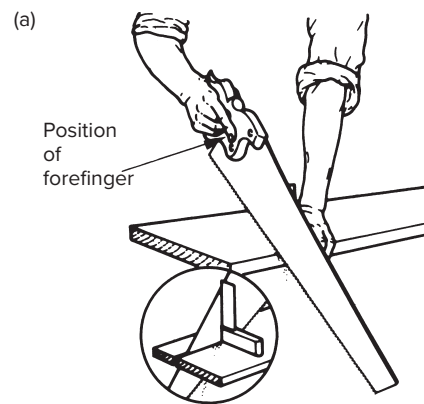
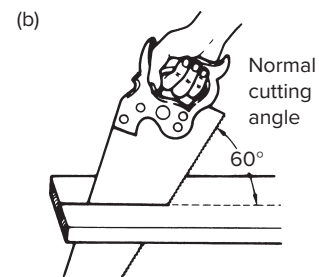
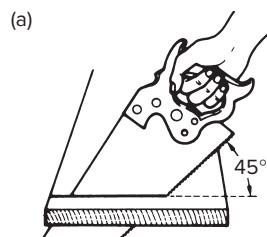


Fig. 7.20 Sawing angles: (a) cross-cutting and (b) ripping



from the shoulder. Support the end of the timber so that it will not collapse and splinter at the end of the cut (Fig. 7.19c).

Most saws manufactured in the West have adopted a tooth shape that is 'leaning forward' (Fig. 7.21a). This type of tooth arrangement will cut more aggressively on the forward stroke and will more or less slide across the fibres on the backward stroke. By altering the angle on the front of the tooth, it will cut well both across and along the fibres of the timber. The angle between the teeth is maintained at 60° so that the teeth can be sharpened by using a triangular saw file.

Another tooth pattern now receiving wide recognition is the *straight tooth* (Fig. 7.21b). This will cut in the same manner both on the forward and backward stroke. It is used on some hand saws and bow saw blades and for cutting across the grain. (Some 'old timers' in the trade may recall seeing this tooth shape on rare occasions; they would refer to them as 'shark tooth'.)

The 'straight' toothing on carpentry saws was originally a Scandinavian type; in modern production this tooth shape is obtained by a grinding wheel (rather than a file), which gives a superior **bevelled** surface and an extremely sharp cutting edge. The precision required in saw toothing is illustrated by the fact that only 0.1 mm to 0.3 mm of the outermost tooth points actually cut into the workpiece. It is the shape of these tiny tooth tips that determines the efficiency of the saw. See Table 7.1 for examples of common hand saws.

Fig. 7.21 (a) Conventional saw teeth; (b) straight saw teeth

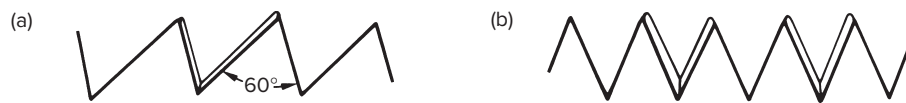


Table 7.1 Common hand saws

Name	Length (mm)	Teeth (25 mm)	Purpose
Rip saw	700	3–5	Ripping with grain
Half rip saw	650	5.5 & 6	General purpose, small amounts of ripping and cross-cutting
Hand saw	650	7, 8, 9	General purpose, cross-cutting
Panel saw	500, 550, 600	10	Light interior fitting and cross-cutting

7.3.5.1 Hard-point saws

Manufacturers, having produced saws with tooth points shaped for maximum efficiency and to very fine tolerances, and also realising the difficulties of resharpening them, have turned their attention to making teeth last so long that they will need resharpening only after considerable time and use.

Hard-point high-frequency hardening was the solution to increasing the lifetime of the tooth points (Fig. 7.22). An extra hardening may seem an easy and natural solution, but it is a rather intricate manufacturing process; the steel has to be heated to the exact temperature and then quickly cooled.

Sometimes hard-point saws are criticised on the grounds that they cannot be resharpened. This is only partly correct as they can be resharpened after they have become dull with use (Fig. 7.23), as follows:

1. Put the saw flat on the workbench and take a fine-grained oilstone with a flat surface.
2. Place the stone so that it rests on the blade and just covers the tooth points.

Fig. 7.22 Area of hardened point

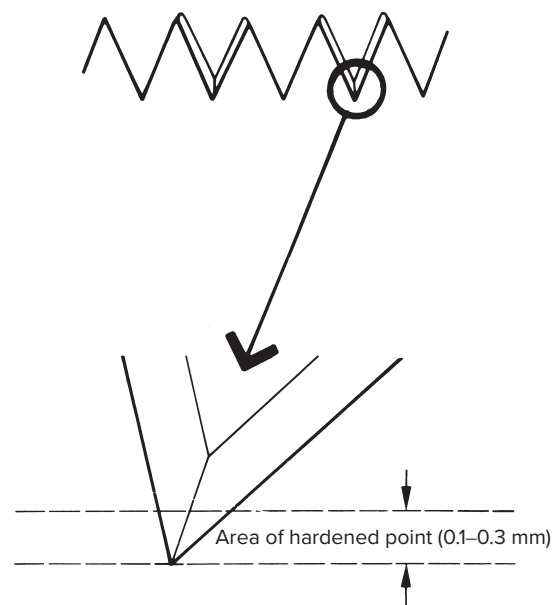
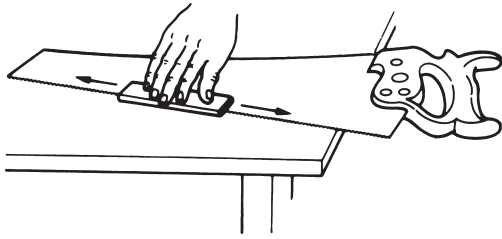
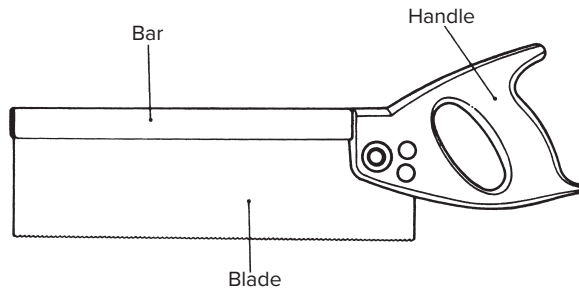


Fig. 7.23 'Sharpening' hard-point teeth**Fig. 7.24** Tenon saw**Fig. 7.25** Stance for using the tenon saw

3. Slide the stone with light pressure from the tip of the saw to the handle twice.
4. Turn the saw and repeat the process on the other side.

This process will grind a little off the tip of any teeth that were bent outwards during the setting and will put a neat and sharp edge on the critical 0.1 mm to 0.3 mm of the point. Press only lightly with the stone as it will remove some of the set, and if the saw develops a tendency to jam in the cut, it will have to be reset to give a wider kerf.

7.3.6 Tenon saw

The tenon saw is used for general benchwork (Fig. 7.24). The blade is straight and parallel, reinforced on the back edge by a bar of steel or brass. Consequently, the saw may sometimes be referred to as a *back saw*.

The length of the tenon saw is 250 mm, 300 mm or 350 mm, with 11 to 15 teeth per 25 mm. A popular choice for the joiner is a 300 mm by 12 teeth per 25 mm tenon saw. As the saw is used mainly for cross-cutting with some ripping operations, the teeth are sharpened with a bevel as for cross-cutting and will provide satisfactory overall performance.

To use the tenon saw, the timber must be held firmly in a bench hook or vice. Grip the saw in the same manner as you would grip other hand saws (Fig. 7.25). Adopt a stance so that the saw cut, the saw and the operator's arm and shoulder are in a straight line. Lift the handle and start the cut with a series of short strokes. Gradually lower the hand and follow the line across the width of the timber until the saw is cutting horizontally. Follow the line down the edge, cutting slightly into the bench hook.

At times, due to misuse, the blade may become buckled and slightly displaced in the back. This can sometimes be corrected by holding the saw around the handle and giving the saw one sharp tap on the back, opposite the buckle, using a block of wood or a mallet. If this does not correct the fault, further attention from a saw doctor must be sought.

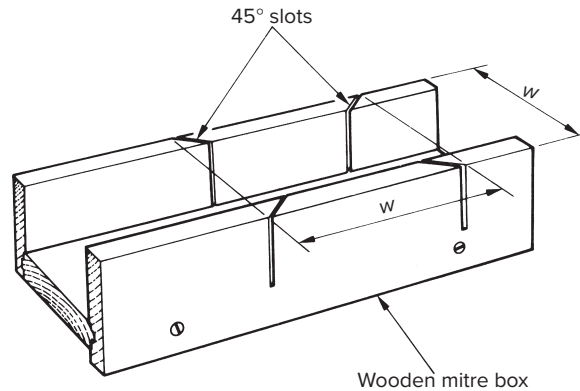
CHECK YOUR UNDERSTANDING

4. List at least three differences between saw teeth intended for ripping and those used for cross-cutting.

7.3.7 Mitre box

The mitre box is a jig in which timber can be held and cut accurately at an angle of 45° . It is most commonly used for making mitred or scribed joints to mouldings. The simplest form of the mitre box is made up of timber in the form of a three-sided box, with slots cut to guide the saw (Fig. 7.26).

Fig. 7.26 Timber mitre box



7.3.7.1 Constructing a mitre box

Material required: 90 × 35 mm pine 1/450 mm, 110 × 19 mm pine 2/450 mm, PVA glue, 4/30 mm bullet head nails, 6/45 mm × 8 gauge countersunk p2 screws.

1. Mark the face and face edge of each piece of timber.
2. Gauge a line using the marking gauge 17.5 mm from the edge of the 19 mm pine along its entire length.
3. Mark in 50 mm along the gauged line from both ends of 19 mm thick timber. This mark is where the nails will go.
4. Make a mark 100 mm from each end and in the centre of the 19 mm thick timber along the gauged line and drill a 3 mm pilot hole at these marks for the screws.
5. Tap the nails into the timber at the corresponding marks. Be sure only to start the nails and not hammer them home.
6. Run a bead of glue along both edges of the 35 mm piece of timber.
7. Position the sides of the mitre box along the base and drive the nails home, pinning the sides and the base together.
8. Drive the screw into the corresponding marks.

7.3.7.2 Setting out a 45° angle

The 45° angle is accurately set out as follows:

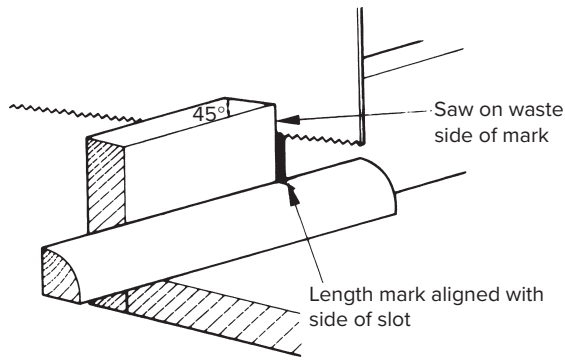
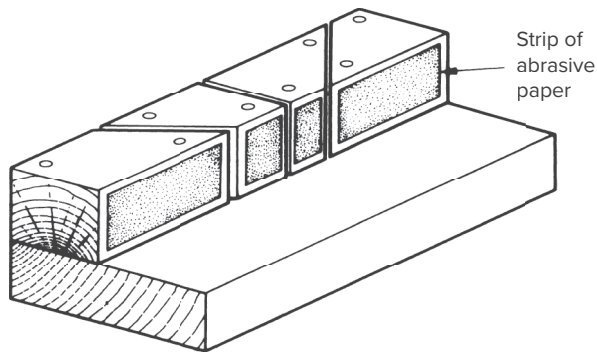
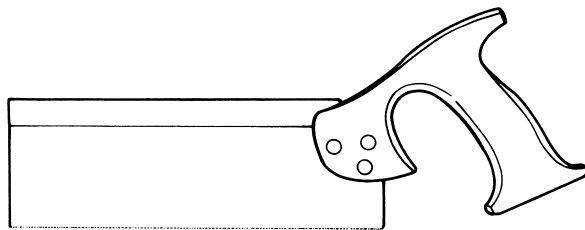
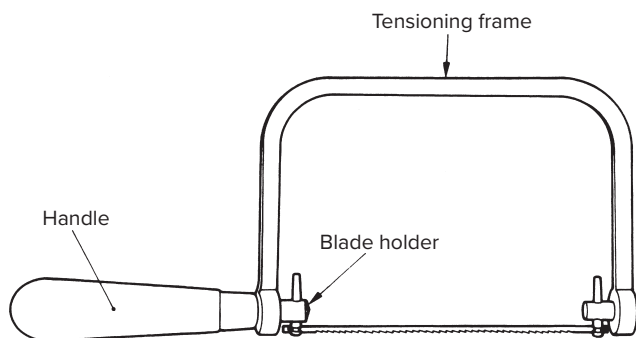
1. Measure square across the overall width (w) of the box.
2. Set off the distance w along the length, and form a square.
3. Mark the diagonals of the square across the top edges.
4. Square down the face and cut the slots accurately with the tenon saw.

To use the mitre box, hold the moulding firmly against the back of the box with the length mark aligned with one side of the slot, and the saw on the waste side of the line (Fig. 7.27). Make the cut with a fine saw, preferably a tenon saw, cutting slightly into the bottom of the box.

7.3.8 Mitre block

To mitre small mouldings, it is often more convenient to use a mitre block (Fig. 7.28). This is used in a manner similar to the mitre box. Glue and screw the block together. Mark a 45° angle and cut the slots with a fine tenon saw.

Often timber can be held in the mitre block or box more securely and with less effort if a strip of abrasive paper (say 120 grit) is glued along the back face. A square cut can be included to quickly square the ends of small sections.

Fig. 7.27 Using the mitre box**Fig. 7.28** Mitre block**Fig. 7.29** Dovetail saw**Fig. 7.30** Coping saw

The modern keyhole saw has a metal handle with interchangeable blades of different sizes, suitable for cutting timber, plasterboard and light-gauge sheet metal.

7.3.9 Dovetail saw

A dovetail saw is a smaller version of the back saw (Fig. 7.29). It is used for fine, accurate cutting; largely, as the name implies, for ripping dovetail pins. The length of this saw is 200 mm or 250 mm, with 14 to 16 teeth per 25 mm, sharpened for ripping.

The dovetail saw can have an open wooden handle or a straight handle.

7.3.10 Saws for cutting curves

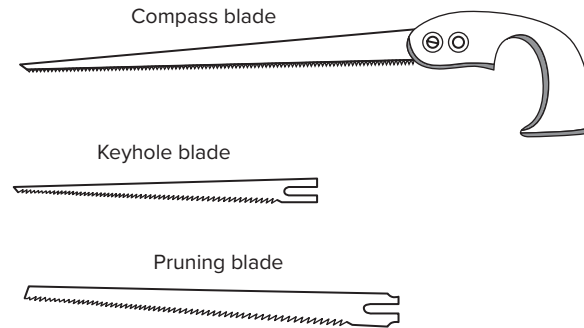
Cutting to curved lines is now a task more likely to be performed with power tools. A hand saw used for cutting around a curve must have a narrow blade, which may have to be held under tension in a spring-loaded frame.

7.3.10.1 Coping saw

The coping saw is used for cutting around tight curves such as scribing mouldings or when removing waste from dovetail pins (Fig. 7.30). The blades are replaceable. They are approximately 150 mm long and 3 mm wide, and are tensioned in the frame by turning the handle. They can be angled to cut in any direction by twisting the pins holding the blade.

7.3.10.2 Keyhole saw

The keyhole saw is used for cutting around curves, starting closed cuts (see also the power jig saw) or, as the name implies, opening up the straight lower part of a keyhole after the top has been drilled (Fig. 7.31). Traditionally, the keyhole saw was included in a set, consisting of a wooden handle with three blades of different sizes, which was sold as a 'nest of saws'. The three blades are, from the smallest, the *keyhole blade*, the *compass blade* and the *pruning blade*.

Fig. 7.31 Keyhole saw

CHECK YOUR UNDERSTANDING

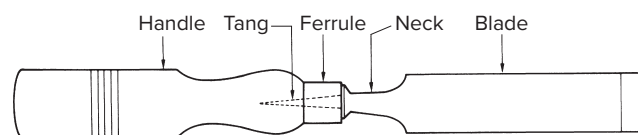
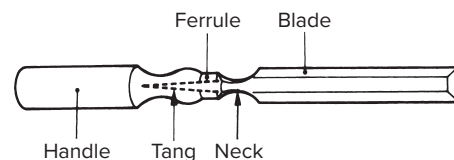
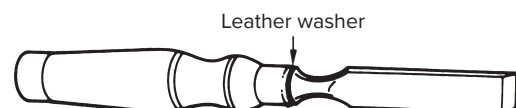
5. What is the main purpose or common use of the following saws?
- Tenon saw
 - Coping saw

7.4 Identify and use chisels

Chisels are designed to meet the demands of different operations: some are intended purely for hand use, while others used for heavy work may require the generous use of a mallet. A suitable chisel should be selected for use in each work situation. The size of the chisel is based on the width of the blade, ranging from 3 mm to 51 mm.

The wood chisel is one of the most basic tools in the carpenter's kit, and consists of a straight blade of specially tempered tool steel, attached to a handle of wood or tough plastic. Other chisels in general use are as follows:

- *Firmer chisel.* This is a general purpose chisel for benchwork or light construction work, where the mallet could be used sparingly. The handle is attached to the blade by the tang and a brass ferrule helps prevent the handle from splitting. Firmer chisels with handles of tough-impact plastic material give excellent service under the strain of heavy work (Fig. 7.32).
- *Bevelled-edge firmer chisel.* The edges of the blade are bevelled off to reduce resistance to the blade, particularly when paring by hand and working into a corner (Fig. 7.33).
- *Registered pattern chisel.* This is designed for heavy work in hard timber. The main features are a heavy blade, a short thick neck and a leather washer between the shoulder and handle. There is also another ferrule at the top of the handle. The registered pattern chisel (Fig. 7.34) is designed to be used with a mallet.
- *Mortise chisels.* These chisels are intended for chopping mortises, using the mallet. Usually they are a socket-type chisel with a thick blade to withstand the heavy use and leverage to which they are subjected.
- *Butt chisel.* This is a short-bladed bevelled-edge chisel for accurately fitting hinges and locks.

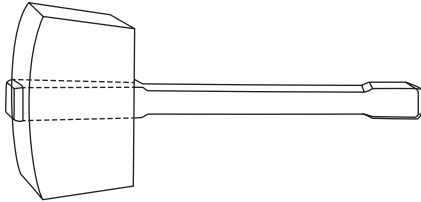
Fig. 7.32 Firmer chisel**Fig. 7.33** Bevelled-edge firmer chisel**Fig. 7.34** Registered pattern chisel

The mallet is used for driving the chisel (Fig. 7.35). The weight of approximately 1 kg provides the necessary force without causing damage to the chisel handle.

CHECK YOUR UNDERSTANDING

6. What type of chisel would you select for chopping out housings in hard timber? Give three reasons for your selection.

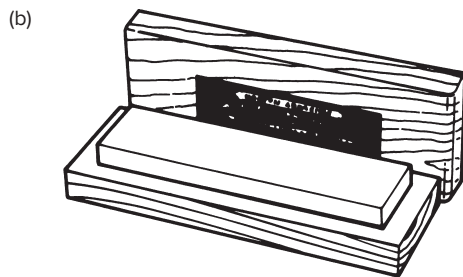
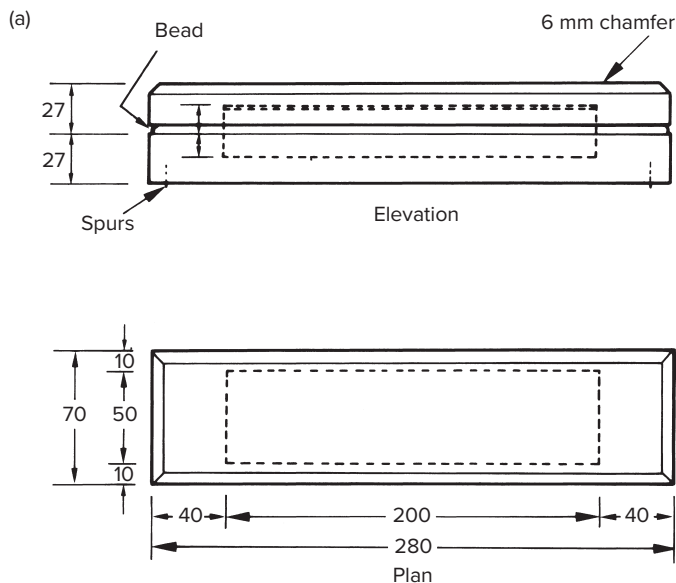
Fig. 7.35 Mallet



7.4.1 Oilstones

The sharp cutting edge on chisels and other carpenter's edge tools is produced by honing on an oilstone, which is composed of abrasive particles bonded together to form a solid stone (Fig. 7.36a). The length of the stone may vary from 150 mm to 200 mm, and they are usually 50 mm wide by 25 mm thick. **Aluminium oxide** is the most suitable abrasive for obtaining a keen edge on good-quality tools.

Fig. 7.36 (a) Oilstone and (b) oilstone case



As the name 'oilstone' implies, some lubrication is necessary to reduce friction and float away the waste particles of steel, and to prevent the pores of the stone from clogging up. The simplest way to provide a suitable lubricant is to mix motor oil and kerosene in about equal parts, and reserve it for use on the oilstone only. Special lubricants such as neatsfoot oil can also be used.

Stones are available in grades of coarse, medium and fine. The fine stone will produce a sharper edge, but the cutting will be very slow. A combination stone with coarse on one side for quick removal of waste, and fine to produce a sharp edge on the other, can be a very useful stone for all occasions.

Natural stones such as the 'Washita' and the 'Soft Arkansas' will give the keenest of cutting edges on quality tools but they are expensive; the cost is hardly warranted except for those who engage in fine hand woodworking. Oilstones should always be housed in a strong wooden case to protect them from dirt and damage (Fig. 7.36b).

Also available are diamond sharpening stones. These are in the shape of an oil stone, but are impregnated with diamond fragments. They are used in the same way as oil stones, although only water is used as the lubricant. Oil will damage these stones and render them useless.

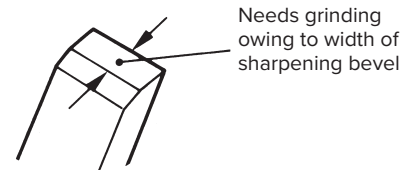
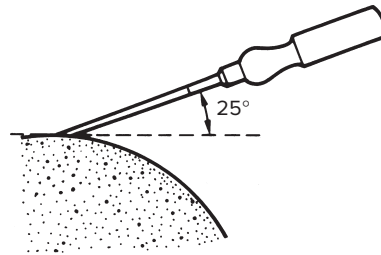
7.4.2 Sharpening chisels

The sharpening and honing of chisels and most carpenter's edge tools involve two angles—a grinding angle and a sharpening angle.

7.4.2.1 The grinding angle

The grinding angle, produced on a grinding wheel, can vary from 25° to 30° and must be square to the blade (Fig. 7.37). When using a grinding wheel, safety is paramount. The wearing of safety glasses is a must. Always refer to the grinder's safe operating procedure prior to using the machine. Care must be taken that the chisel does not become overheated, so it should be cooled frequently with water.

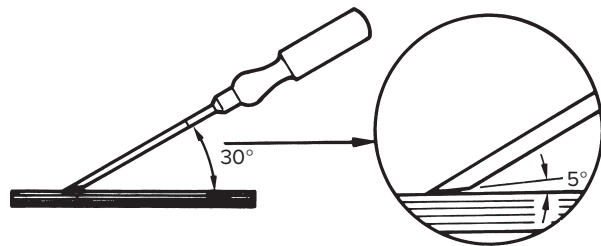
Fig. 7.37 Grinding angle



7.4.2.2 The sharpening angle

As just the point of the blade will do the cutting, only the point needs to be sharpened to a keen edge on the oilstone. The sharpening angle will vary from 30° to 35° (Fig. 7.38). At the lower angle, the chisel would give satisfactory service on light paring work but in hard timber the edge may tend to break away, and sharpening to a greater angle will ensure more reliable service.

Fig. 7.38 Sharpening angle



To sharpen the chisel, follow these steps:

1. Spread sufficient lubricant on the oilstone and place the grinding angle flat on the face of the stone. Lift the blade a little, up to 5° , to obtain the correct sharpening angle.
2. With a light pressure, rub the chisel backwards and forwards over the stone, or use a figure-eight motion until a burr, sometimes called a *wire edge*, appears on the back of the blade (Fig. 7.39). A figure-eight motion is used to prevent the stone from wearing unevenly.
3. Turn the chisel over and, holding the back perfectly flat on the stone, rub to and fro until the wire edge is removed (Fig. 7.40). It may be necessary to reverse the blade a couple of times, for a few strokes only, until the wire edge finally comes away. This is often seen left lying on the stone. Wipe the stone down before further use.

Fig. 7.39 Chisel on oilstone—feeling for wire edge

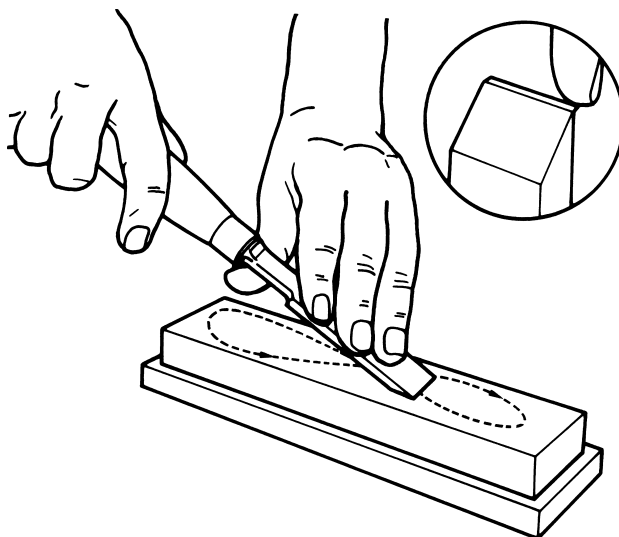
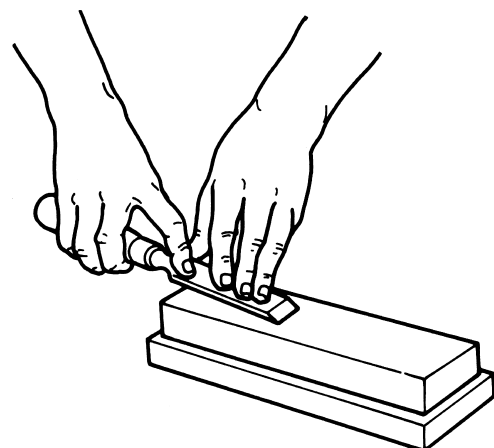


Fig. 7.40 Removing wire edges—turning chisel flat on oilstone



WORKPLACE SCENARIO

It's inevitable that at some point every apprentice will end up hurting themselves with a hand tool. One of the most common injuries I have seen occurs while using a chisel. It's very easy to forget that the leading edge of a chisel is sharp, and apprentices hold the timber they are working on with their non-dominant hand in front of the chisel.

While they are paring the timber, they often push too hard, the cutting-edge slips and pushes into the hand holding the timber and blood starts gushing. The number of stitches they need depends on the sharpness of the chisel. To avoid this happening, always use a clamp to hold the timber, and keep all parts of your body behind the chisel.

The following joints can all be produced using the tools that have already been discussed.

7.5 Construct basic timber joints

7.5.1 Half-lapped/halving joint

The **half-lapped joint** is one of the most commonly used joints, both in detail joinery and construction work and can be referred to as a *scarf joint* when joining timber in length (Fig. 7.41). The setting out of most joints in woodwork requires working from a given face; this is usually clearly indicated by marking the face with a distinguishing mark called a 'face mark', as shown in Figure 7.42.

Fig. 7.41 Half-lapped joint: (a) corner halving; (b) tee-halving; (c) tee-halving with cut plate; (d) extending timber in length (scarf joint)

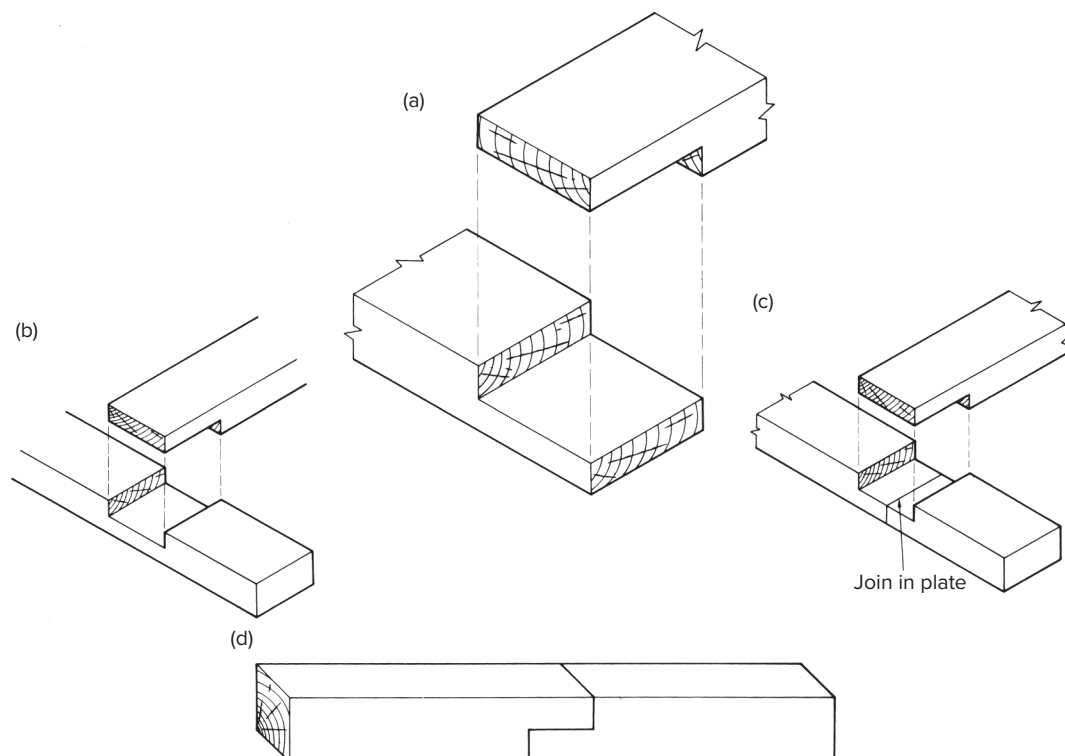
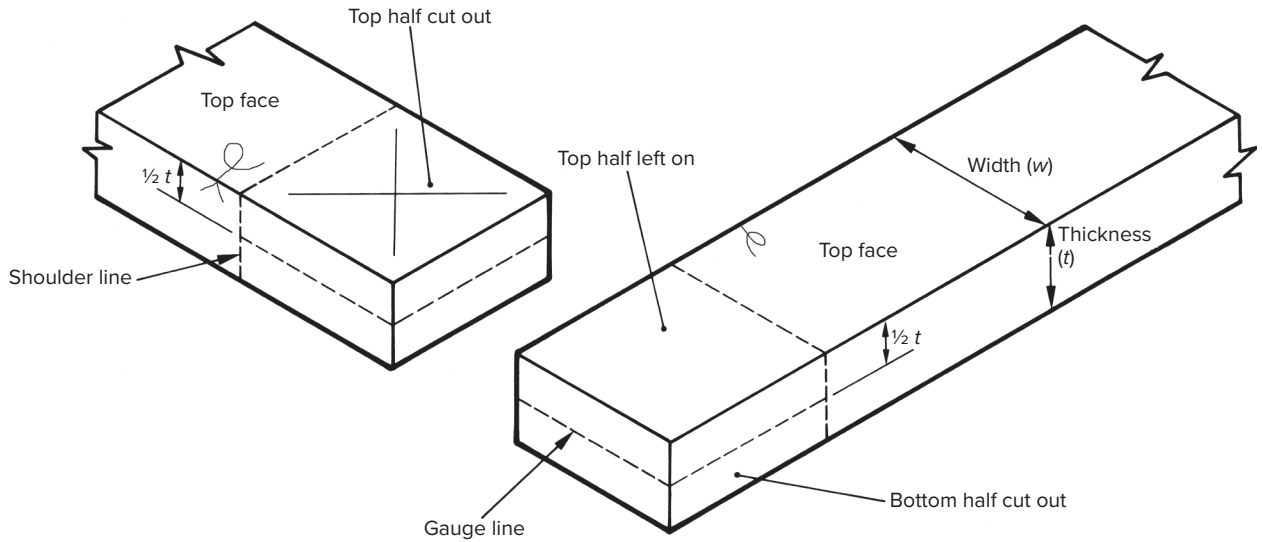
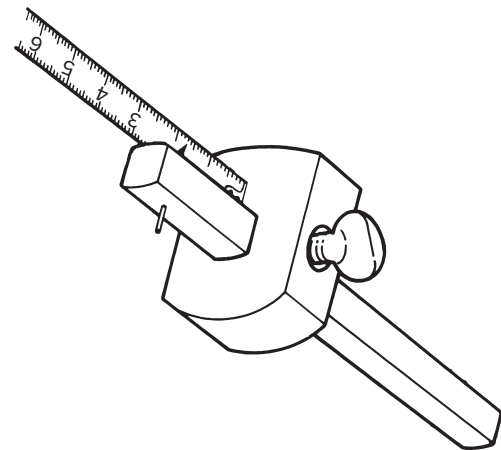


Fig. 7.42 Scarf joint/halving joint set-out

7.5.1.1 Setting out the half-lapped joint

The procedure is as follows:

1. Square the ends of the two pieces of timber to be jointed and mark the working faces.
2. Measure back from the ends the distance equal to the width of the material (w), and square the shoulder line around the timber.
3. Set the marking gauge to half the thickness of the material (t) (Fig. 7.43) and with the stock of the gauge against the face, gauge around the three sides of the joint on both pieces of timber (Fig. 7.44).
4. Mark the waste half to be cut out with a distinct cross.

Fig. 7.43 Setting marking gauge

TIP Ensure that both pieces of timber are gauged the same distance from the face so that when the joint is cut out, the amount left on one piece should be the same as the amount cut out of the other, and the face will be flush.

7.5.1.2 Cutting out the half-lapped joint

Select a suitable saw. This job involves small amounts of ripping and cross-cutting without the need for a high-quality finish, so a panel saw would be an appropriate choice.

When cutting away a 'cheek' from the end of the timber, as in this case as well as a number of other joints, the golden rule is, *rip first and cross-cut second*. The reason for this is that we can rip slightly beyond the shoulder line and the strength of the joint will not be affected. Then cross-cut just up to the first cut. To cross-cut beyond the gauge line would seriously reduce the strength of the joint.

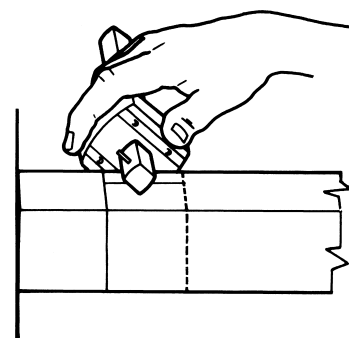
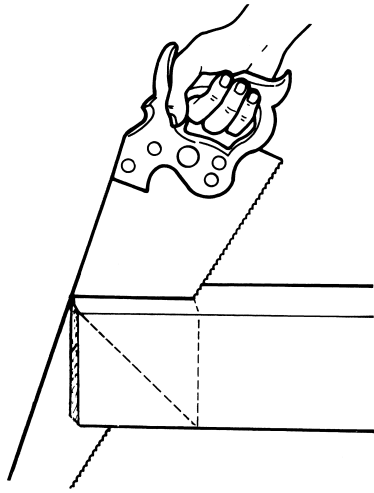
Fig. 7.44 Holding marking gauge

Fig. 7.45 Process of sawing—ripping



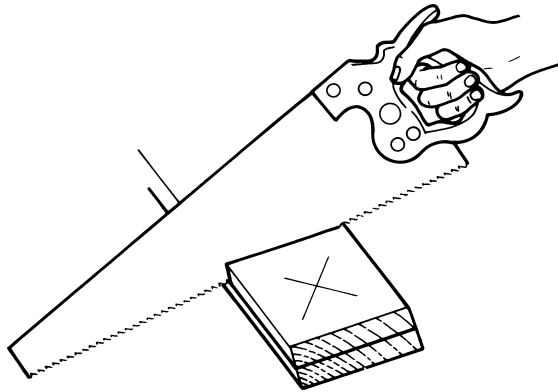
7.5.1.3 Ripping the half-lapped joint

1. With the timber supported on stools, rip diagonally on the waste side of the line for half the joint (Fig. 7.45).
2. Reverse the timber and continue the cut from the opposite side, taking care to keep on the waste side of the line. Lift the handle of the saw to finish the cut slightly beyond the shoulder line.
3. Lay the timber flat on the stools and make the cross-cut on the waste side of the shoulder line, just up to the first cut (Fig. 7.46). Check for accuracy—the shoulder should be a close fit, and the joint should be square and the face flush.

7.5.2 Housed joint

The housed joint is also a commonly used joint in all kinds of carpentry work. Figure 7.47 illustrates an example.

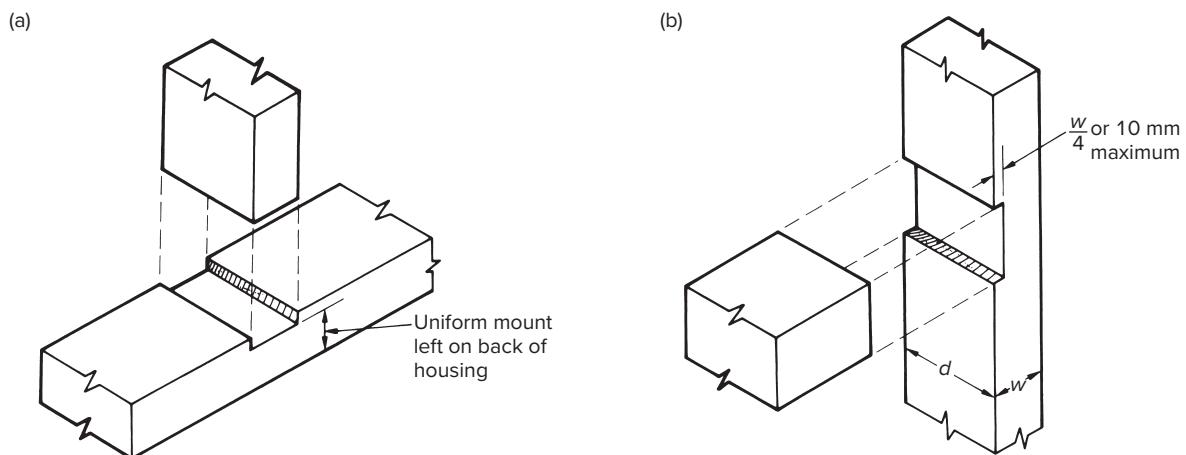
Fig. 7.46 Process of sawing—cross-cut up to first cut



7.5.2.1 To set out the housed joint

1. Locate the position of the housing on the face of the timber and measure the distance equal to the width of the corresponding piece of timber. Square two lines across the depth and partly down the sides. Figure 7.47 shows the designation of the terms w (width) and d (depth).
2. Set the marking gauge to the amount left on the timber and gauge the housing from the top or bottom face as the case may be (Fig. 7.48).

Fig. 7.47 Housed joints (a) horizontal; (b) vertical



7.5.2.2 Cutting the housed joint

1. Using a hand saw, cut down the sides of the housing, keeping on the waste side of the line and taking care not to cut beyond the gauge line.

2. Using a sturdy chisel, together with a mallet or hammer, work from one side and remove the waste approximately halfway across the housing down to the gauge line.
3. Working from the opposite side, remove the remainder of the waste.
4. Paring by hand, smooth the bottom of the housing. Note how the chisel is gripped between the thumb and forefinger, which keeps it under control at all times (Fig. 7.49).

Fig. 7.48 Housed joint set-out

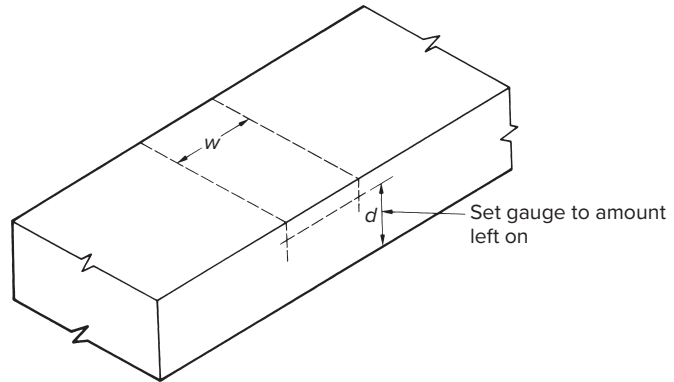
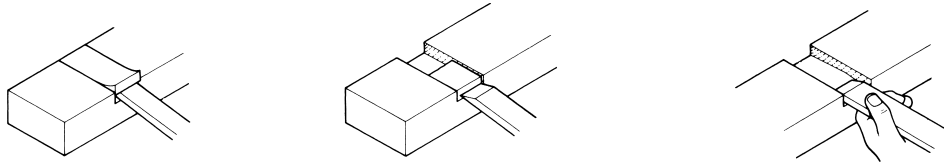


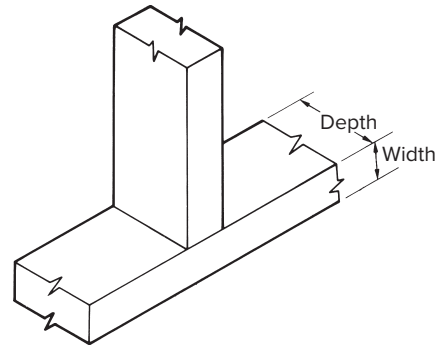
Fig. 7.49 Cutting the housed joint



7.5.3 Butt joint

The **butt joint** shown in Figure 7.50 is extensively used in timber framing.

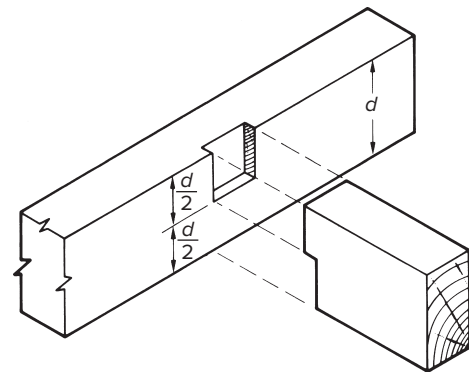
Fig. 7.50 Butt joint



7.5.4 Stopped housed joint

The housing in a **stopped housed joint** does not continue right across the face of the timber; Figure 7.51 shows an example.

Fig. 7.51 Stopped housed joint

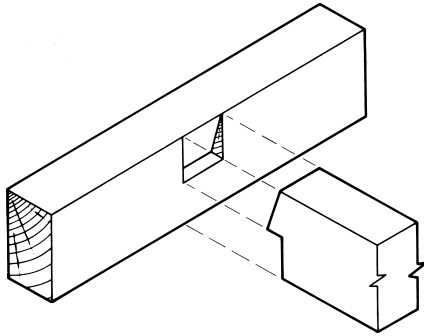
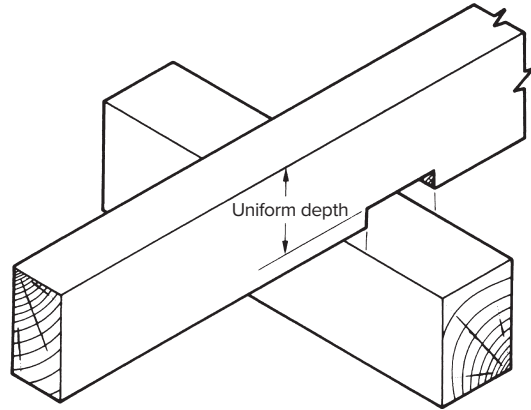


7.5.5 Splayed housed joint

The splayed joint shown in Figure 7.52 will serve the same function as the stopped house joint.

7.5.6 Notched joint

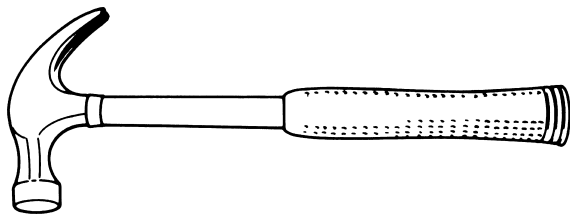
The example shown in Figure 7.53 is another application for floor framing. The joist has been notched to leave a uniform depth where it will be supported on a timber bearer, or in some cases a steel beam. A modification of the notched joint is the *birdsmouth*.

Fig. 7.52 Splayed housed joint**Fig. 7.53** Notched joint

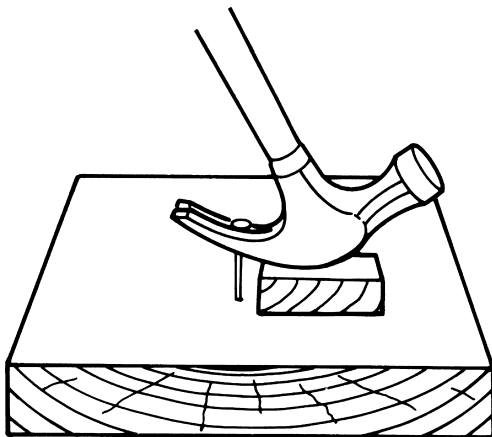
7.6 Identify and use hammers

7.6.1 Claw hammers

Claw hammers are essential equipment for the construction carpenter (Fig. 7.54) and are used, of course, for the driving and extracting of nails (Fig. 7.55). Hammers have a drop forged head with a handle or shaft that may be made of wood, fibreglass or steel, with a shockproof hand grip, which is very popular. The size of the hammer is expressed as the mass of the head and common sizes are 450 g, 570 g and 680 g, or, in imperial units, 16 oz, 20 oz and 24 oz. The face of the claw hammer is case hardened and should never be used to strike another hammer or other hard metals, as the hardened face may chip away. For working on construction carpentry, a heavy hammer is the most suitable.

**Fig. 7.54** Claw hammer

TIP There are many varieties of claw hammers; some have straight claws, some curved claws and some larger heads. Make sure you purchase a hammer that is suitable for the type of work you will be doing and that is not too heavy. Many carpenters end up with tennis elbow because the hammer they use is too heavy.

Fig. 7.55 Using the claw to extract a nail

7.6.2 Warrington hammer

This pattern of hammer is often favoured for light benchwork (Fig. 7.56). It has a tapered cross pein, which is used to start panel pins held between finger and thumb. The polished head varies in mass from 100 g to 450 g and is fitted with an ash handle.

7.6.3 Nail punches

Bullet head nails, used in most finish work, are punched slightly below the surface with a nail punch, which has a concave tip to prevent it slipping off the nail (Fig. 7.57). The diameter of the tip can be 0.8, 1.5, 2.3, 3.3 or 4 mm. Select a tip size approximately equal to the dimension of the nail head.

7.6.4 Pinch bar

Pinch bars are also called *wrecking bars* and are used for demolition work, pulling large nails or for levering building units, such as wall frames, into position. The pinch bar has a claw at one

end, and an offset chisel point at the other (Fig. 7.58).

7.6.5 Pincers

Pincers are designed to pull nails out of timber (Fig. 7.59). The edge of the jaws is not sharpened to a point, so when the nail is clenched, the pincers will not cut through it. The curve of the head provides a fulcrum (pivot point) to pull the nail out. Once the head of the nail is in the jaws, hold the handles together, then push down on the handle, so that the head hits the timber as the handle continues in a downwards direction. The jaws will lift up as the head pivots and the nail will be pulled out. To avoid damage to the timber surface, use a thin timber offcut such as plywood.

7.7 Identify and use bench planes

Bench planes generally refer to a group of planes that are similar to each other in construction but vary in size. Each has a particular function to perform. Figure 7.60 shows a smoothing plane. Planes in the group are listed in Table 7.2.

The term 'fore plane' has now fallen into disuse. It may be regarded as a short trying plane since it is sharpened in a similar manner.

The construction of a bench plane is illustrated in Figure 7.61.

Table 7.2 Types of bench planes

Name	Length (mm)	Blade width (mm)
Smoothing plane	240 & 260	45, 50 & 60
Jack plane	355 & 380	50 & 60
Fore plane	455	60
Trying plane or jointer	560 & 610	60 & 65

7.7.1 Plane iron

The plane iron consists of two main parts:

1. the cutting iron
2. the cap iron or back iron.

These are held together by the *cap iron screw*. The cutting iron does the actual cutting and the cap iron is provided to stiffen the cutting edge and prevent vibration and 'chattering' (Fig. 7.62). The cap iron also performs the important function of putting the curl into the shavings so that they will roll out and clear the waste from the mouth of the plane.

The cap or back iron must fit tightly down on cutting iron; otherwise the shavings will become wedged in the gap and clog the mouth of the plane.

Fig. 7.56 Warrington hammer

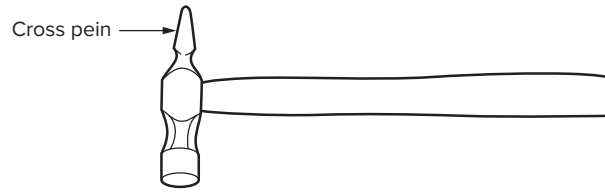


Fig. 7.57 Nail punch



Fig. 7.58 Pinch bar

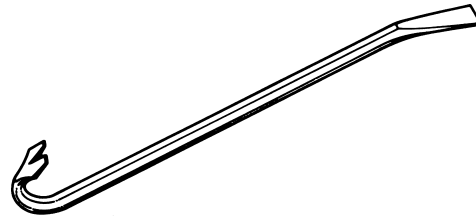


Fig. 7.59 Pincers

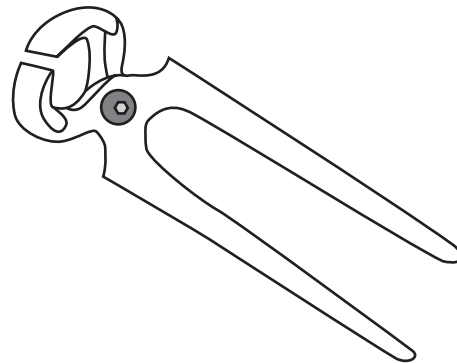
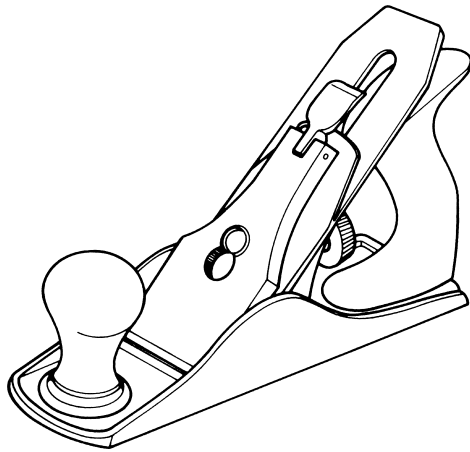
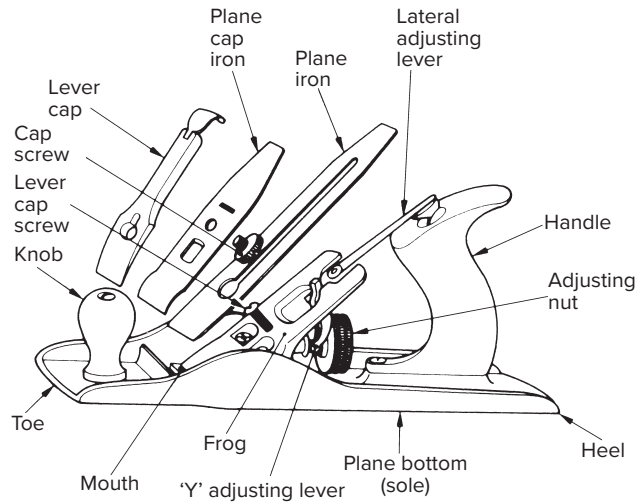
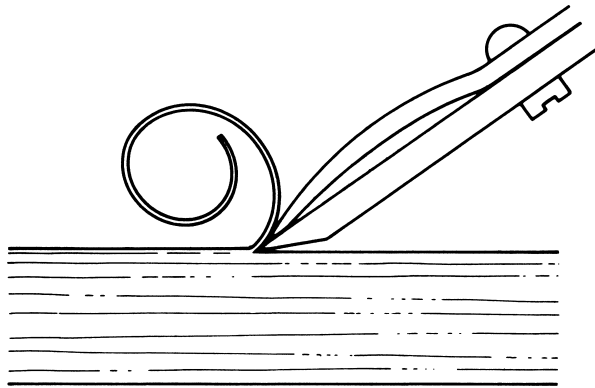
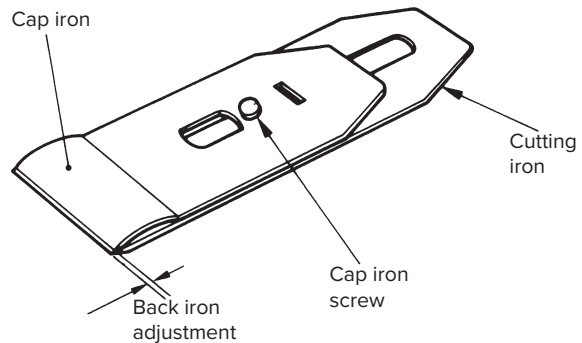
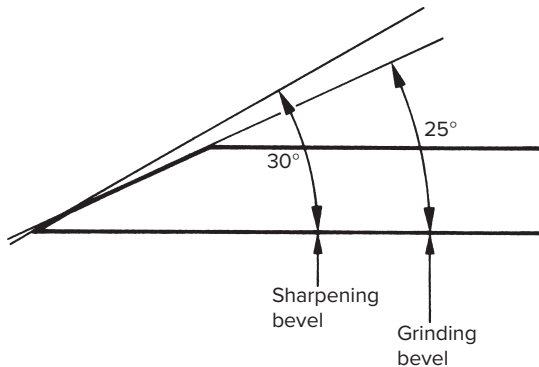


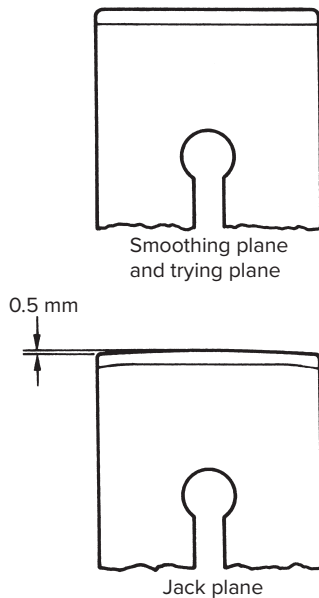
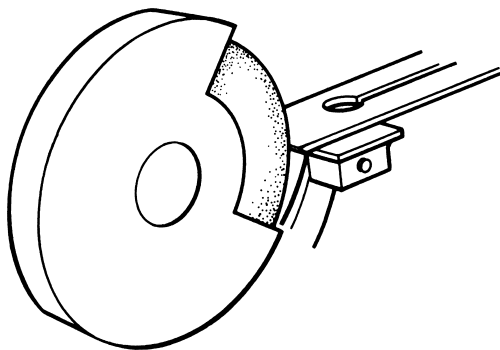
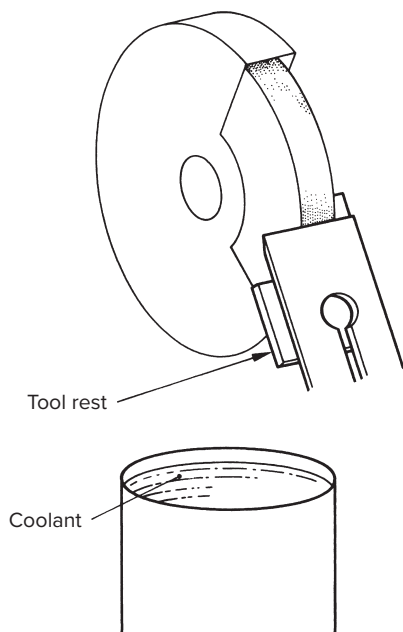
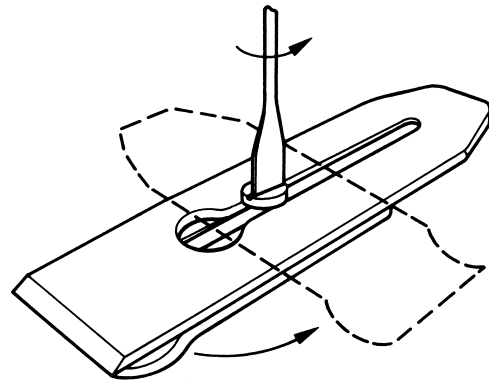
Fig. 7.60 The smoothing plane

Fig. 7.61 Exploded view of the bench plane

Fig. 7.62 Action of the plane iron

Fig. 7.63 Adjustment of the back iron

Fig. 7.64 Sharpening angles


The distance the cap iron is set back from the cutting edge (Fig. 7.63) depends mainly on the nature of the timber. Difficult curly-grained timber requires the cap iron to be set as close as possible, say 0.5 mm, to the cutting edge and a very fine shaving taken. On milder timber, the cap iron can be set back as far as 2 mm and a heavier shaving taken.

The cutting iron, in common with most other edge tools, is sharpened with two distinct bevels (Fig. 7.64):

1. the grinding bevel (25°)
2. the sharpening bevel (30°).

The shape of the blade across the face varies (Fig. 7.65); the explanation for this will become apparent when considering the purposes of the bench planes.

Fig. 7.65 Blade shapes**Fig. 7.67** Squaring the plane iron**Fig. 7.68** Grinding the bevel**Fig. 7.66** Removing the cap iron

7.7.1.1 Grinding the cutting iron

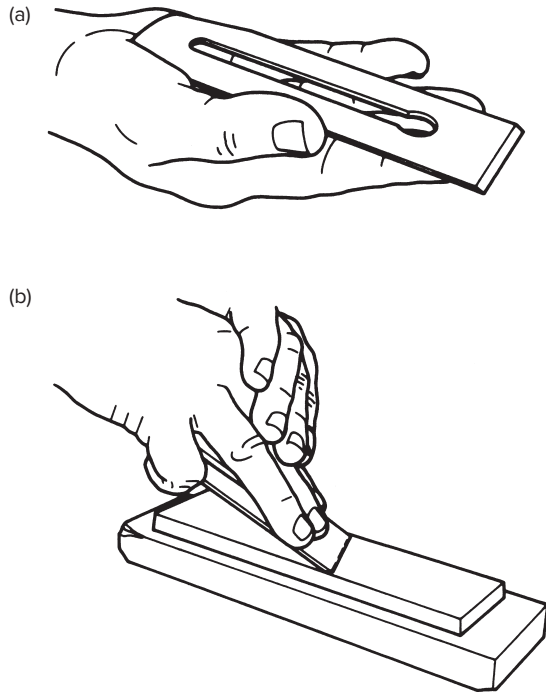
To remove the blade from the plane, lift the lever and remove the lever cap (Fig. 7.66). The plane iron can then be lifted from the body of the plane. Separate the cap iron from the cutting iron by laying the blade flat on the bench and using a large screwdriver to loosen the cap iron screw. Turn the blade over, slide the cap iron back and turn it through 90°. Now slide the cap iron forward and remove the screw through the hole in the blade.

Before grinding a blade, ensure that you read the standard operating procedure for the grinder and follow all of the safety requirements, including using safety glasses and removing any loose items of clothing. To grind the blade:

1. Set the tool rest square to the grinding wheel, lay the blade on the rest and, moving it from side to side, grind the edge just sufficiently to remove any gaps. The grind should finish straight and square, or in the case of the jack plane, with a slight camber (Fig. 7.67). Check with the try square.
2. Adjust the tool rest to grind at the correct angle, which is 25°. Lay the blade on the rest and, moving it from side to side, grind it at this angle until the thick edge is almost removed (Fig. 7.68).
3. Hold the edge between the fingers and up to the light; any remaining thick edge will be visible, showing where further grinding is required. However, do not attempt to produce the final cutting edge on the grinder.
4. Tilt the blade sideways and, with just a slight touch, remove the sharp corners if necessary.

TIP During grinding, it is most important that the blade is kept cool. Keep a container of water nearby and cool the blade frequently. The first sign of overheating is when the surface of the blade turns a light straw colour. Stop immediately and cool the blade. Overheating can ruin a good plane iron as the cutting edge becomes soft due to the loss of temper, and it will not hold a keen edge.

Fig. 7.69 (a) and (b) Gripping the plane iron



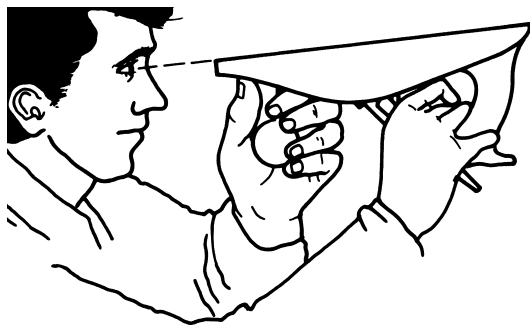
7.7.1.2 Sharpening the cutting iron

Producing a sharp cutting edge requires a fine oilstone or, even better, a good natural abrasive stone. Figure 7.69 shows the way to grip the plane iron to hold it at a constant angle.

1. Rest the grinding angle of the blade on the stone and raise the blade through 5°. Move the blade back and forth using the full length of the stone. Alternatively, move it with a figure-eight motion until a burr appears on the back of the blade.
2. Turn the blade over and, holding the blade perfectly flat on the stone, remove the burr. It may be necessary to reverse the blade for a few strokes to finally remove the burr, which will probably be seen left lying on the stone.

Assembly of the cap iron is the reverse of the removal procedure, except that the cap iron is slid forward to the required setting from the cutting edge. The blade is then turned over and the screw tightened.

Fig. 7.70 Sighting down the sole



cutter adjusting nut (usually clockwise) until the blade can be seen projecting from the mouth. If one corner is projecting more than the other, use the lateral adjusting lever to move the blade sideways until it is projecting uniformly across the full width of the blade. Readjust the projection of the blade to take just a fine shaving. Always commence planing with a fine shaving and, if desired, increase it as conditions permit.

7.7.3 Smoothing plane

The smoothing plane is very often the first plane to be added to the carpenter's and joiner's tool kit. Its function is to smooth off timber, leaving the surface flat and free of planing defects. For this purpose, the blade is sharpened perfectly straight across, with just the corners rounded off to prevent them digging in and leaving small ridges on the surface.

7.7.2 Adjusting the plane for use

Replace the plane iron by placing the cutting edge into the mouth of the plane and resting it on the frog, with the 'Y' adjusting lever and the lateral adjusting lever in the slots provided for them. (Refer to Figure 7.61 to identify the parts of the plane.) Replace the lever cap and press down the lever to lock the blade in place.

Turn the plane upside down and sight down the sole (Fig. 7.70). If the blade is not visible, turn the

The smoothing plane will be constantly at hand for the joiner, to flush off joints and clean off the face of framing, as in doors, windows, etc. It is also used to remove cutter marks from the surface of machine-dressed timber. Although not primarily intended for planing timber to size, it may sometimes be used for this purpose on short lengths.

The work on which a smoothing plane is to be used should always be held securely against the bench stops or in a vice. In order to smooth a wide surface, plane it in strips commencing from the nearest edge and work across the job until the whole surface is covered. Always plane in the direction of the grain. If necessary, reverse the direction of planing to determine which way produces the best result.

To achieve a satisfactory result with the smoothing plane under all conditions, it may be necessary to adjust the mouth (Fig. 7.71). This needs to be carried out on a smoothing plane only rarely. The amount of adjustment, although very small, can be significant when attempting to produce a smooth surface on difficult curly-grained timber.

Figure 7.71(a) shows that when the mouth is adjusted for normal planing, the distance from the cutting edge to the sole of the plane is approximately 1 mm to 1.5 mm. When planing difficult timber, the tendency is for the shaving to split and tear away in front of the cutting iron. Closing the mouth of the plane further (Fig. 7.71b) means that the sole is holding down the timber closer to the front of the cutting iron, preventing the shaving from lifting and breaking away. It naturally follows that if the mouth of the plane is closed up, only a very fine shaving can be taken—a thicker shaving would only become wedged in the narrow mouth. So, if a coarser shaving is to be taken, open the mouth.

To adjust the mouth opening, first remove the plane iron. Then loosen the two screws securing the frog and move the frog backwards or forwards by turning the frog adjusting screw. Tighten the screws when the correct setting is obtained.

In summary, to produce a smooth flat surface with the smoothing plane under difficult conditions, it is necessary to:

1. have the cutting iron correctly shaped and razor sharp
2. set the cap iron close to the cutting edge
3. close the mouth of the plane
4. take a very fine shaving.

Experience and experimentation will establish the best settings for any particular job.

7.7.4 Jack plane

The jack plane is similar to the smoothing plane and is used to dress timber to its approximate size and shape. The greater length of the jack plane makes it easier to produce a straight flat surface. The blade is sharpened with a slight camber, which makes it easier and quicker to remove the waste; however, the surface will be left with a series of corrugations, which must be removed later using a smoothing plane (Fig. 7.72).

If the timber is of a long length, the final truing up may be done with a trying plane.

Fig. 7.71 (a) and (b) Different mouth adjustments

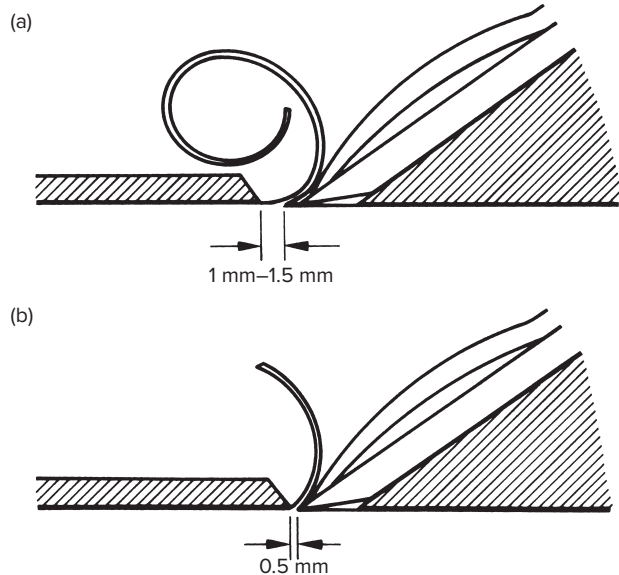
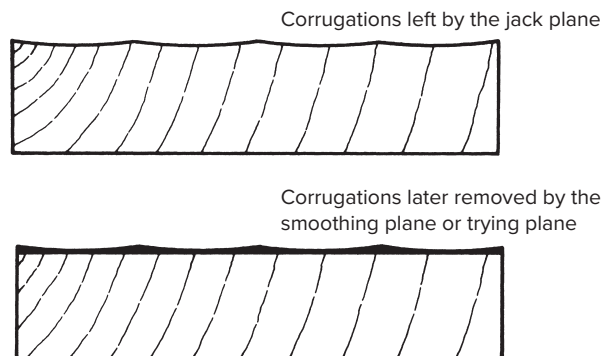


Fig. 7.72 Corrugations to be removed by a smoothing or a trying plane



7.7.5 Trying plane

The longer trying plane is most suitable for straightening long lengths of timber, particularly where the carpenter is edge jointing boards, as may be necessary for table or counter tops. The object is to produce a true flat surface. The blade is therefore sharpened straight across with the corners rounded off.

Many experienced tradespeople like to use the heavier trying plane wherever possible, but it must be conceded that much of the work of the trying plane is now being taken over by power tools. However, when accurate joining is required, nothing can equal the trying plane guided by skilled hands.

CHECK YOUR UNDERSTANDING

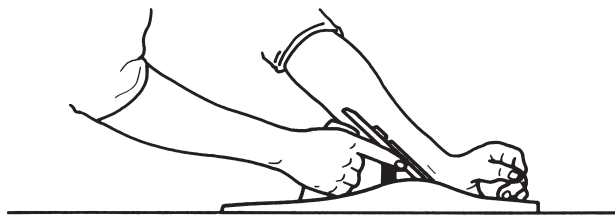
7. What is the function of the back iron?
8. At what angle is a plane iron ground?
9. Why might it be necessary to adjust the mouth of the plane?

7.7.6 Planing rough-sawn stock to section size

For all those seeking to become skilled in the use of hand planes, this is a basic exercise that should be practised. Note not only the way in which the plane is handled, but the procedure that is followed to reduce the rough rectangular stock to a given sectional size. (Trade terms are often used rather loosely, and differ in some areas. In the workshop, the raw unworked timber may sometimes be referred to as stock.)

This is one example of a basic procedure that is followed in the same order whether hand tools or machines are used. The jack plane is the best one to use for this purpose, but practise with the smoothing plane if it is the only one available. Assume for this exercise that a piece of 100 mm × 38 mm rough-sawn Pacific maple, 600 mm in length, is to be dressed to 90 mm × 32 mm finished size. The procedure will be described in four steps; each step will be confined to one of the four sides of the stock to be dressed.

Fig. 7.73 Gripping the plane



1. Select the best face of the timber to become the face side. Lay the timber flat on the bench with the face side up, and the end against the bench stop. Set the jack or trying plane to take a fine to medium shaving, and grip the handle with the finger lying parallel with the edge of the blade (Fig. 7.73).

To commence planing, rest the toe of the plane on the face of the timber and exert a downward pressure. Use the full length of the plane by keeping it parallel with the timber; move it forward maintaining pressure on the front.

As the plane commences to cut, the high spots will be removed first, in short shavings. When the plane is fully supported over the timber, exert forward and downward pressure equally with both hands; towards the end of the stroke, transfer downward pressure to the back to prevent the toe dipping down as it moves over the end of the timber and becomes unsupported. With practise, the distribution of pressure becomes an automatic reaction—pressure on front hand, distribute equally, transfer pressure to back hand (Fig. 7.74).

If the planing is difficult and rough, reverse the timber to see if the grain is running in the opposite direction.

Continue planing in strips across the face of the timber until full shavings are rolling out of the mouth of the plane. Test the face for accuracy in the following three ways:

- (a) Use a straight edge, or the sole of the plane tilted over, to check that the face is straight from end to end (Fig. 7.75).
- (b) Use a short straight edge or try square to check that it is flat across the width (Fig. 7.76). Hold the timber up to the light; any irregularity can be seen more readily under the straight edge.
- (c) The face could also be twisted or, to use the trade term, be in 'wind'. *Wind sticks* are two short lengths of timber, say 300 mm × 40 mm × 15 mm. Their section size can vary, but they must be parallel. Lay a wind stick square across the timber near each end and sight the two top edges; any wind will be exaggerated, indicating the high corners of the stock (Fig. 7.77).

To remove the wind, take shavings diagonally across the high corners. Check again, and when all is correct, mark the face with the traditional *face mark*—a large 'e' with the tail continued to one edge (Fig. 7.78).

Fig. 7.76 Checking the width for flatness

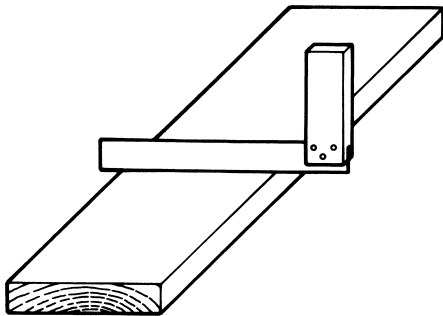


Fig. 7.74 Three pressure steps: (a) pressure at commencement of stroke; (b) pressure distributed equally; and (c) pressure at end of stroke

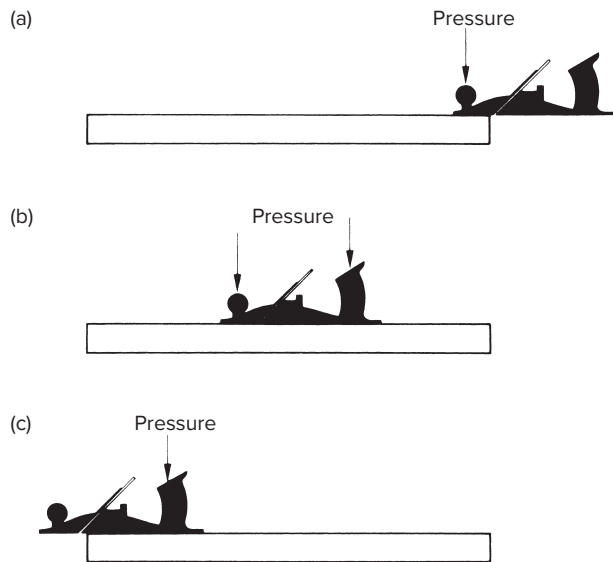


Fig. 7.75 Checking the length for straightness

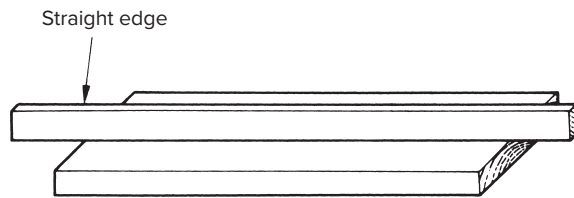
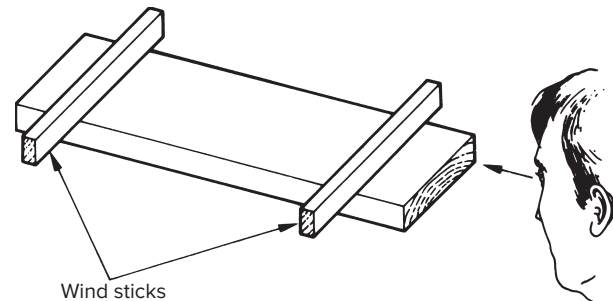
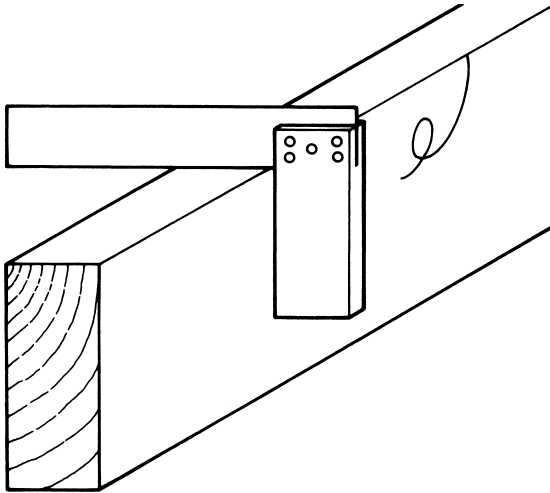


Fig. 7.77 Checking the face for wind



2. On the extended tail of the face, mark points to the face edge, which must now be planed straight and square to the face side; this is called 'shooting the edge' (Fig. 7.79). To do this, first secure the timber in a vice. Grip the plane as shown in Fig. 7.79. Holding the plane square to the face side, plane the edge, distributing the pressure in a similar manner as for the face side. Test the face edge in the following two ways:

- (a) Use a straight edge to check that it is straight from end to end
- (b) Use a try square to check that it is square to the face side (Fig. 7.80).

Fig. 7.78 Face mark**Fig. 7.80** Checking the edge for squareness

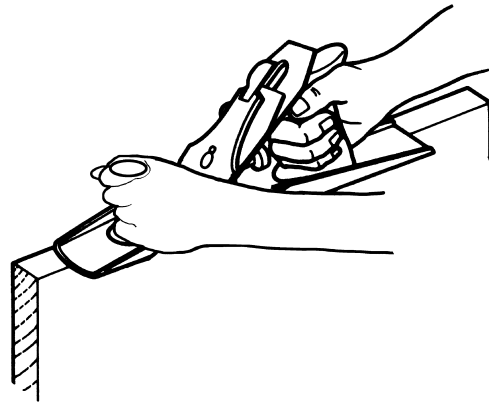
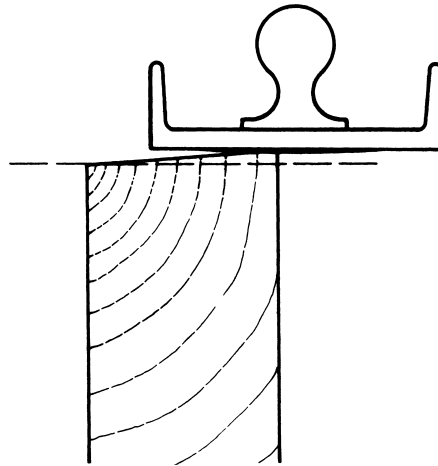
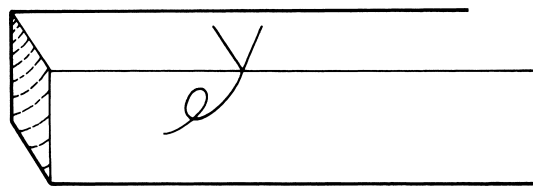
If it is not square, move the plane over to take shavings off the high edge only (Fig. 7.81), finishing with a shaving of full thickness. Test again, and when all is correct, mark with the *face edge mark*—a 'V' with the point to the long tail of the face mark (Fig. 7.82).

When preparing the face side and edge, do not lose sight of the fact that the timber must be finished to a given section size; so do not plane unnecessarily with the result that the timber is finished undersize.

3. The timber must now be reduced to the specified width. Set the marking gauge to width, 90 mm in this case, and with the stock of the gauge to the face edge, gauge the width along the two faces. If there is an excessive amount of waste to be removed in the width, use the rip saw and cut to about a millimetre on the waste side of the gauge line, which is sufficient to smooth the rough edge and finish accurately to size with the jack plane.

When planing away waste, keep a careful watch on the gauge lines and stop planing when you just start to split the lines.

4. The timber must next be reduced to its specified thickness. Set the gauge to the correct thickness, 32 mm in this case, and with the stock to the face side, gauge both edges and ends to thickness. Lay the stock on the bench against the stop and, watching the gauge lines on both edges, plane away the waste, stopping at the gauge lines.

Fig. 7.79 Shooting the edge using a jack or a trying plane**Fig. 7.81** Correcting the edge**Fig. 7.82** Face edge mark

7.7.7 Block plane

The block plane is primarily intended for planing **end grain** but can also be used for trimming other small items (Fig. 7.83).

This plane is approximately 180 mm in length, with a blade 41 mm in width, set at a low angle of 20°. There is no back iron and the blade is sharpened at the same angle as the bench planes—a grinding angle of 25° and a sharpening angle of 30°. It is mounted in the plane with the bevel side up. Different makes will vary in the way the blade is fitted and adjusted; however, the better-quality planes have full screw adjustment for depth of cut and lateral movement. To use the block plane for planing end grain, the blade must be razor sharp and should be set for a very fine shaving (Fig. 7.84). To prevent the timber splitting away at the end of the cut, plane from both directions.

Fig. 7.83 Block plane

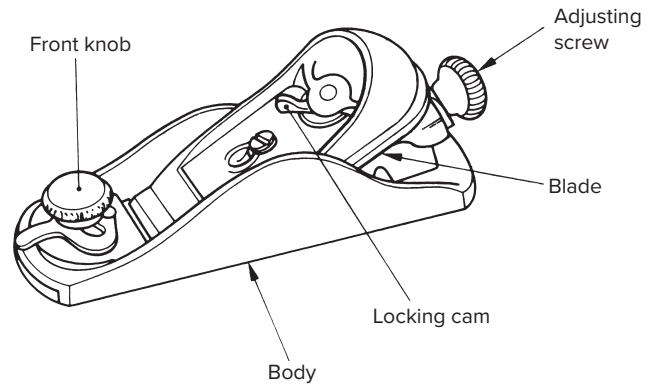
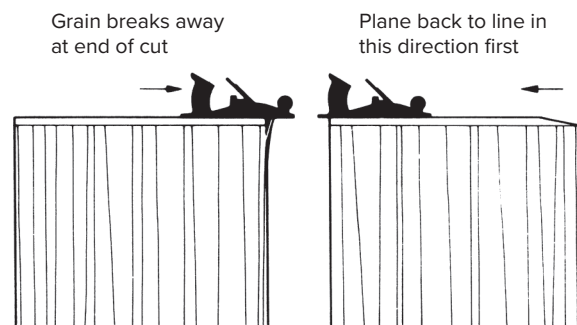


Fig. 7.84 Planing end grain



7.7.8 Lubricating the sole of the plane

Planing will be made much easier if the sole of the plane is lightly lubricated. However, this must be done sparingly, and care must be taken to ensure that the surface of the timber is not contaminated with oil or wax. Candle grease or other dry lubricants are suitable. Alternatively, an oil pad can be made up. Roll a strip of felt into a small tin can and apply neatsfoot oil. Allow the oil to soak into the felt until it seems almost dry. To use the oil pad, wipe just the toe of the plane across the pad so that any residue will be removed from the surface of the timber by the shaving following.

7.7.9 Spokeshave

The spokeshave has a cutting action similar to the planes and its purpose is to clean up curved edges of timber (Fig. 7.85).

The sole is narrow to enable it to follow curves. The general practice is to use a spokeshave with a flat sole to follow convex curves and one with a curved sole on concave surfaces (Fig. 7.86).

The blade is 43 mm to 53 mm wide. There is no cap iron; the single cutter is clamped in place by a lever cap.

Fig. 7.85 Spokeshave

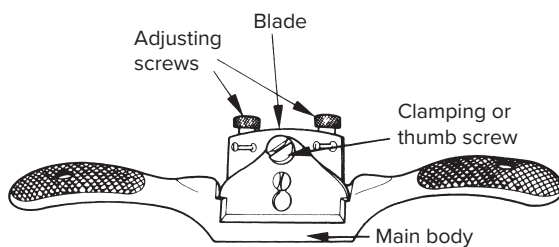


Fig. 7.86 Flat and curved spokeshaves

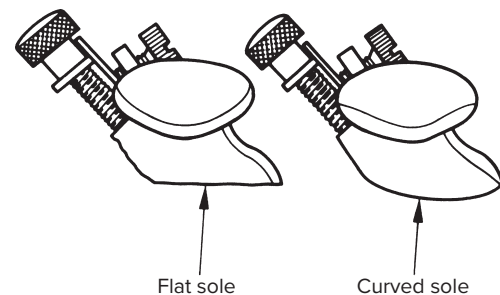
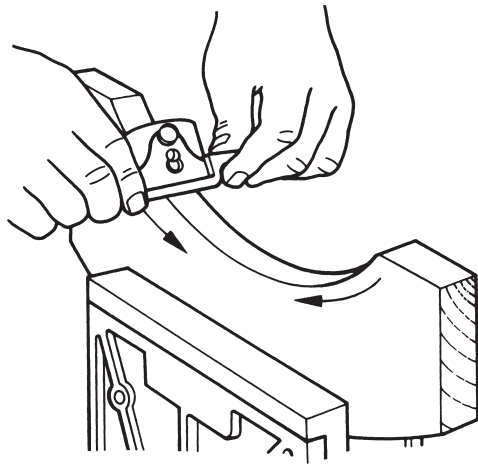


Fig. 7.87 Dressing a concave curve

To set the depth of cut, loosen the thumb screw, use the two adjusting screws to make the adjustment and then tighten the thumb screw.

In use, the spokeshave is set to take a fine shaving and must always follow the direction of the grain. Ideally, the spokeshave should be held square across the timber; however, it is often found that it cuts more cleanly if held at a slight angle to make more of a slicing cut.

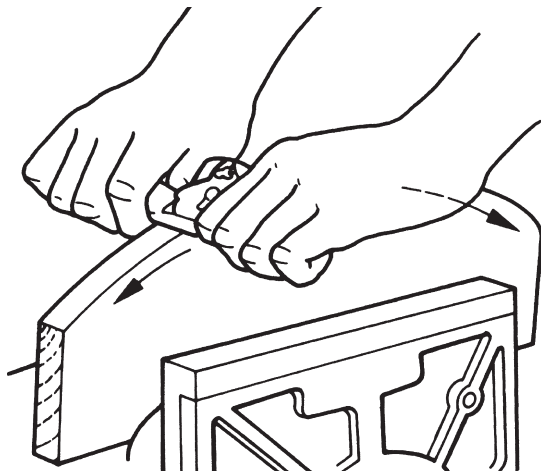
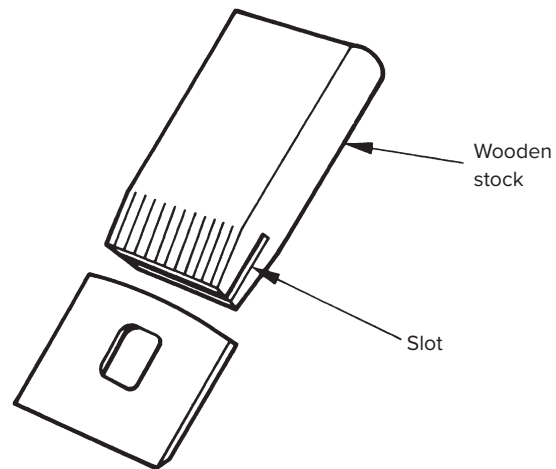
To clean up a concave curve, grip the spokeshave by the handles, with the thumbs resting on the back edge in the small depressions provided for the purpose.

Hold the job securely in the vice and commence at the top of the curve; push the spokeshave away from you, following the direction of the grain to the bottom of the curve. Reverse the timber and work the other half of the curve (Fig. 7.87).

A convex curve can be worked in a similar manner: commence at the centre of the curve and dress each way in the direction of the grain (Fig. 7.88).

The blade of the metal spokeshave is sharpened in a similar manner to the blade of a plane (Fig. 7.89). If it is difficult to hold the small blade, secure it in a stock fashioned from a piece of timber.

The stock consists of a block, approximately 100 mm × 45 mm × 19 mm, with a slot in which the blade is held. The block is rounded off to fit the hand comfortably.

Fig. 7.88 Dressing a convex curve**Fig. 7.89** Sharpening a spokeshave blade

TIP The planes detailed previously are the ones that are now commonly available or used in Australia. Many more hand planes exist and most can still be purchased. They are all designed for specific purposes. It will be useful to do some research and see how many planes you can find.

CHECK YOUR UNDERSTANDING

10. What mark is used to indicate the face of the piece of timber being worked on?
11. Why are the two pieces of timber forming a half-lapped joint both gauged from the same face?

7.8 Understand workbench equipment and its uses

The workbench is an essential item of workshop equipment. The basic requirements of a bench suitable for trade use are illustrated in Figure 7.90.

The bench must be solid and rigid and mortised or bolted together. A double-sided bench where the joiner can work around all sides is preferable, and it must be large enough to lay out items of joinery, doors or large panels of sheet material. The overall dimensions indicated can be taken as a guide—the height can be adjusted to suit the individual.

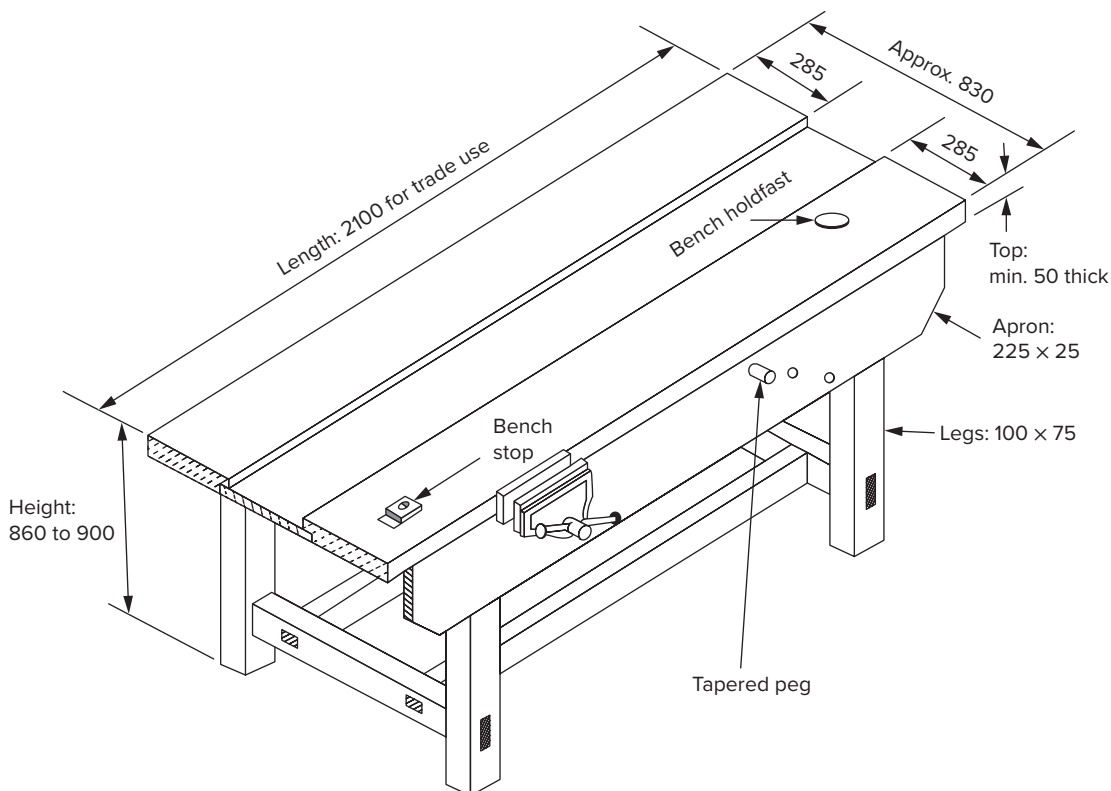
The top must be made from a fine-grained timber (e.g. Klinki pine) that will not bruise other material worked on the bench. Bolts for fixing the top to the frame should be counterbored, and a wooden plug should be set in to cover the head of the bolt.

Attachments to the bench will include a woodworker's vice, a bench stop and a bench holdfast.

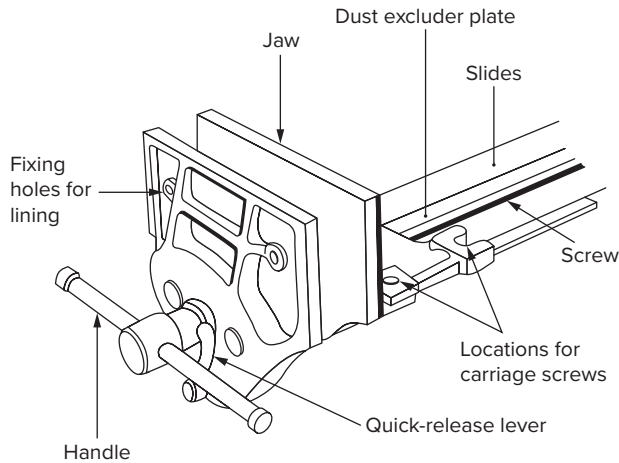
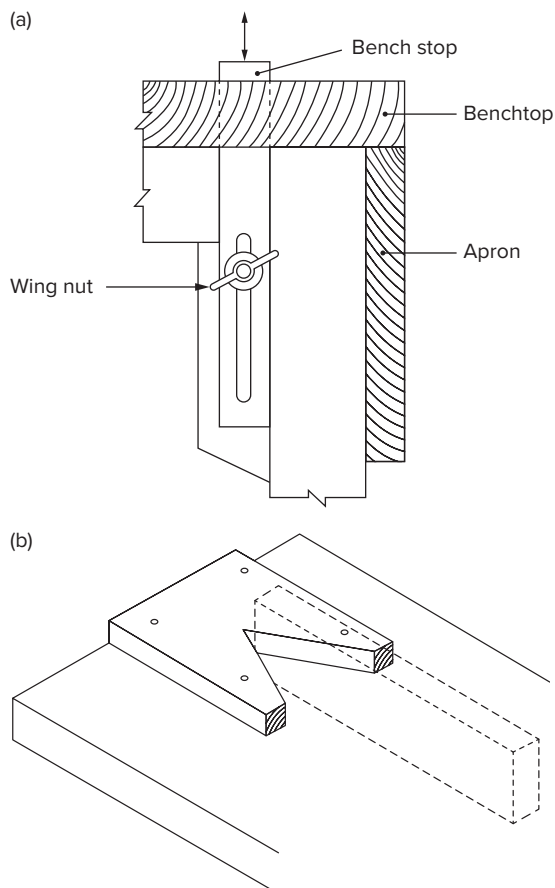
7.8.1 Woodworker's vice

The size of the vice is indicated by the width of the jaws and varies from 150 mm to 250 mm. The movable jaw is operated by a handle that revolves a screw, which in turn engages in a nut at the back of the vice. A useful feature on some vices is a *speed screw*. This consists of a quick-release lever that, when pressed, releases the nut holding the screw, allowing the movable jaws to slide freely so they can be quickly adjusted to any thickness of material.

Fig. 7.90 Workbench



When fixing the vice to the bench, the top of the metal jaws must be kept down at least 10 mm from the top of the bench; wooden liners are fixed inside the jaws and are level with the benchtop (Fig. 7.91).

Fig. 7.91 Bench vice**Fig. 7.92 (a) Bench stop; (b) 'V' block bench stop**

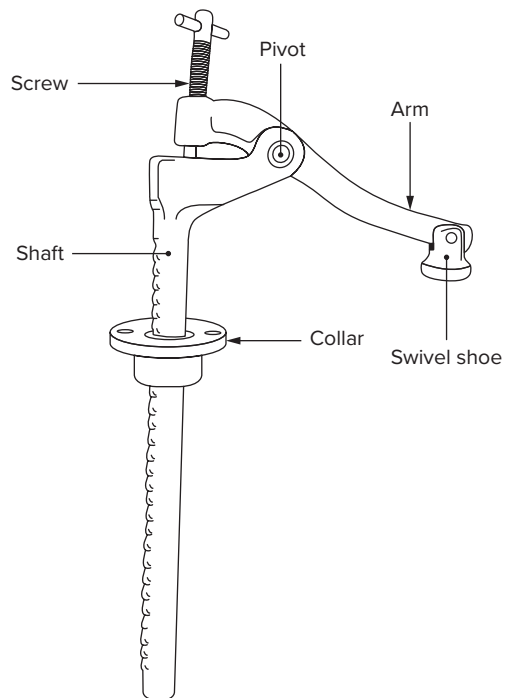
7.8.2 Bench stop

The bench stop is usually located at the left-hand end of the bench. It can be the metal type, set flush into the benchtop and adjustable in height, or a wooden peg projecting from underneath, also adjustable in height (Fig. 7.92a).

Another useful type of stop is a 'V' block (Fig. 7.92b). It serves as a stop and also holds timber upright.

7.8.3 Bench holdfast

One or more collars are set into the benchtop, which engage the shaft of the holdfast (Fig. 7.93). As the screw bears down on the top of the shaft, the arm pivots, holding the work piece firmly down on the benchtop.

Fig. 7.93 Bench holdfast

7.8.4 Other useful features of the workbench

Holes approximately 22 mm in diameter, drilled in the apron of the bench, are used to fit a tapered wooden peg that can support the ends of long pieces of timber when held in the vice.

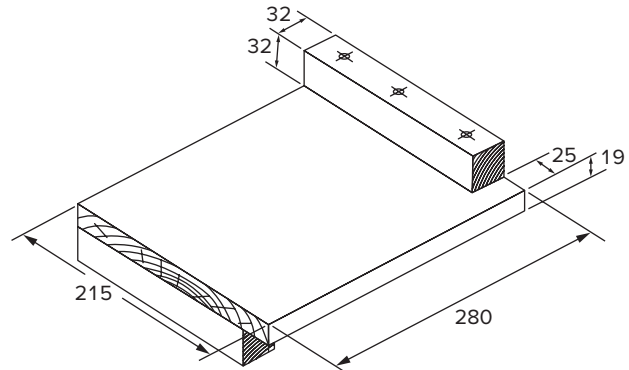
Individual tradespeople will make their own additions to a workbench—for example, a shelf or drawer underneath, or racks across the end, to store tools and small items when not in use.

7.8.5 Workbench accessories

7.8.5.1 Bench hook

The bench hook is used to hold timber firmly and to protect the bench during sawing operations (refer to tenon saws) (Fig. 7.94). The **cleats** can be glued and pegged to the base with a 10 mm dowel. If the cleats are screwed, the screws should be well countersunk to prevent tools being damaged.

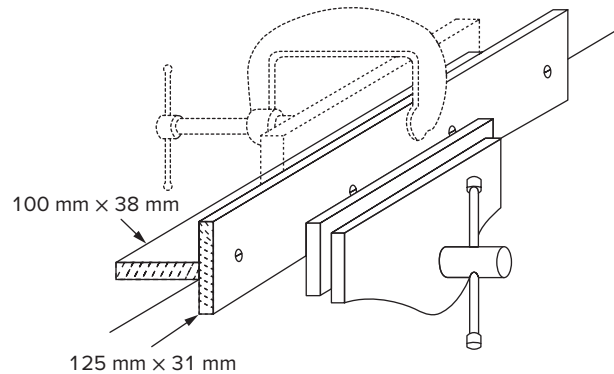
Fig. 7.94 Bench hook



7.8.5.2 Mortise board

Timber being mortised, drilled or chopped can be held securely against the face of the block of the mortise board (Fig. 7.95) with a G-cramp. The mortise board also protects the benchtop.

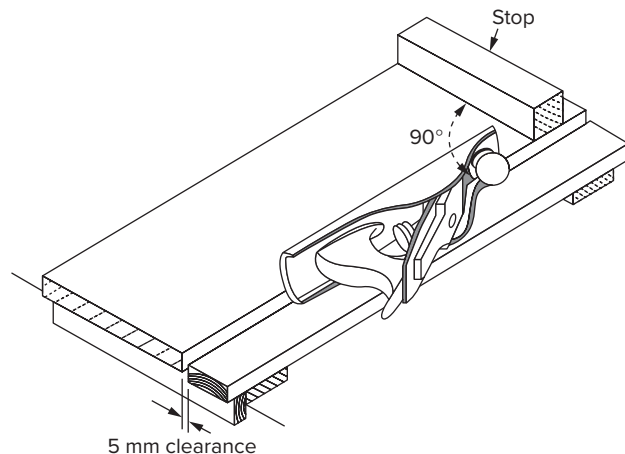
Fig. 7.95 Mortise board



7.8.5.3 Shooting board

A shooting board is another item made up by the joiner (Fig. 7.96). It assists when planing the edges of thin boards straight and square, or when trimming the square ends of timber. Its length is approximately 600 mm. The shooting board consists of two boards forming a rebate in which the plane will slide. A clearance of say 5 mm is allowed for in the corner of the rebate so that the waste can clear and not accumulate, which would affect the accurate running of the plane. The stop must be rigid, and set at right angles to the direction of the plane.

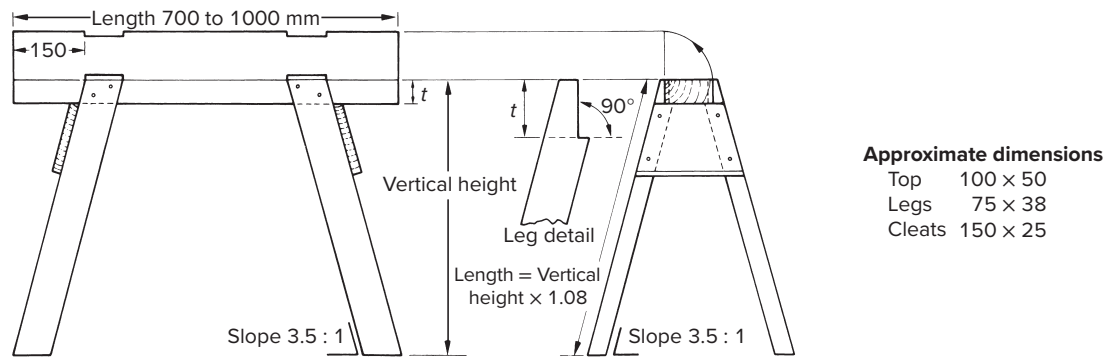
Fig. 7.96 Shooting board



When planing end grain, work from both directions (see section 7.7.7 Block plane) to prevent the corners splitting away. Turn the work piece over, hold at an oblique angle, and trim the corner back to the line. Reverse the timber, and holding it firmly against the stop, trim the end square.

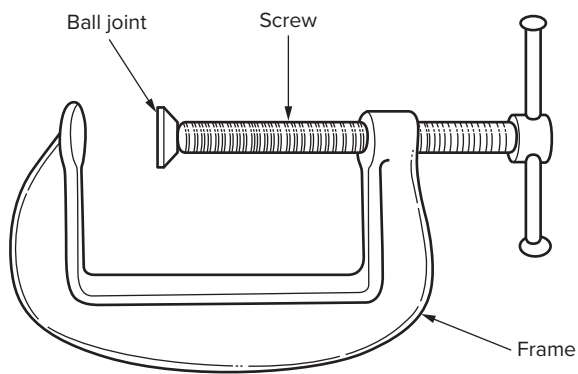
7.8.5.4 Saw stools

Saw stools are essential equipment; they vary in dimensions and construction. Figure 7.97 shows the details of a saw stool suitable for average conditions. The height can vary from approximately 560 mm to 600 mm, and can be adjusted to enable the carpenter to assume a comfortable posture. Note that the legs must be set out in pairs by reversing the direction of the bevels.

Fig. 7.97 Saw stool

7.9 Identify and use cramps

Cramps come in various forms and, as will be shown later, an important consideration when making up any item of joinery is how it can be cramped or pulled together tightly.

Fig. 7.98 G-cramp

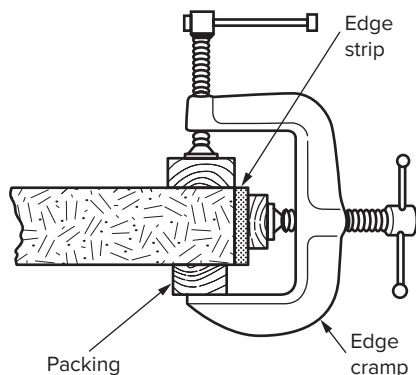
7.9.1 G-cramp

The G-cramp is the most versatile and popular cramp (Fig. 7.98). It is used for holding material securely on the bench and cramping glued joints together; a heavy G-cramp is a valuable aid for holding members together during fixing in construction work.

G-cramps are commonly made in a wide range of sizes from 50 mm to 300 mm, the size being the maximum distance between the jaws of the cramp. For trade use, cramps should be made from forged steel with a steel screw; some smaller sizes may be aluminium or pressed metal.

Always place a block of scrap timber between the cramp and the timber it is holding, to prevent the surface being marked, and only hand-tighten the cramps.

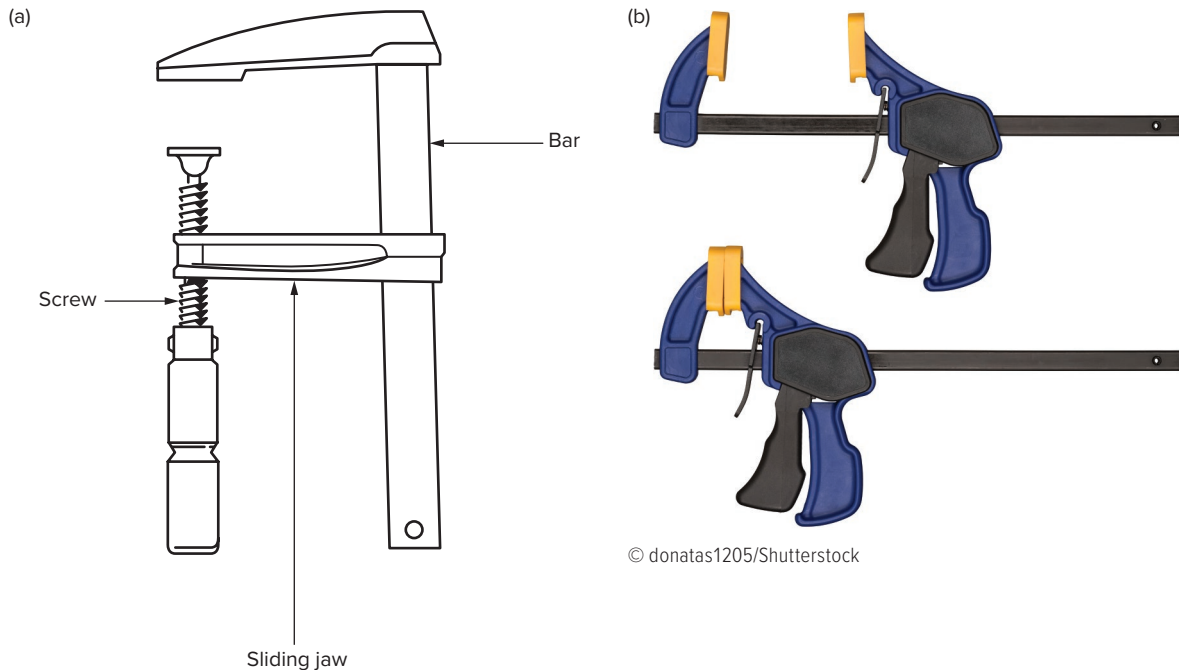
7.9.2 Edge cramps

Fig. 7.99 Edge cramp

Edge cramps are a comparatively recent development of the G-cramp, and are very useful for cramping edge strips to prefinished boards (Fig. 7.99).

7.9.3 Quick-release or fast-action cramp

In a quick-release or fast-action cramp, a sliding jaw moves on a steel bar (Fig. 7.100a). It can be quickly adjusted to any opening and tightened by the steel screw. The size can vary from 100 mm to 1000 mm. They are used in similar circumstances as the G-cramp, and the carpenter should adopt the same precautions.

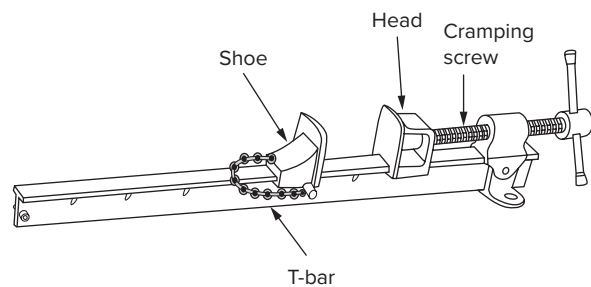
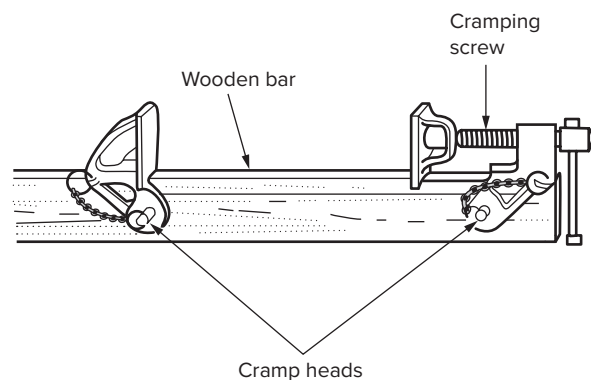
Fig. 7.100 (a) and (b) Quick-release or fast-action cramps

7.9.4 Sash cramps

Sash cramps may vary from a light, flat bar clamp to one with a heavier T-bar section, but all are now generally referred to as sash cramps (Fig. 7.101). The size of the clamp is the length of the steel bar, and may range from 600 mm to 1800 mm.

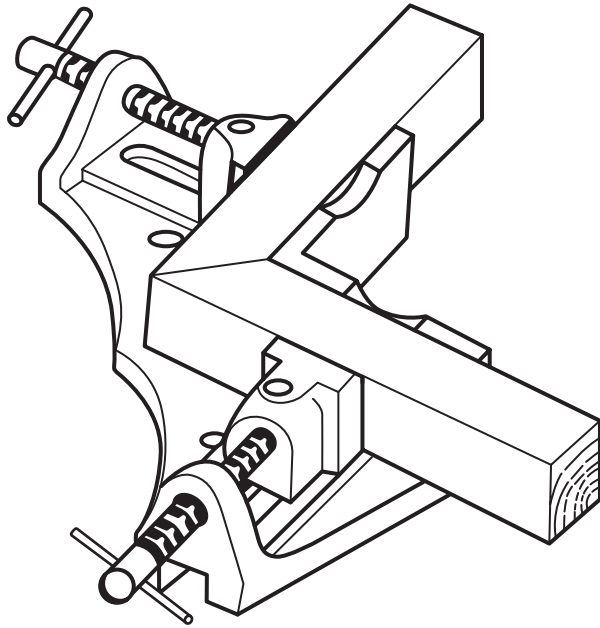
Sash cramps are used for tightly cramping together joinery items, window sashes, doors, wide boards or cabinet framing during gluing-up operations.

The opening of the jaws can be adjusted by moving the sliding shoe along the bar and fixing with a pin through the nearest hole. The final adjustment and tightening is then done using the screw and adjustable head. Blocks of scrap timber should be used under the shoe and head to prevent damage to finished work.

Fig. 7.101 Sash clamp**Fig. 7.102** Cramp heads

7.9.5 Cramp heads

Cramp heads are a convenient way to make up a long sash clamp of any length (Fig. 7.102).

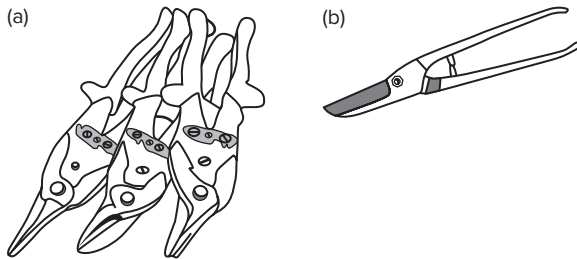
Fig. 7.103 Corner or mitre cramp

The cramp heads are fixed by a pin to a bar of timber 25 mm thick. Another type of cramp head can be fixed to a length of galvanised water pipe, which will serve the same purpose.

7.9.6 Corner or mitre cramp

The corner cramp is used to cramp mitre joints together and hold them securely in place while gluing, nailing or otherwise fixing (Fig. 7.103). It has two sets of screw-adjusted 'feet', which will hold the two halves of the joint at right angles to each other against a fence.

7.10 Identify and use other hand tools

Fig. 7.104 (a) and (b) Tinsnips

7.10.1 Tinsnips

Tinsnips are designed to cut light-gauge metals. There are different types available. Some are designed to cut a curve clockwise, while others are anticlockwise or straight (Fig. 7.104). The tinsnips in the lower image will give a slightly serrated finish to the cut edge, whereas using those above will give a smooth finish to the cut edge.

Carpenters use tinsnips when installing metal flashing around windows, doors and openings. They may also require them when constructing metal framing.

It is always a good idea to wear gloves specially designed to protect the hands from lacerations when using tinsnips, as sharp metal edges are a constant hazard when using this tool.

Fig. 7.105 (a) and (b) Trimming knives

Yogamreet/Shutterstock

lynx/ iconotec.com/Glow Images

7.10.2 Trimming knife

Trimming knives (Fig. 7.105) are designed to use disposable blades, which means no sharpening is required. They can be used to cut materials as diverse as carpet, flashing, cardboard, sisalation and plastic. Some knives have short blades (see left), while others have long blades with multiple segments (see right). When the cutting edge becomes dull, the end segment can be snapped off and the leading cutting edge is now sharp again. The blade must always be retracted when not in use.

Student research

Search online for the PPE requirements of your state or territory workplace safety authority (e.g. WorkSafe Victoria, NT WorkSafe). Read the information about PPE and where and when it should be used.

End-of-chapter activity

Please refer to Chapter 8, Timber joints, for this activity.

AUSTRALIAN BUILDING CODES AND STANDARDS



AS/NZS
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Electric motor-
operated hand-held tools,
transportable tools and lawn
and garden machinery—
Safety—Part 4.1
Particular requirements
for chain saws

Tradie talk—Don't strangle your hammer

Chapter 8

Timber joints

It is important for those students who want to become carpenters within the building industry to understand the content in this chapter, even though it is not explicitly covered in this qualification. This content will enhance the training being undertaken and also provide essential knowledge of the function and application of timber joints.

Learning Objectives

LO 8.1 Construct framing joints

LO 8.2 Identify carcass joints and their uses

LO 8.3 Use joining methods for widening timber

Introduction

In this chapter you will learn about the construction techniques employed and how best to set out and construct the more advanced joints used in the production of furniture, timber doors, timber windows and so on. The techniques you are shown in this chapter can be practised using either hand or power tools. In preparing these joints, attention to detail is a must; it is essential to ensure clean working practices while preparing and constructing the joints—and you must have a thorough knowledge of the tools covered in previous chapters, plus an ability to use them proficiently, if you are to produce high-quality work.

8.1 Construct framing joints

Framing joints are those joints that usually join members at right angles, such as those found in doors, windows and other framed units. However, before proceeding with the details of the various joints, note the names given to the framing members in Figure 8.1. The *stiles* are the vertical side members. The *rails* are the horizontal members connecting the stiles and are named according to their location—top, middle or intermediate, and bottom.

WORKPLACE SCENARIO

For centuries, the only effective way to join two pieces of timber was to construct tight-fitting joints. Such joints were generally based on a mortise and tenon, and were held together using a wooden peg. Many specific joints were developed for particular purposes, but they generally relied on tight-fitting construction and wooden pegs to hold the joint together. In large framing joints, the timber used was green. So once the joint had been constructed, put together and pegged, the drying timber would shrink, causing the joint to tighten and increase in strength.

With the development of modern fixings, such as bolts, nails, screws, brackets and glues, timber can be joined using one of these methods without constructing a joint. This has decreased the time it takes to construct a building, piece of furniture, etc.

8.1.1 Mortise-and-tenon joint

The mortise-and-tenon joint is probably the strongest and most universally used joint in framing and can be adapted to many situations.

8.1.1.1 Common mortise-and-tenon joint

The common mortise-and-tenon joint (Fig. 8.2) is one in which the tenon is the full width of the rail and goes fully through the stile. A typical application would be the joint between a middle rail and stile.

The tenon is made to be one-third of the thickness of the stile or piece to be mortised, or it is made to the nearest chisel size. This ensures equal strength between the tenon and the sides of the mortise. 'Through' tenons are held securely in the mortise by wedges that should penetrate the stile at about two-thirds of the stile's width. To be effective, wedges should be only slightly tapered and not made to a sharp point.

Figure 8.3 shows the effects of both a correctly shaped wedge and one with too much taper. A tapered wedge allowance (WA) is cut back on each end of the mortise. A suitable WA is one-twelfth the width of the stile.

It is not suggested that you should start splitting millimetres or delving into the mortise to measure the wedge, but with experience and by bearing these few rules in mind, you will be able to estimate and proportion wedges that will serve their purpose effectively.

8.1.1.2 Haunched mortise-and-tenon joint

The haunched mortise-and-tenon joint is used where the joint is made at the ends of the stile, i.e. between the top or bottom rail and the stile (refer back to Fig. 8.1).

During manufacture, waste of 10 mm to 20 mm called *horn* is left on the ends of the stiles and is not removed until the item is finally being fitted. The horn serves a number of purposes: it strengthens the end of the stile while it is being worked (mortising and wedging); it can often be used to secure the framing during cramping-up and cleaning-off operations; and it will protect the ends during stacking

Fig. 8.1 Framing members

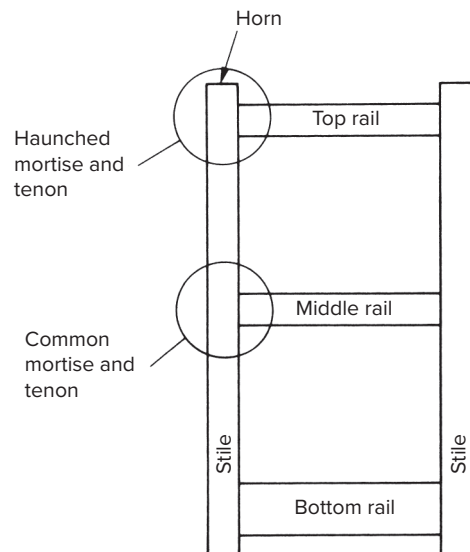
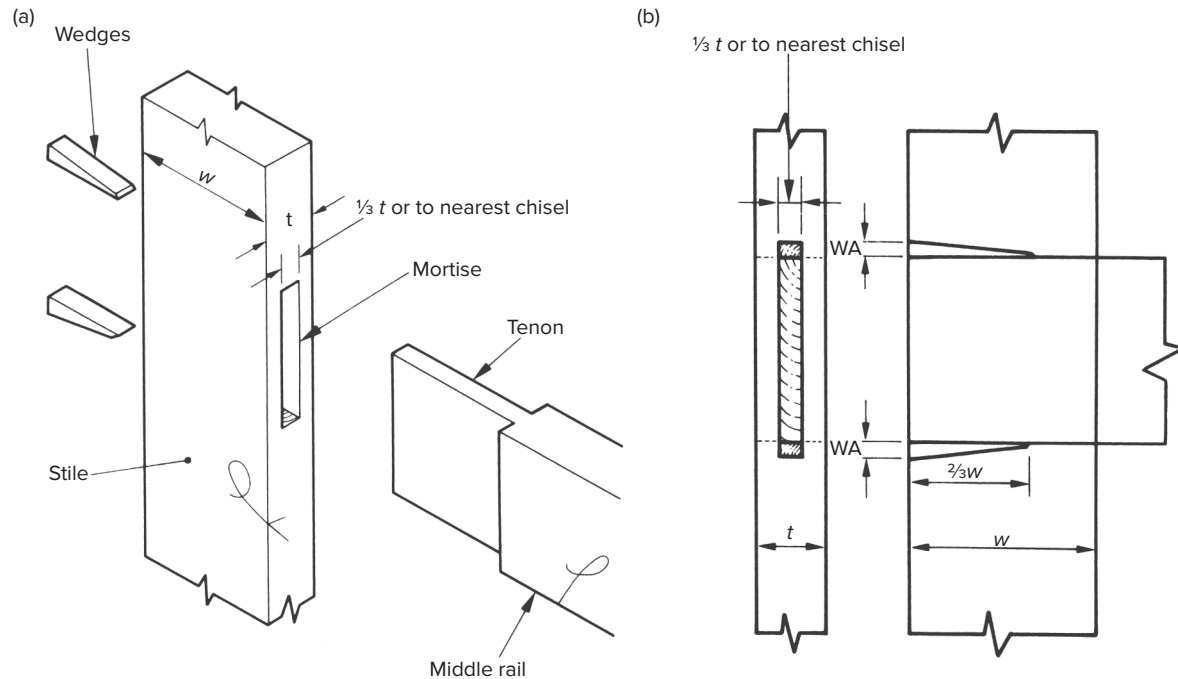


Fig. 8.2 (a) and (b) Common mortise-and-tenon joint

and transporting. When the joint is finished, it can eventually be flushed off accurately.

If the tenon were made the full width of the rail, there would be nothing left to hold it in once the horn was removed. Therefore, it is reduced in width and sufficient material is left on the end of the stile for the wedge to hold. A short portion of tenon, the actual *haunch*, is left near the shoulders to prevent the rail from twisting. The length of haunch is made the same as the thickness of the tenon, to a maximum of 12 mm. A rule for the width of the tenon is that it should be made two-thirds the width of the rail minus one WA (Fig. 8.4).

Other parts of the joint are proportioned as for the common mortise-and-tenon joint.

8.1.1.3 Faults

Some possible faults in mortise-and-tenon joints are shown in Figure 8.5.

8.1.1.4 Modifications to the mortise-and-tenon joint

In joinery work, the mortise-and-tenon joint is seldom as simple as has so far been explained. Where the joint is used for framing up doors or windows, the edges of the members may be plough grooved or rebated to receive panels, and the joint must be modified accordingly.

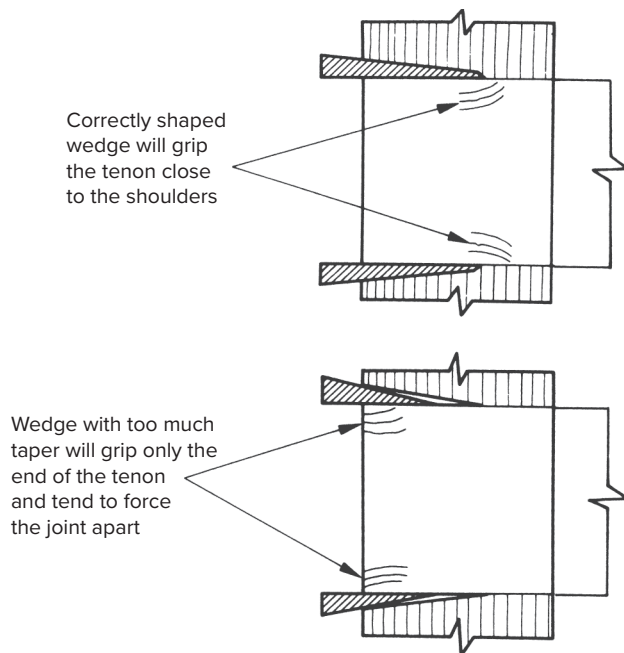
Fig. 8.3 Wedge shape

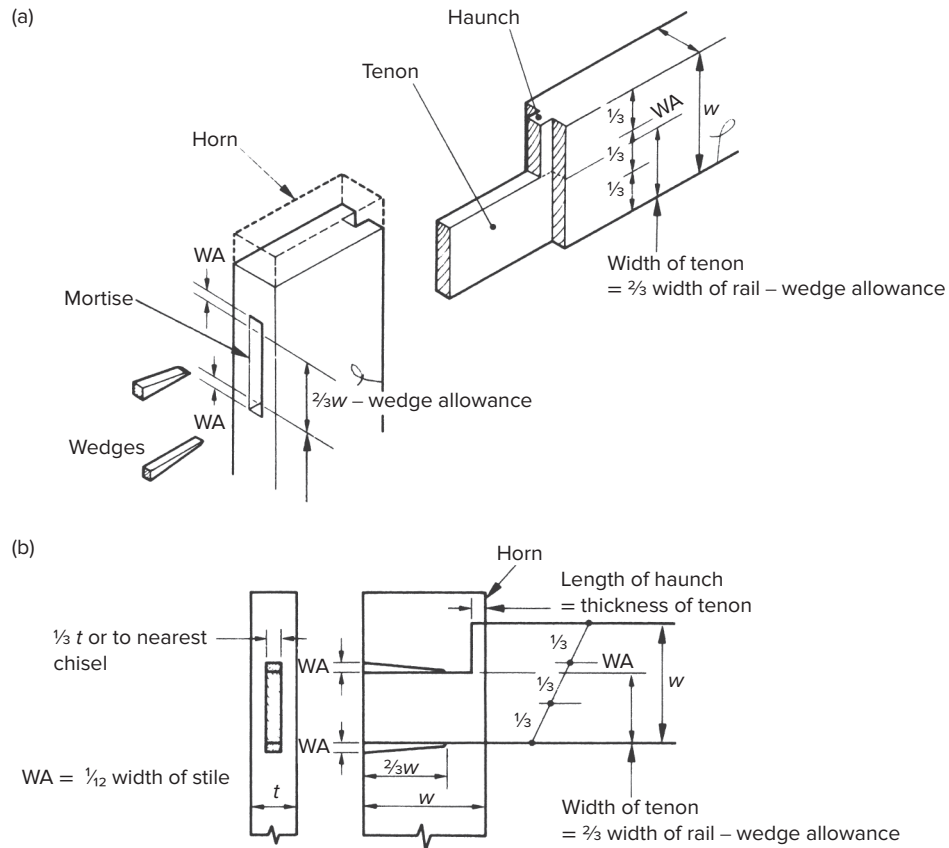
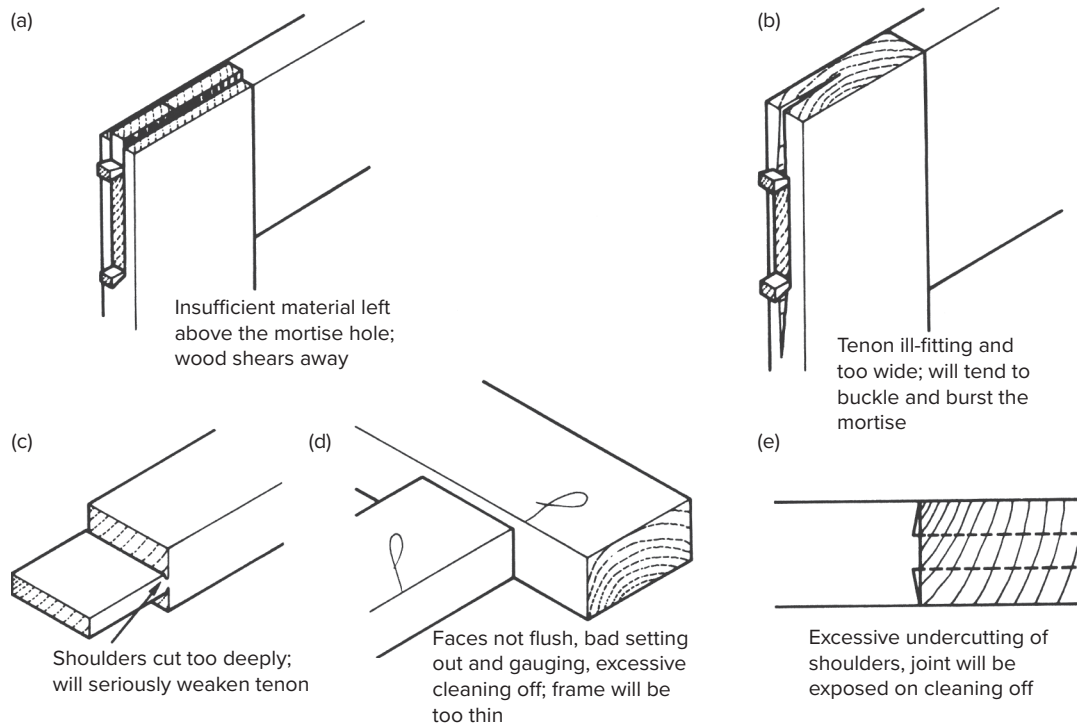
Fig. 8.4 (a) and (b) Haunched mortise-and-tenon joint**Fig. 8.5 (a)–(e)** Faults in mortise-and-tenon joints

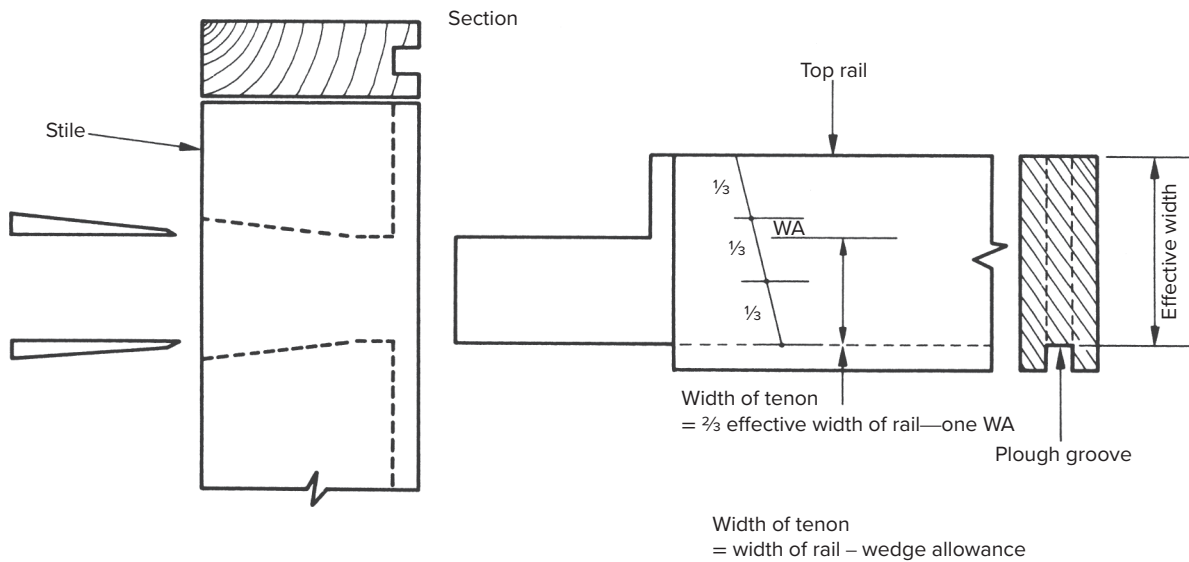
Fig. 8.6 Joint between top rail and stile

Figure 8.6 shows a haunched mortise-and-tenon joint between a rail and stile where a plough groove has been run on the inside edges. To proportion the width of the tenon, the word 'effective' must be added to the rule: the tenon is made two-thirds the effective width of the rail minus one WA.

The effective width of a rail can be defined as the width of the middle one-third, this being the one-third on which the mortise and tenon are located. In this joint, the width of the plough groove is made the same as the thickness of the tenon; the haunch will fill the groove.

8.1.1.5 Double mortise-and-tenon joint

The double mortise-and-tenon joint is used where the rail is considerably wider than the stile, for example, the middle or bottom rail to a framed and panelled door. The stile would be badly weakened if a mortise were cut out long enough to receive a tenon the full width of the rail.

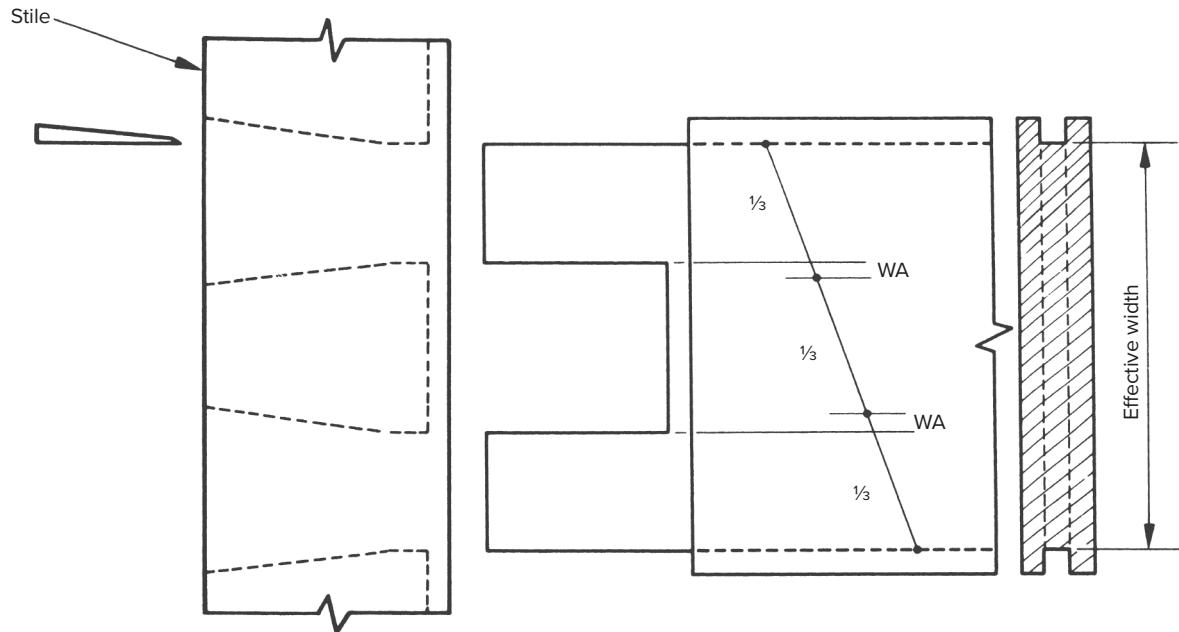
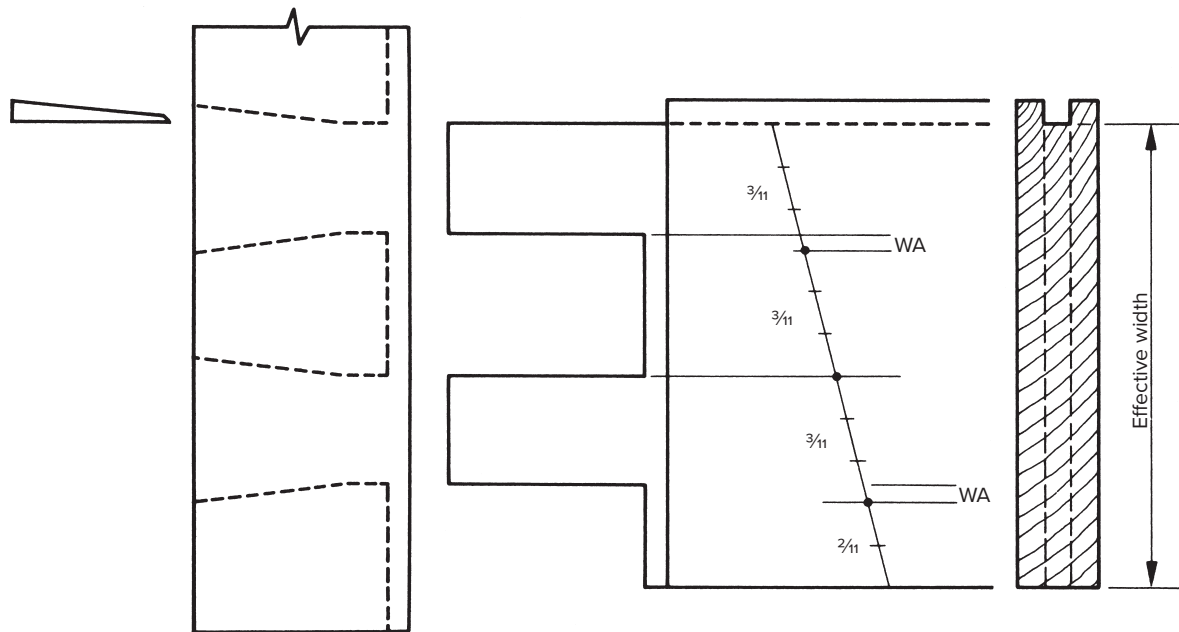
To correct this, a double mortise-and-tenon joint is used. The stile is not weakened, and the wedging power is doubled. The width of a tenon should not exceed five times its thickness. The setting out is shown in Figure 8.7.

Note that the effective width is divided into three parts and each tenon is minus one WA, taken from the middle of the rail.

Figure 8.8 shows the setting out for a wide bottom rail to a stile; besides a double mortise-and-tenon, an allowance has been made for a haunch. The effective width is divided into 11 equal parts and proportioned as shown. One WA is taken from the bottom of each tenon.

8.1.1.6 Long and short shoulder mortise-and-tenon joint

The inside edges of stiles and rails may be rebated to receive panels or glass; the shoulders on the rails are different in length. The difference in length is equal to the depth of the rebate.

Fig. 8.7 Double mortise-and-tenon joint at the middle rail**Fig. 8.8** Joint between bottom rail and stile

When a neat appearance across the edge is more important than maximum strength, as for instance on showcase doors, the splayed haunch can be used. Note that the effective width is again divided into three equal parts when setting out the haunched tenon (Fig. 8.9).

Fig. 8.9 (a) Long and short shoulder mortise-and-tenon; and (b) splayed haunch

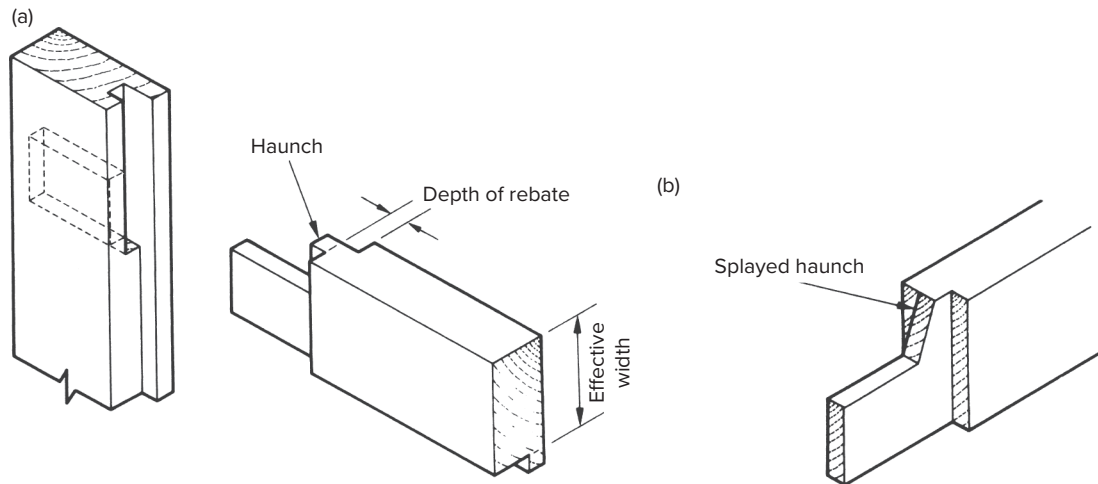
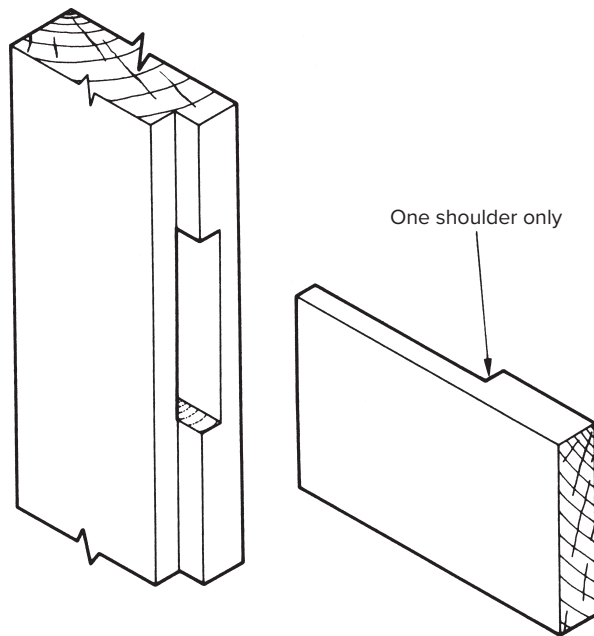


Fig. 8.10 Barefaced mortise-and-tenon joint

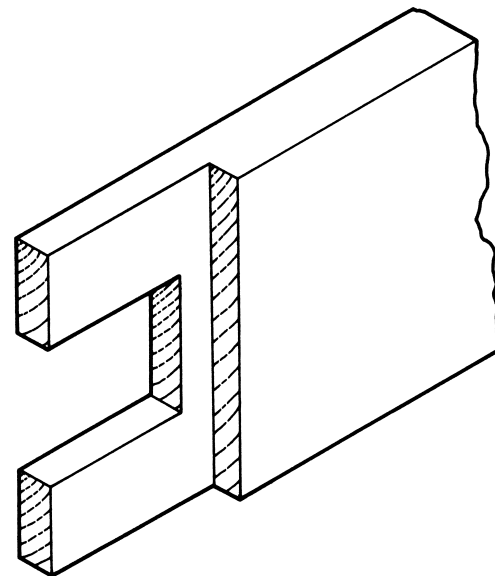


8.1.1.7 Barefaced mortise-and-tenon joint

The barefaced mortise-and-tenon joint is used where the stile is thicker than the rail; this is the case in some doors where the sheeting is continuous over the face of the rail. In this type of mortise-and-tenon joint there is only one shoulder on the rail (Fig. 8.10).

The *double* barefaced mortise-and-tenon joint is suitable for a wide rail (Fig. 8.11).

Fig. 8.11 Double barefaced mortise-and-tenon joint



8.1.1.8 Twin mortise-and-tenon joint

When the rail is very thick, and a tenon one-third the thickness would mean the joint is weakened by an unusually large mortise, the twin mortise-and-tenon joint is used (Fig. 8.12). The rail is prevented from twisting and there is twice the gluing area.

8.1.1.9 Stump mortise-and-tenon joint

The tenon need not always pass fully through the stile. In cases where the end grain and wedges showing on the edges would be objectionable, for example, on cabinet doors, the stump (or stub) mortise-and-tenon joint could be used (Fig. 8.13).

The depth of the mortise is made one-half to two-thirds the width of the stile. The tenon cannot be wedged from the outside, so it can be fitted neatly to the mortise and held with an adhesive, or alternatively it can be wedged using fox wedges. Fox wedging consists of inserting two small wedges into saw cuts in the tenon, which, on striking the bottom of the mortise, wedge the tenon as it is cramped into the mortise.

8.1.2 Making the mortise-and-tenon joint

The setting out of joinery items and the marking off of components in preparation for machining a mortise-and-tenon joint will now be dealt with more fully. Some pointers as to the use of hand tools in the marking out and cutting of mortise-and-tenon joints are included.

1. **Gauging.** Set the distance between the spurs of the mortise gauge to the width of the actual chisel used for mortising (Fig. 8.14).

Gauge the mortise and the tenon, one immediately after the other, using the same gauge and keeping the stock firmly against the face side (Fig. 8.15).

2. **Chopping the mortise.** To chop the mortise, hold the stile in the mortise block, face edge down.

Stand as near as possible to, and in line with, the mortise to get a good view to ensure that the chisel is held

Fig. 8.12 Twin mortise-and-tenon joint

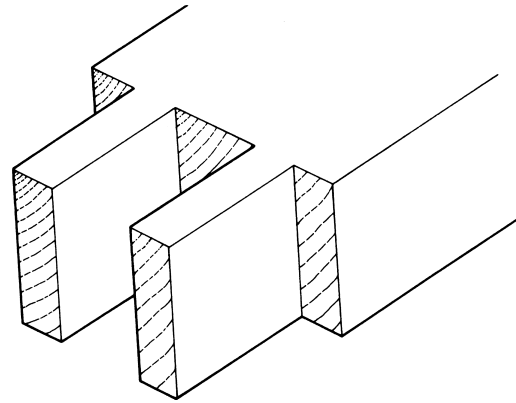


Fig. 8.13 Stump mortise-and-tenon joint

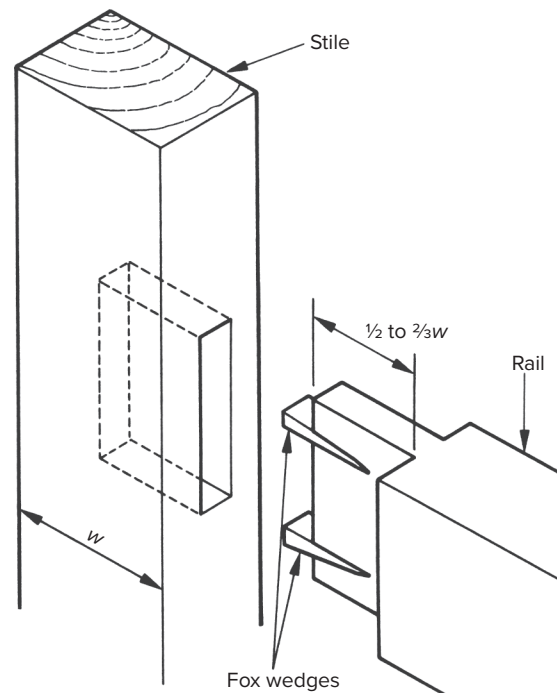


Fig. 8.14 Setting the mortise gauge

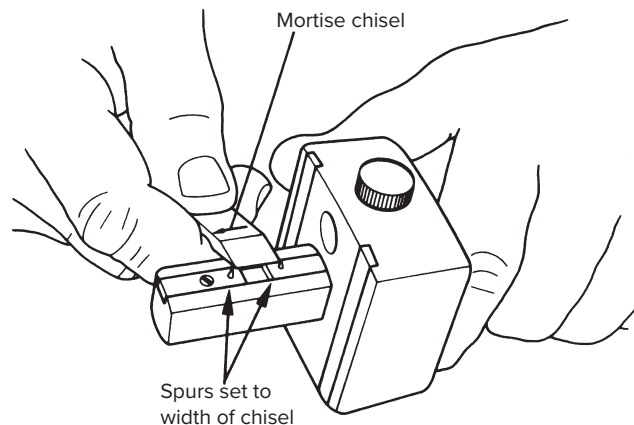
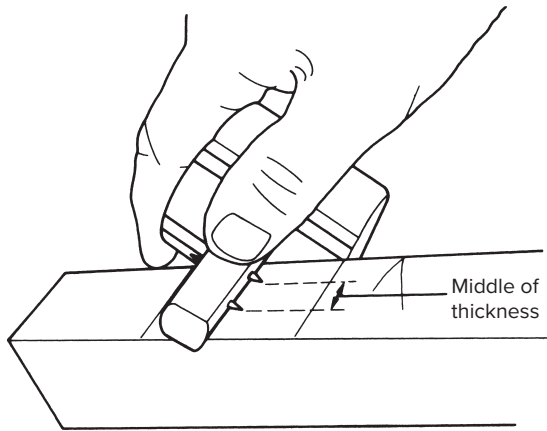
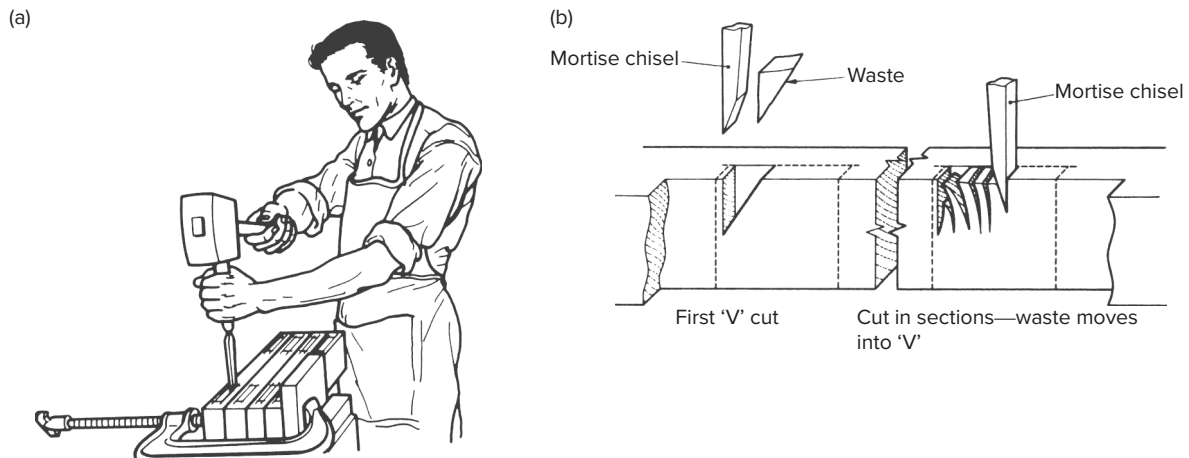


Fig. 8.15 Gauging the mortise-and-tenon joint

straight (Fig. 8.16a). Commence near one end of the mortise and chop a 'V' with the chisel. Turn the chisel around and continue cutting in sections, allowing the waste to move into the space made by the 'V' (Fig. 8.16b).

Cut halfway through and finish by squaring the ends down accurately. It will be easier to remove if you make a number of cuts to chop up the waste more finely. The mortise should finish up exactly the same width as the chisel, and it should never be necessary to turn the chisel and pare away at the sides.

Fig. 8.16 Chopping the mortise: (a) hold the chisel straight; and (b) the waste from each cut moving into the previously cut space

Turn the timber over and repeat the process from the face edge. Chop up the waste more finely and then remove it with a core driver, which is a tapered piece of hardwood slightly smaller than the mortise hole. Finish by cutting back the WAs tapered to about two-thirds the width of the stile.

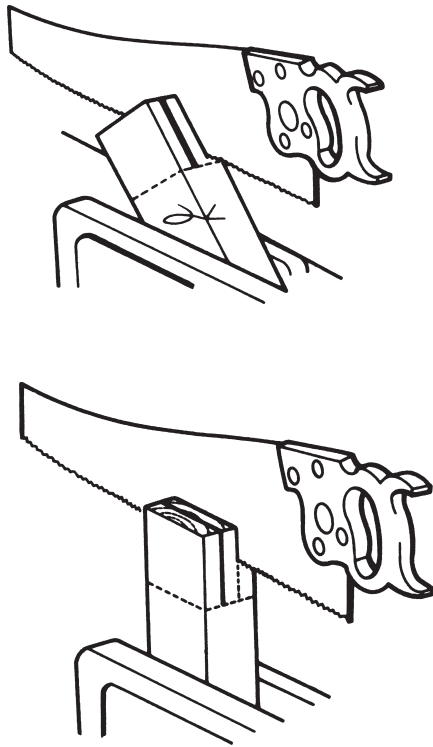
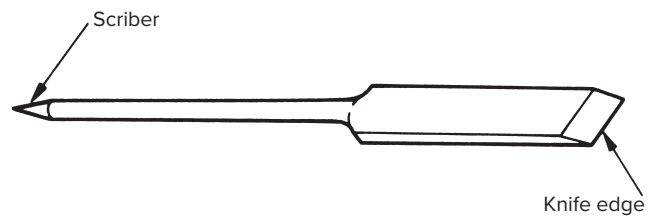
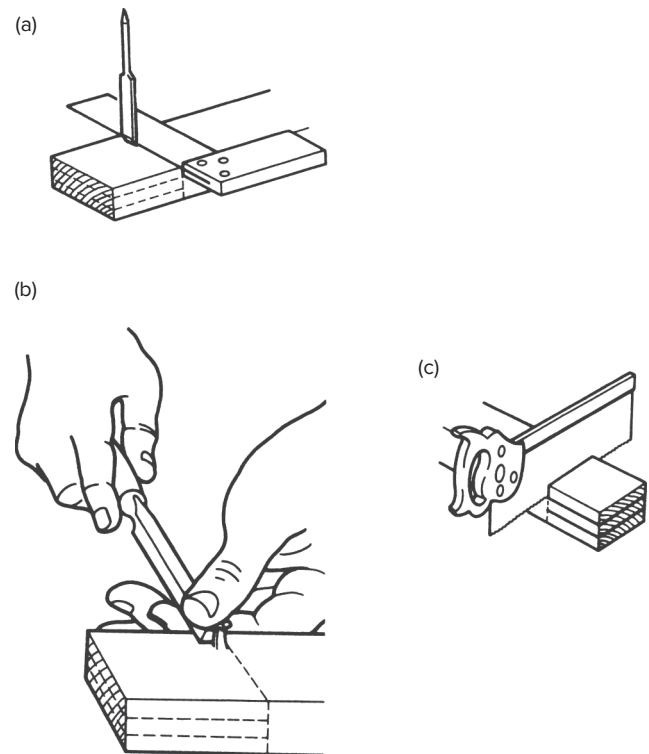
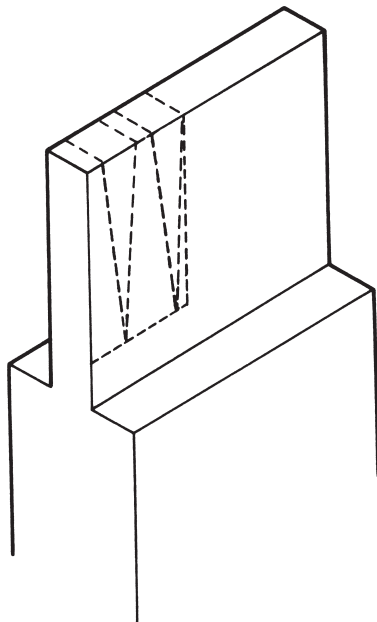
3. **Ripping the tenon.** Small tenons can be cut with the tenon saw; however, an experienced tradesperson would do the job much more quickly and easily with a hand saw. Hold the timber in the vice, leaning away at about 45° (Fig. 8.17). Keep on the waste side and, following the two visible lines, rip one half of the tenon diagonally. Turn the timber around and follow the line along the third side, finishing with the saw square to the shoulder.

The tenon should fit straight off the saw with only very minor smoothing of the cheeks. Always rip first and then cut the shoulder line.

4. **Cutting the shoulder line.** The initial setting out is usually done with a sharp pencil. However, a much cleaner and more accurate shoulder may result if the shoulder line is cut using a marking knife (Fig. 8.18).

Place the blade of the knife on the line, slide the try square up to it and cut the line. If a small recess is chiselled on the waste side of the line, it can then be continued with the tenon saw (Fig. 8.19), only slightly undercutting the shoulder.

5. **Cutting the wedges from the waste.** Remember that wedges will be required when a haunch is being cut. Wedges can be cut from the waste, which will have the exact thickness required.

Fig. 8.17 Ripping the tenon**Fig. 8.18** Marking knife**Fig. 8.19** Cutting the shoulder line: (a) knife cut to shoulder line; (b) form recess; and (c) complete cutting shoulder line**Fig. 8.20** Cutting wedges from waste

CHECK YOUR UNDERSTANDING

1. Where would a haunched mortise-and-tenon joint be used, and why is it suitable in this situation?
2. How would a mortise gauge be set when gauging a mortise-and-tenon joint?

Fig. 8.21 (a) Corner halved joint; (b) cross halved joint; (c) tee halved joint

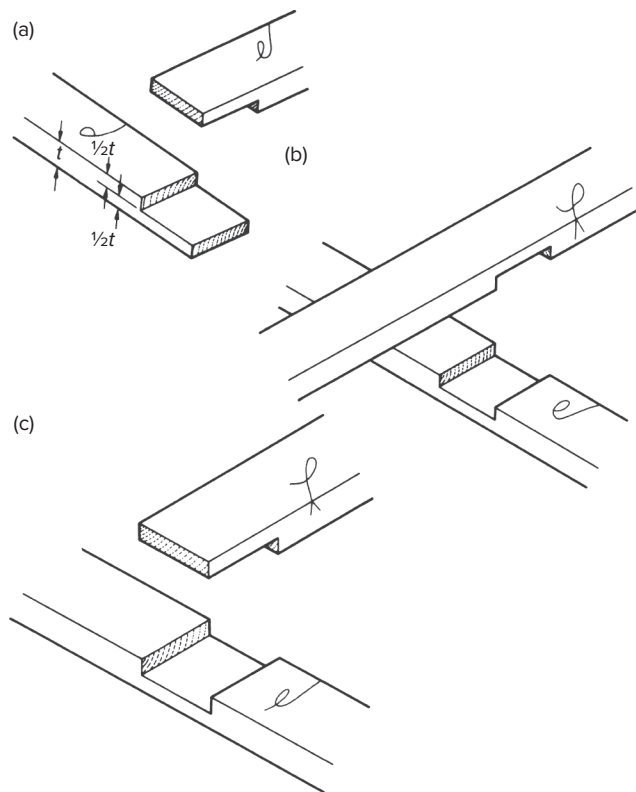


Fig. 8.23 Marking the dovetail

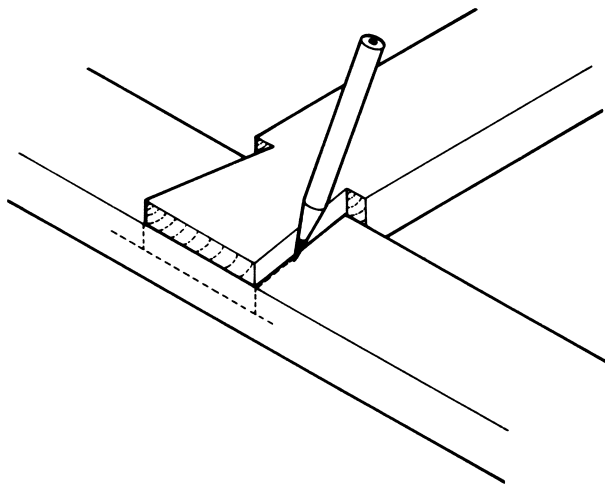
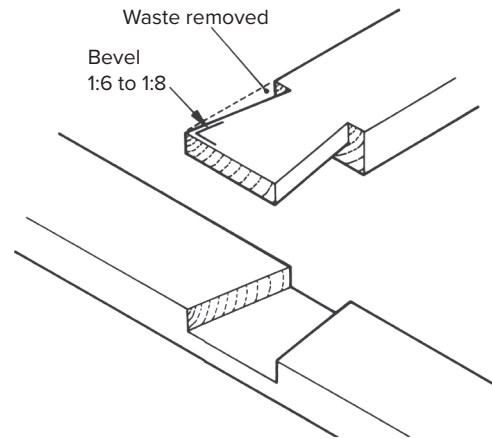


Fig. 8.22 Dovetailed tee halved joint



8.1.3 Half-lapped joint

The half-lapped joint is also called the *halved joint* (Fig. 8.21). The half-lapped joint in timber-frame construction is described in Chapter 7 Carpentry hand tools; this joint also finds applications in joinery and cabinet work.

Set the gauge to one-half the thickness of the timber and gauge both parts from the face side. Cut the halvings, following the same procedure as for the cheeks of the tenon—that is, rip first, cross-cut second.

A modification of the half-lapped joint is the dovetailed tee halved joint (Fig. 8.22). From the dovetail, lay it in position on the second piece and with a sharp pencil mark the bevel (Fig. 8.23). The sides of the tapered trench are then cut on the waste side, leaving the pencil line clearly visible. The dovetail should be a close fit, acting as a wedge to draw the shoulder together.

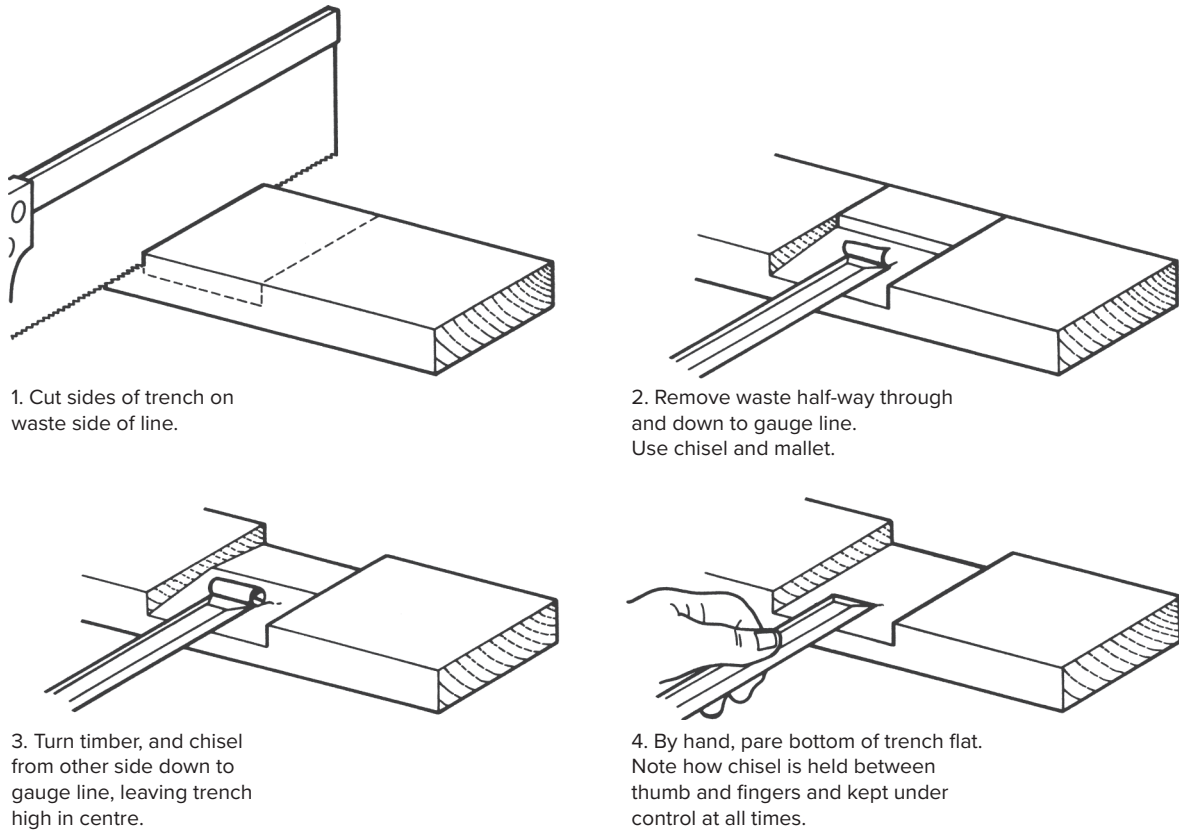
8.1.4 Cutting a trench

The four steps in cutting a trench are illustrated in Figure 8.24. This is applicable to housed joints as well as to the dovetailed tee halved joint and the bridle joint.

8.1.5 Dowelled joint

The dowelled joint consists of mating holes, drilled into the two parts, into which round pegs called *dowels* are inserted, joining the parts together. When correctly proportioned and assembled with a

Fig. 8.24 Four steps in cutting a trench



suitable adhesive, the joint is strong enough for most purposes (Fig 8.25); there is a saving in timber as the rails are cut off at the shoulder line.

Dowels are made from hardwood or softwoods, in the standard diameters of 6, 8, 10 and 12 mm. Dowels have a fluted circumference, which ensures a firm grip on the dowel hole (Fig. 8.26). The fluting also allows the surplus glue and air to escape from the bottom of the hole as the dowel is driven home. Dowel rod is available in long lengths from 1 m to 2 m, or dowels may be ready-cut to length and pointed.

Fig. 8.25 Dowelled framing joint

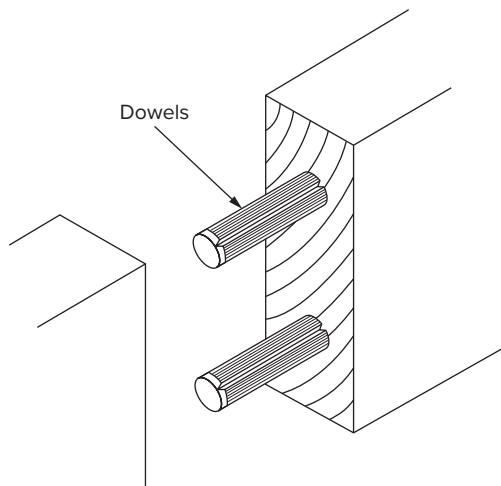
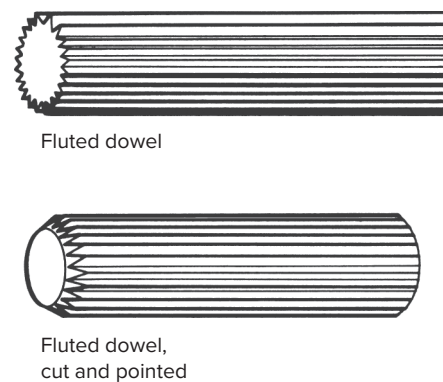


Fig. 8.26 Dowel profiles



TIP Dowels most commonly have a diameter of 10 mm. The dowel should not be an overtight fit in the hole; if the dowel is too tight it will probably split the timber.

The setting out of dowels on the ends of the rails is shown in Figure 8.27. The ideal proportions are shown.

A little compromise may be necessary at times to fit the dowels onto a narrow rail. Remember, however, that a stronger joint may result if a small size of dowel is used rather than a dowel that is too large for the job, which may seriously weaken the timber around the dowel.

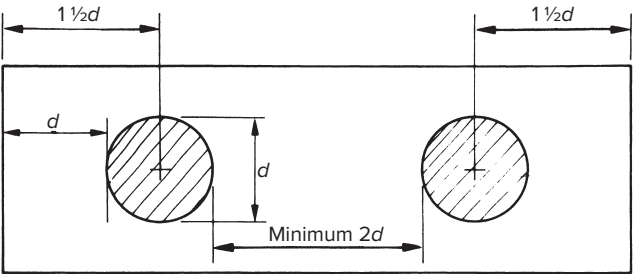
Table 8.1 is a guide to the diameter of dowels to use relative to the thickness of the timber to be dowelled. Because 10 mm is the most common diameter of dowel, it is used over a slightly wider range of timber thicknesses than are the other sizes. If the two parts forming the dowelled joint are of unequal thickness, the dowels must be chosen to suit the thinner of the two.

The dowels used must be long enough to penetrate each part of the joint sufficiently so that maximum strength is attained. Penetration can vary from two to a maximum of three times the diameter (Fig. 8.28).

Table 8.1 Dowel selection chart

Diameter of dowel (mm)	Thickness of timber (mm)
6	10–14
8	15–18
10	19–26
12	27–32

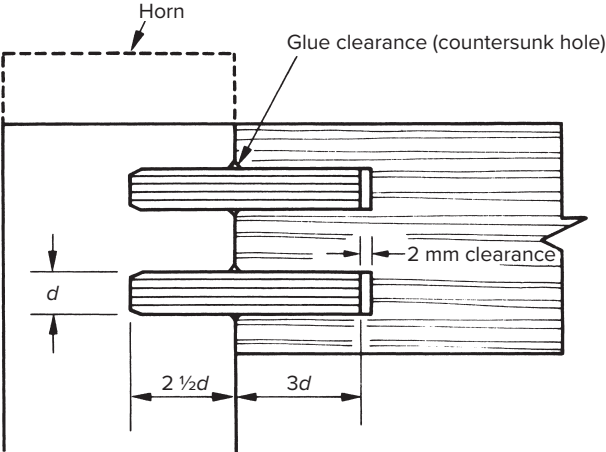
Fig. 8.27 Setting out dowels



The dowel holes must be drilled deep enough to allow at least 2 mm clearance beyond the end of the dowel. The use of a large countersink bit to form a small glue clearance around the hole will also help when cramping the shoulder of the joint tightly together.

On wide rails, more than two dowels can be used provided there is sufficient material left between the dowels—say a minimum of twice the diameter.

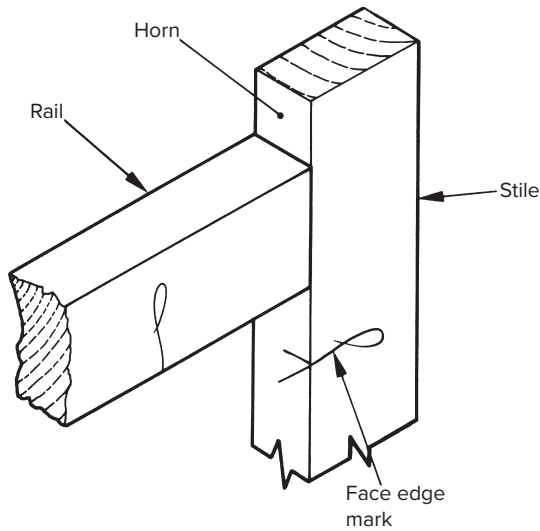
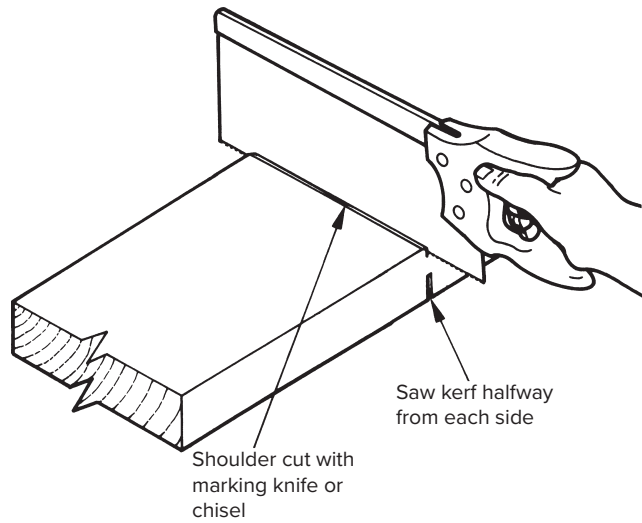
Fig. 8.28 Dowel penetration



8.1.5.1 Making the dowelled joint

The procedure for making the dowelled joint, as found on the corner of a piece of dowelled framing, is outlined below. Note the direction of the face and face edge marks in Figure 8.29.

- Cutting shoulder lines to rails.** To cut the shoulder lines to the rails using the tenon saw, first square completely around the shoulder line, cutting with the marking knife, and chisel a small groove beside the cut line in a similar manner as for the mortise-and-tenon joint.

Fig. 8.29 Corner of a dowelled frame**Fig. 8.30** Cutting the shoulder

Continue to cut the shoulder with the tenon saw, only very slightly undercutting. Cut until halfway through, turn the rail over and repeat the process, meeting up with the first cut (Fig. 8.30).

2. **Marking out.** The dowel holes in the stile and rail must mate together. First, mark the position of the rail on the face edge of the stile and mark the dowel centres (Fig. 8.31).

Transfer the dowel centres onto the end of the rail and square them across.

Set the marking gauge to half the thickness of the material and, keeping the stock to the face side, gauge the centres for the holes. Depending on the equipment available to bore the holes, it may be necessary to gauge the position of one hole only, which can then be used as a guide to setting up a dowel jig or machine to the required setting.

3. **Boring the dowel holes.** The *dowelling jig*, shown in Figure 8.32, used in conjunction with a dowel bit in the electric drill, is a fast and accurate way to reproduce holes.

The jig is supplied with a number of bushes to suit the size of dowel drills—6, 8, 10 and 12 mm. The bush provides the guide for the drill and can be adjusted to drill holes a fixed distance from the face side. A mark on the front of the jig enables it to be lined up accurately with the line of the hole.

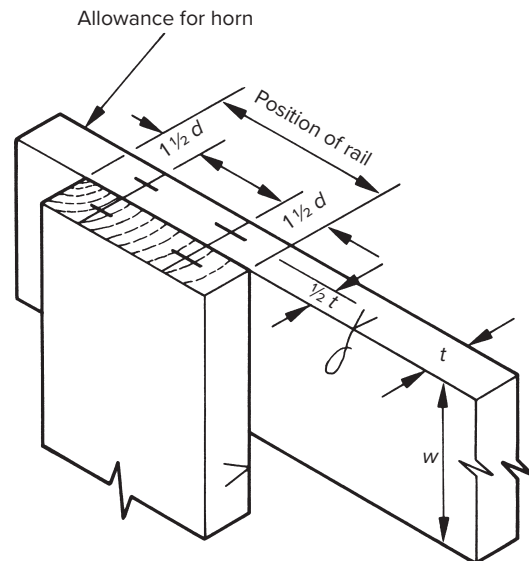
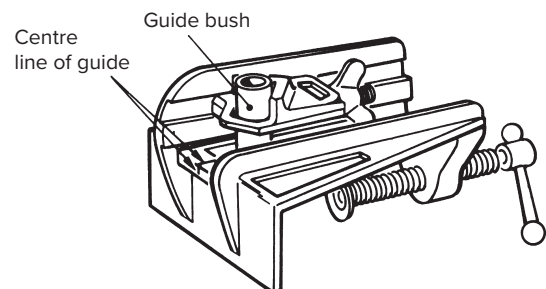
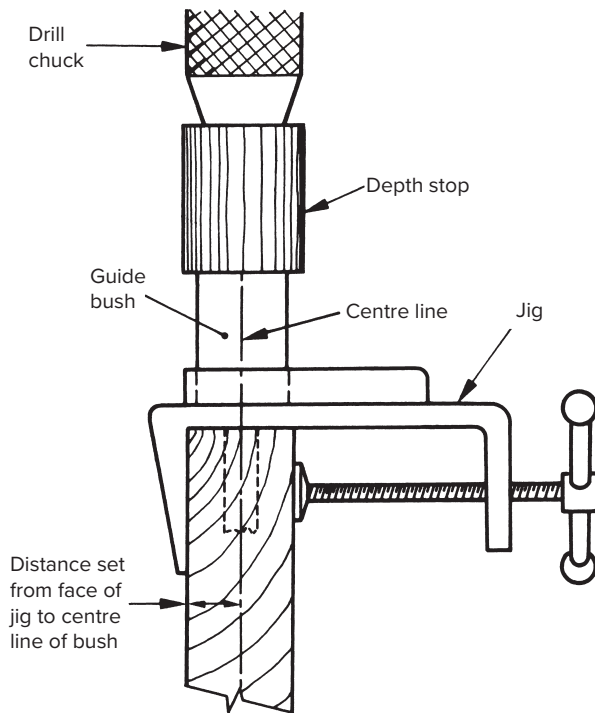
Fig. 8.31 Setting out dowel centres**Fig. 8.32** Dowelling jig

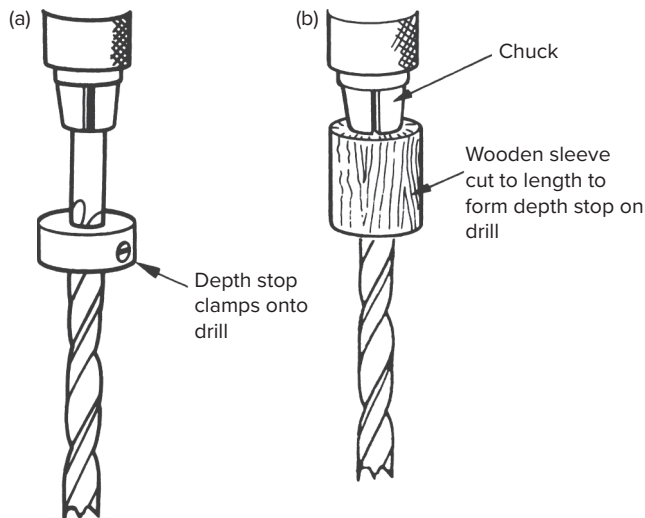
Fig. 8.33 Setting up the dowelling jig

To use the dowelling jig, select and fit the required guide bush to the jig and adjust the centre of the bush to the gauge line for the centre of the dowel holes (Fig. 8.33). Clamp the jig to the timber, aligning the mark on the jig with the line of the hole, and drill the hole to the required depth. A depth stop is necessary on the drill and there are a number of types available that clamp onto the drill. A most effective stop can also be made up as follows: drill a hole lengthwise through a piece of wood and cut off to length; round the corners and fit over the drill (Fig. 8.34).

The *dowel borer* is basically a horizontal drill mounted over a table that is adjustable in height (Fig. 8.35). To set up a dowel borer, fit a drill of the required size and adjust the height of the table so that the distance from the table to the centre of the drill is equal to the distance from the face of the material to the centre of the dowel hole. Set the depth stop to drill the holes to the required depth.

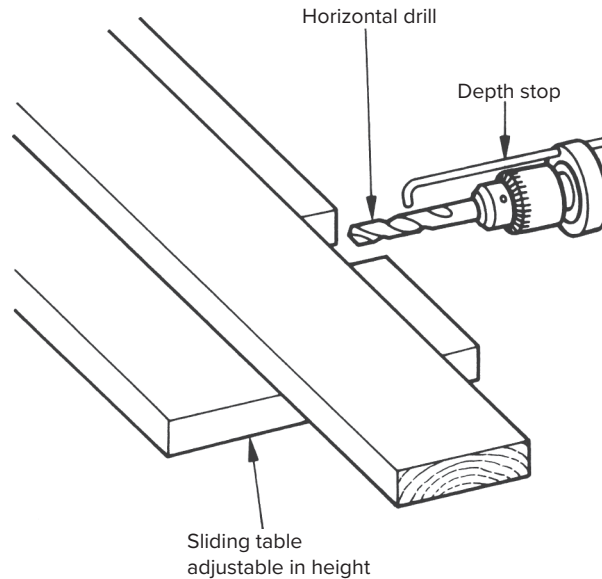
To use the dowel borer, lay the timber on the table face side down, grip firmly and slide the table forward, feeding the timber onto the drill until the depth stop is reached. In a modern workshop, horizontal dowel-boring machines may be much more refined than described here; however, the basic principles remain the same.

4. **Assembling.** After the dowels have been cut to length and pointed, the joint is ready to assemble. Glue the dowel by dipping the ends into the adhesive. Adhesive can also be applied to the

Fig. 8.34 (a) and (b) Depth stops

dowel holes by taking a short length of smaller-diameter dowel or stick, dipping the end into the adhesive and wiping it around the hole.

Drive the dowels into the stile first. Apply a little adhesive to the holes and shoulder line of the rail, then tap the joint together. Pull together firmly with a sash cramp to ensure a tight fit. The well-made dowel joint should be square, with close-fitting shoulders on both sides and with the face side flush, and of course the timber must not be split. If splitting occurs this usually indicates that the dowel is too long or the hole is too tight.

Fig. 8.35 Dowel borer

CHECK YOUR UNDERSTANDING

3. When setting out dowels on the end of a rail, what is the minimum distance the dowels should be kept from the edge?
4. Describe briefly how the dowel jig would be set up for boring dowel holes.

8.1.6 Biscuit joints

Biscuit joints are an alternative to dowel joints. Figure 8.36 shows two examples of corner joints using biscuit joints for butt and mitre joints. The advantage with this method is that the machine for cutting the joint is portable and highly accurate (Fig. 8.37). This method has many applications, including widening boards (Fig. 8.38) and corner joints. This method of joining can also be used without glue, if a means of locating components in large pieces is required.

TIP Setting out biscuit joints follows a similar procedure to dowel joints.

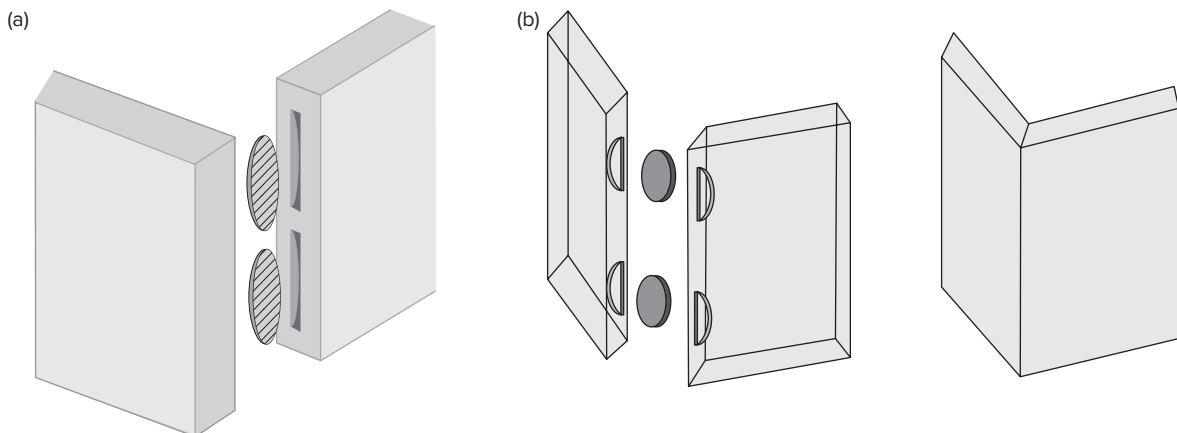
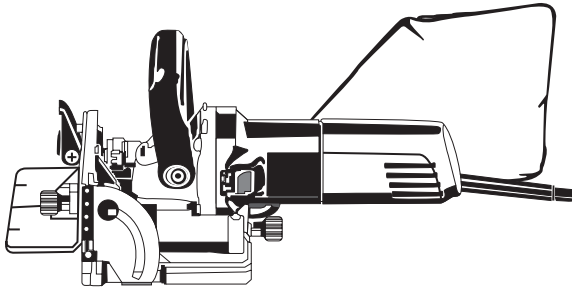
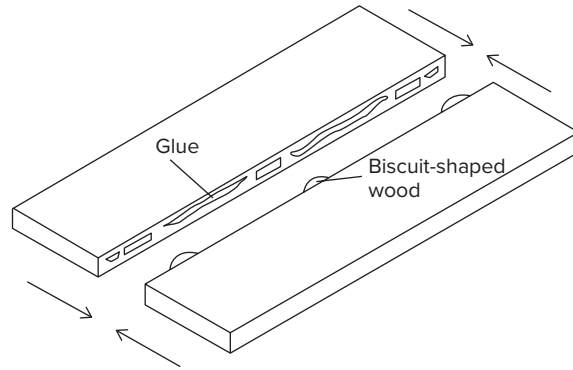
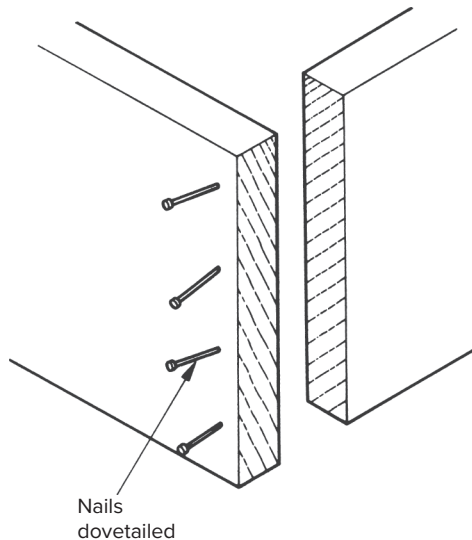
Fig. 8.36 Two examples of corner joints using biscuits for: (a) butt joints; (b) mitre joints

Fig. 8.37 Power tool used to cut biscuit slots**Fig. 8.38** Widening boards using biscuits

8.2 Identify carcase joints

Carcase joints are sometimes referred to as *angle box joints*. Joints in this group are distinguished by the fact that the angle formed is between the face sides. They are used to join up the carcase to cabinets, corners of drawers, shelving and so on.

Again, for satisfactory results, joints must be accurately set out and cut to detail. Fixing is often done using nails and screws in conjunction with an adhesive or, if concealed fixing is required, dowels or 'feathers' can be used. If the joint is cramped, some adhesives on their own may be adequate.

Fig. 8.39 Butt joint

8.2.1 Butt joint

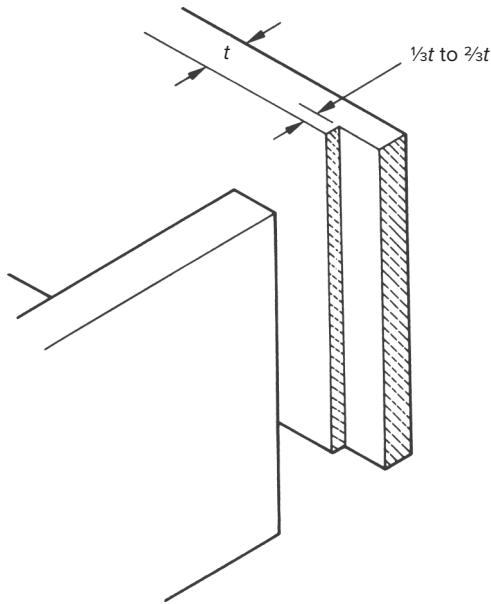
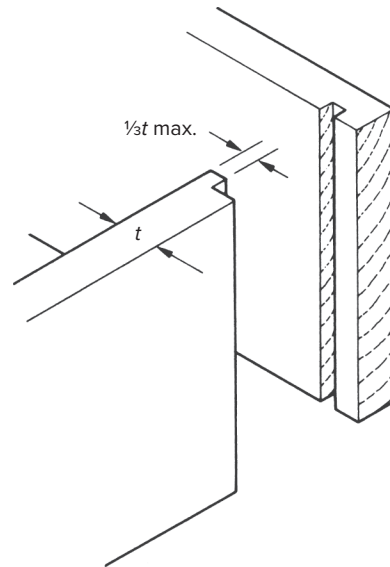
The butt joint is the simplest carcase joint and it can be nailed or screwed (Fig. 8.39). The ends must be cut square across both the face and edge. To nail the joint, start the nails in the top piece, 'dovetailing' them at an angle to secure a better grip, apply adhesive, bring the joint together and complete the nailing. Finish by punching the nails slightly beneath the surface before the glue sets. Otherwise, if the nails are punched after the glue sets, the glue joint could fracture. The butt joint can be strengthened through the addition of glue blocks to the inside corner.

8.2.2 Rebated joint

The rebated joint is commonly used and can be adapted to a variety of materials and applications, including drawers (Fig. 8.40). The depth of the rebate can vary from one-third to two-thirds the thickness of the material, and therefore shows little end grain. Fixing is by adhesive and nailing or screwing; the nailing can be done on either side of the joint.

8.2.3 Tongued and trenched joint

The tongued and trenched joint makes a strong neat joint that can be fixed adequately using only an adhesive (Fig. 8.41). The short grain beside the trench is a weak point that makes it unsuitable for use with manufactured boards. The tongue should be no more than one-third the thickness of the timber.

Fig. 8.40 Rebated joint**Fig. 8.41** Tongued and trenched joint

8.2.4 Mitred joint

The mitred joint shows no end grain (Fig. 8.42). The parts of the joint must be cut at 45° where the joint is to be at right angles and must be dressed accurately. It can be fixed by an adhesive, nailing or screwing, or some combination of the three.

In this case, the nails should be started in the top piece (Fig. 8.43). Apply a little adhesive and bring the joint together.

Keep the top piece a little uphill, because when the joint is nailed, it will slide down into place, pulling the parts together and expelling any surplus adhesive. Nailing can be carried out from both sides; the nails are then punched below the surface. The recess is filled with a suitable stopping compound.

Concealed fixing can be achieved by use of a 'feather' or loose tongue (Fig. 8.44).

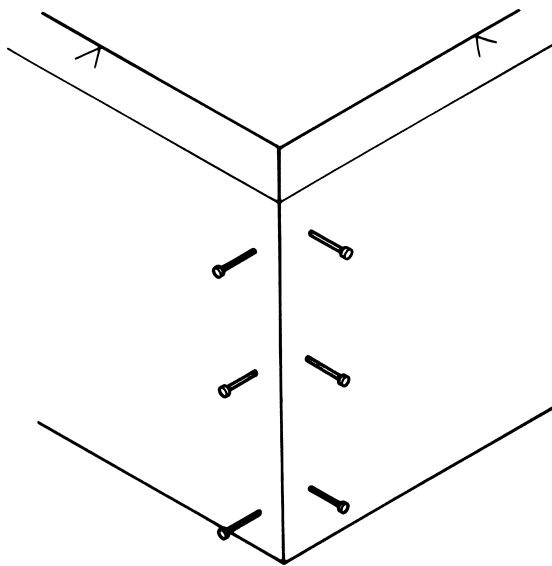
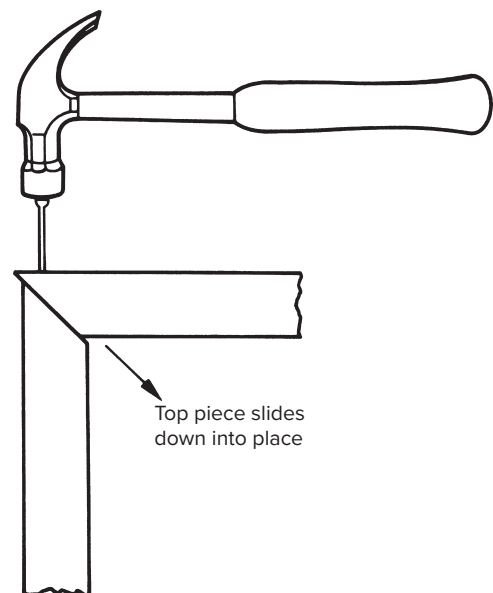
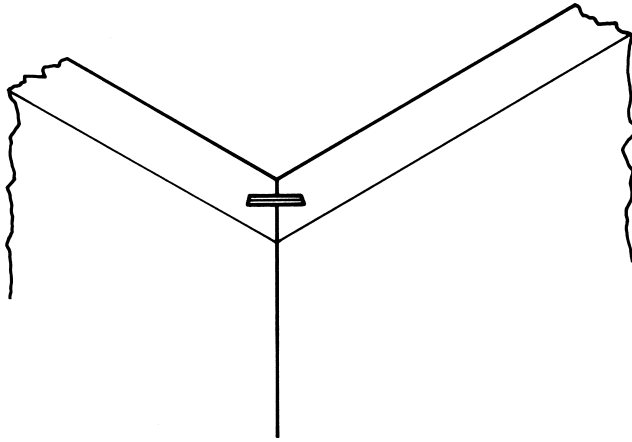
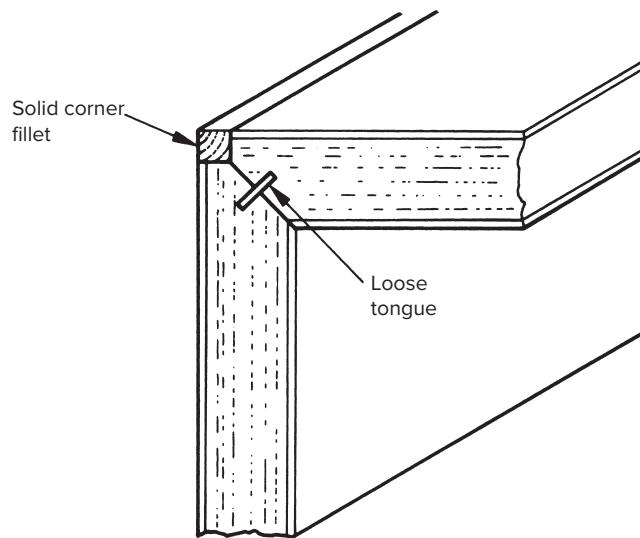
Fig. 8.42 Mitred joint**Fig. 8.43** Nailing the mitred joint

Fig. 8.44 Loose tongue in the mitred joint**Fig. 8.45** Modification of the mitred joint for veneered boards

Make a saw cut, or use the router to run a small groove, across the joint. Into this can be fitted a tongue of thin plywood or veneer.

Due to the thin feathered edge of the mitre, this joint is sometimes unsuitable for use in veneered or manufactured boards as the face veneer can chip away easily. Figure 8.45 shows a modification of the joint to make it more suitable to this material.

8.2.5 Housed joints

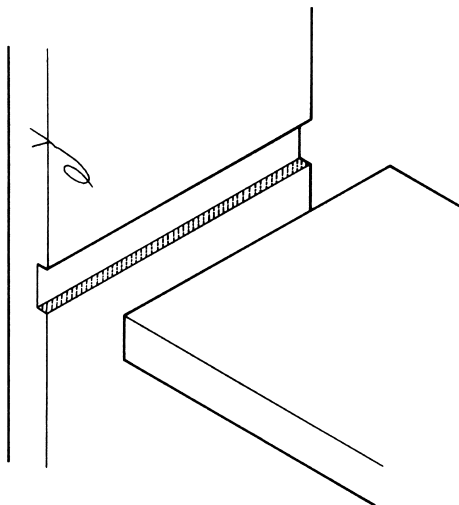
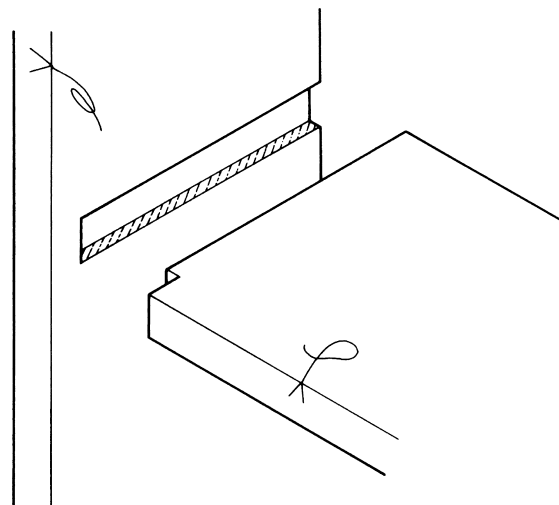
Housed joints are used in solid timber furniture construction, supporting shelving and so on. A *through housing* will show the joint on the exposed edge (Fig. 8.46).

If this is undesirable, a neater joint is the *stopped housed joint* (Fig. 8.47).

In this joint, the housing is stopped short of the edge and the shelf is cut to butt against the side.

To cut the stopped housing using hand tools in solid timber, first mark the position of the housing. Use the thickness of the board to be fitted as a template for marking the exact width, and cut the sides with the marking knife or pencil.

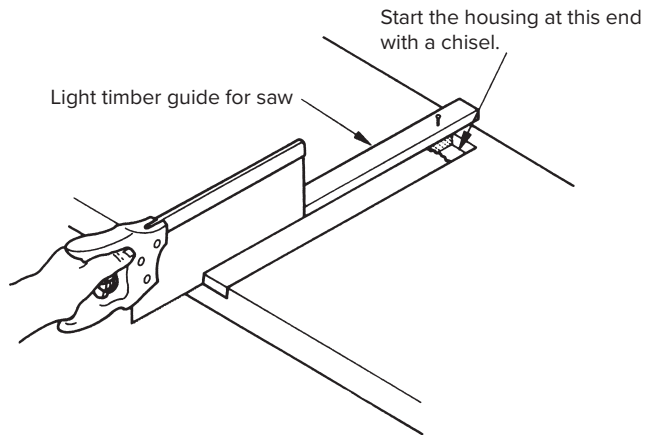
At the stopped end, use the chisel to start the housing sufficiently to allow the

Fig. 8.46 Through housed joint**Fig. 8.47** Stopped housed joint

tenon saw to cut down the sides. A light timber strip, pinned or clamped along the line, is a useful saw guide over a long cut (Fig. 8.48). After sawing both sides, chisel away the waste and smooth the bottom of the housing to a uniform depth, preferably using the hand router plane.

Housed joints can be made readily using an electric router with an appropriate cutter the thickness of the board to cut the housing.

Fig. 8.48 Cutting the stopped housed joint



CHECK YOUR UNDERSTANDING

5. List three types of carcase joints.

8.2.6 Shelf supports

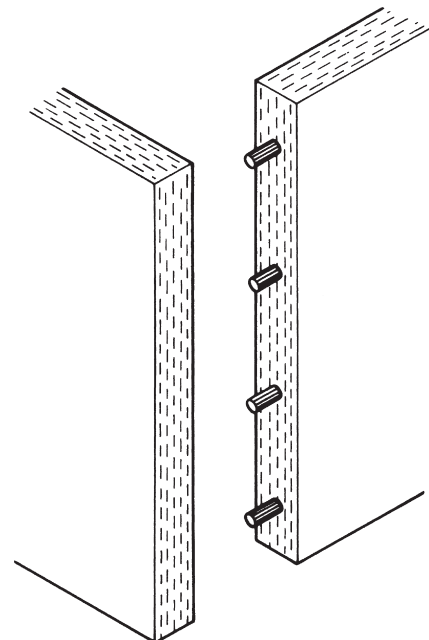
Another popular method for supporting shelves in carcases is to use adjustable shelf supports.

8.2.7 Dowelled joint

The dowelled joint can also be used as a carcase joint and is particularly adaptable for use with particleboard where the range of other suitable joints is limited (Fig. 8.49).

Details on the setting out and construction of the dowelled joint have already been described. Precut 8 mm dowels are convenient for use with 16 mm or 18 mm particleboard. Apply a suitable adhesive to the joint and cramp together until set.

Fig. 8.49 Dowelled carcase joint



8.2.8 Dovetail joints

The dovetail joint is the strongest of the carcase joints. The presence of handmade dovetail joints in manufactured articles has long been regarded as a sign of quality.

Each joint must be individually marked and accurately fitted. Face sides and face edges must be clearly marked and followed so that the joints will come together in the finished article the correct way round. The face sides can be either *all inside* or *all outside*. Face edges must *all* point in the same direction. In the examples shown, the face side has been marked on the inside. The most common use for dovetails in joinery and furniture is to join the fronts and sides of drawers.

All parts must have face and edge marks to avoid confusion. Dovetail joints are set out from the end of the timber, and parts must be cut to their finished length and the ends dressed square as a first step to making the joints.

Types of dovetail joints are now described.

TIP This section covers handmade dovetail joints; however, proprietary dovetail jigs are readily available for use with an electric router fitted with a dedicated 'dovetail' router bit to suit a wide variety of applications.

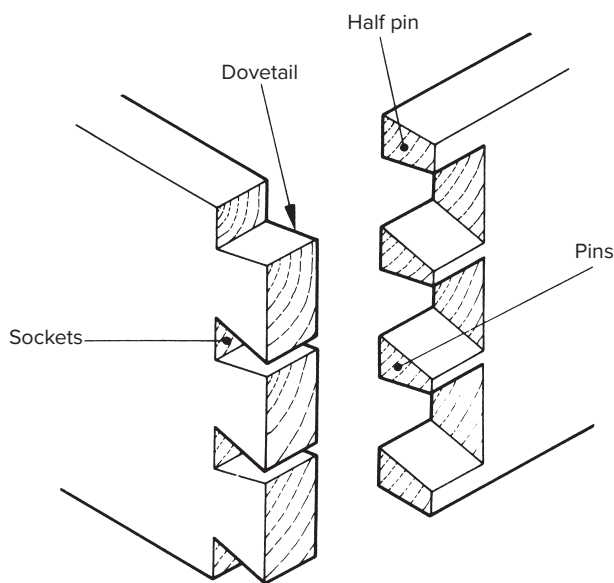
8.2.8.1 Common dovetail joint

The common dovetail joint is one in which the pins and sockets go fully through the timber and, when assembled, show end grain on both of the outside faces (Fig. 8.50). The angle or ratio of the pins illustrated in the following examples can be between 1 in 4 and 1 in 7.

To make the common dovetail joint, proceed as follows:

1. **Squaring.** After the ends have been dressed square, measure back from the end the thickness of the material and square around both pieces to be joined. Use a sharp pencil and a try square.
2. **Setting out the pins.** Set out the pins on the end of the timber. The details of setting out are shown in Figure 8.51. Take three-quarters the thickness ($\frac{3}{4}t$), which is the maximum width of the pins, and round to the nearest millimetre; set a sliding bevel to 1 in 4 (Fig. 8.52).

Fig. 8.50 Common dovetail joint



Mark a half pin (so named because it has a slope on one side only) on each edge of the timber. If there are to be two intermediate pins, there will be three spaces. Adopting the 'in and over' method, divide the width into the required number of equal spaces. Mark out one pin to each space (Fig. 8.51). Then mark the bevel of the pins across the end of the timber (Fig. 8.52). The maximum distance between the pins is three times the width of the pin ($3 \times \frac{3}{4}t$). To ensure a close-fitting shoulder line, use the marking knife to cut along the line of the waste between the pins (Fig. 8.53).

3. **Ripping the pins.** Using a fine dovetail saw, rip the pins, keeping on the waste side of the line (Fig. 8.54).

Fig. 8.51 Setting out pins for a dovetail joint

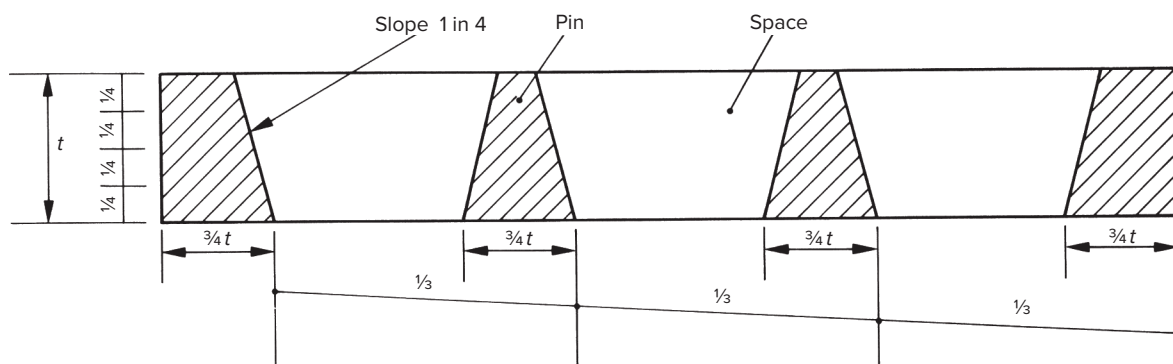


Fig. 8.52 Setting the bevel

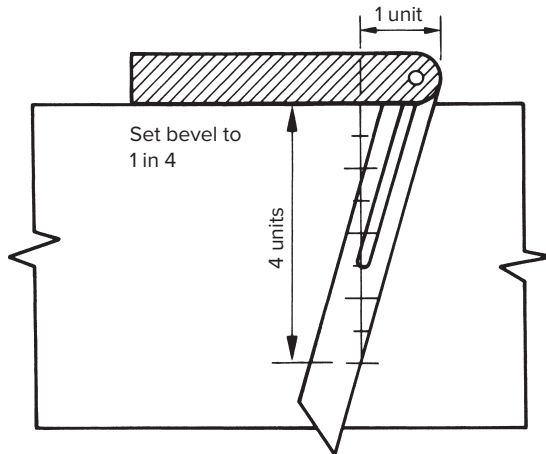


Fig. 8.53 Completed set-out of dovetail pins

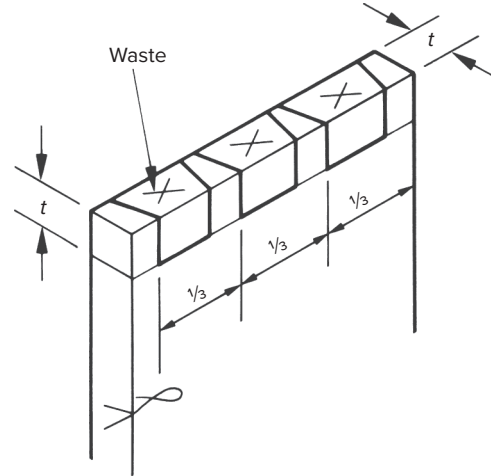


Fig. 8.54 Ripping the pins

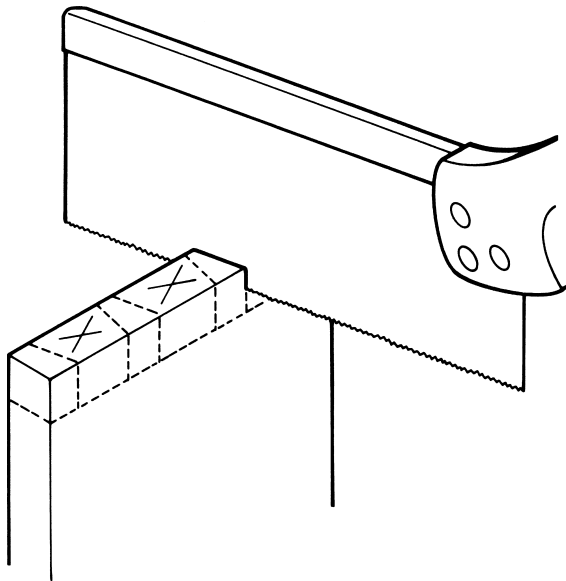
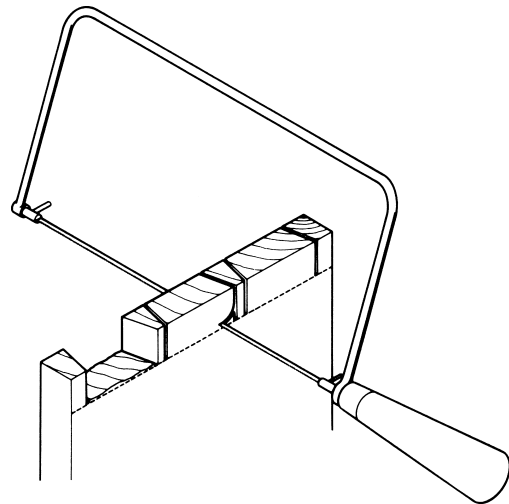


Fig. 8.55 Cutting the waste with a coping saw



4. Removing the waste. There are two recognised methods of removing the waste from between the pins. The first uses the coping saw to cut away the waste (Fig. 8.55). Keep just on the waste side of the line and use a paring chisel to true up the shoulder line. Very slightly undercut, working from both sides of the timber.

The second method is to chisel down the shoulder line and remove the waste in the form of a 'V' for half the thickness (Fig. 8.56). Turn the timber over and remove the other half of the waste in a similar manner; cutting in this way, and leaving the front end of the

Fig. 8.56 Chiselling out the waste

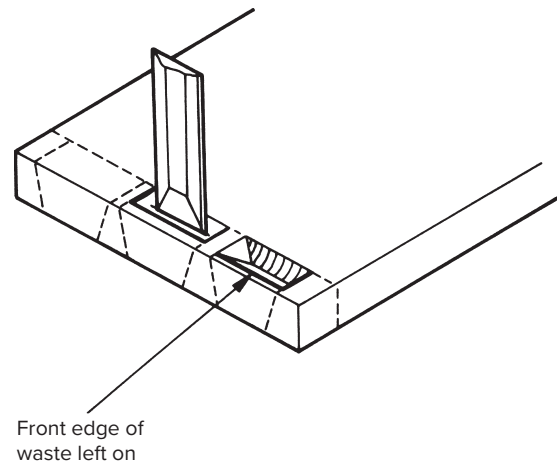
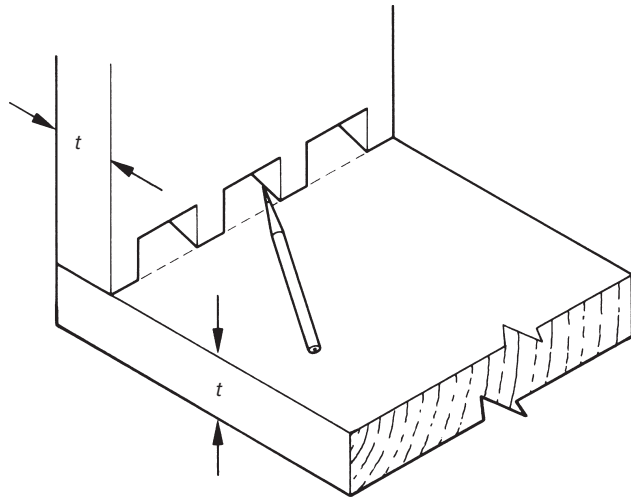
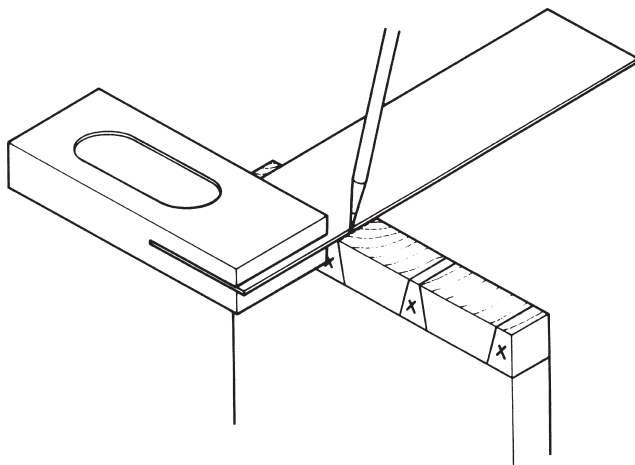


Fig. 8.57 Marking the sockets**Fig. 8.58** Squaring the sockets

joint together. A diagonal brace may be required to hold the article square while the adhesive sets, after which the outside faces can be flushed off with the smoothing plane and sanded.

waste intact, provides support for the end when the timber is turned over. There is always a strong chance that the timber will break out between the pins, so use a very sharp bevelled-edge chisel and proceed cautiously in the manner described.

5. **Marking the sockets.** Use the pins as a template to mark out the sockets on the other piece (Fig. 8.57). Use a sharp pencil and square the line across the edge (Fig. 8.58).
6. **Ripping the sockets.** To rip the sockets, keep on the waste side of the line. The pencil line should remain visible and completely intact (Fig. 8.59).
7. **Removing the waste.** Using a suitable narrow paring chisel, remove the waste, again working from both sides for the intermediate pins and saw away the waste to the half pins. If necessary, use a medium- to fine-grade abrasive paper to sand the inside faces. The joint is ready to assemble.
8. **Assembling.** If the joint has been cut out accurately, it should fit off the saw with only minor adjustments to the fit. The tapered pins should fit neatly, tending to pull the shoulder lines together without the need for any other form of cramping. Apply a small amount of adhesive to the mating surfaces, enter the pins into the sockets and tap the

8.2.8.2 Lapped dovetail joint

The lapped dovetail joint is so named because of the lap formed on one piece, so that when the joint is assembled, end grain will be seen on one side only (Fig. 8.60). The most common application of the lapped dovetail is the joint between the front and side of a drawer. The thicker piece containing the lap is the *front*, and the other piece is the *side*. They will be referred to as such in the description of the procedure.

The setting out of the pins on the drawer front is shown in Figure 8.61. Divide the thickness into three equal parts and make one-third the lap. Dovetail pins are then set out on the remaining two-thirds, their width referred to as p . It can be seen from the set-out that if the maximum width of pins is $\frac{3}{4} p$, this is the same thing as $\frac{1}{2} t$ (t being the thickness of the front), rounded off to the nearest millimetre.

Fig. 8.59 Ripping the sockets

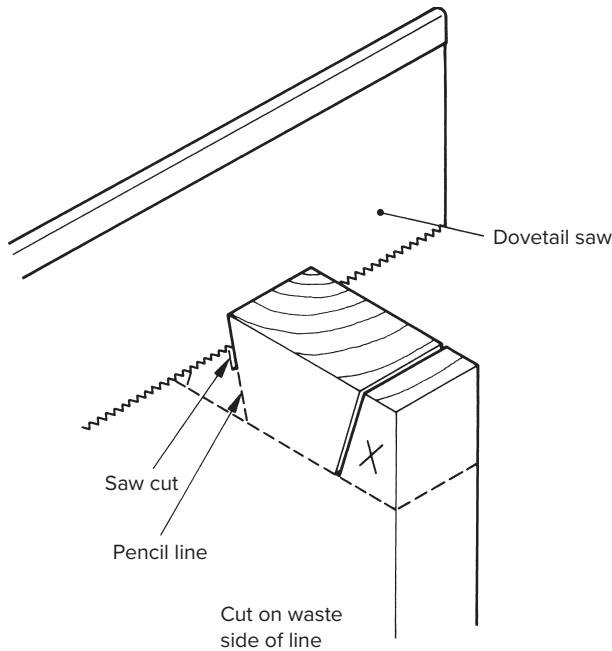


Fig. 8.60 Lapped dovetail joint

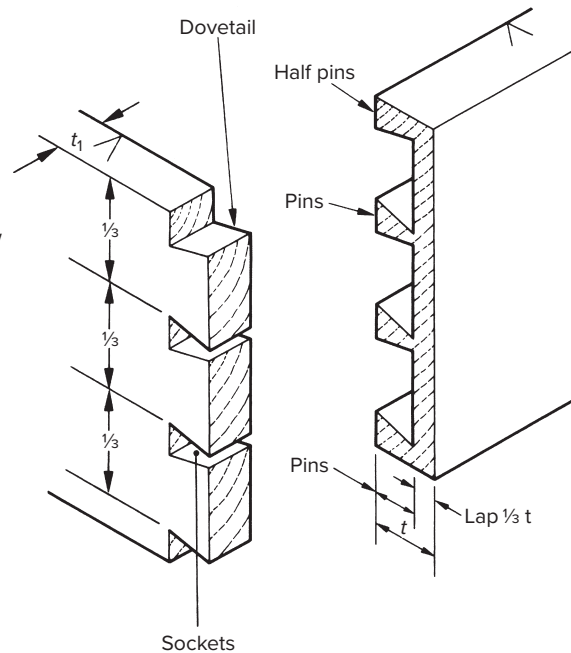
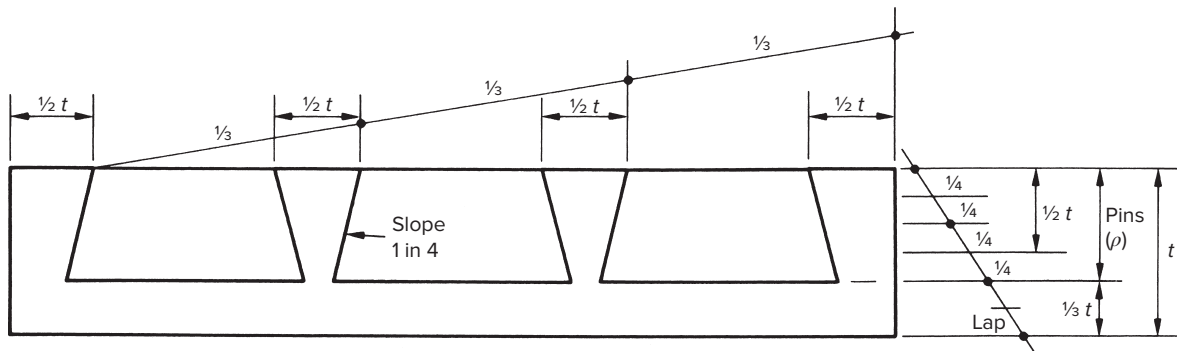


Fig. 8.61 Setting out of pins for a lapped dovetail joint



To make the lapped dovetail joint, proceed as follows:

1. After squaring the ends, gauge the distance p on the end of the front piece and also from the end of the side piece across both faces and edges. Gauge the distance t_1 (the thickness of the side from the end of the front) (Fig. 8.62).

TIP A marking gauge is adequate if a cutting gauge is not available.

Gauging these distances can be done with a cutting gauge, which is similar to a marking gauge except that a small knife replaces the spur (Fig. 8.63). Its purpose is to gauge across the end grain or to cut parallel strips of thin timber. First set the gauge to p and gauge the front and around the end of the side—gauge lightly across the outside face where the mark may be difficult to remove. Reset the gauge to t_1 and gauge across the front.

- Set out the dovetail pins on the end of the front, adopting the 'in and over' method, and mark the slope on the pins with a sliding bevel set to 1 in 4 (refer back to Fig. 8.61).

Fig. 8.62 Gauging for a lapped dovetail joint

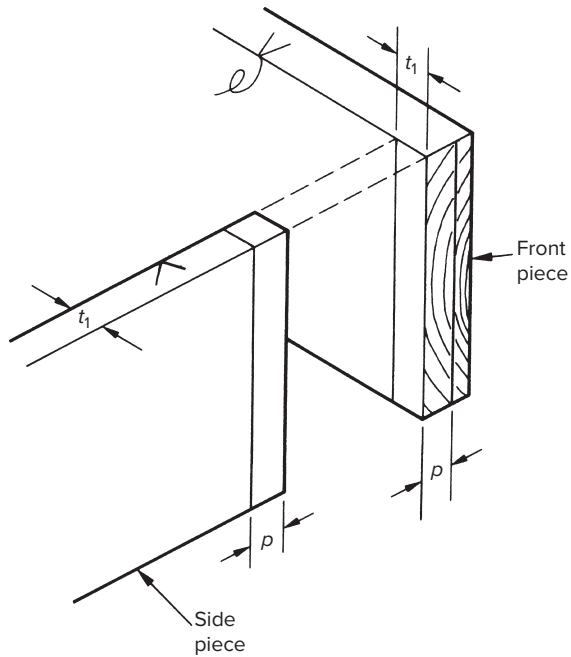


Fig. 8.63 Cutting gauge

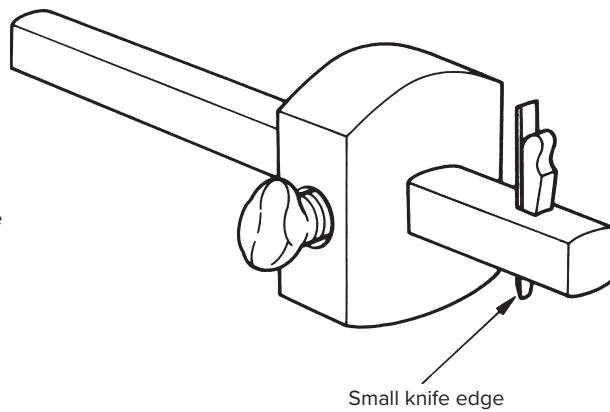
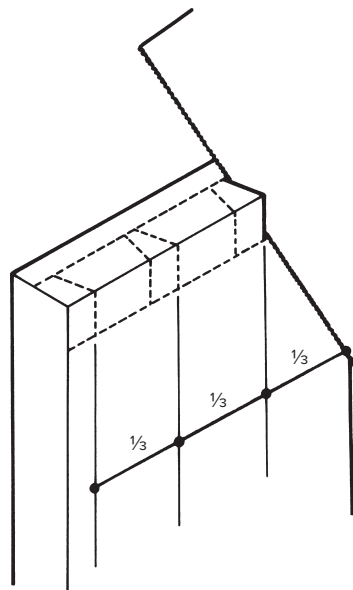


Fig. 8.64 Ripping the dovetail pins halfway



3. Rip the dovetail pins halfway diagonally (Fig. 8.64).
4. Remove the waste from between the pins using a sharp bevelled-edge chisel: cut off the waste, slightly undercutting, and pare it away (Fig. 8.65).
5. Use the dovetail pins as a template to mark the sockets on the side (Fig. 8.66). Stand the front piece on the side and with a sharp pencil mark the pins.

Fig. 8.65 Removing the waste

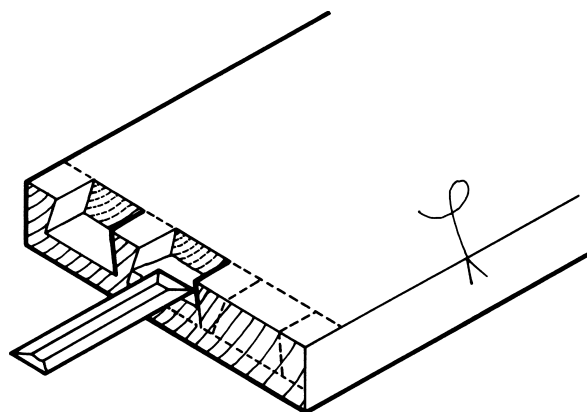
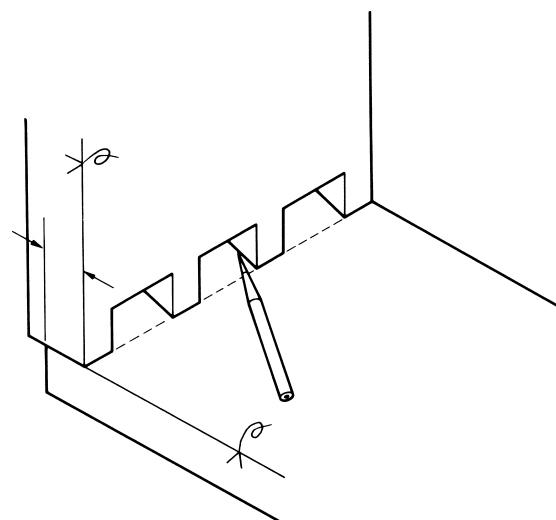


Fig. 8.66 Marking the sockets



6. Remove the waste from the sockets in a manner similar to the common dovetail.
7. Check the joint for fit; if necessary, sand the inside faces. Apply adhesive lightly and tap the joint together. As with the common dovetail, the tapered pins should be a close fit, tending to draw the joint together.
8. After the adhesive has set, clean off and sand the outside face.

CHECK YOUR UNDERSTANDING

6. What ratio/angle can be used when constructing dovetail joints?

8.2.8.3 Alternative method for making the dovetail joint

The alternative method for making a dovetail joint involves marking the pins from the sockets. Proceed as follows:

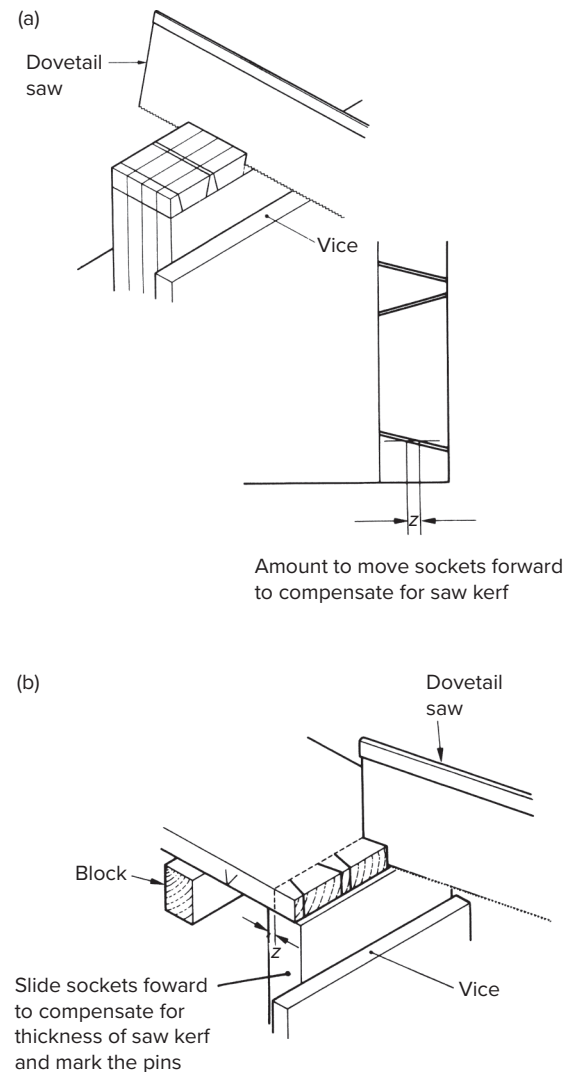
1. Set out the sockets on the side, proportioning in the same manner as for the pins.
2. Use a fine dovetail saw and rip the sockets but do not remove the waste. A number of pieces, say three or four, can be cramped together and the sockets ripped from the set out.
3. Lay the side on the end of the front, moving it forward sufficiently to compensate for the thickness of the saw kerf.

This distance is illustrated in Figure 8.67. Measure square across the sloping saw kerf and note the distance z . If using a fine dovetail saw, this distance may be approximately 2 mm but must be checked with the actual saw being used on the job.

Hold the side in position firmly, place the point of the saw into the saw kerf and mark onto the end of the front for each pin.

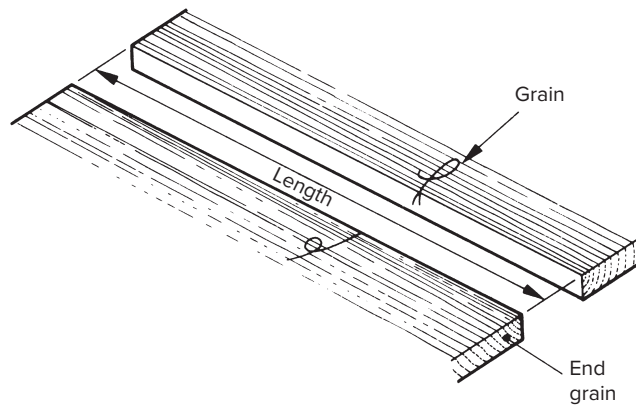
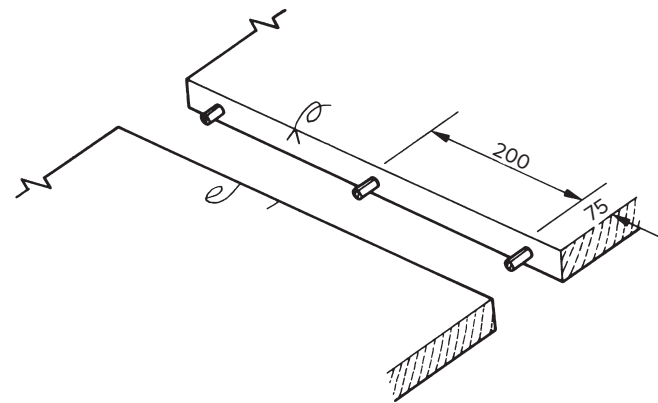
4. Remove the side and square down the face of the front of the line of the saw cut marked on the end; rip the pins on this line.
5. Remove the waste from the sockets and between the pins. Fit and assemble the joint as previously described. Note any correction considered necessary to the distance z for future use.

Fig. 8.67 (a) and (b) Setting out from the sockets



CHECK YOUR UNDERSTANDING

7. Show how the pins for a common dovetail joint would be set out on the end of a piece of timber 100 mm $\times$ 12 mm.
8. What are two forms of dovetail joints?

Fig. 8.68 Butt joint for widening**Fig. 8.69** Dowelled joint for widening

the most commonly used joint for this purpose. The dowels/biscuits are set out at approximately 75 mm from the ends and 200 mm apart. See the section 'Dowelled joint' for the proportioning of dowels.

8.3.2 Loose-tongue or 'feather' joint

The butt joint, after preparation, can also be strengthened through the addition of a loose tongue (Fig. 8.70). The tongue can be of plywood, cut with the greater number of veneer layers lying across the line of the joint. Alternatively, a tongue can be cut from solid timber, with the grain running diagonally across, and a thickness of no more than one-third the thickness of the boards. Cut the width of the tongue about 1 mm less than the combined depth of the plough grooves. The groove that is to receive the tongue is gauged from the face side, which should be flush when the joint is assembled.

8.3.3 Matching boards for edge jointing

Boards should be matched for grain and colour to the best advantage for both ease of working and final appearance. First check and mark the direction of the grain in each board, taking a trial shaving if necessary. If the boards are cut from one long length of timber, take care that their direction is not reversed. Joint the boards with the grain running in the same direction. Besides the difference in colour caused by the light falling on the grain in opposite directions, cleaning off is also made more difficult if the grain in one board is running in the opposite direction to the one adjacent to it.

8.3 Use joining methods for widening timber

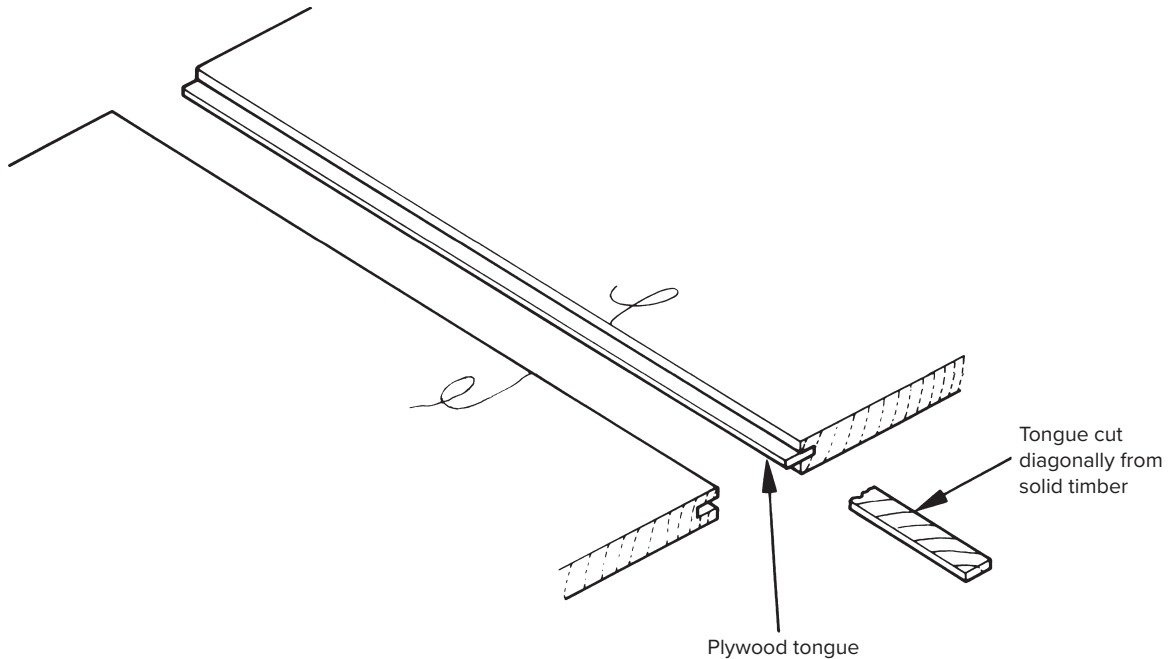
With the widespread use of plywoods, medium-density fibreboard (MDF) and other manufactured boards in large sheet sizes, the need to edge joint solid timber to make up wide boards has greatly diminished. However, for items such as tabletops, countertops and so on, there is often a preference for the individual warmth of solid timber.

8.3.1 Butt joint

The butt joint is suitable for use where the joint is subject to only minor stresses and has a stable moisture content. The jointed edges must be planed or machined straight and square, and be close fitting before being glued and cramped together with a suitable adhesive (Fig. 8.68).

The butt joint can be strengthened through the addition of dowels or biscuits, positioned so that they align with the face of the boards (Fig. 8.69). This is probably

Fig. 8.70 Loose-tongue joint



Lay out the boards, and when it is thought that they are in the best combination, mark the face sides pointing to the edges to be jointed; if there is more than one joint, indicate by marks or numbers the pairs to be joined (Fig. 8.71).

Fig. 8.71 Matching boards

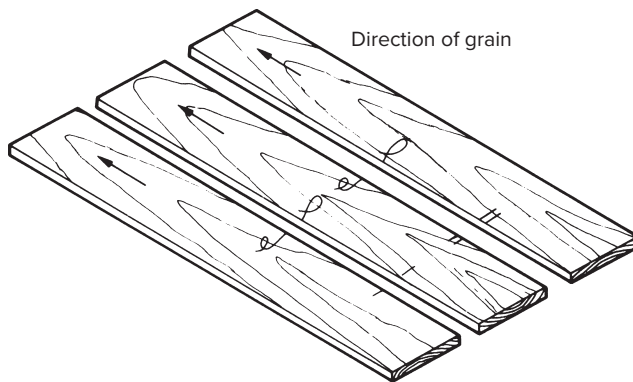
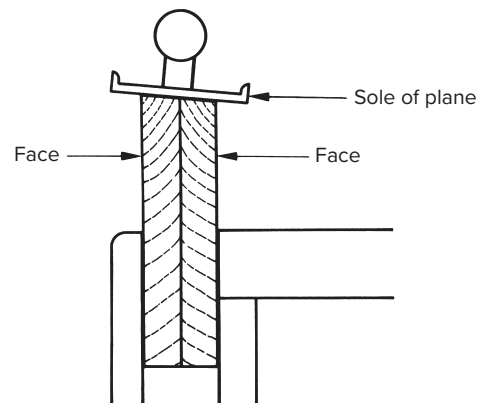


Fig. 8.72 Planing the edges

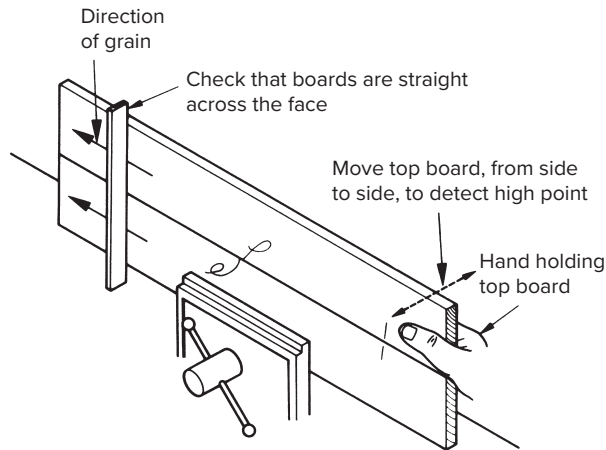
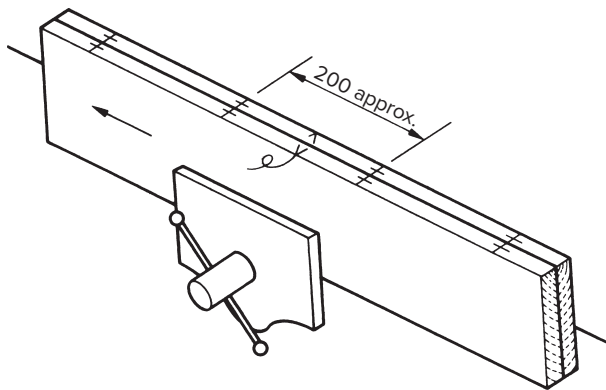


8.3.4 Jointing the boards by hand

Hold the two boards to be jointed back-to-back and secure them in a vice. Straightening a long length of timber is a job for the trying plane. The technique is shown in Figure 8.72.

Shoot the edges of the two boards together. One theory is that if the boards are together and are planed slightly off-square, and the edges are then brought together, the face will lie on a straight line as the bevel on one board will complement the bevel on the other. Experience shows, however, that it is better to keep the edges square by testing with the try square from the face side.

After the boards have been planed straight and square, they can be tested for accuracy as shown in Figure 8.73.

Fig. 8.73 Testing for accuracy**Fig. 8.74** Marking for the dowels or biscuits

biscuits (Fig. 8.74), and square them across both boards; then gauge the holes from the face side on both pieces.

TIP See the procedure for the boring of dowel holes under the heading 'Making the dowelled joint' earlier in this chapter.

8.3.5 Gluing up jointed boards

Lay out sash cramps and have available blocks of scrap timber that can be used under the shoe of the cramps to prevent the edges of boards being damaged.

Hold the two edges to be jointed together, apply adhesive to the dowelled joints or the tongue and groove joints as the case may be, and enter the dowels or the tongue. Align the remainder of the joint, bring it together and tap it lightly. Lay the boards in the sash cramps and, holding them hard down on the bar of the cramps, cramp them together lightly. Lay another cramp across the top and, keeping the bar hard down on the boards, tighten the cramps, as shown in Figure 8.75. This will hold the boards flat and prevent them from buckling as the cramps are tightened uniformly to bring the joint together and expel any surplus adhesive. Do not overtighten the cramps to the point where the boards are distorted.

Finally, wipe away any surplus adhesive with a dry cloth (Fig. 8.76).

Hold one board in the vice and stand the second board on top. First, see that the faces are in a straight line by sighting down or using a short straight edge. Then check that the boards are a close fit along their length. To test, grip one end of the top board and move it from side to side. If there is a high spot, the top board will pivot on this point, which can be easily detected and removed with a fine shaving. If the board pivots on an end point, it is probably too hollow in the centre and the high point at the end is removed. Continue testing until the boards are a close fit along their length and no high spots can be detected.

Another theory is that when boards are planed, they should be finished slightly hollow along their length towards the centre of the board so that a narrow strip of daylight can just be seen when held to the light. This is because when the boards are jointed together, and are adjusting to their environment over a period of time, the ends will tend to shrink to a greater degree than will the centre of the boards. The hollow planing will compensate for this uneven timber movement.

If the boards are to be dowel or biscuit jointed, again hold them back-to-back in the vice, mark the position of the dowels or

Use a trying plane with a sharp blade that is set to take a fine shaving, and commence by planing diagonally across the boards, a practice termed *traversing*. Work in strips the width of the plane iron, overlapping each step slightly. Continue planing in a similar manner across the opposite diagonal until any small irregularities are removed. Complete the cleaning off by planing in strips in the direction of the grain until any surface blemishes are removed.

Sanding the surface of wide boards is carried out in the same sequence as for planing, whether by hand or by electric sander. Start with a fine grade of paper, say 120 grit, so as not to make any deep scratches that will be difficult to remove later, and sand diagonally across the boards in strips. Next, sand in the direction of the grain with a medium grade of paper, say 100 grit, until any scratches are removed, and then finish with a fine paper, 120 or 150 grit.

Fig. 8.75 Cramping the boards

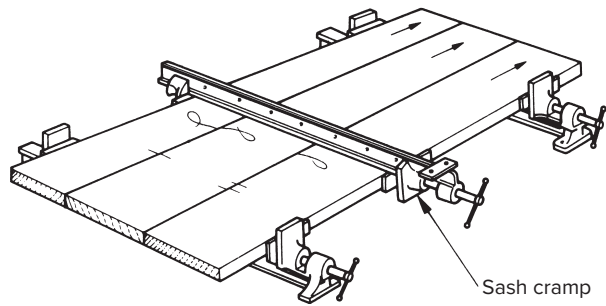
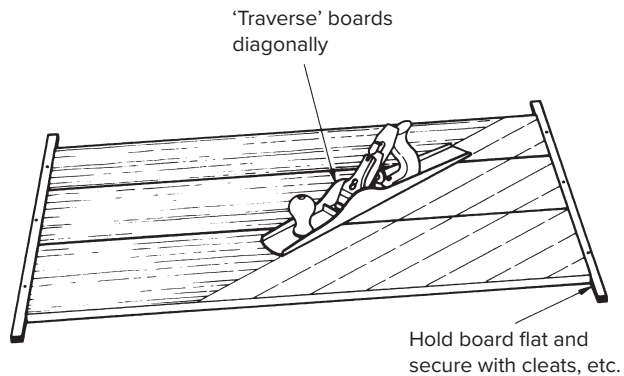


Fig. 8.76 Cleaning off wide boards



TIP If you have access to a static machine called a 'thicknesser', the planing of the jointed boards by hand can be skipped—provided the machine is wide enough to accept the piece. If it is not, the accepted method is to produce the piece in narrower sections, allowing it to fit the thicknesser and later to be glued together and finished as described in the previous section.

8.3.6 Fixing wide boards of solid timber

Wide boards made of solid timber will shrink and expand with changes in moisture content. When they are fixed in place, provision must be made for them to move freely to accommodate these changes.

A good example of what can happen is to be seen in many old tables that have a split right down the middle. Close examination would probably show that the top was simply nailed to the frame around its outer edges and was therefore restrained from shrinking. If this were the case, the stresses set up during one or more long dry summers would be so great that the boards simply split down the centre. The damage would probably not have occurred if the top had been attached to the frame by means of 'buttons', which hold the top down but allow it to shrink or expand with atmospheric changes (Fig. 8.77).

Another example is where the wide board is held flat by cleats screwed across the back, but the screw holes are slotted to allow the board to move as its moisture content changes (Fig. 8.78).

Another procedure that minimises the shrinkage in wide boards is to run a number of plough grooves in the back surface. This means that the shrinkage across the surface will be localised into a number of smaller widths and will be less overall.

CHECK YOUR UNDERSTANDING

9. What are three methods of joining boards to make a wide piece of timber?
10. How is a tabletop held down to the frame?

Fig. 8.77 Buttons for a tabletop: (a) close up; (b) full view

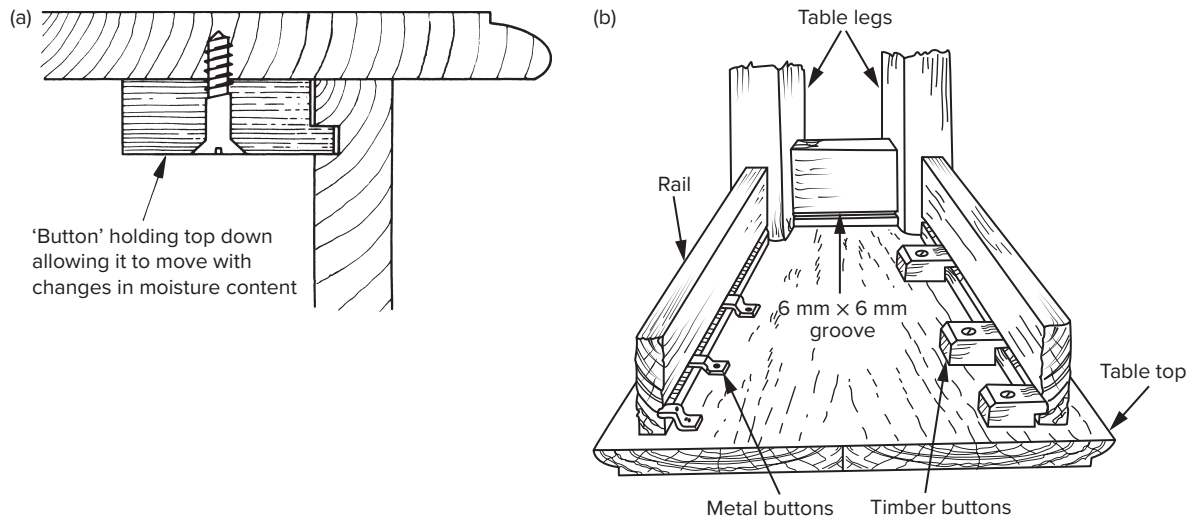
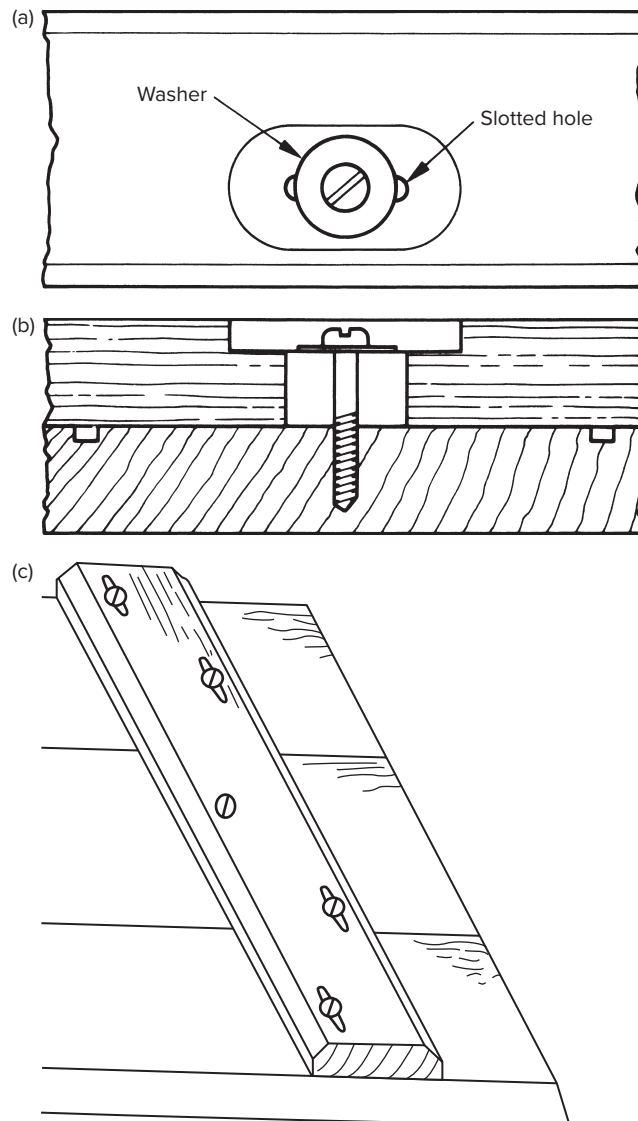


Fig. 8.78 (a–c) Slotted hole in cleat method



Student research

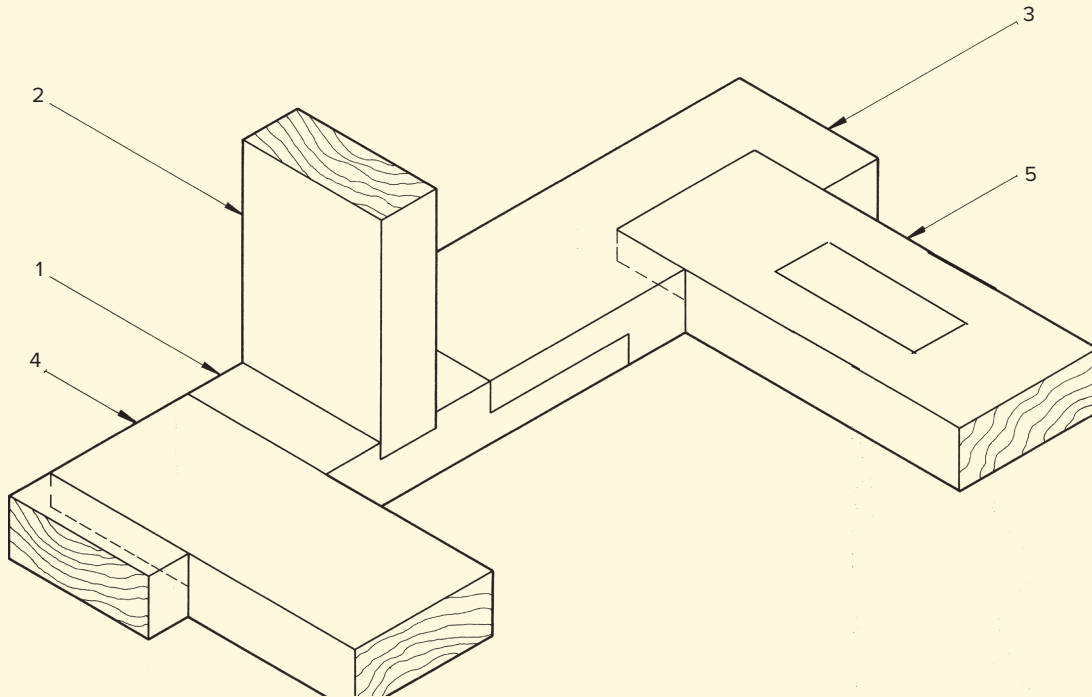
Search the internet for 'heavy framing joints' and look at the other types of joints that can be used to join timber together in large timber-framed buildings.

End-of-chapter activity

Construct the object below. The task combines a number of joints covered in this chapter so far. Read the plans carefully as some of the measurements need to be calculated.

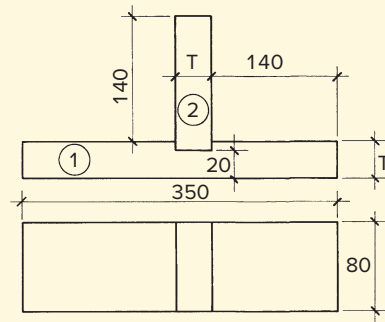
The timber size required to construct this project is 85 mm × 30 mm.

(a) Object to be constructed

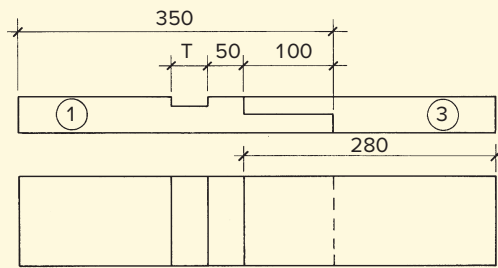


Adapted from NSW Department of Technical and Further Education, School of Building, Carpentry and Joinery, Stage 1

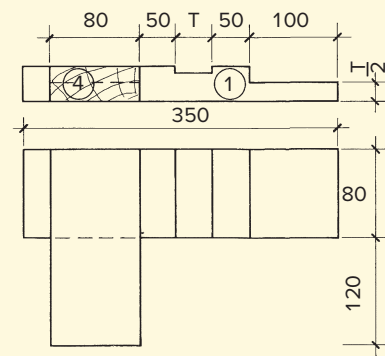
(b) Plans



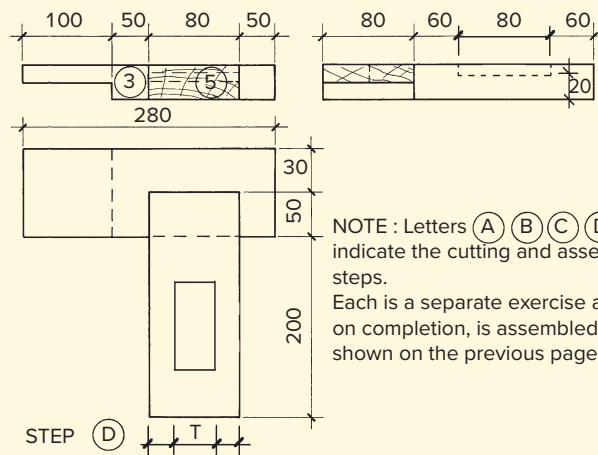
STEP (A)



STEP (B)



STEP (C)



STEP (D)

NOTE : Letters (A) (B) (C) (D) indicate the cutting and assembly steps. Each is a separate exercise and on completion, is assembled as shown on the previous page.

Adapted from NSW Department of Technical and Further Education, School of Building, Carpentry and Joinery, Stage 1

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684—2010
Residential
timber-framed
construction

Chapter 9

Construction fastenings and adhesives

It is important for those students who want to become carpenters within the building industry to understand the content in this chapter, even though it is not explicitly covered in this qualification. This content will enhance the training being undertaken and also provide essential knowledge of the function and application of construction fastenings and adhesives.

Learning Objectives

LO 9.1 Identify nail types and their uses

LO 9.2 Identify the varieties of woodscrews and their application

LO 9.3 Identify bolts, nuts and their uses

LO 9.4 Know about associated tools used with fasteners

LO 9.5 Identify masonry anchors

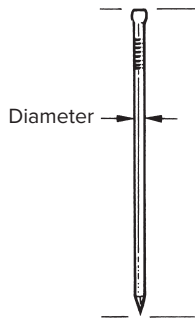
LO 9.6 Understand adhesives and their application

Introduction

There are many ways to connect two pieces of timber together and to connect timber to another material. In this chapter, you will learn about the various types of fixings, fasteners and adhesives available in the construction industry. You will learn about the associated tools used with some of these fixings and the various applications and scenarios to which the fixings and fasteners are suited.

9.1 Identify nail types and their uses

Nails developed from the wooden peg. They have a long and varied history, from the first hand-forged nails to cast nails and nails cut from strips of flat steel sheet, to the mass-produced nails manufactured from steel wire that we use today.

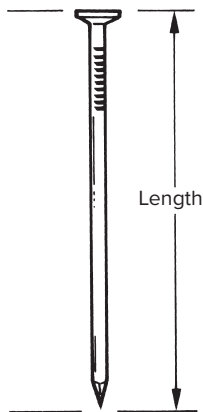
Fig. 9.1 Bullet head nail

Throughout the building industry, nails are one of the most common methods of fastening materials together and they do so quickly and efficiently using the friction created between the nail and the material into which it is driven. Nails are used predominantly for fixing timber to timber, but many types have been developed for use in fixing a range of other materials.

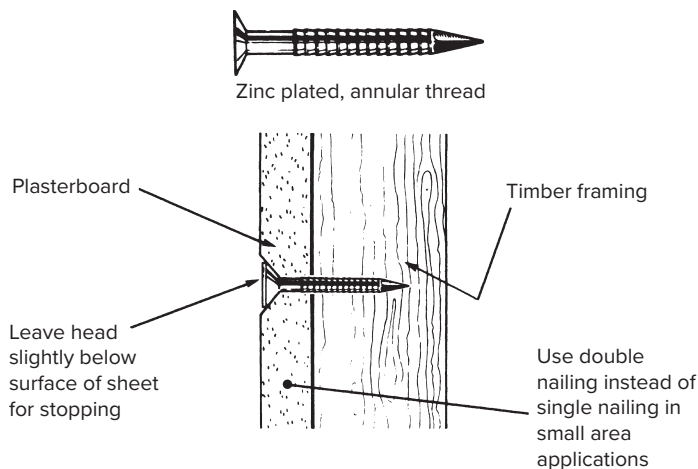
Nails are described by their length and diameter in millimetres and by the shape of the head. One of the most common types is the bullet head nail (Fig. 9.1). It is used in framing and fixing work where the small head is punched below the surface and is relatively inconspicuous.

The flat head nail is used mainly for nailing in low-density timbers and materials where the bullet head would tend to pull through the soft timber (Fig. 9.2). For exterior use, steel nails are **galvanised** to provide protection from corrosion, and this detail is added to their description. A typical description would be 75 × 3.75 bullet head, or 65 × 3.15 galvanised flat head.

The load-carrying capacity of a nail in timber depends primarily on its diameter (*d*). For structural work where maximum strength is required, the thickest possible nail that can be driven without splitting the timber can be taken as the correct size. Where the required number of nails for a joint cannot be driven without splitting the timber, the nail holes should be predrilled using a drill having four-fifths (80%) of the diameter of the nail.

Fig. 9.2 Flat head nail

TIP There are rules governing the use of nails—how many, what length, what type and how they should be used—on a timber-framed house. Refer to AS 1684 Residential timber-framed construction for more information.

Fig. 9.3 Lattice head nail

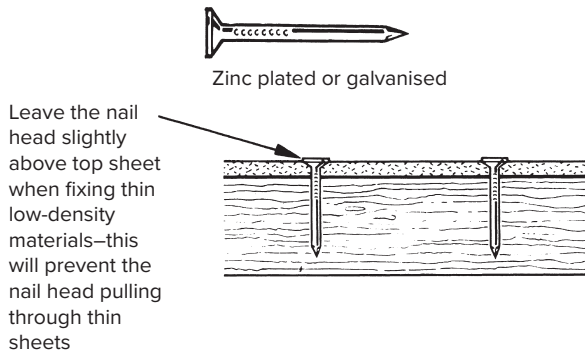
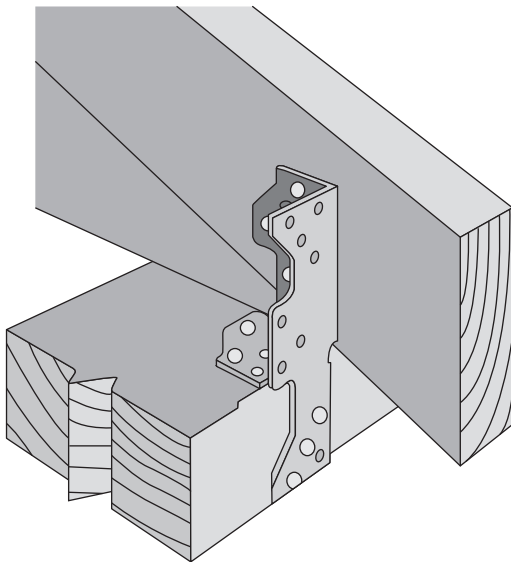
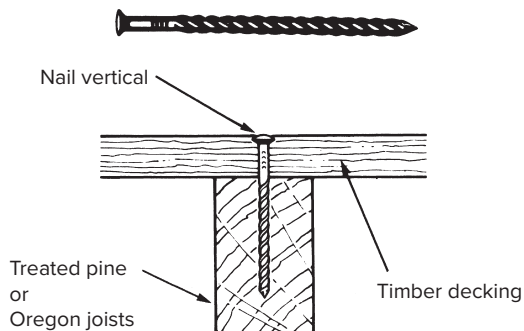
9.1.1 Nail types

9.1.1.1 Lattice head nails

Lattice head nails are used for fixing plasterboard linings to timber frames (Fig. 9.3). The head is driven just below the surface but not far enough to break the heavy paper surface of the plasterboard around the head.

9.1.1.2 Soft sheet nails

Soft sheet nails are zinc plated and designed for fixing thin materials such as fibre cement sheet used as eave lining (Fig. 9.4). The head is left

Fig. 9.4 Soft sheet nails**Fig. 9.5** Bracket nails**Fig. 9.7** Timberlok nail

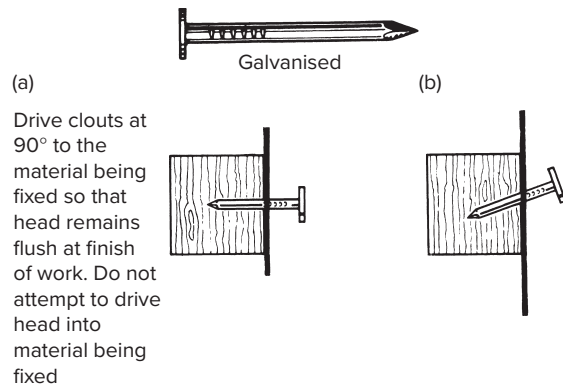
protruding slightly above the surface of the sheet to prevent the head pulling through the sheets.

9.1.1.3 Bracket nails

Bracket nails are galvanised or zinc plated and used in the fixing of metal brackets in timber framing (Fig. 9.5). These must be nailed into solid timber.

9.1.1.4 Clout nails (clouts)

Clouts are galvanised with a large flat head and are designed for fixing thin sheet metal to timber. It is important that the nail is driven at 90° to the surface, so that the head remains flush at the finish of work (Fig. 9.6a). The head should not be driven through the material being fixed (Fig. 9.6b).

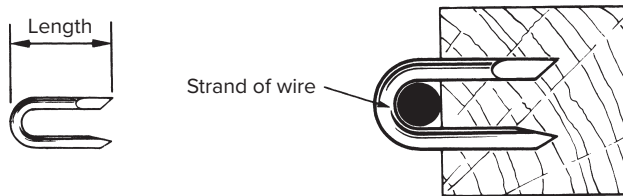
Fig. 9.6 Clouts: (a) correct; (b) incorrect

9.1.1.5 Deformed nails

Deformed nails such as 'Timberlok nails' (Fig. 9.7) are designed to provide extra holding power when fixed into soft timber, such as treated pine or Oregon. The nails have a helical thread, so there is no need to skew nail. When nailing through hardwood decking it is necessary to drill the top piece to avoid splitting.

9.1.1.6 Staples

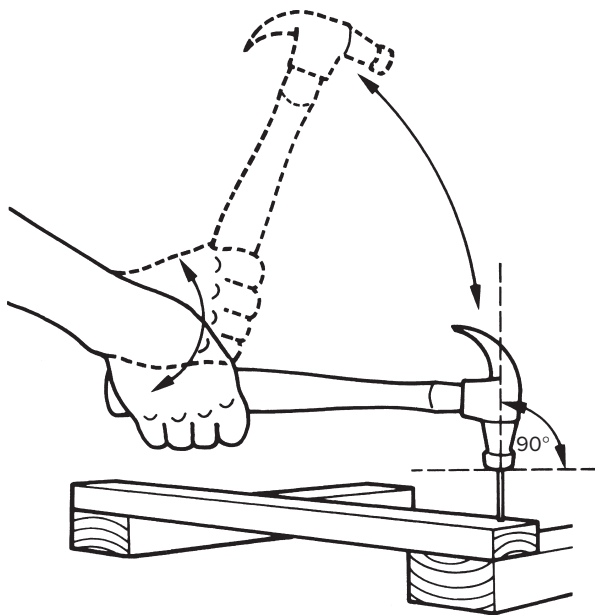
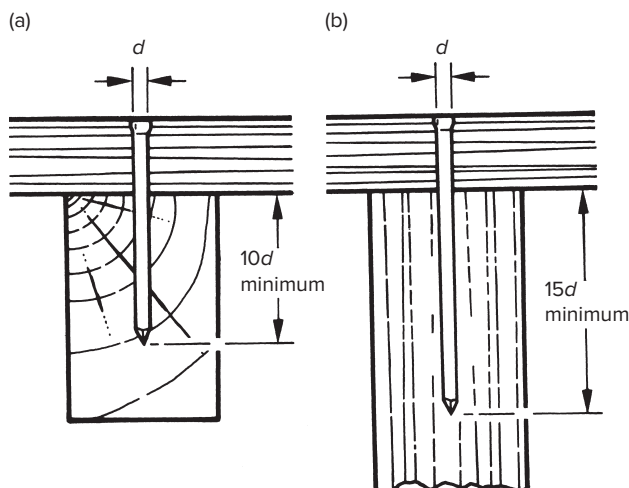
Staples are used for fixing wire strands to timber—for instance, in fencing (Fig. 9.8). To minimise the chance of the timber splitting, the staple is driven at an angle to the grain. Always choose the smallest staple to suit the wire.

Fig. 9.8 Staple

9.1.2 Nailing practice

To drive a nail, select a hammer of sufficient weight, grip it by the hand grip and swing the hammer freely (Fig. 9.9). Aim to strike the head of the nail squarely and with sufficient force to drive it home.

TIP Tapping at the nail with short light strokes and only sufficient force to bend the nail, but not enough to drive it home, can have only one obvious result.

Fig. 9.9 Hammering action**Fig. 9.10** Holding ability of nail: (a) into the side grain; (b) into the end grain

Nailing into end grain requires a nail to be longer than when nailing into cross grain, if the same holding power is required.

Figure 9.10 is a guide to selecting a nail of satisfactory length. Where the minimum depth of penetration for a nail cannot be achieved, the equivalent holding power may be obtained by using nails with a deformed shank, for example, Timberlok nails (see Fig. 9.7). When nailing into thin timber, extra holding power can also be obtained by **clenching** the nail (Fig. 9.11), whereby a nail long enough to protrude through the back of the materials being nailed is hammered in and bent over in the direction of the grain. The point is then punched back into the timber. Extra grip can also be obtained by dovetailing nails (Fig. 9.12), and increasing the strength of the nailed joint against a direct pulling force.

Skew nailing (Fig. 9.13) is widely adopted as a means of fixing structural members in timber framing. First, pull the two members firmly together and skew the nails at an angle somewhere between 45° and 60°. For finished work, complete the process of driving the nails with a nail punch to avoid damaging the timber.

Splitting the timber is one of the most common failures when nailing. Select a nail of a diameter that is no greater than required for the job in hand and avoid nailing too close to the edges. Stagger nails so that they are not in the same line of grain (Fig. 9.14).

Fig. 9.11 Clenching of nail

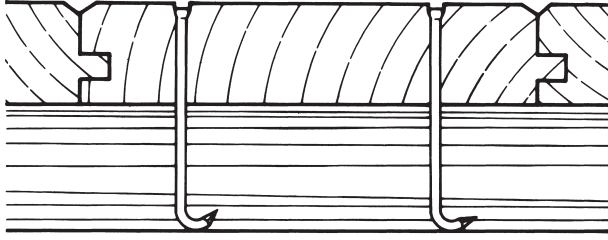


Fig. 9.12 Dovetailing with nails

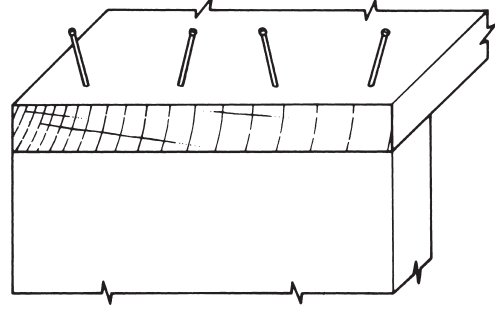


Fig. 9.13 Skew nailing

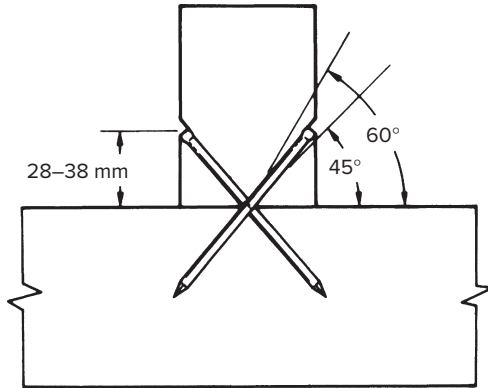
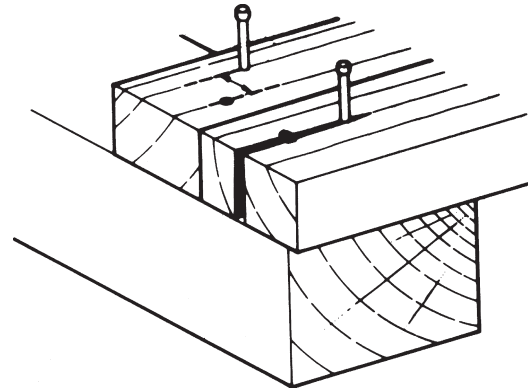


Fig. 9.14 Staggering of nails



A handy tip for nailing without splitting in a difficult situation is illustrated in Figure 9.15. Place the head of the nail on the timber and strike the point with the hammer. This makes an indentation that will later accommodate the nail head and which slightly flattens the point of the nail so that it will tend to punch its way through the fibres without separating them and splitting the timber. Reverse the nail and drive on the spot marked by the nail head.

If all else fails, it then becomes necessary to drill **pilot holes** for the nails in order to avoid splitting.

TIP Driving nails into hard timber can often be helped by some form of dry lubrication on the nail. Often the most convenient method is to stroke the nail through your hair a few times. Even the natural oils in your hair will provide just that little bit of lubrication needed to drive the nail successfully.

CHECK YOUR UNDERSTANDING

1. By what means do nails achieve their holding power when driven into timber?
2. When nailing into cross grain, how far should a 75×3.75 bullet head nail penetrate the final receiving piece of timber to obtain a satisfactory grip?
3. What are three ways in which the holding power of nails can be increased when the minimum amount of penetration cannot be achieved?
4. For what purpose would a lattice head nail be used?

9.1.2.1 Nail punch

The nail punch is an essential accessory when nailing and consists of a tapered point that is slightly hollow (Fig. 9.16). This prevents the punch from slipping off the nail head. In finished work, nail heads are punched just below the surface and the hole is filled during the painting or other finishing process.

Fig. 9.15 Flattening of nail effect (punching through)

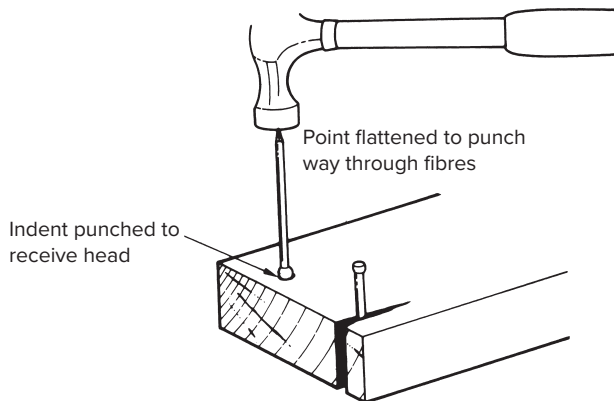


Fig. 9.16 Nail punches



TIP Nail punches come in a range of diameters. Choose the punch that will suit the nail being used.

CHECK YOUR UNDERSTANDING

5. What tool is used to push the head of a bullet head nail below the surface of the timber?
6. List two methods to prevent timber from splitting when nails are being driven close to the end of a piece of timber.

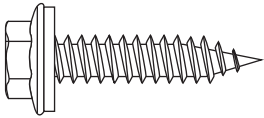
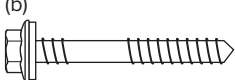
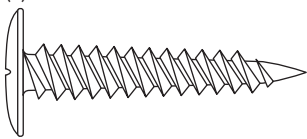
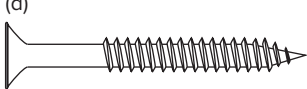
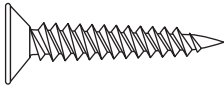
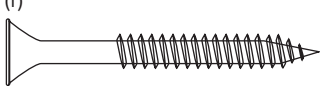
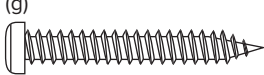
9.2 Identify the varieties of woodscrews and their application

Woodscrews provide great holding power, when correctly inserted, and are used in the assembly of work requiring firm, strong joints (Fig. 9.17). Unlike nails, screws can also be removed readily, without damage to the surrounding material, and are particularly useful for the assembly of temporary work or for fixing metal fittings such as hinges, locks and similar items to timber that may require some adjustment. Screws can also be inserted without vibration, which could cause damage to the adjacent structure.

Woodscrews develop their holding power from the thread cutting its way into the fibres of the timber. They are unsatisfactory for screwing into end grain, as the thread will sever the fibres and the wood around the screw will crumble away. The size of a woodscrew is expressed as the gauge by the length. In general, use woodscrews in the range from 3G to 16G. The higher the gauge number, the thicker the screw.

The length of the screw is expressed in millimetres and is measured from the part of the head normally finishing flush with the surface of the timber to the point.

Fig. 9.17 Screw types

(a) 	Full thread and part thread For general fastening to timber or thin metal with and without seals, in zinc plate or mechanically galvanised to AS 3566 Class 3 or Class 4. Sizes available in 8g, 10g, 12g and 14g.
(b) 	Roofing and cladding screws For fastening roofing and walling profiles to timber and thin metal, with and without seals, incorporating special design features. Available in mechanically galvanised to AS 3566 Class 3 and Class 4. Sizes available in 12g and 14g.
(c) 	Wafer head screws For fastening into timber and thin metal where a flat head is required. Available in zinc plate or mechanically galvanised to AS 3566 Class 3 or Class 4. Sizes available in 8g and 10g.
(d) 	Bugle batten screws For flush fastening of heavy-duty timbers where a flush finish is required. Available in zinc plate and mechanically galvanised to AS 3566 Class 3 and Class 4. Size 14g.
(e) 	Countersunk head screws For fastening predrilled fixtures where a flush finish is required. Available in zinc plate or mechanically galvanised to AS 3566 Class 3 or Class 4. Available in 6g, 8g and 10g.
(f) 	Countersunk rib head screws For fastening sheeting/fibre cement where a self-embedding head is required. Available in zinc plate or mechanically galvanised to AS 3566 Class 3. Available in 8g and 10g.
(g) 	Pan head screws For general fastening to timber and thin metals where a raised head is required. Available in zinc plate in size 8g.

9.2.1 Shape of head

The head of the screw can be a countersunk head, round head or raised head, and is slotted or recessed so that the screw can be turned. The most common is the Phillips or **Pozidrive** head, but other types are available (Fig. 9.18). The screw heads can be aligned more easily and the finished appearance is more decorative. Plastic caps in different colours are available to fit the Pozidrive slot and can be used to cover the heads of countersunk screws.

Screws are manufactured from steel or brass for most purposes, but for special uses there are also screws made in silicon bronze, monel metal, stainless steel and aluminium. The surface can be plain or galvanised, nickel plated, cadmium plated, zinc plated, Florentine bronze or brass plated.

Fig. 9.18 Types of screw heads

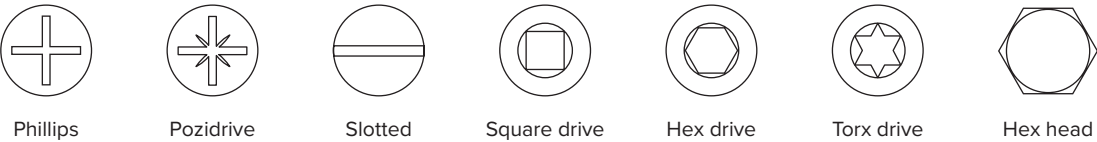
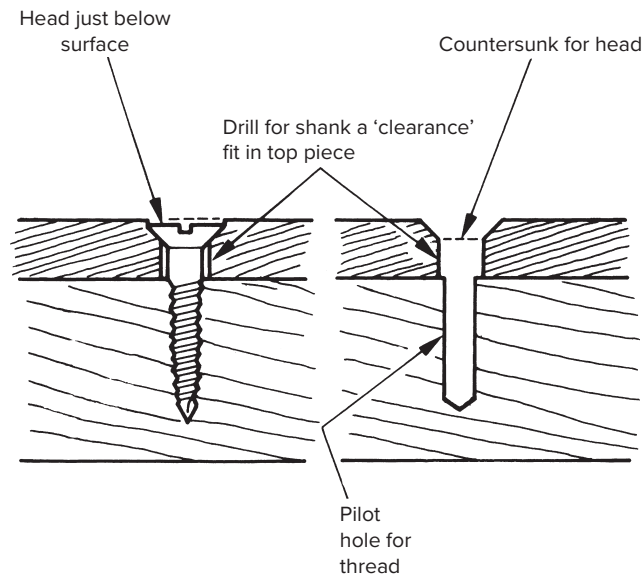


Fig. 9.19 Hole drilling for screws**Table 9.1** Woodscrew pilot holes

Gauge	Nominal diameter shank	Pilot hole for shank	
		mm	inches
3	2.40	2.5	$\frac{5}{64}$
4	2.75	3.0	$\frac{7}{64}$
5	3.10	3.5	$\frac{1}{8}$
6	3.45	3.5	$\frac{9}{64}$
7	3.80	4.0	$\frac{5}{32}$
8	4.20	4.5	$\frac{11}{64}$
9	4.50	4.5	$\frac{3}{16}$
10	4.90	5.0	$\frac{13}{64}$
12	5.55	6.0	$\frac{15}{64}$
14	6.30	6.5	$\frac{1}{4}$
16	7.00	7.0	$\frac{19}{64}$

grain and go in at an angle, so that the head will project above the face of the fitting (Fig. 9.20b). Screws inserted at an angle are a common cause of trouble with 'binding' in hinges.

When inserting countersunk screws into timber, the pilot hole must be countersunk using a **countersinking** bit so that the screw head can pull into the timber and finish just slightly below flush.

Screws will always drive more easily if the thread is lightly lubricated. Tallow or beeswax is sometimes used, but probably the most readily available dry lubricant is a piece of common soap rubbed lightly on the thread.

9.2.2 Drilling for woodscrews

When inserting woodscrews, it is essential to drill suitable pilot holes. The first hole for the shank of the screw must provide a clearance for the shank so that the joint can be pulled together (Fig. 9.19).

Table 9.1 gives a list of the appropriate drill sizes for pilot holes.

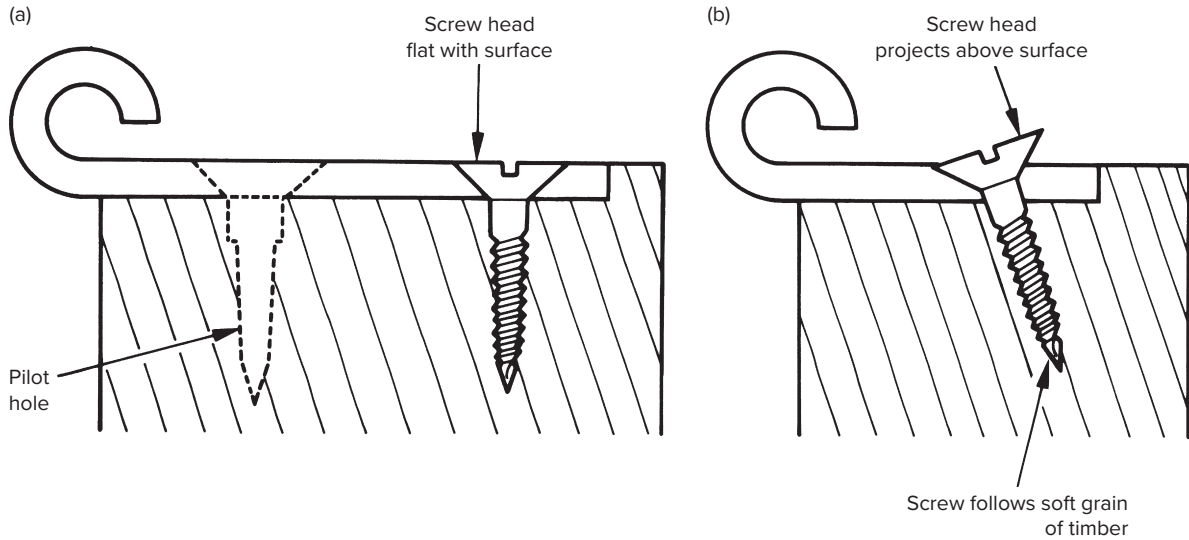
The diameter given for the shank of the screw has been rounded off to enable a quick comparison with drill sizes, but lies within the tolerances permitted and is sufficiently accurate to determine pilot holes in timber. The drill size is adjusted to enable the use of drills most likely to be carried by the carpenter in a metric or imperial drill set.

The second pilot hole for the thread of the screw is approximately equal to the core diameter of the thread. This permits the thread to cut its way into the timber in order to develop its holding power. As a general rule, the pilot hole for the thread in timber of average density is about half the diameter of the shank. Hard timbers may require a slightly larger pilot hole, soft timbers a little less; and in very soft timber, screws up to about 6G may be inserted quite satisfactorily without a second pilot hole.

When fixing metal fittings such as hinges and locks, it is always necessary to drill a small pilot hole so that the screw will go in straight and the head will lie flat in the face of the fitting (Fig. 9.20a). In some timbers, Oregon for example, when a pilot hole is not bored, screws will simply follow the soft

TIP If using flat head screws, it is considered neat practice to leave the slots in the heads of screws all running in the same direction, usually in the direction of the grain.

Fig. 9.20 Correct seating of screw: (a) correct; (b) incorrect



CHECK YOUR UNDERSTANDING

7. What size of drill would be used to drill a pilot hole for the shank of a 10-gauge woodscrew?
8. List at least three reasons why woodscrews would be used for fixing in preference to nails.

9.2.3 Coach screws

Coach screws are a range of large screws similar in principle to woodscrews, but with a hexagonal head that can be turned using a spanner or socket (Fig. 9.21). They are used to attach heavy metal fittings to timber, or timber to timber, where nailing or woodscrews would be inadequate.

The length and the diameter of coach screws are expressed in millimetres. The diameter is often described as 'M6', 'M8' and up to 'M20', which is the diameter of the shank in millimetres.

Drilling for coach screws first requires a hole for the shank that is a clearance fit and then a second hole for the thread. Drilling for an M10 coach screw in securing a heavy metal bracket to timber is shown in Figure 9.22. A washer is used under the head of the coach screw when it is pulling into the timber.

Lubrication will greatly assist the entry of the coach screw and also its removal, if necessary.

Fig. 9.21 Coach screw

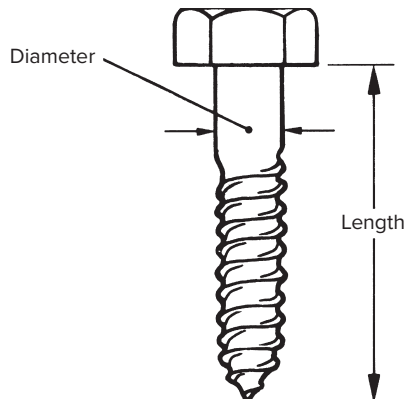
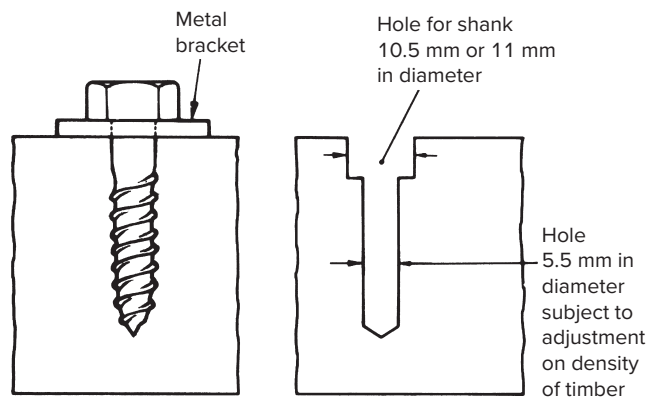


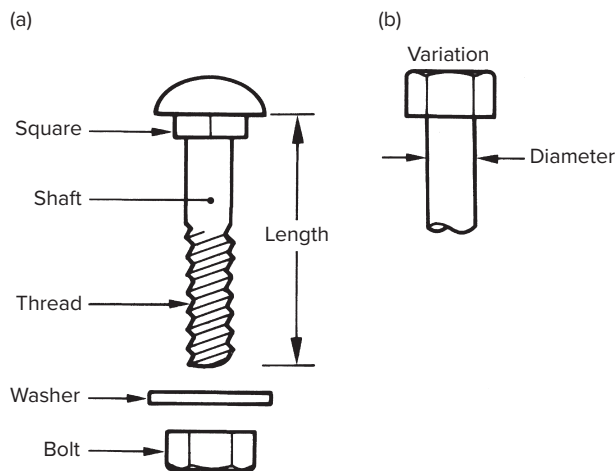
Fig. 9.22 Use of coach screws



WORKPLACE SCENARIO

With advances in battery technology, and the portability and power that a modern impact driver/battery drill now has, it is preferable today to use screwing connections and joints in many cases as the fixing method of choice. Until recently nails were generally preferred, due to the ease and speed with which they can be driven, either by hand or using a nail gun. However, the development of the impact driver and the greater holding power of screws have meant that screws are now preferred in many instances over nails.

Fig. 9.23 (a) Cup head bolt; (b) hexagon head bolt



9.3 Identify bolts, nuts and their uses

Bolts and nuts are sometimes referred to as carriage or coach bolts. They provide a fixing of maximum strength, used largely in construction work that is subject to movement or vibration.

In carpentry work, for use in timber, the most commonly used bolt is the cup head (Fig. 9.23). The bolt has a domed head with a square shank underneath, which prevents the bolt from turning as the nut is being tightened with a spanner. For some applications, the hexagon head bolt may be more suitable. For

protection against corrosion, bolts can be zinc plated or, for maximum protection in exposed locations, they can be heavily galvanised.

Bolts are described by the length × diameter × shape of the head, and surface finish. Length and diameter are measured in millimetres, listed as M6, M8, M10 up to M20, with a metric thread. Bolts are still available in imperial units (length and diameter given in inches), with a Whitworth thread.

TIP Be careful not to mix up imperial and metric nuts and bolts as they are not interchangeable.

A clear hole must be bored through the pieces of timber being joined with bolts, providing clearance for the shaft of the bolt so that the joint can be pulled tightly together. Washers are used under the nuts when pulling into timber; in soft timber a large washer may also be included under the head.

CHECK YOUR UNDERSTANDING

9. List at least four details that must be supplied when ordering bolts and nuts.

9.4 Know about associated tools used with fasteners

9.4.1 Screwdrivers

Screwdrivers have evolved through various designs; today most screwdrivers will have a blade 75 mm to 300 mm in length with a fluted plastic handle (Fig. 9.24). They are available in a range of head patterns such as flat, Pozidrive or Phillips head. Alternatively, screws can be driven using a battery-powered drill/driver or electric screw gun for which a range of screw tips are available (Fig. 9.25).

Fig. 9.24 Screwdriver

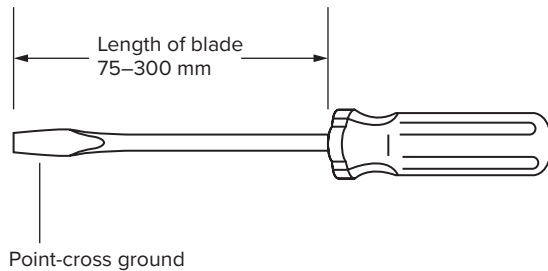


Fig. 9.25 Screw tips

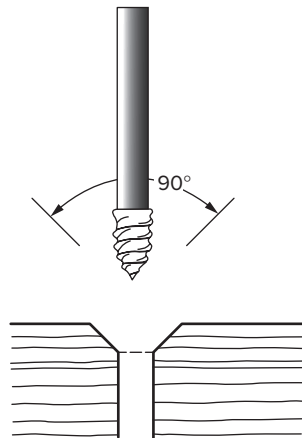


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CHECK YOUR UNDERSTANDING

10. List three different types of screwdriver.

Fig. 9.26 Countersink bit



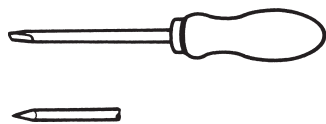
9.4.2 Countersink bit

The countersink bit is used to recess a hole to accept a countersunk screw (Fig. 9.26). The rose countersink is the most common design and its diameter varies from 9 mm to 15 mm.

9.4.3 Bradawl

When inserting very small screws (up to about 4G) in soft timbers, a pilot hole can be made quickly using a bradawl (Fig. 9.27). To prevent the timber from splitting, the bradawl has a small chisel point or square shank sharpened to a point and is twisted up to 45° in each direction to drill a starter hole. It may be found that small screws can be positioned more accurately using a bradawl sharpened to a round point, provided care is taken not to split the timber.

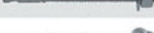
Fig. 9.27 Bradawl



9.5 Identify masonry anchors

This type of hardware is very important in the building industry. The hardware allows other materials such as timber and steel to be attached to masonry products/components. There are numerous types of anchors and each one has a different application. The Hilti chart in Figure 9.28 shows examples of some of the anchors available.

Fig. 9.28 Various types of anchors available for different applications

		Size		Head Type				Base Material				Corrosion Resistance		Features		Approvals	
		Minimum Size Diameter	Maximum Size Diameter	Stud (Externally Threaded)	Flush or Internally Threaded	Hex Bolt	Round/Mushroom	Concrete	Lightweight Concrete	Grout-filled Block	Hollow Block/Brick ¹²	Hot-dip Galvanized Steel	304 Stainless Steel	316 Stainless Steel	Seismic	Cracked Concrete (per ICC-ES) ¹³	1: FM 2: UL 3a: ICC Concrete 3b: ICC Grouted Masonry 3c: ICC Hollow Masonry 3d: ICC Unreinforced Masonry 4: COLA 5: Miami-Dade 6: NSF 61 7: LEED 8: 2010 FBC 9: 2009 IBC 10: 2012 IBC
HDA Undercut Anchor		M10	M20	■				■	□			■ ¹⁵		■	■	■	3a, 4, 7, 9, 10
HSL-3 Heavy-duty Expansion Anchor		M8	M24	■		■		■	□						■	■	3a, 4, 7, 9, 10
KWIK Bolt-TZ Expansion Anchor		3/8"	3/4"	■				■	■	□			■	■	■	■	1, 2, 3a, 4, 7, 9, 10
KWIK Bolt-3 Expansion Anchor		1/4"	1"	■	■	1/4"-3/8"		■	■	■		3/8"-3/4"	■	■	■	A-B	1, 2, 3a, 3b, 4, 7, 8, 9, 10
KWIK Bolt-V Expansion Anchor		1/4"	3/4"	■				■	■	■							2, 7
KWIK HUS-EZ Screw Anchor		1/4"	3/4"			■		■	■	■					■	■	3a, 3b, 4, 7, 8, 9, 10
KWIK HUS Screw Anchor		3/8"	3/4"			■		■	■	□							7
HCA Reusable Coil Anchor		1/4"	3/4"			■	1/4"	■	□								-
HLC Sleeve Anchor		1/4"	3/4"	■	■	1/4"-3/8"	■	■	□	■	■		■				7
KWIK HUS-EZ-I Screw Anchor		1/4"	3/8"		■	1/4"-3/8"		■	■						■	■	1, 3a, 4*, 7, 8, 9, 10
HDI/HDI+/HDI-L+ Drop-in Anchor HDI+ Stop Drill Bit with Setting Tool available		1/4"	3/4"		■			■	■				■	303 SS			1, 2, 7
HDI-P Flush Anchor		3/8"	3/8"		■			■	□								7
HCI Cast-in Anchor Color Coded: ● ● ● ● ● ●		1/4"	3/4"		■			■	■								1, 2, 7
KWIK-CON II + Concrete and Masonry Screw		3/16"	1/4"		■	■		■	□	□	■			■	410 SS		5, 7

Hilti (Aust.) Pty Ltd

CHECK YOUR UNDERSTANDING

11. Using Figure 9.28, which anchors can be used in hollow block/brickwork?

9.6 Understand adhesives and their application

Glues play an important role in joining timber and other construction materials. Adhesives can help provide additional strength to a joint that has been constructed using mechanical fasteners such as screws or nails. Alternatively, glues and adhesives can be used without the assistance of mechanical fasteners; if this method is used, it is imperative that the manufacturer's specifications are followed in the application of the adhesive to achieve maximum strength.

Consult the manufacturers' instructions prior to application, taking note of drying times, required ambient temperatures, clamping requirements and pressures, factors affecting adhesion such as moisture or dust and any potential occupational health and safety (OHS) hazards that could be encountered when using the particular adhesive.

Many products on the market have been developed for specific situations. For example, interior use, exterior use, marine use, etc.

Student research

Research four different types of adhesives commonly used in the construction industry. What application are they designed for, how do they cure and how should they be applied?

End-of-chapter activity

Please refer to Chapter 10, Carpentry power tools, for this activity.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684.2—2010
Residential
timber-framed
construction

AS 5216:2018
Design of post-
installed and cast-in
fastenings
in concrete

National
Construction
Code (NCC)

AS/NZS
2699.2:2000
Built-in components
for masonry
construction—
Connectors and
accessories

Tradie talk—Smack a nail into it to hold it

Chapter 10

Carpentry power tools

Learning Objectives

- LO 10.1 Establish a power supply**
- LO 10.2 Safely handle a portable power saw**
- LO 10.3 Safely use a mitre saw**
- LO 10.4 Safely use an electric drill**
- LO 10.5 Safely use a portable jig saw**
- LO 10.6 Safely handle a portable power planer**
- LO 10.7 Safely use an electric sander**
- LO 10.8 Safely use a portable electric router**
- LO 10.9 Identify battery-powered tools**
- LO 10.10 Safely use nail guns and air compressors**
- LO 10.11 Safely use an angle grinder**
- LO 10.12 Safely use a drill press**
- LO 10.13 Identify load-handling equipment**
- LO 10.14 Use powder-actuated tools**

Introduction

Power tools are an important part of the building industry. Without them it would take longer to perform basic tasks, which would therefore extend the time it takes to construct a building.

In this chapter, you will learn how to identify various power tools and plant. You will learn how to prepare tools for use, including basic maintenance plus changing blades and cutters, as well as identifying the dangers associated with the electricity supply and with tools and equipment, so you

Fig. 10.1 Domestic temporary power pole

Courtesy of Super Safe Hire

will become confident and proficient in using them. It is always a good idea to establish a safe operating procedure (SOP) before using any power tool. (A generic SOP for power tools can be seen in Figure 1.3.) Remember always to refer to the manufacturer's specifications prior to using a tool for the first time.

10.1 Establish a power supply

All construction worksites require an electricity supply for lighting, operating the power tools and the plant, and heating and cooling. The power can usually be found in a temporary power board cabinet for larger construction sites or on a temporary power pole, which is usually found on domestic building sites (Fig. 10.1 and 10.2). It is important that power leads do not extend more than 30 m. Multiple supplies are therefore required on large construction sites.

The mains power supplied is generally 240 volts (V), 50 hertz (Hz); portable power tools suitable for use with this supply will have these figures indicated on a plate attached to the machine.

These temporary power supplies must be installed by a qualified electrician and tested according to state or federal requirements. In addition, the power supply must be fitted with a safety switch.

Fig. 10.2 (a) and (b) Commercial temporary power boards

Courtesy of DNN Australia Pty Ltd

10.1.1 Portable generators

Portable generators (Fig. 10.3) can provide a source of electric power in situations where mains power is unavailable, but some precautions must be observed to ensure their safe and efficient operation. Always check that the quality of electricity being generated by a portable generator is suitable for the efficient operation of the tools in use. It must have a power output sufficient to drive all of the power tools in use at any one time. Refer to the plate attached to the machine for the power required to operate it efficiently, which will be expressed in watts (W) or amperes (A), but most probably both.

Some generators may have a built-in circuit breaker, which will protect the operator by cutting off the power supply should a fault develop in any of the power tools or appliances in use. For example, take the tools shown in Table 10.1. As the total load of these tools is 3100 watts or 13.6 amps, a suitable generator must have this output in watts or amps.

Fig. 10.3 Portable generator



© canoness/123RF.com

Table 10.1 Requirements of common power tools

Tool	Watts		Amps
One power saw	1750	Allow	7.5
One planer	750	Allow	3.5
One hammer drill	600	Allow	2.6
Total	3100	Allow	13.6

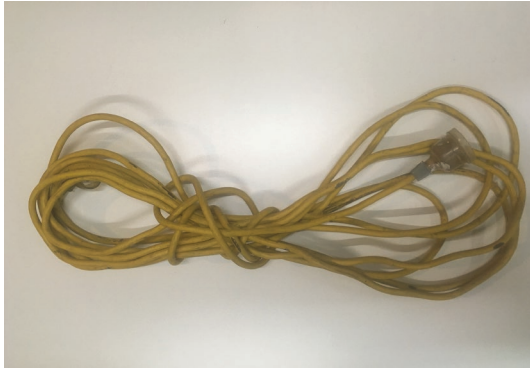
TIP Portable generators generally have a petrol motor as their power source. With this in mind, check to see if the motor is a 2-stroke motor (oil and petrol mixed together) or 4-stroke motor (straight petrol and oil located in a separate sump). Ensure the correct fuel is used and that the oil is appropriate for the machine. Refer to the manufacturer's instruction before operating any machine you are unfamiliar with.

10.1.2 Residual current device (RCD)

Residual current devices (RCD), sometimes referred to as *safety switches*, are mandatory on all building sites. They protect the workers from being electrocuted by monitoring the current flowing in the active and neutral wires supplying the item of equipment.

Under normal circumstances, the current flowing in the two wires is equal. When a fault in the circuit or an accident with the equipment occurs, an imbalance in the current flowing in the two wires is detected by the RCD, which automatically cuts off the power before injury or damage can happen.

RCDs are essential if the work is carried out in an older building as not all buildings have had safety switches installed. So, as a rule, plug the RCD into the wall socket and then connect all of your tools to the RCD so you will be protected from being electrocuted if something happens.

Fig. 10.4 A power lead

Courtesy of Daniel Bonnici

10.1.3 Power leads

Power leads are an important tool for any tradesperson as they allow power to be brought to the area where it is needed (Fig. 10.4). They come in various forms, lengths, thicknesses and ratings. When purchasing power leads, ensure that they are suitable for the tools to be connected to them and will allow enough current through to enable the tool to work properly.

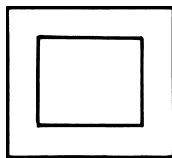
Power leads should:

- be completely unwound when in use—if not they can heat up and melt
- be wound in big loops when in storage (avoid tying knots in them as this will put stress points on the lead and can cause cracking in the lead casing)
- always be checked before use to make sure the internal wires are not exposed, especially at the ends where the plug is connected (if the internal wires are exposed, do not use the lead and get an electrician to check it)
- never be pulled out from the plug by the lead as this will stretch the lead and will pull the casing out of the plug connection
- never be rolled up when plugged in—always unplug the lead first and then roll it up.

10.1.4 Double-insulated and all-insulated appliances

All-insulated appliances are totally enclosed in a casing made of insulating material and have no external metal whatsoever. This form of construction eliminates the need for further earthing or for a second internal barrier of protective insulation.

Portable electric tools of the double-insulated or all-insulated types must not be earthed and so are fitted with a two-core flexible cord. If a three-pin plug is fitted to a two-core lead, no connection is made to the earth terminal of the plug.

Fig. 10.5 The double-insulated symbol

Portable electric tools of the double-insulated type are easily identified as they are required to be clearly marked with the words 'double insulated' or with the symbol shown in Figure 10.5. Some older double-insulated tools may be marked 'do not earth double insulated'.

All-insulated tools are also marked 'double insulated' and can be identified by the casing of non-metallic material.

10.1.5 Electrical hazards checklist

1. Are construction switchboards properly constructed and set up?

Ensure electricity switchboards are of robust design and build and are mounted securely. Where electricity metre and fuse assembly is fitted, make sure the switchboard has an endorsed service fuse locking device.

2. Are there enough switchboards for the job?

Switchboards should be spaced according to the maximum allowable lengths of the extension leads being used. The maximum lengths of the most common types of flexible leads are listed below (generally the shortest length of lead should be used when setting up switchboards):

- 25 metres for 10 amp extension lead with 1.0 mm² flexible cables cores
- 35 metres for 10 amp extension lead with 1.5 mm² flexible cables cores

- 5 metres for 15 amp extension lead with 1.5 mm² flexible cables cores
- 40 metres for 15 amp extension lead with 2.5 mm² flexible cables cores.

3. Are the correct socket outlets being used?

Check that only 240 volt socket outlets with double pole switches are used on relocatable structures and portable equipment.

4. Are portable outlet devices suitable?

Double adapters and other types of domestic multi-plug power boards are not suitable for use on construction sites.

Only use multi-plug portable devices that comply with AS/NZS 3105:2007 (Approval and test specification—Electrical portable outlet devices) and are the industrial type fitted with over current and RCD protection.

5. Is construction cabling identified and protected from mechanical damage?

Make sure construction cabling is clearly identified and has protection where there is a risk of mechanical damage.

6. Are electric tools and flexible leads in a safe condition?

Ensure that electric power leads and tools brought on-site are suitable and in good condition.

- Use only heavy-duty type extension leads and Australian-approved power tools.
- Have leads and tools inspected, tested and tagged by a suitable qualified person at intervals of three months; keep a register of inspections.
- Visually inspect leads and tools for signs of damage before use.
- Make sure unserviceable tools or leads are immediately withdrawn from service.

7. Have Certificates of Electrical Safety been issued?

Ensure the electrical contractor provides you with Certificates of Electrical Safety for all construction wiring, including switchboards.

8. Has the electrical installation been tested?

The electrical installation, including all construction wiring and switchboards, needs to be inspected and tested by a licensed electrician or electrical inspector before use and re-tested every six months for the duration of the project.

9. Are RCDs (safety switches) fitted and have they been tested?

Ensure that all fixed and portable RCDs are tested for tripping current and time by a licensed electrician every calendar month while used on-site. The tripping function of portable RCDs should be checked before use by operating the RCD's test button.

10. Are portable generators suitable?

If portable generators are used on-site, ensure the generator:

- is fully serviceable and has been properly maintained where supplying a fixed installation
- is installed by a licensed electrician.

11. Are extension leads being used safely?

Check that leads are not lying in mud or water, or in areas where they can be damaged or become tripping hazards. Use stable, insulated lead stands to keep them above head height. Do not allow leads to be wrapped around scaffolds or falsework; use s-shaped off-cuts of steel reinforcing bar sheathed in cut-off lengths of garden hose instead.

12. Are plant and temporary structures a safe distance from powerlines?

Make sure there is always a safe distance between live powerlines and cranes, concrete booms, earth-moving equipment, elevating work platforms, hoists, scaffolds, falsework and portable ladders by strictly observing 'no go zone' safe clearances.

13. Is electrical installation and repair work being done safely?

Make sure that all electrical installation work and any repairs to the electrical installation are undertaken only by licensed electricians working for registered electrical contractors.

This checklist is a summary of one found on the WorkSafe Victoria website. To view the complete list, visit www.worksafe.vic.gov.au.

CHECK YOUR UNDERSTANDING

1. What device should be fitted to the electricity supply to ensure the safety of workers? What does it do?
2. How often should leads and power tools be tested and by whom?
3. Are power leads allowed to lie on the ground?

10.2 Safely handle a portable power saw

The portable power saw is one of the most used tools by carpenters. The size of a saw is expressed as the diameter of the largest saw blade the machine will accommodate; with only minor variations, the commonly available sizes are 160, 185, 210 and 235 mm. When selecting a saw for a particular purpose, it is necessary to consider its maximum cutting capacity, when the blade is at both 90° and 45° to the base. For example, a 235 mm saw at 90° may have a maximum depth of cut of 84 mm, or 58 mm at 45°.

The parts of a portable saw are shown in Figure 10.6. The saw blade is coupled to the motor by a series of gears, and cuts as it rotates towards the saw base. A chute ejects the sawdust to the side. The base can be tilted at an angle of between 45° and 90° to the saw blade and is locked in place. The depth of cut can also be varied by an adjustment knob, usually located at the back of the saw, which allows the base to pivot on a point at the front, and to be raised up or down and locked into position.

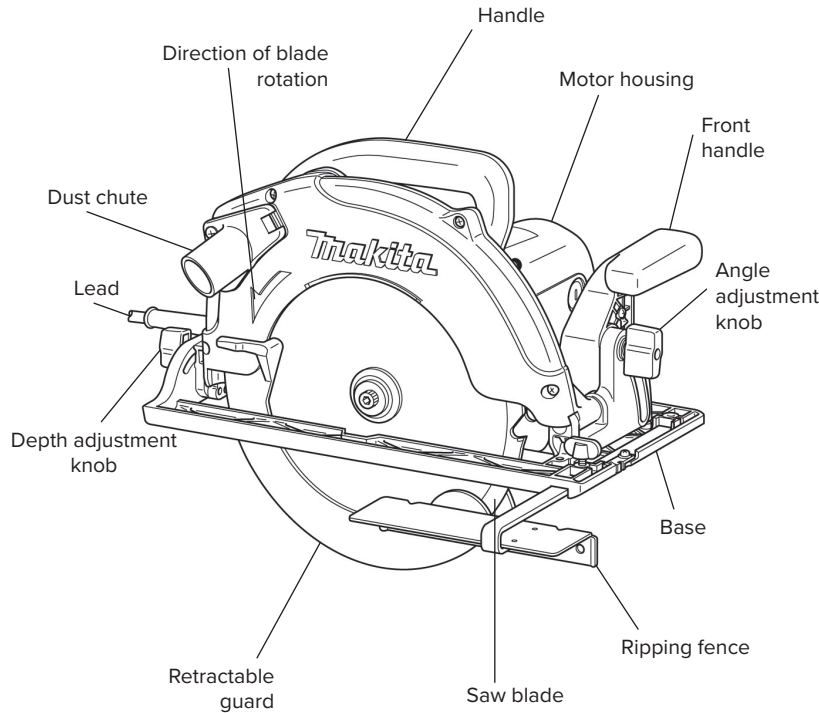
The retractable guard is an important safety feature. This will retract automatically as the cut is started and spring back into position at the conclusion of the cut. The guard must always be kept in good working order, and never be held back, leaving the blade exposed. Power saws incorporating a riving knife behind the saw blade, which will prevent the saw cut from closing on the blade and the saw 'kicking back' dangerously, are also available.

A moulded handle also contains the starting trigger. The larger models have a second handle to provide greater control of the saw.

WORKPLACE SCENARIO

Back when I was an apprentice, I was doing a fit-out for a new fast food restaurant. The site foreman asked me to cut some large holes in pieces of plywood. When I went to my van, I realised I did not have my jig saw with me. The holes had to be cut urgently as some other tradies were waiting to finish this particular job. So, with youthful exuberance, I came up with the bright idea of using my power saw to do the job. I managed to cut some rough, round-shaped holes, but the way in which I had to do the job was extremely dangerous. I was lucky no one saw me and that I didn't injure myself. With hindsight, I should have tried to borrow a jig saw or bought a cheap one from the local hardware store. The moral is, always use the tool as it was designed to be used. Lots of things seem like a good idea at the time but the consequences could be horrific.

Fig. 10.6 Circular saw



Courtesy of Makita Australia

10.2.1 Circular saw blades

There are a number of saw blades available for use with the powered circular saw and these are designed for different purposes. Teeth are shaped to cut with maximum efficiency under a variety of conditions. To describe a particular blade, it is necessary to provide the following information:

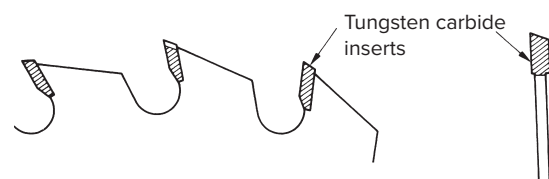
1. the outside diameter of the blade
2. the diameter of the centre hole (also called the **bore**), which, of course, must fit the spindle of the machine; sometimes blades are sold with a large centre hole and adapter rings to reduce the size of the hole to suit various machines
3. the number of teeth on the blade.

For example, a blade for a particular machine may be described as 'carbide tipped, 235 × 25 × 40 tooth', or as 'a cross-cut blade, 160 × 20 × 120 tooth'. One of the types of blades in general use is discussed in section 10.2.1.1. Not every type of blade may be available to fit any particular machine, but manufacturers usually provide details in the literature supplied with the machine.

10.2.1.1 Tungsten-tipped blade

The tungsten-tipped blade consists of a saw plate made from tough, high-quality steel with inserts of tungsten carbon alloy welded in to provide the cutting points (Fig. 10.7). The blades' teeth are ground to close tolerances and will give a very smooth cut. It is claimed that these teeth will last approximately 40 times longer than a traditional steel-toothed blade before they need to be resharpened, but they must then be returned to the saw doctor for reconditioning. Take particular care not to hit hard objects with the teeth as the tungsten carbon alloy is extremely hard and can chip easily or an insert can be knocked out completely.

Fig. 10.7 Tungsten-tipped saw blade



The number of teeth on a tungsten-tipped blade varies considerably. Blades with greater numbers of teeth can be used for the clean cutting of plywoods, etc. Blades with fewer teeth are suitable for ripping and more general building work where a clean cut is not required.

10.2.1.2 Changing the saw blade

To change the saw blade, first disconnect the saw from the power supply. Check whether the particular saw is fitted with a shaft lock. If it is, rest the saw on the bench and press the lever to engage the lock. Using a correctly fitting spanner (usually supplied with the saw), undo the bolt and remove the **collar** holding the saw blade.

If there is no **shaft lock**, lay the base of the saw on a flat board, retract the guard and press the blade against the edge of the board to stop the blade turning. Using the appropriate spanner, remove the bolt and collar holding the blade. The blade is then lifted and removed through the slot in the base plate.

Replacing the blade is the reverse operation, taking care that it will rotate in the right direction. Looking at the machine from the blade side, the saw blade revolves in an anti-clockwise direction and the teeth on the front edge will be moving up towards the base. Saw blades commonly have an arrow indicating the direction of rotation and this should be facing the outside and be visible when the blade is fitted. Replace the collar and bolt, and tighten with the spanner.

10.2.2 Range of work

10.2.2.1 Straight cross-cutting

1. Support the timber to be cut on stools in such a way that it will not collapse and jam against the saw blade as it is cut. Beware of long unsupported ends, which may cause overbalancing or splitting of the timber. Restrain the timber from moving: a cramp or cleats nailed to the stools will provide a stop and prevent the timber from moving away or rotating as the cut is made.
2. Adjust the depth of cut of the saw, so that it will project approximately 6 mm through the bottom of the work (Fig. 10.8). Plug the saw into a power point and switch the power point on.
3. Grip the saw firmly by the grips provided and lay the base on the timber at the start of the cut. On the front of the saw base there are two notches (refer to the instruction manual). One, usually the most conspicuous, is the guide for following the line with the saw cut when the blade is set at 90° to the base.

Fig. 10.8 Depth of cut

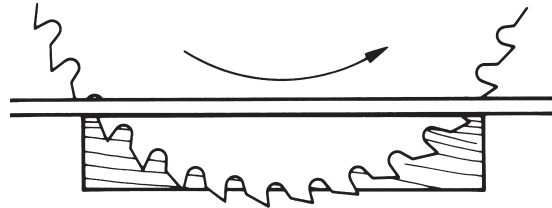
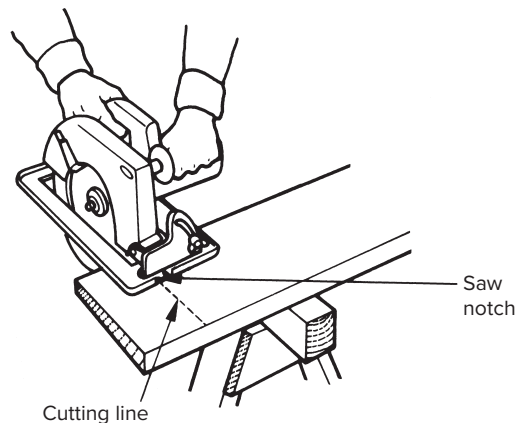


Fig. 10.9 Showing the saw notch and cutting line



The second notch is the guide for following the line when the blade is set at 45° to the base. When the blade is set at angles of between 45° and 90°, sight over the saw and follow the line visually. In the example of straight square cutting shown in Figure 10.9, select the relevant notch and align it with the line marked for the saw cut.

4. With the blade clear of the timber, start the motor using the trigger switch and allow it to gain full speed before feeding it through the timber, following the marked line. The rate

of feed can vary depending on the size and nature of the material being cut. The best guide is to listen to the motor. If it tends to labour and slow down, reduce the rate of feed, but if the motor is running freely, the rate of feed can be increased provided the saw is kept under control at all times. It will soon be seen that the notch on the front of the saw base passes over the edge of the timber, and the line is lost from view before the cut is completed. With practice, there is usually no great difficulty in keeping the saw moving in a straight line to complete the cut. Once the cut is complete, release the trigger and let the blade come to a stop. **Never use your fingers to slow down the blade.**

When it is necessary to cut a number of pieces to the same length—wall studs, for example—it is faster and more accurate to lay a number of pieces side by side and clamp them together (Fig. 10.10). Square a line across and follow this line with the saw.

Fig. 10.10 Multiple cut

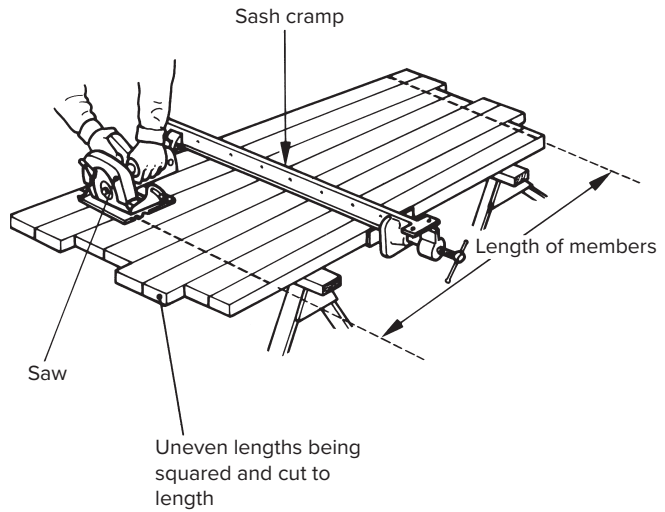
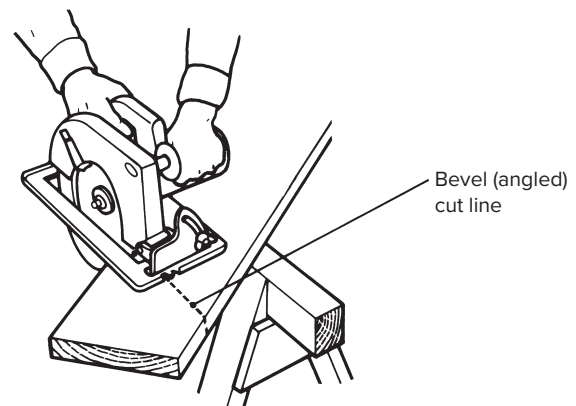


Fig. 10.11 Single bevel cut



10.2.2.2 Single bevel cutting

Single bevel cutting, such as the plumb bevel to roof common rafters, can be carried out without any further adjustment to the saw provided the timber is of the same thickness (Fig. 10.11).

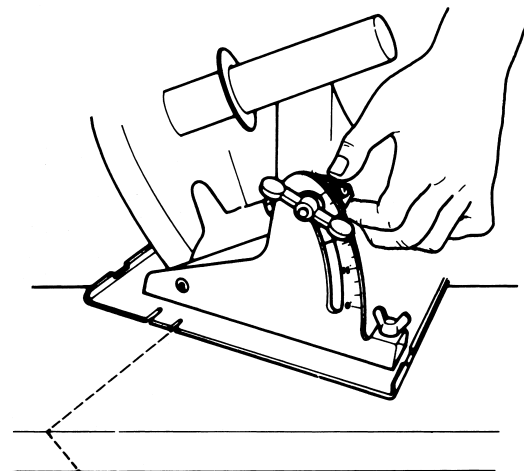
10.2.2.3 Compound bevel cutting

Compound bevel cutting is commonly encountered with the roof creeper rafters (see Chapter 21), which are bevelled in two directions—a plumb bevel across the face and an edge bevel. For most roofs, tilt the blade at 45° to the base for the edge bevel.

To perform the cut, the following steps should be followed:

1. Disconnect the saw from the power supply and tilt and lock the base to 45° , as indicated on the protractor scale on the saw (Fig. 10.12). The depth of cut must now be adjusted so that the blade will again project about 6 mm through the base of the work.

Fig. 10.12 Tilting and locking base



2. Connect the saw to the power and switch on the power.
3. Place the saw base on the face of the timber at the start of the cut and align the second notch on the saw (for 45° cutting) with the line to be cut (Fig. 10.13). Switch on the motor and, when full speed has been reached, feed the saw onto the timber with the guide notch following the line.

Sometimes, when the saw is tilted at an angle, the retractable guard will tend to bind at the start of the cut. In this case, before starting the cut, take the hand from the front handle and lift the guard by the lever provided (Fig. 10.14), for just sufficient time to start the saw feeding freely. Release the lever and again grip the front handle.

10.2.2.4 Ripping cuts

Ripping cuts can be made with the saw using the ripping **fence** as a guide—this can be used on either side of the saw. To set the fence up:

1. Disconnect the saw from the power and adjust the angle of the blade and the depth of cut—again about 6 mm through the bottom of the material.
2. Fix the ripping fence in position and adjust to the width of material to be cut (Fig. 10.15). Using a rule, measure from the fence to the side of the saw teeth.
3. Lay the board to be ripped across the saw stools. So that the saw blade projecting through the bottom of the board will not cut into the stools, pack it up with a piece of scrap material, held in place with small skew nails (Fig. 10.16). The board itself must be held securely with a clamp or pinned with a nail, whichever is suitable, without fouling the saw.
4. Reconnect the saw to the power and place the base of the saw at the start of the cut, with the ripping fence against the edge of the board. Start the motor and feed into the timber, keeping the fence against the edge. When making a long ripping cut, make sure there is sufficient power lead freely available so that the cut can be completed without having to stop to untangle the lead (Fig. 10.17).

This method can also be used to groove or rebate a length of timber, as shown in Figure 10.18. In this case, the blade is set to the depth required for the groove. A wider groove can be cut by gradually altering the setting of the fence, and performing successive cuts to build up the required width of groove.

Fig. 10.13 Compound bevel cut

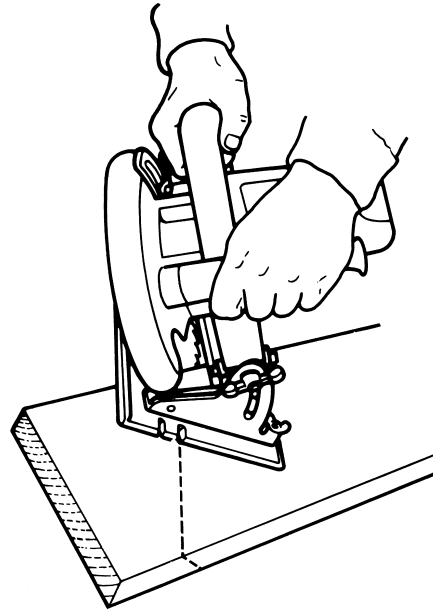


Fig. 10.14 Start of compound cut

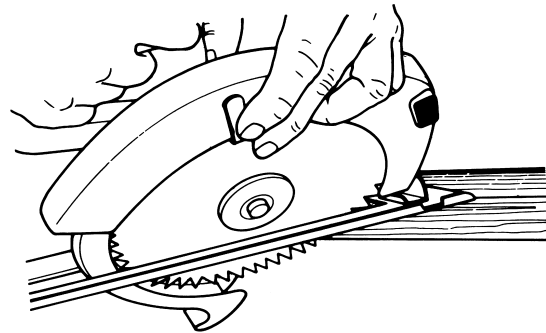


Fig. 10.15 Setting width

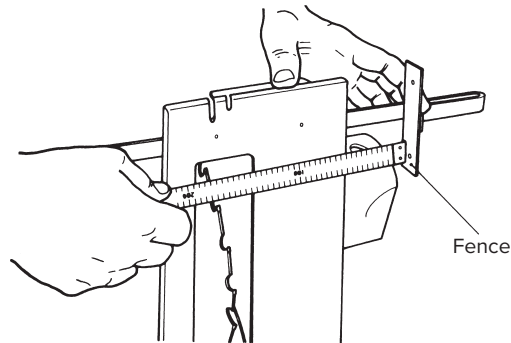
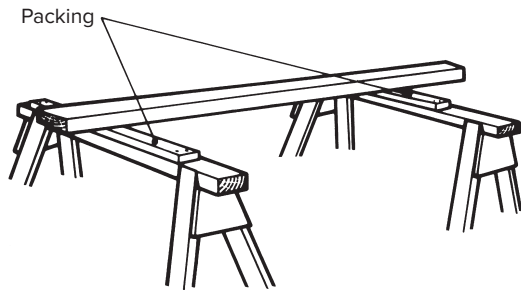
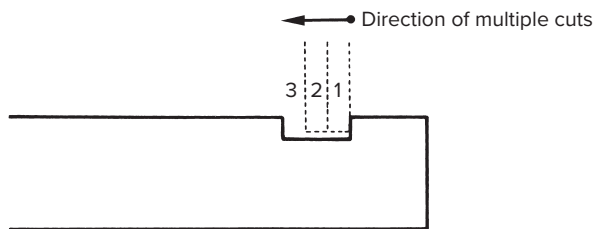
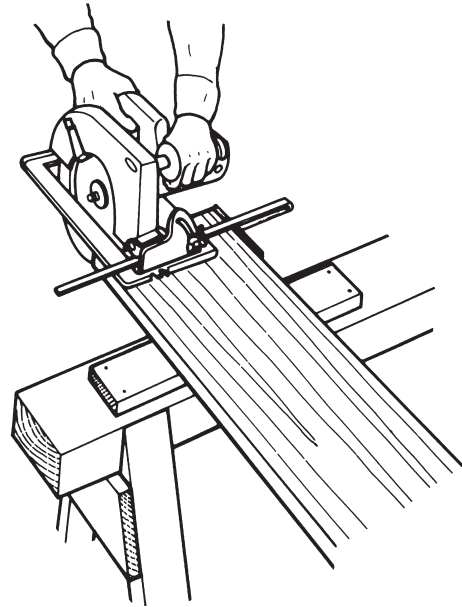


Fig. 10.16 Packing and support for base**Fig. 10.18** Grooving**Fig. 10.17** Ripping cut

CHECK YOUR UNDERSTANDING

4. List the two basic adjustments that can be made to the power saw. What is the effect of each?

10.2.2.5 Cutting sheet material

Sheet materials such as plywood, particleboard and the like are easily cut with a power saw. Select and fit a suitable saw blade for the purpose—a small-toothed cross-cutting blade. Fit the blade and adjust the depth of cut to no more than 6 mm below the sheet to be cut.

1. Large sheets of material must be supported in such a way that they cannot collapse when sawn through (Fig. 10.19). The bearers directly under the sheet will be marked by the saw blade projecting below the sheet but can be reserved for this purpose in the future and regarded as expendable over time.
2. For rough work, sheets can be cut freehand, marking a line and following it with the sawing guide located on the front of the base of the saw.
3. For more accurate work, where the cut is too far from an edge to use the ripping fence, a batten can be clamped across the sheet and used as a guide for the edge of the base plate in order to accurately cut a straight line.
4. For speed and convenience, the guide batten can be made up in the form of a T-square (Fig. 10.20). Screw the blade to the stock at 90°. Leave the stock a little long and when the first cut is made, it will be cut off to the correct distance from the saw blade to the edge of the base. The square can be held in place with small

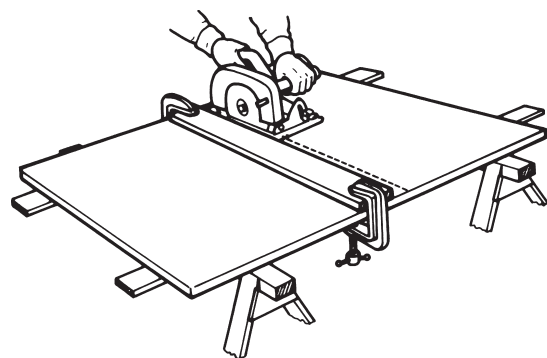
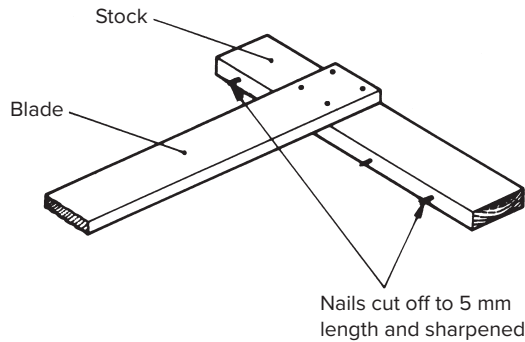
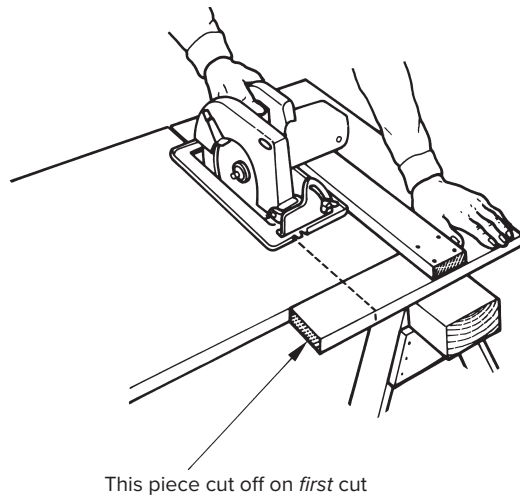
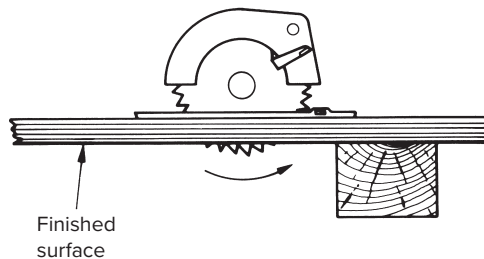
Fig. 10.19 Cutting sheet material—layout

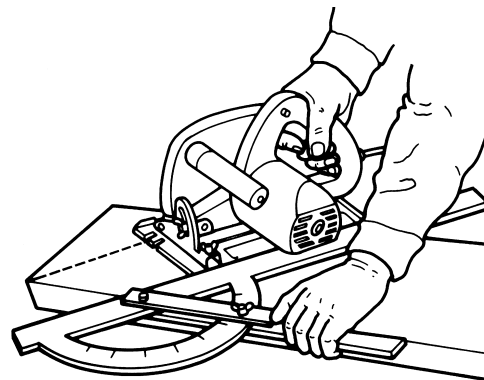
Fig. 10.20 Pinned square**Fig. 10.21** Sawing to the batten**Fig. 10.22** Cutting prefinished sheets (face down)

cramps or fine nails. Another method, particularly suitable for particleboard with a prefinished face, is to drive two nails into the edge of the stock, cut them off at about 5 mm long and sharpen the points. Located in position and lightly driven into the edge of the board, they will hold that end securely while a small G-cramp at the other end will secure a long length (Fig. 10.21).

5. When cutting prefinished sheets such as plywood panelling and veneered particleboard, keep the face side of the sheet down, and mark out and cut from the back of the sheet (Fig. 10.22). The saw teeth cut from the bottom as they rotate up towards the base and tend to leave splinters on the top of the cut. This often does not matter, but it is undesirable on finished surfaces. Setting the saw blade only 6 mm below the base plate helps to minimise the tendency to chip the top surface of the material. Furthermore, the prefinished surface will not be scratched by the saw base passing over it.

10.2.2.6 Protractor and saw guide

The protractor and saw guide is a valuable guide for the accurate cutting of straight and bevel cuts, as in Figure 10.23. Place the saw base on the start of the cut and align the relevant sawing guide with the line to be cut. With the protractor set to the required bevel, slide it up to the side of the saw base. Grip firmly and proceed with the cut, keeping the edge of the saw base against the arm of the saw guide.

Fig. 10.23 Use of protractor

SAFETY TIPS Power saw

1. Always disconnect the saw from the power source before making any adjustments.
2. Carry out all adjustments using correctly fitting spanners and ensure that all bolts or thumb screws are properly tightened before putting the saw back into service.
3. Ensure that all guards—particularly the retractable lower guard—are in place and working correctly at all times.
4. Check lead to ensure there are no nicks or exposed wires.
5. The circular saw is intended only for cutting in a straight line; never attempt to cut around a curved line as the saw may jam and ‘kickback’.
6. The most dangerous place near any circular saw is the area directly behind the blade. Neither the operator nor any assistant should ever be allowed to reach behind the blade to remove waste or support the timber, lest the saw kickback with serious results. Sawing machines incorporating a riving knife afford greater protection in this sensitive area.
7. Do not stand directly behind the saw blade when operating the saw: again, kickback could lead to a badly gashed leg.
8. Always use two hands and grip the saw by the handles provided and learn to control the saw from this position.
9. Keep the sole of the base plate in contact with the face of the timber being cut.
10. When using the saw above ground level, work only from a stable platform that has been erected to state or federal regulations and adopt a comfortable, well-balanced position.
11. Wear safety goggles/glasses and ear protection at all times. A dust mask or respirator may be needed depending on the material being cut. Keep the electric lead away from the saw blade at all times—some operators prefer to sling the lead over their shoulder for this purpose—and at the conclusion of the cut allow the saw blade to stop rotating before laying the saw down.

TIP A good explanation of kickback can be viewed at www.youtube.com/watch?v=R4kxQqBu3ME.

10.3 Safely use a mitre saw

The compound **mitre saw** is designed to dock timber off to length and can be adjusted to cut at right angles or any angle down to 45° (Fig. 10.24a). It has two adjustments: the saw can lay over to 45° and the saw’s table is adjustable to 45°. The slide compound saw has the added extra that it can cut timber generally up to 300 mm wide as well as being adjustable to cut compound angles (Fig. 10.24b). Some saws are designed so that the depth of the cut can be adjusted and slots or trenches can be made.

There are many makes and sizes available, and each can operate in a slightly different manner. Fitted with a suitable blade, the saw can quickly make smooth, accurate cuts and is widely used for interior fixing, fitting architraves, skirtings and so on. The larger models have the capacity to handle most structural timbers and when treated with care will give reliable service.

Ensure you are familiar with the saw and its features by reading the manufacturer’s instructions before you use it. The saw is safely guarded with a retracting lower guard, which is sometimes made of transparent plastic, leaving the saw blade visible. Ensure the saw is set up on a stable surface, for example, a bench with extension tables and adjustable stops.

Fig. 10.24 (a) A compound mitre; (b) a slide compound saw

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10.3.1 Operation of a mitre saw

1. To operate the mitre saw, unlock the rotating table and set the angle of the saw to the desired cutting angle. This can be square to the fence or up to 45° either side of square.
2. Feed the timber onto the saw table and hold firmly in position against the fence by hand. Use the clamping device for large sections of timber, aluminium or plastic.
3. Grip the handle and start the saw by pressing the on/off switch.
4. Lower the saw slowly but with a uniform pressure down on to the material and complete the cutting.
5. Release the downward pressure on the saw and it will return, by spring loading, to its raised position.

SAFETY TIPS Mitre saw

1. Ensure that you never cross your hands when using a mitre saw; that is, never hold a piece of timber with your left hand on the right-hand side of the saw and then operate the saw with your right hand. This action increases the risk of being cut by the blade of the saw if the saw jams.
2. Never rip using a mitre saw.

10.4 Safely use an electric drill

Electric drills, such as the one shown in Figure 10.25, comes in a range of sizes. The size is expressed as the maximum size of drill bit the chuck will accommodate. Common sizes are 8, 10 and 13. Most drills on the market today will take at least a 10 mm drill and this is a good size for a general-purpose machine. The maximum diameters for drilling in steel and wood are often included in the drill specifications, for example 'steel 10 mm and wood 21 mm'.

The speed at which the drill **chuck** rotates with no load is called the *no load speed* and is important. For general use in woodworking and building construction, the following speeds are given as a guide in the selection of a suitable machine. A number of drills on the market will, no doubt, meet these requirements.

On a two-speed drill, the speed is varied by a series of gears and a selector switch. A suitable drill would have a low speed of approximately 950 rpm (revolutions per minute) and a high speed of about 2300 rpm. This provides a speed suitable for most drilling operations in a variety of materials and a range of diameters.

Another option is the variable-speed drill, which has an electronic control: by exerting pressure on the trigger the speed can be varied. Most 10 mm drills will have a no-load speed of between zero to 1800 rpm and zero to 3500 rpm, and the larger-capacity drills will have a lower speed range. In some instances, this type of drill will have a reversing switch.

10.4.1 Hammer drills

Hammer drills can be used for normal drilling operations but also have a hammer feature, which is selected when drilling into any form of masonry (Fig. 10.26a). Special masonry drill **bits** are necessary. When this feature is selected, not only does the drill turn, but hammer blows are also delivered to the head of the drill bit. This gives it a superior performance when drilling into masonry such as rock, brick and concrete.

A number of hammer drill models are available and the features and capacity vary considerably. Some will have variable speed and reversing capabilities. A typical drill in this class may have a 10 mm chuck and a capacity to drill up to 13 mm in concrete. More powerful drills may have a 13 mm chuck and a capacity for drilling concrete of up to 20 mm in diameter.

Two-speed hammer drills also provide reliable service and are a popular choice. A typical two-speed drill will have a 13 mm chuck and a capacity to drill up to 19 mm in concrete.

Some hammer drills use a system called SDS (Special Direct System). The chucks and bits are of a special design, as shown in Figure 10.26(b). This system is designed for masonry drilling, and provides much better results than traditional straight shanked drill bits that are held rigidly in the chuck. No key is required to change the bits; simply insert the bit, twist and the bit is secured. The bit is loose once secured in the chuck. Some of these drills can also be used for chiselling into masonry as the rotation can be turned off and special chiselling bits can be installed.

Fig. 10.25 Electric drill

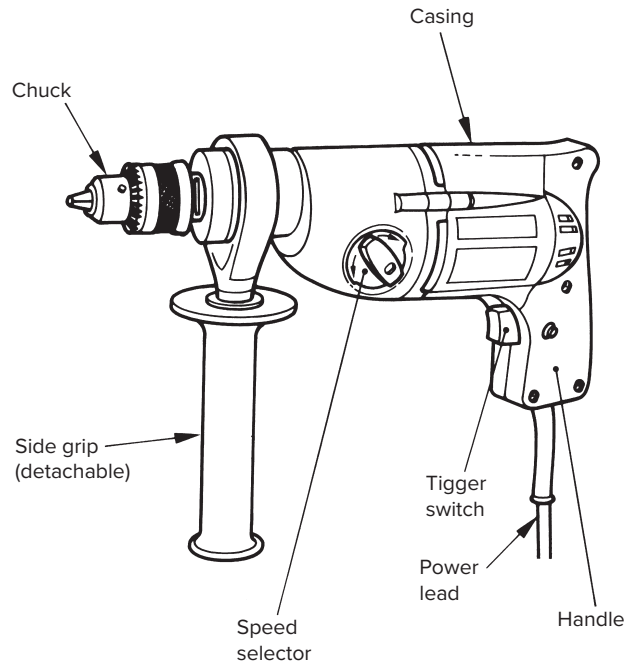


Fig. 10.26 (a) A hammer drill and (b) SDS bit



Hilti (Aust.) Pty Ltd

Hilti (Aust.) Pty Ltd

SAFETY TIPS Electric drill

The electric drill is not always regarded as a dangerous machine; however, observance of a few simple rules will avoid any possible mishap and many broken drill bits:

1. Hold all work firmly when drilling. Small work should not be held in the hand but clamped in a suitable vice.
2. Beware of the drill 'grabbing', particularly when drilling thin metal, causing it to be wrenched from the operator's hands, possibly causing injury. Always grip the drill firmly with both hands, using the detachable side handle where necessary for maximum grip.
3. Beware of any loose clothing or hair getting caught and wrapped around the drill, particularly when using large-capacity and hence more powerful drills.
4. Use safety goggles when drilling metal, and also use ear protection when drilling masonry or other hard materials.
5. Ensure the chuck is done up tightly and never leave the chuck key in the drill chuck; do not attempt to stop a coasting drill by hand.
6. Allow any coasting of a drill to stop before laying it down.
7. Never force a drill beyond its capacity, and do not run a large capacity drill at low speeds for extended periods or cover up ventilation holes with the hands. Lack of ventilation will cause the drill to overheat.

10.4.2 Accessories for drills

10.4.2.1 Twist drills

Twist drills are probably the most commonly used accessory to the drill, and are used for boring holes into wood, metal and various plastic materials (Fig. 10.27). Drilling machines are usually equipped with either a three-jaw keyless chuck or a chuck that is tightened using a chuck key.

Sizes vary from 1 mm to 25.4 mm in diameter with over 300 sizes in between. The woodworker has no need for this vast range of sizes, and drill sets are made up in a range of sizes to meet most requirements. Standard sets may consist of:

1. 12 drills from 1 mm to 6.5 mm in rises of 0.5 mm
2. 19 drills from 1 mm to 10 mm in rises of 0.5 mm
3. 25 drills from 1 mm to 13 mm in rises of 0.5 mm.

Drills are contained in a metal or plastic case and it is advisable to purchase a set this way to keep the sizes in order. Many sets may be purchased in imperial units and a set may range from $\frac{1}{16}$ " to $\frac{1}{4}$ ", $\frac{3}{8}$ " or $\frac{1}{2}$ " in rises of $\frac{1}{64}$ ".

Reduced shank drills permit the larger-sized drills to be used in a machine with a smaller chuck capacity, and can work satisfactorily in timber without overloading the machine.

Drilling into metal requires the hole centre to be marked with a centre punch (Fig. 10.28), sometimes included with the drill set. This engages the point of the drill and stops it wandering off-centre.

Fig. 10.27 Twist drills

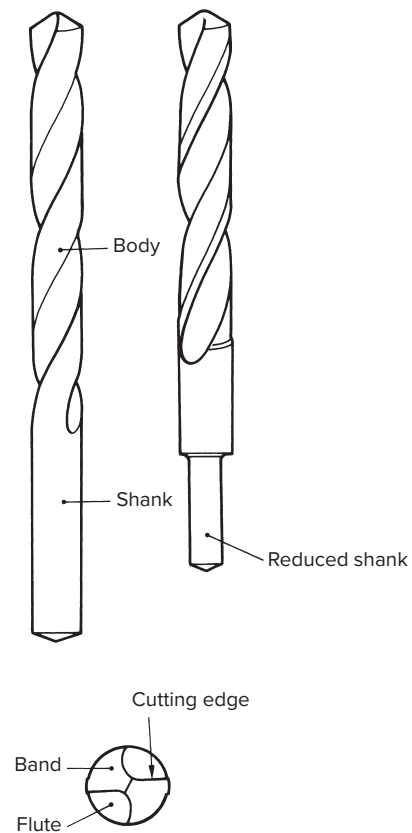


Fig. 10.28 Centre punch

A rough rule, to help select the correct speed on the drilling machine when using twist drill bits, is to use the higher speeds for smaller-diameter drills and the lower speeds for the larger drills.

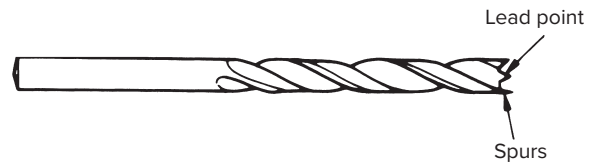
When drilling, particularly into metal, exert sufficient steady pressure on the drill to keep it cutting, otherwise it will simply rub on the metal, generating heat and blunting the drill. Whenever possible, add a lubricant such as light or soluble oil or metal-cutting fluid, which will help to keep the drill cool and performing efficiently.

Always keep drills sharp and remove any waste that becomes clogged in the flutes.

10.4.2.2 Dowel bit

Dowel bits are available in sizes of 3 mm to 13 mm for boring into cross or end grain (Fig. 10.29). They are similar in construction to twist drills but have two spurs and a centre point that prevents them wandering off-centre and following the grain.

Fig. 10.29 Dowel bit



10.4.2.3 Spade bit

Machine bits have either a *brad point* (Fig. 10.30) or a *screwed point*. Spade bits are available in sizes of 6 mm to 38 mm. The spade bit has the long brad point, which holds it positively on centre even when boring diagonally to the direction of the grain. There are two cutting edges, and flat surfaces are ground on the shank to be gripped securely in the three-jaw chuck without turning.

Spade bits are suitable for boring clearance holes for bolts and other fittings. They will not cut particularly clean holes and to work efficiently they must be able to rotate at a high speed, up to approximately 2000 rpm. Long spade bits are available up to 400 mm long in sizes from 6 mm to 25 mm.

Never bore a hole right through wood or particleboard with a flat bit as the wood will splinter away from the edge of the hole. When the tip of the bit emerges, turn the work around and bore from the other side.

Fig. 10.30 Spade bit—point tip (high speed) (a) rough cutter; (b) smooth cutter



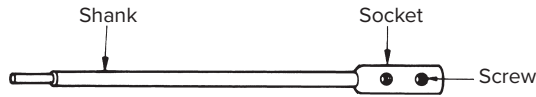
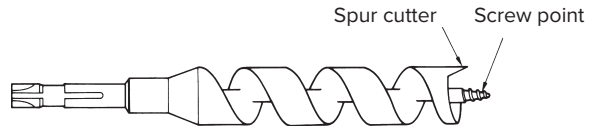
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10.4.2.4 Wood bit extensions

Wood bit extensions are available in 300 mm and 450 mm lengths and can be used to extend the reach of power wood bits over 16 mm diameter (Fig. 10.31). The shank of the standard bit fits into the socket of the extension and is locked with a grub screw. The other end of the extension fits the drill chuck.

10.4.2.5 Machine auger

The machine auger comes in sizes from 6 mm to 32 mm and is used for boring clean holes in timber; it is particularly useful in joinery and cabinet work (Fig. 10.32). The spur cuts the fibres cleanly, and the

Fig. 10.31 Wood bit extension**Fig. 10.32** Machine auger—screwed point (slow speed)

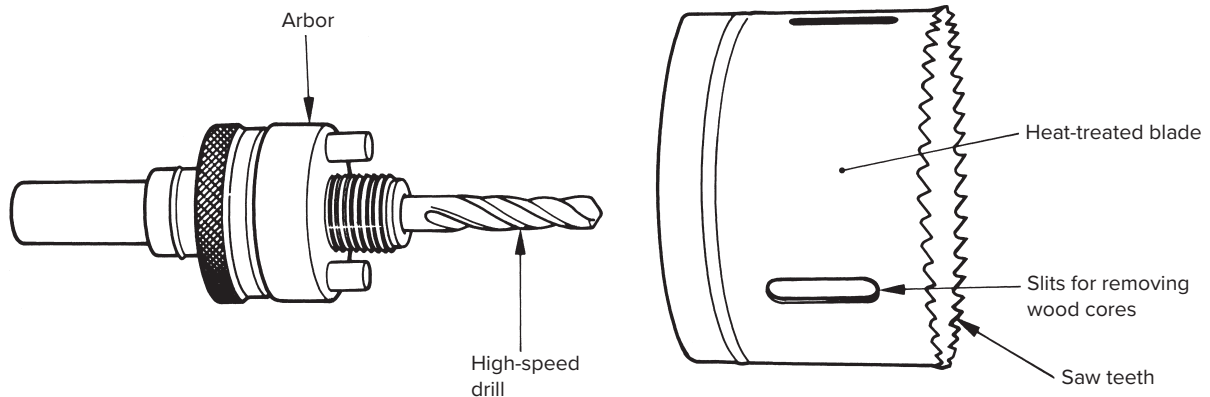
cutting edge removes the waste. It is operated at low speed, allowing the screwed point to draw the bit into the timber at its own pace. The shank is fluted to be gripped securely in the drill chuck. Normally machine augers are about 150 mm long, but they also can be obtained in a longer series, 400 mm in length, with diameters of 6 mm to 25 mm.

10.4.2.6 Hole saws

Hole saws are used for cutting round holes in wood, particleboard, sheet metal and fibreglass (Fig. 10.33). They consist of a centre drill to which a mandrill is attached. The mandrill contains a number of slots into which various diameters of curved saw blades can be fitted. Blades vary from 19 mm to 63 mm in diameter.

To use the hole saw, set the drilling machine to its slowest speed, mark the centre of the hole, and commence with the centre of the drill, feeding the saw into the timber with a light but firm pressure. Bore the hole from both sides; when boring in thin material, back up the sheet with a timber block and bore right through.

Another pattern of hole saw has its blade made up in the form of a cup that is fitted to an arbor held in the drill chuck. Blades range from 14 mm to 152 mm in diameter. They have a cutting edge of high-speed steel, and when used with a suitable drilling machine can cut a range of metal and wood.

Fig. 10.33 Hole saw

10.4.3 Masonry drills

Masonry drills are used when hammer or rotary drilling in masonry such as brick, concrete, stone, ceramic tile and similar materials (Fig. 10.34). The sizes available range from 3 mm to 25 mm. The larger sizes have a reduced shank that will fit a 10 mm or 13 mm chuck.

The tungsten carbide tip is brazed to a toughened steel shank, and is sharpened to grind rather

than cut into the masonry. Operate the drill at a slow speed and exert enough force to keep it cutting, otherwise it will simply rub against the masonry, generating extreme heat and blunting the drill. When drilling deep holes, withdraw the drill occasionally and clear away the spoil.

Fig. 10.34 Masonry drill

10.5 Safely use a portable jig saw

The portable jig saw is used for making closed cuts and circular cuts, and with the aid of a rip fence can be adapted to perform light ripping operations (Fig. 10.35).

The saw blade is approximately 60 mm to 80 mm in length, and moves up and down in a reciprocating action at up to 3700 strokes per minute (Fig. 10.36). Two-speed or variable-speed models permit the selection of a speed more suitable for the job in hand. Some models allow you to change the cutting action from straight (up and down) to an orbital straight line cutting stroke. This option can increase the speed of cut on some materials. Some models come with an inbuilt blower to blow the sawdust away and some models can be attached to a vacuum or extraction system to suck the dust up.

The high speed is selected for cutting timber, while the lower speeds, together with a suitable blade, are selected for cutting metals. Most models are capable of cutting timber up to 50 mm thick and steel up to 6 mm thick.

The cutting is done on the up-stroke and the face of the material being cut should be laid downwards to avoid any chipping out on that surface.

A number of blades are available for the cutting of wood, metals and plastics (Fig. 10.37). They vary in width and in the size of teeth. Consult a selection chart to find out which blade is the most suitable for any particular job. Different makes vary in the way the blade is fitted to the plunger, so it is important to check that the blade is the correct one to fit your machine. Read the manufacturer's instructions to find out.

10.5.1 Using the jig saw

The material to be cut must be supported clear of the bench or on stools to allow clearance underneath for the projecting saw blade. Most work should be clamped securely, but light work may be held with one hand and the saw operated with the other.

To make the cut:

1. Grip the saw by the handle and rest the front of the base plate on the material, so that the blade is aligned with the start of the cut (Fig. 10.38).
2. Switch on the motor and, with the base plate held firmly on the material, feed the saw forward, adjusting the rate of feed so that it will cut freely without labouring. Some machines will have a blower behind the blade that will blow away the sawdust, leaving the line to be followed readily visible.

Fig. 10.35 Jig saw



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Fig. 10.36 Cutting action of the jig saw

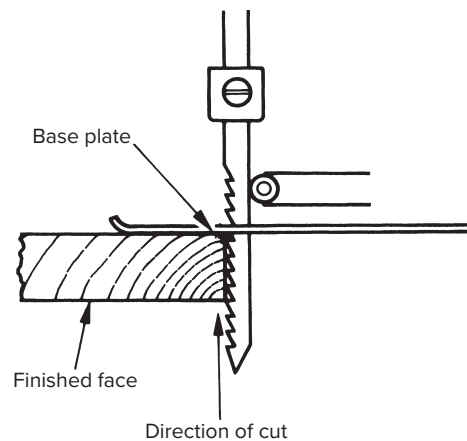


Fig. 10.37 Typical jig saw blades:
(a) coarse wood blade; (b) fine wood blade;
(c) metal-cutting blade;
(d) carbide chip blade

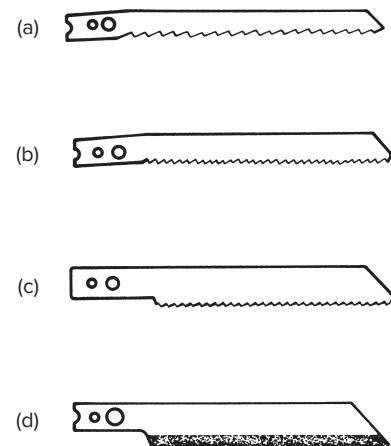
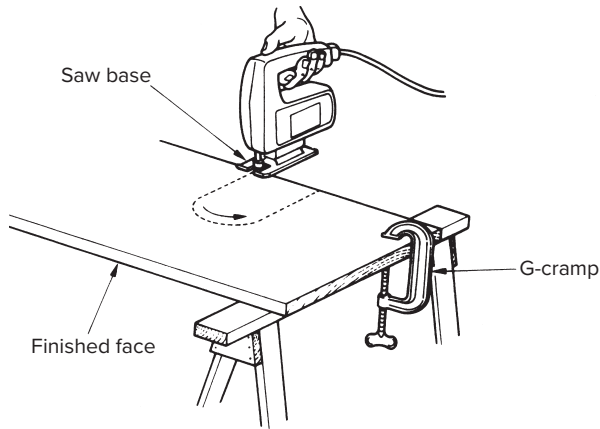
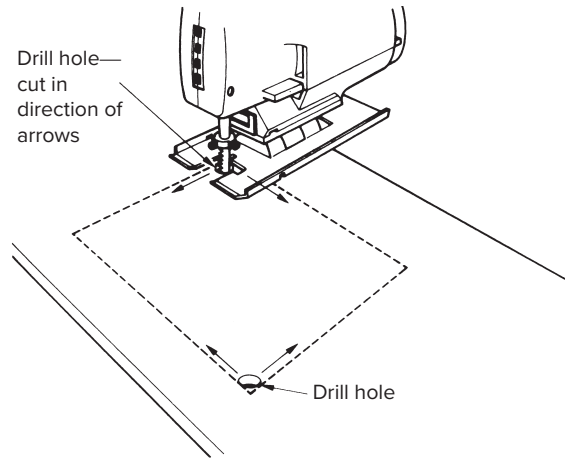


Fig. 10.38 Starting position**Fig. 10.39** Closed cut

3. At the conclusion of the cut, switch off the motor, lift the saw from the surface and lay it on its side with the blade pointed away from the operator.

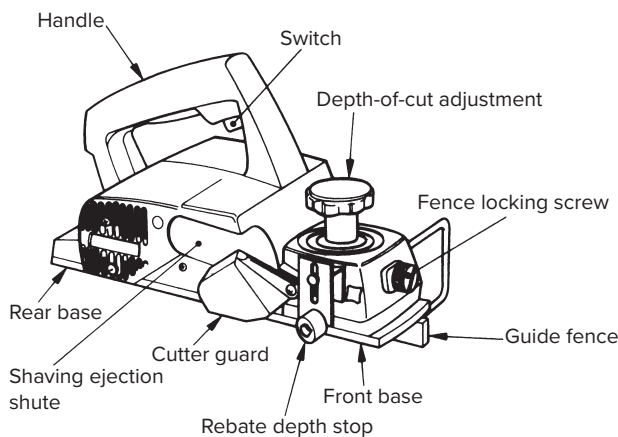
To make a closed cut, such as a cut-out for a basin or an opening in floorboards (Fig. 10.39), drill a hole large enough for the blade to fit through to start the cut, and proceed as previously described.

SAFETY TIPS Jig saw

1. Wear safety eye protection to protect the eyes from chips of brittle material that will flick upwards, and ear protection to protect your hearing.
2. Do not place a hand or power cord underneath to support material—the blade is projecting below.

10.6 Safely handle a portable power planer

The portable power planer is a valuable on-site or workshop machine capable of removing surplus timber at a fast rate, while at the same time producing a smooth planed surface (Fig. 10.40).

Fig. 10.40 Portable power planer

The portable power planer has a cutter block to which the cutters are fitted and which rotates at a high speed (Fig. 10.41). The rear base is set flush with the rotating cutters and the front base is adjustable to the depth of cut. Adjustment is made by rotating the front knob; a graduated scale indicates the depth of cut.

The size of the planer is indicated by the width of cut and is commonly 82 mm. However, planers that can cut up to 155 mm in width are available.

The cutter head contains two blades that are made of high-speed steel or are

tungsten carbide tipped. These revolve at 15 000 to 16 000 rpm. A planer revolving at say 15 000 rpm, may be described as making 30 000 cuts per minute ($15\,000 \times 2$) (Fig. 10.42).

The power planer is frequently used for normal dressing of timber surfaces, fitting doors, and cutting rebates and chamfers.

10.6.1 Using the power planer

To plane straight, flat surfaces, the timber must be held firmly. The action of the planer tends to push the timber forwards, in a manner similar to the hand plane, so the material should be secured in the vice or against a bench stop.

Adjust the planer to the depth of cut. For fast rough planing, the cut can be up to 3 mm deep, but where a fine smooth finish is required on difficult timber with interlocking or curly grain, reduce the depth of cut to no more than 1 mm and advance the planer more slowly. Grip the planer by the two handles provided and lay the front base on the timber at the start of the cut, keeping the cutters clear. Start the motor and allow the machine to reach full speed.

Apply pressure to the front of the planer and advance it forward at a steady rate. Listen to the sound of the motor—if it tends to labour, lessen the rate of feed. When the planer is fully supported by the timber, transfer the pressure equally to the front and rear. Then, as the front base passes over the forward end, apply firm pressure to the rear base to prevent the front dipping down.

Wide boards are planed with a series of parallel passes. At the completion of planing, lift the tool from the surface and switch it off.

Fig. 10.41 Cutting action of the power planer

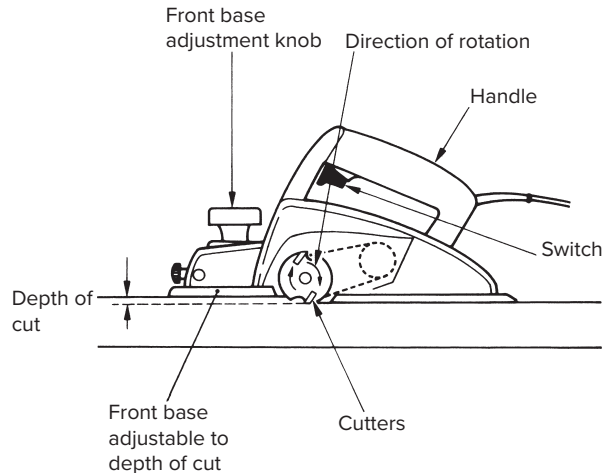
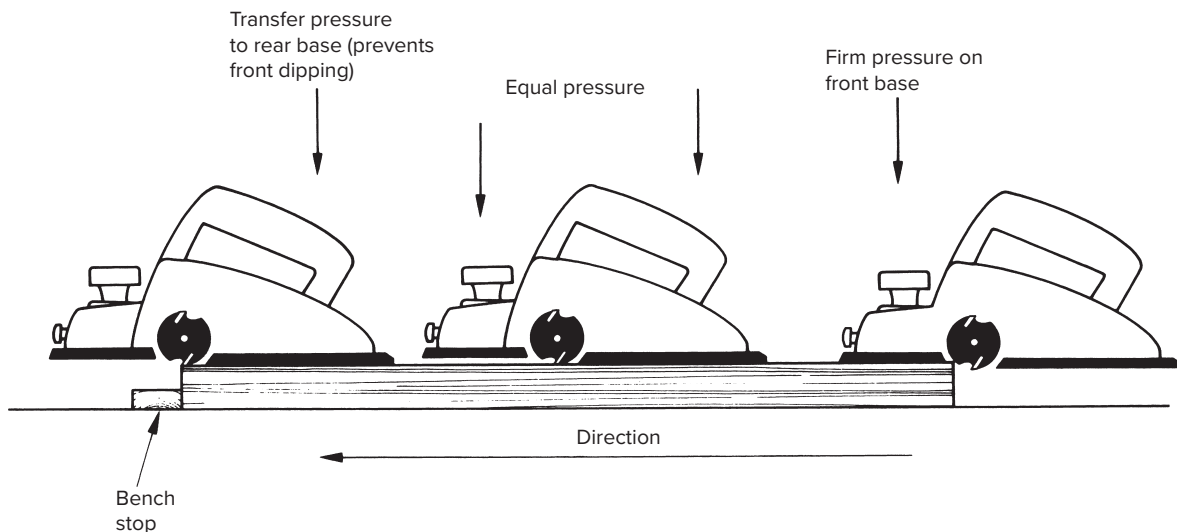


Fig. 10.42 Planing motion



10.6.1.1 Planing narrow edges

The guide fence shown in Figure 10.43 will help to hold the planer square to the face of the timber. The guide fence is attached by rods to the side of the planer and can be adjusted and locked in any position across the base. To make the cut, hold the guide fence against the face of the timber and operate the planer as previously explained.

10.6.1.2 Cutting rebates

Rebates are cut by making a series of passes to the required depth. To set up the planer for rebating, three adjustments must be made:

1. Set the *depth of cut* to the amount required to be removed at each pass, 2 mm to 3 mm.
2. Set the *depth of rebate* required, measured from the face of the rear base, by adjusting the depth gauge found on the side of the planer (Fig. 10.44). (The maximum depth of rebate may be up to approximately 20 mm but will vary on different machines.)
3. Set the *width of rebate* required, i.e. the distance required from the guide fence to the edge of the base (Fig. 10.45).

To cut the rebate, grip the planer by the two handles, hold the guide fence against the face of the timber, and operate the planer as previously described, making a series of passes until the depth stop limits the rebate to the pre-set distance.

It is advisable to cut a rebate on scrap timber to check the adjustments before working on the finished timber.

10.6.2 The cutter head

The cutter head is the most important part of the planer. The cutter blades must be sharp and correctly adjusted at all times for maximum efficiency. The design of the cutter head will vary with different manufacturers.

Some form of adjustment will be provided to set the cutter blades correctly or, alternatively, a cutter gauge may be included, as an accessory, to set the blades before assembly to the cutter head. (Refer to the manufacturer's instruction manual for details.) If the adjustment is correct, the cutting circle should align with the rear base (Fig. 10.46).

Fig. 10.43 Planing narrow edges

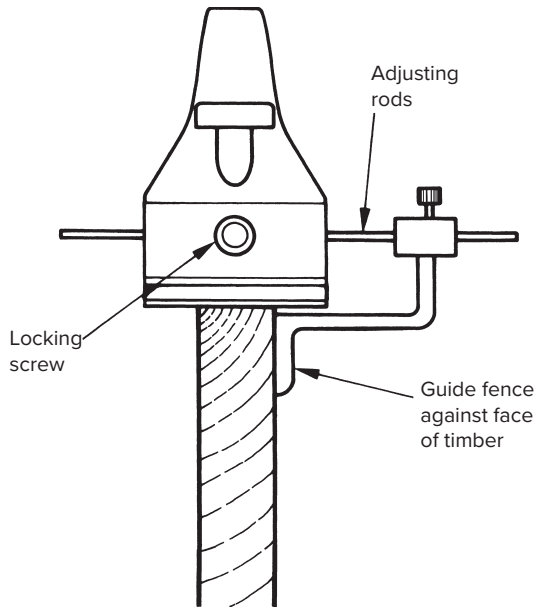


Fig. 10.44 Adjusting the depth for rebate

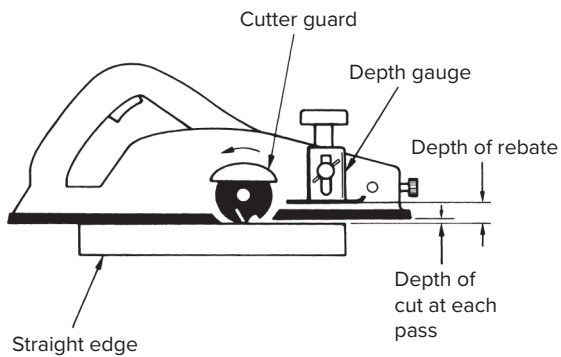


Fig. 10.45 Setting up for width of rebate

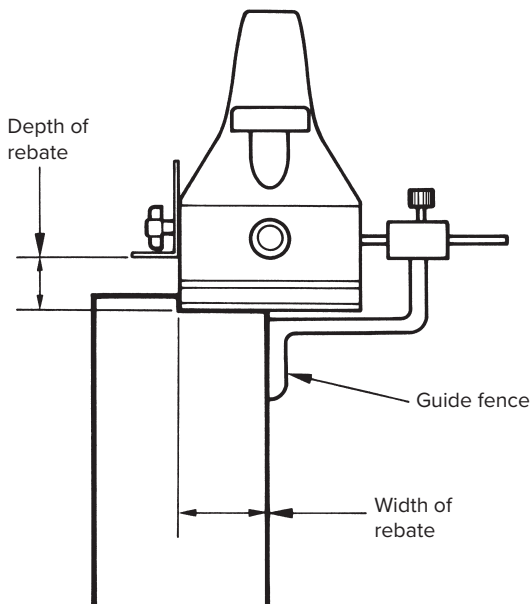
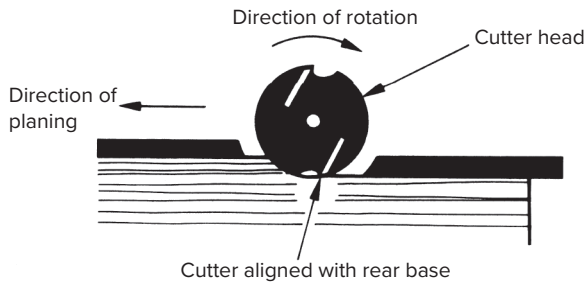
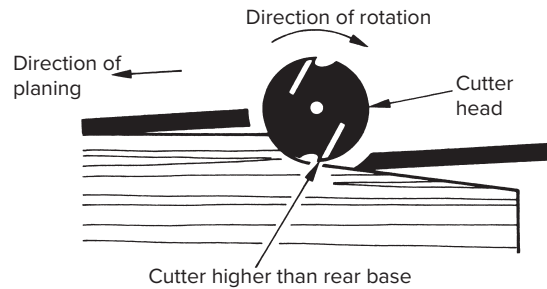
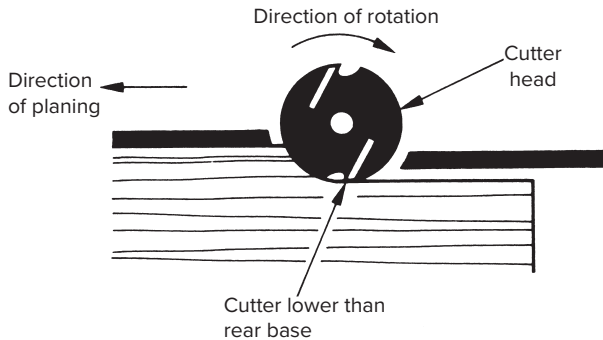


Fig. 10.46 Correct adjustment of cutter blade**Fig. 10.47** Blade not set deeply enough**Fig. 10.48** Blades projecting too far

If the blades do not project far enough, they will gouge out at the beginning of the cut, creep uphill and probably not cut at all (Fig. 10.47). Blades that project too far will leave gouge marks along the cut and at the ends (Fig. 10.48).

SAFETY TIPS Power planer

Always take the following precautions when using the power planer:

1. Disconnect the planer from the power source before attempting to remove the cutter blades or make adjustments.
2. The blades, of course, are exposed across the mouth of the planer. Always grip the tool by the handles provided, and never place the fingers underneath the base.
3. Wait for the machine to stop before placing it on the bench.
4. To protect the blades and the operator when the tool is not in use, lay it across the tool well of the bench or elevate the front on a block of wood and switch off the power.
5. Keep the power lead away from the blades.
6. Always keep the blades sharp and correctly adjusted.
7. Blades will retain their sharp edge for longer if special care is taken to remove any hard obstructions, such as nails and any dirt or grit from the surface, before planing.

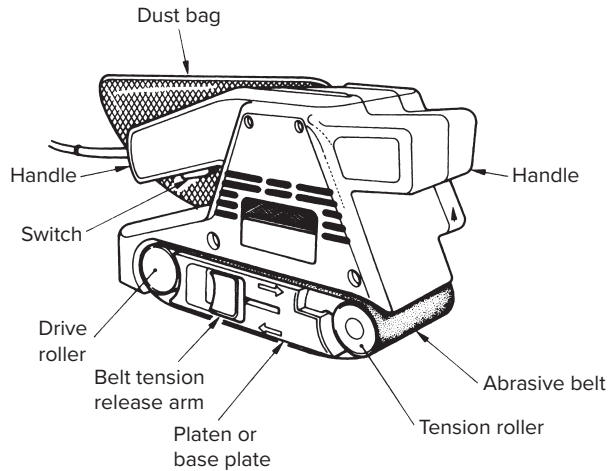
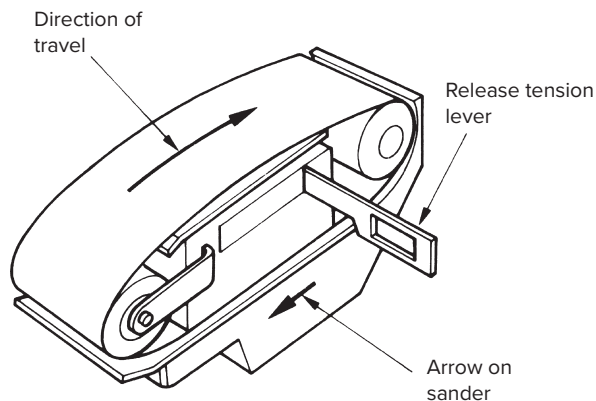
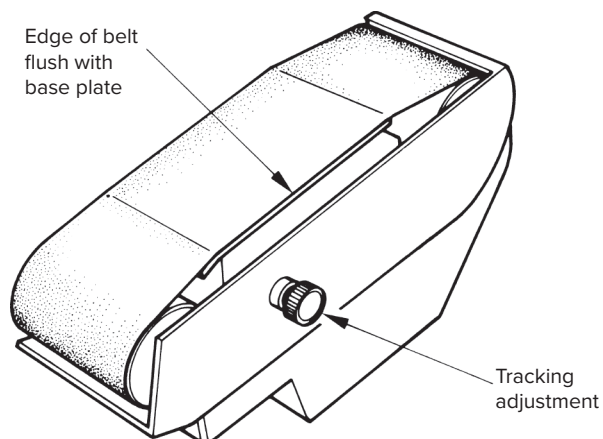
CHECK YOUR UNDERSTANDING

5. If the blades fitted to the cutter head of the power planer do not project far enough, what is the result?

10.7 Safely use an electric sander

10.7.1 Portable belt sander

One of the fundamental components of the **belt sander** is a belt of coated abrasive made up into a continuous loop that runs around two rollers—one a drive roller with a rubberised surface and the other a tensioning and tracking roller (Fig. 10.49). On the sole of the sander, the belt passes over a steel plate or platen, backed by a cork-rubber compound plate that provides a flat working surface where the belt comes in contact with the timber.

Fig. 10.49 Portable belt sander**Fig. 10.50** Fitting the belt**Fig. 10.51** Adjusting the belt

1. Clamp the timber in place or fix a cleat behind the timber to restrict movement (Fig. 10.52).
2. Grip the sander by both hand grips, hold it clear of the material, switch on and allow the motor to reach full speed.

The size of the machine is indicated by the width of the sanding belt, for example, 75 mm or 100 mm.

With a suitable belt, the sander can be used on wood, paint, plastics or metal. However, only the flat sanding of timber surfaces will be discussed here. The 100 mm belt sander is recommended for this purpose.

10.7.1.1 Fitting the abrasive belt to the sander

To fit the abrasive belt to the sander, disconnect the tool from the electrical power source and lay the machine on its side (Fig. 10.50). Find the tensioning release arm. Operate this lever to release the spring tension on the front roller. The belt can now be fitted over the two rollers. Return the tension lever to its former position. It is important that the belt travels in the correct direction so that the lapped joint of the belt will not catch and come apart, therefore reducing its working life.

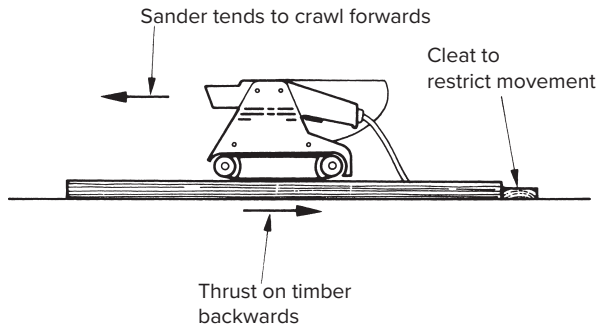
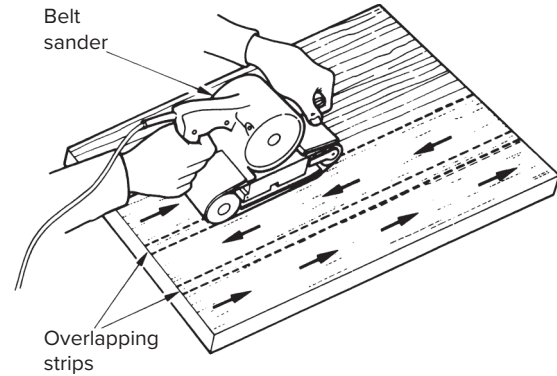
There is an arrow on the belt that indicates its direction of travel, and as the belt passes over the base plate on the sole of the machine, this arrow must be pointing towards the back. To assist in fitting the belt, the machine may have an arrow on one side indicating the direction of travel; the arrow on the belt must point in this direction.

10.7.1.2 Adjusting the belt

To adjust the belt, turn the sander over on its back, connect the power and switch it on in short bursts to observe the way in which the belt is tracking (Fig. 10.51). If it tends to move sideways, use the adjusting knob to correct its position until it runs freely, with the edge flush with the outside edge of the base plate.

10.7.1.3 Using the belt sander

The material to be sanded must be secured firmly, as when in use the sander will tend to crawl forwards, throwing the timber backwards.

Fig. 10.52 Action of the sander**Fig. 10.53** Sanding motion

3. Apply the base plate to the surface of the timber with a forward motion and sand to and fro in strips in the direction of the grain, allowing the sander to move along at a steady uniform pace from one end of the surface to the other. Do not apply downward pressure as the mass of the machine is sufficient for efficient cutting.
4. Overlap each strip by approximately one-quarter the width of the belt (Fig. 10.53). Allow the sander to rest evenly on the surface and sand each area for the same amount of time. Do not allow it to dwell in one spot. This will result in a depression that will show up on the finished surface.
5. Lift the sander from the surface before switching off.

The belt sander used with a coarse belt, 60 to 80 grit, is capable of the fast removal of surplus material but it will leave scratch marks. To produce a fine finish to dressed timber, sanding may have to be done in at least two steps. For the first step, use a medium-grade belt, say 100 grit, followed by a fine-grade belt, 120 to 150 grit. These suggestions can be taken as a guide only; each job must be considered separately as it will depend on the species of timber and the standard of finish required.

SAFETY TIPS Belt sander

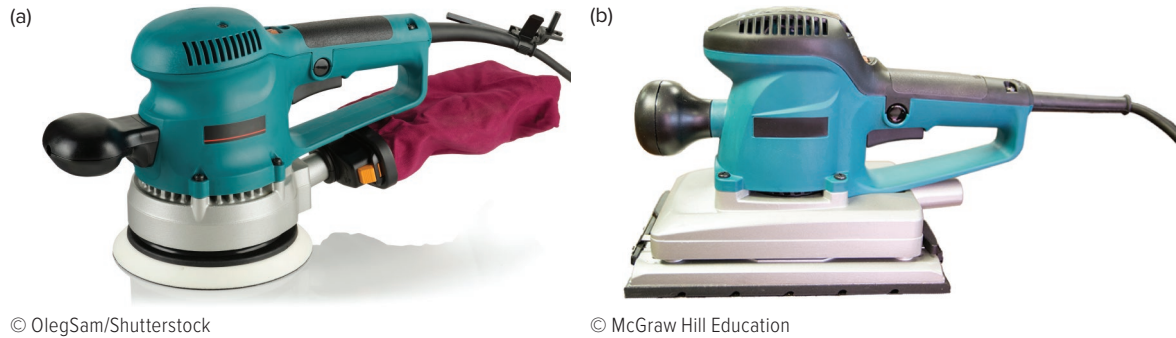
1. Keep the power lead clear of the abrasive belt at all times. Experience shows that the belt can pick up the lead and jam it against the tool housing.
2. Empty the dustbag regularly during use.
3. Sweep away surplus dust from the path of the sander as it will tend to clog the abrasive belt.
4. Remove any oil or grease from the surface, which will also clog the belt.
5. Always wear ear and eye protection. A dust mask may be appropriate as well.

CHECK YOUR UNDERSTANDING

6. Why is it important for the belt of a portable belt sander to rotate in the correct direction?

10.7.2 Orbital and random orbital sanders

The **orbital and random orbital sanders** consist of a motor housed in a plastic casing (Fig. 10.54). An orbiting base plate, faced with a rubber or Velcro pad to which can be fitted the abrasive paper, is coupled to the motor. Some models may be fitted with a blower and dustbag.

Fig. 10.54 (a) Random orbital sander; (b) orbital sander

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To understand the action of the orbital sander, hold the sander upside down, make a pencil dot on the orbiting base, switch on the sander and observe the dot, which will revolve in a small orbit in the same manner as the abrasive particles.

There is a wide variation in the specifications of the considerable number of orbital sanders available.

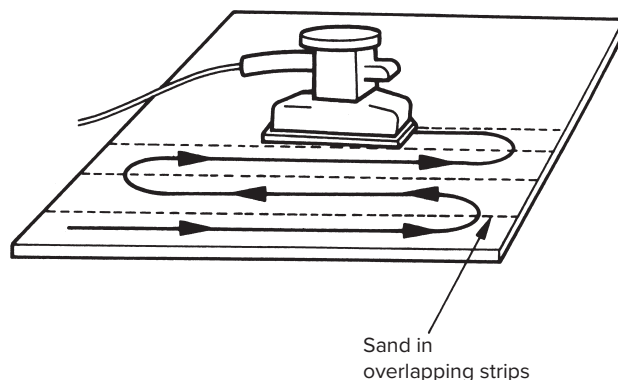
The size of the orbital sander is commonly expressed as that portion of a standard 280 mm × 230 mm sheet of abrasive paper that will fit the machine. For example, a ½-sheet sander takes abrasive paper of 280 mm × 115 mm and a ⅓-sheet sander takes paper of 230 mm × 93 mm.

The size of the random orbital sander is expressed as the diameter of the disc.

For the orbital sander, the paper must be fitted tightly over the rubber pad and be held by the clips. Refer to the instructions with each individual model for fitting details.

The random orbital is fitted with a Velcro pad, so ensure the disc is centred accurately before turning the machine on.

The orbital and random orbital sander will not remove a great amount of timber, but if used with suitable grades of paper, will produce a fine flat finish.

Fig. 10.55 Sanding procedure

10.7.2.1 Using orbital-type sanders

Timber to be sanded must be held firmly; otherwise it will tend to oscillate with the orbits of the sander. The timber is sanded in overlapping strips in the direction of the grain (Fig. 10.55). To use the sander, grip with both hands, switch on and place the orbiting pad flat on the face of the timber. Apply a light pressure and slowly move the sander along each strip, allowing the orbiting action of the base plate to do the work.

Sometimes, after orbital sanding, fine circular scratch marks can be detected on the surface, particularly if it is stained or lacquered. This is most probably caused by the use of an abrasive paper that is too coarse, and by moving the sander along too quickly. When sanding dressed timber for a stained finish, commence with a medium-grade paper, say 100 grit, and finish with a fine-grade paper, 150 or 180 grit. Commencing with a paper that is too coarse will leave scratches that are difficult to remove, and sometimes a satisfactory finish may be obtained only after a final sanding by hand. Lift the sander clear of the timber before switching off.

10.7.3 Sander safety

Obviously, sanding operations produce a quantity of fine dust and it is no doubt a wise move to use the dustbag to reduce this hazard. Most models can be attached to a shop vacuum to reduce the dust produced. The use of a dust mask is also recommended, and many operators, sensitive to the dust produced by some timbers, will find it essential.

CHECK YOUR UNDERSTANDING

7. What precautions are taken to prevent circular swirl marks showing on a finished surface when using the orbital sander?

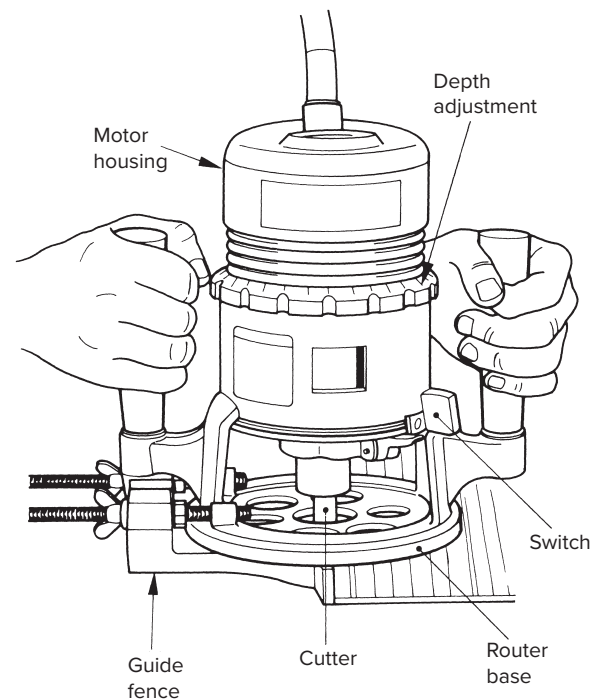
10.8 Safely use a portable electric router

An electric router can be adapted, with suitable cutters and accessories, to laminate trimming, shape straight or curved edges, and reproduce intricate shapes using a template (or templet) guide.

The **router** consists of a wide base that can be controlled by two conveniently placed handles (Fig. 10.56). Fitted to the base is a high-speed electric motor with an on/off switch. Directly coupled to the motor is a collet-type chuck into which the various cutters or *bits* can be fitted. The height of the motor body can be adjusted within the base, and this is how the depth of the cutter, relative to the base plate, is adjusted. Accessories such as a guide fence and template guides are fitted to the base to perform various operations. The speed of the motor may vary from 24 000 to 30 000 rpm, and the power range is from approximately 750 to 2000 watts.

The following description of the router is fundamental to the great number of routers available on the market. However, details of their operation may vary considerably, so always study and follow carefully the manufacturer's instructions when setting up any particular machine for use.

Fig. 10.56 Electric router



10.8.1 Router cutters or bits

The best way to demonstrate the versatility of the router is to consider the large number of cutters—over 300 types and sizes—that can be adapted to a wide variety of operations. A few examples are illustrated below.

10.8.1.1 Straight bits

Straight bits are most commonly used for cutting rebates, plough grooves, housings, etc. (Fig. 10.57). They are manufactured from high-speed steel with tungsten carbide cutting edges brazed onto the shank. This provides a good working life for the bit.

The shank diameter varies from 6 mm to 12 mm, and many cutters are still available where the shank diameter is given in imperial sizes: $\frac{1}{4}$ " (6.35 mm), $\frac{3}{8}$ " (9.5 mm) and $\frac{1}{2}$ " (12.7 mm).

With suitable adapters, bits can be fitted to most machines. The diameter of cut varies from 2 mm to 38 mm. A very useful set of tungsten-tipped cutters consist of bits that give a diameter of cut of 10, 13, 16 and 18 mm, these being the same as the thicknesses of standard particleboard. Straight cutters can have either a double flute, which will cut more smoothly, or a single flute for the smaller sizes up to 6 mm.

Some of the straight bits are shaped on the point to cut a specific shape, e.g. the core box bit and the V-grooving bit (Fig. 10.58).

When using straight cutters, the router must be provided with some form of guide such as the guide fence, the template guide or the guide batten.

10.8.1.2 Edge-forming bits

Edge-forming bits are a group of bits used to give an edge a specific shape (Fig. 10.59). They include a pilot or ball-bearing that guides the bit along the edge of the work.

The edge must be clean and true, as the pilot will follow any irregularities. The bit must be kept moving along the edge or the solid pilot tip will overheat and burn the timber. A much more satisfactory arrangement is with the ball-bearing guide, which rolls along the edge, guiding the cutter. Examples of ball-bearing edge-forming bits are shown in Fig. 10.60.

10.8.1.3 Trimming bits

The trimming bit consists of an arbor, which fits the router chuck, and on which is mounted

Fig. 10.57 Straight cutters

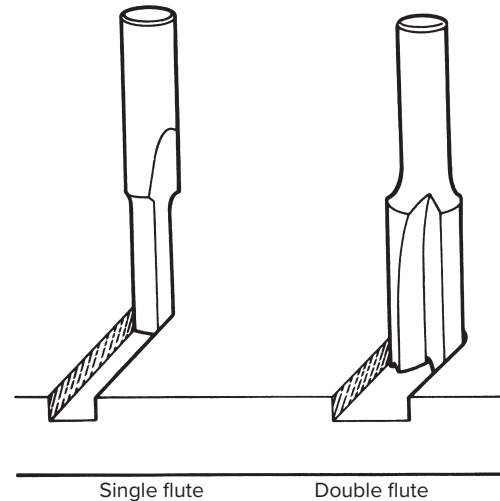


Fig. 10.58 End shapes

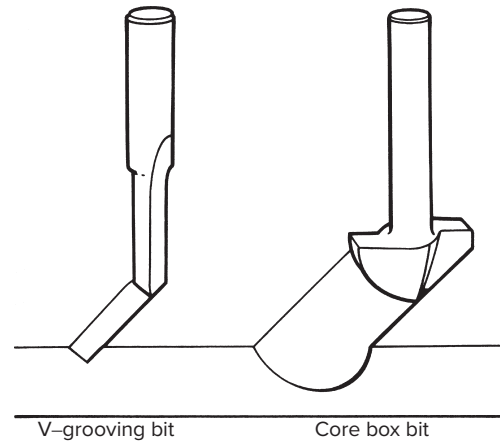


Fig. 10.59 Edge-forming bits with solid pilot

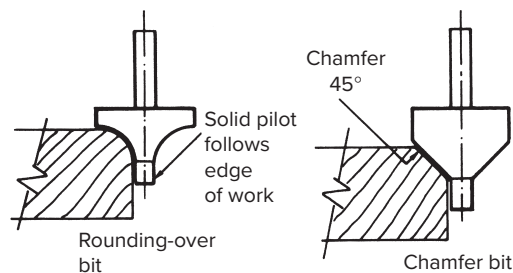
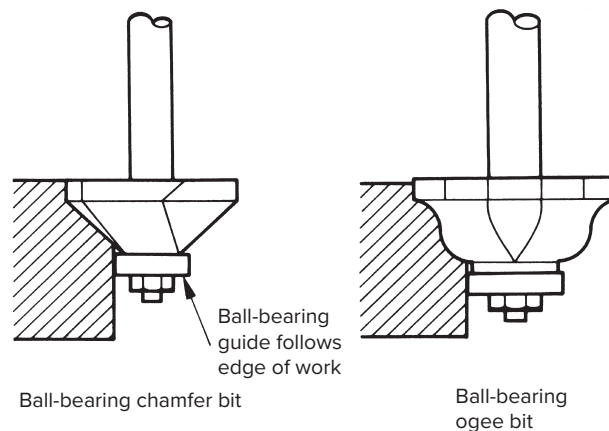


Fig. 10.60 Ball-bearing edge-forming bits



the cutter and a ball-bearing guide (Fig. 10.61). Flush or bevelled edges can be produced with the appropriate cutter.

10.8.1.4 Slotting cutters

Slotting **cutters** are manufactured in a limited range of sizes for the repetitive cutting of a groove or slot, usually to the edge of boards. Their design varies—some are fitted with a ball-bearing guide, others are used with a guide fence.

10.8.1.5 Fitting the cutter

Before attempting to fit any cutter to the router, disconnect the machine from the power source.

To unlock or tighten the chuck, it is necessary to lock the shaft to prevent it turning. Some machines may be fitted with a shaft lock; otherwise it is quite common for two spanners to be supplied as accessories, one to hold the shaft and one to turn the chuck.

So that cutters of different shank diameters can be fitted, the router may be supplied with a number of reduction sleeves and/or collet cones (Fig. 10.62).

These are available in a range of metric and imperial sizes. If difficulty is experienced in fitting cutters, consult the instruction manual of the machine and check that the correct accessories are being used. When all is correct, insert the shank of the cutter a safe distance, say at least 15 mm, into the chuck, then tighten the chuck.

10.8.2 Adjusting the router

The following adjustments are made when setting up the router for use:

1. To set the depth of cut, unlock the motor body clamp and move the motor up or down using the means provided for adjusting (Fig. 10.63). The calibrated dial helps to make fine adjustments; however, it is often more reliable to check the depth of cut from the sole plate. When correct, tighten the motor clamp.
2. To set the guide fence, fit the guide rod together with the fence to the side of the router (Fig. 10.64). Slide the fence along the rods to the required distance from the cutter, using the adjusting screws to make the final setting, and then lock by tightening the wing nuts.

Make a trial cut on a piece of waste timber to check the settings before proceeding to the finished work.

Fig. 10.61 Trimming bits

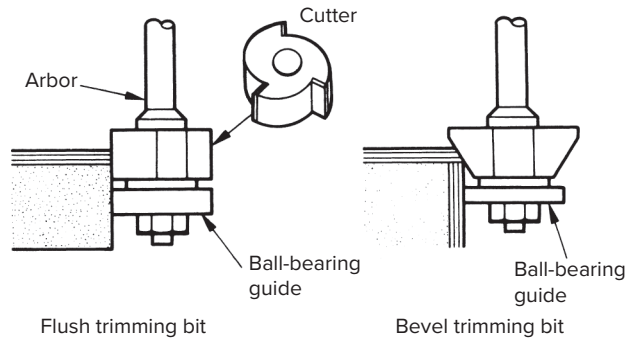


Fig. 10.62 Reduction sleeves and collet cones

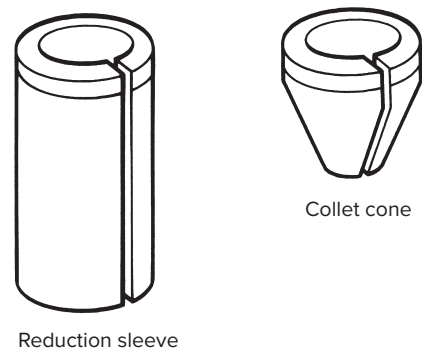


Fig. 10.63 Setting the depth of the cutter

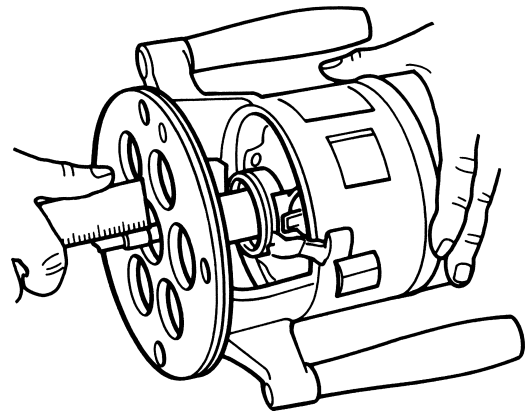
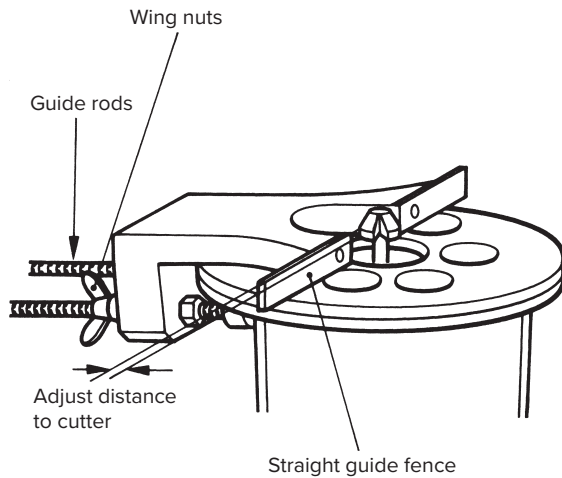
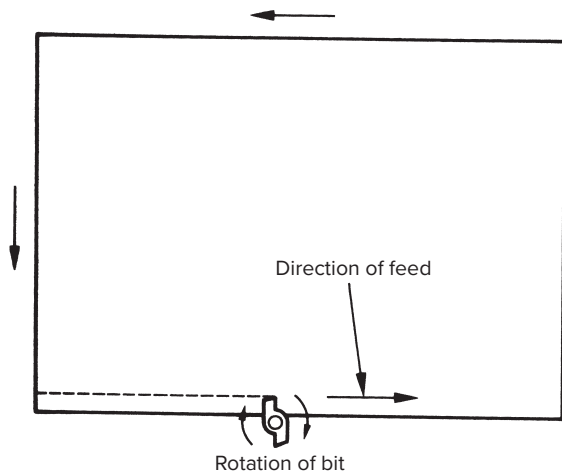
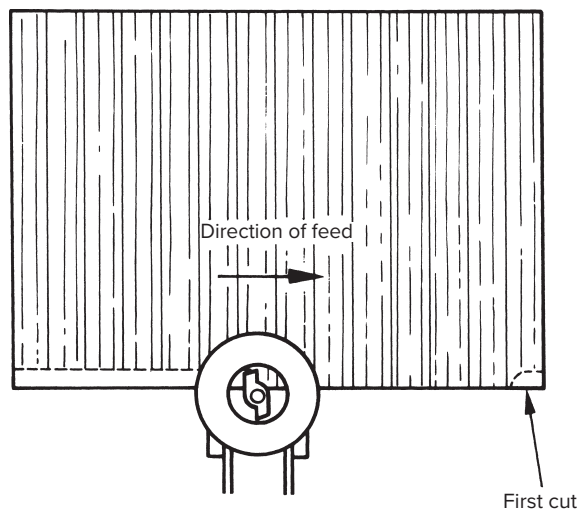


Fig. 10.64 Setting the fence**Fig. 10.65** Motion of cutting**Fig. 10.66** Cutting end grain

10.8.3 Operating the router

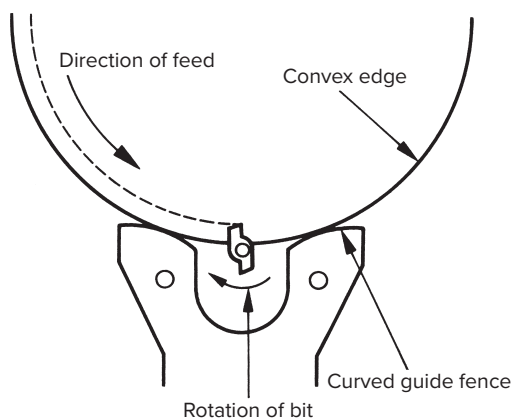
Grip the router firmly using the two hand grips, switch on the motor and allow it to reach full speed. Lay the front portion of the base plate on the timber and slowly feed the cutter into the timber. Proceed with the cut, moving from left to right against the rotation of the cutter (Fig. 10.65).

The rate of feed is best controlled by listening to the sound of the motor—if it tends to labour, slow the rate of feed. It should never slow down to the point where it is almost stationary as this will generate heat and burn the cutter, the motor and the timber. At the conclusion of the cut, withdraw the router from the timber and switch it off.

To prevent the timber splitting away at the end of the cut when cutting completely across end grain, make a short cut, against the direction of feed, where the main cut will finish. Return to the start and make the main cut moving from left to right (Fig. 10.66).

10.8.4 Curved guide fence

The router can be made to follow around a convex edge (e.g. on a round table) by using the curved guide fence (Fig. 10.67).

Fig. 10.67 Curved guide fence

Setting the position of the curved fence to obtain the required width of cut is largely a matter of trial and error. Proceed slowly, making small adjustments, and constantly check until the required width is obtained. Make the cut as previously described, again working from left to right.

10.8.5 Template guide

Where a number of similar shapes are to be duplicated, a template of the shape can be prepared, and this shape can be copied by the router using the template guide (Fig. 10.68). The guide consists of a metal disc with a tubular collar that projects below the base plate.

In use, the collar follows the template, and the bit passing through the collar makes the cut.

Template guides can be obtained in a number of sizes for various machines. When marking out the template, compensate for 'A'—the distance from the edge of the cutter to the outside face of the collar (Fig. 10.69).

Fig. 10.68 Template guide

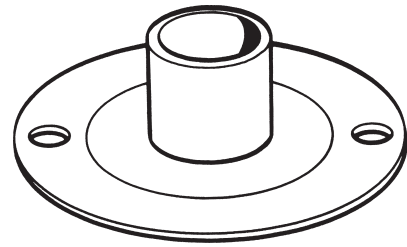
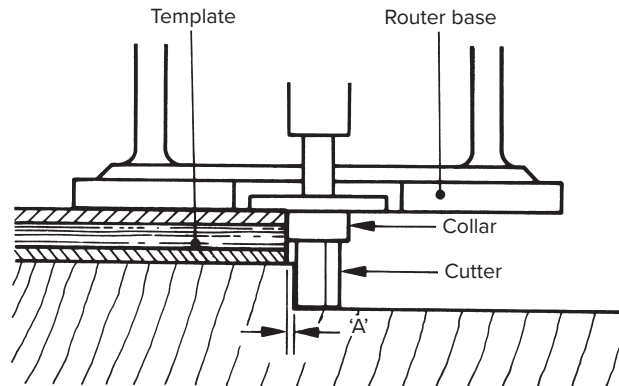


Fig. 10.69 Action of template guide



CHECK YOUR UNDERSTANDING

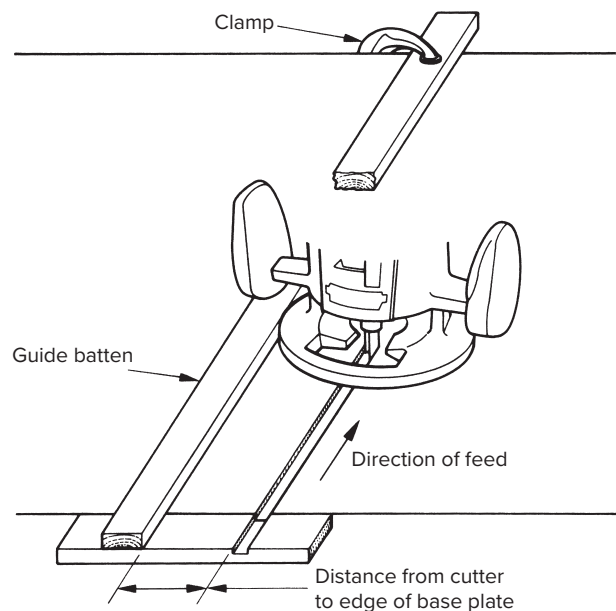
8. In which direction should the router be moved when it is in operation? Why?

10.8.6 Cutting housings

Cutting housings, often used in the assembly of cupboard shelving and so on, can be made using a batten clamped across the material to act as a guide for the router base plate. If the guide is made up in the form of a T-square, the first cut made will set the distance from the cutter to the edge of the router base; the guide can then be quickly set on the mark to produce further housings (Fig. 10.70).

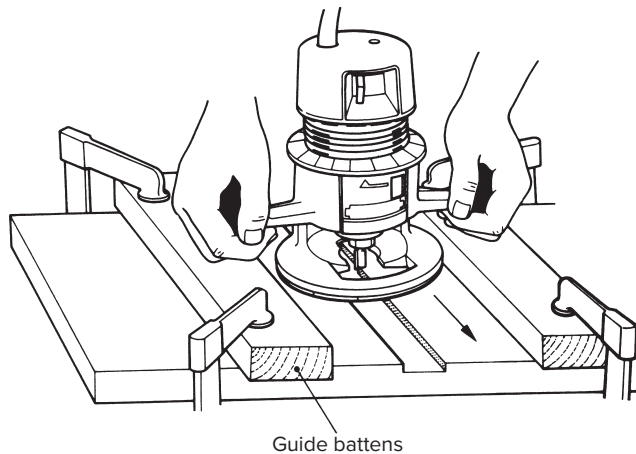
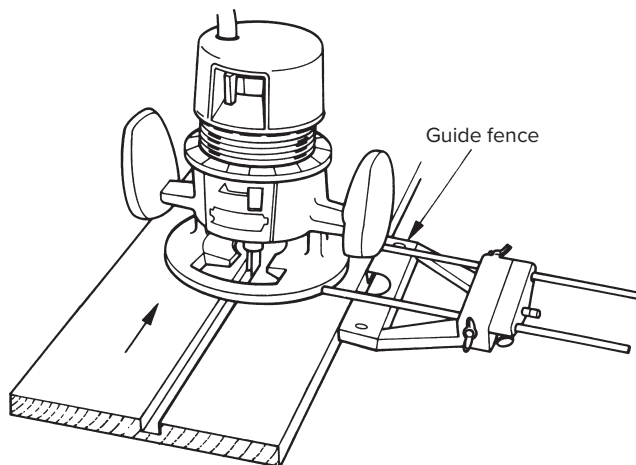
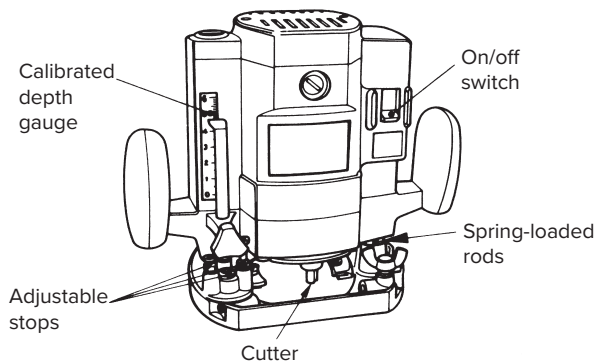
To cut a housing wider than the width of the single cutter, clamp two battens across the material (Fig. 10.71). Follow these to cut the width of the housing, and guide the router freehand to remove any superfluous material in between.

Fig. 10.70 Using a T-square batten guide



10.8.7 Cutting parallel to an edge

Use the guide fence to follow the edge and guide the cutter (Fig. 10.72). If the edge is

Fig. 10.71 Cutting wide housings**Fig. 10.72** Cutting parallel to an edge**Fig. 10.73** Plunge router

narrow, provide added support for the router by clamping a support block to the material.

10.8.8 Cutting to an internal corner

Cutting to an internal corner can be carried out using a corner guide, which consists of a right-angled block of wood screwed to the face of the guide fence. Adjust the corner guide up to the cutter so that there is equal projection on both sides.

10.8.9 Plunge router

On the plunge router, the motor is supported above the base on two spring-loaded rods; a lever is set close to the hand of the operator to lock the motor in position (Fig. 10.73). Located on the base are usually three depth stops, which can be pre-set to control the depth of cut or 'plunge' of the router.

The plunge design is most convenient for use on repetitive work, particularly if areas to be cut are of a different depth, or if deep router cuts are to be made in light progressive stages to avoid overloading the motor.

To use the plunge router, unlock the motor clamp; the motor will lift by spring action to its full height. Rest the base plate on the material and set the first stop to the required depth of cut. Switch on the motor and press down. The cutter will enter the timber and stop at the pre-set depth. Lock the motor clamp and proceed to cut the material over the required area to this depth. Unlock the motor clamp; the motor will rise. Flick the depth stop around to the next pre-set depth, press the motor down again and continue the cutting process. Repeat the operation with the further stop as required and, at the completion of the work, unlock the motor to allow it to rise clear of the material, then switch it off.

The plunge router can be used with the standard accessories, i.e. guide fence, template guide, etc.

SAFETY TIPS Router

1. Disconnect the machine from the power source before fitting cutters.
2. Use only correctly designed and manufactured router bits. Never attempt to fit any other type of drill bit or cutter to the machine.
3. Ensure that the chuck and adjusting screws are securely tightened before use.
4. Wear safety goggles to protect eyes from splinters or chips and ear protection to protect your hearing.
5. Hold the router firmly when switching on. The initial torque may twist it out of the hands.
6. Keep cutter clear of the timber when switching on and off.
7. Hold the router by the two handles provided during use.

10.9 Identify battery-powered tools

All of the tools detailed in this chapter are available in battery-powered versions (Fig. 10.74). Using the most up-to-date battery technology, these tools can perform as well as their corded equivalent in most applications. The advantage battery-powered tools have over corded tools is their portability and the

Fig. 10.74 Battery-powered tools: (a) drill; (b) circular saw; (c) jig saw; (d) sander



(continued)

Fig. 10.74 Battery-powered tools (continued): (e) impact driver; (f) demolition/reciprocating saw; (g) multi-tool; (h) angle grinder

(e)



Courtesy of Makita Australia

(f)



Courtesy of Makita Australia

(g)



Courtesy of Makita Australia

(h)



Courtesy of Makita Australia

tool itself not requiring testing and tagging every three months. Only the battery charger needs to be tested and tagged.

Additional battery-powered tools include:

- impact driver (Fig. 10.74e)
- demolition/reciprocating saw (Fig. 10.74f)
- multi-tool (Fig. 10.74g)
- angle grinder (Fig. 10.74h).

10.10 Safely use nail guns and air compressors

10.10.1 Nail guns

'Nail guns' or nailers, are available in a wide variety of models to suit particular applications.

The models illustrated in Figure 10.75 are most adaptable to the assembly of house framing as they have the capacity to drive nails from 50 mm to 90 mm in length.

The power source for the pneumatic nailer is compressed air supplied via a flexible hose connected to a portable air compressor. The 'Impulse' nailer power source is a disposable gas canister and battery inserted into the tool.

Fig. 10.75 Pneumatic nailers: (a) Senco; (b) Paslode

(a)



© Dusty Cline/Shutterstock

(b)



Courtesy of Paslode (a division of ITW Australia Pty Ltd)

The volume of air for the pneumatic nailer must be sufficient to maintain a continuous flow. It is measured in cubic metres per second (m^3/s) or litres per second (L/s).

Ensure the compressor being used will supply the sufficient volume of air needed for correct operation. The compressor must be fitted with a pressure regulator that can be set to supply the air at a constant and correct operating pressure.

To meet safety standards, some nailers are fitted with a safety catch that will not allow tool operation unless the safety catch attached on the nailer is pressed firmly against the surface of the timber. (This is also known as a 'trigger release', 'work contact' or 'safety attachment'.)

To use the nailer, first set the correct force (or depth of drive) for that nail to be driven, and then simply press the point against the timber in the direction in which the nail is to be driven and squeeze or pull the trigger. The compressed air will operate the nailer, driving the nail and feeding the next nail into position ready to repeat the cycle.

SAFETY TIPS Nailers

1. Never put your hand behind the timber you are nailing, in case the nail protrudes through.
2. Always wear ear and eye protection.
3. Always keep your hands clear of the tool nose piece.
4. Always know what you are nailing into.

CHECK YOUR UNDERSTANDING

9. What safety precautions are built into the pneumatic nailer?

Fig. 10.76 Air compressor

© yevgeniy11/Shutterstock

10.10.2 Air compressors

An air compressor is a mechanical device either powered by electricity or an internal combustion motor that draws air from the atmosphere, compressing and pressurising the air, storing the air in a tank, which can be released in quick bursts to power various tools (Fig. 10.76).

Tips for using an air compressor:

- Always check there is sufficient oil in the sump of the compressor.
- Always ensure a water filter is installed in the outgoing air supply, so any moisture in the compressed air is removed before it gets to the tool.
- Drain the tank of water periodically.
- Never run the tool over its recommended operating pressure.

CHECK YOUR UNDERSTANDING

10. What liquid should be checked in an air compressor to ensure it runs smoothly? What does it do?

10.11 Safely use an angle grinder

Angle grinders are versatile tools that can cut or grind numerous materials using dedicated blades. Each type of blade is generally suitable for cutting only one type of material and can become a hazard if used to cut or grind an incompatible material.

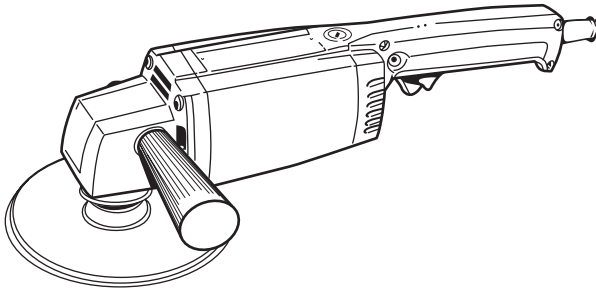
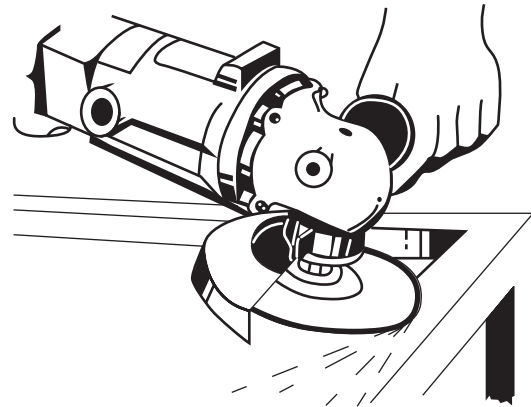
Materials that can be cut or ground include:

- metal
- masonry
- plastic.

The tool is not limited to cutting materials only—it can also be used to sand timber, buff metal or paintwork and remove paint or rust using a wire brush (Figs 10.77 and 10.78). Special accessories are produced for the angle grinder for these applications.

The two sizes commonly found on a building site are 100 mm or 225 mm; this is the size of the blade the machine will take. However, the 225 mm model is becoming less common as it is extremely dangerous and has caused many serious injuries.

The tool has guarding around the disk that directs the sparks away from the operator when cutting steel. It has a trigger or switch operated by one hand and a handle closer to the blade for the other hand.

Fig. 10.77 Angle grinder with sanding disc**Fig. 10.78** Angle grinder, grinding metal

SAFETY TIPS Angle grinder

1. Inspect discs for cracks or chips and replace if needed.
2. Wear appropriate PPE.
3. Grip the machine firmly and ensure a comfortable stance.
4. Start the machine and allow it to reach full speed.
5. Start cutting, maintain consistent pressure and make sure the motor is not slowing down when cutting.
6. Complete the cut, lift the machine and allow the blade to stop rotating before putting the machine down.

Always remember that not all of the blade is guarded, so the operator must always be aware of the position of the blade/disc in relation to their body.

Wear appropriate PPE at all times when using an angle grinder—some of the hazards encountered when using this tool include:

- kickback
- sparks
- dust
- discs shattering
- loud noise
- excessive vibration.

The necessity to change the discs/blades of an angle grinder can vary depending on the model and brand, so be sure to read the manufacturer's instructions prior to using the tool.

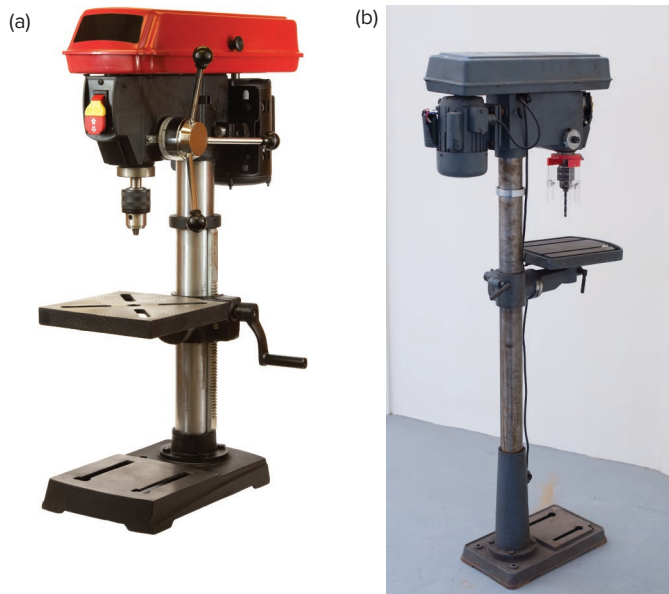
CHECK YOUR UNDERSTANDING

11. What materials can an angle grinder cut?

10.12 Safely use a drill press

The drill press is a very useful workshop machine (Fig. 10.79). Its main function is to drill accurate holes into various types of materials, including:

- wood
- metal
- plastic.

Fig. 10.79 (a) and (b) Drill press

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- General features of a drill press include:
- adjustable depth stop
 - adjustable table height
 - multiple speed settings.

When drilling small or metal items, a drill press vice can be used to secure the item. Before using this tool, ensure you don't have any loose clothing, long hair or anything dangling as this can get caught when the chuck is spinning. Eye protection is required to stop chips, swarf and dust from getting into the eyes. When using the drill press, ensure the material being drilled is secured adequately and that the appropriate speed has been selected for the size of drill bit being used and the type of material.

CHECK YOUR UNDERSTANDING

12. List three features of a drill press.

Fig. 10.80 Hand trolley

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10.13 Identify load-handling equipment

This equipment makes it easier to move heavy objects around. There are various types, including:

- hand trolley (Fig. 10.80)
- pallet jack (Fig. 10.81)
- pallet stacker
- panel trolley.

Load-handling equipment protects workers' bodies from injury as lifting and moving heavy objects manually can cause muscular and skeletal injuries.

Fig. 10.81 Pallet jack

© Baloncici/Shutterstock

10.14 Use powder-actuated tools

A powder-actuated tool is a type of nail gun that uses a powdered charge (similar to a bullet) to provide the force needed to drive a nail into various dense or high-tensile materials, including concrete, stone and steel.

These tools are generally used when many fixings are required in hard or dense substrates. It is quicker to use this method to install such fixings than

drilling holes and using screws with or without plugs. The fixings hold just as well as screwing; however, once installed, they cannot be easily removed.

Powder-actuated tools are operated by loading a charge into the tool and depressing the trigger. This causes a firing pin to strike the shell, which in turn ignites the charge, then the force of the ignited charge drives a piston, which drives the fixing (the nail) into the material (Fig. 10.82).

The depth at which the fixing penetrates the material can be adjusted, and the strength of charge varies depending on the density of the materials being fixed into. These tools are quite dangerous and proper training is required prior to operation. In some states, the operator must hold a licence to operate such tools. There are also special requirements around the storage of the tools and charges due to their similarity to a firearm.

Prior to purchasing or using any of these tools, you must:

- investigate if your state requires the operator to obtain a permit
- undergo extensive training
- understand the legal requirements and the occupational health and safety (OHS) framework on the storage and use of these tools
- wear all required personal protective equipment (PPE)
- know how to use these tools safely according to all legislative requirements.

A number of different fixings can be used with these tools. Figure 10.83 shows some fixings, while Figure 10.84 shows an example of the tool itself.

A variety of tools are available, made by a range of manufacturers. Not all tools operate in the same way, so always read the manufacturer's operating instructions prior to using any powder-actuated tool and ensure you are completely confident about how the tool operates prior to use.

Fig. 10.82 Operation of an indirect powder-actuated tool

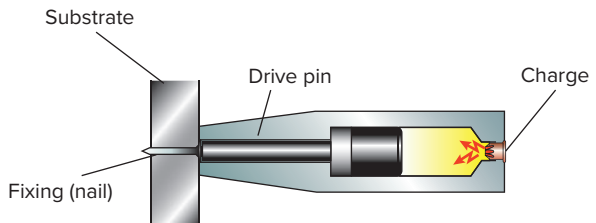


Fig. 10.83 Fixings used with powder-actuated tools

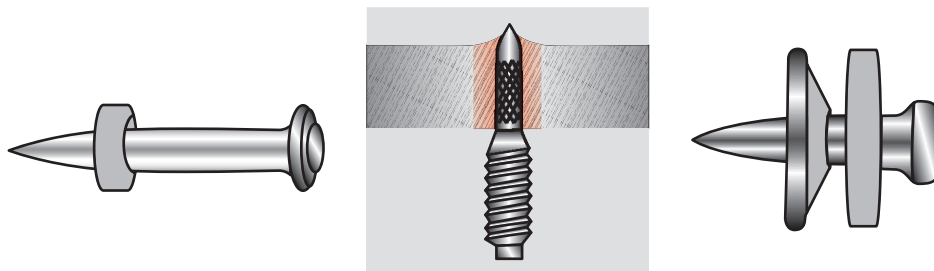


Fig. 10.84 Powder-actuated tool



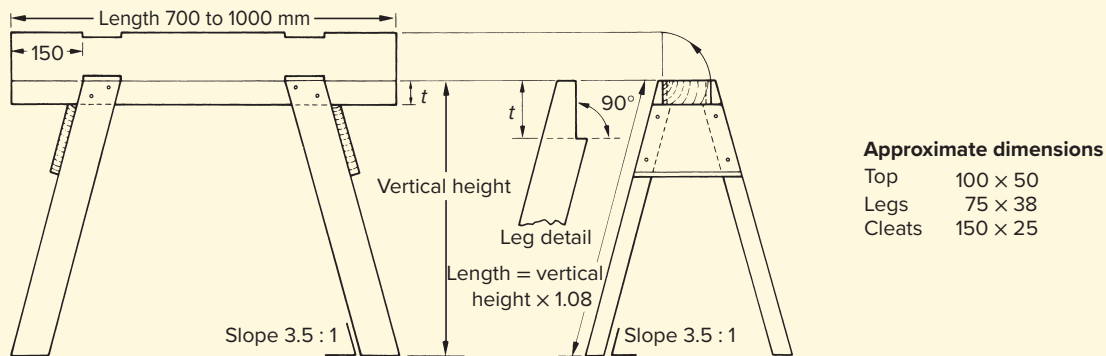
Courtesy of Hilti (Aust.) Pty Ltd

Student research

There are other tools available in the building industry that have not been mentioned in this chapter. Investigate what these are. Compare your findings with those of your classmates.

End-of-chapter activity

Try building a saw stool. These are an essential item for on-site work. A well-constructed saw stool will last for years.



AUSTRALIAN BUILDING CODES AND STANDARDS

AS/NZS 62841.4.1:
 2018 Electric motor-
 operated hand-held tools,
 transportable tools and lawn
 and garden machinery—
 Safety—Part 4.1:
 Particular requirements for
 chain saws

Tradie talk—Don't strangle your hammer

Chapter 11

Static machines

Learning Objectives

- LO 11.1** Categorise the different types of static machines
- LO 11.2** Understand and follow safety regulations for static machines
- LO 11.3** Develop a safe work procedure (SWP)
- LO 11.4** Read and interpret work instructions and plan the sequence of work
- LO 11.5** Safely set up, use and maintain a docking saw/radial arm saw
- LO 11.6** Safely set up, use and maintain a surface planer/buzzer/jointer
- LO 11.7** Safely set up, use and maintain a rip saw/table saw
- LO 11.8** Safely set up, use and maintain a panel saw
- LO 11.9** Safely set up, use and maintain a band saw
- LO 11.10** Safely set up, use and maintain a panel planer/thicknesser

Introduction

In this chapter we will be looking at how to set up, operate and maintain the basic static machines used in the construction industry. The purpose of this resource is to provide you with the necessary knowledge required to operate basic static machines used by carpenters and joiners.

Occupational health and safety (OHS) is paramount when using static woodworking machines. In this chapter you will be introduced to a variety of safety documents and regulations that work in conjunction with each other when developing safe operational procedures.

You will gain an understanding of the process of breaking down and machining timber to various sizes and profiles.

The focus of the chapter will be on six of the standard static machines used to process rough-sawn (RS) timber into dressed all round (DAR) timber:

- radial arm saw
- rip saw
- surface planer
- panel planer
- panel saw
- band saw.

11.1 Categorise the different types of static machines

Basic static machines can be organised into more general categories, for example:

1. **saws**—rip saw (aka table saw/bench saw), docking saw (aka radial arm saw/pop-up dock saw/cross-cut saw), band saw, panel saw
 2. **planers**—surface planer (aka jointer/buzzer), panel planer (aka thicknesser)
 3. **sanders**—belt sander, bobbin sander, disc sander, wide-belt sander, grinder
 4. **drilling machines**—vertical drill press, horizontal borer, multi-drill machine, mortise machine
 5. **shapers**—spindle moulder (aka shaper), tenon machine.
- Rip saws (table saw/bench saw)—this machine's basic purpose is to cut/rip material with the grain (along the timber's length). Some rip saws have capacity for a 550 mm blade, which makes this machine highly useful for cutting thick lengths of timber. The on-site version of this machine is the table saw; most portable table saws have a 254 mm blade, making them handy for cutting materials on-site such as timber flooring, skirting, studs etc.
 - Docking saws (radial arm saw/pop-up dock saw/cross-cut saw)—the primary use of these machines is to roughly cut RS (rough-sawn) materials to the desired length, ready for the straightening process. They can also be set up to complete final size cuts as well. Most machines will have a roller table system set up on either side of the saw with stop plates. The portable power tool closest to this machine is the sliding compound mitre saw.
 - Band saws—these are used primarily for cutting curves, circles and notches out in timber. A jigsaw would be used to do similar and smaller work on-site. The band saw machine can also be set up with a power feed and wide blade to deep saw wide boards of timber (resawing).
 - Panel saws—the main role of these machines within manufacturing is to cut panels of board such as ply, MDF, chipboard and melamine. The machine has been developed so it can be operated by one person as boards can be placed and supported on either side of the saw arm or bench.
 - Surface planers (jointer/buzzer)—these machines' main purpose is to straighten and square timber, usually rough-sawn (RS) material. The portable on-site power tool version is the electric planer, which is used to 'buzz' materials down in size, usually done on the edge of a piece of timber.
 - Panel planers (thicknesser, can also be referred to as a buzzer)—after timber has been flattened and squared on the surface planer, the thicknesser is primarily used to machine timber back to a consistent size. Using the face and edge that have been surface planed, timber is sent through the thicknesser to ensure the timber is parallel, square and of the required finish size.
 - Table sanders (disc/belt/bobbin/wide-belt sanders)—there are a variety of finishing machines available on the market, ranging from wide-belt sanding machines for sanding entire timbers, doors, stairs components and dining table tops etc. to machines that are used to sand edges and curves. These machines use specially formed sanding belts available in an extensive range of grits.

- Grinders—these are used to produce a smooth finish on surfaces through an abrasive machining process that utilises a spinning wheel made from aluminium oxide, silicon carbide or ceramic grains (conventional abrasives). Bench grinders are a staple of most workshops and are used to sharpen up chisels and blades.
- Vertical and horizontal drills (drill press)—the primary function of these machines is to accurately and safely drill holes in timber, metals and plastic. They can be set up with a fence and stop plates. Horizontal drills are excellent for drilling dowel holes, boring and trenching.
- Multi-drill machines—these are generally used for drilling a number of holes simultaneously. They are used in the manufacturing industry in order to increase the productivity of machining and to reduce operation times. Modern computer numerical control (CNC) systems enable tasks to be completed quickly and with a high degree of accuracy. The closest portable power tool is the single chuck drill/cordless drill.
- Mortise machines—these machines are used to cut a trench, hole or recess into a part of a timber that is designed to receive a corresponding timber tenon from another timber, so as to join or lock the parts together. The mortise machine can create a square hole using a special square chisel and auger bit; some machines also use a chain mortise to create a recess. The chain mortise and square mortise machines are also available as portable power tools.
- Spindle moulders—also known as ‘shapers’, these are large routing machines used to process high volumes of materials that require a profile to be routed into timber. (It is recommended that you install a power feed for use with this machine.) The portable power tool equivalent that is used on-site and in the factory is a router, which comes in many hand-held sizes.
- Tenon machines—these machines are used primarily to create a tenon on the ends of timbers. Some tenon machines can dock, tenon and profile timbers all at the same time. Used extensively in the door and window manufacturing industry, such machines save time as they can be set up to create standard sizes and process materials at a high volume. Tenons can be developed by hand using a hand tool, which is a slow process, by using power tools such as a sliding compound saw, or by setting up a router in a jig.

CHECK YOUR UNDERSTANDING

1. Name five different general categories of basic static machines.
2. What does RS stand for in relation to timber?

11.2 Understand and follow safety regulations for static machines

The Australian Standards and Regulations have been developed to ensure a uniform approach is taken in the Australian construction industry to the safe use and guarding of static machines.

11.2.1 National Construction Code (NCC)

The NCC incorporates the Building Code of Australia (BCA) as well as the Plumbing Code of Australia (PCA) to create the single on-site construction code for Australia. The NCC provides the minimum requirements for new building work in existing buildings with regards to health and safety; amenity and accessibility; and sustainability in the design, construction, performance and liveability. (Paraphrased from the NCC website: <https://ncc.abcb.gov.au/ncc-online>.)

11.2.2 Emergency stop switches

The following information about emergency stop switches (Fig. 11.1) is taken from Safe Work Australia's 'Managing risks of plant in the workplace' Code of Practice (September 2013):

If the design of plant at a workplace includes an emergency stop control, the person with management or control of the plant must ensure that:

- the stop control is prominent, clearly and durably marked and immediately accessible to each operator of the plant
- any handle, bar or push button associated with the stop control are coloured red
- the stop control cannot be adversely affected by electrical or electronic circuit malfunction.

Where plant is designed to be operated or attended by more than one person and more than one control is fitted, the multiple controls must be of the 'stop and lock-off' type so that the plant cannot be restarted after a stop control has been used unless each activated stop control is reset.

(Courtesy of Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>.)

Fig. 11.1 Emergency stop switches



• An emergency push stop on a radial arm/docking saw. If this stop switch has been pushed in, it will require the operator to twist or pull it, depending on the type of button, to restore the power. Some of these types of stops require a key to restart the mechanism

• The on/off switch may need to be placed into the off position before the emergency stop can be reset

• Mushroom stop: this emergency stop is located close to the machine and within easy access of the user's foot. In an emergency, this device can be stepped on or tapped from the sides to cut the power to the machine

Courtesy of Michael Hick

TIP To avoid damage to emergency stop switches, they should be used only in an emergency. They should not be used as a general on/off switch as this may cause undue wear and tear. Emergency stops should be tested during the machine's daily start-up procedures.

11.2.2.1 Isolating a machine

Isolating a machine means removing the power source/supply to the machine. Power comes in many forms, such as electricity, fuel, steam, hydraulic power etc. You will need to refer to the manufacturer's manual/guide to locate the isolation points. Most static machines are fitted with an isolation switch that has an ON and OFF position. To isolate the power, you will need to turn the isolation switch to the OFF position. To turn the power back on, the isolation switch will need to be turned to the ON position and a reset button may/will need to be reset. The isolation switches on some machines can be locked to the OFF position (Fig. 11.2) and a key is required to turn the isolation switch back to the ON position.

11.2.3 Housekeeping in a machine shop

Housekeeping is more than just sweeping the floor or dusting. It is crucial to a safe workplace and can help prevent injuries and improve productivity. A written set of rules will help to prevent slips, trips

and falls, eliminate fire hazards, and help control dust and clear clutter. It can also help with tracking materials that come into the machine shop. By stacking and storing materials correctly, falling objects and near-misses can be prevented. It is also important to inspect personal protective equipment (PPE) and tools to make sure they are in good working order.

In a machine shop, the following activities may be performed daily, weekly or monthly:

- floors to be swept, extraction bags to be emptied
- timber waste to be placed in appropriate timber bins, MDF to be disposed of in rubbish bin
- no materials to be stacked or left on machines
- machine guards to be reset
- timbers to be stacked on a trolley/in timber rakes or in a designated laydown area
- machine tools/knives/blades/profiles to be kept in a lockable cabinet, free of dust and grit
- machine tools with a holster on the machine to be stored in these for quick access.

For further information, check on your state's safe worksite advice.

Fig. 11.2 A padlock used to lock off an isolation switch



Courtesy of Michael Hick

11.2.4 Standard operating procedure (SOP)

A standard operating procedure (SOP) is often referred to as a safe operating procedure, depending on where you are in Australia. An SOP is a step-by-step guide on how to operate a machine safely.

Static machines, like most products, will come with a set-up and installation manual. The manual will also outline what the purpose of the machine is, its intended use and the responsibilities of the operator. It will contain information on safe set-up, work safety, personal safety, extraction and guarding requirements, as well as requirements for sizes of blades, arbors, knives, tension of blades and belts etc. Some modern manuals will also go into detail about how to use the machine safely as part of the information on the intended purpose of the machine.

11.2.5 Plant and equipment risk management

A plant and equipment risk management form is a tool used to determine whether there are any hazards associated with any item of plant and machinery, such as the risk of:

- crushing
- entanglement
- cutting/stabbing/shearing
- slips, trips and falls.

The form helps to establish safety control measures to prevent harm to life, health, property or the environment. Each state's safety regulator will have information to help you identify the hazards associated with plant machinery. (An example form can be found at www.worksafe.vic.gov.au by searching 'Plant hazard checklist'.)

For more information on managing the risks of plant (machinery) in the workplace, head to your state safety regulator or Safe Work Australia (www.safeworkaustralia.gov.au).

11.2.6 Material safety data sheet/safety data sheet (MSDS/SDS)

A material safety data sheet (MSDS) is a document that provides health and safety information about products, substances or chemicals that are classified as hazardous or dangerous. (Refer to Chapter 1, Work health and safety, for more information.)

CHECK YOUR UNDERSTANDING

3. What is the purpose of plant and equipment risk management?
4. Name three important pieces of information that can be found in an SOP.
5. Who is the health and safety regulator in your state?
6. What important information can be found on an MSDS/SDS?

11.3 Develop a safe work procedure (SWP)

A safe work procedure (SWP) is usually developed alongside the standard/safe operating procedure (SOP). The SWP takes into consideration more than just the step-by-step use of the machine; it also covers the work environment around the machine, its intended use and who can use the machine. It usually has three main sections: pre-start; operation; end of operation/clean-up.

- The pre-start section will list the checks to be performed before working with a machine, such as whether the guards are in place and the extraction system is connected. Some pre-start checks will be listed on a form that needs to be filled in each morning before the day's work can begin.
- The operation section is an agreed-upon process developed by the company using the SOP and will contain information such as: keeping your hands away from the blade and cutting area; ensuring the workpiece is held against a fence; allowing the saw blade to obtain maximum speed before making a cut.
- The end-of-operation information may consist of advice such as to: switch off the machine; reset all guards to the fully closed position; leave the machine in a safe, clean and tidy state.

The SOP outlines the correct procedures to follow when using a machine and as a requirement should be located on the side of the machine or in close proximity to the machine.

When developing an SWP for a static machine within a workshop, you will need to take into full account the manufacturer's standard/safe operating procedure (SOP) for the machine, what the machine is designed to do, its purpose and function.

There are many SWPs available online on government sites that you can use, adopt and modify to suit your machines, workspace and needs (Fig. 11.3).

Some standard categories on these forms are:

- description of work (what is the machine being used for?)
- potential hazards/don'ts (what are the potential hazards of using this machine, e.g. exposure to moving parts, potential entanglement, electrical hazards, noise, dust, exposure to heat, projectiles, sharp objects?)
- personal protective equipment (PPE) required (earmuffs/defenders, appropriate footwear, protective clothing, safety glasses, gloves, mask)

Fig. 11.3 Example of a safe work procedure (DET Victoria)

Safe Work Procedure						
NOTE: DO NOT use this machine unless you have been trained in its safe use and operation						
Description of Work:		Using a Radial Arm Saw				
		Potential Hazards: Exposed moving parts and electrical hazard with the potential to cause harm through entanglement, impact and cutting, exposure to heat, noise, dust, projectiles and sharp objects.				
Personal Protective Equipment (PPE) Required (Check the box for required PPE):						
 Gloves	 Face Masks	 Eye Protection	 Welding Mask	 Appropriate Footwear	 Hearing Protection	 Protective Clothing
☐	☒	☒	☐	☒	☒	☒
Safe Work Procedure Checklist:						
1. PRE-Operation: - Task (e.g. Drawings, instructions, specifications etc.) is clearly understood. - Ensure guarding is in place. - Ensure the appropriate blade is being used for the task. - Ensure dust extraction is turned on prior to operation (if applicable). - Identify ON/OFF switch and emergency stop button (if applicable). 2. Operation: - Check that saw runs 'true' and does not wobble. - The work piece must be held against a fence. - Allow the saw blade to obtain maximum speed before making a cut. - Operate the saw with the left hand where possible, avoid reaching over the saw line and do not cross arms when cutting. - When using the right hand to pull the saw across, keep the left hand well clear of the line of cut. - Return the cutting head to the rear of the table after each cross cut. - The maximum cut for the machine must not be exceeded. - When cutting bowed timber place the bow against the table to avoid the saw binding. - Before making adjustments switch off and bring the saw to a complete standstill. 3. POST-Operation: - Switch off the saw and reset all guards to a fully closed position. - Make sure good housekeeping practices are in place to minimise dust build-up.						
Competent Persons (The following persons are authorised to operate, supervise and test students on the equipment/process).						
Name:	Title:	Contact Details:				
<i>Last updated: 24 August 2018</i>						

- pre-start checks (check blades, guards, fences and work plans, identify location of switches–on/off/emergency stop–extraction, correct tool(s) installed)
- operation (what is the SOP for the machine? This may also include a list of what the machine is not to be used for or capable of)
- end-of-operation (turning the machine off, resetting guards and blade heights, housekeeping)
- authorised operators of the machine (in some instances, only trained and authorised personnel will be able to operate certain machines).

SWPs are live documents, and each workplace will have different requirements and risk assessments. Remember: static machines should be operated only by a qualified/trained operator; the SWP details an agreed-upon process for the safe operation of the static machine—it is not a training manual.

CHECK YOUR UNDERSTANDING

7. List three pieces of PPE that you may need when using static machines.
8. What is the main purpose of an SWP?

11.3.1 JSA and SWMS in static wood machining

A job safety analysis (JSA) is a form of risk assessment that details step-by-step how a task is to be carried out safely. Sometimes the JSA is called a JSEA (job safety and environmental analysis) and it includes environmental aspects as well. SWPs are displayed near each machine, with the safe work method statement (SWMS) or JSA being completed by the worker/user, informed by the SWP. The SWMS is a legal document that outlines any high-risk construction work activities carried out within a workplace, the hazards that may arise from these activities and the safety measures put in place to control the risks. (For more information on JSAs and SWMSs, see Chapter 1, Work health and safety.)

11.4 Read and interpret work instructions and plan the sequence of work

The cutting list is an integral part of the communication process between people working within a company. It is a list that wood machinists can follow, and may contain a rudimentary drawing of the product, its key components and overall size. The cutting list will have information such as the name of the components, how many pieces, the length × width × thickness of the materials, as well as a space for any special requirements or remarks. The cutting list can also be used as a materials costing list as it has all of the components listed on it.

Traditionally, a cutting list would have been developed from a full-sized set-out, and a story rod would be created from the set-out with all of the critical sizes, rebates, mortises and tenons marked onto it. A story rod is a length of timber that would be cut to the overall height of a product and with the same thickness. Using the rod enables you to transfer all of the critical measurements from one product to another, so you can, for example, mark up every door to be exactly the same.

These days, with the advancements of computer technology, there are many programs that do the work for you—you simply enter in the overall sizes of the space into which the product will be installed and the program will develop and generate a materials and cutting list.

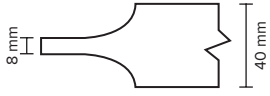
11.4.1 Cutting list

A cutting list shows the complete material requirements for one piece only (Fig. 11.4). If more than one unit is to be produced, then the number of pieces is multiplied by the number of units required.

Fig. 11.4 An example of a cutting list

Materials cutting list 2040 × 900 × 40 solid timber front door							
Job name/no.		Address:					
Start date		Due date					
Item no.	Member name	Material (timber type)	No. of pieces	Finished sizes			Remarks, including cross-section of material
				Length	Width	Thickness	
1	Stile	Vic ash	2	2040	120	40	21 × 10 mm rebate along one edge quad mould 3 mm quirk
2	Bottom rail	Vic ash	1	740	140	40	21 × 10 mm rebate along one edge quad mould 3 mm quirk tenon on both ends
3	Mid-rail/lock rail	Vic ash	1	740	140	40	21 × 10 mm rebate along two edges quad mould 3 mm quirk tenon on both ends
4	Top rail	Vic ash	1	740	120	40	21 × 10 mm rebate along one edge quad mould 3 mm quirk haunched tenon 60 mm both ends
5	Top muntin	Vic ash	1	920	140	40	21 × 10 mm rebate along two edges quad mould 3 mm quirk tenon 25 mm on both ends—no haunch
6	Bottom muntin	Vic ash	1	790	140	40	21 × 10 mm rebate along two edges quad mould 3 mm quirk tenon—25 mm on both ends—no haunch

(continued)

Item no.	Member name	Material (timber type)	No. of pieces	Finished sizes			Remarks, including cross-section of material
				Length	Width	Thickness	
7	Top panels	Glass	2	935	275	8	Glass will be installed into the top two panels, 5 mm clearance has been deducted from overall size
8	Bottom panels	Vic ash	2	755	275	40	Timbers will need to be laminated to achieve desired size. Fielded panel—moulded both sides all way round, 5 mm clearance has been deducted from overall size 
9	Beading	Vic ash	10	1000	10	10	10 mm quad for the installation around the glass and bottom 

The cutting list may contain many columns and can be adjusted as required to suit the needs of the manufacturer. Some companies will have a standard cutting list, with the member names already entered in the column.

11.4.1.1 Item no.

Each item or component is assigned a number in ascending order (Fig. 11.4). It is quite common for the wood machinist to label or mark each component machined with the item number rather than the description for easy identification. Modern computer numerical control (CNC) machines are able to label components as they cut.

11.4.1.2 Member name/description

A drawing of the product that is being manufactured will be part of the cutting list and will have each component labelled or named as a reference. If not, a description of the item can be placed into this column.

11.4.1.3 Material

Due to the wide variety of timbers, manufactured boards and timber products used in the construction industry, it is important to complete each item in the material column—especially if a customer has selected a non-standard material to be used.

11.4.1.4 Number of pieces/quantity

After each part name is entered, the quantity of each component required for the construction of one complete unit is listed. When making multiples of the same unit, the figure in this column will increase to accommodate the required number of components.

11.4.1.5 Length

The length of each part is always measured in the direction in which the grain runs. This also applies to manufactured boards with face veneers or wood grain patterns. Care must be taken as there are times when a width measurement can be greater than the length. In the building and construction industry, all measurements are in metres and millimetres and as such it is not necessary to write 'mm' in the column beside the dimension.

11.4.1.6 Width

The width of solid timber is measured from edge to edge across the face of the grain. Manufactured board materials are simply measured according to length (along the grain where appropriate), width (across the grain) and thickness. If there is no grain or pattern on the board, the length is always the longer of the two sizes.

11.4.1.7 Thickness

The thickness of the material, whether it is manufactured board or solid timber, is usually the smallest measurement, measured from one face of the material to the other.

11.4.1.8 Remarks

All cutting lists should follow a set pattern. A tradesperson will understand most general requirements. This column is used to explain the special requirements.

Remarks may include items such as:

- how the timber is to be dressed
- special requirements for joining and laminating
- details about mouldings/beading/bolection moulding
- sizes of mortise and tenons
- details about shaped components.

This column may also include diagrams or a cross-section of what profiles may need to be machined into the timbers before being assembled. Small mouldings can also be drawn in this column to highlight special machining requirements. Small beads are often sawn off from larger sections for convenience and safety.

Generally, sizes shown on the cutting list are the sizes produced. If an allowance for fitting is required, it needs to be included when compiling the cutting list. Items that often fall into this category include mouldings and facings that need extra timber so mitres can be cut.

11.4.2 Quality control and sustainability

Quality in producing a product involves finding a balance between cost, time and making sure you comply with the industry standards and tolerances. Having quality controls in place will help ensure components and products are made to the required standards, and the requirements of the order and contract are met. Quality controls should be embedded at each step of the production process so as to monitor that the product is being manufactured to plan.

CHECK YOUR UNDERSTANDING

9. What is the purpose of a cutting list?
10. What information can be obtained from the cutting list?
11. Why is quality control so important?

11.4.3 Material selection and characteristics

When machining RS material, it is best practice and more sustainable to order timbers that are close to the required sizes. Using the example cutting list in Figure 11.4, the largest solid timber size is 140 mm wide for the mid-rail, bottom rail and muntins, and all of these components have a finished thickness of 40 mm. The longest length after machining the timber is 2040 mm. It is possible to order a pack of timber in lengths of 2.1 m or 2.4 m. However, most packs of timber will be more random.

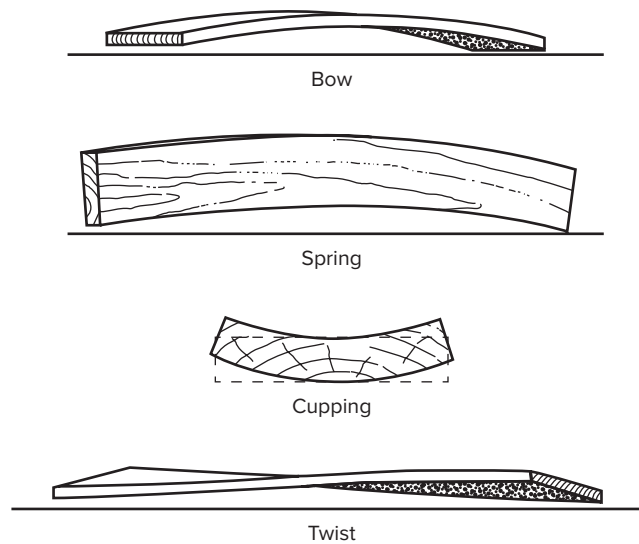
To give ourselves enough material to be able to machine our product, the closest RS size is 150×50 mm. This gives us 10 mm in width and 10 mm in thickness to work with.

When ordering timber from a yard, it is best to speak to someone to get a list of the packs they have in stock and check the sizes of timbers within the pack to see which one best suits your project. They may be able to split a pack for you; however, this will be at a price.

When a pack of timber comes in, it is good practice to open and separate the different sizes, if possible. While doing this, you will also be able to determine the best timbers for your job. What you are looking for are timbers free of defects such as knots, as well as checking that the timbers are as straight as possible, free of bows and twists.

The problem with timbers with large bows and twists (Fig. 11.5) is that it takes a lot to machine them out and you can easily machine too much material off and not get the required finish size.

Fig. 11.5 Timber characteristics



11.4.4 Basic static machines in a practical order of use

1. The order of use for a set of static machines comes down to this: what are you using them for? If you are squaring material that is described as dressed all round (DAR), you may start with docking lengths of timber to the approximate size. It is best to leave an allowance on the timber length of an extra 50–100 mm as this will take into account any machining defects that can/usually occur at the ends of the timbers due to the timber dipping or bouncing through/out of the machine.
2. Using the example above of the door (Fig. 11.4), if you were machining up your components, you would cut out all of the components with the extra allowance for machining. For example, with the stiles ($2040 \times 120 \times 40$ mm), you would use lengths of 150×50 mm Victorian ash and dock it to 2.1 m. The next step would be to surface plane the timber, so you would surface plane the face first to straighten/flatten the timber, then edge against the squaring fence. The timber is still quite wide, so you would next rip the length back to a size 5–10 mm bigger than the finished size. The reason for this is that sometimes a lot of tension can be released from the timber once it is ripped along the grain and as such a bow may appear in the length. You would then need to square the edge of the timber again on the surface planer.
3. The next step is to run the timber through the thicknesser—the procedure is edge first then the face. The reason for machining the edge first is that at this stage the edge is still at its thickest, so the timber has less chance of falling over if it has been run through the thicknesser first. If you were just squaring material (DAR), then at this stage you could take the timber back to the dock saw and cut it back to the required size on the cutting list.
4. To continue on with the example of the door stiles, the next stage would be to set up the spindle moulder to route the profile into the edge of the machined $2100 \times 120 \times 40$ mm timber. The spindle moulder has interchangeable blades and solid block cutters. When setting this machine up, you need to run a test piece first to check the profile is being machined according to the cutting list requirements (i.e. perform a quality check). Once this machine is set up, you can then run your

door components. It is always best practice to set up a power feed for repetitive machining with the spindle moulder; the power feed acts as a guard in front of the spinning blades.

5. At this stage, the components that are to have a tenon cut into the ends will be docked to the required size, ready to be placed through the tenon machine. A panel saw can be used for this step as it has an accurate stop plate and can be set up with a finer blade for a smoother cut. The usual proportion for a tenon is one-third the thickness of the stock material, so in this example the tenon will be 13 mm (a third of 40 mm). The depth of the tenon can vary depending on whether it is through mortise or hidden mortise. A hidden mortise will also be based on the one-third portion.
6. The tenon machine can be set up with its own docking saw to cut the timber to length before the tenons are cut into the timber. The machine also has an adjustable stop, and you can push material that is already cut to size up to this. Once your door components have been placed through the tenon machine, it's time to mark out the haunched tenon. As well as being extremely useful for creating curves and circle work, the band saw is also an excellent tool for cutting out haunched tenons.
7. After transferring your marking from the story rod to the stiles and rails, marking the position of the mortises, it's time to use the mortise machine. In this case, the mortises are not very big, so here we would select a 12 mm chisel mortise to use and create the haunched mortise. All that is left now is to put the door together with dry joints to check the fit. If all of the joints close tightly, then it will need to be disassembled, glued, squared and clamped together.

CHECK YOUR UNDERSTANDING

12. What issues can you have during machining if a piece of timber has a bow/twist?
13. What is a story rod used for?

11.4.5 Blade selection for rip and docking saw

The main differences between the types of saw blades used with these machines are: (a) the number of teeth they have; and (b) the positive or negative angle of the hook. It is important to understand the capabilities of the static machine you are using and the desired outcome when selecting a blade.

Modern blades incorporate tungsten in the teeth, which performs the cutting. For a finer cut across the grain, use a saw blade with more teeth (for example, 60–100 teeth) and a negative angle of hook as found on a radial arm saw/docking saw (Fig. 11.6). A negative hook angle, usually of -5 degrees, helps prevent the blade from self-feeding/climbing over the material and gives the operator greater control of the feed rate. The more teeth, the finer the cut and the less likely you are to have chip outs of the material.

Modern mitre saw (Fig. 11.7) blades have a combination tooth set-up. Popular are alternate top bevel (ATB) teeth, using two different sets of teeth that are a mirror image of one another. The top of the tooth, which is the part that hits the bottom of the groove, or kerf, is ground at an angle, causing

Fig. 11.6 Radial arm saw



Courtesy of Michael Hick

the tooth to cut only one corner out of the kerf. The next tooth in the rotation has the opposite bevel, so it cuts out the other corner. This cutting style has blades with a larger positive angle of hook, of approximately 10–15 degrees.

Rip saw blades make a more aggressive cut, working along the length of the timber. The blade will have fewer teeth (for example, 24–36 teeth) and a larger gullet to help remove fibrous, stringy waste material. It will have a positive angle of hook of between 5 and 22 degrees (standard angles are between 5 and 15 degrees.) A 22-degree positive hook angle is used on rip blades to pull the wood into the blade and is most effective on softwoods. Hard materials require a shallow angle such as 6 degrees. This DEWALT blade (Fig. 11.8) has 24 teeth, a large gullet, anti-kick and a 15-degree angle of hook.

Combination blades for table saws/panel saws are a compromise, aiming to have the best of both worlds. Traditionally, these blades will have more teeth than the same size of rip blade and an angle of hook of between 0 and 10 degrees. Such blades are good for general-purpose applications where the finish may not be an issue or as important. Newer blade technology such as that shown in Figure 11.9 has 50 teeth, with each set of five teeth being separated by a large gullet. The large gullet provides space for the waste to be removed while ripping, and the close grouping of teeth within the set provides a smaller bite size when cross-cutting. This allows the blade to remove more saw dust when cutting across the grain. The table saw in Figure 11.10 uses a combination blade with a 15-degree angle of hook and a 10-degree alternative tooth angle (ATB).

Fig. 11.7 Sliding compound mitre saw



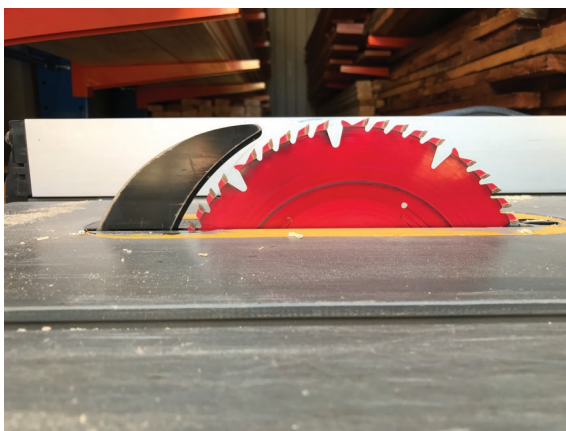
Courtesy of Michael Hick

Fig. 11.8 Rip saw blade



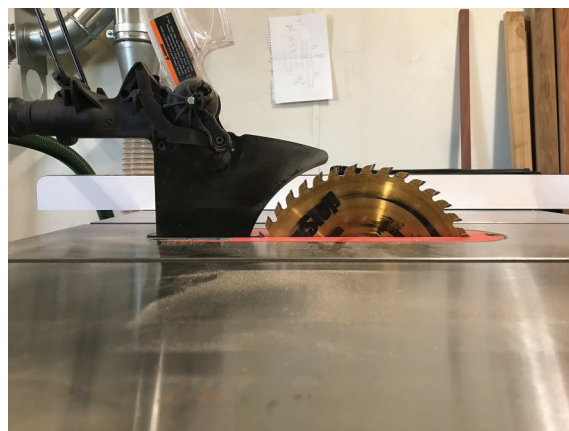
Courtesy of Michael Hick

Fig. 11.9 Combination blade



Courtesy of Michael Hick

Fig. 11.10 Combination blade with a 15-degree hook



Courtesy of Michael Hick

11.4.6 Push sticks

Push sticks can be made of timber or plastic (Fig. 11.11) and shaped as a push shoe or push block. The purpose of a push stick is to help the user safely manoeuvre a workpiece, keeping it flat against a machine table or fence while it is being cut, thus keeping the operator's hand safe from moving parts such as the saw blade.

Fig. 11.11 (a) Plastic push stick; (b) timber push block



Courtesy of Michael Hick



Courtesy of Michael Hick

CHECK YOUR UNDERSTANDING

14. What are modern saw blade teeth made out of?
15. Why are push sticks so important?

WORKPLACE SCENARIO

I had just started working as an apprentice at a joinery, and one of my first tasks was to cut up a pack of 40 mm × 40 mm KD hardwood battens, and cut the 800 lineal metre pack to lengths of 1 m. It was very repetitive and was my first time using a very large radial arm saw. It was going well and, in the beginning, I was cutting one length at a time and then two side by side. I had cut through more than half of the pack in just over an hour and then it happened. I thought if I can cut two at a time, then I must be able to cut three or even four at a time.

This worked for a short period of time. However, on one cut, I had pulled the saw too far out, past the timber that I was cutting. A piece of offcut material had vibrated behind the path of the saw. I didn't see it, and as I pushed the saw back towards the fence, the blade grabbed the offcut and climbed over the top of it. This jammed the saw between the table and the radial arm of the saw, making the saw jump. The saw flung the offcut, jumped the saw into the fence and bent the blade. It all happened so fast and caused a big bang. I was lucky that I had stepped back from the saw. The aftermath was a wrecked aluminium fence and a mangled saw blade. I was okay and lucky not to have been hurt.

So, what had happened? I had become complacent and impatient with the repetitive nature of what I was doing. I wanted to impress my boss by getting through the task as fast as I could. I didn't take a break and I started to use the radial arm saw in a way that I hadn't been shown, but that I thought would be okay. I was fortunate not to have hurt myself. However, I did cause approximately \$800 worth of damage and the saw was not in use for a week due to repairs, which was also a large cost to the business.

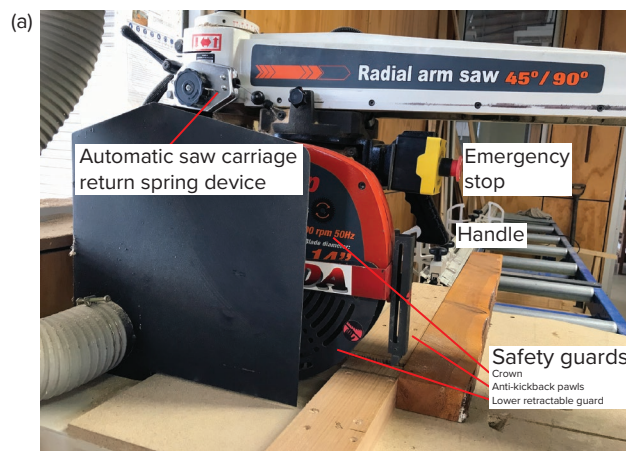
11.5 Safely set up, use and maintain a docking saw/radial arm saw

There are a variety of docking/cross-cut saws on the market, such as:

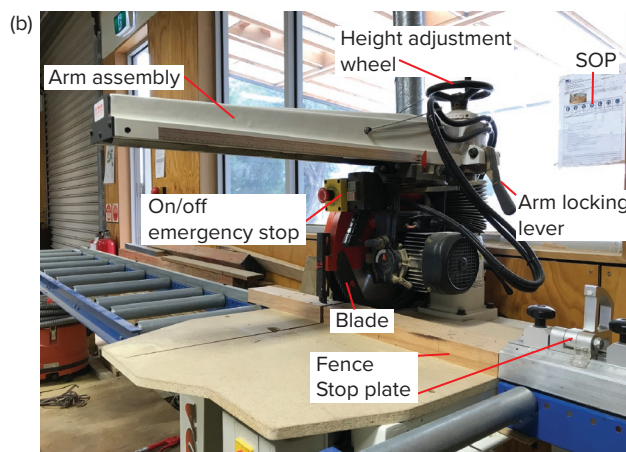
- dock saw/radial arm saw
- cross-cut saw
- panel saw
- pop-up docking saw
- portable sliding compound saw.

The primary function of a traditional radial arm saw is to square cut timber to specific lengths (Fig. 11.12). This machine has also been designed to allow for straight ripping, bevel ripping, trenching, mitre and bevel cutting and compound cutting.

Fig. 11.12 (a) and (b) Radial arm saw guards and components



Courtesy of Michael Hick



Courtesy of Michael Hick

This machine can be operated from either side; however, it is best practice to operate the saw from the side that won't have your body in the direct line of the blade. This reduces the risk of you coming into contact with a spinning blade. Before turning on the radial arm saw, make sure you go through the SWP for the machine.

11.5.1 Pre-checks for a radial arm saw

Before turning on the radial arm saw, make sure you go through the SWP for the machine that you are about to use and the machine's pre-check process. Checks may include but are not limited to: the height of the blade; checking that the bench and the saw blade are set up to make square cuts; checking the emergency stop buttons are working and that the extraction system is connected and operating correctly. A pre-check may be in the form of a tick sheet; for example, Figure 11.13.

11.5.2 Docking timber

When docking timber, make sure you have the timber up against the fence and flat on the table, taking into consideration any twists, bows and wind. Ensure you are in a

comfortable stance, standing on the right side of the saw with your left hand on the handle and your right hand holding the timber (**do not cross your arms**) securely against the fence and table (Fig. 11.14). Turn the dock saw on and allow the machine to come up to full revolution. Pull the saw out from behind the fence to begin the cut (Fig. 11.15), allowing the saw to work at its designed capacity (a slow and steady pace so as not to labour the motor).

Fig. 11.13 Example of a machine pre-check list

Static machine daily pre-check									
Machine: Radial arm saw		Date 21/01/22		Date //		Date //		Date //	
		Signature: Mick	Signature:	Signature:	Signature:	Signature:	Signature:	Signature:	Signature:
		Tick or comment	Tick or comment	Tick or comment	Tick or comment	Tick or comment	Tick or comment	Tick or comment	Tick or comment
Visually check switches wiring/conduit for damage		✓	✓	✓	✓	✓	✓	✓	
Check hood guard		✓							
Check saw blade for damage and wear		E.g. blade has multiple broken teeth							E.g. replaced blade (date); blade sent off to be sharpened and repaired
Check extraction is connected and operational		✓							
Check the automatic saw carriage return spring device is operating correctly		✓							
Check push stick is available and in good order		✓							
Check blade is square to table		✓							
Check blade is square to fence		✓							
Check emergency stop is operating correctly		✓							
Ensure workspaces and walkways are clear and unobstructed and that no slip hazards are present		✓							
Confirm PPE is available for this machine		✓							
Other									

Fig. 11.14 Radial arm saw cutting position

Courtesy of Michael Hick

Fig. 11.15 Cross-cutting

Courtesy of Michael Hick

As soon as the front of the blade has passed through the material (Fig. 11.16), there is no need to pull the saw blade out any further. Use the handle to push the saw back through the cut and behind the fence (Fig. 11.17).

Fig. 11.16 Completed cross-cut

Courtesy of Michael Hick

Fig. 11.17 Saw pushed back behind the fence

Courtesy of Michael Hick

A laboured motor means that undue stress has been put on the machine, exceeding what the motor is designed for. With static machines, a laboured motor can be dangerous and harmful to both the machine and the operator. For example, when using a docking saw, if the saw is pulled through material faster than it is capable of, the blade will slow down. Instead of cutting, the blade will potentially climb over the material being cut, causing a jamming accident between the radial arm and the table. This may damage the radial arm, the blade, the timber and/or the operator.

When using a stop plate (Fig. 11.18), make sure you follow the same cutting procedure as before—securing the timber, and holding firmly against the fence and on the table until the cut is complete and the blade is back behind the fence.

Fig. 11.18 Set-up of stop plate

Courtesy of Michael Hick

The danger point in the operation is when the blade has completed the cut but hasn't been pushed back behind the fence. At that moment, there is potential for a jamming accident, as the timber is between the stop plate and the spinning blade.

Be aware, too, of the possibility of a radial arm saw accident when using the saw in the docking position. This can occur when cutting multiple pieces from a length of timber and operating the machine from the left side of the blade. If a user has not pushed the saw back behind the guard fence, on dragging the length of timber across the bench and passing the face of the saw blade, it is possible to accidentally swipe the fingers against the blade, resulting in cuts or even amputated fingers. To avoid the risk of this type of accident occurring, some companies have removed this type of saw from their workplace in favour of the pop-up docking saw, often referred to as a safety saw.

CHECK YOUR UNDERSTANDING

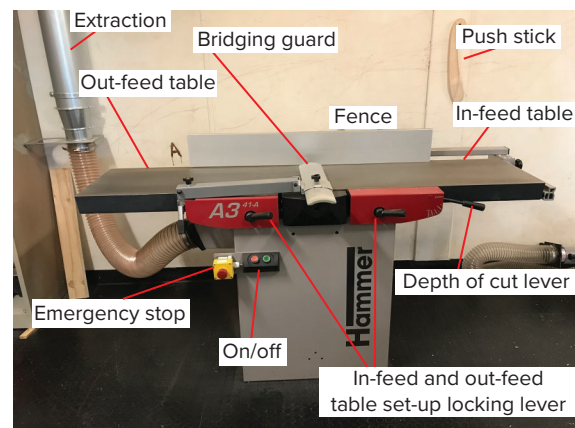
16. On which side of the radial arm saw is it recommended to cut from and why?
17. What is the danger of a labouring motor on a radial arm/docking saw?
18. Research: what is a pop-up docking saw?

TIP If you do not know or are unsure how to use a static machine, do not use it! Seek training from a qualified employee at your worksite or at a registered training organisation.

11.6 Safely set up, use and maintain a surface planer/buzzer/jointer

The main function of a surface planer (Fig. 11.19) is to square (90 degrees) a face and an edge of timber. The first pass over the machine is the widest part of the board (face); once the face has been machined, it is then pressed up against the fence (the fence is square to the table) and the edge of the timber is passed over the blades, creating a square edge between the face and edge. Why? Machining the face gives you that largest surface area to machine against the table, and when squaring the material up, you will have the largest face against the fence. This process of face first, then edge, will give you the most accuracy and stability when squaring your timber.

Fig. 11.19 Surface planer components



Courtesy of Michael Hick

11.6.1 Setting up a bridging guard

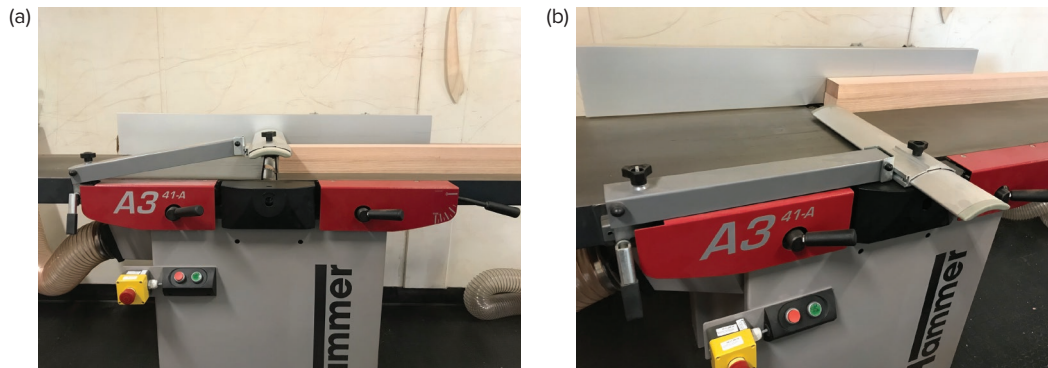
The bridging guard will need to be set up for the height of the material (Fig. 11.20a). However, it does have a maximum working height. If you have a thicker piece of timber, the process would be to have the bridging guard all the way down and adjusted out from the fence to the width of the material being machined (Fig. 11.20b).

Rear guards (Fig. 11.21) are needed due to the squaring fence being able to move to accommodate various timber widths. There is also a back guard that prevents exposure of the cutter head.

Other types of guards are also used. Figure 11.22 shows a traditional-style spring-loaded guard. These guards are also known as leg of mutton. As material is pushed into the guard, it moves to the

side, allowing the material to travel over the top of the spinning surface planer blades. Once the material has passed the blades and the guard, the spring mechanism moves the guard back into place, covering the spinning blades.

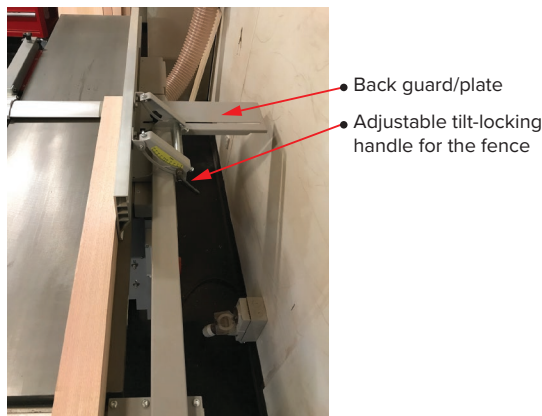
Fig. 11.20 (a) Bridging guard set-up for face planing; (b) bridging guard set-up for edge planing



Courtesy of Michael Hick

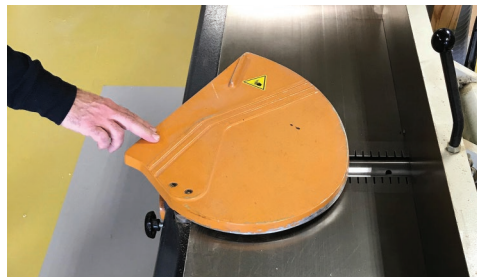
Courtesy of Michael Hick

Fig. 11.21 Surface planer fence and rear guards



Courtesy of Michael Hick

Fig. 11.22 Spring-loaded guard

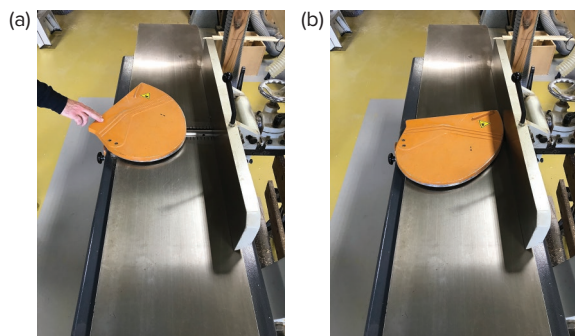


Courtesy of Michael Hick

CHECK YOUR UNDERSTANDING

19. How many guards are on a surface planer and what is their main purpose?

Fig. 11.23 (a) Pulling back the spring-loaded guard to check it is operational; (b) spring-loaded guard returned to correct set-up position



Courtesy of Michael Hick

Courtesy of Michael Hick

11.6.1.1 Pre-checks for a surface planer

Before turning on the surface planer, make sure you go through the SWP for the machine you are about to use and look over the machine's pre-check process. As a pre-check for this machine, which is fitted with a spring-loaded guard (leg of mutton), it is always good practice to make sure the guard is in working order and springs back over the blades/knives (Fig. 11.23).

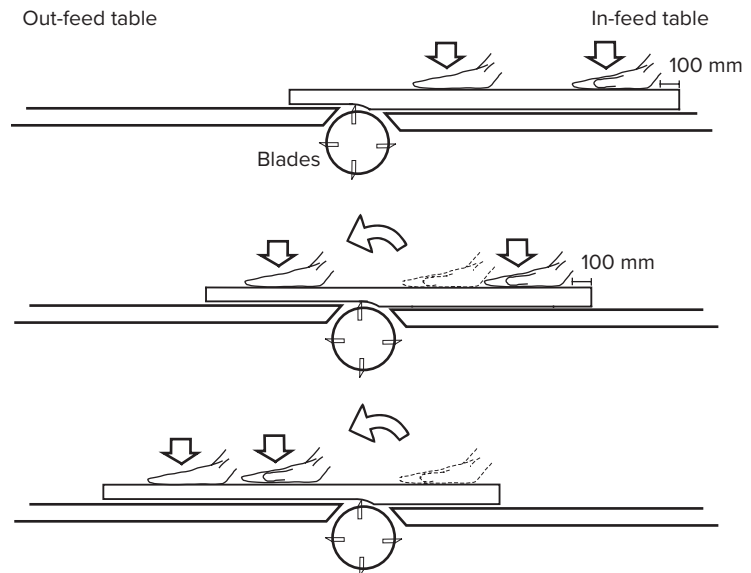
It is also an idea to do the following checks, among others: make sure the fence is square to the table; check the depth of cut; ensure the guards are set up and fixed into position, that emergency stops are in a good working condition and the extraction is connected and operating.

11.6.2 Process for surface planing

At this stage, the most suitable material should have been selected based on straightness; it should be free of defects. Timber should have been docked to almost the finished size (50–100 mm longer, to enable it to be trimmed back to the final size after machining).

If you can't avoid using timbers that are bowed or twisted, then the hollow or twisted side must be placed down on the table. The direction of the grain on the proposed face side must also be determined. The grain must point away from the direction of the rotation of the cutter block when the face is placed on the table. The reason for this is that the knives can catch the grain and chip out the face of the timber. If the material is not bowed or twisted, then the best side is selected as the face. The direction of grain is determined on the side to be planed. Then, place your hands on top of the timber (Fig. 11.24), taking care to make sure your thumbs don't drop down the side of the timber. The hand at the back of the material should remain 100 mm in from the end of the timber, or you may wish to use a push stick/block.

Fig. 11.24 Hand position for surface planing



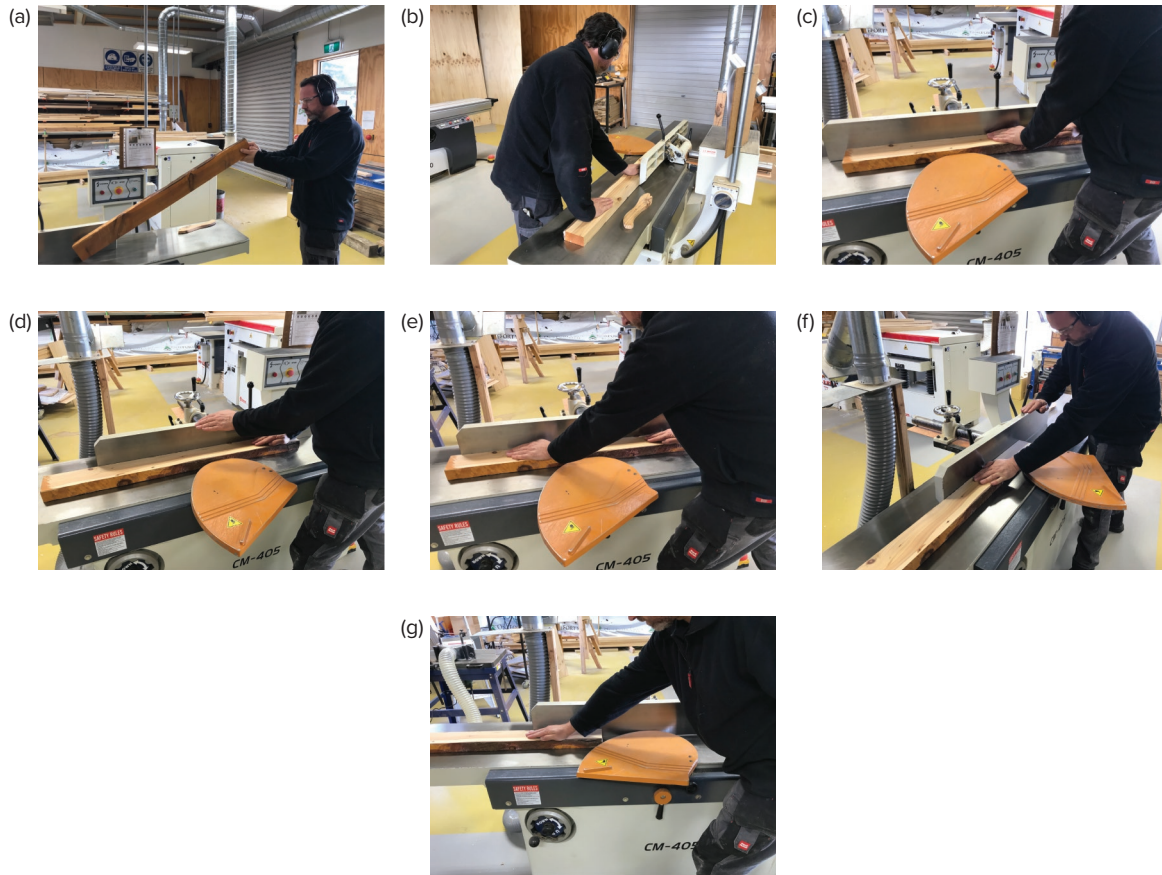
The bridging guard forces you to step your hands over the spinning blades, helping to reduce your risk of coming into contact with the blades. Make sure you don't develop the bad habit, when using a machine fitted with a spring-loaded guard, of forgetting to step your hands over the section where the blades are exposed and where you could potentially come into contact with the blades. If you are not confident with using a spring-loaded guard, make sure you use a push stick/block.

To straighten timber, you will first need to determine the bows and the twists in it (Fig. 11.25a); on a surface planer, the bows face up. When straightening timber, you will need to use a firm and consistent pressure on the timber as you push it over the blades—enough pressure that you can move the timber forward but not so much that you are pushing the bow down. This process will ensure you have the straightest face possible. However, if you don't have a lot of thickness to work with, you may need to be satisfied with being able to make only the face of the timber 'flat'. To make the timber flat, slightly increase the pressure down on the bow in the timber as you push it over the blades, but take care when using this method and use a push stick/block as required. The timber won't be straight, but it will be flat and even and ready to square an edge.

Figure 11.25b–g shows a visual demonstration of machining the face of a piece of timber and the process of safely stepping your hands over the blades. This process ensures you reduce the risk of your fingers coming into contact with the blades and that the timber is always supported.

After the timber's face has been straightened or made flat, the next step is to square your material. Again, check the bow in the timber on its edge this time. Place the straight/flat face against the fence and keep the timber hard against the fence. Your hands will be positioned on top of the timber and, as before, you will need to step your hands over the blades. If you are machining a small narrow timber, make sure you are using a push stick/block. Figure 11.26a–h provides a visual demonstration of machining the edge of a piece of timber and the process of safely stepping your hands over the blades.

Fig. 11.25 Surface planing the face of a piece of timber: (a) checking for bows and twists in timber; (b) bows facing up, ready to machine; (c) hands pushing timber over blades; (d) stepping hand over blades; (e) hand providing even pressure on other side of blade; (f) stepping back hand over blades; (g) back hand clear of blades and pushing timber out of blade, and spring-loaded guard returned to start position



Courtesy of Michael Hick

SAFETY TIP Ensure you are stepping your hands over the blades and make sure the timber is always supported. The operator's body never goes past the spring-loaded guard/bridge guard until the entire length of timber has been machined.

Once the timber has been straightened/flattened and squared, it may need to be ripped back to a workable size and then moved to the process of panel planing (thicknessing).

The surface planer and the panel planer both have a cylindrical head with either knives, disposable double-sided blades or four-sided tungsten carbide knives that can be turned up to four times to access a new cutting edge. The process of changing blades in these machines is detailed in the panel planer section of this chapter.

CHECK YOUR UNDERSTANDING

20. How far from the back of the timber should the palm of your hand be when surface planing the face of the material?
21. What gets machined first: the face or the edge? Why?

Fig. 11.26 Surface planing the edge of a piece of timber/squaring timber: (a) face of timber held firmly against squaring fence; (b) bow of timber facing up; (c) hands firmly supporting timber; (d) stepping hand over blades; (e) hand stepped over blade and supporting timber; (f) front hand in a position to support timber as back hand is ready to be stepped over blade; (g) back hand is stepped over blade; (h) back hand stepped over blade and pushing timber out over blades



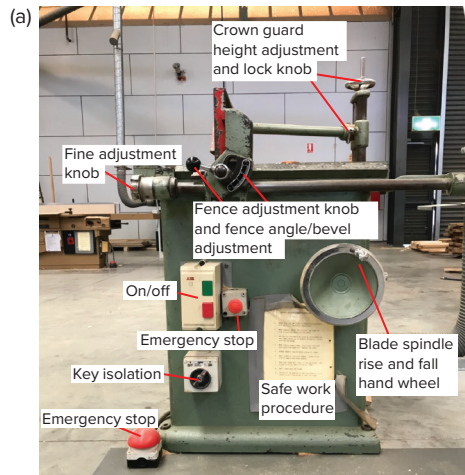
Courtesy of Michael Hick

SAFETY TIP Before operation, always make sure the static machine you are using has a push stick or push pad within reach. This will reduce the chances of you placing your hands and fingers too close to moving parts and blades.

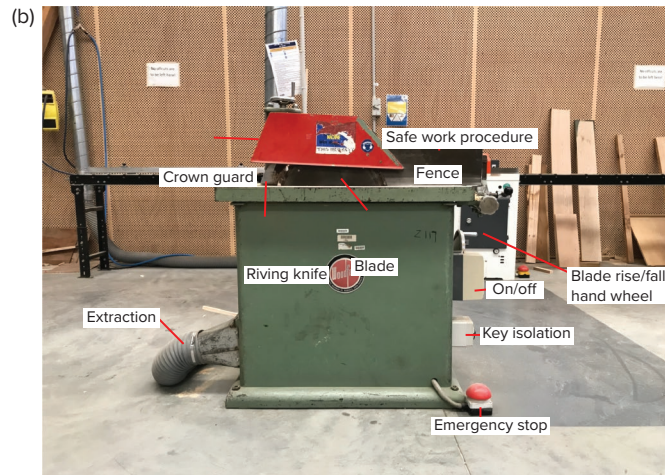
11.7 Safely set up, use and maintain a rip saw/table saw

As with most static machines, there are a variety of rip saws available on the market. These range from traditional rip saws (Fig. 11.27) to combination machines that can rip and cross-cut as well as modern portable rip saws for use in workshops. As time goes by, we are seeing fewer and fewer traditional rip saws in use, with many people opting instead for combination machines that can rip and cross-cut, such as panel saws and modern table saws, which have a large bench/table at either side of the blade and guard.

Rip saws are designed to cut material along the grain. Blade selection is important and dependant on the type of material you are ripping. When ripping with a traditional rip saw, it is important to select the correct type of blade in terms of the type of timber that you are ripping (softwood or hardwood).

Fig. 11.27 (a) Front; and (b) side view of traditional rip saw components

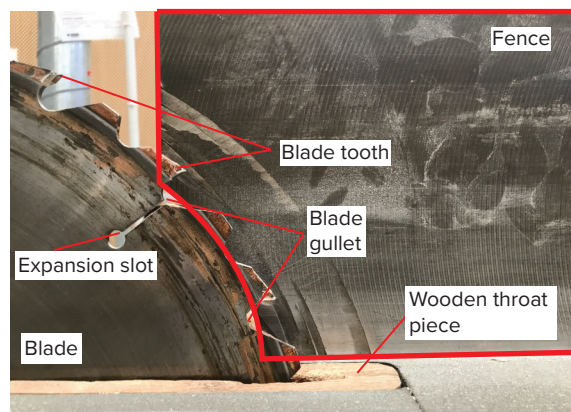
Courtesy of Michael Hick



Courtesy of Michael Hick

It is also important to have the blade raised to its full height, to have the riving knife set up to the Australian Standard and the crown guard set to a workable practicable height (approximately 10 mm above the material that you are ripping). The riving knife is a device designed to stop the timber from binding and jamming on the back of the blade as you are pushing material through the saw; it helps reduce instances of kickback. It is also a safety device as it covers the back of the exposed spinning blade, which isn't covered by the crown guard.

Importance of blade height: when ripping and using a blade that has positive angle of hook, the blade is designed to draw material down and into the saw blade. This is achieved only when the blade is set to its full height; if set to a lower position, the saw blade will throw the timber back towards the operator.

Fig. 11.28 Rip fence and components

Courtesy of Michael Hick

Rip saws are able to accommodate a variety of different blades and sizes of blades. The front of the fence that is closest to the blade has a curved shape machined into it; the curve in the fence is not a radius. The reason why it is not a radius is that a radius would not be able to accommodate the different blade sizes when setting up the blade to the fence (Fig. 11.28). The fence should be set up to the blade with the curve of the fence as close as is practicable, in line with the gullet of the blade.

The purpose of the fence and the blade being set up in this position is to ensure the fence supports the timber as it is being fed through the saw. Once the tip of the tooth has cut the material and the timber has passed the gullet, the potential for the timber to jam between the fence and the blade is greatly reduced. If the fence is set up too far forward, the timber could become jammed between the spinning blade and the fence and kickback may occur.

The distances for a riving knife on a rip saw are set out in the Australian Standard. The standards set out the conditions for the heights and the distance of the riving knife to the blade. Many riving knives are designed to accommodate a variety of blade sizes and, as such, the riving knife is a curve and not a radius. The riving knife should be set up to the same height as the blade and the gap between

the blade and the riving knife should be 3 mm at its closest point and with a maximum gap of 8 mm (see Fig. 11.36 later in the chapter). As blades come in different sizes always refer back to the AS for guidance to the set-up of a riving knife.

The riving knife is designed to act as a spreader and prevent timber from closing up/binding at the rear of the blade, thus helping to prevent kickback. It also acts as a rear guard at the back of the saw blade.

As a rip saw is capable of using different size blades, the wooden throat (refer back to Fig. 11.28) is a filler piece to close the excess mouth of the opening on the saw's bench.

11.7.1 Considerations when flat and deep ripping

The rip saw is primarily used for ripping solid timber. The timber can be dressed, rough-sawn (RS), wet material, bowed and twisted, or long and short lengths. Ripping dressed timber should be the easiest; however, it is still best practice to eye up the material (visually check for bows and twists) the same as if it was rough-sawn.

The bow (or rounded) edge must be placed against the fence and the bow in the face of the material is placed downwards onto the table. The purpose of this is to make sure that the timber is making contact with the fence and the table at all times.

Avoid using twisted material or, if possible, cut it into smaller lengths. This type of material has a tendency to bind between the blade and fence, which increases the chance of kickback. If you can, you may need to surface plane twisted material first.

11.7.2 Rip saw pre-checks

Before starting work, it is important to do some pre-checks on the rip saw; first, make sure it is isolated from the power. Check that the blade is in good condition and raised to the maximum height. Ensure that the fence is square to the table and set to the desired width of cut for the material. The fence may be set using the graduated bar fitted to the table—however, if the machine does not have one of these, measure the distance from the fence to the saw tooth that is set (bent) towards the fence. The crown guard should be set to a practical workable height (approximately 10 mm above the timber to be cut). Make sure all guards and fences are locked off in position and do not impinge (interfere with) the blade.

Once the machine has gone through its pre-checks and set-up, power can be restored to the machine.

Best practice is to make cutting long lengths of timber a two-person job. The first person is the operator, who stands to the left of the material, feeding the material into the blade and keeping it against the fence. The operator must never be standing in the line of the blade in case of kickback—if kickback occurs, the material will be launched into the operator's person.

At no time should the hands be placed in line with the blades or closer than 200 mm to the blade.

The other operator, also known as the person tailing out, should be positioned at the back of the table; as the timber passes the back edge of the table, this person should be able to grasp the timber and support it. The main job here is to make sure the timber is flat on the table and against the fence as it moves through the saw, supporting the material and ensuring it is not pulled through the machine. Note that the rate of feed is controlled by the operator.

As the material comes up to the front of the saw blade, the operator will need to change from using the hands to feed the material to using a push stick, which helps keep pressure on the material against the table and against the fence.

When the material is completely cut from the front of the saw, it is then the job of the person tailing out (at the back of the saw) to pull both pieces through.

If the material is to be ripped again, the person tailing out will need to stack the correct-sized piece of material and return the other sections to the operator the same way that they came out of the machine (don't turn or flip the material).

Deep sawing is completed in a similar manner. Make sure that you have selected a saw blade that has a fair portion of the blade projecting above the material that you wish to cut. If the blade projects

only a few millimetres through the material, the blade will not be able to create a downward force and instead the force will be projected back towards the operator. The operator will need to use extra effort to push the material through the blade, which increases the possibility of kickback.

Always refer to the Australian Standard in regards to the set-up of saws for riving knives, guards, rebating, tenoning, grooving and plunge cutting.

- It is recommended that you surface plane the face and a square edge to help with this type of cut on the rip saw. That way the material can be flat on the table and against the fence.
- If it is not possible to surface plane the material first, take care to ensure that the material is hard up against the fence throughout the cut.

11.7.3 Ripping small material

Cutting smaller-sized material from 500 mm to 2000 mm can be done by one person. It is not recommended that you cut material under 500 mm on a traditional rip saw, due to the risk of your hand coming too close to the blade. Cutting by yourself requires the rip saw table to be extended as this will enable you to support the material that you are cutting. Material that falls off the back of the saw risks becoming jammed in the blade and the crown guard.

11.7.4 Modern table saws

Modern table saws (Fig. 11.29) and portable rip saws (Fig. 11.30) often use a combination blade for cross-cutting and ripping. They are used for solid timber as well as manufactured boards, and often come with a fixed-length fence that runs from the front of the table to the back and which can only move from side to side (the cutting distance from the fence to the blade). With this type of saw, you need to be mindful while ripping that the timber may bind between the blade and the fence.

Fig. 11.29 Table saw



Courtesy of Michael Hick

Fig. 11.30 Portable table rip saw



Courtesy of Michael Hick

11.7.5 Replacing blades

When replacing blades, knives or cutters in any type of static machine, always isolate the machine from the power. After isolating the power, you will need to move the fence out of the way and remove the crown/hood guard and extraction system (Fig. 11.31a). Each machine is different, so you will need to consult with the manual and SOP. The next step is to remove the timber throat piece or the throat insert (Figs 11.31b and 11.31c). In this example, the throat insert on the saw is a fixed size as this particular combination rip saw is capable of running only a 250 mm saw blade.

At this stage, the riving knife should be removed if the replacement blade is larger than the original. You will need to check the gap between the riving knife and the blade once the new blade is installed to check clearances are to the Australian Standard.

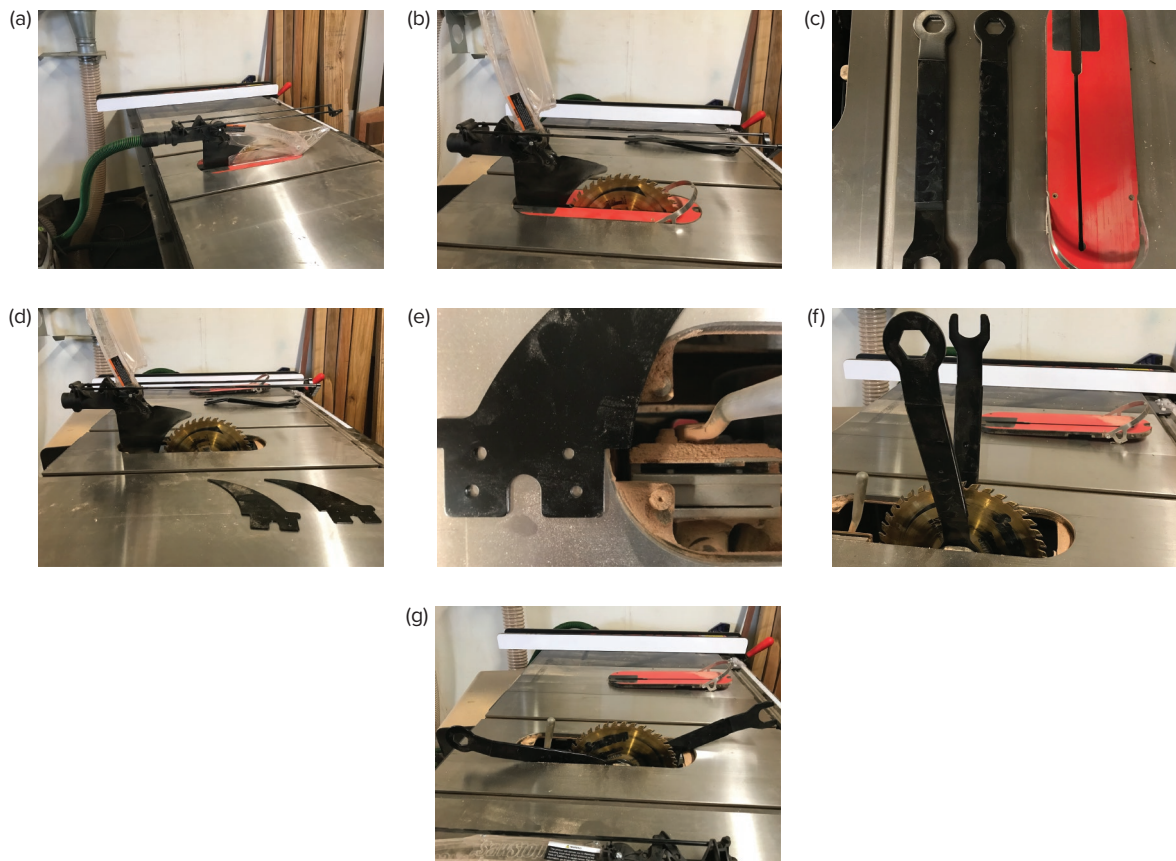
Some combination rip saws/table saws come with a variety of riving knives to suit different sizes of blades (Fig. 11.31d). On the example model shown in Figure 11.31e, the riving knife is held in by a clamp and set to a standard position, alleviating the necessity of having to reset the riving knife each time.

Once the throat insert has been removed, it is time to remove the blade. Newer machines will use a two spanner method to remove the arbor nut whilst older machines may use a block and spanner method.

Some machines have a built in arbor pin to hold the blade in position when undoing the arbor nut (portable power tools such as mitre saws and grinders use this method). The blade will need to be manually rotated as you press the pin down until it locates itself into a recess in the arbor shaft which will result in the shaft being held in position, allowing you to undo the arbor nut with a spanner.

The spanners fit on either side of the blade (Fig. 11.31f), one on the arbor that will have a recess created to accommodate a spanner, and the other on the arbor nut. The nut is reverse threaded, so you will need to wrench the spanner on the arbor nut towards yourself and the other spanner on the saw arbor away from yourself (Fig. 11.31g). Always be vigilant around saw blades—although the machine may not be on, as you are working on it, there is a risk of nicking yourself on the tips of the blade, resulting in a cut.

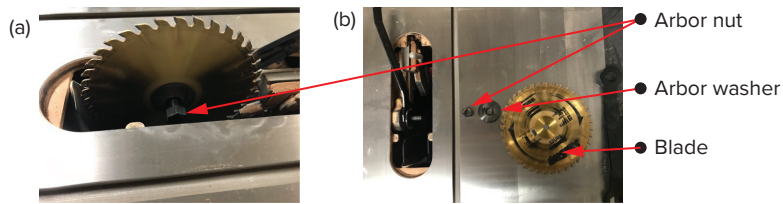
Fig. 11.31 Replacing blades: (a) removing extraction; (b) removing throat insert; (c) removed throat insert/arbor spanners; (d) standard riving knives for table saw; (e) removed riving knife; (f) spanners set up to remove arbor nut; (g) loosening arbor nut



Courtesy of Michael Hick

TIP As you remove the parts of a machine for maintenance, it is good practice to lay the parts out in the order in which you remove them, creating a visual of how the parts go back together (Fig. 11.32).

Fig. 11.32 Removing a blade: (a) the arbor nut; (b) removed arbor nut, arbor washer and blade



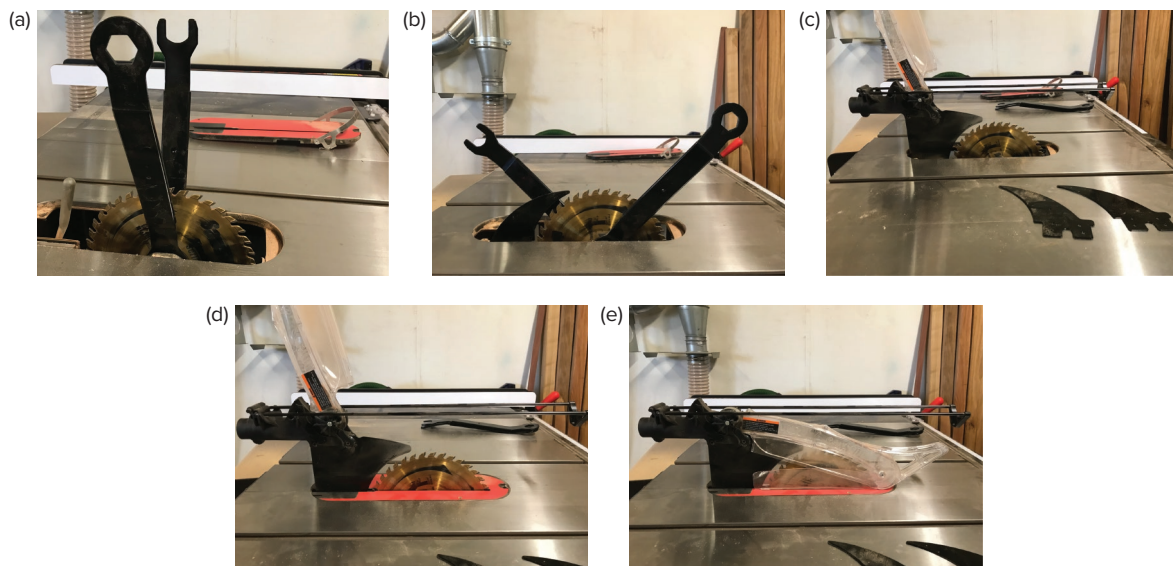
Courtesy of Michael Hick

the back of the machine and the arbor spanner is pulled towards yourself (Fig. 11.33b). At this stage, you can reinstall the hood guard with the riving knife attached (Fig. 11.33c) or install just a riving knife if you have an external crown guard.

Make sure you install the throat inset (Fig. 11.33d) and place the crown guard into position over the blade (Fig. 11.33e).

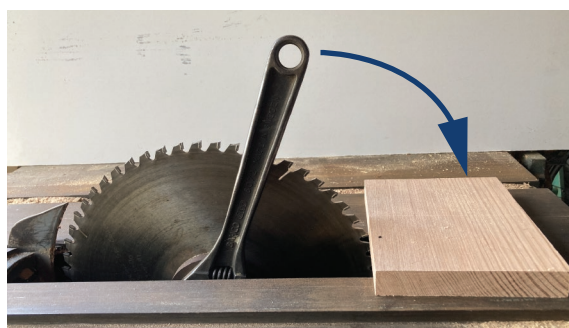
Make sure the replacement blade is facing the correct way when installing it, placing the arbor washer on the arbor and installing the arbor nut. Tightening the blade into place is the reverse of the installation procedure (Fig. 11.33a). The arbor nut spanner is pushed to

Fig. 11.33 (a) Blade ready to be tightened into position; (b) tightening up the arbor nut; (c) installed riving knife and crown guard; (d) installed throat inset; (e) crown guard over blade



Courtesy of Michael Hick

Fig. 11.34 Alternative method of removing a blade



Courtesy of Michael Hick

In this case, one method used to remove the blade is to place a piece of timber on the front of the saw table (not impinging the blade). The timber block prevents causing damage to the saw table when you use the spanner/shifters. Use a spanner or shifter on the arbor nut from the position you can see in Figure 11.34 and, with a little force, tap the spanner into the timber block. On machines that are used often, a few taps should be enough to loosen the nut. There is no need to hold or touch the blade with this technique.

TIP Referring to Figure 11.34, tie a 1 m length of string to the end of the spanner or shifter and hold onto the string; if the spanner or shifter falls off the arbor nut and drops to the bottom of the machine, it will be easier to retrieve.

CHECK YOUR UNDERSTANDING

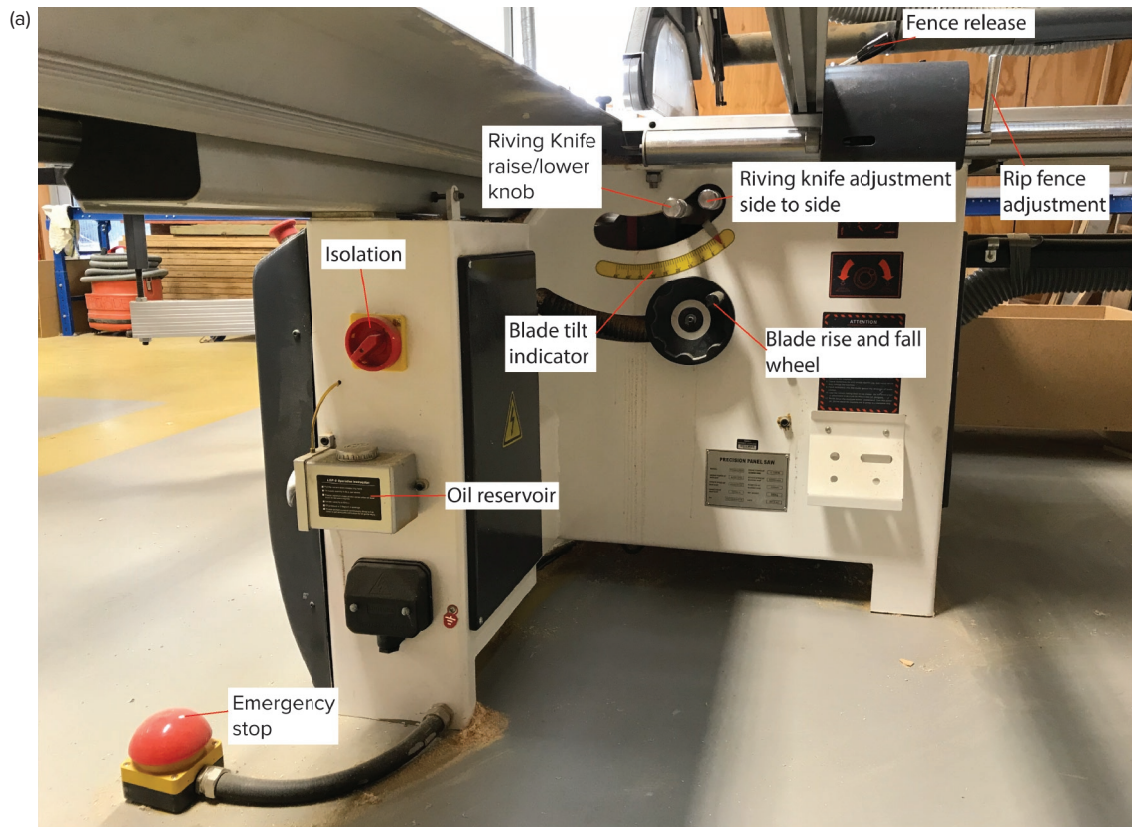
22. On a traditional rip saw, in terms of cutting the timber, why does the fence have a curved toe?
23. What is the job of the person 'tailing out' a rip saw?
24. What is the recommended height for a crown guard that is separate from the riving knife assembly?
25. What must you do before you change the blade on a rip saw?

11.8 Safely set up, use and maintain a panel saw

Panel saws are a great choice of multi-role machine, capable of ripping and cross-cutting, with a large support table and arm. These machines were developed so that one person could operate them and cut sheets of manufactured board 2.4 m × 1.2 m and larger (Fig. 11.35).

Figure 11.36 demonstrates the correct set-up of a riving knife for this particular machine in accordance with the Australian Standard. Panel saws come with a variety of accessories and safety devices to assist with the operation of these machines (Fig. 11.37).

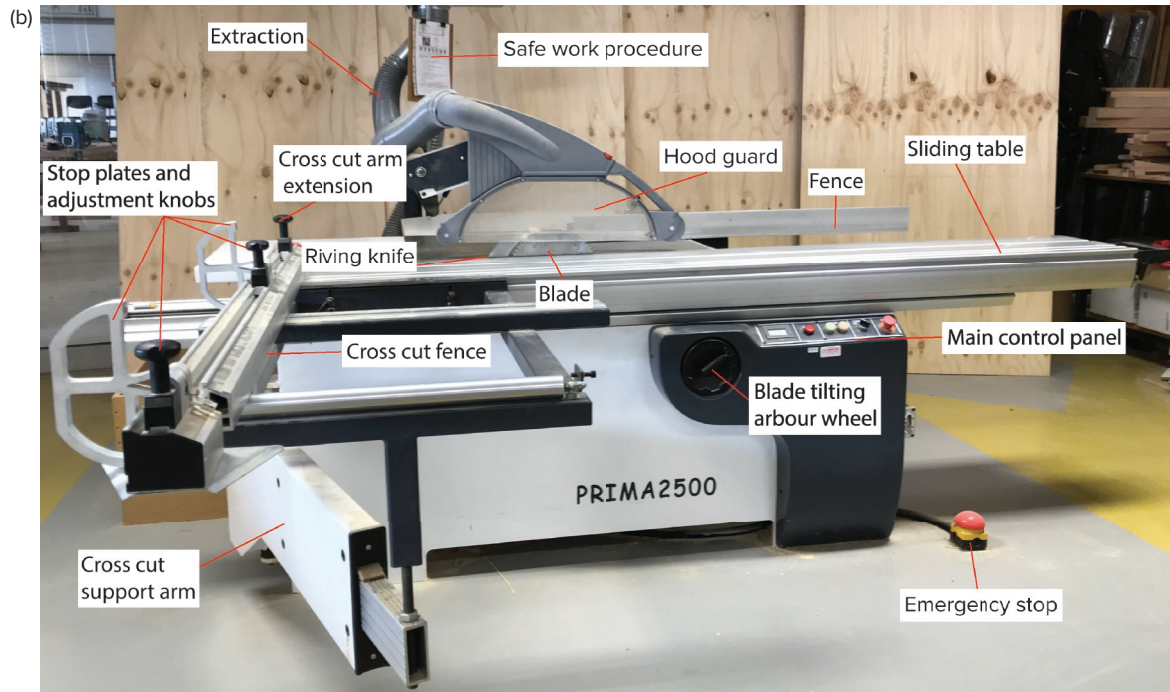
Fig. 11.35 (a) Front view; (b) side view of a panel saw



Courtesy of Michael Hick

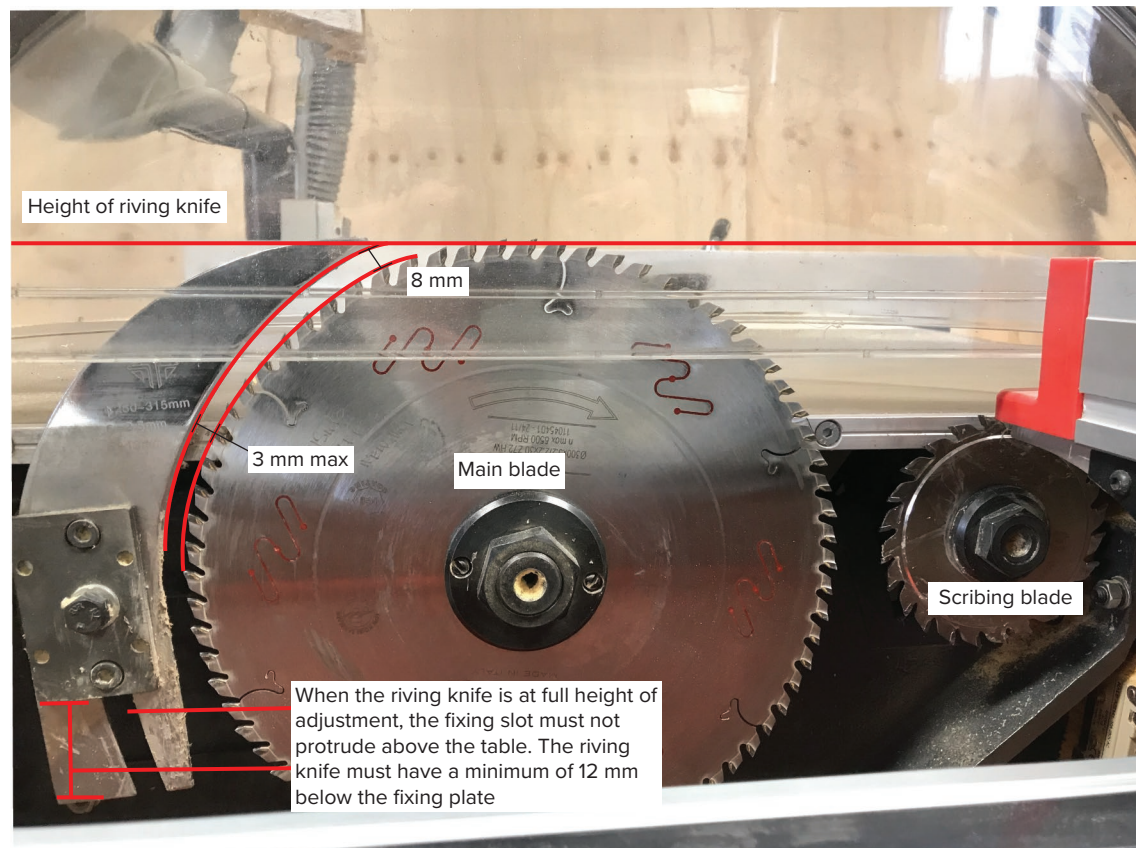
(continued)

Fig. 11.35 (a) Front view; (b) side view of a panel saw (continued)

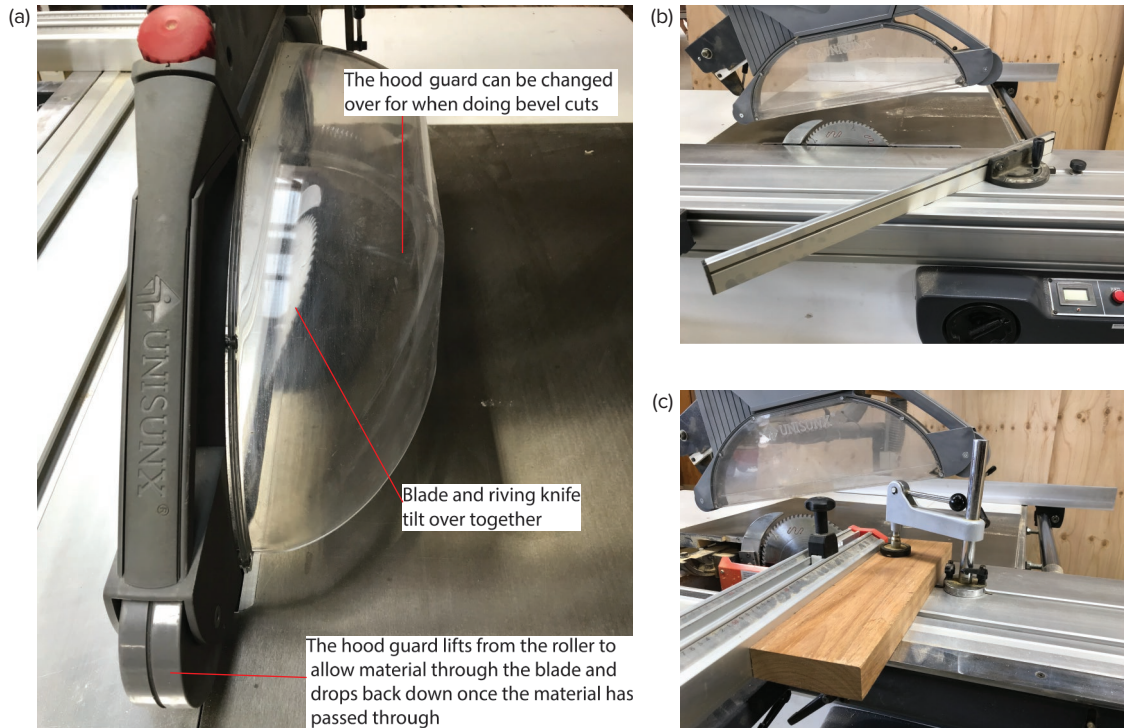


Courtesy of Michael Hick

Fig. 11.36 Panel saw main blade, riving knife and scribing blade



Courtesy of Michael Hick

Fig. 11.37 (a) Hood guard for mitre cutting; (b) mitre fence; (c) table clamp

Courtesy of Michael Hick

11.8.1 Setting up a panel saw

For a panel saw to operate and cut material correctly according to its designed purpose requires, but is not limited to, the following to be in place:

- correct blade selection
- riving knife set up to Australian Standard
- the scribing blade to have the correct size of shims placed between the two split blades so that they match and are in line with the main blade; and for scribing blades to work in conjunction with the main blade to cut panels and prevent chipping on manufactured boards such as laminates and veneer
- the main blade to be squared to the table
- the cross-cut arm/fence to be squared to the main blade
- the rip fence to be squared to the cross-cut arm/fence.

11.8.2 Basic cutting on a panel saw

When cutting up a manufactured board on a panel saw, you should never assume that the board is square; squaring a board is the responsibility of the wood machinist.

In this example, we are squaring up a $2420 \times 1220 \times 16$ mm ply board. The process is to first place the width of the board up against the cross-cut fence and rip a maximum of 10 mm off the board along its length (Fig. 11.38a); this cut will give you a straight and clean edge. The next step is to place the ripped length against the cross-cut fence and cut a maximum of 10 mm off the width (Fig. 11.38b). The board now has a length and width that have been cut straight and square to each other. The board is now ready to be cut into the desired pieces/sizes.

Fig. 11.38 (a) Straightening a board; (b) squaring a board

Courtesy of Michael Hick



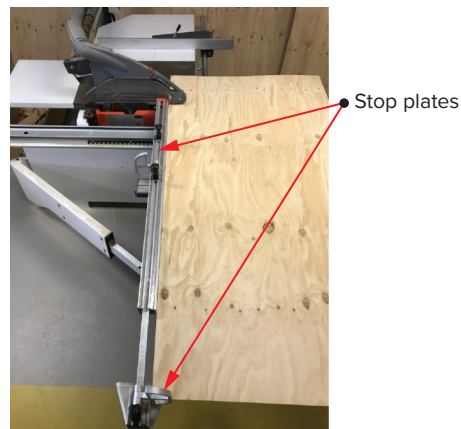
Courtesy of Michael Hick

The operator can set the rip fence and the cross-cut arm with predetermined sizes. Some machines also have multiple stop plates that can be set up (Fig. 11.39).

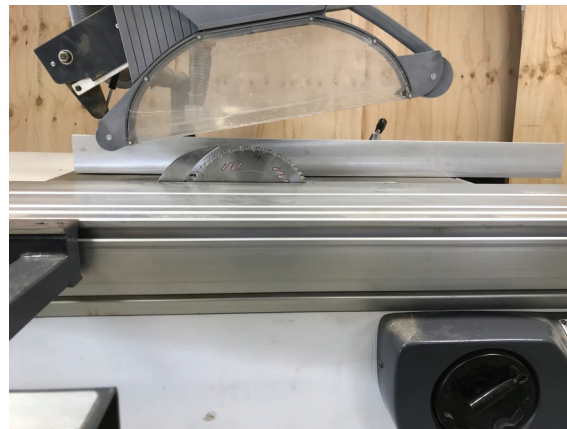
In Figure 11.40, the ripping fence has been set up in a position to rip lengths of manufactured board. The board should be pushed up hard against the rip fence and supported for the entire cut to create an accurate parallel piece of work.

At times on these machines, you may need to rip solid timber. As with a traditional rip saw, it is best to set up the fence with the gullet of the ripping/combination blade that you are using. Although the fence on these machines does not have the same curved toes as on a traditional rip saw fence, a rule of thumb for lining the gullet up is to set up the fence behind the centre of the blade (Fig. 11.41a).

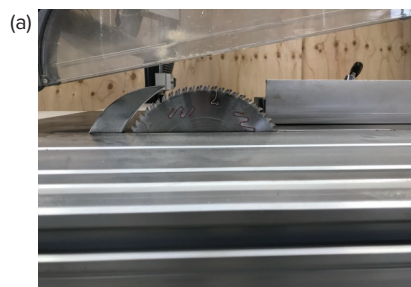
The ripping fence can also be used as a stop plate when cross-cutting material (Fig. 11.41b). The fence has to be set well behind the blade so as not to create a jamming point when cutting.

Fig. 11.39 Panel saw telescopic fence

Courtesy of Michael Hick

Fig. 11.40 Rip fence set-up for manufactured board

Courtesy of Michael Hick

Fig. 11.41 (a) Panel saw rip fence set-up for solid timber; (b) rip fence set-up as a stop plate

Courtesy of Michael Hick



Courtesy of Michael Hick

Rip fence set-up behind blade to be used as a stop plate for cross-cutting

CHECK YOUR UNDERSTANDING

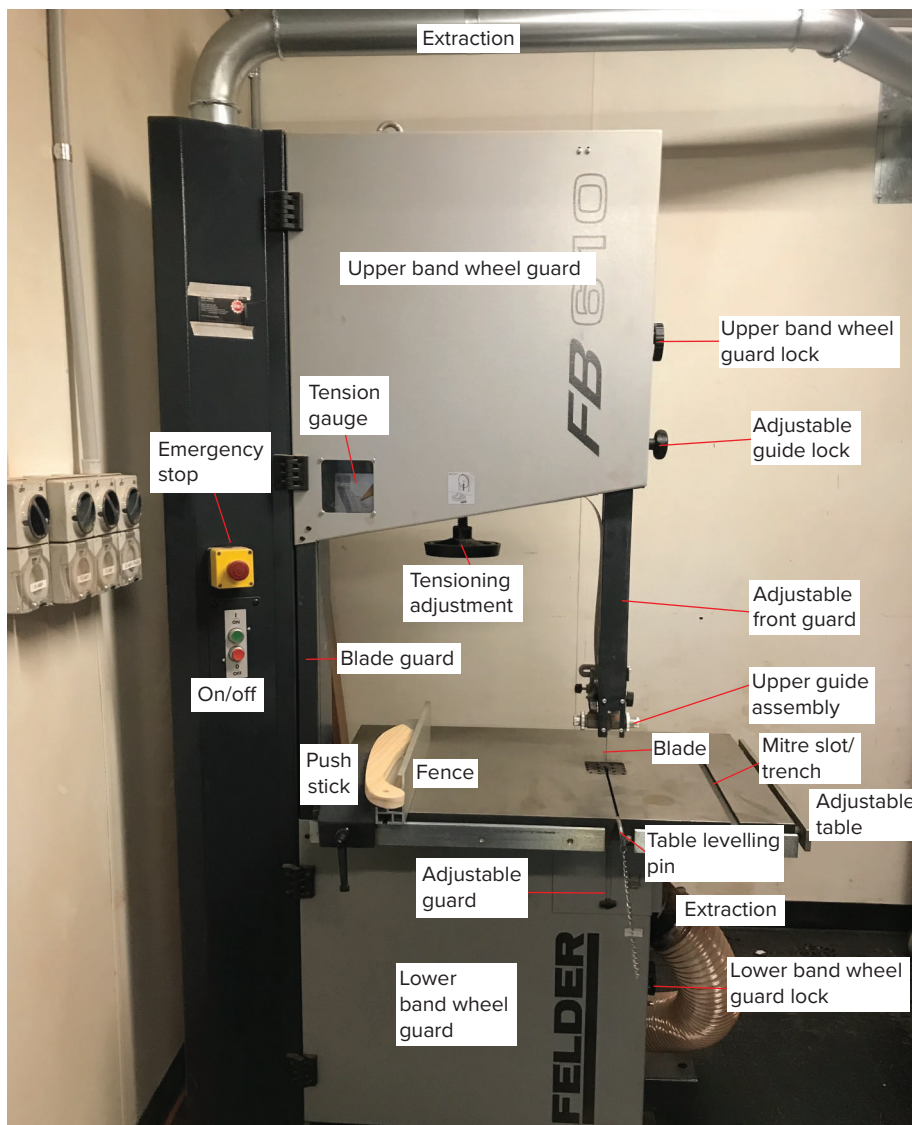
26. What is the main function of a panel saw?
27. What is the first set of cuts required when using panel material?

11.9 Safely set up, use and maintain a band saw

Carpenters and joiners use a variety of band saws, including large industrial versions used in mills to cut up logs into workable sizes, a range of portable horizontal band saws to cut up logs on-site and joinery shop band saws. Joinery shop band saws have various uses such as ripping, cross-cutting, resawing and cutting irregular shapes and curves. Band saws are also found in metal engineering, plastics and food-processing industries.

A band saw is made up of a drive wheel (lower wheel) and an (upper) wheel that can be tensioned and tracked (Fig. 11.42). The blade is a continuous band of steel with teeth on one edge; the teeth are set on alternative sides. The blades are ordered to suit the particular make and model of the saw.

Fig. 11.42 Labelled parts of a band saw



Courtesy of Michael Hick

You should always refer to the manual when setting up a band saw, and ensure the machine is isolated when replacing/installing a blade. For many applications, the band saw will be set up square, meaning the blade and the adjustable table will be 90 degrees to each other. The fence will also need to be set up square to the table and run parallel with the blade. You may need to do a test cut to check if the timber is running out—either the cut is getting bigger or smaller. If so, the fence may need to be adjusted. On some models, the fence will have adjustment screws that allow light adjustments. This configuration is used to rip and cross-cut.

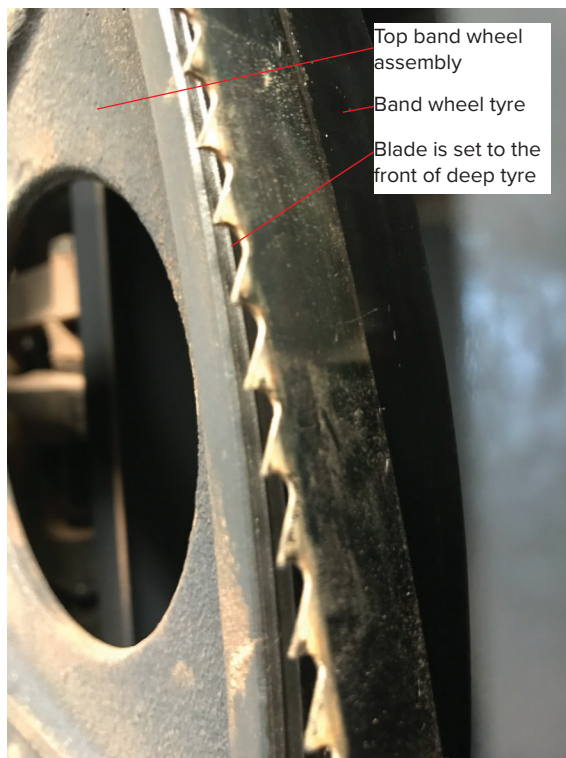
11.9.1 Blade selection and installation

Blade selection is very important and is dependent on what you are trying to achieve with your cut and what you are cutting. Thin blades are excellent for tight curved work whereas resawing or ripping of thick timbers will require a wider blade.

When installing a new band saw blade, you will need to open up the upper and lower band wheel guards as well as the front adjustable guard. Wind the tension of the upper band wheel all the way down and move the guide assemblies back as far as they will go in their cradles.

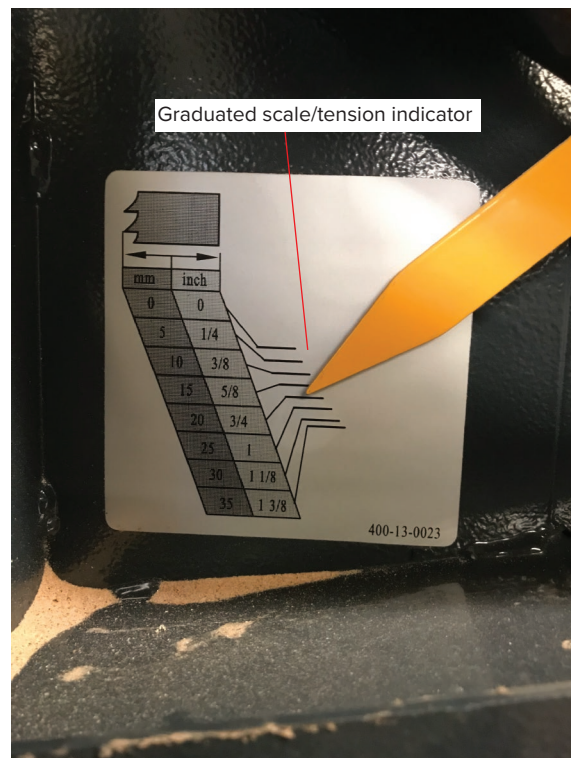
Wide blades can be placed towards the front of the top and bottom band wheel tyres (Fig. 11.43) and the tension adjusted to the appropriate tension for the size of blade (Fig. 11.44). Thin blades will need to be set up in the middle of the top and bottom wheels. Never overtension the blade, as this is the most common cause of blade breakages. Using your hand, turn the top band saw wheel a few

Fig. 11.43 Set-up of a deep saw blade on a top wheel



Courtesy of Michael Hick

Fig. 11.44 Internal tension gauge



Courtesy of Michael Hick

times to check that the blade is tracking correctly (Fig. 11.45). Tracking means that the new blade hasn't moved forward or backwards from the position on which you had installed the blade on the wheel. If the blade is tracking forward or backwards, you will need to use the tracking screw/knob/wheel (Fig. 11.46), which is usually located on the back top of the band saw assembly. The tracking screw/knob/wheel will tilt the top wheel, either forward or backwards. Keep turning the top band saw wheel around and make slight adjustments with the tracking screw/knob/wheel until the blade is tracking true.

Once the blade is tracking true, it is time to set up the guide assembly. There is a top and a bottom guide assembly, and both will need to be set up exactly the same and to the same tolerances.

The bottom one should be set up first (Fig. 11.47b). The guide assembly cradle can be moved forward until the guide blocks are in line with the back of the blade's gullet and wound in until there is a 0.25 mm gap between the blade and the guide blocks. After this is completed, the top guide assembly can be adjusted (Fig. 11.47a).

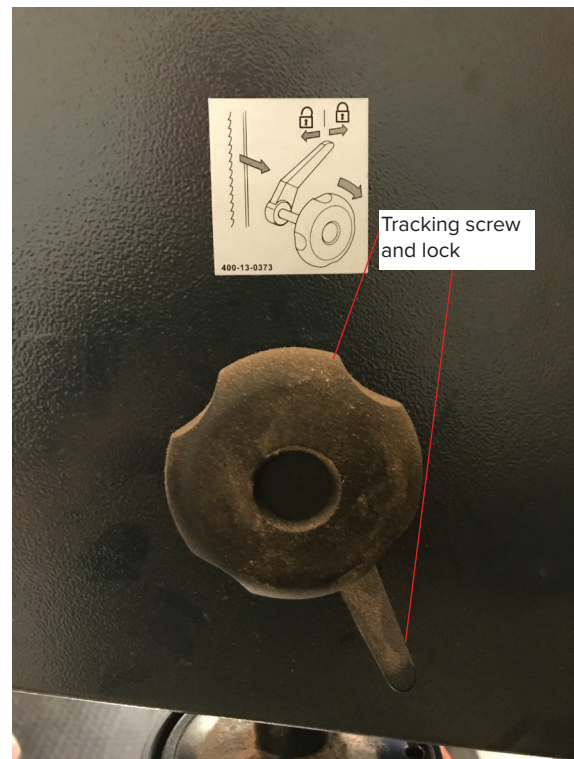
The thrust wheel/friction wheel can be moved into position, which is 0.25 mm behind the blade. On newer machines, the guide blocks may be rubber, as shown above, while on older machines the guide assembly has metal jaws. Extra care needs to be taken when setting up the jaws to ensure you don't accidentally push a new blade into the jaws.

Fig. 11.45 Band saw blade set-up test

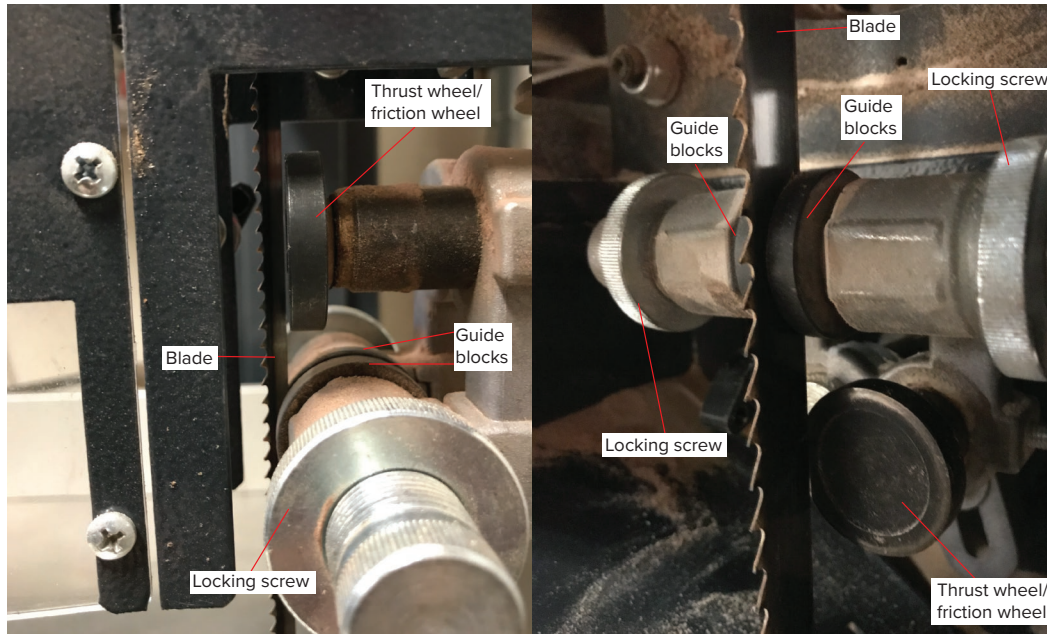


Courtesy of Michael Hick

Fig. 11.46 Band saw tracking knob



Courtesy of Michael Hick

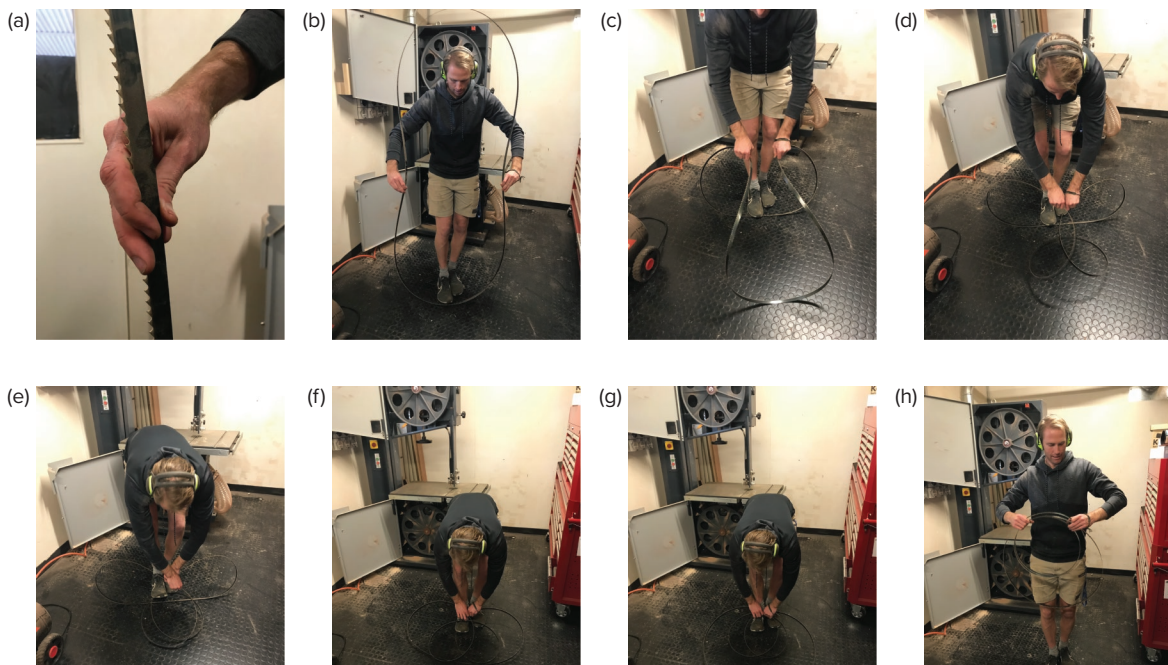
Fig. 11.47 (a) Top guide assembly; (b) lower guide assembly

Courtesy of Michael Hick

11.9.2 Folding a band saw blade for storage and transport

Figure 11.48 demonstrates just one way of folding up a band saw blade. As with any activity using static machines, you must take care when handling machine knives and blades. Always make sure you have had the appropriate training for the task and use the correct PPE.

Be careful when handling the band saw blade, as a blunt blade is still sharp enough to cut through skin. First, have the teeth of the blade facing away from the body (Fig. 11.48a). Using your thumbs, bend the blade over (Fig. 11.48b); the top of the blade that has just touched the ground (Fig. 11.48c) will start to loop towards you as you bend forward, so cross the blade and swap hands (Fig. 11.48d). The blade

Fig. 11.48(a–h) Folding a band saw blade for transport or storage

Courtesy of Michael Hick

will now have created three loops (Fig. 11.48e-g); pick up all three loops and adjust until the loops are relatively all the same size (Fig. 11.48h). The blade is now ready to be stored or sent off to be sharpened.

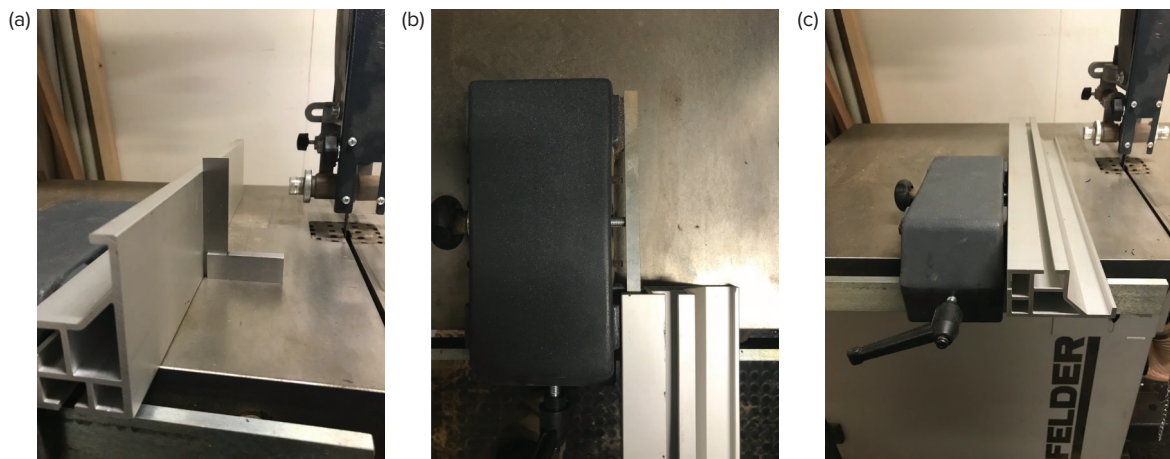
11.9.3 Setting up the fence for parallel cutting

How you set up a band saw square and parallel is dependent on what accessories your band saw has. In this example (Fig. 11.49), the band saw comes with a standard fence (Fig. 11.49a). The fence has two rails built in—standard and small edge (Fig. 11.49c)—that can be adjusted by removing the fence from the fence block (Fig. 11.49b) and turning it over to the small rail position.

The small rail can be used when cutting thin material, as the fence needs to be close to the band saw blade and the front adjustable guard needs to be set at a practicable workable height, approximately 10 mm above the working piece.

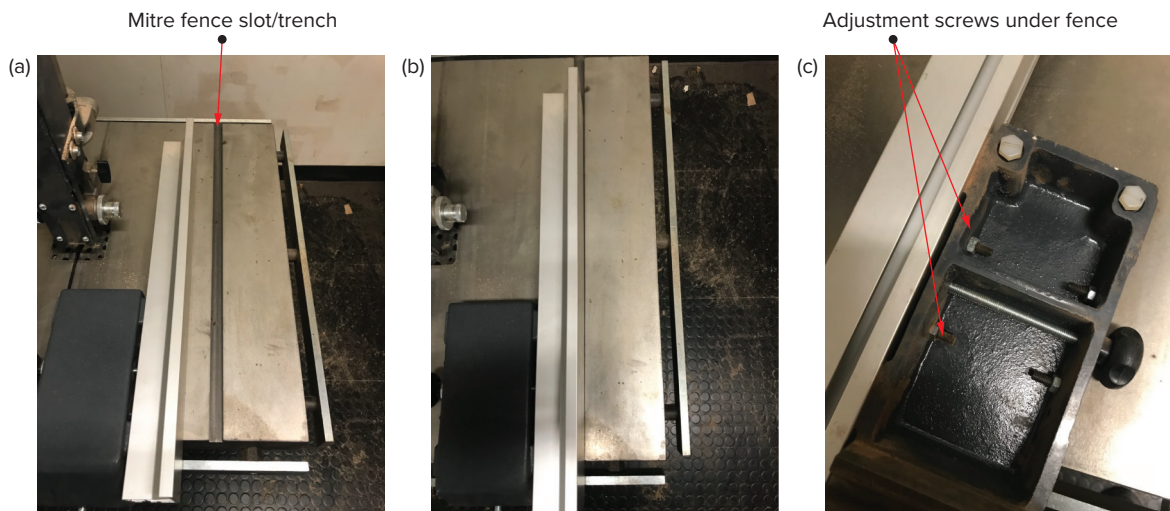
As with the panel saw, you must first check that the table is set square to the blade so that the fence can be set square to the table. If the fence isn't square, you can usually find located under the fence guide block (or on top, on some models) some adjustment screws (Fig. 11.50c). There are a few ways to check that the fence is set up correctly and running parallel to the blade. One way is to set the fence up to the mitre slot trench and check that it is running in line with the trench. (The mitre slot allows an external mitre fence to be attached to the band saw table.)

Fig. 11.49 (a) Band saw standard fence; (b) band saw fence block; (c) band saw small fence



Courtesy of Michael Hick

Fig. 11.50 (a) Mitre slot/trench; (b) squaring fence to mitre slot/trench; (c) adjustable screws under fence block



Courtesy of Michael Hick

Once you have set up the fence to the mitre trench, you will need to do a practice rip to see if the blade and fence are running in parallel. If this technique does not work, another way to set up the fence is to use a square piece of scrap wood and mark a parallel line along one edge (Fig. 11.51a). Move the fence to the side and cut the line free-hand (Fig. 11.51b). Cut your line as accurately as you can

Fig. 11.51(a–h) Alternative method of squaring fence to blade



Courtesy of Michael Hick

until you get halfway. At this point, you will need to stop the band saw (Fig. 11.51c), wait for the blade to stop, then clamp the timber down to the bench (Fig. 11.51d), making sure it hasn't moved from your cut line. Once the board is clamped down, move the fence up against the board and check if the timber is running in line with the fence.

If there is a gap between the fence and the board (Fig. 11.51e), an adjustment will need to be made to the fence (Fig. 11.51f). As we did before with the fence, there are adjustment screws under the fence block. Place the fence back up against the board to check that it is now set to the board (Fig. 11.51g). Continue the cut to check that the board is now being ripped in parallel with the blade (Fig. 11.51h). Check the final cut of the board to make sure that it is a parallel cut.

CHECK YOUR UNDERSTANDING

28. What is the main function of a band saw?
29. What is the purpose of relief cuts?
30. What is the distance between the band saw blade and the guide blocks and thrust wheel?

11.9.4 Cutting curves

When cutting curves, the blade selection is very important. Is the blade fit for purpose? What materials are you cutting? And is the blade capable of tight curves and rounds?

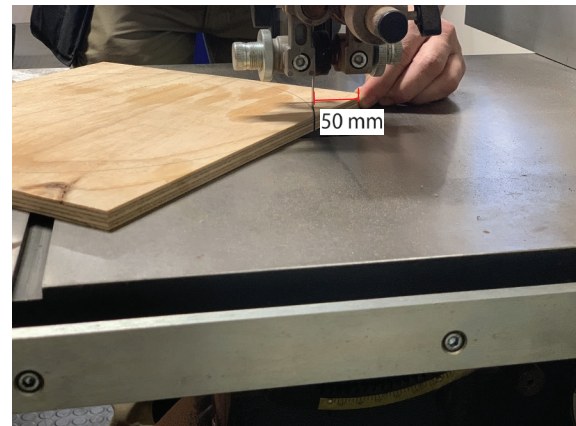
Figure 11.52 demonstrates how close 50 mm is from your fingers to the band saw blade. It is important to ensure the material you are cutting is well supported and that your hands are not in line with the forward cut of the blade. A common accident is for operators to cut their thumbs while pushing material into the band saw blade. To avoid this, never place your fingers too close to the blade—keep them at least 50 mm from either side of the blade.

At times you may not have the correct blade to cut the curve that you wish to produce. However, you may have a blade that is close enough to what you require. To help with the cutting of a tight curve, you can create a section of relief cuts.

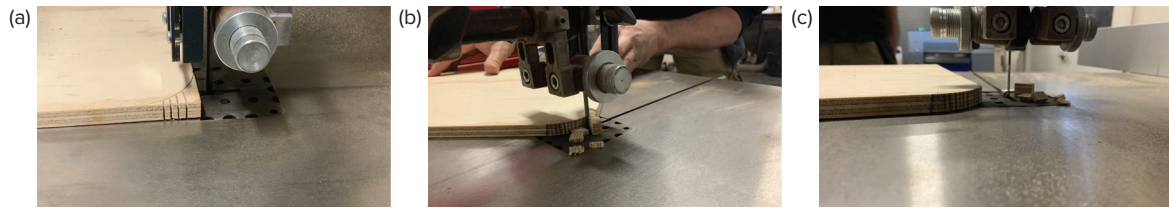
Relief cuts are a series of cuts you make in your material to help guide you in making the desired cut; the method used is to cut straight up to the cutline, then reverse straight back out (Fig. 11.53a). Avoid trying to reverse out of a curved cut as this can cause stress and tracking issues with your band saw and may have a negative result, such as the blade coming off the band saw wheels or the blade coming out of the guide assembly. As the blade cuts past the relief cuts, the waste material that has been removed allows the blade to continue along the line of the tight curve (Fig. 11.53b).

Relief cut waste that is too close to the blade should be removed with a push stick—or switch the machine off and wait for the blade to come to a complete stop and then remove the waste in line with the recommendations in the machine's SWP (Fig. 11.53c).

Fig. 11.52 Cutting curves with a band saw



Courtesy of Michael Hick

Fig. 11.53 (a) Relief cuts; (b) cutting a curved line with relief cuts; (c) relief cut waste

Courtesy of Michael Hick

11.10 Safely set up, use and maintain a panel planer/thicknesser

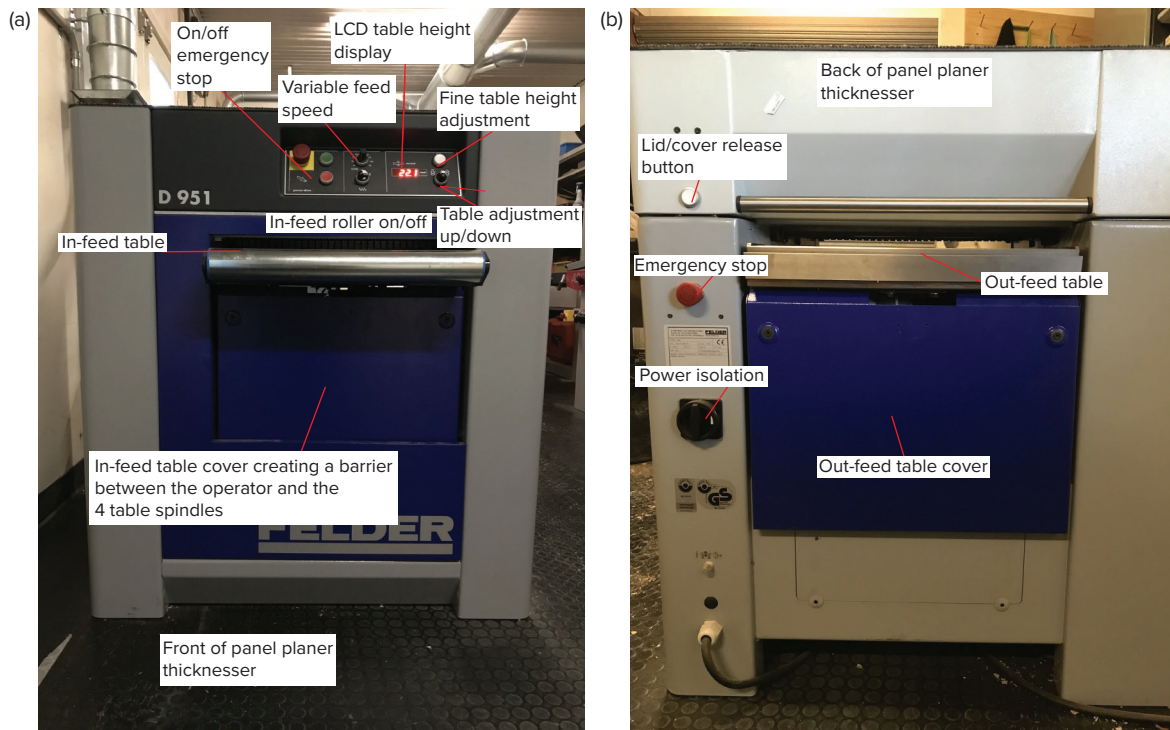
The primary function of the panel planer, also referred to as a thicknesser, is to machine/reduce timber to a required width and thickness parallel to a planed face and edge of the timber.

There are many different types of panel planers/thicknessers on the market, which come in a variety of sizes and machining depth and width capabilities (Fig. 11.54). Traditional machines will have a circular cutter head (Fig. 11.55a), with blades also known as knives (Fig. 11.55b). These knives can be sent off to be resharpened or have double-sided (reversible) blades.

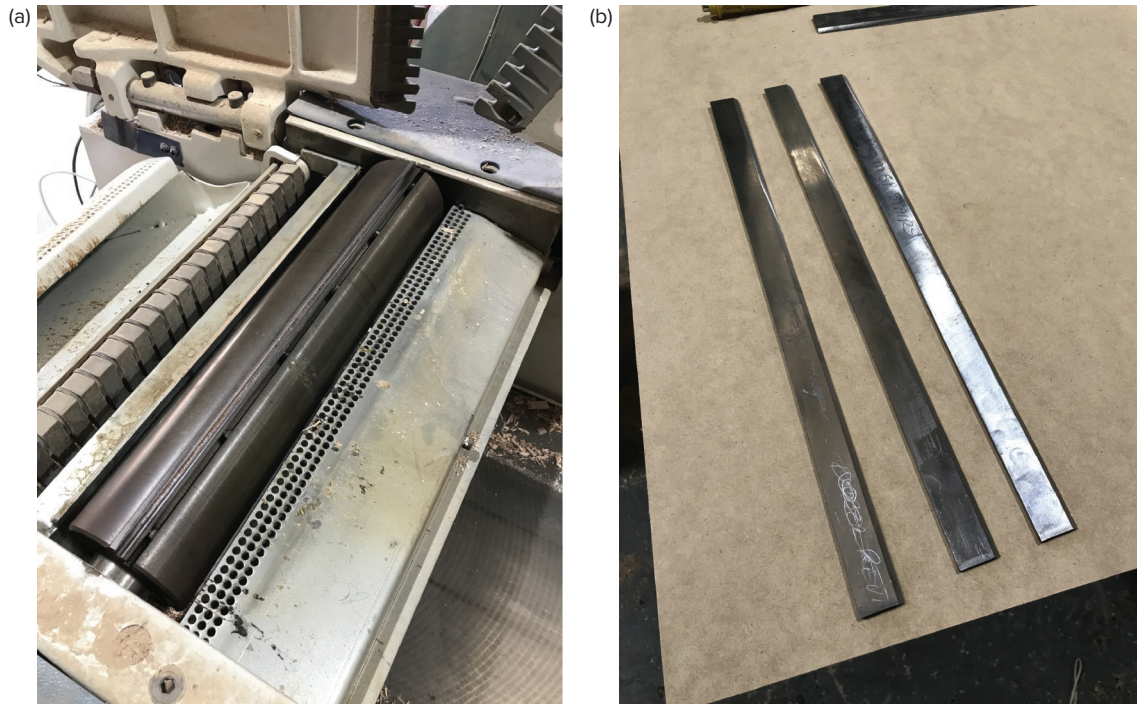
Newer machines will have the option of having a spiral head (Fig. 11.56a), which uses four-sided tungsten carbide knives that can be turned up to four times to access a new cutting edge (Fig. 11.56b).

A traditional panel planer is made up of in-feed and out-feed rollers, with the cutter block located above the table (Fig. 11.57). As material is fed into the panel planer/thicknesser, the material will go past and be held into position by:

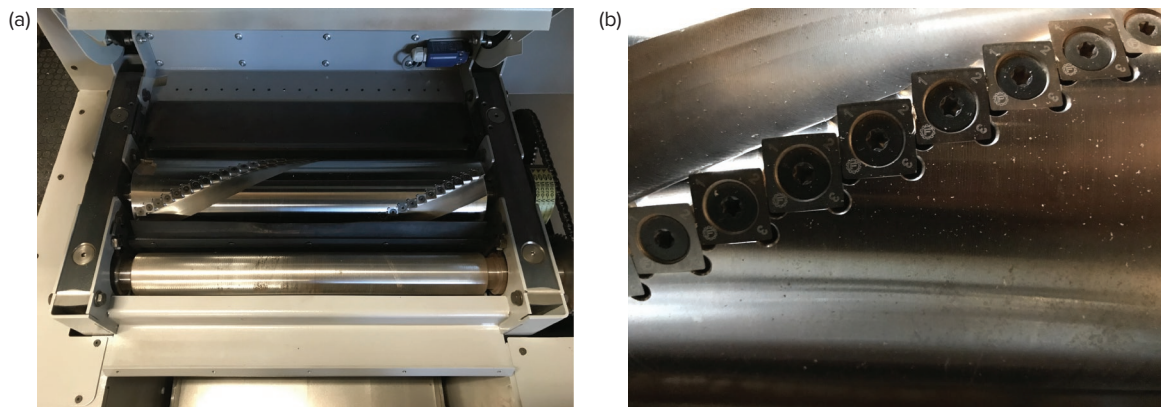
- Anti-kickback fingers—this is a safety device located above the thicknessing bed and is the first part of the in-feed that the timber will pass. Its function is to drop and lock into the face of the

Fig. 11.54 Thicknesser components labelled: (a) front; (b) back

Courtesy of Michael Hick

Fig. 11.55 (a) Combination machine cutter head; (b) planer knives

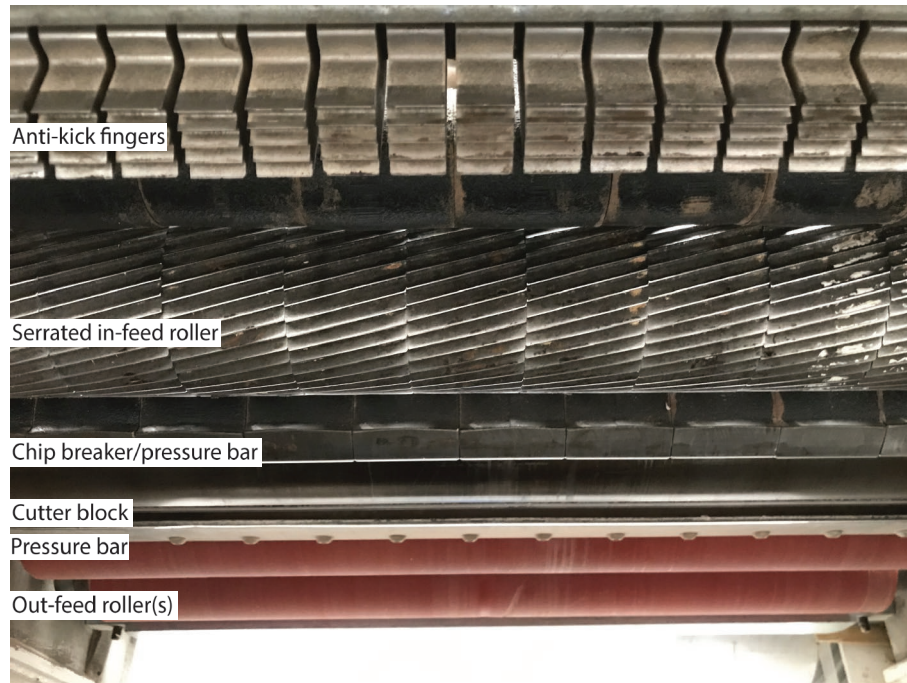
Courtesy of Michael Hick

Fig. 11.56 (a) Spiral head; (b) four-sided tungsten carbide knives

Courtesy of Michael Hick

workpiece in the event of kickback, thereby preventing it from being ejected from the machine. The anti-kickback fingers should all be in place across the full width of the in-feed and moving freely.

- Serrated steel in-feed roller—the serration allows the roller to grab the timber and feed it into the cutter block. The timber will be momentarily imprinted with the serrations of the in-feed roller, but this will be machined off as the timber is machined by the cutter head. On some machines, the serrations can be up to 0.8 mm deep, so this will need to be taken into account when machining the materials to their final size.
- Chip breaker pressure bar—the purpose of this part is to provide pressure on the timber as it heads towards the cutter block. The chip breaker pressure bar is located close to the spinning cutter head. The tight space between them provides an area where the blade hits the timber and is jammed between the edge of the pressure bar and the blade, which causes the timber to break into small chips that are then sent up through the extractor.

Fig. 11.57 Inner workings of a panel planer

Courtesy of Michael Hick

Fig. 11.58 Panel planer anti-friction rollers

Courtesy of Michael Hick

- Cutter block—this may be circular and use knives and double-sided blades, or spiral and use four-sided tungsten carbide knives.
- Rear pressure bar—this is located behind the cutter block and provides pressure on the timber after it has been cut. The rear pressure bar helps to keep the timber in place firmly against the table and prevent chattering and irregular cutting.
- Out-feed roller(s)—the panel planer/thicknesser may have one or more power out-feed rollers, which put pressure on the timber and provide stability. As the timber leaves the in-feed roller, the out-feed roller feeds the material through and out of the machine.

The bottom table of the panel planer/thicknesser may have anti-friction rollers; these are usually located directly under the position of the serrated in-feed roller and the out-feed roller (Fig. 11.58). The purpose of the rollers is to reduce friction created by pressure from the rollers above the material and stop the material sticking to the machine bed.

11.10.1 Procedure for the use of a panel planer/thicknesser

The process of machining timber through the panel planer/thicknesser is intended to make sure the timber that is about to be machined has been surface planed with a straightened edge and face. Timber is fed through the machine with the straightened edge downwards (surface planed side on to the table) and then face up. The reason for the edge being machined first is so the material has the most edge to stand up on/balance (Figs 11.59a and 11.59b).

When machining wood, always work with the biggest sizes first. That way, when you are thicknessing, you are always adjusting the table of the thicknesser up. Once all of the edges are done, it's time to machine the face.

The face of the timber is machined last, again working with the biggest face size first and working the table of the thicknesser up (Fig. 11.59c).

Some panel planers/thicknessers can machine up to 10 mm in one pass; however, this can put undue pressure and load on the machine and wear out the blades and knives faster. If the timber has been prepared properly, you should only need to machine 1–2 mm per pass with a max of 4 mm (always refer to the machine's SOP).

Fig. 11.59 Process of thicknessing material: (a) edge of timber first; (b) machining the edge; (c) machining the face of the timber



Courtesy of Michael Hick

11.10.2 Grain direction

Grain direction is as important with the panel planer/thicknesser as it is with the surface planer. The grain should be identified and point in the opposite direction to the in-feed table. This will help with the machining process and the finish of the timber as it exits the machine.

11.10.3 Feed rate

Feed rates through the machine will depend on what the material you are preparing is to be used for. If the timber is going to be sanded and used as a feature piece of joinery, then a slower feed rate will result in fewer machine marks and reduce the sanding time. Faster feed rates can leave machine marks in the timber and may require an extensive sanding process. The width of the material also needs to be taken into consideration in relation to feed rates as wider material will put the thicknesser under greater strain.

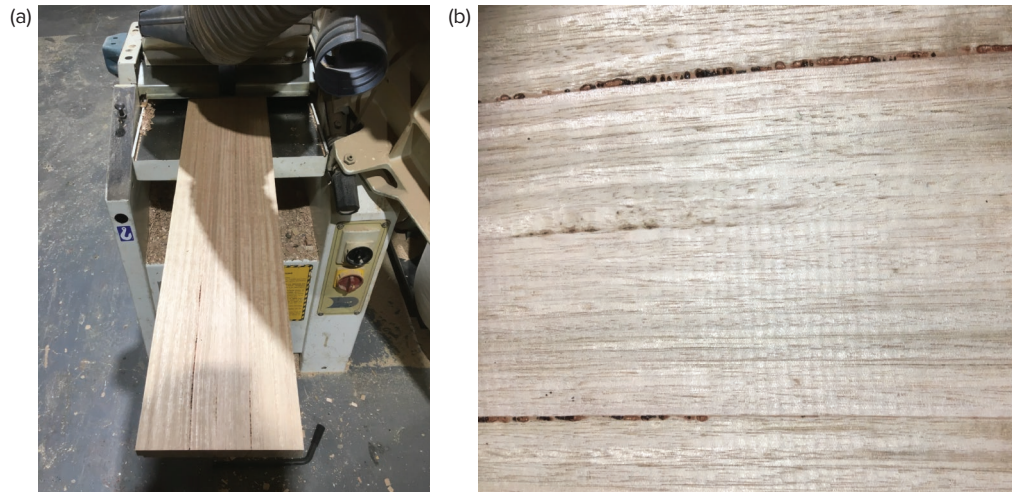
Machine marks are created by the serrated in-feed roller. These will occur if you are trying to machine less than 1 mm off the material (Fig. 11.60).

The machine marks in Figure 11.61 are created when the material that is being machined is passed through the machine at a high rate of feed.

Fig. 11.60 In-feed roller marks



Courtesy of Michael Hick

Fig. 11.61 (a) Material being thickened; (b) machine marks from a fast feed rate

Courtesy of Michael Hick

TIP Machine marks may be left in material if the feed rate is too high. However, in some instances it may be because the blades have become too worn or if they have not been properly installed. If you notice excessive machine marks, take the time to check the blades and set the machine up according to the SOP. This will help save time and money—fewer machine marks in the material will mean less sanding for the final product.

CHECK YOUR UNDERSTANDING

31. What should be machined first, the face or the edge? Why?
32. Why is the in-feed roller serrated?
33. Why do we take grain direction into account when thickening timber?

11.10.4 General maintenance and changing blades (basic models)

Always make sure all machines are isolated (i.e. the power supply to the machine has been turned off) before changing blades and performing maintenance. Maintenance should be conducted regularly and according to the manufacturer's recommendations to ensure machines continue to run safely and to their full potential capacity. Repairs to machines should always be completed by a qualified or authorised person, most likely someone from an external company that specialises in static machine repairs. Records of repairs must be kept on a maintenance schedule.

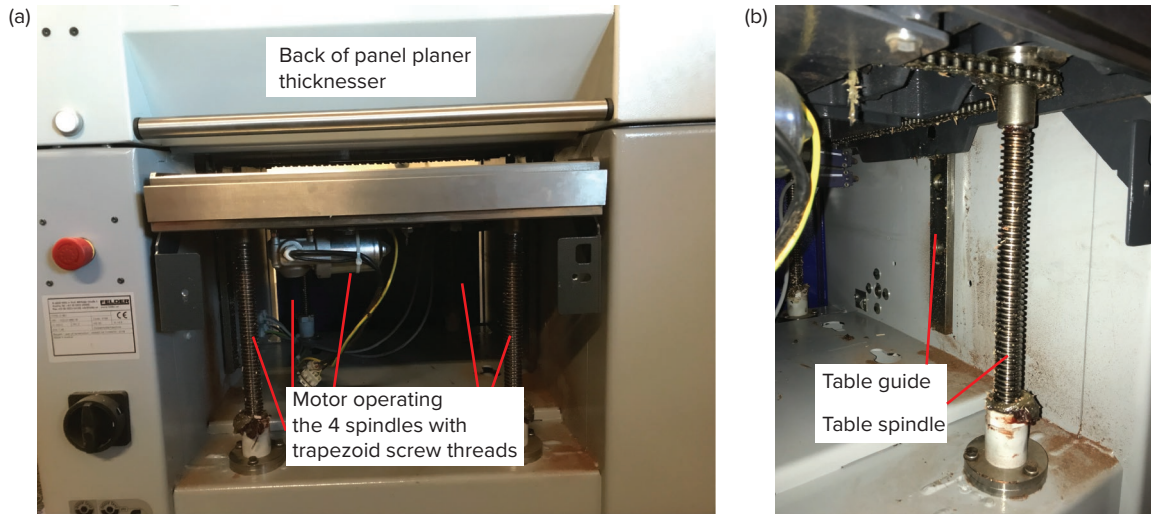
The four spindles on the panel planer/thicknesser will need to be checked and greased. This will require removing the back out-feed cover. The spindles and the table guide will need to be checked and greased regularly (Fig. 11.62).

11.10.5 Removing and replacing knives

The cutter block shown is from a combination thicknesser/surface planer, with each part of the machine sharing the same cutter head (Fig. 11.63a). It is also installed with knives that can be resharpened (Fig. 11.63b).

On a traditional surface planer, to give yourself more space to work in, you can drop the in-feed table down as far as it can go. You will also need a timber wedge to jam between the cutter head and the body of the surface planer to stop the cutter head from moving while you are removing the blades.

Fig. 11.62 Rear access of panel planer: (a) spindles; (b) table guide



Courtesy of Michael Hick

Fig. 11.63 Combination surface planer: (a) panel planer cutter block; (b) cutter block components



Courtesy of Michael Hick

The blade is secured by the gib/wedge bar and bolts (Fig. 11.63b). The gib is a pressure plate that presses against the blade and the circular cutter block. To remove the blade, you will need to loosen the gib bolts.

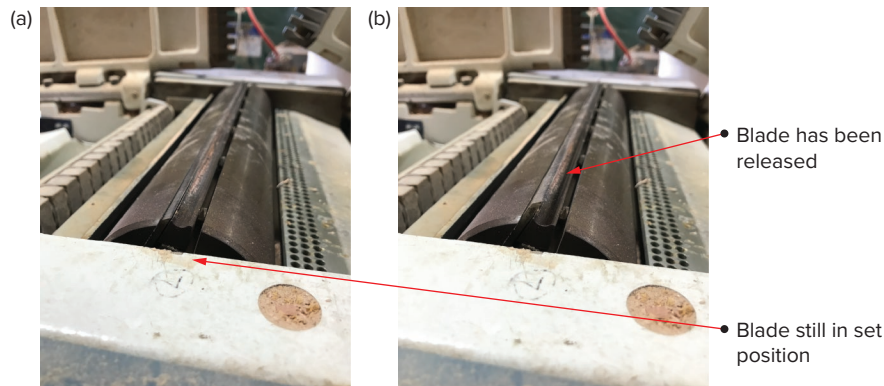
As you release the pressure on the gib/wedge bar bolts, the blade will pop up (Fig. 11.64). Under the blade are two springs that help with the removal and installation of the blade.

In Figure 11.65 a the components displayed are:

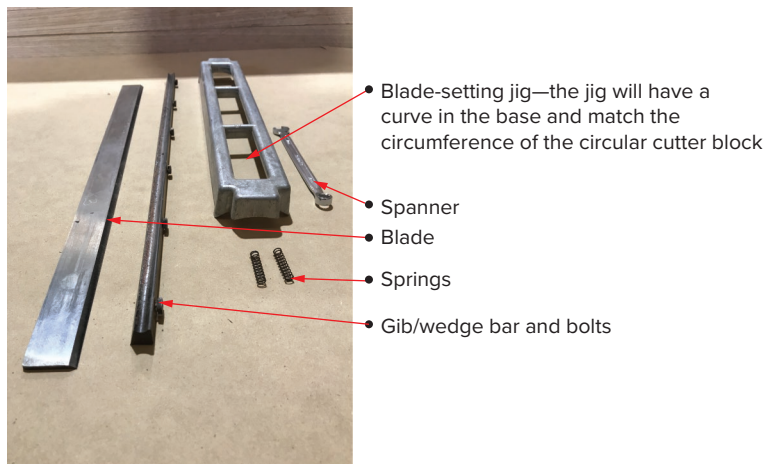
- blade-setting jig—the jig will have a curve in the base and match the circumference of the circular cutter block
- spanner
- blade
- springs
- gib/wedge bar and bolts.

When changing blades, it is common to change one at a time rather than taking them all out at once.

TIP Before installing a new blade, it is always good practice to take your time to clean the bolts, gib/wedge bar and cutter block to ensure they are free from dust and a build-up of gum.

Fig. 11.64 (a) Blade in position; (b) blade released

Courtesy of Michael Hick

Fig. 11.65 Cutter block components, jig and spanner

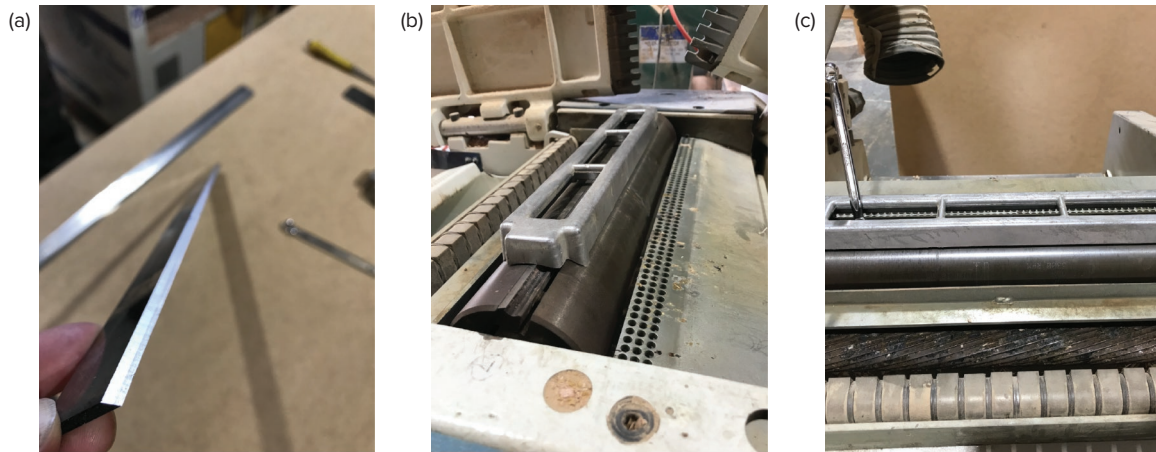
Courtesy of Michael Hick

Make sure the springs have been placed back into their housings in the cutter block. Place the new blade (Fig. 11.66a) and gib/wedge bar into the cutter head and start to lightly tighten the bolts. The blade should still be able to move freely up and down on the springs. Place the jig on top of the blade and cutter head (Fig. 11.66b). The jig will push the blade down into position and the springs will push the blade up against the jig. Start to tighten up the bolts until they are just firm, so that the blade is secure, and check that the blade and jig are still in line (Fig. 11.66c). If the blades are in the correct position, fully tighten the gib/wedge bar bolts. If not, loosen the gib/wedge bar bolts and start again. After installing the new blades, you may need to reset the height display system of your machine, whether it is digital or analogue.

An alternative method of setting blades uses two magnetic planer blade knife jointer setting jigs. The magnetic jigs in Figure 11.67 use a micro-adjustable magnet to help you install your new planer blades in perfect alignment and with accuracy.

11.10.6 Removing and replacing four-sided tungsten carbide knives

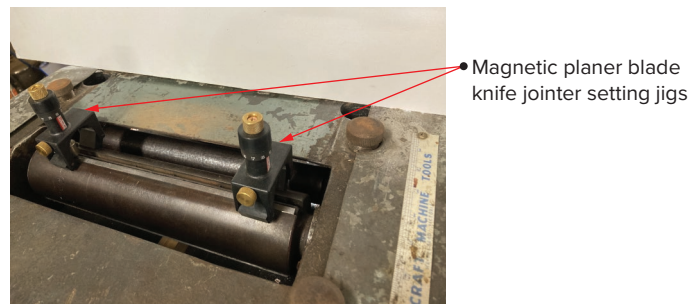
Being able to change the blades on a spiral head cutter has been a leap forward in cutter head technology. The spiral head is made up of a large number of four-sided tungsten carbide knives, which can be

Fig. 11.66 (a) Replacement sharpened knives; (b) blade setting jig; (c) installing knives with jig

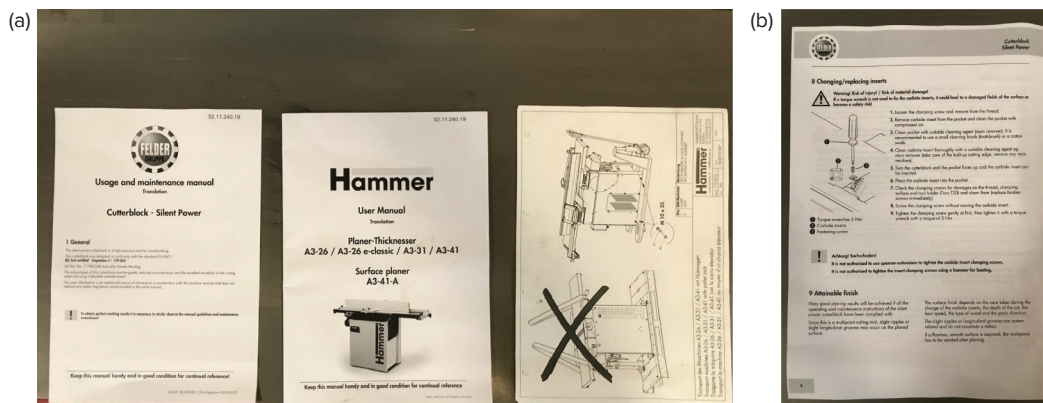
Courtesy of Michael Hick

turned up to four times to access a new cutting edge. When changing blades, always refer to the operation manual and SOP (Fig. 11.68).

These blades are found in surface planers and panel planers/thicknessers. One of the main advantages of this type of cutter head is that the blades will last up to 20 times longer than traditional blade systems. The other is that if you get a nick in the blade, all you need to do is rotate/replace one blade rather than all of the knives, as you would in a traditional set up of knives.

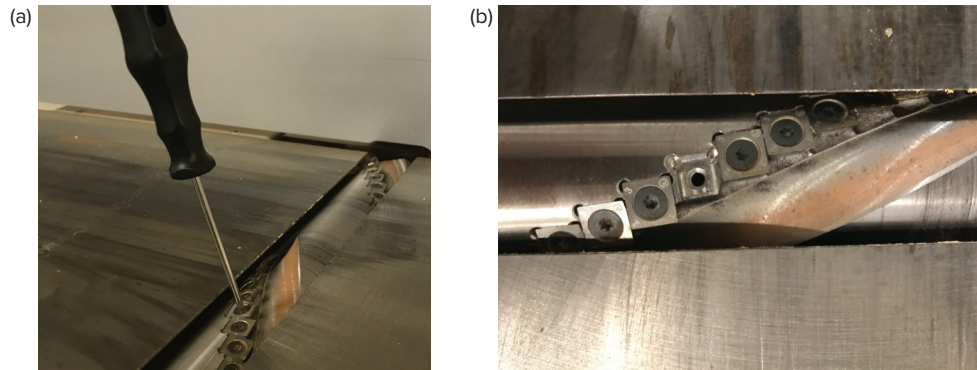
Fig. 11.67 Magnetic setting jig

Courtesy of Michael Hick

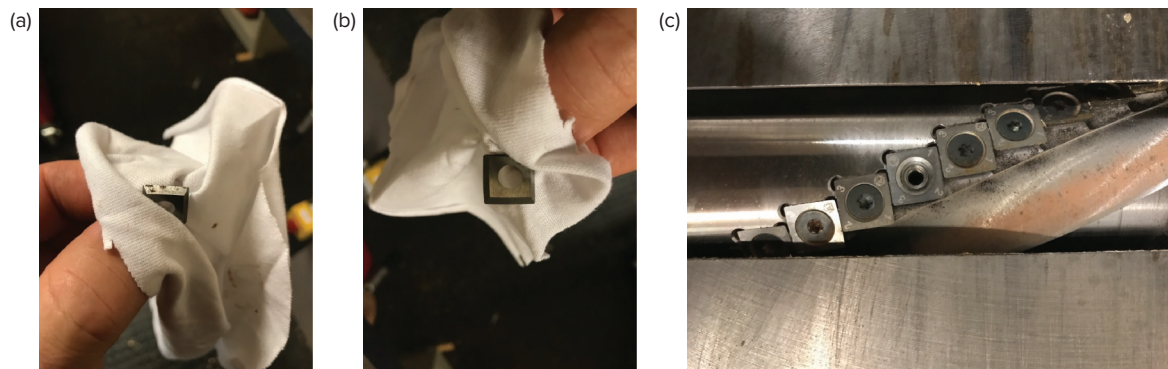
Fig. 11.68 Surface planer manuals

Courtesy of Michael Hick

To replace/rotate a blade, simply unscrew (Fig. 11.69a) a four-sided blade and turn it around to the next sharp edge. However, if you have time, it's always a good idea to clean the seat (Fig. 11.69b) that the blade sits in and clean the blade and holding screw before reinstalling them (Fig. 11.70).

Fig. 11.69 (a) Six-point star-head screwdriver; (b) removed blade seat

Courtesy of Michael Hick

Fig. 11.70 (a) Cleaning; (b) rotating; (c) installing a four-sided knife

Courtesy of Michael Hick

TIP It's a good idea to have a small container (Fig. 11.71) nearby to put the blade and screw into when cleaning components to avoid losing or dropping them on the floor.

11.10.7 Fault reporting

Each workplace will have a policy and procedure for the running and maintenance of its static machines. Faults are usually reported to a supervisor or manager, and it is the responsibility of the operator who identifies the fault to report the fault immediately after first isolating the machine and locking it off (padlocking it) so that others can't accidentally use the faulty machine.

A red and black 'DO NOT OPERATE' warning tag (Fig. 11.72) should be placed on the machine to warn others that the machine has been isolated due to a fault. The tag will be attached to the isolation switch/control of the machine and will state that failure to obey it may cause damage to the equipment and/or injury to a person. It is essential that an isolating mechanism with an out-of-service tag attached to it is not switched on, manipulated or interfered with while the tag is in place.

Fig. 11.71 Cleaning container

Courtesy of Michael Hick

Fig. 11.72 'Do not operate' tag

Courtesy of Michael Hick

CHECK YOUR UNDERSTANDING

34. When changing the blades in a surface planer or panel planer/thicknesser, what needs to be done to the machine first?
35. What is a gib/wedge bar used for in a surface planer?
36. What are the advantages of a spiral head machine over a machine that uses knives?
37. What is the purpose of tagging a machine with a red and black 'DO NOT OPERATE' warning tag?

Student research

Investigate and develop a safe work procedure (SWP) for a static machine that has been mentioned in this chapter but has not been explored in depth; for example, a spindle moulder.

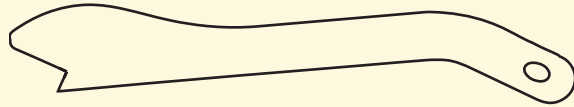
Compare and share your findings with your classmates.

End-of-chapter activity

Create a push stick using a band saw—push sticks are essential safety devices for wood machining.

Photocopy this template and enlarge it. The rectangle in which the push stick is drawn should be approximately 450 × 100 mm. Using the material you have available, either 18 mm-thick ply or timber, trace this push stick and cut it out using the band saw.

Push stick at scale 1:3



AUSTRALIAN BUILDING CODES AND STANDARDS

The Australian Standards are guidelines for all products created within the construction industry; for example, AS 4785.3: 2002 Timber: Softwood—Sawn and milled products: Timber for furniture components.

AS 1473.1: 2000
Wood processing
machinery—
safety: Part 1: Primary
timber milling
machinery

AS 1473.2: 2001
Wood processing
machinery—
safety: Part 2: Finishing
machinery—common
requirements

AS 1473.3: 2001
Wood processing
machinery—
safety: Part 3: Finishing
machinery—circular saw
machines

AS 1473.4: 2001
Wood processing
machinery—safety:
Part 4: Finishing
machinery—bandsawing
machines

**AS 1473.5:
2001**
Wood processing
machinery—safety:
Part 5: Finishing
machinery—moulding
machines and routers
with rotating tool

**AS 1473.6:
2005**
Wood processing
machinery—safety: Part 6:
Finishing machinery—
surface planing and
thicknessing
machines

**AS 1473.7:
2005**
Wood processing
machinery—safety: Part 7:
Finishing machinery—
tenoning, profiling
and edge-banding
machines

**AS 1473.8:
2007**
Wood processing
machinery—safety: Part 8:
Finishing machinery—
milling machines and
circular saw blades

AS 4024.1: 2006
Safety of machinery

Tradie talk—Always run a test piece of timber

Chapter 12

Handle carpentry materials

Learning Objectives

- LO 12.1 Understand safety requirements for manual handling
- LO 12.2 Identify company policies and standards
- LO 12.3 Identify and follow safety requirements for handling carpentry materials
- LO 12.4 Identify tools and mechanical handling devices
- LO 12.5 Identify fixings and adhesives
- LO 12.6 Identify carpentry construction materials
- LO 12.7 Store materials safely
- LO 12.8 Plan to move materials around a job site
- LO 12.9 Understand manual handling procedures
- LO 12.10 Load and unload carpentry materials

Introduction

As a carpenter, you will be working in a variety of construction environments and be introduced to a range of building and construction materials. In this chapter you will be introduced to the main types of construction materials that you are most likely to be working with, and learn how to identify, obtain, prepare and handle them correctly and safely. You will also look at environmental considerations for the use of, recycling and disposal of building and construction materials.

12.1 Understand safety requirements for manual handling

The construction industry is governed by work health and safety (WHS) laws and regulations. Manual handling falls under the *Work Health and Safety Act 2011* and the Work Health and Safety Regulations

2019. The code of practice for manual handling is 'hazardous manual tasks'. The code of practice also covers specific duties related to identifying and controlling the risks of **musculoskeletal disorders (MSD)** from hazardous manual handling.

Excerpt from: Model Code of Practice: Hazardous manual tasks, Safe Work Australia

A hazardous manual task is a task requiring a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any person, animal or thing involving one or more of the following:

- repetitive or sustained force
- high or sudden force
- repetitive movement
- sustained or awkward posture
- exposure to vibration.

These hazards directly stress the body and can lead to an injury.

Duty holders who have a role in managing the risks of hazardous manual tasks include:

- persons conducting a business or undertaking (PCBUs)
- designers, manufacturers, importers, suppliers and installers of plant, substances or structures
- officers.

Workers and other persons at the workplace also have duties under the WHS Act, such as the duty to take reasonable care for their own health and safety at the workplace. A person can have many more than one duty and more than one person can have the same duty at the same time. Early consultation and identification of risks can allow for more options to eliminate or minimise risks and reduce the associated costs.

Courtesy of Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>

The construction materials that you may be working with, such as manufactured board, adhesives, cement etc., will have a material safety data sheet (MSDS)—now more commonly known as a safety data sheet (SDS). This will either come with the product or you will be able to download it from the manufacturer's website. For more information on applying WHS requirements, policies and procedures in the construction industry, please refer to Chapter 1, Work health and safety.

CHECK YOUR UNDERSTANDING

1. A hazardous manual task is a task requiring a person to do what type of physical actions?

12.2 Identify company policies and standards

Each company will have its own workplace quality policies and standards for handling carpentry materials. Before you start work, you need to be aware of these policies and procedures and comply with them when you are handling carpentry materials in a workshop or on a worksite. These policies and procedures may vary from company to company; however, they will all have key points in common, such as:

- the quality standard of the work required
- what materials are to be used
- the procedures for handling and storing materials in the workshop or worksite
- the company's safety policies and procedures, which you must follow.

The materials used in the building and construction industry must be certified to ensure they meet the Australian Standards, particularly in relation to safety, application and where the materials can be used. Buildings are designed with specific materials in mind and failure to comply with the manufacturer's recommendations and specifications can have serious implications—the worst-case scenario could be structural failure. Structural failure is the loss of structural integrity of a material,

affecting the load-carrying capacity of either a structural component or the structure itself. Structural failure happens when a material is stressed beyond its strength limit, causing the material to fail and potentially causing the partial or complete collapse of the structure.

SAFETY TIP No job is so important that it can't be done safely. A manual handling injury can stay with you for your whole life.

12.3 Identify and follow safety requirements for handling carpentry materials

Safety is important and should always be at the forefront in your planning and preparation for a task or project. When working in the construction industry, you must consider safety from a variety of perspectives as you are moving materials around, including:

- your personal safety
- the safety of others, such as other workers and the general public
- the materials you are handling and moving
- the workspace you are in
- the workshop
- the worksite.

The basic personal protective equipment (PPE) that you should have in the building and construction industry comprises:

- appropriate workwear
- safety glasses/goggles
- earmuffs/ear defenders as appropriate
- gloves made of materials such as leather, Kevlar composite, aramid, steel or composite filament fibre
- industry-specific work boots.

Certain jobs may require specialist PPE; for example, for handling hazardous materials. Hazardous materials can pose a threat to your own life and potentially to the lives of your coworkers. Always check the manufacturer's recommendations and the MSDS/SDS for information on the transport, use and disposal of these products.

Some specialist roles—including plant operators of elevated work platforms (EWP)/boom lifts, dogmen, forklift drivers and riggers—are associated with handling materials. These workers will have undergone specialist training to gain a qualification or licence in determining how to handle and transport materials safely around the workplace. For safety reasons, only these trained and/or licensed operators can use such equipment.

The use of signage and barricades must always be considered when handling carpentry materials. Barricades such as hoarding (Fig. 12.1) and temporary fencing (Fig. 12.2) can be used to clearly separate a worksite from the general public, helping to keep both parties safe. Some other reasons for using barricades and signage include:

- warning other construction workers of potential danger such as deep excavation (Fig. 12.3) or explosive power tools in use
- signage for restricted areas (Fig. 12.4)
- site instructions for workers and site visitors (Fig. 12.5)
- hazards or cautions in the materials storage area on a construction site.

Fig. 12.1 Formwork ply hoarding



Courtesy of Michael Hick

Fig. 12.2 Temporary fencing



Courtesy of Michael Hick

Fig. 12.3 Danger sign



Courtesy of Michael Hick

Fig. 12.4 Authorised personnel signage



Courtesy of Michael Hick

Fig. 12.5 Site signage



Courtesy of Michael Hick

CHECK YOUR UNDERSTANDING

2. Name some of the specialist roles that require a licence associated with handling materials.

12.4 Identify tools and mechanical handling devices

As part of your planning and preparation, it is important that you choose the correct tools and equipment to suit the task. Always make sure your tools are fit for purpose, well maintained and in good working order. Some of the basic tools that you may use when handling carpentry materials are:

- Hammers—claw hammers are generally used by carpenters to drive nails into materials, with the claw being used to remove nails. The claw can also be used as a pry bar. (More information can be found in Chapter 7, Carpentry hand tools.)
- Pallets (Fig. 12.6)—the standard Australian pallets are 1165 × 1165 mm and are constructed from either softwood or hardwood. Used for stacking goods, pallets are designed to be moved around from workshop to worksite by a pallet jack/forklift. The size may vary depending on the length of the materials to be stacked. Pallets have a long life and can be recycled and used over and over again.
- Pinch bars and wrecking bars (Fig. 12.7)—also known as pry bars, pinch bars are hand tools that are used to pull two objects apart. They have an angled, flattened end that acts as a lever, allowing you to apply a significant amount of force between objects. (More information can be found in Chapter 7.)
- Tin snips (Fig. 12.8) and shears—these are both hand-held tools similar in design to scissors and are used to cut sheet metal and metal straps.
- Banding tools—these use either a metal strap or polypropylene strapping. They are often used to band timber, sheet material, bricks or metal studs (Fig. 12.9a) and to secure products to a timber pallet (Fig. 12.9b).
- Pallet stretch film wrap—products that need to be secured to a pallet when transported or stored can be covered in a plastic wrap, called pallet wrap. This material stretches and can pull back almost like a rubber band, which makes it ideal for securing materials to pallets. The wrap also helps reduce the chance of breakages and other damage to goods.

Mechanical handling devices are equipment used for the movement, storage, control and protection of materials, goods and products. These are a few examples of mechanical handling devices that you may use in the construction industry.

Fig. 12.6 Timber pallet and pallet jack



Courtesy of Michael Hick

Fig. 12.7 Wrecking bar



Courtesy of Michael Hick

Fig. 12.8 A selection of tin snips for straight, left and right cutting



Courtesy of Michael Hick

Fig. 12.9 (a) Banded metal studs; (b) banded materials ready to be delivered to site



Courtesy of Michael Hick



Fig. 12.10 Standard wheelbarrow



Courtesy of Michael Hick

- Wheelbarrows (Fig. 12.10)—used to carry heavy and bulky loads, wheelbarrows are designed to distribute the weight of the load between the wheel and the operator. They are often used in the construction industry to move construction materials, bricks, concrete, garden materials and waste. Take care not to overload your wheelbarrow as overloaded wheelbarrows can become unbalanced as you move around a worksite and could potentially tip over. It is much safer to make two trips with a smaller load than to risk carrying a big heavy load in one go.

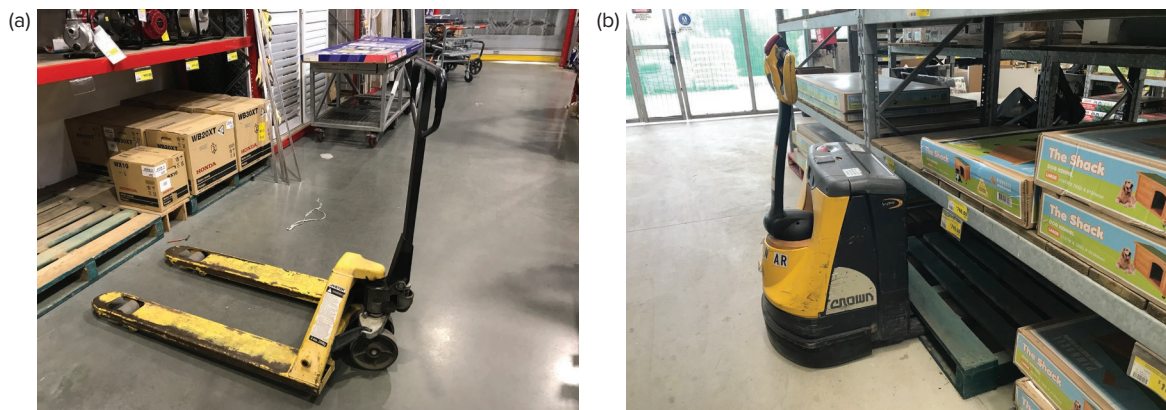
- Hand truck (Fig. 12.11)—these are predominantly used to move large heavy boxes around. They are of an L-shape design, with handles at one end and wheels at the base. They have a small ledge to set objects on and sit flat against the floor when the hand truck is upright. Take care not to overload the hand truck as it can be difficult to manoeuvre when it has too much weight on it. As with the wheelbarrow, consider making multiple trips rather than risking the load falling or finding you are unable to direct the hand trolley.
- Pallet jack (Fig. 12.12a)—a pallet jack/truck is a mechanical lifting device for lifting and moving pallets. Always check the load-carrying capacity of the pallet jack before you attempt to move materials. Make sure you have been trained in the use of this device at your workplace and that you

Fig. 12.11 (a) and (b) Hand trucks

Courtesy of Michael Hick

are aware of its load capacity. It is designed to be used on hard and level surfaces only. It is not the right equipment to use if the site is uneven or comprises gravel or sand. Electric pallet jacks are also available to allow for the lifting and moving of heavier stacked pallets—you must ensure you have been adequately trained in how to operate this equipment before using it (Fig. 12.12b).

- Forklift (Fig. 12.13)—a forklift is a hydraulic-powered truck that can be used to lift and move materials on construction sites. They may have a petrol, diesel, gas or electric motor. The forklift is an efficient and cost-effective way to move and handle heavy and bulky materials. Forklifts can be operated only by a fully trained and licensed operator. A telehandler—also known as a telescopic handler, teleporter or boom lift—is a versatile lifting machine that combines a forklift and a crane. These

Fig. 12.12 (a) Manual pallet jack; (b) electric pallet jack

Courtesy of Michael Hick

Fig. 12.13 (a) and (b) Examples of telehandler forklifts

Courtesy of Michael Hick

Fig. 12.14 Commercial site hoist

Courtesy of Michael Hick

vehicles feature telescopic arms that extend and retract, giving the machine greater reach than a standard forklift.

- Hoists (Fig. 12.14)—these are frequently used on larger high-rise building projects and are attached to the outside of the building. They are used to move people, tools, equipment and materials to various levels. On a residential site, simple hoists may be found; these devices are used to lift or lower loads by means of a drum or lift-wheel around which a rope or chain wraps.
- Mobile cranes are often used on construction sites to lift heavy materials, such as steel beams, roof trusses and concrete formwork shutters, into position. To operate a crane, you must be fully licensed. Mobile cranes can be hired by the hour and will include a fully trained operator.

Tools that are damaged or faulty pose a risk to yourself and others. All faulty equipment should therefore be reported to the appropriate person (supervisor/store person) within your organisation and repaired by an authorised repairer.

Equipment such as a pallet jack or scissor pallet jack will also need regular checks and servicing to keep it in a good working order.

- Inspect pallet jacks and hand trucks for any sign of damage and store them in secure, dry conditions.
- Check and top up the oil of your pallet truck; check the chain regularly for the correct positioning.
- Adjust the lowering valve if the pallet truck can no longer pump or lower its forks.

Wheelbarrows can be washed down with water to remove any sand or debris. Check the tyres for air pressure and punctures before storing, and grease the axel seasonally. Specialist equipment such as forklifts should be regularly serviced and maintained by a fully trained professional.

CHECK YOUR UNDERSTANDING

3. What is a mechanical handling device?
4. Give three examples of these devices.

12.5 Identify fixings and adhesives

(More information can be found in Chapter 9, Construction fastenings and adhesives.)

As a carpenter in the building and construction industry, most of the materials you will use need to be fixed or jointed together in some way. These fixings can arrive on-site in bulk and will have to be stored or moved to where they are needed. The most common way of fixing materials together and the simplest fixings that carpenters use are nails. Nails are cheap and mass-produced fixings that are available in a variety of types, lengths, gauges, coatings and metals. Some examples of types of nails are:

- bullet head
- flat head
- clouts
- soft sheet
- staples
- lattice head
- duplex
- Timberlok.

Each nail is used for a different application, and sometimes the type of fixing to be used is chosen because of a manufacturer's recommendation provided with the installation information. It is important to know which type of nail goes with which carpentry task.

Screws are another very common fixing used by carpenters. They too come in a variety of types, lengths, gauges, coatings and metals. Screws do have some advantages over nails—such as having better holding capacity; they can also be driven into the material, withdrawn if needed, then driven back into the material. You will need to predrill a pilot hole for screws to help avoid splitting the material into which you are driving the screw.

Some common types of screw are:

- bugle batten
- Phillips head
- self-tapping (for metal)
- roofing
- pan head.

There are also different types of screw heads such as:

- Phillips
- Pozidriv
- slotted
- hex
- Torx drive.

These different types of head will need a different tool or drill bit to drive them into the material that you are working on. As with nails, when you are using screws, check the manufacturer's installation guide to make sure you are using the right screw for the job.

As with nails and screws, most bolts are made of steel and are available in a variety of types, lengths, gauges and coatings such as zinc that has been galvanised to help prevent rust. Another metal that may

be used for bolts is stainless steel, which is excellent for corrosion resistance, as well as being resistant to high heat and extremely cold temperatures. Bolts have a larger load-bearing ability than nails and screws, and are used where there are large structural loads involved.

Like nails and screws, bolts come in a variety of heads, which are suited for different types of applications, including:

- cup
- hex
- pan
- counter-sunk
- socket.

Bolts require nuts and washers, which go onto the thread of the bolt and are tightened up to clamp the materials together. Washers provide protection to the surface of the material and prevent damage during installation; they distribute the pressure of the fastener and also act as a spacer if there isn't enough tread on the bolt.

Masonry fixings and anchors have been specially developed to fix materials such as timber and steel to concrete, and come in all shapes, sizes and applications. It is always best to check the product's installation guide to see which type of fixing you need to use.

Other types of fixing that carpenters use are brackets, metal straps and gang nails, including:

- tie-down straps
- wall plugs
- post stirrups
- metal wall bracing
- hanging straps/multi-grip connectors.

Fig. 12.15 Adhesives



Courtesy of Michael Hick

Not all jobs require fixings such as nails or screws, however. In many applications, an adhesive is a better option (Fig. 12.15). There are a large variety of adhesives on the market, all with different applications for different types of materials. They include:

- PVA glue
- urea-formaldehyde (UF)
- polyurethane-based contact adhesive
- epoxy glue
- contact adhesives
- superglue
- construction adhesive.

The two most common adhesives that you will most likely use as a carpenter are PVA and construction adhesive. PVA comes in a variety of strengths and is particularly useful for gluing porous materials such as timber, paper and cloth. It is also very good for laminating timbers together and in the construction of joinery products such as stairs, doors and windows. PVA works under pressure, so you will need to clamp the material together. Construction adhesives are used in a variety of situations and applications such as attaching:

- particle board sheet flooring to joists
- metal or aluminium door strips to floors or walls
- timber or fibre cement sheeting to cement block or brick walls.

Whenever you are using any adhesive, always refer to the instructions and the MSDS/SDS for advice on the application of the product and drying times, first-aid procedures and how to dispose of the product. Never remove the label from an adhesive container, as it will often contain important warnings

about the product, such as if the product is flammable. Some adhesives have toxic or flammable fumes that can be very dangerous if you breathe them in. You should always work in a well-ventilated workspace and wear PPE such as the appropriate face mask, safety glasses and gloves.

When you have finished using the adhesive, make sure you check that the container is closed and sealed properly and stored safely in a way that has been recommended by the MSDS/SDS.

TIP For a better application when using adhesive, always make sure the two surfaces you are laminating together are clean and free of dirt and dust.

12.6 Identify carpentry construction materials

Before you move construction materials around the workshop or worksite, you must consider whether the materials will be used or stored, whether they need to be stacked and banded and how the materials will be moved around the workspace. Each type of construction material will have its own considerations in terms of how it is moved, stacked and stored. Always refer to the MSDS/SDS for the PPE that is required when handling such materials.

Materials include but are not limited to the following.

- Cement—this is a binding agent/substance, most commonly used as one of the components of concrete. Concrete is made up of water, sand, aggregate and cement. The cement sets, hardens and adheres to other materials to bind them together. Cement mixed with fine aggregate produces mortar for masonry, cement mortar, screeds and render.
- Concrete on a worksite is commonly used to create foundations, slabs, columns, beams and walls. When required in large volumes, it will be delivered to the site by a concrete truck and pumped into place by a concrete pump truck.
- Concrete bags may be delivered to the site on pallets, and may require mechanical handling to unload and move them where they are needed. This can be done by a forklift, pallet truck, wheelbarrow or hand truck, if there are multiple bags. You can handle individual bags manually as they are rated at 20 kg (Fig. 12.16). Bags of concrete are a handy size and may be used for applications such as fence post footings, deck footings and even small concrete pads.

If the cement is not going to be used straight away, the bags will need to be stored in a dry and covered space. Cement can set if the bag is exposed to rain and moisture. It is good practice to use the oldest bag first from your storage—‘first in, first out’. This will help to reduce the chances of the cement becoming stale or being affected by moisture or damp.

Cement is extremely hazardous and can cause a variety of health issues, including irritation to the eyes, nose, throat and respiratory system. It can also irritate the skin and cause cracking, and, in some instances, cause skin damage from chemical burns. Exposure to silica, a mineral found in concrete, can lead to lung injuries including silicosis and lung cancer. (More information about silica can be found in Chapter 1.)

Fig. 12.16 Pallet of concrete



Courtesy of Michael Hick

PPE such as gloves, goggles and the correctly rated dust mask should always be worn when using cement. It is also good practice to wear PPE when handling sand and aggregate materials. The cement bags cannot be recycled as they have a thin plastic lining and should be placed in the general rubbish bins.

- Insulation—this comes in many forms, the most common being insulation batts, blankets and boards for use under floors, in walls and in roof spaces (Fig. 12.17). Insulation provides a barrier that helps stop a building from losing or gaining heat. Some insulation products can also help with noise reduction between rooms and dwellings. For many years, the most widely used insulating material was fibreglass; however, these days there are better alternatives, and many companies now use eco-friendly insulating products.

Always wear protective gloves, a dust mask and goggles when you are handling and installing insulation. Fibreglass insulation can cause skin irritation during installation and may be an issue particularly for asthma sufferers.

Bags of insulation (Fig. 12.17) are relatively lightweight and can be moved easily around a building site. Note that if insulation batts become saturated, they will need to be replaced. Even if they dry out, they will not recover their original thickness and the effectiveness of the insulation will therefore be significantly reduced. Wet insulation batts can also provide an environment for mould to grow, so it is important to make sure they are stored in a dry environment, set up off the ground. Transporting insulation batts will require them to be tied down or ratchet strapped to the truck or pallet.

- Joinery units—these include kitchen cabinets, window and doors or staircase components and can weigh a lot. They may be manufactured from solid timbers or manufactured boards and may contain glass and plastics. Such units are usually delivered to the site as required; however, if they are to be stored on-site for a period of time, they will need to be placed in a dry, covered space, preferably away from tradespeople working to avoid being accidentally damaged. Figure 12.18 shows window units that have arrived on-site and been placed in a garage space on gluts—out of the way of workers. These types of units will require two or more people to lift them and move them into position.

Fig. 12.17 (a) A bag of roof insulation; (b) wall insulation



Courtesy of Michael Hick

Fig. 12.18 (a) and (b) Windows stored on-site

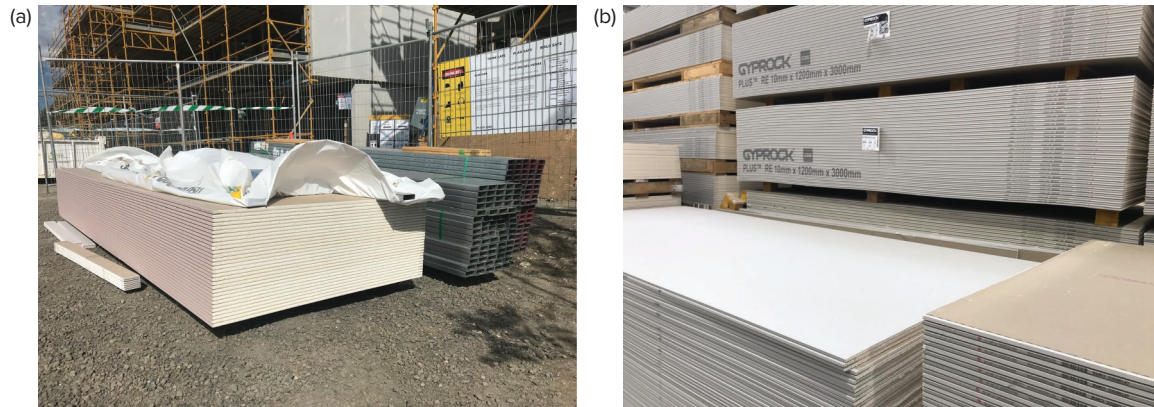
Courtesy of Michael Hick

- **Metal sheeting**—this type of sheeting comes in a range of sizes, lengths and thicknesses. Moving metal sheets around in a workshop may require a team-lifting approach, a suitable pallet jack and a portable lift table or forklift. Other types of sheet metal include roofing sheets and fencing, which come in a variety of sizes. They will be delivered on-site on a pallet and banded together. An on-site team-lifting approach will need to be adopted, or mechanical chain blocks and a hoist used, to move metal sheets into position. PPE should include gloves made of, for example, leather or Kevlar composite, aramid, steel or composite filament fibre. There are a variety of gloves on the market specifically designed for handling metals.
- **Paints and sealants**—when these arrive on-site they will need to be stored in a cool, dry area that is well ventilated. Paint that comes in a 15-litre container (Fig. 12.19) can be individually carried. However, if you have access to a hand truck, it will make the job easier.
- **Plaster or fibre cement sheeting**—plasterboard (Fig. 12.20) is made from gypsum and processed into a board; this is usually faced with a paper covering that can be easily painted and decorated. It is used as a wall and ceiling covering in residential and commercial premises. Cement sheets are commonly used as cladding (Fig. 12.21a), as eaves lining, as a tile underlay on decks (Fig. 12.21b) and in bathrooms (Fig. 12.21c). Cement siding can also be used as a substitute for timber fascias and bargeboards in highly fire-prone areas.

Both plasterboard and cement sheets come in a variety of standard sizes, lengths and thicknesses. Smaller sizes can be moved around a site by one person; however, as the sizes get bigger, you will need to consider working in pairs, as a team or using a mechanical device to move these products into position. Always handle plasterboard from the edges to avoid sheet breakage. Long lengths of board may require a third person to support the material in the middle. Be aware that plaster and cement sheet dust can irritate the eyes, nose and skin and can have long-term effects on health. When cutting

Fig. 12.19 Paint in 15-litre containers

Courtesy of Michael Hick

Fig. 12.20 (a) Pack of plaster on-site; (b) plasterboards stacked at a hardware store

Courtesy of Michael Hick

Fig. 12.21 (a) Pre-primed 7.5 mm cement wall sheets; (b) 19 mm tongue and groove cement sheet; (c) pack of 6 mm Villaboard

Courtesy of Michael Hick

these materials, you should use your PPE—safety glasses, gloves and a dust mask that is correctly rated for such materials.

When cutting cement sheets with a power saw or drop saw (using a cement sheet blade), a vacuum should be used that has a HEPA filter (HEPA stands for high-efficiency particulate air). Where possible, to reduce the amount of dust created when cutting cement sheets, consider using cement sheet cutting tools such as:

- score and snap (Fig. 12.22)
- hand guillotine (Fig. 12.23)
- fibre shear.

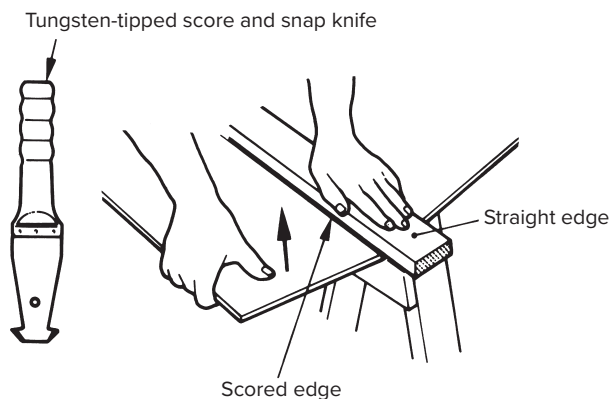
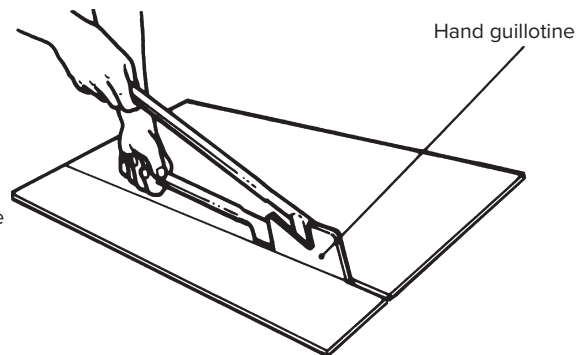
Fig. 12.22 Fibre cement—score and snap**Fig. 12.23** Fibre cement—hand guillotine

Fig. 12.24 (a) 32 mm MDF sheets; (b) 19 mm yellow tongue flooring; (c) MDF staircase treads and risers



Courtesy of Michael Hick

Reconstituted timber products include such products as MDF (medium-density fibreboard; Fig. 12.24a) ply, Masonite, sheet flooring (Fig. 12.24b), particleboard and oriented strand board (OSB). These boards come in standard sizes and thicknesses. Moving these boards may require a pallet jack or involve team lifting. For example, a sheet of 2.4 m × 1.2 m × 32 mm MDF weighs almost 72 kg, so this product would need to be moved by at least two people or by mechanical device such as a trolley or pallet jack. Typical uses for these products can be structural bracing, staircases (Fig. 12.24c), kitchens, flooring and flooring systems, and internal and external cladding. PPE such as glasses, gloves, dust mask and earmuffs should be worn when using and cutting these products. Dust from such products can irritate the skin, nose and eyes and cause respiratory problems.

- Reinforcement materials—the purpose of reinforcement is to provide additional strength for concrete. Hence, reinforcement materials such as steel bars and mesh are incorporated into foundations, slabs (Fig. 12.25), walls, columns and beams. The two products work together to create a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement with higher tensile strength or ductility.

Mesh for slabs can weigh more than 7 kg per square metre and can be awkward to move around a building site by yourself. Where possible, use a mechanical lifting system to move this type of material or, when lifting manually, work as a pair or team to lift, move and place it into position. When handling such material, use your PPE such as gloves to help avoid metal splinters and sharp edges.

- Scaffolding components—scaffold is a temporary structure erected to support access or working platforms. It provides a safe and stable work platform for workers. Scaffolding components, such as Kwikstage scaffolding, can be heavy, meaning it is a two-person job to erect them. This equipment can be very expensive and if not in use it should be stored in a safe, dry environment. (For more information on scaffolding, refer to Chapter 26, Restricted-height scaffolding and work platforms.)
- Structural steel sections and components—these sections come in a variety of sizes and are engineered for particular parts of a building with large loads or spans (Fig. 12.26). The most common

Fig. 12.25 Reinforcement materials used for slab on the ground



Courtesy of Michael Hick

Fig. 12.26 (a) Structural steels used for large door opening; (b and c) structural steel to support second storey of dwelling



Courtesy of Michael Hick

steel beams are W-beam, H-beam, I-beam and C or Channel beam. Depending on the size of the structural steels, these items may need to be craned into position or moved using a chain block and hoist system.

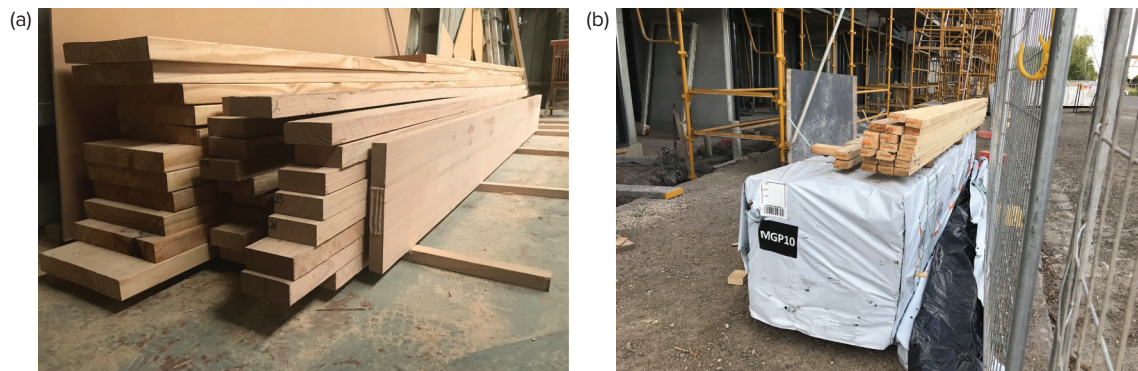
- **Timber**—this is a product made from the processing of trees. The tree is cut up into standard lengths and sizes for use in the construction industry in a variety of applications. Timber can be categorised as hardwoods and softwoods. Hardwood refers to a tree with broad leaves, and may be evergreen or deciduous, such as mountain ash, jarrah and ironbark. Softwood refers to a cone-bearing tree, usually with evergreen 'needle'-type leaves such as pine trees. Softwoods are ideal for building and framing materials due to the fact that the trees grow very fast (compared to hardwood trees). Softwood plantations provide a renewable source of timber for the building and construction industry and Australia has around one million hectares of softwood plantations.

Storage is very important for timber lengths as timber can be affected by moisture and heat. Seasoned timber can be stacked on racks or on timber gluts, which keep the timber off the ground. Timber-stacking systems usually put similar-sized material together (Fig. 12.27a); for example, all of the 90×35 mm timber should be stacked together in a neat and uniform manner. It may also be divided by length. So, for example, all of the lengths between 4.2 m and 6.0 m will be stacked together, lengths over 2.7 m and under 4.0 m will be stacked together, and all lengths that are under 2.7 m will be stacked together.

If you are working on-site and a pack of timber arrives that is not needed straight away, it is best to leave the pack banded up and with the plastic covering on it, and place gluts under the pack to keep it off the ground (Fig. 12.27b). If the pack doesn't have a cover, it will need to be topped by a waterproof covering to keep it protected from the elements.

PPE—when cutting timber you will need to use safety glasses, earmuffs and a dust mask. Timber dust is carcinogenic, and saw dust can cause irritation to the eyes, nose and skin, as well as potentially affecting the respiratory system.

Fig. 12.27 (a) Uniform stacked timber on gluts; (b) pack of timber still covered and banded together awaiting use



Courtesy of Michael Hick

CHECK YOUR UNDERSTANDING

5. What are some of the health risks associated with cement?

12.7 Store materials safely

A big part of preventive safety is the location, organising, stacking and storage of materials. When handling carpentry materials, you will need to determine what materials are needed for a task and the order in which they will be used.

In the workshop, there will usually be a system of shelves and racks for timbers and sheet material as well as a storeroom for fixings and adhesives. A company may have multiple hazardous materials cabinets that can be locked; this is because certain hazardous material cannot be stored together.

On a worksite such as a commercial construction site, materials will be delivered to a laydown yard on-site. The laydown yard may have a container for fixings, adhesives and tools, while hazardous materials may be stored in a vented room within the building. Within the laydown yard, materials will be stacked and stored in the order of use. Usually, there will be an ordering plan for different stages of the building project to avoid having materials sitting in the laydown yard for long periods of time.

Figure 12.28 demonstrates a laydown yard that incorporates site sheds, space for the EWP and forklift (Fig. 12.28a), scaffolding cages (Fig. 12.28b), materials stored on pallets and gluts (Fig. 12.28c) ready for mechanical handling, and a lock-up shipping container (Fig. 12.28d).

Fig. 12.28 Laydown yard showing: (a) EWP and telehandler forklift; (b) scaffold storage cages and baskets; (c) packs of materials; (d) lock-up shipping container



Courtesy of Michael Hick

Materials have to be available where you need them and stored in a way that enables easy handling and transportation. This is very important on residential building sites as there is not usually an on-site storage facility, which means the builder will need to be on top of the material ordering process. At the beginning of a residential build, materials will be dropped off and stacked at the front of the property. Once the building is at the lock-up stage, materials may be stored within the premises. It is very important to ensure that materials aren't in the way of tradespeople and that they don't get stolen or damaged. Storage is an important consideration in relation to carpentry materials, particularly timber, as these products are susceptible to environmental factors such as moisture and heat.

12.8 Plan to move materials around a job site

When materials arrive on-site, it makes sense to place them as close to the job as is practicable or to stack and store them in order of use. You will also have to take into consideration factors such as:

- being able to navigate the worksite safely, avoiding obstacles and hazards
- making sure that you stack and store materials in a designated area and not in the way of the tradespeople on-site
- minimising movement and double handling of materials
- the weight of materials, and how much you can carry using safe manual handling techniques.

Planning is the key to moving materials around a site quickly and safely. This involves:

- assessing the worksite or site plans
- understanding and having knowledge of what materials are required for each workplace task and when the materials are needed
- knowing what materials can be manually handled and carried to locations around the site safely
- knowing what mechanical devices can be used on-site, such as:
 - wheelbarrow
 - pallet jack
 - trolley
 - hand truck.

An industry profile compiled in 2015 found that the most common work-related injuries experienced by workers in the construction industry were:

- cuts and open wounds (31%)
- sprains and strains (21%)
- chronic joint or muscle conditions (16%).

From the above list, incorrect manual handling accounts for 30% of injuries within the construction industry (Safe Work Australia statistic 2015).

Due to the physical nature of the building and construction industry, construction workers are at higher risk of injury from manual handling and, as a result, experiencing time off work. This is due to incorrect manual handling procedures. This only reinforces the need to know how to correctly handle carpentry materials and to understand manual handling processes.

Manual handling is more than just lifting—it involves activities in which you may need to:

- lift
- lower
- push and/or pull

- carry and/or move
- hold or restrain any materials or items.

As a carpenter, you will be required to lift or handle a variety of construction materials manually. Even items that don't seem overly heavy can still cause serious injury if you do not lift them correctly. Some examples of actions that may cause manual handling injuries are:

- lifting at a distance out from the body (overreaching)
- bending to lift heavy items
- lifting heavy items and/or lifting frequently
- awkward postures and/or jerky movements
- lifting heavy or awkward loads
- twisting, turning and bending while carrying
- working in hard-to-reach areas that require stretching
- working in a cramped environment with unstable flooring.

CHECK YOUR UNDERSTANDING

6. What is the percentage of injuries associated with manual handling within the construction industry?

When assessing the risk of injury from manual handling, the following are a few considerations to take into account:

- The nature of the load and how much it weighs. What are its dimensions?
- The location of the load and the work environment; are there any slip, trip or fall hazards?
- Has the person undertaking the task been adequately trained?
- Individual capacity—is the person undertaking the work capable of the task?
- Is it possible to avoid manually handling a load?
- Additionally, be mindful of your own strength and limitations.

TIP Good housekeeping on-site will reduce the number of hazards and materials in the way. This will help when you are manually handling or mechanically moving materials around the worksite.

Some things you can do to help avoid an injury from manual handling are:

- Break up a large load into smaller loads, making it lighter and easier to grasp.
- Consider whether the workplace can be modified to reduce carrying distances. Can you modify storage areas to reduce or remove the need to use twisting movements, or the need to lift things from floor level or from above shoulder height?
- Look at whether the load is a two-person job or if it requires a team-lift.
- Always use mechanical equipment and aids such as a pallet jack, hand truck or trolley.
- Make sure the person doing the lifting has been trained in lifting as safely as possible.
- Check the weight of the load before you attempt to lift it.
- Check that the work area is clear and safe before you start moving loads.
- Take into account distance; although loads can seem light, over a distance you can become fatigued or cramp up, so think about resting the load midway on a table or bench to allow you to change grip, if necessary.
- Avoid carrying loads that are so big they obscure the view of what is in front of you.
- Remember that there is a difference between what people are able to lift and what they can safely lift.

CHECK YOUR UNDERSTANDING

7. List some of the strategies you could consider to reduce your risk of a manual handling injury.

WORKPLACE SCENARIO

Often on-site we can be challenged with the movement of carpentry materials and products. Some materials are awkward in size and shape and traditional mechanical devices may not be suitable to move them around the site. In some instances, you may need a team of people working together to manually move a building product into position.

As an apprentice on one particular job, we needed to get a centre beam timber staircase (beam only, no steps) from the truck and install it into place in a residential house. The centre beam weighed approximately 120 kg with approximate dimensions of 5100 mm × 400 mm × 300 mm. It needed to be moved from the truck at the front of the property and carried down a narrow side-way to the rear of the house, with entry via the back sliding doors. The distance was approximately 60 metres to carry the centre beam. It then needed to be lifted into its position.

Unfortunately, on this particular day we were two workers down, which left only two of us to lift the centre beam. At this point the decision should have been to leave it for another day; however, there was pressure to 'just get the job done' that day. We decided to go through the front door to get the centre beam into the house, as this was the shortest distance from the truck. The front door was on the side of the house, so we had to manoeuvre the centre beam into the house diagonally so as not to hit the hallway wall of the entrance.

It started out well, with one of us at the front and one at the back of the beam. We were holding it close to our bodies to enable us to lift it and were able to start moving it into the house. It was a heavy weight for two people even with the shorter distance. The further we got into the house, the tighter it got through the entryway, making it difficult to get into the hallway. It eventually got stuck between the hallway wall and the front entrance. I was no longer able to hold the weight close to my body and had to keep moving the beam away from my body to get it further into the hallway. Because of the weight of the beam and the fact that I was holding it away from my body, it was becoming increasingly difficult to hold. I was jammed between the beam and the wall and was unable to go any further and as a result I could no longer hold the weight and dropped the beam. When I dropped my end of the beam, the other person dropped theirs.

Consequently, the beam smashed through the plaster wall, broke the front door sill and damaged the centre beam, meaning it could no longer be used that day as it required a repair. The beam therefore had to be manoeuvred out without causing further damage and returned to the truck as it needed to be repaired back at the factory so it could be used to finish the job.

The key learning from this scenario is that no job is so important that it can't be done safely. Injuries can affect you and be with you for a lifetime. In this instance, the job and the house were damaged because we were trying to 'just get the job done'. This decision not only cost lost work time, delays to completion and possible injury, but also meant a monetary loss for the business.

12.9 Understand manual handling procedures

When lifting and carrying loads, your back is at greater risk of injury. That is why it is so important to lift correctly. Lifting is about utilising the strength of your legs. The first steps before you lift are to:

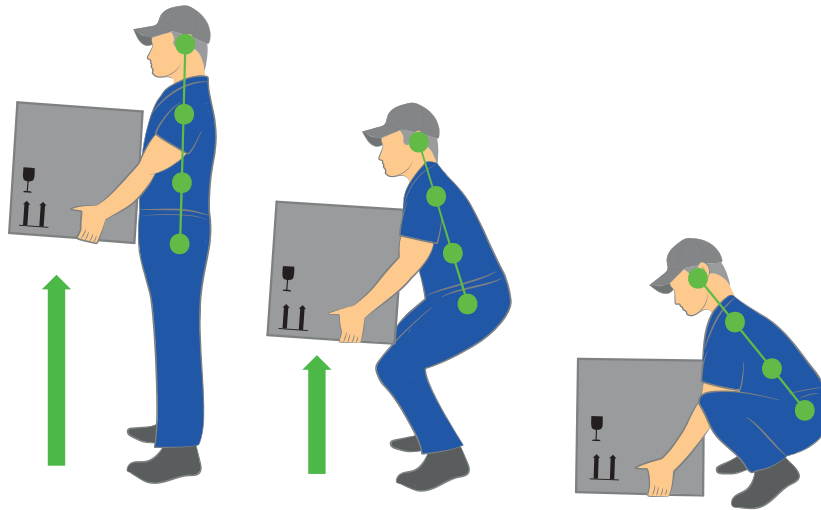
- consider the load, its weight and dimensions
- check for obstacles and hazards
- have a clear plan of where you are going (distance).

12.9.1 Safe lifting

To lift safely (Fig. 12.29):

- Adopt a stable position. Your feet should be apart, with one leg in front of the other alongside the load if it is on the ground to increase stability.
- Have a good firm grip on the load; keep the heaviest side of the load towards your body.
- Do not flex your back when lifting; start in a full/deep squatting position. Be careful not to flex your back while lifting. This can happen if your legs begin to straighten before you start to raise the load.
- Keep the load close to your body—the further away a load is from your body, the heavier it is to handle and the greater the stress on your body and potential for injury.
- Keep your shoulders level and facing in the same direction as your hips. Turning by moving your feet is better than twisting and lifting at the same time.
- Keep your head up when handling. Look ahead, not down at the load, once it is held securely.
- Move smoothly—avoid jerking or twisting motions.
- Don't lift or handle more than you can easily manage. If in doubt, seek advice or get help.
- When putting the load back down, keep your back straight and crouch down using your leg muscles. If you need to precisely position the load, put it down first, then slide it into the desired position.

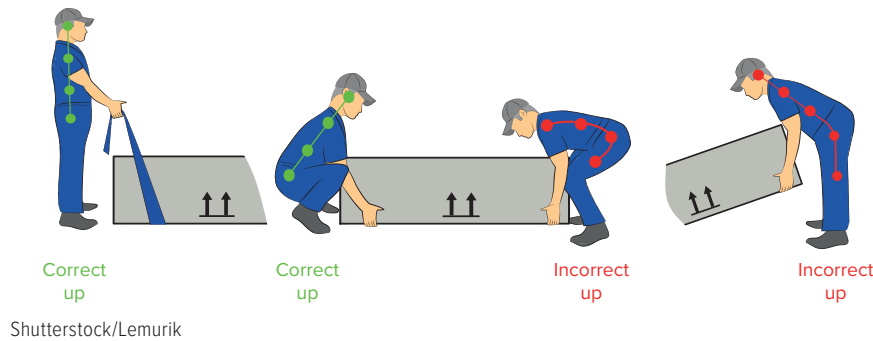
Fig. 12.29 Individual lifting technique



Shutterstock/Lemurik

12.9.2 Team-lifting

Team-lifting, which includes lifting as a pair (Fig. 12.30), and carrying is used when all other solutions are not possible. You will need to take into account that the combined strength of the team is less than the sum of individual strength.

Fig. 12.30 Lifting as a pair

Ideally, make sure you select team members of similar height and strength. You will need to assign a leader to the team, who should determine a simple set of commands that everyone understands when moving the heavy load. For instance:

- lift
- walk
- stop
- up/down.

The team may need to practise a 'lifting and carrying' task with the commands before attempting the actual load to make sure everyone understands the task and all are in sync.

12.10 Load and unload carpentry materials

There are many factors to consider before loading, unloading, moving and relocating materials around a construction site when using mechanical handling devices, for instance:

- Have the people involved been trained?
- Do they have the correct licences?
- Are signs and barricades required?
- Have hazards been identified, e.g. powerlines, trees, pipes, excavations?
- Who are the workers involved? Do they understand their role?
- Will the moving of materials impact or interfere with tradespeople's workspace?

When loading materials, always use the correct manual handling lifting and carrying procedures to avoid injury to yourself and other workers. For ease of movement, make sure the materials are stacked onto a pallet or gluts, which makes them easier to move by pallet jack or forklift. Also, having the materials loaded onto a pallet or on top of gluts will keep the materials off the ground and avoid moisture and dampness. Make sure any banding around the materials is secure. You can also use a clear pallet stretch film wrap, which helps to secure materials to the pallet.

Once the materials have been offloaded, it is the builder's responsibility to move them to a safe place until they are needed. Some considerations when unloading construction materials include:

- Always use safe manual handling processes.
- Unload, stack and store materials in a logical order.
- Do not overload scaffolding and work platforms.
- Consider whether the materials will need to be moved again. Will they need to be stacked on a pallet or gluts?
- Consider if there is somewhere to secure materials that are not needed straight away.
- Look at where you will put materials if they need to be protected from the elements.

Before you move materials mechanically around a construction site, they may need to be stacked safely and/or banded together. Banding is most commonly used in the construction industry for the handling and delivery of packs of timber, sheet materials and bricks. You must take care when cutting bands: they are under tension and when you cut them, they can spring back and fly into your face, causing serious injury. Take care to ensure that once you have cut the bands, the material doesn't fall on your feet, especially if the pack is on uneven ground.

Once you have cut the banding, it is good practice to place it in the waste or metals bin if available. Discarded banding can become a trip hazard on construction sites; it can also get pulled into the wheels and drive shaft of vehicles. Once wrapping has been removed from a pack, place it directly in the bin or, better, in the plastic recycling bin if your site has one, to avoid it being blown around the worksite or escaping into the greater environment.

CHECK YOUR UNDERSTANDING

8. What is the purpose of banding materials on a pallet or gluts?

Student research

1. What are musculoskeletal disorders (MSD)?
2. How may they present (what do the symptoms look like) and how can they occur?

End-of-chapter activities

1. Using varying lengths of timber or similarly proportioned materials, stack and secure a minimum of 0.5 cubic metres onto an Australian standard pallet.
2. Investigate some of the health issues associated with dust created from these construction industry materials: cement, MDF and plaster.
3. Create a JSA of the types of manual handling you do at your worksite/workshop.
4. What innovations are being trialled to assist workers in carrying loads (for example, exoskeletons)?

AUSTRALIAN BUILDING CODES AND STANDARDS

*Work Health and
Safety Act 2011*

**Work Health and
Safety Regulations
2019**

**Safe Work
Australia,
Hazardous manual
tasks, Code of
Practice, October
2018**

Tradie talk—‘Don’t blow ya foofer valve!’

Chapter 13

Site setting out and basic levelling

Learning Objectives

LO 13.1 Identify setting out equipment

LO 13.2 Identify and use levelling equipment

LO 13.3 Set out on-site

LO 13.4 Set out on sloping sites

LO 13.5 Set out screeds for concrete slab

Introduction

Before starting to set out any building it is essential to define the exact boundaries of the building allotment. This can be done only by a registered surveyor who will make a 'peg out' survey, which consists of locating or relocating the boundaries and marking them with a peg or mark on a fence, for example. The surveyor will issue a survey certificate showing a plan of the allotment, where the boundary marks are to be found and how they can be identified. If requested, he or she can also provide further information, such as the levels of the land relative to adjacent streets and drainage services.

The setting out and levelling of a building is the most important part of the building process. The fact that it is the first task done in the construction process means any mistakes made at this point will be carried throughout the entire construction. It is essential that the building is set out accurately in line with the drawings and that the base structure is square and level. If these tasks are achieved, the construction process will be much smoother.

It is crucial to have a clear site when setting out, as any obstruction could pose a tripping hazard or impede the setting out of the building. Maintaining a tidy site throughout the construction process is also important as it will help with site safety as well as ensuring good access when building. Finally, once the setting out has been completed, it is important to ensure the equipment is cleaned and stored appropriately.

In this chapter, you will learn about the various types of equipment used for setting out and levelling a structure on flat and sloping sites. You will also learn about the techniques used when levelling and setting out structures and how to set up concrete screeds.

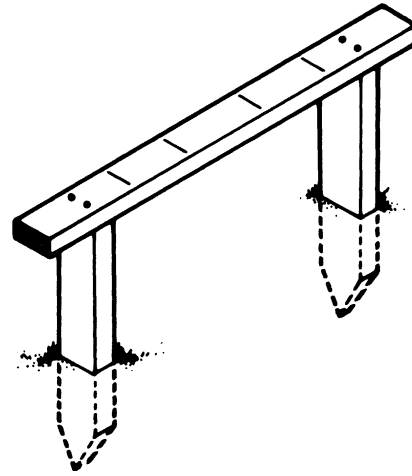
13.1 Identify setting out equipment

The position of the building on the site is indicated by setting up **profiles** and string lines. Profiles may be saddles, hurdles or a continuous profile.

13.1.1 Saddles

Saddles consist of hardwood pegs about 400 mm long, with a cross member or ledger approximately 600 mm long (Fig. 13.1). They are economical in the use of material and are favoured on sites that are level or very nearly so.

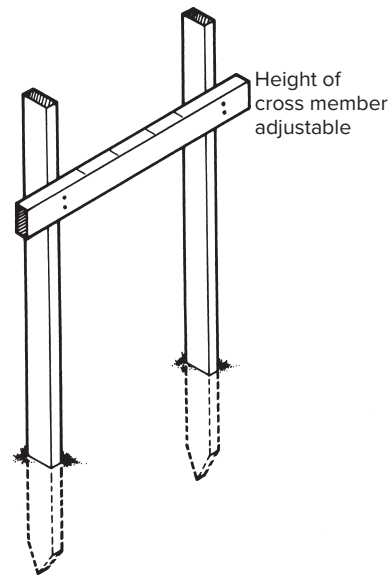
Fig. 13.1 Saddle



13.1.2 Hurdles

The cross member of a hurdle can be adjusted in height (Fig. 13.2). In general, hurdles are more suitable on a sloping site where all of the cross members can be set level. In some cases, very tall hurdles may require some diagonal bracing to keep them rigid.

Fig. 13.2 Hurdle



13.1.3 Continuous profile

In some areas, builders prefer to set up a continuous profile where a level cross member is set up completely around the perimeter of the building at a convenient working distance (Fig. 13.3). String lines can be readily set up on the level at any point and plumb down to the sloping ground line.

Other requirements for setting out include a heavy hammer for driving pegs, string lines, a long steel tape, plumb bob and a spirit level. A large builder's square can be made of timber, where a triangle is set up in the ratio of 3,4,5 to form a right angle (Fig. 13.4).

Fig. 13.3 Continuous profile

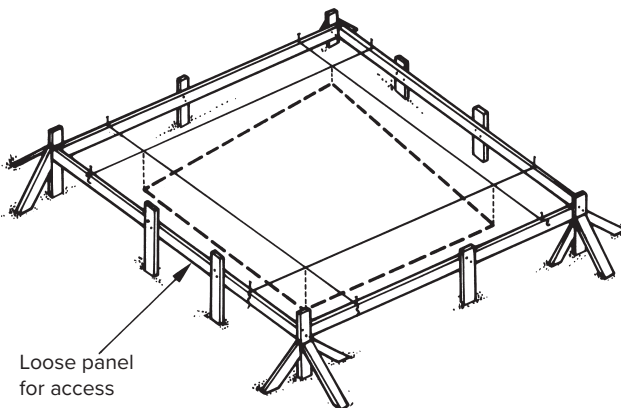
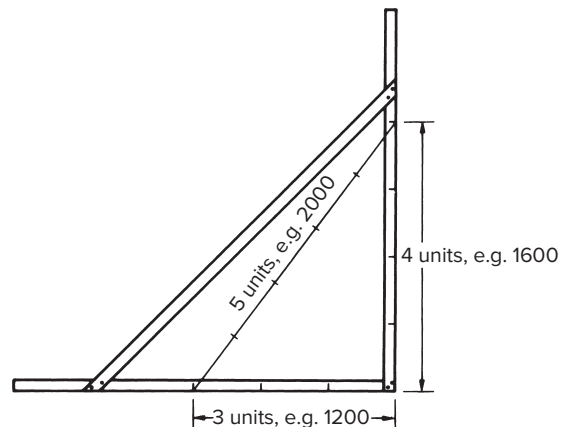


Fig. 13.4 Builder's square



CHECK YOUR UNDERSTANDING

1. Why should a 'peg out' survey be carried out before any building work commences?
2. What are three types of profiles used to indicate building outlines?

WORKPLACE SCENARIO

When setting out any building, it is essential to ensure that it is set out in the correct position and on the correct block. There have been instances of houses being built on the wrong block in a new area, which is usually down to the carpenter not checking to make sure they are on the right site from the plans, not checking lot numbers or street names, etc. It doesn't take long to double check, but it can be costly if you build on someone else's property.

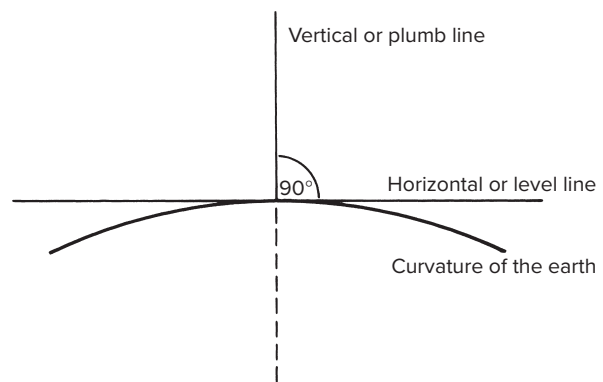
13.2 Identify and use levelling equipment

Accurate levelling is one of the most basic requirements of building construction. Floor levels must be set out so that they lie on a true horizontal plane at the correct height, as specified by the building designer.

A horizontal line, commonly referred to as a *level line*, is one that is at a tangent to the curvature of the earth's surface at any given point (Fig. 13.5). Perhaps the simplest practical example of a horizontal line is to imagine a line lying on the surface of still water.

A vertical line is at right angles to a horizontal line and is usually referred to by the trade term *plumb line*. Other terms used in levelling procedures are as follows.

Fig. 13.5 Horizontal and vertical levelling lines



13.2.1 Bench mark

The bench mark is a fixed point of reference, the elevation of which is known. It may take the form of a metal plug set in concrete or a mark chiselled in a wall. Bench marks can sometimes be observed set in the kerb near street corners, the location and elevation of which have been recorded on surveyors' drawings. On building sites, a temporary bench mark is sometimes established and given an assumed elevation.

13.2.2 Datum

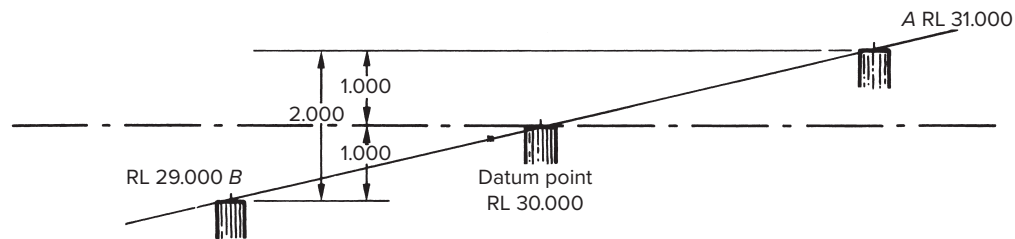
The datum is a fixed point of known elevation; it is the reference point from which the elevations of other points are calculated. The temporary bench mark of assumed elevation, say 30.000 m, becomes the datum for that particular building site and may be referred to as the *job datum*.

13.2.3 Reduced level (RL)

The term *reduced level* (RL) is given to the elevation of a point relative to a given datum. For example, on Figure 13.6, if point A is equal to an RL of 31.000, it is 1.000 m above datum, and if point B is equal to an RL of 29.000, it is 1.000 m below datum. Thus, the difference in level between points A and B equals 2.000 m.

The assumed elevation given to the datum is sufficiently high to ensure there will be no minus quantities where RLs are below the datum.

Fig. 13.6 Reduced level of an elevation point



There are two common methods used to calculate reduced levels: height of collimation, and rise and fall. When taking levels, it is important that the readings are recorded correctly and accurately using a table. Table 13.1 is an example of a table used when taking levels using the rise and fall method. This type of table is also useful to record levels even if the reduced level is not going to be calculated.

Table 13.1 Table used to record readings using the rise and fall method

Reading	Back sight (BS)	Intermediate sight (IS)	Fore sight (FS)	Rise	Fall	Reduced level (RL)	Distance	Remarks
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

CHECK YOUR UNDERSTANDING

- What is the purpose of establishing a datum?

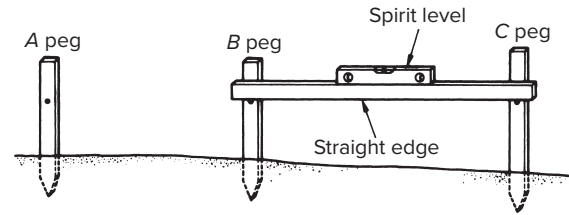
13.2.4 Levelling equipment

Levelling equipment is essential for measuring accurately on-site. The instruments and methods used include the following.

13.2.4.1 Spirit level and straight edge

A spirit level and straight edge can be used together over short distances with great accuracy. The straight edge is normally constructed from aluminium, or sometimes timber, and must be constantly checked for straightness or errors in setting out may occur. When taking levels with a spirit level, reverse the level to ensure that it is reading accurately. Temporary intermediate pegs, as shown in Figure 13.7, can be driven between the points to increase the range of the straight edge.

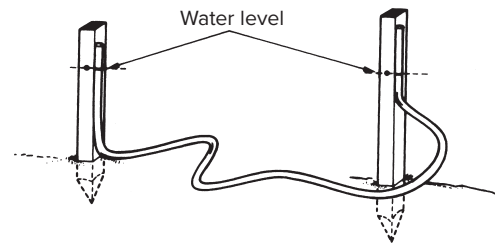
Fig. 13.7 Levelling with a straight edge



13.2.4.2 Water level

A water level consists of a length of clear plastic hose or tube about 10 mm in diameter, which is filled with clean potable water (Fig. 13.8). As the measurement is carried out, each end of the tube is held on the vertical. Care must be taken to remove all air bubbles when the tube is filled.

Fig. 13.8 Water level



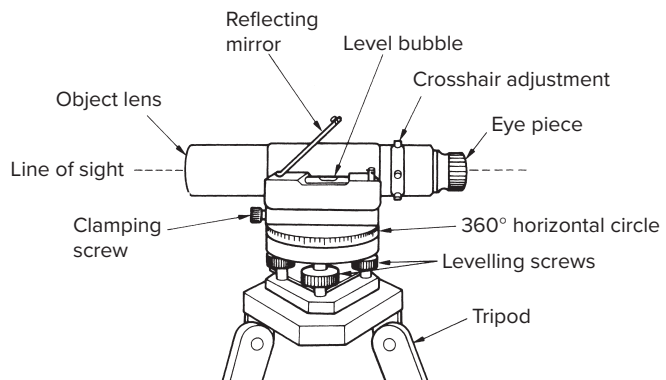
TIP Filling a water level without getting air bubbles in the water can be achieved by siphoning water from a clean bucket.

The level works on the principle that water will always find its own level and therefore each end of the tube will find the water at the same level. This method can be very accurate, and the range is limited only by the length of the tube. A particular advantage is that it does not require a direct viewing from point to point, and can be taken around obstructions. It has been found to be very useful for internal work, levelling from room to room. Plug the ends with a length of dowel when not in use; however, the ends must be open when in use.

13.2.4.3 Dumpy/automatic level

A **dumpy level** is an optical instrument that consists of a telescope fixed to a vertical axis, with a three-screw base used to level the instrument (Fig. 13.9). A set of crosshairs is located in front of the eyepiece of the telescope, and attached to the telescope is an accurate levelling bubble. When the telescope is levelled it will project a horizontal 'line of sight' as it is rotated around its vertical axis. It can also be used to set off horizontal angles.

Fig. 13.9 Dumpy level



The dumpy level is accurate over long distances when used in conjunction with a surveyor's staff. Levelling for most domestic buildings, however, can be carried out by measuring between points, marked on a timber rod with a metric rule.

Checking the dumpy

To check the dumpy level for accuracy, a two-peg test needs to be carried out (Fig. 13.10). Set up a dumpy level in the centre of two pegs. Ensure that the dumpy is exactly 15 m from each peg. To find this measurement you will need to use a plumb bob suspended from the screw on the tripod (Fig. 13.11). Using either a surveyor's staff or a piece of timber, place the staff on top of Peg A and take a reading. Transfer this reading to Peg B (both pegs need to be the same height).

Move the dumpy past one of the pegs, ensuring it is 15 m away from the peg and in line with both of them.

Take the reading on Peg A; this will be a different reading, but don't worry, just note it down. Go to Peg B and take a reading. If both of the new readings are the same, the dumpy is working accurately. If there is a difference in the two new readings, then the dumpy needs to be recalibrated by a specialist company that services surveying equipment.

Fig. 13.10 (a) and (b) The two-peg test

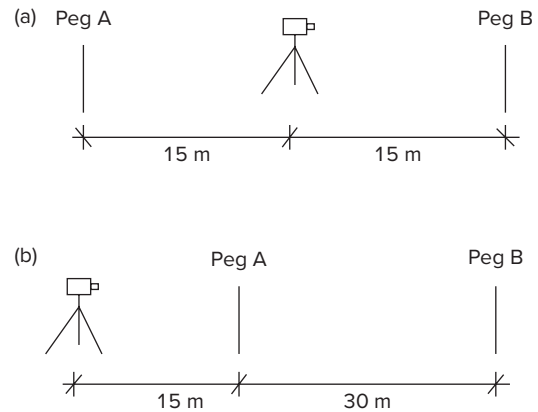


Fig. 13.11 (a) and (b) A plumb bob



Courtesy of Daniel Bonnici



Looking through the dumpy

To look through the dumpy, first adjust the instrument to your eye strength. This is done by rotating the eyepiece until the crosshairs are clear and sharp (refer to Fig. 13.12). You will see large horizontal and vertical crosshairs. The horizontal crosshair is the one that is used for taking height readings

from a surveyor's staff or a piece of timber. The vertical staff can be used to ensure the staff is plumb. There are also two smaller horizontal lines. These are called stadia lines and can be used to calculate distance.

To determine the difference in level between two points, *A* and *B*, set up the level in a convenient position where the two points will be visible, and adjust for level.

Hold a wooden rod/staff vertically at point *A* and mark the level of the crosshairs on the rod/staff using a pencil, chalk or felt marker. Hold the rod on point *B* and mark the level of the crosshairs on the rod. Measure between the two marks; this measurement is the difference in level between points *A* and *B*. The distance from point *B* to the line of sight is the lesser distance; therefore, there is a rise from point *A* to point *B* (Fig. 13.13).

Fig. 13.12 Crosshairs in dumpy eye piece

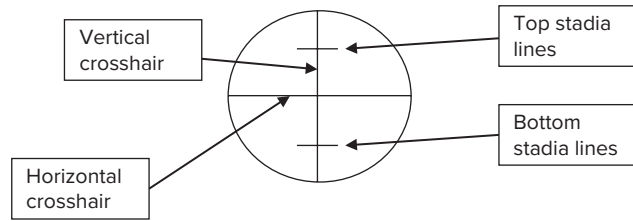
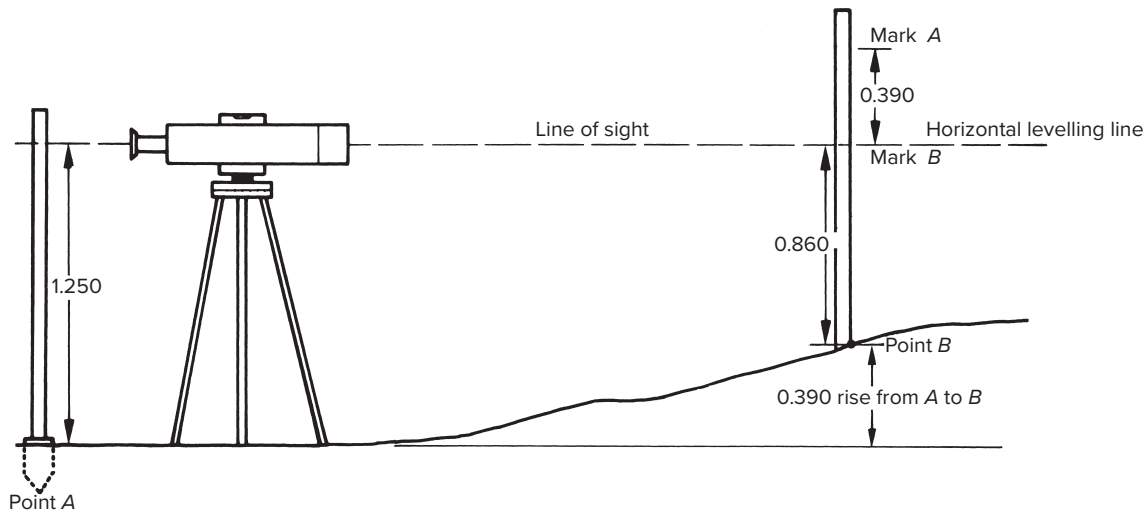


Fig. 13.13 Using the dumpy level



13.2.4.4 Laser level

A laser level is an electronic instrument that has a rotating head that emits a laser beam (Fig. 13.14). It is set up on a tripod like a dumpy. Most modern lasers are self-levelling. Once the instrument is level, the head will start to rotate and the laser beam will start emitting. A receiver is required to detect the laser beam. The receiver normally has an LED screen, which will show when the beam has been detected. Most receivers also have an audible beep. There are normally three different beeps: one pattern to indicate to move the receiver up, one to move the receiver down and a continuous beep that indicates when the beam and receiver are aligned.

Fig. 13.14 Laser level



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The laser level can be used in the same manner as a dumpy level. The main difference is that it is a one-person operation. Instead of having a second person looking through a lens as on the dumpy level, a receiver is used to locate the beam being emitted by the laser level. The receiver is attached to the staff and the required heights can be transferred as with a dumpy level.

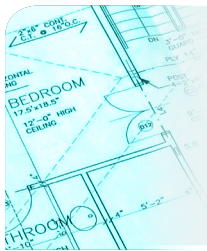
Height differences can also be calculated by moving the receiver up or down along the staff when determining two heights from two points.

It is always a good idea to read the manufacturer's instructions/specifications for the specific laser level being used, to ensure the level is being used appropriately and that you are familiar with all of the laser level's features.

13.2.4.5 The builder's square

The builder's square is a large square fabricated from timber and is used to set out right angles. It is commonly made on the site from available material. Two straight pieces approximately 90 mm × 35 mm and 3 m to 4 m long are required for the arms, together with a suitable brace. The two arms are joined at the corner and then set square by the 3,4,5 principle.

Measure along the arms three units and four units respectively, making the units as large as possible for greatest accuracy. Fix the brace at one end and adjust the arms to measure five units across the hypotenuse of the triangle and finish fixing the brace. To set out horizontal right angles accurately with the builder's square, it is laid on the ground and at least one arm of the square must be level.



INTERPRETING PLANS

Refer to the floor plan in the Appendix.

- Set out the double garage. Set out the entire area, showing all walls.
- Set the height of the hurdles to 200 mm above a datum point set by your teacher.

CHECK YOUR UNDERSTANDING

4. List three levelling devices that can be used over large distances.
5. What is a builder's square and how would you check that it is 'square'?

13.3 Set out on-site

The outline of a domestic building and its position on a near-level allotment are shown in Figure 13.15. The building is of timber-framed construction, and there is a strip footing around the perimeter with a single brick dwarf wall up to under-floor level. The floor level is specified as RL 31.200.

The procedure begins by first clearing the site of long grass, tree stumps and roots. Assemble all of the necessary tools and materials on-site and proceed as follows. (The order of setting the string lines is shown later in Figure 13.17a-f.)

13.3.1 Step 1

Set out the necessary markings on the saddle/hurdle cross members. Figure 13.16 indicates the width of the excavation and the position of the brick dwarf wall. For a concrete footing, the width of the excavation

is the same as the width of the footing. If a brick footing is specified, approximately 150 mm is added to the footing width to provide working clearance. Partly drive a nail at the points where the string lines are to be fixed. To set out the simple outline, twelve profiles are required.

13.3.2 Step 2

Working from the survey pegs, accurately locate the side boundaries. If this is done by setting up a long string line, take care that it is not affected by breezes, thus causing inaccuracies. Placing some temporary intermediate pegs will help to overcome this problem.

13.3.3 Step 3

The general principle adopted in setting out is to take the basic rectangle of the building and set it out first. Then check for accuracy, and add or subtract any minor projections. In this case the rectangle *ABCD* will be set out first (Fig. 13.17d).

It has been decided to set up line *AB* first, because it is close to the minimum clearance from the side boundary and is the longest side. It seems logical to set it out accurately, parallel to the boundary, this being the most critical dimension. Some may prefer to reverse the order of strings 1 and 2, particularly if it were a very wide building lying across the middle of the block. Theoretically, it should not matter which order is adopted but in practice small discrepancies can arise, and it is comforting to know that at least they will not be allowed to happen where they could lead to any serious consequences.

Measure in from the boundaries and roughly locate points *A* and *B*. Beyond point *B*, set up a profile as shown in Figure 13.17a. To erect the saddles/hurdles, refer to Figure 13.18. Lay the cross member on the ground and measure from the boundary to ensure that it is in its correct position. Drive in two pegs of equal height adjacent to the cross member. Lift the cross members up to the top of the pegs, check their position and secure with nails to the pegs.

Fig. 13.15 Site layout

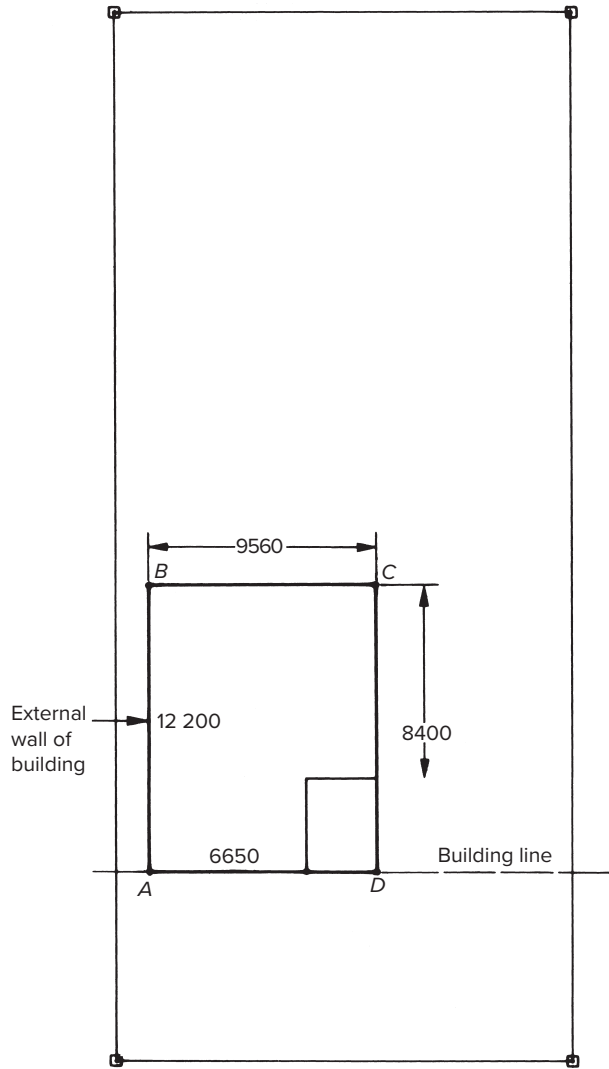


Fig. 13.16 Ledger set-out for timber-framed construction

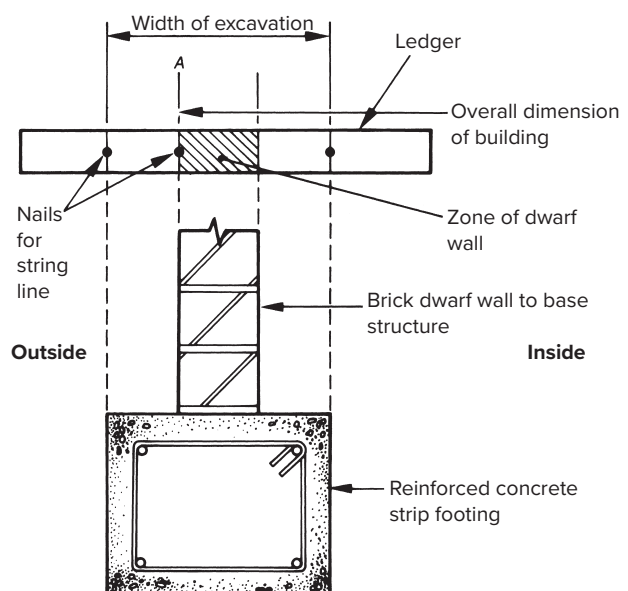
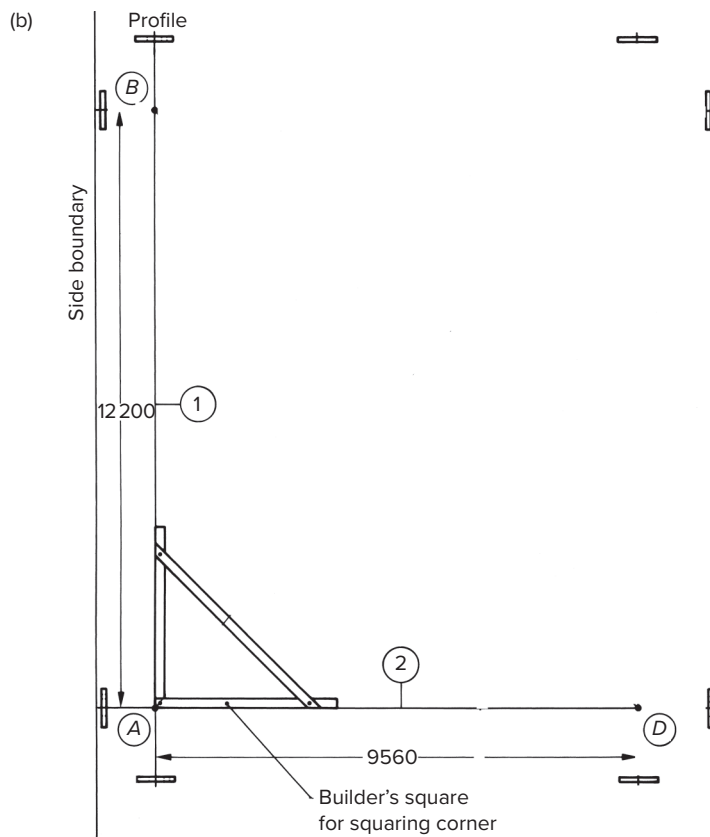
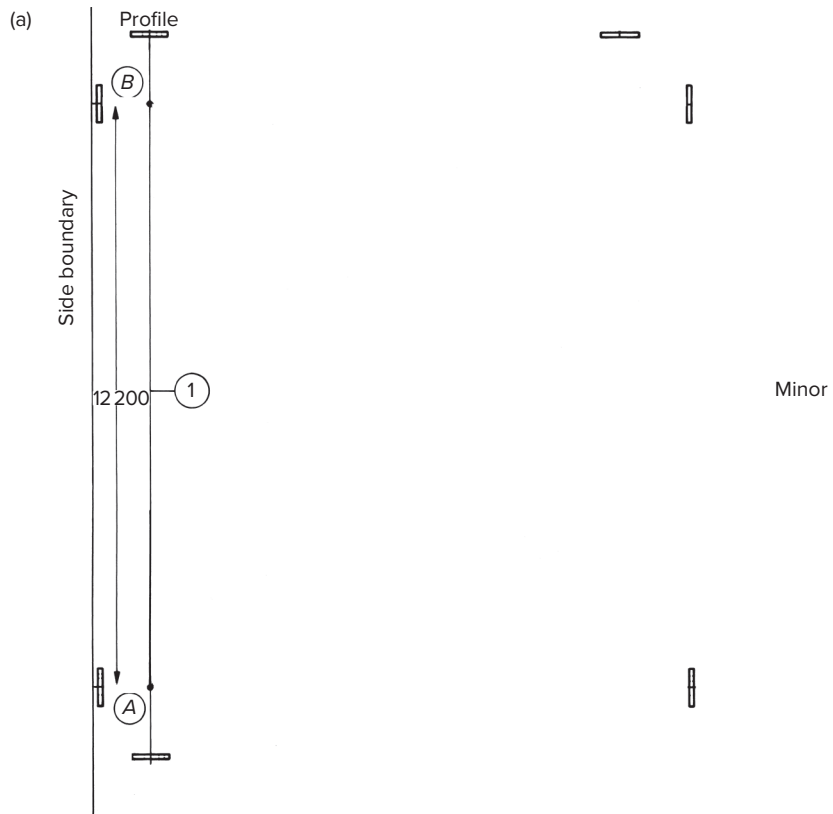
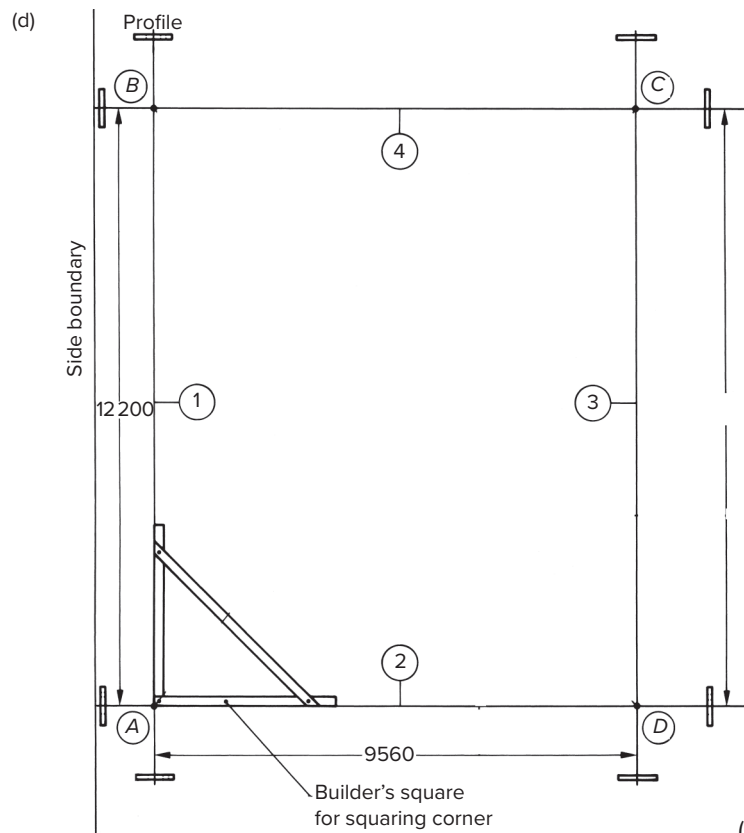
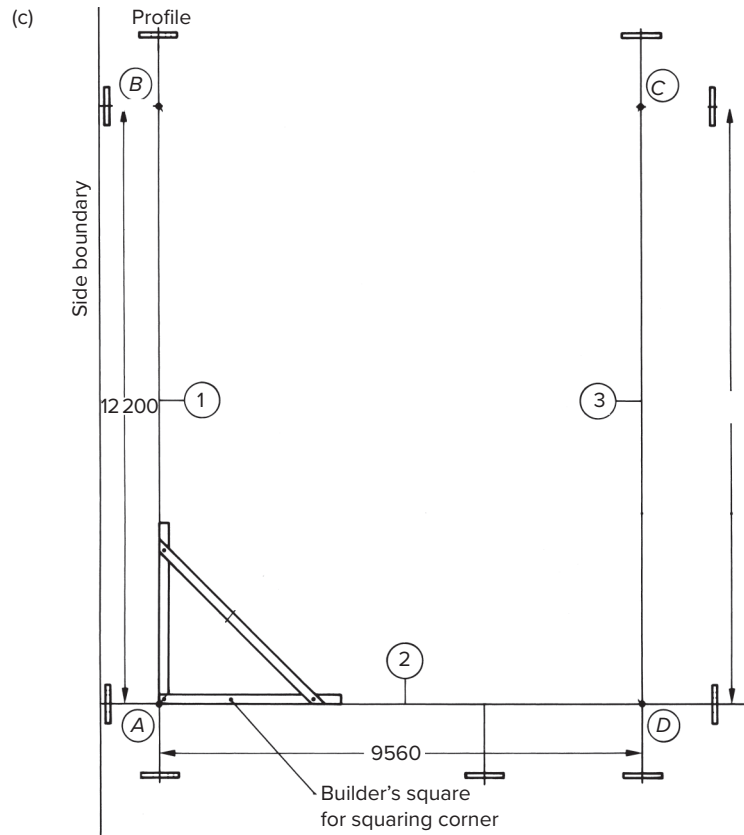


Fig. 13.17 (a) and (b) Basic building rectangle—sequence of operations



(continued)

Fig. 13.17 (c) and (d) Basic building rectangle—sequence of operations (continued)*(continued)*

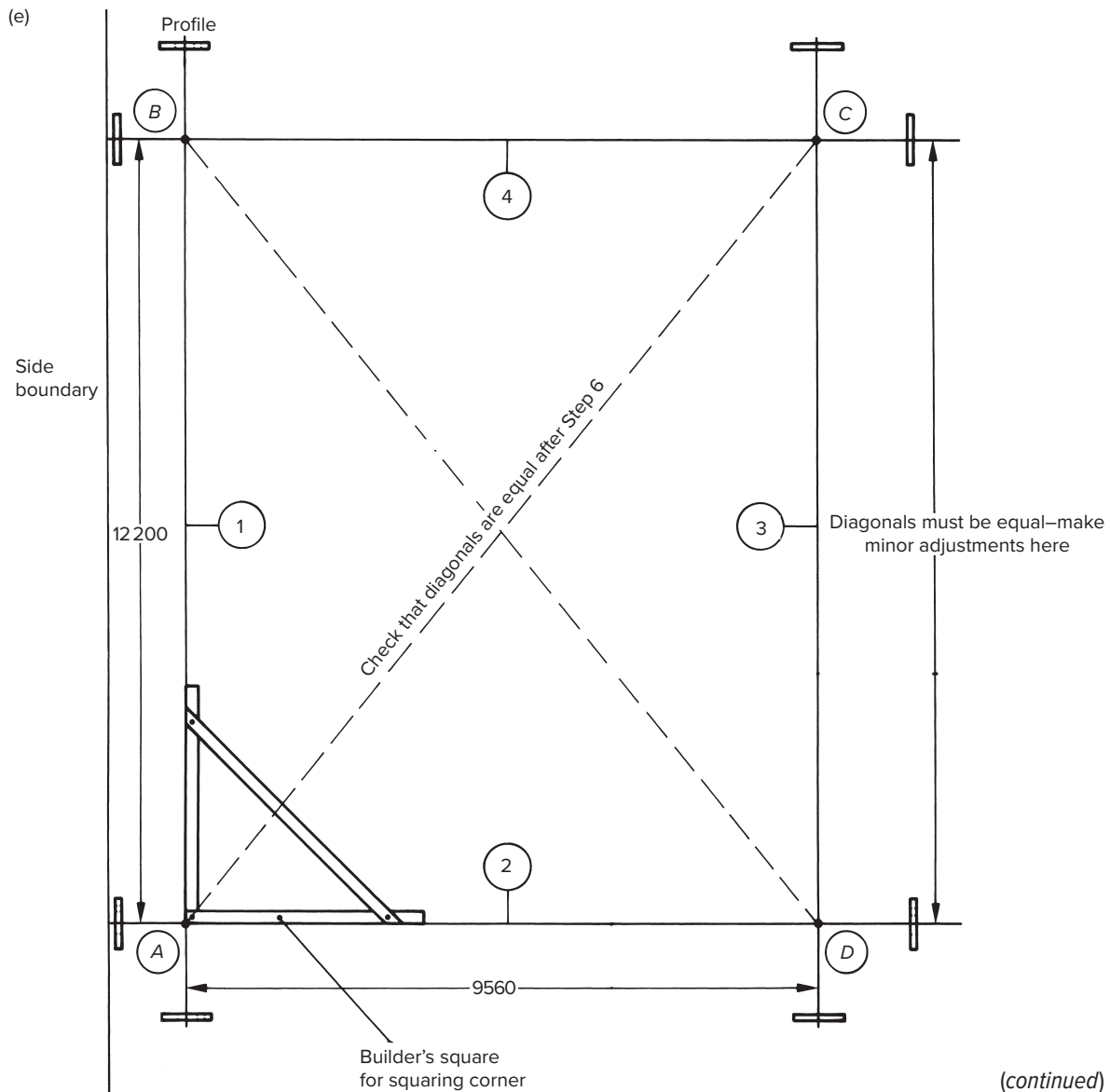
TIP Ensure that the height of the saddle/hurdle profile is set to a predetermined height (e.g. the height of the top of the dwarf wall, piers or stumps).

Beyond point A set up another profile in a similar manner, ensuring it is levelled to the same height as profile A, and stretch a string line indicating the outside face of the brickwork. Profiles must be set back far enough to allow working space when excavating the trenches. If excavating by hand, a 1 metre clearance should be sufficient, but if excavating by machine, 2 or 3 metres may be necessary depending on the particular backhoe being used.

13.3.4 Step 4

To set up line AD (see Fig. 13.17b), measure from the front boundary to the building line and erect and level a profile beyond point A. Attach a string line and secure the other end to a temporary peg beyond point D. The builder's square is commonly used to set this line at right angles to line 1 in Figure 13.19.

Fig. 13.17 (e) Basic building rectangle—sequence of operations (continued)



Plumb down and lay one arm of the square directly under line 1. Adjust line 2 so that it also lines up with the other arm of the square. Erect and level a profile beyond point *D* and attach the string line, indicating the face of the brickwork. Care in setting out an accurate right angle at this stage avoids the need to make adjustments at a later stage.

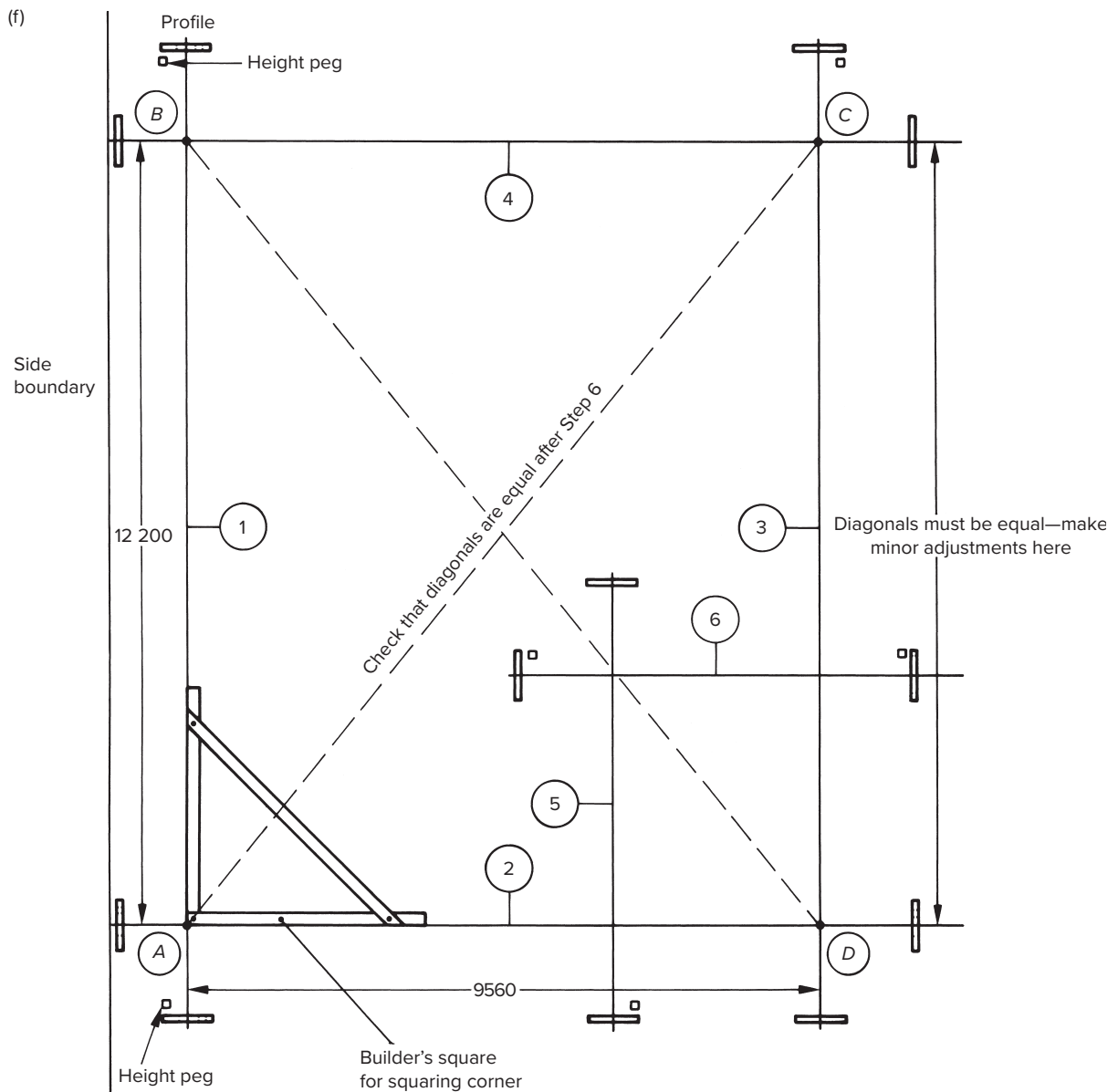
13.3.5 Step 5

Measure the width of the building for the profile beyond points *C* and *D* (Fig. 13.17c). Continue to follow the procedure for erecting and levelling the saddles/hurdles (Fig. 13.18). Attach a string line, which is now parallel to *AB*.

13.3.6 Step 6

Measure the depth of the building from the profiles at *A* and *D* and erect and level the profiles beyond *B* and *C*. Attach a string line, now parallel to *AD* (Fig. 13.17d).

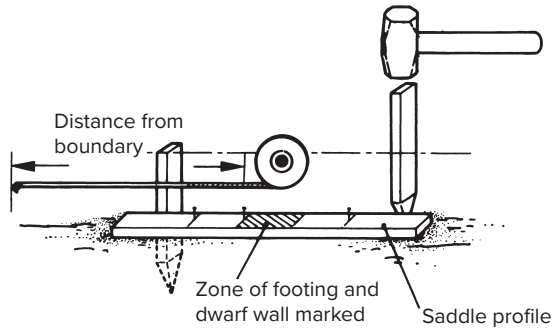
Fig. 13.17 (f) Basic building rectangle—sequence of operations (continued)



13.3.7 Step 7

This completes the basic rectangle, but before proceeding further it must be checked for squareness by measuring the diagonals, which must be equal. Hold the tape as taut as possible. It helps if someone can take the sag out of the tape by supporting it near the centre. If minor adjustments have to be made, the two profiles beyond C and D will both have to be adjusted either way by the same amount (Fig. 13.17e).

Fig. 13.18 Set-up of saddle profile



13.3.8 Step 8

Set up lines 5 and 6 parallel to the sides of the main rectangle to indicate the face of the brickwork (Fig. 13.17f).

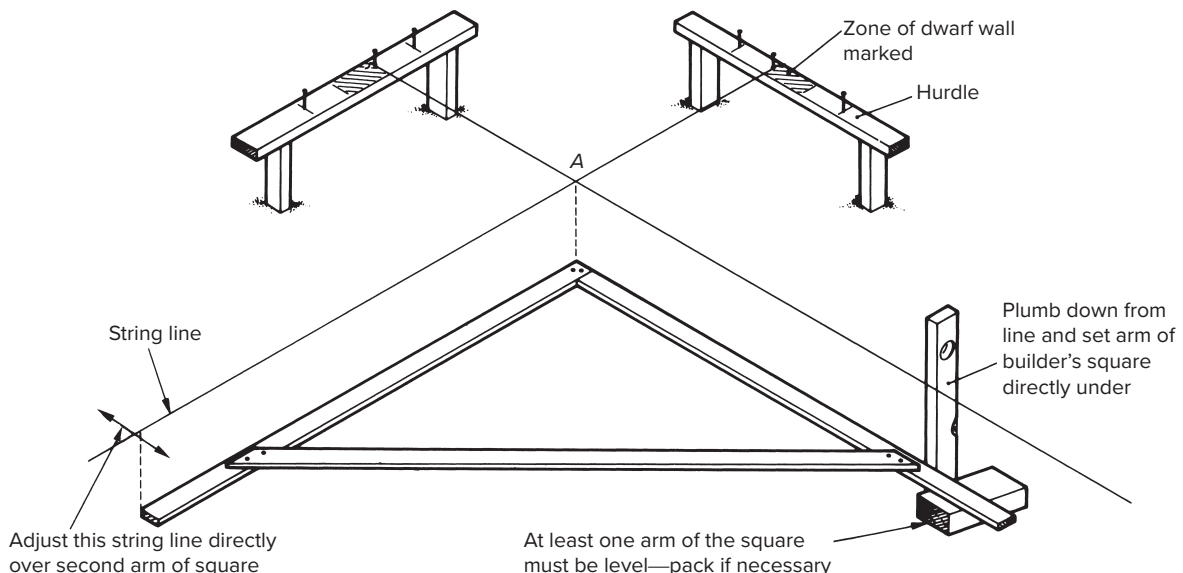
The 3, 4, 5 method

- If a builder's square is not available, the 3, 4, 5 method can be used.
- Measure along line AD 3 metres and drive a small peg into the ground; mark the 3-metre measurement with a nail on the top of the peg.
- Measure along line AB 4 metres and drive a small peg into the ground; mark the 4-metre measurement with a nail on the top of the peg.
- Measure the distance between the two pegs diagonally. This measurement should equal 5 metres. If it isn't, adjust the position of the nails, ensuring the 3-metre and 4-metre distances are maintained.
- Once a 3,4,5 triangle has been created, this will give us a square (90°) corner. The lines AD and AB need to pass directly over the two small pegs we have just used. You can plumb up from the nails to the string line using a spirit level, to check the lines are in the right position.

13.3.9 Step 9

The height pegs are now placed near the corners of the building (Fig. 13.17f). The height indicated on the pegs is to the top of the brick dwarf walls. The depth of the flooring and timber floor members

Fig. 13.19 Corner set-out



must be deducted from the RL for the top of the brickwork (Fig. 13.20). If the depth of floor timbers is 220 mm then the RL to the top of brickwork is equal to 30.980 m (i.e. 31.200 less 0.220 m). Therefore, the top of the brickwork is 0.980 m above datum. (Fig. 13.21 shows the hurdle being levelled using the dumpy level.)

Set the level in a convenient position where the hurdles and datum can be sighted, and adjust the line of sight for level. Stand a wooden rod on the datum and mark the line of the crosshairs, point *E*. Measure down 0.980 and make a second mark *F*. Stand the rod beside the pegs and raise it until point *F* is in line with the crosshairs. Mark the bottom of the rod on the pegs and attach the saddle/hurdle profile to the pegs. The top of the saddle/hurdle should be level with the marks made. The other saddles/hurdles should be levelled in a similar manner. Building regulations require that a minimum clearance be maintained from the ground to the underside of the floor framing timbers and this minimum must always be observed.

13.3.10 Step 10

Excavation of the trenches can now proceed. For each wall, set string lines to indicate the position of the trenches (Fig. 13.22). Plumb down onto the ground and scratch a line or mark the line with a few small pegs. If excavating by machine, a sprinkling of lime to mark the line of the trench can be a good guide for the operator to follow.

The depth of the trench must be adjusted so that the brickwork can be finished in full courses to the height of the hurdles. The standard metric brick measures 230 mm × 110 mm × 76 mm. Joints are 10 mm, so one course of bricks is 86 mm. Prepare a brick gauge rod marked off in brick course increments of 86 mm, and if the footing is of concrete, tack a loose batten on the bottom, equal to the depth of the footing (Fig. 13.23).

Fig. 13.20 RL from top of ground to floor structure—timber-framed construction

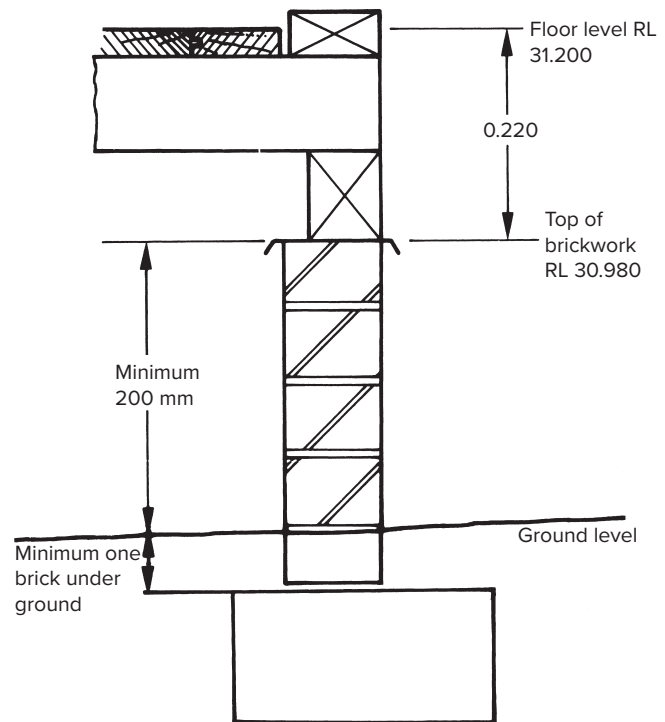


Fig. 13.21 Levelling hurdle

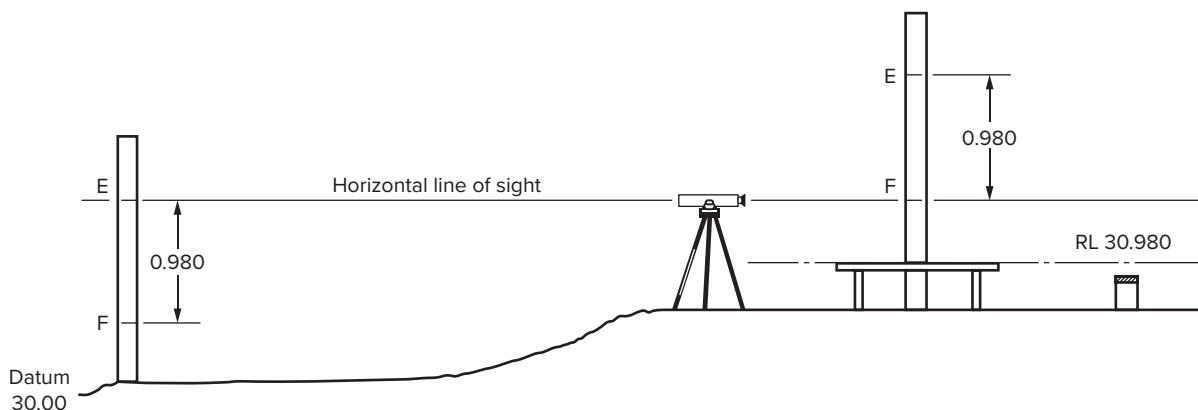
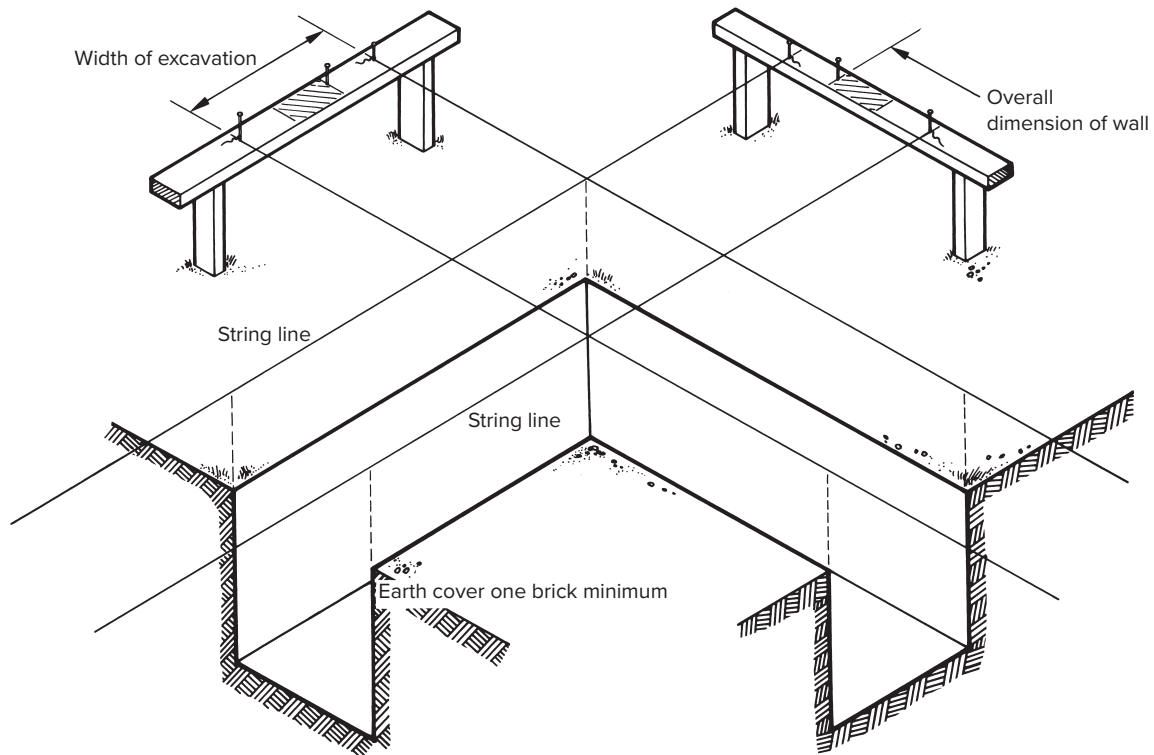
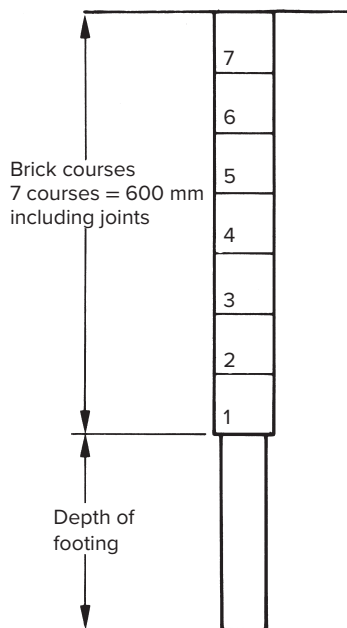
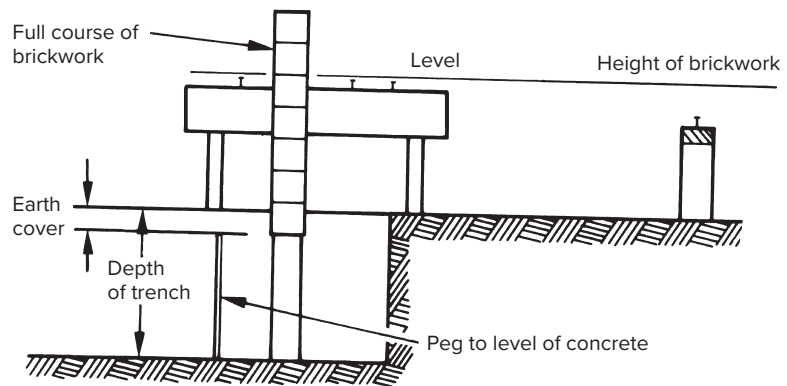


Fig. 13.22 Excavation of trenches

Fig. 13.23 Set-out of a brick or gauge rod

Fig. 13.24 Establishing the depth of trenches


Level across from the saddles/hurdles and use the rod to adjust the depth of the trench to work to brick courses (Fig. 13.24). Establish the depth of the trench at each corner and level between them to complete the excavation.

Pegs, commonly short lengths of 10 mm steel, are placed at suitable intervals along the trenches to indicate the height to the top of the concrete footing.

CHECK YOUR UNDERSTANDING

6. What marks are made on a profile cross member when setting out for a brick wall on a concrete footing?
7. How would you check your basic set-out for square?

13.4 Set out on sloping sites

When setting out on a sloping site, hurdle profiles are often used and are thought to be more convenient and accurate. All of the cross members on the profiles are set level at the height of the brickwork (Fig. 13.25).

Setting out of the string lines can be done in the same order as is shown in Figure 13.17, but it is usually more accurate to set out the marking on the cross member after the profile has been erected. Placing a cross piece on the ground in its approximate position is a good guide to where the profile should be placed.

The bottom of the trenches must always be level, and on a sloping site they must be stepped to form level benches. The height of the steps is a multiple of brick courses or 86 mm (Fig. 13.26).

Start at the lowest corner and excavate to the finished level. Continue along at that level until the depth of earth cover over the footing indicates a step could be made, then continue for another 600 mm to allow for an overlap in the footing, and step up a distance equal to brick course multiples. Benches should preferably be no less than approximately 1200 mm long and not made any closer to a corner. The maximum height of a single step is 600 mm.

Fig. 13.25 Set-out on sloping site

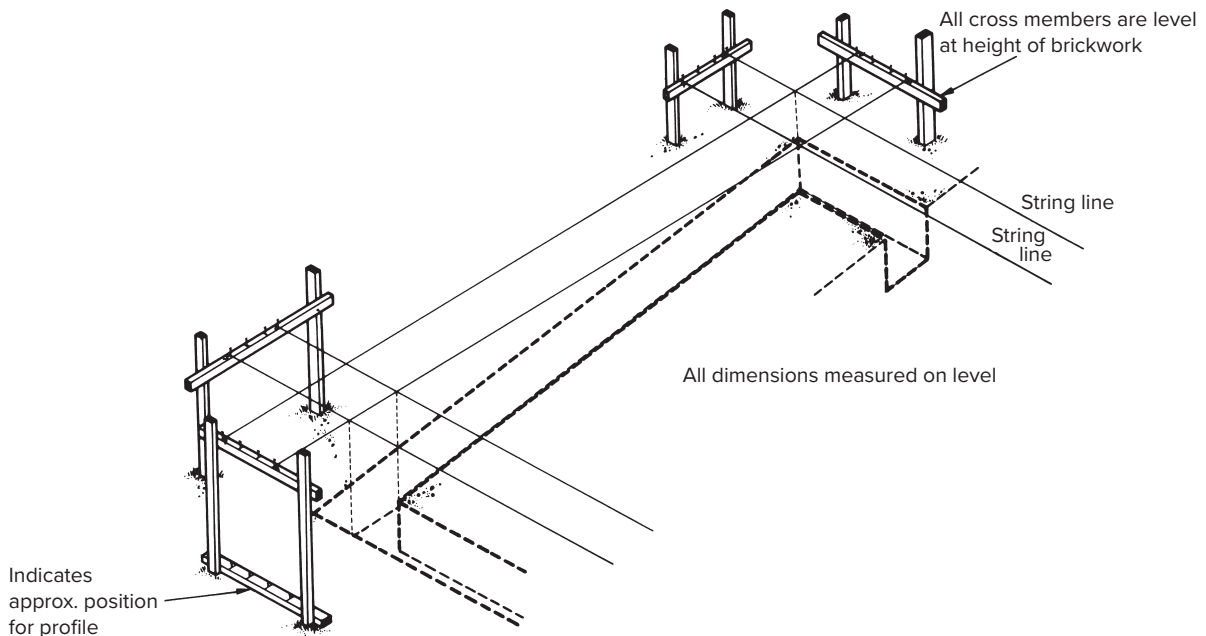
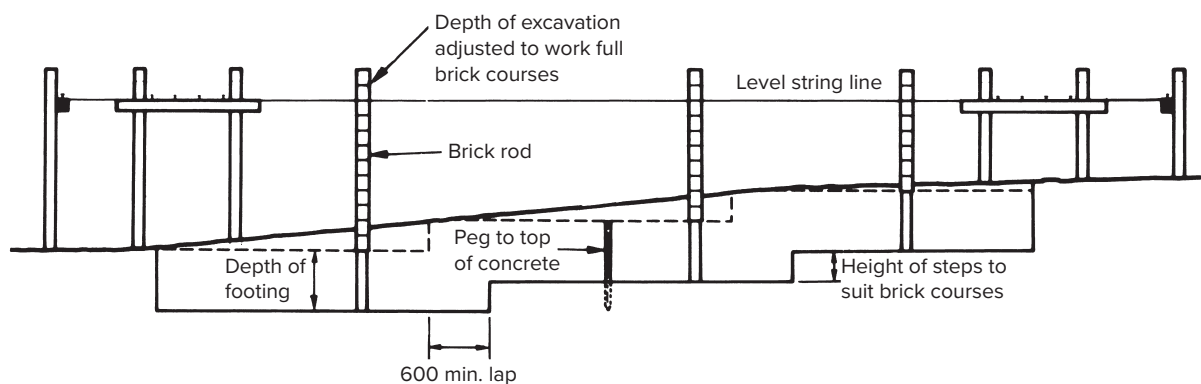


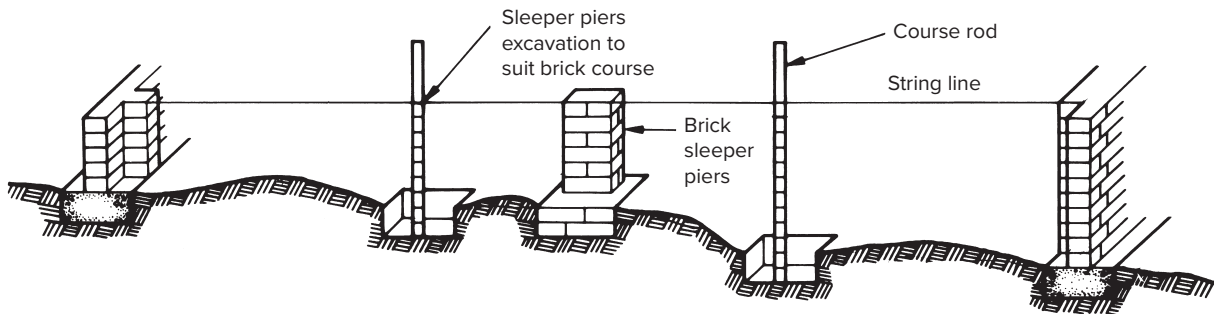
Fig. 13.26 Excavation for footings on sloping site



13.4.1 Setting out for sleeper piers

Sleeper piers are also called intermediate piers, isolated piers or solitary piers. To support the ends of bearers, engaged piers are bonded to the dwarf perimeter walls, and sleeper piers provide intermediate support when the length is more than a single span (Fig. 13.27). To set out for brick sleeper piers, stretch a string line between the engaged piers, indicating the height of the piers, and plumb down to the ground. Mark the position on the ground for the excavations, not exceeding the spacing specified. Excavate for the footings using the brick gauge rod to establish the depth of the excavations, so that two courses will be below ground level and will finish with full courses of brickwork to the string line.

Fig. 13.27 Excavation for isolated or sleeper piers



CHECK YOUR UNDERSTANDING

8. How would the depth of footings be determined for a brick dwarf wall to a timber-framed cottage?

13.5 Set out screeds for concrete slab

Screeds are boards set up to establish the height at which the concrete is to be levelled off. A common example is the boards that are used to form up the sides of a concrete path in order to retain the concrete, and that indicate the height at which the path will be finished. A concrete garage slab is another typical situation that requires the setting out of screeds (Fig. 13.28).

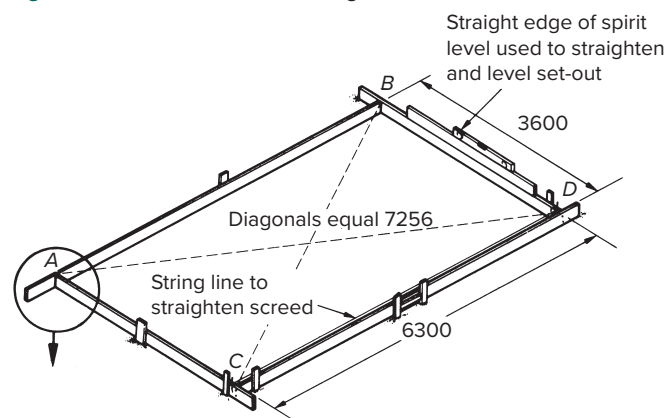
For example, a concrete garage slab 6300 mm × 3600 mm × 100 mm thick is to be set out on a near-level site. Besides the setting out equipment previously used, also required will be screed boards sized at least 100 mm × 25 mm and long enough to form the perimeter of the slab, as well as enough pointed pegs—approximately 50 mm × 25 mm—to support the screeds.

First, level and clear the site of any grass or roots. Soil used for filling should be free of all vegetable matter and well consolidated by ramming to a depth not exceeding 600 mm. Greater depths of fill using road base can be achieved with engineering specifications.

13.5.1 Step 1

Lay a long screed on the ground beside its final location, square one end and mark off

Fig. 13.28 Set-out for screeding boards



the length of the slab AB to 6300 mm (Fig. 13.29). Aim to arrange the screeds so that their length need not be cut any more than necessary. If close to a boundary line, measure from the boundary a distance equal to the clearance, less the thickness of the screed. Drive a peg at each end, which will support the back of the screed.

Establish the height to the top of the slab and mark on one peg, and level this height through to the second peg.

13.5.2 Step 2

Nail or screw the screed to the pegs with the top edge on the level marks. If nailing, dolly up behind the pegs with a heavy hammer to avoid loosening the pegs.

To straighten the screed, attach a string line (Fig. 13.30), packing it out at each end with wooden blocks approximately 10 mm thick. Using a loose block of the same thickness, adjust the screed to the string for both line and height. Drive pegs behind the screed approximately 1 metre apart and secure with a nail or screw.

13.5.3 Step 3

Select a screed for side AC , square one end, mark off the width (3600 mm) and nail in place at A with the inside face of C on the length mark. If one is available, a builder's square could be used to square the corner AC , or use the 3,4,5 method mentioned earlier (Fig. 13.31).

Drive a peg behind the screed at C , level from A to C , and secure with a nail or screw. Straightening screeds over shorter distances can be carried out with a straight edge.

13.5.4 Step 4

Select screeds for CD and BD , square one end and measure off the length and width respectively. If screeds must be joined, a short cleat across the back will keep them in alignment. Assemble the screeds by nailing them together at B , D and C . Level BD and secure to peg at D . Before proceeding and driving in all of the pegs, it is no doubt a wise move to check the accuracy of the setting out at this time. For squareness, measure both of the diagonals AD and BC . Both measurements should be the same. If they are not the same, some

Fig. 13.29 Setting up screeding board length

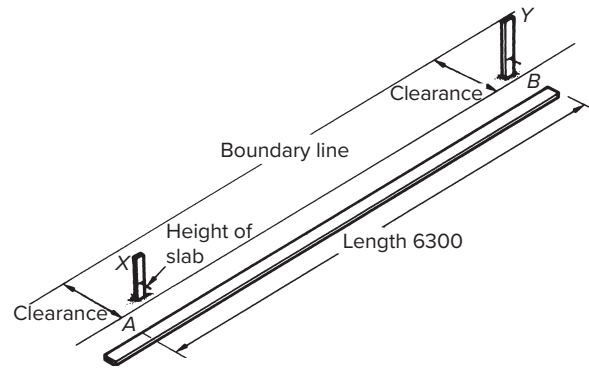


Fig. 13.30 Straightening screed board

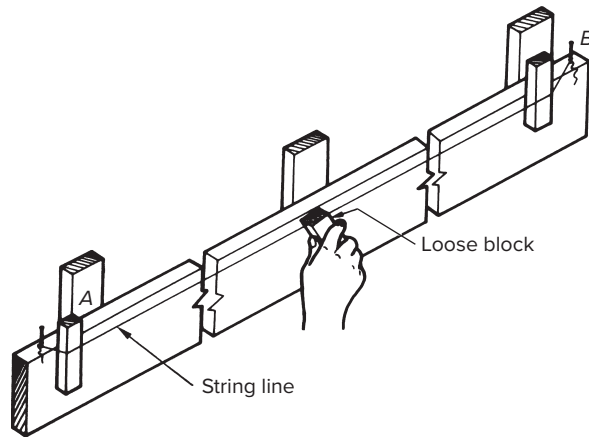
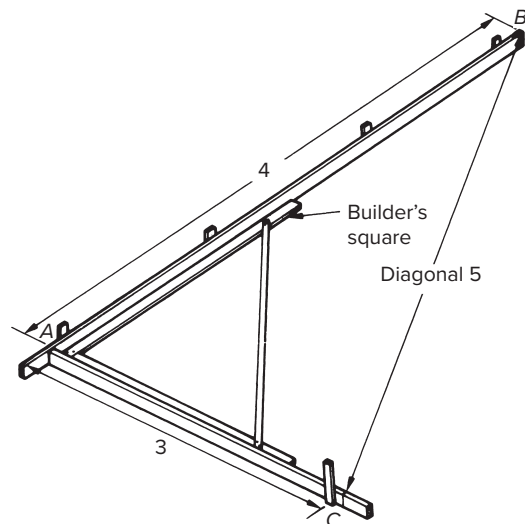


Fig. 13.31 Squaring up corner of screed



adjustments will need to be made. Refer back to Figure 13.17 and Step 7; a check of the levelling can be made by levelling across the diagonals *A* to *D* and *B* to *C*.

13.5.5 Step 5

Set up a string line from *C* to *D* at the thickness of a loose block from the corner. Adjust the screed to the line for both line and height, and secure to pegs. A straight edge can be used to straighten the shorter screeds and secure with the remaining pegs about 1 metre apart.

To calculate the quantity of concrete required:

$$\begin{aligned}\text{Volume} &= \text{length} \times \text{width} \times \text{height} \\ &= 6300 \times 3600 \times 100 \text{ mm} \\ &= 6.3 \times 3.6 \times 0.1 \text{ m} \\ &= 2.268 \text{ m}^3\end{aligned}$$

CHECK YOUR UNDERSTANDING

9. What is the function of a screed?
10. Define the following terms:
 - a. plumb
 - b. level.

Student research

Research what is meant by 'reduced level' and why it is used. Then investigate the different methods for obtaining reduced levels.

End-of-chapter activity

With a partner, set out a rectangular building 4 m × 3 m on some grass.

- Use hurdles and string lines.
- Ensure all the hurdles are the same level (ask your teacher to establish a datum and to allocate a height above the datum for your hurdles).
- Remember to set up the first corner using the 3,4,5 method and check that the final set-out is square by measuring the diagonals.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684—2010
Residential
timber-framed
construction

National
Construction Code
(NCC)

Guide to
Standards and
Tolerances 2015
—VBA

Tradie talk—Is that string line tight enough?

Chapter 14

Advanced levelling operations

Learning Objectives

LO 14.1 Plan and prepare for levelling operations

LO 14.2 Carry out levelling procedures using the rise and fall method

LO 14.3 Carry out levelling procedures using the height of collimation method

LO 14.4 Calculate distances using stadia lines

LO 14.5 Clean up and maintain tools

Introduction

Many different types of levelling instruments and devices are available for use in the construction industry; knowing how each functions will help you to always use the correct instrument for the correct application.

Carrying out levelling operations can sometimes be quite confusing. There are all manner of things to consider such as backsights, intermediate sights, foresights, change points, rise and fall, line of collimation, negative readings, reduced levels, benchmarks, datums, three-part tests and two-peg tests, to name just a few.

The basics and fundamentals of levelling have been covered in Chapter 13, Site setting out and basic levelling. To best understand the content of this chapter, please read Chapter 13 first.

This chapter will give you the knowledge and skills required to carry out levelling procedures such as open and closed traverses using the rise and fall method, and the height of collimation method and recording the readings correctly.

You will also learn how to calculate distances using an automatic level.

The correct use of levelling equipment is vitally important in any construction task. Any mistakes can prove costly as they could affect any subsequent aspect of the construction if they are not detected.

14.1 Plan and prepare for levelling operations

14.1.1 Planning the task

Before any levelling procedures commence, it is important to undertake careful planning and organisation, and ensure that all workers understand every aspect, so that the specified tasks can be carried out safely, efficiently and in accordance with any stated legal requirements.

Mistakes can be costly in terms of lost time and extra monetary expenses through having to redo tasks and correct any work that took place after the levelling mistake was identified.

All safety issues need to be carefully considered as accidents or incidents can lead to equipment damage or lost time for the affected workers on the worksite, followed by the implementation of return-to-work procedures.

Items that need to be in place and understood to enable all workers to safely proceed with the levelling task may include documents covering compliance with national or state laws and regulations such as:

- the National Construction Code (NCC)
- specific Australian Standards
- codes of practice
- national, state or territory legislation
- work health and safety (WHS) procedures.

Examples could include:

- Legal standards (as referenced from WorkSafe Victoria). In Victoria, there are legal standards that need to be adhered to in regard to the use of laser equipment. These are regulated under Part 3.5 (Plant) of the Occupational Health and Safety Regulations 2017. These regulations outline and specify the duties that are relevant to the designers and manufacturers of plant such as lasers. The importers and suppliers of any laser equipment are bound by these regulations as well. Employers also have specific duties under these regulations with regard to plant such as lasers, which include:
 - carrying out hazard and risk identification
 - controlling any identified risks, in accordance with the correct order of the hierarchy of control—that is, elimination of the hazard or risk if practicable, followed by substitution of plant or equipment, engineering controls or isolation, administrative controls and the use of personal protective equipment (PPE) in that order
 - duties in relation to the correct installation, the correct guarding and the correct use of plant
 - duties in relation to the correct training, and providing the relevant information and clear instructions, to employees
 - a duty to consult with elected occupational health and safety (OHS) reps to ensure safe work practices resulting in the desired outcome are achieved.
- Compliance code (as referenced from WorkSafe Victoria). The Compliance Code for Plant, 2019 (which was previously the Code of Practice for Plant, 1995) has now been released. This compliance code provides even more detailed advice and references in relation to the following technical standards, which are relevant to the design, manufacture and use of lasers:
 - AS 2397 Safe use of lasers in the building and construction industry
 - AS/NZS IEC 60825.1 Safety of laser products—equipment classification and requirements
 - AS/NZS ISO 11553 Safety of machinery—laser processing machines—safety requirements
 - BS EN 60825.1 Safety of laser products—equipment classification and requirements
 - Safe Work Australia, Laser classification and potential hazards.

Site-specific documentation and items that would also need to be in place and understood could include:

- The site safety plan, which is developed to give an overview, for every worker, of the safety aspects of all of the specific tasks that are taking place on the construction site at any time. This will include any hazards and risks associated with these tasks.
- A safe work method statement (SWMS) would need to be developed as outlined in Chapter 2, Construction work hazards and risk control strategies, in conjunction with the site safety plan if the levelling tasks are being carried out during the process of conducting high-risk work such as carrying out excavations deeper than 1.5 m, working with heavy machinery or plant or working at heights.
- A job safety analysis (JSA), as outlined in Chapter 2, can be developed with the purpose of enabling all personnel to work safely together, even if the levelling tasks are considered low risk, such as setting out a new house on a vacant block or establishing ceiling heights in a new commercial building.
- Job plans and specifications need to be read and fully understood so that no mistakes are made in relation to important building elements, such as the site set-out, building positioning or specific heights such as excavations for cut and fill, piers or footings, slab levels or finished floor levels.
- Work requirements, sequencing, schedules or charts can be developed by referring to the above points so that the job can be set out with the specific work tasks, safety issues, personnel and timelines taken into account.
- Tolerances are an important factor to consider when carrying out levelling. States and territories provide free online standards and tolerance guides for downloading. These give instructions and advice on all aspects of building work and the related accuracy of all measurements and levels that are deemed acceptable in normal building practices. These documents are listed at the end of this chapter.
- Standard operating procedures (SOP) or manufacturer's manuals and specifications for the required equipment or tools. It is important that all equipment is handled, set up, operated and packed away correctly. The instructions that come with the instrument or equipment need to be followed to ensure it consistently performs its required tasks accurately and safely.
- Hazards and risks—referring back to the SWMS or JSA, identified hazards need to be documented and the necessary actions taken to minimise the risk of incidents occurring.
 - One specific levelling task hazard is the risk of striking overhead power lines with the levelling staff. It is particularly important to remember the adage 'look up and live' at all times.
 - Excavations on a building site can sometimes cause problems if levelling is to be carried out around the site. The need to work alongside open excavations may be required—if so, attention needs to be paid to the condition of the sides of the excavation so that any potential for collapse is identified.
 - Another potential hazard—especially on new, open, uncleared building sites where grass, scrub or any undergrowth are still present—is the risk of snakes. If they are disturbed as you move about on the ground that is their natural habitat, they will generally remove themselves from the area, but not always. So particular care needs to be paid to where you are walking. If moving the levelling instrument to another position or carrying the staff to another station, always concentrate and be aware of where you are putting your feet until you get to where you need to be. Then resume contact with the person or people you are working with.
- Personal protective equipment (PPE) will be itemised in the developed SWMS or JSA against any hazards or risks if required. Always ensure you wear the correct PPE for the hazard identified. Always refer to the manufacturer's operating instructions to identify hazards with the equipment being used. For further information regarding PPE, refer to Chapter 1, Work health and safety.
- Safety signage relating to, for example, hard hats, eye protection, first aid, hearing protection, forklifts in use or heavy machinery in use will be visible as you enter a construction site and may also be displayed in different locations around the site. For levelling procedures, the main consideration

for safety signage relates to whether a laser level is being operated. As laser levels are classified differently according to the strength of the beam that is being emitted, it is advisable to display signage for the safety of all workers and members of the general public whenever a laser level is in use. Relevant information regarding laser classification, potential hazards and required safety signage for laser levels of all classifications can be found in Australian Standard 2397: 2015 Safe use of lasers in the building and construction industry.

14.1.2 Communicating during levelling

Communication is an important factor when carrying out any levelling task. Whichever form of communication is being used, it must be clear, precise and accurate. For further information on communication forms and techniques, refer to Chapter 3, Workplace communication.

14.1.3 Levelling terminology

Understanding and using the correct levelling terminology is a crucial part of carrying out the task accurately, safely and efficiently. Some terminology has already been discussed in Chapter 13, including:

- bench mark
- datum
- level
- reduced level.

Terminology directly related to advanced levelling operations includes:

Line of collimation: Simply put, the imaginary level line that runs directly through the levelling instrument once it has been set up correctly. When you look through the instrument, the line of collimation will be indicated by the instrument's central horizontal crosshair.

Height of collimation: The height of the line of collimation above the known benchmark or datum point. The height of collimation can be calculated by taking the benchmark or datum measurement and adding the backsight measurement.

Backsight (BS): The first reading taken after the instrument has been set up correctly to commence the levelling task or the first reading taken after the instrument has been moved and set up at a new position. The first backsight of the task would generally be taken in relation to a known benchmark or given datum point.

Foresight (FS): The last reading taken before moving the instrument to another position or the final reading of the required traverse.

Intermediate sight: Any reading taken after the backsight and before the foresight have been recorded. There is no limit to the number of intermediate sights that may be taken.

Change point: The designated position of the staff or rod to which the instrument is to be moved during each traverse. Change points may be required to keep a line of sight if levels need to be taken around the outside of a building or if the slope of the ground is such that the top of the staff is either lower or the bottom of the staff is higher than the line of collimation. An important thing to remember is that the position of the instrument is not the change point. The change point is actually the position of the staff or rod. This means that on the booking sheet there will be two measurements recorded on the relevant change point line: a foresight and a backsight. It is also important to note that when the instrument is being moved and set up in another position, the staff remains in the position of the last foresight and is not moved. There is no guarantee that it will be placed back in the exact position for the next backsight reading to be taken and therefore an incorrect measurement may be recorded on the booking sheet.

Negative or inverted reading: Type of reading used to take measurements of points above the line of collimation through the instrument. For example, this could be the height of a large doorway opening in a commercial building, window head heights or ceiling heights. If the inverted readings are

part of a recorded levelling traverse, it is best to try and keep them as intermediate sights only. It can become confusing when using the inverted reading point as a backsight or foresight on a change point. When taking an inverted level reading, the staff must be held upside down and the reading will always be recorded on the booking sheet as a negative number.

Outward traverse or run: The booking of levels between multiple (two or more) points in one direction only.

Return traverse or run: The method of checking the accuracy of the outward run by returning in the opposite direction.

Closed traverse: A series of level readings that either begin and end at the same point or begin and end at points where positions have been clearly determined prior to the levelling being carried out.

14.1.4 Selecting the correct levels and associated equipment for the task

Some levelling equipment has been discussed in Chapter 13, including:

- spirit level
- straight edge
- water level
- automatic/dumpy level
- laser level.

Fig. 14.1 A metric staff showing the change of colour from black to red every metre



Courtesy of Alister Ford

Levelling staff: The tool used to provide height readings at any particular point when taking construction site level readings through an automatic level.

The most commonly used staff is of aluminium boxed extendable section construction and can be used from 1 m when fully closed to 5 m when fully extended. The staff can also be used when partially extended at 2, 3 and 4 m intervals.

Metric staffs (E grad staffs) are commonly used in Australian construction and usually have a white background with black and red markings to distinguish the difference in height by metres, meaning the first metre on the staff will have black on white measurements, while the second metre on the staff will have red on white measurements and so on, up to the full extension of 5 m (Fig. 14.1).

It is important to have a good understanding of how the measurements have been set out on a levelling staff. The metres will be divided up into 100 mm blocks. Each of these 100 mm blocks will be divided into 50 mm blocks and then each 50 mm block will be divided into 10 mm blocks, thus creating an 'E' pattern for each 50 mm block (hence the name 'E grad staff') (Fig. 14.2). The final millimetre reading of the level will rely on the skill of the person looking through the instrument to make a judgement on where the actual level line lies in relation to its position on the 10 mm block.

A good way to familiarise yourself with the set-out of the measurements on a levelling staff is to run a tape measure from the bottom of the staff (Fig. 14.3). The tape measure and the staff markings will correspond, and it will give a clearer indication of how to read the staff correctly.

Fig. 14.2 E grad blocks

Courtesy of Alister Ford

Fig. 14.3 A tape measure can be run over the staff to check readings

Courtesy of Alister Ford

The staff should always be held plumb and vertical on the nominated point for the level to be taken. A levelling bubble may be attached to the staff so that the person holding the staff can ensure that it is held plumb and vertical. A staff not held plumb or vertical may give an incorrect reading as the line of collimation may read higher or lower on the staff than is in fact true, depending on whether the staff is leaning towards or away from the levelling instrument.

TIP If a levelling bubble is not available, a spirit level can be used with the same effect.

Some levelling staffs may have what appears to be a reverse tape measure on the back. This can be used to read established heights without the use of the levelling instrument. As an example, to measure the height of a doorway, you would hold the staff in the doorway and extend the top telescopic section until it clicks in, and then the next section and so on. When the top of the staff strikes the underside of the door opening, the full opening height measurement will be shown at the top of the smallest unextended section of the staff.

It is important to always keep the bottom of the staff clean so that it sits flat on the surface where the reading needs to be taken. Dirt or mud stuck to the bottom of the staff will cause an incorrect reading to be taken.

Tripod: Piece of equipment used to support an automatic level or a laser level in position while levelling procedures are carried out. This piece of equipment has three adjustable legs, so the height of the instrument can be set to suit the operator (Fig. 14.4).

SAFETY TIP If a laser level is being used, the tripod will generally not be extended; this is so the instrument remains well below eye level, minimising the risk of the laser striking any person within range in the eye.

The tripod will have a stage where the instrument sits. This will usually have a curved top, but it may be flat depending on the instrument for which it has been designed to support. The stage will have a hole in the centre through which the tripod screw can fit and be moved around to position

Fig. 14.4 A tripod set at a low height for a laser level to be used



Courtesy of Alister Ford

the instrument, then fasten it in position. On the underside of the fastening handle, there will be a hook to which a plumb bob can be fitted (Fig. 14.5). Once fitted, the plumb bob will indicate the direct line from the measuring point directly inside the instrument to the point on the ground where any measurements of distance may be taken using the instrument (Fig. 14.6).

The feet of the tripod can be pushed into the ground so that it will remain stable and will not move under normal conditions of use while in that position.

Once the tripod and instrument have been set, it is important not to knock it or lean on it while readings are being taken. The slightest movement of the tripod can cause the instrument to be moved out of level, resulting in false readings.

It is also important that the tripod is always set up correctly in a stable position to ensure accurate readings only are taken. Finally, the tripod must always be handled and stored correctly so that it remains serviceable at all times.

Fig. 14.5 The plumb bob attachment point on the underside of the stage



Courtesy of Alister Ford

Fig. 14.6 The instrument set up with a plumb bob over a reference point



Courtesy of Alister Ford

Plumb bob: Piece of equipment that can be fitted to a hook on the underside of the tripod handle as previously mentioned.

14.1.5 Setting up and serviceability

When setting up, using, cleaning or packing up any type of levelling instrument or any of the associated equipment, it is important to handle it in the correct manner, according to the manufacturer's instructions, to avoid causing any damage. Levelling equipment can be expensive to repair or replace

so care must be taken. If you look after the equipment as recommended and have it serviced regularly, it will last a long time and will always be serviceable and reliable.

14.1.6 Checking the automatic level for accuracy

Before commencing any levelling task involving an automatic level, it should be tested to ensure that it is reading accurately. This can be done by carrying out what is known as a 'two-peg test'. The process of carrying out this test is explained in Chapter 13.

14.1.7 Recording (booking) sheets

When carrying out levelling using the *height of collimation* or *rise and fall* method, it is important to ensure all of the readings are kept in the correct order and recorded (or, as this is commonly known in levelling terms, *booked*) against the correct staff stations or positions. A *recording sheet*, also referred to as a *booking sheet*, will be used to carry out this task. The booking sheet may be just a single sheet with columns and rows in table form printed on it, or it may come in notebook form. The columns and rows of the table are named according to the corresponding information taken from the levelling readings, allowing the information to be placed in the correct positions on the sheet and enabling calculations to be made as the readings are being taken (see Tables 14.1 and 14.2).

Table 14.1 Example booking sheet for levelling using the rise and fall method

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A							Datum
B							
C							
D							
E							
F							

Table 14.2 Example booking sheet for levelling using the height of collimation method

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A						Datum
B						
C						
D						
E						
F						

Readings can also be recorded electronically onto spreadsheets if an electronic device that supports such programs is used to record the readings. The information entered can be set up to be calculated automatically. A common method is to use an Excel spreadsheet with the auto sum feature. This can be programmed to automatically calculate the selected cells on the sheet.

A sound knowledge of the use of any electronic spreadsheet program is required to utilise this method of recording information.

In the following sections on recording levels using rise and fall and height of collimation methods, you will be using written booking sheets in the field to record your readings as you go.

14.1.8 Checking the recorded levels

When using the rise and fall method for levelling, your completed booking sheet should be checked to ensure all levels have been taken and recorded correctly and accurately.

This can be done by performing a simple mathematical procedure known as a 'three-part test' because, logically, there are three steps to carrying it out, as follows:

- Part one: the backsight and foresight columns. Total up the sum of the recorded *backsights*, followed by totalling up the sum of all of the recorded *foresights*. Next, subtract the foresight sum from the backsight sum. Depending on the totals of each, you will finish with either a positive or negative total.
- Part two: the rise and fall columns. Total up the sum of all of the recorded *rises* in that column, then total up the sum of all of the recorded *falls* in that column. Next, subtract the fall total from the rise total. Again, depending on the totals of each, you will finish with either a positive or negative total.
- Part three: the reduced levels column. The first *reduced level* recorded will be the job datum height. Subtract the first reduced level from the last calculated reduced level. Again, as per parts one and two, you will finish with either a positive or negative number.

With these calculations completed and all of the readings having been taken and recorded correctly, all three calculations should have the same answer.

14.2 Carry out levelling procedures using the rise and fall method

Carrying out levelling procedures using the *rise and fall* method can range from the simplest levelling tasks where the instrument is set up in one position for the entirety of the job with only several readings being taken, to tasks where many positional changes of the instrument can be required, creating many change points and readings to be noted on the booking sheet.

The term 'rise and fall' in levelling refers to the reading on the staff in relation to the reading that was taken immediately before. So, if the reading on the staff is a higher number than the reading before, we can assume that the bottom of the staff is in a lower position so there has been a fall between the two points. Alternatively, if the staff reading is lower than the last reading taken, we can assume that there has been a rise between the two points.

As mentioned earlier in the chapter, this is where confusion in levelling can occur. Again, put simply, the higher the reading, the lower the ground; the lower the reading, the higher the ground.

Using the rise and fall booking sheet from section 14.1.7, we can now look at some specific levelling procedures, starting with a simple traverse through to more complex tasks.

14.2.1 A simple open traverse using the rise and fall method

First, we take a simple rectangular domestic building block from a site plan that is to have a dwelling constructed on it (see Fig. 14.7). There may not be contour lines marked on the site plan, so to gain some basic, but accurate, measurements and details relating to the rise or fall of the ground, some levels can be taken at various points around the perimeter of the building block.

We will look at the step-by-step process for taking the readings at all four corners only of the building block, recording them on the booking sheet and then checking the accuracy of the levelling procedures and recordings by conducting a three-part test.

To make the task more straightforward, this building block runs exactly north-south on the plan and north will be de as is standard practice in plan drawing or mapping.

We can now set up our levelling instrument and proceed with taking and booking the required levels (see staged booking sheets, Tables 14.4–14.16, below).

The first reading taken is known as the *backsight*.

Let us assume the reading is 2.680 m.

This will be taken at the datum position, so the reading will be entered in the backsight column on the datum position line.

Table 14.4 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner

The staff is then moved to the next position, being position B.

Assume the reading at position B is 2.510 m.

This reading will be entered into the *intermediate* sight column on the position B line.

Table 14.5 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510					North-west corner

The next reading will be taken at position C.

Assume the reading at position C is 1.470 m.

This reading will be entered into the *intermediate* sight column on position line C.

Table 14.6 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510					North-west corner
C		1.470					South-west corner

The final reading, known as the *foresight*, will be taken at position D.

Assume the reading at position D is 1.590 m.

The reading will be entered into the *foresight* column on the position D line.

Table 14.7 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510					North-west corner
C		1.470					South-west corner
D			1.590				South-east corner

Now that all of the readings have been taken and recorded in the correct columns and rows, the rise or fall between each station can be calculated.

Step 1: At the datum position a *backsight* reading of 2.680 m was taken. At position B, an *intermediate* reading of 2.510 m was taken.

Subtract the *intermediate* reading from the *backsight* reading.

$$2.680 - 2.510 = 0.170$$

Enter the total into the *rise* column on the position B row as it has been worked out as a positive total.

Table 14.8 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170			North-west corner

Step 2: Take the position B *intermediate sight* reading and subtract the position C *intermediate* sight reading.

$$2.510 - 1.470 = 1.040$$

Enter the sum into the *rise* column on the position C row as it has been worked out as a positive total.

Table 14.9 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170			North-west corner
C		1.470		1.040			South-west corner

Step 3: Take the position C *intermediate* sight reading and subtract the position D *foresight* reading.

$$1.470 - 1.590 = -0.120$$

Enter the sum into the *fall* column on the position D row as it has been worked out as a negative total.

Table 14.10 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170			North-west corner
C		1.470		1.040			South-west corner
D			1.590		0.120		South-east corner

Now that the rise and fall amounts between each station have been calculated and recorded, the reduced levels for each station can now be calculated and recorded as well.

As mentioned earlier, the rise and fall method calculates the rise or fall from one station to the next. Step 1: Take the original height of the datum point or position A, in this case 15.000 m.

As it has been established that there was a rise of 0.170 m between the datum point and position B, the rise total is added to the original datum.

$$15.000 + 0.170 = 15.170$$

The reduced level of 15.170 for position B is then recorded in the reduced level column on row B.

Table 14.11 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170		15.170	North-west corner

Step 2: The reduced level for position C can now be calculated.

The difference recorded between position B and C is a rise of 1.040 m.

This amount of 1.040 m will be added to the reduced level of position B to find the reduced level of position C.

$$15.170 + 1.040 = 16.210$$

The reduced level of 16.210 for position C is then recorded in the reduced level column on row C.

Table 14.12 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170		15.170	North-west corner
C		1.470		1.040		16.210	South-west corner

Step 3: The reduced level for position D can now be calculated.

The difference recorded between position C and D is a fall of 0.120 m.

As a fall has been recorded, this amount of 0.120 m will be subtracted from the reduced level of position C to find the reduced level of position D.

$$16.210 - 0.120 = 16.090$$

The reduced level of 16.090 for position D is then recorded in the reduced level column on row D.

Table 14.13 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170		15.170	North-west corner
C		1.470		1.040		16.210	South-west corner
D			1.590		0.120	16.090	South-east corner

Now that the positional readings, the rises and falls, and the reduced levels have all been taken, recorded and calculated, a three-part test can be carried out to ensure that all readings and calculations are correct. This process was explained earlier.

Step 1: Find the total sum of the *backsight* column and then find the total sum of the *foresight* column.

Record the total at the bottom of each column. Then subtract the foresight from the backsight and record the difference.

$$2.680 - 1.590 = 1.090$$

Table 14.14 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170		15.170	North-west corner
C		1.470		1.040		16.210	South-west corner
D			1.590		0.120	16.090	South-east corner
	2.680		1.590				
		1.090					

Step 2: Find the total sum of the *rise* column.

$$0.170 + 1.040 = 1.210$$

Record the total at the bottom of the *rise* column.

Find the sum of the *fall* column: 0.120.

Record the total at the bottom of the *fall* column.

Now subtract the fall from the rise and record the difference:

$$1.210 - 0.120 = 1.090$$

Table 14.15 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170		15.170	North-west corner
C		1.470		1.040		16.210	South-west corner
D			1.590		0.120	16.090	South-east corner
	2.680		1.590	1.210	0.120		
		1.090			1.090		

Step 3: The reduced levels.

Subtract the *original reduced level* at the datum point, 15.000, from the *final reduced level* calculated for position D, 16.090, and record the sum at the bottom of the reduced level column.

$$16.090 - 15.000 = 1.090$$

Table 14.16 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A-datum	2.680					15.000	North-east corner
B		2.510		0.170		15.170	North-west corner
C		1.470		1.040		16.210	South-west corner
D			1.590		0.120	16.090	South-east corner
	2.680		1.590	1.210	0.120	-15.000	
		1.090			1.090	1.090	

Now that the three-part test has been completed, it has been established that all of the readings taken, and the calculations carried out, are accurate.

The front boundary of the block of land is relatively level with only a minor rise in the ground from the datum point across the block frontage of 170 mm.

The rise in the ground from the front boundary of the block to the rear boundary of the block is more significant, with the east boundary rising by 1.09 m from front to back and the west side rising by 1.04 m.

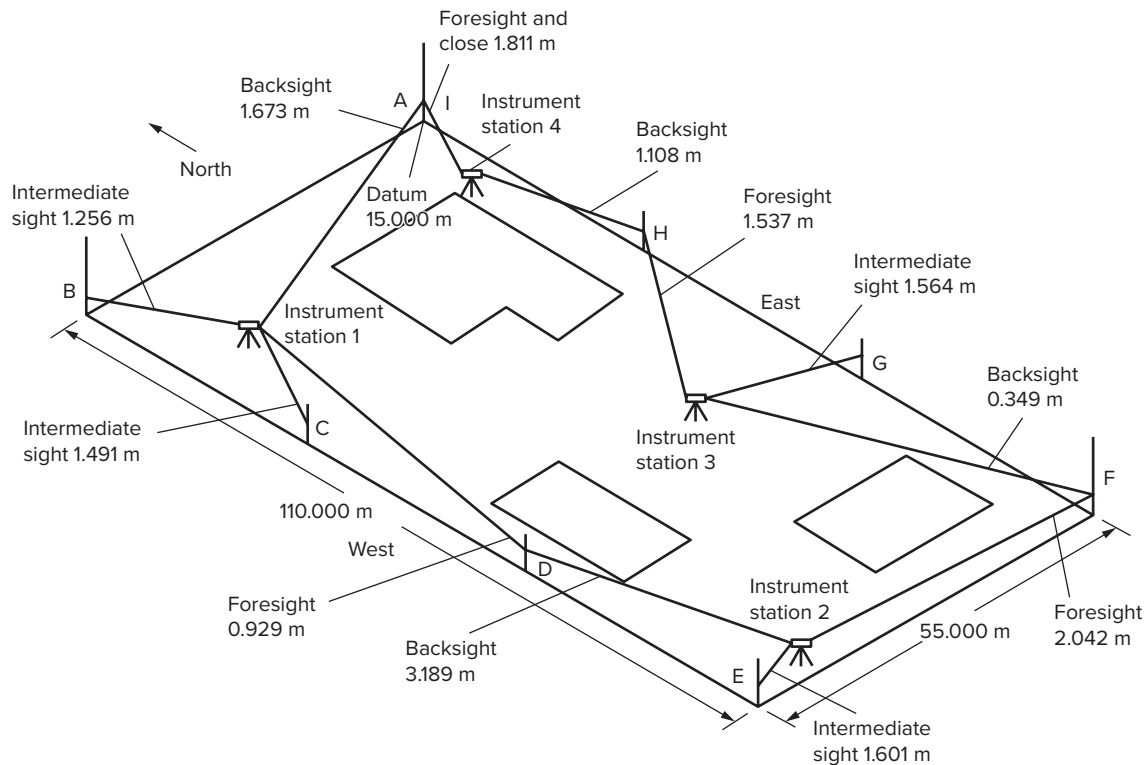
Planning for any required excavations or fill for the construction of the dwelling on the block of land can now take place.

14.2.2 A complex closed traverse using the rise and fall method

As explained earlier in the chapter, a closed traverse is a series of level readings that either begin and end at the same point or begin and end at points where positions have been clearly determined prior to the levelling being carried out.

This section shows and explains the method of conducting a closed traverse around the boundary of an established dwelling and outbuildings on a 1.5 acre block of land (Fig. 14.8).

Fig. 14.8 Closed traverse levelling using rise and fall method



The same standard booking sheet as the ones used previously for the simple traverse can be used. No extra columns are required; only extra rows are needed as more information will have to be added.

The same steps as carried out in the previous task will apply:

- the levels for each position will be taken and booked
- the rise or fall will be calculated and booked
- the reduced levels will be calculated and booked
- a three-part test will be conducted to confirm accuracy.

The main difference with this exercise is that there are more staff positions, which means more readings need to be taken.

Also, on account of the already-established dwelling and outbuildings, the levelling instrument will need to be moved and repositioned at different stations during the course of the exercise as the line of sight from certain instrument stations to staff positions will be obstructed. Known as *change points*, these will be recorded on the booking sheet in the remarks column on the line of the staff position where the change occurs.

Commencing with the instrument's first station, the first series of levels can be taken and booked, as we did on the previous simple levelling exercise. This means the backsight to position A (datum point), intermediate sight (position B), intermediate sight (position C) and foresight (position D) can be booked.

The booking sheet will now look like the one in Table 14.17.

Table 14.17 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256					
C		1.491					
D			0.929				

Because the next staff position (E) is not visible from the instrument station, the instrument must be moved.

This creates a change point that will be recorded in the remarks column on the position D line as this is the staff position when the change point occurs. The important thing to know about creating a change point is that the staff must not be moved. Only the levelling instrument is moved to a new station.

When the levelling instrument has been set up, a backsight will be taken and recorded for position D.

Another important thing to note about a change point is that there will always be two levels recorded on one position line. The first is the foresight for the original instrument position, and the second is a backsight for the new instrument position.

The booking sheet will now look like the one in Table 14.18, with the change point noted and the backsight booked, both on position D.

Table 14.18 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256					
C		1.491					
D	3.189		0.929				Change point

The remaining levels with the instrument at station 2 can now be taken and booked as shown in Table 14.19.

Table 14.19 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256					
C		1.491					
D	3.189		0.929				Change point
E		1.601					
F			2.042				Change point

Now the remaining levels for the traverse can be taken and booked, including the final two instrument change points and the foresight to close the traverse.

The booking sheet will now look like the one in Table 14.20.

Table 14.20 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256					
C		1.491					
D	3.189		0.929				Change point
E		1.601					
F	0.349		2.042				Change point
G		1.564					
H	1.108		1.537				Change point
I			1.811				Close of traverse

The rise or fall for each position in relation to the position immediately before can now be calculated and recorded. Remember that the level booked on one position line must be taken away from the level booked on the position line above.

When the rise and fall calculations have been completed, the booking sheet will look like the one in Table 14.21.

Table 14.21 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256		0.417			
C		1.491			0.235		
D	3.189		0.929	0.562			Change point
E		1.601		1.588			
F	0.349		2.042		0.441		Change point
G		1.564			1.215		
H	1.108		1.537	0.027			Change point
I			1.811		0.703		Close of traverse

Now the reduced levels can be booked. Remember that the reduced level is calculated by either adding the rise to or subtracting the fall from the previous reduced level.

When the reduced levels have been calculated and booked, the booking sheet will look like the one in Table 14.22.

Table 14.22 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256		0.417		15.417	
C		1.491			0.235	15.182	
D	3.189		0.929	0.562		15.744	Change point
E		1.601		1.588		17.332	
F	0.349		2.042		0.441	16.891	Change point
G		1.564			1.215	15.676	
H	1.108		1.537	0.027		15.703	Change point
I			1.811		0.703	15.000	Close of traverse

Finally, a three-part test will determine whether the levels have been taken and booked correctly and whether the calculations on the booking sheet are correct.

An important thing to note about a three-part test on a closed traverse is that because the starting position and the finishing position are one and the same, all of the three-part test calculations should equate to zero.

When the three-part test has been completed, the booking sheet will look like the one in Table 14.23.

Table 14.23 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.673					15.000	Datum
B		1.256		0.417		15.417	
C		1.491			0.235	15.182	
D	3.189		0.929	0.562		15.744	Change point
E		1.601		1.588		17.332	
F	0.349		2.042		0.441	16.891	Change point
G		1.564			1.215	15.676	
H	1.108		1.537	0.027		15.703	Change point
I			1.811		0.703	15.000	Close of traverse
	6.319		6.319	2.594	2.594	-15.000	
		0			0	0	

CHECK YOUR UNDERSTANDING

1. Simple open traverse using rise and fall method

Fill out the rise, fall and reduced level columns and then complete a three-part test for the following booking sheet for an open traverse.

The datum at position A is set at 5.800 m.

The staff readings have already been taken and booked.

Table 14.24 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.886					5.800	Datum
B		1.356					
C		2.497					
D			2.004				

2. A closed traverse using the rise and fall method

Fill out the rise, fall and reduced level columns and then complete a three-part test for the following booking sheet for a closed traverse.

The datum at position A is set at 11.750 m.

The staff readings have already been taken and booked.

(continued)

Table 14.25 Booking sheet

Position	Backsight (BS)	Intermediate sight (IS)	Foresight (FS)	Rise	Fall	Reduced level	Remarks
A	1.717					11.750	Datum
B		0.826					
C	1.622		0.721				Change point
D		2.739					
E		3.372					
F	2.004		3.128				Change point
G		2.333					
H	1.581		0.987				Change point
I		1.030					
J		2.232					
K			2.088				Close

14.3 Carry out levelling procedures using the height of collimation method

As mentioned earlier in the chapter, the line of collimation is the imaginary level line that runs directly through the levelling instrument once it has been set up correctly. When you look through the instrument, the line of collimation will be indicated by the instrument's central horizontal crosshair.

The height of collimation is the height of the line of collimation above the known benchmark or datum point. The height of collimation can be calculated by taking the benchmark or datum measurement and adding the backsight measurement.

The height of collimation method for taking and booking the backsight, intermediate sight and foresight readings is exactly the same process as for the rise and fall method. However, the process after that for working out the reduced levels is somewhat different—although the outcome will be the same for an identical set of positions and readings, whichever method is used.

There are no rise or fall calculations to be carried out. Instead, a height of collimation is established, and this height is used to calculate the reduced level for each staff position while the levelling instrument stays at that station.

If the levelling instrument needs to be moved to another station and a change point is recorded, a new height of collimation will be established for the new station of the levelling instrument.

14.3.1 A simple open traverse using the height of collimation method

Using the simple domestic building block plan that was used for the first rise and fall demonstration, we can now apply this to a height of collimation demonstration.

The backsight, intermediate sight and foresight readings are all known, so they can be booked into the correct columns on the correct rows.

The height of collimation booking sheet will now look like the example in Table 14.26.

Table 14.26 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A-datum	2.680				15.000	North-east corner
B		2.510				North-west corner
C		1.470				South-west corner
D			1.590			South-east corner

The next step is to establish and book the height of collimation.

By taking the existing reduced level and adding the backsight from position A, the height of collimation is established.

$$15.000 + 2.680 = 17.680$$

The height of collimation can now be booked into the height of collimation column on row A (Table 14.27).

Table 14.27 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A-datum	2.680			17.680	15.000	North-east corner

Now that the height of collimation has been established, the remaining reduced levels can be calculated and booked.

The reduced level for position B can be established by subtracting the intermediate sight for that station from the established height of collimation.

$$17.680 - 2.510 = 15.170$$

The reduced level can now be booked into the reduced level column on row B (Table 14.28).

Table 14.28 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A-datum	2.680			17.680	15.000	North-east corner
B		2.510			15.170	North-west corner

The reduced level for position C can be calculated in exactly the same way: height of collimation less the intermediate sight.

$$17.680 - 1.470 = 16.210$$

The reduced level can now be booked into the reduced level column on row C (Table 14.29).

Table 14.29 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A-datum	2.680			17.680	15.000	North-east corner
B		2.510			15.170	North-west corner
C		1.470			16.210	South-west corner

The final reduced level for the traverse can now be calculated by subtracting the foresight for position D from the height of collimation.

$$17.680 - 1.590 = 16.090$$

The reduced level can now be booked into the reduced level column on row D (Table 14.30).

Table 14.30 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A-datum	2.680			17.680	15.000	North-east corner
B		2.510			15.170	North-west corner
C		1.470			16.210	South-west corner
D			1.590		16.090	South-east corner

Now that the positional readings have all been taken and booked, and the height of collimation and the reduced levels have been calculated and booked, a test can be carried out to ensure that all readings and calculations are correct.

This is not a three-part test as there are only two areas that can be calculated for checking—the backsight/foresight, and the reduced levels—although these two calculations are carried out in exactly the same way as a three-part test.

The total of the foresight column is subtracted from the total of the backsight column and the result is recorded.

$$2.680 - 1.590 = 1.090$$

The original reduced level is subtracted from the final reduced level and the result recorded.

$$16.090 - 15.000 = 1.090$$

The final result for both calculations should be the same to indicate that the readings, bookings and calculations are all correct (Table 14.31).

Table 14.31 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A-datum	2.680			17.680	15.000	North-east corner
B		2.510			15.170	North-west corner
C		1.470			16.210	South-west corner
D			1.590		16.090	South-east corner
	2.680		1.590		-15.000	
		1.090			1.090	

14.3.2 A complex closed traverse using the height of collimation method

A more complex task of levelling using the height of collimation method can now be carried out.

Referring to the plan used for the closed traverse for the rise and fall method, a closed traverse can now be conducted using the height of collimation method.

Again, some parts of the process will remain the same, such as the reading and booking of the levels at the various positions, as well as the change points and close of traverse positions.

Other processes will differ as there will be no rises or falls recorded.

The reduced levels will be calculated from the identified height of collimation.

Importantly, it must be noted that at every change point a new height of collimation will need to be established as the levelling instrument has changed position and will be set at a new height.

Assuming as per the rise and fall demonstration that the correct heights have been recorded and booked and the change points have been noted in their correct positions, the height of collimation booking sheet will look as per Table 14.32.

Table 14.32 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A	1.673				15.000	Datum
B		1.256				
C		1.491				
D	3.189		0.929			Change point
E		1.601				
F	0.349		2.042			Change point
G		1.564				
H	1.108		1.537			Change point
I			1.811			Close of traverse

Referring to the steps taken in the simple height of collimation demonstration, the height of collimation and the reduced levels from positions A to D can now be calculated and booked.

The height of collimation will be the sum of the identified reduced level (datum) at position A and the backsight at position A.

$$15.000 + 1.673 = 16.673$$

The reduced level for position B:

$$16.673 - 1.256 = 15.417$$

The reduced level for position C:

$$16.673 - 1.491 = 15.182$$

The reduced level for position D:

$$16.673 - 0.929 = 15.744$$

The height of collimation booking sheet will now look like Table 14.33.

Table 14.33 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A	1.673			16.673	15.000	Datum
B		1.256			15.417	
C		1.491			15.182	
D	3.189		0.929		15.744	Change point
E		1.601				
F	0.349		2.042			Change point
G		1.564				
H	1.108		1.537			Change point
I			1.811			Close of traverse

As mentioned earlier, because there is now a change point, and the levelling instrument has been moved and set up in a new position at a new height, a new height of collimation must be established.

Because the change point occurred while the staff was at position D, the new height of collimation will be the sum of the reduced level and the new backsight taken at position D and will be recorded in the height of collimation column on the position D line.

$$15.744 + 3.189 = 18.933$$

The reduced levels and new heights of collimation through to the close of traverse can now be calculated and booked.

The reduced level for position E:

$$18.933 - 1.601 = 17.332$$

The reduced level for position F:

$$18.933 - 2.042 = 16.891$$

A change point has occurred, so a new height of collimation is required for position F. This will be the sum of the position F reduced level and the position F backsight.

$$16.891 + 0.349 = 17.240$$

The reduced level for position G:

$$17.240 - 1.564 = 15.676$$

The reduced level for position H:

$$17.240 - 1.537 = 15.703$$

A change point has occurred, so a new height of collimation is required for position H. This will be the sum of the position H reduced level and the position H backsight.

$$15.703 + 1.108 = 16.811$$

The reduced level for position I:

$$16.811 - 1.811 = 15.000$$

The height of collimation sheet will now look like Table 14.34.

Table 14.34 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A	1.673			16.673	15.000	Datum
B		1.256			15.417	
C		1.491			15.182	
D	3.189		0.929	18.933	15.744	Change point
E		1.601			17.332	
F	0.349		2.042	17.240	16.891	Change point
G		1.564			15.676	
H	1.108		1.537	16.811	15.703	Change point
I			1.811		15.000	Close of traverse

The final test to check the recorded levels and calculations can now be carried out.

Again, the total sum of the backsight column is calculated, as is the total sum of the foresight column. The foresight column total is then subtracted from the backsight column total and the result is recorded.

The original reduced level is subtracted from the final reduced level and the result recorded.

$$6.319 - 6.319 = 0$$

The original reduced level (datum) from position A is then subtracted from the reduced level for position I (close of traverse).

$$15.000 - 15.000 = 0$$

Because the task was a closed traverse, the final result for both calculations should be zero to indicate that the readings, bookings and calculations are all correct (Table 14.35).

Table 14.35 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A	1.673			16.673	15.000	Datum
B		1.256			15.417	
C		1.491			15.182	
D	3.189		0.929	18.933	15.744	Change point
E		1.601			17.332	
F	0.349		2.042	17.240	16.891	Change point
G		1.564			15.676	
H	1.108		1.537	16.811	15.703	Change point
I			1.811		15.000	Close of traverse
	6.319		6.319		-15.000	
		0			0	

CHECK YOUR UNDERSTANDING

3. Simple open traverse using the height of collimation method

Fill out the height of collimation and reduced level columns and then complete the test for the following booking sheet for an open traverse.

The datum at position A is set at 8.200 m.

The staff readings have already been taken and booked.

Table 14.36 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A	1.596				8.200	Datum
B		1.933				
C		1.641				
D						

4. Closed traverse using the height of collimation method

Fill out the height of collimation and reduced level columns and then complete the test for the following booking sheet for a closed traverse.

The datum at position A is set at 10.450 m.

The staff readings have already been taken and booked.

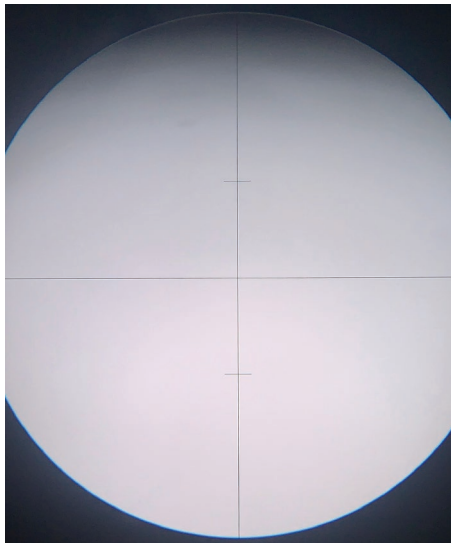
(continued)

Table 14.37 Booking sheet

Position	Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
A	1.715				10.450	Datum
B		1.389				
C	1.947		1.111			Change point
D		1.506				
E		0.988				
F	1.855		1.092			Change point
G		1.930				
H	1.404		2.122			Change point
I		2.009				
J			2.596			Close

14.4 Calculate distances using stadia lines

Fig. 14.9 The smaller stadia lines shown at the top and bottom of the plumb crosshair line are used for calculating distance



Courtesy of Alister Ford

When looking through the eyepiece of an automatic level, you will see several visible lines that can be used for referencing specific readings. As explained in Chapter 13, the main crosshairs will be used for the majority of tasks carried out with the automatic level.

The main horizontal crosshair is always used for reading the level position on the staff as this line represents the line of collimation passing through the levelling instrument. The main vertical crosshair is used for referencing the position or points if angles are being determined using the automatic level. The two minor horizontal crosshairs, one above and one below the major crosshair, are known as stadia lines. These stadia lines are used as a reference for calculating distances (Fig. 14.9).

The formula for using stadia lines to measure distance is:

Top stadia line reading minus bottom stadia line reading. The resulting answer is then multiplied by 100.

The levelling instrument can be set up over a specific point if need be. A plumb bob can be attached to the underside of the screw handle on the tripod that holds the levelling instrument firmly in place and can then be adjusted to line up directly over the desired point on the ground or floor (Fig. 14.10). This will ensure that the centre of the levelling instrument is directly over the desired point of reference.

The staff can now be held on the reference point to be measured to, and the top and bottom stadia lines can be read and recorded.

The calculation can now be made to determine the distance between the reference point directly below the levelling instrument and the reference point where the staff is positioned.

As an example:

Top stadia line reading: 2.154 m.

Bottom stadia line reading 1.693 m.

The distance would be worked out as:

$$(2.154 - 1.693) \times 100 = 0.461 \times 100 = 46.100\text{m}$$

The distance between both reference points is **46.1 m**.

Fig. 14.10 Plumb bob set up over reference point



Courtesy of Alister Ford

14.5 Clean up and maintain tools

When the levelling task is complete, it is important to carry out any required clean-up and ensure the site is left in a safe state for the next stage of work to continue.

Materials, plant, equipment or anything else on the site that had to be moved for the levelling task will need to be reinstated to its original position or made safe in the position to which it has been moved.

The levelling equipment will need to be checked as it is carefully packed away into the correct boxes or sleeves, and then stored correctly and safely in the designated spot in the tool storage area (Fig. 14.11).

- *Automatic levels* need to be handled carefully and wiped of any dust or dirt. The lenses should be inspected for cleanliness or any damage, then the lens caps fitted correctly.
- *Laser levels* require careful handling. Batteries need to be checked for charge or totally removed for storage if noted in the operating instructions.
- *Staffs* need to be wiped down and cleaned. It is especially important to check the bottom of the staff for any mud or dirt that may normally be out of sight. The staff should be stowed in the protective sleeve if one is supplied.
- *Tripods* should be wiped down and have the legs fully retracted without overtightening the grub screws. The bottoms of the legs should be cleaned as the spikes at the ends can easily pick up mud or dirt during use. The strap and buckle should be secured in order to hold the legs in position for storage.

Fig. 14.11 Levelling equipment ready to be correctly packed and stored



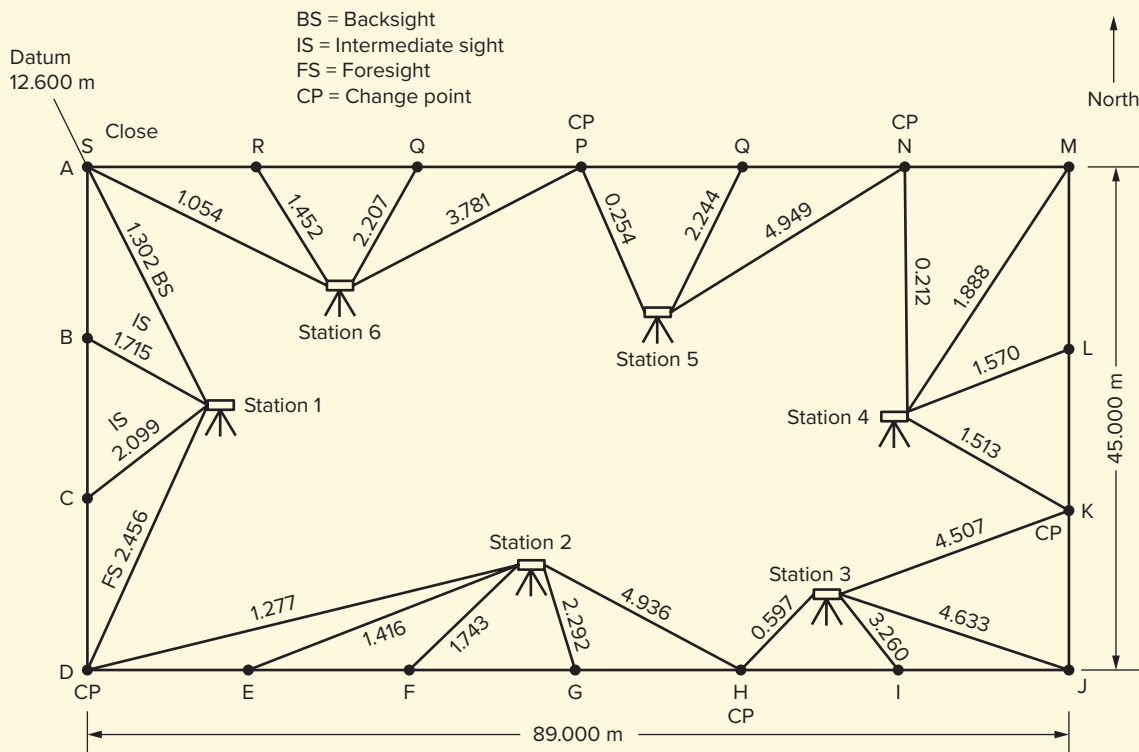
Courtesy of Alister Ford

Student research

Using the internet, access the document 'Laser classification and potential hazards' at the Safe Work Australia website. From the information provided, draw up a detailed table reporting on the classification and potential hazards of laser levels that are allowed for use in the construction industry.

End-of-chapter activity

Complete a rise and fall booking sheet as supplied by your instructor for the closed traverse levelling task shown on the following site plan.



AUSTRALIAN BUILDING CODES AND STANDARDS

National
Construction
Code (NCC)

Occupational
Health and
Safety Regulations,
2017

WorkSafe
Victoria,
Compliance Code
for Plant, 2019

AS 2397
Safe use
of lasers in the
building
and construction
industry

AS/NZS IEC
60825.1 Safety
of laser products—
equipment
classification and
requirements

AS/
NZS ISO
11553 Safety
of machinery—
laser processing
machines—safety
requirements

BS EN
608251 Safety
of laser products—
equipment
classification and
requirements

Other documents:

Laser classification and potential hazards | Safe Work Australia

Victoria: *Guide to Standards and Tolerances* (currently under review) (vba.vic.gov.au)

Tasmania: *Guide to Standards and Tolerances 2017* (cbos.tas.gov.au)

New South Wales: *Guide to Standards and Tolerances* | NSW Fair Trading

Queensland: *Standards and Tolerances Guide* (qbcc.qld.gov.au)

Western Australia: *Guide to Standards and Tolerances 2019 WA* (commerce.wa.gov.au)

Northern Territory: *Design Standards and Construction Specification for Buildings* | Department of Infrastructure, Planning and Logistics

ACT: *Standards and Tolerances* | Build, Buy or Renovate (act.gov.au)

**Tradie talk—The higher the reading, the lower the ground
The lower the reading, the higher the ground**

Chapter 15

Carry out excavation

Learning Objectives

LO 15.1 Plan and prepare for excavation

LO 15.2 Prepare the excavation site and erect safety equipment

LO 15.3 Follow safe excavation practices

Introduction

Almost all construction work, domestic or commercial, will need some form of ground preparation before the building work can commence. This ground preparation generally involves what is referred to as 'excavation'.

Excavation is the removal of earth, soil, stones and/or rock to create a hole or trench in, or the flattening, raising, lowering or reshaping of, the ground (Fig. 15.1). The area or volume of this work may be larger than the house itself, requiring a range of mechanised equipment, or small enough to need no more than one worker with a shovel. In either case, you must be aware of the hazards and risks involved before you begin. In addition, you will need to determine:

- the required tools and equipment
- how much material (and what type) is to be excavated
- how much material can remain on-site and how much must be transported elsewhere.

Fig. 15.1 A typical domestic site cut



Courtesy of Alister Ford

Excavation, like all aspects of building, therefore, requires careful planning if you are to remain on budget.

There is no Australian Standard specific to excavation; however, there is a code of practice (Fig. 15.2). Produced by Safe Work Australia, the current 'Excavation Work Code of Practice', October 2018, has been adopted by most states and territories and is your best guide to safe work practices. (This document is freely available on the Safe Work website.)

While staying in line with the Code of Practice, this chapter aims to provide you with the knowledge required to carry out excavation work common to domestic construction. In so doing, you will cover planning and preparation, safe excavation practices, the types and uses of various excavation equipment, plus your environmental responsibilities.

Fig. 15.2 Safe Work Australia Code of Practice: Excavation Work, October 2018



Courtesy of Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>

15.1 Plan and prepare for excavation

Planning and preparing for excavation require knowledge of a range of factors such as:

- soil classifications
- ground types
- angle of repose
- tools and equipment and how to use/operate them correctly
- environmental responsibilities
- safety considerations including appropriate signage, barricading and personal protective equipment (PPE)
- quantities and estimating.

It is only with a firm grasp of these factors that you can develop a planned approach to the proposed excavation.

15.1.1 Ground types

Aside from such places as Antarctica, almost all excavations will take place on the ground. This 'ground', however, can vary considerably from site to site. In general (ignoring ice), the ground on any particular site will fall into one or more of the following categories:

- rock
- cohesive ground
- non-cohesive ground.

15.1.1.1 Rock

There are many forms of rock. Some are concrete-like conglomerates (many small stones bound together to make a larger rock), others are more homogenous such as basalt or obsidian; some are very hard such as granite, while others, like sandstone, are quite soft.

Rock can form the whole foundation of a site, or it may be what is known as a 'floater', a large rock (or number of rocks) that are 'suspended' in other soil types such as clay or shale. In such cases, an engineer may be required to determine if they need to be removed, partially excavated into or left to be directly built upon. Solid rock seldom needs excavation other than drilling for hold-down ties or bolts.

15.1.1.2 Cohesive ground

Cohesive ground is a form of ground made up of materials that readily bind together. As such they are relatively stable to excavate as they do not collapse easily. Examples include clay, shale and silt clays or loams.

15.1.1.3 Non-cohesive ground

Sand, wet or powdery silts, muds and gravels are all examples of non-cohesive ground. Also referred to as 'granular ground', such material is difficult to excavate to any defined shape or depth without collapse, or very high risk of collapse.

While collapse prevention will be dealt with later in this chapter, one technique for ensuring that that granular or non-cohesive ground will not collapse is to work within its 'angle of repose'.

TIP The services of a geotechnical engineer may be invaluable on tasks of high value or high risk, irrespective of size. These professionals have a wealth of knowledge regarding soil, the mechanics of soil and excavation practices in general. Where risk is involved, be it financial or human, such help is not to be dismissed.

15.1.2 Angle of repose

The easiest way to understand this concept is to look at a pile of sand (Fig. 15.3). The surface of the sand naturally settles at an angle to the horizontal that is common to most dry sands, that is, about 33°. This angle is known as the 'angle of repose'—the angle at which the material repose (naturally rests).

This angle differs for each different type of material. The angle of repose for a range of common materials are given in Table 15.1.

Fig. 15.3 Pile of sand resting at the angle of repose



Courtesy of Alister Ford

Table 15.1 The angle of repose of common types of soil

Material	Angle of repose (approx.)
Wet clay	18°
Wet sand, sandy gravel	25°
Dry earth or clay	30°
Dry sand	33°
Shingle	40°
Well-drained clay/moist earth	45°
Clean gravel in natural deposit	50°

TIP While cutting back the earth at the sides of the excavated area to an angle less than the angle of repose for that material may help in preventing a collapse, it is very poor practice to rely upon this action alone. (See ‘Collapse prevention controls’ later in this chapter.)

As may be expected, different ground types will need different approaches to the excavation, including the types of equipment to be used.

15.1.3 Tools and equipment types and their uses

Excavation equipment ranges from basic hand tools and hand-held power tools through to large mobile plant and the correct personal protective equipment (PPE) required for any excavation task being undertaken. PPE for excavation work can include:

- hi-vis clothing
- eye protection
- hearing protection
- head protection (hard hat)
- steel-capped work boots
- gloves.

Common hand tools include:

- shovels (Fig. 15.4)
- picks
- mattocks
- hand augers (Fig 15.5)
- sledgehammers
- crowbars and pinch bars.

With speed and efficiency of earth removal being the essence of excavation, these tools are frequently supplemented by hand-held electrically or pneumatically powered tools such as jack-hammers, air chisels and post hole diggers. Such tools will often include the need for air compressors or electric generators.

The digging of a small footing may require no more than the tools listed above. However, it is seldom that a house requires just one or two small holes. It is, therefore, more common today to find that most excavation work is undertaken by mobile machinery of some form, the manual labour being reduced where possible to light clearing.

Referred to as ‘plant’, this machinery can range from mini excavators, bobcats and backhoes through to large tracked excavators and rock breakers. Examples of some of the more common of these machines are shown in Figure 15.6.

Fig. 15.4 Some of the basic hand and power tools used by the excavator



Courtesy of Alister Ford

Fig. 15.5 Petrol-powered, hand-operated auger



Courtesy of Alister Ford

Fig. 15.6(a) and (b) Some common excavation plant

(a)



Courtesy of Alister Ford

(b)



Courtesy of Alister Ford

Determining the tools, plant or equipment a particular task requires takes experience. You are looking for an efficient outcome, whereby efficiency is determined by the factors of safety, speed and economy. Note that cost is not a driving factor in itself. This is because taking the 'cheap' route can often lead to time delays (cost), injury (cost) and poor work (cost). In choosing your plant you should, therefore, discuss options with those who you know have extensive experience and expertise both with the equipment and in excavation.

Coupled with your determination of plant and equipment is the requirement of training, licences and availability: availability of the equipment and the availability of trained and/or licensed operators. A 'good operator' is highly valued as they tend to produce a clean and timely excavation yet do so without unduly causing degradation to the rest of the site. This will make it easier to meet your environmental responsibilities.

15.1.4 Environmental responsibilities

Each state and territory has its own environmental protection legislation that imposes stiff penalties for actions leading to the degradation (harm or damage) of the environment. With regards to excavation, for example, section 120 of the NSW *Protection of the Environment Operations Act 1997* allows for heavy

finer, including on-the-spot fines, for any individual or corporation that causes or permits waters to be polluted. This includes allowing soil, earth, mud, clay, rock dust or concrete debris to enter stormwater drains or directly enter water courses.

Your strategy for managing erosion and hence the water quality of run-off entering drains and water courses is dependent upon a number of factors, including:

- soil classification
- ground type
- slope of site
- distance to water courses (creeks, streams, rivers)
- surface over which the run-off will travel
- extent of excavation and how long the earth will remain exposed.

You should remember that erosion can also be caused by wind. Dust in the air is also a form of pollution for which you will be held accountable by the local council as well as your relevant state environmental agency.

Your excavation plan must, therefore, include measures for not only controlling run-off should it rain but some means of dust mitigation (limiting) if it doesn't.

15.1.4.1 Other environmental considerations

The overall environmental impact of an excavation can be limited by simply keeping your excavation activities to the bare minimum. Retention of vegetation, wherever possible, is one way

Fig. 15.7 Building area with the topsoil removed, ready for set-out



Courtesy of Alister Ford

Fig. 15.8 Re-usable topsoil ready for removal from the site



Courtesy of Alister Ford

to reduce erosion while improving the quality of run-off water. In addition, it helps reduce the loss of another key environmental concern in Australia—topsoil.

Australia is a land that is geologically very old in terms of its period of exposure to the elements. Ancient glaciers, wind, rain and sun have all led to a much-reduced depth of topsoil in many parts of the country. Given its scarcity, topsoil is expensive to replace and so its wasteful removal should be avoided. It is also hard for nature to replace it, taking millions of years.

When excavating, your first task, therefore, is to remove any usable topsoil from the excavation area (Fig. 15.7) and safely stockpile it. Consideration should be given to prevailing winds and deposits in adjoining neighbours' homes, ensuring the stockpile is in a well-drained location away from further works and with sediment control on the downward slope. If the stockpiled re-usable topsoil is to remain on the site for the duration of construction, perhaps to be used later for landscaping (Fig. 15.8), consideration should also be given to covering the pile to reduce the chance of any of it washing away in wet conditions or blowing away in windy conditions.

At the end of the excavation day or when the specific excavation task has been completed,

make sure all your excavation equipment and tools are properly cleaned in the appropriate wash-down area that has been set aside and constructed to the correct EPA requirements on the job site. Never wash anything down where the contaminated water, silt, dirt or chemicals could wash directly into the stormwater system or a natural water course.

After cleaning, check all your tools and equipment for any damage that may need to be reported as requiring repair and take the appropriate action as per company policy regarding this process. If the tools and equipment are in good working order, they should then be properly maintained and stored appropriately in the correct areas set aside for them, in the site sheds or in the work vehicle or trailer ready for use on the next task.

15.1.5 Safety considerations

A key element in your planning will be a safe work method statement (SWMS). It is advisable to formulate a SWMS for any excavation work being carried out. Note that if the excavation involves trenching or shafts greater than 1.5 m in depth or tunnelling, it will be classified as *high-risk work* and by law a SWMS must be formulated before any excavation work commences. Your SWMS will include:

- a breakdown of the work being undertaken
- identification of the hazards and risks
- risk control measures
- an approach to monitoring and reviewing the control measures.

As per your previous training (CPCCOHS2001A: Apply WHS requirements, policies and procedures in the construction industry), your SWMS should be developed in conjunction with all those who are involved in the excavation process as well as those who may be affected by that process. These are collectively known as 'stakeholders', a non-exclusive list that may include:

- labourers and tradespeople who may be on-site during excavation works or when such works are still exposed
- machine operators
- local council and/or relevant authorities (power, telecommunications and water and sewer)
- neighbours
- engineers.

Issues that arise from such discussions may include, for example, the location of underground services (power, water, gas, etc.) and/or dust and noise. Striking services are not just a costly inconvenience, it is also highly dangerous. In the case of gas, it can lead to whole neighbourhoods needing to be evacuated. The well-known expression 'dial before you dig' applies here. 'Dial Before You Dig' (DBYD) is a free national service that can be accessed by calling 1100. DBYD is now also a fully online national service whereby information regarding a construction site is submitted via an app to the DBYD website and all services relating to the property are immediately notified. Relevant information will then be forwarded by the individual services to the applicant's nominated email address within a very short time, with site plans showing the position of the services and any other related information so that work can proceed immediately (Fig. 15.9). Service information may include details of power, gas, water mains, stormwater, sewerage, fire services and telecommunications. Within existing services trenching, there may already be underground services detectable or non-detectable warning tape in place to give warning that specific services have been installed directly below (Fig. 15.10).

These tapes are colour-coded according to the service that they protect and also have the name of the service printed on them. They are manufactured in different widths depending on the depth below ground at which they will be buried.

Detectable warning tape may be buried above non-metallic pipes. This tape is foil-based and can be located easily using a metal detector.

Non-metallic tape is designed to be buried above metal piping and cabling.

Fig. 15.9 Stormwater information supplied by DBYD

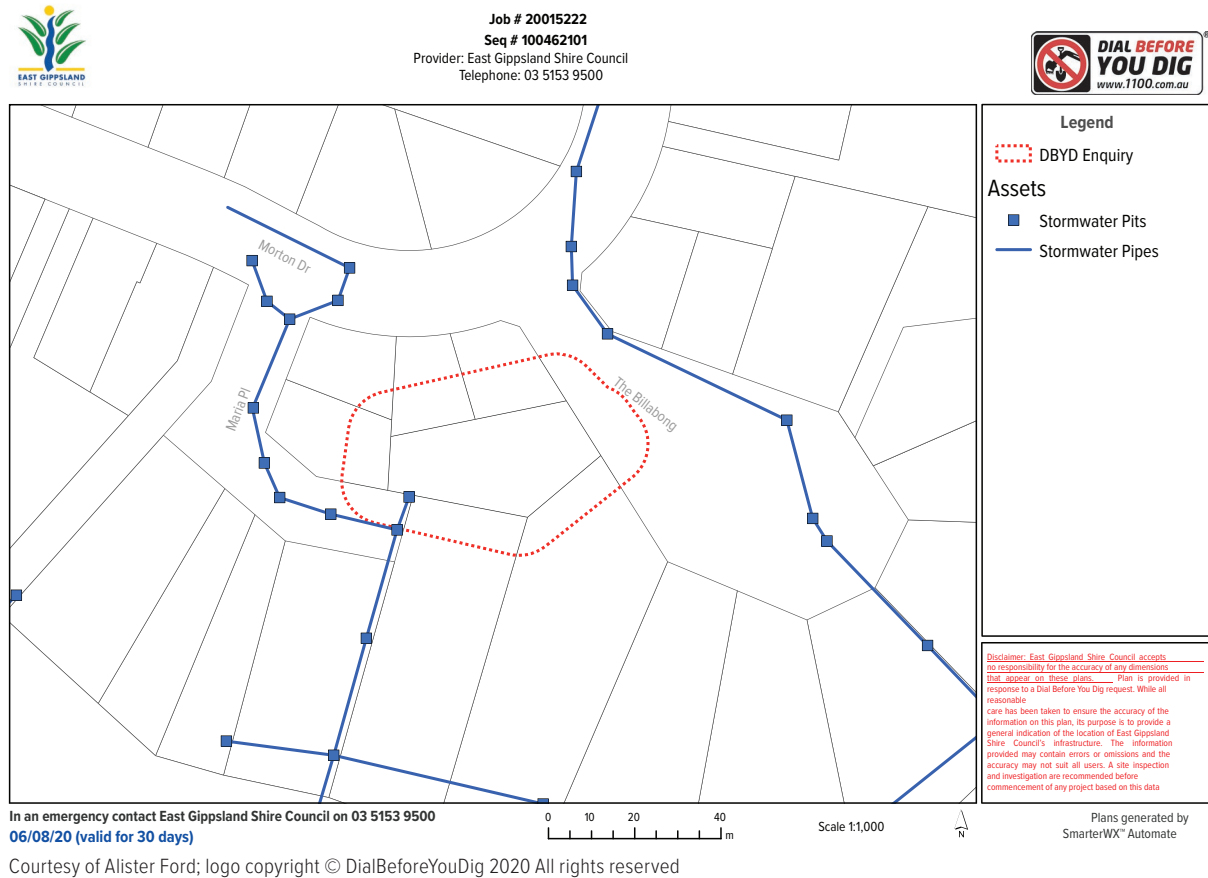


Fig. 15.10 Warning! Electrical cables below



Courtesy of Alister Ford

Dust, particularly rock and concrete dust, can be particularly harmful both to workers and neighbours. Likewise, noise can be both a nuisance and a danger. Such being the case, concerns around these issues must receive as much attention as any other aspect of your planning.

15.1.5.1 General safety considerations

There are a number of general safety considerations you should consider that may or may not be identified by your SWMS for a specific excavation task. These include:

- access and egress
- deep excavations
- lighting
- signage
- general inspection routine.

Access and egress of any excavation 1 metre deep or greater must be by means of a properly installed ladder. Climbing in or out of a trench using the components of a collapse prevention system such as shoring is prohibited.

Your plan should also identify any excavated areas deeper than 1.5 metres as it is a legal requirement to have a safe work method statement in place, as mentioned earlier in this chapter. Being the most likely areas where you may interrupt existing services, be sure to provide service providers with a plan identifying these depths. Access to such areas must be limited by means of barriers and warning notices. These areas of the excavation are also the most dangerous with regards to possible collapse, an issue further discussed in the section 'Follow safe excavation practices'.

Deep excavations (particularly deep trenches) may also be very dark and need lighting to increase visibility for the workers. Visibility of the excavation itself is necessary for works undertaken in public spaces. In such cases, flashing warning lights should be added to the barricades and signage.

Signage is not limited to public spaces, it is also necessary on the construction site. This ensures workers and visitors are aware of any potential risks posed by the excavation works. Traffic and/or pedestrian control also fits under this banner and may include 'stop/go' personnel.

Often left off the list with regards to planning is a regulated inspection routine. New excavations are always potentially at risk of sudden collapse, but this danger increases significantly with time. That is, the longer an excavation remains exposed, the more likely it is to cave in. Your inspection routine should therefore include the following three points in time when an excavation is checked:

- when the excavation is first completed
- before any work on or around the site commences for the day
- at the end of the work day, after all work has ceased on-site to ensure barriers, warning lights, signage etc. are correctly positioned.

In addition, you may need to consider the excavation before any work commences immediately after heavy rain and also periodically during a period of days of intense heat. This is because these conditions can have a severely negative influence upon the walls of an excavation through drying out, softening or undermining.

Other safety factors that you will need to consider outside of the SWMS are general access and egress of the site. Limiting access to those who are trained and inducted into construction work greatly reduces the chance of mishap. In addition, limiting vehicle movement reduces noise and dust levels when dry and erosion and general site degradation when wet. Further information regarding access limitation is provided in the section 'Setting out and establishing the excavation site'.

15.1.6 Quantities and estimating

When digging small holes in the ground for a pad or stump, you would seldom have to consider much of that which has been discussed up to now. Likewise, the amount of earth to be removed (known as 'spoil') is not of great concern as you can dispose of it somewhere on the site.

As you will have noted, large excavations need thorough planning. This applies just as equally to considerations of the spoil as it does to the environment, safety and your choice of equipment. Indeed, your calculations of spoil to be removed may influence the other three. This is because large excavations mean large amounts of spoil that must be either relocated onsite or trucked offsite. Your capacity to calculate spoil quantities accurately is an integral part of the overall job cost and can lead to significant losses if not properly understood.

Soil, rock and excavation calculations, in general, are measured as mass (kg/m^3) or volume (m^3).

15.1.6.1 Soil bulking

Before you can begin this calculation, you must be aware that the volume of earth you take out is larger than the volume of the hole you took it from. This is because the earth in the ground is compacted, but it becomes aerated and loose once it's removed. This is known as 'bulking'. Each type of soil has its own 'bulking factor', which is offered as a percentage increase in the volume of the soil once excavated. The bulking factors for a range of common soil types, along with their approximate in situ and loose masses, are given in Table 15.2.

Table 15.2 Bulking and masses of common soil types

Material	In situ (approx. kg/m ³)	Bulking (%)	Loose (approx. kg/m ³)
Dry sand	1600	12	1425
Wet sand (compacted)	2100	10	1900
Gravel (natural with sand)	1900	25	1525
Ordinary soil	1450	20	1200
Dry clay	1750	60	1100
Wet clay	2000	10	1825
Loam	1650	25	1325
Shale (solid)	2675	70	1575
Sandstone	2350	60	1450

Source: Adapted from www.simetric.co.uk/si_materials.htm

15.1.6.2 Example calculations for excavated soil quantities

Example 1

Figures 15.11 and 15.12 show a typical pad footing for a verandah or carport post or column. In this case, the footing is 500 mm wide, 500 mm long and 500 mm deep (i.e. a cube). There are four posts supporting the carport roof and the soil type for this excavation is loam.

The calculation for this excavation is as follows:

(Note: Your first step is to convert dimensions from millimetres to metres.)

Volume (V) of footing:

$$V = \text{Length} \times \text{Height} \times \text{Width}$$

$$V = 0.5 \times 0.5 \times 0.5$$

$$V = 0.125 \text{ m}^3$$

Multiply by number of footings—in this case, four (4).

$$\text{Total excavation} = 4 \times 0.125$$

$$= 0.5 \text{ m}^3$$

Now allow for *bulking*—in this case, it is loam, so the factor is 25%.

$$\text{Total spoil} = 0.5 \times 1.25$$

$$= 0.625 \text{ m}^3$$

Fig. 15.11 500 mm cubic concrete pad footing excavation

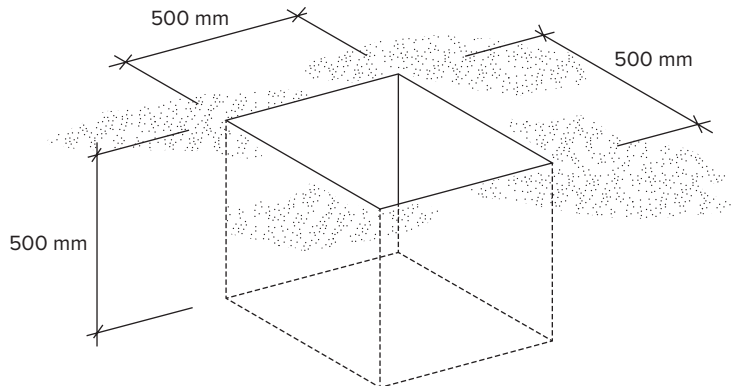


Fig. 15.12 Example verandah post on a concrete pad footing

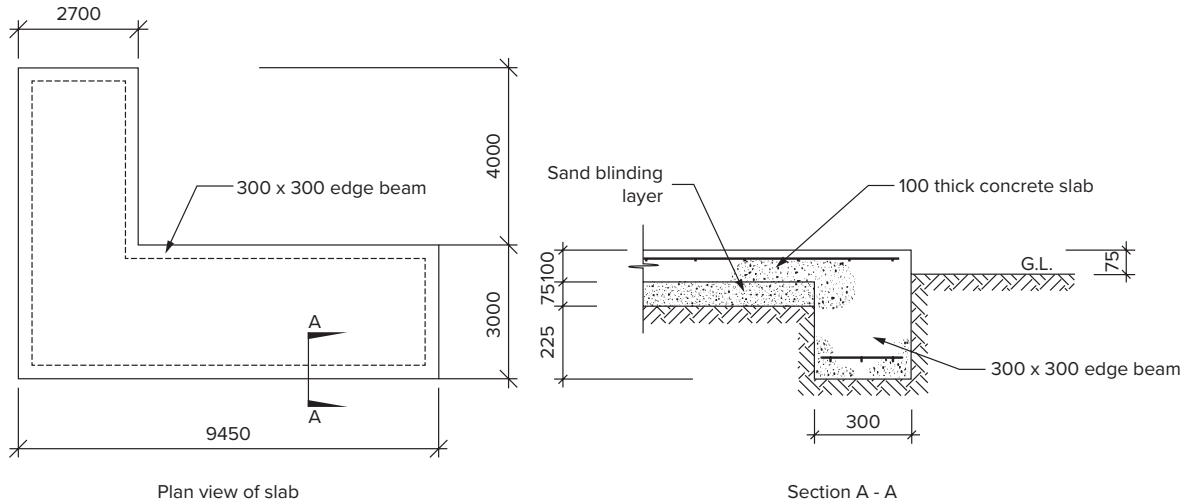


Courtesy of Alister Ford

Example 2

Figure 15.13 is an 'L'-shaped shed slab that will be formed up and poured on level ground. You will be excavating in ordinary soil. This is a slightly more complex calculation requiring several steps.

Fig. 15.13 Plan and section details of concrete slab with edge beam



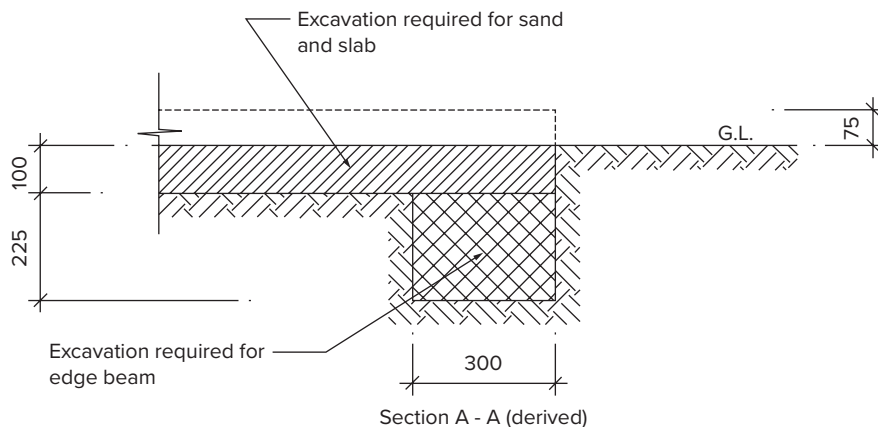
Step 1: You begin this excavation calculation by visualising the project as a series of discrete parts. These parts will then, in turn, be further broken down into simpler parts again as necessary.

Your first break-up is to identify the slab versus the footing or edge beam.

In this case, our slab is 100 mm thick, and the footing is 300 mm by 300 mm, and it will run around all external edges of the slab as shown in Figure 15.13. This edge beam sits 'under' the slab (see section A-A).

Beneath the slab is a 75 mm thick layer of sand. Note that the concrete slab sits out of the ground also by 75 mm. This means that the amount of earth needing to be dug out is only 100 mm deep. This is shown in the new or 'derived' section A-A (Fig. 15.14).

Fig. 15.14 Derived section A-A of excavation for slab and edge beam

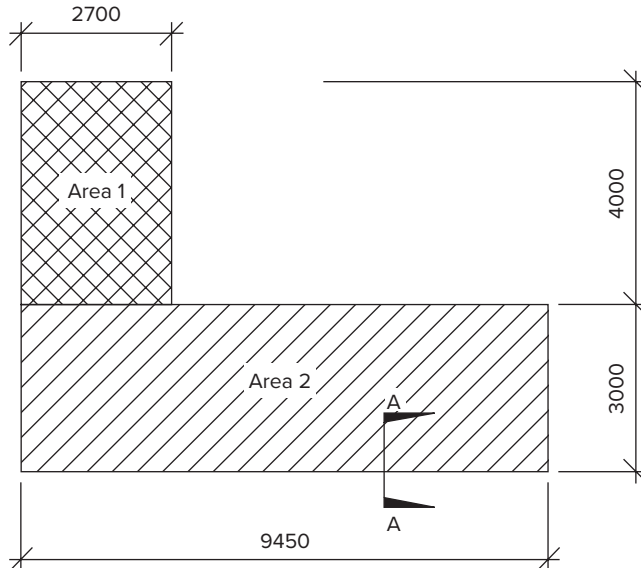


It is usual to calculate the volume of the slab first, so that is our next step.

Step 2: The volume of a slab is best found by finding the area first, then multiplying the area by the depth of the excavation. (Note again that you should convert all millimetre measurements into metres.)

Areas are, in turn, best found by dividing complex shapes into simple ones, such as rectangles, squares, circles and the like. The break-up for this project is shown in Figure 15.15.

Fig. 15.15 Break-up of slab into simplified areas



So:

$$\text{Area 1} = 4.0 \times 2.7 \\ = 10.8 \text{ m}^2$$

$$\text{Area 2} = 9.45 \times 3.0 \\ = 28.35 \text{ m}^2$$

$$\text{Total area} = 10.8 + 28.35 \\ = 39.15 \text{ m}^2$$

Volume (V) can now be found by multiplying the total area by the required depth (100 mm):

$$V = 39.15 \times 0.100$$

$$V = 3.915 \text{ m}^3$$

Step 3: Having found the volume of the excavation required for the slab, you must now find the volume for the edge beam.

The derived section A-A shown previously also shows the end or 'sectional' area required to be excavated for this edge beam, that is it is 225 mm deep $\times$ 300 mm wide.

Your task is to calculate this sectional area and then multiply it by the total length of the edge beam. Finding the sectional or end area is easy. Finding the total length of the edge beam involves once again breaking the task down into simple sections as shown in Figure 15.16.

These 'pieces' are then added together and the volume found as if for a single beam as shown in Figure 15.17.

Note that with some pieces of the edge beam (e.g. A) you must allow for it being shortened in length by the width of the piece it butts up to (300 mm).

In others (e.g. B and C), this allowance is not required. This is because at one end (B meeting A) it would lose a width, but at the other end (B meeting C) it gains by the same width.

Fig. 15.16 Break-up of edge beam

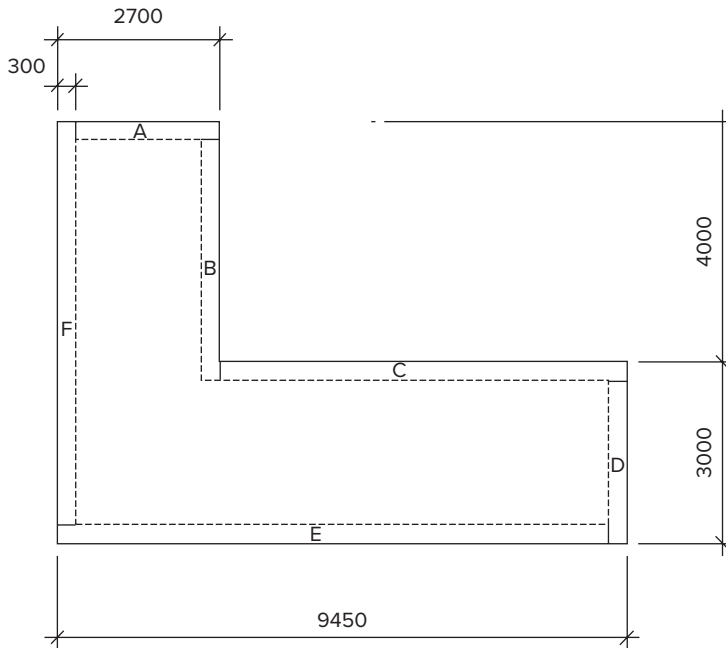
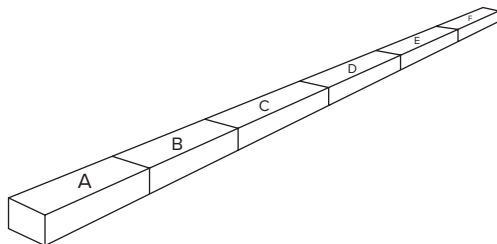


Fig. 15.17 Visualisation of summing of edge beam volumes



So your total length calculation looks like this:

$$A = 2.700 - 0.300 = 2.400$$

$$B = 4.000 = 4.000$$

$$C = 6.750^* = 6.750 (^*9.450 - 2.700 = 6.750; \text{ see plan})$$

$$D = 3.000 - 0.300 = 2.700$$

$$E = 9.450 - 0.300 = 9.150$$

$$F = 7.000^* - 0.300 = 6.700 (^*4.000 + 3.000 = 7.000; \text{ see plan})$$

$$\text{Total length} = 31.700 \text{ m}$$

You can now find the volume (V) by:

$$V = \text{End area} \times \text{Length}$$

$$V = (0.225 \times 0.300) \times 31.700$$

$$V = 0.0675 \times 31.700$$

$$V = 2.13975 \text{ m}^3$$

Step 4: Now you can calculate the total volume of spoil. This is found as follows:

$$\begin{aligned} \text{Total excavated volume} &= 2.13975 + 3.915 \\ &= 6.05475 \text{ m}^3 \end{aligned}$$

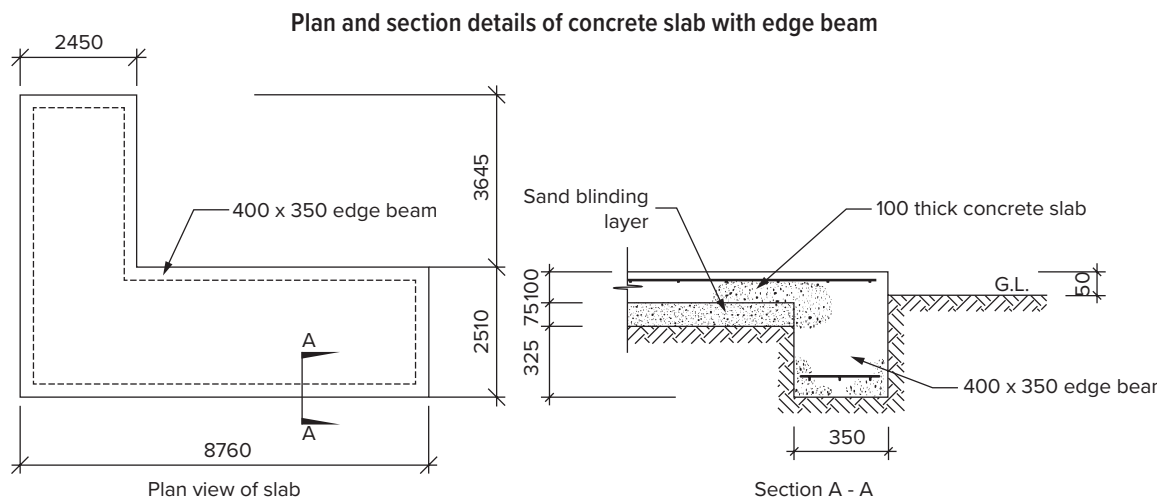
Allow for bulking for ordinary soil (20%):

$$\begin{aligned} \text{Bulking} &= 6.05475 \times 1.20 \\ &= 7.2657 \text{ m}^3 \end{aligned}$$

Assuming you will need to remove this spoil from the site and that trucking companies will charge by the cubic metre or part thereof, you would round this up to 8 m³ for costing purposes.

CHECK YOUR UNDERSTANDING

1. What are the three categories of soil types?
2. What is meant by the term 'angle of repose'?
3. List five factors that will influence your plan for erosion control.
4. Why is stockpiling topsoil important when excavating?
5. At which three points in time should you carry out inspections?
6. Calculate the amount of soil needed to be removed when excavating for the concrete slab described in the figure below. The soil type is clay.



15.2 Prepare the excavation site and erect safety equipment

Correctly establishing a building site involves a lot of planning and is beyond the scope of this chapter (it forms a significant part of several units at Certificate IV level). Likewise, as an apprentice, it is highly unlikely that you will be asked to draw up a site establishment plan in your first year (though it's not impossible). However, you should be able to read one, and to do this, there are some basics you need to know. This knowledge revolves around two key areas:

- (a) identifying and locating the excavation requirements. This may, in turn, be broken down into elements of:
 - plan reading—developing a simple site establishment plan
 - identifying and establishing all-weather access point
 - setting out and ground marking
 - services and other trades
 - planning for the excavation depth.
- (b) additional site establishment requirements, such as:
 - safety barriers and signage
 - silt and run-off filtering.

We will begin with (a) identifying and locating excavation requirements, and so, logically, with plan reading.

15.2.1 Plan reading—developing a simple site establishment plan

The primary source of any information regarding a building is always going to be the plans and specifications. The main information you seek from these documents is generally found on the site plan. From this and an initial site inspection, you will be able to derive a simple site establishment or site set-out plan. Such a plan should include the following:

- the location of site datum
- an all-weather access point
- storage areas for new materials including bricks, sand and timber
- excavation stockpiles including separate topsoil stockpile
- storage areas for waste management (skips and the like)
- brick and timber cutting areas (as required)
- wash-down areas for vehicles
- wash-down areas for plastering, paint and concrete waste
- sediment retention systems (fences, pits, straw bales).

The site establishment plan should note the location of each element listed above, paying attention to water run-off as well as logic with regards to the construction process.

Most importantly, you must locate items with regards to the excavation requirements. This is of the utmost importance when mechanical excavation is to be used (e.g. bobcats, backhoes and excavators). Consideration is also given to the timing of deliveries, removal of waste and general access.

15.2.2 Identifying and establishing the all-weather access point

In developing the site establishment plan, you will have to identify and establish your access point. Access should, wherever possible, be limited to one point only. This will become your wash-down area

as well. While it need not be the location of the proposed driveway, this is usually the case due to it also being the kerb access point from the road.

A wash-down/all-weather access point (Fig. 15.18) should be constructed as shown in Figure 15.19.

Other elements of your site establishment plan, such as the design (rather than the location) of sediment retention systems, will be discussed later in this chapter.

15.2.3 Setting out and ground marking

Chapter 13, Site setting out and basic levelling, offers a full description of basic set-out procedures.

There may be two or even more periods of excavation required on a site. In some cases, a 'cut' or 'cut and fill' action may be required before being able to set up the profiles and complete the full set-out of the project (Fig. 15.20).

At other times, you may be able to establish the full set-out immediately due to the ground already being reasonably level, or the construction technique involved not requiring a cut on the slope.

Fig. 15.18 All-weather access point



Courtesy of Alister Ford

Fig. 15.19 Environmental Protection Authority (in most states and territories) approved dimensions of a site wash-down/all-weather site access point

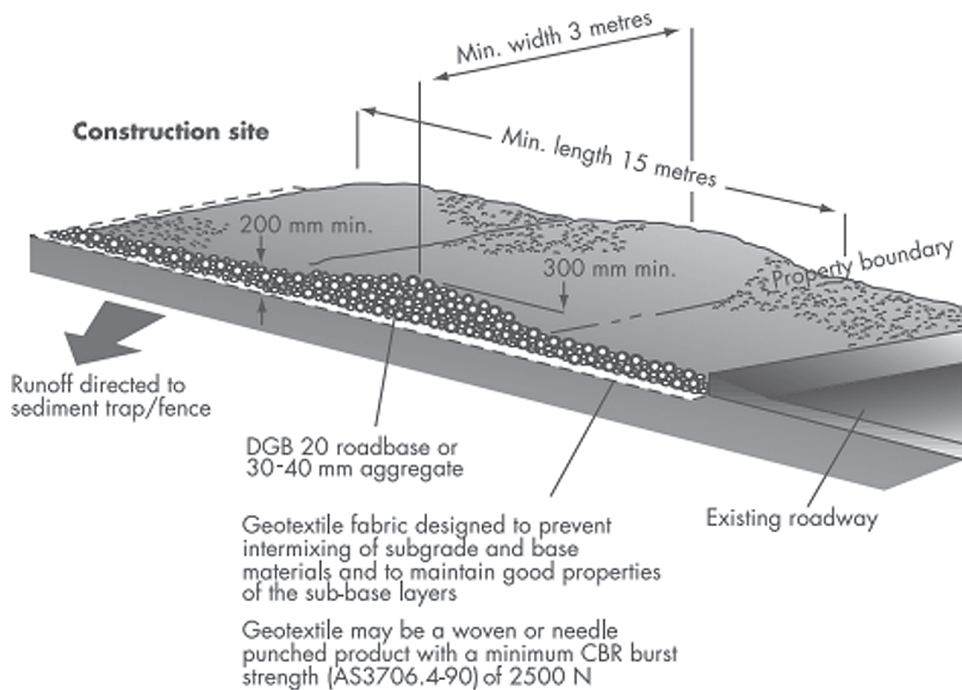


Fig. 15.20 Typical cut and fill site for a domestic house

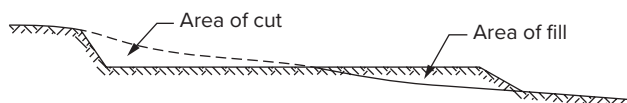


Fig. 15.21 Marking paint used to mark out the perimeter of the excavation



Courtesy of Alister Ford

Fig. 15.23 Marking paint and timber pegs used to mark the position of the pier holes



Courtesy of Alister Ford

Fig. 15.22 Marking paint and lime used to mark out the auger boring positions on this sloping site



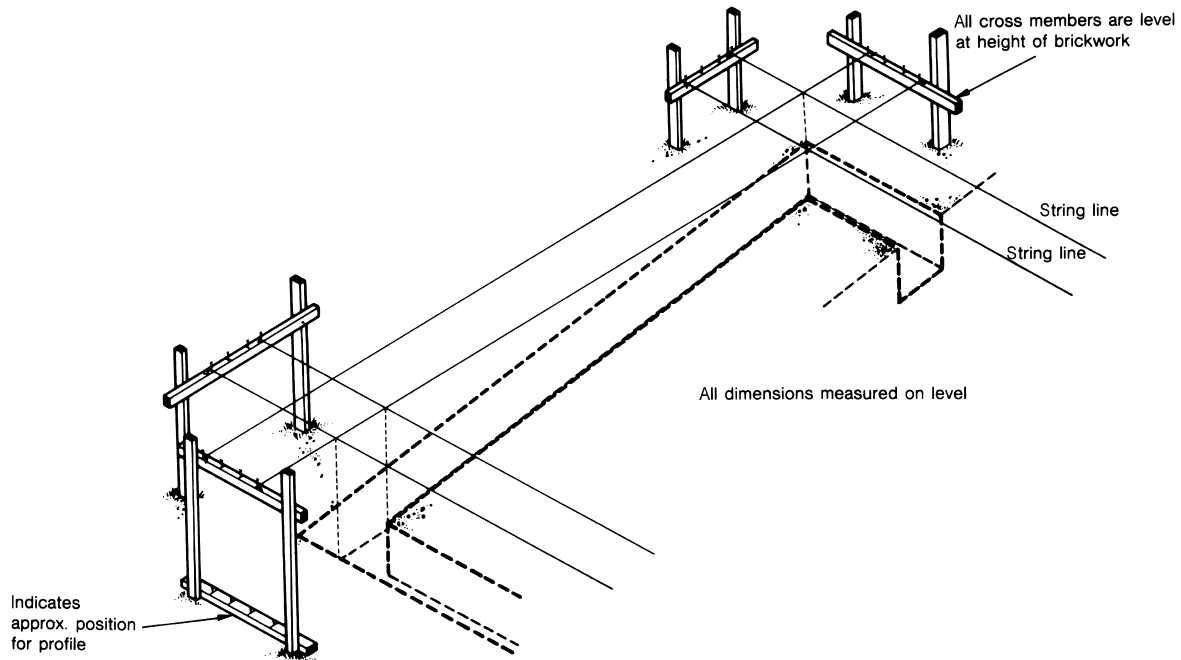
Courtesy of Alister Ford

In the case of a cut and fill site, the footprint and siting of the house must be identified and then allowance made for any retaining walls as required (Figs 15.21–15.23). With this surface prepared you may then set out the house as per Chapter 13.

Looking at Figure 15.24, you can see that the usual building profiles are established and the key dimensions of the structure marked upon them. What comes next depends on the type of footing required for that specific building.

15.2.4 Slab on ground and stiffened raft slabs

For these types of footings, you only require the outside edge of the slab or brickwork of the building (Fig 15.25). With this line marked on the ground using a water-based line spray (Fig. 15.21), the excavator only needs to be informed of the width of the edge beam required. Having installed the right width bucket on the backhoe/excavator or bobcat, the operator will then dig to the required depth inside of this line.

Fig. 15.24 Standard set-out of footings using hurdle-style profiles

15.2.5 Strip footings

These footings are used to support the dwarf walls that form the perimeter of many timber or steel-framed subfloors (Figs 15.26–15.28).

As shown in Figure 15.29, the information required on the profiles this time is the inside and outside lines of the footing. (Note that although Figure 15.29 shows a step in the width of the footing around engaged piers, this seldom occurs on contemporary sites; instead, a single-width footing is designed to cater for these piers.)

Fig. 15.25 Typical excavation for a slab on ground

Courtesy of Alister Ford

Figure 15.27 Stepped perimeter strip footing

Courtesy of Alister Ford

Figure 15.26 Hand-tool excavated verandah strip footing

Courtesy of Alister Ford

While both internal and external footing lines may be marked on the profile, some excavators are happy working from just the external one with an appropriate width bucket. Some builders, however, prefer marking out both lines on the ground. This can sometimes assist the excavator in maintaining sight of the excavation lines and hence produce a straighter trench.

15.2.6 Services and other trades

Almost all domestic construction will require access to services such as water, sewerage, electrical, gas and telecommunications. The setting out of these excavations will need to be developed with input from the relevant tradespeople (plumbers, electricians and the like), who may engage their excavator after the primary work is complete or seek to work in conjunction with you and your team.

As mentioned in the section 'Safety considerations', you should also consult both the relevant tradespeople and the service providers (power, water, sewer, gas, telecommunications suppliers) regarding the existence of any pre-existing services that may lay beneath your proposed excavation site. These should be identified on your site plan and, where applicable, on your site establishment plan. Such issues are of particular importance on renovation and extension works where such services will almost definitely be in existence.

Fig. 15.28 Typical strip footing detail

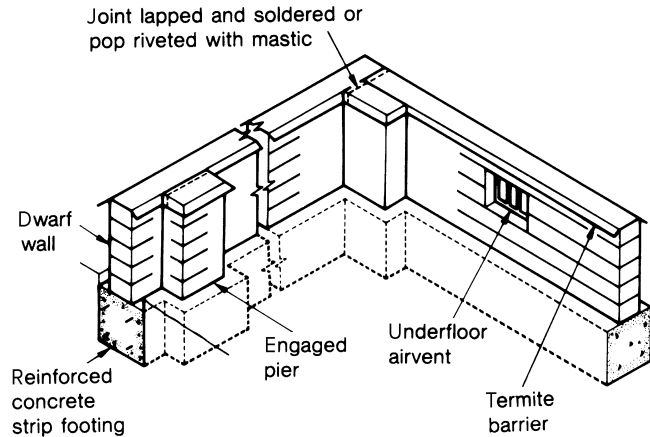
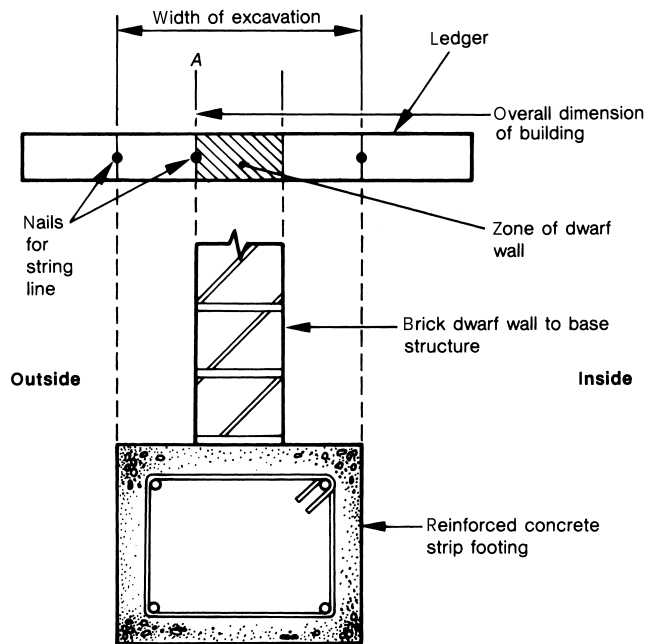


Fig. 15.29 Strip footing information applied to profile head



15.2.7 Planning for the excavation depth

While setting out the shape of the excavation on the ground is the greater part of the set-out process, there is another important element that must be considered—the depth of the excavation.

There are a number of ways by which the footing depth may be determined. Your choice of which depends greatly upon:

- the skill of the excavator
- the equipment being used
- the depth of the excavation
- the overall size of the excavation (such as a cut and fill project)
- the importance of the finished level.

Beginning from the bottom of the above list, the finished level of a cut and fill site, for example, may or may not be of a critical nature. This is dependent upon the location of the site and the desired

finished floor levels. In most urban and suburban areas, councils will nominate a finished floor level (FFL), which is to be derived (reduced) from a known reference point—your site datum or a nearby permanent bench mark (see Chapter 13). This could be because of flood levels or as means of governing maximum building heights.

In such projects, a minor cut or scrape is made to ascertain the appropriate level (in some cases a number of scrapes). A datum set up by a surveyor is used to determine these points. The remainder is then excavated with these points as a guide. Constant reference checks must be made back to the datum to be sure of a level surface.

With the advent of laser technology, a reader can be fixed on the head of an auger or backhoe allowing the operator to work confidently to produce a horizontal and even surface on sloping sites. Other systems are calibrated to the varying actions of the excavator boom and bucket configuration.

Without such technology, controlling the depth of the excavation will depend much more upon operator skill and the aid of a guide. And even with this technology, once all required mechanical excavations are complete you will still need to follow up with shovels to manually complete and tidy up the work. In addition, most mechanical excavation will require some manual labour during the works in order to clear site lines or otherwise guide the operator.

15.2.8 Safety barriers and signage

The need and location of signs and barriers have been covered previously (see 'General safety considerations'). Anywhere there is a potential fall of 1.5 metres, or when an excavation of any depth in a public space is to be left unattended, barriers and warning notices must be installed.

What has not been discussed is the requirements of such barriers to be effective. The Excavation Work Code of Practice also provides two definitions:

- barrier: 'a physical structure that blocks or impedes something'
- barricade: 'any object or structure that creates a barrier obstacle to control, block passage or force the flow of traffic in the desired direction'.

When considering your barrier or barricade you should think of the purpose: What is it that you require the item to do, and thus what form must it take to be effective? Within a construction site that is already enclosed by an unclimbable fence, it may be sufficient to use plastic barrier fencing that is between 0.9 and 1.1 metres in height (Fig. 15.31). In a public space, where people will be less alert to possible excavations or impediments to free passage, something more substantial will be required. This is because people may accidentally walk, back into or be accidentally pushed up against the barrier.

Fig. 15.30 Pier holes bored to the correct depth for the coated timber stumps



Courtesy of Alister Ford

Fig. 15.31 Plastic water-filled barriers, signage and flags



Courtesy of Alister Ford

The depth, and hence the potential risk, will also be an indication of how secure and/or how high a barrier must be.

With regards to traffic, you must consider the likelihood of the barricade being struck. Again, the potential risk of accidental or unauthorised entry should be considered in determining the nature of the barricade, both in visibility, permanence and integrity. Often barricades are used in conjunction with barriers: the barrier being an unclimbable fence and the barricade being a means of diverting vehicular traffic away from the zone.

15.2.9 Silt and run-off filtering

Figures 15.32 and 15.33 describe the more common approaches to sediment control. The first and preferred method is the geotextile sediment fence. By acting as a dam, these barriers allow the water to filter through while the sediment is mostly contained within the site. Note that to be effective, the base of the fabric must be embedded into the ground by at least 150 mm.

The straw bale system, while also common, does not filter the water so much as trap it. This reduces the flow rate and allows the sediment to drift to the bottom. Note again that to be effective the straw bales must be embedded 100 mm into the ground.

There are many other controls that you may need to consider with regards to sediment outflows such as kerb drain filters. For more information on these and other filtering systems, you are directed to a range of state government documents listed at the end of this chapter.

Fig. 15.32 Geotextile silt barrier fence requirements

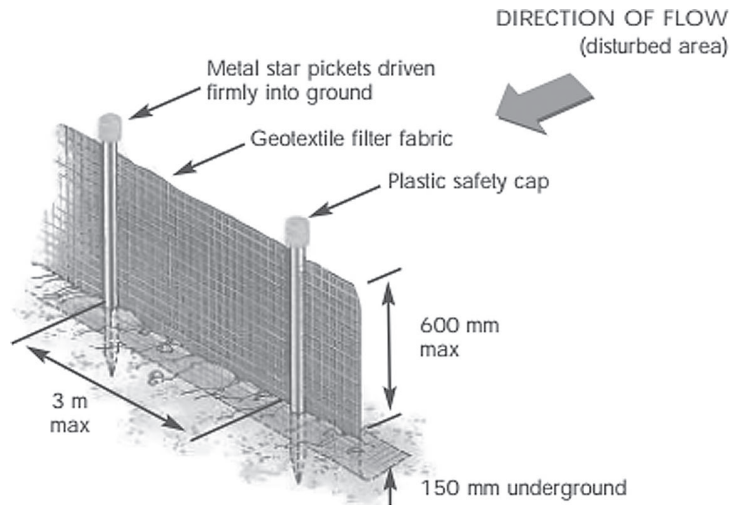
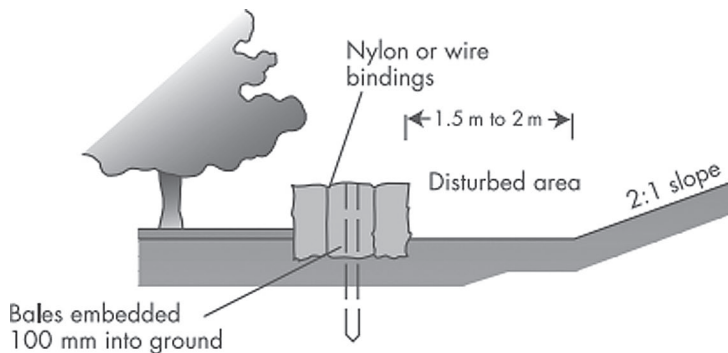


Fig. 15.33 Straw bale silt retention barrier requirements



CHECK YOUR UNDERSTANDING

7. List at least five elements you should include in your site establishment plan.

15.3 Follow safe excavation practices

15.3.1 Collapse prevention controls

The most frightening word in the excavation industry is 'collapse'. Also referred to as cave-ins, such events pose significant risks to workers, neighbouring structures and equipment. Collapse can be

caused by any number of factors, applied individually or collectively. With regards to vertical or near vertical earth walls, the main causes tend to be:

- drying out of the earth such that it becomes friable (its particles easily separable)
- wetting of the earth such that it becomes incapable of supporting its weight
- wetting of the earth such that it becomes fluid (mud)
- downward forces close to the sides of the excavation (materials, machines, buildings, stockpiles of spoil, etc.)
- groundwater undercutting the walls of the excavation
- vibration (traffic, machinery or seismic)
- excessive depth (the greater the depth, the greater the downwards, and hence sideways, pressure upon the walls).

Collapse can be brought about by any one of these but commonly it will be a combination. The straw and the camel's back is a good idiom here. A machine may be working nearby but a person walking past may initiate the collapse. Collapse may occur rapidly and without warning.

TIP Old excavations (i.e. ones that have been left exposed for over a week) pose the greater risks as the exposed earth will have either dried out or taken up moisture; either way the material will have changed, which changes how it may behave.

No worker is allowed to be in an excavation 1.5 metres or deeper without collapse prevention in place. Collapse prevention controls may be clustered into three categories:

- benching and battering
- shoring
- shielding.

Benching (Fig. 15.34a) involves the creation of a series of small vertical 'steps' that effectively widen the excavation, thereby reducing the pressure on the walls and reducing the chance of collapsing material trapping workers.

Battering (Fig. 15.34b) is also a widening technique, effected by cutting back the sides of the excavation at an angle that is less than the angle of repose. This technique is sometimes

Fig. 15.34(a) Benching

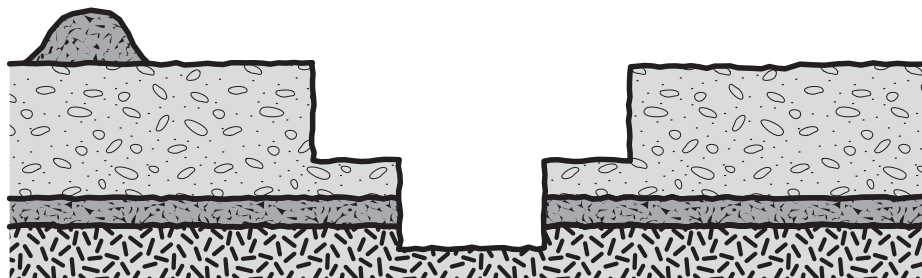
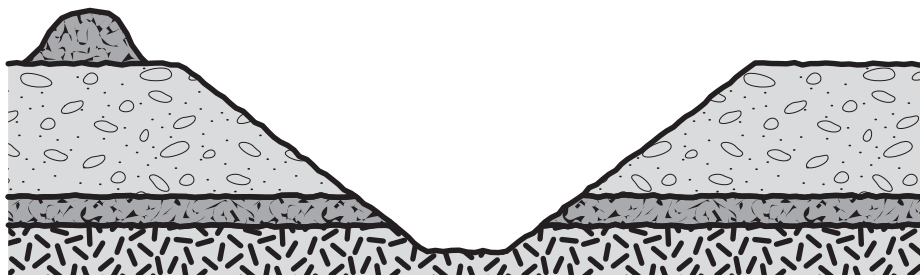


Fig. 15.34(b) Battering



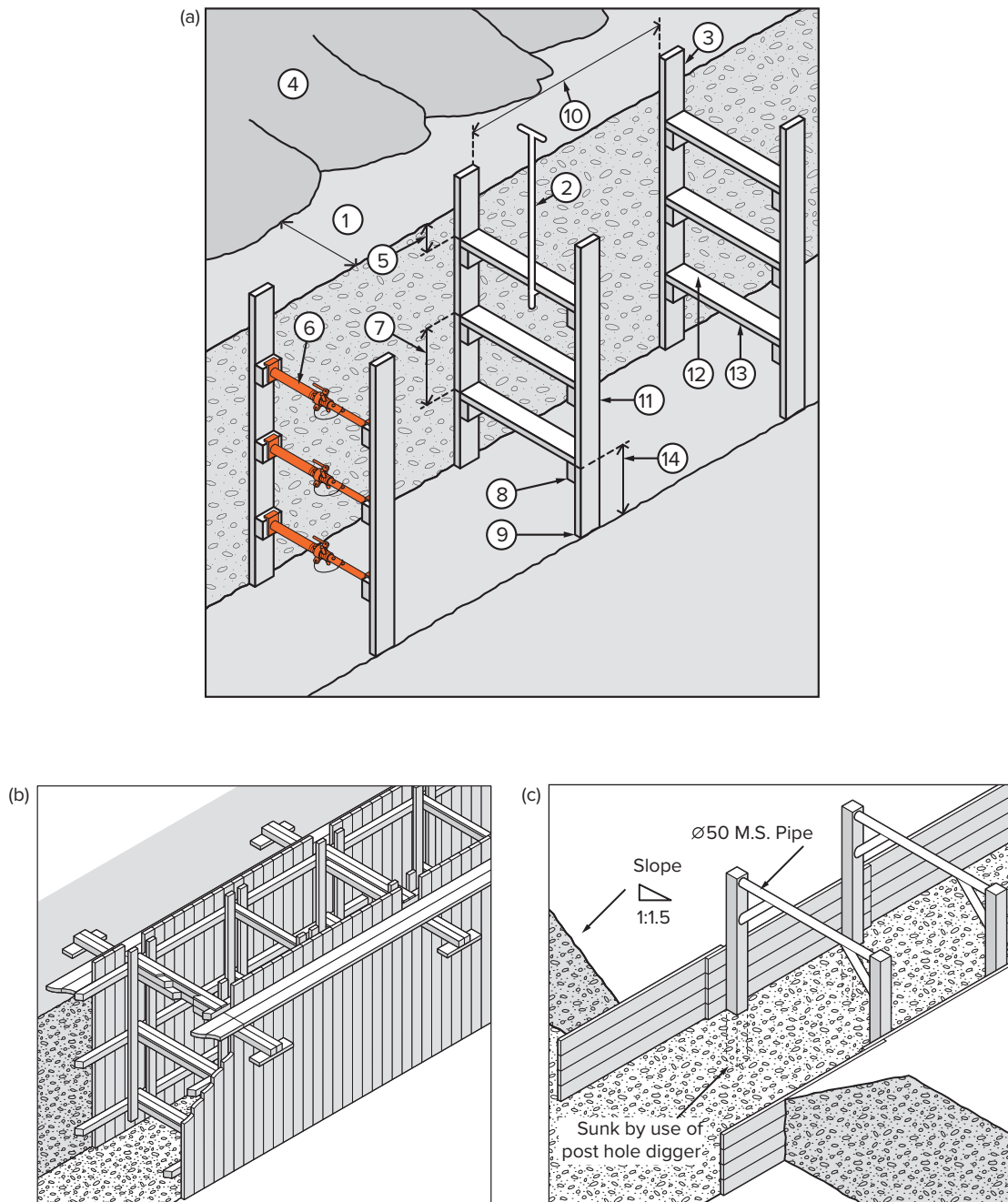
done in conjunction with benching when the surface material is less stable than that which is reached further down.

Shoring is a mechanical means of vertically retaining the sides of a trench or excavation. There are a number of common shoring systems available such as:

- timber (soldier sets and closed sheeting systems)
- steel sheeting and piling
- hydraulic struts (may be applied to any of the above).

Timber shoring can be in the form of soldier sets, closed sheeting or side lacing (Fig. 15.35). In each case, entry to the excavation must be by an appropriately installed ladder. (Note: Soldier sets only provide support at intervals and so are suitable solely for stable soil conditions.)

Fig. 15.35 (a) Soldier sets; (b) closed sheeting; (c) side lacing



Steel sheet piling is constructed similarly to timber closed sheeting (Fig. 15.36). The sheet piling is driven into the ground as the excavation proceeds up to a point at which a minimum of 300 millimetres of piling remains above the natural ground line. In both timber and steel systems, hydraulic struts may be used in place of conventional struts.

Shielding systems differ from shoring in that they are not designed to prevent a trench from collapsing, but to shield workers in the event of a collapse (Fig. 15.37). Shields are therefore designed to be lowered into a trench after it has been dug, unlike shoring, which is driven into the ground and the excavation undertaken by them.

One further issue that may bring about collapse is the location of the removed spoil. Note in Figure 15.34a, which shows benching, the spoil is located at least the height of the bench away. Spoil located closer than this distance adds to the effective height of the excavated wall. This increased height coupled with the loose nature of the material radically increases the chance of collapse. This is demonstrated further by Figure 15.38 of a trench on a sloping site.

Spoil located close to the excavation wall also increases trip and slip hazards to workers engaged in aiding the machine operator. This brings us to the final element of this chapter—working around machinery.

Fig. 15.36(a) Steel sheet piling

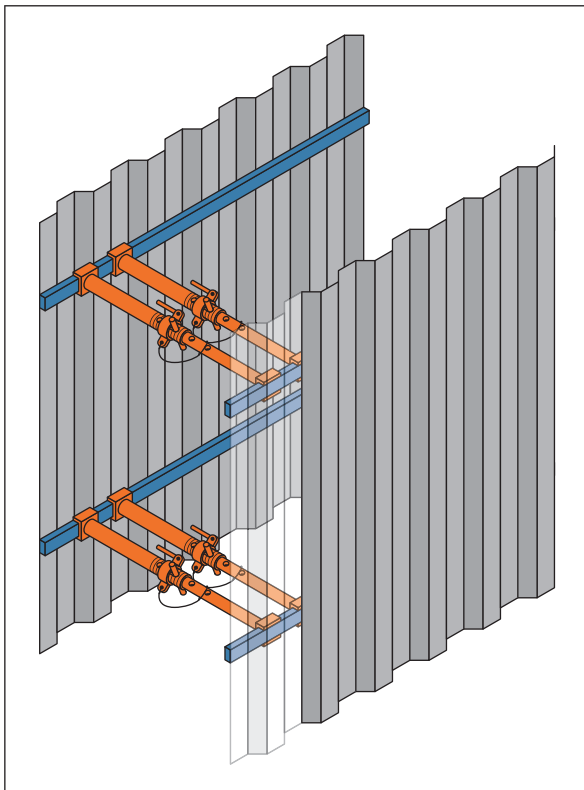
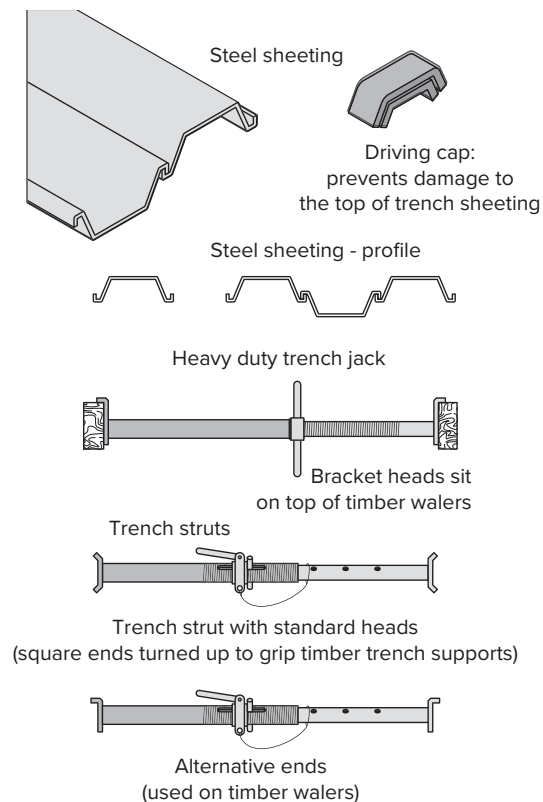


Fig. 15.36(b) Components



15.3.2 Working around machinery

Learning to work with and around excavation machinery is a critical skill in the contemporary construction industry. On the one hand it must be second nature, on the other you must maintain a constant sense of alertness no matter how experienced you become. Excavating equipment moves

Fig. 15.37 Steel trench shield

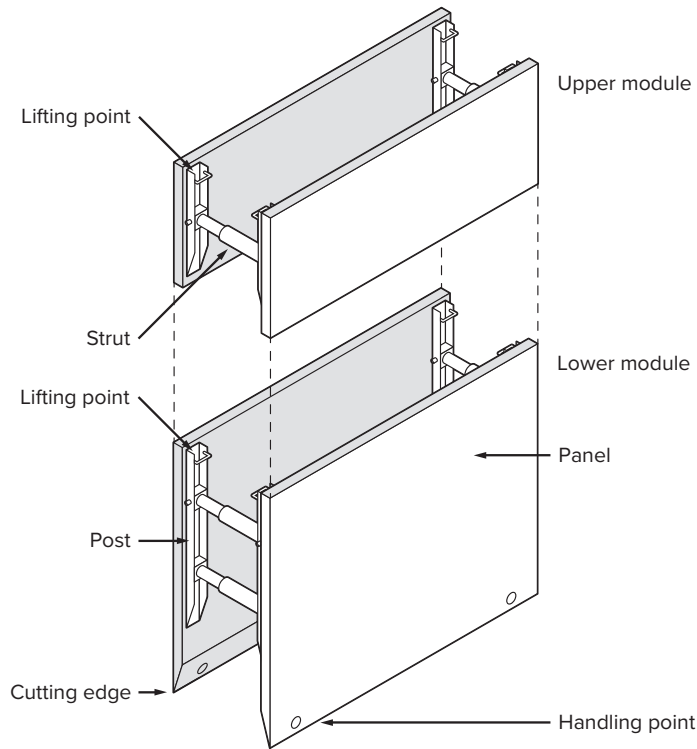
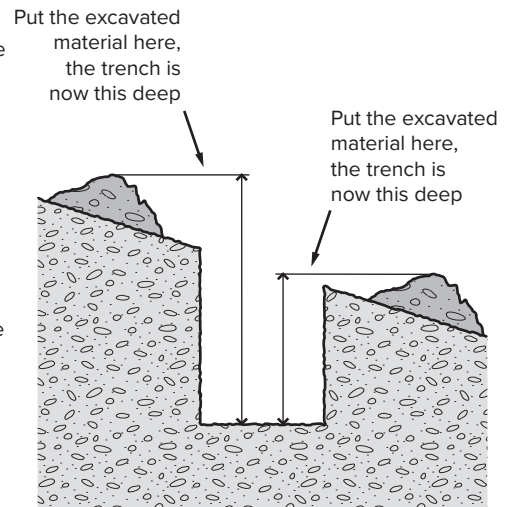


Fig. 15.38 Effective height of trench derived from spoil location



deceptively fast, yet can be slow to stop, and can cause very serious or even fatal injuries if it impacts with the human body.

There are two things to keep clear in your mind when working around mechanical excavation equipment, both of which require clear communications with the operator:

- the duty of care to yourself or personal safety
- the duty of care to others or safety of others.

Personal safety requires that you:

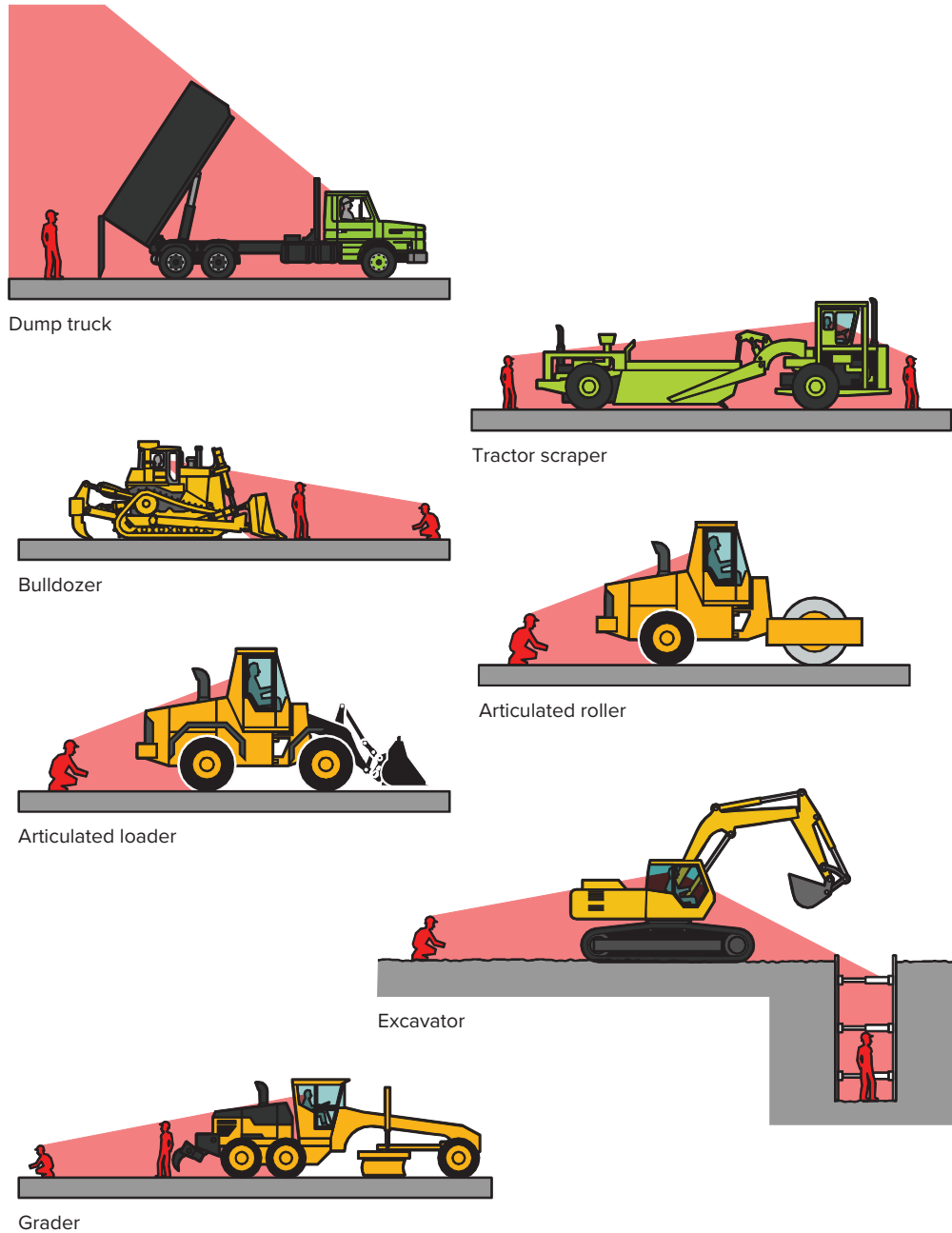
- wear appropriate personal protective equipment (PPE)
- remain alert and in visual contact
- be aware of the blind spots of each type of machine
- never approach any operational machine without visual confirmation from the operator
- be wary of turning your back on an operational machine
- never work in a deep (1.5 m or greater) trench without appropriate trench collapse prevention mechanisms in place
- never work in a deep (1.5 m or greater) trench alone—always ensure there is someone working with you or spotting who can render assistance immediately if required.

Figure 15.39 shows examples of blind spots of various machines. Never enter these zones when the machine is operational.

The *safety of others* demands that you consider creating an 'exclusion' or 'no go' zone. This area may be identified by high-visibility tapes, mesh barriers, fencing or barricades, depending upon your risk evaluation. Only the operator and required guides, spotters or clearers should then be within the designated area while the machine is in operation.

The safety of the machine operator is also part of your duty of care to others. If you are not the operator then most likely your role will be as the guide, spotter or clearer. As the guide or spotter, your task is to keep the operator informed of the proximity of obstacles and dangers such as powerlines,

Fig. 15.39 Blind spots of common excavation plant



other trenches, buildings, trees, exposed or identified services and the like. You must do this while maintaining visual contact with the operator even if you have a radio connection.

As the clearer, you may be requested to enter the trench or get close to the excavated wall so as to remove small areas of spoil that are limiting the operator's sight line. Likewise, you may be asked to enter the excavation zone to clear away surface spoil or aid in identifying an obstruction or possible previously unidentified service line.

When inspecting or clearing a trench, never enter one that is at a depth greater than 1.5 metres and unshored. Working close to excavation edges is also dangerous as such edges are unstable and may collapse without warning. Likewise, be very wary of inspecting possible underground services that have been come across unexpectedly: gas, electrical, telecommunications and even water and sewerage lines all expose you to extreme risks. If you are uncertain, then an appropriate tradesperson and/or service provider should be contacted.

CHECK YOUR UNDERSTANDING

8. How does benching limit chances of collapse occurring?
9. Define the term 'shoring'.
10. Ground support systems must be installed in any trench of which depth or greater?

Student research

Within your class, or by using the internet if working alone, investigate systems or methods that can reduce the amount of excavation required. Examples include bored piles, driven piles and screw piles. This information may be presented verbally or by means of a very short (1 page max.) essay using diagrams as required.

End-of-chapter activities

1. Refer to the Safe Work Australia 'Excavation Work Code of Practice' October 2018, and answer the following:
 - (a) List the eight WHS regulations and their references for the risk management process.
 - (b) List the 14 examples of excavation-specific hazards.
 - (c) List the six hierarchy of control measures for excavation in order from the highest level of protection and reliability to the lowest.
 - (d) When planning excavation work and consulting with the relevant people, which 14 important points should be included in your discussions?
 - (e) It is critical to review and revise your emergency plans on a regular basis to retain currency. List four situations when such a review or revision should take place.
 - (f) Give a brief description of the term 'zone of influence'.
 - (g) List six critical points that should be considered when selecting a powered mobile plant to carry out an excavation.
 - (h) A fall prevention device can be made up of materials, equipment or a combination of both. List four fall prevention devices that could be used to prevent falls into open excavations.
 - (i) Give a brief description of the preparation and excavation methods for trenching.
 - (j) List six common types of shoring systems.
2. Locate and download (or contact your state or territory safety authority) the code of practice for excavation applicable to your state or territory. From this document, address the following points:
 - (a) How close may spoil be located to, or a vehicle be allowed to come near to, an excavation that is shored to carry soil loads only?
 - (b) What method is recommended to prevent equipment from getting too close to the edges of excavations?
 - (c) Ground anchors are another technique that may be used in shoring. What are they and what are the risks of their use?
 - (d) List three occasions when it is advised that the services of a geotechnical engineer may be required.

AUSTRALIAN BUILDING CODES AND STANDARDS

Safe Work
Australia,
Excavation Code
of Practice,
October 2018

Tradie talk—There is no job that important that it can't be done safely

Chapter 16

Construction calculations in carpentry work

Learning Objectives

- LO 16.1 Understand and review drawings, specifications and workplace requirements for a construction project**
- LO 16.2 Use different types of equipment and formulas to perform construction calculations**
- LO 16.3 Calculate the area of lining material**
- LO 16.4 Perform external building calculations**
- LO 16.5 Perform timber frame calculations**
- LO 16.6 Calculate volume**

Introduction

In the construction industry, tradespeople make multiple calculations every day. Carpenters are no exception—they will be working out simple and complex calculations on each job that they are working on, from calculating materials needed to construct wall and roof frames and working out the square metres of walls and floors, to calculating the lineal metres of cladding, lining materials and flooring required. Calculations are also used to work out the way in which materials are used and installed to produce the best and most economical layout.

Having the skills and knowledge to plan and perform calculations to determine material requirements will help in your work on costings and estimating jobs and build your capacity to be a more efficient and more effective tradesperson. Understanding the relationship between calculations and materials will also help increase your business's profits and reduce the environmental impact of construction industry waste.

Materials used in the construction industry are ordered in lineal metres, square metres, cubic metres, coverage and volume. The relationship between perimeter, area and volume is key to understanding how much of a material needs to be ordered for a task or project.

16.1 Understand and review drawings, specifications and workplace requirements for a construction project

When planning and organising to determine the amount of carpentry materials required for a construction project, the project plans and specifications are your best resource. Make sure you have the latest version of the project plans, as sometimes there may have been a few revisions. The plans and specifications will have a high level of detail, including but not limited to:

- site plan and orientation
- floor plan and elevation
- footings
- roof
- location of services, e.g. sewer, water, electrical
- bracing plan
- layout of room, windows and doors.

Planning and organising are essential skills, necessary to achieve high-quality outcomes on construction projects; this works hand in hand with being able to calculate the required amount of building materials for tasks and projects. Determining the materials that are suitable for construction projects will take into consideration factors such as:

- work health and safety (WHS) requirements
- National Construction Code (NCC)
- Australian Standards
- workplace policies and standards
- environmental and workplace requirements
- manufacturer's literature for product installation.

The model WHS Act is the legislation governing all aspects of the building and construction industry and provides a balanced and nationally consistent framework to secure the health and safety of workers and workplaces. The regulations support the legislation, and are laws made by federal, state and territory governments about all aspects of the construction industry, including working conditions, quality and safety requirements. Codes of practice provide practical advice on how the laws should be applied.

All work must comply with laws and regulations, the National Construction Code (NCC), Australian Standards, work health and safety (WHS) and environmental requirements, manufacturer's specifications, workplace requirements, drawings and specifications. No matter the size and scope of the works, you will need to comply with the laws of the model WHS Act. Building in a safe and compliant environment will add a significant cost to the project. Safety equipment should be a separate line item in your costing, along with any extra time required to perform the task safely. More information on the model WHS laws can be found at the 'Law and regulation' section at www.safeworkaustralia.gov.au.

The specifications will have details of the National Construction Code (NCC) related to the construction, along with the corresponding Australian Standards (Fig. 16.1). The NCC is a performance-based code that sets the minimum requirements in relation to structure, fire safety, access and egress, accessibility, health and amenity, and sustainability. All new buildings, new building work, and new plumbing and drainage systems must comply with the NCC.

The Australian Standards are sets of nationally recognised documents establishing the minimum set of requirements that define quality and safety criteria within the industry and within building and construction. The Australian Standards have specifications and procedures designed to ensure products, services and systems are safe and reliable, and that they consistently perform the way they are intended to.

Fig. 16.1 Excerpt from drawing 06 in the Appendix

GENERAL NCC NOTES

ALL MATERIALS AND WORK PRACTICES SHALL COMPLY WITH, BUT NOT LIMITED TO THE BUILDING REGULATIONS 2018, NATIONAL CONSTRUCTION CODE SERIES 2019 BUILDING CODE OF AUSTRALIA VOLUME 2 AND ALL RELEVANT CURRENT AUSTRALIAN STANDARDS (AS AMENDED) REFERRED TO THEREIN.

UNLESS OTHERWISE SPECIFIED, THE TERM BCA SHALL REFER TO NATIONAL CONSTRUCTION CODE SERIES 2019 BUILDING CODE OF AUSTRALIA VOLUME 2.

ALL MATERIALS AND CONSTRUCTION PRACTICE SHALL MEET THE PERFORMANCE REQUIREMENTS OF THE BCA. WHERE A PERFORMANCE SOLUTION IS PROPOSED THEN, PRIOR TO IMPLEMENTATION OR INSTALLATION, IT FIRST MUST BE ASSESSED AND APPROVED BY THE RELEVANT BUILDING SURVEYOR AS MEETING THE PERFORMANCE REQUIREMENTS OF THE BCA.

ALL WORKS SHALL COMPLY TO THE FOLLOWING AUSTRALIAN STANDARDS:

- AS 1288 - GLASS IN BUILDINGS: SELECTION AND INSTALLATION
- AS 1562 - DESIGN AND INSTALLATION OF SHEET ROOF AND WALL CLADDING
- AS 1684 - NATIONAL TIMBER FRAMING CODE
- AS 1860 - INSTALLATION OF PARTICLEBOARD FLOORING
- AS 2049 - ROOF TILES
- AS 2050 - FIXING OF ROOF TILES
- AS 2870 - RESIDENTIAL SLABS AND FOOTINGS
- AS 2904 - DAMP PROOF COURSES AND FLASHINGS
- AS 3600 - CONCRETE STRUCTURES
- AS 3660.1 - CODE OF PRACTICE FOR PHYSICAL BARRIERS USED IN THE PROTECTION OF BUILDINGS AGAINST SUBTERRANEAN TERMITES
- AS 3700 - MASONRY IN BUILDINGS
- AS 3786 - SMOKE ALARMS
- AS 4055 - WIND LOADINGS FOR HOUSING
- AS 4100 - STEEL STRUCTURES

Regardless of the size of the project, from multistorey city buildings to residential home extensions, calculating and costing building and construction materials and selecting the correct materials is crucial to creating accurate quotes, tenders and submissions. Inaccuracies in your calculations will cost time, money and profit and lead to you not being competitive in the market.

CHECK YOUR UNDERSTANDING

1. Do you need to comply with the WHS Act if the job that you are working on is a small construction project?
2. What are some of the outcomes if you are inaccurate with your estimations and quotes?
3. What general information are you able to obtain from a set of plans and specifications?

16.2 Use different types of equipment and formulas to perform construction calculations

The types of equipment required for planning and performing measurements and calculations and their characteristics, uses and limitations include:

- calculators
- computer estimating programs
- laser measuring devices
- tape measures (various lengths)
- scale rulers and rulers.

These are covered in Chapter 4, Trade calculations and measurements, and Chapter 7, Carpentry hand tools.

The formulas for calculating area and volume and to convert from millimetres to metres in a construction environment for the following shapes are covered in Chapter 4, Trade calculations and measurements:

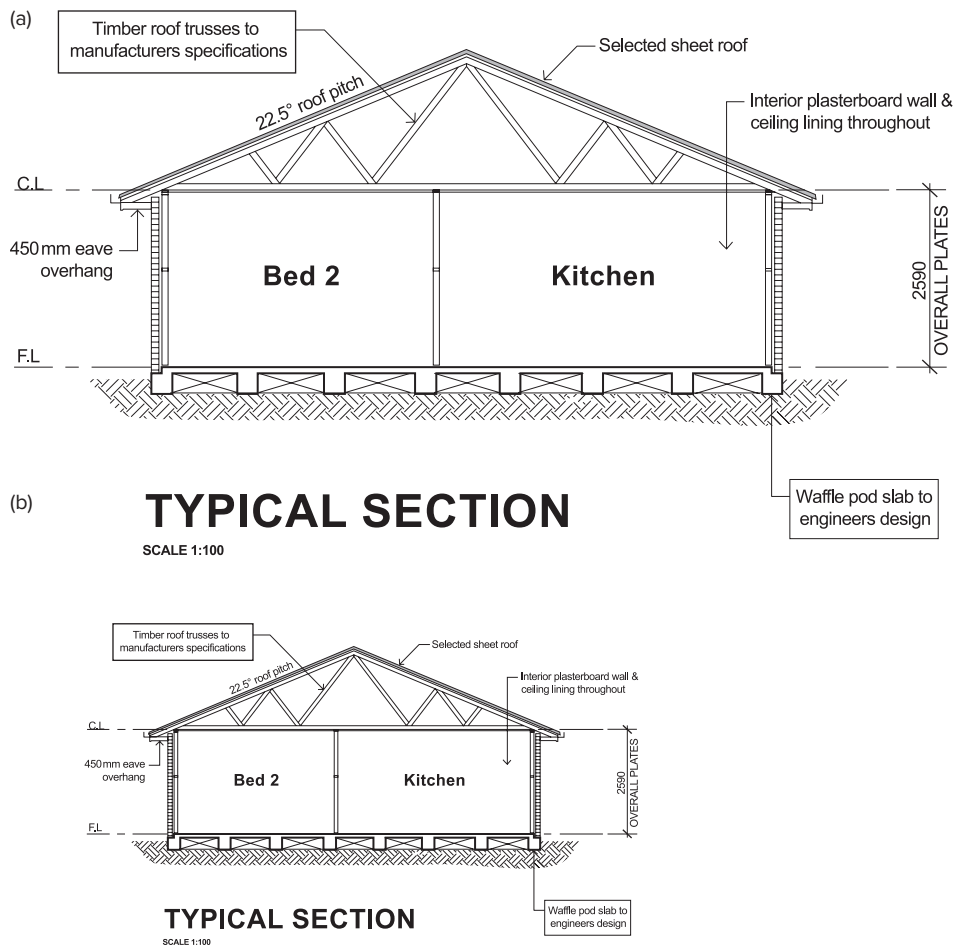
- rectangles
- squares
- circles
- triangles
- trapeziums
- cubes
- cylinders.

16.2.1 Scale

The methods of accurately determining the dimensions of materials for construction projects by scaling requirements from drawings and specifications have been covered in Chapter 5, Trade drawings. Most architectural plans and specifications will have a scale in the legend to be used in conjunction with a scale ruler—always check that the scale is correct as plans are often photocopies, which can be enlarged or reduced, affecting the scale when using a scale ruler.

For example (Fig. 16.2), you could have a set of original plans with a scale of 1:100 on an A3 sheet of paper, but if we reduce the plan to A4, is the scale still 1:100 for a scale ruler? The answer is no—by reducing the drawings you have changed the size of the drawing but not the scale to be used. You will not be able to use a scale ruler for taking measurements from plans that have altered in size from the originals; if you are reading from a set of plans that are not the original architectural plans, then you should always use the written measurements on the plans.

Fig. 16.2 (a) Scale 1:100; (b) reduced drawing no longer to scale



On the plans you will find that there is an abundance of measurements for lengths, heights and widths. The measurements on architectural working drawings will always take precedence over scaled measurements.

Correctly drawn plans and well-documented specifications along with manufacturer's specifications have all the information for a carpenter to be able to work out and calculate the amount of materials required for a job or project. A carpenter will use these documents for the construction of:

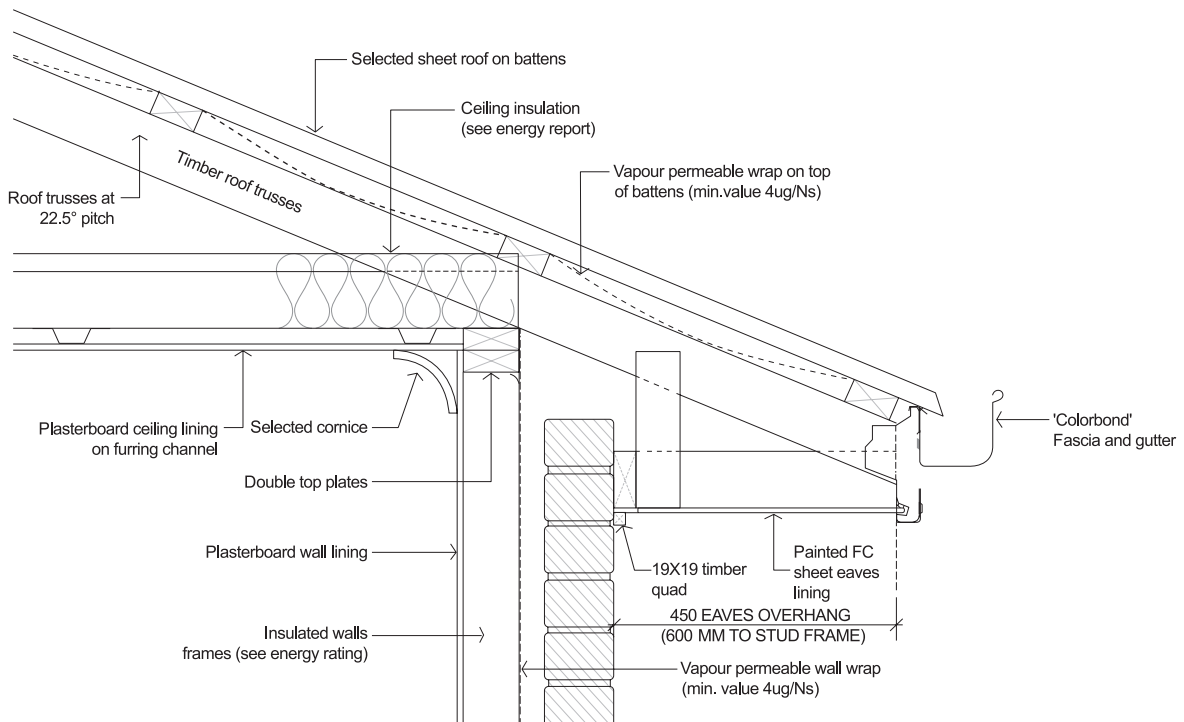
- wall and roof framing (the roofing materials will determine the type of roof constructed)
- internal linings and flooring
- external linear linings (cladding).

Other information that we can gather from the plans and specifications with regards to the materials includes but is not limited to:

- slabs (type, e.g. concrete waffle pod)
- structural steel sizes
- exterior walls (brick, weatherboards etc.)
- roofs (corrugated iron/zinc, cement tile, terracotta etc.)
- window openings and sizes
- door openings and sizes
- wet area requirements
- floor and wall tiles
- plaster walls and cornices
- eaves (fibro cement)
- insulation (sarking material).

Figure 16.3 is an example of the type of information that can be gathered from the plans. The image shows the timber walls, insulation, sarking for the roof and walls, eave construction, furring channel, plaster and cornice, steel ceiling battens, roof battens, type of roof, fascia and gutter.

Fig. 16.3 Typical eaves detail (Appendix, drawing 04)



TYPICAL EAVES DETAIL

SCALE 1:10

The set of plans and specifications will also help you determine the dimensions of each construction material for your project. For example, the window schedule (Fig. 16.4a) gives you the actual size of the windows, and the timber-framing schedule (Fig. 16.4b) has information on the timber floors, stud walls and the required timber sizes. The steel lintel list provides information on the size of lintels required for the openings (Fig. 16.4c).

Fig. 16.4 (a) Window schedule; (b) timber-framing schedule example; (c) steel lintel schedule

(a)

Window schedule			
ID	Height (mm)	Width (mm)	Description
W01	2100	1500	Glazed door w/highlight
W02	1800	1800	Slide over fixed window
W03	1200	1800	Sliding window
W04	1000	900	Sliding window
W05	1000	900	Sliding window
W06	2100	1800	Slide over fixed window
W07	2100	900	Door
W08	2100	1500	Sliding door
W09	1200	1800	Sliding window
W10	1000	1500	Sliding window
W11	1200	1800	Sliding window
W12	2100	4800	Garage

Note: Window schedule to be read in conjunction with elevations and energy report.

(b)

TIMBER FRAMING SCHEDULE						
FLOORING MATERIAL		GRADE	JOIST SPACING			
19 THICK VICTORIAN HW		STANDARD	620			
19 THICK RADIATA PINE		STANDARD	510			
PARTICLEBOARD SHEET FLOORING		600 SERIES	600			
FRAMING TIMBER		MAX. SPAN		SUPP AT 2 POINTS	CONT. OVER 2 SPANS	MAXIMUM SPACING
MEMBER	SIZE					
CEILING HEIGHT - 2700						
EFFECTIVE ROOF LENGTH - 12000						
SIZES FOR SINGLE STOREY AND UPPER STOREY OF 2 STOREY CONSTRUCTION						
BOTTOM PLATE	90 x 45	600	600	-	-	F5
TOP PLATE	90 x 45	600	600	-	-	F5
STUDS - COMMON	90 x 35	2400	2400	600	-	F5
	90 x 35	2700	2700	600	-	F5
	90 x 45	3000	3000	450	-	F5
STUDS - AT SIDES OF OPENINGS	90 x 45	2400	2400	1150	-	F5
	90 x 70	2400	2400	3000	-	F5
	90 x 70	2700	2700	1800	-	F5
	90 x 90	2700	2700	2700	-	F5
	90 x 90	3000	3000	1500	-	F5
LINTELS (REFER TRUSS DESIGN)	90 x 35	1300	-	-	-	F17
	140 x 35	1900	-	-	-	F17
	190 x 35	2400	-	-	-	F17
	240 x 35	3000	-	-	-	F17
	240 x 45	3200	-	-	-	F17
NOGGINGS	70 x 35	600	-	1350	-	F5
	BRACING METAL STRAP - REFER A.S. 1684					
ROOF BATTENS	75 x 38	-	900	900	-	F8
SIZES FOR LOWER STOREY OF 2 STOREY CONSTRUCTION						
TOP & BOTTOM PLATE	90 x 70	600	600	-	-	F5
STUDS - COMMON	90 x 45	2400	-	600	-	F5
	90 x 45	2700	-	450	-	F5
	90 x 70	3000	-	450	-	F5
STUDS - AT SIDES OF OPENINGS	90 x 45	2400	2400	900	-	F5
	90 x 70	2700	2700	1500	-	F5
	90 x 90	2700	2700	2100	-	F5
	90 x 70	2700	2700	3900	-	F17
LINTELS	REFER TO ENGINEERS DETAILS					
FLOOR JOISTS	REFER TO ENGINEERS DETAILS					
STRESS GRADE F17 REFERS TO SEASONED HARDWOOD						
STRESS GRADE F8 REFERS TO UN-SEASONED HARDWOOD						
STRESS GRADE F7 REFERS TO UN-SEASONED OREGON						
STRESS GRADE F5 REFERS TO SEASONED RADIATA PINE						
2 STOREY - SLAB ON GROUND - SHEET / TRUSSED ROOF						

(c)

STEEL BRICKWORK LINTEL SCHEDULE: REFERENCE: PAGE 23 OF ONE STEEL MANUAL 'STRUCTURAL STEEL IN HOUSING'								
B/WORK	CLEAR SPAN OF OPENINGS (mm)							
	1000	1200	1500	1800	2100	2400	2700	3000
500	75X75X6	75X75X6	75X100X6	75X100X6	75X100X6	100X100X6	100X100X6	100X100X6
1000	75X75X6	75X100X6	75X100X6	75X100X6	100X100X6	100X100X6	100X100X6	150X90X8
1500	75X100X6	75X100X6	75X100X6	100X100X6	100X100X6	100X100X6	150X90X8	150X90X8
2000	75X100X6	75X100X6	100X100X6	100X100X6	100X100X6	150X90X8	150X90X8	150X90X8
2500	75X100X6	75X100X6	100X100X6	100X100X6	100X100X6	150X90X8	150X90X8	150X100X10
3000	75X100X6	75X100X6	100X100X6	100X100X6	100X100X6	150X90X8	ENGINEERED	
LENGTH	1200	1500	1800	2100	2400	2700	3000	3300

NOTE: FIRST DIMENSION CORRESPONDS TO VERTICAL LINTEL LEG

CHECK YOUR UNDERSTANDING

- On a set of plans and specifications, what takes precedent—the plans or measurements?

16.3 Calculate the area of lining material

The term 'lining material' refers to the covering on the inside of a house. External coverings are commonly referred to as cladding. Insulation must also be considered and it would be installed in the walls before any coverings. On the inside of a common residential house you would find these types of linings:

- plaster walls
- plaster ceiling
- plaster cornice
- fibre cement sheet in wet areas
- feature timber lining boards
- flooring.

Using the set of plans from Figures 16.2, 16.3, 16.5 and 16.6, we can determine the dimensions of the internal linings. The distance between the finished floor level (FFL) and the finished ceiling level (FCL) gives an internal finished height of 2550 mm from floor to ceiling (in Fig.16.6 the measurements are taken from the elevation). From the plan view of the house in Figure 16.5 we are able to get all of the external and internal wall length. The overall height of the external wall is 2590 mm (Fig. 16.2a) which includes the ribbon plate. When developing the stud wall height, the floor coverings need to be taken into account. In Figure 16.5, the floor coverings are carpet in the bedrooms, vinyl planks in the living areas and ceramic tiles in the bathroom and en-suite.

Fig. 16.5 House plan view (Appendix, drawing 02)

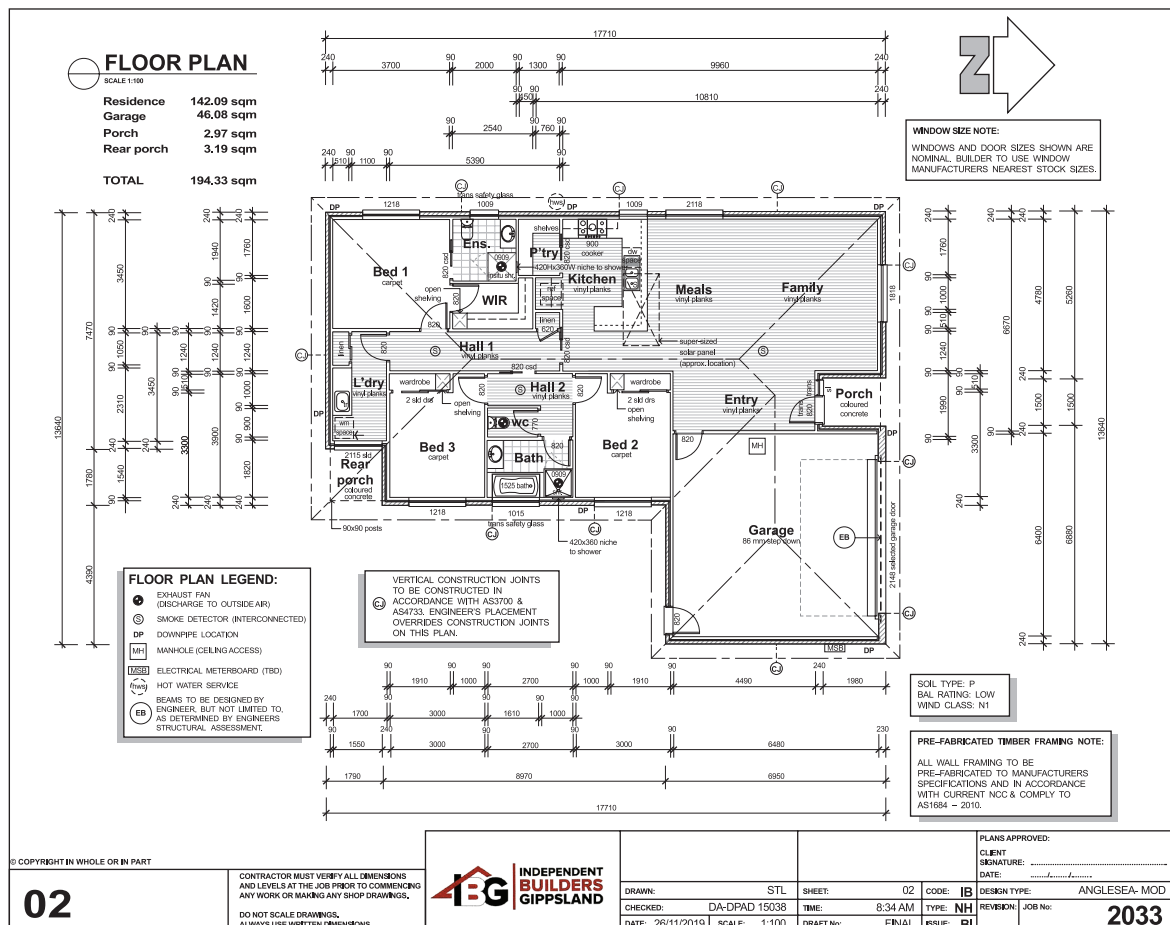
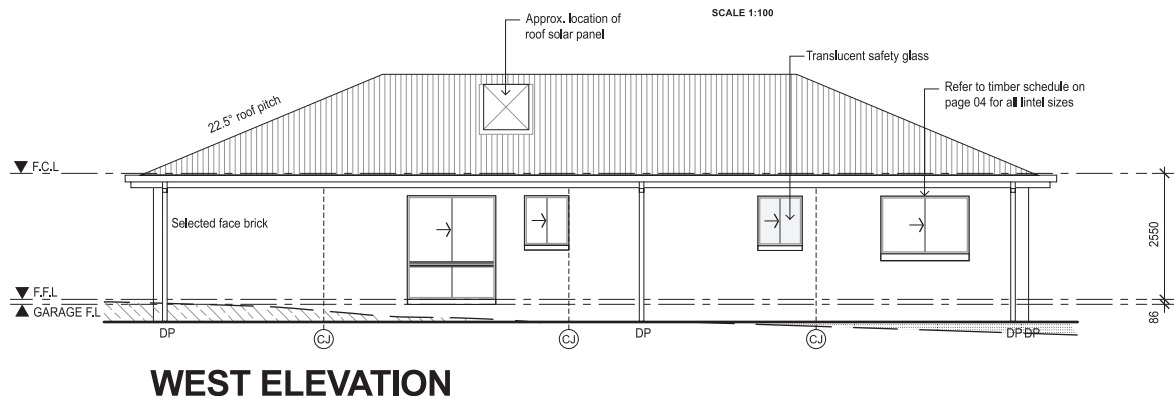


Fig. 16.6 West elevation (Appendix, drawing 03)

16.3.1 Plaster

Standard residential plaster is 10 mm thick and comes in widths of 1200 mm and 1350 mm. The width of plaster sheet to be used will depend on the height of the wall and the overall size of the ceiling. Plaster sheets come in a variety of lengths from 2400 mm to 6000 mm. When ordering plaster, you would usually order full sheets that cover the entire length of the walls. However, this isn't always possible for large rooms and long hallways—6 m lengths of plaster are long and heavy and require a few people to help lift them into position, or you may need to use a mechanical panel lifting device. Plasterboard has become a very versatile product as it can be used in wet areas as well as assisting with sound-proofing.

TIP Plastering is a specialised trade; however, on occasion carpenters may need to hang sheets of plaster. When plastering long walls and ceilings, make sure you stagger the joints in the same way as you would with solid timber flooring.

16.3.2 Fibre cement

Fibre cement products can be found on the inside and outside of the house and are used heavily in fire-prone areas as fibre cement is fire-proof. On the inside of the house, fibre cement sheets are used predominantly in wet areas and around fireplaces.

16.3.3 Timber lining boards

Timber lining boards come in a variety of timber species and sizes, and can be used on walls and ceilings. Most systems of timber lining boards will be tongue and groove or shiplap. The timber can vary in width from approximately 80 mm to 140 mm and is available in random lengths. Engineered and laminate linings are available in standard lengths and provide a cost-effective alternative.

16.3.4 Floor and wall tiles

Tiles are available in a variety of sizes and styles. They are most often made of ceramic or porcelain, with some porcelain tiles being made to look like timber flooring. Other materials used are glass, cork, concrete and other composite materials, as well as stone. Tiling stone is typically marble, onyx, granite or slate.

16.3.5 Timber flooring

There has been much innovation in terms of timber flooring, and there are many alternatives to solid timber floors, such as engineered boards and laminate boards. Engineered boards come in standard sizes and lengths, with the boards being comprised of a ply or MDF base and a top layer of veneer of timber

of approximately 3–7 mm. Laminate boards are made of an MDF base with an image layer designed to make the board look like timber, stone or various other materials. Vinyl planks are similar to laminate in having a vinyl base with an image layer on top and come in various thicknesses from 2–8 mm.

Bamboo flooring is created from bamboo plants and manufactured into a board that has a similar appearance to a timber floor. It is available in the form of solid compressed board and as engineered board.

Solid timber flooring is available in a variety of widths from 60–180 mm and in random lengths with standard thicknesses of 14 mm, 19 mm and 20.5 mm. Popular Australian timbers are:

- Blackbutt
- Blue gum
- Brush box
- Ironbark
- Pine
- Victorian ash
- Tasmanian oak
- Jarrah.

16.3.6 Carpet

Carpet is a floor covering made from woven fibre, and comes in a variety of styles, patterns and colours.

Each of the materials listed can be ordered in a variety of ways—per board, lineal metres or square metres. When you measure up a house and start calculating the materials, you will need to look at the plans and identify what linings are required for each of the spaces. One way to record your measurements is to create a checklist.

There are many computer programs on the market that can record this information and it is now common practice to use them in the industry. Having a designated book or diary to record information will help you keep track of your calculations and material costings. All of the information gathered can later be transferred to a digital format if needed.

TIP Resist the urge to write down information on an offcut of timber or plaster—most times you will not transfer that information to a job book or digital device and you will find yourself back out on-site remeasuring the task/job.

16.3.7 Calculating the amounts needed

In the following example, we will use Figure 16.5 to calculate the square metres required for vinyl plank flooring; the areas have been highlighted in Figure 16.7, and we will also record the information in Figure 16.8. A square metre is calculated as being the area equal to a square that is 1 metre on each side (1 m × 1 m).

From the plans, you can read and ascertain that the vinyl plank flooring is located in:

- the main entrance
- meals and family room
- both hallways
- kitchen and pantry
- the water closet (WC) next to hallway 2
- the laundry.

The set of plans also stipulates the direction in which the vinyl planks are to be laid, which is from the front door, lengthways towards the laundry or simply north to south of the house. (The kitchen in this example has been worked out based on the standard size cabinets used in cabinet making.)

Fig. 16.7 Identified rooms with vinyl plank flooring (Appendix, amended drawing 02)

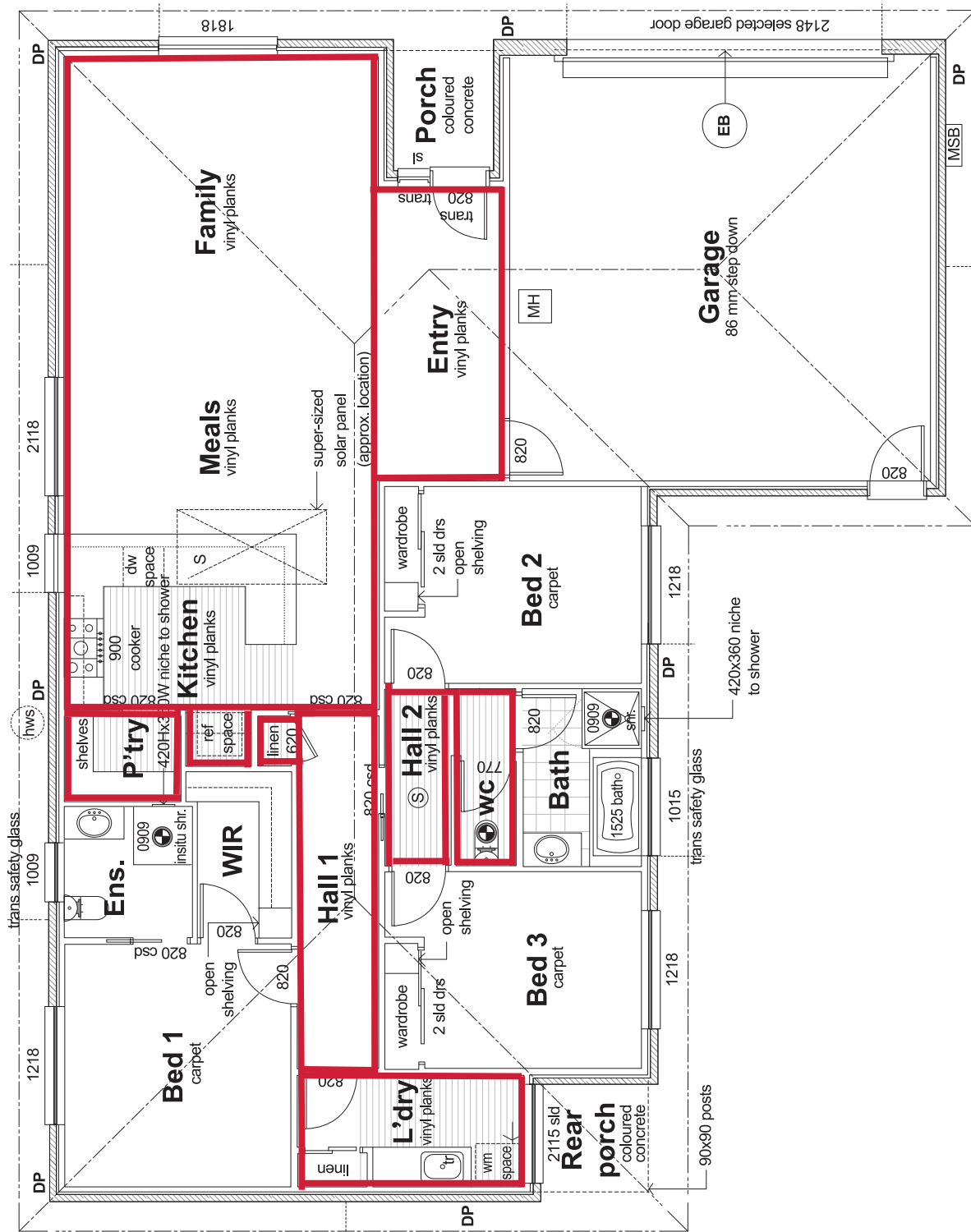


Fig. 16.8 Calculation checklist

Client: Andrew Smith Job address: Mill Park Contact/phone:			Date: Quote number: 00109			
Room	Floor L × W (mm)	Wall area (mm)	Wall covering	Floor covering	Notes	Area (m ²)/lineal metre (lm)
Kitchen	9960 × 4780 combined area with meals and family		Plaster/glass splashback	Vinyl planks	Total size of kitchen, meals and family space	43.91 m ²
Meals	Refer to kitchen		Plaster	Vinyl planks	Minus the size of the kitchen 3.69 m ²	
Family	Refer to kitchen		Plaster	Vinyl planks	Approximate size of the kitchen is in 3 parts 3450 × 600 (sink) 1900 × 600 (cooker) 800 × 600 (return)	
Pantry	1760 × 1390		Plaster	Vinyl planks		2.446 m ²
Fridge	1000 × 850					0.85 m ²
Entry	4490 × 2080		Plaster	Vinyl planks	Planks to run from the front door longways through the house	9.339 m ²
Hall 1	5570 × 1240		Plaster	Vinyl planks		6.906 m ²
Hall 2	2700 × 1000 + door opening		Plaster	Vinyl planks	Door opening 820 × 110	2.79 m ²
Hall 3				N/A		
Linen closet 1	760 × 510 + door opening 620 × 110		Plaster	Vinyl planks	620 × 110	0.445 m ²
Linen closet 2	1050 × 510 + plus door opening 1050 × 110		Plaster	Vinyl planks	1050 × 110	0.65 m ²
Bath 1		Cement sheet wall length: 1/2700 2/1820 1/1900	Cement sheet + tiles	Tiles	Cement sheet for bath frame to cover 1800 × 900 × 400 (2.34 m ²)	
Bath 2				N/A		
WC 1	2700 × 900 + door opening to bath 1		Plaster	Vinyl planks	Walkway between hall and WC 1000 × 110 Door to bath 820 × 110	3.33 m ²
WC 2				N/A		
En-suite 1		Cement sheet wall length: 2/2000 1/1940 1/1200 (9 mm required for sliding cavity door)	Cement sheet + tiles	Tiles		
En-suite 2				N/A		
Bedroom 1			Plaster	Carpet	Walk-in robe to be carpeted	
Bedroom 2			Plaster	Carpet		
Bedroom 3			Plaster	Carpet		
Bedroom 4				N/A		
Laundry	3450 × 1700	Cement sheet wall length: 1/3450 1/2550 1/1700	Cement sheet + tiles	Vinyl planks	This size includes trough—approx. 1600 × 600	4.905 m ²
Garage			Plaster	N/A		

When working out square metres, it is easiest to convert your measurements into metres (Fig. 16.9).

Fig. 16.9 Calculating the square metres of the vinyl floor planks

Kitchen			
3450 mm × 600 mm (sink)	Converted to metres		$3.450 \text{ m} \times 0.6 \text{ m} = 2.07 \text{ m}^2$
1900 mm × 600 mm (cooker)			$1.9 \text{ m} \times 0.6 \text{ m} = 1.14 \text{ m}^2$
800 mm × 600 mm (return)			$0.8 \text{ m} \times 0.6 \text{ m} = 0.48 \text{ m}^2$
			Total: 3.69 m^2
Total area of:			
Kitchen, meals, family:			
9960 mm × 4780 mm – kitchen			$(9.960 \text{ m} \times 4.780 \text{ m}) - 3.69 \text{ m}^2 = 43.91 \text{ m}^2$
Pantry			
1760 mm × 1390 mm			$1.76 \text{ m} \times 1.390 \text{ m} = 2.446 \text{ m}^2$
Fridge space			
1000 mm × 850 mm			$1.0 \text{ m} \times 0.85 \text{ m} = 0.85 \text{ m}^2$
Entry			
4490 mm × 2080 mm			$4.490 \text{ m} \times 2.080 \text{ m} = 9.339 \text{ m}^2$
Hall 1			
5570 mm × 1240 mm			$5.570 \text{ m} \times 1.240 \text{ m} = 6.906 \text{ m}^2$
Kitchen			
Hall 2			
2700 mm × 1000 mm			$2.7 \text{ m} \times 1.0 \text{ m} = 2.7 \text{ m}^2$
820 mm × 110 mm (door)		+	$0.820 \text{ m} \times 0.110 \text{ m} = 0.09 \text{ m}^2$
			$2.7 \text{ m}^2 + 0.09 \text{ m}^2 = 2.79 \text{ m}^2$
Linen closet 1			
760 mm × 510 mm			$0.760 \text{ m} \times 0.510 \text{ m} = 0.387 \text{ m}^2$
620 mm × 110 mm (door)		+	$0.620 \text{ m} \times 0.110 \text{ m} = 0.068 \text{ m}^2$
			$0.387 \text{ m}^2 + 0.068 \text{ m}^2 = 0.455 \text{ m}^2$
Linen closet 2			
1050 mm × 510 mm			$1.050 \text{ m} \times 0.510 \text{ m} = 0.535 \text{ m}^2$
1050 mm × 110 mm (door)		+	$1.050 \text{ m} \times 0.110 \text{ m} = 0.115 \text{ m}^2$
			$0.535 \text{ m}^2 + 0.115 \text{ m}^2 = 0.65 \text{ m}^2$
WC 1 (water closet/toilet)			
2700 mm × 900 mm			$2.7 \text{ m} \times 0.9 \text{ m} = 2.43 \text{ m}^2$
820 mm × 110 mm		+	$0.820 \text{ m} \times 0.110 \text{ m} = 0.09 \text{ m}^2$
			$2.43 \text{ m}^2 + 0.09 \text{ m}^2 = 3.33 \text{ m}^2$
Laundry			
3450 mm × 1700 mm			$3.450 \text{ m} \times 1.7 \text{ m} = 5.865 \text{ m}^2$
1600 mm × 600 mm (bench and trough)		+	$1.6 \text{ m} \times 0.6 \text{ m} = 0.96 \text{ m}^2$
			$5.865 \text{ m}^2 - 0.96 \text{ m}^2 = 4.905 \text{ m}^2$
		Total	75.581 m²

The required minimum amount of vinyl planks required for this example is 75.581 m². When ordering vinyl planks, they are available in a variety of lengths, widths and thicknesses, and are sold in boxes with a square meterage rate.

Some examples of sizes of vinyl planks that are available, with prices (for illustrative purposes only) are:

- (a) 1220 mm × 184 mm × 5 mm with a coverage area of 2.24 m² per box (approx. \$154 per box)
- (b) 1524 mm × 225 mm × 6 mm with a coverage area of 1.71 m² per box (approx. \$99 per box)
- (c) 914 mm × 152 mm × 2 mm with a coverage area of 2.20 m² per box (approx. \$60 per box).

If the particular type of coverings and linings are not nominated in the specifications, you will have to determine with the client which vinyl plank they want. The specification will include a prime cost item to cover this and a nominated m^2 rate. A variation will need to be signed off in the contract showing whether the client's choice is more or less than the prime cost m^2 rate.

16.3.8 Costings

Using the example of the vinyl plank above and knowing the total area required, you are now able to determine the cost.

The vinyl planks in the above example cover a variety of areas; to determine how many boxes are needed, you will have to divide the overall square metres with the coverage per box:

- (a) $75.581 \text{ m}^2 \div 2.24 \text{ m}^2 = 33.74$ (34 complete boxes)
- (b) $75.581 \text{ m}^2 \div 1.71 \text{ m}^2 = 44.19$ (45 complete boxes)
- (c) $75.581 \text{ m}^2 \div 2.20 \text{ m}^2 = 34.35$ (35 complete boxes)

As with any job or task, you will have to factor in a percentage of wastage due to factors such as cuts and damaged boards. You should factor an extra 5–10% into your costings. In this example, we will add an extra 10% (when using a calculator, 5% is represented by 0.05 and 10% is represented by 0.1).

- (a) $34 \text{ boxes} \times 10\% = 3.4 \text{ boxes}$ (rounded up) 4 boxes Total 38 boxes
- (b) $45 \text{ boxes} \times 10\% = 4.5 \text{ boxes}$ (rounded up) 5 boxes Total 50 boxes
- (c) $35 \text{ boxes} \times 10\% = 3.5 \text{ boxes}$ (rounded up) 4 boxes Total 39 boxes

The total costing of each of the different types of vinyl board as a total job is:

- (a) $38 \text{ boxes} \times \$154 = \$5852$
- (b) $50 \text{ boxes} \times \$99 = \$4950$
- (c) $39 \text{ boxes} \times \$60 = \$2340$

Now that you have the square metres (area) for the areas requiring vinyl planks, you can use this information if there is a change in material. The client may change their minds as to the type of flooring to be used in these areas. For example, they may want solid 19 mm timber flooring and request a quote for a few different types of Australian timbers. Some examples of sizes that are available, with prices (for illustrative purposes only) are:

- (1) Spotted gum 85 mm $\times$ 19 mm (\$9.35 per metre)
- (2) Jarrah 130 mm $\times$ 19 mm (\$13.95 per metre)
- (3) Victorian ash 108 mm $\times$ 19 mm (\$4.00 per metre)

An easy way of working out how much timber flooring you will need to cover the designated area is to work out a square meterage rate for the timber flooring.

The method we use to determine the square meterage rate is to work out how many pieces of timber flooring will fit into a square of 1 m $\times$ 1 m (length $\times$ width).

For the equation each length of timber flooring will be 1 m. The next step is to work out how many times the width of the timber flooring goes into 1 m. Below are some examples of how to determine how many timber floor boards are required (width) to fit into 1 m.

- (1) Spotted gum $1000 \text{ mm} \div 85 \text{ mm} = 11.76$ boards per square metre (m^2)
- (2) Jarrah $1000 \text{ mm} \div 130 \text{ mm} = 7.69$ boards per square metre (m^2)
- (3) Victorian ash $1000 \text{ mm} \div 108 \text{ mm} = 9.25$ boards per square metre (m^2)

From this information, we can create a square meterage cost for different types of timber flooring. This calculation will be the square metre of boards multiplied by the lineal metre price.

- (1) Spotted gum 11.76 boards $\times$ \$9.35 = \$109.95 m²
- (2) Jarrah 7.69 boards $\times$ \$13.95 = \$107.27 m²
- (3) Victorian ash 9.25 boards $\times$ \$4.00 = \$37.00 m²

In our example, 75.581 m² is the minimum floor coverage without adding a percentage of wastage. As with any job or task, you will have to factor in a percentage for wastage due to factors such as cuts and damaged boards, normally around 5–10%. With some materials, you may need to factor in a higher percentage of wastage due to the nature of the material, the batch, and the availability of sizes and colours. Some materials require a special order and are not available off the shelf at a timber store. In this example, we will use a 5% factor for extra material. The calculation will be the square metres multiplied by 5%, and from this we can now work out how much timber flooring we need to cost.

$$75.581 \text{ m}^2 \times 5\% (0.05) = 3.779 \text{ m}^2$$

$$75.581 \text{ m}^2 + 3.779 \text{ m}^2 = 79.36 \text{ m}^2$$

- (1) Spotted gum 79.36 m² $\times$ \$109.95 = \$8725.63
- (2) Jarrah 79.36 m² $\times$ \$107.27 = \$8512.94
- (3) Victorian ash 79.36 m² $\times$ \$37.00 = \$2936.32

We can now work out the lineal metres required for this job by dividing the total square metre cost by the lineal metre (lm) cost of the timber board.

- (1) Spotted gum \$8725.63 $\div$ \$9.35 = 933.22 lm
- (2) Jarrah \$8512.94 $\div$ \$13.95 = 610.24 lm
- (3) Victorian ash \$2936.32 $\div$ \$4.00 = 734.08 lm

16.3.8.1 Costings for cement sheets

The calculations above can be used when working out lining boards for walls and ceilings. The other type of wall covering that you would use as a carpenter is cement sheet. In residential houses, this material is commonly found in wet areas such as bathrooms, en-suites and laundries. Using Figure 16.5, you can calculate the amount of cement sheets required to cover the walls in the wet areas. Cement sheet can be ordered in a variety of lengths, from 1.8 m to 4.2 m, and various widths such as 900 mm, 1200 mm and 1350 mm. Most wet areas will use 6 mm cement sheet (always refer to the user guide for installation information and applications) and 9 mm if attached to a sliding cavity door unit.

Wall lengths in these spaces (the finished ceiling level [FCL] of the house is 2550 mm as in Fig. 16.6):

Bath	1/2700 mm	2/1820 mm	1/1900 mm
Bath frame	1800 mm $\times$ 900 mm	1800 mm $\times$ 400 mm	
En-suite	2/2000 mm	1/1940 mm	1/1200 mm (cavity slider wall)
Laundry	1/3450 mm	1/2550 mm	1/1700 mm

It is possible to simply order one size of cement sheet and join sheets on a stud and stagger the joints. This can be a good option due to the weight of this product. A 2400 mm $\times$ 1200 mm $\times$ 6 mm sheet weighs almost 28 kg and is manageable between two people—in contrast to a sheet of 3000 mm $\times$ 1200 mm $\times$ 12 mm, which will weigh more than 65 kg.

In this example the best fit sheet would be a standard 2400 mm × 1350 mm × 6 mm sheet (the FCL is 2550 mm), which has a coverage of 3.24 m² and a weight of 31 kg. To work out how many sheets we would need to order, we need to work out the area (square metres/m² of the wall).

In this equation, we can add all of the length of the rooms together and multiply by the FCL of 2550 mm:

$$\text{Bath 6 mm:} \quad 2700 \text{ mm} + (2 \times 1820 \text{ mm}) + 1900 \text{ mm} = 8240 \text{ mm}$$

$$\text{Area:} \quad 8.240 \text{ m} \times 2.550 \text{ m} = 21.012 \text{ m}^2$$

$$\text{Bath frame 6 mm:} \quad 900 \text{ mm} + 400 \text{ mm} = 1300 \text{ mm}$$

$$\text{Area:} \quad 1.3 \text{ m} \times 1.8 \text{ m (length of frame)} = 2.34 \text{ m}^2$$

$$\text{En-suite 6 mm:} \quad (2 \times 2000 \text{ mm}) + 1940 \text{ mm} = 5940 \text{ mm}$$

$$\text{Area:} \quad 5.940 \text{ m} \times 2.550 \text{ m} = 15.147 \text{ m}^2$$

$$\text{En-suite 9 mm:} \quad 1200 \text{ mm}$$

$$\text{Area:} \quad 1.2 \text{ m} \times 2.550 \text{ m} = 3.06 \text{ m}^2$$

$$\text{Laundry 6 mm:} \quad 3450 \text{ mm} + 2550 \text{ mm} + 1700 \text{ mm} = 7700 \text{ mm}$$

$$\text{Area:} \quad 7.7 \text{ m} \times 2.550 \text{ m} = 19.635 \text{ m}^2$$

$$\text{Total area of 6 mm cement sheet: } 21.012 \text{ m}^2 + 2.34 \text{ m}^2 + 15.147 \text{ m}^2 + 19.635 \text{ m}^2 = 58.134 \text{ m}^2$$

$$\text{Total area of 9 mm cement sheet: } 3.06 \text{ m}^2$$

The next step is to work out how many sheets to order from the square meterage.

$$\text{Total area of 6 mm } 58.134 \text{ m}^2 \div 3.24 \text{ m}^2 \text{ (sheet coverage)} = 17.94 \text{ sheets}$$

Rounding up to 18 sheets

$$\text{Total area of 9 mm } 3.06 \text{ m}^2 \div 3.24 \text{ m}^2 \text{ (sheet coverage)} = 0.944 \text{ sheets}$$

Rounding up to 1 sheet

As with any job or task, you will have to factor in a percentage of wastage due to factors such as cuts and damaged boards; an extra 10–15% would be needed as an estimate.

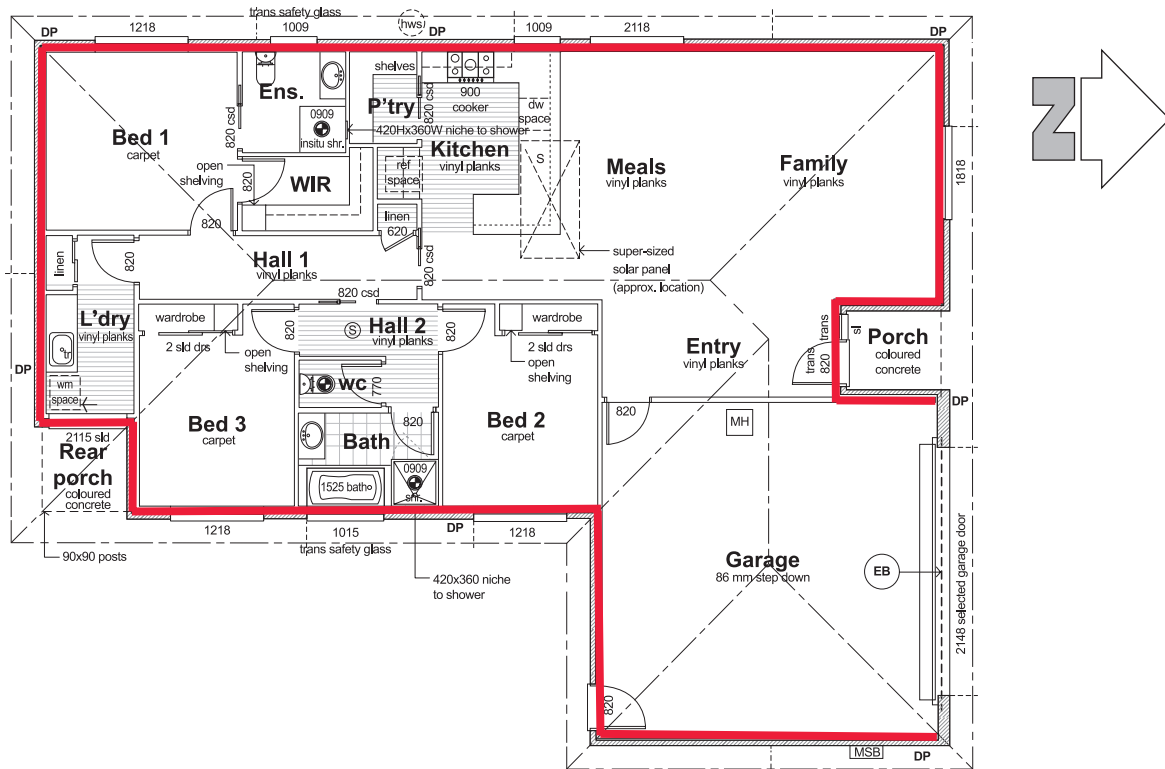
CHECK YOUR UNDERSTANDING

5. What does the term 'lining materials' refer to? What are three examples of lining materials?
6. Why would you factor in wastage when costing building materials such as timber flooring?

16.4 Perform external building calculations

When constructing a timber-framed house, you will need to be able to work out area (m²) and lineal metres (lm). This will help you when ordering materials and calculating the required amounts. Knowing the total area of the external walls of a building will help determine the cladding materials, sarking and insulation materials.

Using the house plan in Figure 16.5, you will be able to work out the external wall length of the L-shaped building. The example building is a brick veneer house with a timber frame all around the building—except for the placement of the double garage door. Figure 16.10 highlights in red the external timber wall frames.

Fig. 16.10 External timber frame (Appendix, amended drawing 02)

You can calculate the external timber wall frames as follows:

North wall: 4.960 m + front porch (1.980 m + 1.800 m + 1.980 m) = 10.72 m

South wall: 7.040 m + 1.910 m + 4.390 m = 13.340 m

East wall: 6.570 m + 8.970 m + 1.790 m = 17.330 m

West wall: 17.410 m

Total external timber wall frame:	10.720 m
	+ 13.340 m
	+ 17.330 m
	+ 17.410 m
	= 58.800 m

This calculation can now be used to work out the external area of the timber wall for sarking. Using the length $\times$ the wall height (Figure 16.2 has the overall external plate height: 2590 mm):

$$58.800 \text{ m (length)} \times 2.590 \text{ m (height)} = 152.292 \text{ m}^2$$

Sarking comes in different roll lengths, from 30 m to 60 m, and in widths of between 1.2 m and 1.5m. You will need to take into account that when wrapping a building in sarking, the material needs to overlap itself by 50 mm and should be taped on the overlap or have an overlap of 150 mm if it is not going to be taped. Always refer to the installation guide for the product that you are using. Sarking will need to be installed horizontally and will also need to be overlapped on the joins and at the start of a new roll.

In this example we need to know the length around the building that is being covered, the height of the external wall as well as the external wall area.

Length of external walls = 58.800 lm

Height of external walls = 2550 mm

Area = 152.292 m²

In this example we will be using the 1350 mm × 60 m roll of sarking (81 m²). Each roll of sarking is long enough to wrap around the building's timber frame once. By using the 1350 mm wide material we are able to run the material around the house twice, with a 150 mm overlap.

The first time around the house would have a coverage of 1200mm in width due to the 150 mm overlap, the second run would cover the remaining 1350mm without needing to be cut down in size and would complete the coverage of the external wall.

Cost of heavy duty 1350 × 60 m roll is approximately \$125 and in this example, we would require 2 rolls $2 \times \$125 = \250 . In this calculation, we didn't take into account any of the door or window openings, which is what we will use as our percentage of waste and cuts of the sarking.

If you were doing a rough estimation you could use the square metres of the building that is required to be covered. In this example the area that needs to be covered is 152.929 m². However, you will still need to consider the length of the area being covered and the overlap of the sarking. Using our above example, we know that we only need 2 rolls. The first roll around the house will have a 150 mm overlap; this reduces its square metre coverage from 81 m² to 72 m² ($1200 \times 60 = 72 \text{ m}^2$). As we only need to have 2 runs around the external frame the second run will have full coverage of 81 m².

$$\text{Coverage} = \text{First run } 72 \text{ m}^2 + \text{Second run } 81 \text{ m}^2 = 153 \text{ m}^2$$

Let's try another example using a different size sarking—let's say 1.2 m × 60 m (72 m²) at \$115 a roll, and this is the only size wrap available due to a shortage. This time we will overlap the material by 50 mm and tape the overlapped joints.

You will also need to purchase sarking tape, to tape all of the overlap. The tape costs approximately \$20 a roll and comes in 50 m lengths.

The first roll will wrap around the building and cover a width of 1150 mm, and the second roll will overlap the first roll. The 2 rolls are not enough to cover the full height of the external timber wall:

$$\text{First run } 1150 \text{ mm} + \text{Second run } 1150 \text{ mm} = 2300 \text{ mm}$$

A third run will need to be used with a 50 mm overlap of the second run. The third run will end up being a small strip:

$$\text{External wall } 2550 - (\text{First run } 1150 \text{ mm} - \text{Second run } 1150 \text{ mm}) = 250 \text{ mm}$$

$$\text{First run } 1150 \text{ mm} + \text{Second run } 1150 \text{ mm} + \text{Third run } 250 \text{ mm} = 2550 \text{ mm}$$

For this example, we would need to purchase 3 rolls of wrap and 3 rolls of sarking tape:

$$\text{Sarking rolls } (3 \times \$115) = \$345$$

$$\text{Sarking tape } (3 \times 20) = \$60$$

$$\text{Total cost } (\$345 + 60) = \$405$$

In the second example we could have saved money by overlapping the sarking by 150 mm and not taping the 50 mm joint. However, we would still have to cut in the third run.

From these examples we can see that the 1350 mm roll will give you sufficient overlap that doesn't need taping and only needs to be run twice around the house. Whereas the 1200 mm roll needs to be run three times around and uses more labour including cutting a small strip for the third run.

16.4.1 External cladding

Modern designs often use a range and mix of building materials as cladding material, incorporating brick, timber, render, glass, aluminium, cement sheet and many more.

Using Figure 16.5, we will calculate and determine the materials needed to clad the house in Baltic pine weatherboards instead of a brick veneer. We will calculate the lengths from the current location of

the stud walls as per the plan, even though they are set out for a brick veneer home. The main materials we need to calculate are:

- Baltic pine weatherboards
- weather stops.

Other considerations that we need to take into account so we can get the best estimation of materials required for weatherboarding the house is the eave drop. The eave drop is created from the overhang of the rafters, and in this example the house has a boxed eave. Using Figures 16.2 and 16.3 we are able to calculate the eave drop using the pitch of the roof and the distance of the plumb cut of the rafter back to the stud wall.

Figure 16.11 represents the eave drop. In the calculation we have two knowns, the distance from the plumb cut of the rafter which is 600 mm back to the stud wall and the pitch of the roof which is 22.5°. Technically, we know all of the angles, as the total degrees of a right-angled triangle will equal 180°.

Figure 16.12 represents the standard way of representing a right-angled triangle when using trigonometry. The capital letters represent the angles and the lowercase letters represent the sides.

Angle $A = 22.5^\circ$

$$B = 180^\circ - (A + C) = 180^\circ - (22.5^\circ + 90^\circ) = 68^\circ$$

$$C = 90^\circ$$

In trigonometry, 'SOH-CAH-TOA' is a mnemonic device used to remember the ratios of sine, cosine and tangent. It is a way of remembering which function to use when working out the sides of a triangle:

'SOH-CAH-TOA' $\sin = \text{opposite over hypotenuse}$
 $\cosine = \text{adjacent over hypotenuse}$
 $\text{tangent} = \text{opposite over adjacent}$

Using simple trigonometry to work out the eave drop from Figure 16.11, we need to find side 'a'. As side 'a' is opposite to the known angle (22.5° degrees) and is adjacent to the known side 'b' we will be using 'TOA':

$$\tan 22.5^\circ = \frac{\text{opposite}}{\text{adjacent}}$$

$$\tan 22.5^\circ = \frac{a}{0.600 \text{ m}}$$

To solve this equation, we will need to get the 'a' (the unknown) on its own; to do this we need to multiply both sides of the equation by the known side of 0.600 m. So, the equation will now look like this:

$$0.600 \text{ m} \times \tan 22.5^\circ = \frac{a}{0.600 \text{ m}} \times 0.600 \text{ m} \quad \text{by doing this it will cancel out the } 0.600 \text{ m on this side of the equation.}$$

What we are left with is:

$$a = 0.600 \text{ m} \times 22.5^\circ \tan$$

$$a = 0.2485 \text{ m}$$

Fig. 16.11 Eave representation in the form of a calculation

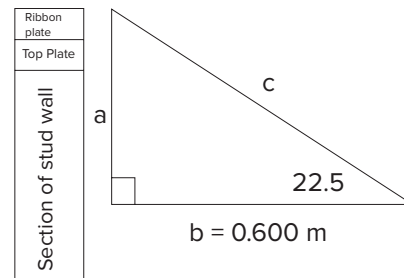
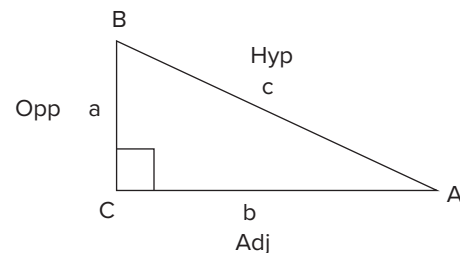


Fig. 16.12 Standard labelling of a right-angled triangle for trigonometry



TIP When using a scientific calculator, make sure you are in degree mode when doing these equations.

The eave drop will be close to 0.2485 m. To work out the actual external wall height that needs to be cladded will be:

$$\text{Stud wall height } 2.590 \text{ m} - \text{eave drop } 0.2485 \text{ m} = 2.3415 \text{ m}$$

The external wall height after the eave drop has been taken into consideration will be 2.3415 m. Knowing this measurement will help in developing the best estimation of materials required for the external cladding.

Baltic pine weatherboards are available in a variety of lengths, both short and long. At present, packs of pre-primed 175 mm round-edge profile boards come in lengths of 4.8 m (pack of 10) and are available at a cost of \$16.56 per length (or \$3.45 per metre).

Weather stops are also available in a range of lengths and timbers—best suited to this job are the 2.7 m pre-primed pine weather stops:

57 mm × 30 mm external weatherboard stops at \$23.20 per length

30 mm × 30 mm internal weatherboard stops at \$14.50 per length.

(All costings have been developed as close approximations for this example.)

By studying Figure 16.5 we can calculate how many weather stops we will need. At each change of direction, you will need a weather stop for the internal corners and external corners. The doors, windows and garage will have reveals for the weatherboards to butt into.

From Figure 16.13 we can determine that we will require 12 weather stops (4 internal and 8 external). In this instance, you will not need to consider wastage as weather stops are readily available in the size you require.

External weatherboard stops $8 \times \$23.20 = \185.60

Internal weatherboard stops $4 \times \$14.50 = \58.00

Total cost for weatherboard stops $\$185.60 + \$58.00 = \$243.60$

From our previous calculation for the building wrap, we know the timber frame covers 58.800 m and then we calculated the area of coverage of the wrap to the full height of the external stud wall. In this example for the coverage of the weatherboards we will need to calculate the area using this eave drop height:

$$\text{Length } 58.800 \text{ m} \times \text{eave drop } 2.3415 \text{ m} = \text{area of } 137.68 \text{ m}^2$$

The garage wall had not previously been considered in the calculations as it is a brick wall. In this calculation for weatherboards we will need to add the garage wall space to the overall timber frame wall area.

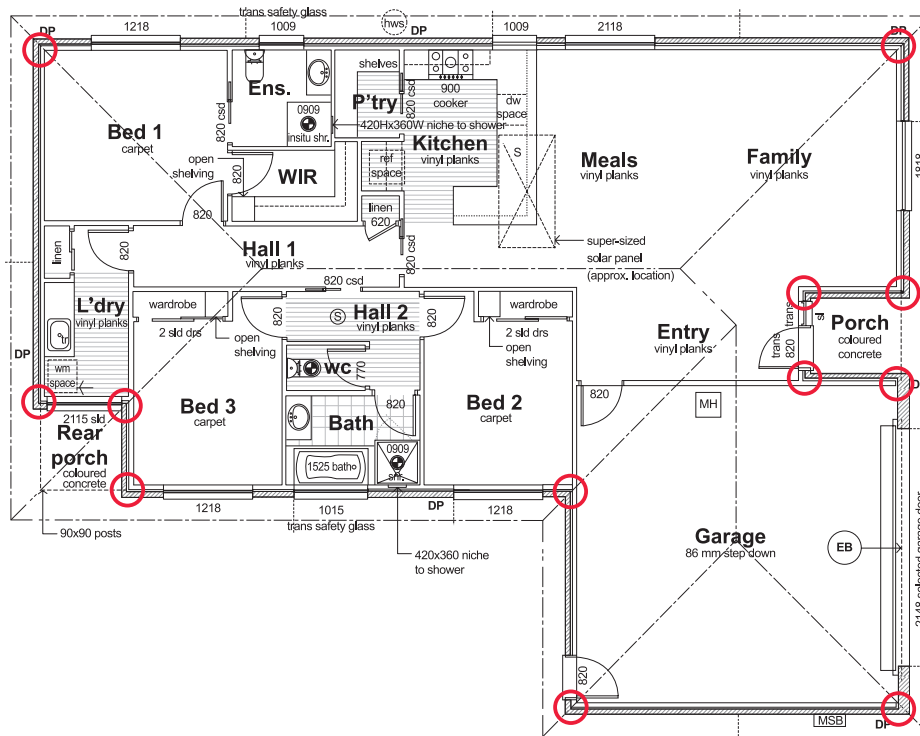
From the plans in Figure 16.5, the garage timber-framed wall will be 6.160 m to fit in between the frames that we have already calculated.

$6.160 \text{ m (length)} \times 2.3415 \text{ m (eave drop height)} = 14.42 \text{ m}^2$ (garage timber wall area)

Previous total: $137.68 \text{ m}^2 + 14.42 \text{ m}^2 = 152.10 \text{ m}^2$ (total external timber wall frame)

Using the window schedule in Figure 16.14, we can work out the area taken up by the windows, doors and garage door. The total area taken up by the doors, windows and garage is 35.07 m^2 (Fig. 16.14).

Baltic pine boards should have a minimum 25 mm overlap from board to board and should be nailed so that they do not penetrate the tip or thinner edge of the board beneath. (For more information on how to mark and install weatherboards, refer to Chapter 27, External cladding.)

Fig. 16.13 Weather stops, internal and external (Appendix, amended drawing 02)**Fig. 16.14** Door, window and garage area

Window schedule				
ID	Height	Width	Description	Area
W01	2100	1500	Glazed door w/highlight	3.15 m ²
W02	1800	1800	Slide over fixed window	3.24 m ²
W03	1200	1800	Sliding window	2.16 m ²
W04	1000	900	Sliding window	0.9 m ²
W05	1000	900	Sliding window	0.9 m ²
W06	2100	1800	Slide over fixed window	3.78 m ²
W07	2100	900	Door	1.89 m ²
W08	2100	1500	Sliding door	3.15 m ²
W09	1200	1800	Sliding window	2.16 m ²
W10	1000	1500	Sliding window	1.5 m ²
W11	1200	1800	Sliding window	2.16 m ²
W12	2100	4800	Garage	10.08 m ²
Total area				35.07 m ²

Note: Window schedule to be read in conjunction with elevations and energy report.

The total area of the house that requires weatherboards is:

$$152.10 \text{ m}^2 \text{ (total external timber wall frame)} - 35.07 \text{ m}^2 \text{ (area of doors, windows and garage)} \\ = 117.03 \text{ m}^2 \text{ of area that requires Baltic pine weatherboard cladding}$$

The calculation begins with working out how many weatherboards we need to cover the height of the timber frame. We also know that the minimum overlap is 25 mm, giving a coverage of 150 mm

per board. To work out the maximum coverage of a Baltic pine weatherboard, we need to subtract the minimum regulation coverage from the width of the board.

The Baltic pine weatherboards that we are using in this example are 175 mm in width.

The equation will be 175 mm (board) – 25 mm (regulation) = 150 mm maximum coverage.

Height of external timber frame:

$$2.3415 \text{ m} \div 150 \text{ mm} = 15.61 \text{ boards (rounded up to 16 full boards)}$$

To check our calculations and ensure we have the correct coverage, we can divide the height of the external frame by 17 boards and 18 boards:

$$2.3415 \text{ m} \div 15 = 156.10 \text{ mm does not conform to the minimum overlap}$$

$$2.3415 \text{ m} \div 16 = 146.34 \text{ mm correct, fits in with the minimum overlap}$$

Using this information, we can work out the coverage of the weatherboards per square metre.

The coverage of the Baltic pine weatherboards is 146.34 mm, and the square metre rate can be worked out to be how many 1 m boards at a height of 146.34 mm fit into a square metre:

$$1000 \text{ mm} \div 146.34 \text{ mm} = 6.833 \text{ boards per square metre (m}^2\text{)}$$

We can double-check this figure by working out if it fits in with our external wall height of 2.3415 m:

$$6.833 \text{ (boards per m}^2\text{)} \times 2.3415 \text{ m (external wall height)} = 16.00 \text{ boards}$$

The external walls that need to be cladded in weatherboards total 117.03 m², so the actual lineal metres of boards required is:

$$117.03 \text{ m}^2 \times 6.833 \text{ (boards per m}^2\text{)} = 799.66 \text{ lm (rounded to the full metre = 800 lm)}$$

The coverage of Baltic pine weatherboards is 800 lm. As with any job or task, you will have to factor in a percentage of wastage due to factors such as cuts and damaged boards, normally an extra 5-10%. In this example we will add an extra 5%.

$$800 \text{ lm} \times 5\% = 40 \text{ lm}$$

$$800 \text{ lm} + 40 \text{ lm} = 840 \text{ lm of Baltic pine}$$

For the purpose of this example, we are using pre-primed 175 mm round-edge profile in lengths of 4.8 m (pack of 10), which are available at a cost of \$16.56 per length (or \$3.45 per metre).

The cost of the material is:

$$840 \text{ lm} \times \$3.45 = \$2898.00$$

To calculate how many packs are required, we need to divide the total lineal metres by the pack meterage, which is:

$$4.8 \text{ m} \times 10 \text{ lengths}$$

$$= 48 \text{ lm per pack at a cost of } \$165.60 \text{ per pack (48 lm} \times \$3.45\text{)}$$

$$840 \text{ lm (required amount)} \div 48 \text{ lm per pack} = 17.50 \text{ packs of Baltic pine weatherboards.}$$

From this calculation, you may need to purchase to the nearest full pack, which would be 18 packs. This would increase the price to:

$$18 \text{ packs} \times \$165.60 = \$2980.80$$

However, you are able to purchase boards loose and not in a full pack.

CHECK YOUR UNDERSTANDING

- When developing an estimation for external cladding, why is it important to take the eave drop into consideration?

16.5 Perform timber frame calculations

Thanks to modern machinery, materials and processes and current construction techniques, houses can be built quicker and faster than ever before. This is especially true when it comes to wall and roof frames. The roof structure can be made in a factory and delivered on-site in the form of roof trusses and the same is possible with wall frames. Both are constructed off-site in a factory and delivered by truck to the site as pre-fabricated sections.

In this section we will use the set of plans in Figure 16.5 (pre-fab timber frame) and calculate the amount of timber needed to build the west wall on-site. We will also use the example timber-framing schedule in Figure 16.4b for our timber sizes. This calculation will be an estimation only.

(For the construction of timber walls, please refer to Chapter 18, Wall framing.)

The set of plans for the west wall (Fig. 16.5) shows that the stud wall is the overall length minus the brickwork and the cavity space, which will give us the total wall length.

The total length of the west wall is 17 710 mm and the plan shows that this includes brickwork, cavity space and the timber stud, which make up 240 mm on either end of the wall. Within that 240 mm is the 90 mm stud, which we need for our wall length.

$$240 \text{ mm} - 90 \text{ mm (stud)} = 150 \text{ mm (the leftover cavity space and brick work)}$$

The brickwork and cavity are at both ends of the wall, so we will need to take 300 mm from the total length of the wall to get the overall timber frame size.

$$17710 \text{ mm} - 300 \text{ mm} = 17410 \text{ mm}$$

The west wall is 17 410 mm (17.410 m) in length, and within that length are four windows that will require lintels, trimmer studs, jack studs and extra studs.

- 2 sliding windows at 1000 mm × 900 mm
- 1 sliding window at 1200 mm × 1800 mm
- 1 slide over fixed window 2100 mm × 1800 mm

Timber framing materials for studs come in standard sizes, from 2.4 m to 6 m (in increments of 300 mm).

TIP Consideration will need to be given to the weight of the wall to be lifted into place. This example uses top and bottom plates of 6 m; however, this can become very heavy when lintels and trimmers are added. You will also need to add more studs into the frame for the internal walls to connect to.

Figure 16.15 shows the components and the total cost of the west wall, which will be \$825.36. This price does not include any extras for wastage. As you can see from this example, many timbers and components make up a timber-framed wall, and it can be easy to miss something. Using a check sheet such as the one in Figure 16.14 will help you keep track of the components that have been included and any you may have missed.

16.5.1 Calculating the area of a section of roof

Roofs are constructed of many different shapes. In this example, we are using the broken hip roof from Figure 16.5. From a set of scale plans (Fig. 16.3), you will be able to obtain the area of the roof. In this example we will be using the west side of the house (Fig. 16.16) and working out how many sheets of corrugated iron/zinc will be needed to sheet that side of the house.

Fig. 16.15 West wall timber components

Timber component	Size	Quantity	Price	Cost	Notes
Top plate	90 mm × 45 mm	3/6.0 m	\$4.00 lm	\$72	
Bottom plate	90 mm × 45 mm	3/6.0 m	\$4.00 lm	\$72	
Studs	90 mm × 45 mm	40/2.7 m	\$4.00 lm	\$432	Stud spacing of 450 mm Double studs each end and at window openings
Lintel	90 mm × 35 mm	2/1.2 m	\$4.50 lm	\$10.80	2 sliding windows at 1000 mm × 900 mm F17 grade
Lintel	190 mm × 35 mm	2/2.1 m	\$10 lm	\$42	1 sliding window at 1200 mm × 1800 mm 1 slide over fixed window 2100 mm × 1800 mm F17 grade
Noggins	70 mm × 45 mm	7/2.4 m	\$3.70 lm	\$62.16	70 mm × 45 mm to be used as the size will not interfere when walls are being straightened
Sill trimmer	90 mm × 45 mm	3/2.4 m	\$4.00 lm	\$28.80	
Head trimmer	90 mm × 45 mm	3/2.4 m	\$4.00 lm	\$28.80	
Jack studs (combined top and bottom)	90 mm × 45 mm	8/2.4 m	\$4.00 lm	\$76.80	
Bracing					
			Total	\$825.36	

To estimate the area of the roof as accurately as possible, we will need some information from the plan view of the house as well as the elevation that has the roof lines (Fig. 16.17). The elevation will help in determining the finished height of the roof above the finished timber stud wall height.

This example will be a close estimation of the area of the west side of the house roof. The following measurements have been taken from the scale drawing (Figs 16.14 and 16.15) and from the plan view shown in Figure 16.5 (for comprehensively accurate measurements, you will need to do a site measurement):

- dimension of the main section of roof: 18.910 m × 10.150 m (including eaves)
- length along the ridge: 8.7 m
- hip ends (both sides): 7.4 m
- roof height from top plate to top of ridge: 2.0 m (from the elevation plans using a scale ruler)
- half-span of main section of roof: 4.452 m.

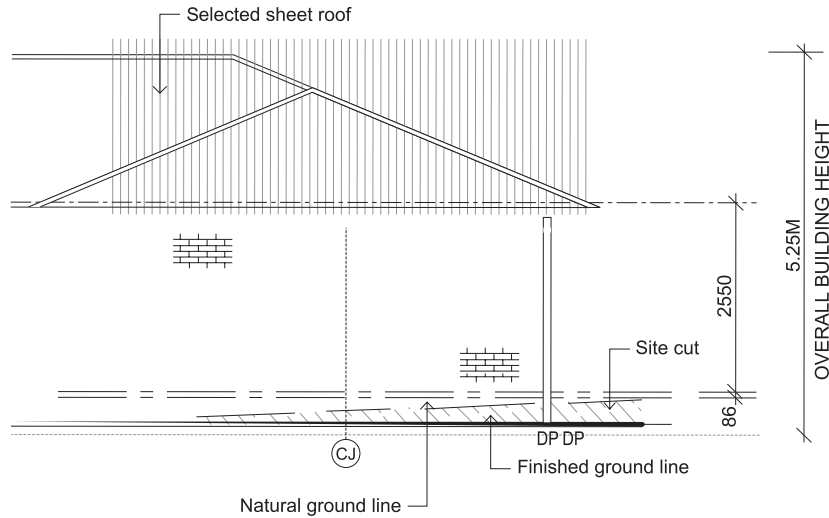
It is not possible from the plans to get the length from the ridge to the fascia. For this, you need to take into account the pitch of the roof, which is 22.5°. You will need to calculate this measurement using Pythagoras' theorem ($a^2 + b^2 = c^2$) or trigonometry (sin, cos, tan).

Using the measurements that we have gathered from the scale drawings, the roof height above the top plate is 2.0 m (Fig. 16.18) and the half-span of the main section of roof is 4.4525 m. The unknown in this equation is X, which is the distance from the top of the ridge to the top plate. When using Pythagoras' theorem, it is easier to convert your equation into metres to simplify the calculation; however, you can use millimetres—it isn't crucial.

The calculation below has been represented in metres and millimetres:

$$\begin{aligned}
 a^2 + b^2 &= c^2 \\
 a^2 (2.0 \text{ m} \times 2.0 \text{ m}) + b^2 (4.4525 \text{ m} \times 4.4525 \text{ m}) \\
 a^2 (2000 \text{ mm} \times 2000 \text{ mm}) + b^2 (4452.5 \text{ mm} \times 4452.5 \text{ mm}) \\
 &= 4.0 \text{ m}^2 + 19.824 \text{ m}^2 = 23.824 \text{ m}^2 \\
 &= 4\,000\,000 \text{ mm}^2 + 19\,824\,756.2 \text{ mm}^2 = 23\,824\,756.2 \text{ mm}^2 \\
 c^2 &= 23.824 \text{ m}^2 \\
 c^2 &= 23\,824\,756.2 \text{ mm}^2
 \end{aligned}$$

Fig. 16.17 Section of roof with dimensions scale 1:100



Another way to do this calculation is to use the principles of trigonometry. Using the half-span and the pitch of the roof:

- pitch of the roof is 22.5°
- half-span is 4.4525 m.

In Figure 16.19 we have a known 'side' and a known 'angle'. The side opposite the angle will be labelled as Opp (opposite), the long side will be the Hyp (hypotenuse) and the side next to the known angle is referred to as Adj (adjacent).

In this example, we are trying to find the length of side 'a'—this will give us an accurate height measurement from the top plate to the top of the ridge. The side that we are trying to find is on the opposite side to the known angle, and we have a known side, which is the adjacent. The formula that we will use is TAN (opposite over adjacent). The formula for this calculation will look like this:

$$\tan 22.5^\circ = \frac{a \text{ (opposite)}}{b \text{ (adjacent)}} = \frac{a}{4.4525 \text{ m}}$$

To solve this equation, we will need to get the 'a' (the unknown) on its own; to do this we need to multiply both sides of the equation by the known side of 4.4545 m. So, the equation will now look like this:

$$4.4525 \text{ m} \times \tan 22.5^\circ = \frac{a}{4.4525 \text{ m}} \times 4.4525 \text{ m}$$

To simplify it, the equation will now read:

$$a = 4.4525 \text{ m} \times \tan 22.5^\circ = 1.844 \text{ m}$$

Side a = 1.844 m

This calculation has shown that there is approximately 150 mm difference between reading the scale drawing (2 m) and using the plan measurements and roof pitch to determine the height of the ridge (1.844 m).

Fig. 16.18 Calculating the hypotenuse

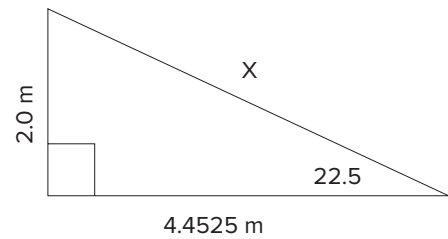
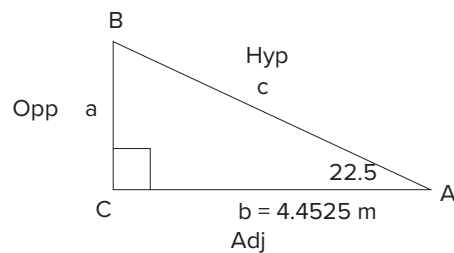


Fig. 16.19 Using trigonometry in roof calculations



We can also use trigonometry to work out the side of the hypotenuse, which is our hip side represented by the letter 'c' in Figure 16.19. The formula that we will use is COS (adjacent over hypotenuse):

$$\cos 22.5^\circ = \frac{b}{c} \quad \text{which is adjacent over hypotenuse } \frac{4.4525 \text{ m}}{c}$$

$$\cos 22.5^\circ = \frac{4.4525 \text{ m}}{c}$$

For this calculation to work, we will need to get the 'c' on its own. To do this, we will need to multiply both sides of the equation by 'c'. The equation will now read:

$$c \times \cos 22.5^\circ = \frac{4.4525 \text{ m}}{c} \times c$$

$$c \times \cos 22.5^\circ = 4.4525 \text{ m}$$

The next step is that we need to divide both sides by 'cos 22.5°' in order to get the 'c' by itself:

$$c \times \frac{\cos 22.5^\circ}{\cos 22.5^\circ} = \frac{4.4525 \text{ m}}{\cos 22.5^\circ} \quad \text{by dividing both sides by } \cos 22.5^\circ \text{ we are able to get the 'c' on its own.}$$

The final equation now reads as:

$$c = \frac{4.4525 \text{ m}}{\cos 22.5^\circ}$$

$$c = 4.4525 \text{ m} \div \cos 22.5^\circ = 4.819 \text{ m}$$

or we could have used sin to calculate the hypotenuse (opposite over hypotenuse)

$$\sin 22.5^\circ = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\sin 22.5^\circ = \frac{1.844 \text{ m}}{\text{hypotenuse}}$$

Similar to the above equation, we will need to get the hypotenuse (side c) by itself; following the same process the equation is developed as follows:

$$\text{Hypotenuse} \times \sin 22.5^\circ = \frac{1.844 \text{ m}}{\text{hypotenuse}} \times \text{hypotenuse}$$

$$\text{Hypotenuse} \times \sin 22.5^\circ = 1.844 \text{ m}$$

$$\text{Hypotenuse} \times \frac{\sin 22.5^\circ}{\sin 22.5^\circ} = \frac{1.844 \text{ m}}{\sin 22.5^\circ}$$

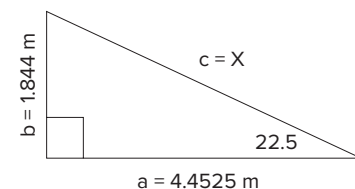
$$\text{Hypotenuse} = \frac{1.844 \text{ m}}{\sin 22.5^\circ}$$

$$\text{Hypotenuse} = 4.818 \text{ m}$$

As we continue, we will start to use the more accurate calculation from the plan measurements rather than relying on the scale.

Another way to calculate the rafter (hypotenuse) is to use Pythagoras' theorem. We now have two known sides (calculated using trigonometry): the half-span and the height of the ridge above the top plates of 1.844 m (Fig. 16.20).

Fig. 16.20 Known measurements



$$a^2(1.844 \text{ m} \times 1.844 \text{ m}) + b^2(4.4525 \text{ m} \times 4.4525 \text{ m}) = c^2$$

$$3.400 \text{ m}^2 + 19.824 \text{ m}^2 = 23.224 \text{ m}^2$$

$$c^2 = 23.224 \text{ m}^2$$

To get the length of X, we will need the square root of c^2 :

$$c^2 = \sqrt{23.224 \text{ m}^2}$$

$$c = 4.819 \text{ m}$$

As we can see using either trigonometry or Pythagoras' theorem our answers for side 'c' are both the same 4.819 m.

The ridge is calculated by taking the overall length of the wall and subtracting the half-spans from both ends (refer back Fig. 16.16):

$$17.410 \text{ m (plate to plate measurement)} - 4.4525 \text{ m} + 4.4525 \text{ m (half-span} \times 2) \\ 17.410 \text{ m} - 8.905 \text{ m} = 8.505 \text{ m}$$

The ridge length is 8.505 m.

TIP There are many ways to develop roofing timber member sizes, from roofing tables, ready reckoners and other publications. There are now apps available to help you with working out the ridge, rafters, hips and creepers etc.

From the measurements that we have calculated, we can now work out the length of the hips. We can use Pythagoras' theorem ($a^2 + b^2 + c^2$) to calculate the hips (Fig. 16.21).

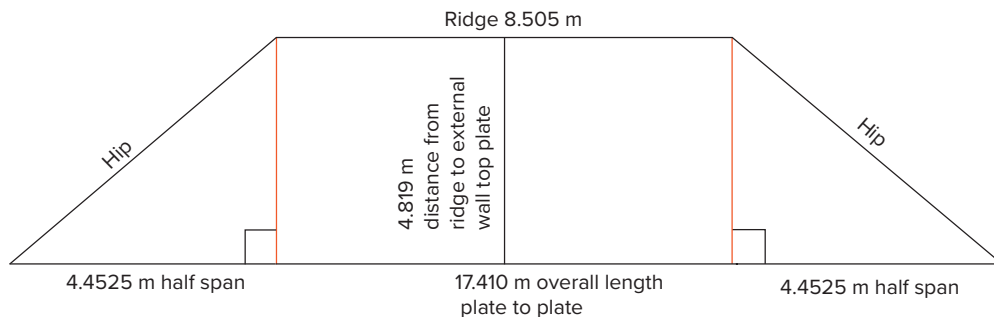
As we have two known side lengths—the half-span and the distance from the ridge to the top plate—we will be able to calculate the hypotenuse (hip):

$$a^2(4.4525 \text{ m} \times 4.4525 \text{ m half-span}) + b^2(4.819 \text{ m} \times 4.819 \text{ m distance from ridge to top plate}) \\ = 19.824 \text{ m}^2 + 23.222 \text{ m}^2 = 43.046 \text{ m}^2 \\ c^2 = 43.046 \text{ m}^2$$

To get the length of the hip we will need the square root of c^2 :

$$c^2 = \sqrt{43.046 \text{ m}^2} \\ c = 6.560 \text{ m}$$

Fig. 16.21 Geometry of west side of main roof

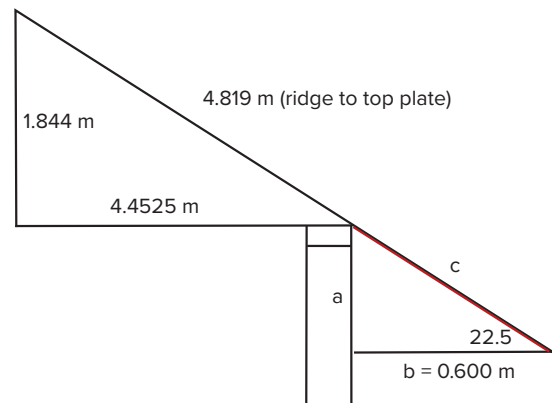


The hip lengths are therefore 6.560 m from the ridge to the top plate.

The calculations thus far have taken into account only the roof in line with the top plate and have not included the 600 mm eave. Figure 16.3 shows that the roof has a boxed eave, so we will also have to work out the boxed eave section. The eave is measured 600 mm out from the stud wall horizontally (refer back to Fig. 16.3). We will need to calculate the extra length of the roof sheets.

The calculations are the same as before. To work out 'a', we can use the principles of trigonometry and to find side 'c', or we can use Pythagoras' theorem (Fig. 16.22).

Fig. 16.22 Side view of roof including eave



To find 'a' we will need to use tan: $\text{TOA} = \tan \frac{\text{opposite}}{\text{adjacent}}$

$$\begin{aligned}\tan 22.5^\circ &= \frac{a}{0.600 \text{ m}} \\ a &= 0.600 \text{ m} \times \tan 22.5^\circ \\ a &= 0.2485 \text{ m}\end{aligned}$$

Side 'a' is 0.2485m or 248.5 mm.

Now that we have two known sides we can use Pythagoras' theorem to find 'c'. The equation that we use is $(a^2 + b^2 + c^2)$:

$$\begin{aligned}a^2(0.2485 \text{ m} \times 0.2485 \text{ m}) + b^2(0.600 \text{ m} \times 0.600 \text{ m}) &= c^2 \\ c^2 &= 0.4217 \text{ m}^2 & 0.0617 \text{ m}^2 + 0.36 \text{ m}^2 &= 0.4217 \text{ m}^2 \\ c^2 &= \sqrt{0.4217 \text{ m}^2} \\ c &= 0.649 \text{ m}\end{aligned}$$

Side 'c' is an extra 0.649 m that needs to be added to the length of the sheet:

$$\begin{aligned}4.819 \text{ m (rafter length to top plate)} + \\ 0.649 \text{ m} &= 5.468 \text{ m}\end{aligned}$$

Figure 16.23 shows all heights and lengths added together to visually represent the sheet length from the ridge to the fascia board.

With all of the measurements added together, we now just need to recalculate the hip length using Pythagoras' theorem (Fig. 16.24).

Calculating the hip:

$$\begin{aligned}c^2 &= a^2(5.468 \text{ m} \times 5.468 \text{ m}) + b^2(5.0525 \text{ m} \times 5.0525 \text{ m}) \\ c^2 &= 29.899 \text{ m}^2 + 25.527 \text{ m}^2 \\ c^2 &= \sqrt{55.426 \text{ m}^2} \\ c &= 7.444 \text{ m}\end{aligned}$$

Fig. 16.23 All calculations added together to give overall size of iron sheet

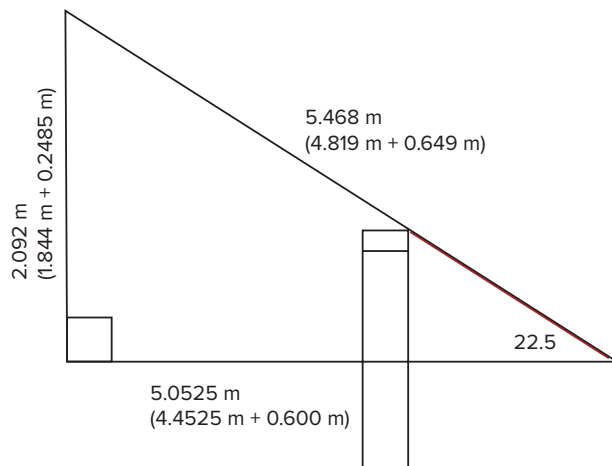
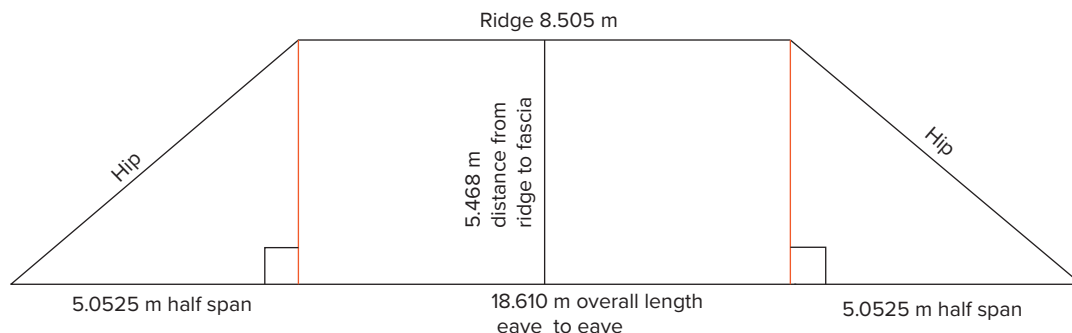


Fig. 16.24 West side of roof measurement including eave calculations



The area of the west roof can be calculated in sections: a rectangular section (Fig. 16.24) and two triangular sections (Fig. 16.25).

The rectangle section will be:

$$(\text{ridge}) 8.505 \text{ m} \times (\text{distance from the ridge to fascia}) 5.468 \text{ m} = 46.505 \text{ m}^2$$

The rectangular area is 46.505 m^2 .

The triangle sections can be worked out as two triangles, or combined to create a square:

The area of a triangle is $L \times W \div 2$:

$$(5.468 \text{ m} \times 5.0525 \text{ m}) \div 2 = 13.8135 \text{ m}^2 \text{ per triangular section (Fig. 16.25)}$$

Both triangles added together will be:

$$13.813 \text{ m}^2 + 13.813 \text{ m}^2 = 27.627 \text{ m}^2$$

Or this equation can be worked out by combining both triangular sections, as they are both right-angle triangles (Fig. 16.26):

$$5.468 \text{ m} \times 5.0525 \text{ m} = 27.627 \text{ m}^2$$

The total square metre area of this section of roof is:

$$27.627 \text{ m}^2 + 46.505 \text{ m}^2 = 74.132 \text{ m}^2$$

Knowing the square metres will help when estimating and costing roof cladding. Corrugated iron roofing sheets can be ordered in lengths from 1.0 m to 10 m (in increments of 100 mm) and can be custom cut to order. The sheets are a standard 850 mm wide with a coverage of 762 mm (1.5 ribs overlap).

Consideration needs to be made when estimating roof sheets for the fact that they will need to overhang the fascia to feed into the gutters and that they are close to the ridge. To estimate the number of sheets needed, we can look at the roof (Fig. 16.27) as a rectangle, with the hip ends being added together to create this shape.

Fig. 16.25 Triangular section of west section of roof

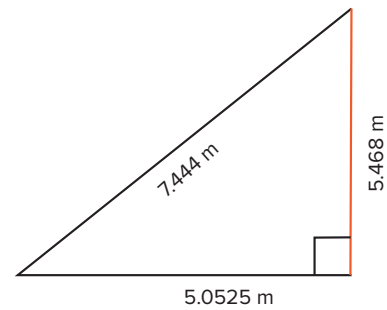


Fig. 16.26 Both triangular sections of west section of roof

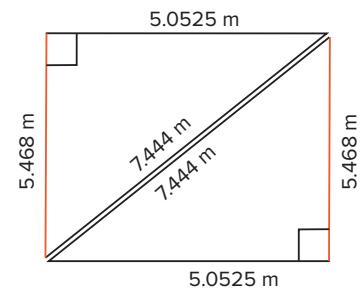
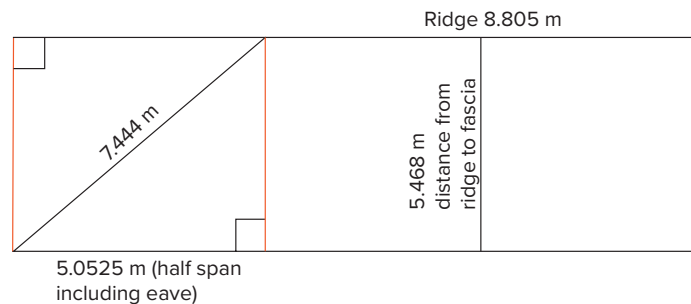


Fig. 16.27 Roof coverage for west side of house



The dimensions for our estimation are:

$$5.0525 \text{ m} + 8.805 \text{ m} = 13.857 \text{ m to be covered}$$

The coverage of a sheet is 762 mm, so to calculate the number of sheets required you will need to divide the length by the coverage:

$$13.857 \text{ m} \div 762 \text{ mm} = 18.18 \text{ sheets (rounded to the nearest full sheet} = 19)$$

As always, you will have to factor in a percentage of waste from cuts of 5–10%. For this estimation, we will require 20 corrugated sheets at a length of 5500 mm ($20 \times 5500 \text{ mm} = 110 \text{ m}$). The price per sheet can vary depending on the finish and thickness:

\$19.50 per metre for galvanised corrugated iron at 0.42 BMT (base metal thickness)

$$110 \text{ m} \times \$19.50 = \$2145$$

\$12.40 per metre for Zinalume at 0.42 BMT

$$110 \text{ m} \times \$12.40 = \$1364$$

\$30.00 per metre for Zinalume at 0.60 BMT

$$110 \text{ m} \times \$30.00 = \$3300$$

16.5.2 Roofing timbers

Hand-cut roofs are a rarity these days; however, that doesn't mean that they are not being constructed in the industry. Most new builds will have a truss roof (metal or timber) and be manufactured off-site and delivered on-site in components. Bulk builders will have a set of standard plans for their buildings and will have the walls and roof built quickly and affordably as a pre-fab wall and a truss roof. (For more information on truss roofs, please refer to Chapter 23, Erect roof trusses.)

A traditional roof has many parts. It can be as simple as a vaulted/cathedral roof, with main components comprising:

- ridge
- rafters
- collar ties
- fascia
- rafter ties.

A standard traditional house would have a roof constructed with:

- ridge
- common rafters/crown rafter
- collar ties
- purlins
- struts
- jack rafters
- creeper rafters
- hips and valleys
- ridge board
- top plate
- valley rafters
- fascia
- valley creepers.

A traditional roof would also be designed with the ceiling structure in mind, which would incorporate ceiling joists, hanging beams and strutting beams.

A simple example would be the construction of a hipped timber-framed roof. The size of the building in this example is 5 m × 3 m (overall frame dimensions), with a 30° pitch, 200 mm eave and a 450 mm rafter spacing. See Figures 16.28 and 16.29 for the timber members of the roof frame.

Fig. 16.28 Plan view of simple hip and gable roof

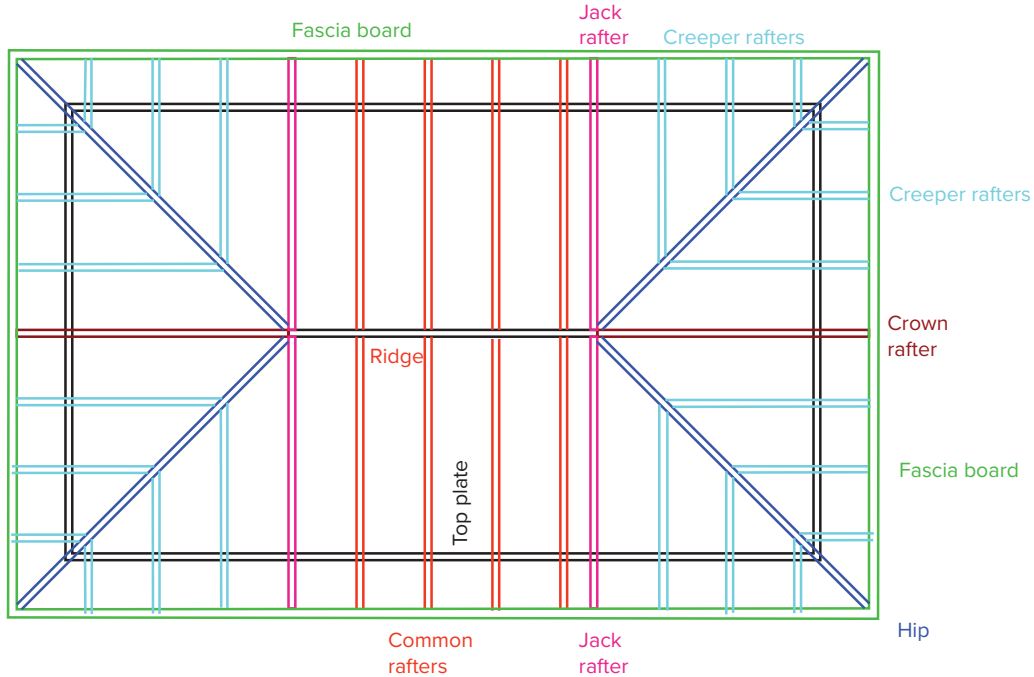


Fig. 16.29 Example of a costing sheet for a simple roof (prices are not indicative of the current market)

Member name	Section size	Material	Spacing	Stress grade	Cost
Common rafters (jacks and crown) and creeper rafters	120 mm × 45 mm	Pine	450mm c/c	MGP 10	\$9.42 1m
Ridge	140 mm × 45 mm	Pine		MGP 10	\$10.25 1m
Fascia	188 mm × 30 mm	Treated pine		H3	\$12.26 1m
Eaves/soffit	2.4 m × 1.2 m × 6 mm	Cement sheet			\$31.00 sheet

From the plan view of the roof and the measurements that have been provided, we can determine the lengths of the different timber members required to construct this simple roof. Remember, we are calculating and estimating timber lengths not cutting timbers to finished sizes (for further information on pitching a roof, please see Chapter 21, Pitched roofing).

The top plates are 5 m × 3 m; from this we can work out the half-span of the roof:

$$3000 \text{ mm} - 45 \text{ mm (rafter thickness)} = 2955 \text{ mm}$$

$$2955 \text{ mm} \div 2 = 1477.5 \text{ mm half-span}$$

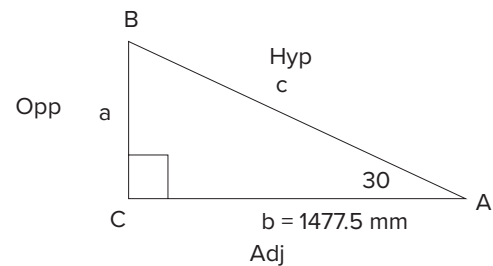
As there are hips at both ends of the roof, we can also calculate the length of the ridge. The ridge will be the overall length of the wall minus 2 × the half-span:

$$5000 \text{ mm} - (1477.5 \text{ mm} + 1477.5 \text{ mm}) = 2045 \text{ mm}$$

The ridge length is 2045 mm with the half-span being 1477.5 mm.

Using this information, we can now calculate the length of the rafters (Fig. 16.30).

Fig. 16.30 Calculating the unknown sides



Using the half-span as a known measurement and the pitch of the roof, which is 30°, we can use trigonometry to calculate 'a' (height of ridge) and side 'c' (hypotenuse/rafter length to top plate):

$$\tan 30^\circ = \frac{(\text{opposite})}{(\text{adjacent})}$$

$$\tan 30^\circ = \frac{a}{1477.5 \text{ mm}} \quad \text{to get 'a' on its own we need to multiply both sides by the adjacent 1477.5 mm}$$

$$a = 1477.5 \text{ mm} \times \tan 30^\circ = 853.00 \text{ mm}$$

$$\text{Side a} = 853.00 \text{ mm}$$

The height of the bottom of the ridge is 853.00 mm.

To work out 'c', we can use Pythagoras' theorem as we now have two side measurements ($a^2 + b^2 + c^2$):

$$c^2 = \text{side a}^2(0.853 \text{ m} \times 0.853 \text{ m}) + \text{side b}^2(1.4775 \text{ m} \times 1.4775 \text{ m})$$

$$c^2 = 0.727 \text{ m}^2 + 2.183 \text{ m}^2 = 2.91 \text{ m}^2$$

$$c^2 = \sqrt{2.91 \text{ m}^2}$$

$$c = 1.705 \text{ m}$$

The length from the ridge board to the top plate is 1.705 m.

The next step is to work out the length of the rafter from the ridge to the eave (Fig. 16.31) and we will have to calculate side 'a' and 'c' of the boxed eave.

$$\tan 30^\circ = \frac{a}{200 \text{ mm}} \quad \text{both sides need to be multiplied by 200 mm to get 'a' on its own.}$$

$$a = 200 \text{ mm} \times \tan 30^\circ = 115.47 \text{ mm}$$

To work out 'c', we can use Pythagoras' theorem as we now have two side measurements—($a^2 + b^2 + c^2$):

$$c^2 = (0.11547 \text{ m} \times 0.11547 \text{ m}) + (0.200 \text{ m} \times 0.200 \text{ m})$$

$$c^2 = 0.01333 \text{ m}^2 + 0.04 \text{ m}^2 = 0.05333 \text{ m}^2$$

$$c^2 = 0.05333 \text{ m}^2$$

$$c = \sqrt{0.05333 \text{ m}^2}$$

$$c = 0.2309 \text{ m} \quad \text{or} \quad 230.9 \text{ mm}$$

The length from the top plate to the plum cut of the rafter is 230.9 mm (Fig. 16.32).

Figure 16.31 shows all heights and lengths added together to visually represent the rafter length; however, this measurement does not take into account plumb cuts in relation to the actual length of timber required to create the rafter.

Fig. 16.31 Calculating approximate length of rafter to construct eave

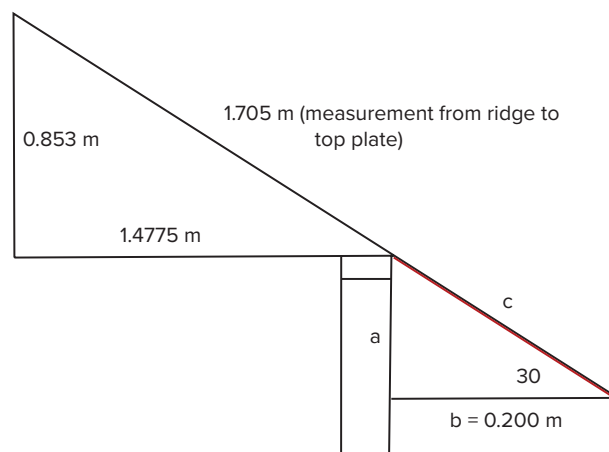


Fig. 16.32 Calculated length of rafter

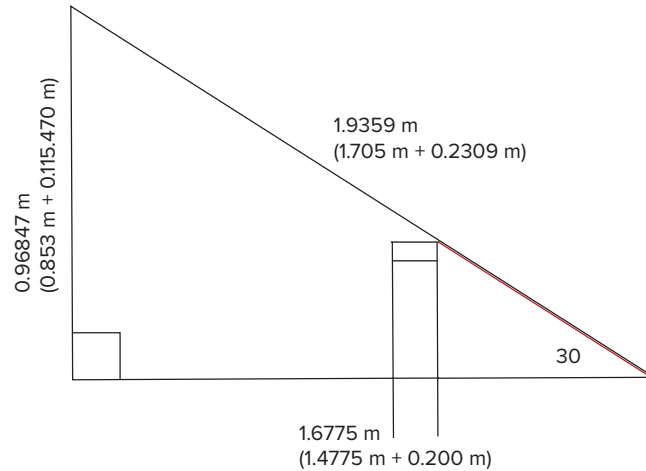
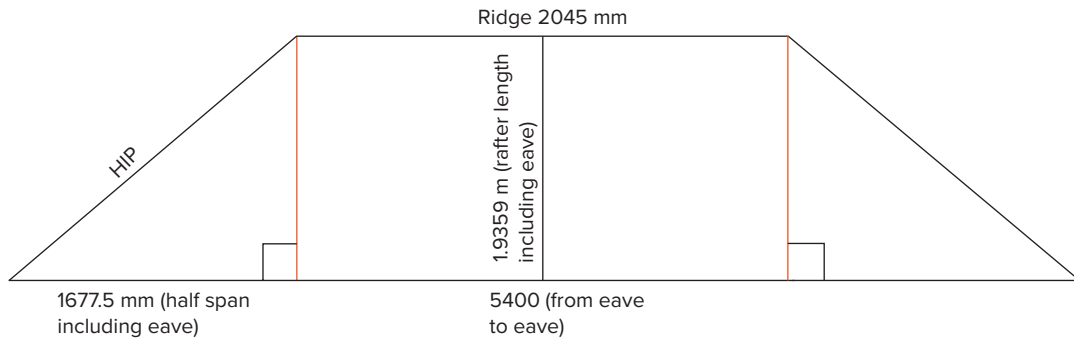


Fig. 16.33 Development of roof measurements



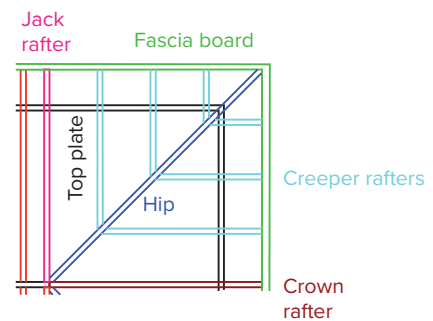
Now that we have the distance from the ridge to the fascia board, we can calculate the approximate length of the hips using Pythagoras' theorem:

$$\begin{aligned}
 a^2 + b^2 + c^2 \\
 a^2(1.6775 \text{ m} \times 1.6775 \text{ m}) + b^2(1.9359 \text{ m} \times 1.9359 \text{ m}) &= c^2 \\
 2.814 \text{ m}^2 + 3.747 \text{ m}^2 &= c^2 \\
 c^2 &= 6.561 \text{ m}^2 \\
 c^2 &= \sqrt{6.561 \text{ m}^2} \\
 c &= 2.561 \text{ m}
 \end{aligned}$$

The length of the hip is 2.561 m ; however, this measurement does not take into account plumb cuts in relation to the actual length of timber required to create the rafter. These are considerations that will need to be taken into account when ordering materials.

As we know the space where the creeper rafters are located and that they are spaced at 450 mm centres, we are able to calculate each creeper rafter (Fig. 16.34). The calculations will use the pitch of the roof and a 450 mm reduction from the jack rafter for each creeper rafter. We will also have to add the overhang of the rafter, which we worked out to be 230.90 mm .

Fig. 16.34 Section of jack rafters



To work out our spacing for the creepers we will work back from the jack rafter. The following measurements are for locating the creepers on the top plate in relation to the jack rafters:

$$\text{Half-span } 1477.5 + 45 \text{ mm} = 1522.50$$

$$\text{Creeper 1} = 1522.50 \text{ mm} - 450 \text{ mm} = 1072.50 \text{ mm}$$

$$\text{Creeper 2} = 1072.50 \text{ mm} - 450 \text{ mm} = 622.50 \text{ mm}$$

$$\text{Creeper 3} = 622.50 \text{ mm} - 450 \text{ mm} = 172.50 \text{ mm}$$

The trigonometry equation used in the following example will be $\cos = \frac{\text{adjacent}}{\text{hypotenuse}}$. Creeper rafter 1 is represented by side 'c' (Fig. 16.35) and is calculated as follows:

$$c = 1072.50 \text{ mm} \div \cos 30^\circ = 1237.83 \text{ mm}$$

Creeper rafter 1 will need the 230.90 mm overhang added to its length:

$$1237.83 \text{ mm} + 230.90 \text{ mm (overhang)} = 1468.73 \text{ mm}$$

Creeper rafter 2 is represented by side 'c' (Fig. 16.36) and is calculated as follows:

$$c = 622.50 \text{ mm} \div \cos 30^\circ = 718.80 \text{ mm}$$

Creeper rafter 2 will need the 230.90 mm overhang added to its length:

$$718.80 \text{ mm} + 230.90 \text{ mm} = 949.70 \text{ mm}$$

Creeper rafter 3 is represented by side 'c' (Fig. 16.37) and is calculated as follows:

$$c = 172.50 \text{ mm} \div \cos 30^\circ = 199.18 \text{ mm}$$

Creeper rafter 3 will need the 230.90 mm overhang added to its length:

$$199.18 \text{ mm} + 230.90 \text{ mm} = 430.08 \text{ mm}$$

At this point we are only at a point of ordering materials and not working out exact roofing timber member sizes, plumb cuts, birdmouths, bevels, etc. A set of creeper rafters comprise approximate lengths of:

- 1468.73 mm
- 949.70 mm
- 430.08 mm.

These lengths can be added together to work out the length of material required to do each section (eight sections):

$$1468.73 \text{ mm} + 949.70 \text{ mm} + 430.08 \text{ mm} = 2848.51 \text{ mm} \text{ or } 2.848 \text{ m}$$

Taking into account cuts and wastage, the creeper rafters could be all cut from a 3.3 m length of timber. Traditionally, you would not have made these calculations—you would have simply added a pair of rafters per section to the estimation and used them as creeper rafters. This has been done simply to show the method and practice of using simple trigonometry and Pythagoras' theorem.

Cement sheet for the eaves will be calculated by working out the area that needs to be covered. The overall size of the eaves is:

$$(5.4 \text{ m} + 5.4 \text{ m} + 3.0 \text{ m} + 3.0 \text{ m}) \times 0.200 \text{ m} = 3.36 \text{ m}^2 \text{ of coverage}$$

Fig. 16.35 Calculating creeper 1

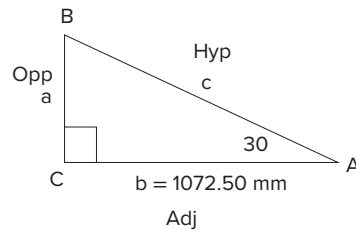


Fig. 16.36 Calculating creeper 2

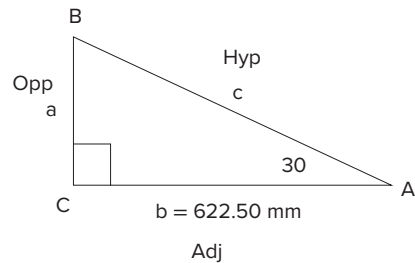
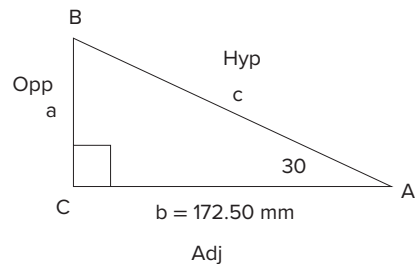


Fig. 16.37 Calculating creeper 3



A standard 2400 mm × 1200 mm × 6 mm sheet has a coverage of 2.88 m², so for this example we would need to order two sheets (this includes cuts and wastage).

Materials have to be ordered in lengths, so we can add a column to our sheet for 'Material length', taking into account 5–10% for wastage (Fig. 16.38).

Fig. 16.38 Costing sheet with timber member lengths

Member name	Section size	Material	Material length	Total lineal metres	Spacing	Stress grade	Cost	Totals
Common rafters (jacks and crown) and creeper rafters	120 mm × 45 mm	Pine	15 @ 2.4 m 9 @ 3.3 m	36 m + 29.7 m = 65.7 lm	450 mm c/c	MGP 10	\$9.42/lm	\$618.89
Hips	140 mm × 45 mm	Pine	4 @ 3.0 m	12 lm		MGP 10	\$10.25/lm	\$123.00
Ridge	140 mm × 45 mm	Pine	1 @ 2.4 m	2.4 lm		MGP 10	\$10.25/lm	\$24.60
Fascia	188 mm × 30 mm	Treated pine	2 @ 6.0 m 2 @ 3.6 m	19.2 lm		H3	\$12.26/lm	\$235.39
Eaves/soffit	2.4 m × 1.2 m × 6 mm	Cement sheet	2 sheets				\$31.00/sheet	\$62.00
						Total cost		\$1063.88

CHECK YOUR UNDERSTANDING

8. What is the purpose of using a components checklist?

16.6 Calculate volume

The L-shaped house in Figure 16.5 has a double garage. From the plans, we can see that the dimensions are 6580 mm × 6570 mm (infill slab).

To order concrete for this space, you will need to calculate the square metres to be covered. Volume is calculated by length × width × depth (L × W × D) and ordered in cubic metres, m³. Concrete can be ordered in a variety of strengths depending on its application. A high MPa (megapascal is a measure of the compressive strength of concrete) will cost more. The average cost of concrete at present is between \$200 and \$300 per m³. Typically, a residential garage requires a depth of 100 mm, so the equation will look like this:

$$(L) 6580 \text{ mm} \times (W) 6570 \text{ mm} = 43.23 \text{ m}^2$$

$$43.23 \text{ m}^2 \times 0.100 \text{ m (D)} = 4.32 \text{ m}^3$$

As with all estimations, you will need to add at least 5% for wastage: $4.32 \text{ m}^3 \times 5\% = 0.216 \text{ m}^3$.

The order would be: $4.32 \text{ m}^3 + 0.216 \text{ m}^3 = 4.536 \text{ m}^3$.

This figure will need to be rounded up to the nearest 0.2 m³ due to concrete incremental delivery volumes.

The total order would be 4.6 m³.

The cost of the garage floor at the higher end of the cubic price would be:

$$\$300 \times 4.6 \text{ m}^3 = \$1\,380.00$$

Other materials that are ordered in volume (m³) include sand, soil, woodchips, etc. At times it can be confusing as most people think of volume as a liquid measurement. However, it is a three-dimensional measurement, and includes cubic metres.

CHECK YOUR UNDERSTANDING

9. What are three examples of construction materials that can be ordered by volume?

Student research

A handy reference for a tradesperson is www.blocklayer.com. Explore this website and see how it could help you with your calculations and estimations.

End-of-chapter activity

As part of your training, you will be required to prepare a detailed list of materials and calculate quantities of each material for:

- wall and roof framing
- internal lining and flooring
- external cladding and roofing.

AUSTRALIAN BUILDING CODES AND STANDARDS

**AS/NZS
4200.2:2017**
Pliable building
membranes and
underlays

AS 1684—2010
Residential timber-
framed construction

**National
Construction
Code (NCC)**

Tradie talk—The only way to learn maths, is to do maths

Chapter 17

Subfloor and flooring

Learning Objectives

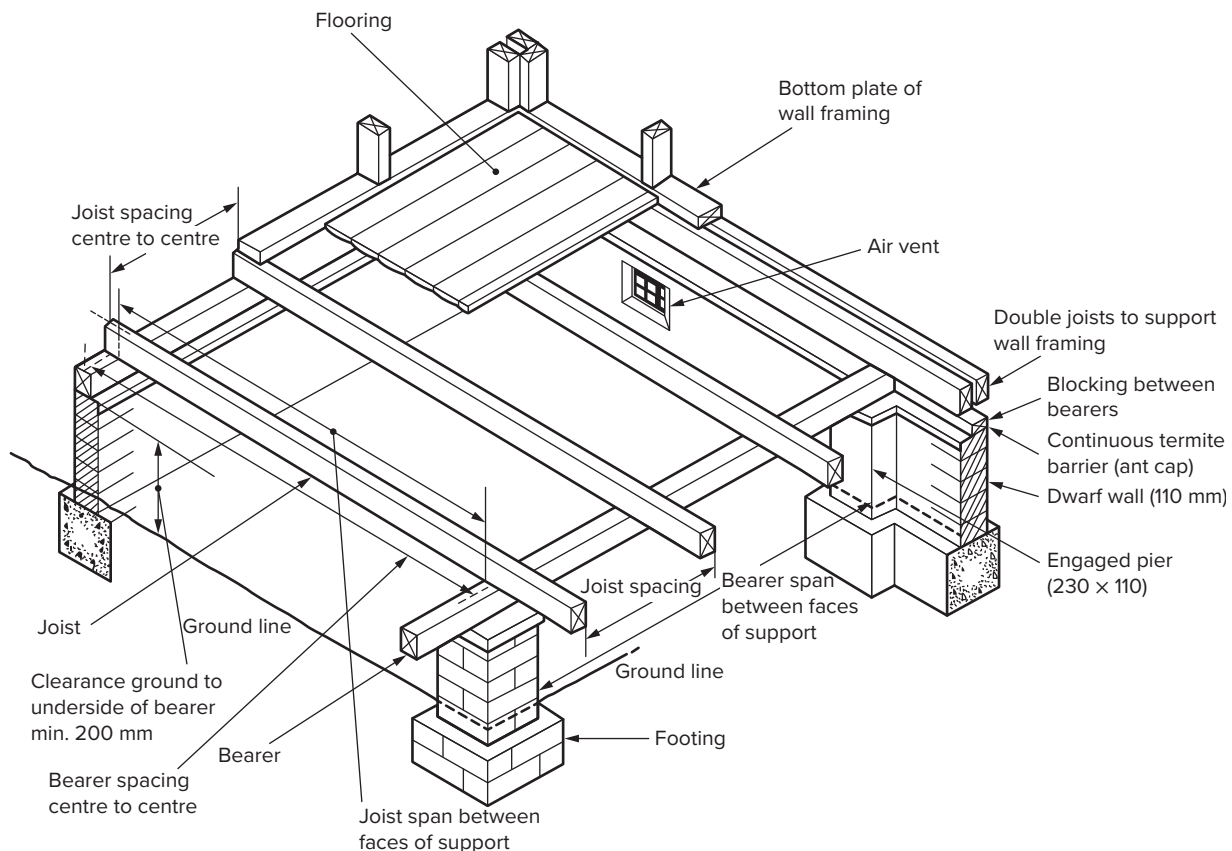
- LO 17.1 Identify types of flooring**
- LO 17.2 Know about brick base structures**
- LO 17.3 Install posts and stumps**
- LO 17.4 Install bearers and joists**
- LO 17.5 Lay strip flooring**
- LO 17.6 Lay fitted floors**
- LO 17.7 Install platform floors (using strip flooring)**
- LO 17.8 Lay sheet flooring**
- LO 17.9 Lay wet area flooring**
- LO 17.10 Know about alternative subfloor materials and their uses**
- LO 17.11 Identify the building envelope**
- LO 17.12 Identify types of underfloor insulation**
- LO 17.13 Construct decks and balconies**

Introduction

In this chapter you will learn about how the **subfloor** is the first part of any timber-framed house to be constructed. The subfloor is what the rest of the structure is built upon. All of the loads are transferred to the foundations through the subfloor framing and it can be a conduit for insect attack or damp infiltration to the rest of the building. It is important that the subfloor is constructed level and square and made of suitable materials to deal with the prevailing ground conditions. Mistakes made in the construction of the subfloor can cause problems later in the build that can be hard to overcome.

The subfloor framing to timber-framed domestic buildings, as shown in Figure 17.1, consists of bearers supported clear of the ground on piers, stumps or dwarf walls. Running at right angles to the bearers, and supported by them, are joists that in turn support the actual flooring.

Fig. 17.1 Subfloor framing



The spacing of bearers and joists is taken as the centre-to-centre distance apart; however, when setting out a number of members of equal thickness in practice, it is more convenient to adopt the 'in and over' method of spacing, which is the same distance as centre to centre. 'In and over' is the practice of measuring from the face of one member, over its thickness, and to the face of the next similar member. The span of the bearers and joists is the face-to-face distance between points of support.

Substructure design and loading

The substructure holds up the entire building and all loads are transferred through it to the foundation (ground). An important part of the design process is ensuring that the substructure is strong enough to support all of the various types of loads it could potentially encounter throughout the life of the building. These include:

- **Dead loads**—permanent, static or structural elements that impose stress on the structure. Such loads include atmospheric loads on the roof structure, mass of the individual components of the structure, heavy furniture items that never move, appliances, baths and spas etc.
- **Live loads**—loads that arise from the use of the building or structure. These include people, furniture, floor coverings etc.
- **Concentrated loads**—loads applied to a localised part of a structure. These include loads being supported by a lintel and which the jamb studs in turn support. The point where the jamb studs are supported by the subfloor is considered a point load. Therefore, additional support is required to transfer that point load from the jamb studs efficiently to the foundation.

When designing the substructure of the building, the loading needs be accounted for, so the substructure members are adequately sized to take all of the loads that will be encountered and transfer them efficiently to the foundation without failing. AS 1684 Residential timber-framed construction is used to determine the sizes of the structural timber members in a typical building. Additionally, an engineer can design the structural members if AS 1684 is not suitable.

17.1 Identify types of flooring

Flooring can be strip flooring made up of individual tongued and grooved boards varying from approximately 75 mm to 150 mm in width, or sheet flooring manufactured from special grades of particleboard or structural plywood, in sheets of up to 3600 mm × 900 mm.

There are two procedures that can be followed for laying flooring to the joists.

17.1.1 Fitted floor

The **floor is fitted** to each room after the wall framing has been erected (Fig. 17.2). In this case it is necessary to provide double joists under all external and internal walls that run parallel to the floor joists. These are spaced to provide support for the wall framing and for the ends of the floorboards. The flooring is not finally laid until the building has been made watertight.

17.1.2 Platform floor

This type of floor is laid over the whole area of the floor joists before the wall framing is erected (Fig. 17.3). Double joists are provided under external load-bearing walls that run parallel to the floor joists, but for the remainder of the building, joists may be spaced without reference to the positioning of the walls. An exception is in the case of particleboard flooring where a single joist is required under all load-bearing walls that run parallel to the floor joists.

Platform floors can be laid quickly; they provide a convenient and safe working platform during the construction process. Generally, manufactured sheet flooring is used that has a water-resistant treatment; however, construction should proceed promptly as the flooring cannot be exposed to the weather for long periods.

Before discussing the timber flooring members in greater detail, we should consider the footings and supporting structure relevant to timber-framed buildings, sheathed externally with weatherboard, fibre cement products or other lightweight cladding materials. (Refer to Chapter 13, Site setting out and basic levelling, for information on setting out the site.)

Fig. 17.2 Fitted floor

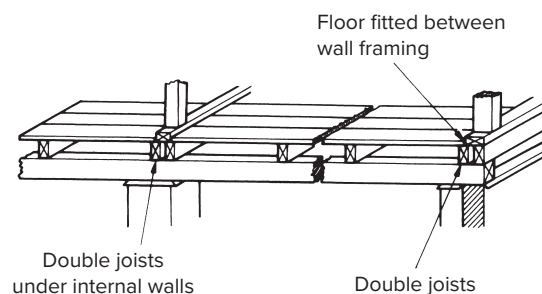
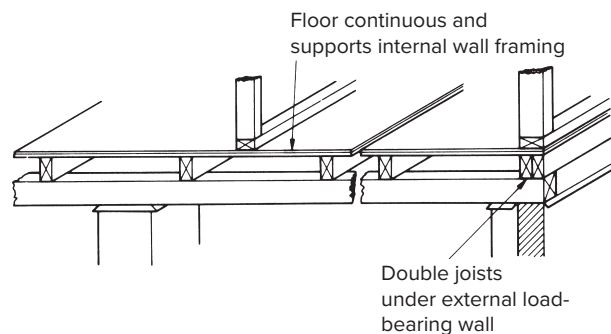


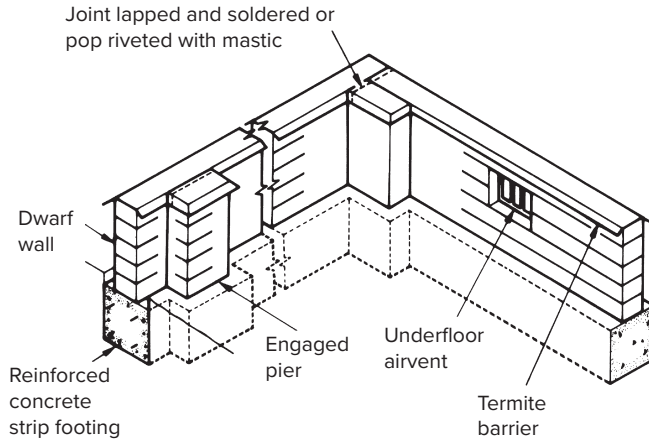
Fig. 17.3 Platform floor



CHECK YOUR UNDERSTANDING

1. Describe, with a sketch if necessary, the difference between a fitted floor and a platform floor.

Fig. 17.4 Base structure



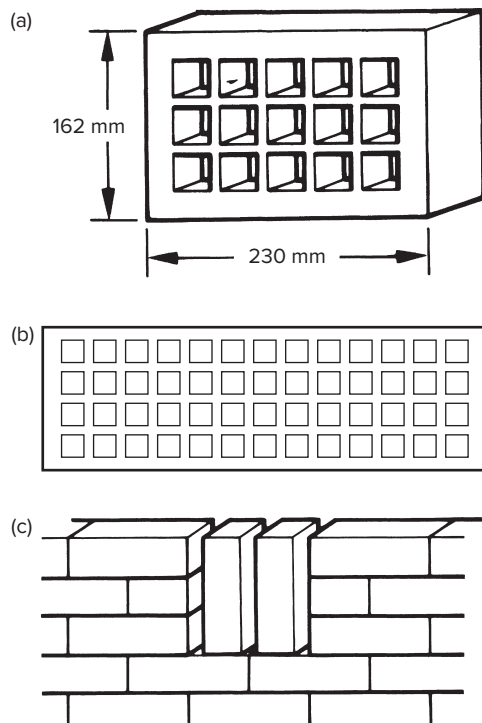
17.2 Know about brick base structures

Foundation walls constructed of brick are 110 mm thick and are strengthened by having engaged piers, 230 mm × 110 mm, bonded or tied to them at 1800 mm centres to support bearers (Fig. 17.4). Footings for a base brick structure are constructed from reinforced concrete. Between external foundation walls, bearers can be supported by isolated piers or **stumps**.

Foundation walls and piers must be built to sufficient height to allow for adequate clearance between the ground and the underside of the bearer.

TIP For dimensions for strip footing and reinforcement requirements, please refer to AS 2870: 2011 Residential slabs and footings.

Fig. 17.5 Air vents: (a) terracotta; (b) Acme-type vent; (c) open brick



17.2.1 Underfloor ventilation

The space between the ground and the underside of the floor must be thoroughly ventilated; failure to provide adequate measures can lead to serious problems. Damp, ill-ventilated places can become a haven for termites or fungal growth, and flooring boards can become distorted due to the absorption of a large amount of available moisture under the house.

Any tendency for excessive underfloor dampness must be corrected to the satisfaction of the local government authority; this can usually be provided by adequate drainage. Regulations that specify the amount of ventilation may vary in different areas.

Figure 17.5 shows three methods of providing ventilation in a base brick structure.

17.2.2 Termite barriers

Termite barriers, or ant caps as they are sometimes known, are made of galvanised steel or other approved metal, and are laid over all foundation walls, piers and stumps at the level of the underside of the floor timbers (Fig. 17.4).

Ant capping must project 40 mm beyond the internal face of the wall and be turned down at an angle of 45° (Fig. 17.6). All joints must be lapped and soldered, or otherwise sealed in an approved manner.

17.3 Install posts and stumps

Sawn timber posts placed on timber sole plates is one method used to support bearers in areas where termite attack is not a serious threat (Fig. 17.7). Posts and sole plates must be of a durable timber species as they are in contact with the ground. Suitable species are ironbark, white cypress pine, red gum or treated radiata pine that has been pressure preservative impregnated.

Traditionally, timber stumps are 100 mm × 100 mm, set a minimum of 450 mm into the ground and at a maximum height of 1200 mm above the ground. Sole plates can be 300 mm × 150 mm × 38 mm or as specified.

For information regarding timber stumps, posts and sole plates, please refer to AS 1684 Residential timber-framed construction. The soil type will need to be established before designing the footing structure.

Where the height of posts and stumps exceeds 1200 mm, bracing is required (Fig. 17.8). Refer to AS 1684 for the requirements. It is usual trade practice to space stumps 1200 mm apart along the length of the bearers, with bearers spaced 1800 mm apart, centre to centre.

17.3.1 On-site setting out of timber stump/posts

The procedure outlined for measuring and levelling in Chapter 13 remains constant and it is again suggested that it is sound practice to set out the main rectangle of the building by measuring first from the side boundary, often the most critical dimension to be observed.

17.3.1.1 Step 1

Establish the side boundary and, if necessary, set up a string line.

17.3.1.2 Step 2

Measure from the front boundary and locate the approximate position of the building. Set up hurdles parallel to the side boundary and at the required distance for the side of the building nearest to the boundary.

Fig. 17.6 Ant capping—continuous

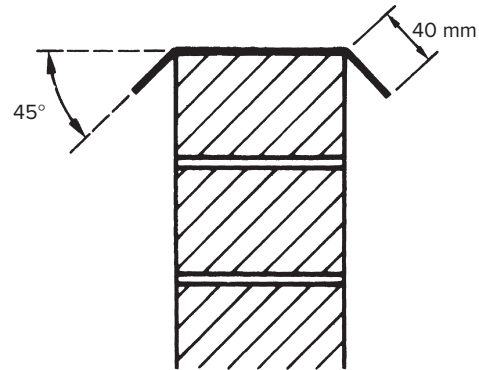


Fig. 17.7 Timber stump and bearer

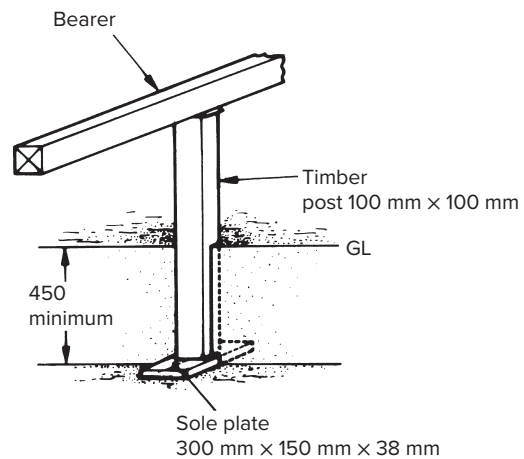


Fig. 17.8 Corner bracing

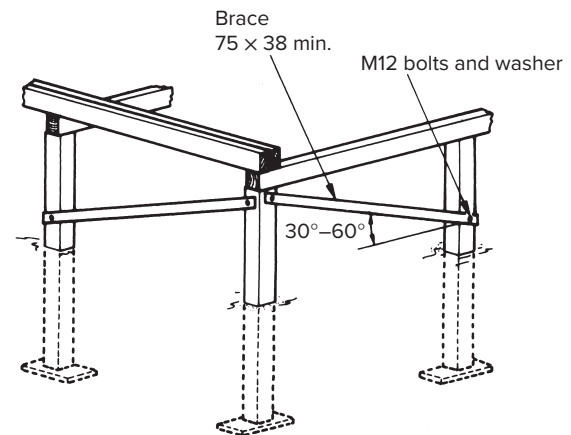
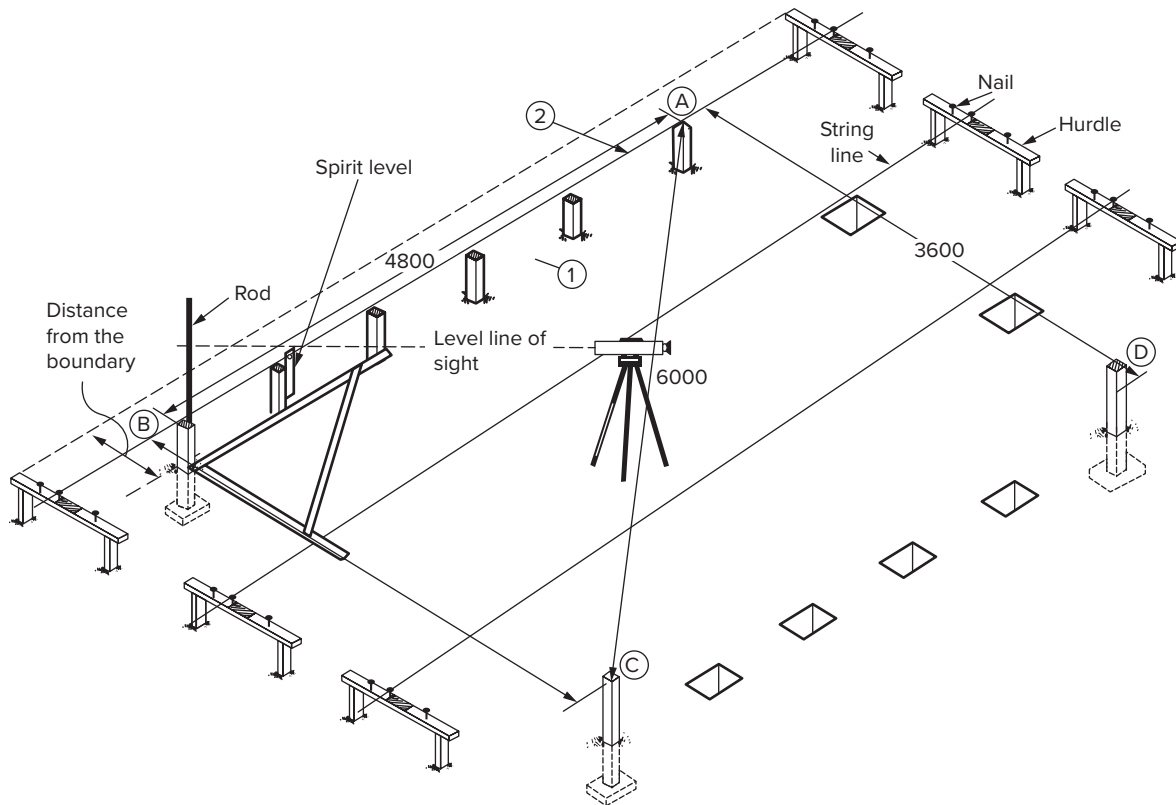
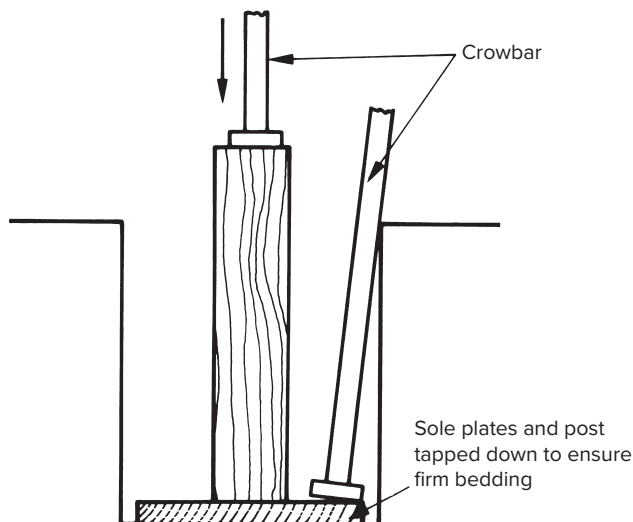


Fig. 17.9 Site set-out**17.3.1.3 Step 3**

Measure back from the front boundary to locate the position of the front of the building set-up, two more hurdles parallel to the front boundary. At this point a square corner will need to be established. Add the depth of the building in order to locate the back of the building accurately. Set up all required hurdles to establish the perimeter of the building (eight in total for Figure 17.9). Set up two extra hurdles to locate the centre row of stumps (refer to Figure 17.9); the string line for the centre row of stumps should be offset 50 mm from the centre line of the stumps. This will mean the string line will be running along the side of the stumps and not on the top.

Ensure all hurdles or profiles are set up to the height of the top of the stump so the string line can be used to level the stumps when being installed.

The posts can be cut slightly long and tapped down with the head of the crowbar to their correct height (Fig. 17.10). Backfill the soil in layers, no more than 150 mm thick, and ram firmly.

Fig. 17.10 Setting the timber stump in position**17.3.1.4 Step 4**

Excavate holes to the required depth, ensuring the floor of excavation is reasonably flat and straight with no loose soil. Place the correct-sized sole plate on the floor and 'ram'

it with the head of a crowbar until it won't sink any further into the ground. Measure from the sole plate to the string line, which has been set to the height of the underside of the bearer; cut the stump to that length then place the stump, plumb and to the string line. Backfill and compact the soil as you go to ensure the stump remains in the correct position. To check the height of the stumps, use a dumpy level set up near the centre of the area and use a timber rod to transfer the height from the hurdles to the top of the stumps.

17.3.1.5 Step 5

Set out the position of the intermediate stumps/posts between A and B and excavate to the required depth. Set the stump/posts in position, aligning them with the string lines, and plumbing up in the other directions. Tap each post down to the height of the string line.

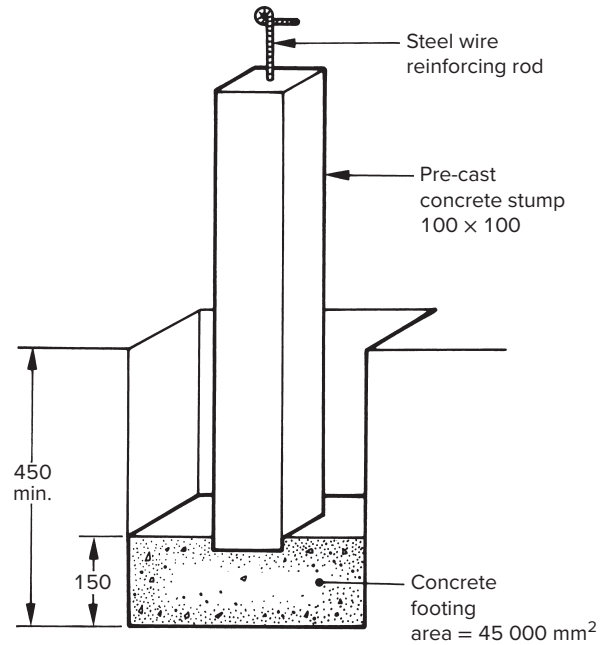
17.3.1.6 Step 6

Repeat the process with the next two rows of stumps.

17.3.2 Pre-cast concrete stumps

Pre-cast concrete stumps have superseded timber posts in many places. This type of stump is 100 mm × 100 mm, sunk no more than 25 mm into a concrete base/pad at least 150 mm thick (Fig. 17.11).

Fig. 17.11 Pre-cast concrete stump



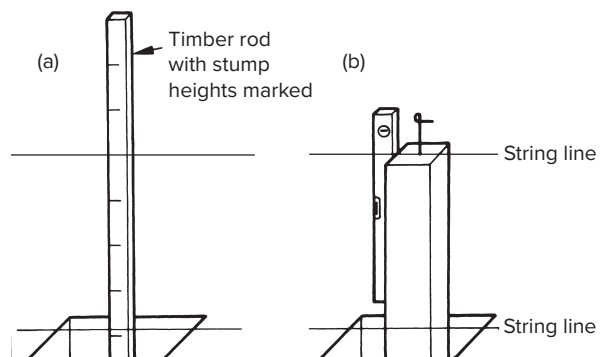
TIP For information of pad thickness, diameter and depth, the soil type will need to be established and then AS 1684 will need to be consulted.

Pre-cast concrete stumps are reinforced with steel wire rods, which are left projecting from the top and bent over in order to secure the bearers; a threaded rod is sometimes used instead of wire reinforcement and left projecting 150 mm for the same purpose.

When ant caps placed over the stumps are pierced, the hole must be sealed with a bitumen compound or other suitable means to prevent the entry of termites.

Concrete stumps are manufactured in lengths in multiples of 100 mm so that the depths of excavation must vary to make minor adjustments in the height of the stumps. Use a light timber rod marked off in the length of stumps to determine the depth of excavation (Fig. 17.12). See the procedure steps listed below.

Fig. 17.12 (a) Determining the stump height; (b) positioning the stump



17.3.2.1 Calculating the amount of concrete required for installing concrete stumps

Calculate the amount of concrete required to form the stump pads. Generally, the stump holes will be round, so use the formula $\pi r^2 \times h$, where:

$$\pi = 3.142 \quad r = \text{radius of the stump hole} \quad h = \text{thickness of the concrete pad.}$$

Once you have calculated the amount of concrete required for one pad, multiply that answer by the number of holes that have been dug. Do not forget that the final answer should be in cubic metres, so you can tell the company how many cubic metres of concrete are required. You can order concrete in increments of 0.2 of a cubic metre—it is always a good idea to order an additional 0.2 of a metre of concrete just to make sure you don't run short.

To set the stump in position:

1. Using a wheelbarrow, place the concrete into the stump holes to form the base. Ensure the concrete mix is sufficiently dry to prevent the heavy concrete stump from sinking too fast or too far into the soft liquid concrete.
2. Stand the stump in position and align in one direction with string lines and plumb in the other direction.
3. Tap the stump down to the correct height—if necessary, using a wooden block to protect the head of the stump from damage.
4. Backfill the soil in layers not more than 150 mm thick; pack the dirt gently as too much force will cause the stump to move as the concrete is still wet.
5. Thoroughly clean all of the tools and equipment that were used to place the concrete and store them appropriately.
6. Let the concrete set overnight. The following day, to further compact the soil around the stump, pour half to a full bucket of water around the stump.

TIP To determine the stump hole depth, diameter and the thickness of the concrete pad, a soil test must first be carried out by a geotechnical engineer to determine what soil type is found on the site.

WORKPLACE SCENARIO

The use of concrete stumps is commonplace today and, as a product, they are far superior to red gum stumps as they do not rot. However, the installation of concrete stumps can be quite a frantic process to carry out. Generally, the concrete is ordered and comes to the site already mixed. The first job is to distribute the correct amount of concrete into each hole using a wheelbarrow, then, working quickly, place each stump in the correct position, ensuring it is plumb and in the right line. The speed at which the stumps have to be placed into the already-hardening concrete can vary depending on the weather: the hotter the day, the quicker you have to work. Cooler overcast days are ideal as the concrete sets slower, therefore providing additional time to get the job done.

17.3.3 Steel stump supports

Steel stump supports are widely available as an alternative to timber and concrete stumps (Fig. 17.13). Setting out is carried out in the same manner as concrete stumps. Steel stumps can be installed in a similar manner to concrete stumps and cast into concrete. Alternatively, a concrete pad is poured to

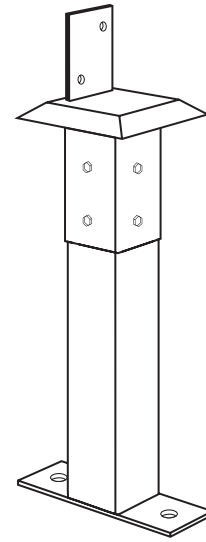
the top of the ground level and no backfilling with dirt and tamping is required. The posts are bolted down to a concrete pad and are screwed or bolted to the bearer. Many of the types available are adjustable in height, so the use of packers is not required. They are generally galvanised, so they are suitable in damp environments. The steel posts are also termite resistant.

17.3.4 Patented adjustable supports

This style of support differs from the stumps/piers detailed elsewhere in this chapter as they are all adjustable in length. Additionally, many can be adjusted once they have been installed and are taking the load.

Designs and concepts do vary depending on the manufacturer; however, they all use the concept of a thread system incorporated into the support design. This thread enables the support to be lengthened or shortened so that the correct height can be achieved.

Fig. 17.13 Steel stump supports



CHECK YOUR UNDERSTANDING

2. What precautions must be taken to prevent termite attack on ground-floor timbers?

17.4 Install bearers and joists

The complete details of the possible combinations of spans, spacings, dimensions and stress grades of timbers that could be used in floor framing can be found in AS 1684. These can be quite extensive. The figures given below can be taken as an example of what is traditionally common trade practice.

TIP Steel can also be used as an alternative to timber. These sections would need to be engineered for a specific purpose or bought off the shelf from a manufacturer of steel subfloor members.

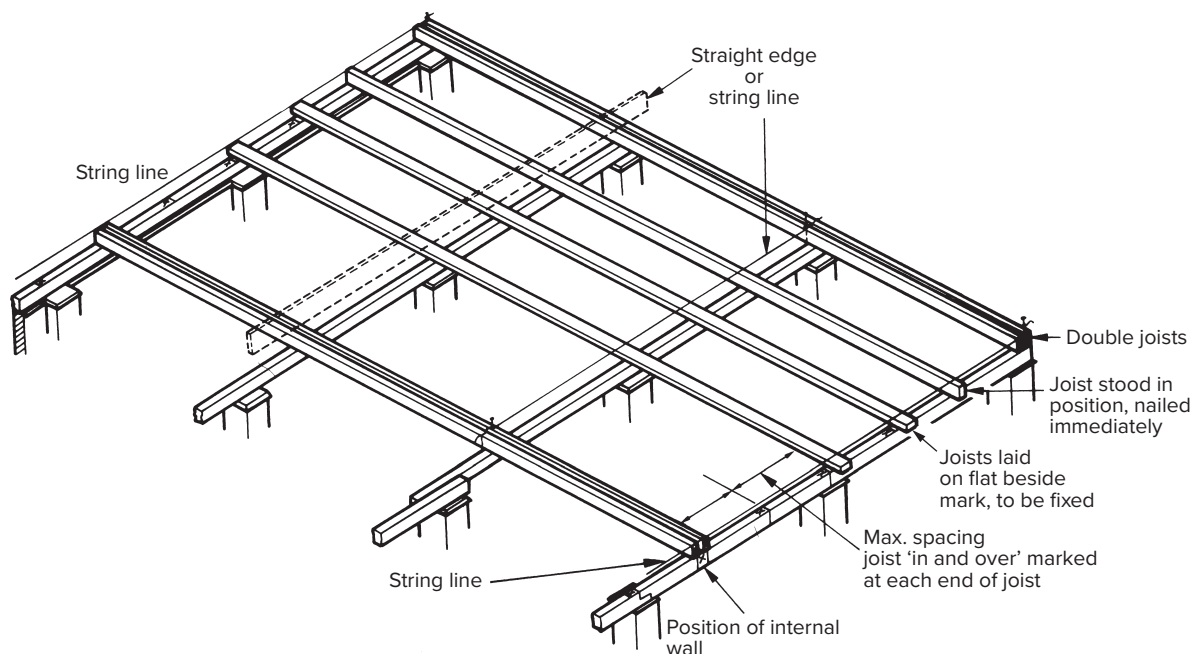
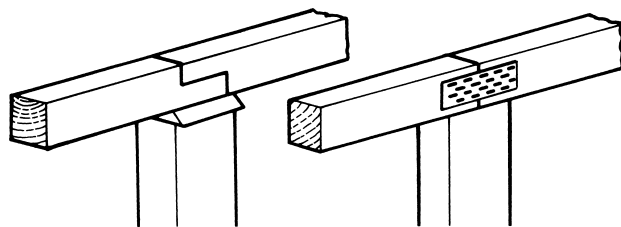
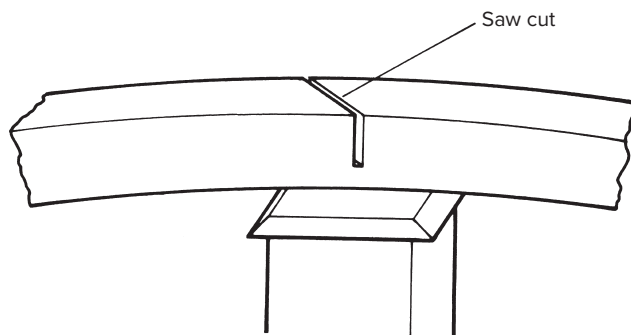
Traditionally, bearers would be 100 mm × 75 mm hardwood, F8 or F11, laid on edge with a maximum span of 1200 mm for **single span** bearer, and 1500 mm for **continuous span** bearer supporting, for example, load-bearing external walls carrying roof sheet. AS 1684.4 Part 4: Non-cyclonic Construction details alternative spans and spacings for all timber framing members achievable by using different timber grades and/or sizes. Care should be taken to ensure compliance.

Traditionally, joists are commonly 100 mm × 38 mm or 50 mm hardwood, F8 or F11, with a maximum span of 1800 mm, spaced at 450 mm or 600 mm centre to centre.

The common practice today is to use timber that has been kiln dried to construct a subfloor. Kiln-dried timber is stable and consistent in size, unlike green timber. The commonly available species and stress grades of kiln-dried timber are: radiata pine (treated and untreated), F5, MGP10, MGP12; native hardwoods (mountain ash), F17, F27; Baltic pine, F5, MGP10.

17.4.1 Laying bearers and joists

The laying of bearers and joists is an important operation and must be carried out in an orderly manner. The objective is to finish up with the tops of the joists level and in a straight line (Fig. 17.14). This is

Fig. 17.14 Laying bearers and joists**Fig. 17.15** Joining bearers**Fig. 17.16** Seating bearers on piers

stump (Fig. 17.16). Where a bearer has an excessive round and will not bed down securely, it is sometimes cut partially through over the pier. The cut is made diagonally across the edge and over the centre of the pier, only deep enough to weaken the bearer so that it will rest down firmly on the pier. If it is supported by wooden stumps, the bearer is skew nailed to the stump.

essential if they are to provide an accurate base on which the rest of the framework can be erected: they must provide firm support for floorboards so that there are no uneven and creaking floors. After the initial work of clearing the underfloor area and setting the termite capping in place, the laying of the bearers and joists can commence.

The procedure is set out below.

17.4.1.1 Step 1

Lay out the bearers over piers, stumps or foundation walls and join in length (Fig. 17.15). Intermediate bearers can be lapped and skew nailed together, but outside bearers must be kept in a straight line and joined with a scarfed joint or butted with a nail plate.

Bearers are laid with the round edge up and must bed down firmly on each pier or

TIP When a bearer or joist is cut over a point of support to remove an excessive bow, it can no longer be deemed 'continuous span' and may not comply with AS 1684.4.

17.4.1.2 Step 2

From the stack of joists available, select the straightest. Use these for double joists.

17.4.1.3 Step 3

Plumb up from the foundation walls, stumps or piers. Measure and mark the overall dimension of the wall along the bearers. Measure and mark the length of the double joists and, by skew nailing, fix the pairs of double joists to the external walls in position. Ensure they are straight by using a string line or by sighting. More secure nailing will be obtained if the surplus ends are left on and then cut off after nailing.

17.4.1.4 Step 4

If the building is to have a fitted floor, set out and mark the location of the interior walls on the bearers. Fix double joists to provide support for the wall and the ends of the floorboards and to maintain the correct overall dimension of the building.

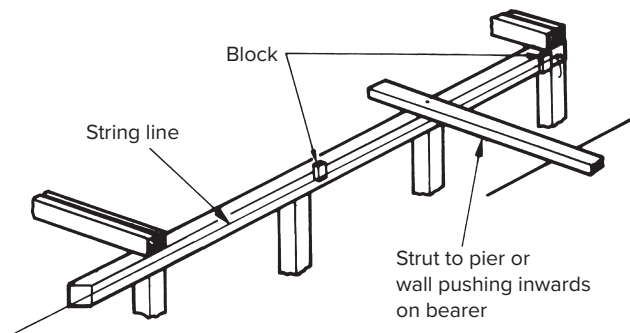
17.4.1.5 Step 5

Between the pairs of double joists, set out the spacing for the intermediate joists using the 'in and over' method of measurement.

17.4.1.6 Step 6

Before proceeding to fix the remainder of the joists, straighten the outside bearers by setting up a string line packed out from the side of the bearers (Fig. 17.17). Some light raking struts from the ground may be necessary to hold them straight.

Fig. 17.17 Straightening bearers



17.4.1.7 Step 7

Lay the joists on flat across the bearers beside each mark.

TIP Never, under any circumstances, leave a joist standing on edge until immediately before it is to be nailed permanently into position. Should anyone step on a loose joist on edge it can easily roll, leading to severe injury to the carpenter or an unsuspecting workmate.

17.4.1.8 Step 8

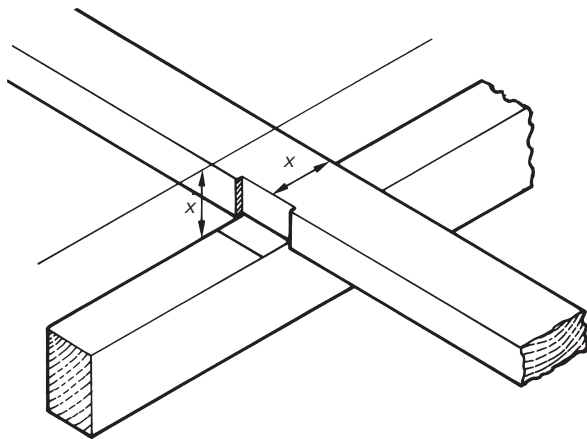
If using **green hardwood** or recycled timber of inconsistent sizes, set up the external joists, then string a line above the edge of the outside bearers and at the level of the top of the joists (Fig. 17.18). To align the tops of the joists over the intermediate bearers, a long straight edge can be a suitable alternative, although it may be cumbersome to use.

If using dressed seasoned timber or a manufactured product, the joists can be positioned and nailed into position. Step 9 is not required.

17.4.1.9 Step 9

If using green hardwood or recycled timber with the joists laid on flat beside each mark, measure the distances from the top of the bearer to the string line or straight edge (distance x). In many cases the

Fig. 17.18 Notching joist to obtain level floor (green hardwood or recycled timber)



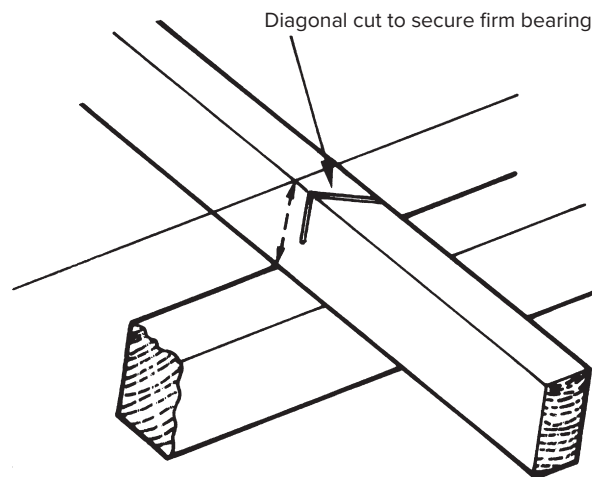
joist may be the correct width and can be stood on edge and skew nailed to the bearers. If it is too wide, however, measure down from the top the distance x and notch out the bottom edge. After checking each point of contact, stand it on edge and nail it into position.

If the narrowest joists are selected and used as external double joists to establish the height of the joists, theoretically none of the joists should need packing to bring them up to the correct height. In practice, however, the odd joist may need packing up to the correct height at some point. The material used for packing should be non-compressible and should cover the whole bearing area. Heavy fibre cement

board has been found to be satisfactory. It can be nailed through with no chance of cracking or 'shivering' out. Small chips of wood are not permissible.

Joists are laid with the round edge up; if they are badly rounded, they are sometimes partly cut through diagonally over the bearer to secure a firm fixing (Fig. 17.19).

Fig. 17.19 Straightening rounded joists (spring)



TIP When a bearer or joist is treated in this way, it can no longer be deemed 'continuous span' and may not comply with AS 1684.4.

17.4.1.10 Step 10

Mark joists to length from the outside string lines and cut them to length.

Laying joists for a platform floor can be carried out with just a few variations. Set up the pairs of outside double joists and space out the intermediate joists over the full area of the floor. Using string lines, permanently fix some of the intermediate joists in position at their correct height. Use a straight edge or string line to fix the remaining joists in between, as previously described.

CHECK YOUR UNDERSTANDING

3. Define the following terms:
 - a. sole plate
 - b. pad
 - c. stump/post
 - d. bearer
 - e. joist.
4. Which species and section size of timber is traditionally used for the following?
 - a. Bearers
 - b. Joists
5. Describe two methods of joining bearers over a stump/pier.
6. Briefly describe how the tops can be kept in line when laying green hardwood or recycled timber floor joists.
7. List three materials from which stumps can be made.
8. Where should double joists be located for the following?
 - a. Platform floor
 - b. Fitted floor

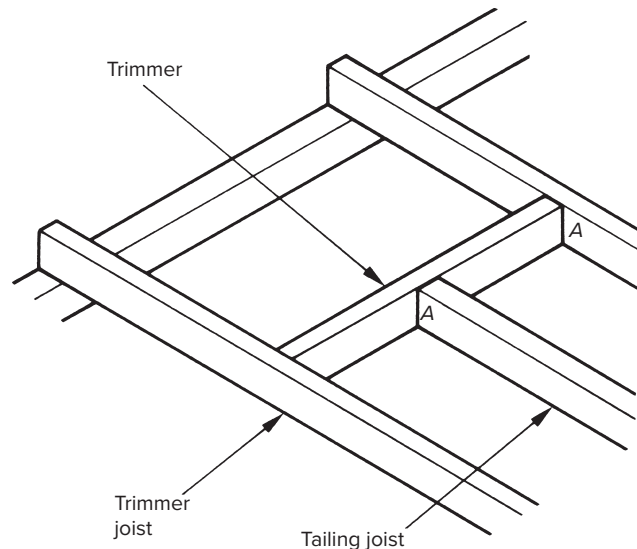
17.4.2 Trimming and openings in floors

Where there are openings in floors, it is necessary to trim around the opening. This procedure consists of shortening one or more of the joists. They are then called *curtailed* or *tailing joists*. The ends of the tailing joists must be supported by a trimmer, which is then supported by the adjacent joists, known as *trimming joists* (Fig. 17.20).

Joints between these joists must be made in such a way as to transfer the load without seriously weakening the joists. They also must not rely on nails in the end grain to carry the load. Suitable metal fittings are used to strengthen the joints. Where the trimmer exceeds 1 metre in length, it is increased in width to carry the increased load. The trimming joists must be of the same section as the trimmer they support.

Trimming out under wall plates (blocking) is used when there is a join in the bottom plate that does not land on a joist. Joist material is used to block under the wall plate, in line with the plate; therefore, these trimmers run at 90 degrees to the joists. The entire plate must be supported, so a double trimmer would be used.

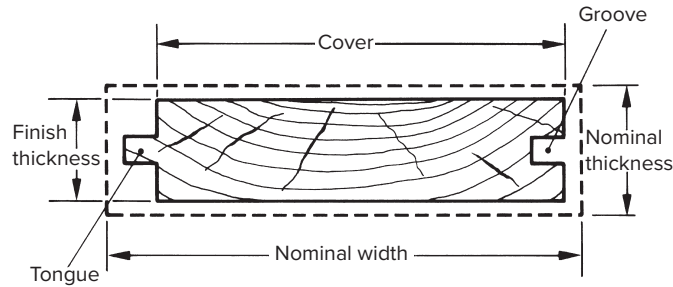
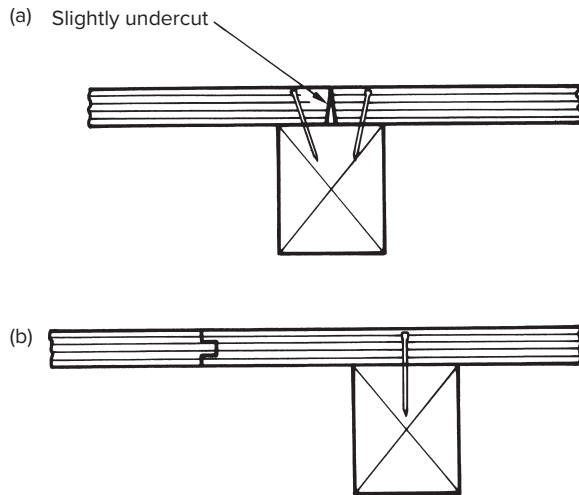
Fig. 17.20 Trimming around openings



17.5 Lay strip flooring

17.5.1 Timber strip flooring

Traditionally, strip flooring consists of individually milled tongued and grooved (T & G) boards. Throughout Australia and New Zealand, many species of timber are available for flooring, including

Fig. 17.21 Strip flooring profile (cross-section)**Fig. 17.22** (a) Butt joint and (b) end-matched joint

mixed hardwoods or selected hardwoods such as tallowwood, brush box, blue gum, merbau, blackbutt, turpentine, mountain and alpine ash, as well as the softwoods, cypress pine and radiata pine.

Flooring is described by its species and *nominal sectional size* (Fig. 17.21), that is, the width and thickness of the sawn board from which it is milled. Widths vary from 75 mm to 150 mm; thicknesses are usually 19 mm or 25 mm. For example:

- 85 × 25 tallowwood T & G flooring
- 110 × 25 cypress pine T & G flooring.

To calculate the number of linear metres of flooring required to cover 1 square metre, divide the 'cover' into the 1 metre, expressed as

1000 mm. For example, the linear metres needed to cover 1 square metre is equal to 1000 divided by 85, which equals 11.77 m. Cutting waste must be added to this total in order to allow for cutting out defects, cutting boards back over joists, or cutting to room lengths. The amount of waste will vary; however, a figure of, say, 6% is a fair average for good-quality flooring.

End joints in floorboards are usually made over a joist and the ends are only slightly undercut so that they will butt tightly at the face (Fig. 17.22). End-matched flooring has the tongue and groove continued across the ends, and the joints are not necessarily placed over a joist, thus there will be less waste in cutting down.

17.5.2 Engineered strip flooring

Strip flooring, generally installed over an existing floor and in newbuilds, is also available in alternative materials to solid timber. This could be particleboard or a concrete slab. How the boards are installed varies depending on the product. Some are laid as a floating floor, so no adhesive is used to hold the product down, while other products are glued onto the existing floor structure. Sometimes a membrane needs to be installed between the existing floor and the new floor. These boards are usually manufactured with an interlocking system, which keeps the boards together once installed so there are no large gaps between them. Always refer to the product's installation instructions prior to installing the product.

The advantages of these products are that they are generally very stable. Unlike timber, which will expand and contract depending on the environmental atmospheric moisture, these products will have

very little or no movement once installed. In addition, they require a small fraction of high-quality timber, compared to a solid wood floor.

The materials used to produce these boards include:

- vinyl/composite—such boards generally have a timber look and are prefinished
- Engineered timber—these boards generally have a plywood-style composition, with the top veneer being of high-quality timber. Such products can be either prefinished or have a thicker top veneer, so that once installed they can be sanded and coated like a traditional solid wood strip floor.

17.5.3 Calculating strip flooring

To calculate the linear metres of flooring required to cover a given area, apply the following formula:

$$\text{linear m} = \text{area} \times \text{metres of flooring per m}^2 + \text{cutting waste.}$$

For example, an area 12.60 m by 5.65 m is to be covered in 85 mm $\times$ 25 mm tallowwood flooring. Allow 6% for wastage.

$$\begin{aligned} \text{linear metres} &= 12.6 \times 5.65 \times 11.77 \\ &= 838 \text{ m} \\ \text{plus cutting waste} &= 838 \times 6/100 \\ &= 50 \\ \text{Total} &= 888 \text{ m} \end{aligned}$$

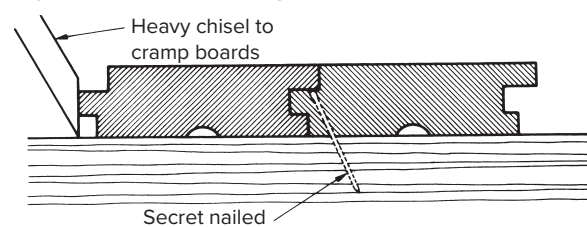
Alternatively,

$$\begin{aligned} \text{linear metres} &= (12.6 \times 5.65 \times 11.77) \times 1.06 \\ &= 888 \text{ m.} \end{aligned}$$

17.5.4 Secret nailed flooring

Secret nailing is used where a top-quality floor is required, such as a dance floor (Fig. 17.23). The boards are no more than 75 mm wide so that there is a minimum of shrinkage, and they are specially milled so that they can be nailed through the tongue and end-matched. Each board must be cramped and nailed separately. These floors are obviously comparatively slow to lay and thus expensive.

Fig. 17.23 Secret nailing



17.5.5 Moisture content

The moisture content of the flooring boards at the time of laying is important. Boards that are unseasoned or have a high moisture content will shrink excessively, leaving unsightly gaps or, in extreme cases, will allow cold air to seep up past the tongue and groove.

Boards with too low a moisture content will absorb moisture and expand, lifting the joists and bearers up from the piers, thus causing a very springy and unstable floor—a condition for which there is no simple cure.

The moisture content of boards should be tested at the time of laying. Alternatively, the boards should be brought in directly from a mill at a specified moisture content. Even where the regulation amount of underfloor ventilation is provided, there is a tendency for the area to remain damp. Generally, fewer flooring problems will arise if the boards are laid with a moisture content of about 2% above average for the area.

In some areas, particularly where cypress pine flooring is used, it is common practice to use unseasoned flooring that is cut down, turned upside down and left to lie loose for a few weeks.

It provides a safe working platform while construction proceeds and also allows the moisture content to stabilise. When the building is finally enclosed and the roof covered, it is then turned over and fixed before the interior finishing commences. Strip flooring is more suited to a fitted floor.

As a rule, all strip flooring needs to be acclimatised before laying. This is commonly done by stacking the floorboards in the room in which they are going to be laid. When stacking them, the boards need to be separated using timber laths to enable good airflow. Follow the manufacturer's instructions with regards to how long the acclimatisation process will take.

17.6 Lay fitted floors

The starting point for laying a fitted floor will vary with each individual plan, but as a general rule the longest run of boards can be found somewhere near the centre of the building, probably along a passageway and into some of the rooms (Fig. 17.24). From this starting point, continue laying the flooring in both directions through doorways and into individual rooms.

AS 1684 states that the boards should be kept 10 mm clear of wall plates, parallel to the direction in which they are laid, and that the ends of the flooring boards should not bear against the bottom plate at right angles to the direction of laying.

Refer to AS 1684 or the manufacturer's recommendations for the fixing of floorboards. Boards are generally nailed and the nails punched well below the surface.

The flooring cramp has two cams that separate and grip the joists, plus a screw or ratchet action that cramps the floorboards (Fig. 17.25). Two are usually needed for a satisfactory job.

Fig. 17.24 Starting point for fitted floor

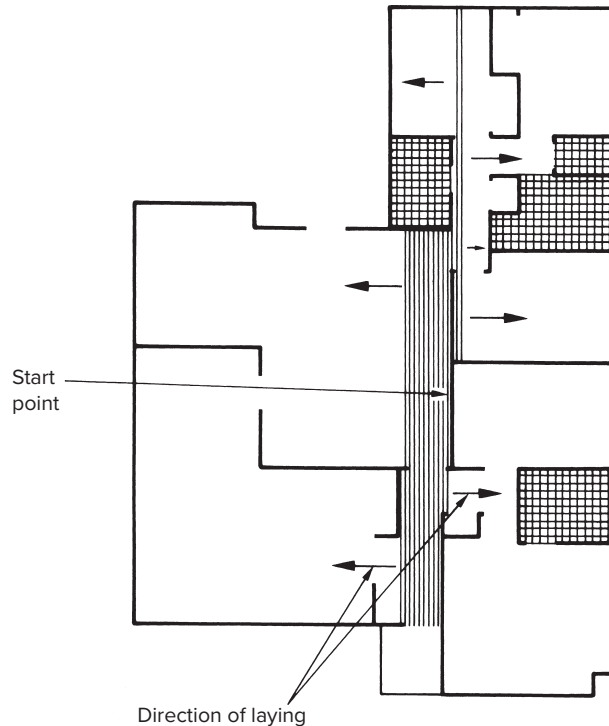
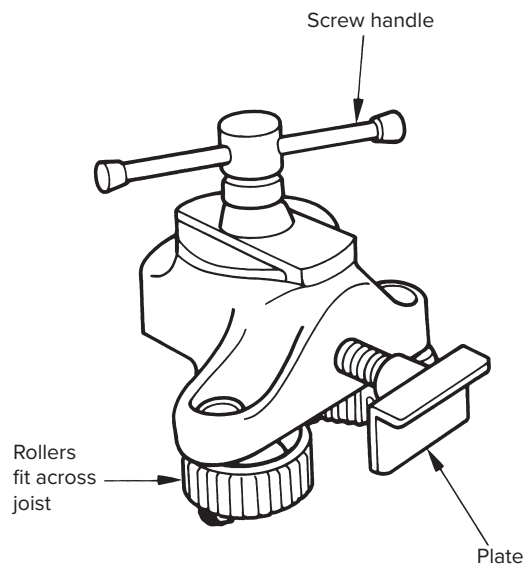


Fig. 17.25 Floor cramp



17.6.1 Step 1

Start by fixing the first board 10 mm clear of walls and keeping it straight, particularly where it continues into other rooms. Use a string line if necessary.

17.6.2 Step 2

Cut down enough boards to cover up to about 900 mm, enter the tongues into the grooves and tap up lightly.

17.6.3 Step 3

Lay a straight buffer piece along the edge of the boards and fix the floor cramps behind them (Fig. 17.26). Lay a short piece of board at right angles over the boards, and stand on this to prevent the boards buckling while cramping them up to a pressure relevant to the moisture content. Mark the centre line of the joists across the face of the boards and start nailing from the cramped edge, omitting the first nail to expedite the entry of the next board.

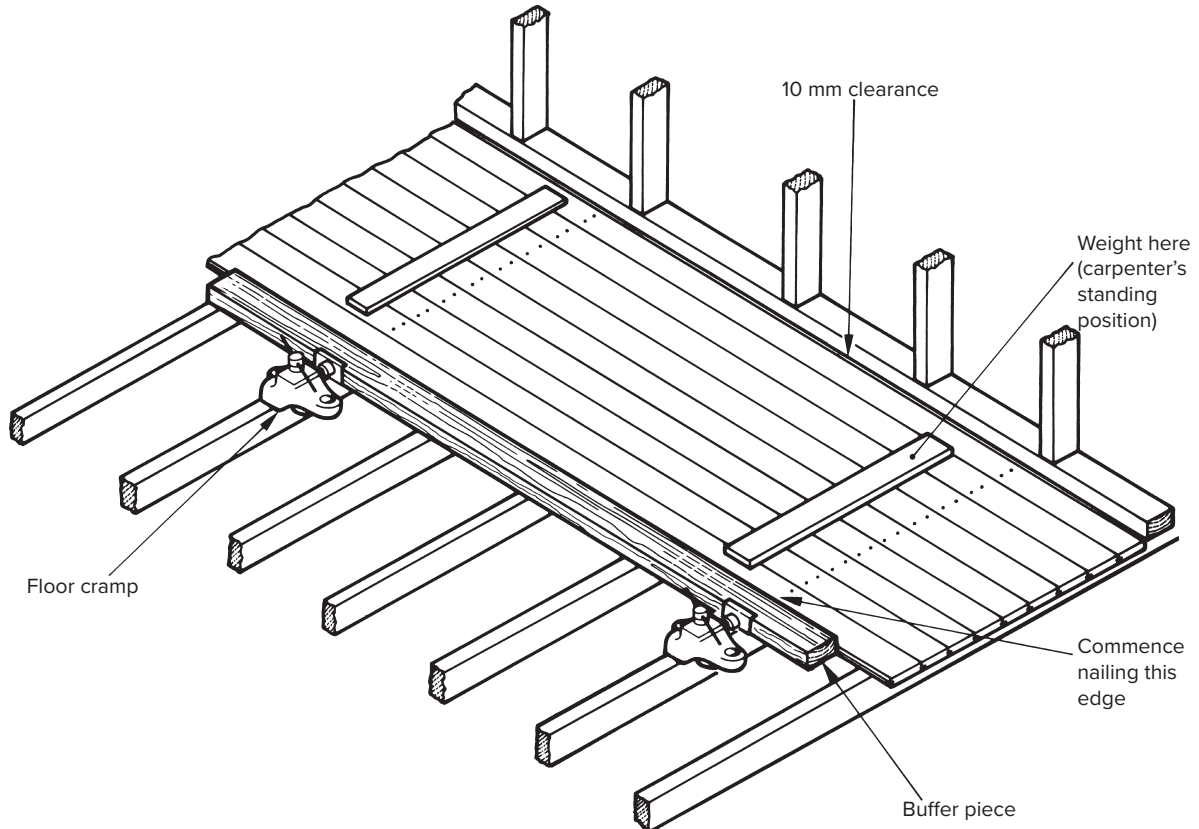
17.6.4 Step 4

It is usually sufficient to cramp boards at every second joist. To keep them straight, cramp only lightly near the ends where the boards will pull in more easily.

17.6.5 Step 5

Continue laying in a similar manner until the last few boards—these will have to be cramped with a lever or heavy chisel (Fig. 17.26). Cut the last board to fit 10 mm clear of the wall.

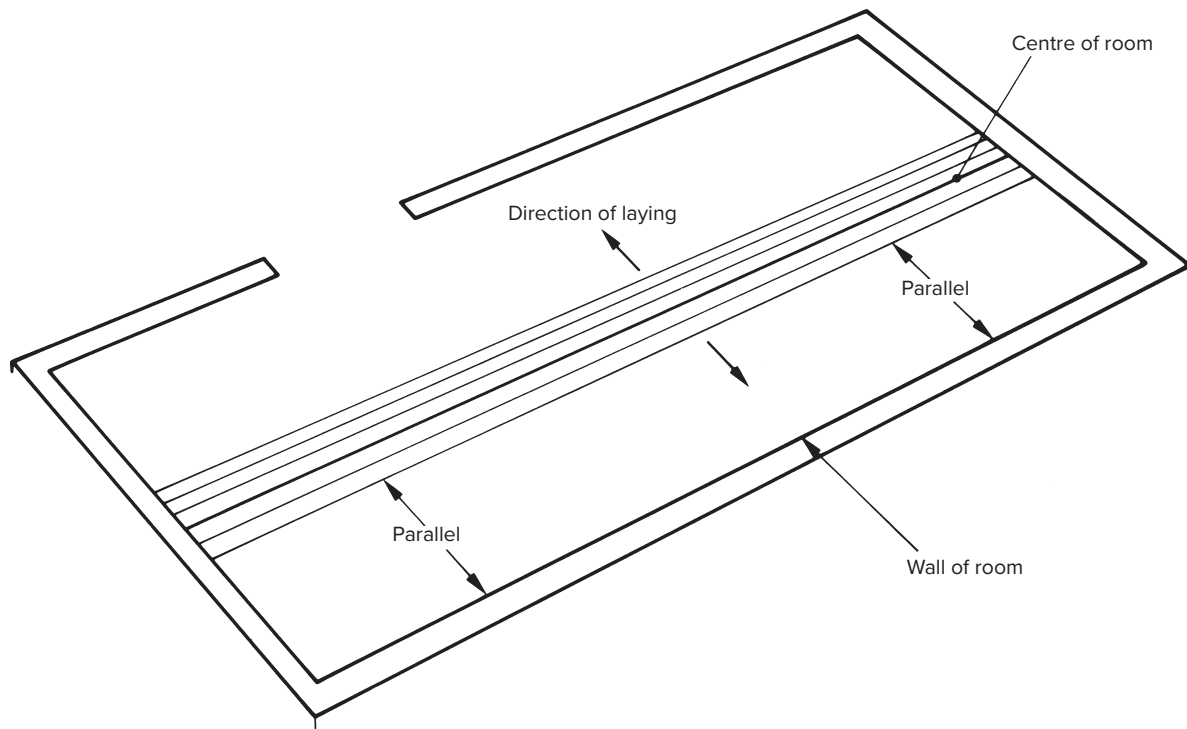
Fig. 17.26 Nailing and cramping a fitted floor



17.7 Install platform floors (using strip flooring)

When laying a floor over a large rectangular area—a platform floor or the floor of a public hall—start by laying the first boards down the centre of the area, using a string line to keep them straight. Continue laying each side of the centre towards the outer walls. Take care that the boards are kept straight and parallel at each cramping (Fig. 17.27).

Fig. 17.27 Laying a platform floor (strip)



17.8 Lay sheet flooring

Sheet flooring is widely used and permits floors to be laid very quickly, particularly when applied as a platform floor.

17.8.1 Particleboard

Structural particleboard sheet flooring is manufactured to AS 1859 Reconstituted wood-based panels and is available in two thicknesses—19.5 mm for joists spaced at 450 mm centres and 22 mm for joists spaced at 600 mm centres. The common sheet sizes are 3600 mm × 900 mm, 3600 mm × 600 mm, and 1800 mm × 900 mm. The edges of the sheets are grooved and have a factory fitted plastic tongue (Fig. 17.28). The ends of the sheets are sealed and are butted together over joists.

Sheets are fixed to joists with 50 × 2.8 galvanised nails with a flat or bullet head. It is also recommended that a 5 mm bead of structural adhesive be laid on the joists before positioning the sheets and nailing off.

Figure 17.29 illustrates a common pattern for nailing; however, always refer to the manufacturer's recommendations.

Regulations may vary between states and territories throughout Australia; the manufacturer's instructions should always be referred to before using particleboard flooring.

17.8.2 Procedure for fixing platform floor

17.8.2.1 Step 1

Fix joists to suit the thickness of sheet being used: 450 mm or 600 mm centre to centre. Add an extra joist under any load-bearing walls running parallel to the direction of the joists.

17.8.2.2 Step 2

Set a string line to the outside edge of the building and at right angles to the joists.

17.8.2.3 Step 3

Position the first sheet with its tongue edge to the string line and nail to the joists. Do not hard nail the grooved edge: this will make mating of the next sheet easier. It is highly recommended that construction-grade adhesive be used on the joists before positioning the sheets. The adhesive will dry quickly, and the sheet should be placed no more than 10 minutes after laying the adhesive, then nailed to joists within 15 minutes of placing.

17.8.2.4 Step 4

Fix the second sheet again with its tongued edge to the string line and ensure that it is butted firmly end to end with the first sheet.

17.8.2.5 Step 5

Repeat Step 4 for subsequent sheets to complete the first row.

17.8.2.6 Step 6

Fix the second and subsequent rows of sheets, ensuring that the butt joints are staggered and that the plastic tongues are entered into the grooves. After each row has been laid, nail off the previous row.

17.8.3 Structural plywood flooring

The installation of structural plywood flooring is a similar process to that described for particleboard, and it is particularly suitable for platform floor installations (Fig. 17.30). The material may be softwood or hardwood plywood, and is classified as a structural 'A' bond ply. This means that the adhesives used to hold the laminations of the board together are waterproof. Structural plywood is available in two thicknesses for flooring: 12 to 25 mm.

Refer to the manufacturer's instructions for fixing of these products.

17.8.3.1 Installing plywood flooring

Some important factors to consider when installing plywood flooring are as follows:

1. The grain of the face of the boards must run parallel to the span or perpendicular to the joists and the sheets must be continuous over more than one span.

Fig. 17.28 Detail of tongue for sheet flooring

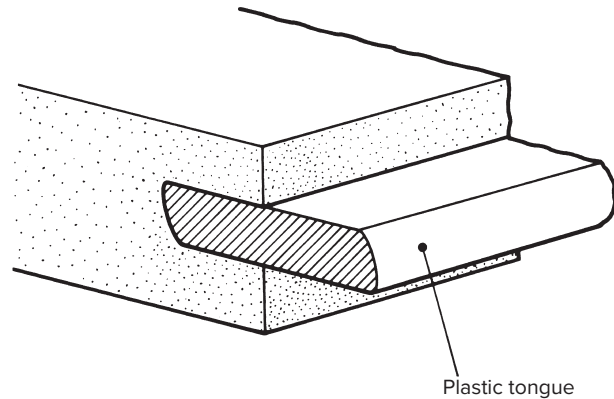
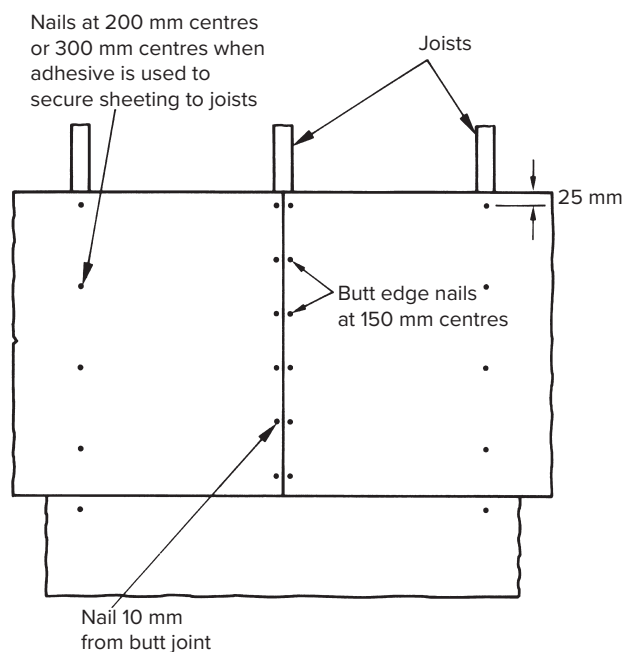
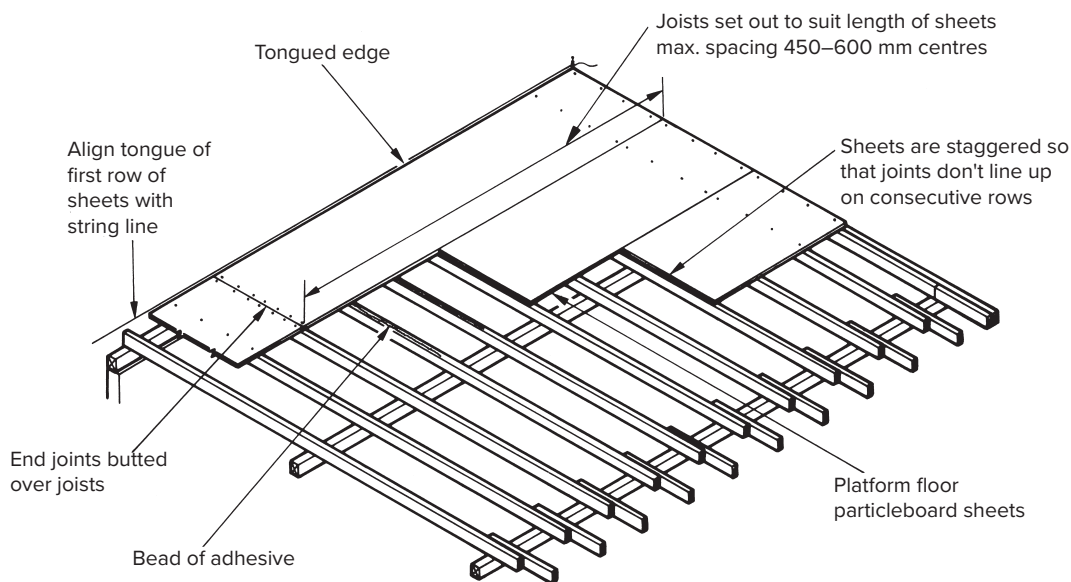


Fig. 17.29 Nailing pattern for sheet flooring



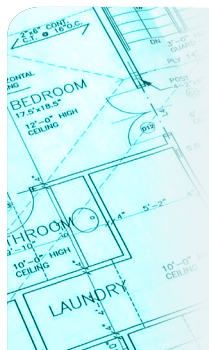
2. The sheets should always be laid with the face side upwards. The back side is normally marked.
3. The joists must be butted over bearers, and cannot be lapped, as is often the case with strip flooring. All butted joints must be central over a joist.
4. Nail spacing is similar to other sheet materials, but it is suggested that a flooring adhesive also be used.

Fig. 17.30 Laying sheet flooring



17.9 Lay wet area flooring

Wet area flooring is required in rooms such as bathrooms and laundries.



INTERPRETING PLANS

Refer to the set of plans located in the Appendix.

1. How many rooms in the building would be considered as wet areas?
2. What is the total floor area of all of the wet areas combined? Please provide your answer in square metres.
3. If the wet area sheet flooring is 3.6 m × 9 m wide, how many sheets would be needed to floor all of the wet areas? Add 10% for waste.

17.9.1 Fibre cement compressed sheets

Fibre cement compressed sheets are high-density water-resistant sheets that can be laid directly over the timber floor joists to provide a highly durable floor for wet areas. The sheets are available in thicknesses of 15 mm to 24 mm. It is preferable to lay sheets before the wall frames have been stood in place.

17.9.1.1 Fixing fibre cement sheets

Sheets are fixed to joists by the use of screws placed no more than is recommended by the manufacturer. The ends of sheets must be fully supported. Butt joints in adjacent sheets are sealed by a liberal application of epoxy adhesive.

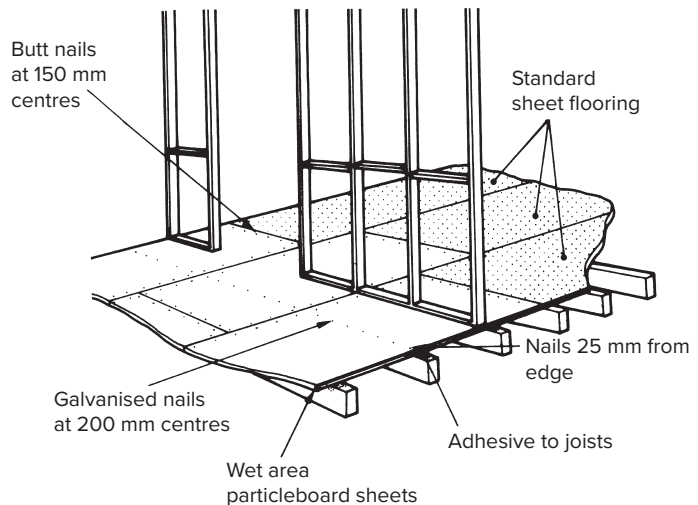
17.9.2 Particleboard flooring to wet areas

Manufactured particleboard flooring that contains formulated additives can be used in wet areas (Fig. 17.31). The thickness and sheet sizes are compatible with standard particleboard and are marked in a distinctive manner on both faces to prevent them from being confused or misplaced.

To use wet area particleboard, simply cover the wet area with the wet area sheets. The wet area sheets may extend beyond the designated wet area in order to bond with other sheets.

The wet area sheets are fixed in the same manner as standard sheets except that the use of structural adhesive together with galvanised nails is mandatory. The necessary materials and detailed instructions are available from the manufacturer and should be carefully followed.

Fig. 17.31 Wet area particleboard



17.9.3 Structural wet area plywood

Plywood may also be used in wet areas, as long as it is a tongue and grooved structural grade plywood with a type 'A' waterproof glue bonding the laminations. Either softwood structural or hardwood structural plywoods are acceptable.

The thickness of plywoods should be matched to the joist spacing. The installation of plywood wet area flooring is similar to the sheets already described; however, the basic requirements are as follows:

1. The face grain of the sheets should run at right angles to the direction of the joists and should be continuous over two or more spans.
2. Sheets should be butted over joists, and these joints should be staggered.
3. Plywoods in wet areas should be glued and nailed. The adhesive and fixing methods should follow the manufacturer's recommendations.
4. Prior to tiling, the floor should be coated with a waterproof epoxy sealer approved for the material.

CHECK YOUR UNDERSTANDING

9. Using suitable sketches, show the meaning of the following terms applied to strip flooring:
 - a. secret nailed flooring
 - b. end-matched flooring
 - c. standard strip flooring.
10. Briefly describe how you would proceed to lay structural sheet material over a platform floor.

17.10 Know about alternative subfloor materials and their uses

17.10.1 Laminated veneer lumber

Laminated veneer lumber (LVL) is a high-strength engineered wood product used primarily for structural applications. It is comparable in strength to solid timber, concrete and steel and is manufactured by

bonding together rotary peeled or sliced thin wood veneers under heat and pressure. LVL was developed in the 1970s and is used today for permanent structural applications, including bearers, joists, beams, lintels, underpurlins, truss chords and formwork. LVL can be used wherever sawn timber is used. However, one of its main advantages is that it can be manufactured to almost any length, restricted only by the availability of transportation to site.

17.10.2 Steel

Steel is another material that can be used to construct a subfloor. There are a number of cold-formed steel profiles available to use as either bearers or joists, as shown in Figure 17.32.

Used as a subfloor material, cold-formed steel is robust and termite resistant; it also resists corrosion as the section is galvanised and is lightweight. The components can be used in either a traditional configuration, as shown in Figure 17.33, or an inline system, as shown in Figure 17.34.

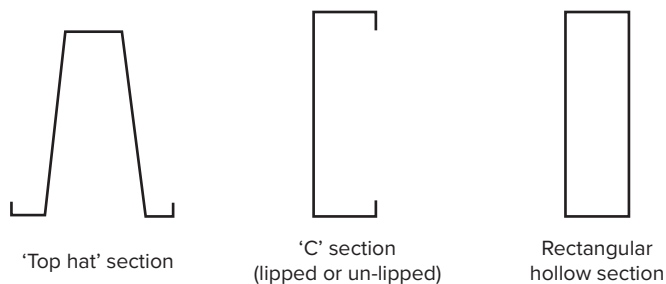
The method used to construct a subfloor using steel is very similar to that for a timber subfloor. However, where nails would be used to connect the components, screws are commonly used instead, as shown in Figure 17.35.

As with any construction, the steel components' size and application, connection specifications and tiedown requirements need to comply with relevant codes and standards. The National Association

of Steel-Framed Housing (NASH) produces the technical information for the use of cold-formed steel-framed components—in particular, the standards that are referenced in the National Construction Code (NCC).

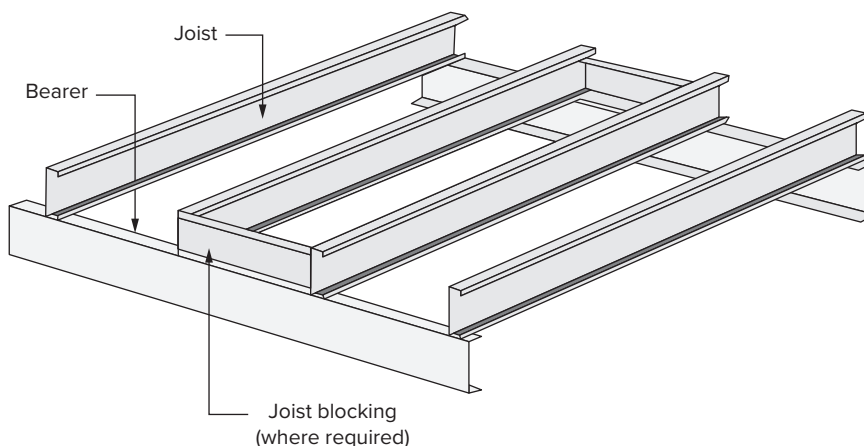
NASH also produces fact sheets, PowerPoint presentations, trade instruction sheets and the General Guide to Steel-Framed Building; refer to the NASH website at www.nash.asn.au. NASH standards and handbooks may also be purchased through the website.

Fig. 17.32 Typical joists and bearers

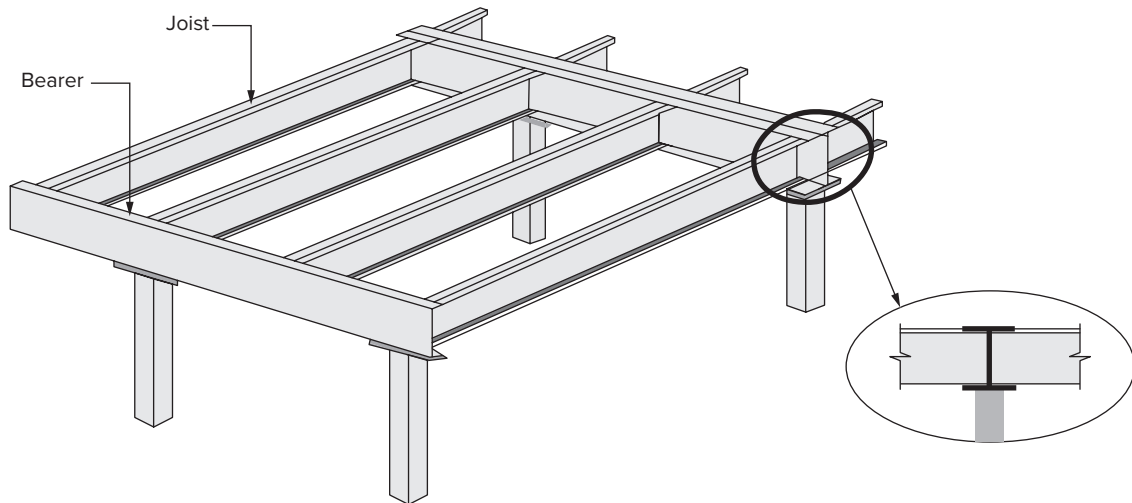


Reproduced with permission of NASH Inc. www.nash.asn.au

Fig. 17.33 Joist over bearer floor framing system



Reproduced with permission of NASH Inc. www.nash.asn.au

Fig. 17.34 Inline floor framing system

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17.11 Identify the building envelope

This is a concept that describes all of the exterior parts of a building—the foundation, structure, the 'skin', roof, walls, floor, windows and doors, and building services (water, sewerage, electricity, gas).

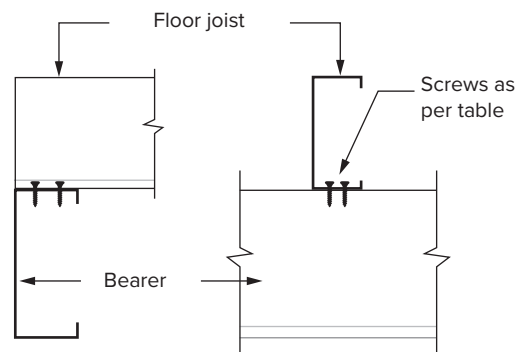
The function of a building's envelope (Fig. 17.36) is to:

- provide structural support to the building parts
- manage or control the flow of air, energy, water and matter from the outside to the inside
- allow the building's materials to enclose the space, connect together sensibly and provide security.

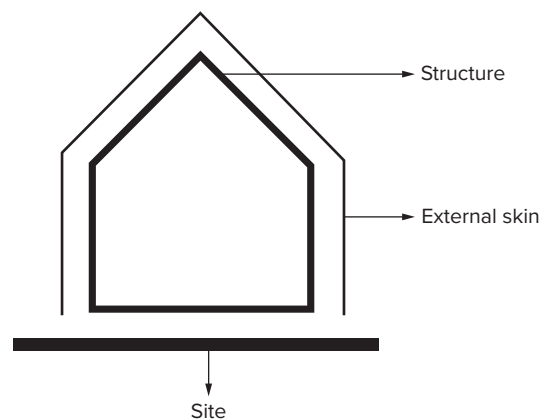
The effectiveness of the envelope centres on the management of weather and climate, indoor air quality, thermal comfort and energy efficiency. Achieving this depends on a sound structure, suitable materials and barriers to water, heat and cold penetration.

In addition, the ability of the envelope to drain water away, and control internal moisture are paramount. For example:

- a brick veneer wall is a dual-stage system—it comprises a primary barrier (the brick skin), through which water penetrates, and a secondary waterproofing barrier or membrane and flashing system to prevent water penetration and divert it back to the exterior.
- a timber-frame wall with timber cladding—any water penetration or condensation (due to humid weather) that is behind the exterior skin becomes trapped and begins the process of decay.

Fig. 17.35 Floor joists to bearer connection: lower storey

Reproduced with permission of NASH Inc. www.nash.asn.au

Fig. 17.36 The building envelope

17.12 Identify types of underfloor insulation

Installing underfloor insulation is an important part of making a traditional subfloor more thermally efficient. The insulation performs the following functions:

- reduces draughts from coming up through the floor
- reduces loss of heat through the floor during winter
- reduces the amount of heat coming up through the floor during summer.

There are various products available, and it is always a good idea where possible to install the insulation while the subfloor is being constructed, rather than once the building is finished. Always consult the manufacturer's installation instructions to achieve the product's maximum insulation properties.

Types of underfloor insulation:

- Solid foam boards—such products generally come in various thicknesses, and some have an additional foil backing. The board is generally installed to a prescribed distance below the sheet or strip flooring to provide an air gap in order to maximise the product's isolative properties. It is important to install the board tightly between the floor joists to prevent any airflow, and it needs to be fixed in place so it does not drop out.
- Batt style—these products are made from various materials including glass wool and polyester. They tend to be quite soft and have a structure that holds air within the batt itself. The batts are tucked up between the joists to fill the space under the flooring material. Some sort of cleat, mesh or tape etc. needs to be installed on the bottom of the joists so that the batts don't drop out.
- Spray foam—this product is sprayed onto the underside of the flooring materials and joists. The product adheres to the structure and is good for filling gaps that could allow a draught to enter the house. This product can only be installed once the flooring material has been laid. Access issues could be a consideration.

17.13 Construct decks and balconies

Where a balcony or deck is to be constructed, the connection between it and the main dwelling is crucial. If not constructed properly, this connection could fail, causing damage to the house or injuring a person who is on the balcony or deck. The main house structure will be supporting part of the balcony or deck, so it is essential to adhere to the current standards and codes concerning the construction and design of the structure.

The connection point of a deck or balcony to a house is addressed in the National Construction Code (NCC) Volume 2, Part 3.10.6, Attachment of decks and balconies to external walls of buildings. This section of the NCC details the design of the connection, material sizes, and bracing and fixing requirements. Figure 17.37 shows how the connection of a deck to a house would be constructed.

The construction of the deck or balcony may be similar to a dwelling subfloor featuring a stump or post set into the foundation that is supporting the bearers, joists and decking. Alternatively, the substructure could be entirely in one line, eliminating traditional bearers. The stump or post supports a pitching plate that is in line with the joist, which in turn supports the joist (Fig. 17.38).

Once the substructure is constructed, the deck or flooring material can be installed. Generally, patios will have decking installed; these are boards made from timber or composite. They are laid on the joists with a gap between each board. Decking material can be face screwed or nailed (using deformed nails—see Chapter 9, Construction fastenings and adhesives). Alternatively, the decking can be

Fig. 17.37 Fixing of a waling plate to a timber frame for deck construction

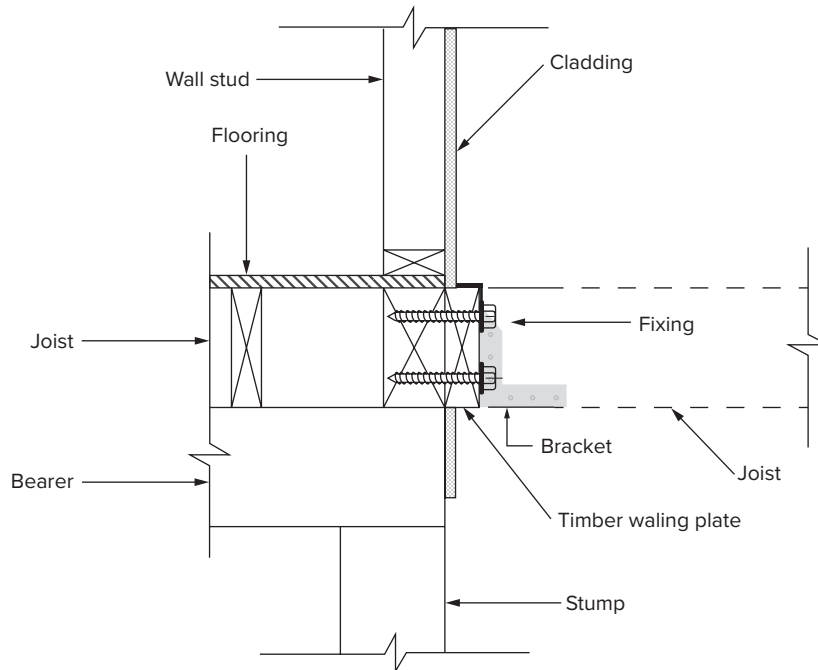


Image adapted from 3.10.6.1b, Volume 2, National Construction Code

fixed down using a system that holds the side of the decking board, therefore hiding the fixings. Figure 17.39 shows different timber decking profiles. These fixings are generally made from a weather-resistant material such as stainless steel or galvanised steel. When installing any decking product, always refer to the manufacturer's installation instructions.

There are some occasions when sheet material is laid on a balcony to create a solid floor; this is usually done to accommodate the installation of tiles or pavers. On these occasions, drainage for the removal of water and waterproofing needs to be installed prior to the tiles, to stop any water from penetrating the substructure.

Fig. 17.38 Deck or balcony detail, inline substructure

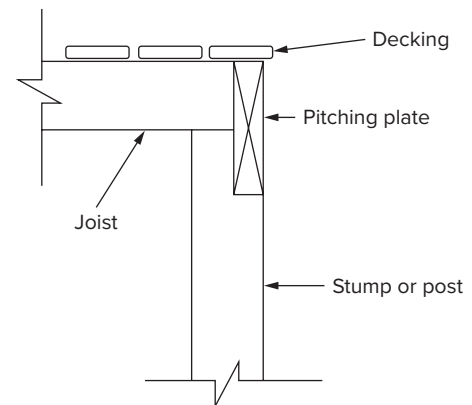
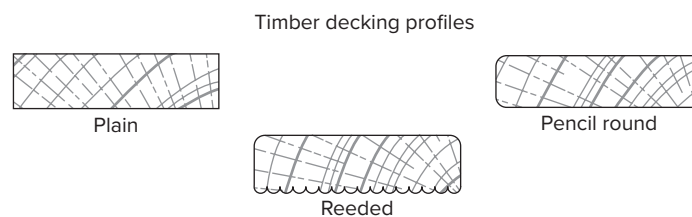


Fig. 17.39 Timber decking profiles



Student research

Obtain a copy of AS 1684. With your teacher's help, go through the section that deals with subfloor construction. Research the following:

- stress grading—what is it and what are its forms?
- green timber definition
- seasoned timber definition.

End-of-chapter activity

As part of your training, you will be required to set out and construct a timber subfloor, including digging holes, placing stumps and installing bearers and joists suitable for a platform or cut in the floor.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684—2010
Residential
timber-framed
construction

National
Construction Code
(NCC)

The National
Association of
Steel-House
Framing (NASH)

Tradie talk—Breaking the timber's back

Chapter 18

Wall framing

Learning Objectives

LO 18.1 Identify wall framing parts

LO 18.2 Arrange studs at wall junctions

LO 18.3 Identify bracing types

LO 18.4 Identify timber sizes

LO 18.5 Set out wall plates

LO 18.6 Assemble timber wall frames

LO 18.7 Use tie-downs and brackets

LO 18.8 Assemble steel wall framing

LO 18.9 Construct two-storey dwellings

Introduction

In this chapter you will learn how to plan, prepare, set out, construct and erect wall frames for different types of roof loadings. This includes the setting out, cutting and fabrication of both timber and steel wall frames, and the erection, connection and bracing of wall frames to appropriate standards. You will also learn how to plan, prepare and install window frame units to required plans and specifications.

The notes contained in this section on timber wall framing are based on the requirements of the following construction standards:

- AS 1684.2: 2010 Residential timber-framed construction–Part 2: Non-cyclonic areas
- AS 1684.4: 2010 Residential timber-framed construction–Part 4: Simplified–Non-cyclonic areas.

18.1 Identify wall framing parts

The wall framing must provide fixing support for interior and exterior wall sheeting as well as support for the ceiling, roof framing and roof covering. The members comprising the wall framing are named and illustrated in Figure 18.1.

Walls can be *load-bearing* or *non-load-bearing*. The exterior walls of a timber-framed building are load-bearing; in the case of the untrussed roof, where some of the roof loads are transferred to internal walls by way of underpurlins and struts, internal walls also become load-bearing.

A building with a trussed roof has load-bearing external walls, but the interior walls maintain a clearance between the top plate and the truss and carry none of the roof loads; these walls are termed non-load-bearing. When selecting suitable section sizes for members of wall framing, it is necessary to consider how much of the roof loads will be supported by each wall. For this reason, span tables refer to the **roof load width (RLW)**.

Two common examples are shown in Figure 18.2 and include the formula used for determining the RLW factor for member sizing. The trussed roof carries all of the roof loads on the external walls and the RLW is equal to the full span of the top chord as shown; however, in the untrussed roof where some of the loads are diverted to the interior walls, the roof load is reduced as shown.

The RLW is used as an indicator of the loading carried by some roof members as well as the load-bearing wall frame members and supporting substructure.

The range of sectional sizes for wall framing members is considerable and can depend on many factors such as spacing, RLWs, timber species and stress grade. Dimensions quoted in the following notes are examples only of common trade practice. Always refer to the relevant span tables included within AS 1684 Residential Timber-framed Construction for firm details.

Fig. 18.1 Wall frame—general view

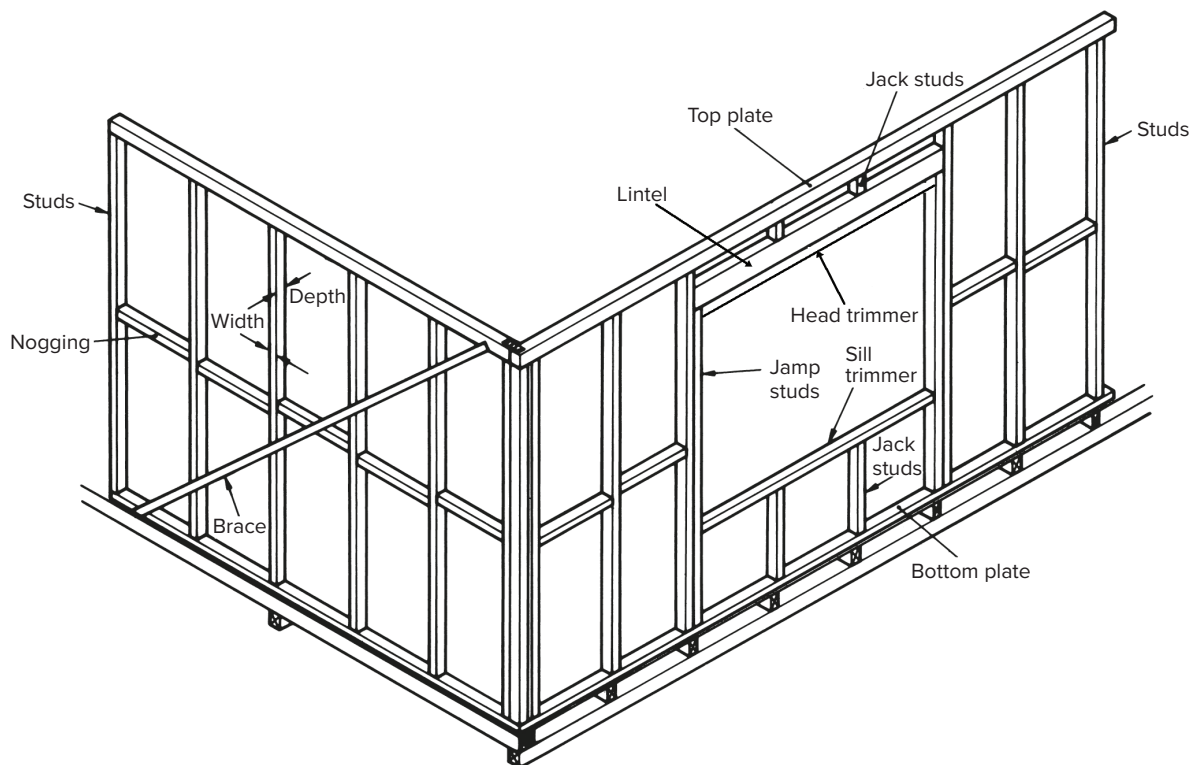
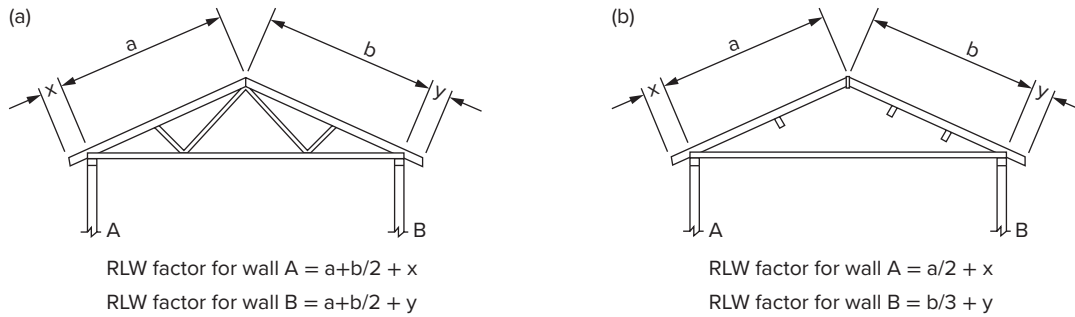


Fig. 18.2 Roof load width (RLW): (a) trussed roof; (b) coupled roof with underpurlins

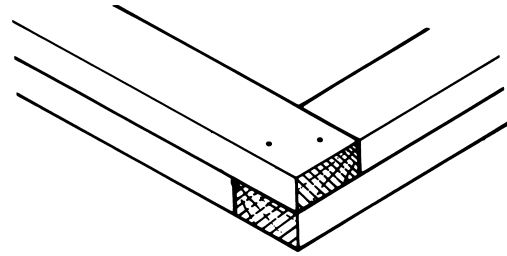


For details of alternative roof designs, refer to AS 1684.

18.1.1 Top plate

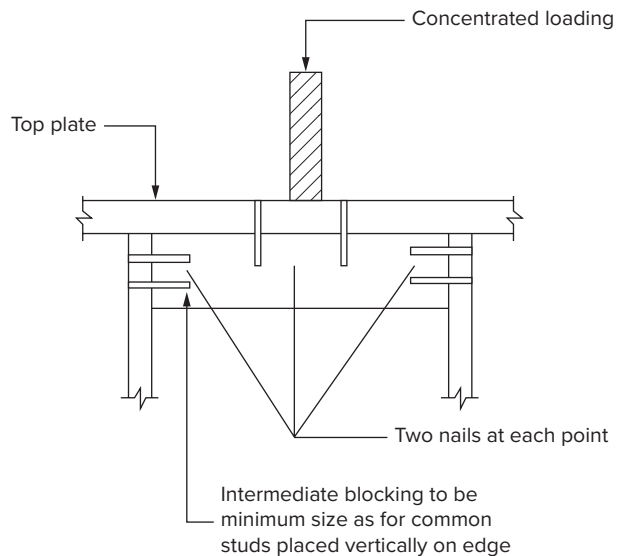
The top plate frames the top of the wall and supports the ceiling joists and rafters (refer back to Fig. 18.1). Top plates can be described as having **direct load** where the rafters are located directly over the studs, or are placed within 1.5 times the thickness of the plate from the stud. A **random load** is where the rafters are placed without reference to the location of the studs and exceed the limit. When the top plate is directly loaded, the section size can be reduced to a minimum 35 mm thickness, but if random loaded they must be increased in thickness. Deep top plates can be built up in two laminations, for example, a 75 mm × 75 mm plate can be two lengths of 75 mm × 38 mm (Fig. 18.3).

Fig. 18.3 Laminated top plate



TIP Where a concentrated load such as roof struts, strutting beams, hanging beams and girder trusses sit on the top plate but are not directly supported by studs designed for that purpose, the top plate shall be stiffened in accordance with the requirements of AS 1684.10 Section 6: Wall Framing (Fig. 18.4).

Fig. 18.4 Top plate stiffening



18.1.2 Bottom plate

The **bottom plate** frames the bottom edge of the wall frame and, provided it is supported under the studs by joists, **blocking** or a concrete slab, it can be the same section size as the studs.

Plates can be trenched to a maximum depth of 3 mm to adjust any difference in plate thickness. This is gauged from the outside face of the plate to leave a uniform thickness on each plate. When trenching exceeds this depth, the remaining net depth of the plate shall be used to determine the section size of the plate in accordance with the design limits

outlined in the AS 1684 span tables. Trenching is unnecessary when plates are machine gauged to a uniform thickness.

Traditionally, the joints between top plates were done using a butt joint (Fig. 18.5) with a nail plate fixing or half-lapped joints with the joints being nailed together. Bottom plates were permitted to be butt joined at corner intersections as well as the straight joints in continuous wall lengths.

The same joint method applies today for bottom plates, providing both ends are fixed and supported by floor joists, solid blocking or a concrete slab.

Top plates are now joined at corner intersections with the butt joint/nailing plate method, while straight joints in top plates will need to be one of the methods shown in Figure 18.6.

Fig. 18.5 Joining of plates: (a) butt joint; (b) half-lapped joint; (c) tee half-lapped

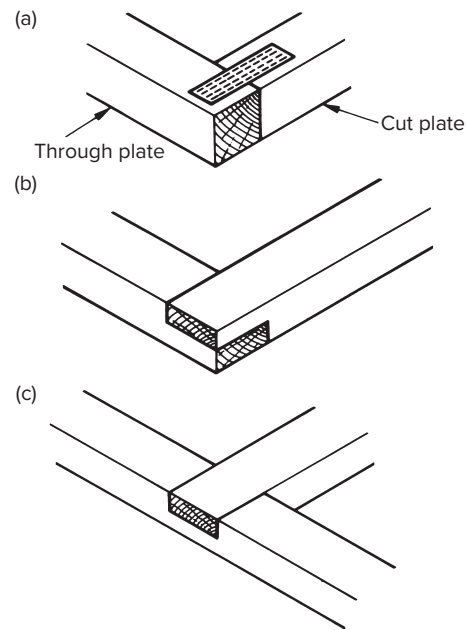
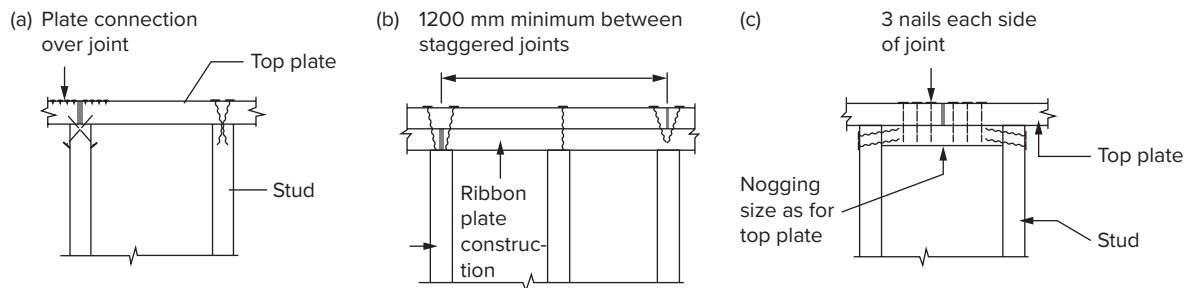


Fig. 18.6 Joining of top plates: (a) top plates joined using plate connection method; (b) ribbon plate construction; (c) plate joints secured with nogging support



CHECK YOUR UNDERSTANDING

1. When selecting a section size for wall top plates, what is the difference between random load and direct load?

18.1.3 Studs

Studs are vertical members fixed between plates spaced at 450 mm or 600 mm centre to centre. The length of the stud must be calculated to preserve the specified dimension from floor to ceiling, the minimum for habitable rooms being 2400 mm.

18.2 Arrange studs at wall junctions

Studs must be arranged at wall junctions to support the corner and to provide firm ground for fixing the interior linings and the outside sheeting (Fig. 18.10). Corner junctions require three studs.

The placing of the studs also depends on the order in which the walls are erected and the way in which the wall plates are joined. The three studs must be securely nailed together using blocking pieces at least 200 mm in length where necessary. In the case of brick veneer construction, two studs cleated together are sufficient (Fig. 18.11).

At other wall intersections, three studs can also be used (Fig. 18.12), or an alternative arrangement is to use a single stud at the end of the intersecting wall with a backing board. The backing board is 25 mm thick and 50 mm wider than the depth of the end stud, and is let in flush with the face of the intersected wall to provide grounds for fixing internal linings (Fig. 18.13).

The advantage of this method is that the studs in the external wall can be spaced along the full length of the building at their maximum spacing and the interior walls attached in this manner wherever they occur, leading to a saving in the number of studs required at wall junctions. Also, if the roof rafters are spaced to come over the studs, the section size for the top plates can be taken as for direct loading, permitting further economy in timber.

Fig. 18.10 Corner junctions

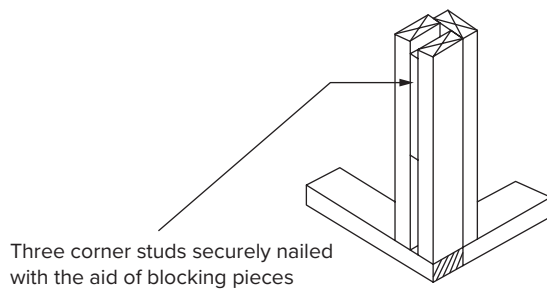


Fig. 18.11 Corner junction—cleating method

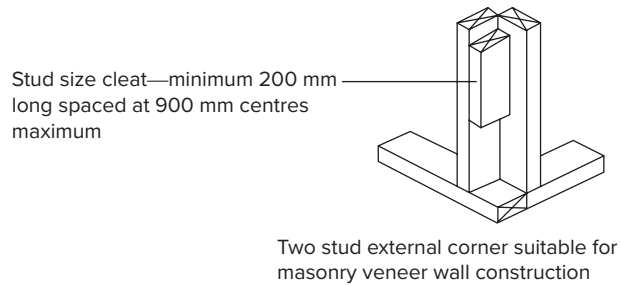


Fig. 18.12 Internal junction

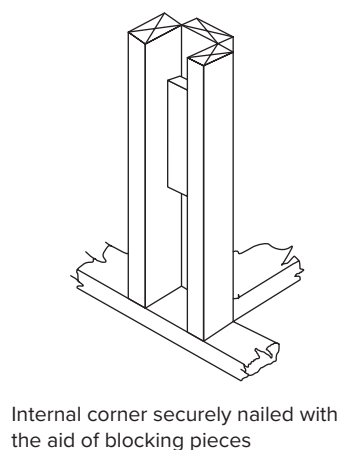
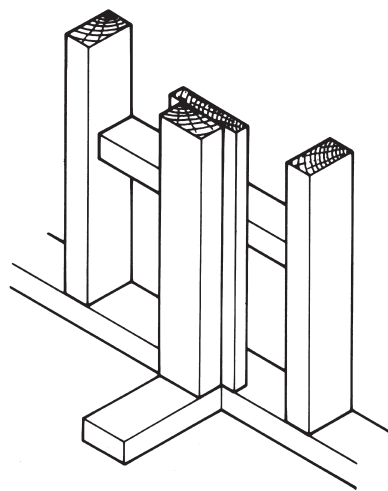


Fig. 18.13 Internal junction—backing board



CHECK YOUR UNDERSTANDING

2. Sketch two arrangements of wall studs suitable for an external corner of wall framing.

18.2.1 Lintels

Where openings occur in the wall framing to provide for a door or window, the load over the opening is supported by a lintel. The section size of the lintel will depend on the stress grade of timber selected, the span of the lintel, the rafter/truss spacing and the RLW.

TIP A minimum clearance of 15 mm must be provided from the top of the window frame to the underside of the lintel or lintel trimmer when determining the opening height to allow for weight deflection of the roof members.

18.2.2 Jamb studs

The ends of lintels must be supported by studs at each side of an opening and the studs must be increased in size to carry the additional load. These are referred to as *jamb studs*.

The joints between lintels and jamb studs must provide adequate bearing for the lintel and also secure fixing to the studs. The examples shown in Figures 18.14 to 18.16 can be adopted as appropriate.

This method is designed to be used for spans not exceeding 900 mm (load-bearing walls) and for spans not exceeding 1800 mm (non-load-bearing walls).

Fig. 18.14 Lintel housing into jamb stud

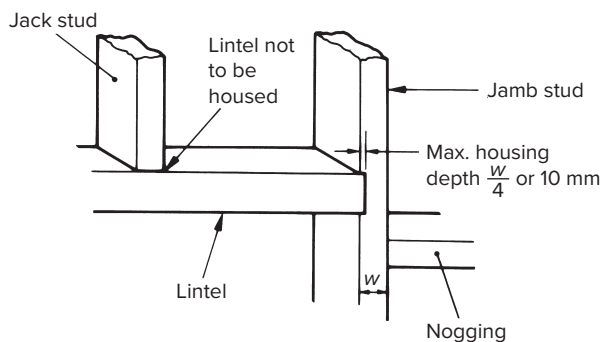
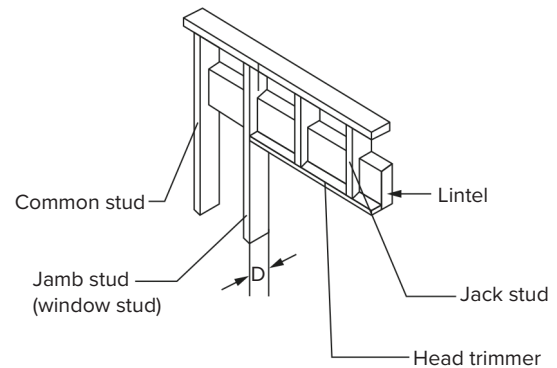


Fig. 18.15 Lintel thickness less than or equal to half the stud depth and notched through jamb stud



18.2.2.1 Sill trimmers

Sill trimmers are generally of the same section size as the common studs in that wall.

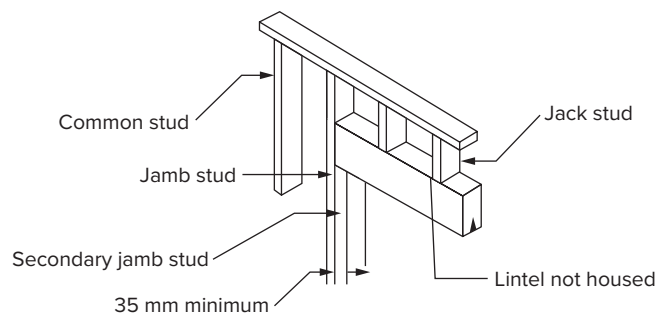
18.2.2.2 Jack studs

Jack studs are short studs above and below window and door openings.

18.2.2.3 Noggings

The studs in each panel of framing are stiffened by the addition of noggings closely fitted between the studs at not more than 1350 mm centres in height. Noggings are usually made in the same section size as the common studs in that wall.

Fig. 18.16 Lintel supported by jamb stud



18.3 Identify bracing types

Stud walls must be stiffened against longitudinal distortion by means of permanent bracing; otherwise, a rectangular frame can be readily pushed out of shape (Fig. 18.17).

Wall-bracing design, as referred to in AS 1684, describes two types: nominal wall bracing and structural wall bracing.

1. Nominal wall bracing. This refers to the lining fitted to the wall frame such as plasterboard, fibre cement, hardboard, plywood or similar materials that are fixed in accordance with the relevant Australian Standards. Nominal bracing can provide up to a maximum 50% of the total bracing required.

2. Structural wall bracing. This is purpose-fitted bracing that can be of sheet type, diagonal timber or steel bracing (Fig. 18.18). The introduction of a brace converts the rectangle into two triangular frames and a triangle cannot be distorted without breaking at least one of the sides or joints. The principle of the triangular frame will occur frequently in building when considering the strength of structural methods. The most effective angle for a brace is 45° , with each wall including at least two braces acting in opposite directions.

Fig. 18.17 Need for bracing frame: (a) rectangle readily distorted; (b) brace corrects rectangle to two triangles

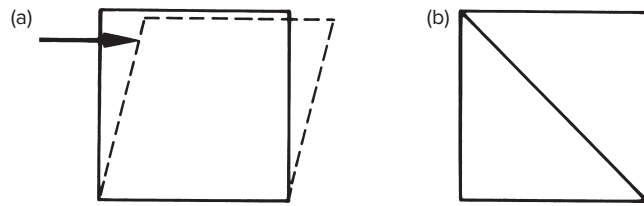
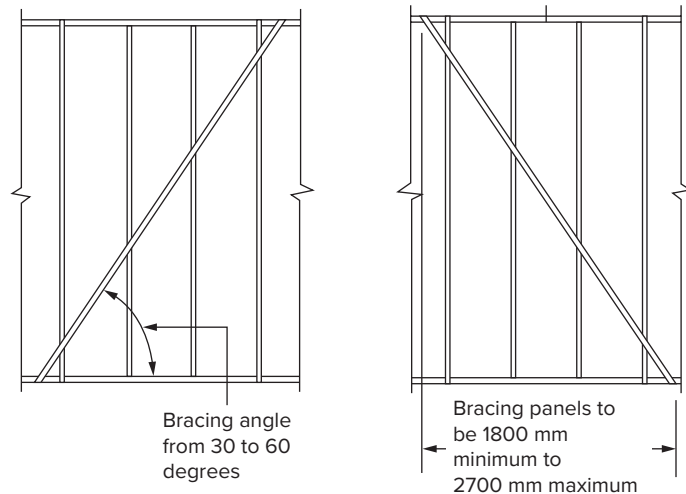


Fig. 18.18 Structural wall bracing: two diagonally opposed timber or metal angle braces



CHECK YOUR UNDERSTANDING

3. What function is served by the following members in timber wall framing?
- Top plate
 - Jamb studs
 - Head trimmer
 - Nogging
 - Diagonal brace
 - Backboard

18.3.1 Timber bracing

The minimum section size for timber bracing in single-storey construction is 45 mm × 19 mm hardwood. The studs must be notched and the brace let in flush. To calculate the approximate length of material required for a **diagonal brace**, calculate 1.5 times the height of the wall.

For example, for a wall height of 2.4 m, then:

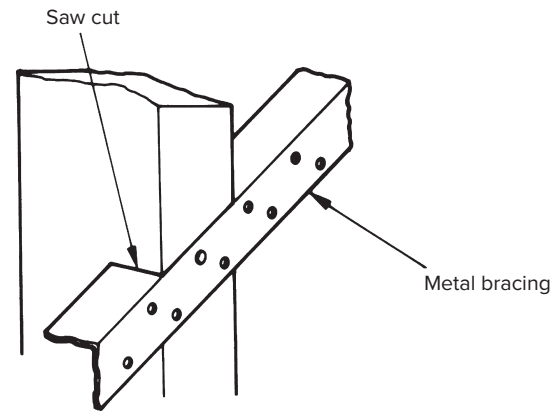
$$\begin{aligned}\text{brace} &= 2.4 \text{ m} \times 1.5 \\ &= 3.6 \text{ m.}\end{aligned}$$

18.3.2 Metal bracing

A galvanised steel angle, 20 mm by 20 mm with a series of preformed holes, can be used as bracing (Fig. 18.19). A single saw cut is necessary to let in one leg of the angle to finish flush with the stud, and the stud must then be regarded as being notched for the purpose of selecting a suitable size.

If weatherboards or similar cladding is to be used, the face of the brace needs to be flush with the face of the stud. Therefore, a portion of the stud needs to be removed, adjacent to the saw cut on the stud. The saw cut also needs to be 5 mm deeper than the leg of the brace to accommodate the brace being recessed and to sit below the face of the stud. Additionally, always ensure that the perforated leg of the brace has its edge pointing down towards the bottom plate. This is to prevent cuts and abrasions occurring once the walls are stood up.

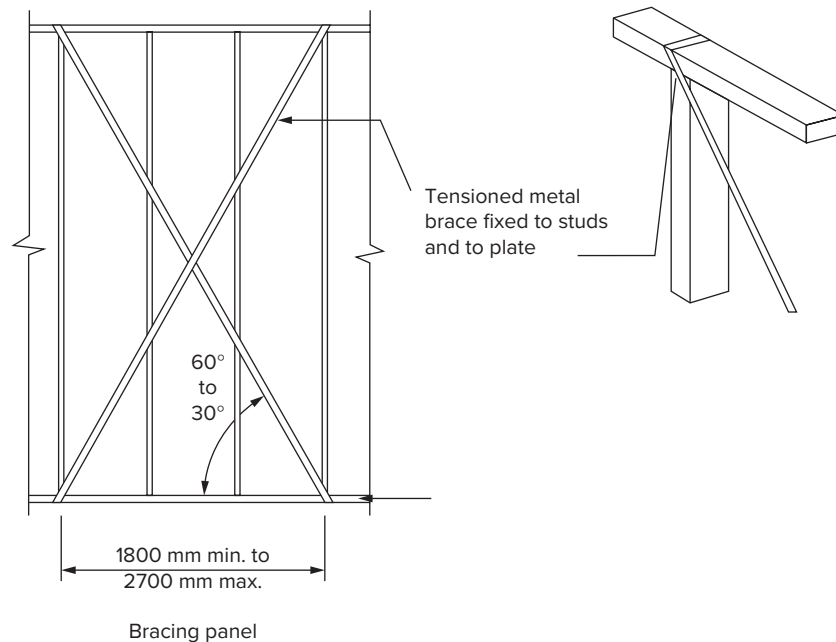
Fig. 18.19 Steel angle bracing



18.3.3 Tension bracing

Tension bracing can be used in walls with un-notched studs (Fig. 18.20). The bracing consists

Fig. 18.20 Tension bracing

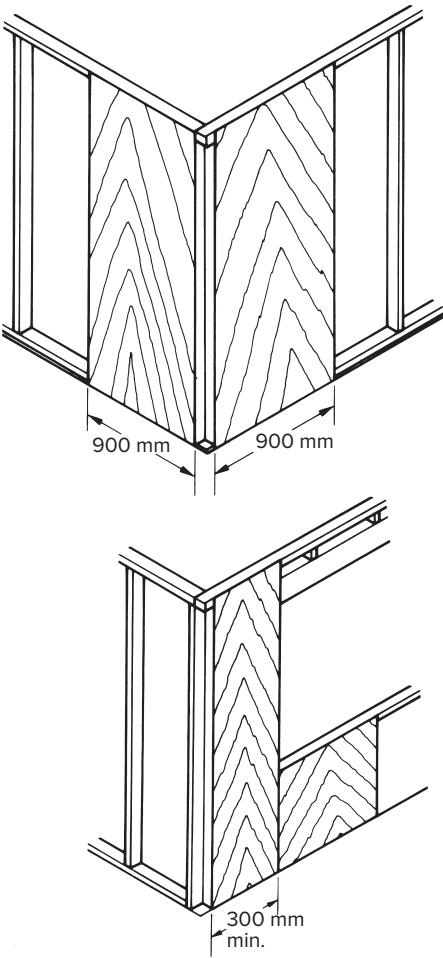


of flat galvanised steel at least 19 mm × 0.8 mm. As it is effective as a brace in tension only, two braces must be used on each panel of wall framing, acting in opposing directions to each other. The braces must be fixed from the top to the bottom plate at an angle of between 30° and 60° to the horizontal and be adequately tensioned.

18.3.4 Plywood bracing

Structural plywood from 4 mm to 9 mm in thickness can provide effective bracing when applied to un-notched studs (Fig. 18.21). The minimum length of plywood bracing to each straight wall is 1.8 m and is usually fixed as two 0.9 m panels at the corners.

Fig. 18.21 Surface bracing



The plywood can be fixed to the internal or external face of the walls, and narrow panels (300 mm minimum) can be applied beside window or door openings to make up the required length of plywood bracing. Structural particleboard, fibro cement and hardboard are acceptable as alternative sheet bracing materials.

18.4 Identify timber sizes

The selection of suitable sizes for members of wall framing depends on a variety of factors.

A full range of span tables for designing various timber frame components is available in the supplement to AS 1684.2. This supplement contains a selection of design tables for all critical framing members, from floor bearers to roof battens, and covers a range of the common stress grades (strength) of timber available. Table 18.1 shows one example that details how to select the correct **lintel** size for a door or window opening when using F17 seasoned hardwood and meets the requirements for non-cyclonic areas. The example is for lintels that are to support the load of a tile roof and are built into a single- or upper-storey load-bearing wall. Table 18.1 shows only the key heading of the required input for determining the allowable spans and lintel sizes. For firmer details you will need to refer to the current AS 1684.2 supplement Timber Framing Span Tables.

Table 18.1 Span tables for lintels: tile roof, single- or upper-storey load-bearing walls, seasoned hardwood, stress grade F17

Table 18 for LINTELS—Supporting tile roof on single- or upper-storey load-bearing walls										
	Roof load width (mm)									
	1500		3000		4500		6000		7500	
Rafter or truss spacing (mm)	600	1200	600	1200	600	1200	600	1200	600	1200
Lintel beam size D × B (mm)	Maximum lintel span (mm)									

Source: Adapted from AS 1684.2 N1/N2 Supplement 8 2010

TIP You will need to calculate the RLW and also give input for the rafter/truss spacing and the lintel span when using this table.

18.5 Set out wall plates

Setting out wall plates is a responsible task that is generally entrusted to an experienced tradesperson. An ability to read plans and interpret information from specifications and trade literature is essential. The procedures outlined here have been found to work successfully and emphasise the basic principles.

It is well recognised, however, that some minor modifications may be necessary to adapt these principles to different flooring systems. The following example looks at the procedures of setting out wall plates on a timber platform floor system. However, similar methods would be applied if the wall plates were to be set out on a concrete floor slab.

CHECK YOUR UNDERSTANDING

4. Why does the RWL become significant when designing external wall framing?

18.5.1 Procedure

18.5.1.1 Step 1

Mark out wall frame positions

Before wall plates can be laid out, the position of the walls will need to be accurately marked out on the floor with the aid of chalk lines. Some wall marks will have been set out previously on the external subfloor bearers to assist with the positioning of floor joists under walls. These marks can now be transferred onto the platform floor. Carefully check that measurements are accurate to the floor plan dimensions. Set out all remaining wall positions and mark off the location of both sides of the plates for their full length. Show all junctions and where walls may end.



INTERPRETING PLANS

Refer to the floor plan (drawing 02) in the Appendix and identify the internal width that the robes in Bedrooms 2 and 3 need to be set out at when marking out the wall plate.

18.5.1.2 Step 2

Select suitable lengths of plate material from the timber ordered

Always choose the straightest lengths for the **top plates** as this will make it easier for straightening at a later stage. The plates should now be cut to length in pairs and tacked together in place on the floor with the top plate uppermost (Fig. 18.22).

Plates are joined at the wall junctions and can be made to span more than one small room, but they should be constructed in sections that suit ease of handling. Consideration will need to be given to deciding which wall plates will run through and which plate will butt into the other at junctions. A general rule is that the long walls running the length of the building at right angles to the roof span will run through. End walls will run between these, butting into them to form the corner junction.

Where an internal partition wall meets an external wall ('T' junction), the external wall will run through with the internal wall butting into it (Fig. 18.23).

Joints in long walls can be made away from a corner junction. (For information on the joining of top plates, refer back to Figure 18.6.)

Fig. 18.22 Wall plates tacked in position on the floor

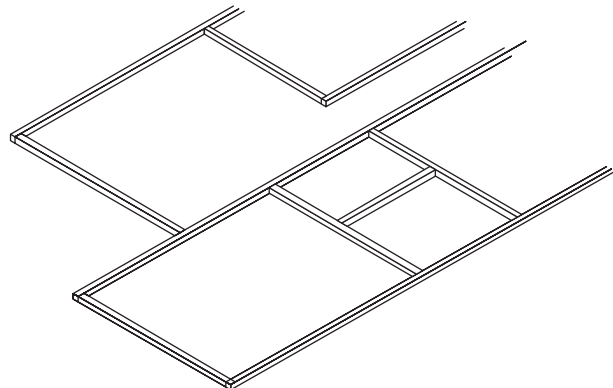
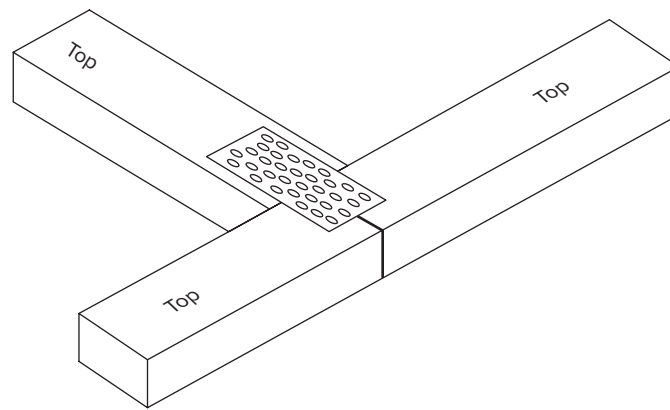


Fig. 18.23 Joining top plate at a 'T' junction

Joins made in top plates should not be made over a door or window opening.

When the plates are all cut to length in pairs and tacked together on the floor as described, the next task will be to accurately mark out the position of the wall studs.

Set out and mark stud positions in the following order:

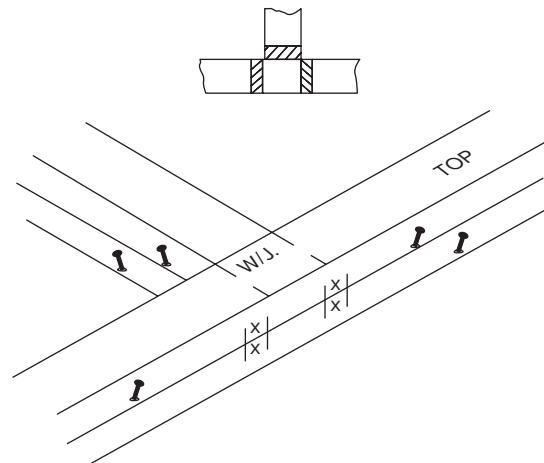
- wall junctions
- door and window openings
- studs identified to support concentrated loads
- intermediate common studs including jack studs.

18.5.1.3 Step 3

Mark set out for wall junctions

Where the walls intersect, mark two lines halfway across the top plate and identify with the letter 'W'. This identification is placed on the face side where the two plates meet. This is to make recognition easier when assembling wall frames later. Using these two intersecting lines you can now locate and mark the position of the corner studs. The stud positions are marked on the edge of both the top and bottom plate as shown in Figure 18.24.

Refer to Figures 18.10 to 18.12, which display various corner stud layouts.

Fig. 18.24 Wall junction and stud marking

18.5.1.4 Step 4

Set out door and window openings (Fig. 18.25)

Locate the positions for window and door openings and mark for jamb studs. Plates are left running through door openings and this portion of the bottom plate is not cut out until the walls are permanently fixed in position. The stud opening size for a window and door must be made larger than the overall size of the frame, so that the frame can be accurately levelled and plumbed up when it is fixed. In the case of timber window frames, add approximately 20 mm to the overall frame size in height and width to obtain

Fig. 18.25 Marking door and window openings

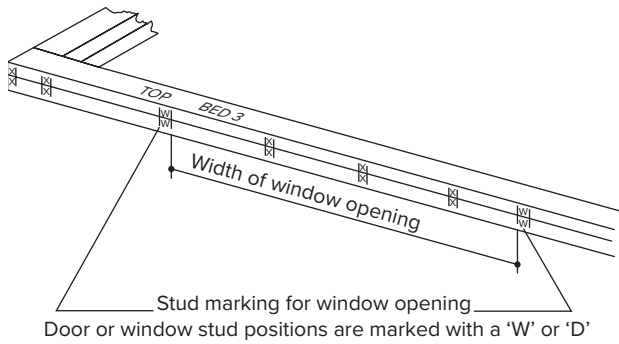
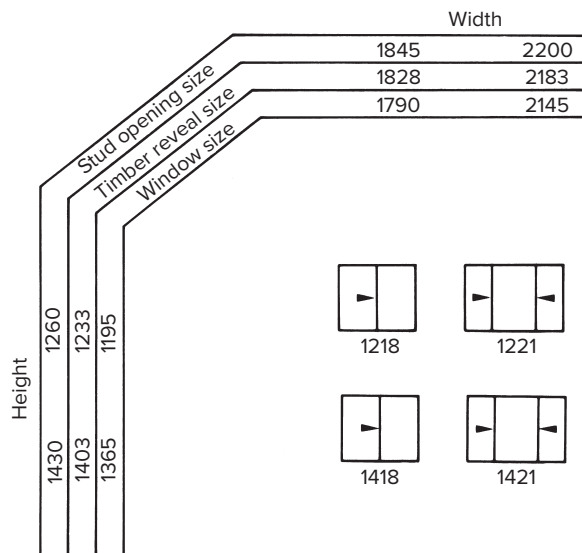


Fig. 18.26 Window manufacturer's information



the stud opening size. Some manufacturers of stock size frames provide the necessary information in their trade literature.

The stud opening size for aluminium frames can be obtained from the manufacturer's instruction sheets, an extract from which is shown in Figure 18.26.

The nominal size of an aluminium frame is represented in the ordering code as the height times the width, to the nearest 100 mm. For example, a 1218 frame is approximately 1200 mm in height by 1800 mm in width. The exact dimensions, however, are shown at the side and top in line with the frame diagram. For example, the 1218 frame is exactly 1195 mm in height and 1790 mm wide. The dimensions overall, including timber reveals, is also given as 1233 mm × 1828 mm, and the stud opening size is 1260 mm × 1845 mm. A full selection chart will give this information for the manufacturer's full range of windows.

Standard door openings are made 2100 mm in height, and around 700, 800, 900 and 1000 mm in width. These openings will accommodate a standard-sized door plus the jamb and necessary clearances. If the use of narrow architraves is anticipated, it may be possible to close those openings in a little. Use a lumber crayon to mark the extent of the window and door openings.

18.5.1.5 Step 5

Mark studs supporting any concentrated loads that may be required

These studs are designed to carry major loads such as roof struts, strutting beams, and girder beams, and their design will be in accordance with the requirements of the AS 1684 Span Tables—Studs Supporting Concentrated Loads.

18.5.1.6 Step 6

Set out rafter/truss positions to top plate

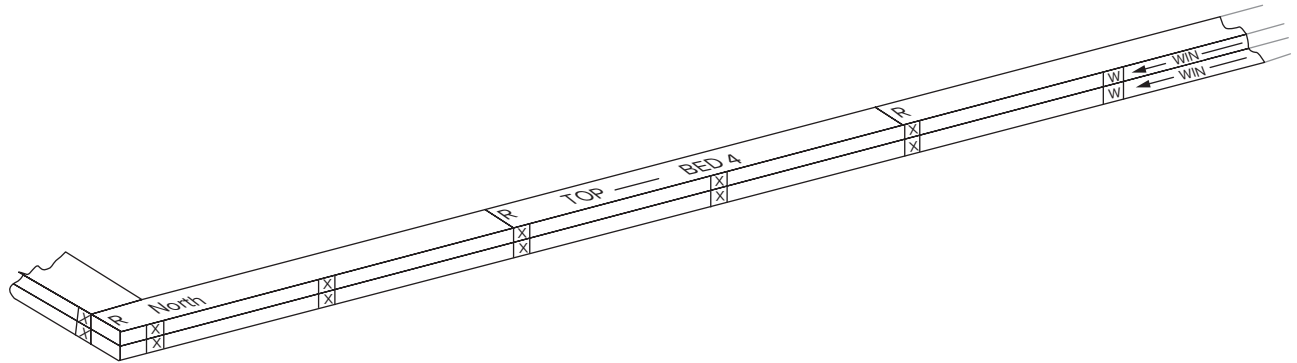
At this stage, it is a good idea to set out the rafter/truss positions now while the plates are still tacked in position near ground level. This will make the task much easier than later when the walls are stood up in position. It may also be necessary to locate common studs under the roof members. This will depend on the thickness of the top plate and spacing of roof members (refer to the details given earlier in this chapter on top plates). If the roof members are directly loaded over the studs, marking the position of the rafters now will assist in locating and marking the common stud positions, which is our next task.

18.5.1.7 Step 7

Set out intermediate common studs

Mark in the position of all remaining common studs, referring to details given earlier in the chapter (Fig. 18.27). Space out and mark the studs in between using the 'in and over' method where possible, not exceeding the maximum specified spacing.

Fig. 18.27 Marking common studs

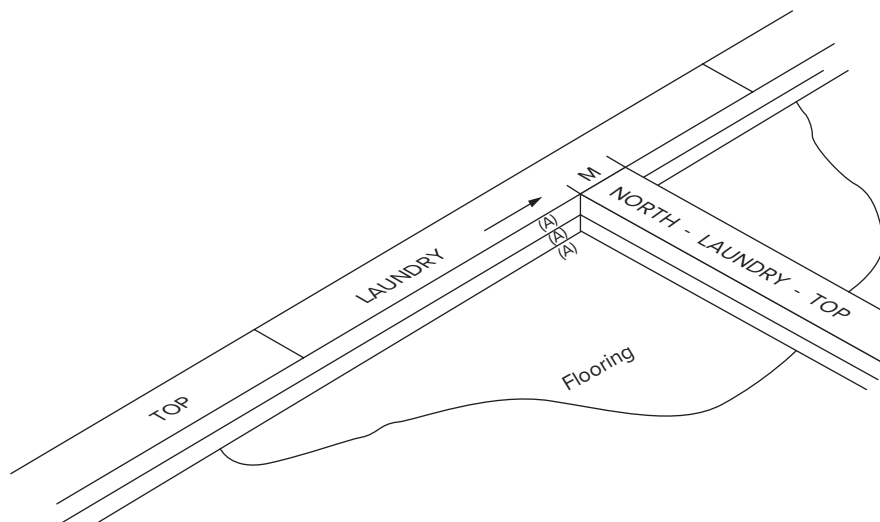


18.5.1.8 Step 8

Mark plates with an identification mark (Fig. 18.28)

It will be necessary to provide clear identity marks on the plates with a crayon to locate their position in the building. This is done before the plates are removed from the floor in readiness for assembly of the walls. Mark 'TOP' and 'BTM' (bottom) on the face of each plate. Also mark on the plate sufficient information that will locate the position of the plate in the building. For example, 'LOUNGE', 'BED 1', 'LAUNDRY', etc. Some builders identify, close to one end of both plates, the direction in which they are facing—that is, 'NORTH', 'SOUTH', etc. Also near the end of the plate, an identification number or letter (in brackets) can be placed on the edge of the paired plates with a corresponding number marked alongside on the floor. This will help to relocate plates in their correct position should they get mixed up during the wall assembly stage.

Fig. 18.28 Identity marks on plates



18.5.2 Setting out studs

The length of the studs can be calculated and a pattern stud marked to length (refer back to Fig. 18.7). On the face of the pattern stud, mark the height of the window and the door lintels and sill trimmers. It is common practice to carry the window openings up to the **eaves soffit**, in which case the drop of the eaves soffit must be determined. Mark the door heads to provide an opening 2100 mm in height where standard sized doors are specified. Select the straightest of the studs and mark out the jamb studs in pairs, ready for trenching if required.

18.6 Assemble timber wall frames

To assemble wall frames on-site, lay out the wall plates and studs on the platform floor as close as possible to the position where the wall frame will finally be erected (Fig. 18.29).

A number of frames can often be made on top of each other, so keep in mind the order in which the walls will be erected and assemble first the frame to be erected last.

As the studs are laid out, quickly sight them in length and lay all of the round edges facing one way, usually round edge up. Some may prefer to lay studs the opposite way round, but the important thing is that they are all laid the *same* way round.

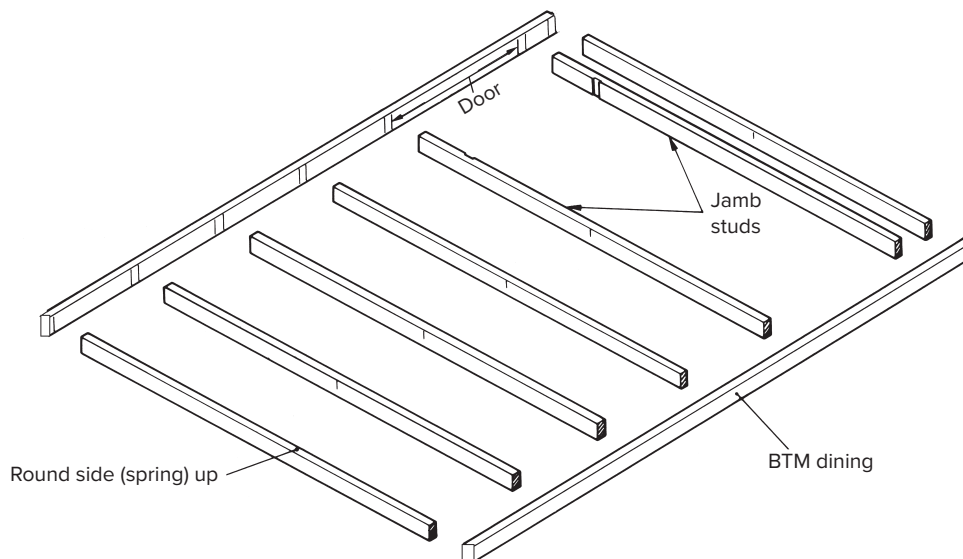
With a carpenter at each end, nail the plates to the studs with two nails at each joint. Cut to length and fix the lintels, trimmers and jack studs. To fix the **noggings**, measure the length along the plate between the studs and cut to length. If the material has been **machine gauged**, much of the nogging can be cut to a standard length to suit the studs spaced at their maximum spacing.

Noggings are spaced at no more than 1350 mm centres in their height. They are fixed in a straight line wherever nail-fixed sheet material is to be butt jointed along that line or, in order to provide more secure nailing, they can be offset by not more than their own width from that line.

18.6.1 Squaring up wall frames

Wall frames are squared up by making the two diagonals equal. Sight that the plates are lying straight and secure one plate against movement by two skew nails.

Fig. 18.29 Layout of wall frame for assembly

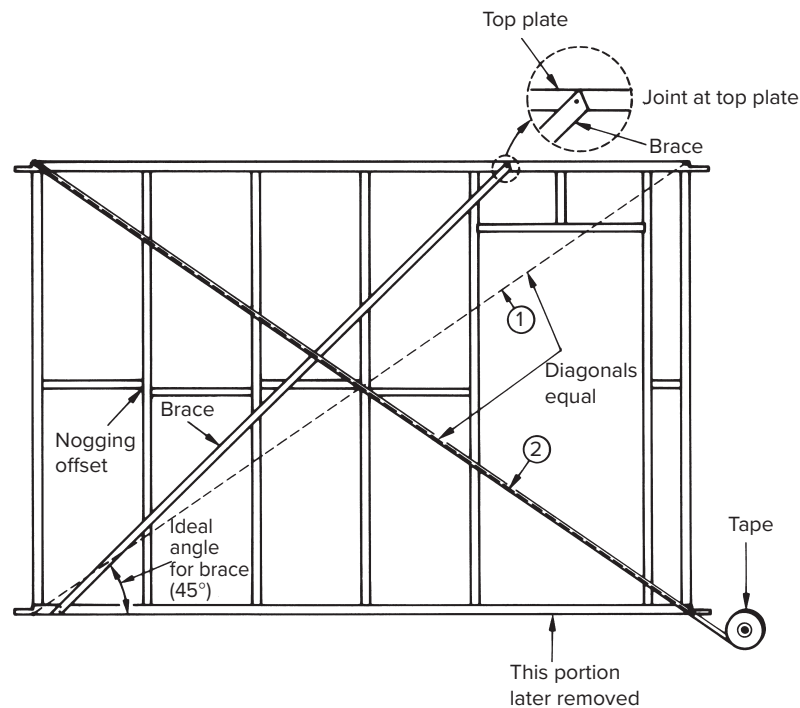


The diagonals can be measured with a long squaring rod or, perhaps more conveniently, with a steel tape. Measure diagonal 1 and assume it measures 4340 mm. Measure diagonal 2, which measures, say, 4310 mm. The difference between diagonals is then 30 mm. Take half this difference, 15 mm, and add it to the shorter diagonal or subtract it from the longer diagonal to give a dimension of 4325 mm. Move the loose plate sufficiently to make the two diagonals equal at 4325 mm and secure the plates with a skew nail ready for fitting the brace.

18.6.2 Bracing

To fit a timber brace, lay the brace across the studs as near as possible to the ideal angle of 45° and tack it lightly in place (Fig. 18.30). Mark each side of the brace, lift it aside and gauge the depth of the notching to allow the brace to finish flush with the framing. Remove the waste and replace the brace, but do not nail it permanently at this stage.

Fig. 18.30 Squaring up wall frames



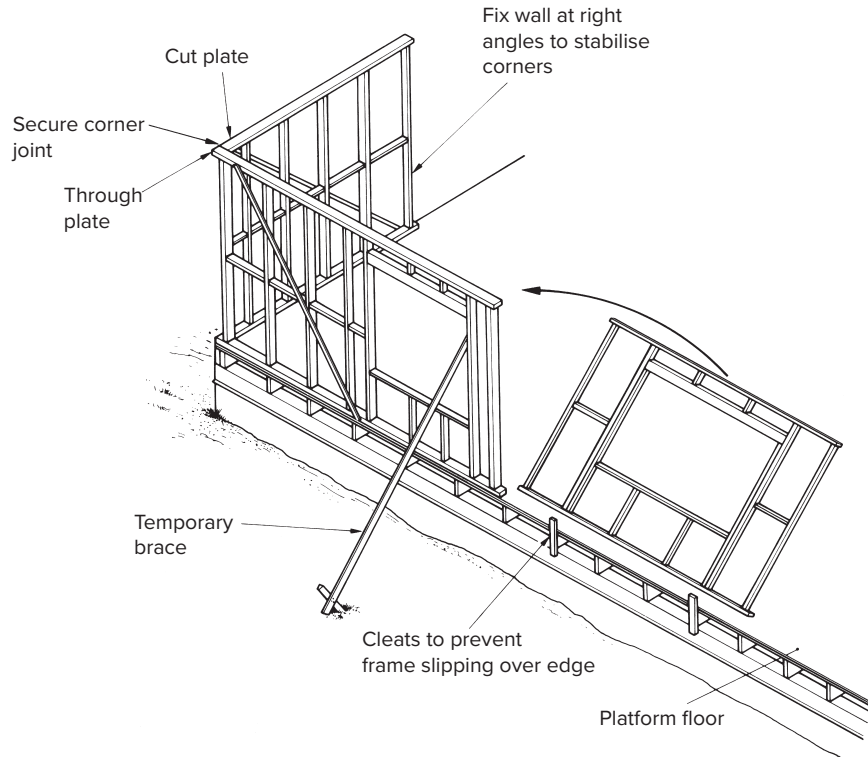
CHECK YOUR UNDERSTANDING

- How are wall frames squared up prior to being erected?

18.6.3 Erection of wall frames

Erecting wall frames is an operation that warrants special attention to safe working procedures, particularly when working on open floor joists (Fig. 18.31). Ensure there is an ample labour force available to safely lift and stand the frames into position. Care must be taken when standing the walls—workers must be sure to bend from the legs and maintain a straight back when lifting. Short cleats nailed to the end of joists will prevent the frames from slipping over the edge. When the frames have been stood upright, ensure that enough people are steadying the now-vertical frames while the frames are secured with temporary bracing until a more permanent fixing is possible.

Fig. 18.31 Erection of wall frames



The most effective way to stabilise walls is to erect frames at right angles to each other and secure the top joints together with the aid of metal nailing plates. A big plus for the platform floor is that it renders this part of the work easier and much safer.

Proceed to stand all of the wall frames. Do not fix any permanently in position, but proceed with the next operation.

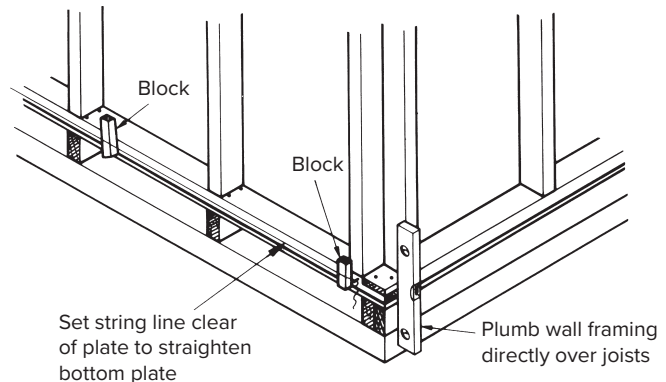
For fixing requirements of plates to joists or slabs once in the final position, refer to AS 1684.

18.6.4 Trueing wall framing

The wall framing must be trued accurately and the job carried out in an orderly manner, as follows:

1. At each external corner, plumb up from the joists and bearers, and fix the bottom plates directly above, nailing through into the joists.
2. Between external corners, straighten the bottom plates by attaching a string line packed out from the plate with blocks of equal thickness. Nail through into the joists. Straighten and fix the bottom plates to the internal walls with a string line or long **straight edge**, or fix to the chalk line marks previously set out on the platform floor (Fig. 18.32). Refer to details given earlier in this chapter.
3. Plumb external corners (Fig. 18.33). Suspend a plumb bob from the corner

Fig. 18.32 Fixing external corners



of the top plate and release the braces where necessary to force the frame to plumb up directly over the corner of the bottom plate. Alternatively, use a long straight edge and spirit level in place of the plumb bob. Replace the braces and nail permanently in position. Apply the same procedure if using alternative bracing materials.

4. Straighten the top plates by attaching a string line packed out from the plate (Fig. 18.34). First adjust the plate to the string line at each intermediate wall junction by releasing the brace and adjusting the internal wall over to the string line, where necessary. Replace and permanently fix internal wall braces. Straighten the plates between the wall junctions and secure them with temporary braces. The top plates to internal walls are straightened by sighting or by the use of a straight edge, and are stabilised by temporary braces where necessary until the next operation (fixing of the ceiling framing) is completed.
5. Complete fixing of corner studs and blocking as required.

Fig. 18.33 Plumbing external corner

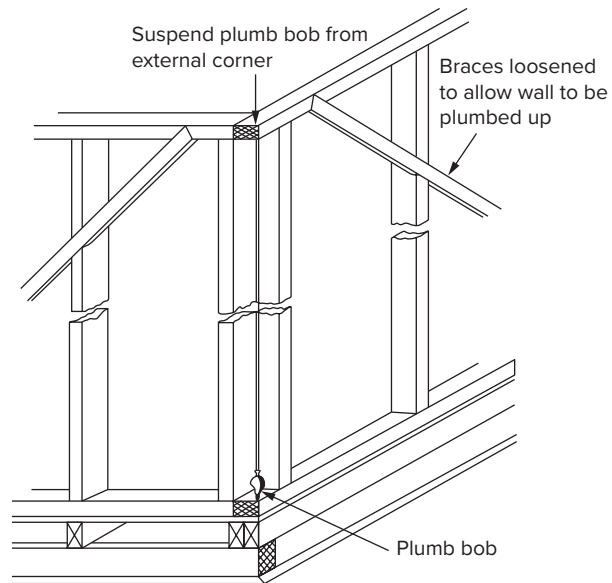
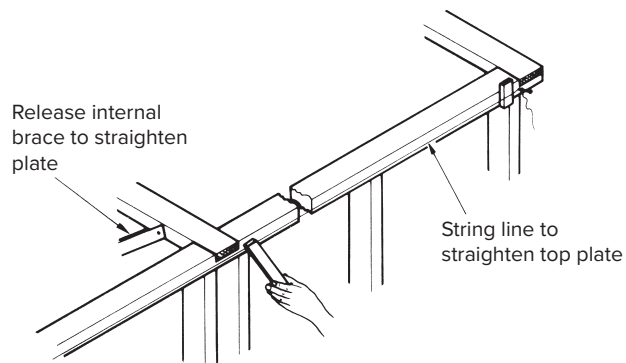


Fig. 18.34 Straightening top plate



CHECK YOUR UNDERSTANDING

6. What safety precautions should be taken when erecting wall frames?
7. Briefly outline, in sequence, the procedure taken to true up the wall framing after it has been stood in position.

18.7 Use tie-downs and brackets

18.7.1 Tie-downs

Tie-downs are extremely important as they assist in anchoring the entire frame down to the foundations in order to resist wind loads, whether on the side of the building or passing over a roof—there is potential for lift to be generated when lower pitch roofs are constructed.

The idea behind tie-downs is that instead of relying solely on nails, screws, etc. to hold one component to another, like the top plate to the stud, additional holding power can be achieved using a length of hoop iron that runs up one side of the stud, across the top plate and then down the other side of the stud. The hoop iron is then nailed in place using the appropriate fixings. This process is repeated at other connections so that the roof is literally tied down to the foundation using hoop iron or specific brackets. Tie-down details and specifications can be found in AS 1684.

18.7.2 Brackets

There are many types of brackets available on the market. Most have a particular function and, generally, they strengthen the intersection of two pieces of timber. Additionally, there are some metal brackets available that replace traditional timber joints.

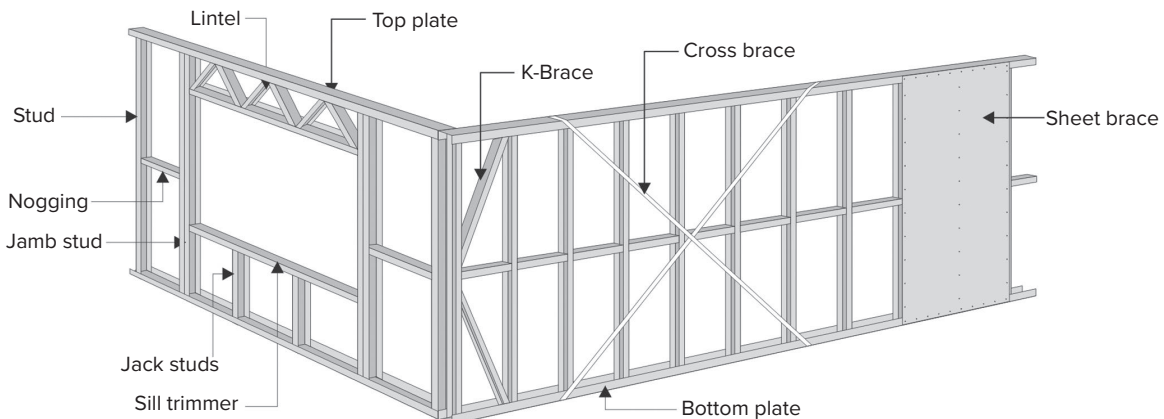
18.8 Assemble steel wall framing

Steel-framed house construction is used in around one in seven new homes in Australia and provides an alternative method to traditional timber framing (Fig. 18.35). Steel framing systems vary, with manufacturers using different sections, steel thickness and joining methods such as screws, rivets, bolts and welding. However, all systems are designed to the same structural standards and the general principles of wall frame construction on-site are the same for all systems and are quite similar to timber construction.

There are two approaches for constructing steel house frames. The most common method is to have the wall frames pre-fabricated at the factory. These are then transported to the building site and erected in position on the prepared slab or floor system. The other method is to deliver all of the framing component members to the site precut to length, with all fabrication and assembly done on-site. The latter is the less popular approach in urban areas, but it is more commonly used in remote areas.

In either case, the wall component specifications and panel layouts are generated by computer design and detailing software operated by trained frame detailers.

Fig. 18.35 Steel wall framing



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CHECK YOUR UNDERSTANDING

8. Name two ways in which steel wall framing can be supplied.

18.8.1 Steel wall framing erection

Pre-fabricated steel wall framing can be erected on all standard flooring systems. The framing is erected using the same set-out techniques and follows the same sequence that you would use for timber framing. The frames are pre-fabricated in lengths up to 7.5 m maximum for ease of transport and site handling. Fixings used on-site will include screws, rivets, masonry anchors, power-driven nails and occasionally bolts and special clips.

Factory prepunched holes are usually provided in the studs and top plates at convenient locations to accommodate the installation of plumbing and electrical wiring.

Plastic grommets are fitted to the service holes and are one method of avoiding damage to cabling during installation. Most grommets have anti-vibration fins to support the water pipes once installed. Corrosion caused by contact of dissimilar metals is always a possibility; the grommets isolate the metal frame, thus avoiding metal-to-metal contact with copper piping and brass fittings. Another factor to consider in order to avoid unintended galvanic corrosion is the use of incorrect fixings made from metals too dissimilar to the frame. Refer to BlueScope, Corrosion Technical Bulletin 12 on dissimilar metals, for more details.

Holes may also be swaged or flared to prevent cable damage, but service pipes must be supported when passing through studs and plates.

Wall locations are set out on the slab or platform using a chalk line, starting with the external walls. To compensate for possible differences in slab dimensions, mark the inside of the external wall frame positions. Continue on to the internal walls, checking constantly for squareness (Fig.18.36).

Fig. 18.36 Wall frame layout

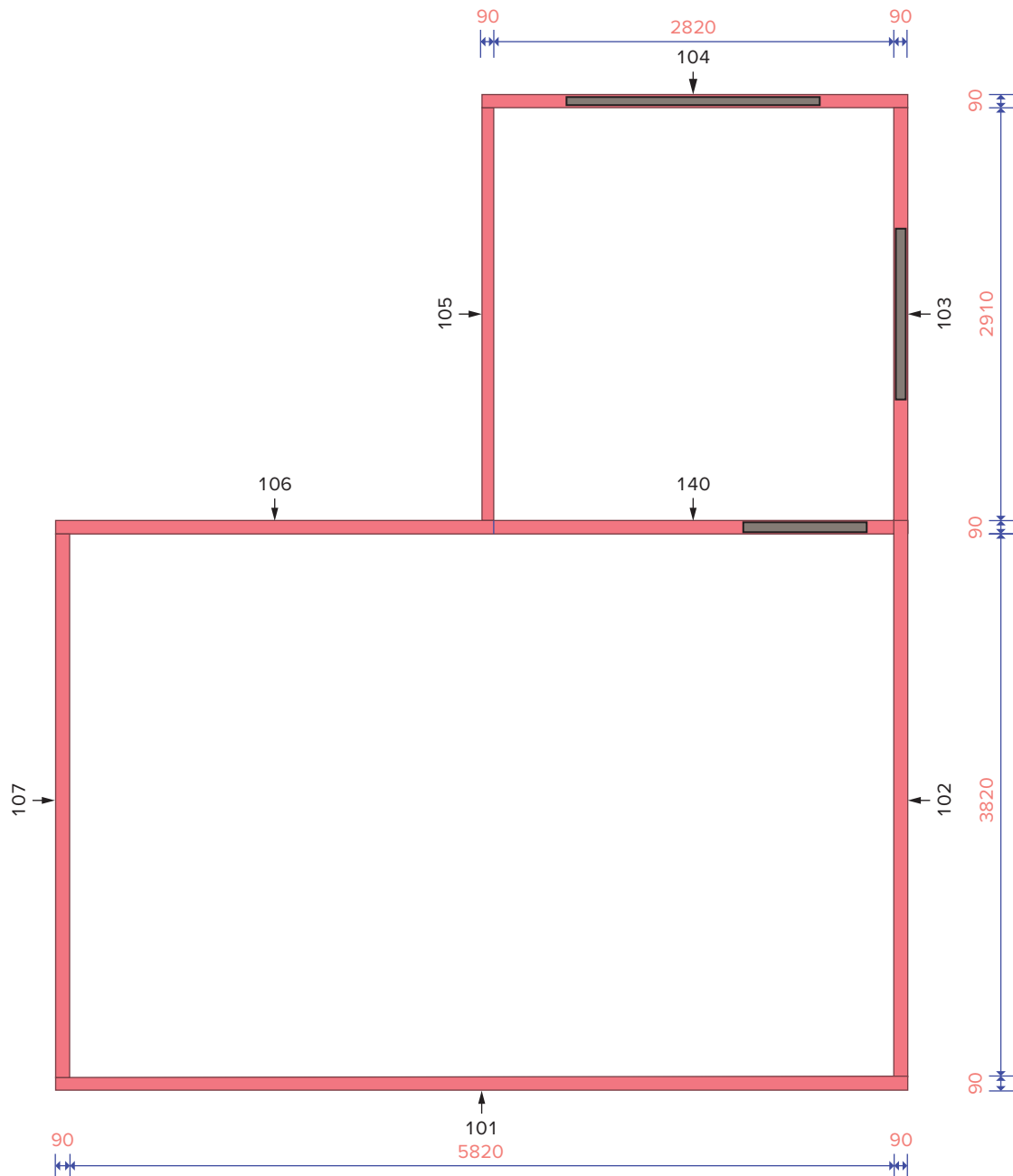
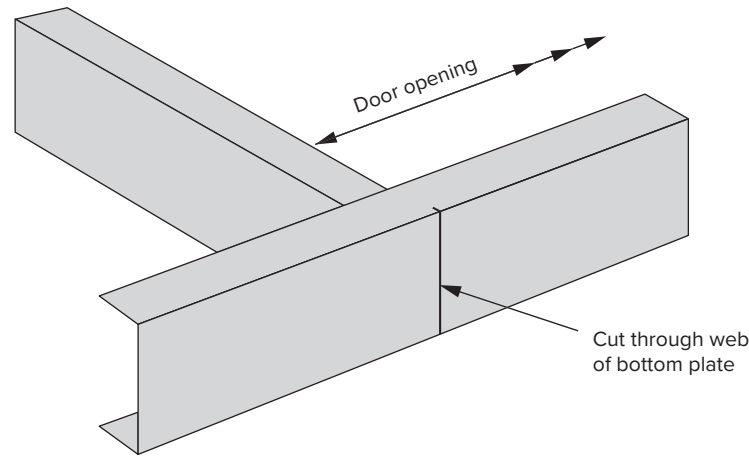


Fig. 18.37 Preparation of door opening

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Where perimeter wall frames are placed on a concrete slab-on-ground, a durable impermeable membrane should be placed between the bottom plate of perimeter wall frames and the slab and extend up the weather side flange of the bottom plate. The membrane is not required beneath internal wall frames or upper-storey wall frames. The membrane may be the same as that used for damp-proof courses, a paintable bitumen product or a self-adhesive polyethylene.

Note: Drawings and specifications should be carefully checked as the membrane may be required as a condition of product warranty.

Before standing the wall frames:

- mark out the positions of the roof trusses on the top plates
- drill any holes in the bottom plate that may be required for fixing to the slab/floor frame
- cut the web of the bottom plate at either side of the doorways using an angle grinder with a metal cutting disc or preferably using a power saw with a cold-cutting metal blade (Fig. 18.37). This makes the removal of the bottom plates in doorways easier after the frames are erected.

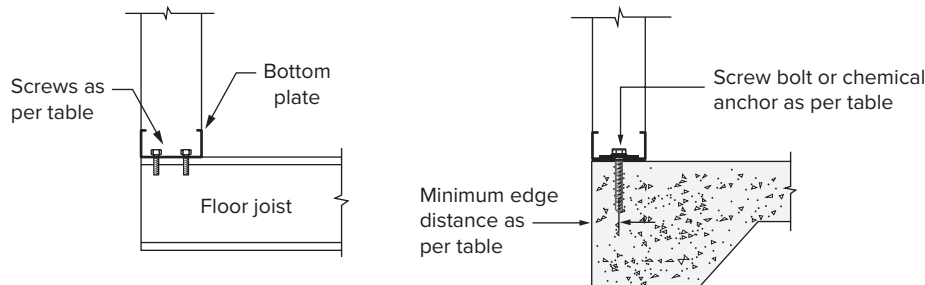
When all wall locations are marked out and the frames prepared, place the frames near their required location as shown on the layout plan. Stand the frames, commencing with an external corner, fixing them together as indicated by the frame supplier on the panel layout drawing. This is typically done with self-drilling screws but may also involve special brackets or clips. Continue to work around the building adding one frame at a time, checking that each frame is aligned with the set-out marks and plumb before proceeding to the next. Use temporary bracing as required to stabilise the frames until the wall and roof framing is complete and fully braced.

CHECK YOUR UNDERSTANDING

9. What methods are used to join steel frames together?

18.8.2 Hold-down

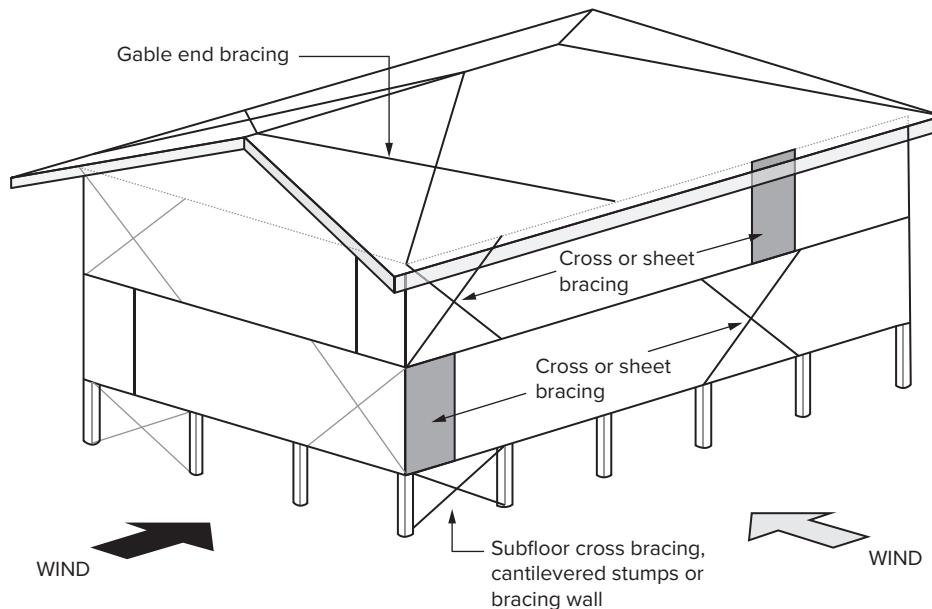
The frames are then fixed down to the slab or floor using methods and spacings specified on the frame supplier's drawings. The specifications will vary depending on the type of floor, type of roof and wind region. Particularly important are the fixings beside the openings, at wall ends and corners, and where bracing straps or sections meet the bottom wall plates. Screw bolts are a common fixing method for concrete slabs as they are fast and reliable (Fig. 18.38). Where a steel floor frame is used, self-drilling screws of the correct size and length are commonly used. In cyclonic areas where hold-down requirements can be very large, the frame supplier will pay particular attention to the continuity of the load path from roof structure to foundations. This may involve specialised fastening arrangements for the wall frames.

Fig. 18.38 Connection details for wall frame to slab and floor joists

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18.8.3 Bracing

Bracing strength is critical to the structure both during and after construction. Bracing usually consists of a combination of methods such as metal strapping, K-braces, sheet materials such as steel, fibre cement or plywood, and plasterboard lining. You will need to provide and fix all bracing as specified by the frame supplier (Fig. 18.39).

Fig. 18.39 Bracing of wall frames

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The final step in wall framing is to remove the bottom plates in doorways by cutting the flanges at each jamb stud down to the precut plate webs (see Fig. 18.37).

For further information, including fact sheets, PowerPoint presentations, trade instruction sheets and the General Guide to Steel-Framed Building, refer to the National Association of Steel-House Framing (NASH) website at www.nash.asn.au. NASH standards and handbooks may also be purchased through the website.

18.9 Construct two-storey dwellings

18.9.1 Timber-framed buildings

The principles of timber framing described for single-storey buildings in Chapters 17, 18 and 27 are equally applicable to two-storey buildings, with the addition of details of the construction between the first and second floors.

To support the increased load due to a second storey, some minor modifications are necessary to the **footings** and ground-floor timbers. Specifications usually require an increase in the width of the footings—80 mm to 100 mm or as otherwise approved by the local building authority—with an appropriate increase in the amount of steel used for reinforcing.

In the ground-floor framing of a two-storey construction, a bearer should be located directly under any wall that supports loads from upper floors and is running at right angles to the joists. (Their size must be obtained from AS 1684.2.) Also, a joist should be located directly under all load-bearing walls that are parallel to joists.

WORKPLACE SCENARIO

When stick building timber wall frames, consideration must be given to the quality of the timber being used. Even with kiln-dried timber, not all of it is straight and true, so selecting the straightest lengths and reserving them for the wall plates, corner and jamb studs is best practice. The very worst and most twisted timber should be cut up for blocking and noggins. The remaining timber should be used for the rest of the wall frame components.

18.9.2 Upper-floor joists

The joists to upper floors must be increased in depth to span the various rooms without the need for intermediate support. (Their section size can be obtained from tables in AS 1684.2.) To obtain the size, span and spacing of the joists, the **stress grade** of the timber species being used must be known. As an example of how these factors will affect the maximum allowable joist spans, refer to Table 18.2, which is for joists spaced at 450 mm centres. For other joist spacings, refer to AS 1684.2.

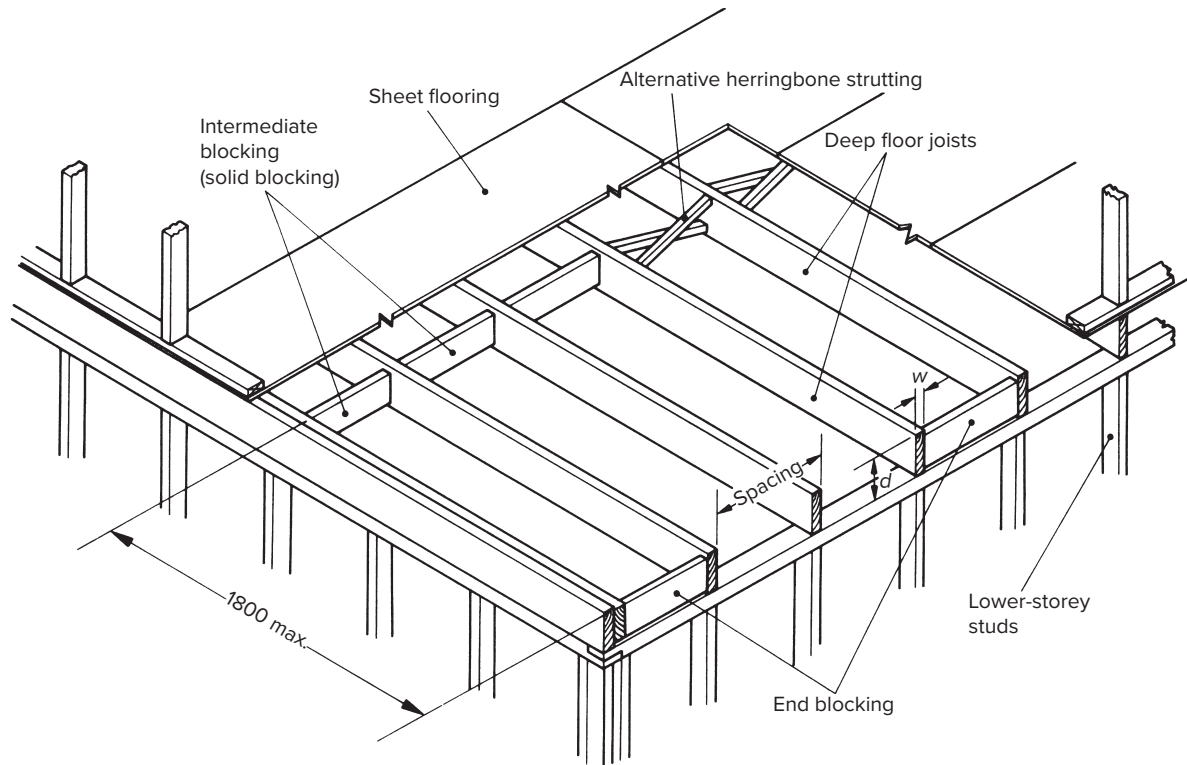
Table 18.2 shows only an example of joist spans for selected timber species. In practice, and for much firmer detail, you should refer to AS 1684.2: 2010, Supplement 10.

Table 18.2 Maximum allowable joist spans (joists spaced at 450 mm centres)

Joist size	Unseasoned				Seasoned softwood	
	F4	F5	F8	F11	F5	F8
150 × 50	2600	2800	3200	3400		
175 × 50	3300	3400	3700	3900		
200 × 50	3700	3800	4100	4300		
250 × 50	4400	4500				
300 × 50	5100	5200				
140 × 35					2300	2600
190 × 35					3500	3700

18.9.3 Platform construction

A common method of two-storey construction, as shown in Figure 18.40, is referred to as **platform construction**. The **studs** are not continuous from the ground floor to the roof, and the joists bear on, and are spiked to, the top plates of the lower-storey load-bearing walls at points immediately above the wall studs.

Fig. 18.40 Platform construction

Where the required depth of joist is equal to, or exceeds, four times the joist width, it is deemed to be a deep joist and is subject to some special provisions. If no continuous trimming joists are provided to the ends of joists above external wall plates, their ends should have solid blocking or herringbone strutting, at least between the outer pairs of joists and between intermediate pairs, at no more than 1800 mm centres. Trimmers or solid blocking should be approximately 25 mm less in depth than the joists and should have a minimum thickness of 25 mm.

Where the unsupported span of joists exceeds 2700 mm for timber less than stress grade F11, then solid or herringbone strutting should be provided between joists and along their span at no more than 1800 mm centres.

The depth of solid strutting is again 25 mm less than the depth of joists; they are fixed centrally to allow for unobstructed through-ventilation of the floor cavity. Herringbone strutting should be 38 mm × 38 mm, and a method of using the steel square to set out a pattern for strutting is shown in Figure 18.41.

An alternative arrangement for supporting upper floors over external load-bearing walls running parallel to the joists is shown in Figure 18.42. Here, the depth of the deep joists is built up by a pair of double joists, 100 mm in depth, plus trimmers fixed at right angles to the wall. This arrangement eliminates a deep end joist and is suitable for either a platform or a fitted floor.

18.9.3.1 Shrinkage of floor joists

One problem that arises when platform construction is adopted for two-storey buildings is the shrinkage of the floor joists. There can be well in excess of 400 mm to 450 mm of cross-grained timber that may shrink considerably, depending on the species and its moisture content.

In single-storey brick veneer construction, a clearance of 10 mm is allowed under all windowsills and at the eaves soffit. In two-storey buildings, where timber with low shrinkage is used in both levels of floor framing, 20 mm clear space should be provided to the underside of first-floor windowsills and

Fig. 18.41 Set-out pattern for herringbone strutting

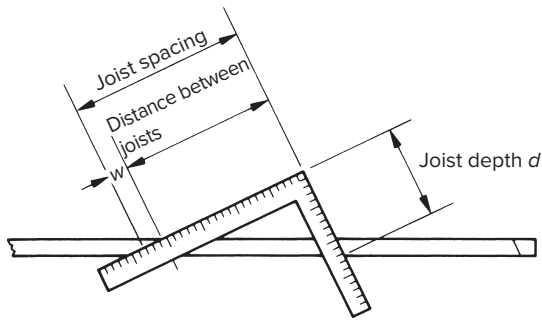
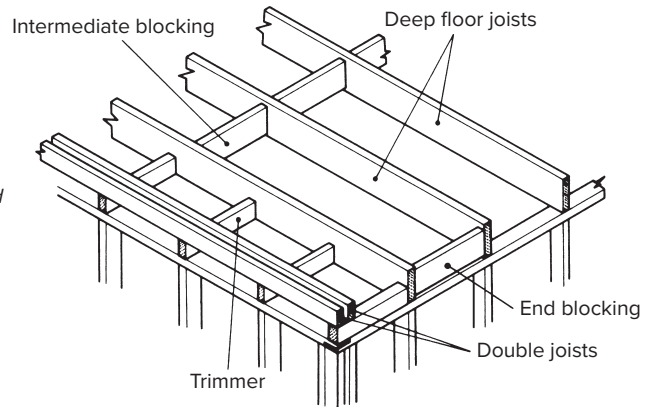


Fig. 18.42 Alternative second-storey floor framing



at the eaves soffit, while 10 mm is still sufficient for the lower windows. Where unseasoned hardwood is used in both levels of floor framing, the above clearance should be increased by 50%.

A method of construction referred to as *balloon framing*, where studs are continuous from the bottom plate of the ground floor to the top plate of the upper storey, is used in the United States to overcome the problem of shrinkage, but it is rarely used in Australia today.

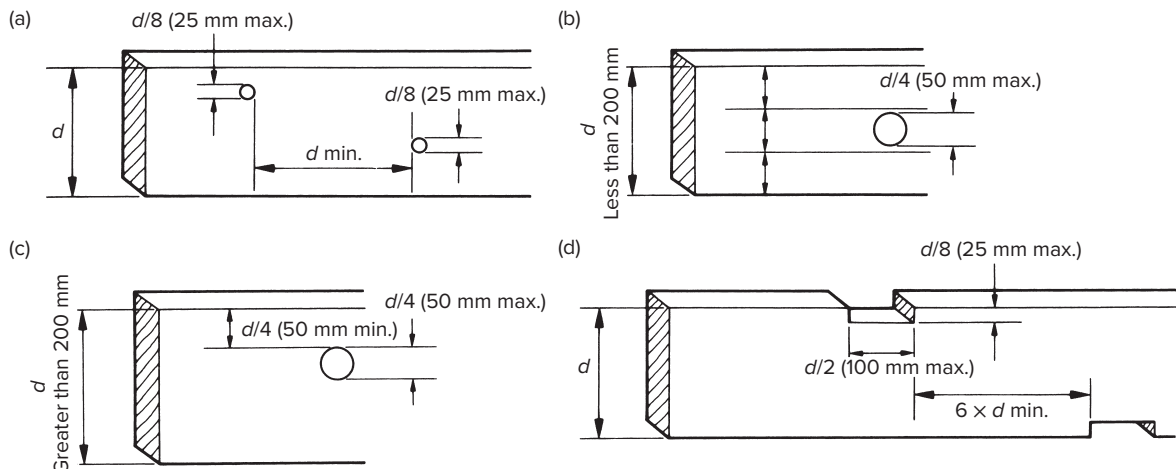
In concrete slab on-ground construction, windowsills on the ground floor do not require a clear space, but those on the first floor require a space of 10 mm.

18.9.3.2 Drilling or notching deep floor joists

It is important that deep floor joists are not weakened by indiscriminate boring or notching to provide access for such things as plumbing and electrical services. Any drilling or notching should meet the requirements as illustrated in Figure 18.43.

1. Holes not exceeding $d/8$, or 25 mm maximum, can be drilled at random provided the holes are not spaced at less than the depth of the member. Also, no more than three drillings should occur in any 1800 mm of span (Fig. 18.43a).
2. For holes not exceeding $d/4$, or 50 mm maximum, where d is less than 200 mm, the drilling must be contained entirely within the centre one-third of the face depth, with no more than one drilling in any 1800 mm of span (Fig. 18.43b).

Fig. 18.43 (a)–(d) Requirements for notching and drilling deep floor joists



3. Where d exceeds 200 mm, holes must be no closer than the diameter of the holes ($d/4$ or 50 mm maximum) to either edge, with no more than one drilling in any 1800 mm of span (Fig. 18.43c).
4. Notching the edges of joists should be avoided, but where unavoidable, must fall within the limits illustrated in the figure (Fig. 18.43d).

18.9.3.3 Engineered timber floor joists

Today, engineered timber beams are becoming more popular as an alternative to using solid timber joists. These products are manufactured in a range of sizes and designs that are suitable to span over small to large open areas. Design factors, span tables and installing information are available from the various manufacturers (Fig. 18.44).

18.9.3.4 Upper floor joists in masonry construction

Where load-bearing walls of a building are of masonry or concrete construction, the ends of upper-floor joists may bear in pockets formed in the wall. This practice was common in the era when load-bearing walls were often of solid brick construction, but would rarely be seen in today's building practice for new work.

Where pockets formed in the wall are adopted to support ends of members, they must allow at least 12 mm of clear air space at the sides and end of members, and provide a solid bearing in the wall of at least 75 mm in depth.

18.9.3.5 Fire cutting

Where deep joists are used in conjunction with masonry or concrete wall structures, the ends of the joists that are bearing in wall pockets should be splayed towards their tops so that they are not restrained by walls in the event of collapse of the floor system caused by fire or overload. This is referred to as *fire cutting* (Fig. 18.45).

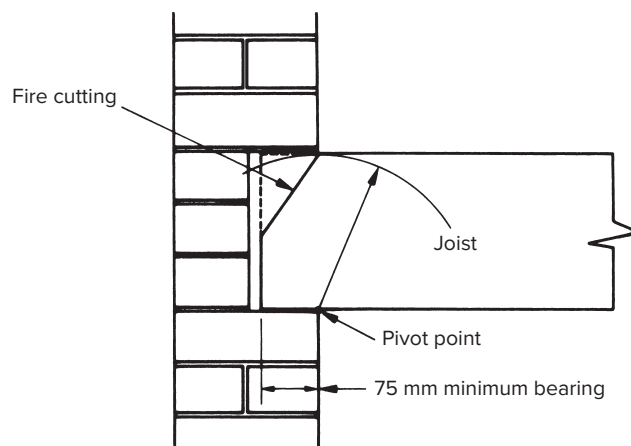
Note that if the joist was not splayed off, the top corner would lift as the joist rotated about the pivot point, no doubt collapsing the wall.

Fig. 18.44 Engineered timber upper floor joist



© Trong Nguyen/Shutterstock

Fig. 18.45 Fire cutting floor joists



CHECK YOUR UNDERSTANDING

10. State what blocking or strutting is required to strengthen deep joists.

Student research

Refer to the following Standards, which are relevant to this chapter:

- AS 1684.2–2010 Residential timber-framed construction—Part 2: Non-cyclonic areas
- AS 1684.4–2010 Residential timber-framed construction—Part 4: Simplified—Non-cyclonic areas.

In particular, see the following sections:

- Section 4.2.2.3 Deep joists
- Section 6 Wall framing
- Section 8.3.6 Wall bracing
- Section 9.2.8 Joining of top plates.

Refer also to the National Association of Steel-House Framing (NASH) website at www.nash.asn.au.

End-of-chapter activity

As part of your training, you are required to construct a timber wall frame, containing a door and window opening, noggins, bracing, lintels, jack studs, sill trimmers and head trimmers.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684–2010
Residential
timber-framed
construction

National
Construction Code
(NCC)

The National
Association of Steel
House-Framing
(NASH)

Tradie talk—Sight that stud for straight

Chapter 19

Wet areas

Learning Objectives

LO 19.1 Set out wet areas

LO 19.2 Install a shower base

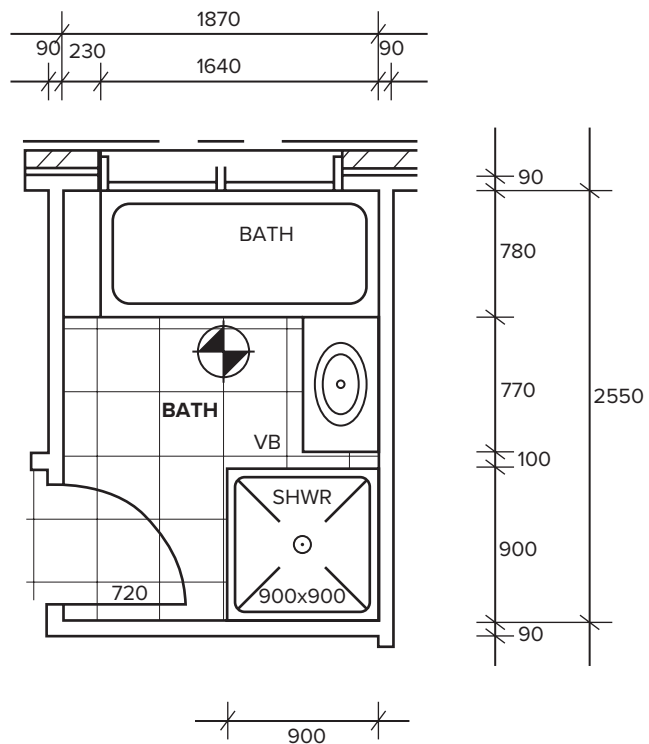
LO 19.3 Install a bath

LO 19.4 Install sinks and vanities

Introduction

This chapter concentrates on the role of the carpenter in constructing a standard bathroom in a new timber-framed house. Figure 19.1 shows the floor plan of a standard bathroom, which this chapter uses as a case study. In this chapter you will learn how to prepare a timber frame and install a shower base, bath and vanity. You will also learn about setting out the bathroom and flashing.

Fig. 19.1 Exploded view of a typical bathroom



What is a wet area?

The National Construction Code (NCC) defines a wet area as:

An area within a building supplied with water from a water supply system. This includes bathrooms, showers, laundries and sanitary compartments. It excludes kitchens, bar areas, kitchenettes or domestic food and beverage preparation areas.

In this chapter we are concentrating on the construction of a typical bathroom. Constructing a bathroom usually involves a number of different trades:

- a carpenter builds the frame and installs the shower, bath and vanity
- a plumber installs and connects the water pipe and wastes
- an electrician installs the electrical items such as lights, exhaust fans, etc.

- a plasterer installs the wall sheeting
- a waterproofer coats the required surfaces with a water-resistant membrane
- a tiler installs the tile underlay on the floor and lays the floor and wall tiles
- a glazier installs the shower screen.

As so many stages are involved in the construction of a bathroom, it is important that all tradespersons complete their tasks to the required standard before the next tradesperson steps in to avoid any problems. Wet areas can cause a lot of headaches for the owners if they are not constructed properly as water can cause huge amounts of damage if it gets into unwanted areas.

Figure 19.1 shows an exploded view of a bathroom with all of the measurements indicated. The house in which this bathroom exists is of brick veneer construction with a timber subfloor incorporating concrete stumps and a particleboard platform floor. The wall frames are of timber construction.

CHECK YOUR UNDERSTANDING

1. List three types of wet areas.

19.1 Set out wet areas

Setting out a wet area is the first critical task to be performed as this determines where the bath, shower and other features will be located. When constructing the subfloor, it is good practice to decide where the bath will be going and to strengthen that area with extra floor joists to take the load from the bath when it is full of water and has a person in it. This is a must when installing large spa baths as there is the potential for the floor to fail if it is overloaded. In some cases, extra stumps and bearers may need to be incorporated in the design to take the potential load from the spa; an engineer or architect should be consulted in those instances. The location of waste penetrations should also be considered to ensure that any substructure does not get in the way of the placement of the waste installation.

Once the floor is complete, mark out where the bath and shower will sit. Then determine where (a) the wastes for these items will go so that the plumber can locate the waste pipes in the right position and (b) where the taps will go and at what height so that the plumber can also rough in the water pipe once the walls are built. The location of the noggings for fixing the tap set will also need to be determined.

When the wall frame is being constructed, it is important next to identify the walls on which the shower base is going to be installed so that the bottom of the walls can be prepared to take the shower base.

TIP When constructing a new bathroom in an existing building, **always** inspect the existing materials to ensure no asbestos was used. If you are unsure, get an expert to check for you. If asbestos is present, you must arrange to have it removed by a licensed contractor. Then locate all of the electrical and water services prior to any demolition work. These services will likely need to be relocated to suit the new bathroom layout. A qualified tradesperson must be used to move these services. A carpenter is not qualified to move or alter any water or electrical services.

CHECK YOUR UNDERSTANDING

2. List four trades that have jobs to do in the construction of a bathroom.

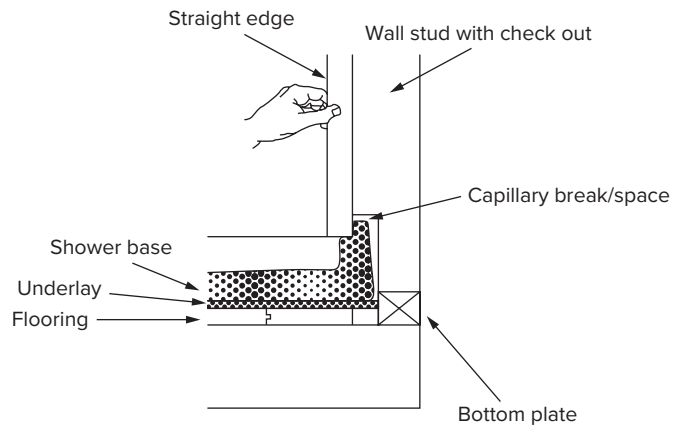
19.2 Install a shower base

It is important to construct the bathroom wall in a way that allows the shower base to recess into the wall. Figure 19.2 shows how the bottom plate has been ripped and stud checked so that the shower base fits into the wall cavity. The use of a straight edge shows how the wall covering will act as an over-flashing and run into the recess in the shower base. This will allow any run-off water to find its way to the drain. The size of the check-out in the wall frame will vary depending on which base is used.

The height of the check-out for a platform floor is calculated by adding the:

- height of the shower base
- thickness of the underlay
- thickness of glue or mortar that the shower base is bedded on
- gap or space between the top of the base and the top of the check-out (minimum 5 mm).

Fig. 19.2 Including a capillary break is important to prevent mould, rot and frame failure



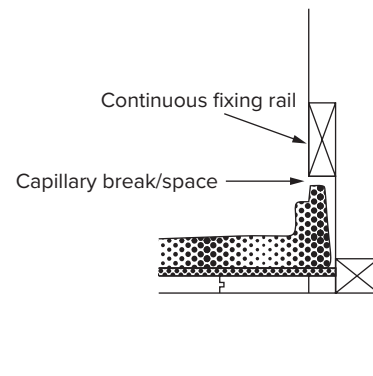
TIP When installing a sink, vanity basin, bath or shower base, there must be a 'capillary break' to prevent water from encroaching into the timber framing to avoid mould, rot and frame failure. The space (or break) should be maintained at no less than 5 mm (it can be more depending on the site requirements).

If the floor is a fitted floor, as shown in Figure 19.2, then the thickness of the floor also needs to be added to the height of the check-out.

Once the walls are complete, it is time to lay the tile underlay and install the shower.

1. Locate where the waste pipe is going to go so that a hole can be cut through the flooring and underlay.
2. Install noggings from the top of the shower rebate to take the wall linings, or the check-out can be made bigger and a continuous fixing rail installed (Fig. 19.3). The latter method has the benefit of being less time-consuming and it is easier to fix securely than installing individual noggings.
3. Install the shower according to the manufacturer's instructions, using either mortar or silicon. If using mortar, a softer mix is required so that the shower base can be bedded firmly.

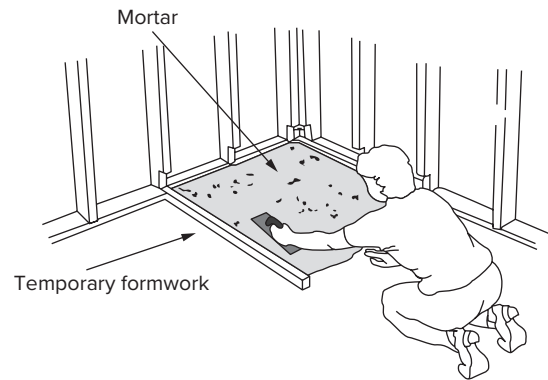
Fig. 19.3 A continuous fixing rail



TIP If a polymarble base is not bedded properly into the mortar there is a good possibility that the polymarble base will crack, so ensure the mortar is fresh and moist.

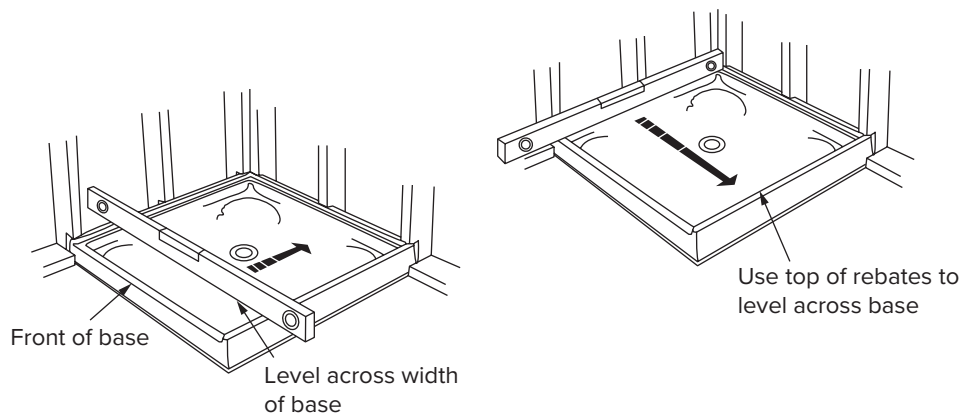
4. If using mortar, a temporary formwork needs to be used to stop the mortar from spreading (Fig. 19.4). Then spread the mortar as level as possible and roughly trowel it off.
5. Place the shower base onto the mortar; you will need to wiggle it so that it beds down. Then check it for level (Fig. 19.5). Wiggling or twisting the base can help level it.

Fig. 19.4 A temporary formwork prevents mortar from spreading



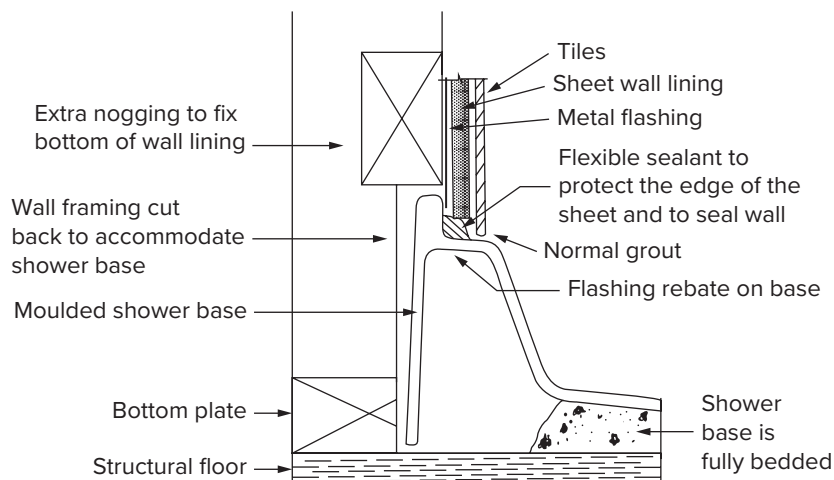
TIP If the shower base has a twist in it, ensure the sides of the base where the shower screens are to be installed are perfectly level. Otherwise, the screens, which are delivered in a square configuration, may not be able to be installed properly.

Fig. 19.5 Levelling the shower base

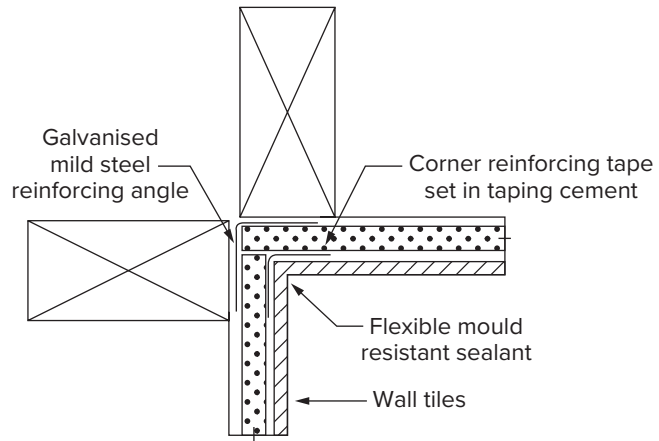


6. Once the shower base is secure, install metal flashing to run over the studs and into the shower base (Fig. 19.6). Then install a metal angle in the wall corner of the shower (Fig. 19.7).

Fig. 19.6 Flashing detail for shower base



7. The plumber (if it hasn't already been done) runs all of the water pipes and connects the waste pipe up to the sewer. You may be asked to install some noggings to hold the tap sets, shower head and so on. (It is also the carpenter's responsibility to install noggings for towel rails, soap holders and anything else that will hang off the wall.)
8. Once flashed and nogged out, the plasterer installs the water-resistant wall lining. Then the wet area needs to be waterproofed. (AS 3740: 2012 Waterproofing of domestic wet areas and the NCC detail waterproofing requirements.)
9. The tiler installs the tiles to finish off the bathroom, then all of the accessories can be installed.

Fig. 19.7 Wall flashing detail for corner of shower cubicle

TIP A high-quality frame construction is vital to ensure the waterproofing membrane and flashing do their job. A straight, neat and well-constructed frame means the flashings can be installed properly and in their correct positions. The wall and floor linings can also be installed as per the manufacturer's specifications and will create a consistent and flat surface. This ideal surface will allow the waterproofing membrane to adhere properly and ensure the membrane will repel any water that comes into contact with it.

CHECK YOUR UNDERSTANDING

3. How is the height of the check-out for a shower base calculated to suit a platform floor?
4. What needs to be installed in the corner of the shower recess before the wall lining is installed?
5. What two methods are used to bed a shower base down to a floor?

19.3 Install a bath

Installing a bath is similar to that of a shower base; however, certain installation methods result in the finished bath having a specific look. The method detailed below is one of the more common methods used in the industry.

1. Referring back to Figure 19.1, we can see that the bathtub abuts two walls and has a hob (dwarf wall) at one end. Locate this position in the bathroom and set out where the bath is going to sit. Mark where the waste pipe will be and cut a hole to allow for the connection.
2. The walls will be built at this stage, so all of the remaining work is carried out on the walls in place. First, determine what the finished height of the bath will be—this is paramount. This height could be determined by the type of tiles being used or the owner requesting that a full tile sits on the top lip of the bath, or it could just be that a specific height is preferred for comfort.
3. If the height is determined by the tiles, then use a gauge rod with the height of the tiles marked and the gap between each tile shown so that an accurate measurement can be made. Figure 19.8 shows how the gauge rod works and how the bath height and the height of the hob can be determined.

4. Once the height is determined, the wall needs to be prepared to take the bath. The check-out needs to be marked on each stud where the long side and end will be located, as can be seen in Figure 19.9. Note the small wall at the end—this is the hob. In this case, the hob is one tile higher than the bath, hence the check-outs have to be cut into the hob as well.

Fig. 19.8 Using a gauge rod to determine height of the bath

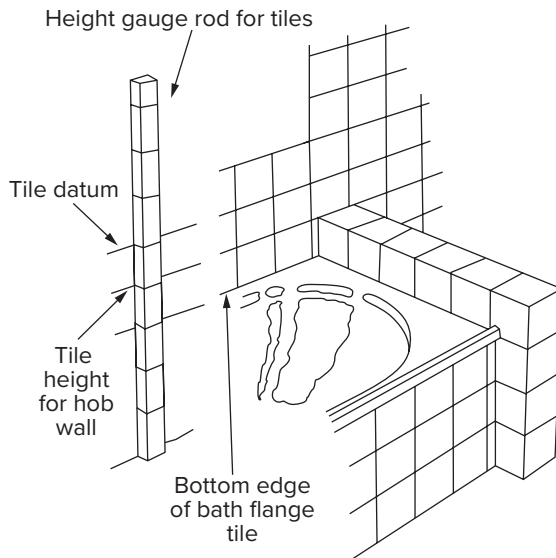


Fig. 19.9 Marking check-outs on studs

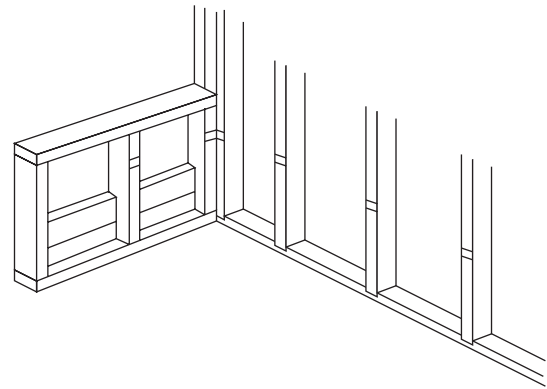
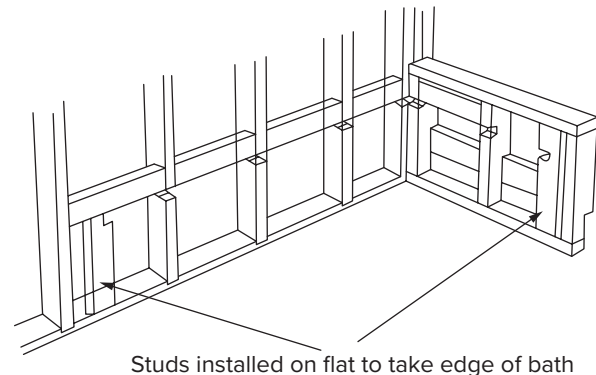


Fig. 19.10 Additional studs installed to accommodate wall lining and flashing



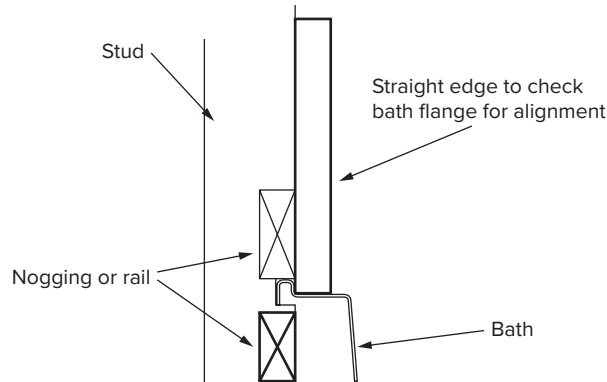
5. Once the check-out is completed, an extra stud can be installed at each end to pick up the edges of the bath, and noggings can be installed at the top of the check-out to accommodate the wall lining and flashings (Fig. 19.10). Alternatively, the check-out can be made bigger and a continuous fixing rail can be installed. This method is less time-consuming and it is easier to fix securely than installing individual noggings.

TIP AS 1684 Residential timber-framed construction states that 'a horizontal line of notches up to 25 mm may be provided for the installation of baths'.

6. The plumber runs all of the water pipes and will indicate if any noggings are needed for tap sets, etc.
7. Try the bath to ensure the check-out is adequate and the bath is well supported and level (Fig. 19.11).

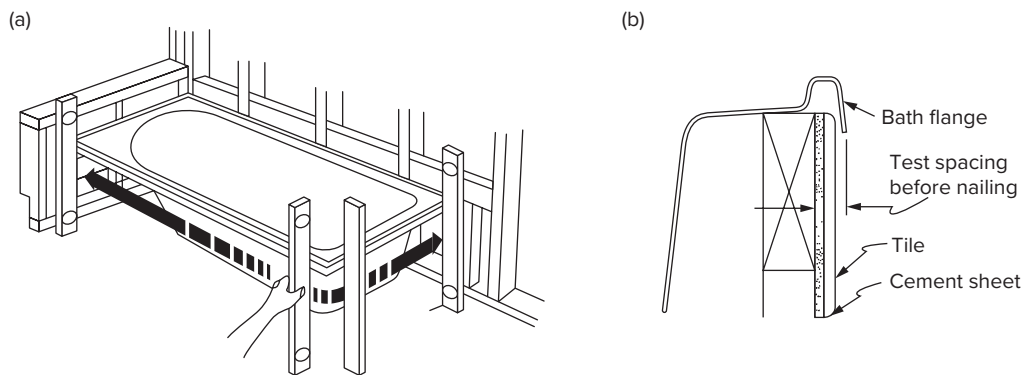
TIP It is good practice to install noggings or a rail on the bottom of the check-out for the bath flange. These will give continuous support to the bath and may prevent the bath flange from splitting the stud where it is sitting.

Fig. 19.11 Checking the level of the bath



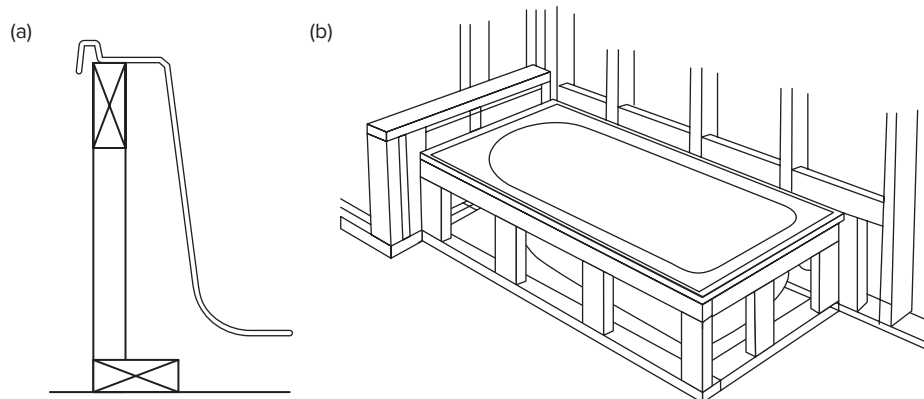
8. With the bath in place, mark out on the floor where the infill walls will go using a spirit level (Fig. 19.12a). This mark will indicate where the finished wall will be or, in this case, where the tiles will be (Fig. 19.12b). From this line, calculate how far back the plate has to be positioned.

Fig. 19.12 Marking the line of the finished wall: (a) using a spirit level; (b) a cross-section



9. Once the back set has been calculated, install the plate onto the floor and build the infill walls. For this case, the timber will be orientated so that the face of the timber is facing into the room; this will eliminate the need to rip down the timber studs and the top plate. Figure 19.13 shows a detail of how the infill wall is built and the completed bath installation.

Fig. 19.13 The infill wall: (a) a cross-section; (b) the completed bath installation



TIP When installing a bathtub, refer to the manufacturer's instructions as the bottom of the bath may need to be bedded into mortar.

10. Install the flashing. The process is the same as detailed in the installation of the shower base (Figs 19.6 and 19.7).

CHECK YOUR UNDERSTANDING

6. How can the height of the bathtub be determined?
7. What is the dwarf wall on the end of the bath called?

19.4 Install sinks and vanities

It is common today for a bathroom vanity to come in a unit, where the sink is installed in a cupboard and all of the tapware is installed in the sink and not in the wall, as seen in the vanity shown in Figure 19.14. The carpenter may need to install some noggings in the wall frame so that the vanity can be fixed to it.

Fig. 19.14 A typical bathroom vanity



Courtesy of Reece Bathrooms

TIP Ensure you find out what type of vanity is being specified and what work you may need to perform so that the vanity can be installed.

CHECK YOUR UNDERSTANDING

8. List three reasons why extra noggins are installed into bathroom walls.
9. Once the wall linings and the tile underlay are installed, what needs to be applied to the walls and floor?
10. Which Australian Standard deals with the waterproofing of wet areas?

Student research

Investigate at least four different types of wall linings that can be used in wet areas.

End-of-chapter activity

As part of your apprentice carpentry training, you will be required to install a bath and shower base into a timber frame.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 3740: 2012
Waterproofing
of domestic wet
areas

National
Construction Code
(NCC)

AS 1684—2010
Residential
timber-framed
construction

Tradie talk—Water will always find its way into areas it shouldn't

Chapter 20

Ceiling framing

Learning Objectives

LO 20.1 Know about ceiling framing components

LO 20.2 Construct ceiling frames

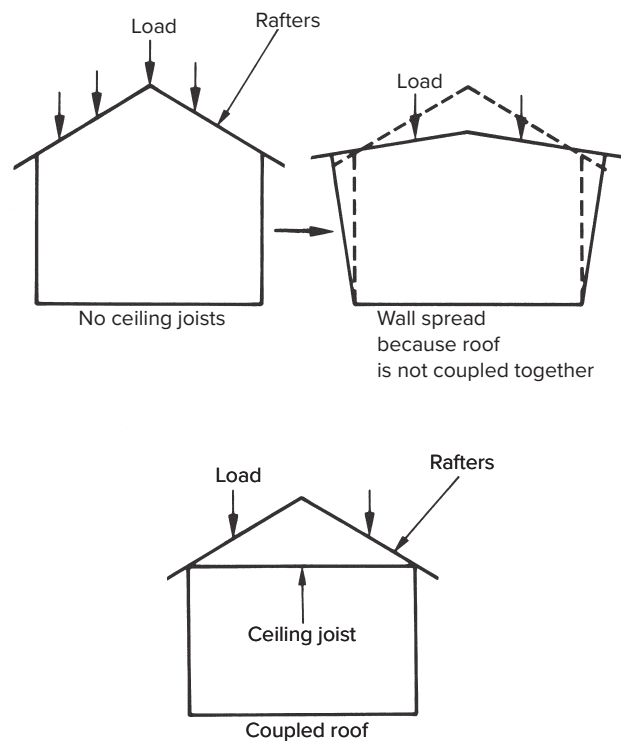
LO 20.3 Understand ceiling framing safety

LO 20.4 Understand ceiling frame design

Introduction

Ceiling framing is closely integrated with pitched roof construction: when a ceiling frame is constructed, it strengthens the structure by tying opposite walls together and stopping them from spreading apart once the roof is constructed and loaded as shown in Figure 20.1. The ceiling frame holds up the materials used to create the ceiling, e.g. plaster and timber. Some specific members of ceiling frames can be used to support the roof and its loads. In double-storey buildings, the ceiling frame can also be the floor framing for the floor above. Australian Standard (AS) 1684 Residential timber-framed construction details the fixing requirements, allowable spans for the ceiling framing components and basic design of a timber ceiling frame. If metal or other engineered products are used to construct the ceiling frame, you must consult with the appropriate standards, codes or manufacturer's specifications.

Fig. 20.1 Ceiling framing—concept



In this chapter, you will learn how to set out and construct a ceiling frame for a single-storey building.

Reference to Chapter 21, Pitched roofing, and Chapter 22, Construct advanced roofing, may be helpful for a complete understanding.

20.1 Know about ceiling framing components

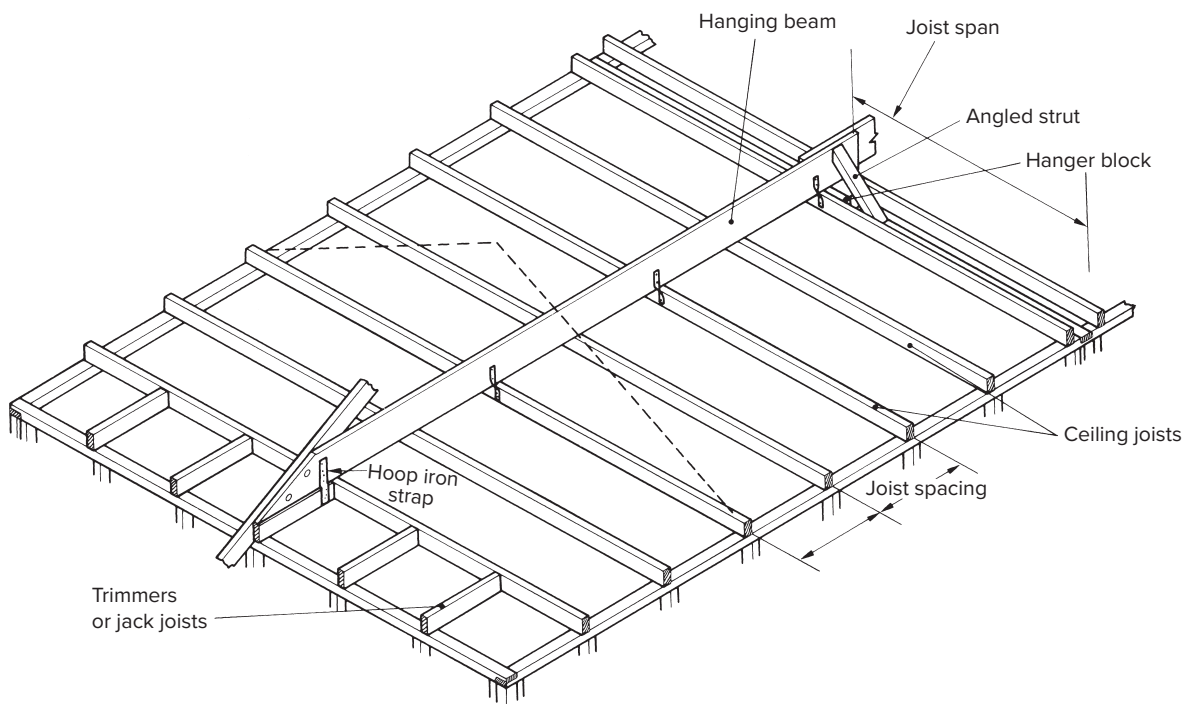
The ceiling frame consists of a number of different members/components. Each component has a specific purpose and name. These are listed below with a description of their purpose and location in the structure.

20.1.1 Ceiling joists

Ceiling joists serve multiple functions:

- they provide fixing for various types of internal ceiling materials
- they tie opposite walls together (Fig. 20.2)
- they form an integral part of the roof framing, completing the couple with the sloping rafters.

Fig. 20.2 Ceiling frame—general view



Ceiling joists should run in the same direction as the **common rafters**, as shown in Figure 20.3 and later in Figure 20.10. They can be securely fastened to the heel/foot of the rafter depending on the spacings of the rafters. The ceiling joist spacings can vary, but 450 mm or 600 mm between centres are common. The spacing is usually determined by the type of material being used to line the ceiling and how far it can span.

20.1.2 Ceiling trimmers

Where the ceiling joist at the end of a building would foul the rafters, it is omitted and replaced with *ceiling trimmers*, which run at right angles to the ceiling joists (Fig. 20.3).

20.1.3 Hanging beams

Hanging beams are placed on edge over the ceiling joists to prevent them sagging over long spans (Fig. 20.3).

20.1.4 Blocking

Blocking is provided over load-bearing walls to support the ends of hanging beams (Fig. 20.4).

20.1.5 Ceiling ties

Ceiling ties, ceiling joist supports/hangers, ceiling dogs and timber cleats are devices used to strengthen the joint between the hanging beam and ceiling joist (Fig. 20.5).

Fig. 20.3 Ceiling framing component locations

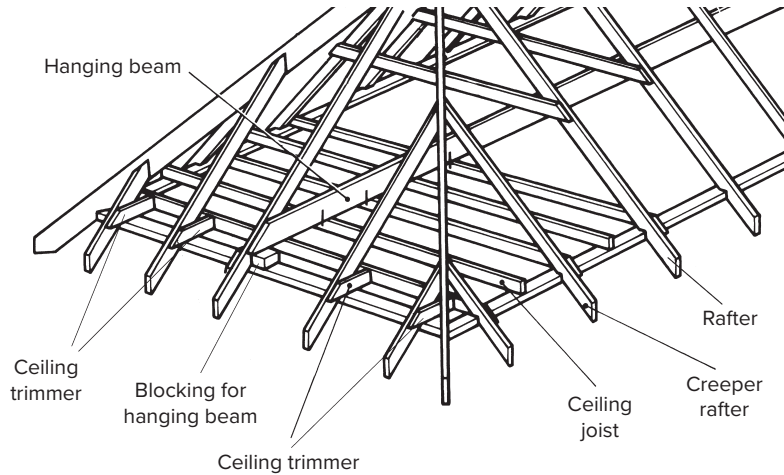


Fig. 20.4 Hanging beam blocking

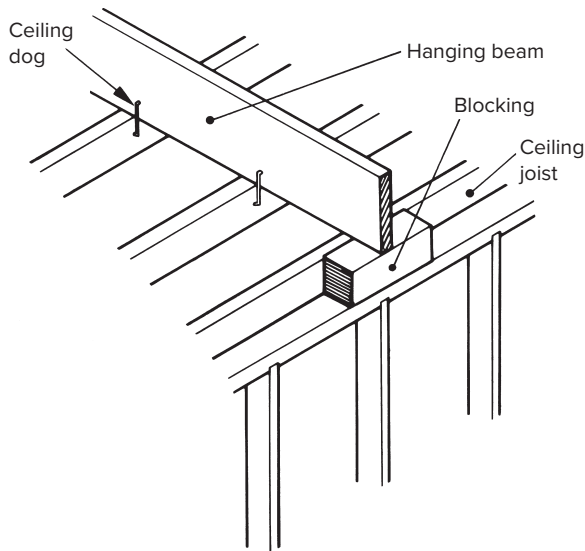
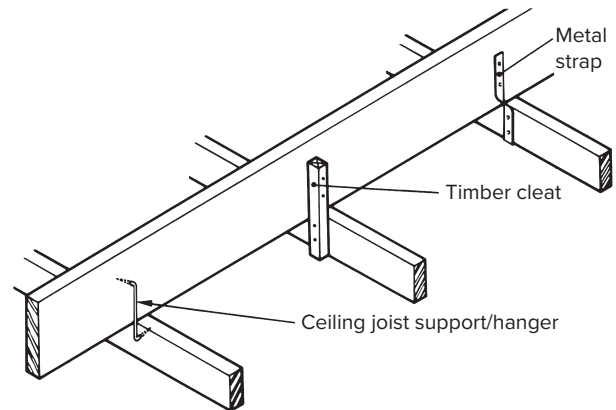


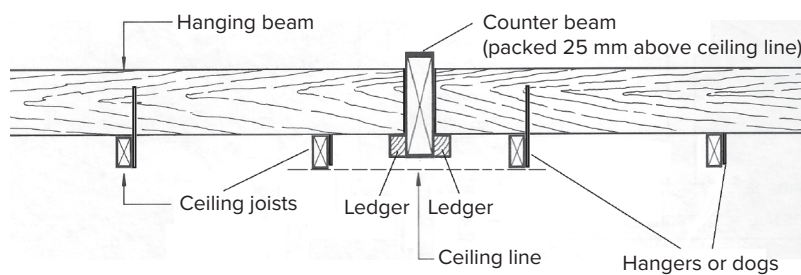
Fig. 20.5 Ceiling ties/support



20.1.6 Counter beams

Counter beams are used to provide support for the end of a hanging beam, where a wall is not available to support the end of the hanging beam (Fig. 20.6).

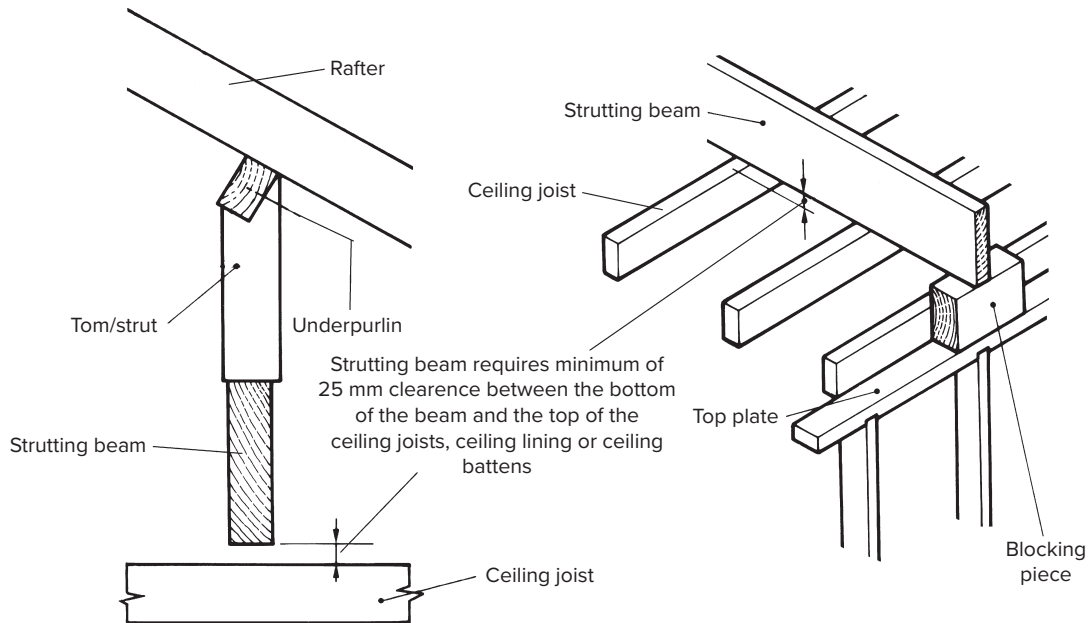
Fig. 20.6 Counter beam



20.1.7 Strutting beams

Strutting beams are used when an underpurlin is supported by a tom/strut and no wall is present to support the strut and take the roof load (Fig. 20.7).

Fig. 20.7 Strutting beam



20.1.8 Combination strutting and counter beams

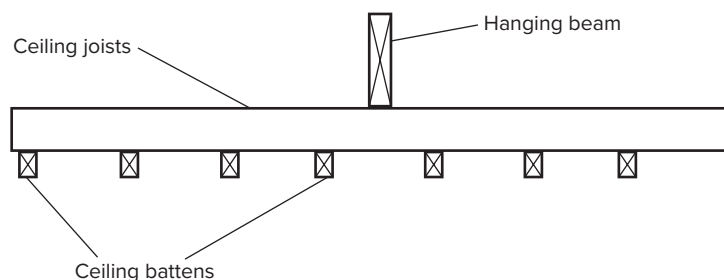
This type of beam combines the purposes of a strutting beam and counter beam in one. It is used when the internal wall frames provide little support to the roof and ceiling loads.

20.1.9 Ceiling battens

Ceiling battens may need to be installed on the underside of the ceiling joists when the ceiling lining will not be installed directly onto the ceiling joists. The battens run at 90 degrees to the ceiling joists (Fig. 20.8). The reasons for installing ceiling battens include:

- the ceiling lining requires extra support as the ceiling joists are too far apart
- the direction in which the ceiling lining is installed does not correspond with the direction of the ceiling joists
- the ceiling joists cannot be straightened adequately, so battens are installed to provide a true flat surface for the lining materials to be attached to.

Fig. 20.8 Ceiling battens

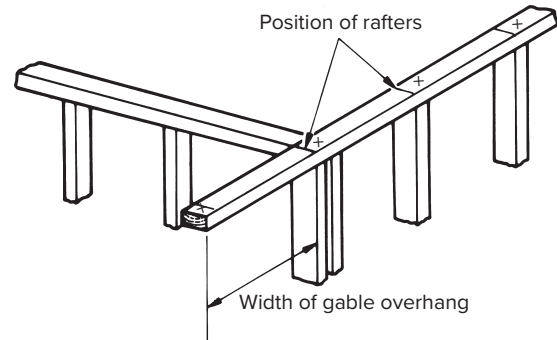


20.2 Construct ceiling frames

The section dimensions for natural timber ceiling framing members and their spans can be found in AS 1684. If the material being used is a manufactured product, an engineer should perform the calculations or consult the manufacturer's specifications to establish the performance characteristics and limitations of the product being used.

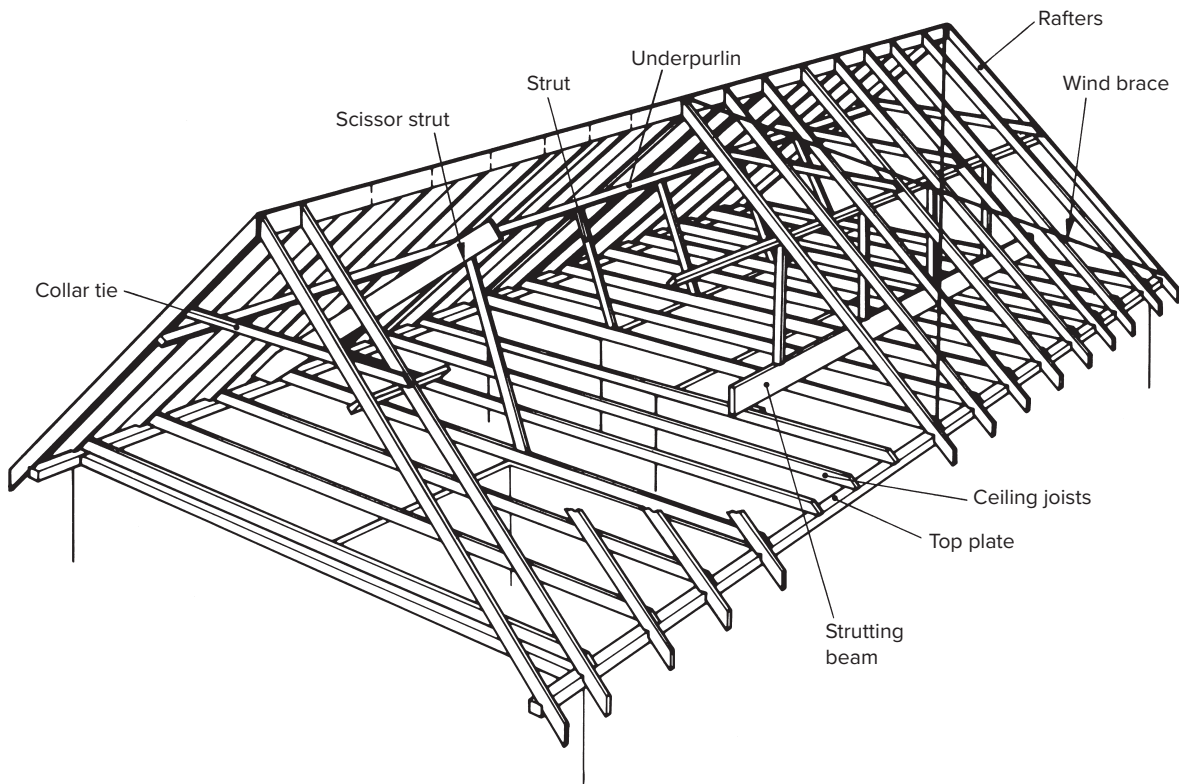
Before the ceiling joists are fixed, the location of the rafters must first be marked out on the upper face of the top plate. It is preferable that this be done at an earlier stage, when the plates are being set out on the ground. Marking out on the top of the walls after they have been erected can be a slow and precarious procedure. At this stage, note that the ceiling joists are placed beside the positions marked and are reserved for the rafters (Fig. 20.9).

Fig. 20.9 Rafter/ceiling joist set-out



TIP If the ceiling joists being used are quite deep, the top external corner of the ceiling joist may need to be trimmed off in line with the top of the rafter, as shown in Figure 20.10. The ceiling joist must not sit above the rafter at any point as it will foul the roof battens or roofing material.

Fig. 20.10 Gable roof showing ceiling structure



20.2.1 Procedure for constructing ceiling frames

1. Stand ceiling joists on end against the wall of the building, approximately where they will be required. Load the roof, laying each ceiling joist on the flat, adjacent to its final location.
2. With a carpenter at each end, stand each joist upright, with the round edge up, and skew nail to the top plates. Where joists are joined in their length, they can be lapped over a wall with the joists of an adjacent room and securely nailed together.
3. Mark the position for the hanging beam and fix the blocking to support the beam at each end (refer back to Fig. 20.4).
4. Lay the hanging beam across the ceiling joist—stand it upright and skew nail to blocking.
5. Lay a plank across the ceiling joists beside the hanging beam and, using a short sash cramp or other suitable clamping device, work across each room, cramping each joist up to the hanging beam. Ensure that the joists are in line; a string line 90° to the ceiling joists, strung on the underside of ceiling joists and stretched from one wall to the other. It can be useful to ensure the centre of the joists are in line. Usually, sighting by eye will keep the joists sufficiently straight, but for greater accuracy, the position for ceiling joists can be marked onto the hanging beam. Fix a ceiling tie or cleat at each junction on alternate sides of the hanging beam (refer back to Fig. 20.5).
6. Cut ceiling trimmers to length where required and fix in position, again beside the positions marked out for the rafters.

SAFETY TIP Never walk across the ceiling joists until they have finally been fixed and supported by the hanging beam as a joist could roll or collapse due to a knot or other defect, leading to a serious injury.

20.3 Understand ceiling framing safety

Constructing a ceiling frame will be performed as part of the overall construction of a roof. This construction will take place above ground at a height which, if you were to fall, would cause serious injury.

Working at height exposes the carpenter to numerous risks, and all precautions should be taken to reduce these risks, including:

- using scaffolds or some other platform to work from
- ensuring handrails/guardrails are used
- keeping the floor area clear and free of debris so that if you were to fall, you would not fall onto anything
- avoiding using ladders
- avoiding walking on top wall plates
- not rushing
- ensuring you have adequate training.

SAFETY TIP Consult your local WorkSafe authority to find out your jurisdiction requirements for working at height on a building site.

20.4 Understand ceiling frame design

The design of a ceiling frame is dependent on many factors, including:

- room size
- available materials
- choice of ceiling lining material
- roof construction and whether the roof requires support
- rafter spacing
- roof pitch
- whether the roof space is to be used for storage
- whether anything heavy will be stored in the roof space, such as a heating or cooling system
- roof cladding.

If using natural milled timber to construct the ceiling frame, AS 1684 must be consulted as it details:

- member sizes and their spans according to their stress grade
- ceiling frame design
- fixing requirements.

If manufactured materials are to be used to construct the ceiling frame, the manufacturer's specifications should be consulted in conjunction with an engineer, taking into consideration the ceiling frame design factors listed above.

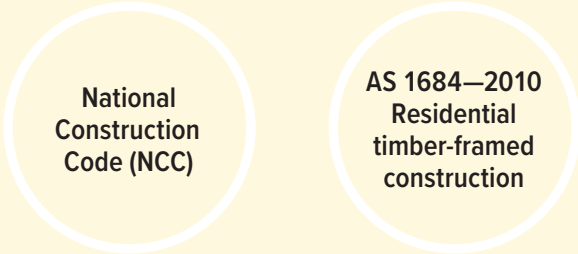
Student research

Research what alternative products to natural timber can be used to construct a ceiling frame.

End-of-chapter activity

As part of your apprenticeship training, you will be required to construct a ceiling frame. This will be done as you are constructing a roof.

AUSTRALIAN BUILDING CODES AND STANDARDS



National
Construction
Code (NCC)

AS 1684—2010
Residential
timber-framed
construction

Tradie talk—Always stagger the joist hangers

Chapter 21

Pitched roofing

Learning Objectives

- LO 21.1 Identify roof structures**
- LO 21.2 Express pitch**
- LO 21.3 Calculate roof pitch**
- LO 21.4 Know how to construct a skillion roof**
- LO 21.5 Identify gable roof components**
- LO 21.6 Set out rafters**
- LO 21.7 Prepare the ridge and underpurlins**
- LO 21.8 Erect the gable roof**
- LO 21.9 Finish the roof frame**
- LO 21.10 Identify hipped roof components**
- LO 21.11 Set out the hipped roof**
- LO 21.12 Develop crown end assembly and shortening distances**
- LO 21.13 Cut rafters to length**
- LO 21.14 Erect the hipped roof**
- LO 21.15 Identify hip and valley roof components**
- LO 21.16 Set out the minor roof**
- LO 21.17 Set out valley rafters and creepers**
- LO 21.18 Construct a scotch valley roof**
- LO 21.19 Identify fixings, tie-downs and other materials**

Introduction

The roof is one of the most important components in a building and generally involves some of the most skilled work in the carpentry trade. The purpose of the roof is to protect the interior of the building and its occupants from the weather. Therefore, roofs are built with some slope to their surface so that water can run off.

The structure must be sufficiently strong to withstand the load of the roof covering, rain (snow in some areas) and collected water, and wind loads. Australian Standard 1684 is used to calculate the correct timber size and stress grading for the individual components of the roof.

In this chapter, you will learn roofing calculations, how to calculate roof member lengths, develop roof cuts and how they are applied to the construction of a gable-end roof, hipped roof, hip and valley, broken hip and valley, and scotch valley roofs. Additionally, you will learn how to set out and cut roofing members, the sequence of pitching the roof and how to construct a skillion roof. You will also learn about the importance of AS 1684 Residential timber-framed construction, and how it must be referred to so that the correct roof framing member sizes and stress grade can be determined.

The **hipped roof** is extensively used throughout Australia. The roof is pitched on all sides of the building, and if the pitch angle is the same on all sides, it is termed *equally pitched*. If an L-shaped building is to be constructed, then the addition of a valley and a minor span to the hipped roof is incorporated into the roof design.

The hipped roof style of roof construction is most common and allows for a wide variety of roof cladding materials to be used—for example, slate, terracotta, cement tiles and metal. As this roof is very prominent and thus becomes part of the overall aesthetic of the building, attractive roofing materials are often used.

Prior to building any roof, the wall frames must be checked to ensure they are level, straight, parallel and square, and corrected if required. This is important to ensure the roof is constructed properly and fits correctly. The roofing discussed in this chapter assumes that all of these elements are correct; if not many of the methods shown to calculate angles and cuts won't work and the individual roof components may not actually fit together.

21.1 Identify roof structures

Roof forms in common use are illustrated in Figure 21.1. The elements that make up a roof are as follows.

21.1.1 Pitch

As previously mentioned, all roof surfaces are built with some slope so that water can run off. The angle formed between the sloping roof surface and a horizontal surface is termed the **pitch** of the roof. In Figure 21.2, the line *XY* represents a horizontal surface, and *AB* and *BD* are sloping roof surfaces. The angle *BAC* is the pitch of the roof. If the angle *BDC* is the same angle, then the roof is referred to as being *equally pitched*. This is the case with the vast majority of roofs.

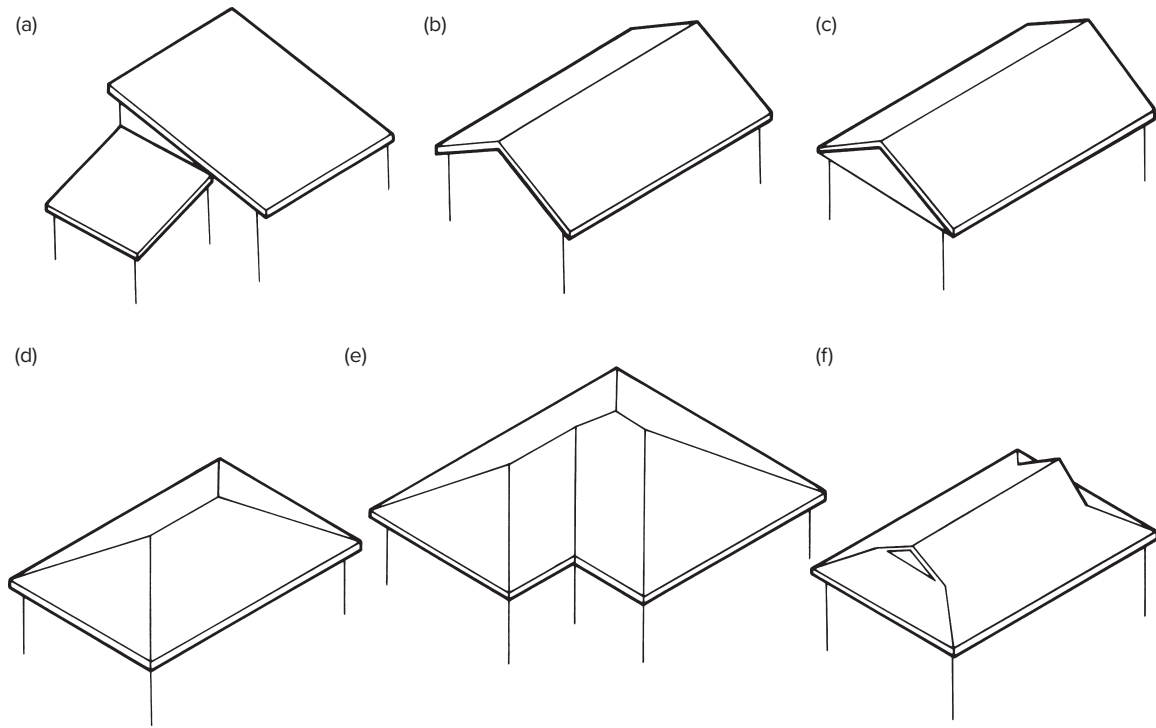
21.1.1.1 Span

AD is the **span** of the roof and is measured over all of the wall plates that support the roof.

21.1.1.2 Rise

BC is the **rise** of the roof measured from the *XY* line to the apex of the roof.

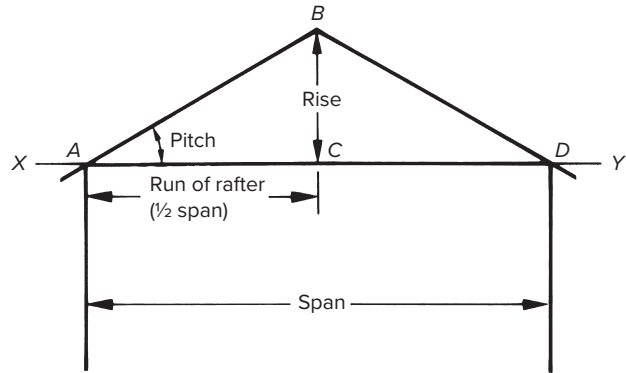
Fig. 21.1 Common roof types: (a) lean-to (skillion); (b) gable; (c) boxed gable; (d) hip; (e) hip and valley; and (f) gambrel



21.1.1.3 Run

The **run** (half span) is the horizontal distance covered by a sloping roof member. It can also be referred to as the *plan length of the member* and can be found by reading directly from the plan drawing. For example, if AB is a sloping roof rafter, then AC is the run (half span) of that rafter, if the roof is equally pitched, as in the roof types shown in Figure 21.1.

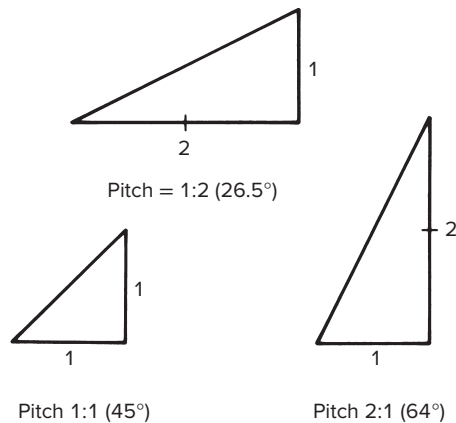
Fig. 21.2 Basic roof geometry/pitch triangle



21.2 Express pitch

The pitch of the roof is the angle at which the rafters sit in relation to the horizontal. The roof pitch can be expressed in a number of different ways (Fig. 21.3). The pitch can be expressed as an angle (e.g. 22.5°) or a ratio (e.g. 1:2), that is, the vertical component being given first. For slopes up to 45° , the vertical component is given as one, and for slopes over 45° , the horizontal component is given as one.

Fig. 21.3 How roof pitch is expressed



21.3 Calculate roof pitch

21.3.1 Pitch as a ratio

Note that the ratio is given a non-dimensional ratio. Putting it into trade terms, it is referred to as the **rise/run ratio**, where the rise is the vertical component and the run is the horizontal component. Therefore, a rise/run ratio of 1:2 can be 1 mm:2 mm, 100 mm:200 mm or 500 mm:1000 mm.

21.3.2 Pitch in degrees

If the pitch is given in degrees, then the use of tables or manuals is possible. There are a number of these publications available, and they will give the carpenter the required information to construct the roof. If the carpenter needs the pitch in degrees to be converted to a rise/run ratio, then the following calculation using trigonometrical ratios should be used. For example, if the pitch = 32°:

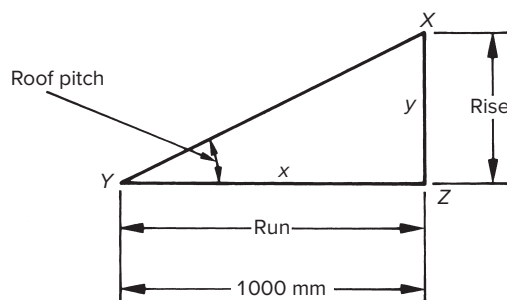
$$\begin{aligned} \text{then opposite/adjacent} &= y/x = \tan 32^\circ \\ \text{if } y &= 1 \text{ then } 1/x &= \tan 32^\circ \\ \text{then } x &= 1/\tan 32^\circ \\ &= 1/0.6248 \\ &= 1.6 \end{aligned}$$

Therefore, the rise/run ratio = 1:1.6.

CHECK YOUR UNDERSTANDING

1. Name two ways in which the slope of a roof surface can be specified.
2. What is meant by the following terms as applied to roofing?
 - a. Equally pitched
 - b. Run of rafter
 - c. Rise
 - d. Rise/run ratio
 - e. Pitch

Fig. 21.4 Rise/run concept for roof pitch



21.3.3 Pitch—rise in millimetres/metre runs

When it comes to setting up the roof members, it is particularly valuable if the pitch (however it is specified) can be converted to a ratio of rise in millimetres to a metre run (Fig. 21.4).

21.3.3.1 Example 1

Take the right-angled triangle XYZ. Side YZ is the run and is fixed at one metre (1000 mm). Calculate the rise XZ in millimetres if the pitch ratio is 1:2.

$$\begin{aligned} \text{Pitch} &= \text{rise:run} \\ &= 1:2 \\ &= 1 \times 1000/2 \\ &= 500 \text{ mm/m} \end{aligned}$$

21.3.3.2 Example 2

Calculate the rise XZ in millimetres if the pitch ratio is 1:1.6.

$$\begin{aligned}\text{Pitch} &= \text{rise:run} \\ &= 1:1.6 \\ &= 1 \times 1000/1.6 \\ &= 625 \text{ mm/m}\end{aligned}$$

When pitch is expressed in degrees, conversion can be carried out by using trigonometrical methods. For example, if the pitch = 32° :

$$\begin{aligned}\text{then } y/x \text{ or opposite/adjacent} &= \tan 32, \text{ or} \\ \text{rise}/1000 &= \tan 32 \\ \therefore \text{rise} &= \tan 32 \times 1000 \\ &= 0.6248 \times 1000 \\ &= 624.8, \text{ or } 625 \text{ mm}\end{aligned}$$

(Note that answers will be given to the nearest millimetre in future roof calculations.)

Table 21.1 provides a ready means of converting pitch from degrees to rise/run ratio to mm/m run. Column 1 is the roof pitch expressed in degrees from 1° to 45° in $\frac{1}{2}^\circ$ intervals. Column 2 is the pitch in degrees converted to a rise/run ratio and Column 3 is the same pitch converted to a rise in millimetres per metre run.

21.3.3.3 Example 3

$$\text{Pitch} = 27.5^\circ = 1:1.92 = 521 \text{ mm/m}$$

21.3.3.4 Example 4

$$\text{Pitch} = 1:2.6 = 21^\circ = 384 \text{ mm/m}$$

For a rise/run ratio other than those calculated in Table 21.1, select the closest ratio shown; any error must be less than half a degree, which is a reasonable tolerance. Alternatively, carry out calculations and prepare a more accurate conversion.

A roof can be commonly referred to as:

- *flat*— 5° to 1° pitch, or ratios 1:12 to 1:57
- *low pitch*— 22.5° to 5° pitch, or ratio 1:2.4 to 1:12
- *traditional*—over 22.5° pitch, or over a ratio of 1:2.4.

WORKPLACE SCENARIO

Chris Nance—owner of Traditional Timber Frames

I guess the thing about roofing is that every part is critical; if you get any element wrong, there's no way of hiding it! I remember working in the United Kingdom on a large oak roof restoration project where I had to scribe in a 4 metre-long underpurlin in 200×200 oak. It was part of a very old building and every joint had to be perfectly cut as it was all visible and carrying some very heavy loads. I set up string lines, performed a hundred calculations, worked out every angle imaginable and then cut the joint beautifully—I thought. I was really happy with the joints.

I organised the crane, we slung the timber way up onto this huge roof and lowered it into position only to realise that someone had cut it 100 mm short. Back to the drawing board! The lesson here is measure twice and cut once.

Table 21.1 Conversion of roof pitch:ratio:rise mm/m

Pitch angle	Pitch ratio	Rise mm/m	Pitch angle	Pitch ratio	Rise mm/m	Pitch angle	Pitch ratio	Rise mm/m
1	1:57.29	17.5	16	1:3.49	287	31	1:1.66	601
1.5	38.19	26	16.5	3.38	296	31.5	1.63	613
2	28.64	35	17	3.27	306	32	1.60	625
2.5	22.90	44	17.5	3.17	315	32.5	1.57	637
3	19.08	52	18	3.08	325	33	1.54	649
3.5	16.35	61	18.5	2.99	335	33.5	1.51	662
4	14.30	70	19	2.90	344	34	1.48	675
4.5	12.71	79	19.5	2.82	354	34.5	1.46	687
5	11.43	87	20	2.75	364	35	1.43	700
5.5	10.39	96	20.5	2.67	374	35.5	1.40	713
6	9.51	105	21	2.61	384	36	1.38	727
6.5	8.78	114	21.5	2.54	394	36.5	1.35	740
7	8.14	123	22	2.48	404	37	1.33	754
7.5	7.60	132	22.5	2.41	414	37.5	1.30	767
8	7.12	141	23	2.36	424	38	1.28	781
8.5	6.69	149	23.5	2.30	435	38.5	1.26	795
9	6.31	158	24	2.25	445	39	1.23	810
9.5	5.98	167	24.5	2.19	456	39.5	1.21	824
10	5.67	176	25	2.14	466	40	1.19	839
10.5	5.40	185	25.5	2.10	477	40.5	1.17	854
11	5.14	194	26	2.05	488	41	1.15	869
11.5	4.92	203	26.5	2.01	499	41.5	1.13	885
12	4.70	213	27	1.96	510	42	1.11	900
12.5	4.51	222	27.5	1.92	521	42.5	1.09	916
13	4.33	231	28	1.88	532	43	1.07	933
13.5	4.17	240	28.5	1.84	543	43.5	1.05	949
14	4.01	249	29	1.80	554	44	1.04	966
14.5	3.87	259	29.5	1.77	566	44.5	1.02	983
15	3.73	268	30	1.73	577	45	1.00	1000
15.5	3.61	277	30.5	1.70	589			

Calculations for this table have been carried out to four decimal places and then abbreviated to two decimal places.

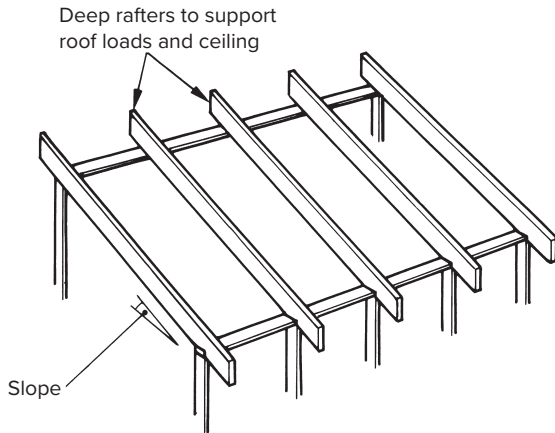
21.4 Know how to construct a skillion roof

The **skillion** roof, also referred to as a lean-to or a mono-pitch roof, was for a long time thought to be suitable only for building works of minor importance such as additions, garages and laundries. However, with the introduction of sheet metal roofing materials in long lengths, it has now been adapted successfully to contemporary design in both residential and commercial buildings. The skillion roof can be comparatively quick and simple to install, particularly over irregularly shaped buildings, whereas other roof forms can become very complicated and unattractive.

The function of the rafter and ceiling joist are combined in the one member, which must be sufficiently strong to carry its own mass plus the mass of the roof covering and ceiling linings (Fig. 21.5).

The lower pitched skillion roof (minimum 1:60 = 1°) can be subject to considerable suction due to wind pressure, which tends to lift the roof covering and framing (Fig. 21.6). For this reason, the roof covering must be securely fixed in accordance with the manufacturer's instructions and the rafters skew nailed to plates and tied down to the wall plates with triple-grip connectors.

Fig. 21.5 Skillion roof frame



Setting out the rafters for the skillion roof is usually carried out in a very practical manner. After the walls have been plumbed up, the rafter is laid in position across the walls, which will be of different heights. The location of a birdsmouth (to give the rafter secure fixing to the wall plates) is marked directly from the plates using a small straight edge, for example, a rule and pencil (Fig. 21.7).

If there is to be an overhanging eave, the width of the eave can be set off along a horizontal line and a plumb line marked on the rafter. It is then cut to length. Alternatively, the rafters can be cut to length after they have been fixed, in the same manner as for the gable roof.

Deep rafters over 200 mm must be blocked to ensure they will not tend to topple sideways when placed under a load. Solid blocking in rows no more than 1500 mm apart is required (Fig. 21.8).

Fig. 21.6 Wind pressure on skillion roof

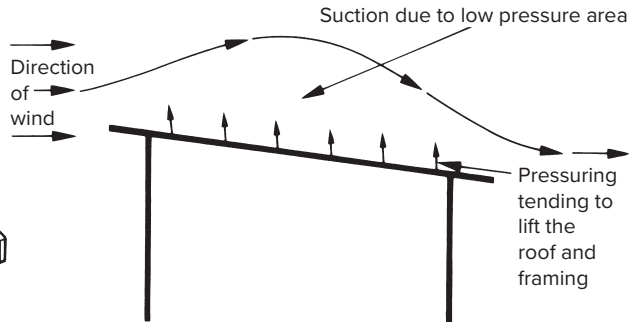


Fig. 21.7 Marking out rafter for skillion roof

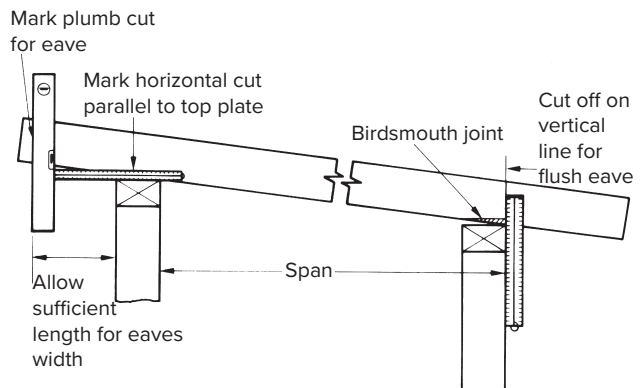
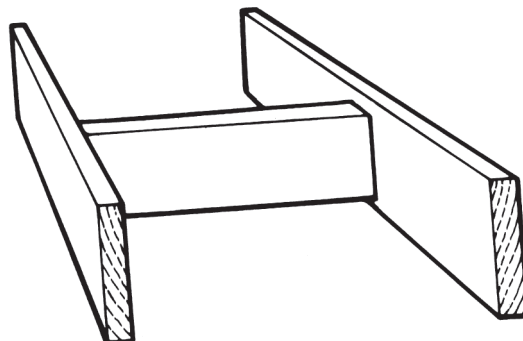


Fig. 21.8 Solid blocking for deep rafters



CHECK YOUR UNDERSTANDING

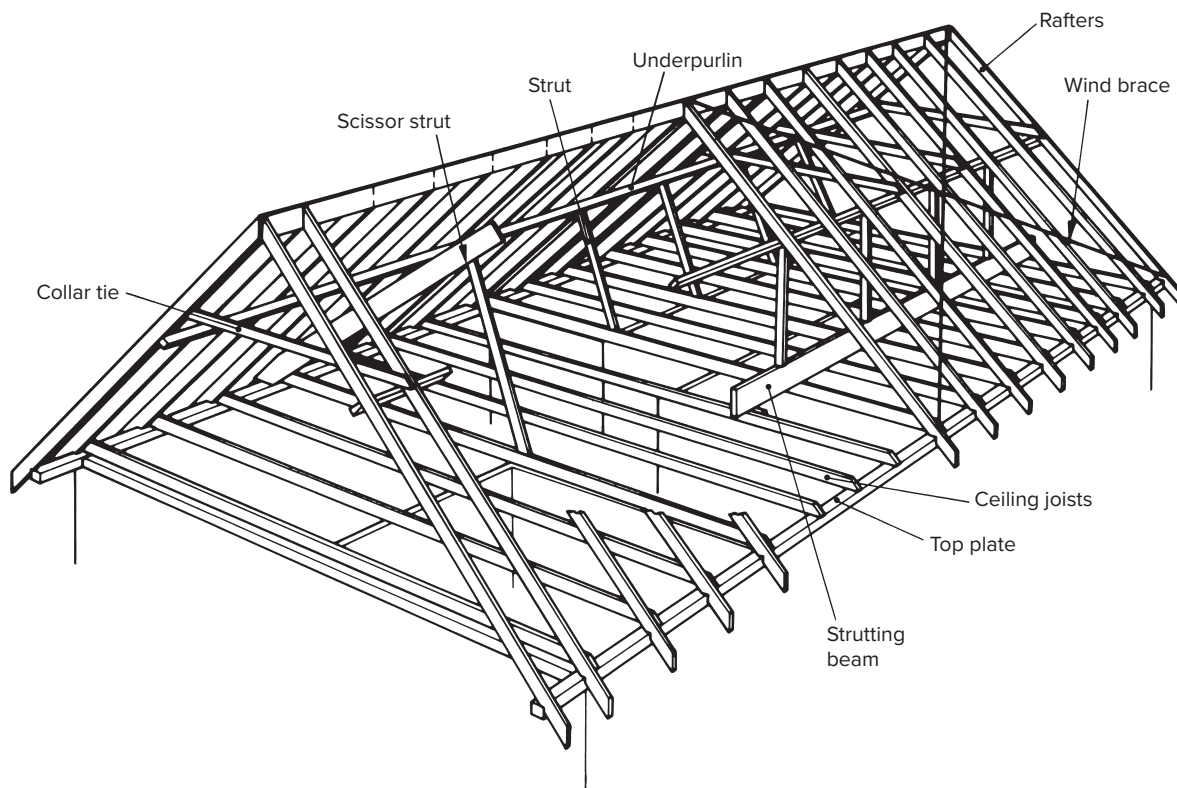
3. How can the rafters of a skillion roof be set out in a practical situation?

21.5 Identify gable roof components

The gable roof is a very popular roof form, being comparatively simple in design and readily adaptable to a wide variety of different roof pitches (Fig. 21.9). This type of roof is generally more economical to erect over a plain rectangular floor plan, but it can be adapted to other floor shapes.

The actual part referred to as the **gable** is the vertical triangular section at the end of the roof, from the top plate to the roof rafters. Over many years and in different places it has been traditional to decorate the gable in various distinctive ways; however, the gable can be exposed to the harshest weather conditions and is often finished with materials that will minimise maintenance.

Fig. 21.9 Gable roof—general view



21.5.1 The structural members

21.5.1.1 Common rafters

Common rafters are sloping roof members complete from the wall plate to the ridge. In a gable roof all of the rafters meet this definition, and because of this they can simply be referred to as *rafters*. However, in other roof forms it is necessary to distinguish them from other rafters and give them their full title of **common rafters**. On a plan, the common rafters always lie at right angles to the wall plate on which they are supported. One of the first problems facing the carpenter erecting the gable roof is to determine the length of the common rafters and the bevel required for setting out. This will be discussed in detail later.

21.5.1.2 Ridge

The ridge runs the length of the roof and provides fixing for the rafters at their apex.

21.5.1.3 Gable studs

Gable studs enclose the gable and provide fixing for external sheeting materials.

21.5.1.4 Underpurlins

Underpurlins run the length of the roof and support the rafters usually midway in their length.

21.5.1.5 Struts/toms/props

Struts support the underpurlins, which in turn support the rafters. These struts then transfer the load of the roof structure and covering to internal load-bearing walls or suitable strutting beams.

21.5.1.6 Strutting beam

The strutting beam is sometimes used over large rooms to support struts where no internal walls are available. **Strutting beams** can run in any direction and must be supported by load-bearing walls and packed up to maintain a 25 mm clearance over the ceiling joists.

21.5.1.7 Collar ties

Collar ties are usually placed resting on the underpurlins and tie the two sloping roof surfaces together.

21.5.1.8 Wind braces

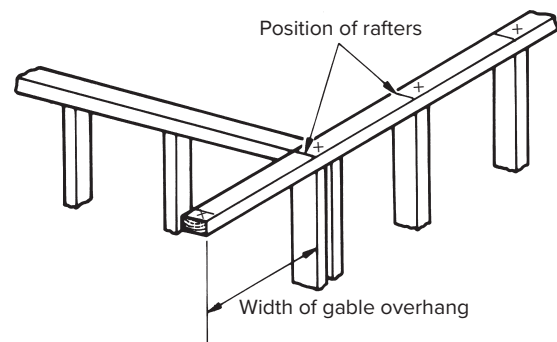
Wind braces are diagonal braces supported over load-bearing walls, bracing the ridge to prevent the pairs of rafters tending to topple sideways, particularly due to heavy wind loads.

21.6 Set out rafters

Figure 21.10 shows the position of the rafters set out along the top plate. Usually, a pair of rafters is located at each end of the building and if there is to be an overhanging gable, a pair of rafters is located at the end of the plate to form the gable overhang.

The remaining rafters are set out along the length of the building, not exceeding the maximum spacing. Remember, the rafters must be fixed over the wall studs if the wall framing was designed with this intention. The ceiling joists will be fixed beside these marks.

Fig. 21.10 Rafter set-out



CHECK YOUR UNDERSTANDING

4. Describe the function of the following members in a gable roof:
 - a. common rafter
 - b. ridge
 - c. underpurlin
 - d. strutting beam
 - e. wind brace.

21.6.1 Setting out the common rafter

In Figure 21.11, the equally pitched roof can be regarded as a right triangular prism resting on a horizontal surface. Angle BAC is the pitch of the roof and AD is the span. Lines AB and BD are common rafters represented by a single line.

Isolate the right-angled triangle ABC . Then AC is the **half span** or run of the common rafter, BC is the rise and AB is the true length of the common rafter.

Angle BAC is the pitch of the roof; it can also be referred to as the **level bevel** for the common rafter. Angle ABC is the plumb bevel or cut for the common rafter and is the bevel most commonly used in setting out and cutting the rafters.

As can be seen, if we reproduce triangle ABC to the specified information, then the true length of the common rafter and its plumb bevel can be readily obtained. For the purpose of explanation, let us assume that the span of a gable roof—equally pitched—is 8400 mm and the pitch is specified as 1:1.6 or 41° . Therefore, the run (half span) of the rafter is 4200 mm (Fig. 21.12).

There are two methods for determining rafter length and plumb bevel/cut: by scale drawing and by calculation.

Fig. 21.11 Common rafter

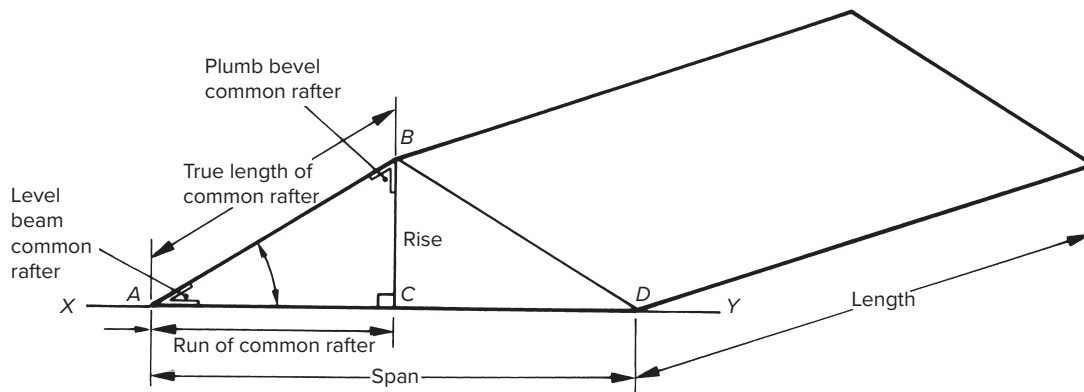
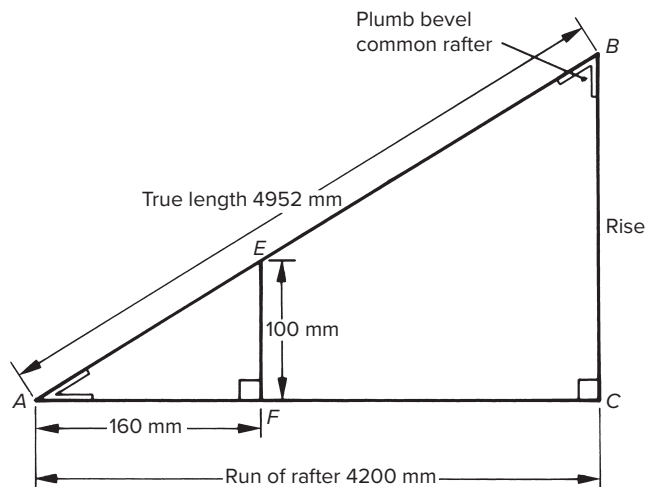


Fig. 21.12 Scale/pitch triangle



21.6.1.1 By scale drawing

This is done on a suitable plane surface such as paper or plywood. A scale of 1:10 is convenient. A rule can be used if a scale rule is unavailable.

1. Using a scale rule, set off the run of common rafter AC equal to 4200 mm. If a scale rule is not available, use a rule and divide each dimension by 10, e.g. $4200/10 = 420$ mm.
2. From A , set off the pitch of the roof by setting off the vertical and horizontal components as shown. For example, with a ratio of 1:1.6, multiply both components by 100 (100:160).
3. From C , set off a right angle to intersect the pitch line at B .

4. Measure AB , which equals the true length of the common rafter: 4952 mm.
5. Set the sliding bevel to angle ABC , which equals the plumb bevel/cut of the common rafter. When setting out to scale, care is essential to ensure accurate results. Set off the pitch with a protractor if the pitch is specified in degrees.

21.6.1.2 By calculation

Run of common rafter = 4200 mm

Roof pitch = 1:1.6

Rise (refer to Table 21.1) = 625 mm/m

Calculate the true length of the common rafter per metre run in Figures 21.13 and 21.14 using Pythagoras' theorem (see Chapter 4, Trade calculations and measurements).

$$\begin{aligned}
 XY^2 &= YZ^2 + ZX^2 \\
 XY &= \sqrt{YZ^2 + ZX^2} \\
 &= \sqrt{1000^2 + 625^2} \\
 &= \sqrt{1000000 + 390625} \\
 &= \sqrt{1390625} \\
 &= 1179 \text{ mm}
 \end{aligned}$$

Fig. 21.13 Calculation triangle—common rafter

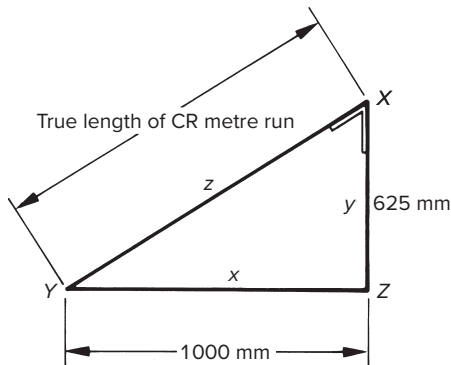
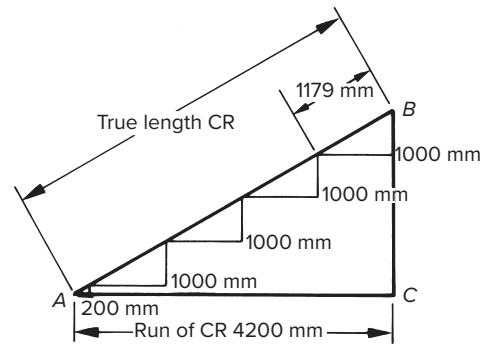


Fig. 21.14 Application of common rafter triangle to true length of rafter



To calculate the length of the common rafter:

$$\begin{aligned}
 \text{True length of CR} &= \text{CR mm/m run} \times \text{run of rafter in metres} \\
 &= 1179 \times 4.2 \\
 &= 4952 \text{ mm}
 \end{aligned}$$

From the set-out drawing (Fig. 21.12), the length of the common rafter and the plumb bevel/cut can be obtained. But roof members have width and thickness, so it is now necessary to consider where this angle and dimension are applied to the common rafter. Also, in most instances, the roof will have an eaves width and this must be provided for in setting out the finished rafter.

Figure 21.15 shows a vertical section through the gable roof. Width, thickness and overhang have been added to the roof members. The triangle ABC is also the triangle ABC that was isolated and considered in Figure 21.12. Note that AB is the geometrical length of the common rafter and is measured along the top edge of the rafter.

Allowance must be made at the apex of the roof for the ridge to fit between the common rafters. Each rafter is shortened by half the thickness of the ridge measured square off the plumb line. A birdsmouth is cut into the foot of the rafter to obtain a firm bearing and to secure the nailing to the top plate.

The maximum depth of the birdsmouth is one-third the depth of the rafter (Fig. 21.16). In any case, it is more important to leave a constant amount on each rafter from the top plate; this will ensure the tops of the rafters are consistent and in the same plain as the XY line; this distance will be referred to as *distance x*, which is not less than two-thirds the length of the plumb cut. No matter what the width of the rafter or pitch of the roof may be, there is no reason for the horizontal cut of the birdsmouth to be greater than the width of the top plate.

The distance FA in Figure 21.15 is the eaves width and is a horizontal distance, usually specified by the building designer. The distance EA, the eaves overhang, is, of course, a greater distance and is measured along the slope of the rafter.

21.6.2 Setting out the pattern rafter

A pattern rafter can now be prepared from which other rafters can be duplicated (Fig. 21.17). The procedure for setting out a pattern rafter is as follows:

1. Select a common rafter, as straight as practicable, and set a sliding bevel to the plumb bevel of the common rafter.
2. Near the end of the rafter, select point B and mark the plumb bevel/cut of the common rafter through this point.
3. From point B measure off the length of the common rafter to point A and mark the plumb bevel/cut of the common rafter through this point.
4. From the plumb line through point B, measure off at right angles half the thickness of the ridge and again set off the plumb bevel of the common rafter. This is the line at which the rafter will be cut to length.
5. From point A measure down the plumb line distance *x* and mark off at right angles for the horizontal cut to the birdsmouth.
6. The eaves overhang is set off by measuring square off the plumb line through point A, a distance equal to the eaves width, and establishing point E. Again, mark the plumb bevel of the common rafter through this point. The eaves overhang EA can also be calculated readily. For example, if the eaves width is specified at, say, 600 mm, then:

$$\begin{aligned}
 \text{Eaves overhang} &= \text{common rafter mm/m run} \times \text{eaves width (m)} \\
 &= 1179 \times 0.6 \\
 &= 707 \text{ mm}
 \end{aligned}$$

Fig. 21.15 Vertical section through gable roof

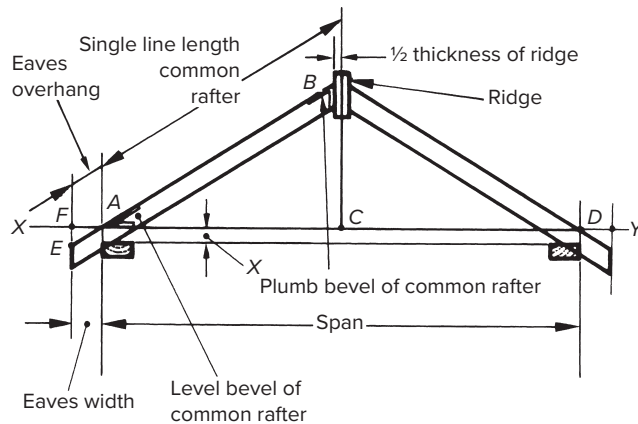
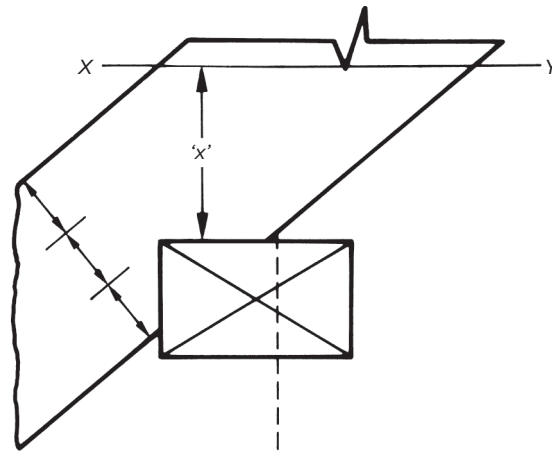


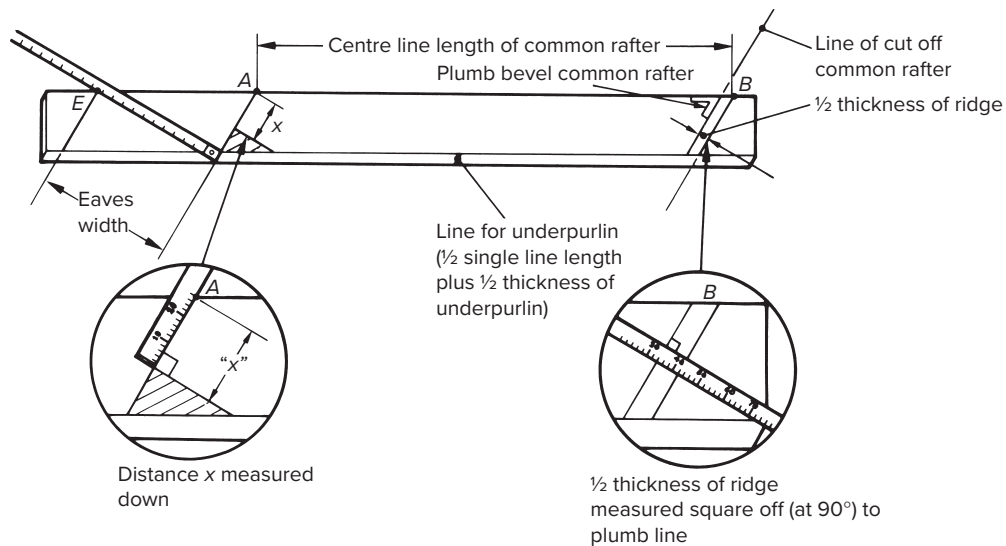
Fig. 21.16 Birdsmouth joint depth



This distance can be measured along the rafter from point *A* to point *E*. The eaves overhang plus an allowance for making the plumb cut is commonly referred to as the tail of the rafter. Quite often the eaves overhang is not marked on the rafter at this stage, but the tail must be left sufficiently long, so that it can be marked and cut off (as described) at a later stage.

TIP At this time, it is no doubt good insurance against possible error to cut a duplicate rafter and test the pair of rafters for accuracy over the span of the roof. Place a small block of wood, the thickness of the ridge, between the apex of the rafters to allow for the ridge to be fitted between them.

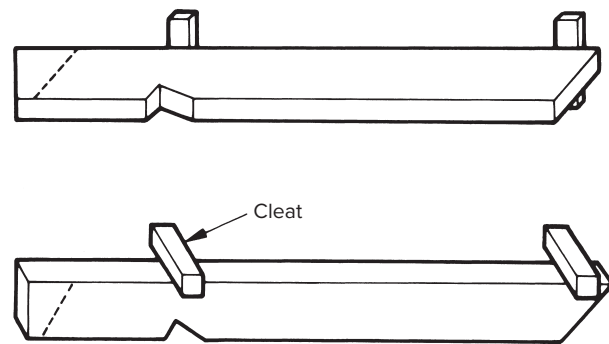
Fig. 21.17 Setting out pattern rafter



21.6.3 Cutting rafters to pattern

To cut the remaining rafters accurately to the pattern, nail a short cleat across the rafter directly above the birdsmouth and at the top of the rafter. Lay the pattern rafter on each rafter, keeping the round edge up and the cleats hard against the top edge of the rafter. Mark the plumb cut and the birdsmouth. Finish cutting out the remaining rafters (Fig. 21.18).

Fig. 21.18 Cutting rafters to pattern



21.6.4 Constructing a rafter boat

The **rafter boat** is another option that can be used when cutting a large number of rafters (Fig. 21.19). It works on a similar principle to a pattern rafter.

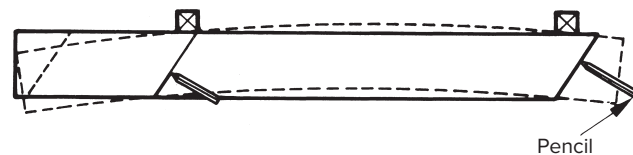
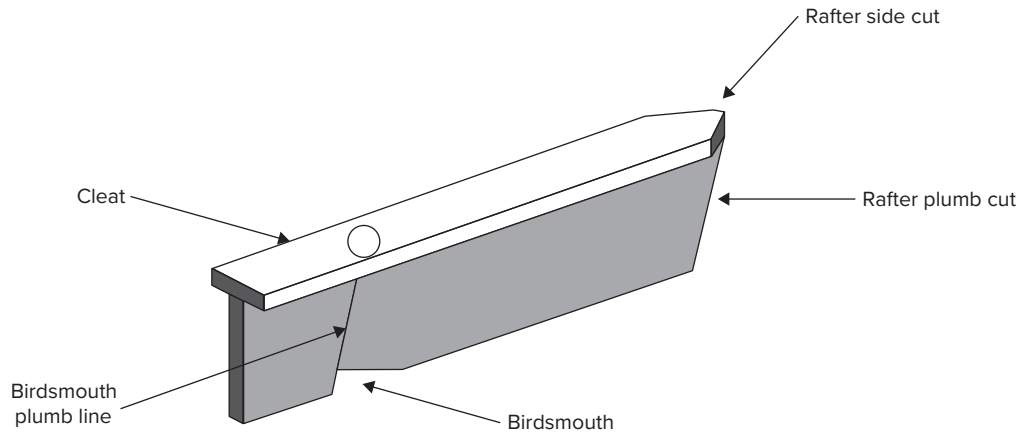


Fig. 21.19 Finished rafter boat

TIP The rafter boat is much smaller and lighter than a pattern rafter and can be kept to use on another job with the same roof pitch.

The main difference is that the rafter boat will not give you the rafter length. It will give the plumb cut, the birdsmouth, rafter side cuts and even the eave overhang.

Two pieces of timber are required, generally something light such as pine or plywood. The large piece of timber should be the same depth as the rafter; a cleat of material 19 mm × 70 mm is needed for the top of the boat so it can be positioned and slid along the rafter.

1. First, ensure the timber to be used is straight and free of defects.
2. Identify which edge of the boat will be the top and mark.
3. Transfer the plumb cut to one end of the boat and cut accurately.
4. Locate the position of the birdsmouth at the other end of the boat, mark and cut. It must be identical to the birdsmouth on the rafters.
5. If needed, work out the eave overhang and mark on the boat past the birdsmouth.
6. Centre the cleat along the top of the boat, glue and nail. Ensure the cleat overhang on both sides of the boat are the same.
7. If required, mark and cut the rafter side cuts on the cleat at the plumb cut end of the boat (for a hip roof).
 - (a) Use the rafter boat in a similar way to a pattern rafter; select a rafter and ensure the rounds are up.
 - (b) Place the boat at the end at which the plumb cut will be and mark the cut using the boat.
 - (c) Now the plumb cut has been marked, measure along the top of the rafter to the desired length. Mark this position.
 - (d) Slide the boat down to this new mark and mark out the birdsmouth. To improve the use of the boat, a hole of approximately 25 mm can be drilled on the plumb line located on the birdsmouth to make positioning the boat easier.
 - (e) If the eave overhang is marked on the boat, mark this while the boat is at the birdsmouth position.

21.7 Prepare the ridge and underpurlins

On the gable roof, the ridge usually has to be joined along its length with a splice joint (Fig. 21.20). It is preferable to make the splice where a pair of rafters will be located, as this ensures that the ridge will be locked in place and kept in alignment.

The ridge is laid out on top of the ceiling joists above the top plate, and the position of the rafters is squared up from the plate on to the ridge and marked (Fig. 21.21).

Underpurlins can be prepared on the ground. Where they have to be joined in length, a half-lapped joint is used (Fig. 21.22). It is better to adjust the length of the underpurlins so that the joint falls over a wall and a strut can be fixed underneath the joint.

Fig. 21.20 Joint along length of ridge

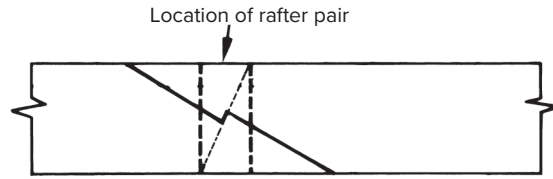


Fig. 21.21 Marking rafters on the ridge

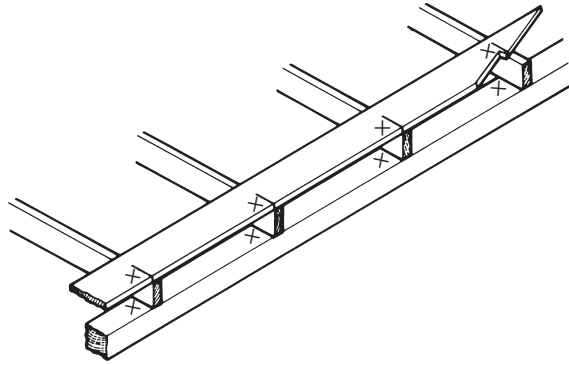
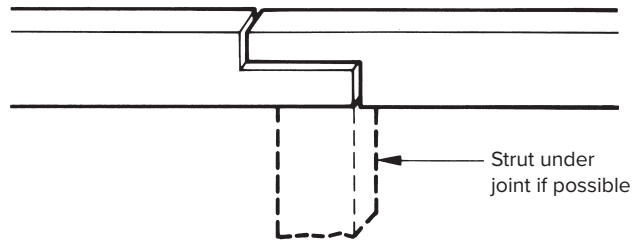


Fig. 21.22 Joining underpurlins

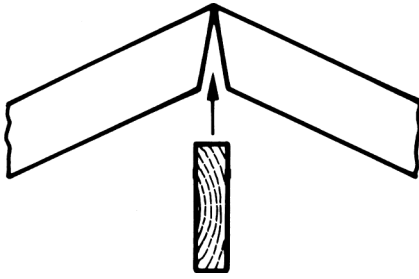
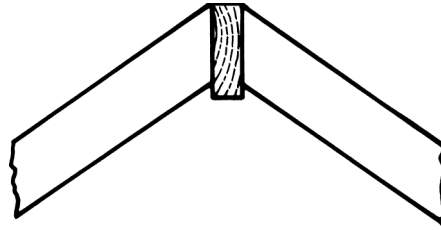


21.8 Erect the gable roof

Before erecting the roof, a safe working platform should be provided by either laying planks across and along the length of the ridge or erecting a scaffold. Never commit yourself to working from some insecure or rickety structure, as a fall at this time through the joists can result in some very serious injuries. A catch platform needs to be erected around the perimeter of the building so that, in the case of a fall, you don't fall to the ground. Also, the platform is used to erect the roof. (Refer to Safe Work Australia's 'Code of Practice: Managing the risk of falls in housing construction'.)

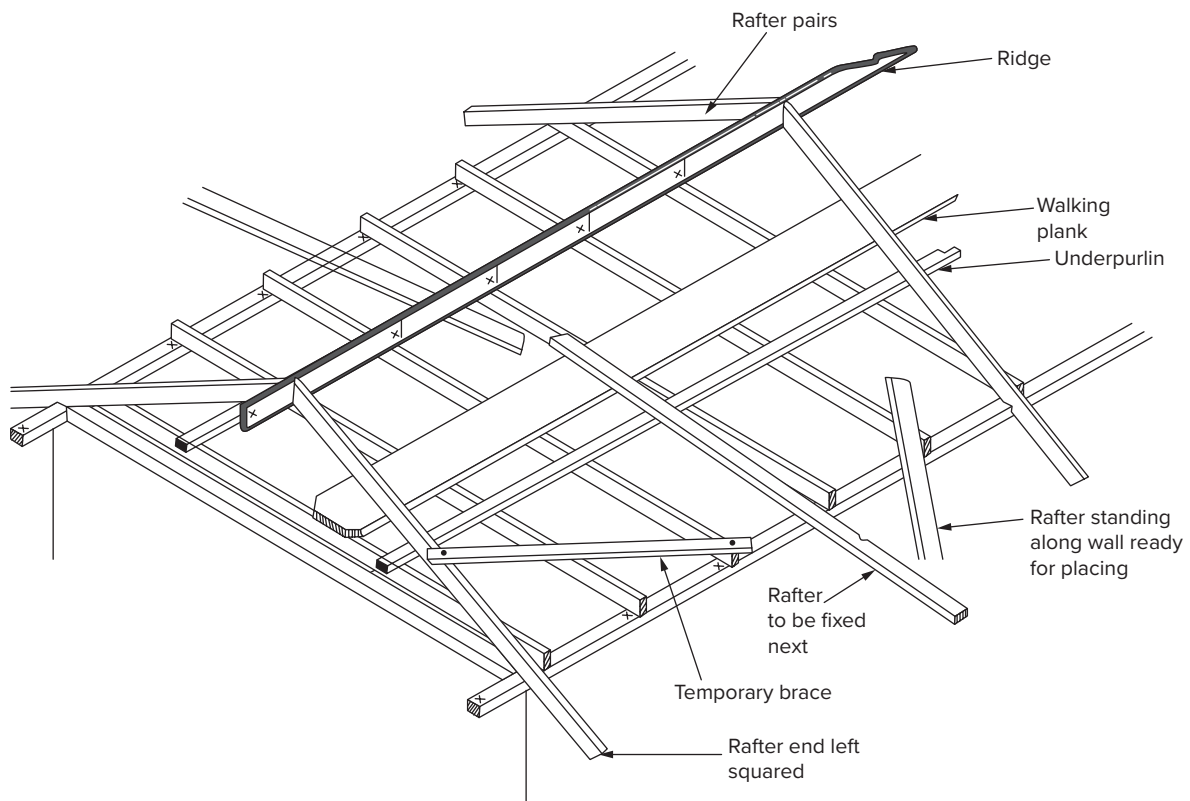
21.8.1 Procedure

1. Lay out the ridge along the centre of the building.
2. Load underpurlins onto the roof and lay them on the ceiling joists near their final location. If any strutting beams are to be used, also load these onto the ceiling and lay them on their flat face near to the fixing position.
3. Stand the rafters on end along the length of the building beside their fixed position. Pull up the rafters and load the roof with sufficient rafters to set the ridge in place—usually rafters near the end of the building and adjacent to any joint in the ridge.
4. Fix selected pairs of rafters into position, skew nailing through the birdsmouth into the top plate and resting against each other at the apex. Stabilise with a light diagonal brace if necessary.
5. With a carpenter at each end of the ridge, lift it up, separating the rafters so that it can pass between them. Let it down so that it is gripped between the rafters. Taking the weight of the ridge, ease the rafters into place (Figs 21.23 and 21.24).

Fig. 21.23 Rafters ready to join ridge**Fig. 21.24** Rafters in place

Nailing for the rafter on one side can be carried out directly through the ridge, while the other side is usually secured by skew nailing through the rafter to the ridge. The roof will now be erected to the stage as shown in Figure 21.25.

6. Plumb up the pair of rafters at the end of the roof using the plumb bob or spirit level and straight edge and secure in place with a temporary, but sturdy, brace that will remain in place until permanent wind bracing is provided (Fig. 21.26).
7. Fix the remaining section of the ridge and the rafters as previously described. Remember that underpurlins and struts have to be cut and fixed to the underside of the rafters, and this can be done much more quickly and easily if the under-roof working area is kept as accessible as possible.

Fig. 21.25 Pairs of rafters in place

SAFETY TIP At this stage it is suggested that no more rafters than are necessary to keep the ridge and underpurlins in alignment are loaded onto the roof and fixed in position. This is particularly the case if it is a fairly low pitched roof, as you could well save many hours of work and an aching back.

8. Partly drive a nail into the underside of selected rafters on the mark indicating the top edge of the underpurlin. Lift the underpurlins, holding them firmly against the stop provided by the nails, and skew nail the rafters to the underpurlins. A short sash cramp is very useful for pulling the rafters and underpurlins tightly together. Sometimes it is better to fix the underpurlins hollow side up to counteract the rafters that were fixed round side up. This tendency will be much more pronounced in the case of a green hardwood roof.
9. Check that rafters and underpurlins are tightly pulled together and are now straight enough for strutting. Sighting by eye is usually sufficient. Struts/**props** can be fixed either vertically or at right angles to the common rafter (Fig. 21.27). Struts/props must be supported by a load-bearing wall, not over a doorway, unless the doorway has been specifically designed to take the load.

Fig. 21.26 Plumb up of gable end

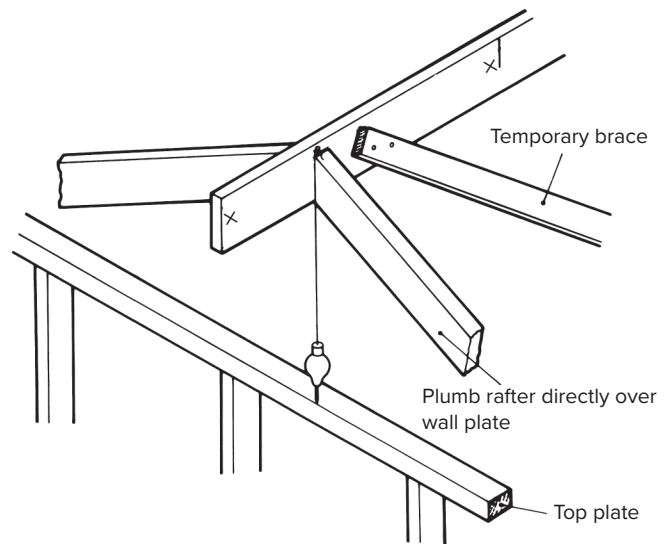


Fig. 21.27 Strutting to support underpurlins

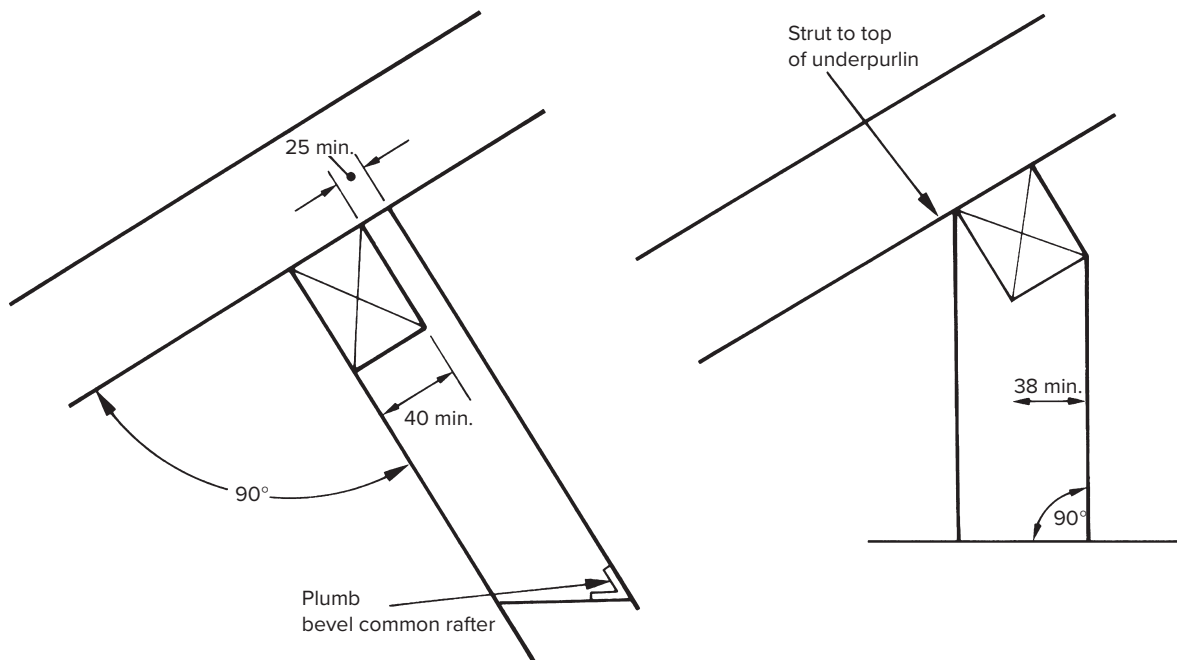
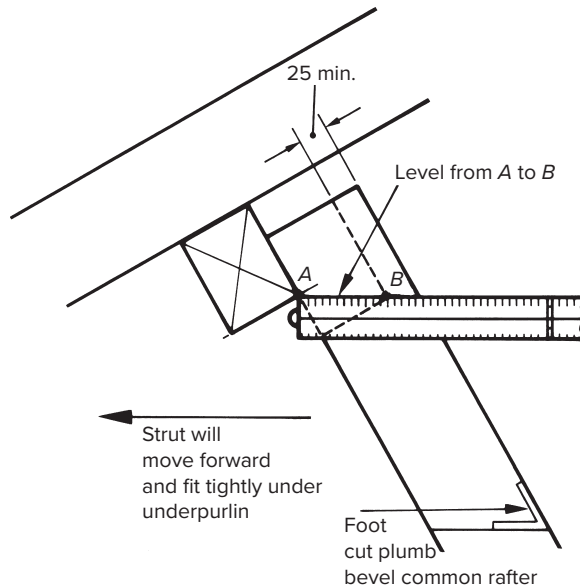
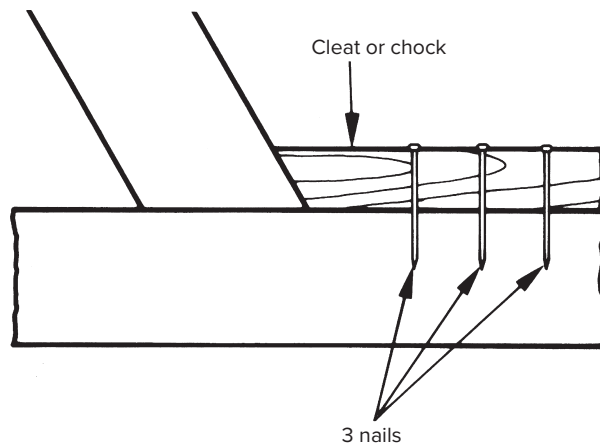
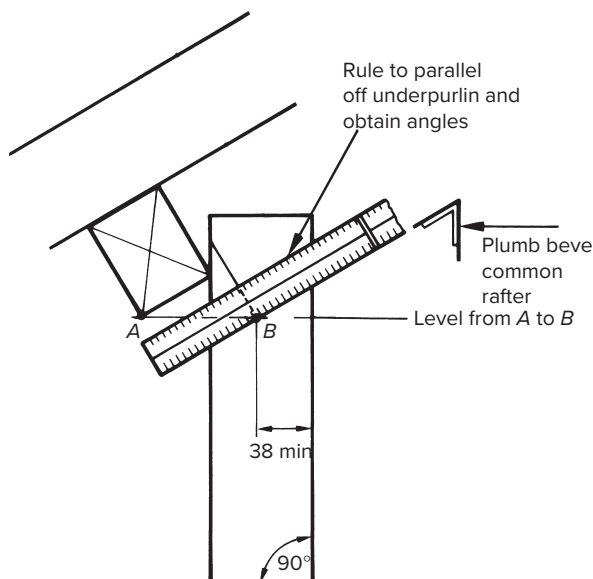


Fig. 21.28 Marking strut at right angle to rafters**Fig. 21.29** Cleat to foot of strut**Fig. 21.30** Marking out a vertical strut

(a) Cut the foot of the strut at the plumb bevel of the common rafter and stand beside the underpurlins (Fig. 21.28). Level across from point A to point B on the strut and from B mark out and cut a notch for the underpurlin. The strut will move forward as shown, tightly under the underpurlin. Nail a cleat behind the heel of the strut (Fig. 21.29).

(b) Stand the strut vertically beside the underpurlin, and level across from point A to point B on the strut. The angle for the notch on the strut is the plumb bevel of the common rafter, but to allow for any little practical discrepancies, the notch for the underpurlins is probably best marked by paralleling the sides of the underpurlin with the rule as shown (Fig. 21.30).

Sometimes struts can be more securely and easily fixed if a short sole plate is laid over the ceiling joists on top of a load-bearing wall (Fig. 21.31).

Alternatively, prop gauges/sticks (Fig. 21.32) are available, which are used to create a quick template for the strut/prop to be cut. The head and foot are adjustable, so any desired angle can be achieved. The tool is also telescopic, so the length of the strut/prop can be ascertained.

10. Strutting beams should be made of seasoned timber and can be used over large rooms where no internal wall is available for supporting struts (Fig. 21.33). Strutting beams can run in any direction across a room, but must be supported by a load-bearing wall and be packed up at least 25 mm above the ceiling joists at both ends. The ceiling joists must *not* support the strutting beam. The struts are fixed from the strutting beam to the underside of the underpurlin.

11. Fix two permanent wind braces running in opposite directions. The foot of the brace must be over a load-bearing wall, sloping at an angle of approximately 45°, and scarfed at the top to fit under the ridge. Remember, more

CHECK YOUR UNDERSTANDING

5. How is the ridge marked out for the position of the rafters?

Fig. 21.31 Use of sole plate where strut would land on joist

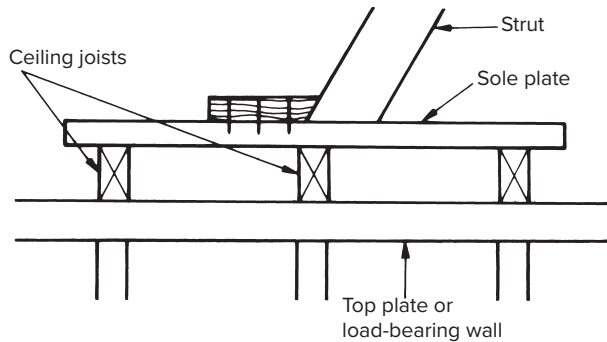
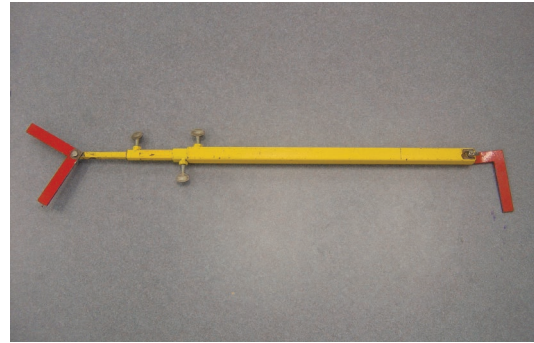


Fig. 21.32 Prop stick/gauge



Courtesy of Daniel Bonnici

rafters and collar ties have to be fixed later, so try to adjust the wind brace so as not to foul other members. Vertical **toms** supporting long sections of ridge can also be fixed at this time. Some carpenters may prefer to fix the rafters and collar ties before the wind braces.

12. Fix the remainder of the rafters. No doubt, many would have been fixed as required during the progress of the job.
13. Cut and fix collar ties (Fig. 21.34). Lay a collar tie in position on top of the underpurlins and mark the length and shoulder to fit under the rafters. Prepare collar ties on the ground, cutting the shoulder on one end but leaving the other shoulder to be cut when each collar tie is being fixed in its final position, usually to every second pair of rafters.
14. The lower end of the rafter is the eaves line. The eaves width is usually specified and must be measured along a level line from the face of the wall. Theoretically, the foot of the common rafter can be cut off before it is fixed in place. But to ensure a straight fascia line, it is generally agreed that it is much more satisfactory to strike a straight line and cut the rafters to length only after they have been finally fixed and strutted in position.

Measure the eaves width at each end of the wall and mark the plumb line on the rafters. Set up a string line directly over these marks and plumb down from the string line on each rafter, and cut the rafters off to line (Fig. 21.35).

Fig. 21.33 Strutting beam

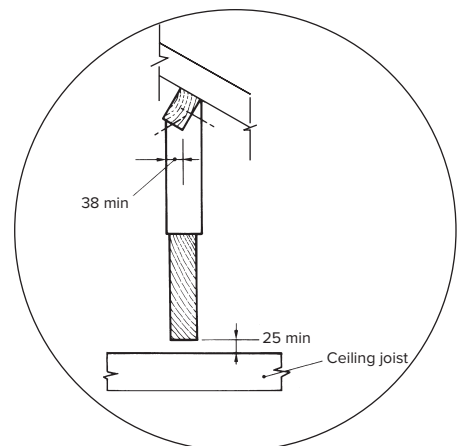
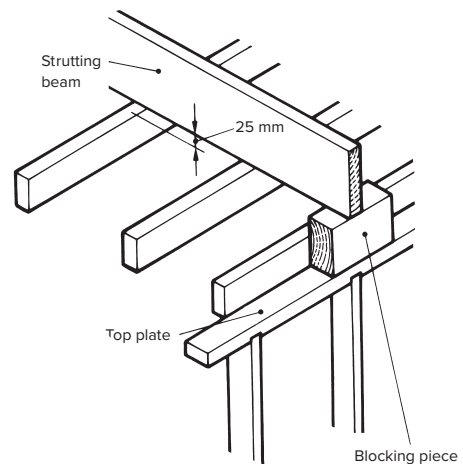
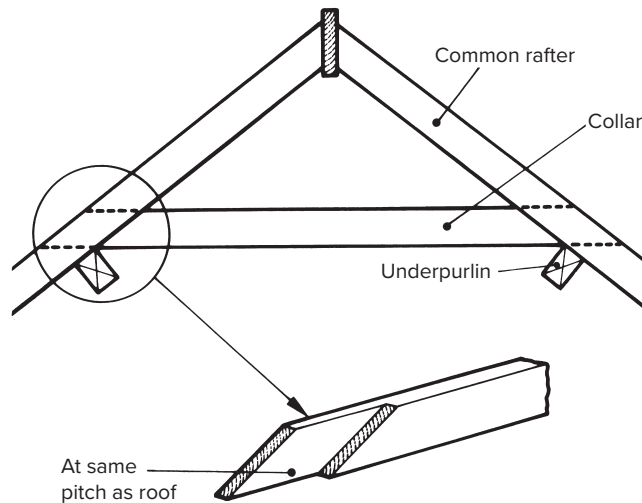
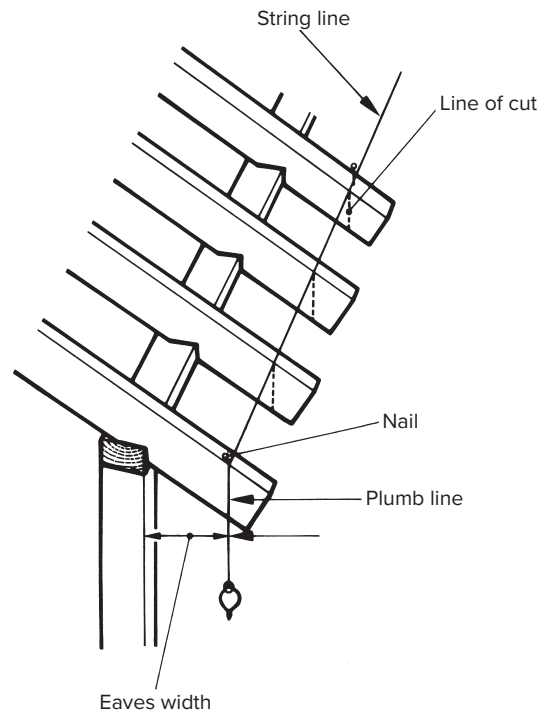


Fig. 21.34 Collar tie**Fig. 21.35** Marking rafters to length

21.9 Finish the roof frame

Once all of the roof members are up and secured and all of the supporting timbers such as toms, underpurlins etc. are installed, the roof structure can be tidied up and finished. This process includes cutting the rafters to length, installing gable outriggers, installing fascia, barge boards and roof battens. For more details on eave construction and finishing, refer to Chapter 24, Construct eaves.

21.9.1 Finishing gable ends

There are a number of ways to construct and finish off the gable end of a roof. Figure 21.36a shows that gable studs are fixed from the top plate and checked out to fit behind the rafters. Alternative methods of finishing off a gable are shown in Figures 21.36b and 21.36c. Note that Figure 21.36c shows the gable end is complete with barge boards installed and the boxed eaves are fully constructed including fascia. Both the eaves and gable are ready for the soffit lining to be installed.

Figure 21.36c shows battens installed to suit a tiled roof; batten spacings differ for alternative roofing products. Refer to AS 1684 or the manufacturer's specifications for the specific spacing when installing battens to suit the nominated roof cladding.

21.9.1.1 Eaves finishes

Eaves can be finished in a number of ways, but some basic requirements should be taken into consideration, namely:

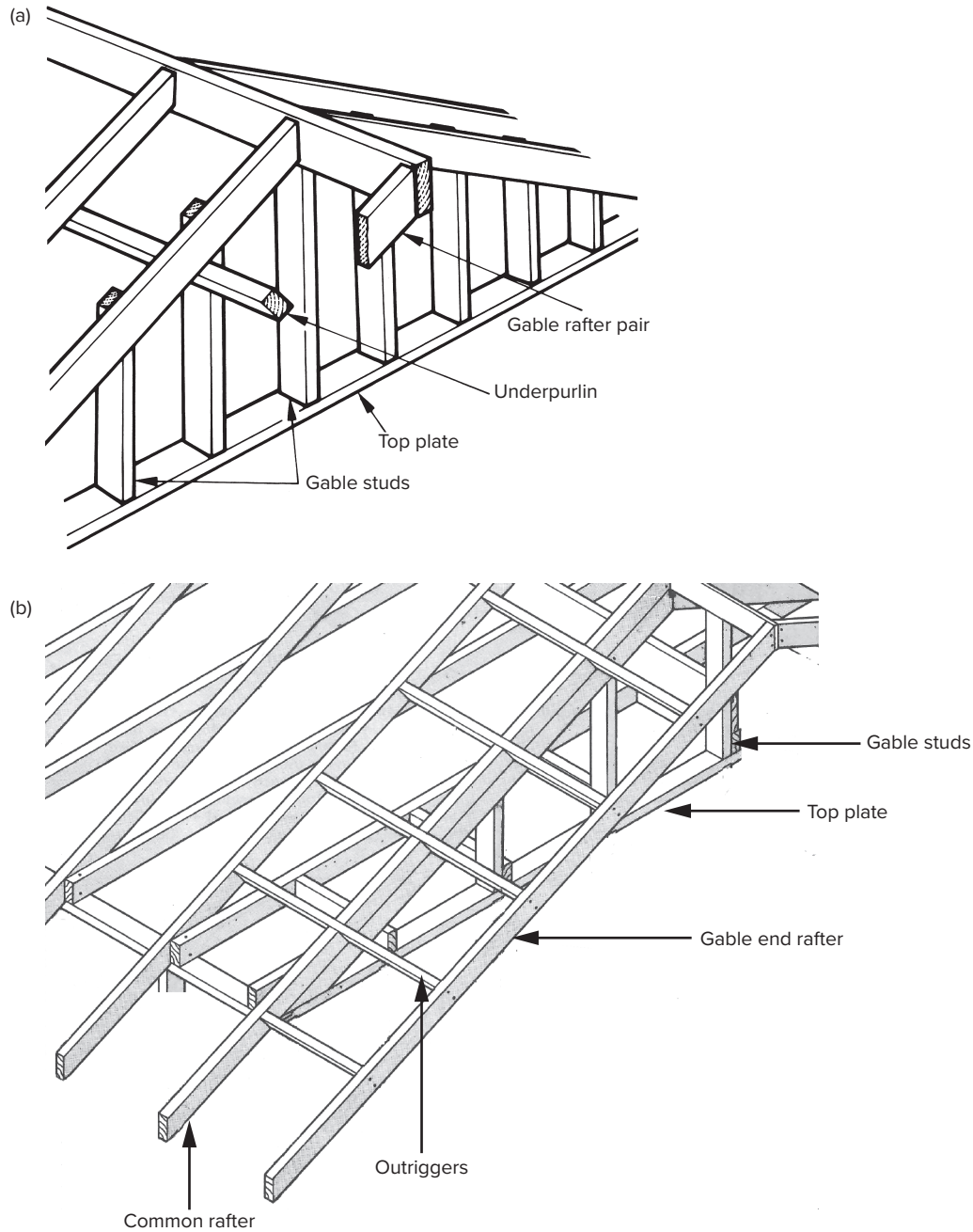
- provision for interior room ventilation, where and if required
- fixing for fascia and gutters
- bird proofing
- support for soffit/eave lining if required
- any fire zone area requirements.

The most commonly adopted finish for eaves is probably the **boxed eave** (Fig. 21.37).

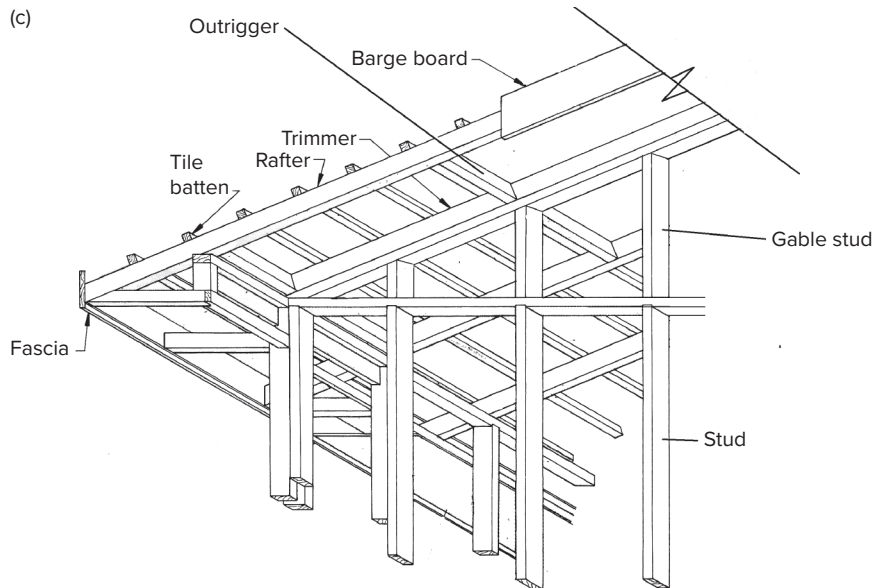
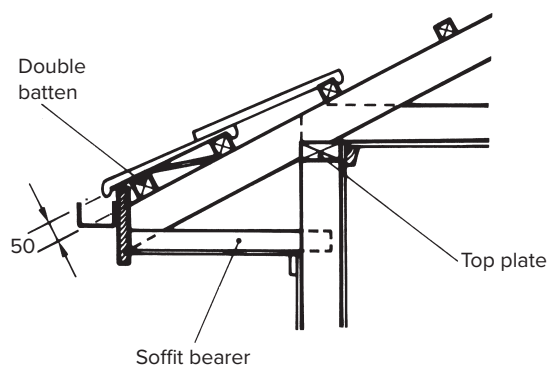
CHECK YOUR UNDERSTANDING

6. How can the tail of the rafter be cut off to a straight line ready for fixing the fascia?

Fig. 21.36 (a) Gable end construction method 1; (b) gable end construction method 2



(continued)

Fig. 21.36 (continued) (c) completed gable end roof showing barge and fascia**Fig. 21.37** Boxed eaves

21.10 Identify hipped roof components

Figure 21.38 illustrates the general construction of the hipped roof and the names of the roof members.

21.10.1 Roof members

21.10.1.1 Common rafter

The common rafter is a rafter complete from wall plate to the ridge; it is similar in all respects to the rafter of the gable roof.

21.10.1.2 Centring rafters

Centring rafters are a particular pair of common rafters. They are located at each end of the ridge and, as will be shown later, form the starting point for the setting out and erection of the roof.

21.10.1.3 Crown end rafter or jack rafter

The crown end rafter or jack rafter is a rafter complete from the wall plate to the end of the ridge. Its single line length is the same as the common rafter, but some small adjustment is necessary to allow for the different thicknesses of the roof members.

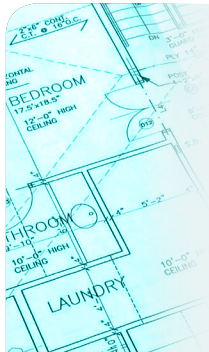
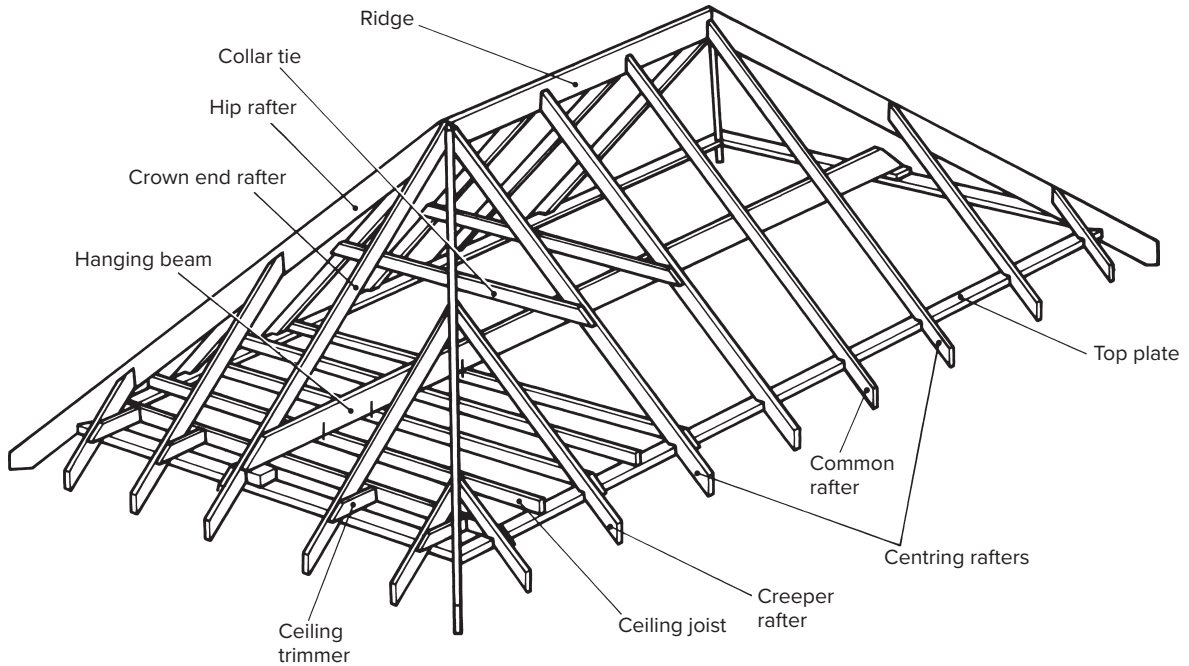
21.10.1.4 Hip rafter

The **hip rafter** is a rafter complete from an external corner to the ridge. It forms the junction of two sloping roof surfaces and requires a plumb bevel and an edge bevel. Refer to Table 21.2 later in the chapter.

21.10.1.5 Creeper rafter

The creeper rafter is a rafter running from the wall plate to the hip rafter and varies in length as it meets the hip. It has the same plumb bevel as the common rafter, and the edge bevel will be developed.

Fig. 21.38 General view of a hipped roof



INTERPRETING PLANS

Refer to the floor plan, drawing 02, in the Appendix, then highlight in different colours the following:

- ridge beam
- hip rafters
- valley rafters
- broken hip.

21.10.1.6 Underpurlins

The function and strutting of underpurlins are the same as described for the gable roof. The ends of underpurlins butt against the hip rafter and require a face and edge bevel.

TIP To calculate the roof member sizes, timber species and stress grades, refer to AS 1684.

CHECK YOUR UNDERSTANDING

7. Describe the function of the following members in the hipped roof:
 - a. centring rafter
 - b. crown end rafter
 - c. hip rafter
 - d. creeper rafter.

21.11 Set out the hipped roof

21.11.1 Development of roof bevels

To set out and erect the hipped roof, one of the foremost problems facing the carpenter is to develop the necessary bevels to cut the roof members accurately (Fig. 21.39). These are found by developing a series of right-angled triangles, the included angles of which are applicable to the roof members.

The development and construction of a typical hipped roof is described in the following pages and the general principles demonstrated can be applied to any hipped roof. But for the purpose of explanation, any specific references or dimensions indicated will apply to the drawing and specification for the hipped roof shown in Figure 21.40.

Figure 21.41 shows the hipped roof drawn in single lines (centre lines), resting on a horizontal plane represented by the line XY. Refer to the plan and note that as the roof is equally pitched, the hip will bisect the external corners, and if the roof is rectangular on plan, they can be drawn in using a 45° square.

The plumb and level bevels for the common rafter are the only bevels found directly from the drawing. Note how the hip plumb cut and length can also be obtained from the drawing. The rise of the roof is drawn 90° to the run of the hip. The hypotenuse is then drawn in, which is the true actual length of the hip rafter prior to the shortening (half the ridge thickness) is removed.

Follow the arrows indicating the direction in which the developments were carried out.

A tabulated list (Table 21.2) can now be prepared and is shown listing the roof bevels and the triangle in which they can be found. In each right-angled triangle, there are two other angles, and the last column indicates on which side of the triangle the required bevel is to be found.

Fig. 21.39 (a) Common rafter; (b) creeper rafter; and (c) hip rafter

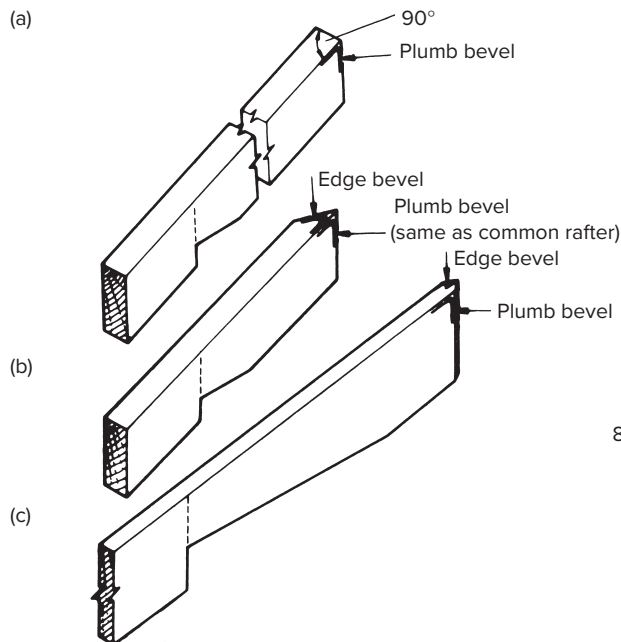


Fig. 21.40 Roof specification

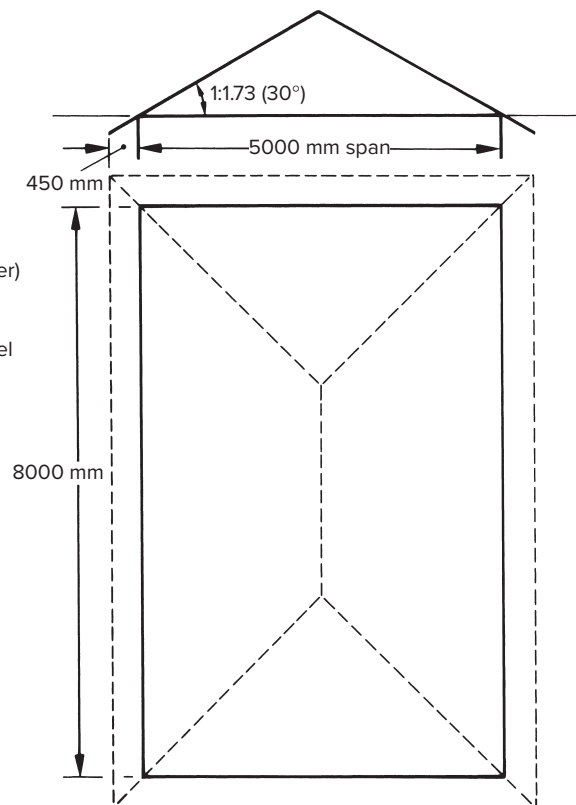


Fig. 21.41 Line representation of rafters

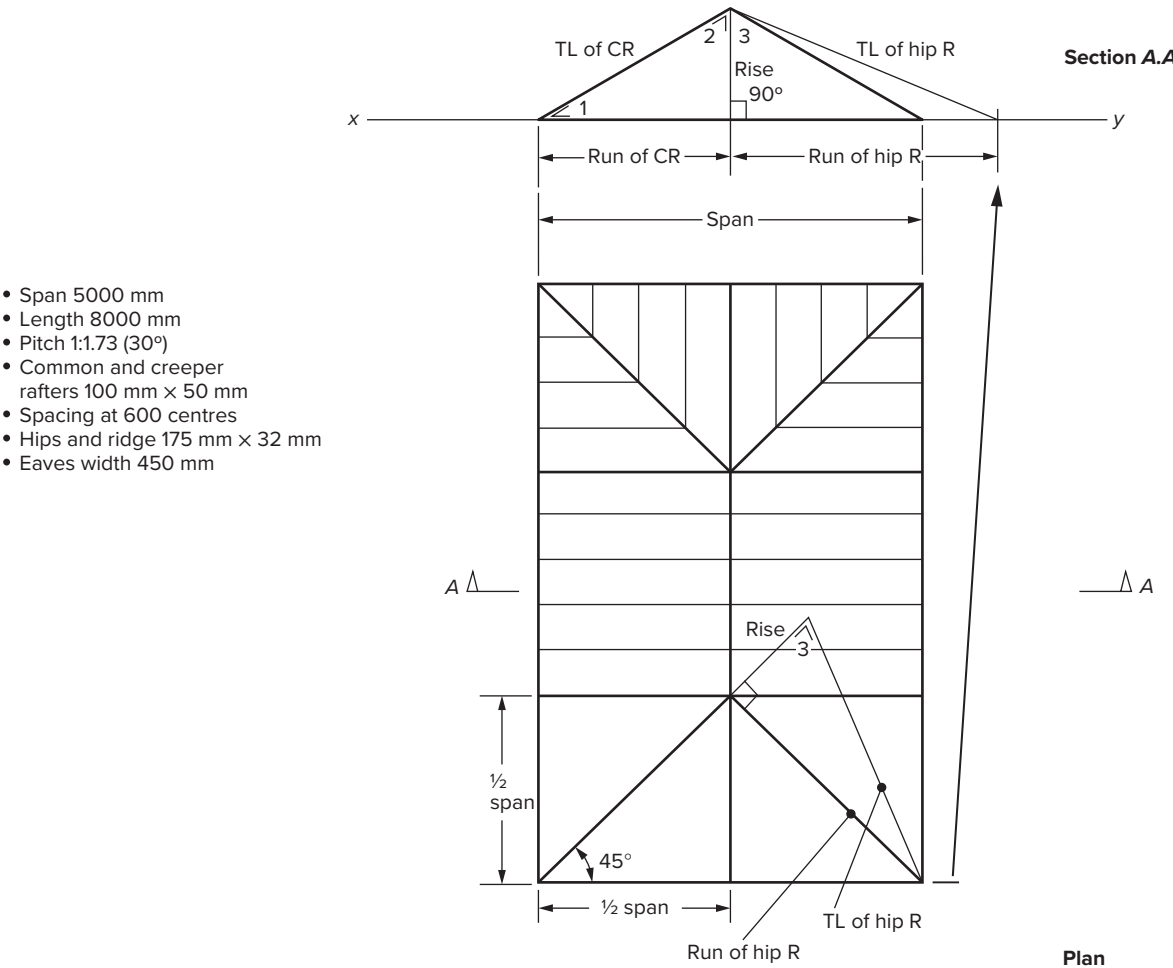


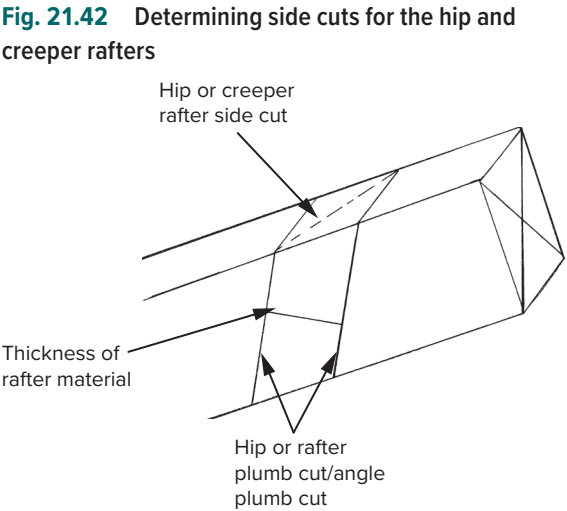
Table 21.2 Roof bevels

No.	Bevel	Triangle		Bevel on
1	Level/foot bevel common R	Run common R	Rise	Run common R
2	Plumb bevel/cut common R	Run common R	Rise	Rise
3	Plumb bevel/cut hip R	Run hip R	Rise	Rise

21.11.2 Determining the side cuts of the hip and creeper rafters

The following practical method is required (Fig. 21.42):

1. Using a bevel set to the appropriate angle, plumb a line down one face of the rafter.
2. Measure 90 degrees to the plumb line, the thickness of the material being used for the hip or creeper rafters.
3. Plumb a second line using the original bevel angle at the point marked in step 2.
4. Square a line across the top edge of the timber, connecting to the top of the two plumb lines.



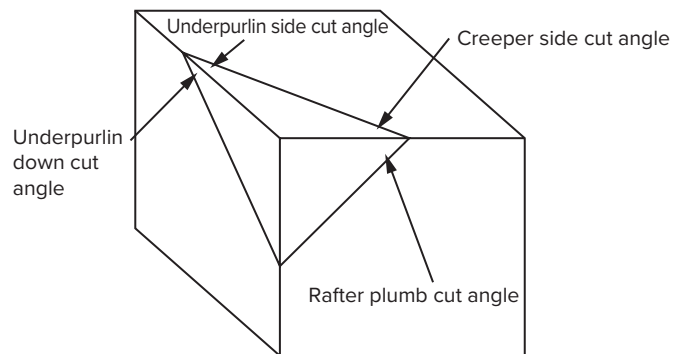
5. Draw a diagonal line from one corner to the other on the top edge of the timber. This diagonal line is the site cut for either the hip or creeper rafters.

21.11.3 Determining underpurlin bevels for a hipped roof

Using a block of timber that is cut square on the end, develop the underpurlin bevels following the method below:

1. Set a bevel to the rafter plumb cut angle and transfer the angle onto the end of the block of timber.
2. Set the bevel to the creeper side cut angle and transfer this angle onto the top of the piece of timber, ensuring this new line connects with the first line.
3. Using a straight edge, join up the lines from steps 1 and 2 on the side of the timber (Fig. 21.43).
4. The required angles for the underpurlin can now be found as indicated in Figure 21.43.

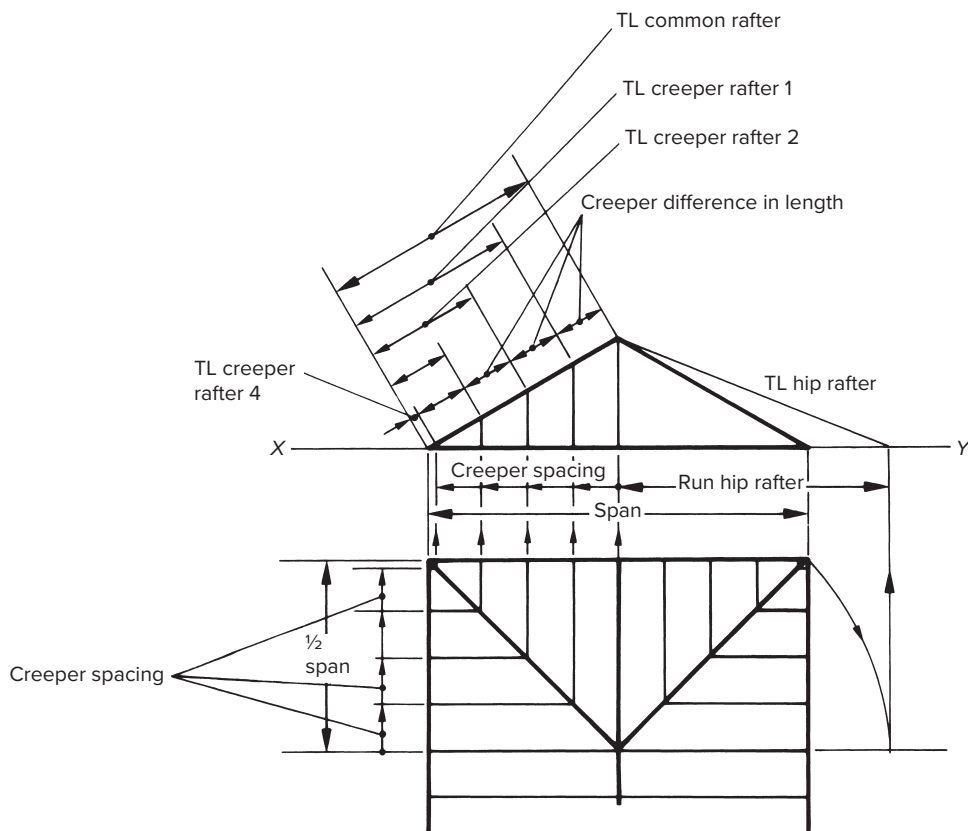
Fig. 21.43 Practical method for obtaining underpurlin cuts for a hipped roof



21.11.4 Determining the length of the creeper rafters

Figure 21.44 shows the part plan and vertical section of the hipped roof, with the centre line of the rafters indicated on the plan. Note that the creeper rafters are located by commencing at the centring rafter and crown end rafter and then marking off the rafter spacing back towards the corner. In the

Fig. 21.44 Rafter spacing—part plan



process, each pair of creeper rafters diminishes in length, and on the plan each creeper will shorten by a distance equal to the spacing between them.

The true length of the creeper on the centre line is found by projecting its length on the plan up to the vertical section and measuring along the line of the common rafter. Also along this line can be found the difference in the length of the creeper rafters, actually measured along the length of the rafter. This dimension is an important one, and will be used when a pattern rafter is being set out.

The true length of the hip rafter on the centre line is also shown in this drawing.

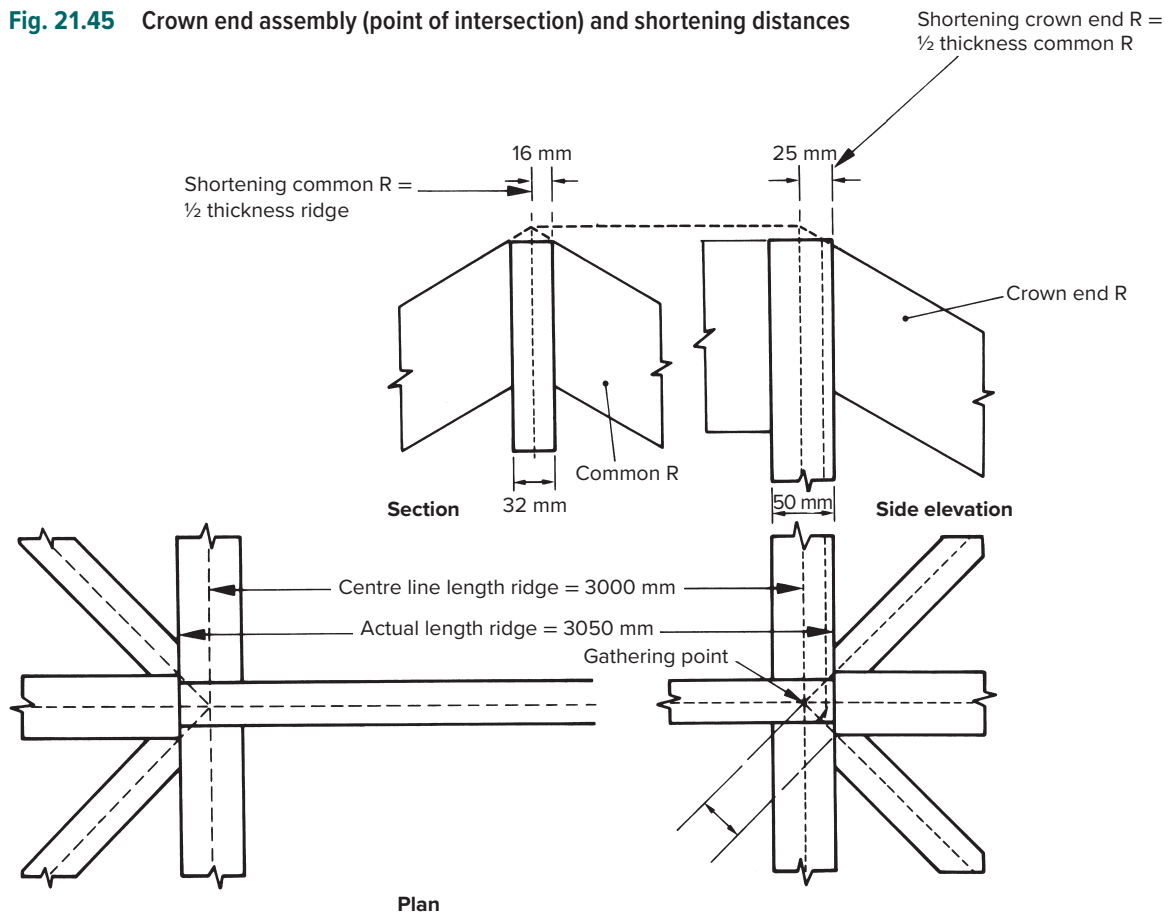
21.12 Develop crown end assembly and shortening distances

The centre lines of the common rafter, crown end rafter and the hips all gather together to meet at a common point at the end of the ridge, which is referred to as the *gathering point*. Figure 21.45 shows the details of the most commonly adopted arrangement of the crown end assembly using a double edge cut on the hip rafter.

The common rafters are shortened by half the thickness of the ridge, similar to the gable roof. The crown end rafter that butts against the end of the ridge is shortened by half the thickness of the common rafter, and if it is shorter than the common rafter, as in this example, it will also be fixed slightly below the top of the ridge.

The plan shows how the hip rafter is shortened by measuring along the hip centre line between the end of the hip rafter to the intersection of the centre lines at the crown. This measurement is then subtracted from the length of the hip rafter, square of the hip plumb cut.

Fig. 21.45 Crown end assembly (point of intersection) and shortening distances



TIP Remember that all of these shortening distances must be measured at right angles to the plumb cut.

CHECK YOUR UNDERSTANDING

8. What is the difference in length between adjacent creeper rafters if they are measured at right angles to the plumb cut?

21.12.1 Length of ridge

Figure 21.45 shows how the centre line length of the ridge is measured between the gathering points at each end of the roof, but it must be extended by half the thickness of the common rafter at each end.

The centre line length can be calculated using our example:

centre line length of ridge

$$\begin{aligned} &= \text{length of roof} - \text{span} \\ &= 8000 \text{ mm} - 5000 \text{ mm} \\ &= 3000 \text{ mm} \end{aligned}$$

actual length of ridge

$$\begin{aligned} &= \text{length of roof} - \text{span} + \text{thickness of the common rafter} \\ &= 8000 \text{ mm} - 5000 \text{ mm} + 50 \text{ mm} \\ &= 3050 \text{ mm} \end{aligned}$$

21.12.2 Setting out wall plates

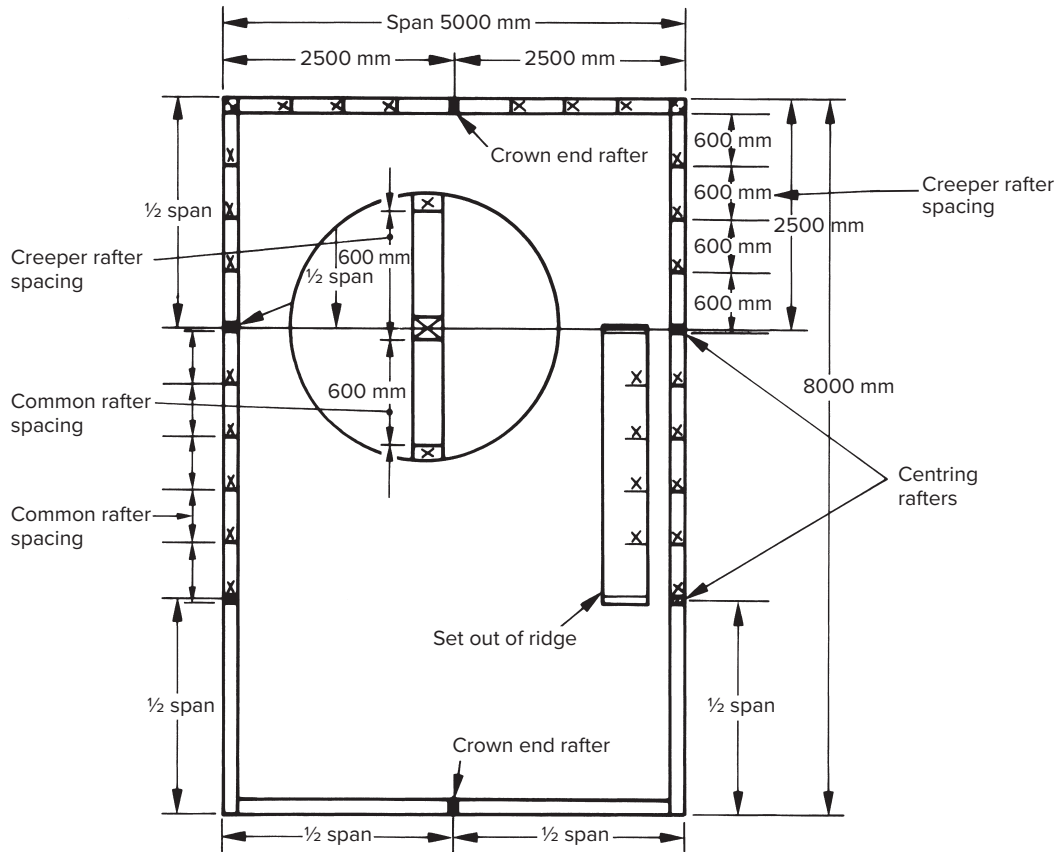
Figure 21.46 illustrates the set-out on the upper surface of the wall plates for the hipped roof. Commence at each corner and measure back a distance equal to half the span, which gives the centre line for the centring and crown end/jack rafters. The location for these rafters is marked in a distinctive way so that they can be easily identified when the roof is erected. A common practice is to mark them with a double line, crossed diagonally, or to write the letter *J* for jack rafter and *C* for centring rafter at these positions.

Starting from the side of these marks, furthest from the corner, mark off the spacings for the creeper rafter using the 'in and over' method. It is sufficient to mark the creeper rafter with a single line and a cross indicating the side of the mark on which the rafter will be placed. Between the centring rafters, mark out the positions for the common rafter, not exceeding the maximum spacing.

It is preferable to mark out the ridge at this time by laying it beside the wall plate and transferring the rafter positions onto the face.

CHECK YOUR UNDERSTANDING

9. How can the length of ridge for the hipped roof be calculated?
10. How could you determine the position of the centring rafters and crown end rafters when setting out for the roof members on the top wall plates?

Fig. 21.46 Wall plate set-out

21.12.3 Length of creeper rafter to long point

From the method previously described, the centre line length of the creeper rafters and their difference in length was obtained, but allowance must now be made for the thickness of the hip to be located between the pairs of creeper rafters.

It is usual to measure the creeper rafter length to the long point. Figure 21.47 illustrates the difference between the length of the creeper rafter on the centre line and the length to its long point. This difference will be referred to as the **long point correction** (LP correction) and may be either added to or subtracted from the centre line length.

The LP correction can be calculated from the formula:

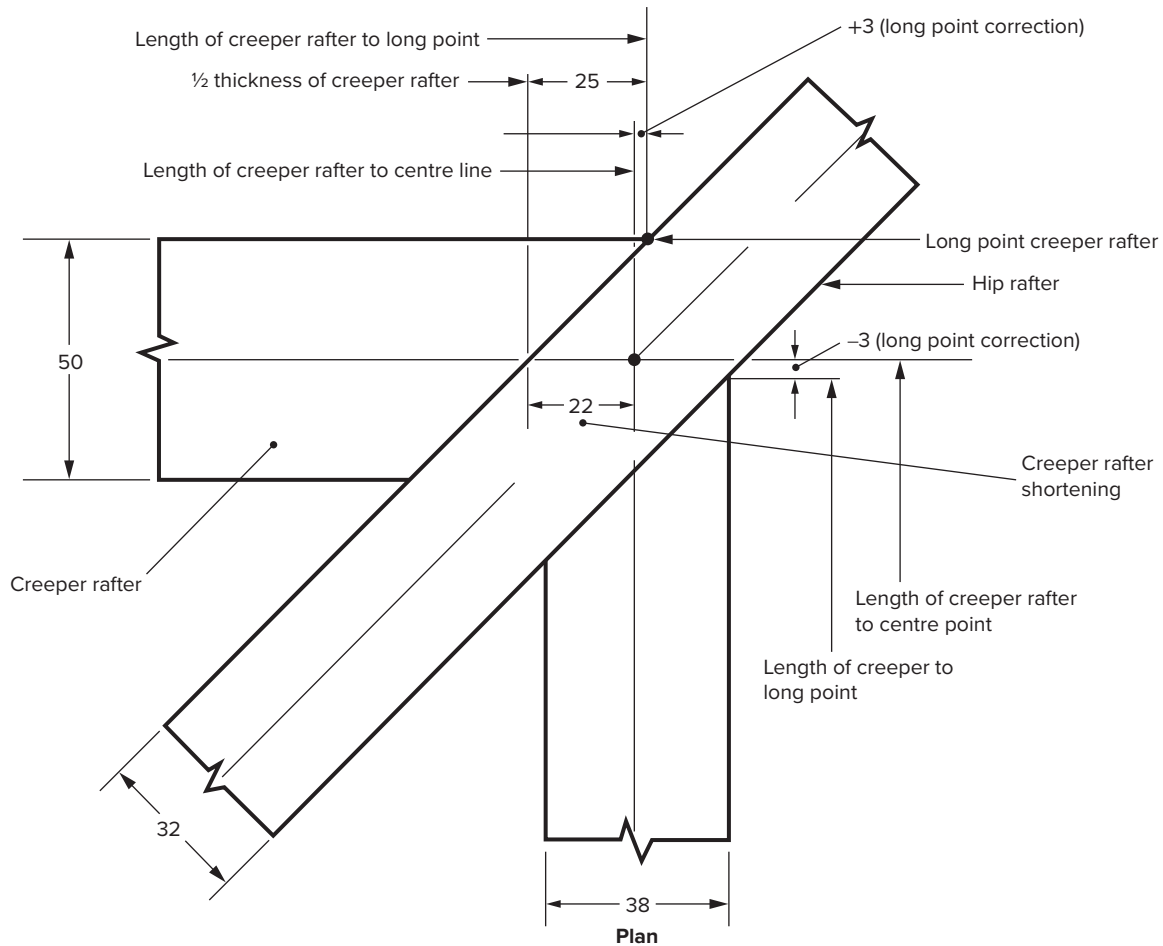
$$\text{LP correction} = - \text{creeper rafter shortening} + \text{half thickness of creeper rafter}$$

then,

$$\begin{aligned} \text{LP correction} &= -22 \text{ mm} + 25 \text{ mm} \\ &= +3 \text{ mm} \end{aligned}$$

It will be quickly observed that, in the majority of cases, the LP correction is a very small amount, and no great error would result if it is assumed that the length to long point is the same as the centre line length. Many of the most self-respecting carpenters agree that they could not cut the creepers any more accurately in any case.

As will be shown later, it is quite a simple matter to make the correction. Always be wary of the unusual situation where a correction may have to be calculated or determined as in Figure 21.47.

Fig. 21.47 Length of creeper rafter to long point

21.13 Cut rafters to length

Nail two short cleats across the back of the rafter and mark out the common rafters in the same manner as for the gable roof. Select two crown end rafters and mark them to length. Creeper rafters must be set out in pairs for each length required by reversing the direction of the edge cut to give rafters of opposite hand (Fig. 21.48a). The most economical use of timber and the minimum amount of cutting will result if the creepers are cut from each length of timber as in Figure 21.48b.

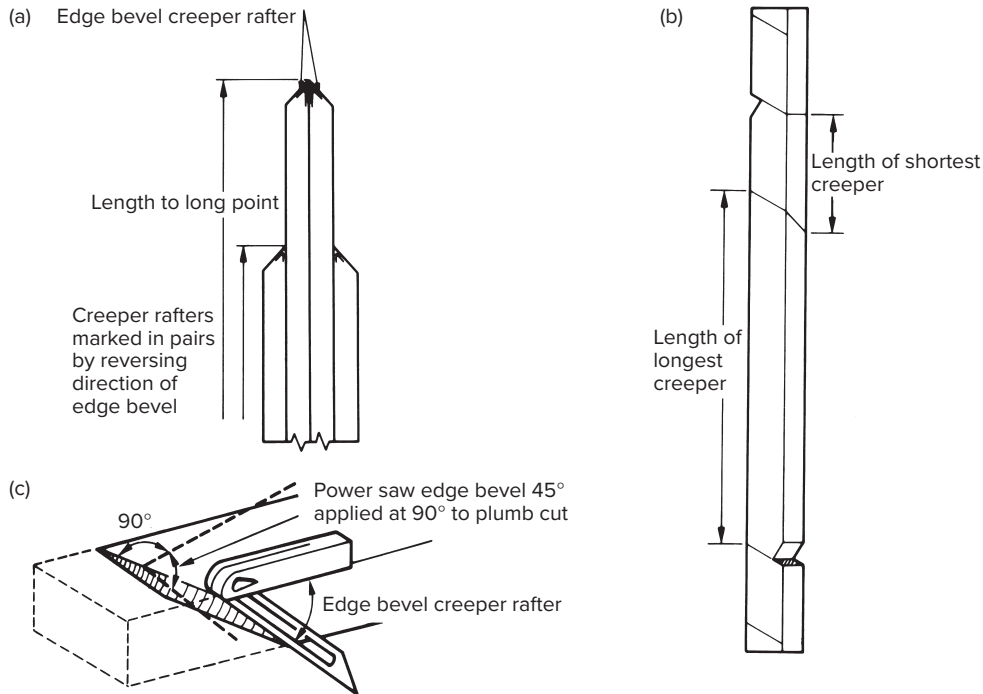
When cutting creeper rafters with a power saw (either a radial arm saw or powered hand saw), the edge bevel for the creeper rafter is formed by tilting the saw blade to 45° . Figure 21.48c shows how the edge bevel developed on the set-out is applied to the square edge of the rafter for cutting with a hand saw.

When a power saw is used, the blade follows the plumb cut; the axis of the blade tilts at right angles to the plumb line, which is the plan angle of the edge bevel or 45° when the roof is rectangular.

CHECK YOUR UNDERSTANDING

11. To which angle would you tilt the base of the powered circular saw to cut the edge bevel of the creeper rafters for a hip roof rectangular on plan?

Fig. 21.48(a)–(c) Cutting of rafter



21.13.1 Development and cutting of hip rafter

Figure 21.49 illustrates how the hip rafter is developed from the single line set-out. To simplify the fitting of the hip at the birdsmouth (Fig. 21.50), the corner of the plates are cut off at 45° for the thickness of the hip rafter.

Theoretically, it is possible to obtain the true length of the hip by scale drawing or calculation, and to deduct the shortening distances. In practice, however, it is much more satisfactory to measure the length of the hip directly from the roof as it is being erected. Use a steel tape and measure between the points *H* and *J* in Figure 21.51. Proceed to set out the hip in Figure 21.52 as follows:

1. From one end of the hip, allow sufficient for the tail, and mark the plumb bevel hip on the face. A practical formula for the tail allowance is shown on the drawing. If necessary, the tail can be cut back to the width of the common rafters.
2. Measure down the plumb line distance *x* and mark off at right angles, giving the horizontal cut for the birdsmouth and establishing point *J*.

Fig. 21.49 Hip rafter—development

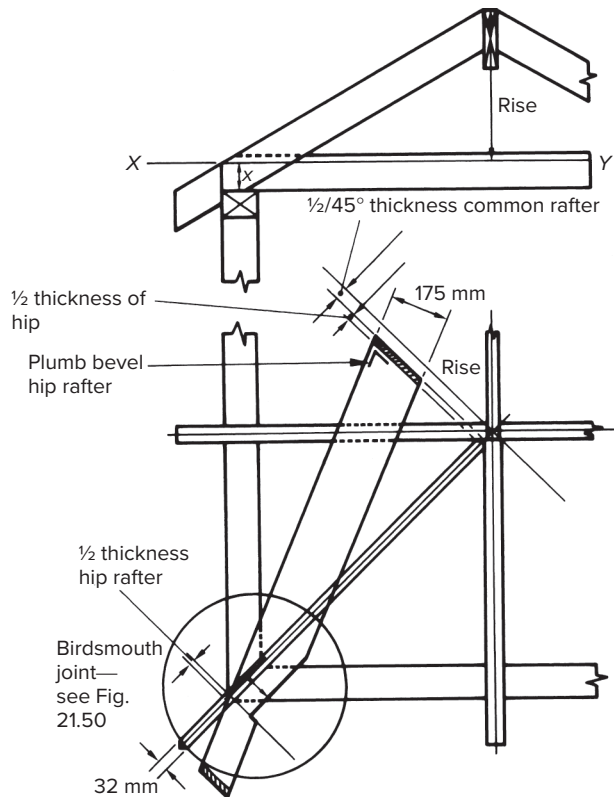
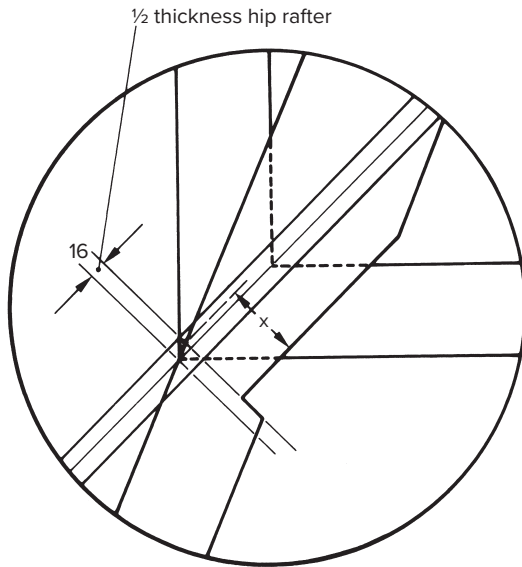
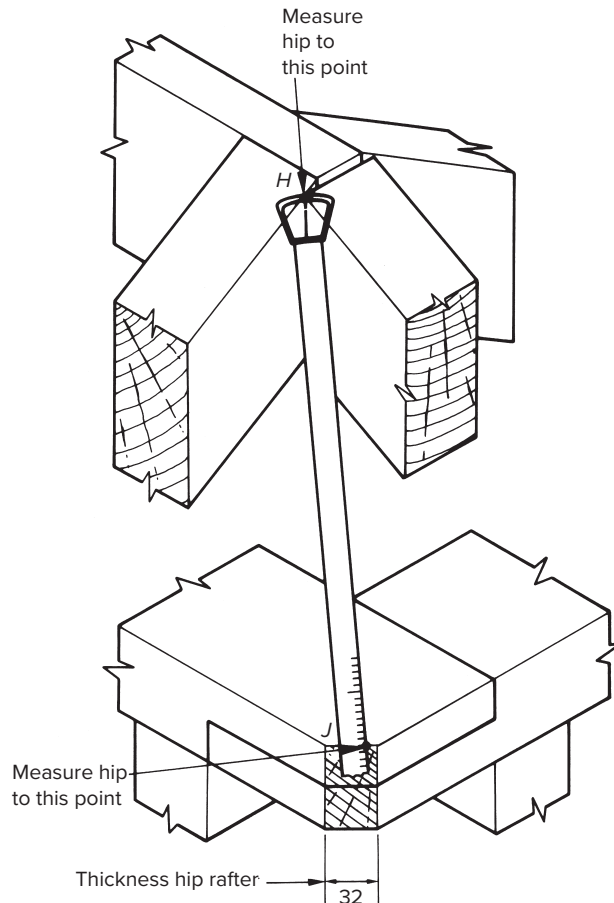
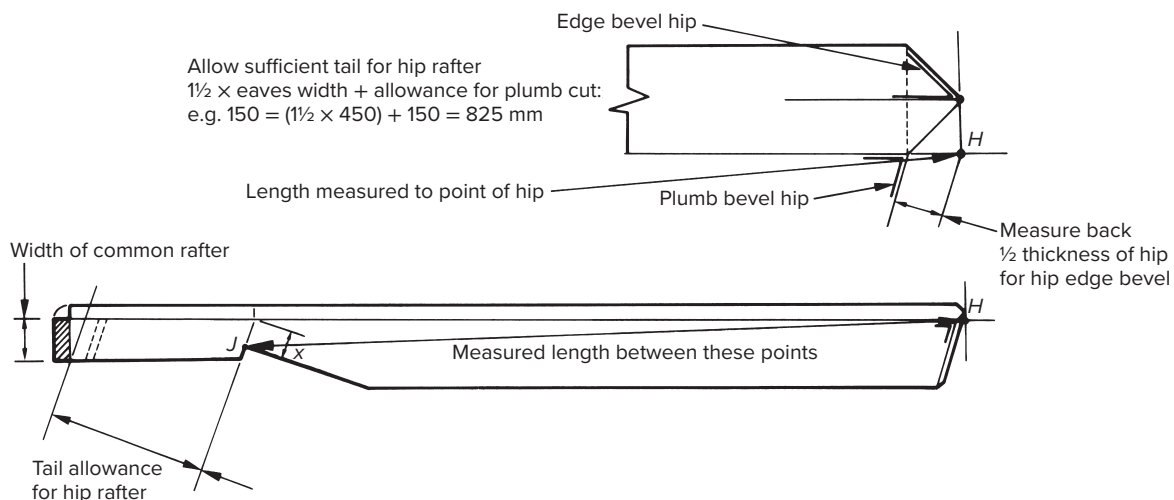


Fig. 21.50 Birdsmouth joint—detail

3. Measure along hip from point *J* to point *H* on the top edge and square across the edge to the centre line. Mark the plumb line for the hip partly across the face.
4. To obtain the hip edge bevel, refer to the method described earlier.

While the development of the hip edge bevel has been shown in earlier figures, in practice it is simpler to mark the hip directly onto the timber as outlined above.

Fig. 21.51 Measuring length of hip rafter with tape**Fig. 21.52** Hip rafter set-out

TIP When cutting the hip edge bevel with a power saw, the correct angle to tilt the saw is 45° , in the same manner as for the creeper rafter (Fig. 21.48c).

CHECK YOUR UNDERSTANDING

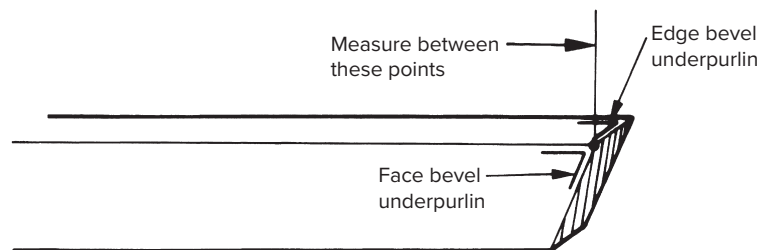
12. How would you mark in the edge bevel when setting out the hip rafter?

21.14 Erect the hipped roof

To erect the hipped roof—or to use the trade term for this operation, *to pitch the hipped roof*—follow these steps:

1. Make preliminary preparations and load the roof in a manner similar to that described for the gable roof.
2. Commence erection with the pairs of centring rafters. Secure these in position and lift the ridge up between the rafters and fix in place.
3. Locate the mark for the crown end/jack rafters and fix these in place by skew nailing them to the wall plates and the end of the ridge.
4. Fix sufficient common rafters in place to keep the ridge in alignment.
5. Hip rafters can now be measured on-site and set out (Fig. 21.51). Cut them to length (Fig. 21.52) and fix in position.
6. Lay out pairs of creeper rafters for each hip and commence fixing. Start with a pair near the centre of the hip and, if they are correctly cut and fixed directly opposite each other, the hip should be straight; however, some carpenters may prefer to erect a string line directly over the centre line of the hip to keep it straight as the creeper rafters are fixed.
7. To fix the underpurlins, locate the top edge of the underpurlin on the underside of the rafters and partly drive a few nails to establish the line. Hold a steel tape along this line and extend it to the point where it strikes the hip at each end. Measure this distance for cutting the underpurlin to length (Fig. 21.53). Apply a face bevel and edge bevel to the underpurlin where it will butt against the hip.
8. Refer to the procedure for fixing underpurlins, strutting, collar ties and any more common rafters to the gable roof and proceed in a similar manner for the hipped roof.

Fig. 21.53 Measured length of underpurlin



WORKPLACE SCENARIO

Chris Nance—owner of Traditional Timber Frames

Pitching roofs or standing up trusses are dangerous activities. Scaffolding and working platforms are necessary to be safe, to give a good footing and eliminate the risk of falling to the ground. However, as I drive around my home town and see new houses being built, I still see carpenters walking on plates, sometimes on the second storey, with no scaffolding or catch platforms installed. They are walking around on a 90 mm-wide plate, working and carrying—one wrong step and they could fall up to 5 m. It's not worth it; the injuries a person could sustain would be numerous and there would be weeks, if not months, of recovery time. It could also be fatal. The cost of installing the scaffolding is a small price to pay for safety, and it's definitely worth waiting for the scaffold to be installed rather than rushing ahead so you can get on to the next job.

CHECK YOUR UNDERSTANDING

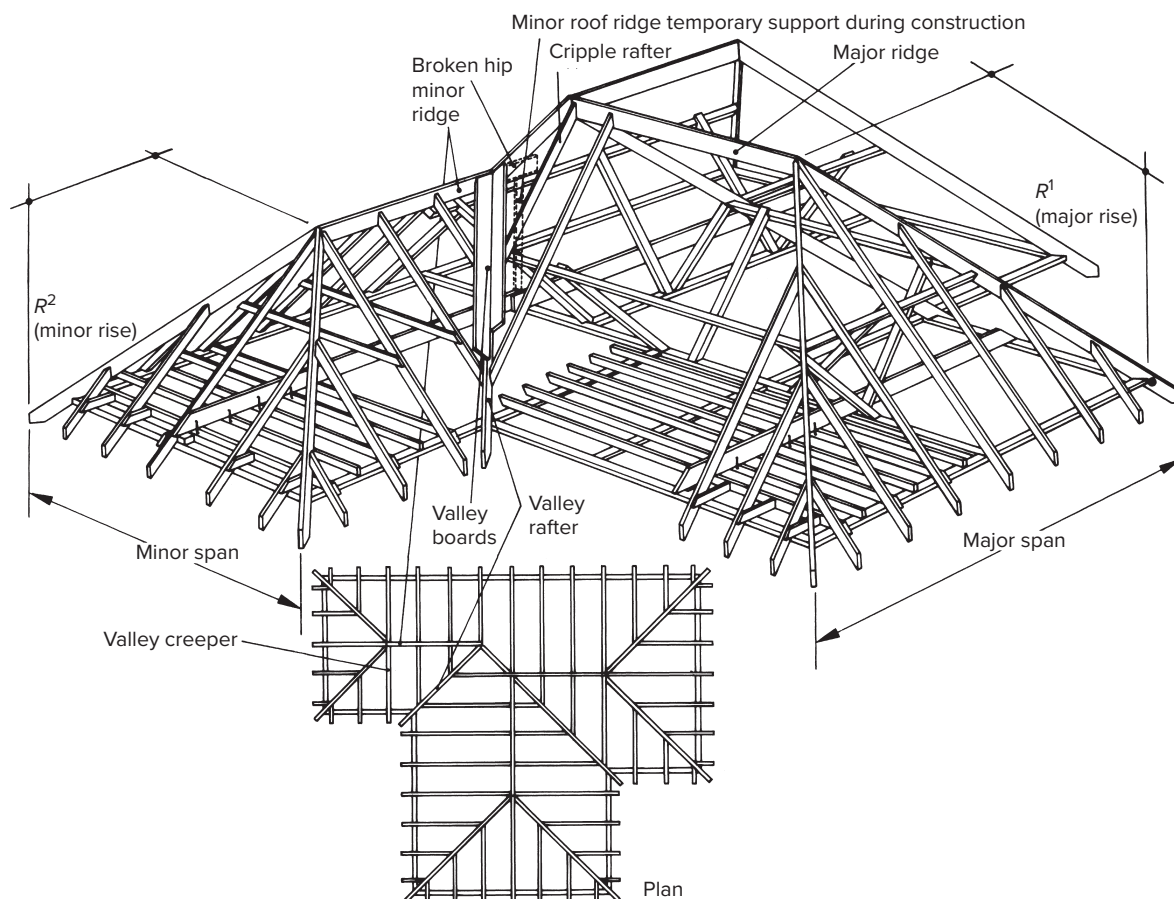
13. Indicate the order in which you would fix the following members when erecting a hipped roof:
- hip rafter
 - crown end rafter
 - centring rafters
 - underpurlins
 - creeper rafters
 - common rafters.

21.15 Identify hip and valley roof components

A valley is formed in a pitched roof wherever an internal angle is found on the roof plan. A typical example of this is shown in Figure 21.54, where offsets are made, projecting off the main roof. The main roof is usually referred to as the *major roof* and contains the *major span* (S^1) and the *major rise* (R^1). There are two offsets in this image, one showing the *minor roof*, which has the *minor span* (S^2) and the *minor rise* (R^2), and this is called a broken hip and valley. The other offset is set at the same pitch as the main roof and is called a hip and valley.

In our example (Fig. 21.55), the major and minor spans are unequal and a new set-out must be prepared for the rafters of the minor roof. But if the pitch of the roof remains the same, with the

Fig. 21.54 General view—hip and valley roof



introduction of the valley, no new bevels need to be developed. Figure 21.55 shows how the roof bevels can be developed for a hip and valley roof. The process for development is the same as described earlier.

21.15.1 Roof members

The new members now found in the roof are the valley rafter, broken hip rafter, valley creepers and cripple rafter.

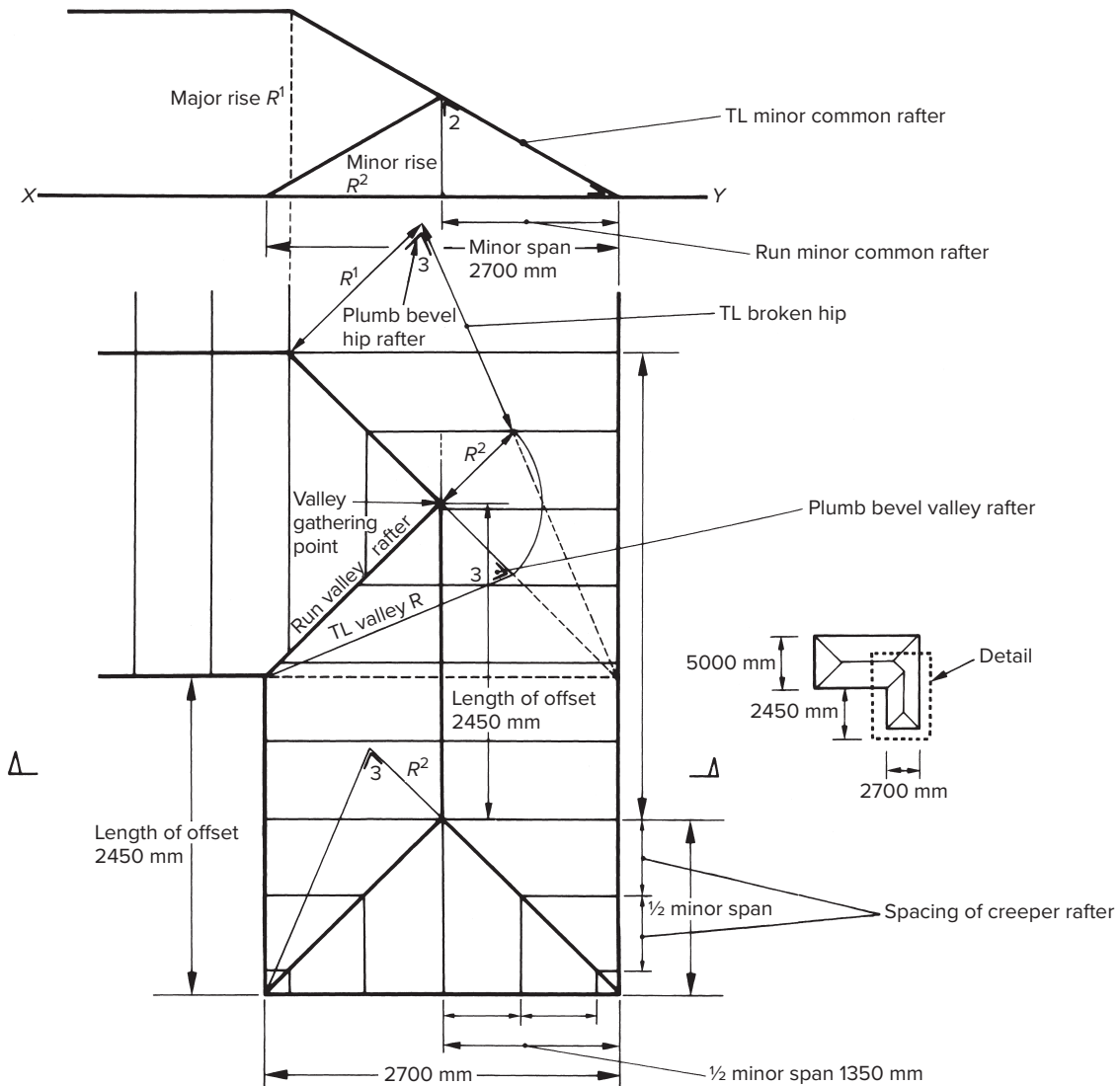
21.15.1.1 Valley rafter

The valley rafter runs from an internal corner to the minor ridge and forms the junction of the sloping roof members. On plan it will bisect the internal corner and has a plumb and edge bevel, which are the same as the plumb and edge bevel hip rafter.

21.15.1.2 Broken hip rafter

This rafter joins the main ridge to the minor ridge and is part of a full hip rafter that would form the corner of the main roof before the offset was added; refer to the dotted lines in Figure 21.55.

Fig. 21.55 Development of hip and valley roof



21.15.1.3 Valley creepers

These are rafters running from a ridge to the valley rafter (Fig. 21.56a) and have the same bevels as other creepers, and, provided the spacing remains constant, the same difference in length.

21.15.1.4 Cripple rafter

The cripple rafter (Fig. 21.56b) runs from the broken hip to the valley rafter (Fig. 21.57), isolating the offset and valley.

Figure 21.57 illustrates the arrangement of the roof members when thickness is added and will be referred to in some of the following explanations.

Fig. 21.56 (a) Valley creeper rafter; and (b) cripple rafter

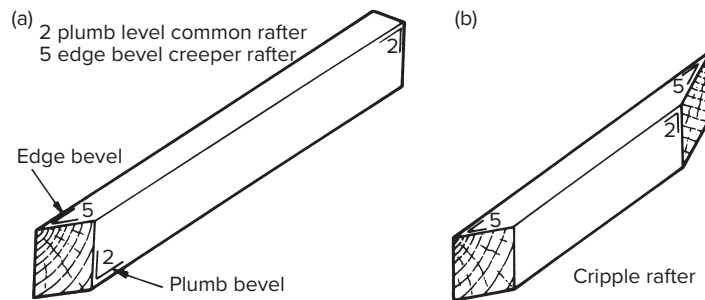
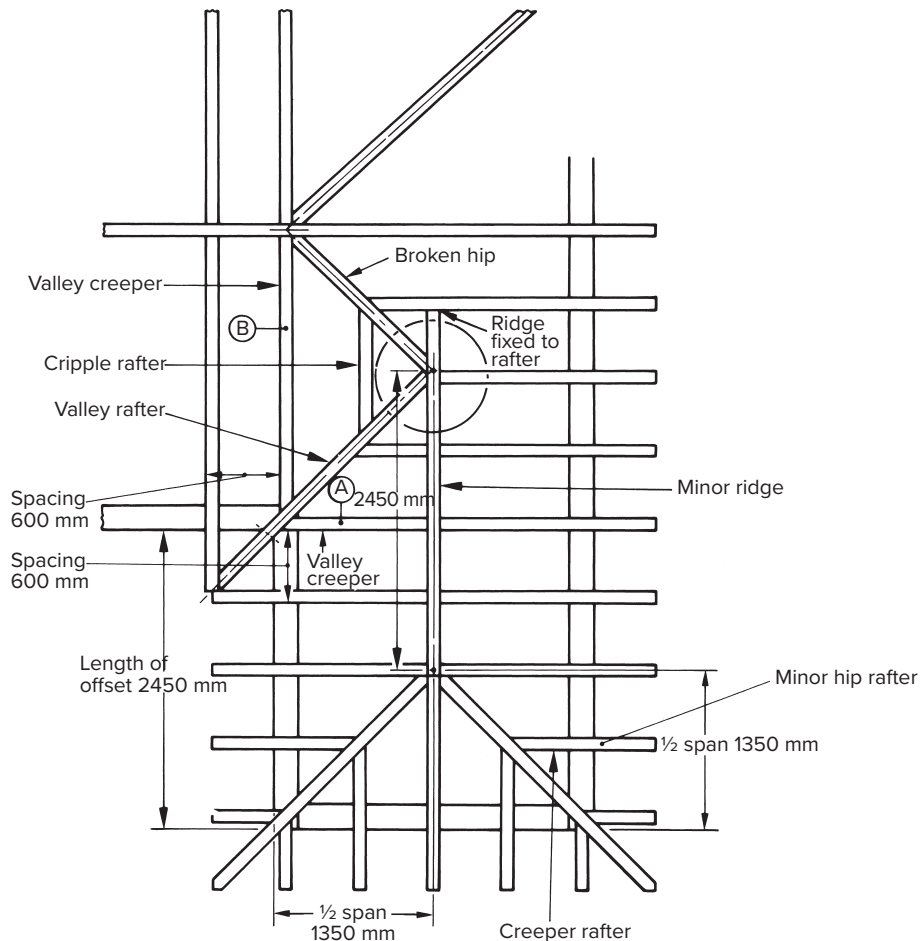


Fig. 21.57 Plan development



21.15.2 Set-out of wall plates

As shown in Figure 21.59, the wall plates are set out in a manner similar to the main roof. Commence with the centring and crown end rafters at the offset end and mark off common rafters back towards the main roof.

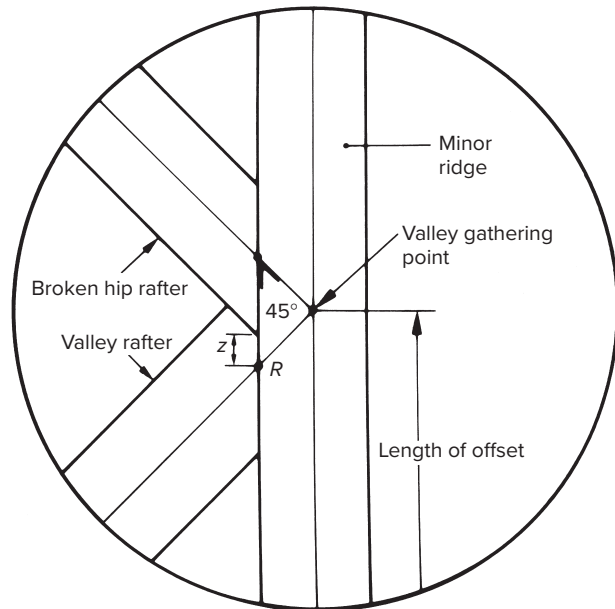
CHECK YOUR UNDERSTANDING

14. Describe briefly the location and function of the following members in the hip and valley roof:
- broken hip
 - cripple rafter
 - valley creeper
 - minor ridge.

21.16 Set out the minor roof

As the wall plates are being set out, it is also an opportune time for setting out the minor ridge. A very strong job will result if this ridge is projected beyond the valley gathering point and fixed to the next rafter (Fig. 21.57). This practice is frequently adopted. Lay the ridge board beside the wall plates and mark the position of the rafters on to the face. The distance from the hip gathering point to the valley gathering point is the same as the length of the offset (Fig. 21.58). Extend the ridge beyond this point to the face of the next rafter in order to determine its length (Fig. 21.59).

Fig. 21.58 Valley gathering point



21.16.1 Setting out the pattern rafter for a hipped roof

Figure 21.60 shows how a pattern rafter for a hip roof is set out. Note that the creeper rafters are drawn on the pattern rafter indicating their length and side cut. For a detailed explanation of how to set out a pattern rafter, refer to the pattern rafter processes described earlier in this chapter.

A pattern rafter can also show the lengths of all the creeper rafters (Fig. 21.61).

Figure 21.62 shows how the creeper rafter lengths are developed for the minor roof. The procedure is as follows:

1. Select a common rafter and set sliding bevels to the plumb bevel for common and creeper rafters and edge bevel creeper rafters.
2. Setting out for the common rafter is a similar procedure to that described for the gable roof (Fig. 21.17), except that the dimensions will be those calculated previously in this chapter.

Fig. 21.59 Wall plate set-out for valley

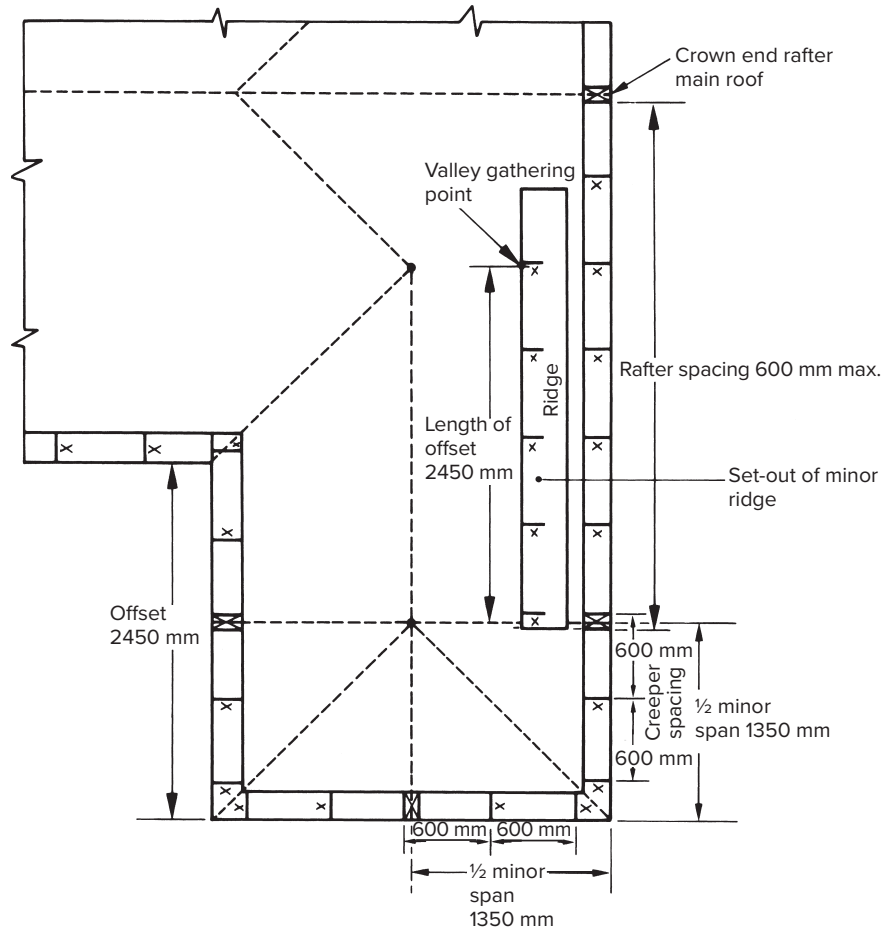
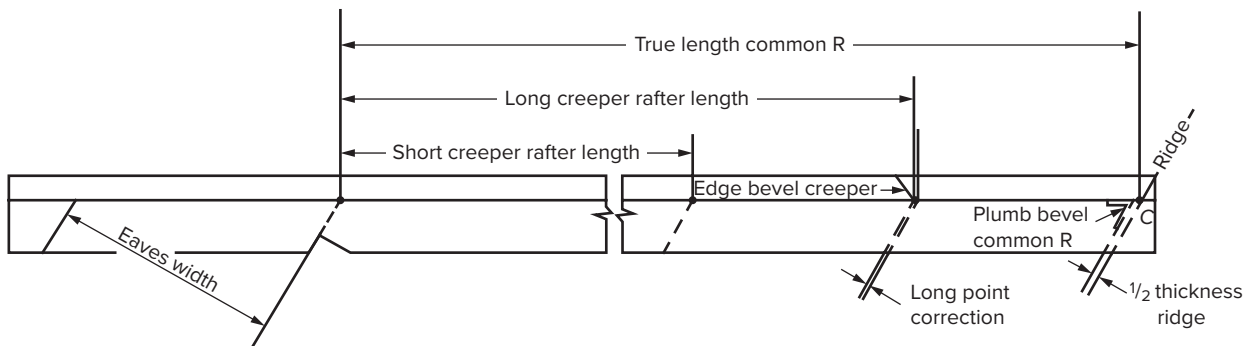
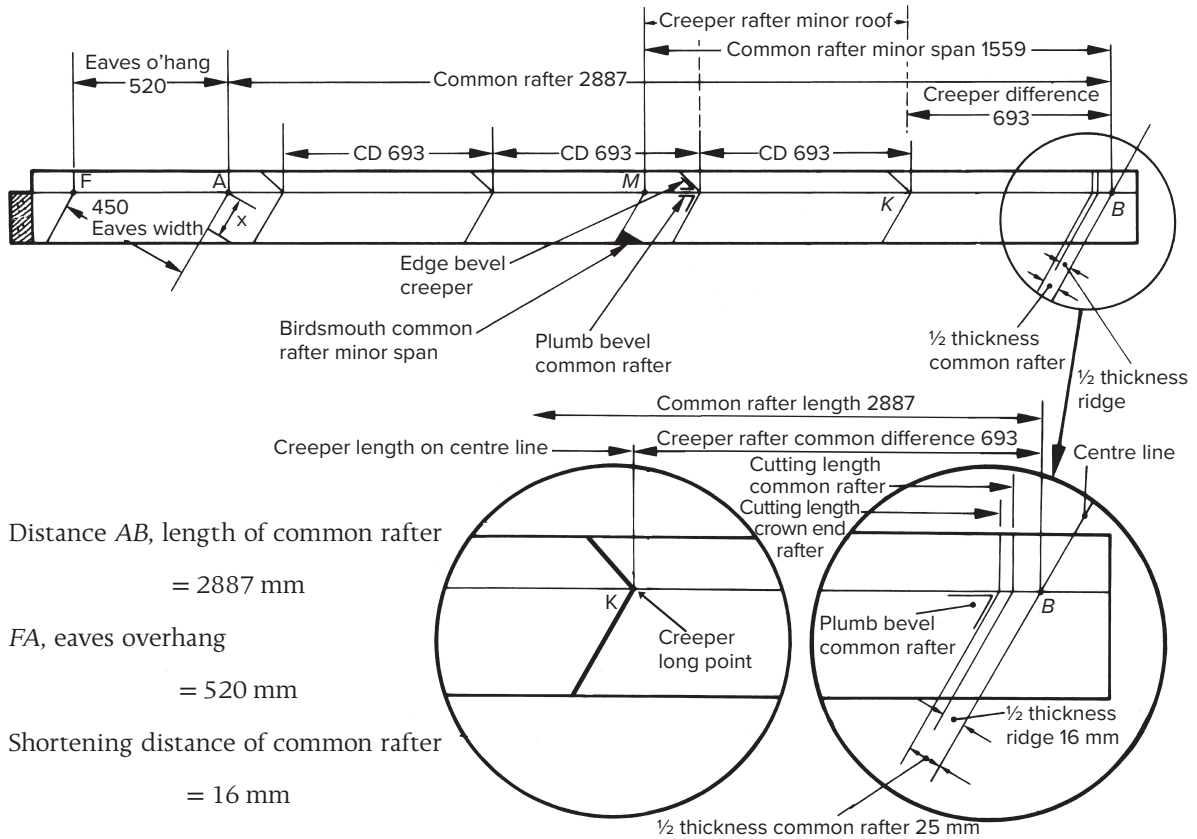


Fig. 21.60 Pattern rafter for hipped roof incorporating creepers



3. From plumb line through point B, again measure off at a right angle half the thickness of the common rafter (25 mm), which gives the length for cutting the crown end rafters.
4. From point B measure along the rafter 693 mm, the difference in length between the creeper rafters, to point K, and lightly draw a plumb line through this point. This establishes the length of

Fig. 21.61 Pattern rafter set-out



the first creeper rafter to the long point. From this point measure back along the rafter the creeper difference (693 mm) to obtain the length of the remaining creeper rafters to their long point.

5. Mark in the edge bevel of the creeper rafters from their long point. Cut out the birdsmouth and cut to length for the common rafter.

This is only one method of constructing a pattern rafter for a hip and valley roof. Alternatively, separate rafters can be constructed for the major and minor roof spans. This method is described earlier in this chapter.

Fig. 21.62 Minor roof triangle

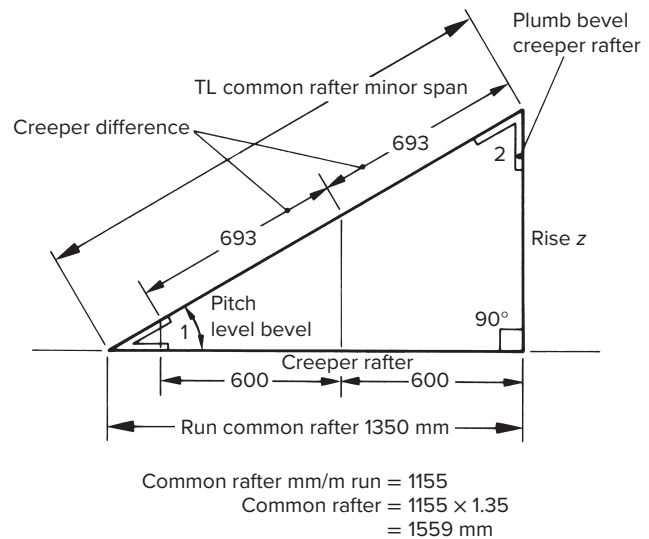
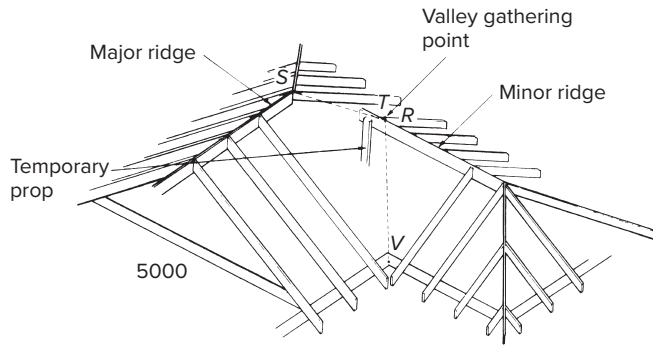


Fig. 21.63 Ready for fixing broken hip and valley

21.16.2 Pitching the hip and valley roof

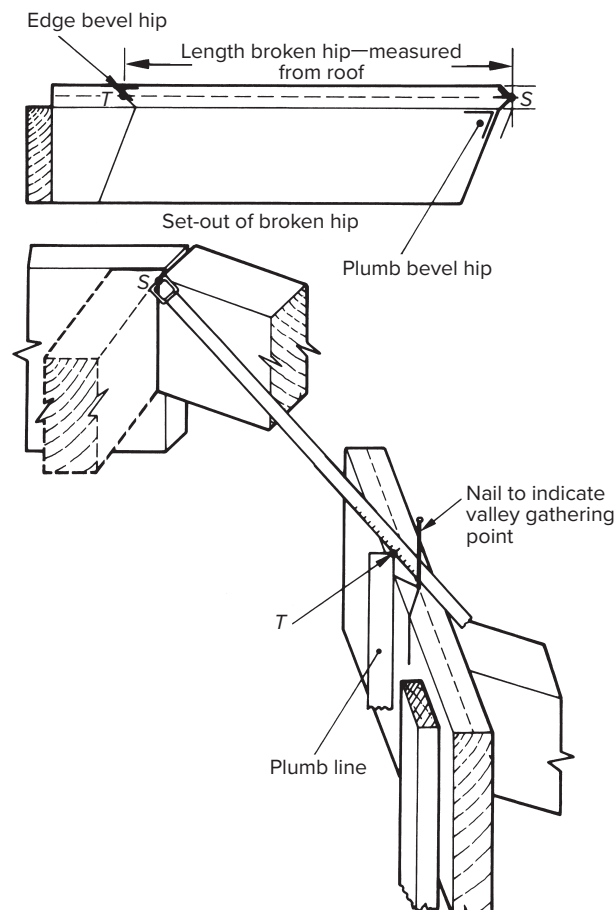
Proceed as previously described to the stage illustrated in Figure 21.63. Using a straight edge, check that the minor ridge will line up with the rafters of the main roof and that it is level. A temporary prop may be necessary for holding it firmly in position.

21.17 Set out valley rafters and creepers

The valley can now be completed as follows.

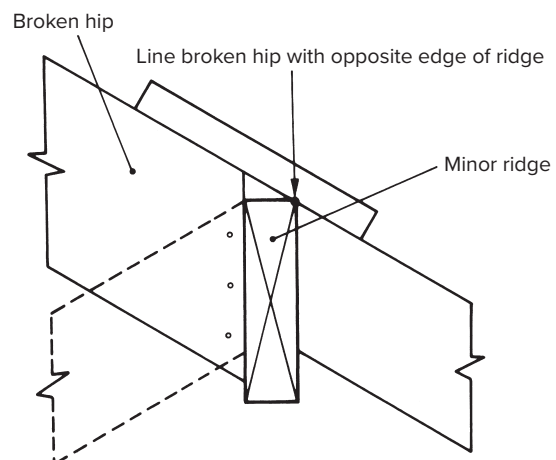
21.17.1 Gathering point

Locate the valley gathering point and partly drive a nail to indicate its position clearly. The centre line of the broken hip and valley must gather at this point.

Fig. 21.64 Measurement of broken hip

21.17.2 Length of broken hip

Use a steel tape to measure the length of the broken hip along its centre line from the major ridge, point S, to a point directly above the centre line where it strikes the face of the minor ridge, point T (Fig. 21.64). Use the edge of a rule to project this point accurately on to the tape. Prepare the broken hip and fix it in position, using a short straight edge to align the top of the hip with the opposite edge of the minor ridge (Fig. 21.65).

Fig. 21.65 Fixing broken hip rafter

21.17.3 Length of valley rafter

Again using the steel tape, measure the length of the valley rafter from point *R* to point *V* (Fig. 21.66) and set out the valley (Fig. 21.67).

The set-out is shown with a tail on the valley rafter, but it is common practice to end the valley rafter at point *V* and to allow any common rafters to be located near the internal corner to run through and support the end of the fascia and the valley boards. From one end of the valley, allow for a tail and mark a plumb line across the face. From the top edge, measure down distance *x* to locate point *V*, giving the line for the horizontal cut of the birdsmouth. Mark back half the thickness of the valley rafter for the vertical cut of the birdsmouth. From point *V*, measure the length of the valley to the top edge and locate *R* on the centre line; mark the valley edge bevel through this point and continue the plumb bevel across the face.

Depending on the thickness of the members, it may be necessary to make a square cut on the end of the valley where it will butt against the broken hip. Refer to Figure 21.58 detail and note the distance *z*. Measure distance *z* on the roof and transfer this distance to the edge of the valley from the centre line in order to give the position for the square cut. After cutting to detail, fix the valley rafter in position.

Fig. 21.66 Valley rafter measurement

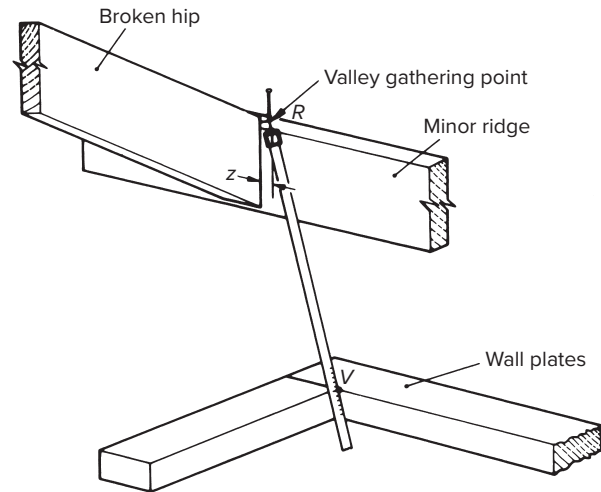
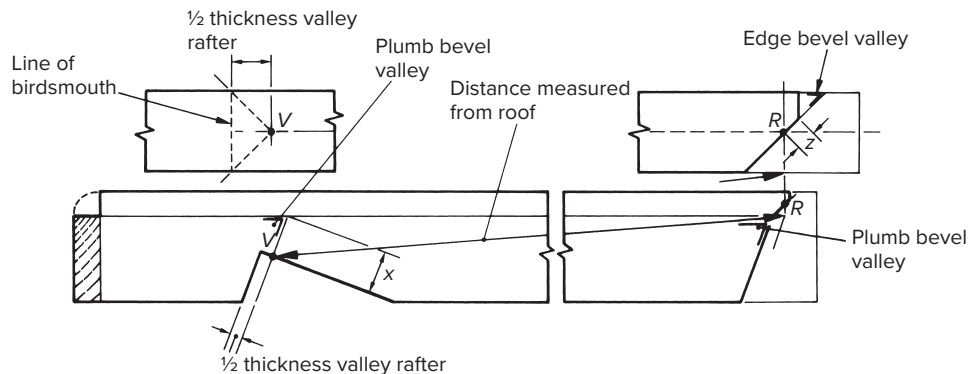


Fig. 21.67 Valley rafter set-out

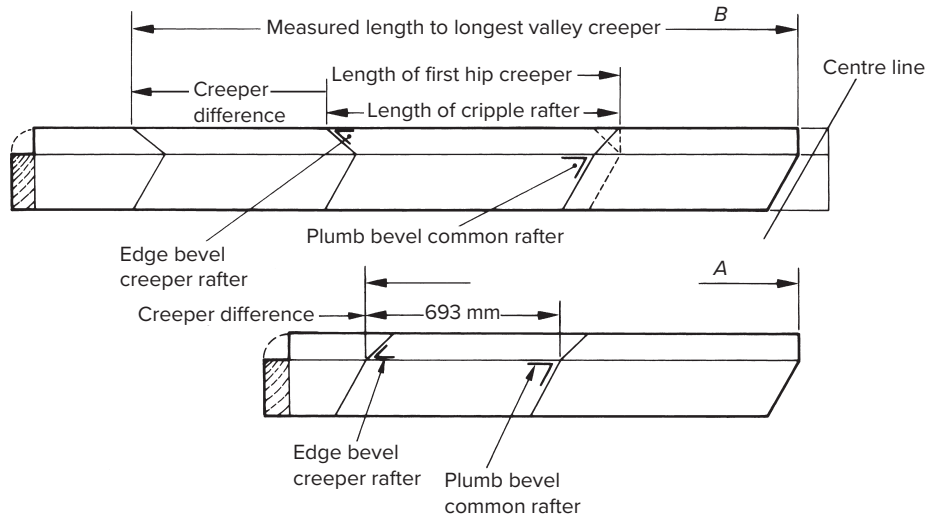
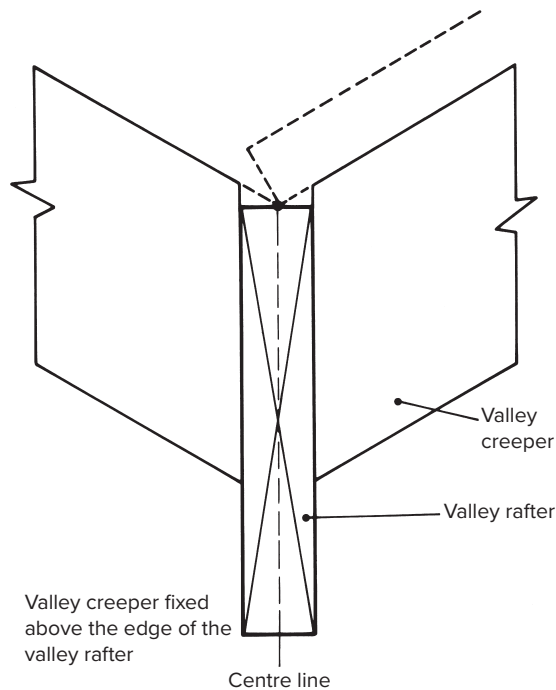


CHECK YOUR UNDERSTANDING

15. In an on-site situation:
 - a. How can the length of the valley creeper be obtained?
 - b. What is the recommended method for obtaining the length of a hip rafter?
 - c. How can the valley gathering point be located in a fully hipped roof? (Refer to the relevant figures if necessary.)

21.17.4 Cutting valley creepers

With the broken hip and valley now in position, the valley creepers can be cut and fixed. Provided the spacing remains the same, the difference in the length of the valley creepers is the same as for the hip creepers—indicated as *A* and *B* in Figure 21.68—and the practical way to find the lengths of the first valley

Fig. 21.68 Valley creepers set-out**Fig. 21.69** Fixing of valley creeper rafters

creepers—indicated as A and B in Figure 21.57—is to mark the rafter spacing from the last common rafter to the long point of the creeper. Using the steel tape, measure from the ridge to this point.

Other creepers will then shorten in length by the creeper difference and the cripple rafters will be shortened by twice the creeper difference. Valley creepers are fixed above the edge of the valley rafter. Use a short straight edge, and the top of the creepers should strike the valley on its centre line (see Fig. 21.69).

21.17.5 Finishing the hip and valley frame

Proceed to fix any outstanding common or creeper rafters and continue with underpurlins and strutting as previously described. The eaves overhang is marked and cut to length prior to fixing the fascia board. Valley boards are fixed to support the valley gutter and the roof is now ready for the roof plumber. Refer to Figure 21.54.

CHECK YOUR UNDERSTANDING

- Using AS 1684, what size of timber member would you need for a single span rafter 3.4 m long of stress-grade MGP12 with a metal roof and collar ties installed?

21.18 Construct a scotch valley roof

The scotch valley roof is commonly used in the construction of additions to an existing dwelling. The beauty of this type of roof is that it can be constructed without disturbing the existing structure. Only the eaves of the existing roof need to be removed to allow the construction of the scotch valley.

Essentially, the new roof is built over the existing roof, and once completed and clad, there is no difference in appearance between a scotch valley roof and a conventional hip and valley roof with a broken hip (described earlier in this chapter).

Figure 21.70 is a diagram of an existing house with a hip roof where an addition is to be built. Notice the dotted line where the existing wall plate is. The plate will remain as it is required to support the existing rafters.

Generally, the new roof will be the same pitch as the existing roof, so the existing roof with the larger span will become the major span roof and the new addition with the smaller span will become the minor span roof.

To calculate the rafter length and roof bevels, follow the processes described earlier in this chapter.

1. Once the minor span rafter has been calculated, the position of the new minor span ridge can be determined. Place the minor span rafter next to the two rafters that will sit on either side of the centre of the new ridge and mark the end of the minor span rafter (Fig. 21.71). This mark locates where a trimmer that will support the new minor span ridge will be situated.

Assuming the minor span roof has a gable end, calculate the ridge length using the following calculation:

$$\text{extension length} + \text{ridge overhang at gable} + \text{distance between the existing wall plate and the ridge trimmer for the new minor span ridge} = \text{ridge length.}$$

Mark out the rafter positions on the ridge and the top plates, using the same method as described earlier. Remember, it is good practice to mark the plates first and then lay the ridge next to the plate and transfer the marks. Install the trimmer to support the new ridge. Then cut a second minor span rafter and the new ridge can be installed (Fig. 21.72).

TIP You will notice the rafter tails of the major span roof have been removed.

Fig. 21.70 Existing house with planned addition

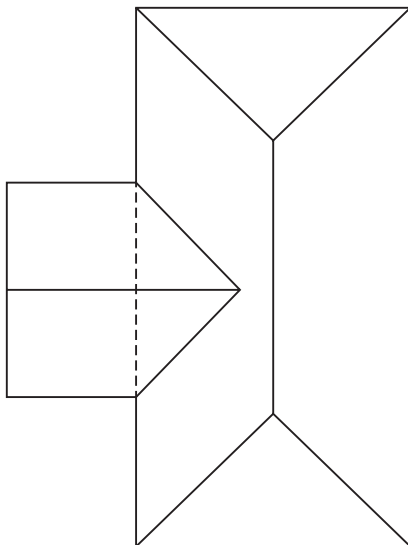


Fig. 21.71 Marking the end of the new minor span rafter

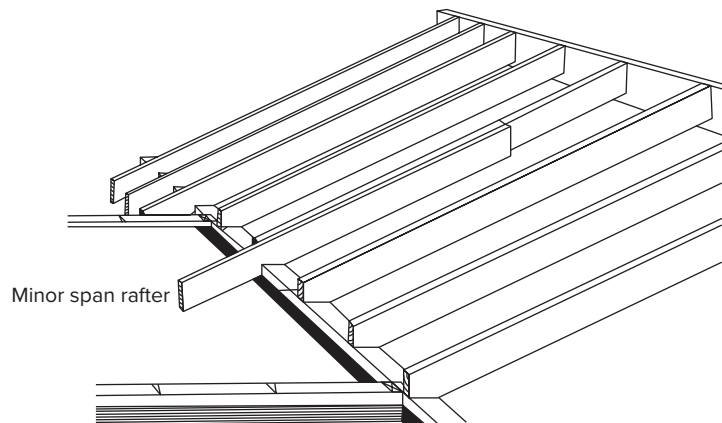
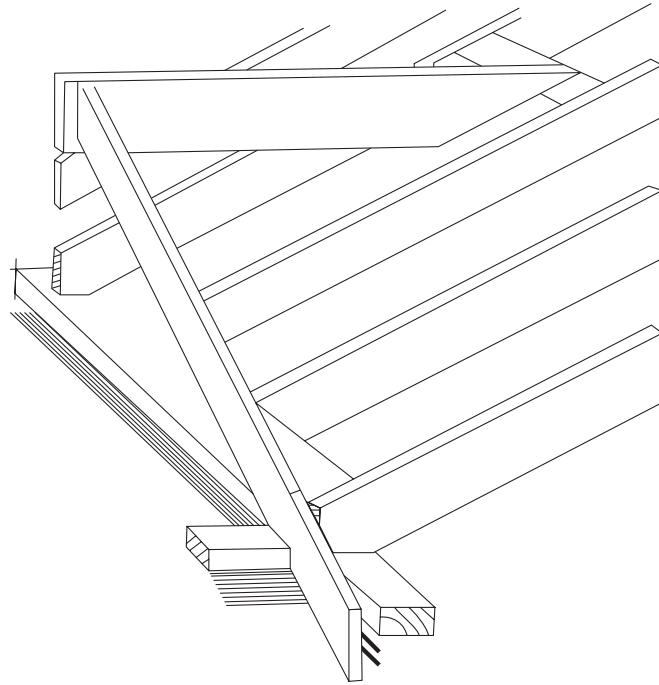
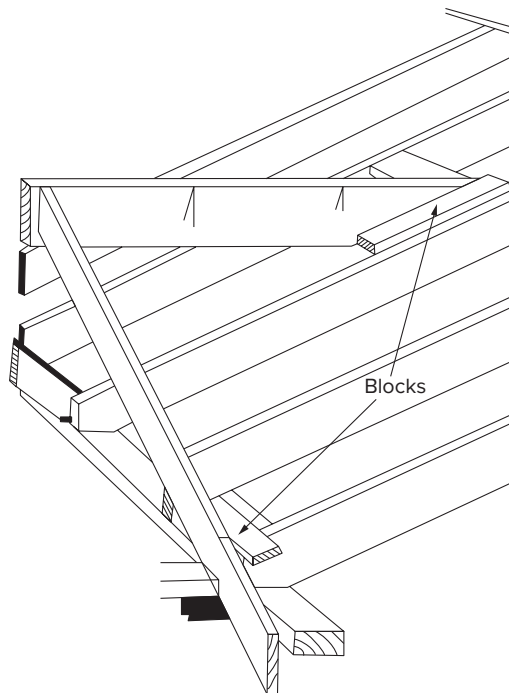


Fig. 21.72 Installing the new ridge

2. Now the position of the sleeper can be found using a gauge block, of the same thickness as the sleeper; to locate its position, where the gauge block intersects with the leading edge of the ridge and the common rafter, mark this point and square the line across (Fig. 21.73).

Now the position of the sleeper has been found, run a string line between these two points (Fig. 21.74).

Fig. 21.73 Finding the sleeper position with a gauge block

3. The string line will allow a bevel to be set for the top face angle of the sleeper. The edge cut you see will be square. When finding the bevel angle, ensure that the bevel is lying in the same plane as that in which the sleeper will eventually be.

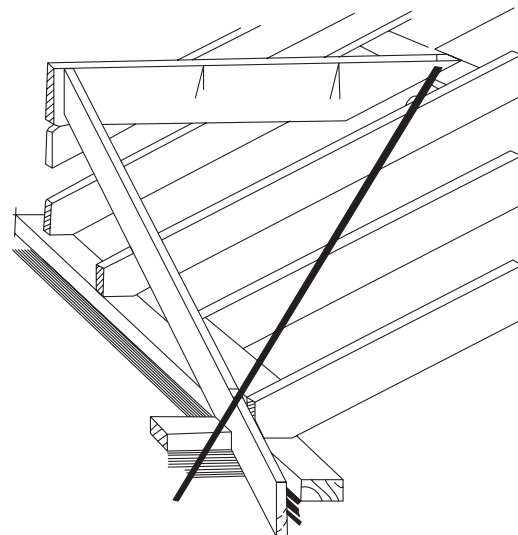
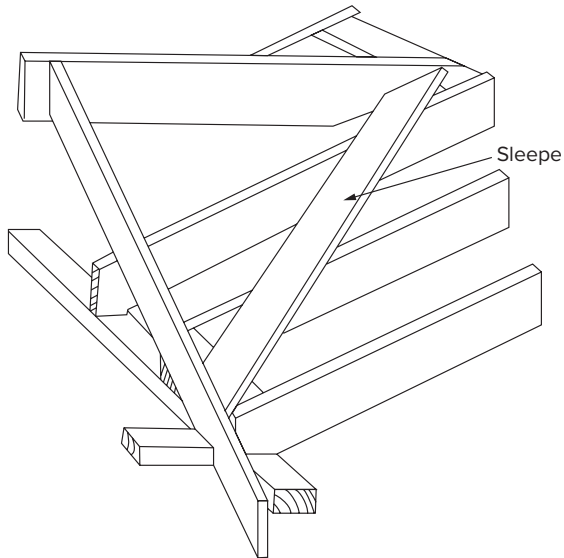
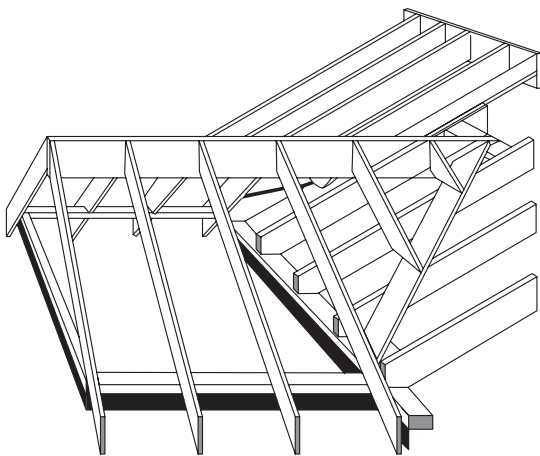
Fig. 21.74 String line along the sleeper position

Fig. 21.75 Sleeper installed**Fig. 21.76** Finished roof

4. The bottom cut of the sleeper can now be found. The face bevel can be found in the same way as the top cut by sliding the bevel. The edge bevel is found by using an offcut of the sleeper material, laying it next to the string line and scribing the angle off the common rafter using a block of timber or a 4-fold rule. Now measure the length of the sleeper and install it (Fig. 21.75).
5. Mark the position of the creeper rafters on the sleeper by measuring square of the common rafter; once done, the length of the creepers can be found by measuring from the top of the ridge to the outside edge of the sleeper.
6. The plumb cut and foot cut for the creeper rafters are the same as the common rafter. The edge cut on the foot of the creeper is the same as the creeper side cut used on the creeper rafters connecting to the hip.
7. Install the remaining creeper and common rafters and the roof is built (Fig. 21.76).

21.19 Identify fixings, ties-downs and other materials

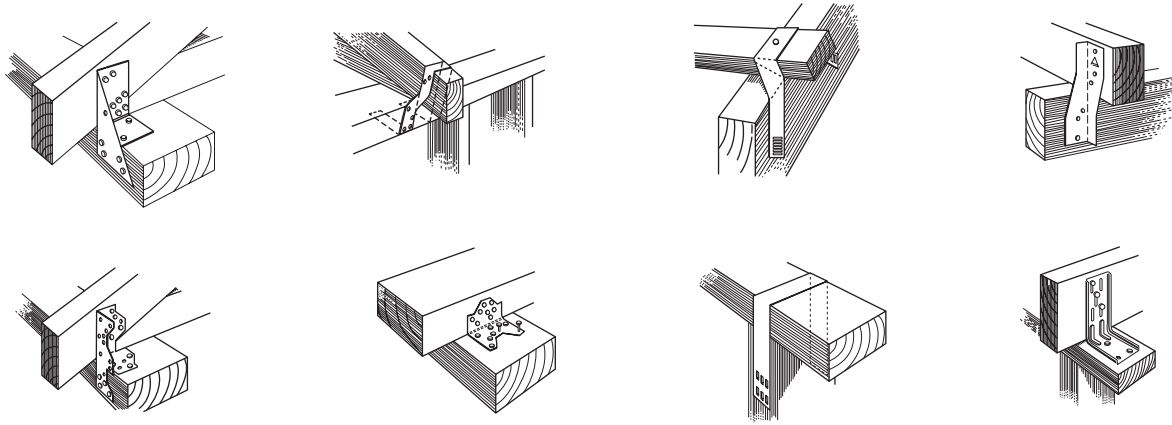
21.19.1 Fixings and tie-downs

When constructing a roof, the fixings used and the manner in which they are used are crucial to the overall strength of the roof and the entire building.

Fixings include bolts, screws and nails. There are specific requirements for the types of fixings used in most situations; these requirements will cover the length, type, amount and spacings for each joint, junction and application. Further details about fixings can be found in Chapter 9, Construction fastenings and adhesives.

Tie-downs are another aspect of roof framing that must be installed when building a house roof. Tie-downs do exactly what the name suggests: they tie down separate framing components to each other, ultimately tying the entire structure down to the foundation (see Fig. 21.77 for examples of tie downs and framing brackets). This is very important in stopping a building from blowing over or being lifted up and blown away. Tie-down requirements can vary depending on the area in which the house is built and the specific environmental conditions the structure will experience. Likewise, the design of the structure will also influence the tie-down requirements. For example, a house with a low pitch or flat roof will be more susceptible to uplift and the roof being blown off the structure than a roof that has a high pitch.

Fixing and tie-down requirements for timber framing are found in AS 1684, Residential timber-framed construction.

Fig. 21.77 Tie downs and framing brackets

21.19.2 Alternative materials to traditional timber roof framing

Besides milled timber, roof structures can be constructed from other materials, including:

- manufactured timber products such as laminated veneer lumbar (LVL), glued laminated timber (glulam), etc.
- light- or heavy-gauge steel.

As these are man-made products, AS 1684 cannot be used to calculate the allowable spans and sizes. In many cases, these products have a superior strength and fewer defects than sawn and kiln-dried timber. When these alternative products are used to build a roof, the manufacturer's specified span tables must be consulted during the design process. Additionally, for light-gauge steel, the National Association of Steel-House Framing (NASH) Standards would be used.

Many of these products can be manufactured for a specific project, which would require a consulting engineer to ensure the product will be able to meet the loading and spanning requirements for that particular application.

Student research

Research the different types of roofing apps available and see if you can use them.

End-of-chapter activity

Ask your teacher for a half span and pitch of a roof you will be required to build in class. Develop the roof by drawing it to as large a scale as possible and construct a pattern rafter that you will use for the roof construction.

AUSTRALIAN BUILDING CODES AND STANDARDS



AS 1684–2010
Residential
timber-framed
construction

National
Construction
Code (NCC)

National
Association
of Steel-House
Framing (NASH)
Standards

Tradie talk—Sighting the rafter for bow

Chapter 22

Advanced roofing

Learning Objectives

- LO 22.1 Understand the hipped roof with oblique end (skew end)**
- LO 22.2 Set out wall plates**
- LO 22.3 Obtain roof bevels**
- LO 22.4 Calculate rafter lengths**
- LO 22.5 Perform calculations**
- LO 22.6 Develop the ridge bevel, rafter shortening, level difference and side cuts**
- LO 22.7 Obtain underpurlin bevels**
- LO 22.8 Understand the hipped roof of unequal pitch**
- LO 22.9 Do a graphic set-out**
- LO 22.10 Erect an unequally pitched roof**
- LO 22.11 Understand the octagonal end roof**
- LO 22.12 Set out an octagonal roof**
- LO 22.13 Develop level shortenings/difference for an octagonal roof**
- LO 22.14 Develop side cuts**
- LO 22.15 Pitch the roof and creeper rafters for an octagonal end roof**
- LO 22.16 Understand roofs constructed with multiple pitches**

Introduction

This chapter covers roof design and construction methods of advanced roofing. The roofs covered in this chapter are skew end, unequal pitched and octagonal end. This chapter is an extension of Chapter 21, Pitched roofing, the basic roofing chapter. You should review that chapter first before proceeding with this chapter. The types of roofs covered in this chapter are of a more complex nature; however, all of the underpinning knowledge and techniques are transferable. These roofs will test your skills and knowledge and reinforce your previous learning.

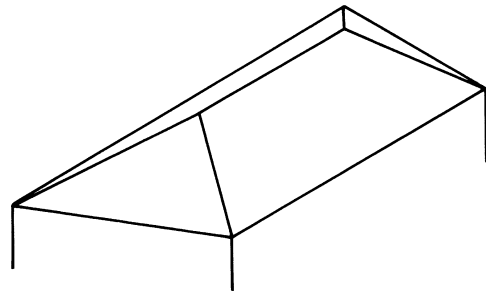
This chapter covers roofing theory using both mathematical and practical methods. Drawing is an important part of the process of constructing these roofs, so care and accuracy must be taken when preparing any drawings. This chapter shows simple and commonly used methods for undertaking advanced roofing.

TIP It is important to take your time when drawing and calculating the roof members as a simple mistake can make the construction of these roofs difficult.

22.1 Understand the hipped roof with oblique end

Figure 22.1 illustrates a hipped roof, equally pitched, with an oblique end. As the remainder of the roof has been dealt with previously, only the oblique end will be described in this chapter.

Fig. 22.1 Hipped roof with oblique end



22.2 Set out wall plates

Refer to Figure 22.2 and note the following points:

1. The amount by which the oblique end is splayed will be called the *offset*; if the roof is rectangular at its other end, this will be the difference in length between the two sides.
2. The distance across the oblique end is the hypotenuse of the right-angled triangle ABH ; if not already indicated on the plans, it can be measured directly off the job once the wall plates are in position, or it can be calculated from the following formula:

$$\text{end} = \sqrt{\text{span}^2 + \text{offset}^2}$$

3. As the roof is equally pitched, the hips AC and BC will bisect the corners and meet at C . The centring rafters are then CF and CE .
4. Rafters on the plan are always at right angles to the wall plate that supports them. Therefore, CG will become the crown end rafter and one centre line will be the same length as the centring rafters.
5. It can be shown that the angle between the hips, $\angle ACB$, is a right angle; if a semicircle is drawn on the end with centre D and the radius equal to half the end, it will join points A , C and B .
6. Any triangle drawn within a semicircle with the hypotenuse corresponding to the diameter of the circle and with the third point on the circumference will be a right-angled triangle. Therefore, the distance CD is also equal to half the end, and Bf and Hj will each be equal to half the offset. From

this information, the position of the centre lines for the centring rafters and the crown end rafter can be determined from the following formula:

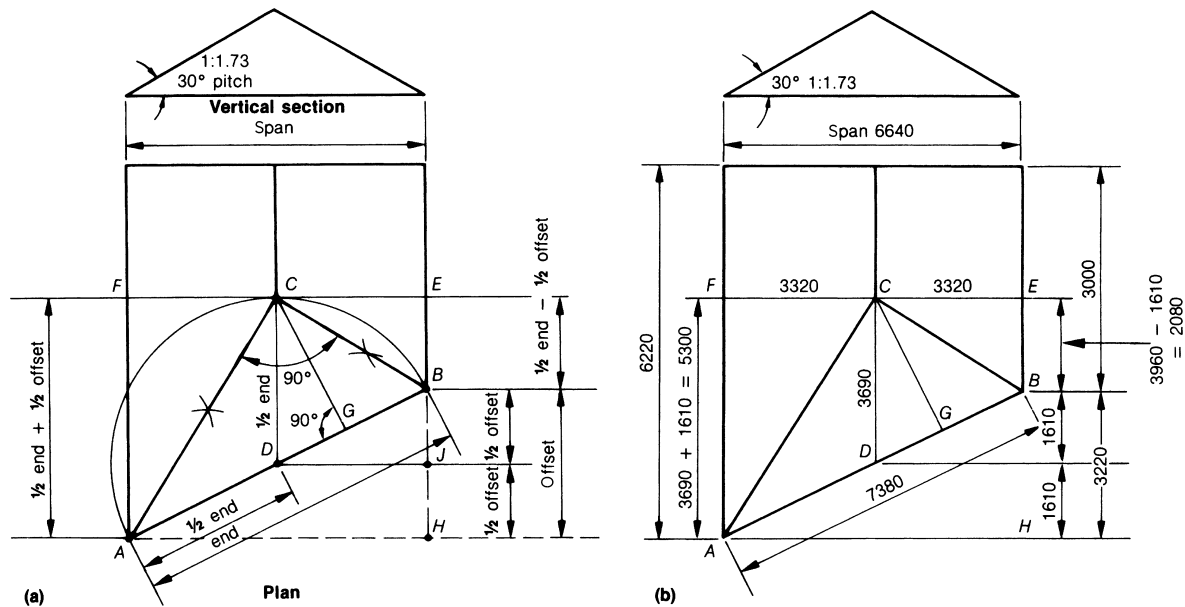
$$AF \text{ and } AG = \frac{1}{2} \text{ end} + \frac{1}{2} \text{ offset}$$

$$BE \text{ and } BG = \frac{1}{2} \text{ end} - \frac{1}{2} \text{ offset}$$

If sufficient information is given, these distances can be calculated and, in practice, can be applied to the roof when setting out the position of rafters on the wall plates.

Note: the following brief specification will be used as an example in further calculations (Fig. 22.2b).

Fig. 22.2 (a) Set-out of an oblique end; (b) an example



Key information from Fig. 22.2:

rafters = 100 mm × 50 mm
 hips and ridge = 175 mm × 32 mm
 rafters spacing = 600 mm
 span = 6640 mm
 $\frac{1}{2}$ span = 3320 mm
 pitch = 30°
 long side = 6220 mm
 short side = 3000 mm
 $\therefore$ offset = 3220 mm
 $\frac{1}{2}$ offset = 1610 mm

$$\text{end} = \sqrt{6640^2 + 3220^2}$$

$$= \sqrt{6.64^2 + 3.22^2}$$

$$= 7.38 \text{ m}$$

$$= 7380 \text{ mm}$$

$$\therefore \frac{1}{2} \text{ end} = 3690 \text{ mm}$$

$$\therefore AF \text{ and } AG = 3690 + 1610$$

$$= 5300 \text{ mm}$$
 and $BE \text{ and } BG = 3690 - 1610$

$$= 2080$$

From these figures, mark the position of the centre lines of the centring and crown end rafters and indicate them in a distinctive way. From these marks, using the 'in and over' method, set out the creeper rafters at their maximum spacing towards corners *A* and *B*.

22.3 Obtain roof bevels

To obtain the necessary bevels to cut the oblique end roof, set out a single-line drawing to a suitable scale, including the plan and the vertical section as shown in Figure 22.3; the accompanying table of roof bevels (Table 22.1) must also be drawn up.

Table 22.1 Roof bevels

No.	Bevel
1	Level bevel common rafter, creeper rafter and crown end rafter
2	Plumb bevel common rafter, creeper rafter and crown end rafter
Bevels hip A	
3	Plumb bevel hip rafter
Bevels hip B	
4	Plumb bevel hip rafter

TIP Set out the majority of roofs to a scale of 1:10 on a sheet of plywood or MDF.

The roof is equally pitched; therefore, the level bevel and plumb bevel must be the same for all common rafters. These are the only bevels that are common throughout the whole roof and can be taken directly from the vertical section. The crown end rafter will now also require an edge bevel. Beyond this point, a separate set of bevels must be developed for each hip (hip *A* and hip *B*) and the creeper rafters for hip *A* and hip *B*.

22.4 Calculate rafter lengths

Details relevant to the length of rafters have been indicated on a separate scale drawing (Fig. 22.4), for the sake of clarity. With practice, sufficient information can be taken from a single drawing.

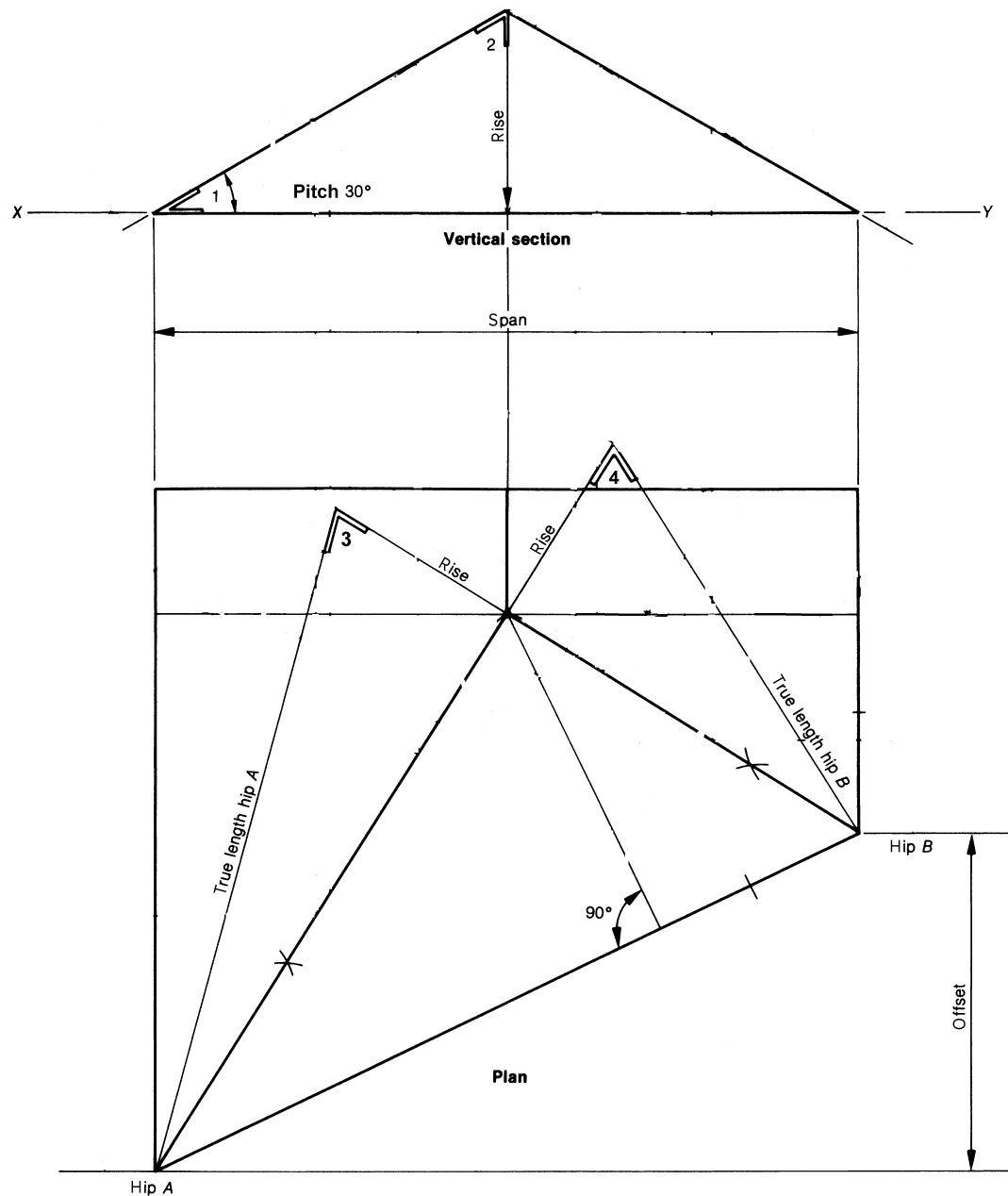
The true length of the common rafter is measured directly from the vertical section at the appropriate scale and converted to the full-size dimension.

Creeper rafters are indicated on the plan set out at their maximum spacing; their true length on the centre line is then found by projecting the plan length up to the vertical section onto the common rafter.

In practice, only enough of the creeper rafter needs be projected up to the vertical section to obtain the necessary information to set out a pattern rafter. This can be done in a number of ways:

- From the birdsmouth, mark off the length of the shortest creeper and divide the remainder of the rafter into as many parts as there are creeper spacings—in this example, eight in the case of hip *A* and three for hip *B*.

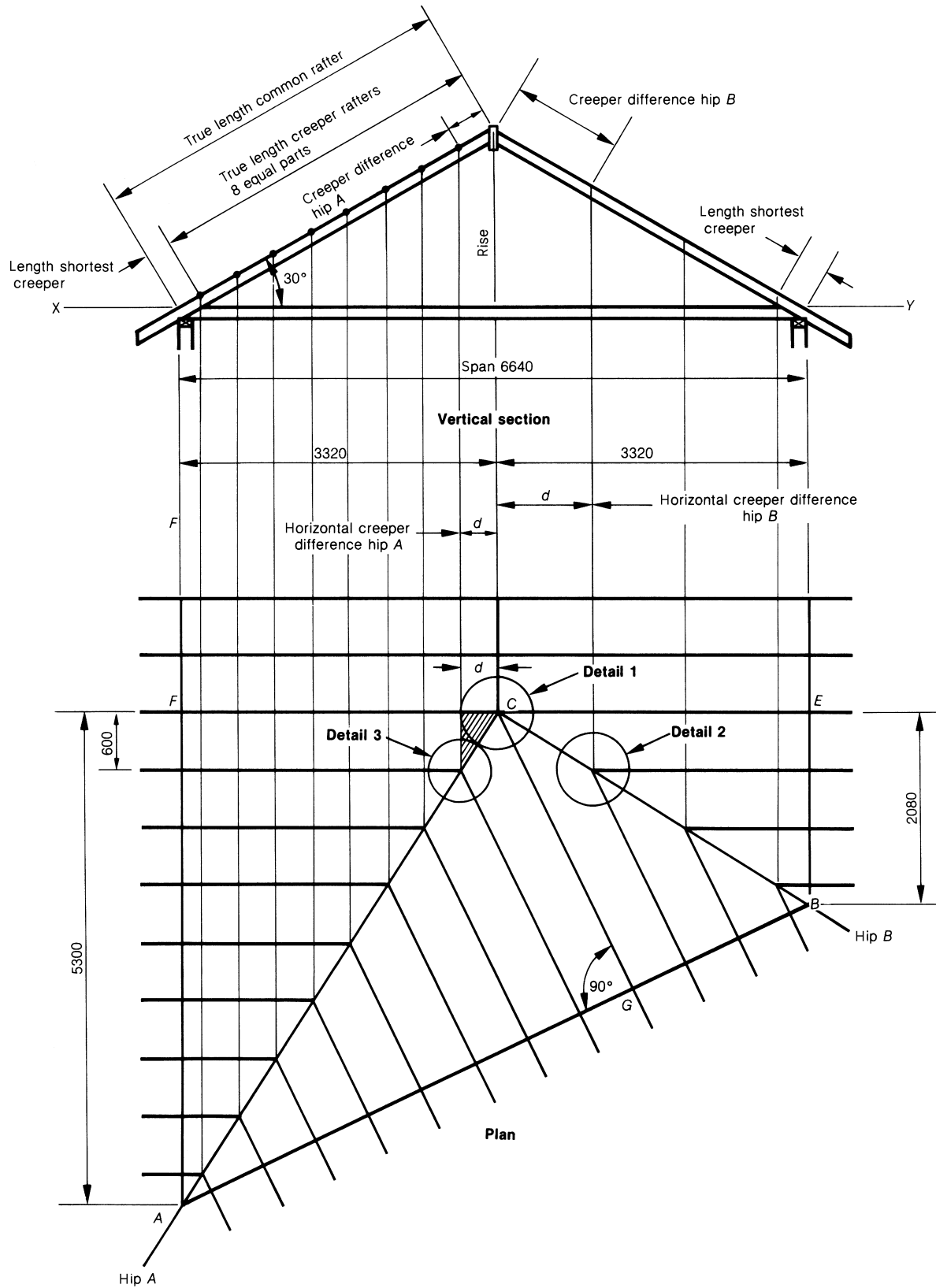
Fig. 22.3 Roof bevels



- Obtain the creeper difference by measuring the length along the common rafter between any two adjacent creeper rafters.
- Obtain the horizontal difference in the length of creeper rafters. This can be found by measuring from the scale drawing or, more accurately, by using the calculations as described later.

The true length of the hip rafters can be measured from the development of bevels and may be useful in obtaining an order length. However, in practice, it is more satisfactory to measure the length of hips directly from the job and set them out as described previously, using bevels developed from hip A or hip B.

Fig. 22.4 Rafter length



22.5 Perform calculations

Much of the information necessary for the setting out of a pattern rafter can be obtained from the following calculations.

22.5.1 Length of common rafter

Refer to Table 22.1 in Chapter 21, which gives the length of common rafter per metre of run.

The following is a calculation using the example in Figures 22.3 and 22.4:

Pitch angle (°)	Pitch ratio	Common rafter mm/m run
30	1:1.73	1155

$$\begin{aligned}
 \therefore \text{length of common rafter} &= \text{length mm/m run} \times \text{run in metres} \\
 &= 1155 \times 3.32 \\
 &= 3835 \text{ mm}
 \end{aligned}$$

22.5.2 Horizontal creeper difference

The horizontal difference in the length of creepers can be calculated from a simple ratio.

For hip A, take the triangle *AFC* in Figure 22.4. The sides *FC* and *AF* are in the ratio 3320:5300. Take also the similar shaded triangle at corner C, where the horizontal difference in the length of creepers is indicated as *d*. Then we have:

$$\begin{aligned}
 d:600 &= 3320:5300 \\
 \therefore d/600 &= 3320/5300 \\
 d &= 3320 \times 600/5300 \\
 &= 376 \text{ mm}
 \end{aligned}$$

Therefore, the horizontal creeper difference is 376 mm.

22.5.3 True creeper difference

For hip A, the true distance between the length of creeper rafters is:

$$\begin{aligned}
 &\text{common rafter mm/m run} \times \text{run in metres} \\
 &= 1155 \times 0.376 \\
 &= 434 \text{ mm}
 \end{aligned}$$

For hip B, take the triangle *BEC*. Then we have:

$$\begin{aligned}
 d:600 &= 3320:2080 \\
 d &= 600 \times 3320/2080 \\
 &= 958 \text{ mm}
 \end{aligned}$$

Therefore, the horizontal creeper difference is 958 mm.

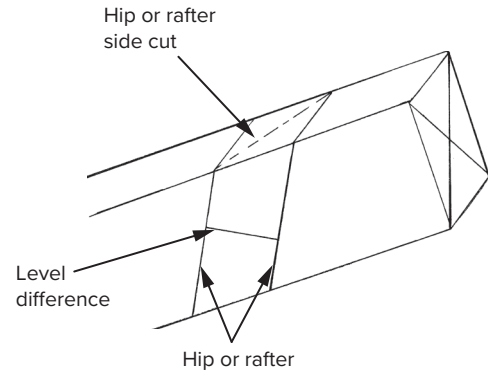
For hip B:

$$\begin{aligned}
 \text{true creeper difference} &= 1155 \times 0.958 \\
 &= 1106 \text{ mm}
 \end{aligned}$$

22.6 Develop the ridge bevel, rafter shortening, level difference and side cuts

Figure 22.7 shows the detail of the encircled parts of Figure 22.4. The thickness has been added to the members and the crown end assembly has been arranged with a single edge cut on the hips. The common rafters must be shortened by half the thickness of the ridge and the crown end rafter/jack rafter by the level shortening measurement indicated. Detail 1 indicates the angle at which the end of the ridge needs to be cut to accommodate the jack rafter. Figure 22.7 shows how the level difference distances are calculated; these measurements are required so the side cuts for the hips and creeper rafters can be worked out. Figure 22.5 shows how the level difference measurements are applied and the hip and creeper side cuts are obtained.

Fig. 22.5 Developing hip and rafter side cuts



TIP When applying the level difference, hold the rule at 90° to the plumb cut (Fig. 22.5).

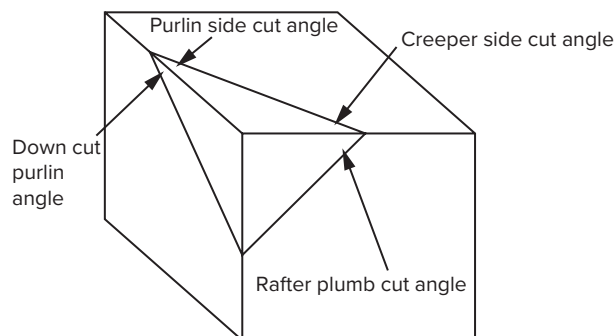
22.7 Obtain underpurlin bevels

Figure 22.6 indicates how the underpurlin side and down cuts can be obtained. Use the known rafter plumb and side cuts and apply them to a block of timber as shown in Figure 22.6.

CHECK YOUR UNDERSTANDING

1. Explain why the distance from the acute angle corner of the oblique end to the centring rafter is equal to half the end plus half the offset.

Fig. 22.6 Developing underpurlin side and down cuts



22.8 Understand the hipped roof of unequal pitch

The construction of a hipped roof where the surfaces are of unequal pitch introduces a number of problems. The length of the common rafters will vary with the pitch and can place some limitations on the type of roof covering that can be used. For example, courses of roof tiles will not meet up at the unequally pitched hip unless the lap can be varied sufficiently to accommodate the change.

If the unequally pitched roof were to have no overhang, many of the problems would be eliminated. However, if an overhang is added, and if a level fascia line is to be maintained, as is most probable, then either the eaves width must be varied, or if the eaves width is to remain equal, the height of the wall plates must be varied. The second solution seems to be the one most likely to be adopted, and the following description of the unequally pitched roof will be based on this assumption.

Figure 22.8 is a set-out for a roof, rectangular in plan and unequally pitched; the surfaces are pitched at 1:1.73 (30°) and 1:1.19 (40°). To avoid confusion on the drawing, only information relating to the unequal pitch is shown. The parts are not necessarily drawn to scale. To distinguish between the roof members of surfaces of different pitch, all surfaces pitched at 30° are distinguished by an (A) and all surfaces pitched at 40° are distinguished by a (B).

Fig. 22.7 Rafter shortening distances

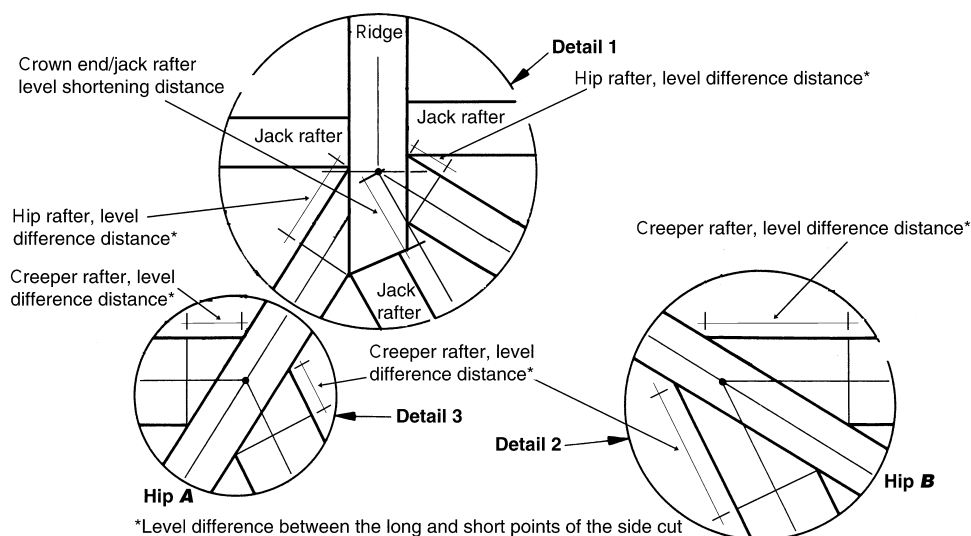


Table 22.2 Roof bevels

No.	Bevel
Surface A	
1	Level bevel common rafter, 1:1.73 (30°)
2	Plumb bevel common rafter
3	Plumb bevel hip A to B
Surface B	
4	Level bevel common rafter, 1:1.19 (40°)
5	Plumb bevel common rafter

TIP One side and the end are equally pitched at 40° and the junction of these surfaces will be the same as described in the pitched roof chapter with Chapter 21.

22.9 Do a graphic set-out

The length of rafters and the necessary bevels, together with other details, can be obtained from a graphic set-out drawn to a scale of at least 1:10; for some of the information, full-size details will give a more accurate result. A sheet of plywood makes an excellent drawing board and should accommodate the dimensions of most roofs.

To draw the set-out, refer to Figure 22.8 and work through the following steps:

1. Note that the XY line has been moved down to the eaves line, which is to remain level throughout the roof. It is important that the new position of the XY line and the reason for the change be understood. Along the XY line, mark off the distance from A to C, which is equal to the span plus twice the eaves width. From A, set off the roof pitch 1:1.73 (30°) and from C set off the pitch 1:1.19 (40°); these meet at point B. The vertical height from the XY line to B is then the total rise of the roof. From A and C, measure the eaves width in along the XY line and square up to the rafter; establish points E and D. Note the difference in height between E and D. From the set-out so far, the following information is obtainable:
 - AB = total length common rafter (A)
 - AE = eaves overhang (A)
 - BC = total length common rafter (B)
 - DC = eaves overhang (B).
2. From the vertical section, project down and draw, in single lines, enough of the plan to indicate the line of the hips. As the surfaces indicated by (B) are equally pitched, the hip will bisect the corner at 45°. However, the remaining hip forming the junction between surfaces A and B must be drawn in by joining the corner of the roof at the eaves line to the gathering point. For convenience, it will be referred to as the *unequally pitched hip*. Note that when this hip is drawn in, the point where it meets the plate moves away from the corner of the walls. This distance can be scaled from the drawing, or perhaps more accurately determined by measuring from full-size details as shown later. From the gathering point, set off at right angles a distance equal to the total rise; join back to the corner to obtain the plumb bevel hip (no. 3 in Table 22.2) and its total length from which an order length can be obtained.
3. Commence from the crown end and centring rafters, and mark on the plan the centre line of the creeper rafters at their specified spacing. Note that they will not meet opposite each other along the unequally pitched hip. The true lengths of creepers to surface A are found by projecting the plan length up to the vertical section and measuring their lengths along the common rafter. The lengths of creepers to surface B are obtained by introducing an auxiliary vertical section, shown to the left of the plan. Project their plan length onto this section and measure along the common rafter. Remember, the length as scaled from the drawing is the length on the centre line.
4. For greatest accuracy, some of the details can best be found from full-size sections.

In Figure 22.9, the relevant parts of the roof have been separated to avoid confusion. With experience, however, much of the drawing can be superimposed over other set-outs and the information obtained with a minimum of line work. Referring to Figure 22.9, establish an XY line and, from points A and C, measure in the eaves width, square up to the common rafter and locate points E and D. Mark in the width of the common rafters, and take out approximately one-third the width for a birdsmouth. Note the amounts left above the birdsmouth: x and x_1 .

The wall plates can be drawn in and their difference in height measured directly from the set-out. Depending on how great the difference is, the height of the plates can be adjusted either by laying a second plate over an existing plate and packing it up to the required height, or by adding the difference in height to the length of the studs to raise the plate to the higher level.

Fig. 22.8 Set-out for unequally pitched roof—not to scale

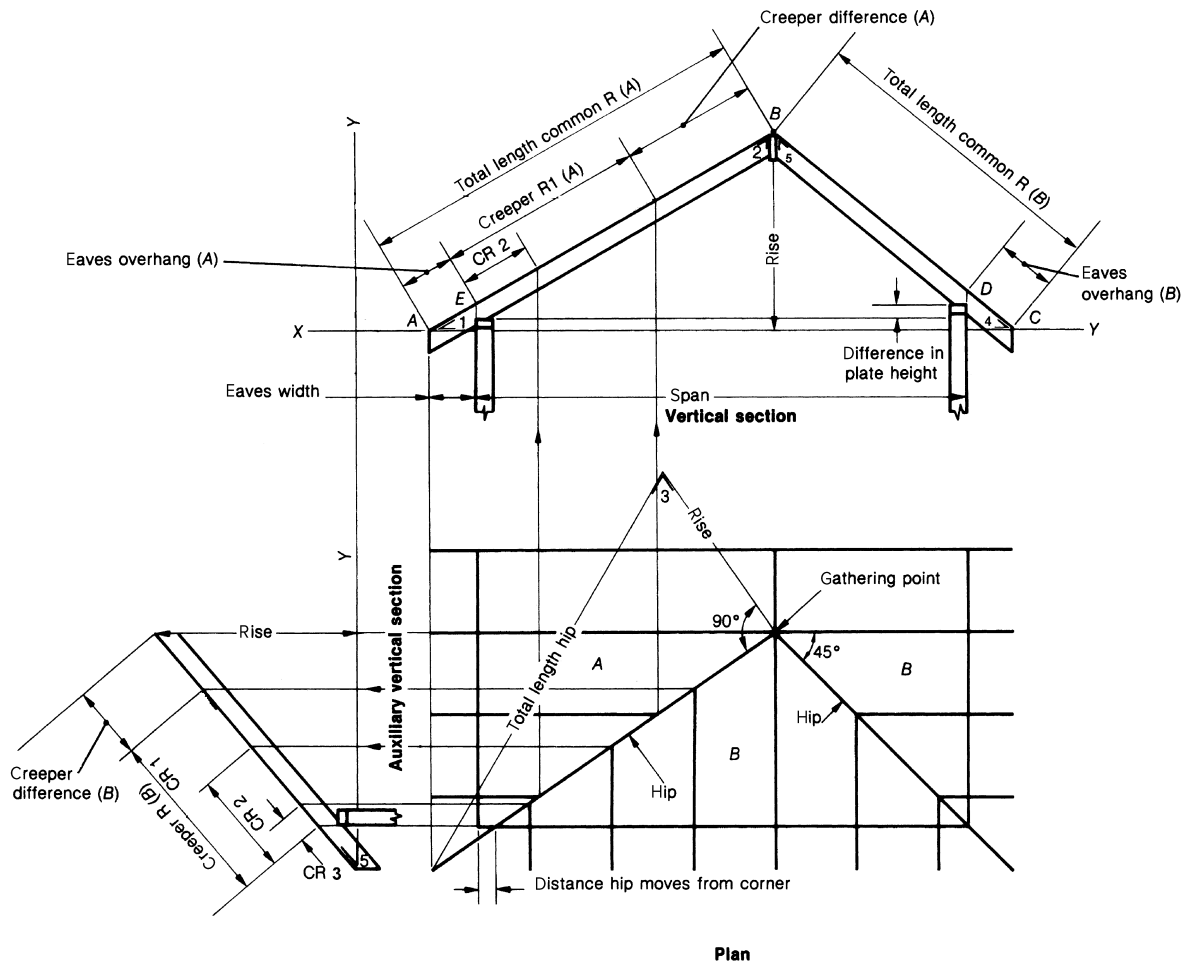
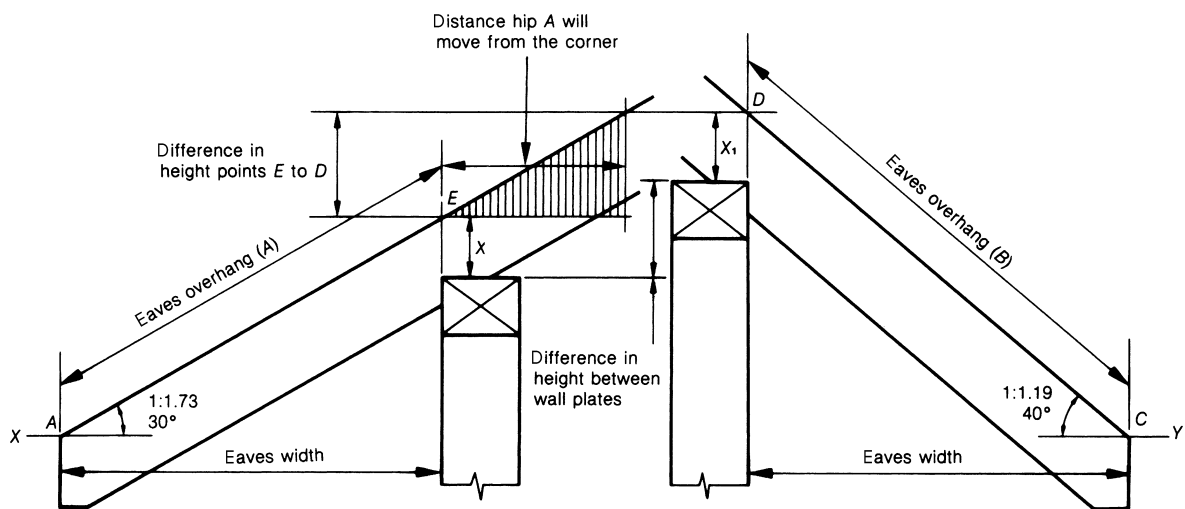
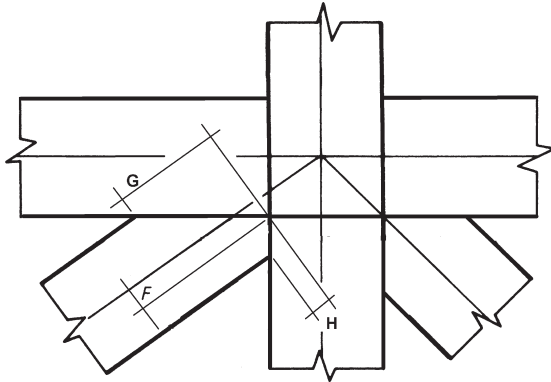


Fig. 22.9 Section through unequally pitched roof



5. The distance the unequally pitched hip moves from the corner is readily obtained from the full-size set-out. Measured to the *top* of the rafters, the difference in height from the corner to the point where the hip meets the plate is equal to the difference in height between points *E* and *D*. Measure the horizontal component of this distance when the pitch is 30°; this is the amount the centre line of the hip will move from the corner.
6. The edge bevels to the hip will also be unequal and the point will move away from the centre line. Details can be taken from a full-size set-out of the gathering point. Note how far the

Fig. 22.10 Crown end assembly

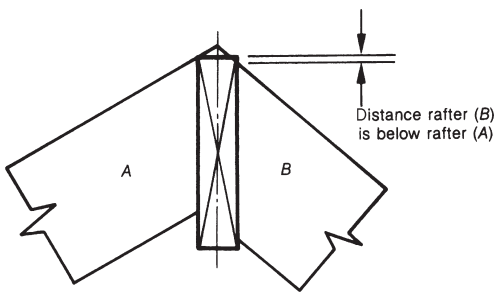


point is off the centre line *F* and set off the side cuts *G* and *H*. The level difference measurements for *G* and *H* will be needed to develop the hip side cuts. Refer to Figure 22.5 for details. The side cuts for the creeper rafters adjoining the unequally pitched hip will have to be developed. First, the level difference for the cuts will need to be developed by drawing a pair of creeper rafters onto the crown end drawing for this roof (Fig. 22.10). For an example, refer to Figure 22.7, Detail 2 and 3.

CHECK YOUR UNDERSTANDING

2. Why are the walls of an unequally pitched roof at different heights?
3. In setting out an unequally pitched roof, what is the reason for moving the *XY* line down to the fascia line?

Fig. 22.11 Ridge detail



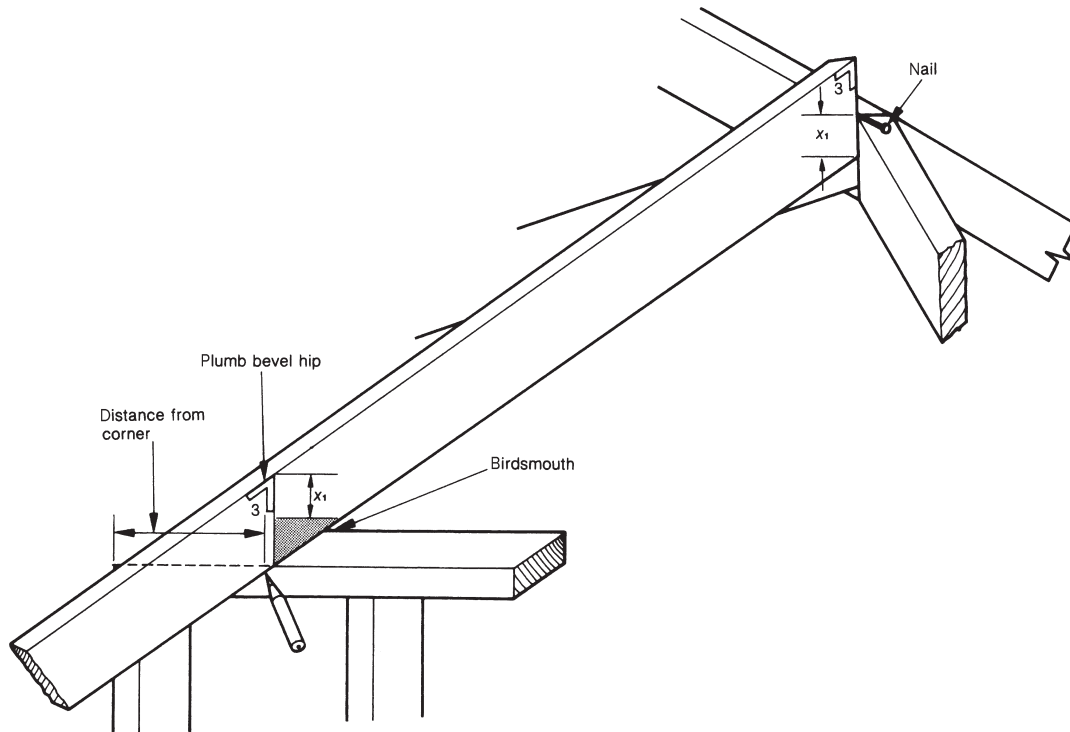
22.10 Erect an unequally pitched roof

Follow the procedures described in Chapter 21, except that at the ridge, the rafters to surface *B* will fix slightly below the level of rafters to surface *A* (Fig. 22.11).

Measuring and fixing the unequally pitched hip is best carried out in a practical manner.

Figure 22.12 shows a method of marking a hip; it is very adaptable to this situation. The procedure is as follows:

1. Mark and cut the plumb and edge bevels to the top of the hip. Measure up from the bottom edge, along the plumb line, the distance X_1 and drive a nail through the point of the hip.
2. Stand the hip in position, supported by the nail at the top, and with its centre line over the point marked from the corner.
3. Mark the single-edge bevel underneath and a plumb line on the face. Mark down the distance X_1 to the level cut on the birdsmouth.

Fig. 22.12 Practical hip set-out

4. When the birdsmouth is cut and the nail removed, the whole hip will move down into position.
5. Fix the creeper rafters and complete the purlins and strutting. Cut the tail of the rafters off to a straight line at the required eaves width, and fix the level fascia.

CHECK YOUR UNDERSTANDING

4. Describe, using sketches if necessary, a practical method by which the unequally pitched hip in an unequally pitched roof can be marked to length and fixed.

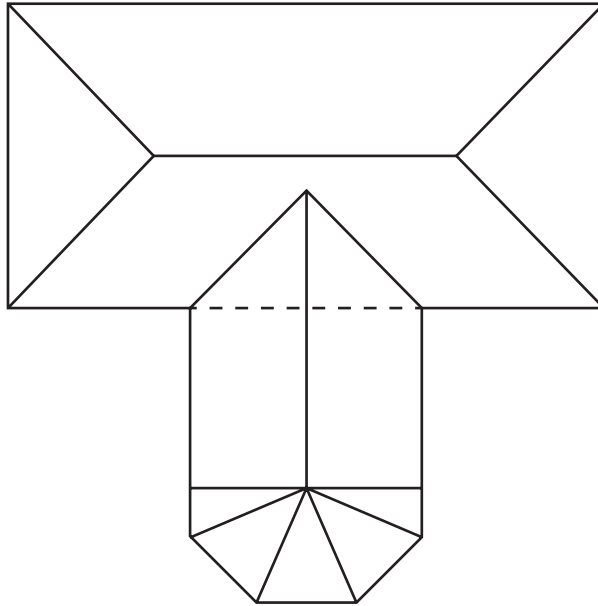
22.11 Understand the octagonal end roof

This roof design is based on an octagon. Figure 22.13 shows a hipped roof, with a scotch valley (covered in Chapter 21), incorporating an octagonal end. As you can see, it is not quite a true half-octagon. The set-out is based on three full sides of an octagon, and two half-sides. This allows for one full side of the octagon to face directly out from the building. This type of construction is often used to highlight views in the surrounding environment and the three full sides will generally have windows installed. This feature in a building is often called a bay window. Figure 22.13 shows only the skeleton of the roof and an outline of the building (hip, valley and jack rafters, and ridge line).

There are many methods of setting out an octagonal end. The method used depends on the information provided on the plan.

If the plan does not provide a measurement for the side of the octagon, then the sides have to be calculated or developed. A development method is shown in Figure 22.14. This requires a scale drawing to be produced of the outside perimeter of the building.

Fig. 22.13 Setting out an octagonal roof



This method of developing the octagon uses the span of the roof to create a square, then use a compass or trammel, set to the diagonal half-measurement of the square indicated by *O* (radius of the circle).

Once the trammel is set, the points are placed on each corner of the square and an arch is drawn as shown in Figure 22.14. Where the arch intersects with the outline of the square (indicated by *X*), these points show where to draw the sides of the octagon.

Alternatively, if the length and position of one side of the octagon are nominated on the plan, as shown in Figure 22.15, it is relatively simple to determine the other sides. As each side of the octagon is the same length, all you have to determine is the angle at which the next side goes off. That angle is 45° .

Fig. 22.14 Developing the octagon

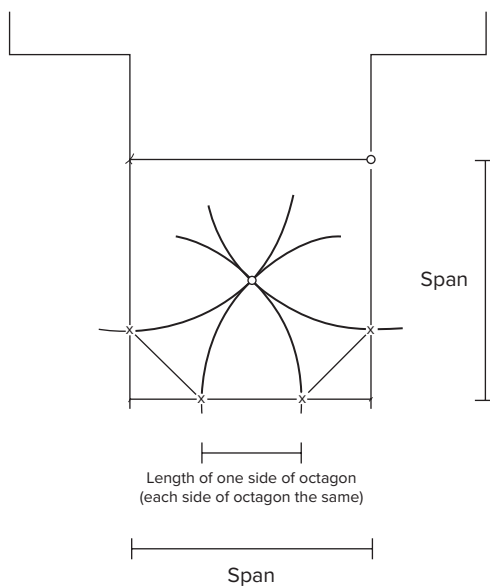
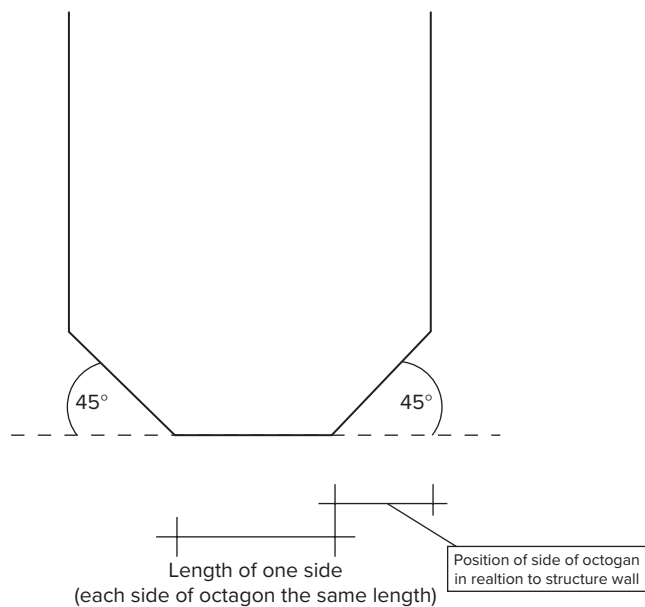


Fig. 22.15 Establishing sides of the octagon



22.11.1 Developing the roof members of the octagon

Once you have set out the octagonal end on your scale drawing, you can now determine where the roof members are located. This will assist you in calculating their length and developing the rafter cuts. There is more than one way to construct this type of roof. The method shown will be hip rafters with creepers.

Draw a scale drawing of the roof with the main roof members (centre lines). Figure 22.16 shows the main roof members for the octagonal end, including the first pair of jack rafters. It is important to measure the half-span measurement in both directions, as this will establish where the first pair of jack rafters are positioned and where the crown of the roof (indicated on Figure 22.16) is situated. The

location of the hips is straightforward as all of the centre lines intersect at the crown, and the other end of the hips will sit above the points of the octagon. The centre lines are actually the centre of each roof member. These lines are also the plan length of each roof member and these measurements are needed to develop the rafter length.

Next, draw in the actual roof members as shown in Figure 22.17. It is always a good idea to draw the members to the correct scale. You will notice that jack rafters are offset from the jack rafter centre lines. This eliminates the need for a double plumb cut on two hip rafters. Figure 22.17 also shows how the plan length of the jack rafters (run) can be used to develop the true length of the rafter.

To calculate the jack rafter length, you need to know the rise of the roof. For the example shown in Figure 22.17, the pitch of the roof is 25° . The rise can be calculated using the roof pitch conversion table shown in Chapter 21 (Table 21.1). You also need the half-span roof; for this example it is 4 m. Therefore, the rise of the roof is calculated to be 1.864 m.

Now you have the rise (1.864 m) and the run (4 m), you can calculate the actual length of the rafter.

Fig. 22.16 Location of the main roof members

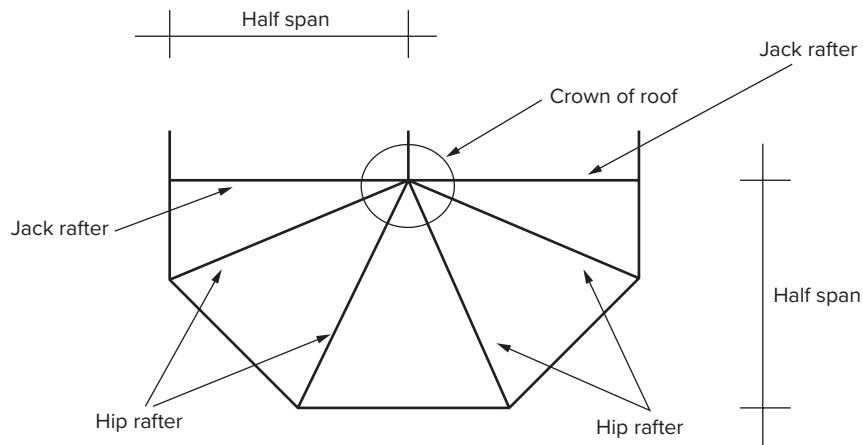
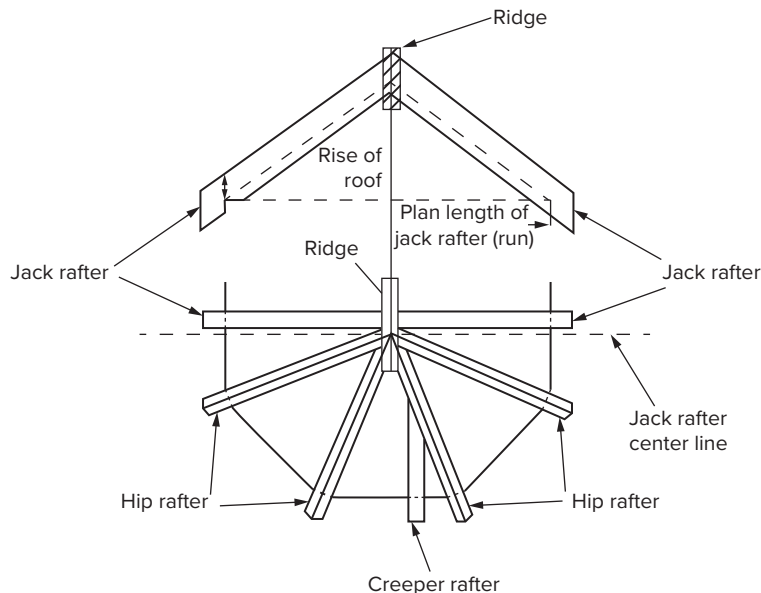


Fig. 22.17 Roof members of an octagonal roof



22.11.2 Practical development of rafter lengths

This method can be used to develop the rafter lengths, plumb cuts, side cuts etc. for any roof. The key to this method is to ensure that the drawings are as accurate as possible and that the scale used to create the drawings is as large as practicable, as the larger the drawing, the less likely you are to make an error and the easier it is to draw.

Now the positions of the roof members are calculated based on the rise of the roof as described earlier.

The next step is to draw a pitch triangle (Fig. 22.18).

The **run** of the triangle is the plan length of the rafter (this is equal to the half-span for common rafters).

The **rise** of the triangle is the height of the roof that has been calculated.

Once you have drawn the pitch triangle, the next step is to draw in the rest of the rafter.

The drawing in Figure 22.19 is obtained using the procedure below.

TIP The drawing should be completed to as large a scale as possible.

Once the pitch triangle has been drawn, the next step is to draw in the top plate. This is located at the point of the triangle.

The next step is to draw in the top of the rafter. This position is determined by the height of the ceiling joists or is a nominated height between the top of the birdsmouth and the top of the rafter, ensuring the birdsmouth is no deeper than a third of the depth of the rafter (Fig. 22.20).

Fig. 22.18 Pitch triangle

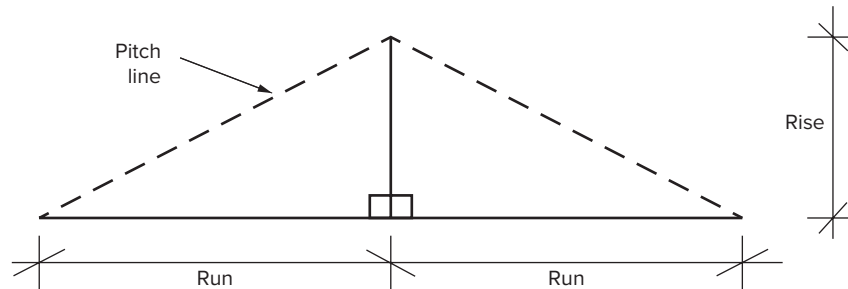
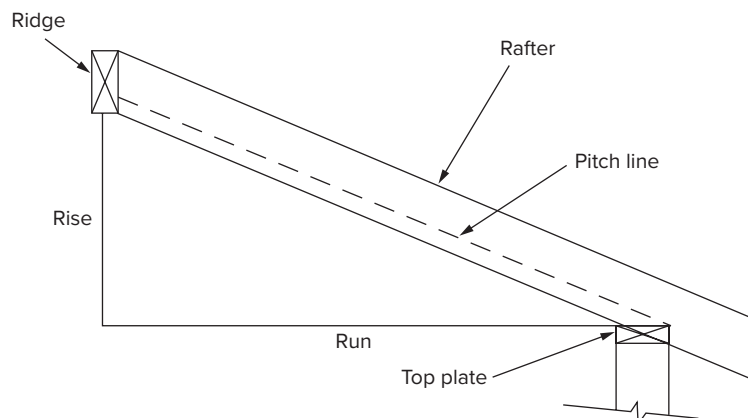


Fig. 22.19 Completed rafter development



Then, the same distance should be measured at the highest part of the pitch triangle so that a parallel line can be drawn with the pitch line (Fig. 22.21).

Now the bottom of the rafter can be drawn in; this is the total depth of the timber being used to make the rafter. The dimension should be measured square down, from the top line of the rafter (Fig. 22.22).

Fig. 22.20 Determining the birdsmouth

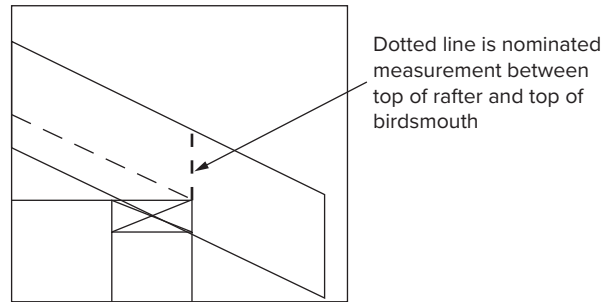


Fig. 22.21 Drawing in top of rafter

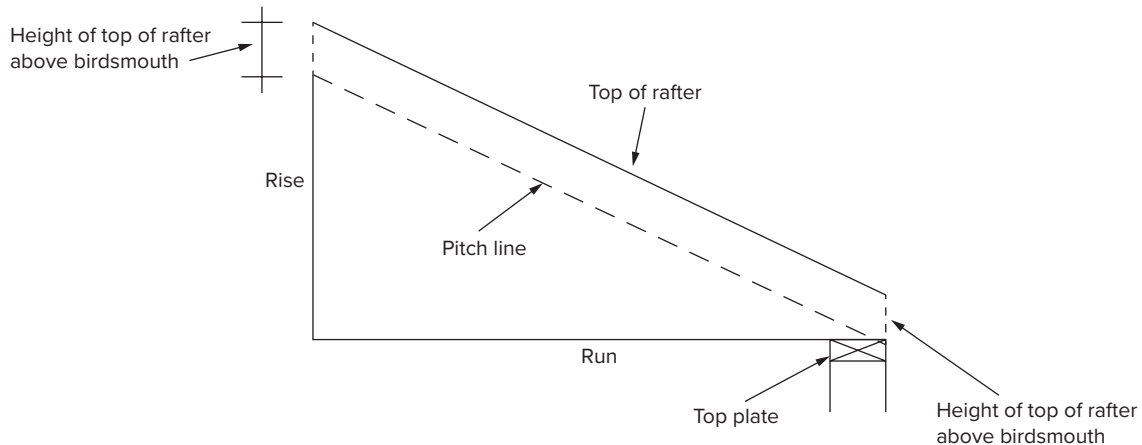
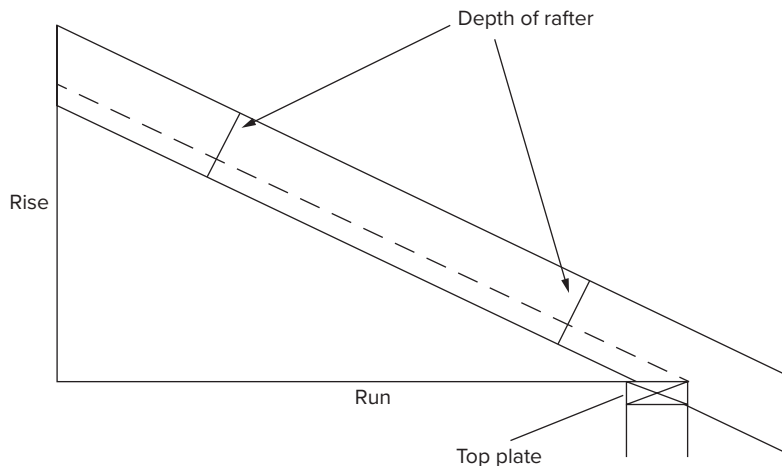


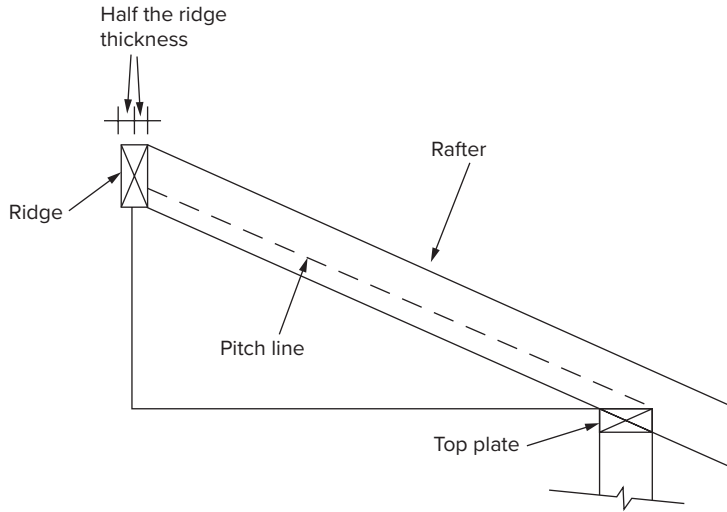
Fig. 22.22 Drawing in the rafter



The last part that needs to be drawn in is the ridge. This is drawn at the highest part of the pitch triangle. Only half of the ridge should project into the rafter (Fig. 22.23).

Once the drawing is finished, from it you can take the rafter plumb cut, the birdsmouth position and depth, and the length of the rafter. (The length of the rafter is measured from the corner of the ridge along the top of the rafter to a point, plumb with the outside of the top plate; Fig. 22.24.) This information is used to mark out the first common rafter, which can be used as a pattern to make the remaining common rafters. This is commonly called a pattern rafter (Fig. 22.25).

Fig. 22.23 Drawing in the ridge



The length of the hip rafters can be developed using the same process as described for common rafters above. Refer back to the original plan drawing of the roof (Fig. 22.16), where the plan length of the hip (**run**) can be obtained (Fig. 22.26a). The height (**rise**) of the roof is the same as for the common rafter; however, instead of reducing the length of the rafter by half the ridge thickness, you need to find a distance called the level difference (Fig. 22.26b).

Fig. 22.24 Completed rafter drawing

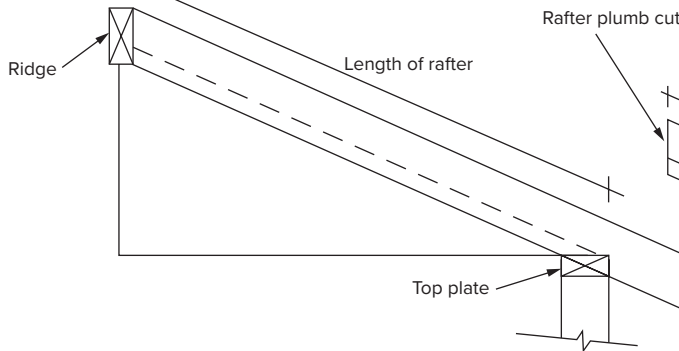


Fig. 22.25 Pattern rafter

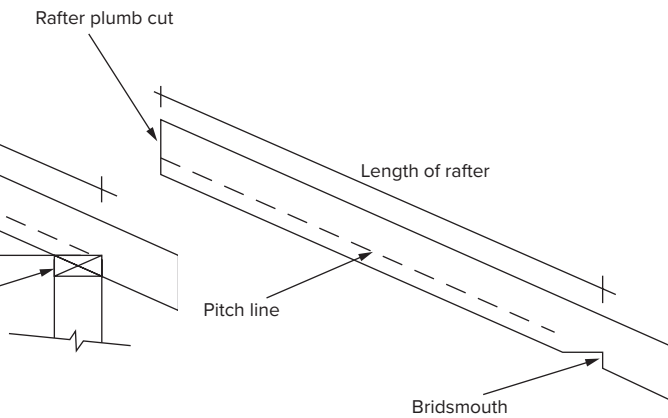
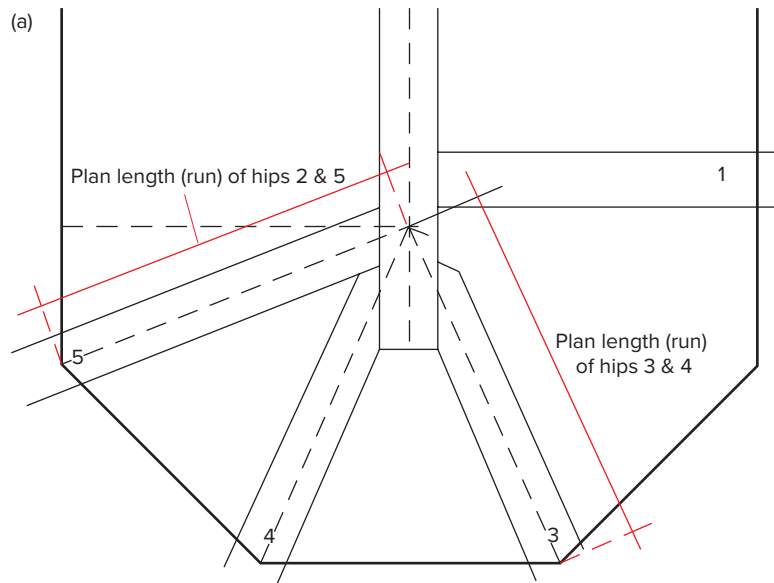
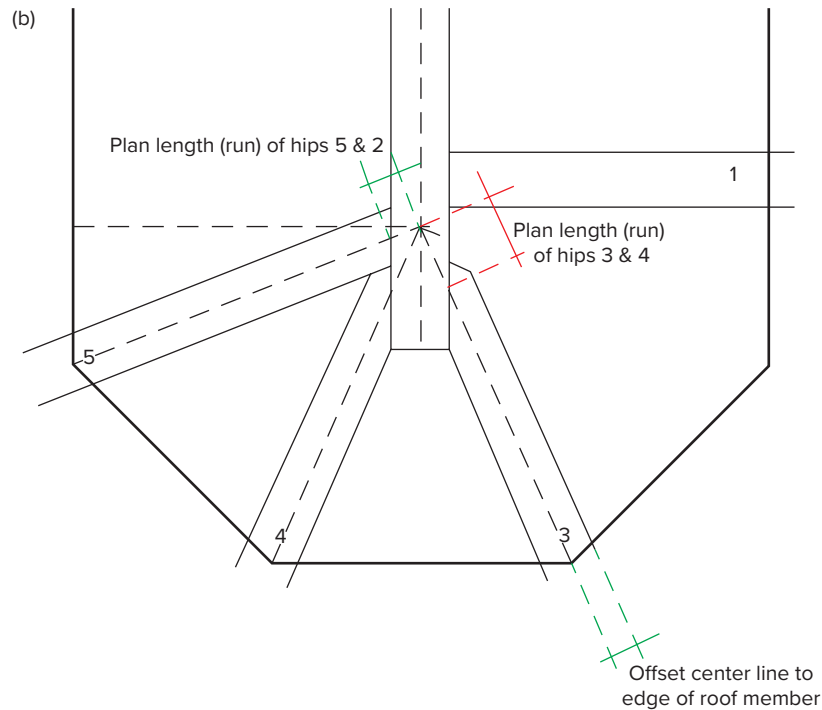


Fig. 22.26 (a) Run of hip rafters; (b) level difference of hip rafters



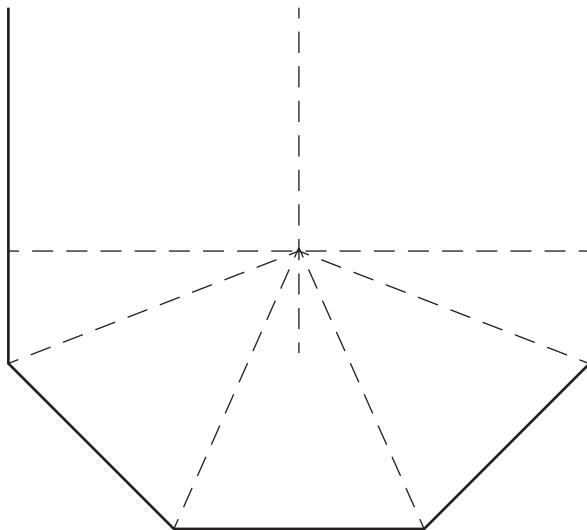
(continued)



CHECK YOUR UNDERSTANDING

5. Explain, using relevant diagrams, how the plan length of hip rafters for an octagonal roof can be calculated.

Fig. 22.27 Main roof member centre lines for an octagonal roof



22.13 Develop level shortenings for an octagonal roof

The hip rafters on the octagonal end all have side cuts. One method used to obtain these cuts is developing level shortenings. This is a practical method that requires some drawing. First, draw the octagonal end of the roof to scale (as big as you can), then draw in the centre lines for all of the main roof members (ridge, common and hip rafter) (Fig. 22.27).

Once the centre lines are drawn, the roofing members can be filled in. For this process, draw the actual thickness of the material being used; it's very important

that the correct thickness is drawn, otherwise the level shortening measurements won't be correct. Figure 22.28 shows the start of this process. As you draw in the roof members, the position of the members reveal themselves.

1. Start by drawing in the ridge. Extend the lines further than you think into the octagon.
2. Draw in hips 2 and 5. These hips should extend all the way to the ridge. These two hips will have only a single side cut.
3. Now draw in hips 3 and 4. Where the short points of these hips intersect with the ridge, this indicates where the ridge will end. Hips 3 and 4 have two side cuts.
4. Lastly, draw in the jack rafters. The position of these rafters are where the long points of hip rafters 2 and 5 intersect with the ridge (Fig. 22.28b).

Now that the roof members have been drawn, the level shortenings for each side cut can be obtained. Figure 22.29 shows where the level shortenings for each roof member side cut can be found.

Fig. 22.28(a) and (b) Drawing in the roof members

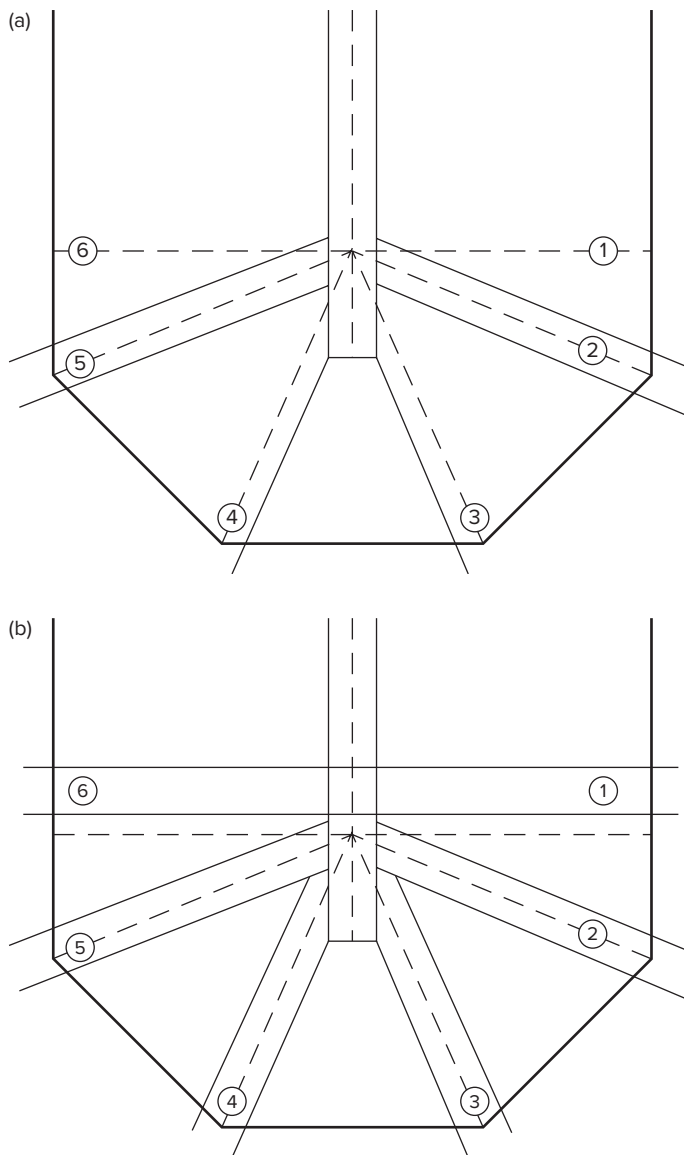
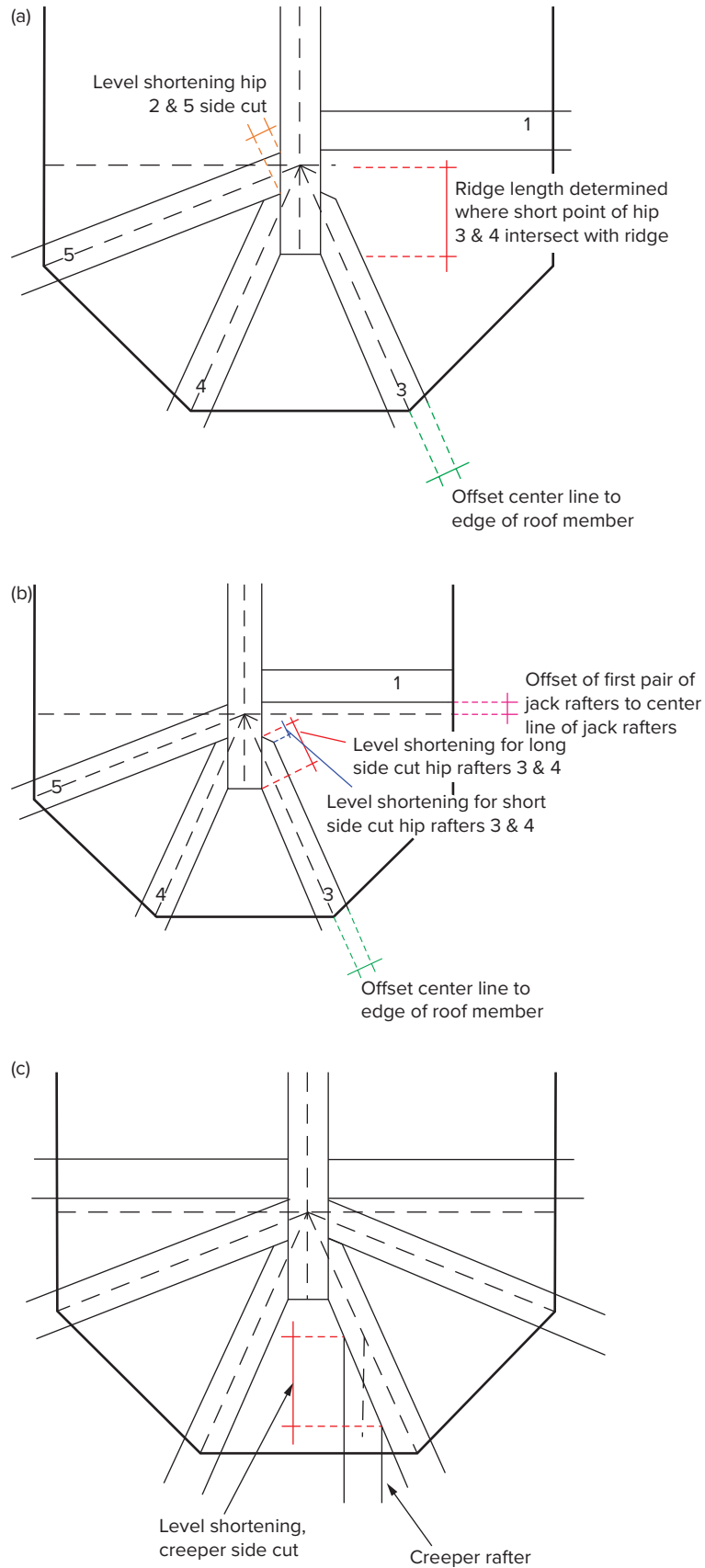


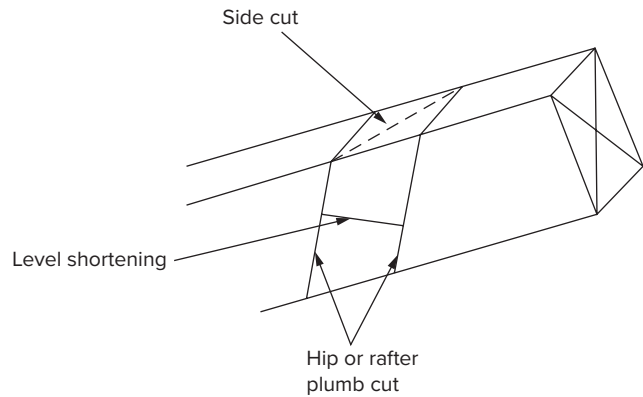
Fig. 22.29(a)–(c) Level shortenings



22.14 Develop side cuts

The side cuts for the hips and the creeper rafters can now be developed using the level shortenings obtained in the previous section. Using the appropriate plumb cut angle, transfer the plumb cut angle onto a piece of timber, measure square of that line the appropriate level shortening measurement of the chosen roofing member. Mark another plumb cut angle on the timber, then square across the top of the timber and join up the diagonals. This diagonal line is the side cut (Fig. 22.30).

Fig. 22.30 Finding the side cuts



CHECK YOUR UNDERSTANDING

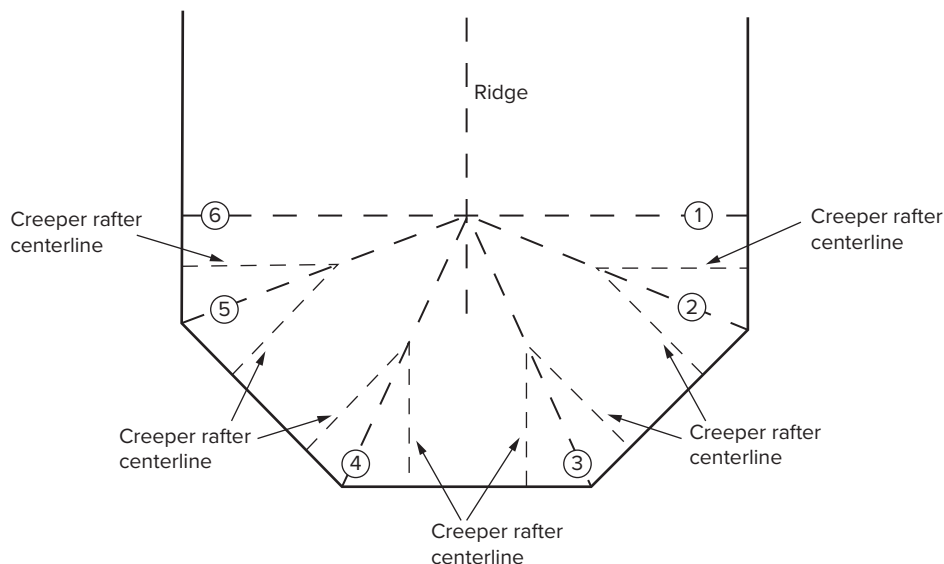
6. Why do the level shortening measurements need to be found for the side cuts of hip and creeper rafters?
7. At what angle must the rule be held when marking off the level shortening distance to the plumb cut when finding the side cut?

22.15 Pitch the roof and creeper rafters for an octagonal end roof

Pitching the octagonal end is carried out in a similar process to the other roofs discussed in this book. Ideally, the first pair of common rafters are used to hold the ridge in position, with the other end of the ridge being held up at the scotch valley end attached to the main roof. Ensure the gathering point (crown) is drawn on the ridge so that the hips can be installed in their correct positions.

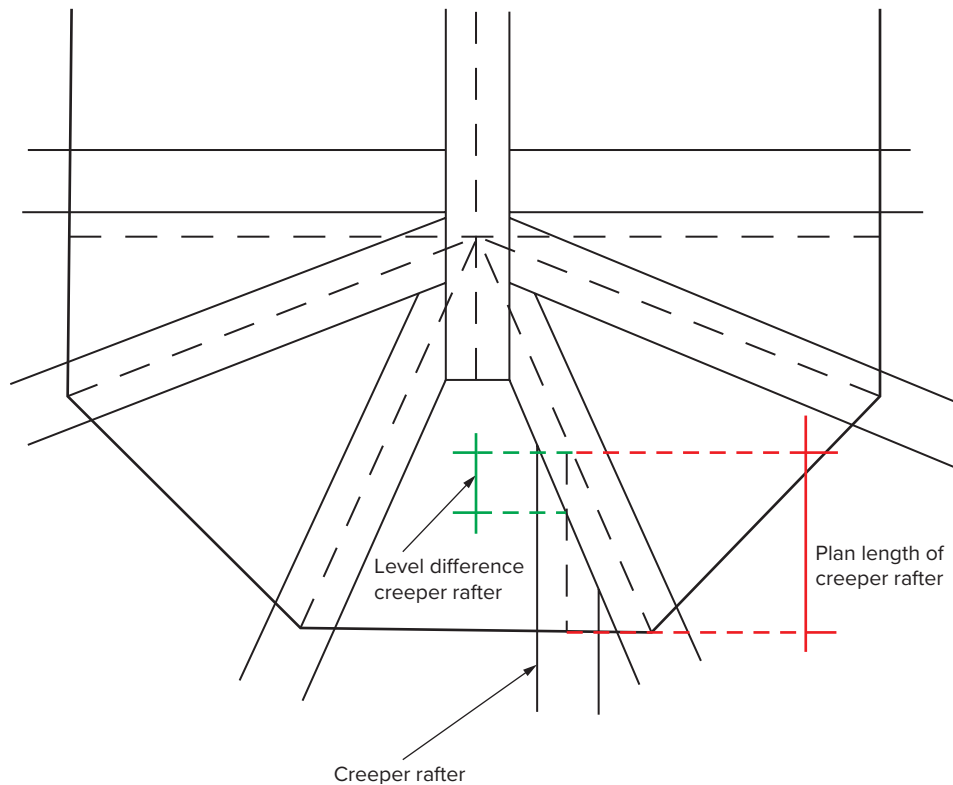
Creeper rafters are now cut and installed. Developing the length of the creepers is carried out in the same manner as described for the hip rafters. Again, the plan length of the creeper rafter is required. First, draw in the centre lines for the creeper rafters (Fig. 22.31).

Fig. 22.31 Creeper rafter centre lines



Next, draw in the roof members. Remember to use the actual thickness of the timber being used to construct the roof. The plan length and the level difference of the creeper rafters can now be found and used to develop the length of the creeper (Fig. 22.32). The level shortening of the creeper rafter is now required, so the side cut can be developed. Refer to Figure 22.29c to locate the level shortening.

Fig. 22.32 Plan length and level difference of creeper rafters

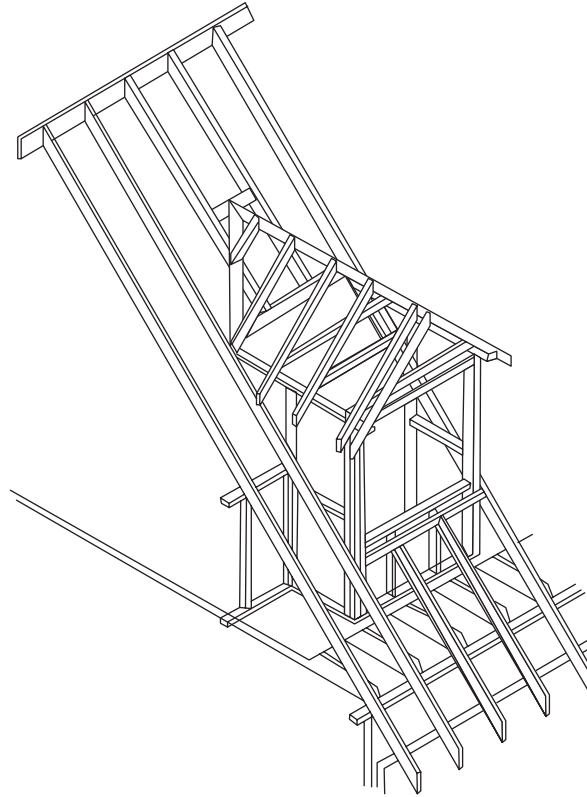


22.16 Understand roofs constructed with multiple pitches

Some roofs are constructed with multiple pitches. This occurs when the main roof structure is one pitch and an intersecting roof or minor span is of a different pitch. One example of this style of roof construction is when a dormer window is constructed to allow the installation of a window in a roof space (Fig. 22.33).

Figure 22.33 shows that the major roof is of a steep pitch and the intersecting dormer roof is of a much lower pitch. The image shows that the dormer roof is constructed in the same manner as a scotch valley (as detailed in Chapter 21)—the only difference is the different pitches. The construction process described in the scotch valley section can be used to construct the dormer roof.

Fig. 22.33 Different roof pitches intersecting—dormer



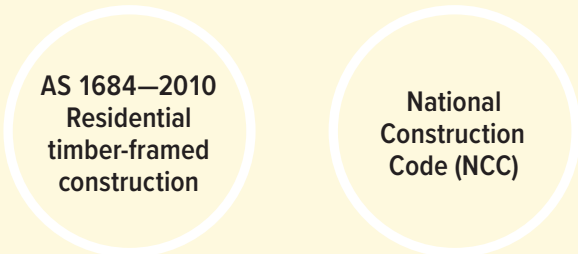
Student research

Research at least three other roof types that are not covered in this chapter. For what reasons are these roof types usually constructed?

End-of-chapter activity

Build a gable and skew end hip roof. Then add in a minor span roof using a scotch valley, incorporating an octagonal end.

AUSTRALIAN BUILDING CODES AND STANDARDS



AS 1684—2010
Residential
timber-framed
construction

National
Construction
Code (NCC)

Tradie talk—Ensure the ridge is straight

Chapter 23

Erect roof trusses

Learning Objectives

- LO 23.1 Plan and prepare to erect roof trusses**
- LO 23.2 Understand loads and forces**
- LO 23.3 Understand camber and deflection**
- LO 23.4 Understand lightweight timber trusses**
- LO 23.5 Understand wall framing support**
- LO 23.6 Fix trusses to wall framing**
- LO 23.7 Know about roof shapes and truss layouts**
- LO 23.8 Undertake job storage and lifting**
- LO 23.9 Erect roof trusses**
- LO 23.10 Clean up the site and maintain tools**

Introduction

Roof trusses have long been used as the roofing system for industrial and commercial buildings. Trusses permit large areas to be spanned without the need for intermediate supports in the form of internal walls or columns. This chapter covers all aspects of erecting roof trusses, including truss manufacturing, truss materials, roof shapes, types of trusses and layouts, planning and preparing to erect trusses, and then erecting trusses and fixing them to wall framing, tying them off and bracing.

23.1 Plan and prepare to erect roof trusses

23.1.1 Job safety

The planning and preparation that takes place before commencing the job of erecting the roof trusses can dictate whether the job runs smoothly without any incidents or accidents from a work health and safety (WHS) perspective and whether the job is carried out correctly as outlined in the plans and specifications.

The task will require some work to be carried out at height, so a safe work method statement (SWMS) for high-risk work should be in place before the work commences. The SWMS can be formulated after a worksite inspection has taken place and a hazard and risk assessment have been done for the job at hand.

Safe Work Australia's 'Code of Practice: Managing the risk of falls in housing construction', October 2018, will give good guidance on what needs to be included in the SWMS in regard to safely working at heights.

Any personal protective equipment (PPE) that has been identified as mandatory for the job must be in good condition, be fitted properly and used at all times in accordance with the SWMS.

23.1.2 Job compliance

The task of installing trusses needs to be carried out to the letter of the manufacturer's plans and specifications. Trusses are specifically designed and engineered, in accordance with the National Construction Code 2019 and the AS 4440-2004 Installation of nailplated timber roof trusses, to enable them to play their own individual part in supporting a roof. Any alterations to the placement or design of the trusses could lead to failure when the construction is taking place or has been completed.

The supplied fixings and accessories must be used, and installed, in the correct positions and manner as stated in the plans and specifications.

Any specific local authority environmental requirements or company workplace requirements that are to be carried out must be understood and adhered to.

23.2 Understand loads and forces

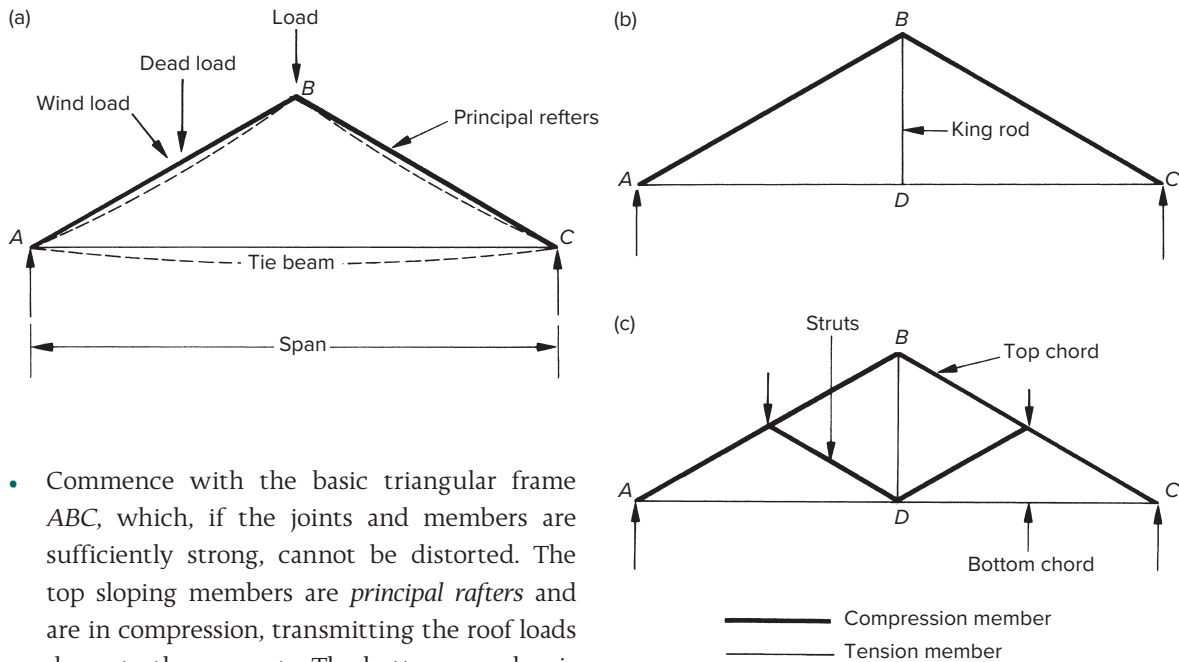
Roof trusses are subjected to a combination of loads (as are other roofs):

- *Dead load.* This is the permanent load due to the mass of materials—roof tiles, ceiling lining, timber, steel, etc.—carried by the truss and includes the weight of the truss itself.
- *Live load.* This is due to the weight of workers and materials that will be applied for short periods during erection and maintenance of the truss.
- *Wind load.* This is due to the wind presence; it can have a strong uplifting effect on roof surfaces. The members of the truss must be designed to restrain one or more of the following forces:
 - *compression*—a pushing or crushing force
 - *tension*—a pulling or stretching force
 - *bending force* or *bending moment*—causes members to deflect or sag under load.

Truss members may be subjected to a combination of these forces, including bending and compression, or bending and tension.

To understand the principle of the truss and how it is able to support loads over wide spans, refer to Figure 23.1.

Fig. 23.1 Basic principles of the truss: (a) basic triangular form showing different load types; (b) the king rod is a vertical post supplying support; (c) the struts and top and bottom chord



- Commence with the basic triangular frame ABC, which, if the joints and members are sufficiently strong, cannot be distorted. The top sloping members are *principal rafters* and are in compression, transmitting the roof loads down to the supports. The bottom member is the *tie beam* and is in tension, preventing A and C from spreading under the applied load (Fig. 23.1a).
- As the span increases, the members will begin to deflect in their length due to bending, so they must be supported. This is generally achieved by inserting a king rod (Fig. 23.1b) and additional struts (Fig. 23.1c). These struts will have different types of forces acting upon them (either tension or compression) depending on their location. The space between the top and bottom chords (or the top and bottom beams) determines the depth of the truss (Fig. 23.1c).

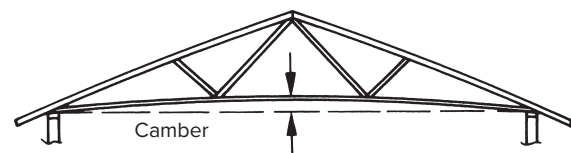
CHECK YOUR UNDERSTANDING

1. What is meant by the following?
 - a. live load
 - b. compression force
 - c. wind load
 - d. bending moment

23.3 Understand camber and deflection

The bottom chord of the truss has a camber built in to allow for deflection when the truss is loaded (Fig. 23.2). The amount of camber depends on a number of factors and is specified by the designer; it may vary from 6 mm to 20 mm, with a minimum camber of 3 mm.

Fig. 23.2 Camber in the bottom chord



CHECK YOUR UNDERSTANDING

- Why are lightweight timber trusses built with a camber in the bottom chord?

23.4 Understand lightweight timber trusses

Fig. 23.3 Typical timber truss nailplated webbing and bottom and top chord connections



Courtesy of Alister Ford

Fig. 23.5 Hydraulic press and nail plate

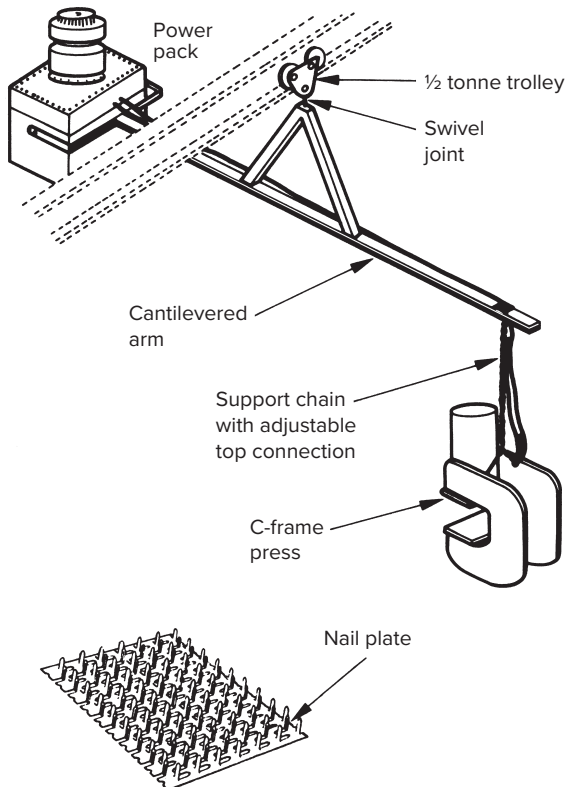
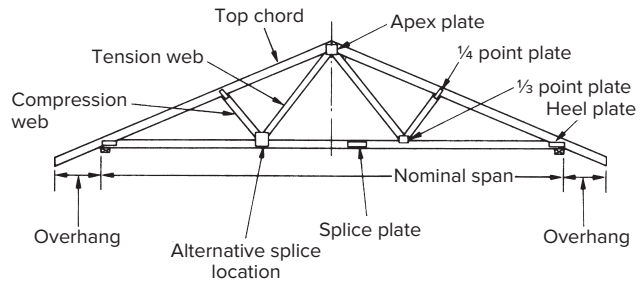


Fig. 23.4 Lightweight timber trusses



In recent years, the most notable change in the application of roof trusses has been the development of the lightweight timber truss. Its use has now largely superseded conventional roof framing in residential and some commercial buildings.

A typical lightweight truss is illustrated in Figures 23.3 and 23.4. The joints are secured with patented metal nail plates, which, when correctly applied, produce joints that are immensely strong in comparatively small timber sections. The nail plates are fixed to both sides of the joint and require considerable pressure to drive them into the timber.

Pressure may be applied with the use of a hydraulic C-frame press (Fig. 23.5) or, in more automated production plants, by passing the truss through metal rollers that embed the nail plates by just the right amount for maximum strength.

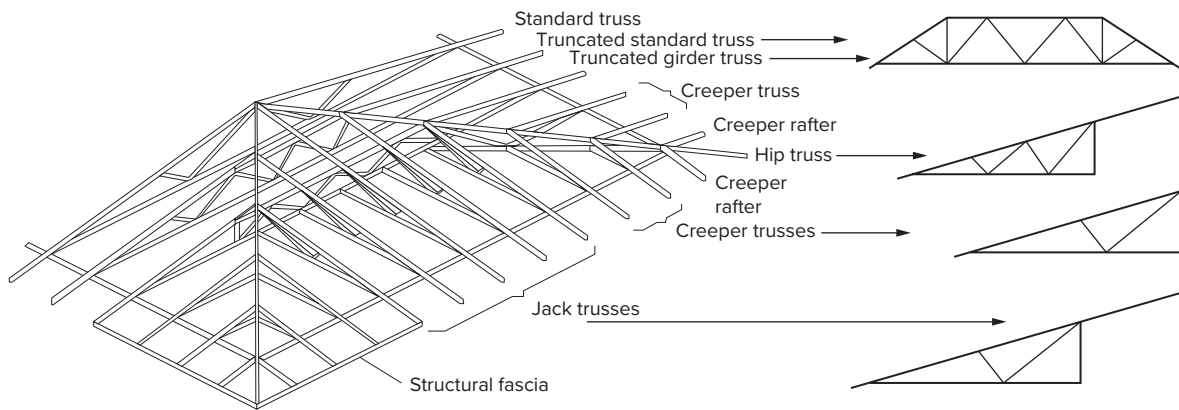
Factory-made trusses are manufactured through a network of licensed and franchised fabricators and are available in most areas.

The general construction of a trussed roof is shown in Figure 23.6.

The use of prefabricated lightweight trusses provides a number of advantages over a conventionally pitched roof:

- The advanced truss design permits the various stress grades of timber to be used to their best advantage and is more economical in the utilisation of timber resources.

Fig. 23.6 Prefabricated truss roof



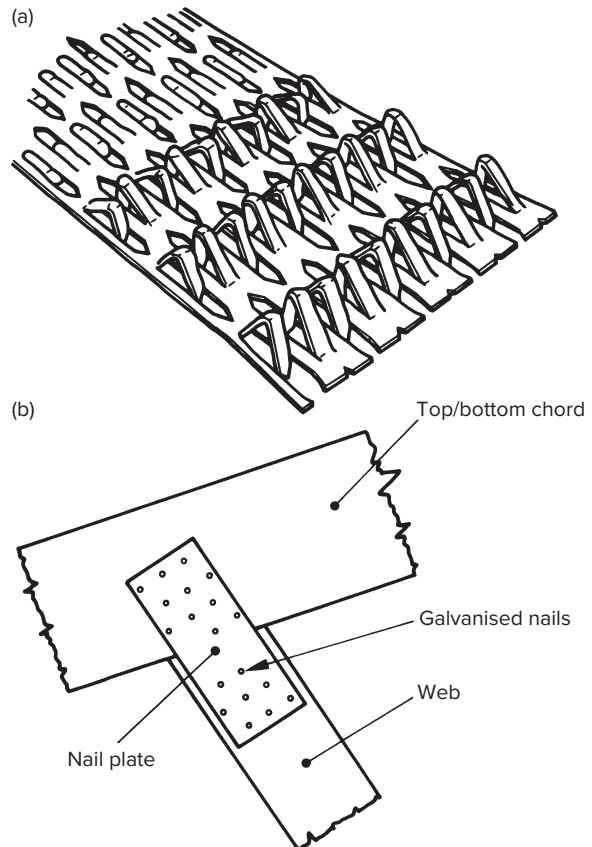
- Trusses are supported only on external load-bearing walls or columns, permitting maximum clear internal areas without permanent obstructions. Internal divisions can be made simply with the use of lightweight partitions; in domestic buildings, these can be readily relocated as the needs of the household change.
- Trusses are produced under controlled conditions in a 'ready-cut'-type workshop and can be speedily erected with a minimum of on-site labour.
- Trusses can be manufactured in a variety of shapes and sizes to meet almost any architectural design.

Manufacturers offer a comprehensive design and advisory service and provide detailed instructions, which should be followed carefully, with each roof supplied. This information is delivered with the trusses and includes a layout for the trusses, the location of bracing and the nailing information for all the fixing and tie down points.

Spans up to 25 m are practical, in a range of standard pitches from 7.5° to 27.5°. The spacing of trusses is dependent on the type of roof covering: generally, 600 mm and occasionally 900 mm for terracotta or concrete-tiled roofs, and 900, 1200 or 1800 mm for sheet-metal roofing. However, for most domestic situations, the 600 mm spacing is the most convenient and economical and generally will be found on terracotta or concrete-tiled roofs, while the 900 mm spacing is used for sheet roof materials.

Metal plate connectors are manufactured in a variety of sizes from light-gauge galvanised steel with teeth spaced and formed within the parent metal. Nail plates are normally pressed into the side of the timber, into opposite faces of the timber pieces to form a spliced or gusseted type of joint (Fig. 23.7a and b).

Fig. 23.7(a) and (b) Nail plates



CHECK YOUR UNDERSTANDING

3. What advantages does a truss roof system have over a conventionally pitched roof frame?

23.5 Understand wall framing support

Roof trusses are supported on the external walls only, and the effective roof length for the selection of studs, lintels and verandah beams is equal to the full roof span. Supporting walls must be designed as load-bearing walls, and if framed in timber, they must be in accordance with AS 1684 Residential timber-framed construction. It is preferable for trusses to be located directly over the wall studs, in which case top plates can be selected as for direct loading.

TIP It is important that the walls are fixed plumb and the top plates are level and parallel. If not, it can be very difficult to get the truss heels fixed in the correct position and the apex of the trusses in line.

Generally, in today's construction, all wall frames are made to the same height and adding an extra top plate to the external wall frames will give the required clearance between the internal wall frames (the minimum clearance is 10 mm) and external frames (Fig. 23.8). This also creates a thicker top plate that allows the truss to sit without the need for the studs to be directly underneath the truss. Generally, if the truss is within 100 mm of a stud it is acceptable. There are exceptions to this, and the girder truss is one, along with some truncated girder trusses where it is required to have extra support under the truss (Fig. 23.9).

This extra support can be either double or triple studs directly under the truss and, in some cases, a metal post to help distribute the load into the rest of the frame, foundations and footings.

Fig. 23.8 Top plate clearance

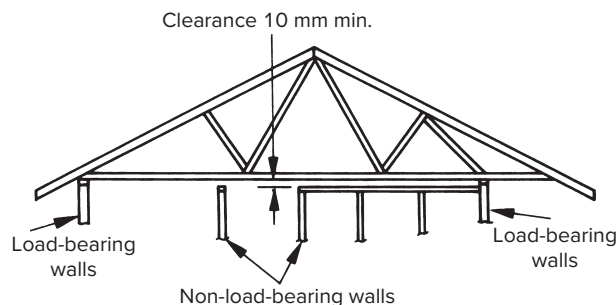


Fig. 23.9 A typical girder truss with a double stud directly below for support



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

4. Why may it be necessary to strengthen the wall framing that supports girder trusses?

23.6 Fix trusses to wall framing

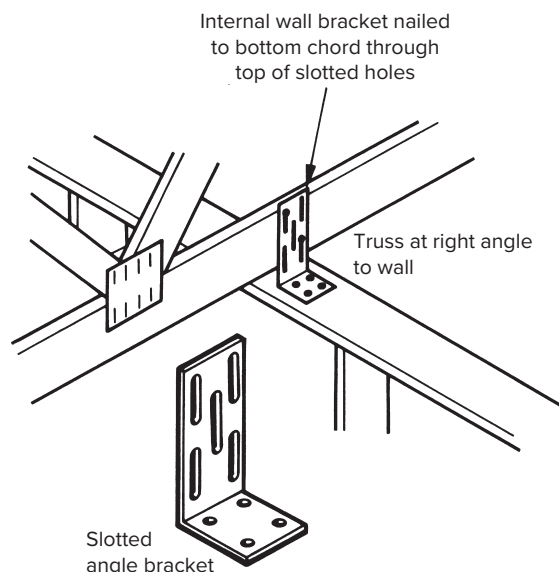
To allow the truss to settle down under the load, the top plate of the non-load-bearing walls is fixed to the truss with the use of slotted angle brackets at 1800 mm centres (Figs 23.10 and 23.11).

Fig. 23.10 Typical slotted truss to internal wall top plate bracket



Courtesy of Alister Ford

Fig. 23.11 Truss to top plate connection—slotted angle bracket



TIP The nails shown in the slot in Figures 23.10 and 23.11 must *not* be nailed home so as to allow for movement of the trusses. Refer to information supplied by the manufacturer of the truss on how to nail the 'L' bracket.

The brackets are fixed to the truss through the top of the slot with galvanised nails (Figs 23.10 and 23.11). Where walls are parallel with the trusses, trimmers are fixed between the trusses and the angle brackets are attached to the trimmer.

Recently, some new methods of fixing roof trusses to load-bearing external walls and to non-load-bearing internal walls and trimmers have been developed. The process of fixing the bottom chord to the non-load-bearing walls and trimmers while still allowing the truss to settle under the roof load as it is applied is often now done with a specially manufactured self-drilling and cutting screw (Fig. 23.12).

This screw can be driven through the top plate of the wall from the underside directly into the bottom of the truss bottom chord or truss/wall trimmer until the screw thread is fully embedded into the bottom chord or trimmer. At the end of the screw thread there is another cutter, which will create a pilot hole for the end of the screw shaft to sit comfortably inside the top plate of the wall. While not allowing any lateral movement of the wall, trimmer or truss, it will still allow the truss to settle under any weight applied when the roof is fully loaded (Figs 23.13–23.16).

Fig. 23.12 Internal wall-to-truss screw



Courtesy of Alister Ford

Fig. 23.13 Driving the screw through the top plate



Courtesy of Alister Ford

Fig. 23.14 Attaching the truss and cutting the pilot hole



Courtesy of Alister Ford

Fig. 23.15 Screw fully embedded into the truss with pilot hole cut



Courtesy of Alister Ford

Fig. 23.16 The screw fixed into its final position



Courtesy of Alister Ford

Considerable stress may be placed on the joint between the roof truss and the top plate, particularly in high-wind areas. Skew nailing is unsatisfactory as it offers little resistance to wind uplift and will probably split the bottom chord. The use of galvanised steel framing anchors is recommended at each end of the truss. Figure 23.17 shows the 'Trip-L-Grip', an economical connecting unit that simplifies jointing in framing. Cyclone strap tie-downs may also be required and should be installed as directed in the specifications as supplied by the manufacturer (Fig. 23.18).

Fixing the truss to the external load-bearing walls, as mentioned earlier, is also often done now with a longer self-drilling screw or screws, which will be driven up through the double top plate into the underside of the truss bottom chord. These screws replace the triple grip that would normally have been used, saving a considerable amount of time when fixing off the truss roof.

These specially made screws are approximately 150 mm long and are fully threaded for the entire length of the screw shank to allow maximum holding. They are easily held in place for driving using the installation bracket and special driver bit that come with the screws when purchased (Fig. 23.19).

The installation bracket is designed to fit up under the roof truss as it sits in position. The screw lies in the bracket slot, putting it at the correct angle—which is ideally 22.5°, although there is a tolerance

Fig. 23.17 'Trip-L-Grip'

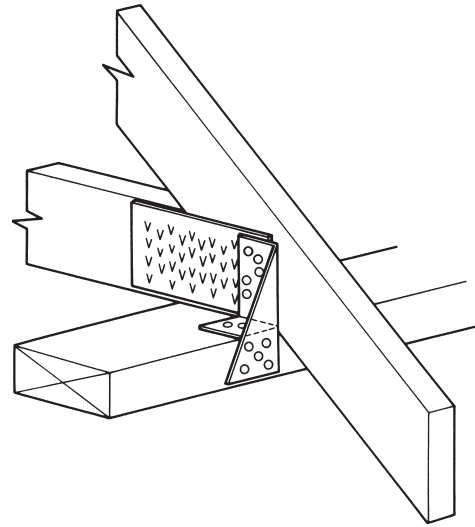


Fig. 23.18 A cyclone strap truss anchor nailed in place



Courtesy of Alister Ford

Fig. 23.19 Truss tie-down screws, installation bracket and driver bit



Courtesy of Alister Ford

that allows screws to be angled at between 10° and 30°. The screw can then be driven in to its full extent, as the slot in the bracket allows the screw head to pass through to be fully embedded in the top plate. All of the installation specifications are readily available from any specific fixing system manufacturer's website, from the supplier of the product or inside the product box itself.

Extension arms are available that can be fitted to a drill/driver to enable the driving of the screws, allowing the task to be carried out safely from floor level without the need to work at heights.

23.7 Know about roof shapes and truss layouts

23.7.1 Gable roof

The most economical trussed roof is the gable roof. It consists of a number of identical standard trusses. The overhanging gable end may require some variation.

Fig. 23.20 A gable end 'raking' or 'set-down' truss

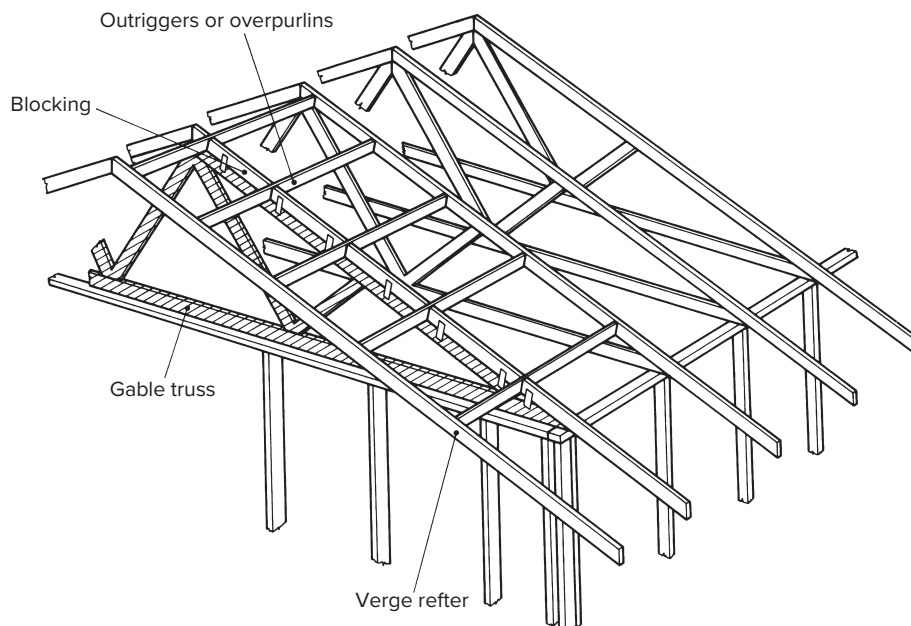


Fig. 23.21 Verge sprockets forming the verge overhang on the gable end



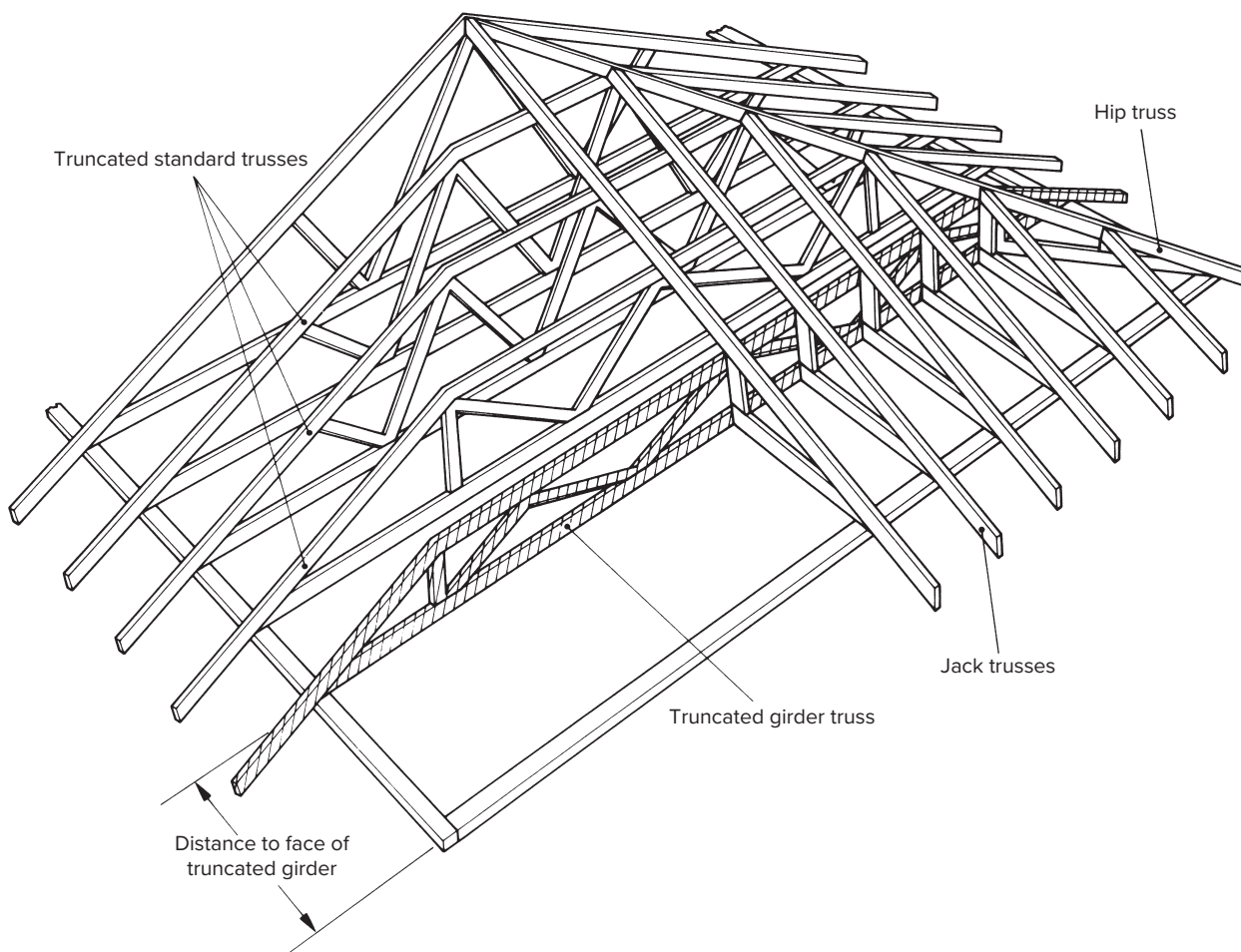
Courtesy of Alister Ford

The exact positioning of the gable truss will depend on the type of external finish. Figure 23.20 shows a *raking truss* (also known as set-down or cut-down truss) being used to accommodate outriggers. The other way to form an eave or overhang on a gable end is to use verge sprockets (Fig. 23.21).

23.7.2 Hipped roof

A system of truncated standard trusses and a truncated girder are used to form the hipped end

of a hipped roof (Fig. 23.22). Positioning of the girder truss is important and the correct distance from the corner to the face of the truss must be set out first. The point where the girder truss sits is commonly referred to as the *station* or *station point*. This measurement is on the plan supplied by the truss manufacturer: it is critical to get this measurement right. The hipped end can be completed

Fig. 23.22 Hipped roof truss

with a hip truss with a series of jack trusses—short trusses with an extended top chord fixed to the truncated girder (Fig. 23.23).

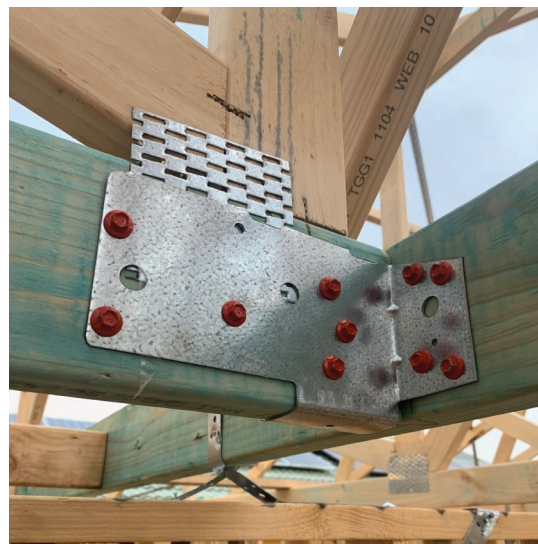
23.7.3 Dutch gable roof

The Dutch gable roof (also called the *gambrel roof*) is a popular shape for the trussed roof (Fig. 23.24). It permits the maximum number of standard trusses to be used and still retains the main features of the hipped roof. A Dutch hip girder truss, to which a waling plate is fixed, must first be set out at the correct distance from each corner.

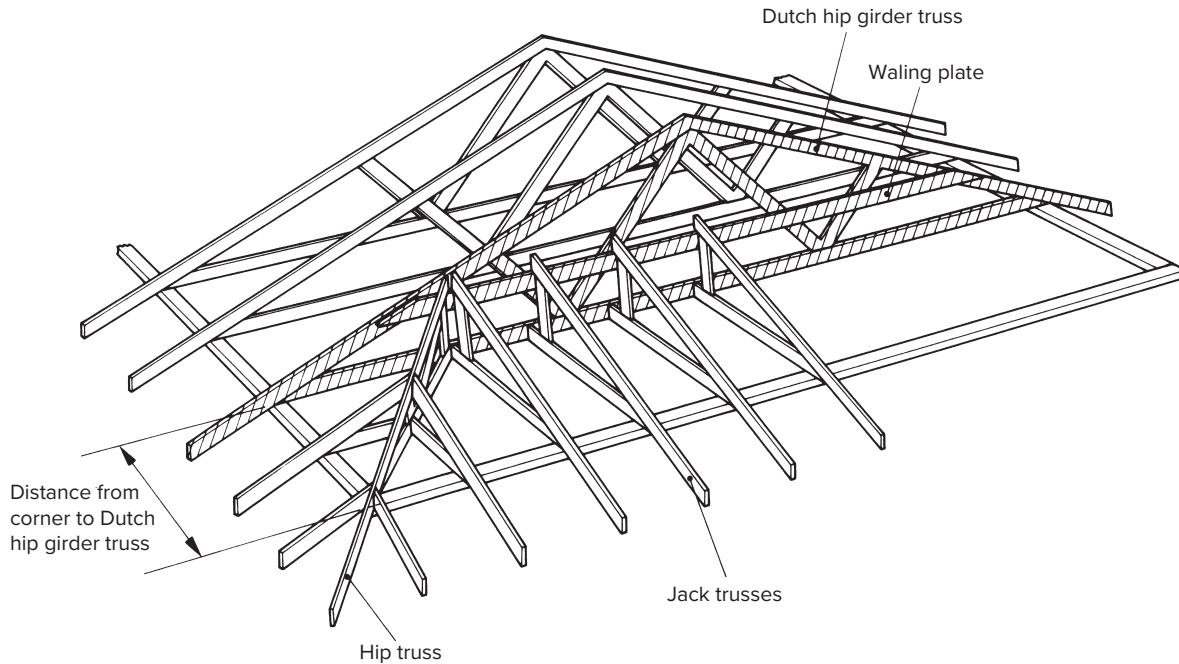
The hipped end can be completed with either conventional framing or a hip truss with a number of jack trusses fixed to the Dutch hip girder truss.

23.7.4 Intersecting roofs

Roofs that intersect at 90°, either L- or T-shaped, will form a valley at the junction of the roof surfaces to the internal corner.

Fig. 23.23 The main jack truss bracketed connection point to the truncated girder truss

Courtesy of Alister Ford

Fig. 23.24 Dutch hip or gambrel roof truss

Refer to Figure 23.25 and note how the girder truss, placed parallel to the truss of the secondary roof, will support the ends of the trusses of the primary roof with brackets without the need for load-bearing internal walls. The girder truss carries a considerable load and may need to be a double truss requiring additional supporting structure (Fig. 23.26), which should be completed before the trusses are erected.

Saddle trusses, placed over the trusses of the primary roof, complete the ridge and valley at the roof intersection (Fig. 23.27).

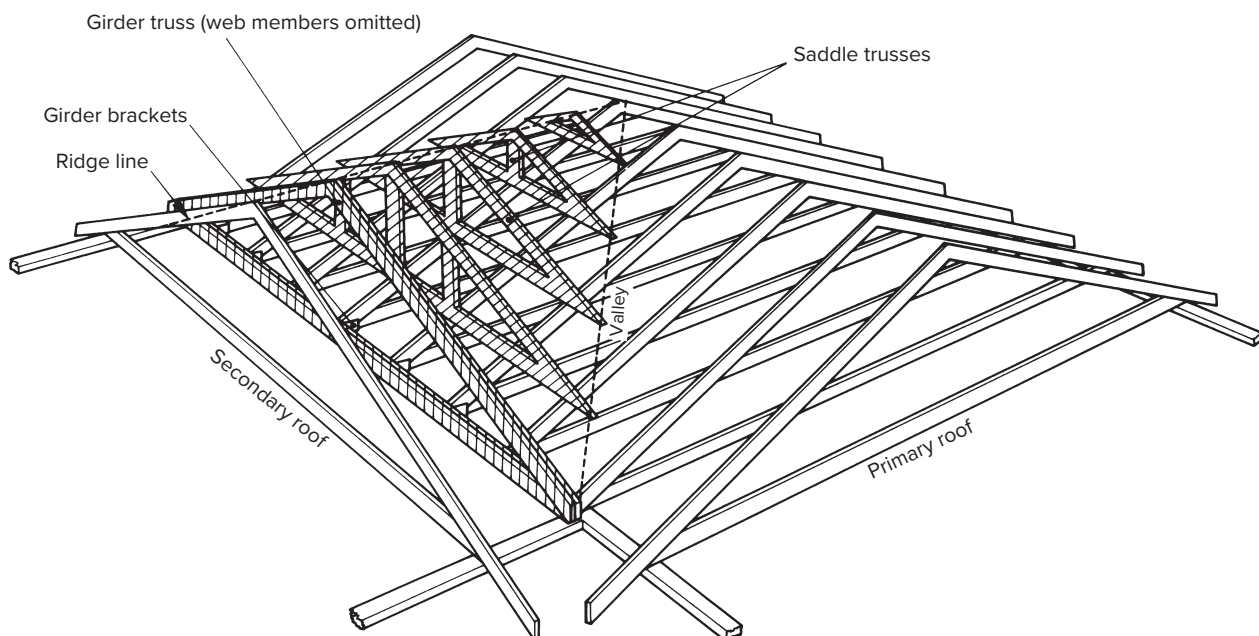
Fig. 23.25 Intersecting roof

Fig. 23.26 A supporting double truncated girder truss fixed over double studs



Courtesy of Alister Ford

Fig. 23.27 Saddle trusses creating the roof intersection and valleys



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

- When erecting trusses for a hip roof, what is the first truss to be positioned?

23.8 Undertake job storage and lifting

When trusses are delivered to the job site in an undamaged condition (Fig. 23.28), they must be handled with care until such time as they are finally fixed in position. It is important that any excessive lateral distortion be avoided, otherwise the joints and the timber will be damaged. Trusses should be stored flat on billets of timber clear of the ground. The best option is to have the main truss pack lifted and placed on top of the wall frames when it is delivered, which saves you having to lift it up yourself (Fig. 23.29).

When lifting trusses, attachments must be made at the panel points otherwise damage can occur to the truss (Fig. 23.30). Generally, they are delivered on a truck supplied by the truss manufacturer.

Fig. 23.28 Truss delivery using slings for correct lifting of the packed trusses

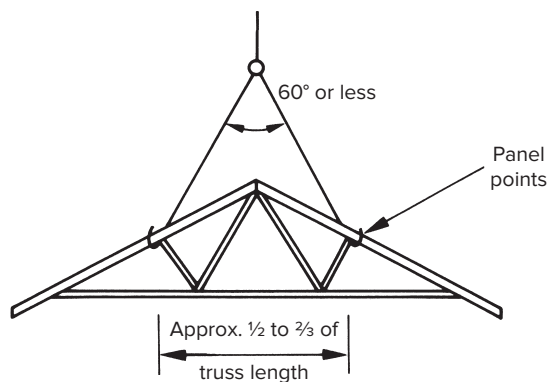


Courtesy of Alister Ford

Fig. 23.29 Trusses placed on the frame for easier handling during installation

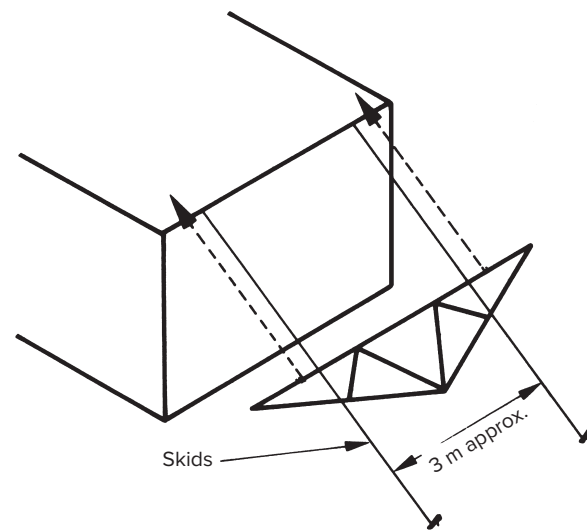


Courtesy of Alister Ford

Fig. 23.30 Lifting a single truss under 9 m wide using slings attached at the panel points

Never lift from the apex joint only. When lifting trusses of larger spans, spreader bars attached to the panel points are necessary.

In most domestic-type buildings, trusses can be placed on the top plates by pulling them up skids spaced about 3 m apart (Fig. 23.31). It is important to ensure that they do not sag between supports.

Fig. 23.31 Skids for lifting trusses

CHECK YOUR UNDERSTANDING

- Describe the precautions that should be adopted to protect lightweight timber roof trusses from damage during storage and lifting.

23.9 Erect roof trusses

Ensure you are using safe work practices when erecting roof trusses. Your local WorkSafe office will have information to help you with this.

TIP Each state or territory will have information from their respective WorkCover authority on fall protection and the installation of trusses. These should be consulted before work begins.

AS 4440 Installation of nailplated timber trusses suggests that the supplier and the builder must discuss all options during the manufacturing process to ensure that trusses are manufactured correctly, and that the right information is delivered for the job.

It is also important to have a crane deliver trusses for a double-storey house and ensure that carpenters are on-site to help with the delivery. The trusses should be placed in the best position for installation and not damaged in the delivery as this would cause delays for the builder.

A useful publication in this regard is *Compliance Code—Prevention of Falls in General Construction*, 2nd edition, 2019, available from the WorkSafe Victoria website (www.worksafe.vic.gov.au) or any WorkSafe Victoria office.

TIP Temporary bracing should be strong enough to stop the trusses being pushed over in strong winds while they are being erected, as outlined in AS 4440 Section 3 and Appendix C.

Before proceeding, it is important to ensure that all of the top plates are straight and braced so that the wall frames will not move when the trusses are erected or when the trusses are delivered and placed onto the top plate.

The procedure for erecting a roof truss is as follows:

1. Accurately locate the position of any gable end or girder truss (the station point). Set out the position of intermediate trusses, not exceeding the maximum spacing.
2. Stand the first truss, which must then be plumbed. Straighten the top and bottom chords within allowable tolerances and place erection props at the panel points. Figure 23.32 illustrates suitable erection props to a gable end.
3. Set up a string line along the apex of the trusses (Fig. 23.33). Stand each successive truss and space accurately using a gauging rod. Align each apex with the string line and fix with erection ties at the top chord panel points.
4. Brace all trusses adequately so that they do not move or fall over while being erected. All temporary bracing should *not* be removed until permanent bracing is installed.

Fig. 23.32 Erection prop: (a) elevation view; (b) plan view

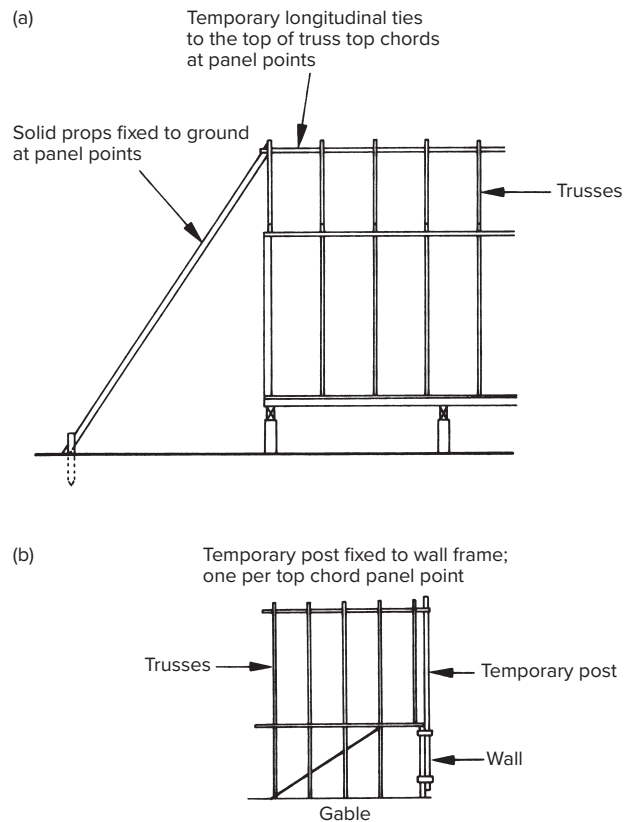
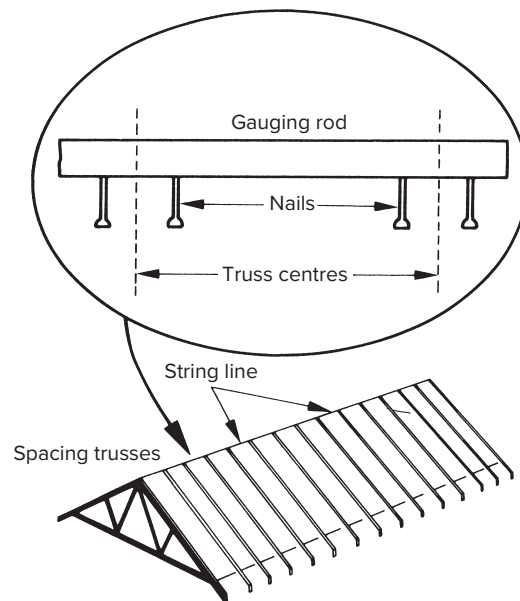


Fig. 23.33 String line and detail of gauging rod



23.9.1 Permanent bracing

Permanent bracing should include all the following:

- sideways (lateral) restraints to the truss top chords—these can include roof battens or purlins
- diagonal bracing to truss top chords using either timber or steel (the most common form of bracing is steel brace)
- bottom chord bracing—this is to stop the sideways movement of the bottom chord. It can be achieved through a few different methods:
 - (a) battens fixed directly to the bottom chords and the plaster attached to the battens
 - (b) bottom chord restraint (another term would be *strong back*)—this can be retained as permanent bracing; it is used where the plaster is fixed directly to the bottom chord of the truss
- web ties, if required—this will be in the information supplied by the manufacturer.

TIP Any bracing must be installed in a straight line from top to bottom, not 'zig-zagging', which negates its effectiveness during high wind loads.

Fig. 23.34 Speed brace fitted in a diagonal pattern before the roof battens are fitted



Courtesy of Alister Ford

brace (commonly referred to as a *speed brace*). This is fixed diagonally over the top chords in two directions and is securely anchored at its ends to both a point near the apex of the roof and to the wall top plate (Figs 23.34 and 23.35). Always refer to the manufacturer's installation specifications for fixing details.

During this time, it is important to place all of the fittings, triple grips, L brackets, cyclone ties (if required) and truss boots (if they have not been completed) so that everything is ready for the frame inspection. The location of these and the fixing requirements for these fittings can be found in the information supplied by the truss manufacturer and will need to be followed for the truss roof to work correctly.

23.9.2 Erection tolerances

When erecting the trusses, they should be as straight and plumb as possible. If a truss is out of plumb too much, it will reduce the effectiveness of that particular truss and cause stress on the other truss, which in turn could cause the whole frame to collapse.

23.9.3 Straightness of the top and bottom chords

The formula to ensure any bow in the top or bottom chord is not too great is:

Chord length $\div$ 200 or 50 mm

Use whichever is the *least* measurement.

For example, if we have a top chord length of 3495 mm and a bottom chord length of 6120 mm, then:

Working out: $3495 \div 200 = 17.475$

Thus, the maximum amount the top chord can have for a bow is 17.475 mm as this is the *least* amount.

Working out: $6120 \div 200 = 30.6$

Likewise, the maximum amount the bottom chord can have for a bow is 30.6 mm as it is the *least* amount.

Thus, the formula to make sure the trusses are level enough is:

Height $\div$ 50 or 50 mm.

Use whichever is the *least* measurement.

For example, we have 1500 mm where the level is placed to plumb the truss.

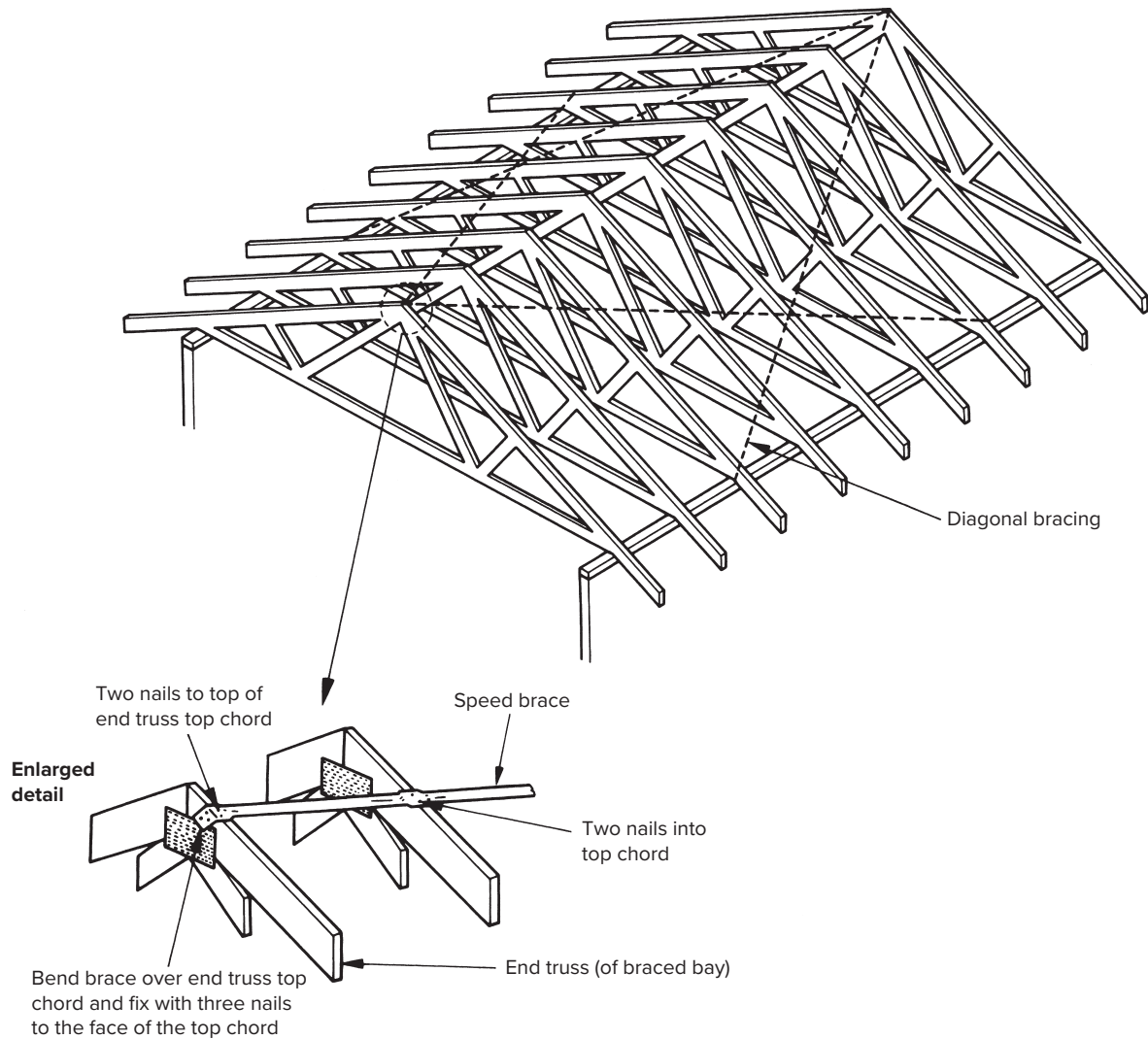
Working out: $1500 \div 50 = 30$

Therefore, 30 mm is the most the truss can be out of level at that point because it is the *least* amount of measurement.

More information on permanent bracing can be found in AS 4440, Section 4, Roof bracing.

Requirements for each individual roof may vary; details should be supplied by the truss manufacturer. Diagonal bracing may consist of timber fixed to the underside of the truss top chord. It should run continuously from near the apex of the roof to the wall top plate at an angle of 30° . This form of bracing is done only with the gable ends.

A fast and effective system of permanent bracing can be provided using a patented metal

Fig. 23.35 Diagonal metal bracing

23.9.4 Steel trusses

Steel-framed houses have grown in popularity in recent years. They have been around for a very long time—more than 50 years, in fact—but it is only in the past 20 years that they have had a reasonable market share. There are many different types of steel-frame manufacturers, most of which will have different ways of building their frames.

While the truss system used in a steel-framed house is similar to traditional trusses, it is also very different in its application and it is advisable to follow the instructions supplied by any steel truss system manufacturer.

Steel trusses will generally be manufactured with the webbing fixed to the flat face of the truss frame chords, creating a truss that is twice the thickness of a traditional timber truss (Figs 23.36, 23.37 and 23.38).

Fig. 23.36 Common steel truss

Courtesy of Alister Ford

Fig. 23.37 Steel truss webbing joint detail

Courtesy of Alister Ford

from the correct PPE for the task and the tools, fixing, fastening, tie-down and bracing requirements (Figs 23.39 and 23.40) through to the identification and installation of all truss types involved in constructing a steel-framed truss roof.

Fig. 23.39 Steel truss to top plate fixing bracket and bolts

Courtesy of Alister Ford

Fig. 23.38 Truncated steel truss

Courtesy of Alister Ford

It is important that steel trusses are placed the correct way round during installation. On the truss plan, the truss face position and direction will be indicated by an arrow on the dimension line for each individual truss. This should be carefully studied and understood to avoid any mix-ups with trusses, which subsequently need to be shuffled along or dismantled and turned around.

The National Association of Steel-Framed Housing (NASH) has very useful resources on steel frame assembly.

The *AusSteel Roof Truss Installation Guide* is a very comprehensive guide on all aspects of erecting steel roof trusses, covering topics ranging

Fig. 23.40 Steel truss flat metal cross bracing with tensioners

Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

7. Describe briefly in point form both the procedure for erecting lightweight timber roof trusses and the safety precautions that should be taken.
8. Describe two forms of wind bracing used with lightweight timber roof trusses.

23.10 Clean up the site and maintain tools

As with any task, cleaning up the worksite and the correct care and maintenance of tools are essential. Timber or steel offcuts should be cleared and neatly stacked, ready to be taken away or placed in a site skip bin or rubbish cage.

Power tools should be checked for any damage, making sure the leads have not been cut or sliced, especially if working in a steel-framed house or a timber frame with metal bracing installed. All guards on any power tools must be operating freely. Hand tools should be cleaned, maintained and stored correctly so they are ready for immediate use when required on the next task. If any damage to a tool or piece of equipment is detected, the item should be put aside, and the correct procedures followed to ensure the repair or replacement is carried out as soon as practicable.

Student research

1. Timber truss systems

Access the Safe Work Australia website and go to the 'Code of Practice: Managing the risk of falls in housing construction' and refer to Section 9.5: 'Installing prefabricated roof trusses' or obtain a copy from your instructor and carry out the following research tasks.

- (a) If the work is to be carried out at height, discuss six critical points regarding the truss bottom chords providing a safe working area.
- (b) Discuss in detail three critical points regarding the methods of reaching high bracing points or the apex of the truss.
- (c) Discuss in detail the seven points of erecting the first and second trusses if a crane is not used for the task.
- (d) Discuss in detail the process of erecting the subsequent roof trusses to complete the roof.

2. Steel truss systems

(a) Access the National Association of Steel-Framed Housing Inc. (NASH) website and go to the General Guide to Steel-Framed Building or obtain a copy of this guide from your instructor and carry out the following research tasks.

- (i) Identify and list and explain eight benefits that steel framing systems offer.
- (ii) Identify and explain the two different screws used for fixing trusses in place for a:
 - tiled roof
 - sheet roof.
- (b) Access the National Construction Code 2019: Class 1 and Class 10 buildings and identify and carry out the following tasks.
 - (i) Identify and explain the section and part giving reference to structural stability and resistance.
 - (ii) Identify and explain the section and part giving reference to steel framing.
 - (iii) Identify and explain the acceptable construction manuals and Australian Standards for steel-frame construction that will satisfy the requirements of Part 2.1.1 Structural stability and resistance.

End-of-chapter activity

Using the house plans as supplied in the Appendix, in line form on a sheet of A2 or A3 paper, create a truss layout and plan, including the overhang for a 450 mm eave to suit the roof of the house at a scale of 1:50.

Trusses will be spaced as normal to accommodate a colorbond sheet roof. All truss types should be noted and numbered as per a conventional truss plan.

AUSTRALIAN BUILDING CODES AND STANDARDS

Safe Work
Australia—Code
of Practice 2018:
Managing the risk
of falls in housing
construction

WorkSafe
Victoria, *Compliance
Code—Prevention
of Falls in General
Construction*, 2nd
edition, 2019

National
Construction Code
(NCC): Building Code
of Australia

AS 4440–2004
Installation of
nailplated timber roof
trusses

AS 1684–2010
Residential timber-
framed construction

Tradie talk—We will be working at height to erect the trusses today. This is high-risk work. By law we must have a SWMS in place before we start. Let's have a toolbox and get it done

Chapter 24

Construct eaves

Learning Outcomes

LO 24.1 Know about types of eaves and their construction

LO 24.2 Understand barge design and construction

LO 24.3 Construct eaves

LO 24.4 Construct the gable end

LO 24.5 Line eaves

LO 24.6 Know about metal fascia

Introduction

Eaves are a very important part of the roof structure of a building. The eaves are the part of the roof structure that extends past the wall line. The eaves provide the building with protection from the sun and rain. They can assist in regulating the temperature inside the building. They can be decorative as well as ensuring that rain or snow fall away from the wall cladding.

The design and size of the eaves will be specified on the plans for the structure, as can be seen on drawing 04 in the Appendix.

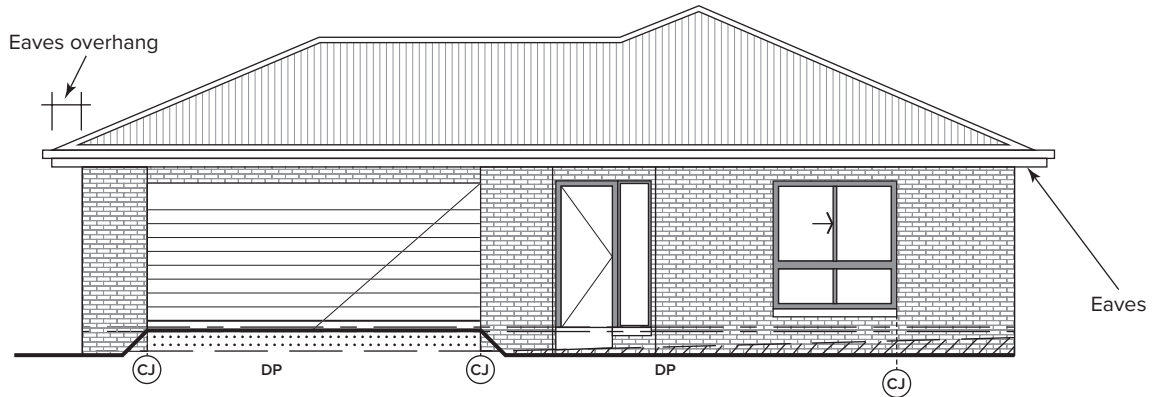
While constructing the eaves framing, always refer to AS 1684 Residential timber-framed construction to determine the correct timber sizing and stress grading for the various timber framing components. If using metal framing components, refer to the National Association of Steel-Framed Housing (NASH) Standards.

The construction of eaves is carried out off the ground and normally requires some sort of platform to be built. You must ensure the platform used is compliant and safe. If the platform deck is above 2 m, handrails must be installed and you must comply with working at height regulations and codes.

In this chapter you will learn how to set out, construct and line eaves and barges on a domestic building, including the installation of metal and timber fascia.

Figure 24.1 shows the eaves on a building and their overhang (this figure is part of the plans that can be found in the Appendix).

Fig. 24.1 Eaves overhang



The eaves overhang can vary depending on the design of the building. If the eaves are merely for decoration, they can be quite short. However, if the eaves are to be used to stop direct sunlight from entering the windows at the height of summer, the overhang will be much greater.

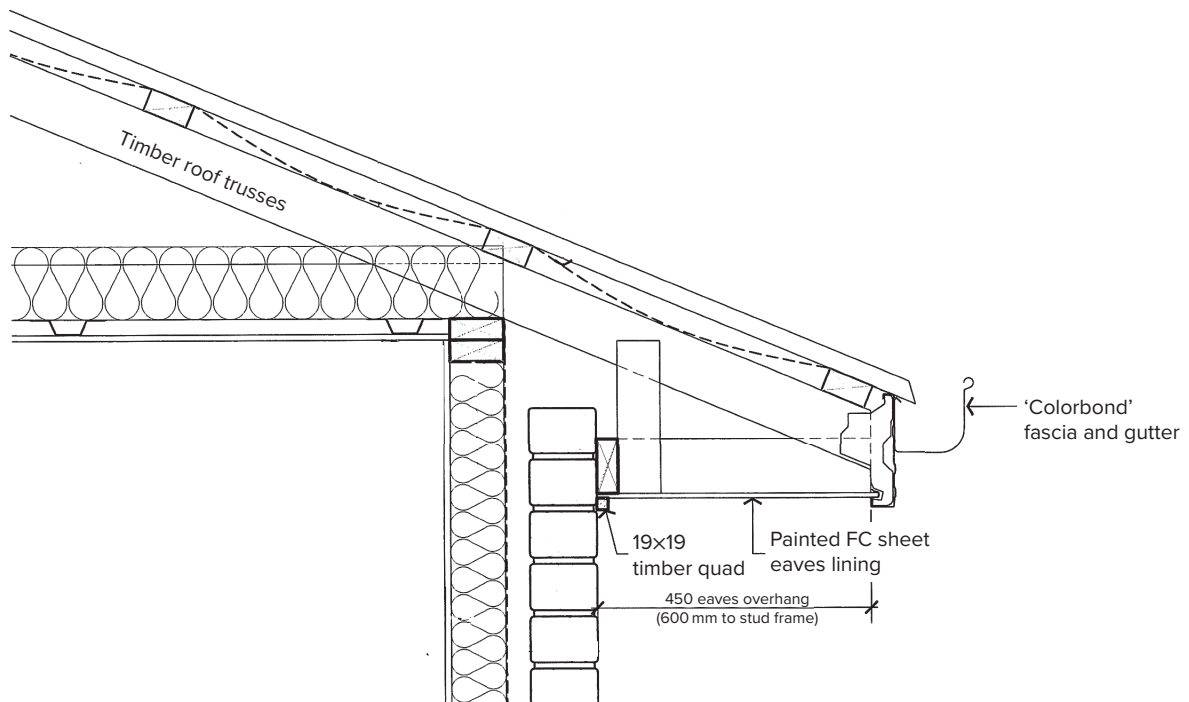
Figure 24.2 shows an exploded sectional view of the eaves from the plans located in the Appendix.

It also shows the construction of the eaves plus the distance between the fascia and the brickwork/eaves lining.

The design and construction of this type of eaves is very common and could be considered typical of many Australian homes.

TIP Care must be taken during eaves construction to ensure the top course of the brickwork is not dislodged. A gap should be left between the eaves trimmer/batten and the top of the brickwork. This gap is required to allow for any settling of the roof, which would push inwards onto the brickwork, compromising the integrity of the brickwork.

Fig. 24.2 Eaves sectional view

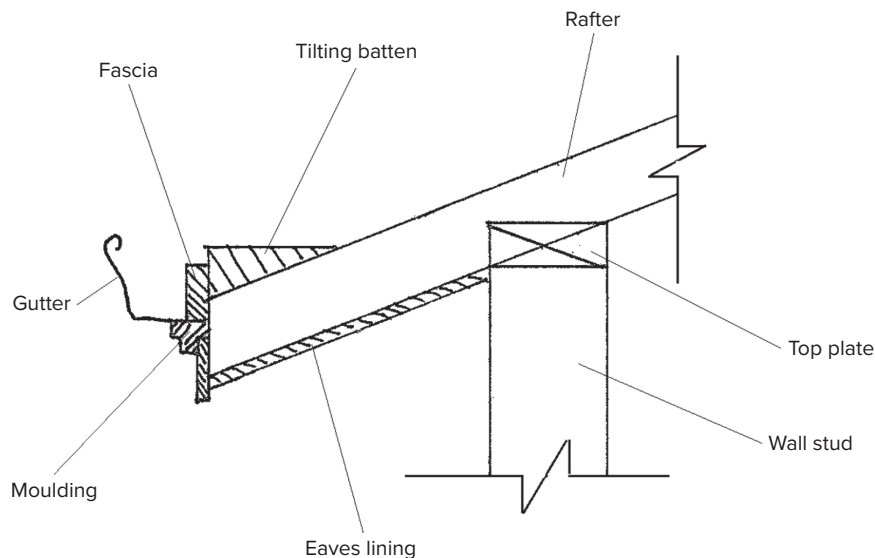


24.1 Know about types of eaves and their construction

24.1.1 Raking eaves

This type of eaves could be considered the simplest to construct. The rafter tails become the structure of the eaves. Figure 24.3 shows that the lining is attached to the bottom of the rafter; however, the lining can be installed on the top of the rafter tails or not at all. A small fascia is shown, installed at the end of the rafters so the gutter can be secured. This is not always the case—the fascia may be omitted and the gutter attached directly to the end of the rafters.

Fig. 24.3 Raking eaves



24.1.2 Boxed eaves/level eaves

Various methods of construction may be used for boxed eaves. This is the most commonly used type of eaves and is more complicated to construct than those already discussed.

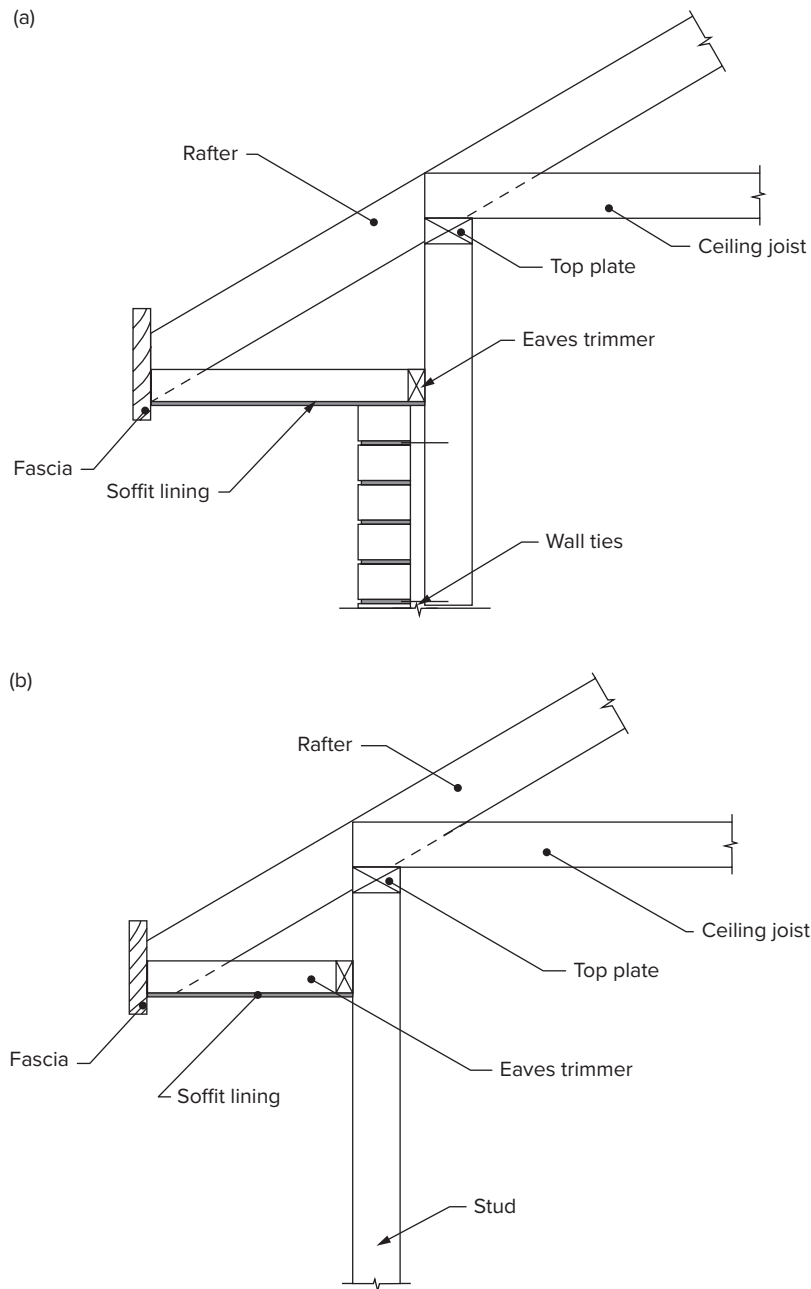
Figures 24.4a and b show two methods of constructing boxed eaves. The eaves trimmer is supported by the stud wall, and the height of the trimmer is determined by the bottom groove machined into the back of the fascia to accept the eaves/soffit lining. This height is levelled across to the wall and the batten is installed. The cladding butts up to the eaves/soffit lining.

24.1.2.1 Boxed eaves with hanger

Figures 24.5a and b show the construction of a boxed eaves using a hanger to support the trimmer. Two methods are shown: Figure 24.5a shows the cladding butting up to the eaves lining, while Figure 24.5b shows the brick cladding extending past the level of the eaves. This second method could be considered the norm for brick veneer buildings as it allows the cladding and the frame to move independently of each other. The quad is fixed to the eaves trimmer only.

Figure 24.6 shows a boxed eaves as described earlier; however, the gutter is concealed behind the fascia. This method of eaves design/construction is not currently used, the big drawback being that once the gutter requires replacing, the roofing material needs to be lifted to replace the gutter; the timber fascia also tends to rot quicker compared to a non-concealed gutter.

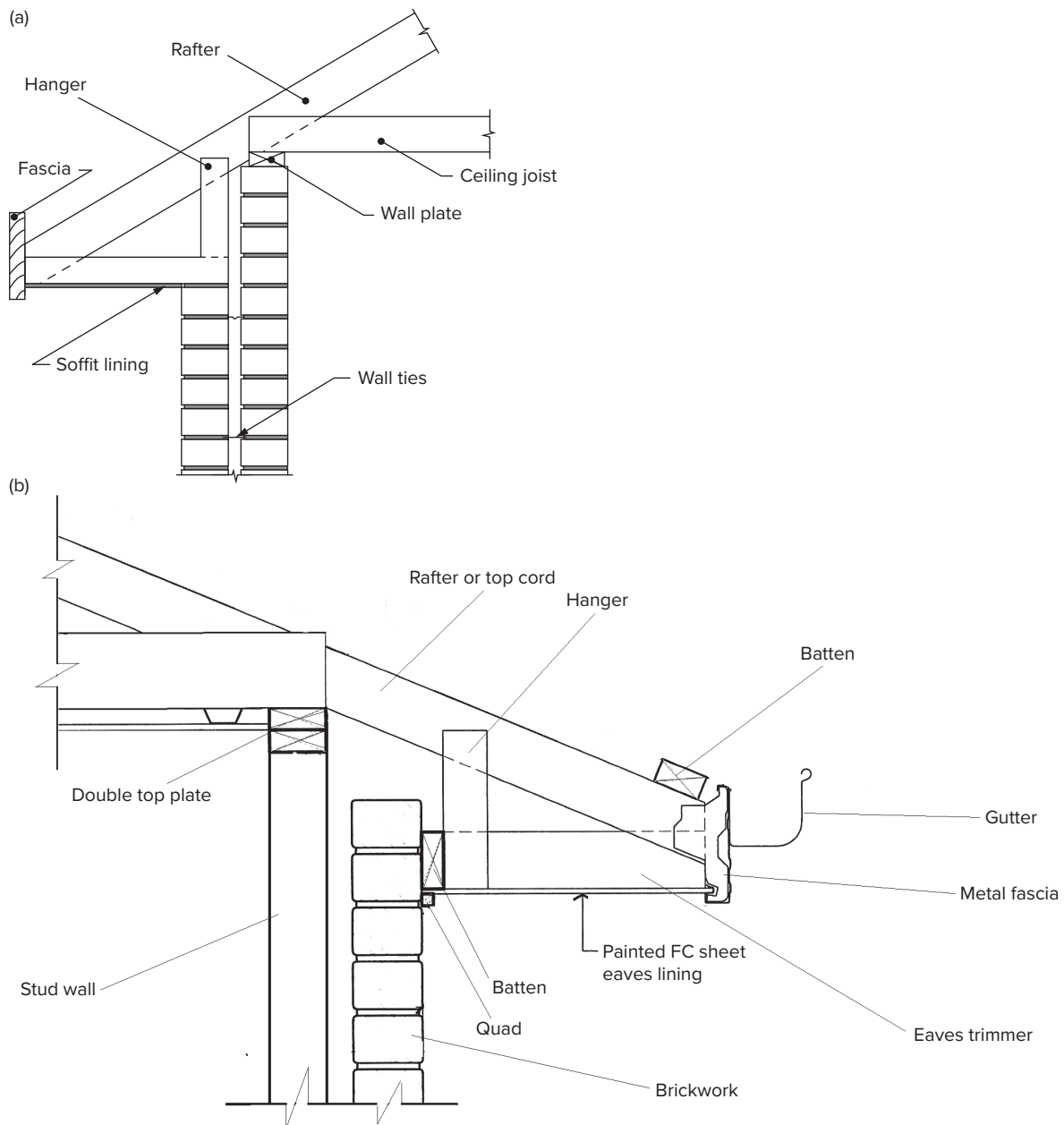
Fig. 24.4(a) Boxed eaves: (a) method 1—brick veneer; (b) method 2—timber cladding



CHECK YOUR UNDERSTANDING

1. Name four different types of eaves construction.
2. There are two types of boxed eaves. What is the difference between them?

Fig. 24.5(a) Boxed eaves with: (a) hanger double brick; (b) hanger brick veneer



24.2 Understand barge design and construction

There are a number of ways to construct and finish the gable end on a roof.

Figure 24.7 shows a gable end roof with an overhanging barge. This example shows the eaves is raking.

Figure 24.8 shows a boxed gable. In this case, the whole gable end is built in and overhangs the wall below.

Fig. 24.6 Boxed eaves with concealed gutter

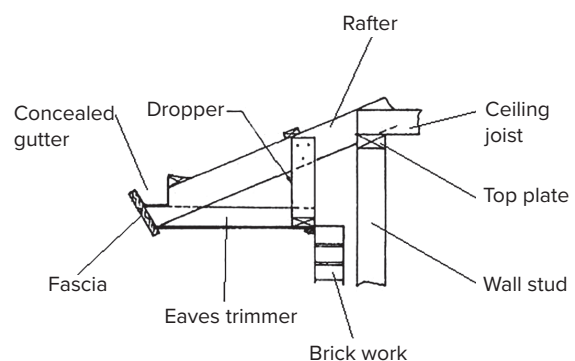


Fig. 24.7 Gable end roof with overhanging barge

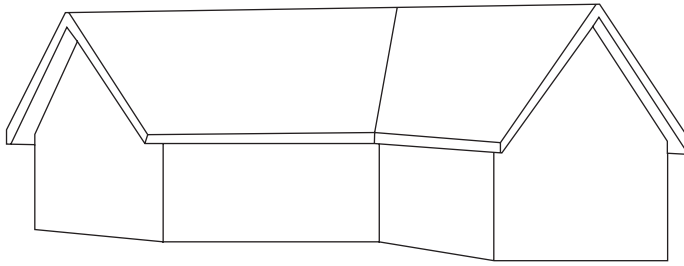
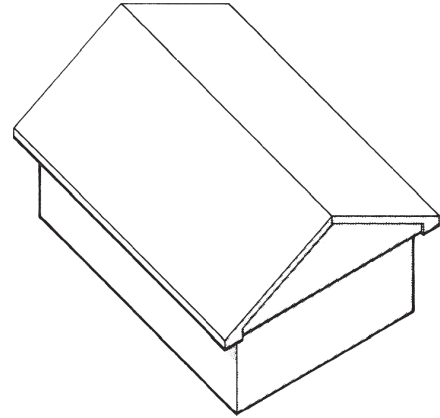


Fig. 24.8 Boxed gable



Lastly, the gable end can be finished off without any barge overhang. It would look similar to Figure 24.7 but without an overhang.

In any of the examples shown, the eaves can be constructed on either the rake or level. The finishing off and transition to the gable end and barge can vary.

24.2.1 Transition of eaves to gable

24.2.1.1 Method 1

This is used when constructing a level boxed eaves that abuts a gable end. The transition point requires special attention, and an eaves stop end has to be constructed. The position of this stop end can be either in line with the barge or in line with the external wall. Figure 24.9 shows a gable end roof with an overhanging barge, with the eaves stop end constructed in line with the barge. This method would also be similar for a box gable end. The fascia on the eaves would butt into the back of the barge board, and the bottom of the boxing and the fascia are level. The point at the bottom of the fascia indicated as 'A' in Figure 24.10 determines the height of the barge in relation to the fascia. The bottom of the barge and the bottom outside point of the eaves are flush at this point.

Fig. 24.9 Eaves stop end

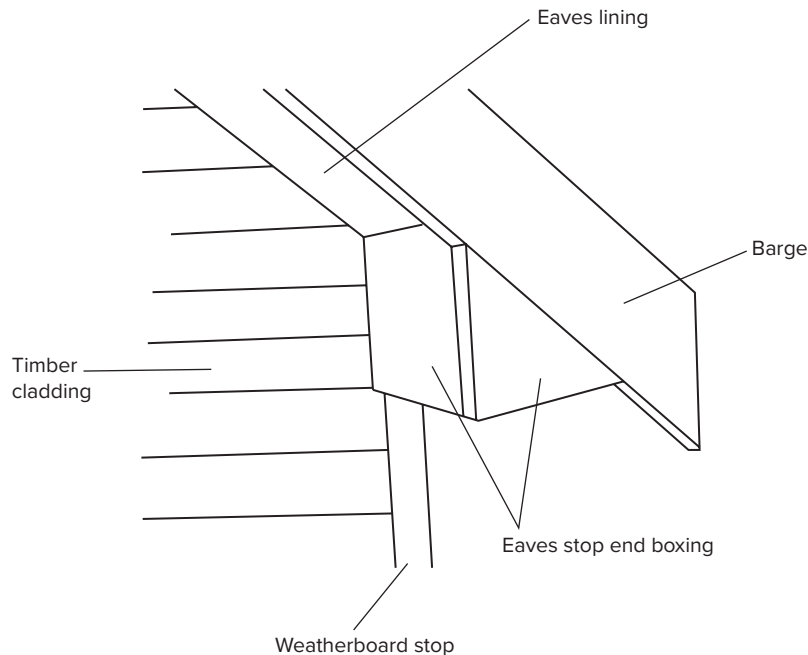
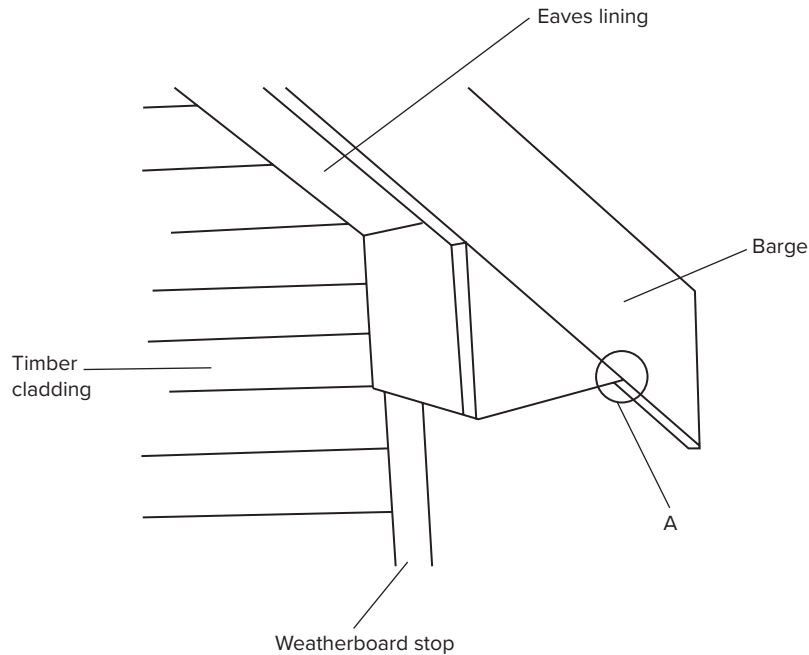
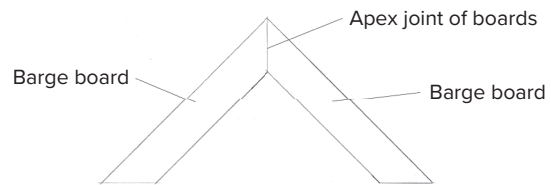
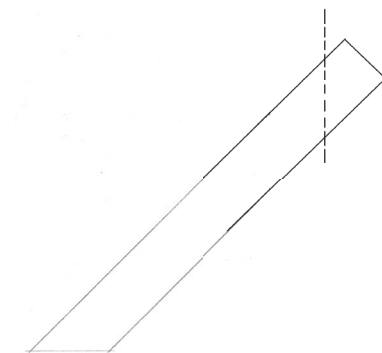


Fig. 24.10 Determining the height of the barge**24.2.1.2 Method 2**

Another way to achieve this transition is to install the barge with its groove meeting the fascia groove accurately, so that the gable end soffit lining runs down and into the fascia groove. There is then a neat little triangle to infill, transitioning from eaves lining to gable soffit lining. The barge can run past the fascia cut-off to cover the end of the guttering, and the bottom of the barge overhang can be trimmed off level with the bottom edge of the fascia. The offcut becomes the 'sprocket' and is attached to the top edge of the barge to further hide the end of the gutter.

Fig. 24.11 Apex joint of barge boards**Fig. 24.12** Measuring up the barge**24.2.2 Apex junction of a barge board**

This junction point at the apex of the roof where the barges meet is important—the joint needs to be neat and plumb (Fig. 24.11). When installing the barge, one side should be offered up and tacked in place. The barge should be longer than required (Fig. 24.12). Once up, locate where the apex is (the dashed line in Fig. 24.12). Using a spirit level, plumb a line down and mark, then cut to the line. Install the cut barge and then fit the next barge to the one already installed.

CHECK YOUR UNDERSTANDING

3. List three ways in which the end of a gable can be finished.

24.3 Construct eaves

Once the roof is constructed, the first step in constructing the eaves is to work out the eaves overhang. This is normally given as a horizontal measurement, which can be found in one of the drawings in the building plans. Figure 24.2 shows how this measurement may be given. This measurement is applied to the rafter tails at either end of a roof (Fig. 24.13).

TIP Never measure the eaves overhang on each individual rafter. If the top plate is not straight, then the rafter cuts won't be in line and there will be a bow in the fascia. Measure only at each end and then string a line through to get the cut-off positions, as shown in Figure 24.13.

Once the length of the rafter tails are marked, a spirit level can be used to plumb the line down for the cut (this angle should be the plumb cut of the rafter).

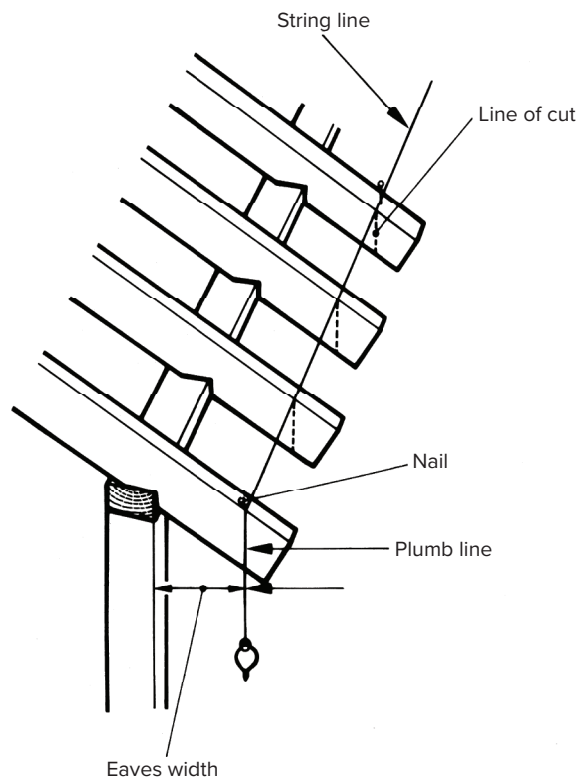
This method of marking out the rafter tail length is also used at the external corners of a hip end, as shown in Figure 24.14, and internal corners where a valley is formed.

Once the rafter tails have been cut off, the timber fascia can be installed. When installing timber fascia, the external corners need to be mitred if joining the fascia along its length. First, the joint needs to be supported, either at a rafter, or noggins can be installed between two rafters to support the fascia joint. The fascia should be mitred when joining it, in its length.

The roof battens determine the height of the fascia. Figure 24.5b shows that the top of the fascia is in line with the top of the roof battens. This line needs to be used, so that the roofing material can easily go over the fascia and finish directly over the gutter, as shown in Figure 24.2. If raking eaves have been specified, the lining materials can be installed either on top of the rafter or on the bottom, as stipulated by the plans, and the eaves finished.

If boxed eaves have been specified with a hanger, then the remaining framing needs to be installed. Figure 24.5b shows that the position of the eaves/soffit lining determines the position of the eaves trimmers. The eaves trimmers need to be installed level. The hanger holds the eaves trimmers in place and the eaves/soffit lining can be installed. A timber moulding is then installed at the junction of the wall cladding and eaves/soffit lining (Fig. 24.5b).

Fig. 24.13 Marking rafters to a line



CHECK YOUR UNDERSTANDING

4. What method should be used to mark the eaves width on the rafter tails prior to cutting?

Fig. 24.14 Marking rafter tails on a hip roof

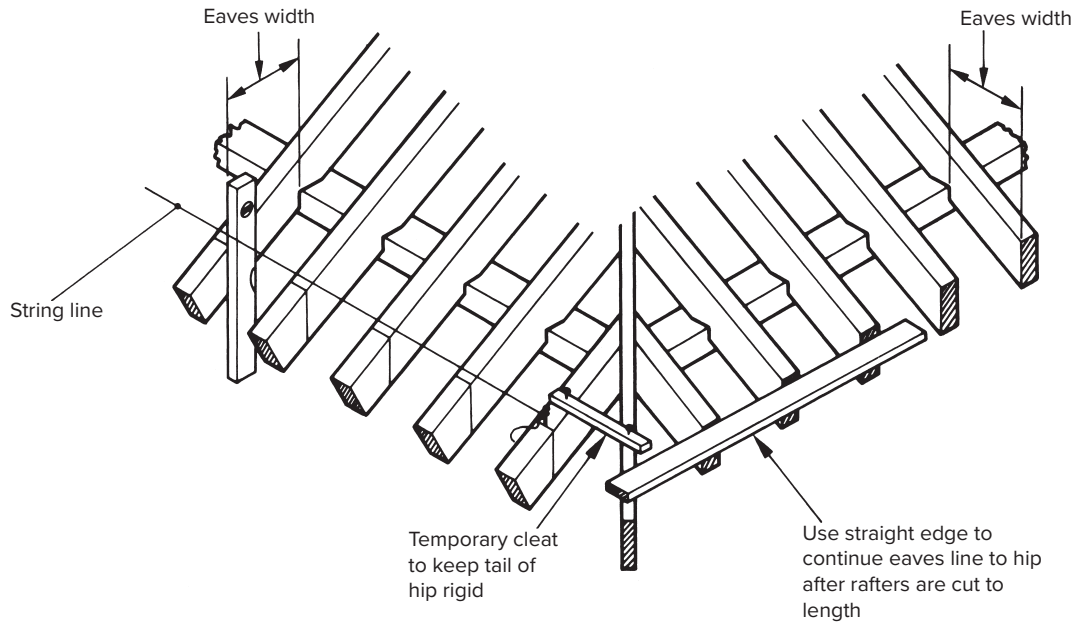
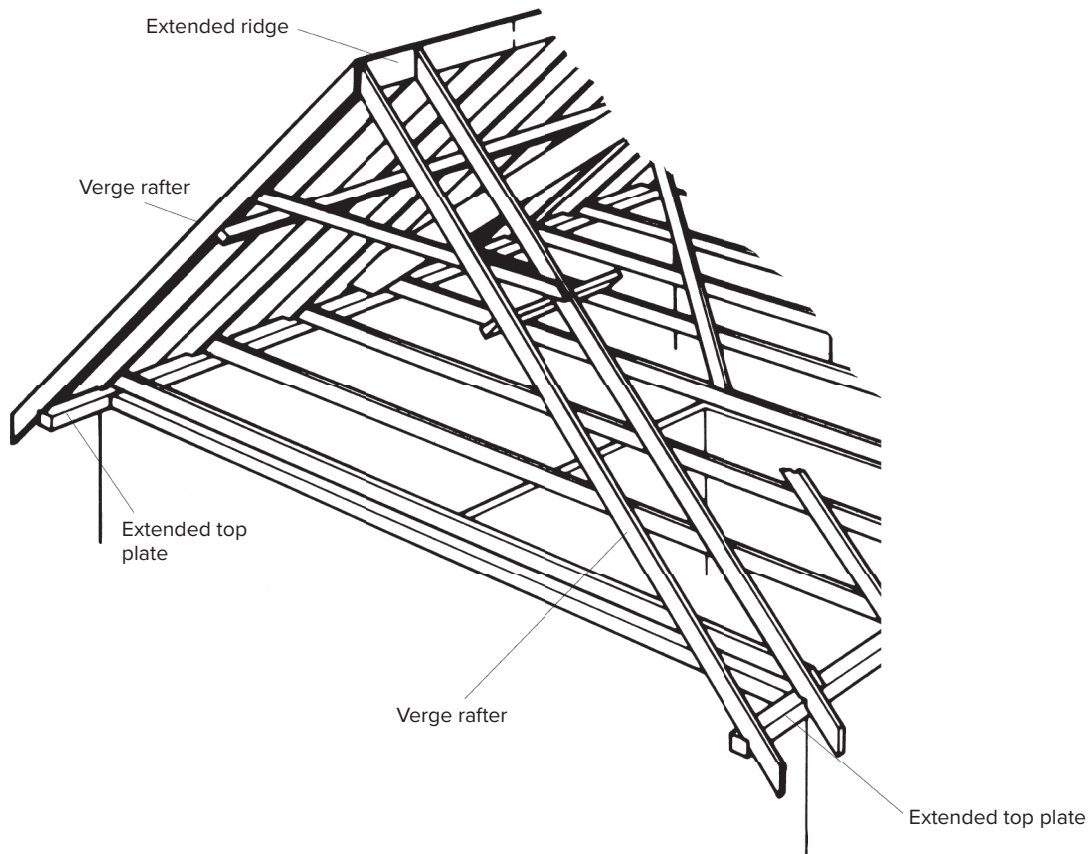


Fig. 24.15 Verge rafters



24.4 Construct the gable end

As discussed earlier in this chapter, there are a number of ways to finish off the gable ends of a building. If there is to be a gable overhang, one method of construction is to run the top plates or another larger section of timber past the end of the wall the width of the overhang as stipulated in the plans. The ridge is also run long by the same measurement. This is to accommodate a verge rafter (Fig. 24.15). Figure 24.16 shows the underpurlin running through to provide extra support. The roof battens are also run long.

The infill wall can now be constructed as shown in Figure 24.16 to accommodate the wall cladding.

An alternative method used to construct a gable overhang is to use outriggers that extend over the gable end infill wall (Fig. 24.17).

On many occasions, no gable overhang is required, in which case the gable wall and verge rafter are flush (Fig. 24.18).

Fig. 24.16 Gable end infill wall

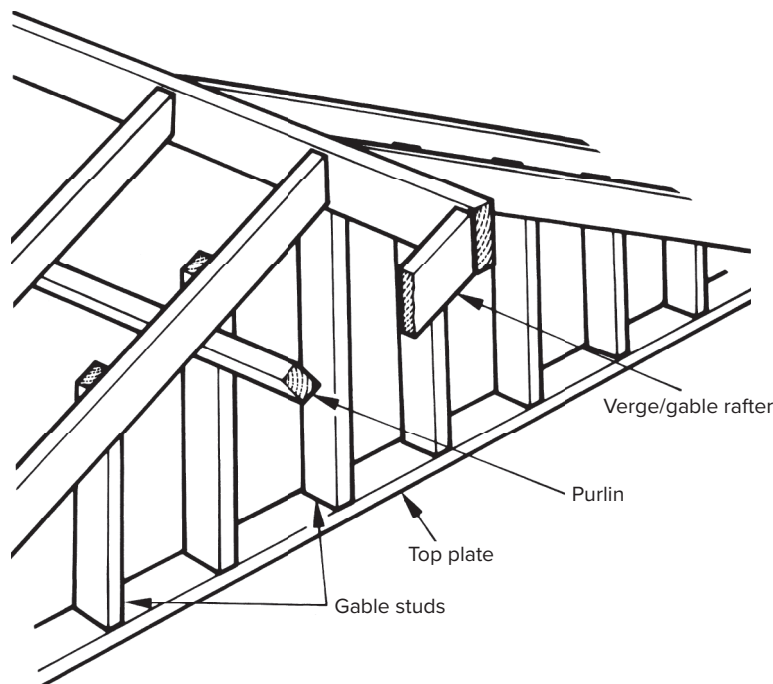


Fig. 24.17 Gable overhang using outriggers

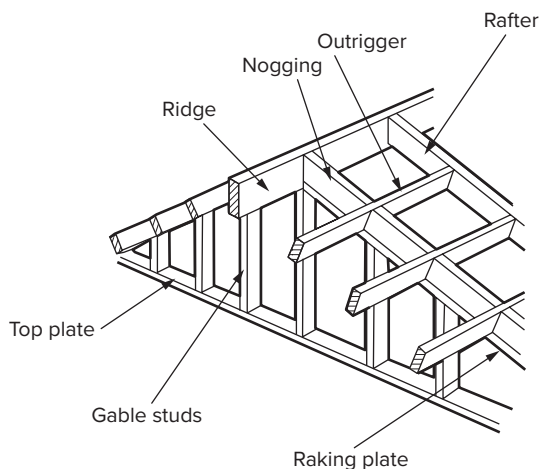
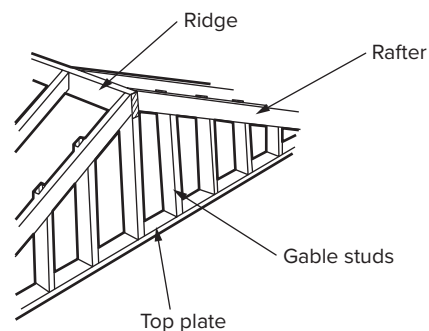


Fig. 24.18 Gable end flush with infill wall



CHECK YOUR UNDERSTANDING

5. What are two methods of constructing a gable overhang?

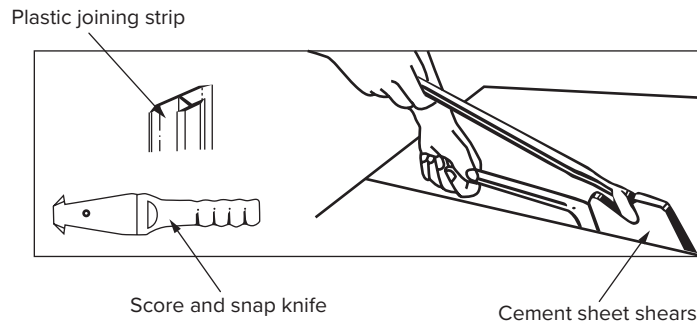
24.5 Line eaves

A number of materials can be used to line eaves, including timber lining boards, cement sheets and plywood. Information on these materials can be found in Chapter 29, Internal linings and fixings.

The most common material used to line eaves is 4.5 mm cement sheet. This product can be purchased in standard sheet widths of 450 mm, 600 mm and 750 mm by 2400 mm long to suit the eaves. This product is easy to install and can be nailed or screwed into position. Bonding agents are available to help with securing the product, and plastic joining strips are used to join the sheets at the ends. Joining strips also cover any cut edges. An example of a joining strip is shown in Figure 24.19.

Cement sheets can be cut using a variety of tools, including cement sheet shears, score and snap knives (Fig. 24.19), electric shears or wet/dry circular saws. Always read the product's safety data sheet (SDS) prior to using any of these products.

Fig. 24.19 Cutting and joining a cement sheet

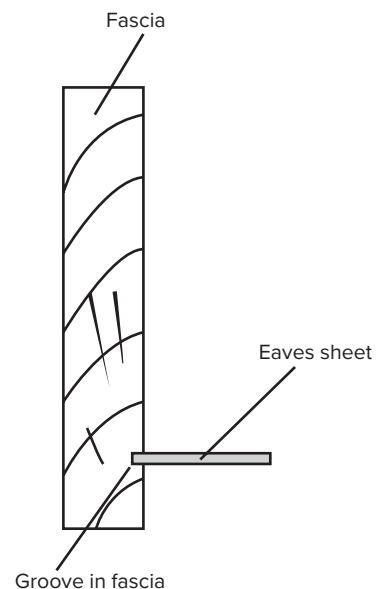


24.5.1 Installation of eaves sheet lining to boxed eaves

The installation of cement sheet eaves lining is relatively straightforward; however, the manufacturer's installation instructions should always be consulted prior to installing any product.

1. Complete the eaves framing, ensuring the bottom of the eaves trimmer is level with the top of the bottom groove on the back of the fascia (refer back to Fig. 24.2).
2. Measure the width of the eaves, not including the depth of the groove, between the cladding and the back of the fascia.
3. Cut the eaves sheet to size.
4. Offer up the eaves sheet on a slight angle with the cut edge towards the wall cladding.
5. Line up the salvage edge of the sheet to the groove on the back of the fascia and gently push the sheet into the groove while lifting up the other side of the eaves sheet (Fig. 24.20).
6. Once the sheet is hard up on the eaves trimmer, using a chisel lever off the wall cladding to push the eaves sheet into the groove on the back of the fascia.
7. Secure the sheet to the trimmers using the manufacturer's recommended fixings.
8. Cut a piece of plastic joiner and slide over the end of the sheet, so that the end of the next sheet is supported and any cut edges are hidden.
9. Repeat this process until all of the eaves lining are installed.

Fig. 24.20 Timber fascia



10. Use a timber moulding (usually a quad) installed at the junction of the eaves lining and wall cladding to cover up any small gaps and the cut edge of the cement sheet (refer back to Fig. 24.2). When nailing the moulding, make sure you don't nail it into the wall cladding—secure into the trimmers only.

TIP When joining the timber moulding in length, always use a mitred cut. For external corners (at the hip end), an external mitre should be used. For internal corners (where a valley occurs), a scribe joint should be used. Refer to Chapter 29 for further details.

CHECK YOUR UNDERSTANDING

6. List three materials that can be used as eaves/soffit lining.

24.6 Know about metal fascia

Metal fascia is increasingly being used instead of timber fascia in contemporary homes for a number of reasons, including the fact that it is:

- lightweight
- easy to install
- free of defects compared to timber fascia
- uniform in size
- available in many colours
- not liable to rot
- paint-free
- available in multiple lengths.

The construction of the eaves framing does not differ all that much when using metal rather than timber fascia. The main difference is that the fascia is supported by brackets that are secured to the end of the rafters (Fig. 24.21).

These brackets are installed to a string line to ensure the fascia remains straight and level when installed. The metal fascia clips onto the brackets, which means the fixings are not visible (Fig. 24.22).

Fig. 24.21 Metal fascia and bracket

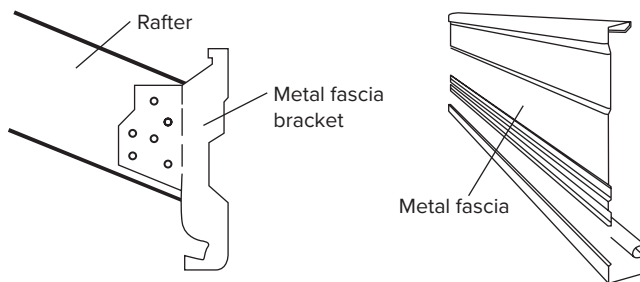
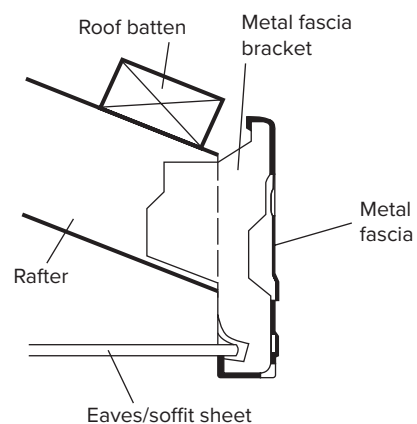


Fig. 24.22 Installed metal fascia



CHECK YOUR UNDERSTANDING

7. How is a metal fascia attached to the rafters?

Student research

Investigate different verandah roof designs that can be used on a domestic building.

End-of-chapter activity

As part of your apprenticeship training, you will be required to construct 3 m of:

- timber verge gable eaves
- timber boxed gable eaves
- timber boxed eaves
- timber raked eaves
- steel fascia with hangers.

In constructing these timber eaves, the following must be included:

- an apex junction on the barge board
- a junction between the barge board and the plumb fascia
- a junction between the fascia and eaves lining at the valley
- a junction between the fascia and eaves lining at the hip.

AUSTRALIAN BUILDING CODES AND STANDARDS

National
Construction
Code (NCC)

AS 1684–10
Residential
timber-framed
construction

National
Association
of Steel-Framed
Housing (NASH)
Standards

Tradie talk—Sight the fascia for straight

Chapter 25

Work safely at heights

Learning Objectives

LO 25.1 Understand the risks of working at heights in building and construction

LO 25.2 Follow workplace and regulatory requirements for working safely at heights

LO 25.3 Select and prepare fall-protection equipment

LO 25.4 Carry out equipment safety checks

LO 25.5 Conduct work tasks

Introduction

Chapter 1, Work health and safety, covered some of the most common causes of injuries in the Australian construction industry. Falls from heights and being hit by falling objects are the two most common causes of death in the building and construction industry. Although fall-related deaths occur in many sectors, nearly half of all such deaths take place in the construction industry.

For this reason, it is essential that you understand safe work practices when working at heights.

This chapter looks at the risks of working at heights above 2 metres. You will learn about the types of equipment available to access areas where work is undertaken at heights, and how to work safely while you are above ground. In this chapter you will learn about:

- how to identify and report problems with scaffold or work platform systems before commencing work
- the different equipment used to work safely at heights
- workplace and regulatory requirements and how they apply to working safely at heights
- how to identify hazards and reduce risks associated with working at heights.

WORKPLACE SCENARIO

Here is a snapshot of just three different falls from height recorded by WorkSafe Victoria in the first two months of 2018. They illustrate that falling from heights can happen to anyone at any age, doing different types of construction work. In one of the cases, the height was only 1.5 metres off the ground and yet the fall resulted in a broken hip for the worker.

- A 21-year-old man suffered a neck fracture after he fell through a suspended floor while carrying out renovation work in the Geelong suburb of Bell Post Hill.
- A 61-year-old worker fractured his hip after slipping off a 1.5 metre ladder at a multi-storey development in Southbank.
- A worker in his 20s was taken to hospital with a head laceration after falling almost 2.5 metres while installing battens on the roof of an office building in Colac.

As you can see from these real cases, a fall from height may not always lead to death. Injury and long-term pain, rehabilitation, suffering and time lost on the job can all result from a fall.

25.1 Understand the risks of working at heights in building and construction

All construction work carries some type of risk, but when work is undertaken at heights, the risks can change and increase dramatically. A low-risk task at ground level might become a high-risk task when conducted above 2 metres.

Chapter 1 explained how to use the hierarchy of hazard control to identify, document and control the hazards and risks associated with a site and the job tasks, before work commences. The processes for planning to work at heights follow the same steps as covered in Chapter 1. The only difference is that now you also need to consider the specific risks of doing work at heights.

25.1.1 What are the work requirements?

The first step is to understand the requirements of the work to be undertaken. You can find out about the work requirements by:

- reading the plans and specifications for the work
- attending toolbox meetings with your site supervisor and teammates
- communicating with your supervisor or employer about the work.

As you learn the requirements of the work, think carefully about the conditions under which the work must be done and the hazards of the work. Will any hazardous chemicals be required? If so, review the relevant material safety data sheet (MSDS) for each product and include the use of these chemicals in discussions about the risk.

Once you understand the requirements of the work, you must contribute to the development of the safe work method statement (SWMS). Depending on the nature of the work, a job safety and environmental analysis (JSEA) may also need to be documented.

Contributing to both the SWMS and JSEA involves identifying the hazards and risks associated with the work.

The following is a recap of the key things to know about hazards, risks and risk control.

25.1.2 Hazard versus risk

A **hazard** is something that has the potential to cause harm to a person. Harm can include injury, illness, including psychological illness, or death.

A **risk** is the *likelihood* that a hazard will cause harm (death, injury or illness) to a person. For example, climbing a ladder is hazard. The risk when climbing a ladder is the risk of falling and causing harm to yourself and/or to others. The risk varies depending on the height climbed, angle of the ladder against the surface and even the weather conditions.

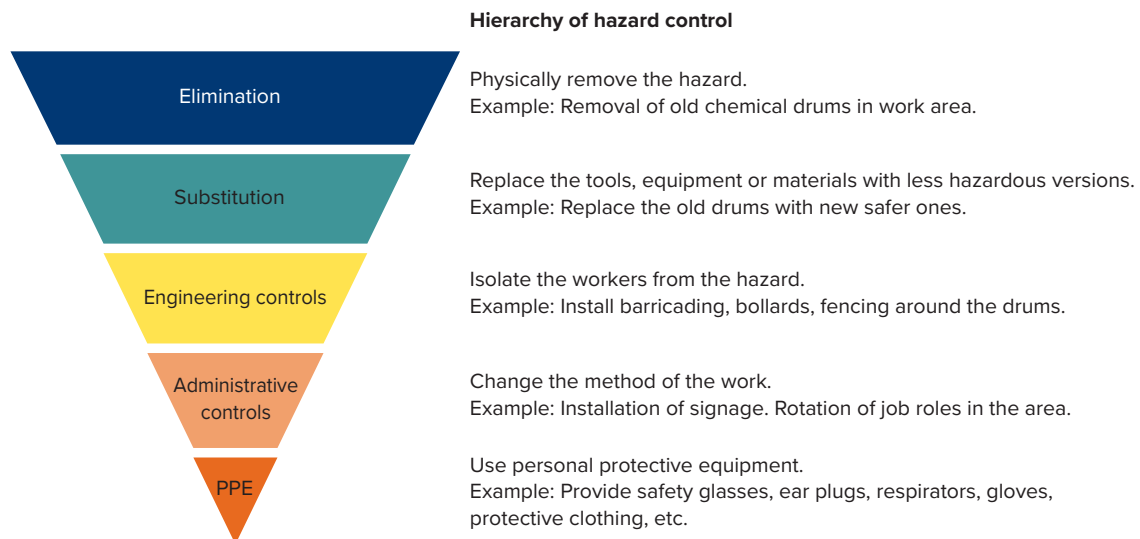
Once the hazards of working at heights have been identified, the likelihood that the risks associated with the hazards will cause harm must be assessed and documented in the SWMS and/or JSEA.

You must review these completed documents and check with your site supervisor or boss if you have any questions, doubts or concerns about the ways in which the risks are going to be controlled.

25.1.3 Hierarchy of controls

Think back to the hierarchy of hazard control (Fig. 25.1) that was introduced in Chapter 1.

Fig. 25.1 Hierarchy of hazard control



The highest level (i.e. the best way) of controlling a hazard is elimination of the hazard.

If working at heights is a hazard, then in practical terms, eliminating the hazard would require doing the work at ground level. If it is possible to do any or all of a task at ground level rather than at height, the SWMS should document the part of the work to be conducted at ground level.

In reality, however, some construction work can only be done at height. Consider, for example:

- roof work such as erecting roof trusses, installing roof insulation or solar panels
- erecting the internal walls of a second-storey house renovation
- replacing windows on the second storey or above of an existing building.

Where the hazard cannot be eliminated, controls that *reduce* the risks must be identified, documented in the SWMS and followed. As a worker on-site, you have a responsibility to participate in developing the SWMS for the tasks you will undertake.

Let's take a closer look at the risks associated with working at heights and what you need to assess before you start.

25.1.3.1 Risks above you

When working at heights, think about what there is above you. One of the major risks when working at heights is the risk of electrocution from contact with live overhead powerlines.

These overhead powerlines contain high-voltage electricity; if this passes through someone it can cause death or permanent disability. Death can occur from the sheer surge of electrical force passing through the person. Even if the electrical shock itself does not cause death, it can cause the worker to fall to their death.

State and territory work health and safety regulators provide guidance material on this risk, including information sheets and Codes of Practice for use when working near overhead powerlines.

Make sure you understand your jurisdiction's requirements. In Victoria, for example, if work is to be conducted within 3 metres of an overhead powerline, the employer must obtain permission from the relevant electricity company and may be required to put in place a range of preventative measures, such as 'no-go zones' before the work can legally commence.

25.1.3.2 Risks below you

Working safely requires you to consider not only your own safety but that of others. People working or walking under your work area are at risk of objects falling on them from above. Tools, construction materials and debris can easily fall from a height and hit those below if proper controls are not in place.

It is important to consider how to control the risk of objects falling from the work area at height. Some of the relevant controls are discussed later in the chapter.

25.1.3.3 Weather conditions

Much of the work done on a construction site is done outdoors, and weather conditions can significantly increase the risks for those working at heights. Rain, wind and extreme heat or cold can create slippery or unstable conditions for workers and equipment.

Think about climbing a ladder, which involves risk at the best of times. Going up and down a ladder during strong winds or heavy rain further increases the risk of workers falling because they have lost their footing, slipped or lost their grip on the ladder.

Wet weather can also turn the solid foundations used for positioning elevated work platforms and ladders into unstable foundations.

Working at heights in extreme heat can lead to workers becoming dehydrated quickly, which can cause dizziness, nausea and even blurred vision, all of which can compromise safety.

Your workplace must take steps to eliminate hazards or reduce risks caused by poor weather conditions.

Controls can include:

- working indoors (where practicable)
- postponing outdoor work until the weather conditions improve
- providing access to shelter
- providing personal protective equipment (PPE), such as eye protection to protect against the glare of the sun.

SAFETY TIP Before commencing work at height, check local weather forecasts for extreme weather warnings in your area. Check for signs of rain, hail, strong wind and other conditions that may make working at heights unsafe.

CHECK YOUR UNDERSTANDING

1. For each of the following activities, tick the relevant column to identify if it is a hazard or a risk. Provide a reason for each answer.

Activity	Risk	Hazard	Reason
Working outdoors on a hot day, exposed to the sun			
Noisy machinery			
An open wound			
Handling chemicals			
Workplace bullying and/or violence			
Lifting a heavy object			
Working at heights			

25.2 Follow workplace and regulatory requirements for working safely at heights

Chapter 1 looked at workers' obligations to follow Commonwealth, state or territory work health and safety (WHS) legislation, Australian Standards and Codes of Practice when working on construction sites.

A person conducting the business or undertaking (PCBU) has a responsibility to manage the risk of falls in the workplace, but as a worker you also have a responsibility to take care of your own health and safety in the workplace. Your employer has a duty to consult with you about how to control risks, so the more you understand about the risks associated with working at heights and the controls involved, the more you will be able to participate in the consultation process.

Once the control measures have been agreed, you must follow the procedures for safely accessing and exiting work areas, moving between access points and, importantly, for checking and reporting any faults and defects in equipment.

25.2.1 Legislation and regulations

Under the *Work Health and Safety Act 2011* (Cth), workers and employers have shared roles and responsibilities to ensure that construction worksites are safe. Most states and territories have adopted the Model WHS Act, and it is important that you understand the nature of your role and responsibilities according to your state or territory legislation.

All states and territories agree that work conducted above 2 metres in height is high-risk work. This means that a SWMS must be prepared before the work starts, and the work must be performed in accordance with the SWMS. You have the right to participate in developing the SWMS for work you will be doing on a construction site.

25.2.2 Codes of practice

Health and safety legislation and regulations can be difficult to understand and apply in practice. They are often very long, with sections, subsections and clauses that can be difficult to interpret if you are not a lawyer.

To help all workers comply with the relevant legislation, health and safety regulators have developed Codes of Practice (CoP). A CoP is a guidance document that, if followed, will ensure you comply with the relevant laws.

Check the website of your state or territory regulator for relevant compliance Codes of Practice. In Victoria, for example, the relevant CoP that relate to working at heights include:

- Compliance code: Prevention of falls in general construction
- Compliance code: Prevention of falls in housing construction.

TIP Safe Work Australia provides Model Codes of Practice that may also be approved in your state or territory. Check the Safe Work Australia website for the following:

1. National Code of Practice for the Prevention of Falls in General Construction
2. Model Code of Practice: Managing the Risk of Falls at Workplaces
3. Model Code of Practice: Managing the Risk of Falls in Housing and Construction
4. Model Code of Practice: Construction Work

25.2.3 Australian Standards

On their own, Australian Standards are not law. To become mandatory, a standard must be 'called up' or referenced in an existing law such as in the National Construction Code or in health and safety legislation.

In previous chapters, you have seen the names of many Australian Standards specific to every part of the construction process and specific risks. Australian Standards provide the minimum requirements to be followed for a relevant task.

Some examples of Australian Standards that relate to working at heights include:

- AS/NZS 1892.5: 2000 Portable ladders—selection, safe use and care
- AS/NZS 1891.3: 2020 Personal equipment for work at height—manufacturing requirements for fall-arrest devices

TIP Australian Standards are not available for free—accessing them requires a membership to SAI Global.

25.2.4 Workplace policies and procedures

Workplace policies and procedures are written to incorporate the applicable legislation, Codes of Practice and Australian Standards and are designed to provide a safe working environment. It is your responsibility to follow all workplace policies and procedures when in the workplace. This can include familiarising yourself with:

- your employer's health and safety policy, which will include the processes for reporting and rectifying faulty tools and equipment and the use and fitting of PPE
- site-specific environmental and safety plans, including the range of safety signs and barricades required to protect workers and the public
- site-specific safe work method statements (SWMS)
- safety data sheets that outline the health and safety information you need to understand about the products, substances or chemicals you are using or that are being used on-site
- the safety manuals for plant, tools and equipment that you will be using on-site and any specific manufacturer specifications for the materials you are handling.

While you need to be aware of the legislation, codes and standards, if you follow your workplace policies and procedures you can be assured that you are meeting their requirements.

WORKPLACE SCENARIO

In March 2020, two construction workers in Western Australia were installing a roof on a building when a strong wind picked up. A roof sheet became loose and the sheer force of the wind on the sheeting knocked both workers off the roof. One worker fell 9 metres to the ground and died. The other fell 7 metres and sustained serious injuries.

Just over a year later, in May 2021, Esperance Magistrates Court handed down a significant sentence to the director of the company that had employed the two workers:

- the director was sentenced to two years and two months in jail
- the company was fined \$605 000 for safety breaches
- the director was personally fined \$2250 for operating a crane without a licence.

The director was found liable for failing to do everything reasonably practicable to ensure the workers were not exposed to harm due to the hazard of working at heights. This included failing to provide relevant training for working at heights and not holding the appropriate licences.

CHECK YOUR UNDERSTANDING

2. How are SWMS used to control the risks associated with working at heights?
3. Identify one code of practice that covers working at heights in your state or territory **plus** one other state or territory.

25.3 Select and prepare fall-protection equipment

Chapter 1, Work health and safety, and Chapter 26, Restricted-height scaffolding and work platforms, discuss some of the equipment used when working at heights.

When working above 2 metres, you need to ensure that all equipment:

- is inspected before use to ascertain that it is working correctly and is free from damage
- will give you safe access to the work area
- enables you to work at the required height safely without causing harm to yourself or anyone else on-site
- is inspected immediately after use and at regular intervals for wear and tear.

If equipment such as a static line or inertia reel have been used, each component of the fall-arrest system should be inspected by a competent person in accordance with the manufacturer's specifications.

The sections below look at some of the key pieces of equipment and their components in more detail and explain how to check them for faults before you commence work.

25.3.1 Fall-arrest systems

A fall-arrest system limits how far a worker can fall from a height. It **does not prevent** a worker from falling, but rather limits how far they can fall and therefore reduces the potential impact of a fall.

For this reason, fall-arrest systems are low in the hierarchy of controls.

Examples of fall-arrest systems include catch platforms, safety nets and individual fall-arrest systems. Fall-arrest systems should be used when workers:

- could physically reach an area from which they could fall (for example, if nothing prevents them from reaching the edge of a roof with no barriers)
- have an adjustable restraint line that could lead to a free-fall position
- might fall through a surface

Individual fall-arrest systems are comprised of some or all of the following components:

- anchor points
- harnesses and lanyards
- snap hooks.

25.3.1.1 Anchor points

Anchor points can be permanent or temporary. A permanent anchor is one that remains securely fixed at an appropriate point; for example, on a roof (Fig. 25.2). A permanent anchor would typically be installed in locations where other controls such as guardrails or fall-restraint systems are not appropriate or practicable.

A temporary or portable anchor might be used if there is no place in the structure to attach permanent anchor points. For example, large temporary anchors can be secured to a flat surface (Fig. 25.3), allowing several lanyards to be anchored for a one-off job.

Fig. 25.2 Permanent roof anchor

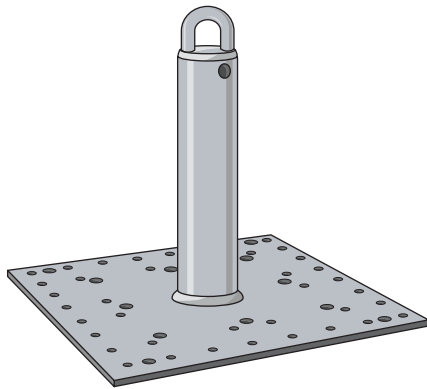
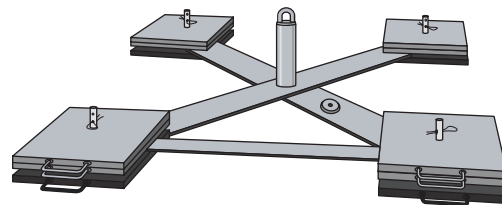


Fig. 25.3 Temporary portable anchor system with four anchorage points



25.3.1.2 Anchorage line

Other smaller fall-arrest systems—for instance, an anchorage line system—can be attached to equipment such as ladders depending on the type of work being undertaken; for example, to ensure safe access to a worksite, elevated work platform or scaffold (Fig. 25.4).

Where an individual fall-arrest system must be used, some important safety and regulatory considerations include:

- Individual fall-arrest systems should be used only if it is not practicable to eliminate work at height or use a higher-level control measure (refer back to Fig. 25.1). For further information on the use of fall-arrest systems, see Safe Work Australia, 'Model Code of Practice: Managing the Risk of Falls at Workplaces'.
- Anyone using a fall-arrest system should wear appropriate head protection to protect them in the event of a fall.

- If a fall has occurred, the equipment used to arrest the fall should not be used again until it has been inspected and certified safe for use again by a competent person.
- Each anchorage point should comply with the anchor strength specified in AS/NZS 1891.4: 2009 Industrial fall-arrest systems and devices—selection, use and maintenance.

25.3.1.3 Snap hooks

Snap hooks provide the locking mechanism required to connect the worker's harness to another part of a fall-arrest restraint system, such as the anchorage line. Harnesses can be with or without an integrated lanyard. At height, it is important to consider the weight the lanyard and safety system may need to hold in the event of a fall. The best protection will come from snap hooks made of steel.

25.3.2 Fall-restraint systems

A fall-restraint system is designed to control a worker's movement to prevent a fall. This is different to a fall-arrest system, which limits how far a worker can fall from a height (as described in section 25.3.1).

Components of fall-restraint systems include guardrails, walkway systems and static restraint lines. A lanyard is used at a length that prevents the wearer from getting too close to an edge.

Where guardrails and walkways are not present or practicable and a restraint line must be used, it is important that an appropriately rated body harness is worn and correctly fitted.

Workers should connect the lanyard to the attachment point on their harness. The length of the lanyard-restraint line combination must be set to prevent the worker from reaching an unprotected edge (Fig. 25.5).

25.3.2.1 Harnesses and lanyards

Harnesses and lanyards are components used to attach a worker to another part of a fall-arrest or fall-restraint system. The harness and lanyard must be appropriate to the situation and the worker. If an incorrect harness and lanyard combination is selected, the worker may fall from the edge of a structure, which can result in severe psychological trauma to the worker as well as physical injury.

Fig. 25.4 Anchorage line system used for ladder safety

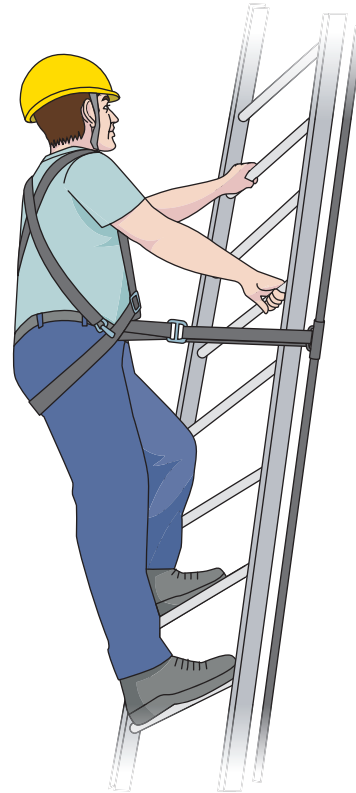
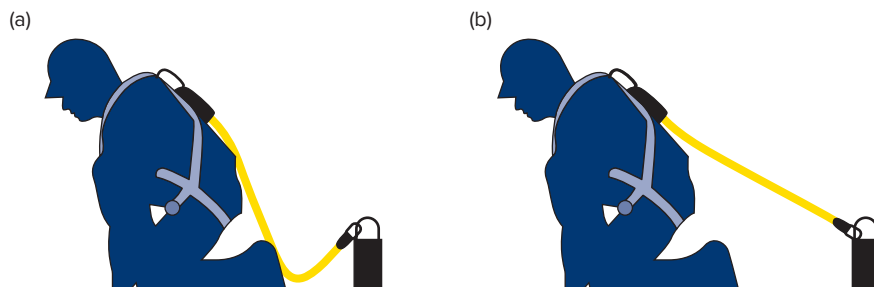


Fig. 25.5 (a) Incorrect technique: lanyard-restraint line combination is too long; (b) correct technique: length of lanyard-restraint line combination will prevent a fall



Before use, it is important that the harness and lanyard are visually inspected for signs of defects, damage or wear and tear. Any visibly worn or damaged components must be reported to the person in charge, who should ensure you are provided with replacement components that are serviceable.

25.3.2.2 Static line systems

Static lines are installed across the working area or close to potential hazards around a work area. They are horizontal, near-horizontal or vertical lines to which a worker may be attached. Static line systems provide continuous attachment between the worker and the structure and are designed to prevent a fall.

SAFETY TIP Fall-restraint systems based on static lines, harnesses and lanyards should be used only when physical barriers such as edge protection and guardrails are not appropriate or practicable.

25.3.3 Scaffolding

Scaffolding enables workers to access various heights and work above ground safely.

Safe Work Australia's *General Guide for Scaffolds and Scaffolding Work* categorises scaffolding as:

- light duty
- medium duty
- heavy duty.

Review your notes from Chapter 26; do you recall the different types of scaffolding?

25.3.4 Elevated work platforms

Elevated work platforms (EWPs) include equipment such as scissor lifts and cherry pickers, which elevate workers from the ground to the height where the work is being conducted. There are different types available, and the correct EWP must be selected for the site ground conditions.

While EWPs provide workers with safe access to heights, there are still many risks associated with their use that must be controlled. The use of an EWP requires its own dedicated SWMS.

In some states and territories, you may need a licence to operate an EWP above a certain height. Regardless of the type of EWP, always consult with the operator before you get onto an EWP to make sure the relevant pre-operational checks have been conducted.

It is also important to ensure you and your equipment do not exceed the weight limit for which the EWP was designed. Before entering an EWP, check the load limit, which should be clearly marked on it.

SAFETY TIPS

- Never enter or leave the platform when it is elevated.
- Always secure your tools and equipment while working on an EWP to prevent them from falling onto workers below.

25.3.5 Check and fit your personal protective equipment

Before you start to work at height, check that you have the correct personal protective equipment (PPE) for the task you are about to perform.

Check the PPE is free of wear and tear or signs of damage. Report any defects to the person in charge and ensure you are provided with PPE that is safe and in good condition.

Follow all of the manufacturer's requirements for correctly fitting your PPE.

Note: Using PPE is **not** a way of controlling the risk of a fall from height.

CHECK YOUR UNDERSTANDING

4. Refer to Safe Work Australia's *General Guide for Scaffolds and Scaffolding Work*. What are the different weights that light-, medium- and heavy-duty scaffolding are designed to tolerate?

25.4 Carry out equipment safety checks

All equipment must be checked before, during and after use. Signs of wear and tear and any damaged or defective components must be identified and rectified before use.

Table 25.1 summarises some of the most commonly used fall-protection equipment, their characteristics and limitations. The main points to check before using the equipment are listed in the final column.

Table 25.1 Fall-protection equipment—characteristics, limitations and what to check before use

Equipment	Characteristics	Limitations	What to check
Scaffolding	- Enables workers and their equipment to reach various heights safely. - Includes handrails, midrails and catch platforms designed to reduce the risk of workers falling. - Minimises the risk of equipment and materials falling through use of kickboards and work platforms.	- Requires other measures to be taken to prevent harm such as installing barriers at ground level to prevent workers members of the public from walking under the scaffold. - Various restrictions must be adhered to, including: - the height it can be erected to - the weight it can safely hold—if overloaded, scaffold can collapse. - Lightweight scaffold may be susceptible to strong winds and rain.	- Is the scaffolding level, vertical and not leaning? - Is it clear of powerlines, open floor edges and penetrations? - Are there signs of damaged components? - Is it fully erected and not incomplete? - Are the castor wheels on mobile scaffolding locked? - Is the internal access ladder in mobile scaffolding: - in place? - fixed at the base? - at the correct angle? - projecting 1 m above the deck? - Is all diagonal bracing secured? - Is the base frame square and level? - Are end-clip mechanisms in place? - What are the weather conditions like? In the case of high wind or rain, it must be secured to a supporting structure or, in extreme conditions, not used at all! - Are no-go zones required to be in place above or around scaffold? Have they been established?

(continued)

Table 25.1 Fall-protection equipment—characteristics, limitations and what to check before use (continued)

Equipment	Characteristics	Limitations	What to check
Ladders	Only for use as a last resort on construction sites.	- Suitable for use by only one person at a time. - Require level and stable ground for support and another person to foot the ladder. - Dangerous if working around electrical hazards and ladder is made of conductive material.	- Are they placed on a solid, stable foundation or surface? - Do they extend at least 1 m above highest rung stood on or as far as possible above area where work is being carried out? - Are they placed at a slope of 4:1? - Are the top and bottom of the ladder secured to stop slipping? - Does the worker have three points of contact when on the ladder?
Elevated work platforms (EWPs)	- Enable workers and their equipment to reach various heights. - Can be powered by battery or engine. - Different types available to suit both flat or rough terrain.	- Must have a trained EWP spotter at all times during operation. - Can use only EWPs specifically designed for rough terrain if ground is not flat and stable - Not suitable for use in poor weather conditions, e.g. strong winds.	- Is the EWP positioned on a solid, level surface free of holes or obstructions? - Are you and your equipment within the safe working load limit of the EWP? - Do the manufacturer's specifications require a safety harness system to be used on the EWP?
Safety harnesses	- Full body and fitted to the individual. - Interconnected shoulder and leg straps support the hips, back, legs and chest of the worker in the event of a fall.	- Relies on proper inspection, fitting and maintenance. - Cannot be used on its own to minimise risk.	- Are there any defects or signs of damage to the straps? - Are the D-rings free of rust? - Is all stitching in good condition? - Has the harness been secured correctly? - Has the harness been designed to meet AS/NZS 1891.1: 2007?

SAFETY TIP Safety checks on equipment should always be performed before and after using equipment. If equipment is being used in poor weather conditions, it is essential that all safety procedures are followed to protect and shield the equipment so that it is not made unsafe through exposure to rain and other hazards such as lightning.

CHECK YOUR UNDERSTANDING

5. Complete the table below, filling in the definitions of important terms, height-safety PPE and equipment by accessing Safe Work Australia's 'Code of Practice: Managing the Risk of Falls at Workplaces' at www.safeworkaustralia.gov.au.

PPE or equipment	Definition
Anchorage	
Fall	
Fall-arrest system	
Hazard	
Inertia reel	
Karabiners	
Lanyard	
Restraint line	
Risk	
Scaffolding	
Static line	

25.5 Conduct work tasks

Before commencing work, ensure that all relevant signage and barricades are in place at the site. Any requirements will be documented in the SWMS, so check to ensure the correct signs have been positioned.

Once you have assessed the site and made sure your equipment is safely in place and have correctly fitted your PPE, you are ready to access the work area and commence the task at hand.

Here are some key things to keep in mind as you work at height.

25.5.1 Monitor and respond to changing conditions

Always follow the risk controls identified in the SWMS or JSEA. If conditions change during the work, stop and communicate this with the person in charge and your colleagues. The risks of the work in general and of working at height may have altered and additional or new risk controls might be needed.

25.5.2 Traverse between anchor points

In order to do your work, you will most likely need to move around the work area at height. As you move around, make sure you stay connected to the fall-prevention system at all times. If you need to make adjustments to the fall-prevention system, do so within the agreed specifications and this will maintain your safety throughout the job.

Ensure that any edge protection is kept in place at all times and under no circumstances should you or anyone else shift the edge protection just to make the job quicker or easier.

25.5.3 Exit the work area safely

Plans for safely exiting the area where work at height is being conducted must be understood and followed. Different procedures will apply for different types of exits and fall-protection equipment.

When using a ladder, for example, the ladder must be firmly placed on solid ground and have another worker holding it steady at its base before you climb down it.

As you walk towards the equipment that will enable you to exit the area at height, you must be aware of any trip hazards such as electrical power cords or uneven surfaces. The work area must be left clean and tidy, and you must remain connected to the fall-prevention system at all times.

If you are exiting the area using an EWP, you must ensure your tools are safely secured, and that you are secured if required. Avoid making any sharp or quick movements as the EWP is being lowered as this could destabilise both yourself and any other workers on the EWP.

If the weather conditions have changed, additional measures may need to be taken before exiting the area at height. Check, confirm and carry out any additional tasks safely.

CHECK YOUR UNDERSTANDING

6. Why should you secure your tools and equipment on an EWP when exiting the work area?

Student research

1. Find three construction sites where work is being conducted above 2 metres—you could choose sites you are working on or other sites near where you live or work. Observe and write down the different risk controls used to protect workers and others from the risks associated with working at heights; for example, 'edge protection'.
2. Ask your boss or an experienced building practitioner if you can chat with them about keeping safe while working at heights. Ask them to share their experiences. Questions you might ask include:
 - Have they or anyone they know, ever been injured because of working at heights?
 - Have they personally ever felt unsafe working at heights—if so, when and why?

End-of-chapter activity

Go online to identify and list four different Australian Standards that cover fall-protection systems.

AUSTRALIAN BUILDING CODES AND STANDARDS

*Work Health
and Safety
Act 2011*

AS/NZS 1892.5: 2000
Portable ladders—
selection, safe use
and care

**AS/NZS 1891.3:
2020 Personal
equipment for work at
height—manufacturing
requirements for fall-
arrest devices**

Tradie talk—Always follow safe work practices when working at heights

Chapter 26

Restricted-height scaffolding and work platforms

Learning Objectives

LO 26.1 Understand licensing and regulation

LO 26.2 Identify types of scaffolding/working platforms

LO 26.3 Understand environmental conditions and scaffolding choice

LO 26.4 Apply scaffolding safety procedures

LO 26.5 Identify scaffolding equipment/components and their application

LO 26.6 Erect scaffolding

LO 26.7 Inspect working platforms for compliance

LO 26.8 Identify other types of scaffolding

LO 26.9 Know about ladders and their use

Introduction

This chapter deals with the basics of some of the most common scaffolding and working platform systems you would find in use on an Australian building site.

It deals with the use of scaffolding and working platforms up to a height of 4 metres, which do not require a specific high-risk licence.

The chapter covers how to identify and select the appropriate working platforms for a given task and environmental conditions, plus how to identify various scaffolding components and how to erect and safely use working platforms, ladders and scaffolds. You will also learn about safety and compliance requirements during the erection, use and dismantling of scaffolds, ladders and working platforms.

The erection of all scaffolding or working platforms exceeding 4 metres requires a competent person who possesses the relevant scaffolding accreditation to be present and in charge of all works. In addition,

WORKPLACE SCENARIO

The training you will undertake at trade school is designed to give you an appreciation of how to use scaffolding, ladders and working platforms in a way that is safe and compliant with regulations. You will learn what they should look and feel like when being used, and will be shown how to erect them safely and appropriately for the job you are doing. This training doesn't make you a qualified scaffolder, but it does give you the vital information needed to assess whether the equipment you are being asked to use is safe.

TIP A person who erects, alters or dismantles a scaffold where there is a risk of people or objects falling 4 m or less from the platform or structure does *not* require a high-risk work licence.

the placement, erection, use, disassembly and storage of any scaffold or working platform system must comply with the relevant Australian Standards, Codes of Practice, manufacturer's specifications and legislation (which also include more detailed information about usage), including:

- AS/NZS 1577:2018 Scaffold decking components
- AS/NZS 1576.1:2019 Scaffolding, Part 1: General requirements
- AS/NZS 1576.2:2016 Scaffolding, Part 2: Couplers and accessories
- AS 4576:2020 Guidelines for scaffolding
- AS/NZS 1576.5:1995 Scaffolding, Part 5: Prefabricated splitheads and trestles
- AS 1576.6:2020 Scaffolding, Part 6: Metal tube-and-coupler scaffolding—deemed to conform to AS/NZS 1576.1
- AS 1576.3:2015 Scaffolding, Part 3: Prefabricated and tube-and-coupler scaffolding
- AS 1576.4-1991 AMDT 1 Scaffolding—suspended scaffolding
- AS/NZS 1892.1-1996 Portable ladders—metal
- AS 1892.2-1992 Portable ladders, Part 2: Timber
- AS 1892.5:2020 Portable ladders, Part 5: Selection, safe use and care
- AS 1892.1:2018 Portable ladders, Part 1: Performance and geometric requirements.

Safe Work Australia publishes many guides dealing with the erection and use of scaffolding and working platform requirements. Lastly, always consult your state's relevant WorkSafe authority to ensure all works comply with any specific state requirements.

26.1 Understand licensing and regulation

If the scaffolding work exceeds 4 m in height, then a licence is required, as detailed in the Safe Work Australia *General Guide for Scaffolds and Scaffolding Work*.

A person undertaking scaffolding work must hold the relevant class of scaffolding high-risk work licence as required by the WHS Regulations. The scaffolding high-risk work licence classes are:

Basic scaffolding licence—required for scaffolding work involving:

- modular or pre-fabricated scaffolds
- cantilevered materials hoists with a maximum working load of 500 kg
- ropes
- gin wheels

- fall arrest systems, including safety nets and static lines
- bracket scaffolds (tank and formwork).

Intermediate scaffolding licence—required for scaffolding work involving:

- cantilevered crane loading platforms
- cantilevered scaffolds
- spur scaffolds
- barrow ramps and sloping platforms
- scaffolding associated with perimeter safety screens and shutters
- mast climbing work platforms
- tube and coupler scaffolds, including tube and coupler covered ways and gantries.

Advanced scaffolding licence—required for scaffolding work involving:

- cantilevered hoists
- hung scaffolds, including scaffolds hung from tubes, wire ropes or chains
- suspended scaffolds.

As scaffolding is a regulated activity in all states of Australia and is considered a high-risk activity, there are numerous Australian standards and codes that cover the production and use of scaffolding systems. These include:

- AS/NZS 1576.3:2015 Scaffolding—Prefabricated and tube-and-coupler scaffolding
- AS 1577:1993 Scaffold planks
- AS/NZS 4576:1995 Guidelines for scaffolding
- AS/NZS 1576.1:2019 Scaffolding—General requirements.

The codes that cover scaffolding can be found at Safe Work Australia or your state's or territory's WorkCover authority. Keep your high-risk activities knowledge current by regularly checking their websites or subscribing to their newsletters and alerts.

26.2 Identify types of scaffolding/working platforms

The scaffolds or working platforms covered in this chapter fall into three main categories of use, as defined in Safe Work Australia's *General Guide for Scaffolds and Scaffolding Work*:

- *Light duty*—up to 225 kg per platform per bay including a concentrated load of 120 kg. Platforms should be at least two traditional scaffold planks wide—approximately 450 mm. Examples of use include painting, electrical work, many carpentry tasks and other light tasks.
- *Medium duty*—up to 450 kg per platform per bay including a concentrated load of 150 kg. Platforms should be at least four traditional scaffold planks wide—approximately 900 mm. Examples of use include general trades work such as tiling and light steel framing.
- *Heavy duty*—up to 675 kg per platform per bay including a concentrated load of 200 kg. Platforms should be at least 1000 mm wide. This duty of scaffold is needed for concrete blocklaying, bricklaying, concreting, demolition work and most other tasks involving heavy loads or heavy impact forces.

Fig. 26.1 Quickstage or modular scaffold



Courtesy of Daniel Bonnici

Fig. 26.2 Aluminium mobile scaffold

© Baloncici/Shutterstock

Fig. 26.3 Trestles and planks scaffolding

Courtesy of Daniel Bonnici

The three types of scaffold covered in the chapter are:

- *quickstage or modular scaffold* (Fig. 26.1). This scaffold is used extensively in the building industry. It can be found on domestic or commercial construction projects. It is very strong and will deal with most building activities. It is very safe and is generally tied into the building being constructed, making it very secure. These scaffolds require a minimum of two people to construct.
- *aluminium mobile scaffold* (Fig. 26.2). This scaffold is very common on construction sites. It is lightweight and moveable, which makes it ideal for jobs such as painting, where it is necessary to be in particular places for only a short period of time before moving on to the next spot. These types of scaffolds don't cope with very heavy loads or too many people on them, so they have their limitations. They require a firm and relatively level surface to make it easy to move them around and be safe to use. They can be susceptible to strong winds and have limitations in the height they can be built to. These scaffolds require a minimum of two people to construct.
- *trestles and planks* (Fig. 26.3). These scaffolds are very versatile as they can be made as long or as short as the task requires, take relatively heavy loads (e.g. are used by bricklayers) and can be transported to jobs quite easily. They can be built by a single person on a hard level surface. They are fairly stable, but they can topple if overloaded or used inappropriately. They generally extend to only 1.8 m so they don't require handrails (handrails are required when the potential fall is 2 m or greater).

SAFETY TIP When using a scaffold, ladder or work platform, always investigate the equipment before you use it.

- Can you see any repairs? If so, do they look sound?
- Are all of the components present?
- Has it been well maintained (does it appear to be in good condition)?
- Does it feel stable? Does it rock?
- Is the person erecting it qualified?
- Do you know the equipment's limitations?
- Do you feel safe on the equipment?

If you have any doubts, don't use the equipment.

CHECK YOUR UNDERSTANDING

1. Up to what height can a person construct a scaffold without a licence?

26.3 Understand environmental conditions and scaffolding choice

There are many factors to take into consideration when choosing the most suitable scaffold to use for a task.

First, determine if the ground or base is suitable to support the scaffold:

- Can the scaffold support the combined weight of the scaffold itself, the people using it and any tools, equipment and materials that will be placed on it?
- Are there any possible voids, pipes, cellars, etc. located in the ground beneath or near where the scaffold is to be set up that could cave in when the scaffold is erected?

TIP If any of these factors are present, then an alternative method may need to be found or work may have to be done to the site to make it suitable to accommodate a scaffold.

Determine the most suitable scaffold for the type of work and the location:

- If the job is small and not too high, a mobile scaffold may be most appropriate.
- If the job is large, is high off the ground and the scaffold will need to accommodate heavy materials and many trades for a long time, then a modular scaffold might be the most appropriate choice.

Remember to keep in mind that each scaffold has its limitations, such as:

- how much weight it can hold
- how high it can go
- how heavy it is
- how easy it is to get the scaffold to the area.

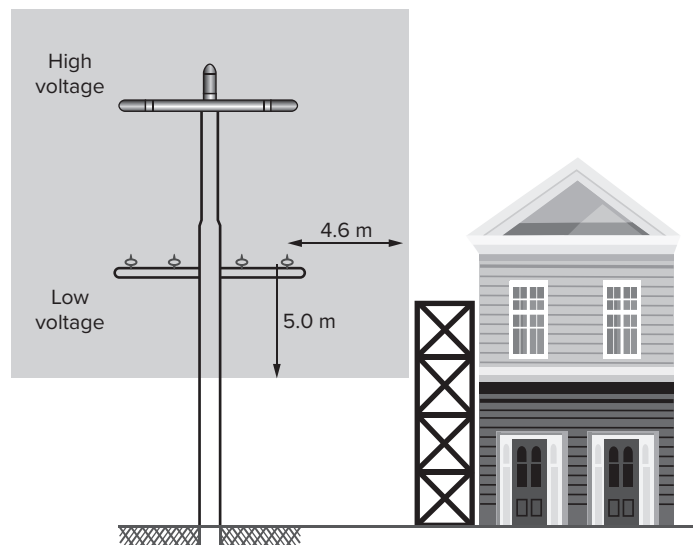
Consider environmental factors:

- Will the scaffold be subject to high winds, rain, etc.? If so, the scaffold will need to be tied into a supporting structure.
- Could the scaffold be subject to potential impacts? If so, an exclusion zone needs to be established to avoid this happening.

Assess the area above for powerlines:

- Are there any overhead powerlines where the scaffold is to be built? If so, Figure 26.4 shows the no-go zone for working near overhead powerlines in Victoria. (If you are in another state or territory, check the requirements with your local power supplier/regulator.)

Fig. 26.4 No-go zone around powerlines



TIP The erection of exclusion zones, fencing, bunting and signs will minimise any of the above incidents occurring.

Assess the area around where the scaffold is to be placed:

- Will the scaffold be located near a road, driveway or anywhere that a powered vehicle, such as a bobcat, forklift or truck could potentially hit the scaffold and make it unsafe to use?
- Will the scaffold be located near a pedestrian walkway, footpath, accessway, etc.? If so, how are people going to be protected from potential items falling from the scaffold or entering the scaffolding zone?
- Will the scaffold be located in an area of a building site where workers will be exposed to potential falling objects?

26.4 Apply scaffolding safety procedures

Scaffolding work and working at heights are high-risk activities, and accordingly the work health and safety requirements are many. The reasons we use scaffolds are to:

- provide a safe and stable working platform at various heights to support work activities and associated equipment and materials required for the specific task
- reduce the risk of workers falling when working at heights over 2 m by providing handrails, midrails, catch platforms and a fully decked-out work platform
- protect workers and the public below the scaffold by minimising equipment and materials falling from the scaffold by having kickboards and a fully decked-out work platform
- provide easy and safe temporary access to work areas located above ground level.

When using scaffolds there are a number of safety signs that are used, as shown in Figures 26.5–26.7.

These signs let people know what stage of construction the scaffold is at. Signs are only one part of the process to keep both workers and the general public safe. Barriers need to be erected to stop people from walking under the scaffold or getting too close to it just in case, for example, something is dropped. Temporary fencing is ideal if the scaffold is to be left up for an extended period of time.

If the scaffold being used is mobile or consists of trestles and planks, then safety tape/bunting and signs indicating people working overhead will suffice. A person acting as a spotter is also a good idea in certain circumstances.

Fig. 26.5 Incomplete scaffolding sign



Fig. 26.7 A worker's overhead warning sign



Fig. 26.6 Temporary fencing around building site



Courtesy of Daniel Bonnici

26.4.1 Safe work method statements for scaffolding work

Erecting a scaffold or working on a scaffold may involve activities defined as high-risk construction work under WHS regulations. High-risk construction work includes any construction work where there is a risk of a person falling more than 2 m. Scaffolding work is defined with a 4 m threshold for licensing purposes. This means that in some cases a high-risk work licence may not be required to erect a scaffold because it is less than 4 m, but there may still be a need for a safe work method statement (SWMS) because it is more than 2 m.

To identify the potential hazards associated with scaffold use and the control measures, an SWMS must be used. An SWMS must be prepared for high-risk construction work before the work starts. The SWMS must:

- identify the type of high-risk construction work being done
- specify the health and safety hazards and risks arising from the work
- describe how the risks will be controlled
- describe how the control measures are to be implemented, monitored and reviewed.

The SWMS must be developed in consultation with workers and their representatives who are carrying out the high-risk construction work.

Further information on high-risk construction work, an SWMS and an SWMS template can be found in the 'Model Code of Practice—Construction Work' at the Safe Work Australia website (www.safeworkaustralia.gov.au).

26.5 Identify scaffolding equipment/components and their application

Scaffolding equipment and components are shown in Figure 26.8. They can be held in a waist belt so they are easy to access when constructing and dismantling the scaffold.

26.6 Erect scaffolding

26.6.1 Trestle scaffolds and planks

Trestle scaffolds should be built on a hard, level surface. If the trestle is to be built on compacted ground or crushed rock, then sole plates need to be used. Each trestle should be in the fully open position. If the trestle scaffold has a height adjustment to allow for the thickness of the plank, it is important to ensure that the pin supplied with the trestle is used. **Don't use a nail or screw.**

The working platform of a trestle scaffold should not be more than 2 m above the ground, as any work platform above 2 m requires fall and edge protection (handrails). If the trestle is being used next to a pit or the edge of a balcony, ensure that the maximum distance a person can fall is not greater than 2 m. Do not piggy-back trestles.

The maximum spacings of trestles should not exceed the maximum spacings given in Table 26.1, or the maximum span of the planks being used as advised by the plank manufacturer.

Table 26.1 Maximum span of solid timber scaffold planks, complying with AS 1577: Scaffolding Planks

Nominal thickness of plank (mm)	Maximum span between putlogs (mm) (point of support)
32 (hardwood only)	1.0
38	1.5
50	2.0
63	2.5

Fig. 26.8 Basic scaffolding equipment/tools

	The podger/hammer is used to adjust the height of the jacks (pointy end) and to tap down the captive wedges on a modular scaffold.
	Scaffold keys are mainly used with tube and coupler scaffold (not covered in this chapter), but can also be used with modular scaffold when the scaffold is constructed in a way that couplers need to be used to make the scaffold safe and there is no standard component available. They are also used to tighten the bolts on ladder putlogs and short toeboards.
	A turbo level is used to level the scaffold and has a magnet on the bottom so that it adheres to steel scaffold.
	A tape measure is used to square the first bay of a modular scaffold by measuring the diagonals of the first bay; it can also be used to work out the required laps and overhangs of the planks when using trestles.
	A shifter is used when the scaffold keys are the wrong size or can't be used in certain situations.

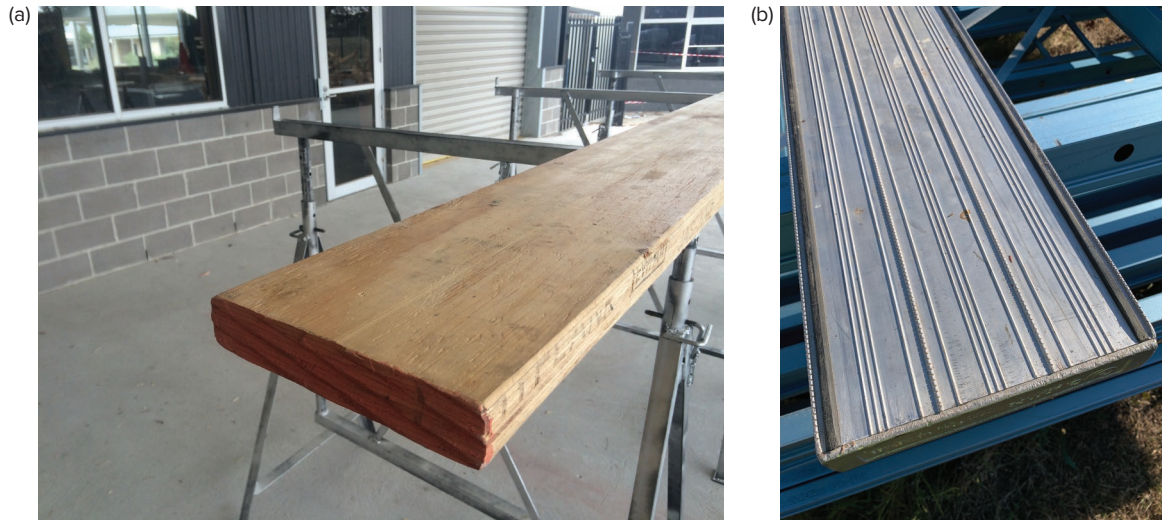
Courtesy of Daniel Bonnici

The full width of the trestles being used should be planked. Planks should overhang their end supports by not less than 150 mm or more than 250 mm and where necessary be secured against uplift. Planks may be lapped to form multiple bays of scaffolding, provided there is no obstruction along the full length of the working platform. The working platform should be horizontal.

Work only on the part of the planks between the trestle; don't stand on the overhang of the plank. If the trestle scaffold is more than one bay in length and is being used for bricklaying, blocklaying or similar work, concentrated loads should be placed directly over the trestle.

Scaffold planks can be made of natural timber, aluminium (Fig. 26.9) or a man-made timber product such as laminated veneered lumber (LVL).

When constructing the trestle scaffold, inspect the components to make sure the trestles are not damaged or bent and the planks are not cracked, twisted, split, bent or cut through.

Fig. 26.9 Types of scaffold planks: (a) timber planks; (b) aluminium planks

Courtesy of Daniel Bonnici

Courtesy of Alistair Ford

26.6.1.1 Erecting a trestle scaffold

Below is the sequence for erecting a trestle scaffold.

1. Assess the site on which the trestles are to be used. The area needs to be flat, compact (e.g. concrete) and relatively level. If the area is flat and level but made of dirt, sole plates will need to be used.
2. Unpack the trestles and extend them to the desired height. Ensure that locking pins are present and functioning and that there is a mechanism that will prevent the pins from falling out. As well as the desired height, there is an option of a high hole and a low hole.
3. Space the required number of trestles out for the required distance of scaffold to be used (taking into account the maximum span of the plank being used) (Fig. 26.10). For this example, the planks will span a maximum of 1.8 m, so the trestles can be no further apart than 1.8 m.
4. Use planks that are in sound condition only—check that they are not split, cut or damaged. Start placing the planks on the trestles set on the low hole first (Fig. 26.11). Ensure the trestles are fully decked out; if the trestles are designed to take five planks, then use five planks. Ensure that the plank overhang meets the Australian Standard.

Fig. 26.10 Space trestles according to plank length

Courtesy of Daniel Bonnici

Fig. 26.11 Place planks on trestle

Courtesy of Daniel Bonnici

5. Now place the planks on the trestles set on the high holes; these planks will also sit on the planks already in place on their ends, causing an overlap to occur (Fig. 26.12). This is normal, but ensure the overlap meets the requirements set out in the Australian Standard.
6. Now the scaffold can be used. However, remember:
 - don't overload the scaffold
 - don't run or jump on the scaffold
 - if the planks are not sitting neatly and wobble, check the trestles are erected properly
 - make sure you can't fall more than 2 m:
 - if the scaffold is set up in an area where a person could fall further than 2 m, then the trestles and planks are the wrong type of scaffold to be using.

Fig. 26.12 The finished scaffold

Courtesy of Daniel Bonnici

26.6.2 Mobile scaffold

Mobile scaffolds are generally made from aluminium due to its reduced weight. They are a free-standing scaffold supported on wheels, which vary to suit differing ground conditions. The wheels must be lockable and locked when the scaffold is in use.

Never:

- move the scaffold with a person on it
- climb the outside of a scaffold
- pull the scaffold when moving it as it could tip and fall on you; always push it
- mix components of two different scaffolds
- hit the components of the scaffold with a hammer as they will bend and dent
- force the scaffold components as they could be damaged
- use the scaffold on an uneven surface or a slope
- place near powerlines
- use an incomplete mobile scaffold
- use damaged scaffold components/parts
- use in high winds
- allow the scaffold height to exceed three times the minimum base measurement
- exceed the scaffold's maximum working load.

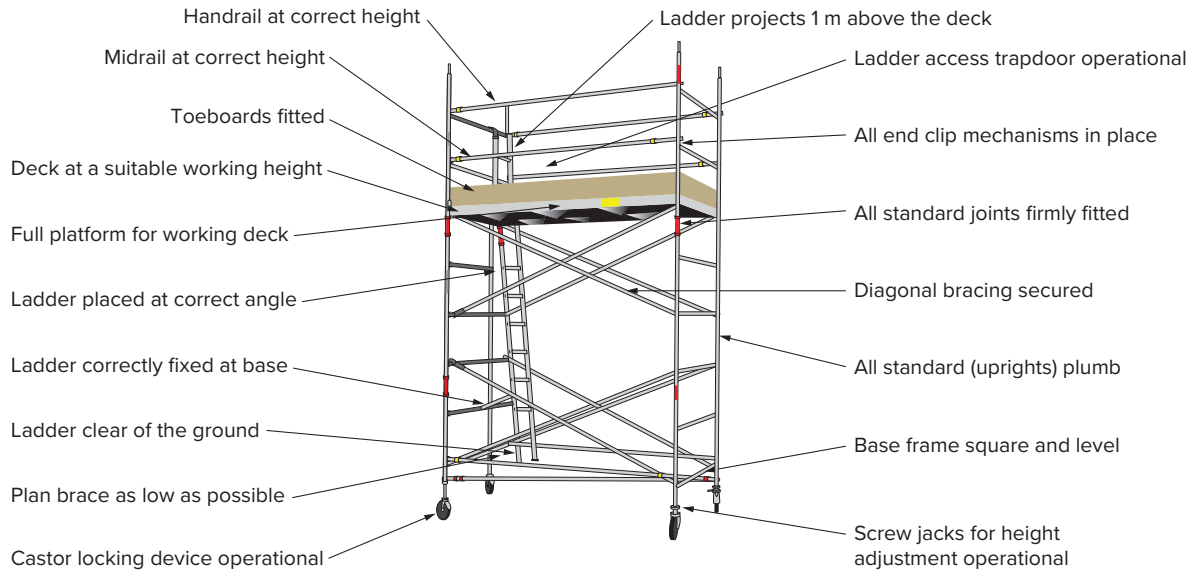
CHECK YOUR UNDERSTANDING

2. At what height must handrails be installed when working on a trestle or quickstage scaffold?

26.6.3 Modular/quickstage scaffold

This type of scaffold is used widely in the domestic and commercial building sectors (Fig. 26.13). It is designed to take large loads and to have many people working on it. Its height is limited by the height of the building supporting it. It is very stable and heavy and the weight of the scaffold itself must be taken into account when calculating the loads being exerted onto the ground as well as the loads of the materials, equipment and people working on it.

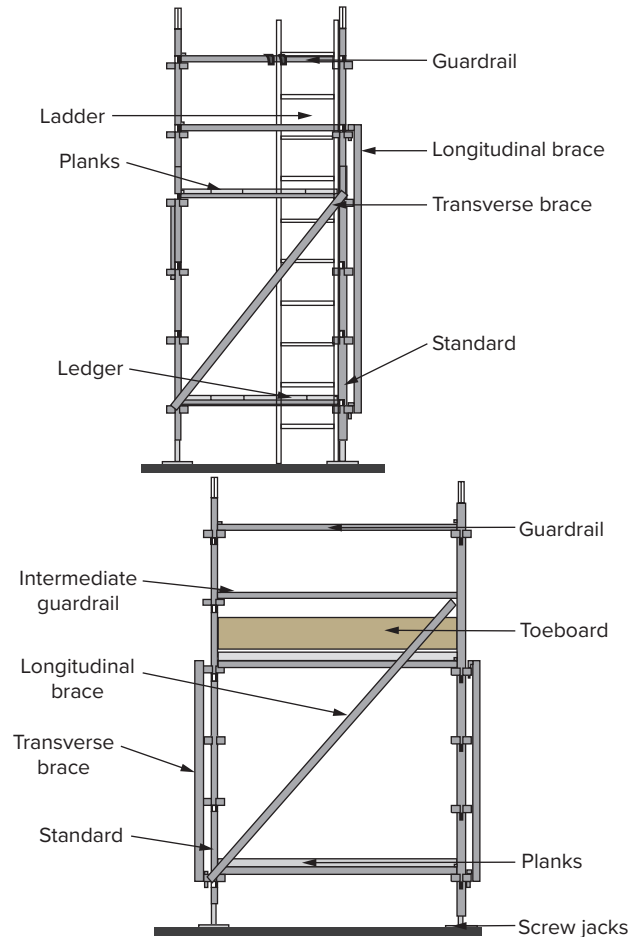
Fig. 26.13 How a correctly erected mobile scaffold should look before use



Foundation suitable for the scaffold, level and firm.

Figure 26.14 shows the major components and where they should be placed.

Fig. 26.14 Components of a modular scaffold



26.6.3.1 Erection procedures for modular scaffold

Inspect the scaffolding components and ensure they are not damaged. Damaged components need to be isolated from the rest of the scaffold and identified as being damaged so that they can be either repaired or destroyed. Also, ensure that components from different scaffolds are not being mixed as not all types of modular scaffold are compatible.

The procedure to erect the modular scaffold is as follows (see also Figs 26.15–26.21):

1. Adjust the height of the screw jacks so that two- to three-thirds of the shaft is located inside the standard.
2. Choose sole plates to be placed underneath the screw jacks; they will usually be timber, such as damaged trestle planks that can no longer be used safely. The sole plates spread the load from the screw jack over a larger area of the ground on which the scaffold is built. Set out their positions and bed them as level as possible, unless the surface is concrete or another firm surface.

Fig. 26.15 How modular scaffold components fit together

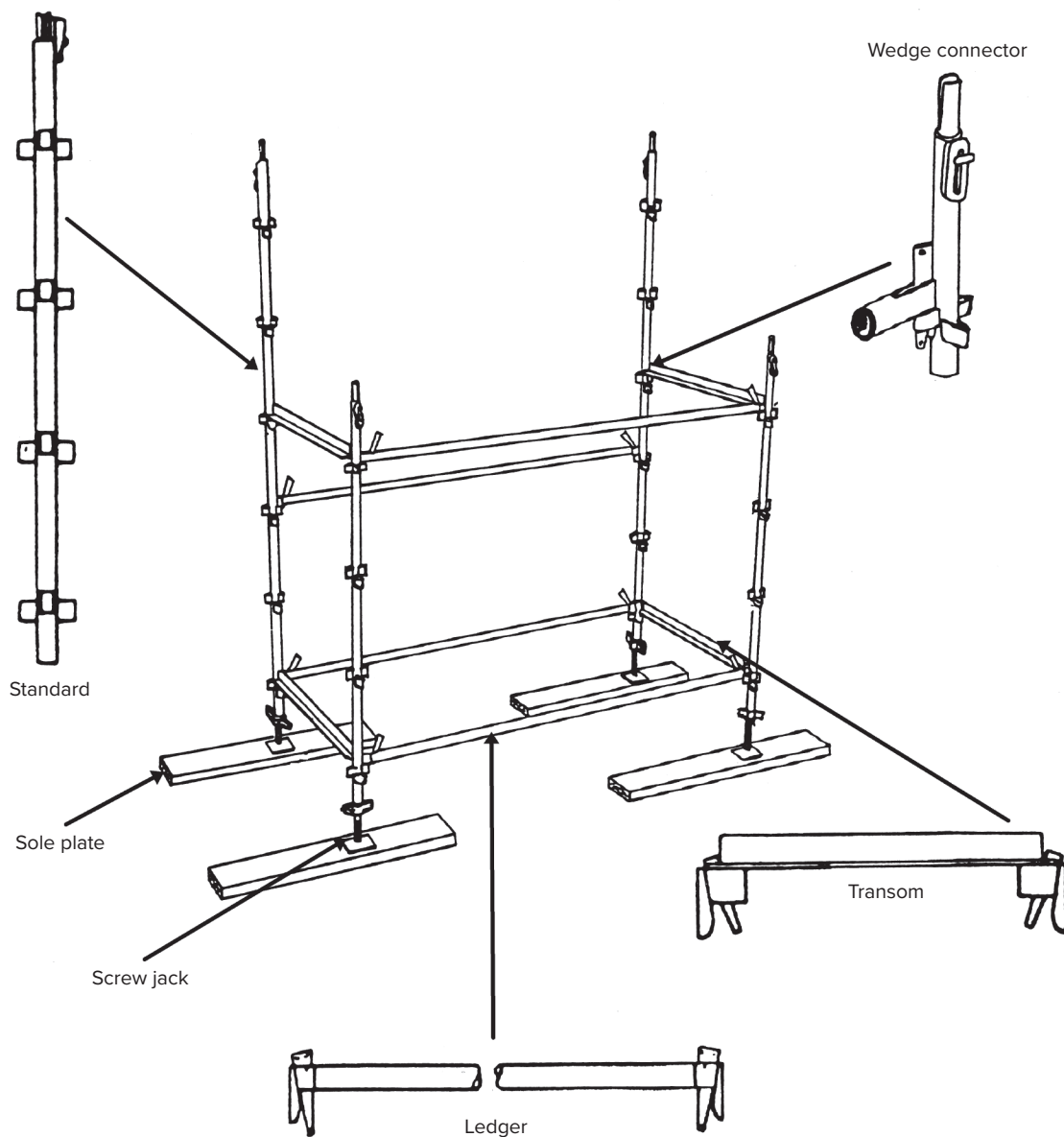


Fig. 26.16 Standard being placed on screw jack

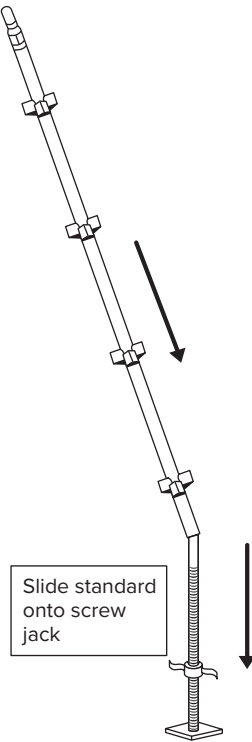


Fig. 26.17 Constructing first end

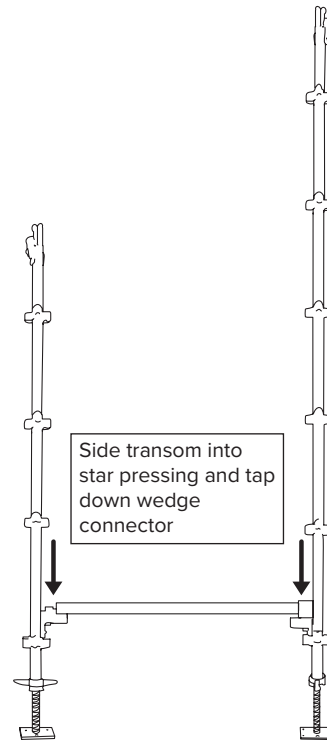


Fig. 26.18 Attach ledgers to the standards

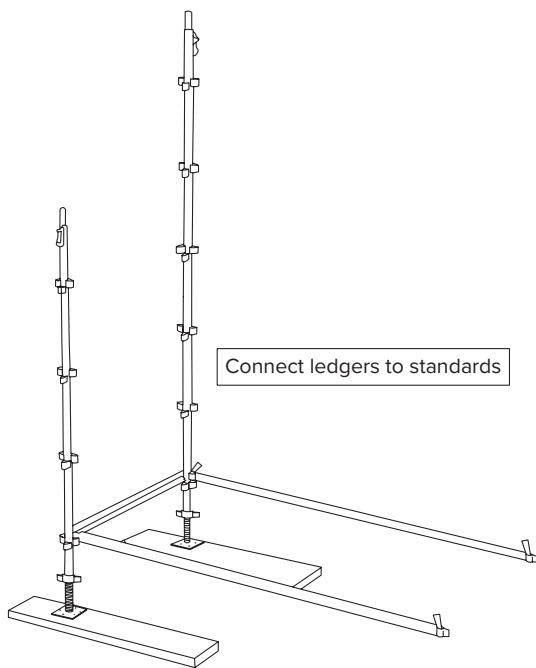
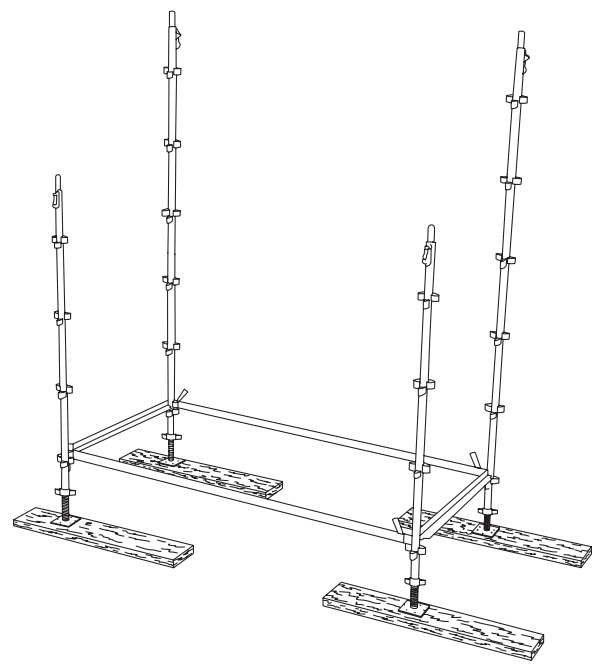


Fig. 26.19 Completed base of first bay



3. Starting at one end of the proposed scaffold, place a pair of screw jacks set to their lowest adjustment on top of the sole plate and slide the end of a standard over the top of each jack.

Use different height standards on each so that the joins in the standard will be staggered throughout the height, which will increase strength. Insert the transom and fit the wedges to the lowest possible point of connection on the star pressing; do not tighten the wedges at this stage. Ensure that the captive spigots are facing out.

4. With one person holding the two standards, get a second person to attach the ledgers to the standards at the same height as the transom. Do not tighten the wedges.
5. Attach the next two standards to the ends of the ledgers and then fit a transom between them. Do not tighten the wedges at this stage.

At this point, the scaffold can be levelled. Start at one transom: adjust the jacks to make it level and then move on to the ledgers. Only adjust the jacks that were not adjusted when the first transom was levelled. Once both ledgers have been levelled to the first transom, check the second transom. It should not require any adjustment. If the second transom is not level, check the first transom and then the ledgers and repeat the process. Now the wedges can be tapped down to make the connection rigid.

6. Extend the length of the scaffold, making sure you continue to level the next bay from the previous bay. The first lift can be established, usually 2 m above the first ledger/transom.

To increase the height of the scaffold, additional standards need to be placed onto the bottom standards and locked in with a captive spigot wedge. A light tap of the hammer will do the trick.

7. Install the galvanised metal planks that fit in between and rest on the transoms. Each subsequent lift should be decked out with planks to enable erection and lifting of members.

Fig. 26.20 Levelling first bay

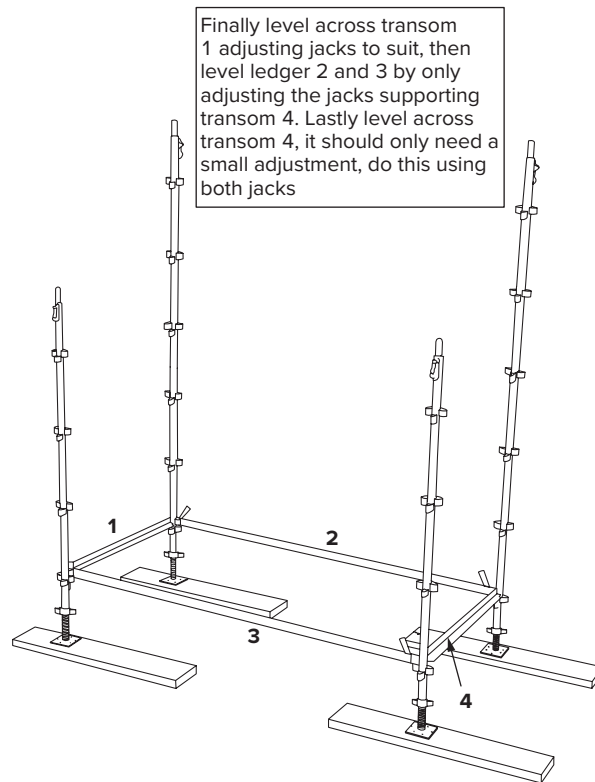
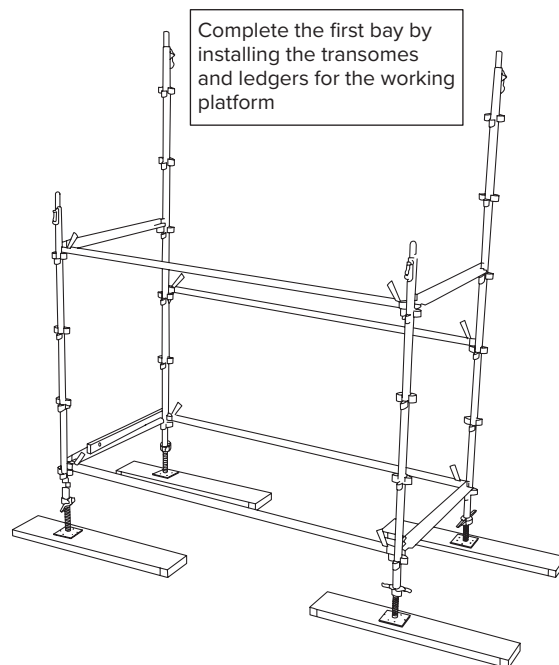


Fig. 26.21 Completed first bay



When the desired height is reached, fit the longitudinal bracing on the face of the scaffold that is not the working face and the diagonal brace on the ends. Ensure all of the bracing starts off from the same hand; that is, the bottom of the brace has its lowest connection on the left-hand side when you are looking at it. Ensure the wedges are tapped down. Complete the scaffold by fitting toeboards, handrails, midrails, etc (Fig. 26.22). Remember that a separate access bay must be provided as no work is allowed to be conducted on the access bay (Fig. 26.23).

Fig. 26.22 Completed scaffold with toeboards, handrails and midrails



Courtesy of Daniel Bonnici

Fig. 26.23 Access bay should be separate from the working platform



Courtesy of Daniel Bonnici

TIP To dismantle the scaffold, reverse the sequence described above. For the correct bracing requirements, please refer to the relevant Australian Standard.

26.7 Inspect working platforms for compliance

Scaffolds need to be regularly inspected to ensure they are compliant. Scaffold tags are useful for this task (Fig. 26.24). The tag provides information of when the scaffold was inspected, who inspected it and where the inspection occurred.

For the full details of scaffold inspection and maintenance and an inspection checklist, refer to Safe Work Australia's *Guide to Scaffold Inspection and Maintenance*.

Fig. 26.24 Scaffold inspection tags

FRONT TAG

SCAFFOLD TAG

ERECTION AND INSPECTION RECORD

TO BE COMPLETED BY INSPECTOR

LOCATION _____

REF NO. _____

REQUESTED BY _____

BUILT BY _____

DATE _____

INSPECTOR _____

SIGNATURE _____

SCAFFOLD TO BE USED FOR

LIGHT DUTY 225 Kg

MEDIUM DUTY 450 Kg

HEAVY DUTY 675 Kg

THE ABOVE WEIGHTS ARE FOR ANY ONE WORKING PLATFORM DAY AND INCLUDES PEOPLE AND MATERIALS

UNLAWFUL REMOVAL OR INTERFERENCE WITH THIS SIGN COULD MAKE YOU LIABLE TO PROSECUTION AND FINES

BACK TAG

INSPECTION RECORD

AUTHORISED PERSON

DATE	TIME	SIGNED

LADDER NO. RUNGS: _____
NO. OF STANDARDS: _____
NO. OF LIFTS: _____
M2 BOARDING: _____
STRUCTURE DECOMMISSIONED
DATE: _____

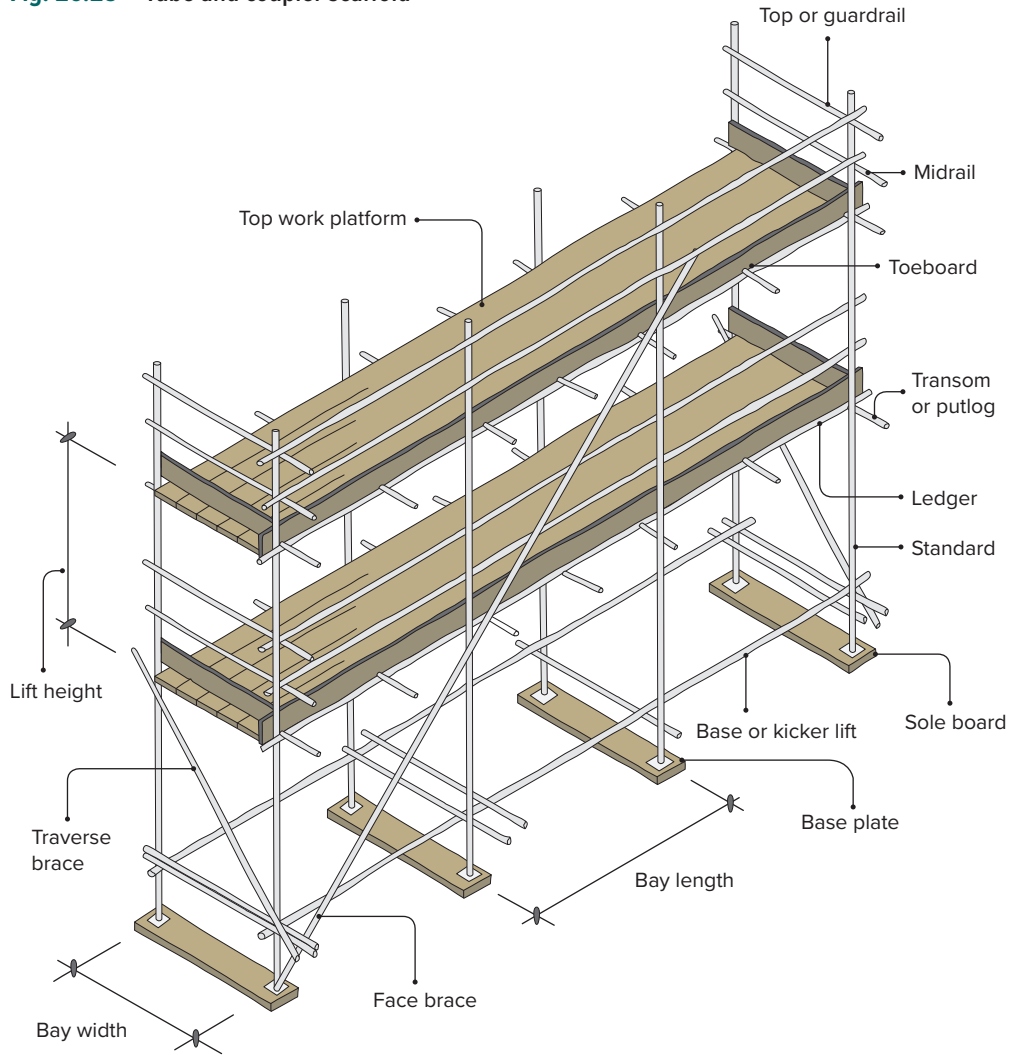
CHECK YOUR UNDERSTANDING

3. What two common materials can scaffold planks be made from?

26.8 Identify other types of scaffolding

The other types of scaffold in use today include:

- *tube and coupler*—this type of scaffold is made up of lengths of steel tubes and clips/connectors that tie the tubes together (Fig. 26.25)
- *single pole scaffold*—this type of scaffold consists of a single row of standards connected by ledgers (Fig. 26.26). Putlogs are fixed to the ledgers and built into the wall of the building or structure.

Fig. 26.25 Tube and coupler scaffold

26.9 Know about ladders and their use

Ladders are an essential and important part of the building industry. They come in various forms (Figs 26.27–26.29).

26.9.1 Stepladders

Ladders are used as a last resort when completing construction tasks and should be used only if there is no other suitable alternative. If completing a large project and access at height is required, more suitable equipment such as scaffolds, trestles, cherry pickers, scissor lifts, etc. should be used. This is because ladders are quite dangerous and are unstable compared to the alternatives.

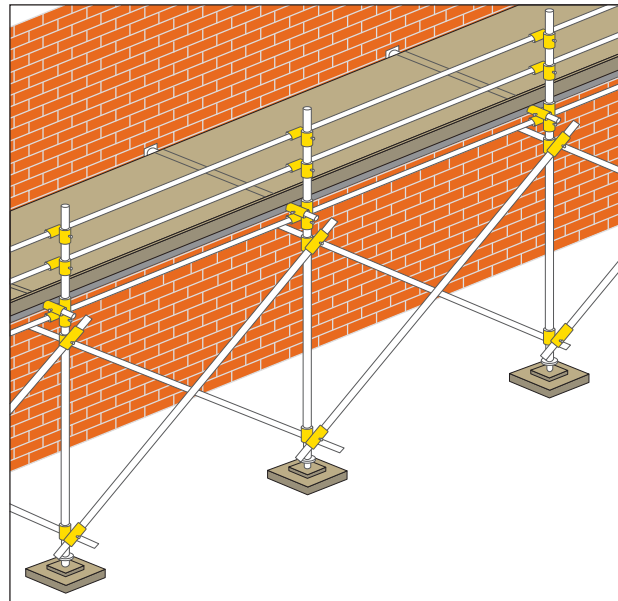
Fig. 26.26 Single pole scaffold

Fig. 26.27 Stepladder



© BK foto/Shutterstock

Fig. 26.28 Platform ladder



© lynx/iconotec.com/Glow Images

Fig. 26.29 Extension ladders



© Margo Harrison/Shutterstock

As a general rule:

- use ladders only on level and stable ground
- never climb past the second-highest rung on a stepladder
- always try to have someone to foot the ladder you are using
- ensure an extension ladder is at the correct angle when using it—4 to 1
- ensure extension ladders are secured at the top while in use
- make sure extension ladders extend 1 m past the work surface if being used to access a high area such as a roof
- if working around electrical hazards, ensure the ladder is made of non-conductive material such as timber or fibreglass.

For more information about the use of ladders, refer to the 'National Code of Practice for the Prevention of Falls in General Construction'—Safe Work Australia.

CHECK YOUR UNDERSTANDING

4. What part of a stepladder should a person not climb past?

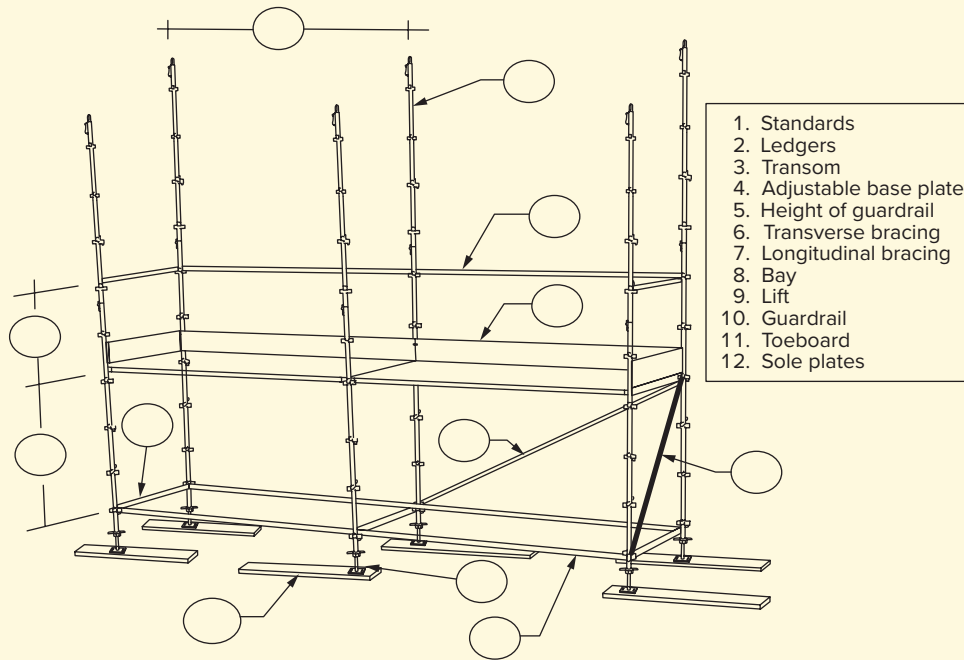
Student research

Check out Safe Work Australia's *General Guide for Scaffolds and Scaffolding Work* and research other types of scaffolds that are used in Australia.

End-of-chapter activity

Label the diagram below.

Scaffolding



AUSTRALIAN BUILDING CODES AND STANDARDS

**AS/NZS
1576.3: 2015**
Scaffolding—
Prefabricated and
tube-and-coupler
scaffolding

AS 1577: 1993
Scaffold planks

AS/NZS 4576: 1995
Guidelines for
scaffolding

**AS/NZS
1576.1: 2019**
Scaffolding—General
requirements

**Safe Work
Australia, National
Code of Practice for the
Prevention of Falls
in General
Construction**

Tradie talk—Never take a backward step

Chapter 27

External cladding

Learning objective

LO 27.1 Identify and install different types of cladding

LO 27.2 Install sheet/panel cladding

LO 27.3 Understand energy efficiency and the fire-resistant properties of cladding

Introduction

Cladding is the outer covering applied to the external walls of a framed building. While its main purpose is to protect against elements such as wind, rain, heat and cold, it is also recognised as providing some thermal and acoustic insulation to the building as well as preventing access by intruders. In addition, it contributes to the structural bracing of the building. In this chapter you will learn how to identify various types of cladding, and their installation and fixing requirements. These include sheet material and weatherboarding made of timber, plastic, metal and fibre cement. You will also learn how to calculate the amount of cladding required for a given project.

When commencing cladding work it is important to set up the work area appropriately. Ensure it is safe, that leads are off the ground, there are areas or receptacles for waste and recyclable material, that scaffolds or ladders are well-grounded and the work area is clear of obstacles, etc.

It is good practice to first become familiar with the product that will be used. Read the manufacturer's installation instructions, the SDS (safety data sheet) for the product, taking note of any hazards, and check if the product is recyclable. It is important to familiarise yourself with National Construction Code (NCC) requirements for cladding as any installation needs to be compliant.

Once the cladding has been installed, ensure the worksite has been cleared, that any waste and recyclables have been disposed of appropriately, and that leftover materials, tools and equipment are stored away neatly. If any tools are faulty, this needs to be reported to the supervisor.

CHECK YOUR UNDERSTANDING

1. List the four principal functions of wall cladding.

WORKPLACE SCENARIO

When building in bushfire-prone areas, a dwelling's cladding is an important factor in protecting the house from any fires. All areas that are prone to bushfires now have a BAL (Bushfire Attack Level) rating.

The aim of the residential building standard for bushfire protection is to improve the ability of a building to withstand a bushfire attack. This will provide greater protection for the occupants who may be sheltering inside while the fire front passes. A great deal of scientific modelling has gone into the standard.

The chart in the link below outlines how the baseline data, defined as a BAL, determines the type of construction required. The BAL takes into consideration a number of factors, including the Fire Danger Index, the slope of the land, the types of surrounding vegetation and the proximity to any other building (see www.vba.vic.gov.au/consumers/bushfires).

As a carpenter, it is very important when installing cladding that you follow the manufacturer's instructions and the Australian Standard so that the cladding installation is in line with the provisions for bushfire-prone areas. If these provisions are not adhered to, then the effectiveness of the cladding to protect the occupants and the house from bushfire could be severely compromised.

27.1 Identify and install different types of cladding

Several materials are commonly used as external wall coverings on timber/metal-framed buildings. Known as **timber siding**, weatherboards or chamferboards, external wall sidings are milled from a number of timber species and to a variety of profiles. Some of the popular profiles are shown in Figure 27.1.

1. **Dressed rusticated siding**—is normally milled from cypress pine, hardwood and pressure-treated radiata pine.
2. **Double log siding**—is milled from cypress pine and pressure-treated radiata pine.
3. **Checked and nosed**—or checked and splayed siding is milled from Western red cedar or Baltic pine.
4. **Sawn splayed siding**—is milled from Western red cedar, Californian redwood or in some areas may be produced as rough splayed from sawn hardwood. **Splayed timber weatherboards** are also milled from Baltic pine and these can be ordered with a dressed face finish. They are available primed with a nominal width of 175 mm in either a square edge or round edge profile.

The nominal sizes and **cover** of the boards also are indicated in Figure 27.1. To calculate the number of linear metres of boards required to cover one square metre, divide 1000 by the cover in millimetres. For example:

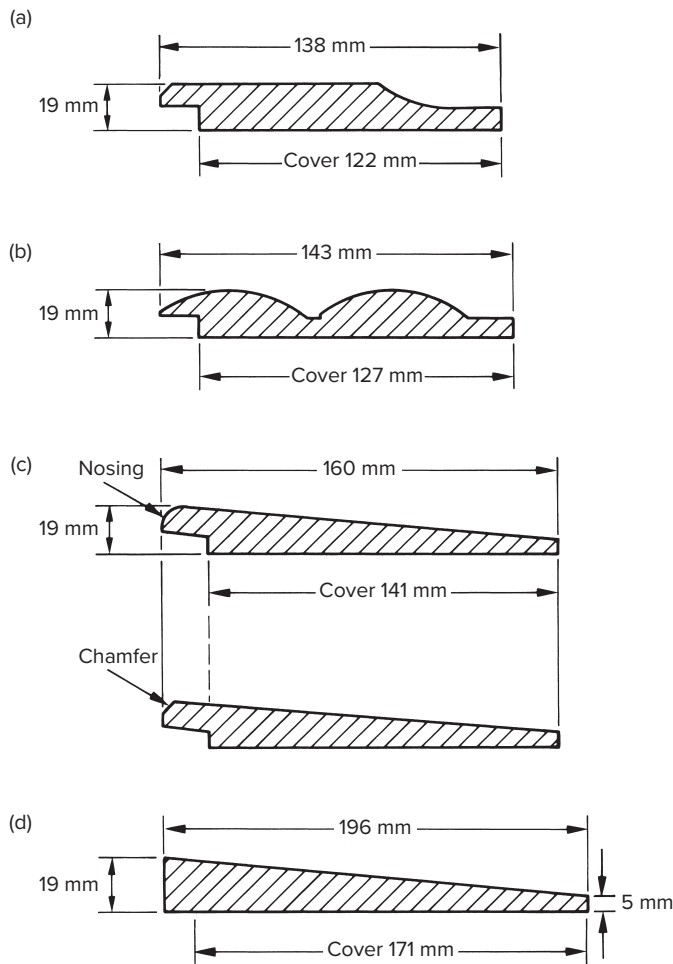
$$\begin{aligned}
 \text{rusticated—nominal width} &= 150, \text{ cover } 122 \text{ mm} \\
 \text{linear metres/m}^2 &= 1000/122 \\
 &= 8.2 \text{ m} \\
 \text{sawn splayed—nominal width} &= 200 \text{ mm, cover } 171 \text{ mm} \\
 \text{linear metres/m}^2 &= 1000/171 \\
 &= 5.9 \text{ m}
 \end{aligned}$$

Add an allowance for cutting waste to obtain the total ordering requirements.

Boards are normally finished at external and internal corners by being butt-jointed to corner fillets (weatherboard stops), as shown in Figure 27.2. External corners may sometimes be mitred. Boards should be fixed in long lengths, with the end joints staggered and made over studs. Boards with rebated joints and over 100 mm in width are double nailed at each bearing point.

To apply rebated weatherboards, first fix the internal and external corner stops. Take the first or starter board and cut it to length, taking care not to fit the boards too tightly as this can force the stops out of

Fig. 27.1 Common weatherboard profiles: (a) rusticated nominal 150×25 ; (b) double log cabin 150×25 ; (c) checked and nosed, checked and chamfered; (d) sawn splayed nominal width 200



plumbed. Then, the top and bottom plates are straightened and plumbed, with the bottom plate being nailed off and the top plate being temporarily braced. This process is covered in Chapter 18, Wall framing.

place and open other joints. Tack it lightly into position in line with the bottom edge of the bearer. Permanently nail the two ends and set up a string line to the top edge of the board. Adjust the edge of the board to the string line and permanently nail it into position (Fig. 27.3). Continue fixing subsequent boards, pulling them tightly down on to the rebate and nailing through the face. Sight along the boards occasionally to maintain a straight line.

Splayed weatherboards must be fixed only with hot-dipped galvanised or other non-corrosive nails. First set out the internal and external weatherboard stops, allowing for a minimum lap of at least 25 mm for Baltic pine and 30 mm for hardwood. The stops are marked out evenly to suit the spacing (cover width) of the weatherboards. They are designed so that the boards will fit evenly spaced between the base plinth line and the eaveline (Fig. 27.4).

It is important that stud walls are straightened prior to the installation of any cladding and building paper/vapour barrier. The straightening process is twofold. First, after the walls have been erected, the corner studs and wall junctions are straightened, fixed and

Fig. 27.2 Corner fillets for siding

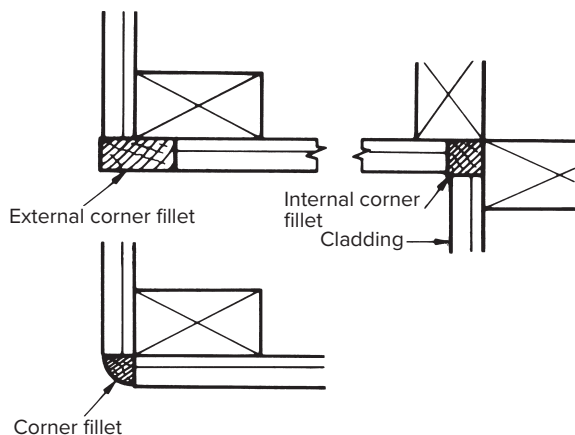


Fig. 27.3 Starting to fix weatherboards

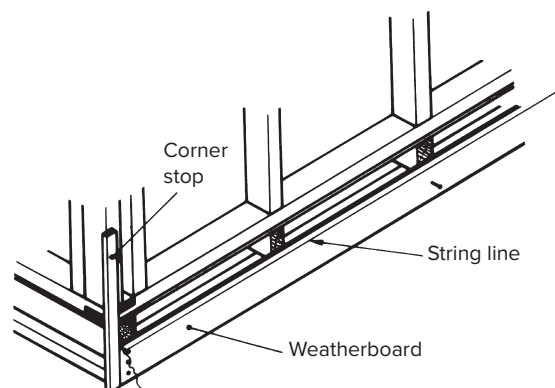
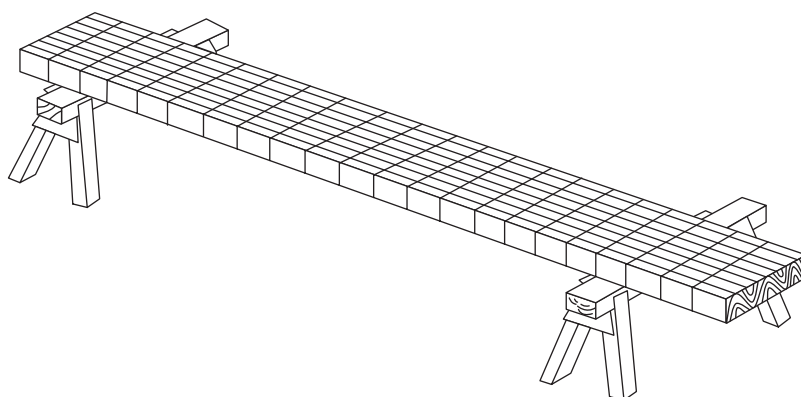


Fig. 27.4 Setting out weatherboard stops

Straightening prior to cladding installation is similar to the process of straightening floor joists before installing floorboards. Using a long straight edge and holding it across the timber studs, identify any high spots. Those high spots on the studs can be planed using an electric plane, ensuring the planed area is feathered with every stroke. Continue this process all over the wall, so as to achieve a consistent flat surface. If any low spots are found, pack them using masonite and again feather out the packing away from the low point on that stud. Once the wall is straightened, a vapour barrier needs to be installed; this will aid with the insulation and weatherproofing of the wall, and help stop moisture from getting into the stud wall.

The stops are now nailed in position at the corner junctions resting on the plinth board. The starter board is packed along the bottom edge to the same thickness as the tapered edge of the boards and is nailed permanently to a straight line. With the first board in place, insert nails into the next lower marking on the weatherboard stops and stretch a line through from end to end. Sight and check the line for any sag and if necessary lift the line in the centre. Nails can now be inserted to the line on every third or fourth stud and act as a rest for the next board while it is being fitted. Boards are scribed and fitted to the corner stops. Joints in the length of a wall are cut square and centred over the studs. Adjacent boards must not be joined on the same stud; all joints must be staggered.

Nailing is done through the face so that the nails will just clear the tip of the board underneath. Continue fixing subsequent boards, checking that joints are neat and not over tight (Fig. 27.5).

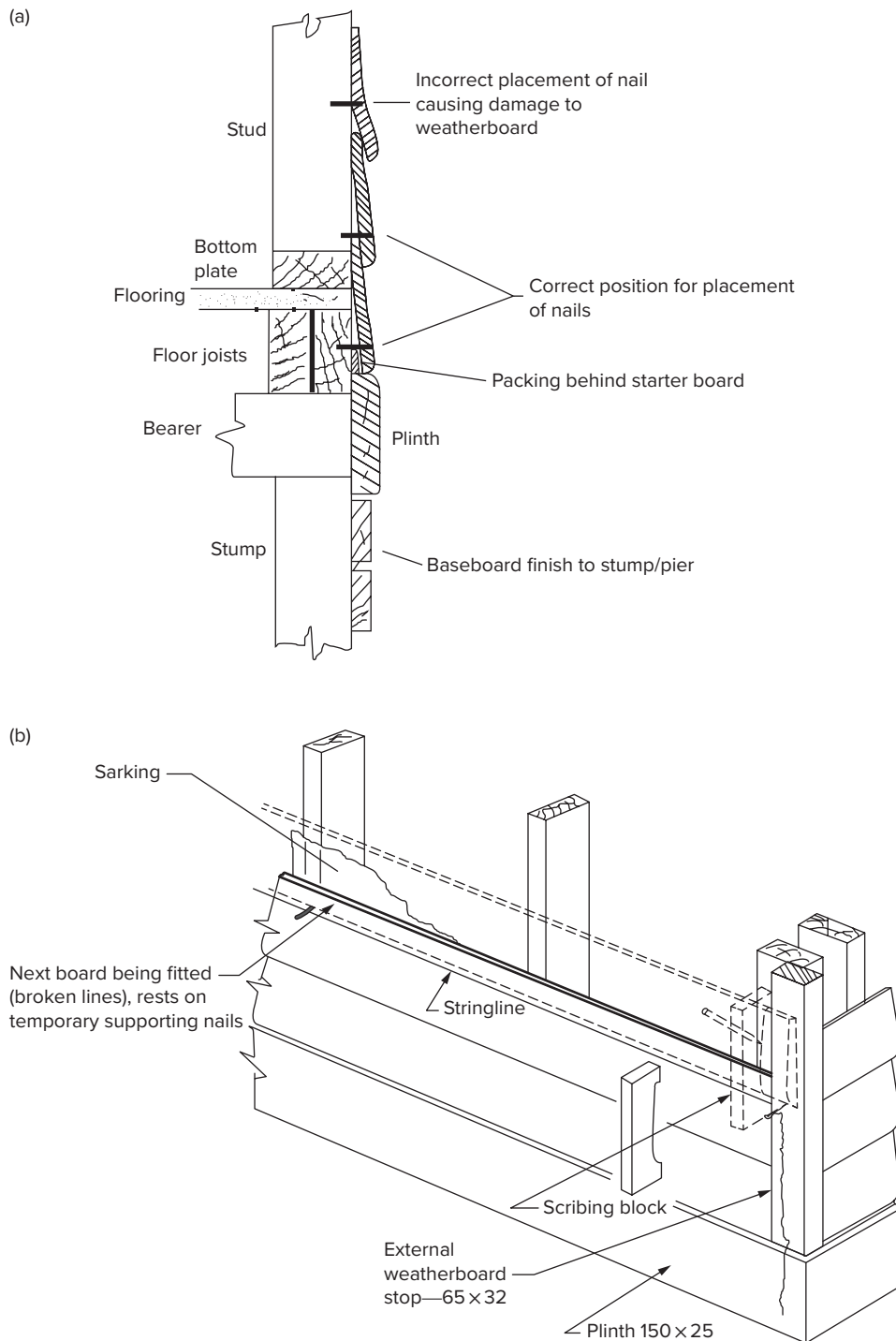
Weatherboards, including any with rebates and their ends, should be sealed with primer or some other means, preferably before they are fixed.

TIP Never at any time nail through both boards. Always place the nail so that the board below is narrowly missed.

CHECK YOUR UNDERSTANDING

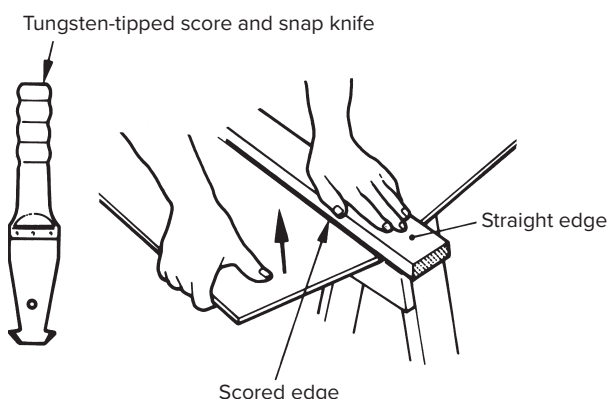
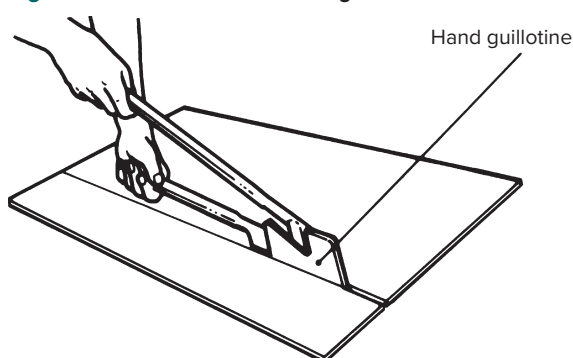
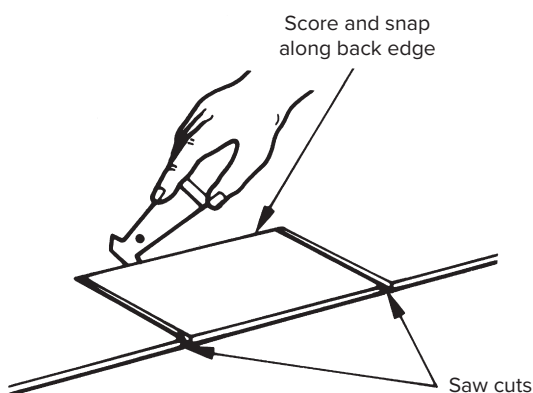
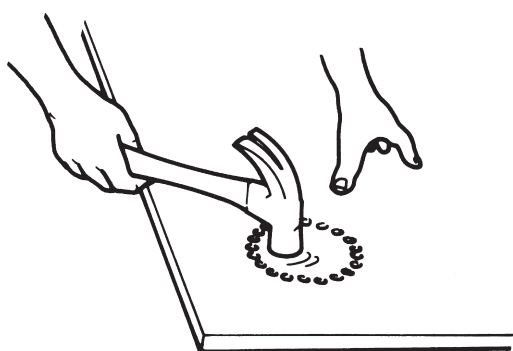
2. Illustrate with a sketch at least four profiles used in timber siding.
3. Splayed weatherboards with lapped joints must have a minimum lap of how many millimetres?
4. Sketch a neat sectional view of a stud wall with splayed Baltic pine weatherboards attached. Show the position of the plinth board and the bottom three weatherboards nailed correctly in position.
5. What is the recommended fastener for fixing splayed weatherboards to a timber frame?
6. Before fixing weatherboards or chamfer boards to a stud wall, what treatment should be applied to the lap and end joints of those boards?

Fig. 27.5 Fixing splayed weatherboards: (a) to a frame on a timber subfloor system; and (b) to a timber wall frame



27.1.1 Fibre cement products

Fibre cement products are manufactured from Portland cement, ground sand, cellulose **fibre** and water. They are widely used as external sheeting to timber-framed structures. They will not rot and are fire resistant, comparatively easy to maintain, economical and, if correctly applied, have an almost indefinite life.

Fig. 27.6 Fibre cement—scoring and snapping**Fig. 27.7** Fibre cement—hand guillotine**Fig. 27.8** Fibre cement—scoring and hand sawing**Fig. 27.9** Fibre cement—hole forming

27.1.2 Fibre cement flexible sheet

Single-sided building sheet is manufactured in two thicknesses: 4.5 mm and 6.0 mm thick. The sheet width is 900 mm and 1200 mm, and lengths range from 1200 mm to 3600 mm in 300 mm intervals. Like all fibre cement products, all sizes may not be available in all states, so check with local suppliers. The methods of cutting flexible sheet include the following.

27.1.2.1 'Score and snap'

Support the sheet, face side up, on stools and position a straight edge along the line of the cut. Using a tungsten-tipped score and snap knife, score the sheet along the straight edge to about a third of its thickness and snap upwards to achieve a break (Fig. 27.6). Rough edges can be trimmed up with a rasp if necessary.

27.1.2.2 Hand guillotine

This method will produce a clean straight edge. The cut is made on the waste side of the line to allow for the thickness of the blade (Fig. 27.7).

27.1.2.3 Hand sawing

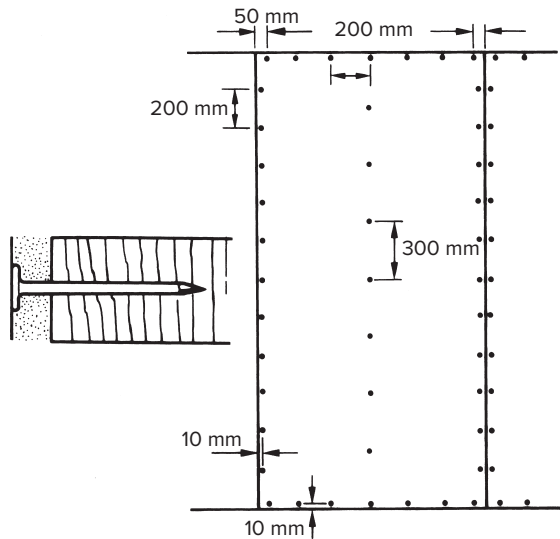
Hand sawing is suitable for making small cuts, but preferably use an old saw (Fig. 27.8).

27.1.2.4 Hole forming

Small rectangular and circular holes can be formed by drilling a series of small holes around the perimeter of the hole and tapping out the waste piece from the face of the sheet (Fig. 27.9). Ensure that the sheet edges are properly supported and trim the hole to shape with a rasp if necessary.

27.1.2.5 Fixing

To fix flexible sheets to a frame, use galvanised fibre cement nails of 25 × 2.0 diameter into hardwood, and 30 × 2.0 diameter into softwood. Nails are spaced 200 mm apart and no closer than 10 mm to the edge of sheets and 300 mm apart to the body of the sheets. No nail should be closer than 50 mm to the corners (Fig. 27.10).

Fig. 27.10 Nailing fibre cement sheets

Fibre cement flat cover moulds and a range of PVC jointers and angle cover moulds are available for joining flat flexible sheets.

27.1.3 Vertical joints

Wall 'vee' joints (Fig. 27.11a) are formed by using a coarse file to form a small chamfer to the edges of the adjoining sheets. Nail both edges at 200 mm apart. Include a strip of aluminium foil flashing between the sheeting and the timber frame.

27.1.3.1 PVC jointer

Nail through the extended leg of the jointer to the framing at 150 mm centres (Fig 27.11b).

27.1.3.2 Fibre cement corner mould

Nail sheets to framing before the cover mould is fixed. Nail clearance holes should be predrilled in the cover mould (Fig. 27.11c).

27.1.4 Horizontal joints

When forming horizontal joints, it is essential to include a metal or PVC weather strip. First fix the lower sheet, then apply the weather strip followed by the upper sheet, nailed as recommended (Fig. 27.12).

27.1.5 Fibre cement plank siding

Fibre cement planks are a single-sided building plank, the face of which can be smooth or textured in a variety of wood grains or other patterns. They

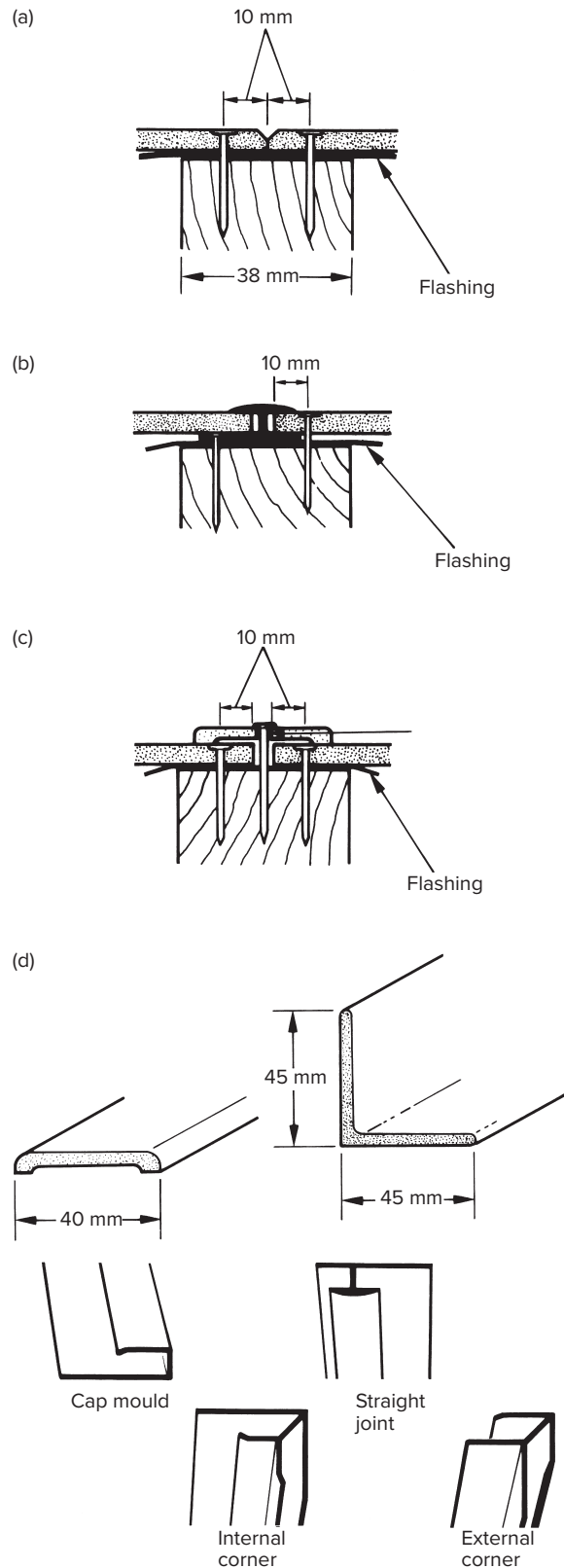
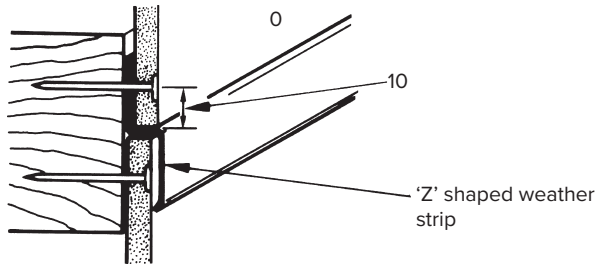
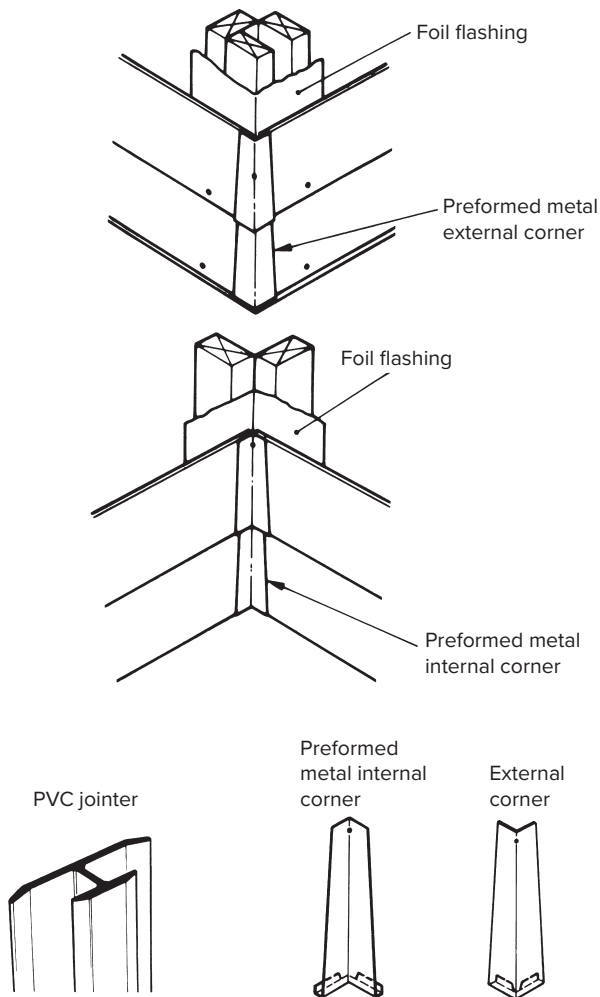
Fig. 27.11 Vertical cover strips and mouldings: (a) vee joint; (b) PVC jointer; (c) cover mould; and (d) PVC accessories

Fig. 27.12 Horizontal cover strip

Accessories consist of PVC joiners and preformed metal internal and external corners. Planks are fixed to studs by nailing through both thicknesses of planks with 40×2.8 fibre cement nails (Figs 27.13 and 27.14).

TIP Always refer to the manufacturer's technical notes for the correct fixing details.

Fig. 27.13 Fibre cement plank accessories

are used mainly as cladding or part cladding for domestic buildings, particularly in upper floor additions, or as recladding when rejuvenating tired dwellings.

Planks are 7.5 mm thick, and the width can be 170, 180, 230, 300 or 310 mm. Lengths are 3600 mm or 4200 mm. Note again that all sizes may not be available in all states, so check with local suppliers.

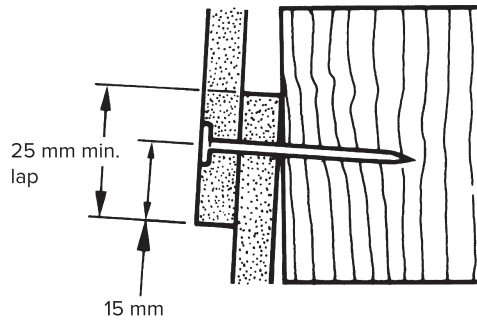
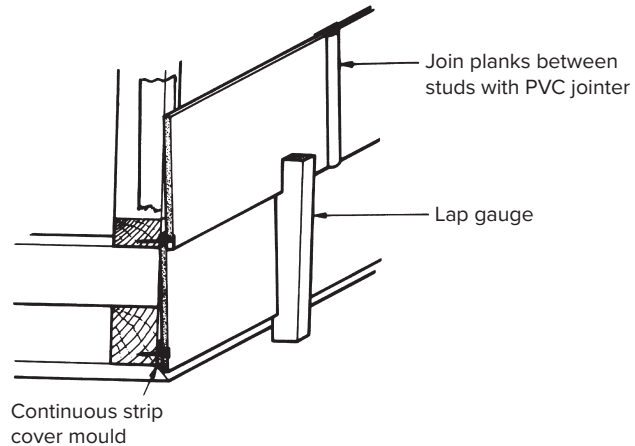
27.1.5.1 Fixing procedure

Fix vertical flashings to all external and internal corners. Also fit any sill or head flashings to openings as required. Nail a continuous strip of 40 mm fibre cement cover mould around the perimeter of the building, level with the top of the ant capping.

Locate the height of the top edge of the first plank and level this line around the frame of the building to establish a datum for fixing the first course. Drive a series of nails along this line to act as a guide for fixing the starter plank. Start with the end of the first plank flush with an external corner and against the guide nails, and fix to the framing. Continue fixing the planks around the perimeter of the building, jointing the ends with PVC joiners as necessary and removing the guide nails (Fig. 27.15). Insert preformed metal corners and fix through the hole at the top.

Calculate the overlap of the planks, the minimum overlap being 25 mm. This can be varied to work even courses of planks to the height of the wall. Fabricate two lap gauges. Commence the second course with an offcut so that the vertical joints will be staggered, and use the gauge to maintain the correct lap. Fix subsequent courses by inserting the PVC joiners and metal corners as necessary.

Complete fixing details are available from the manufacturer's information sheets and should be obtained and closely followed when carrying out this work.

Fig. 27.14 Plank nailing**Fig. 27.15** Fixing fibre cement planks

TIP An alternative method to using a lap gauge is to position subsequent courses using a storey rod. A storey rod is set out to the required spacing of the boards using a similar procedure that is used for setting out weatherboard stops. Refer to details previously covered in this chapter.

CHECK YOUR UNDERSTANDING

7. Fibre cement flexible sheeting is available in two widths for wall lining. What are those widths?
8. With the aid of a neat sketch, show the nailing requirements for fixing a fibre cement sheet to a timber frame.
9. Describe three effective ways to cut fibre cement flexible sheets.

27.1.6 Hardboard siding

Hardboard is a manufactured timber product, commonly found used as a siding or more often as cladding to upper-storey extensions. The fixing is essentially similar to the fixing of fibre cement products. Again, refer to and check the manufacturer's information sheets for fixing details.

27.1.7 Aluminium siding

Aluminium siding has been available for many years but essentially it is fixed only by licensed applicators. The material is formed from precoloured strip aluminium, either in precut lengths, or as a continuous strip rolled and cut to length on-site. It is installed with insulation backing, usually a foamed plastic. The siding is available in both horizontal and vertical profiles.

27.1.8 Vinyl siding

As with aluminium siding, vinyl siding is generally available only through applicators. The vinyls are available in both thin and thicker grades.

27.1.8.1 Thin vinyls

These are mainly used in the recladding market, and are applied over existing wall claddings. They are less than 2 mm in thickness.

27.1.8.2 Thick vinyls

These sidings are approximately 10 mm thick, and have a board width of around 270 mm with a cover of 250 mm. They are tough faced with a cellular core. The boards are made of PVC powder, with ultraviolet ray inhibitors and fillers added, which is then heated and extruded through a die. The continuous lengths are cut to standard lengths of 5 m, with the join being treated with a preformed joiner strip. The boards interlock when fixed, and can be fixed directly to timber framework.

27.1.9 Plywood cladding

Plywood cladding is a great alternative to other cladding types. It comes in large sheets and in a number styles, including:

- grooved
- textured surface
- flat surface.

Generally, plywood cladding comes in a standard sheet size of 2400 mm × 1200 mm × 12 mm. It is impregnated with a chemical to assist with weatherproofing and inhibit deterioration over time from the elements. (Always refer to the material safety data sheets for the chosen product to establish which chemical has been used in the manufacturing.) Many of the products can be left raw, although it is possible to paint them. Plywood cladding comes with a pre-machined shiplap joint, as can be seen in Figure 27.16.

This shiplap profile weatherproofs the joint and also allows for any movement that can occur in the sheet over time. The installation and fixing detail for plywood cladding is important to keep the waterproof integrity of the product and to accommodate any movement. Figure 27.17 gives an example of the installation and fixing requirements of plywood cladding; however, the manufacturer's specifications for the chosen product should always be consulted prior to use.

Fig. 27.16 Shiplap joint for plywood cladding

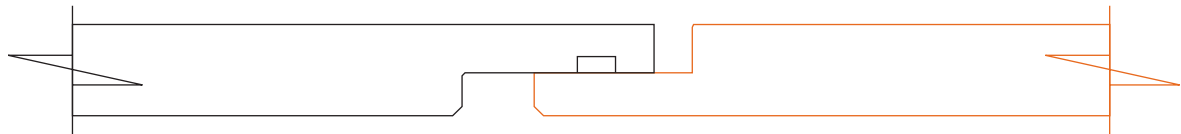
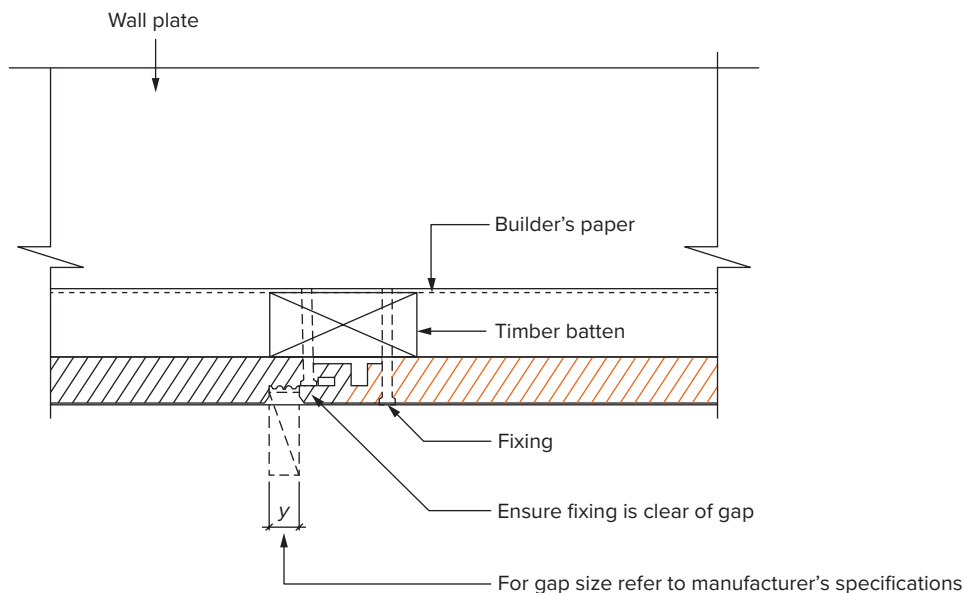


Fig. 27.17 Fixing details for shiplap cladding



CHECK YOUR UNDERSTANDING

10. Name two styles of plywood cladding.
11. What type of joint does plywood cladding use?

27.2 Install sheet/panel cladding

There are many types of sheet/panel cladding available. The material from which they are manufactured can vary. Earlier in this chapter, we discussed plywood cladding. Other materials from which cladding panels are made include metal (aluminium, steel, zinc, copper etc.) and cement-based sheets. The design, fixing, application and installation of these products varies; it is therefore important to have an in-depth understanding of the product being installed. Always refer to the manufacturer's specifications and installation instructions prior to installing any of these products. Consult the product's SDS to establish if there are any particular hazards when using the product and make sure you know about the recommended disposal methods for the waste produced when using the product.

Many of these products are installed on metal or timber battens fixed to the structure. The fixings may be visible or concealed. Some of the products are prefinished while others can be painted or rendered.

Some products are installed in a matrix-style arrangement, highlighting each individual sheet. This style of cladding is said to have expressed joints, as the junctions between each sheet are visible. As the joints are exposed, they need to be waterproofed, and in many cases a rubber gasket is installed prior to the panels being installed. The gasket serves to waterproof the exposed joints, therefore making the cladding waterproof. In some cases, silicon or mastic may be used to weatherproof the joint.

27.3 Understand energy efficiency and the fire-resistant properties of cladding

Cladding can increase the energy efficiency of a building depending on the material it is manufactured from. In some cases, additional materials are installed to achieve this. For instance, when metal cladding is to be installed onto a metal frame, a thermal break also needs to be installed, which stops the transfer of heat or cold from the cladding to the frame. Moisture control can also be an issue for some claddings, requiring some form of barrier to be placed between the cladding and the frame. This could be in the form of builder's paper or some other non-porous product.

Claddings can also provide resistance to fire. This depends on the material the cladding is manufactured from and how the cladding is installed. As mentioned earlier in the chapter, this is of particular importance in bushfire-prone areas. It is important always to install fire-resistant cladding according to the manufacturer's installation instructions and the relevant Australian Standard or code.

Student research

Investigate what other types of cladding are available.

End-of-chapter activity

Produce a set-out rod for a minimum height of 2.1 metres using the effective cover of a 180-wide Baltic pine weatherboard.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684 —2010
Residential
timber-framed
construction

AS/NZS
2904:1995
Damp-proof
courses and
flashings

National
Construction
Code (NCC)

Tradie talk—‘Work the cover’ for a full board finish

Chapter 28

Installation of windows and doors

Learning Objectives

LO 28.1 Identify window types

LO 28.2 Understand window construction

LO 28.3 Set out rods

LO 28.4 Assemble and glue up the sash

LO 28.5 Construct vertical sliding slash windows

LO 28.6 Fit window frames and flashing

LO 28.7 Install glazing

LO 28.8 Construct doors

Introduction

In this chapter you will learn how to identify different types of doors and windows. You will learn how to construct timber doors and windows and learn about the installation of windows—techniques that require a tradesperson to have a high level of skill. These items can become beautiful adornments to the dwelling as well as serving a practical purpose. Many of the techniques identified in Chapter 8, Timber joints, are used in the construction of these items.

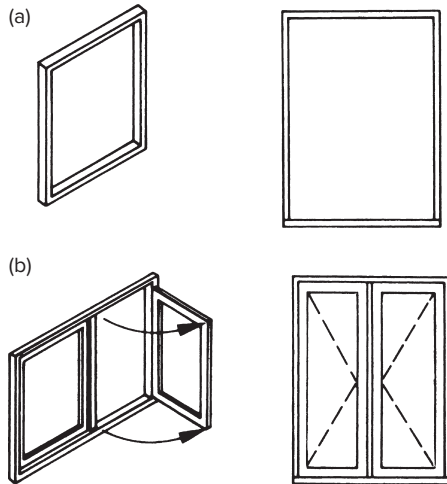
28.1 Identify window types

Windows are an essential component in residential buildings, their purpose being to admit light and ventilation. Building regulations specify the minimum requirements. Windows are composed of two parts:

1. the window *frame*, which is permanently fixed into the structure of the building
2. the *sashes*, which are the movable parts of the window (in some cases fixed) and are fitted to the frame.

TIP Windows are named according to the way in which the sashes operate within the frame.

Fig. 28.1 (a) Fixed sashes; (b) casement sashes



28.1.1 Fixed sashes

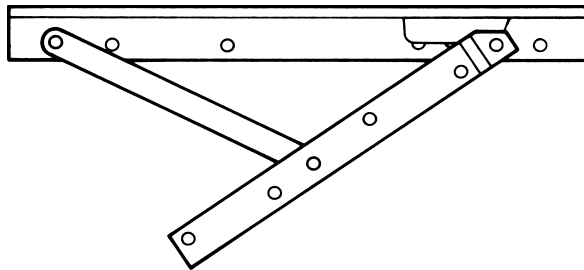
Fixed sashes are permanently fixed in the frame and admit light only (Fig. 28.1a). All of the sashes to a room cannot be fixed; some must be operable to meet building regulation requirements.

28.1.2 Casement sashes

Casement sashes are either hinged on the side or have a friction stay (Fig. 28.1b). The friction stay allows the sash to pivot near the side and open to its full extent, or lock by friction to any intermediate position (Fig. 28.2).

The advantages of casement sashes are that they will provide maximum ventilation and can be cleaned readily from the inside. On the other hand, ventilation is not so easy to control, insect screens are more difficult to fit, and the sash projecting beyond the face of the wall can sometimes be a dangerous obstruction.

Fig. 28.2 Friction stay



28.1.3 Awning-type sashes

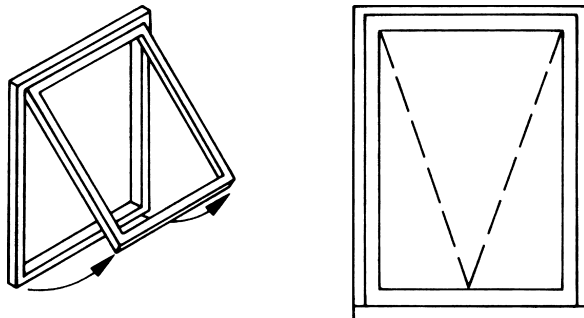
Awning sashes pivot from near the top and can be a single sash or a number of sashes arranged above each other (Fig. 28.3). They are sometimes wrongly named *hopper windows*.

Sashes can be fixed on friction stays; this allows them to open and be held in any position. The manufacturer's instructions should be consulted when selecting a stay so that one long enough to suit the overall height and weight of the sash is chosen.

Single-awning sashes are a popular type of window. They are often fixed with a non-friction-type hinge; an extending chain winder on the sill opens the sash and holds it in position (Fig. 28.4).

Ventilation can be controlled, avoiding direct draughts, and insect screens can be conveniently fitted inside.

Fig. 28.3 Awning sash



28.1.4 Horizontal sliding sashes

Sliding windows are widely used and an extensive range of stock sizes is available in aluminium windows. The sash slides on metal or plastic rollers along tracks fixed to the sill. The sashes should have a wheel base as wide as possible, and preferably the height of the sash should be no more than two times its width. The sash pull should be

set close to the base, where it will not tend to tilt the sash sideways in operation. On a single track, no more than half the window can be opened (Fig. 28.5), and ventilation is not readily controlled. However, as the sash is contained wholly within the frame, insect screens can be conveniently fitted to the outside, and the windows can be quite economical.

28.1.5 Vertical sliding sashes

Vertical sliding sashes are also sometimes referred to as *box-frame sashes*, or commonly as *double-hung sashes*.

Double-hung windows have long been a very popular type of window; they were originally developed from the box-frame window with sashes hung on cords and counterbalanced by cast-iron weights (Fig. 28.6). Today the timber or aluminium sashes are hung on spiral spring balances.

Double-hung sashes have a number of advantages. Ventilation is readily controlled and can be at the top, bottom or both. The sashes are contained within the frame and insect screens can be fitted to the outside. However, only half the window area can be opened at any one time, and poorly fitted sashes can present some problems such as jamming or rattling.

Some double-hung sashes are available that are 'sash-less'; that is, the window glass is held in a counterbalanced suspension system, without being fitted into a timber or metal frame.

28.1.6 Other window types

Other sashes still seen occasionally, but practically 'extinct' in new construction, are the *hopper-type sash* and the *pivot-hung sash* window (Fig. 28.7). More recently, European-type window systems have started to be seen in Australia. These windows systems are generally made from uPVC and are double glazed. The windows have a high thermal efficiency as well as sound insulation properties. The system can be adapted so that various types of window can be produced from the stock materials, including casement, awning, sliding, tilt and turn, and tilt and slide.

28.2 Understand window construction

Window frames built into the external walls of a building are subject to some of the harshest weather conditions. They must be made from durable materials and constructed in such a way as to resist

Fig. 28.4 Sash winders

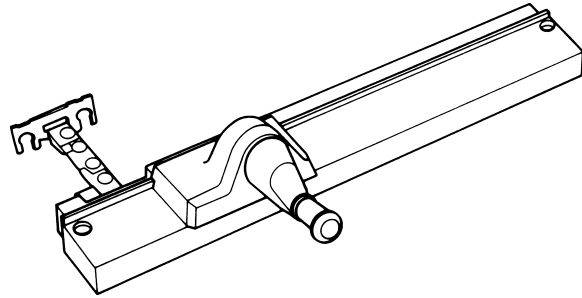


Fig. 28.5 Horizontal sliding sash

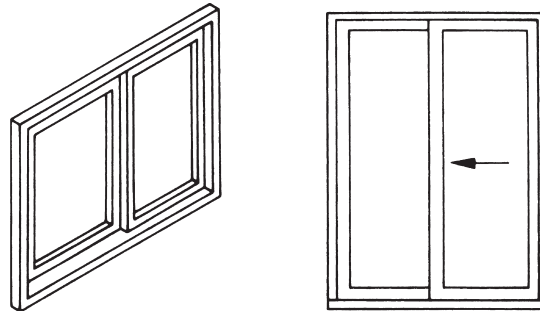


Fig. 28.6 Double-hung window

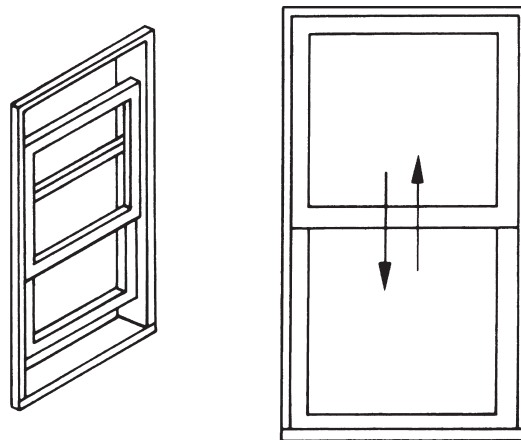
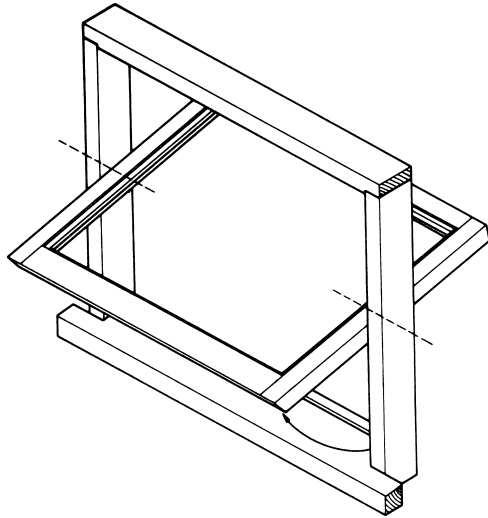
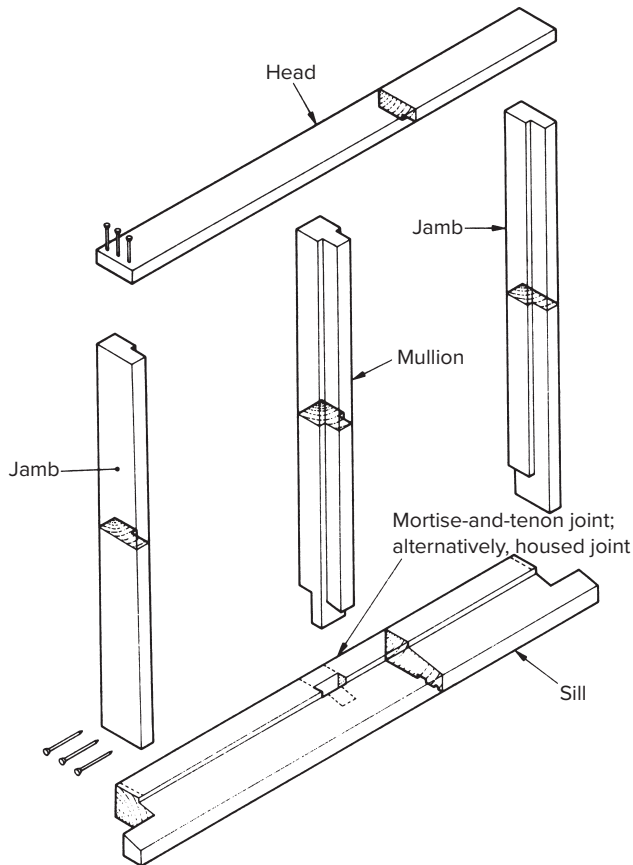


Fig. 28.7 Pivot-hung sash window**Fig. 28.8** Elements of a solid window frame

the penetration of dampness around the sashes. Timber species used include clear Oregon, western red cedar, Tasmanian oak, meranti (Pacific maple) or pressure-treated pine. For sills, which are the most exposed parts, tallowwood, redgum and merbau are often used, and no doubt in some areas other local timbers serve equally well. Window frames vary in construction according to the type of sashes to be fitted.

28.2.1 Solid-rebated window frame

A solid rebate is used with casement and awning sashes. Fixed sashes can be fitted; however, it is more usual to set a glass panel directly into the rebate of the frame and secure it with timber fillets or beads.

The basic construction of the solid frame is shown in Figure 28.8. The timber sections are an example of standard metric profiles for milled products available from timber merchants. Manufacturers of mass-produced frames will mill sections to their own details, which also meet the demands of durability and weatherproofing.

Parts of the solid frame include the *head* and the *stiles*, which are of the same section as single-rebated material. A vertical dividing member between sections is called a *mullion* and may be double-rebated. The bottom member of the frame is the *sill*; this is of special interest as it must resist most of the weather.

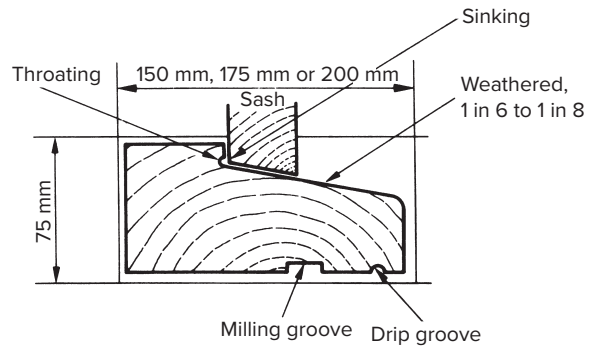
Figure 28.9 shows the detail of the sill section, which is described as *sunk*, *throated* and *weathered*. These are all features that enable the sill to fulfil its function. *Sinking* is the drop in level behind the sash. *Weathering* is the slope on the sill, which varies from 1 in 6 to 1 in 8. *Throating* is the small groove formed at the corner of the sinking; it may not be included in the standard section, but it will increase the weatherproofing of the sill by breaking the capillary action of water tending to seep under the sash, especially when assisted by a stiff breeze.

On the bottom of the sill is a *drip groove* for the purpose of preventing droplets of water forming on the edge of the sill and running underneath. The *milling groove* helps to prevent distortion of the sill by breaking up the wide underside into narrower widths and reducing the overall amount of shrinkage.

The stiles and mullion are housed into the head of the frame (Fig. 28.8). Note the mortise-and-tenon joint between the mullion and sill. The mortise is made 25 mm wide and lines up on one side with the sinking in the sill. The shoulders on the mullion are bevelled where necessary to butt down tightly onto the sill. The tenon is wedged from underneath the sill. Wedges are driven uniformly to avoid forcing the frame out of square. Alternatively, a housed joint may be used.

Frames are assembled after painting the joints with a timber primer or other equivalent product. They are nailed together with galvanised flat head nails, checked for square by making the diagonals equal, and a temporary brace is fixed to the inside face.

Fig. 28.9 Detail of a windowsill



WORKPLACE SCENARIO

When installing windows, it is always good practice to pack the sill of the window. It must be packed level, so start by placing the same size of packer, e.g. 3 mm, on both sides of the opening and then place the spirit level on top of the packers to ensure it's level. If not, increase or decrease the packing on one side until level. (Make sure there is enough room in the opening such that when the window is installed, there is still a gap above the top of the window.)

When the sill of the window is packed, it must be done directly under the stiles to ensure no pressure is put onto the glass or the operating section of the window.

28.2.2 Finishing window frames

The outside is finished with an architrave when used in a timber wall or with storm mouldings in brick-veneer construction, as shown in Figure 28.10.

28.2.3 Sashes

Sashes are made from comparatively slender sections; the names of the members are shown in Figure 28.11.

The procedure for joining the stiles and the top and bottom rails is consistent with the procedure for other framed joinery items. Members dividing the glazing into smaller areas are called *glazing bars* and are either vertical or horizontal; horizontal bars are referred to as *lay bars*.

Each separate pane of glass is a *light*, and a sash can be described by the number of lights and the arrangement of the glazing bars. Examples are given in Figure 28.12.

Fig. 28.10 External trim to a solid window frame: (a) timber frame construction; (b) brick veneer; and (c) cavity brick construction

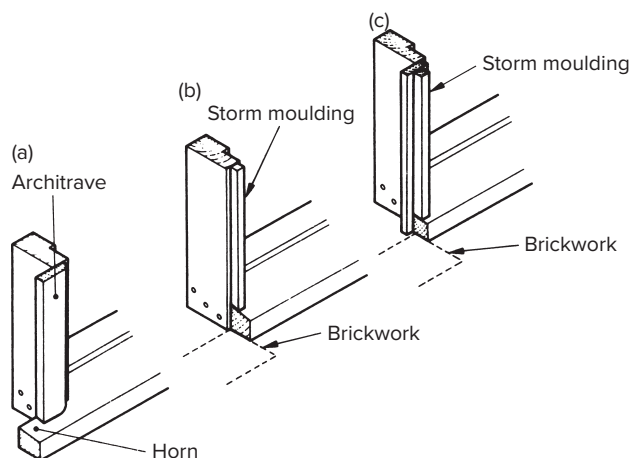
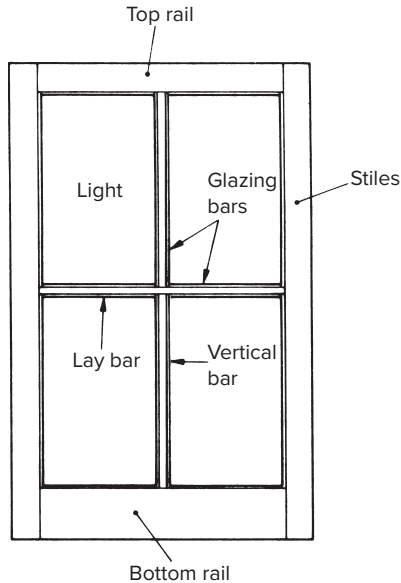


Fig. 28.11 Parts of a sash



Sash stock is shaped in a particular manner and the thickness is divided into three approximately equal parts.

The rebate is necessary to hold the glass panels, which are secured in place with putty or glazing beads; it is on the external face of the sash.

The actual amount of daylight seen through the sash is measured to the *daylight line*, and the glass size is measured to the *glass line*, allowing a clearance for expansion and contraction. The difference between these two dimensions is the depth of the rebate. The centre third is the ribbon, on which are located the mortise-and-tenon joints; it is approximately 10 mm wide. The mould on the interior third softens the harsh bulky edge of the frame and can be an *ovolo* mould or, commonly, a *splayed* mould (Fig. 28.13).

The mould 'sticks down' on the face the same distance as the rebate, making a straight shoulder line on the rails. Note that the effective width is the full-face width of the members, giving the maximum amount of material on which to proportion the mortise-and-tenon joints. Dimensions of members, including sash bars, are given as examples of stock material.

28.2.4 Sash joint

Stiles and rails are joined with mortise-and-tenon joints, modified to the situation and referred to as *sash joints* (Fig. 28.14).

Fig. 28.12 Arrangement of lights and glazing (lay) bars

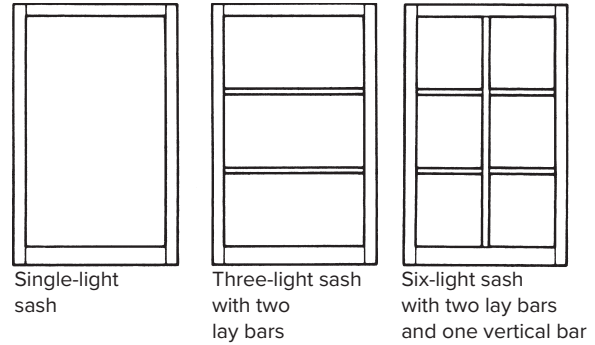
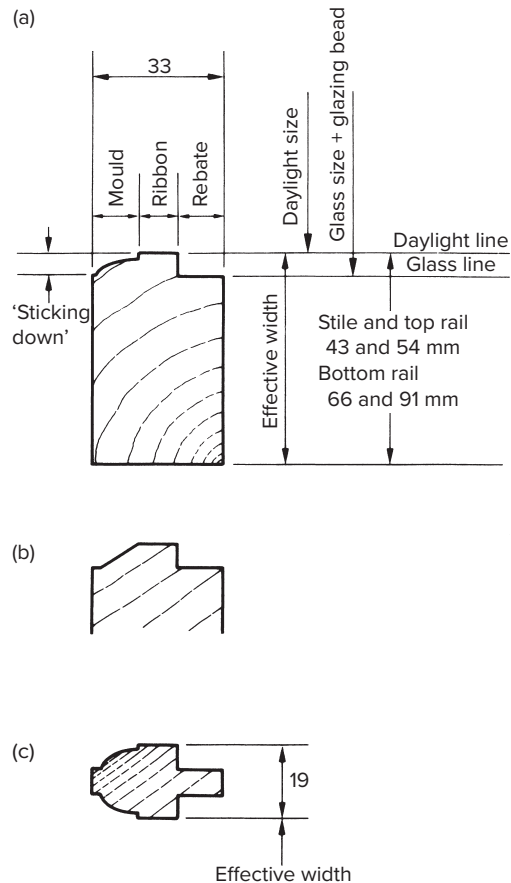


Fig. 28.13 Sections of sash stock: (a) ovolo moulding; (b) splayed moulding; and (c) sash bar



The width of tenon is again two-thirds the effective width of the rail minus one wedge allowance; the thickness is 10 mm. Due to the slenderness of the stile, it is not haunched, but a projection is left on the stile that engages into a corresponding recess in the rail. This type of joint is called a *franked joint* and the actual *franking* is the projection on the stile.

The shoulder on the rail is scribed over the mould on the stile. In a machine-made joint, the scribing is across the full width of the rail (Fig. 28.15). However, if this part of the job is done by hand, it is simpler to remove some of the mould from the stile and scribe only sufficient of the shoulder to make the joint between the moulds.

Where sash bars meet at right angles, there will be a *through bar* and a *cut bar*. The through bar is made in the direction where it will tend to strengthen the sash most effectively. The bars can be stub-tenoned into the stiles and rails. The joint between the bars is shown in Figure 28.16.

The procedure for setting out, using set-out rods, and for making a casement frame and sash, including the glazing bars, will now be described. It is well realised that the bars are not always included in new sashes; so, if single-light sashes are being made up, ignore any reference to glazing bars.

Fig. 28.14 Sash joint

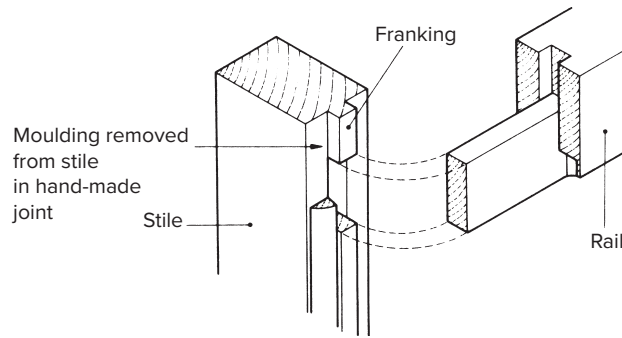


Fig. 28.15 Machine-made sash joint

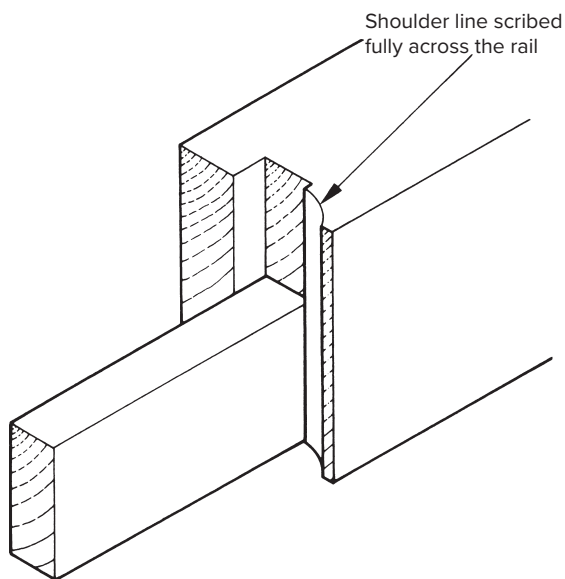
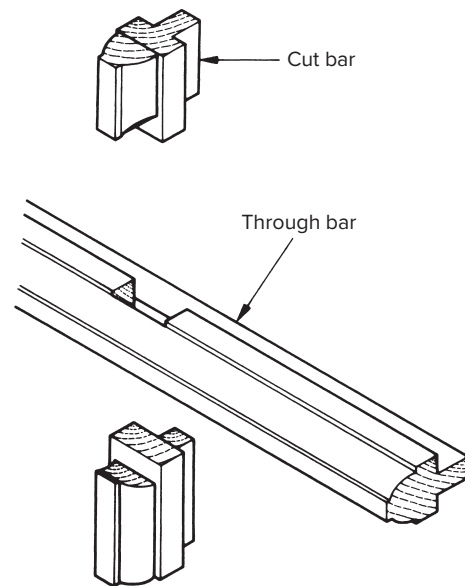


Fig. 28.16 Through and cut glazing bars



CHECK YOUR UNDERSTANDING

1. List five types of windows and indicate for each type how the sashes operate within the frame.

28.3 Set out rods

The manufacture of joinery items requires that information be extracted from building plans, correctly interpreted and passed on to the various personnel engaged in the production process. The only adequate way for this information to be prepared and clearly passed on to others is through the preparation of full-size workshop drawings; these drawings are termed *rods*.

An experienced joiner can no doubt make up a piece of simple joinery without the aid of detailed rods, but when he or she becomes part of a production team where the job will pass through different hands for each stage—setting out, preparation of the material, marking off, machining and assembly—before it is completed, a detailed drawing to which all can refer is essential.

The setting out of rods is carried out by a responsible person who must be able to read drawings, be conversant with production methods and have a sound knowledge of building construction so that adequate allowances for manufacture and building in can be provided.

For simple joinery items, such as a rectangular door or window frame, a vertical and a horizontal section will provide all of the necessary information; these can usually be set out full-size on a board, 150 mm to 200 mm wide.

When more complicated shapes such as curves are involved, elevations become necessary and these are set out on a sheet of plywood or hardboard. In rare instances, the only space large enough for a set-out is the floor of the workshop, made available by pushing back the benches.

The main points when setting out a rod are as follows:

1. Dimensions must be accurate—any discrepancies at this stage will carry on through the job and assume greater proportions the further the job progresses.
2. To assist in the reading of the rod, the sections should always be drawn with the face of the item facing the person setting out, with the bottom member, such as the sill or bottom rail, to his or her right-hand side.
3. Sections are drawn to full size and should show clearly the actual size of the various members and their relationship to each other. Dimensions are not shown except for an overall height and width.
4. The rod should be clearly and easily interpreted. Remove any surplus setting-out lines that could be misleading. Light hatching can be shown on end sections, but remember that the purpose is to make the area easier to identify and not to obliterate the essential information.

The method of fixing should be clearly indicated—mortises are crossed diagonally and wedge allowances are not shown. The centres of dowel holes are indicated with a cross and circled, with the diameter of the dowel indicated.

5. A cutting list should accompany the rod (Tables 28.1 and 28.2). This can be regarded as an order for the material required to complete the job. The length of members can be measured directly off the full-size rod and should include any allowances for cutting waste or horns required during manufacture or building in.

Table 28.1 Cutting list for sash

Member	Width	Thick	Material	No.	Length	Remarks
Stile	54	33	Oregon	2		Stock ovolo moulded
Top rail	54	33	Oregon	1		Stock ovolo moulded
Bottom rail	91	33	Oregon	1		Stock ovolo moulded
Lay bar	19	33	Oregon	2		Stock ovolo moulded
Vertical bar	19	33	Oregon	1		Stock ovolo moulded

Table 28.2 Cutting list for frame

Member	Width	Thick	Material	No.	Length	Remarks
Sill	142	66	Tallowwood	1		Stock casement sill
Stile	91	41	Oregon	2		Stock rebated
Head	91	41	Oregon	1		Stock rebated
Storm mould	19	19	Oregon	21		Standard quad

Order each item as the number of pieces of the actual length required; do not add them up into long lengths as this could result in many wasted short lengths.

The section sizes of members, if these are finished sizes, are indicated and included in the remarks column. They also draw attention to any other machining necessary, such as rebates or plough grooves indicated on the rod. If making up items from stock material, some of these details can be omitted and the different sections identified by a number or other description.

Copies of the cutting list will probably be required to pass to another part of the workshop for ordering the material, or to go to the office for the job to be costed.

An example of a set-out rod for a solid-frame six-light casement sash is shown in Figure 28.17.

If the frame is to suit a brick veneer or brick cavity wall, the height is measured from underneath the sill to the top of the storm moulding and is a multiple of brick courses. Deduct 10 mm from the height to allow for packing or bedding under the sill. Width is measured over the backs of the storm mouldings and is made to suit the opening in the brickwork.

When bars are set out, it is important that the daylight size to each light is exactly equal. Even with only a small variation, it is possible that every square of glass would have to be cut to a different size—an expensive mistake. The bars are set out by the ‘in and over’ method.

To set out the rod, straighten one edge and secure the rod to the bench with the straight edge overhanging 10 mm to 15 mm. All gauging is done in pencil from the straight edge, the quickest way being with the rule and forefinger (Fig. 28.18).

Alternatively, a wooden runner attached to the rule and gripped between the thumb and forefinger is an aid to accurate gauging. Square across the rod from the straight edge (Fig. 28.19).

The steps in setting out the rod are illustrated in Figure 28.20 and are described as follows:

1. Mark off the overall height and gauge a line to represent the interior face of the frame. Use short lengths of the stock material, cut from scrap, as templates to mark in the outline of each section.
2. After the sill is marked, continue with the head, first positioning the storm moulding and then locating the head relative to it. Using short lengths of sash stock, mark in the sash top and bottom rails, and space the bars in between (Fig. 28.17).
3. Proportion the mortise-and-tenon joints, mark in and cross the mortises.
4. Follow a similar procedure with the horizontal section, first setting off the width and locating the storm mouldings, followed by the other members.
5. Finally prepare the cutting list.

Fig. 28.17 Set-out rod for casement window sash

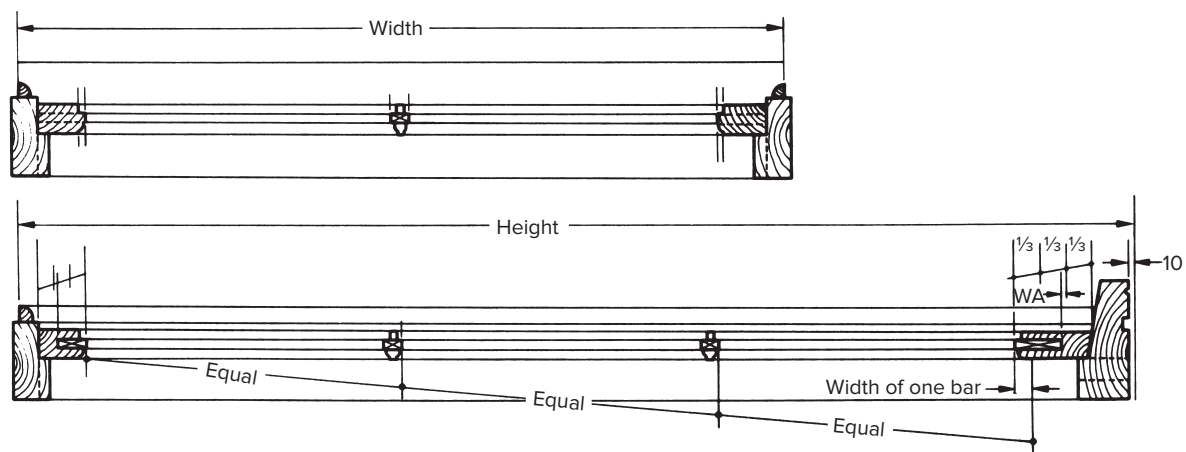


Fig. 28.18 Finger gauging

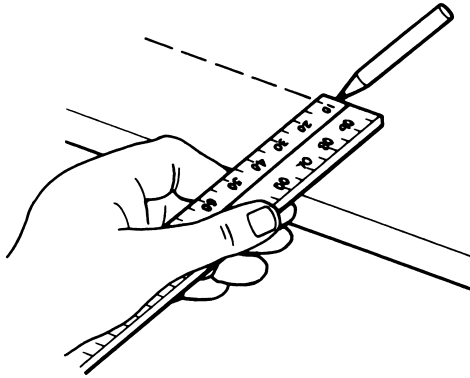


Fig. 28.19 Using a wooden runner

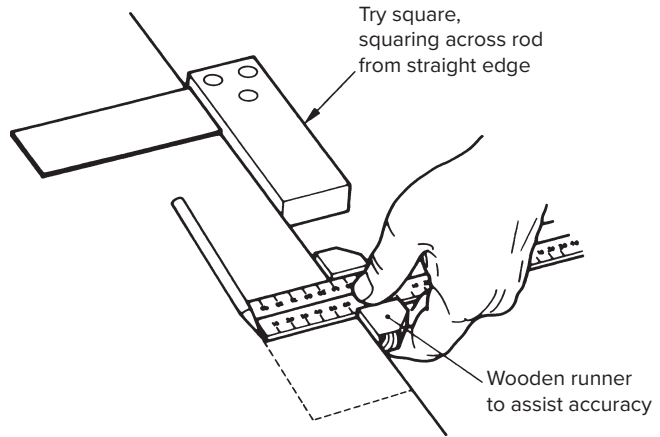
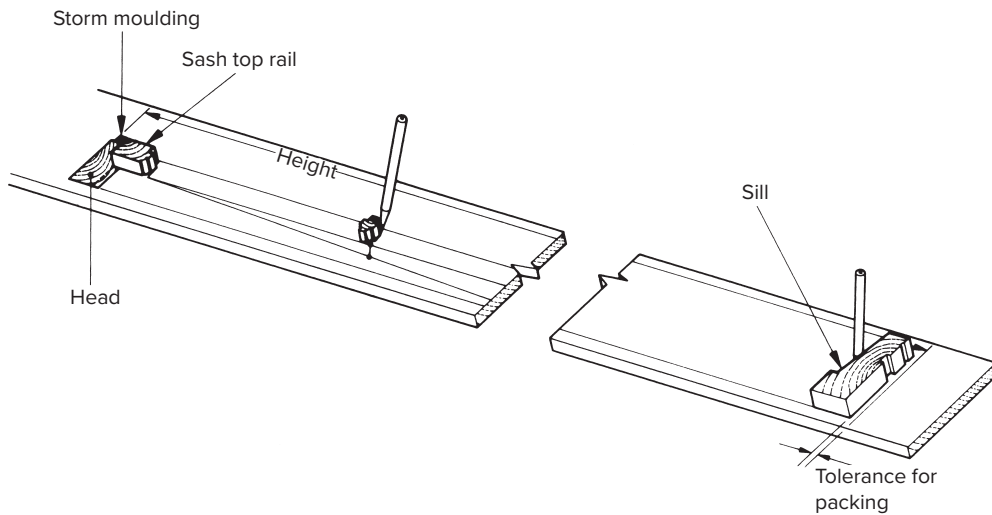


Fig. 28.20 Setting out steps for the rod



28.3.1 Marking out from the set-out rod

Marking out members of both the frame and the sash is done by laying them face down on the rod and projecting the relevant points directly onto the timber.

28.3.2 Marking out the stiles

Marking out the sash stiles is shown in Figure 28.21.

The procedure is as follows:

1. Lay the stile on the vertical section; the point of the try square can assist in transferring the position of the mortises onto the ribbon of the stile. To square around a section where the sharp corner has been removed by a mould, etc., use a *box square*. This is made up from wood, or folded from metal, and the ends must be square (Fig. 28.22).
2. Always mark out stiles in pairs; hold them together with the face edges together and the face sides opposite (Fig. 28.23). With sash stock, the moulded side is taken as the face side.
3. Square the mortises across both stiles and transfer the position around to the back of the stiles where there are to be through members. The try square can be adapted to square across the stiles by attaching an extension to the face: make a saw cut in a light lath of timber and slide it over the blade of the square.

Fig. 28.21 Marking out the stiles

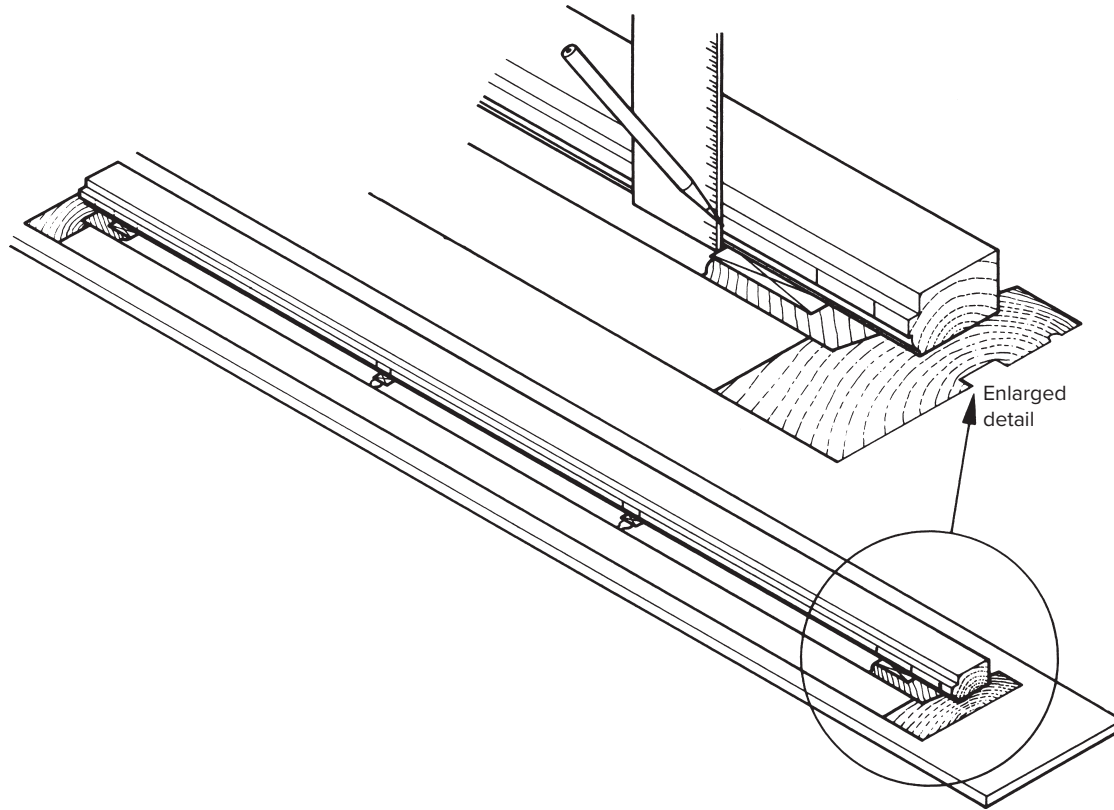


Fig. 28.22 Box square for mouldings

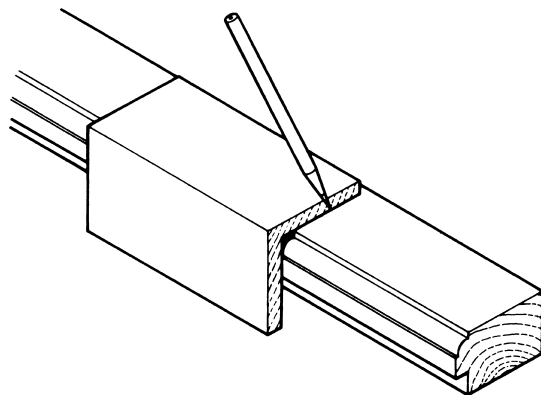
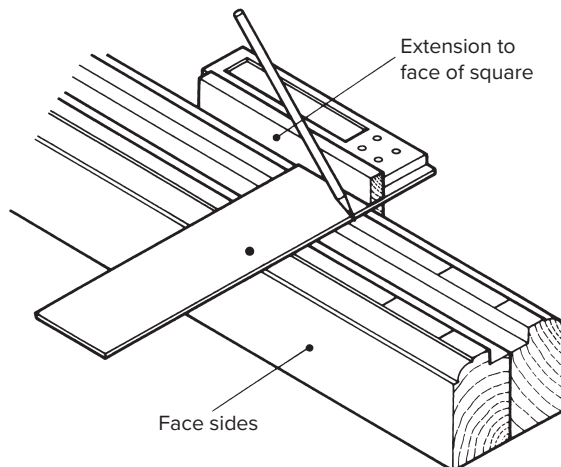
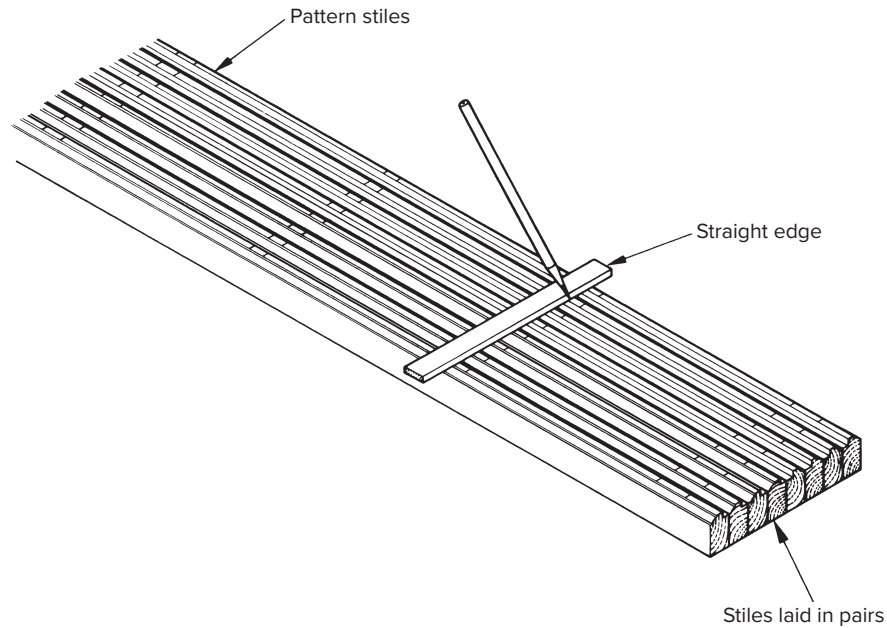
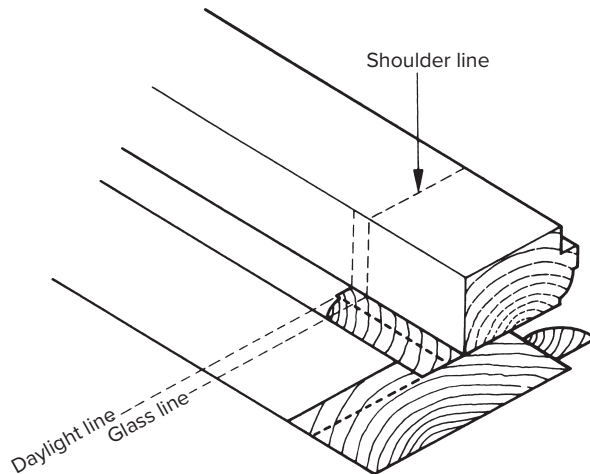


Fig. 28.23 Marking out the stiles in pairs



If a number of stiles are to be marked out to the same pattern, proceed as shown in Figure 28.24.

Arrange the stiles in pairs, half of the face sides pointing in one direction, the other half pointing in the other direction, with the pattern stiles to the outside. Square the ends and hold them together with a light sash cramp. Use a short straight edge to mark the mortises across.

Fig. 28.24 Marking out multiple stiles**Fig. 28.25** Marking out the rails

28.3.3 Marking out the rails

The procedure for marking out the rails is as follows:

1. Lay a rail on the horizontal section and transfer from the rod both the glass line and the daylight line (Fig. 28.25). Square the glass line across the faces; this becomes the shoulder line. Cut back, to the daylight line, the recess for the franking. If there is to be a vertical glazing bar, mark also the position of the mortise.
2. Hold the rails together and mark from the pattern rail to ensure they are all of the same length.
3. Gauge the mortise-and-tenon joints as described previously, lining up one side of the mortise with the rebate.

Depending on the type of machining equipment available in the workshop, it may be necessary to set out only one rail in detail to enable the machines to be set up.

28.3.4 Making the sash joints

Proceed by carrying out the following steps. (Some of these steps are more fully described in Chapter 8, 8.1.1 Mortise-and-tenon joint.)

1. Chop the mortises.
2. Rip the tenons.
3. Cut the shoulder lines.
4. Cut the tenon to width, including cutting wedges from the waste.

From this stage on, the joint is modified, as illustrated in the following figures. If the joint is to be finished by hand, follow these steps:

5. Cut the recess for franking (Fig. 28.26).
6. Remove a portion of the mould from the stile, being careful not to damage the franking (Fig. 28.27). Leave sufficient of the mould on the rail to scribe over later.
7. To scribe the mould on the rail, first mitre the corner (Fig. 28.28). Use a brass mitre template or use a wooden one which can be made up. Hold the template across the corner and, using a sharp chisel guided by the face of the template, pare the mould at 45°.
8. Use a scribing gouge to scribe the shoulder line to the contour of the mitre, and remove the shaded portion shown in Figure 28.29. The joint is now ready for fitting.

Fig. 28.26 Recess for franking

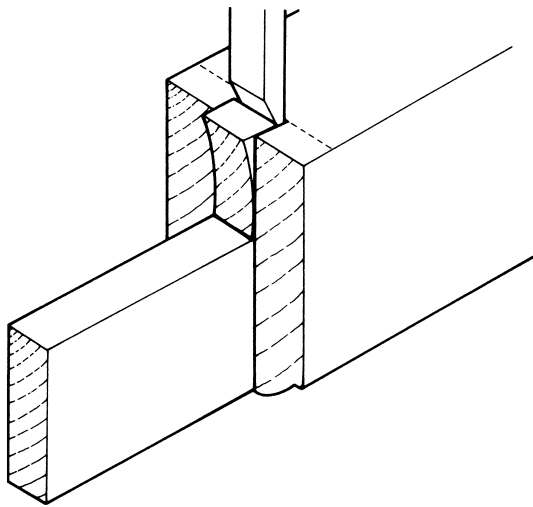


Fig. 28.27 Portion of moulding removed from stile

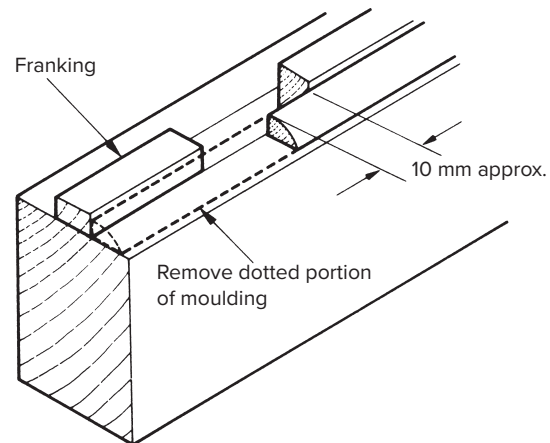


Fig. 28.28 Scribing the moulding

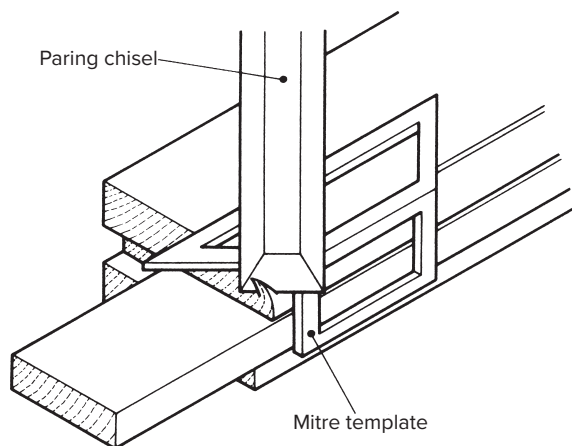
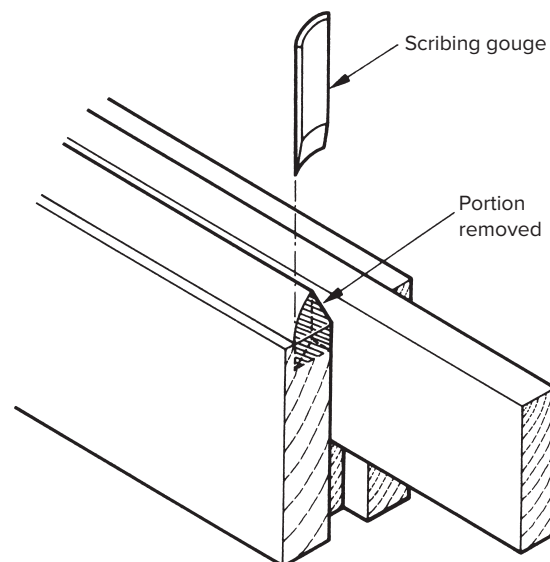
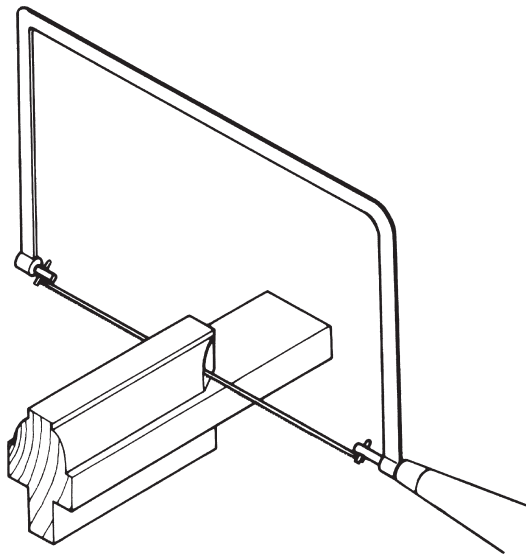


Fig. 28.29 Scribing the shoulder line



Other moulded shapes can be undercut using a chisel or suitable gouge. The mould on glazing bars is scribed over the other moulds as shown in Figure 28.30. Mitre the mould and undercut to the mitred contour using a coping saw.

Fig. 28.30 Scribing the mould on glazing bars over other moulds



28.4 Assemble and glue up the sash

Before proceeding to glue up the sash, assemble the necessary equipment and materials. Lay sash cramps out on the gluing-up bench and site across the bars of the cramps to ensure that they are out of 'wind'. Another requirement is a squaring rod, consisting of a light lath of timber, which is at least long enough to measure the diagonals of the frame. At one end of the squaring rod, drive a nail in, or attach a block, to positively locate the end when measuring.

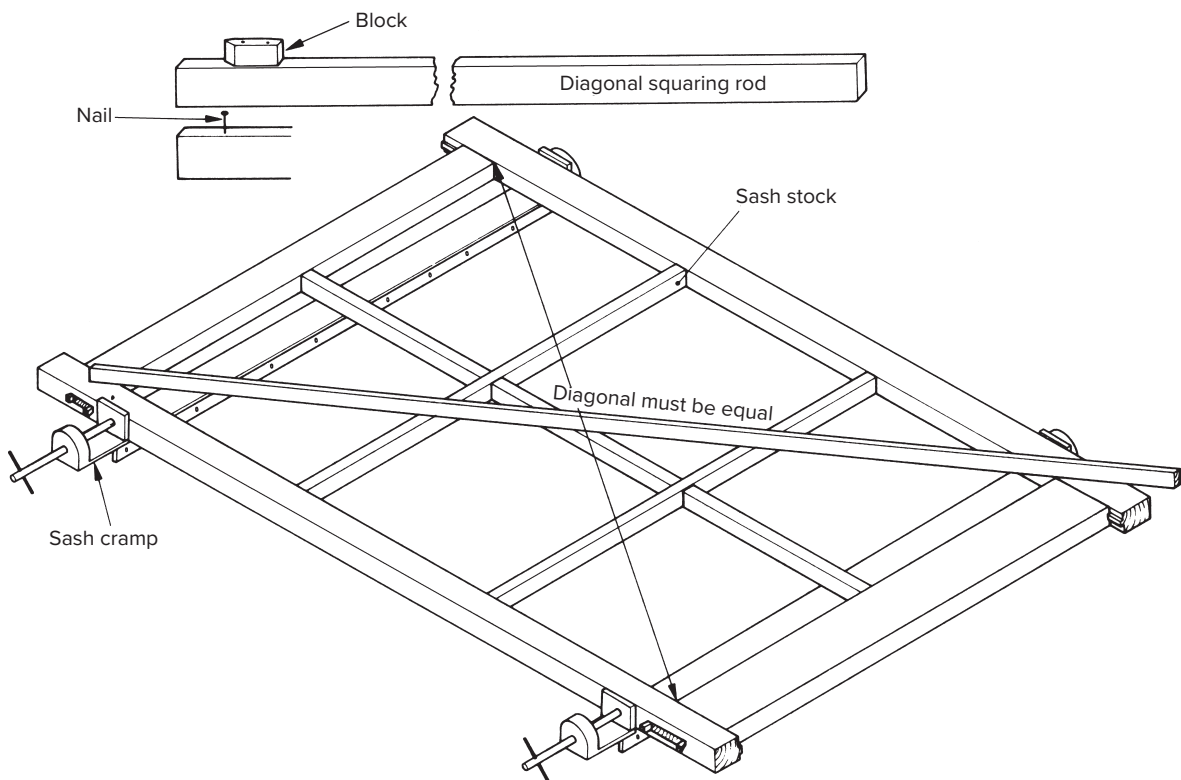
Prepare the adhesive and have ready a suitable application brush. For most joinery, a PVA adhesive is satisfactory unless a more water-resistant adhesive is specified. Wedges and hand tools must also be to hand.

To assemble the sash, proceed as follows:

1. Apply adhesive to the tenons, particularly around the shoulder line and the franking to the stiles.

Enter the joints and tap the frame lightly together. The procedure may vary depending on the arrangement of members. In the example shown in Figure 28.31, the assembly would commence with the sash bars, followed by the top and bottom rails and finally the stiles.

Fig. 28.31 Gluing-up procedure



2. Lay the sash in the cramps, keeping it hard down on the bars. Ensure that the cramps are applied square across the sash, and cramp the joints together. The cramp should be positioned so as not to foul the wedges or bow the stiles; positioning across the horns is often the most satisfactory.
3. To square the sash, use the squaring rod to measure the diagonals. These must be made equal. If one diagonal is longer than the other, slacken off the cramps and position them at a slight angle across the sash to pull the long diagonal shorter.
4. Before wedging, it is essential that the sash is square and perfectly flat or, to use the trade term, out of 'wind'. Apply adhesive to the wedges and enter them into the wedge allowance. Commence driving the end wedge first, followed by the other wedges; drive them uniformly so as not to force the sash out of square.
5. Wipe away any surplus adhesive with a cloth that is just damp, remove the sash from the cramps, and stack flat for the adhesive to set ready for the cleaning off.

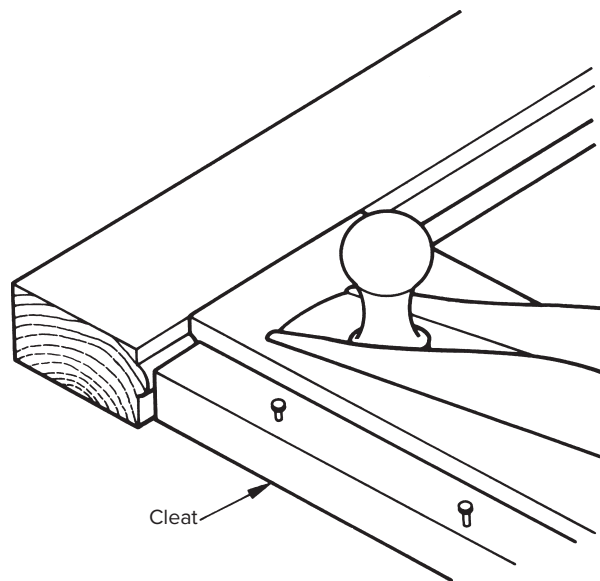
28.4.1 Cleaning off the sash

Cleaning off the sash by hand requires a smoothing plane, the blade of which is sharp and set to remove a fine shaving. The sash must be laid flat on the benchtop and held securely. Corner blocks, or often a cleat fitting between the horns and attached to the bench, will provide adequate restraint.

Hold the plane as shown in Figure 28.32, with the toe pointing to the outside edge of the stiles or rails. Work around the framing, flushing off the joints by removing any rough spots or other blemishes, and setting-out marks. Take only a fine shaving and follow the direction of the grain. Test the surface for flatness, particularly across the joints, using a straight edge or tilting the sole of the plane.

Finish the surface with an abrasive paper held over a sanding block. First sand across the rails, followed by the stiles and work up to the shoulder line; remove any scratches. If the sanding is carried out with an electric sander, follow a similar procedure.

Fig. 28.32 Cleaning off joints



28.5 Construct vertical sliding slash windows

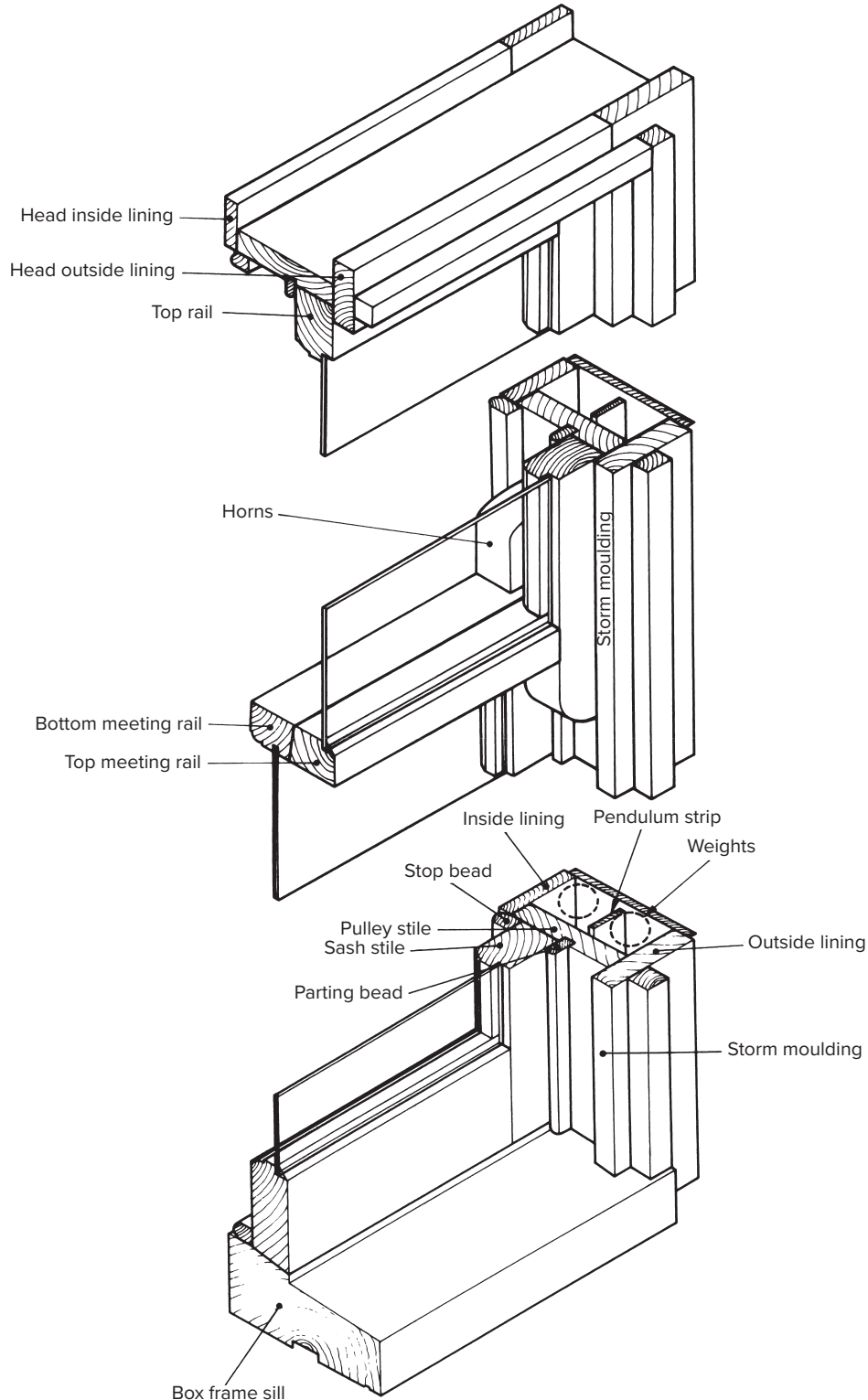
28.5.1 Box frames

Box frames are used with vertical sliding sashes that are counterbalanced with cast-iron or lead weights. The jambs of the frame are made up from comparatively light sections and are formed into a boxed section, which gives them rigidity and provides a space in which the weights can operate.

The frame members that form the box are the *pulley stile*, the *outside lining*, the *inside lining* and, in brick construction, the *back lining*. A *pendulum strip* hangs in the box and separates the weights. Two *sash channels* are formed on the face of the box by the outside lining, the parting bead that separates the sliding sashes and the stop bead. The sashes slide vertically in the sash channels. In addition to the

stile and the top and bottom rails, there are the *meeting* rails, which come together when the sashes are closed. Note the difference in the profile of the top and bottom meeting rails and the manner in which they are splayed to come together and seal the junction (Fig. 28.33). The sashes are hung on *sash cords*, which are fixed into a plough groove at the back of the sash stile; they pass up and over axle pulleys

Fig. 28.33 Structure of a box frame



near the top of the frame and are attached to the weights inside the boxed section. Some very old windows may even have a chain instead of cords.

For many years, well-made box-frame windows provided one of the most popular and reliable types of window available. However, in recent years, for various reasons—possibly mainly economic—the box frame has been almost completely superseded by other types of window in new constructions.

CHECK YOUR UNDERSTANDING

2. Draw the profile of a typical casement windowsill; name each part and state its purpose.
3. Illustrate with a sketch what is meant by the description 'a six-light sash with two vertical bars and one lay bar'.
4. What is the purpose of a joiner's rod?
5. What views are shown on the rod for most joinery items?

28.5.2 Repairing box-frame windows

The main interest in box-frame windows, for today's practising carpenter, is their maintenance, installing new sash cords in particular. The following discussion will be limited to the procedure for re-cording a box-frame window. The steps are as follows:

1. **Removing the sashes.** To remove the sashes from the frame, use a suitable chisel to prise away the stop beads and remove them from the frame. Remove the bottom sash. If there is a cord that is not broken, lift the sash to near the top of the frame and cut the cord. The weight will fall the short distance to the bottom of the box.

Prise out the parting bead—it should not be nailed, but it can be stuck in with paint, and care is necessary to avoid it being broken. Remove the top sash.

2. **Removing the weights.** When the sashes are removed, find the axle pulleys near the top of the frame (Fig. 28.34). Apply a spot of oil to ensure that they are rotating freely.

On the inside sash channel, near the bottom, is the *pocket piece*.

This provides access to the weights. Remove the pocket piece. Move the pendulum strip aside and remove the weights through the pocket. Do not mix the weights as the top and bottom sashes may have slightly different weights—with the bottom sash usually being the heavier.

3. **Marking the length of the cords.** To mark the length of the cords, note the plough groove in the back edge of the sash stile in which the sash cord has been fixed. Mark the end of the cord on the stile and remove the old sash cord. Measure the distance from the end of the cord to the bottom of the sash and mark the same distance up from the sill on the pulley side. On the drawing in Figure 28.35, this distance is indicated as *c*. Do this for both sashes—the marks might not necessarily come in line.
4. **Threading new cord** (Fig. 28.36). To thread new sash cords, a 'mouse' is necessary (Fig. 28.37). This consists of a length of string with a small weight on the end, which can be passed over the axle pulleys.

Fig. 28.34 Axle pulleys and pocket piece

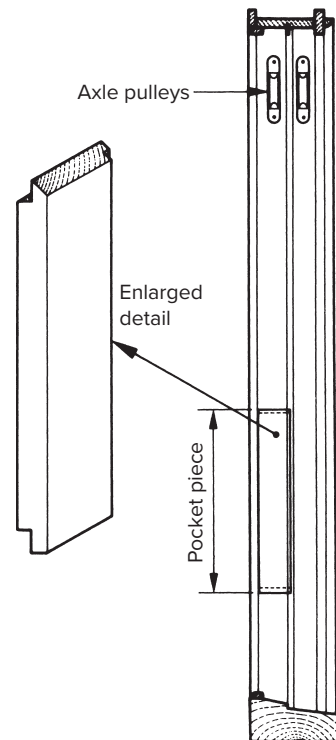


Fig. 28.35 Marking the length of the sash cords

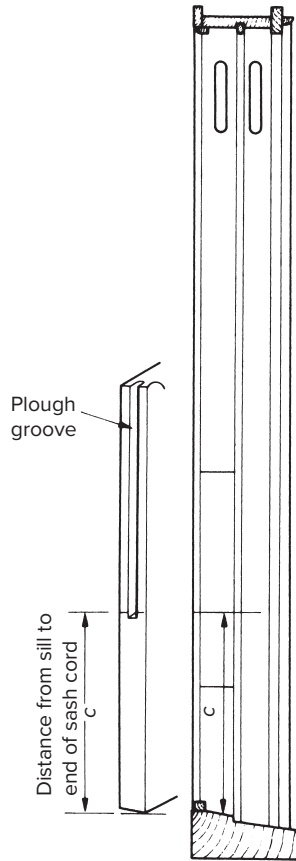
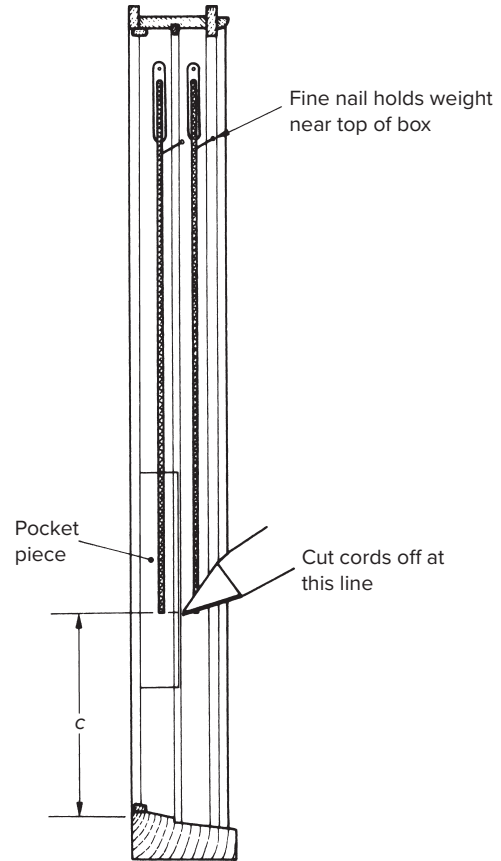
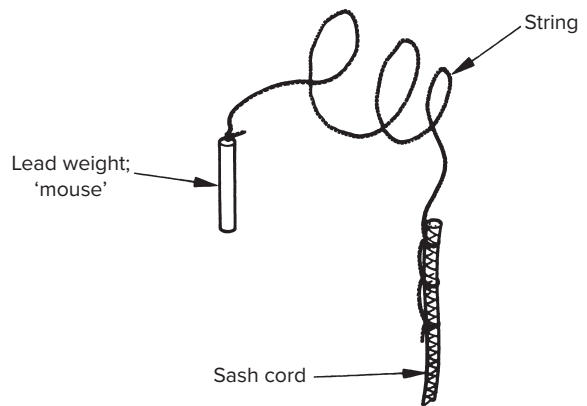


Fig. 28.36 Threading new sash cord



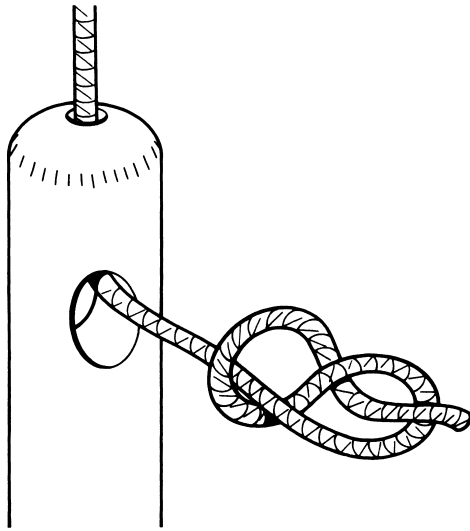
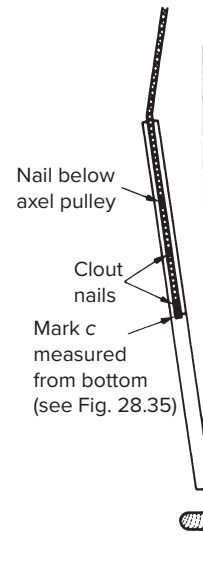
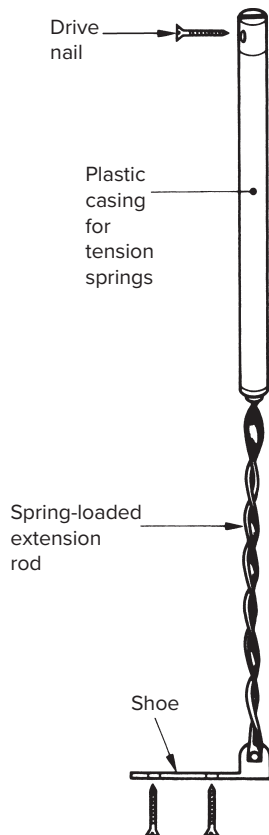
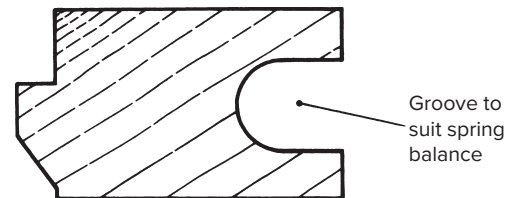
Use a No. 8 sash cord for most applications. Attach the mouse to the end of the cord with a few half hitches. Pass the weighted end over the axle pulley and out through the pocket, followed by the end of the sash cord. Attach the appropriate weight to the ends of the cord and secure by a figure-eight knot on the end of the cord (Fig. 28.38).

Fig. 28.37 A 'mouse'



Place the weight back into the box and pull it to the top of its travel. Drop it back about 30 mm from the top and secure it in this position by driving a fine nail through the cord just below the axle pulley (Fig. 28.39). Cut the cord off at the mark on the pulley stile. Repeat this step for each weight and replace the pocket piece.

- 5. Attaching the cords to the sashes** (Fig. 28.39). Replace the top sash first. Fit the new sash cords into the plough groove with the end on the mark made previously and secure with no more than three 20 mm clout nails. The top nail must be below the level of the axle pulley when the sash is fully up. Remove the nail holding the weight and locate the sash in its channel. Replace the parting beads, first sanding off any surplus paint that will affect the smooth operation of the sash. Attach the bottom sash to the new cords in a similar manner and locate it in its channel.

Fig. 28.38 Attaching the weight**Fig. 28.39** Attaching the cord to the sash**Fig. 28.40** Spiral spring balance**Fig. 28.41** Sash–stile groove for spring balance

De-nail the stop beads—usually less damage to the bead will result if the heads of the nails are pulled right through with a pair of pincers. Replace the stop beads and renail, allowing the sash a clearance of no more than 2 mm in the channel so that it can operate freely without rattling.

Check the pair of sashes for satisfactory operation.

28.5.3 Spiral spring balances

Spiral spring balances have almost entirely superseded cast-iron weights as a means of counterbalancing vertical sliding sashes in new domestic constructions. The balance in Figure 28.40 consists of a plastic casing in which are housed the tension springs and a twisted extension rod to which the sash is attached. The balance is accommodated in a groove, formed in the back edge of the sash stile (Fig. 28.41).

For trouble-free operation, it is important that the grooves be of the correct size (check with the manufacturer), and it is recommended that they be made after the sashes have been fitted to the frame.

Window frames incorporating spiral spring balances can be adapted to any type of construction. The example in Figure 28.42 shows a frame fitted into timber-framed construction. Note the two sash channels and how the outside lining also functions as an architrave.

28.5.3.1 Set-out for spiral balances

Details of a set-out rod for a double frame and sashes with spiral spring balances to suit the situation in Figure 28.42 are shown in Figure 28.43.

Fig. 28.42 Spiral spring balance in a double-hung window

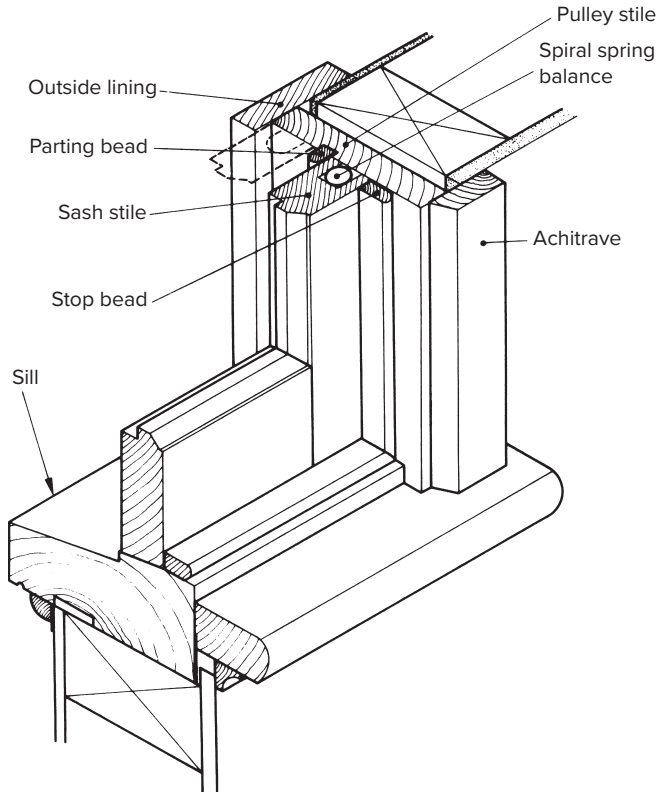
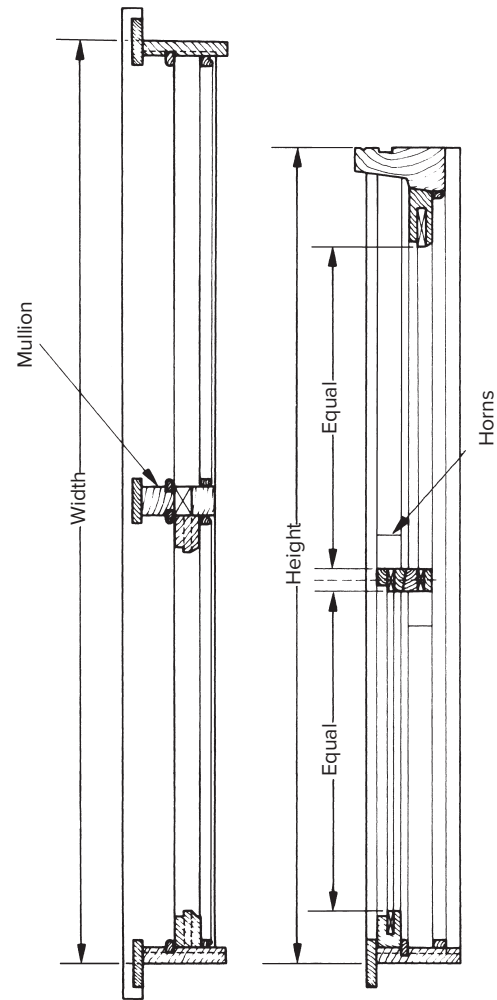


Fig. 28.43 Set-out rod for a double-hung window with spiral spring balances



A standard box-frame sill is used, and when grooving the pulley stiles for the parting bead, make the outside width of the sash channel equal to the thickness of the sashes plus 2 mm clearance.

To set out the sashes, mark in the sash channels; bisect the distance between the daylight lines to locate the centre line of the meeting rails, which can now be marked in. If the setting out is correct, there should be equal daylight opening to both the top and bottom sashes. Mark the length of the horns and a common mortise-and-tenon joint on the meeting rails. Note, in the horizontal or width section, how the spring balances allow the use of a narrow mullion, therefore permitting a maximum daylight opening to the frame.

Spring balances are sold in sets and it is necessary to know the overall height of sashes, and their weight after glazing, to select the correct set. It has been found that most problems involving the faulty operation of spiral balances are the result of faulty installation rather than any defect in the balance itself. With each set of balances, detailed installation instructions are included and should be carefully followed for satisfactory results.

CHECK YOUR UNDERSTANDING

6. What information is required on a cutting list?
7. What information must be provided to select the correct spiral balance for a pair of vertical sliding sashes?
8. List five steps carried out when renewing cords on a pair of box-frame sashes.

28.5.4 Window hardware

Window hardware is an integral part of a window's operation.

Window hardware includes:

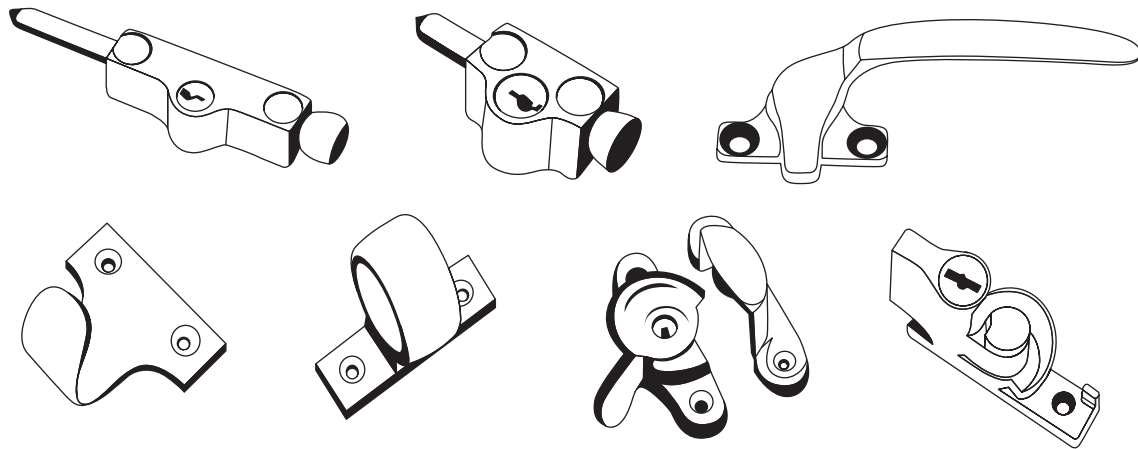
- latches/locks
- stays
- winders
- handles
- hinges (Fig. 28.44).

The type of hardware to be used on a window is generally determined by the type of window being used as particular hardware may be suited only to a particular window type. The manufacturer's instructions should always be consulted for installation advice. Elements of aesthetics such as finish, colour, design and material type largely vary, so it is essential to consult with the designer or client.

If the windows are new, the hardware will generally already be installed, so the job of a carpenter is to install the completed window to the wall frame opening and then install the architrave once the house is at the lock-up stage.

If the windows are second-hand or already installed, the carpenter's job may be to repair them, replace any broken hardware or even replace all of the hardware if it doesn't suit the client's needs.

Fig. 28.44 Various types of window hardware



CHECK YOUR UNDERSTANDING

9. Name three types of window hardware.

28.6 Fit window frames and flashing

Window frames are made up complete with outside architraves and should fit the wall openings, allowing a minimum clearance of 10 mm on the sides and 15 mm between the window head and the wall frame lintel. This is to allow adequate clearance to adjust the frame for levelling and plumbing up. **Flashing** of 1 mm sheet metal or other approved material such as aluminium or plastic must be provided over the head and underneath the sill. Failure to carry out this work adequately could lead

Fig. 28.45 Windowsill flashing

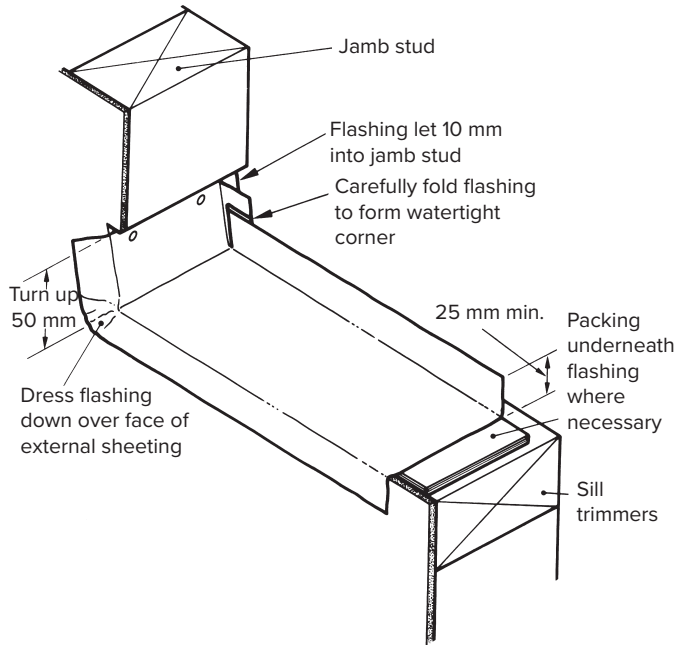
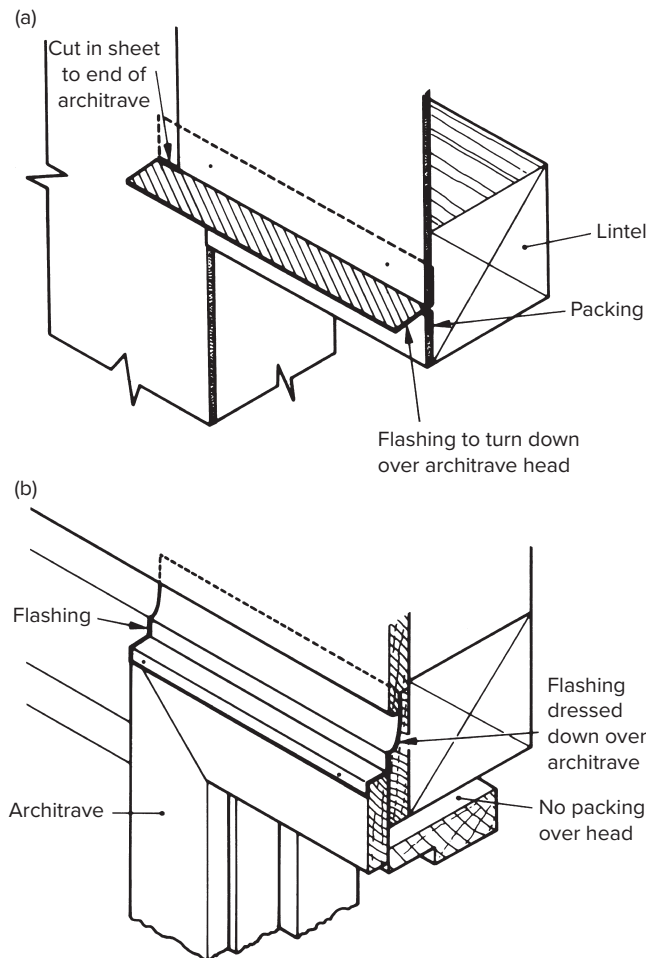


Fig. 28.46 Head flashing: (a) fibre cement sheeting; and (b) weatherboard siding



to damp patches on the inside walls, a condition that can be very difficult and expensive to rectify.

28.6.1 Sill flashing

The sill flashing consists of a one-piece tray that will turn up at the ends at least 50 mm (Fig. 28.45). The width must be sufficient to turn up the back of the sill at least 25 mm and turn down 25 mm over the face of the external sheeting, whether it is sheet material or timber siding. Care must be taken to fold the flashing without damaging it in order to form a watertight corner.

28.6.2 Head flashing

The head flashing is provided across the head of the frame and must turn up under the wall sheeting (Fig. 28.46). It will then cover and turn down over the frame or architrave. In the case of weatherboard wall coverings, the flashing can be inserted into the horizontal joint above the frame and then turned down over the architrave.

Under some circumstances, where adequate overhead protection from the weather is provided, the head flashing can be omitted.

When the head and sill flashings are in place, stand the window frame in the opening provided and first level the sill, placing any sheet material used as packing underneath the sill flashing. Ensure that the sill is straight and adequately supported. Horns left on the sills are used to secure the ends to the wall framing (Fig. 28.47).

Bore a clearance hole through the horn and nail to the framing. Take care that the flashing is not punctured by any nail holes. Plumb the window jambs, pack as necessary and nail through into the jamb stud. Plywood or hardboard offcuts and bituminous felt for making minor adjustments make satisfactory packing.

TIP Flashing and fixing requirements for windows needs to comply with the relevant codes, standards and manufacturer's instructions. Refer to the Australian Window Association's *Fixing: An Industry Guide to the Correct Fixing of Windows and Doors*.

Fig. 28.47 Fixing a windowsill

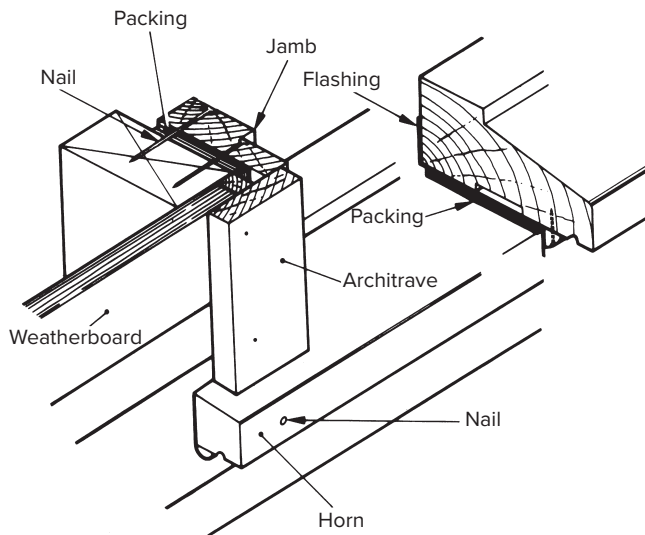


Fig. 28.49 Fixing timber windows

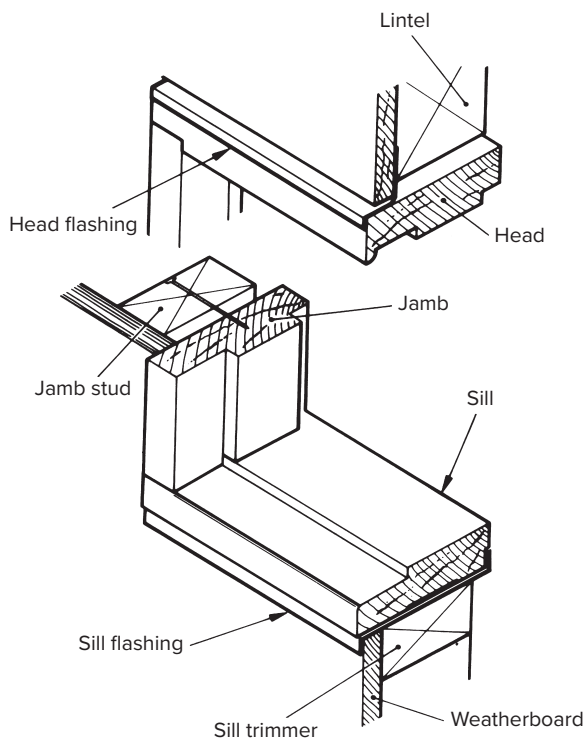
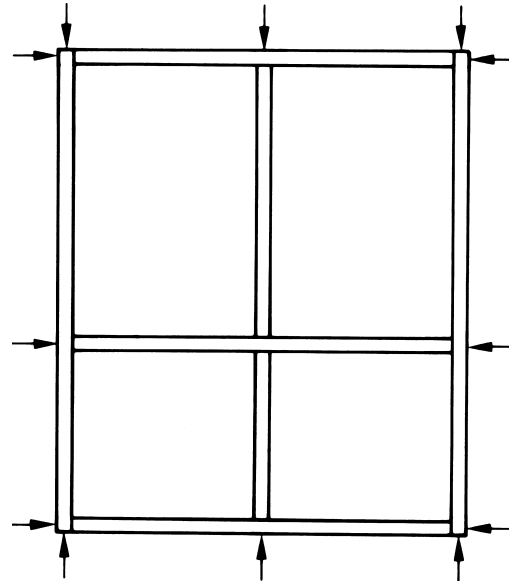


Fig. 28.48 Nailing points for timber-frame window



There can be a tendency to open up the joints of the window frame, and it is recommended that, where practical, nailing be done through the framing at the points indicated in Figure 28.48.

The lintel will carry the load over the window opening and no packing should be inserted between the lintel and the window head. Alternative details in fixing window frames are shown in Figure 28.49. This figure is adopted from a popular range of window frames manufactured from Western red cedar, and the application of the head and sill flashing is clearly seen. Note that the ends of the weatherboards butt up to the window frame and that the frame will have to be fixed in place before the weatherboards are applied. Sealing this joint with a bead of **silicone mastic** would be sound building practice.

TIP Always check the manufacturer's installation requirements. Many manufacturers of timber window and door frames will now request that additional side flashings be fitted to the frames on installation.

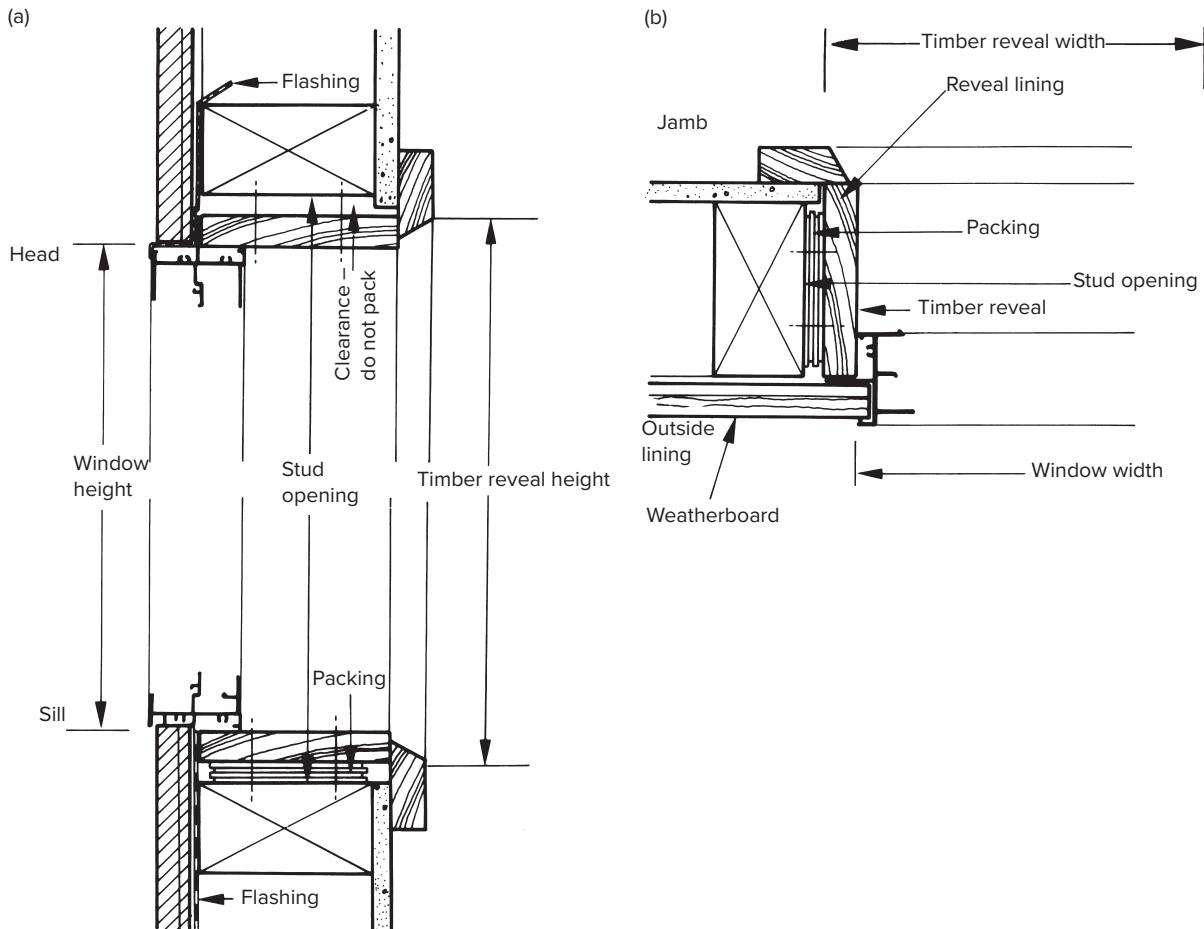
28.6.3 Aluminium window frames

Aluminium frames from different manufacturers vary considerably in the way they are fixed and waterproofed. Some include a metal flashing, while others rely heavily on the application of a non-hardening sealant to render them watertight. Always obtain the manufacturer's instructions and follow them carefully when fixing aluminium frames.

Flashings to metal window frames should be of a non-reactive approved material usually supplied by the manufacturer on request. A simple and attractive method of fixing aluminium frames into timber-framed construction is to purchase the frames with the timber reveal linings attached.

A typical example of an aluminium window frame with timber reveals is given in Figure 28.50. The frame must be fixed into the wall first and then the external siding is fitted to the metal frame. To fix the frame, stand it in position in the opening. Check that the sill is level, packing where necessary, and nail through the timber reveal into the sill trimmer. Pack the sides of the frame, taking care not to fix the frame out of square and nail through into the jamb studs. Do not pack above the window heads.

Fig. 28.50 Fixing aluminium windows: (a) section through window; and (b) plan of jamb



CHECK YOUR UNDERSTANDING

10. Show with a sketch what flashings must be provided for a timber window frame.

28.7 Install glazing

Sashes are usually glazed with a flat transparent glass; in bathrooms and WCs, obscure glass in a variety of patterns may be specified.

Most flat transparent glass used today is termed *float glass*. It is manufactured by a process where the raw materials are melted in a furnace and the molten glass moves from the furnace in a continuous ribbon over a bath of molten tin. Here, all irregularities are melted out and both surfaces become flat and parallel with a fire-polished finish.

Float glass is manufactured in thicknesses of 3, 4, 5, 6, 8, 10, 12, 15, 19 and 25 mm. Most domestic glazing uses thicknesses of 3, 4, 5 and 6 mm.

There must always be a proper relationship between size, thickness and use of glass. Where doubt exists, it is better to use a thicker glass. For internal applications, consideration should be given to the degree of use, exposure to traffic and the possibility of accidents; some situations may indicate that a toughened form of glass should be used. In situations such as picture windows, window walls and full-height windows adjacent to doors, authorities may require the use of toughened or laminated safety glass in accordance with AS 1288:2006 Glass in buildings—Selection and installation.

The glass is bedded and fixed in the sash rebate with linseed-oil putty and metal sprigs (Fig. 28.51). The rebate should be primed with a suitable priming paint (or similar) before glazing. This will seal the timber and prevent the oil from the putty soaking into the timber, causing it to dry out and crack prematurely.

The procedure for glazing sashes using putty is now described.

After the rebate has been primed and the paint is dry, apply a bead of putty to the rebate and press the glass into place, allowing a bed of about 2 mm. Fix the glass with sprigs 300 mm apart, and apply the front putty splayed off to a point 2 mm below the daylight line of the sash (Fig. 28.51).

When it is specified that sashes keep their natural clear finish, the glass may be bedded in clear glazing mastic and then secured on the face with a timber-glazing bead (Fig. 28.52).

Fig. 28.51 Glazing with putty

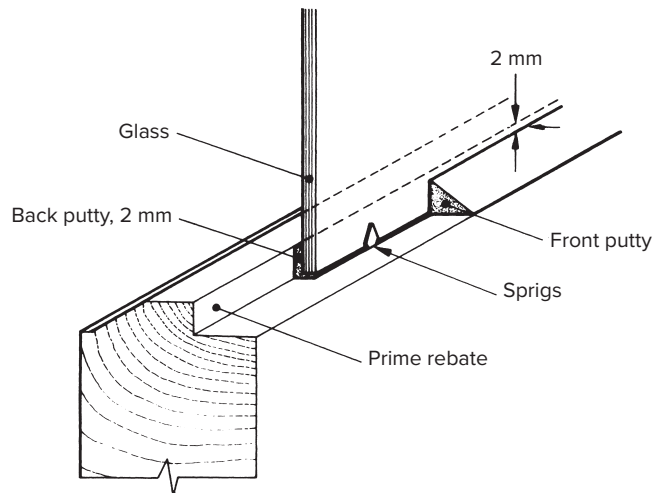
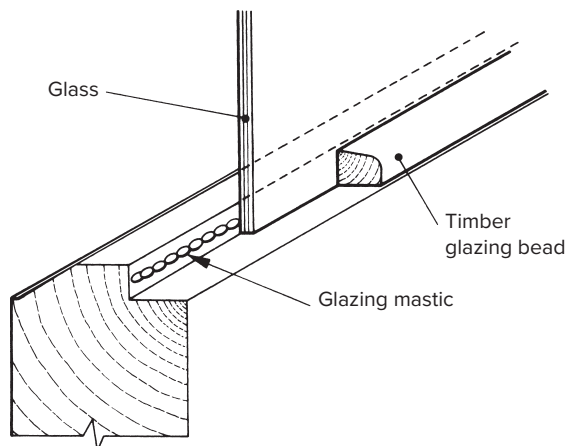


Fig. 28.52 Timber-glazing bead



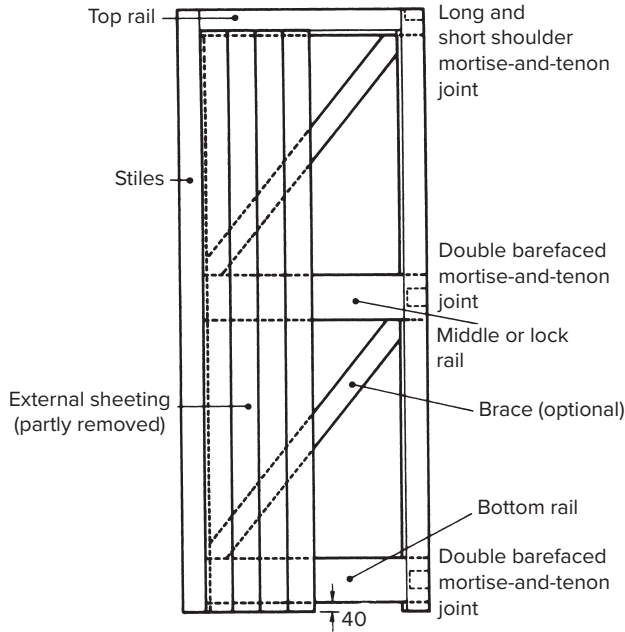
28.8 Construct doors

Doors are made in a number of types, each designed to provide satisfactory service in different situations. Two broad divisions can be made:

1. doors suitable for exterior use
2. doors intended only for interior use.

A door designed for exterior use must have a flat face so that water can run off freely. It must be made in such a way that

Fig. 28.53 Framed ledge door (sheeting partly removed)



variations in moisture content of the timber can occur without the door becoming distorted.

Doors for interior use can incorporate elaborate panels and moulds to achieve their purpose without fear of moisture and decay penetrating the joints and ruining the door.

28.8.1 Door types

Factory-made flush-panel doors are now the most commonly used door in new constructions. They are suitable for interior use, and also exterior use when bonded with water-resistant adhesives. Other types of fabricated doors, sometimes referred to as *joinery doors*, include these which are now described.

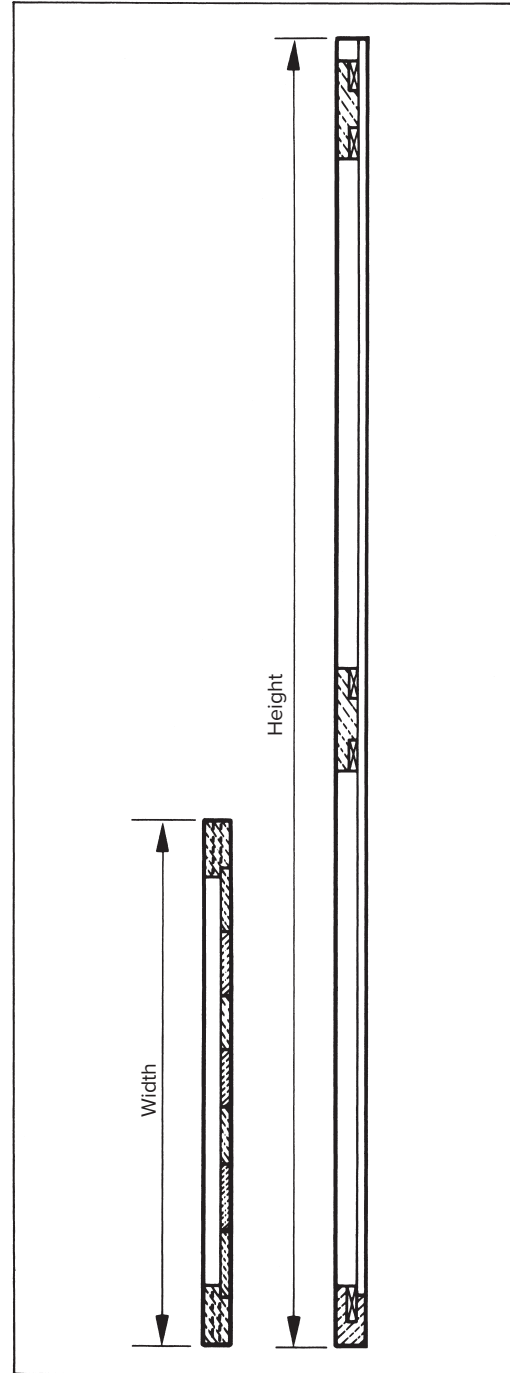
28.8.1.1 Framed ledge door

The framed ledge door is a very strong type of door, suitable for exterior use where it could be subjected to hard wear and tear (Fig. 28.53). The stiles and ledges are mortised and tenoned together to form a rigid frame, which can be further strengthened by the addition of a brace. The face is then sheeted with vertical tongue and grooved boards.

The top rail has the same thickness as the stiles, but the thickness of the ledges is less the thickness of the sheeting. The ledges are joined to the stiles with barefaced mortise-and-tenon joints, as explained earlier. If the ledge is wide, a double barefaced mortise-and-tenon joint is used. The external sheeting is fitted to rebates in the top rail and the stiles and over the ledges to the bottom of the door.

A set-out rod for a framed ledge door, shown in Figure 28.54, illustrates the construction. Details of proportioning the mortise-and-tenon joints are explained earlier in this chapter.

Fig. 28.54 Set-out rod for a framed ledge door



28.8.1.2 Framed and panelled doors

The use of panelled doors is now usually limited to interior situations; however, they may be used as external entrance doors only where adequate protection is provided from the prevailing weather.

The design of panel doors can vary considerably; a basic four-panel door is shown in Figure 28.55.

Note that the stiles and the top rail are of the same width and that the bottom rail is about twice that width. The middle rail, also called the *lock rail*, is about the same width as the bottom rail. Vertical members dividing panels into smaller areas are *muntins*.

The following sections will describe some of the traditional features of panelled doors and how they have been adapted to the mass-produced doors of today.

28.8.1.3 Panels

Framed and panelled doors are largely identified by the arrangement and type of panels used in the design. The panels can be solid timber, plywood, glass or various hardboards. Sections through panels are shown in Figure 28.56.

1. **Flush panels** are for external use and are made from solid timber. A bead joint, where the panel meets the framing, will help to hide any shrinkage that occurs in the width of the panel during seasonal changes. Note that the face of the panel is slightly below the level of framing by approximately 1 mm. This allows the face of the panel to be cleaned off before being assembled into the framing; the framing can then be cleaned off without touching the face of the panel.

Fig. 28.55 Four-panel door

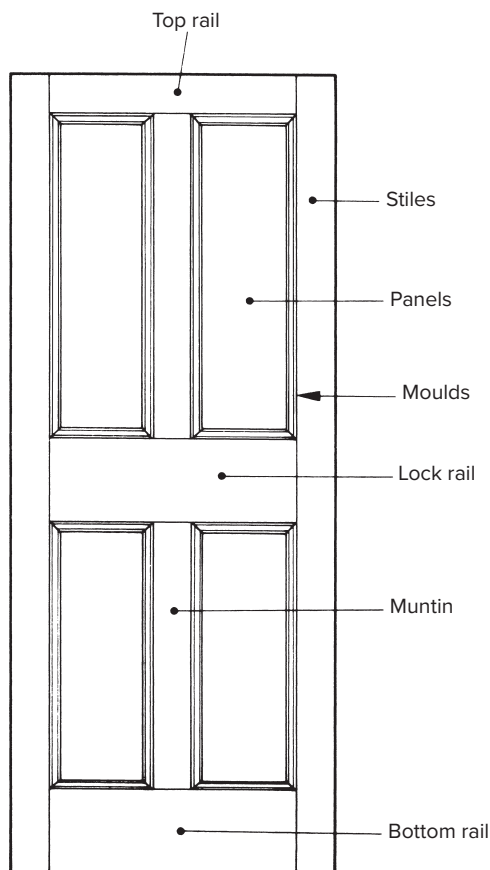
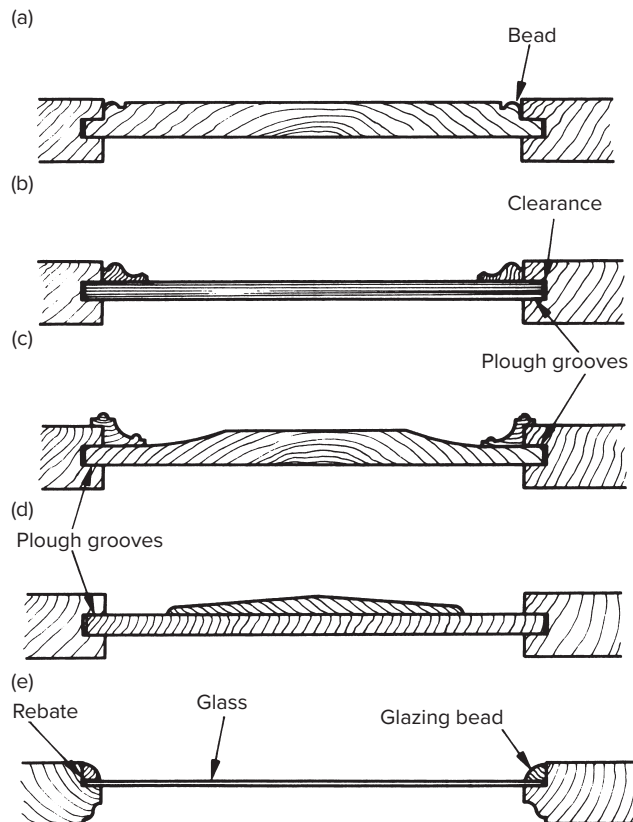


Fig. 28.56 Sections through panels: (a) flush panel; (b) flat-sunk panel; (c) raised panel; (d) laminated raised panel; and (e) panel fixed into rebates



2. **Flat-sunk panels** have a flat face that is sunk below the level of the framing. They may be of plywood, but if they are of solid timber, they must be free to move with changes in moisture content. Any mouldings applied around the panel should be fixed to the framing; if fixed to the panel, they will shrink away as the panel moves.
3. **Raised panels** have the centre of the panel raised and the outside perimeter moulded and may be referred to as the *field*. The contour can be varied, and the face of the panel is again kept just below the level of framing. A simple way of forming a raised panel is to fix a raised centre section to a flat-sunk panel.

Timber panels are usually held in the framing by being fitted to a plough groove that runs around the inside edge. A clearance is allowed in the bottom of the groove.

Using a rebate is another way of fixing panels. Rebates are used particularly for installing glass panels, which, of course, cannot be fitted until the framing is completed. The glass is retained with glazing beads or putty.

28.8.1.4 Mouldings

Mouldings are placed around panels to soften the harsh change in level between the panel and framing, and to improve the appearance of the door. Mouldings can be of two types: they may be 'run in the solid', where the moulding is run directly into the solid timber (Fig. 28.57), or they may be 'planted', where the moulded section is machined as a separate piece in long lengths, and then mitred and fixed around the panels (Fig. 28.58).

Planted mouldings are again divided into two types:

1. **inlay mouldings**, where the profiles can vary but the thickness is such that the top of the moulding will finish just below the level of the framing
2. **bolection mouldings**, where the moulding will rebate over, and finish above, the level of the framing.

Bolection mouldings give a door the appearance of being thicker and more solid than perhaps it really is. In conjunction with raised panels, it makes a most impressive entrance door.

28.8.1.5 Simulated panelled doors

Figures 28.59 and 28.60 show examples of modern doors where the design is routed out of the solid panel. The panel material is usually MDF. The routing may be further enhanced by the addition of planted mouldings.

Fig. 28.57 'Run in the solid' mouldings

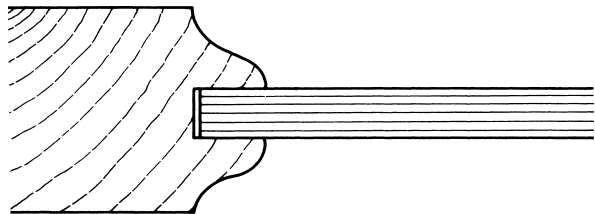


Fig. 28.58 'Planted' mouldings

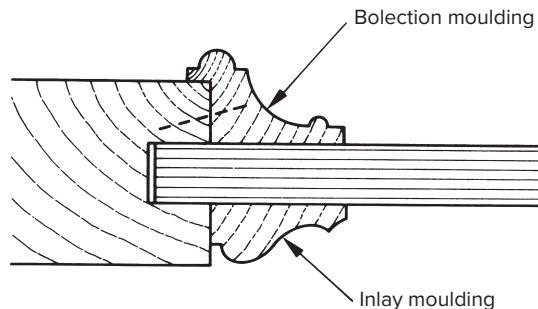


Fig. 28.59 Simulated panelled door

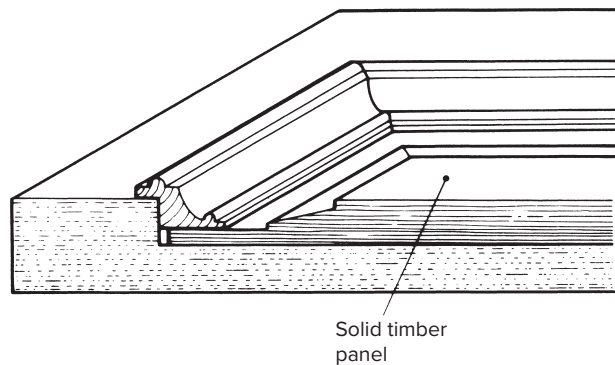
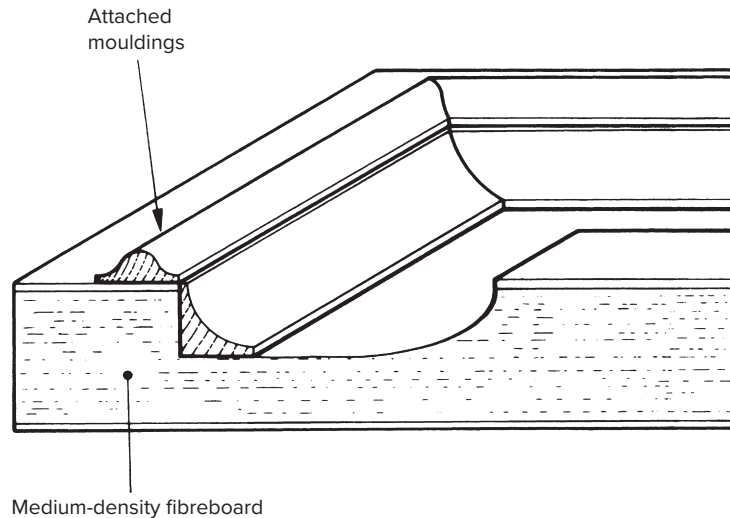


Fig. 28.60 Simulated panelled door, routed and with a planted moulding

CHECK YOUR UNDERSTANDING

11. List five types of panels that can be found in doors.
12. Draw a horizontal section through a framed and panelled door, incorporating the following features: plough groove, raised panel, muntin, bolection moulding, inlay moulding.

28.8.2 Windows and glazing

Approximately 10 per cent of energy is gained or lost through typical window openings in a house. Heat energy is gained or lost through:

- radiation through the glazing (about two-thirds)
- conduction through glazing bars (if any)
- air leakage around the opening sash and frame (about one-third)
- conduction through the window frame itself.

The actual amount is dependent on the frame material and its sealing in the wall structure. In general, timber frames perform better than metal frames, although some composite material frames (metal with softwood core and PVC and softwood core) outperform timber.

The type of opening sash also determines the amount of air leakage (heat in or heat out). Traditional double-hung windows perform the worst and casement/awning windows the best. Gaps between the frame and wall should be sealed with low-expanding foam and single-sided, preformed and high-performance adhesive tape to provide an airtight bond and vapour-control seal.

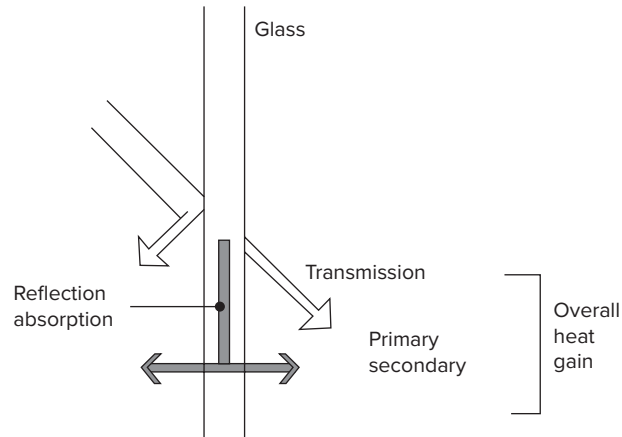
Heat is absorbed through the glazing in two ways:

- solar gain directly transmitted through the glass
- energy absorbed by the glass itself and subsequently transferred inwards by convection and radiation (Fig. 28.61).

The type of glass specified for windows is an important decision for lowering heat gain. Glass is available in a range of thicknesses and types. The most common are:

- *low-emissivity glass (low-e)*—glass that has a coating on the outer surface of metal oxide
- *double glazing or insulated glass unit*—two panes of glass in a frame where the gap between the panes is filled with a gas; improves the window performance by reducing the conduction of heat

Fig. 28.61 Heat is absorbed through glazing in two ways: direct transmission and energy absorbed and transferred inwards



- *solar control glass*—glass with a high iron content, which reduces its light transmittance and therefore its solar gain
- *tinted glass*—glass with a ceramic non-metallic film or coating applied to the outer surface, which converts solar gain to infrared radiation; similar to low-e glass
- *laminated glass*—this consists of two sheets of glass on either side of a centre layer, which bonds the glass; this glass eliminates approximately 99% of harmful UV rays.

Student research

Investigate the other types of windows that are available for modern buildings. Find out about the range of materials that windows can be made from as an alternative to timber.

End-of-chapter activity

Refer to the plans located in the Appendix of this publication.

1. Identify how many external windows and doors the building has.
2. Identify how many internal doors (excluding cupboards, etc.) are located in the building, and what size they are.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 2688:2017
Timber and
composite doors

AS 2047—2014
Windows and external
glazed doors in
buildings

Australian Window
Association—An
Industry Guide to the
Correct Fixing of
Windows and Doors

AS 4145.2—2008
Locksets and
hardware for doors and
windows—Mechanical
locksets for doors and
windows in buildings

Tradie talk—Make sure the jambs are in wind

Chapter 29

Internal linings and fixings

Learning Objectives

LO 29.1 Install internal lining materials

LO 29.2 Install timber mouldings

LO 29.3 Install doorsets and jambs

LO 29.4 Hang doors

LO 29.5 Install trims

Introduction

Fixing is the term applied to the interior finishing of a building and includes such things as fitting door frames and hanging doors, applying finishing moulds around door and window frames, fixing built-in cupboards and fitting hardware furniture to doors and windows. (Note: If a fitted floor is used in a timber-framed building, it must first be laid before any fixing out work can be commenced.) This chapter deals with the traditional methods of fixing out a house.

Setting up a good work area is essential for achieving the best results. If possible, one room should be used as a cutting area workstation, to minimise the spread of waste, dust, etc. around the new building. Where possible, the materials you will be using should be located next to the machines, waste vessels should be established, and tools should have a base, instead of being scattered throughout the building—which means they are harder to locate and risk getting lost.

29.1 Install internal lining materials

29.1.1 Plywood

Plywood for interior use will have one side with a face veneer of an attractive timber species. Plywood is commonly available in lengths of 2400 mm or 2440 mm, with a width of 1200 mm to 1220 mm. Occasionally, longer sheets are available.

Plywood can be supported on battens or studs, and spacings should suit the width of the sheet being used. Noggings should be inserted at 600 mm centres for vertical support. Ply sheets can be nailed or screwed.

Refer to the manufacturer's specifications for fixing details. The fixings can be hidden where nail holes are punched, or screws are recessed and filled with a coloured stopping compound matching the veneer colour. Sometimes the fixings are part of the desired look, usually screws, so it is very important to get the spacings and lines of screws right.

Plywood may also be fixed using wallboard adhesive, according to the manufacturer's instructions.

29.1.2 Fibre cement sheet

Fibre cement sheet includes a range of sheet materials manufactured from Portland cement, ground sand, cellulose fibre and water. It is specially formulated to produce a highly durable, water-resistant and fire-retardant interior lining board.

These sheets are available in thicknesses of 4.5 mm and 6 mm. Sheet widths are 900 mm, 1200 mm and 1350 mm, and lengths vary from 1800 mm to 4200 mm. The product can be cut using fibre cement shears, snap and score or a wet saw. Sheets are applied across wall studs and fixed with fibre cement nails or screws and adhesives. The maximum spacing of studs is 600 mm and all joints must coincide with the centre of a stud or nogging. Sheets may have a bevelled edge to enable finishing with a flush joint.

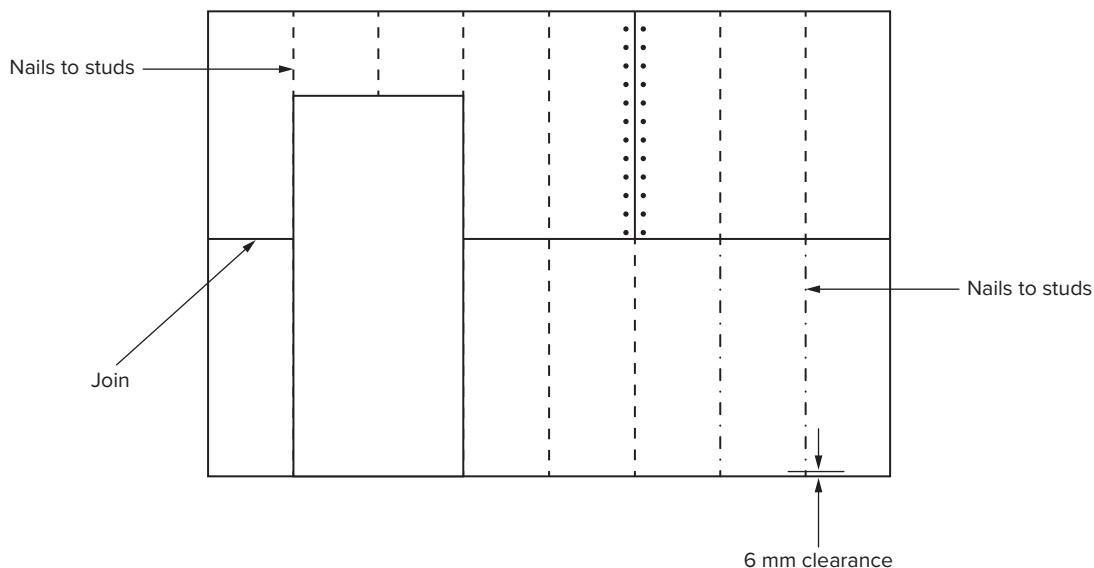
Bedding and topping compounds are used on the joints and are reinforced with perforated or paper tape and finished in a manner similar to plasterboard.

Because of their water-resistant qualities, fibre cement sheets are particularly suited to wet areas; the manufacturer's instructions should be followed carefully. Figure 29.1 shows the installation of cement sheets on a timber-framed wall.

29.1.3 Medium-density fibreboard

Medium-density fibreboard (MDF board) is a manufactured board made from wood fibres. Unlike hardboard, it is resin-bonded. The common trade names are Craftwood or Customwood. This uniform and very stable board is commonly used not only in sheet form, but also as reveals and mouldings. It is available in raw sheets, laminated sheets or veneered sheets with a decorative finish.

Fig. 29.1 Installation of cement sheet



MDF is mainly used in the construction of furniture, built-in fittings, shelving, stairs, shop fittings, drawer fronts, door panels and mouldings such as architraves and skirtings.

It is easily worked with normal hand tools, and it is worth noting that the board can be moulded with a router to produce a variety of decorative shapes and panels. The material is uniform throughout, with no grain, and will tend not to chip or splinter. The mouldings can be stained and finished as for solid timber.

MDF board is available in various thicknesses. The standard width is 1220 mm and the standard length is 2440 mm.

MDF can be fixed by screwing, stapling, nailing or using an adhesive. Screws hold well in fibreboard, but pilot holes should be drilled for best results.

Care must be taken when cutting this product as the resin can be toxic when heated and the dust produced is extremely fine. The product's SDS should be consulted prior to use. It is highly recommended that you use a respirator and attach extraction to any power tools when cutting MDF. In many situations, a dedicated cutting room will be established if this product is being used on-site.

29.1.4 Timber panelling

Jointed timber panelling is also referred to as *shiplap* and *tongue and grooved (T & G) panelling* (Fig. 29.2). For internal linings it is normally at least 12 mm thick.

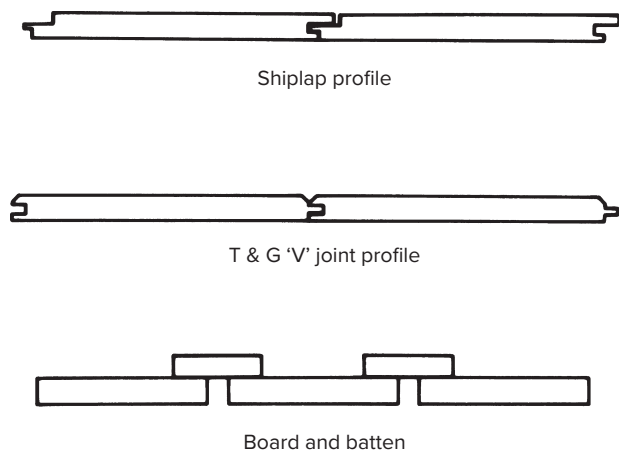
The lining boards selected should be seasoned. Wide boards should be avoided where there are extremes of temperature or humidity, as the timber may tend to cup or otherwise distort, affecting the appearance of the surface. Where wide fluctuations in atmospheric conditions are likely to occur, it may be best to use shiplap rather than tongue and grooved boards because of the easier movement between timber panels.

Tongue and grooved boards may be 'V' jointed or flush-edge jointed as in floorboards. Most popular is the 'V' joint, often with a separate 'V' machined out of the back of the board to give the choice of widths for different effects.

Shiplap boards were originally designed so that one panel overlapped the next, thus hiding a direct joint. Modern milling methods make available shiplap with a tongue and groove jointing system, which allows for secret nailing so that no nails are visible in the finished panelled surface.

Timber panelling is either fixed to the noggings or to battens nailed to the studs when the panels are vertical. Occasionally, they may be installed diagonally or horizontally where the studs themselves must then be used. The nails are normally 40 mm × 1.6 mm bullet head nails, for the smallest possible head size.

Fig. 29.2 Profiles of lining boards



29.1.5 Hardboard

Hardboard is an extremely dense board manufactured from wood fibres and known by the trade name Masonite.

The manufacturing process does not use any additional glues or resins to bond the wood fibres. Instead, the fibres are pressed together under great pressure and the naturally occurring lignin contained

in the wood fibres bonds the product. Hardboard generally has only one good face that is burnished, smooth and true. The back of the product has a rougher surface that is not usable.

Hardboard comes in a number of products, including:

- standard
- tempered
- underlay
- pegboard
- whitecoat.

29.1.6 Installation of panels and linings

When preparing a timber frame for linings or panellings, it is important to make sure the frame is set up and in a good enough condition to accept the material being installed.

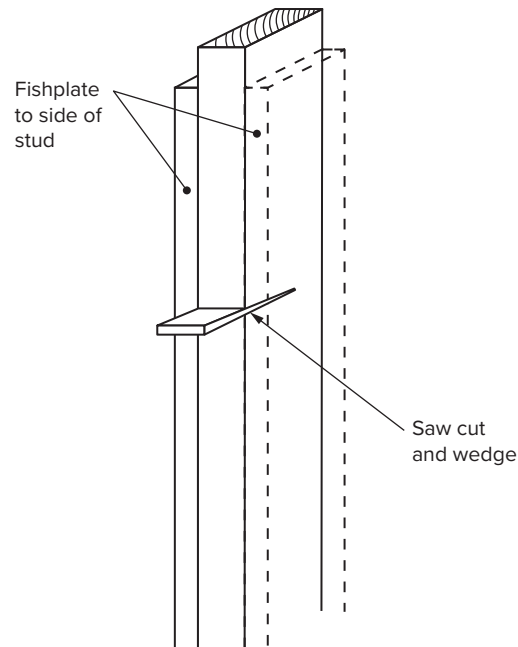
For all products, ensure the frame is straight and plumb and all in one plane. Plane or pack studs where required. If a stud is badly bowed, it can be wedged straight. This is done by cutting a slot from the hollow side of the stud, then pulling the stud towards you and driving a small wedge into the cut to straighten it. If this is carried out on a load-bearing wall, another stud needs to be installed next to it and the two should be laminated together. If the wall is non-load-bearing, then a fishplate should be installed (Fig. 29.3).

The process of preparing the frame for lining boards is similar to that of installing timber weatherboards (described in Chapter 27, External cladding).

When working with sheet materials, close attention needs to be paid to the size of the board to ensure there is adequate support for the sheets where they are joined. This can be addressed when constructing the wall, so the studs are spaced to correspond to the sheet length or width. Alternatively, battens can be installed on the frame to accommodate the size of sheets. Additional noggins and blocking will need to be installed to provide adequate support at joins.

No matter which product is being installed, always refer to the manufacturer's installation instructions.

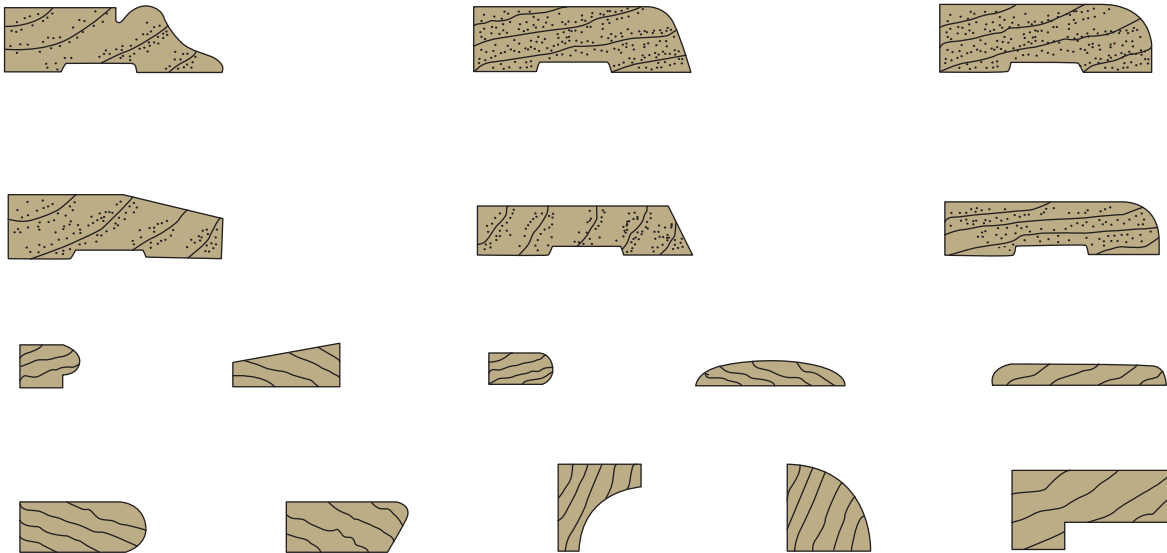
Fig. 29.3 Straightening a bowed wall stud using a wedge



29.2 Install timber mouldings

Timber mouldings have numerous uses, including:

- to cover junctions where wall linings meet, e.g. the corner of a wall
- to cover a junction where two different wall linings meet, e.g. where dado pine lining meets plasterboard, generally 1.2 metres up from the floor
- as an alternative to cornice at the wall-to-ceiling junction
- to provide decoration or adornment around windows, doors, openings, etc.
- to cover a gap.

Fig. 29.4 Examples of common timber mouldings

There are countless profiles (shapes) (Fig. 29.4); traditionally, many of the profiles had specific applications.

Joining mouldings along a run or around an external corner requires a mitred joint to be used. If joining at an internal corner, then a scribed joint is preferable. These joining methods are discussed in more detail later in this chapter.

29.2.1 Joining mouldings

29.2.1.1 Mitre joints

The most commonly used joint for joining mouldings is the mitre joint (Fig. 29.5). If the mouldings are of equal width, each piece is cut to an angle half the angle of intersection; e.g. if the mouldings intersect at an angle of 90° , the mitre angle is 45° .

29.2.1.2 Scribed joints

The scribed joint is sometimes preferred, particularly where the mouldings intersect at an internal corner. One piece is first mitred and then cut to the contour of the mould; it can then butt tightly against the other part (Fig. 29.6).

The cutting of mitred and scribed joints is explained in more detail later in this chapter.

Where mouldings are of unequal width, the line of the mitre is found by joining the points at which the outside and inside edges intersect. These moulding profiles of different widths must be developed so that the moulds will match up on the line of the mitre (Fig. 29.7).

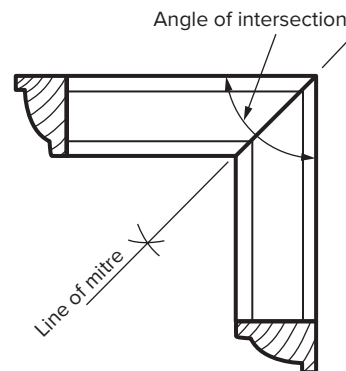
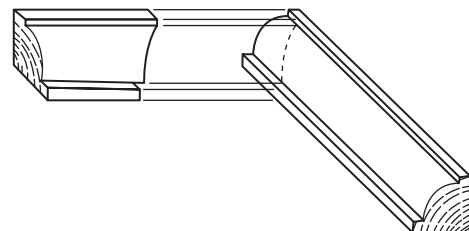
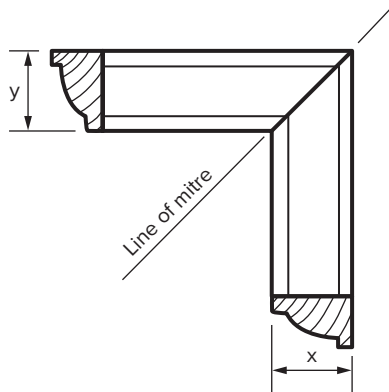
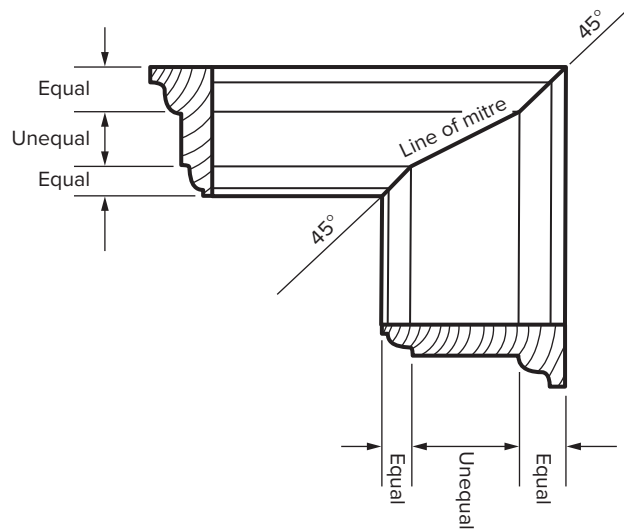
Fig. 29.5 Mitre joint**Fig. 29.6** Scribed joint

Fig. 29.7 Joining mouldings of unequal width**Fig. 29.8** Dog-leg mitre

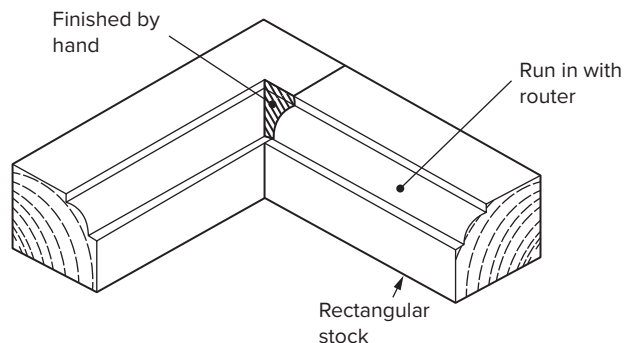
29.2.1.3 Dog-leg mitre

When restoring old buildings, examples may be found where mouldings of unequal width were made up (Fig. 29.8).

The difference is in the width of the flat connecting member only. In this case, the line of the mitre is not straight; it is termed a *dog-leg mitre*.

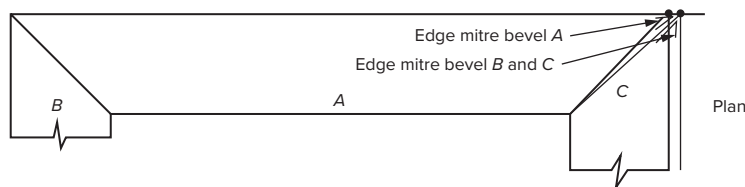
29.2.1.4 Mason's mitre

The mason's mitre can be found in some of the oldest examples of joinery work; today it is again becoming popular. Its use greatly simplifies the joint between the two parts. The stock used is rectangular, the shoulder line is straight and the parts butt together. The mould is then run, usually with the router, and the return mitre is finished by hand (Fig. 29.9).

Fig. 29.9 Mason's mitre

29.2.1.5 Raking mouldings

The problem with raking (sloping) mouldings occurs where they must intersect with a level return mould. A typical example is a cornice in a room with a sloping ceiling, where the moulding will meet at right angles on plan. This situation is illustrated in Figure 29.10.

Fig. 29.10 Development of a raking mould

29.3 Install doorsets and jambs

Doorsets consist of two components:

- the jamb/frame lining, which is accurately fixed into the structural opening and which will support the door
- the door, which is, of course, the movable leaf fitted to the jamb lining.

29.3.1 Standard dimensions of the door opening

Doors come in standard sizes and, as described below, the required opening sizes to be incorporated into the wall frames need to be of an adequate size. Never assume the opening in the frame is the correct size, especially for pre-fabricated frames. Check the opening sizes before the wall lining and cladding are installed. If any alterations are required, they can be made quite easily at this stage. Standard opening sizes in a frame for doors are:

- Height—2100, 2400 and 2700 mm
- Width—700, 800, 900 and 1000 mm for single doors
—1200, 1500, 1800 for double doors.

Standard-sized doors are made to fit into these opening sizes together with their jambs/frames, with room for adjustment for squareness and packing.

The actual standard door sizes are:

- Height—2040, 2340 and 2640 mm
- Width—620, 720, 820 and 920 mm for single doors
—1120, 1420 and 1720 mm for double doors.

Robe doors are also available in odd sizes such as 2340 mm × 840 mm.

The thickness of doors should not be less than 35 mm for internal doors and 40 mm for external openings. Doors manufactured to these standard sizes are readily available and should be adopted for greatest economy. However, doors can be made to any required size.

29.3.2 Door types

29.3.2.1 Flush doors

Flush doors are widely used in domestic construction. They have a flat, smooth face and are easy to keep clean. Since they are mass produced, they are the most economical.

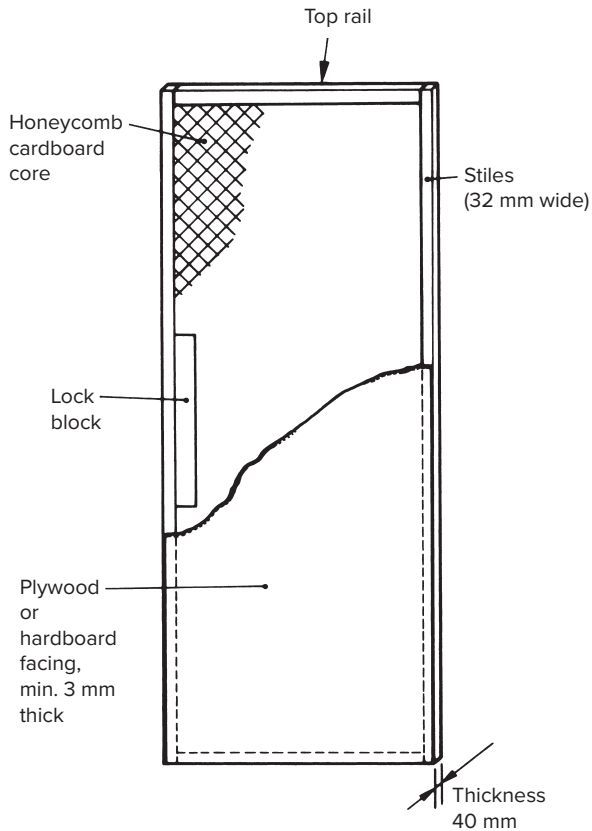
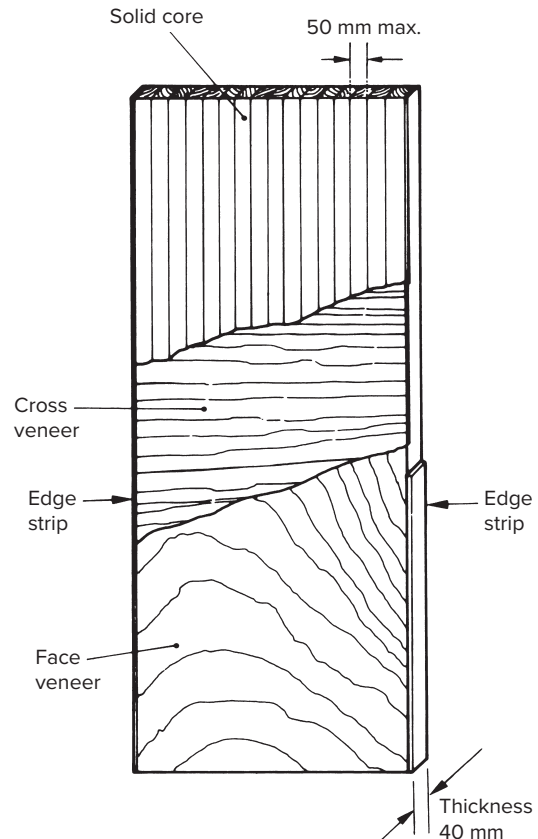
29.3.2.2 Hollow core doors

Hollow core or honeycomb doors are one of the most common types in use. The stiles and rails are timber with a minimum width of 32 mm, held together at the corners by staples (Fig. 29.11). The core of the door is composed of a cellular infill of expanded cardboard the same thickness as the stiles. Bonded to each side by an adhesive is a sheet of plywood or hardboard with a minimum thickness of 3 mm. A lock block at least 400 mm long can be located on one or both sides depending on the manufacturer; its position is indicated on the outside edge of the stile.

For external use, doors made up with waterproof adhesives are available. This fact should be indicated on the edge of the door.

29.3.2.3 Solid core doors

In solid core doors the core is made of a blockboard infill consisting of individual strips of timber no more than 50 mm wide and all of the same species. Veneers are then bonded to each face: first a cross

Fig. 29.11 Hollow core door**Fig. 29.12** Solid core door

veneer on each side and finally a face veneer of selected timber, with the grain running in the same direction as the core. Edge strips matching the face veneer are applied to the edges (Fig. 29.12).

29.3.2.4 Medium-density fibreboard core doors

In medium-density fibreboard core doors, the stiles are of timber no less than 42 mm wide. The top and bottom rails are doubled with a minimum width of 84 mm. The infill consists of solid fibreboard. Veneers are bonded to the faces, or the faces can be of a hardboard or plywood no less than 3 mm thick. The face of this type of door is often carved to give a panelled effect and can be most impressive as an entrance door.

29.3.2.5 Other door types

Other door types available include:

- fly-wire doors to allow air in and keep insects out
- aluminium-framed doors incorporating large glass panels
- combination window and door units
- door sidelight units
- intricate and decorative timber doors (these are described in Chapter 28, Installation of windows and doors).

CHECK YOUR UNDERSTANDING

1. What are the standard sizes for single doors?
2. Select one type of flush door and describe its construction.

29.3.3 Jamb linings

Solid jamb linings/door frames come pre-made or in sets that need to be made up. They should have a nominal thickness of at least 38 mm and are rebated 12 mm deep to receive the door, as shown in Figure 29.13. The width of the rebate must be at least equal to the thickness of the door plus 3 mm for clearance. These frames can also come with a timber sill.

Rectangular door jambs at least 25 mm thick with a separate planted door stop can also be used. In the example shown in Figure 29.14, the jamb lining is fixed and the door is hung before the planted stop is fixed to the line of the door. For security reasons, loose stops are not recommended for external door openings.

Jamb linings are made up into sets: the vertical side members are the *jamb*s and the top is the *head*. A set of rebated jamb linings is shown made up in Figure 29.15. Note the *brace* and the *spreader* to maintain the correct width at the bottom. Accuracy is essential in setting out jamb linings if the door is to fit with a minimum of effort.

Many doors have very narrow stiles and rails and it is good practice to remove no more than is absolutely necessary during fitting. Allowance should be made at the bottom to allow for floor coverings. For carpets allow at least 20 mm and sometimes even more. The clearance at each side and top should be no more than 3 mm. In our example, 2 mm is allowed.

Fig. 29.13 Solid jamb lining

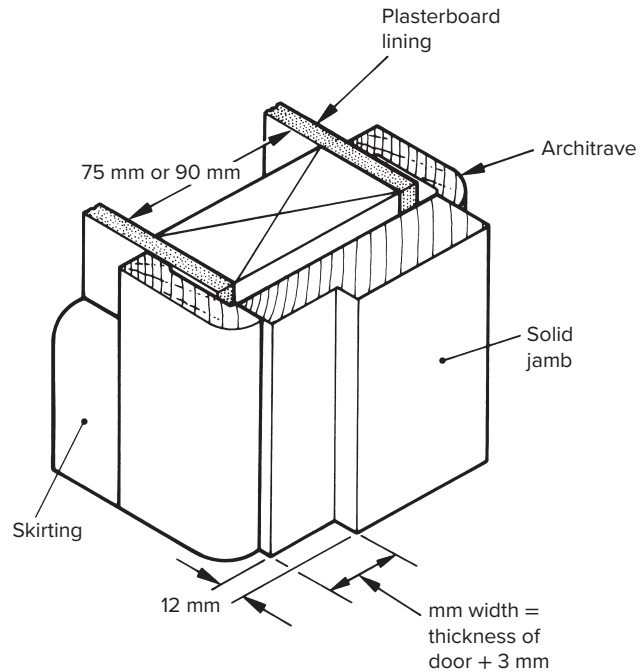


Fig. 29.14 Assembled or 'made up' jamb linings

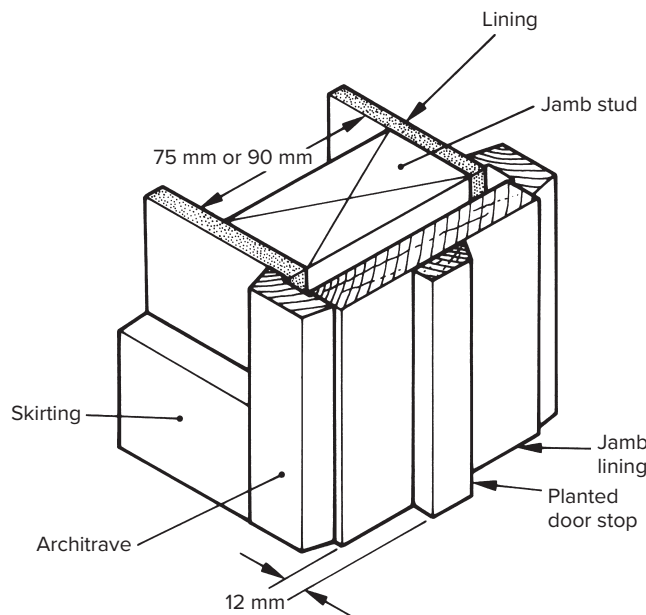
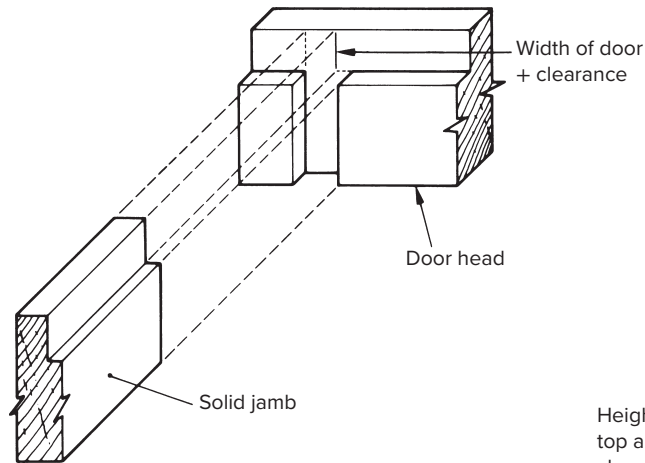


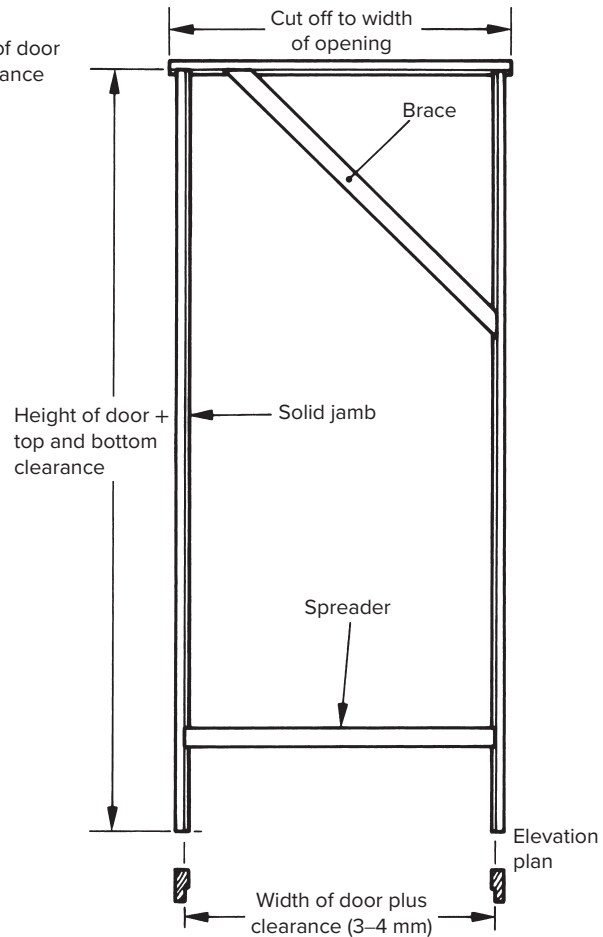
Fig. 29.15 Housing of jamb linings

The length of the stile is set out to the height of the door plus the top and bottom clearances, say 2040 plus 2 plus 20 equals 2062 mm at least. If it is certain that a carpet is not being contemplated, then the bottom clearance can be reduced to 10 mm.

For width, set out the distance between the rebates equal to the width of the door plus a clearance of, say, 4 mm. The stile is housed into the head; see Figures 29.16 and 29.17, which show the setting out of the head.

Mark the distance between the rebates on the face. Take a short piece of jamb material and line the rebate up on this mark, and then mark each side for the width of the housing. Gauge to the depth of the rebate and remove the waste. Cut the spreader to the distance between rebates, assemble the jambs, hold square and attach the brace.

Sets of rectangular jambs with loose stops are made up in much the same manner except that the stiles are made longer to house into the head at least 5 mm. The loose stops can be cut to length, temporarily pinned to the jamb and finally fixed after the door has been hung.

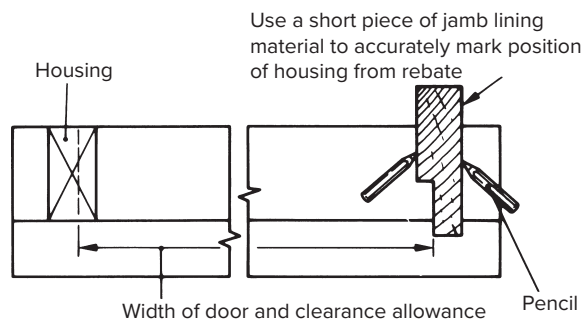
Fig. 29.16 Set-out of head

29.3.4 Fixing jamb linings

To fix the jamb linings, follow these steps.

29.3.4.1 Step 1

Check the floor across the opening for level. Theoretically it should be level, but due to some of the uncertainties when working with timber, there could be some minor discrepancies. Say the floor at B is found to be 5 mm lower than at A, then 5 mm must be cut off the stile at A so that the head will remain level (Fig. 29.18).

Fig. 29.17 Marking out jamb and head

29.3.4.2 Step 2

The jamb head is cut 1 mm shorter than the stud opening; this alleviates packing/wedging the top of the jamb and also allows for equal clearance on both sides of the jambs.

29.3.4.3 Step 3

Stand the linings in the opening and lightly drive a wedge directly over the stile between the jamb and the head trimmer to hold the jambs in place.

29.3.4.4 Step 4

Using a straight edge and level, check the jamb on one side for plumb in both directions and adjust as necessary. At a point about 150 mm from the bottom, pack the space between the jamb and door stud and secure the jamb to the stud. Suitable packing can consist of strips of plywood, hardboard or bituminous felt for making minor adjustments. Ensure that the nails are below the packing so that the packing does not fall and minor adjustments can be made to the packing if needed. Fixings need to comply with the Australian Window Association's *Fixing: An Industry Guide to the Correct Fixing of Windows and Doors*. Use two nails at each fixing point, one through the face and one through the rebate. Continue packing and fixing the jamb lining at the top and at intermediate points, taking care to keep it straight and plumb (Fig. 29.19).

29.3.4.5 Step 5

Test and adjust the second side for straightness and plumb. Pack and secure in place, maintaining the correct width between the rebates. Take care that the two stiles are accurately plumbed laterally and are in 'wind' (i.e. the jambs are parallel in the vertical plane, when sited through opening). Remove spreaders and braces ready for fitting and hanging the door.

Fig. 29.18 Checking floor for level at door opening

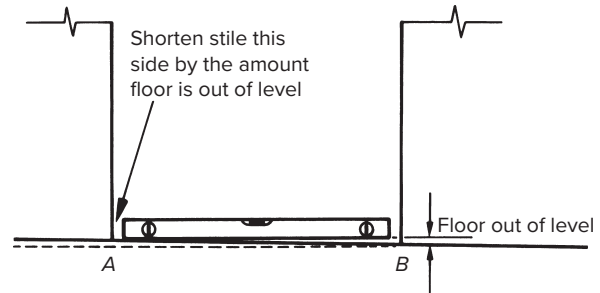
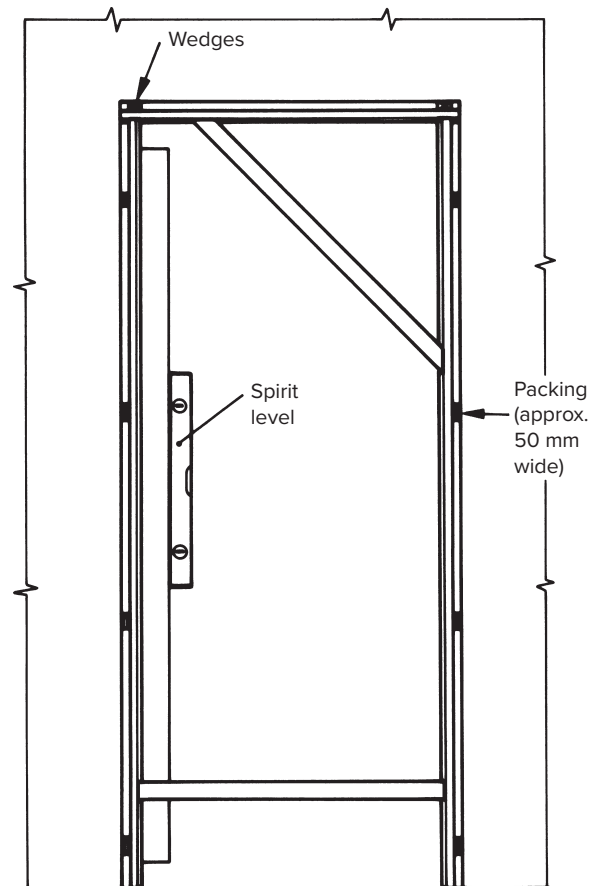


Fig. 29.19 Fixing jamb linings



TIP When installing external door frames, ensure that the correct flashings are installed above the head of the frame and between the sill and subfloor/slab. This will stop water from entering the building and moisture from damaging the frame. Ensure that the flashing complies with the relevant standards and codes or the manufacturer's instructions.

CHECK YOUR UNDERSTANDING

3. When making up a set of door jambs, how would you determine the length of the stile?
4. When fixing a set of door jambs, how would you ensure that the head will be level?

29.4 Hang doors

The process of fitting—hinging and applying the lock furniture to doors—is covered by the trade term *hanging doors*. When a door is hung, the sides assume a particular identity and are referred to as the *hinge side*, or *hanging side*, and the *closing side*. Doors are sometimes referred to as *right* or *left hand* (Figs 29.20–29.22).

If you view the door from the hinge side, then the side of the hinges is the *hand* of the door. Where pairs of double rebate doors are specified, the leaf that will open first is indicated as the left or right hand. When fitting doors with a separate lock block on one side, this side must become the closing stile and the hinges will be fitted to the opposite stile.

A *door block* is used on-site to hold the door upright when planing or working on the edges. It is worthwhile making up a door block that will clamp the door and hold it rigid without damaging the face. Figure 29.23 shows a door block using the flat wedging principle that will give satisfactory service for a long time.

Doors in domestic construction are usually hung with steel butt hinges; however, brass butts may sometimes be specified.

Generally speaking, only two hinges are required for the installation of most doors. It is good practice for external doors to have three hinges. Usually external doors are heavier and three hinges provide more security. Very heavy and tall doors may have four hinges, with two hinges being installed close together at the top of the door to support the door weight and stop the door from sagging.

The standard hinge is satisfactory for any domestic doors, but where the door is required to open through 180°, this type of hinge will often foul the architrave and lead to the edge splitting and pulling away from the hinges. The broad butt hinge will overcome this.

Fig. 29.20 Door swing for right-hand door

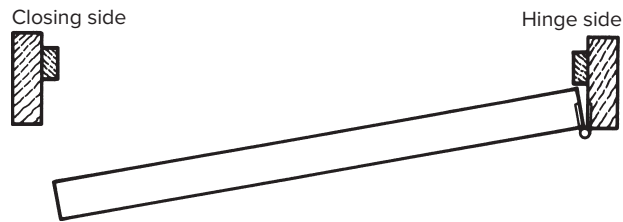


Fig. 29.21 Door swing for left-hand door

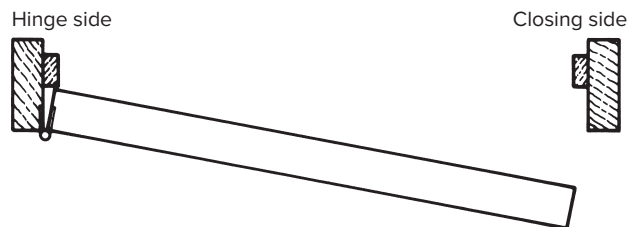


Fig. 29.22 Double door opening

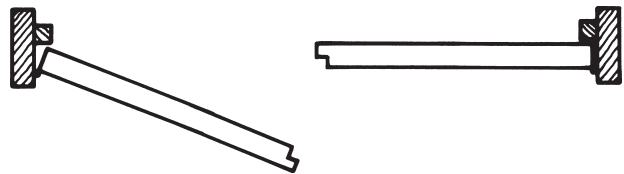


Fig. 29.23 Door block

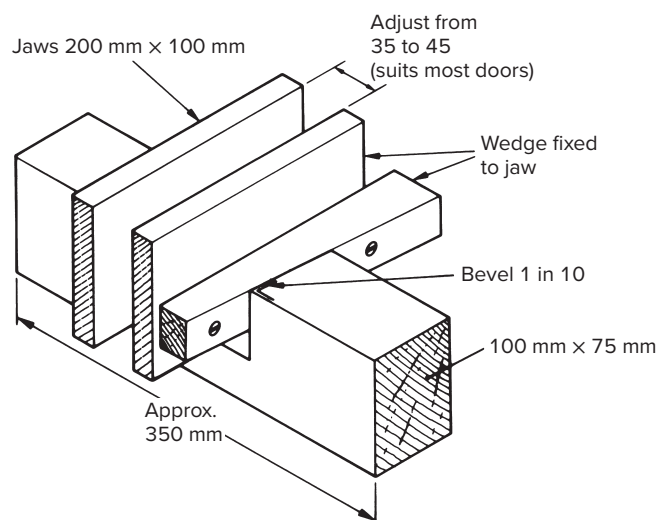
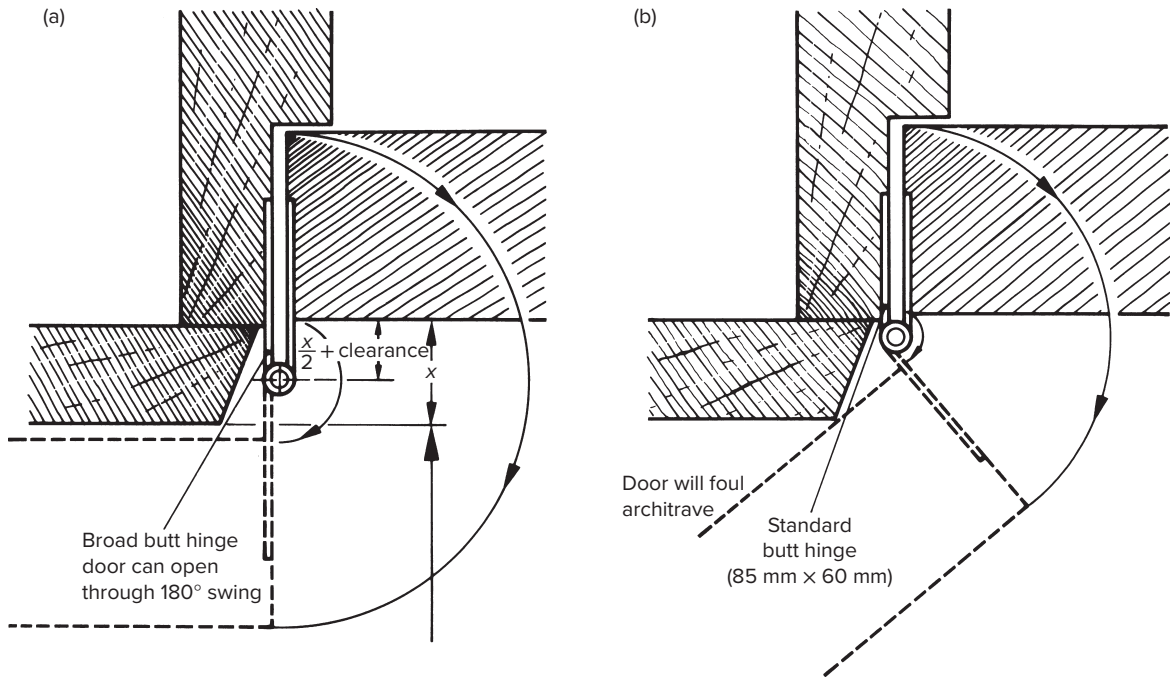


Fig. 29.24 (a) Broad butt hinge; and (b) standard butt hinge



Note the distance x from the hinge face of the door to the face of the architrave in Figure 29.24a. The position of the hinge must now be adjusted so that the distance from the centre of the pin to the face of the door is half of x plus an allowance for clearance, say at least 2 mm, giving a clearance over the architrave of twice that amount.

TIP Figure 29.22 shows double doors installed in an opening. The installation process of double doors is similar to the process shown for a single door. It is critical to ensure that the head is level and the jambs are parallel, plumb and 100% in wind. If these aspects of the jamb installation are not correct, once hung, the doors will not meet properly when they are closed.

29.4.1 Slide-in door sets

Sliding doors that disappear into a cavity formed within the thickness of the wall are commonly used as an alternative to hinged doors and permit the maximum use of floor and wall area.

A precision factory-made cavity unit can be obtained and fitted into walls as little as 70 mm thick. Split jambs are on one side of the unit, and concealed behind the jambs are steel angles that keep the sides of the cavity quite rigid. Built-in noggings on each side of the unit provide fixing for any specified wall sheeting, which is applied according to normal practice (Fig. 29.25). The manufacturer's installation details are supplied with each unit and should be followed carefully.

TIP Determining opening dimensions for doors

The dimension of the opening required to install various applications of sliding door pockets is provided. As an example, for a single door 2040 mm x 820 mm that will project 50 mm beyond the split jambs, the wall opening size is as follows:

height (h) = door height + 110 mm measured from top of floor to underneath head

width (w) = 2 x door width + 15 mm

Therefore, opening size, $h = 2150$ and $w = 1655$ mm.

Only one jamb lining is required in the door opening and the door running track is fixed to a pelmet across the head of the opening. A removable pelmet permits the door to be installed or removed from the cavity within a few minutes and conceals the running gear. The bottom of the door is fitted with a low-friction rubbing strip and nylon guides that are adjustable and fixed to the split jambs (Fig. 29.26).

29.4.2 Fitting and hinging of doors

Follow these steps when fitting and hinging doors.

29.4.2.1 Step 1

Stand the door in the opening and note any adjustments that should be made to maintain a 2 mm clearance at both sides and at the top. The object is to reduce individual fitting to a minimum by making up and fitting the jambs accurately. For the average door, the closing stile is bevelled off 2 mm so that the back edge will clear the jamb as it rotates around the hinge pivot point. Very narrow or thick doors may have to be bevelled even more.

29.4.2.2 Step 2

With the door standing in the opening and with a spacer at the top to maintain a clearance, lightly wedge underneath to hold the door in position. Mark the position of the hinges—down 150 mm to 180 mm for the top hinge and up 200 to 250 mm from the bottom, are the usual positions.

Fig. 29.26 Split jambs

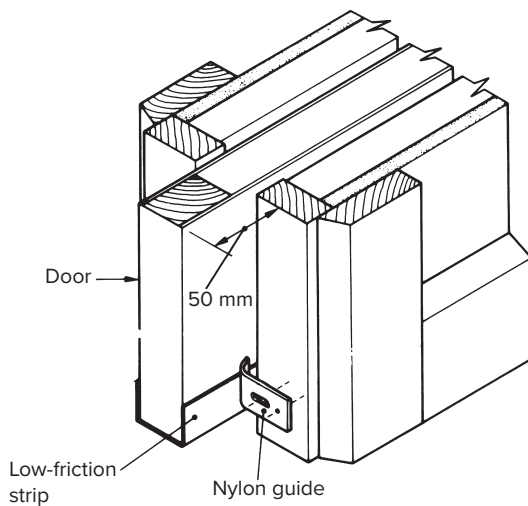


Fig. 29.25 Slide-in door sets

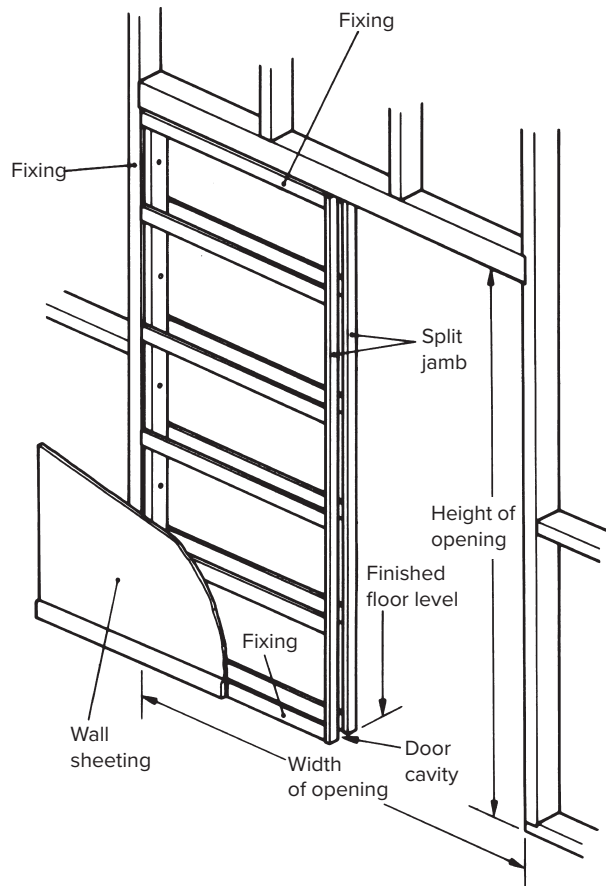


Fig. 29.27 Head and door track

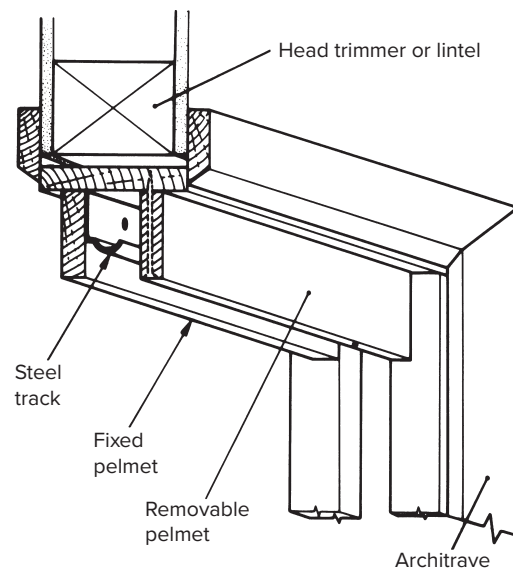
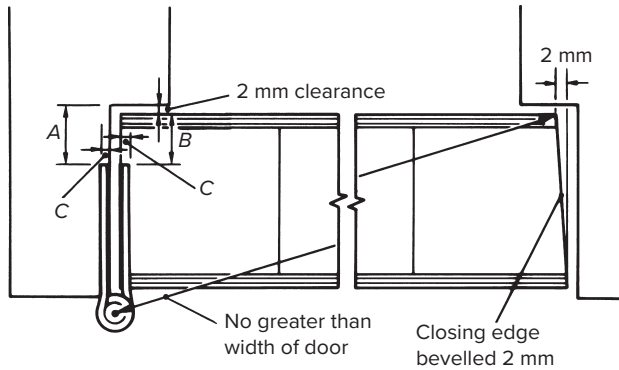


Fig. 29.28 Half and half hinging



29.4.2.3 Step 3

Doors are usually hung by *half and half hinging*, that is, the flaps of the hinges are let into the door and into the jamb, maintaining the required clearance in between. When hanging a door to a rebated jamb there are three dimensions to be gauged to locate the door on the jamb (Fig. 29.28).

- Distance A is from the face of the rebate to the back edge of the hinge.
- B is the distance from the closing face of the door to the hinge where the difference between the two is the clearance against the rebate.
- C is the depth of the check-out for the thickness of the hinge and is gauged on the face of the door and the edge of the jamb. There is no need to let the back edge of the hinge in any more than just below flush.

29.4.2.4 Step 4

Hold the door in the door block and, using the hinge as a template, mark the length of the hinge (Fig. 29.29). Gauge for distances B and C. Check out for the hinge and fix the flap of the hinges with two screws.

29.4.2.5 Step 5

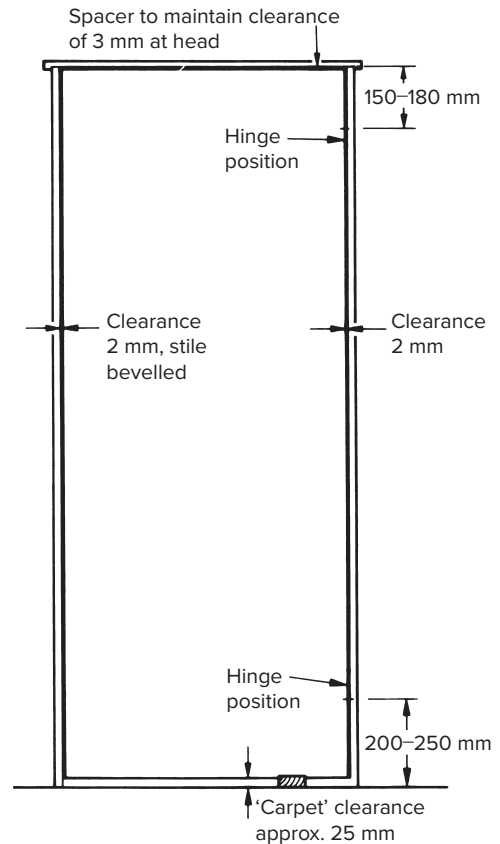
Again using a hinge, mark the length of the hinges on the jamb. Gauge A from the face of the rebate and C on the edge of the jamb. Check out for the hinge.

TIP The checking out of the hinge can either be performed with a chisel or a router. If installing many doors in the one job, a jig can be constructed to use with the router to speed up the checking in process.

29.4.2.6 Step 6

Stand the door beside the opening, locate the hinges in the check-out in the jamb and secure with two screws. Always drill a pilot hole for screws so that they can enter squarely and accurately without damaging the door or jamb.

Fig. 29.29 Marking the length of the hinge



29.4.2.7 Step 7

Check the operation of the door and make any minor adjustments to maintain a minimum clearance of about 2 mm. The thickness of the blade of a combination square is a handy gauge to check for clearance. Insert the remaining screws and make any minor adjustments to the gauge setting for further use.

In some areas, with the spread of the sub-contract system, door hanging and hinging has become a specialist task; some carpenters do nothing else. By equipping themselves with special tools (often made up by themselves), such as hinge router templates and portable mortise machines for fitting locks, it is remarkable how the work can be sped up. Once the basic requirements are understood, the procedures can also be varied. For example, some carpenters hinge the door to the jamb before it is fixed into the opening and adjust the jambs to suit the door.

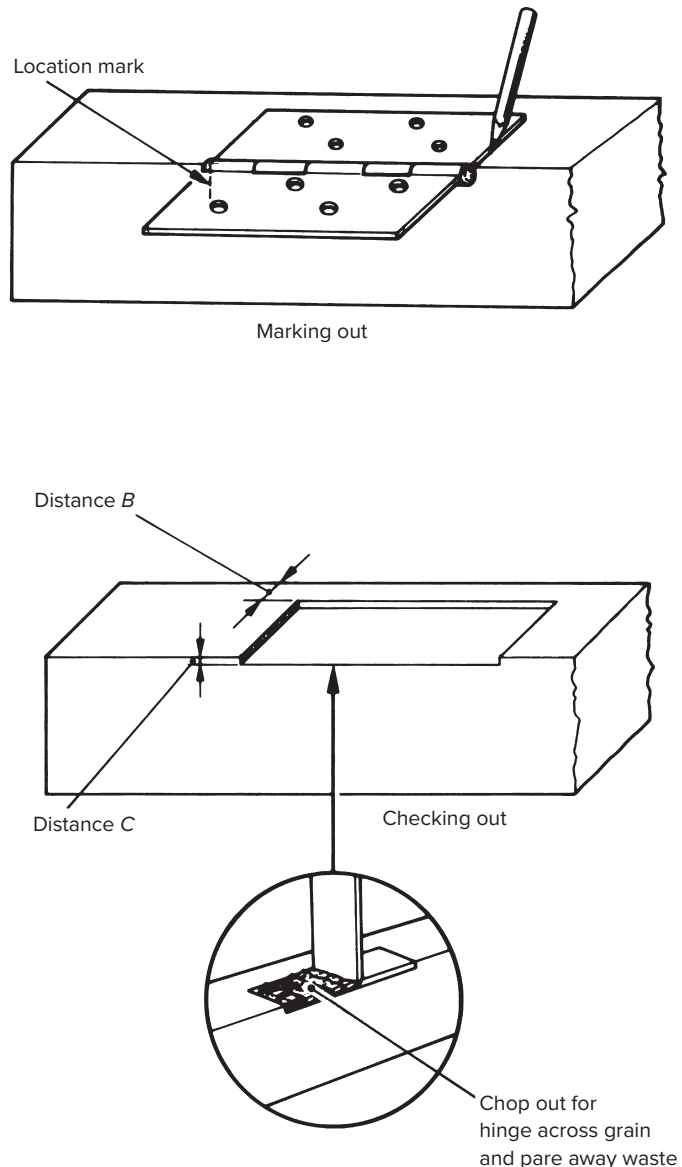
1. Cut the jambs to length, set out and trench the head.
2. Prepare the door, bevel off the closing stile.
3. Preferably using a router with a router template, check out for flap of hinges on jamb and door hanging stile. Using loose pin hinges, fix mating flaps to door and stile.
4. Make up jamb linings, check the floor for level and adjust. Stand in the opening and fix the hinge stile, accurately plumbing up in both directions.
5. Using loose pins, hang the door; the closing stile can now be fixed, adjusting clearances to suit the door.

Obviously, whatever procedure is adopted, accuracy in working is essential if it is to produce the expected results and adequate rewards for the carpenter.

29.4.3 Butt gauge

The butt gauge is a gauge specially designed for use when fitting butt hinges (Fig. 29.32). Gauging for A, B and C can be done with the one gauge, without any need for change. The gauge is adjusted so that when distance B is set, distance A will automatically be approximately 2 mm greater, that is, the allowance for clearance.

Fig. 29.30 Marking and check-out for hinge on door



29.4.4 Fitting to the jamb with loose stop

When doors are being hinged to a jamb with loose stop, gauging for the width of the hinge check-out is made from the hinge face of the door and the outside edge of the jamb, so that the face of the door will be a little below the level of the jamb. The loose stop is later fixed, allowing a clearance to the door.

29.4.5 Door furniture

Door furniture serves a dual purpose: it enables the door to stay closed, open or locked; plus, it adorns the door, almost like a piece of jewellery, enhancing the door's appearance and the interaction between it and the user.

Types of door furniture include:

- barrel bolts/panic bolts
- rim or mortise locks
- passage sets
- indicator bolts
- closers
- push plates and pull handles
- flush pulls
- deadlocks
- door closers.

Additionally, locks require separate door handles, escutcheons, etc. and the style, shape, colour or finish are generally infinite. These items, along with the hardware listed above, are what people see and interact with when using a door.

When installing the door furniture, it is important to read the construction specifications, and to talk to the client or designer to establish the height at which the hardware is to be installed. All locks and passage sets require some sort of drilling of the door, so it is essential to know the correct height at which to install the hardware.

Figure 29.33 illustrates the installation sequence of a mortise lock and passage set. Accuracy in marking is essential.

Fig. 29.31 Hinge check-out on jamb

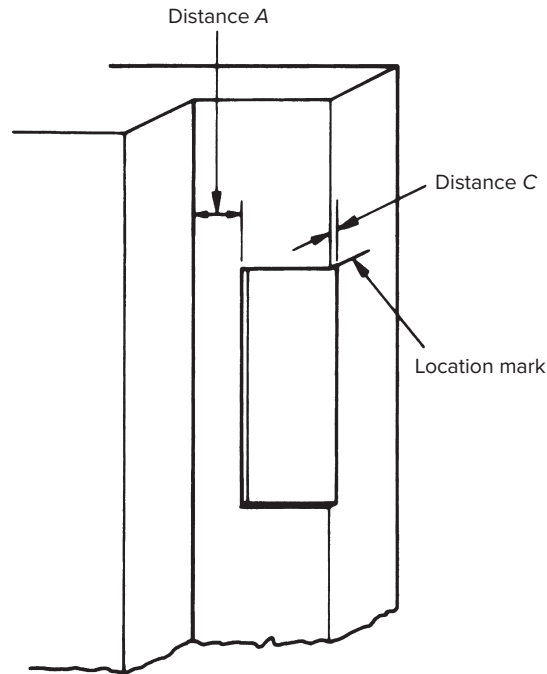


Fig. 29.32 Butt gauge

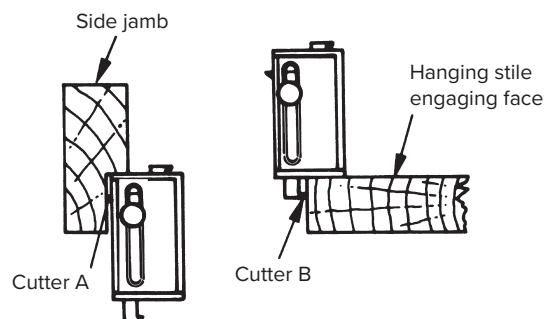
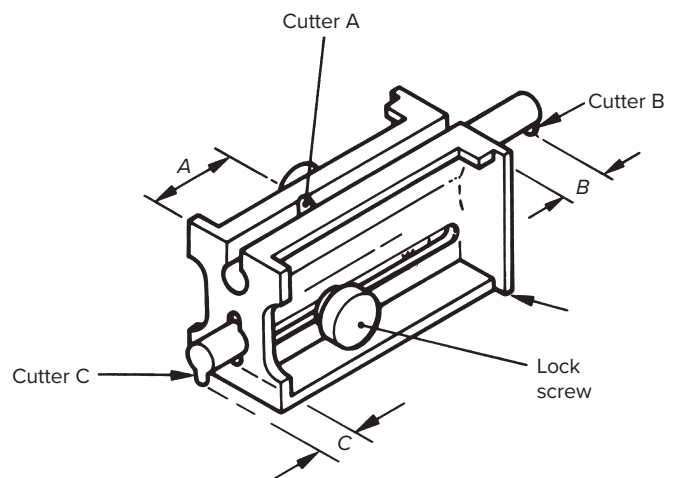


Fig. 29.33 (a) and (b) Installation sequence of a mortise lock and passage set

(a)

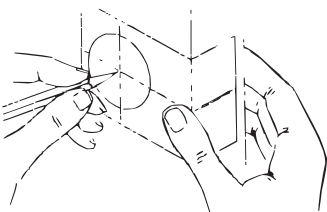


5400 Series Grade 1 Cylindrical Knob Lockset Installation Instructions

Tools Required		
- Chisel & hammer #2 phillips screw driver - Handle removal tool (supplied) 3/8" or 1/2" drill	2 1/8" (54mm) hole saw 1" (26mm) boring bit 7/64" (2.8mm) drill bit	Any retrofit or other field modification to a fire-rated opening can potentially impact the fire rating of the opening, and Yale Locks & Hardware makes no representations or warranties concerning what such impact may be in any specific situation. When retrofitting any portion of an existing fire-rated opening, or specifying and installing a new fire-rated opening, please consult with a code specialist or local code official (Authority Having Jurisdiction) to ensure compliance with all applicable codes and ratings.

1 Mark Door

Mark line across edge of door for centerline of lock. Fold template over edge of door, centering on horizontal line. Mark centers of holes at proper backset.

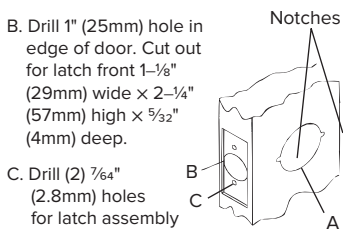


2 Drill Door

A. Drill 2-1/8" (54mm) hole thru the door. Cut Notches as shown on the template.

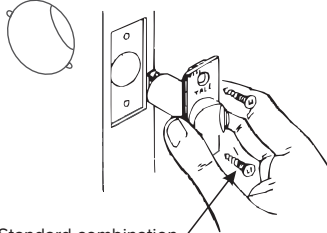
B. Drill 1" (25mm) hole in edge of door. Cut out for latch front 1-1/8" (29mm) wide x 2-1/4" (57mm) high x 5/32" (4mm) deep.

C. Drill (2) 7/64" (2.8mm) holes for latch assembly



3 Install Latch Unit

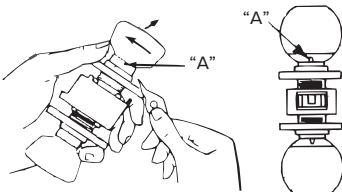
Install latch assembly with screws provided.



Standard combination wood and machine screw #8-32 x 3/4"

4 Remove Inside Knob

To remove knob, depress retainer with small end of spanner wrench, through small hole "A" in trim cap. Keep spanner wrench perpendicular with spindle. Pull knob off. Remove inside rose by unscrewing counterclockwise. For cylinder knob see step 8 and 9.

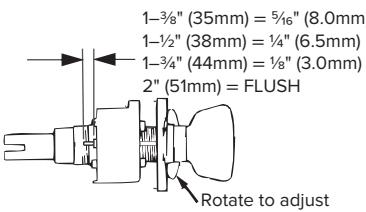


5 Adjust for Door Thickness *If necessary*

(Lock is packed preadjusted for 1-3/4" (44mm) doors.)

Rotate the outside rose nut assembly until proper dimension is reached for required door thickness. Measure from the end of the pin to the lock flange.

1-3/8" (35mm)	= 5/16" (8.0mm)
1-1/2" (38mm)	= 1/4" (6.5mm)
1-3/4" (44mm)	= 1/8" (3.0mm)
2" (51mm)	= FLUSH

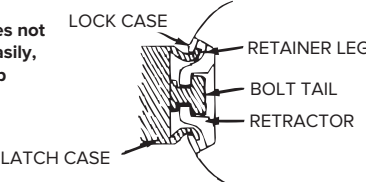


6 Install Lock

With lock case in place, insert lock assembly into 2-1/8" (54mm) hole, making sure that lock case hooks the retainer legs and retractor engages the bolt tail.

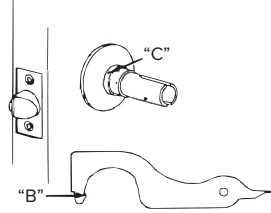
Caution: Do Not Force

If Lockbody does not engage latch easily, check door prep for errors.



7 Attach Inside Rose

Slide inside rose over inside spindle and sleeve and screw rose into place. Tighten securely with spanner wrench supplied. Catch small lug "B" of spanner wrench in small hole "C" in rose and turn clockwise until tight.





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(b)



3770 SERIES MORTICE LOCK MOUNTING INSTRUCTIONS FOR TIMBER BOOKS

P/No. 3770-2101-6

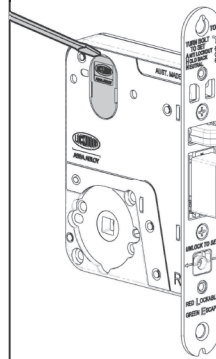
HAND OF DOOR ACCORDING TO ENGLISH PRACTICE

DOOR OPENING IN		DOOR OPENING OUT	
INSIDE		INSIDE	
RIGHT HAND LOCK	LEFT HAND LOCK	RIGHT HAND LOCK	LEFT HAND LOCK
OUTSIDE		OUTSIDE	

- Determine hand of lock required from chart above.
- Ensure only holes required by handling, function and furniture are cut into door.
- Disregard instructions referring to features not required.
- The lock is supplied in passage mode. The hold back and anti-lock functions are de-activated.

1

LOCK SETTING



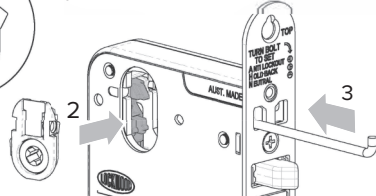
- Where cylinders or turn knobs are required, remove the cylinder plugs from the lock using a small screwdriver.
- Set the required lock function as per **SETTING AND OPERATING INSTRUCTIONS**.

2A

LOCKING ADAPTOR INSTALLATION



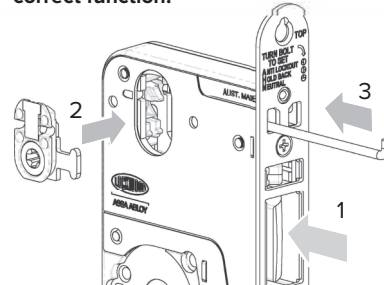
- Rotate the locking adaptor so one leg is pointing towards the locking bar.
- With the locking bar in the unlocked (up) position; fit the locking adaptor into the lock. Ensure the cam is engaged within the locking bar.
- Secure by pressing in the cylinder retainer pin.



2B

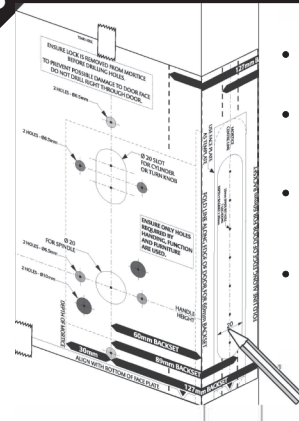
LATCHING ADAPTOR INSTALLATION

- Depress the latch bolt and fit the latching adaptor.
- Secure by pressing in the cylinder retaining pin.
- **Note: The face plate must be fitted to ensure correct function.**



3

DOOR PREPARATION



- Establish height that lock will be on the door.
- Cut mortise in door as per sizes shown on template.
- Determine what lever, cylinder or turn knob holes are required.
- Drill required furniture holes from both sides of door.

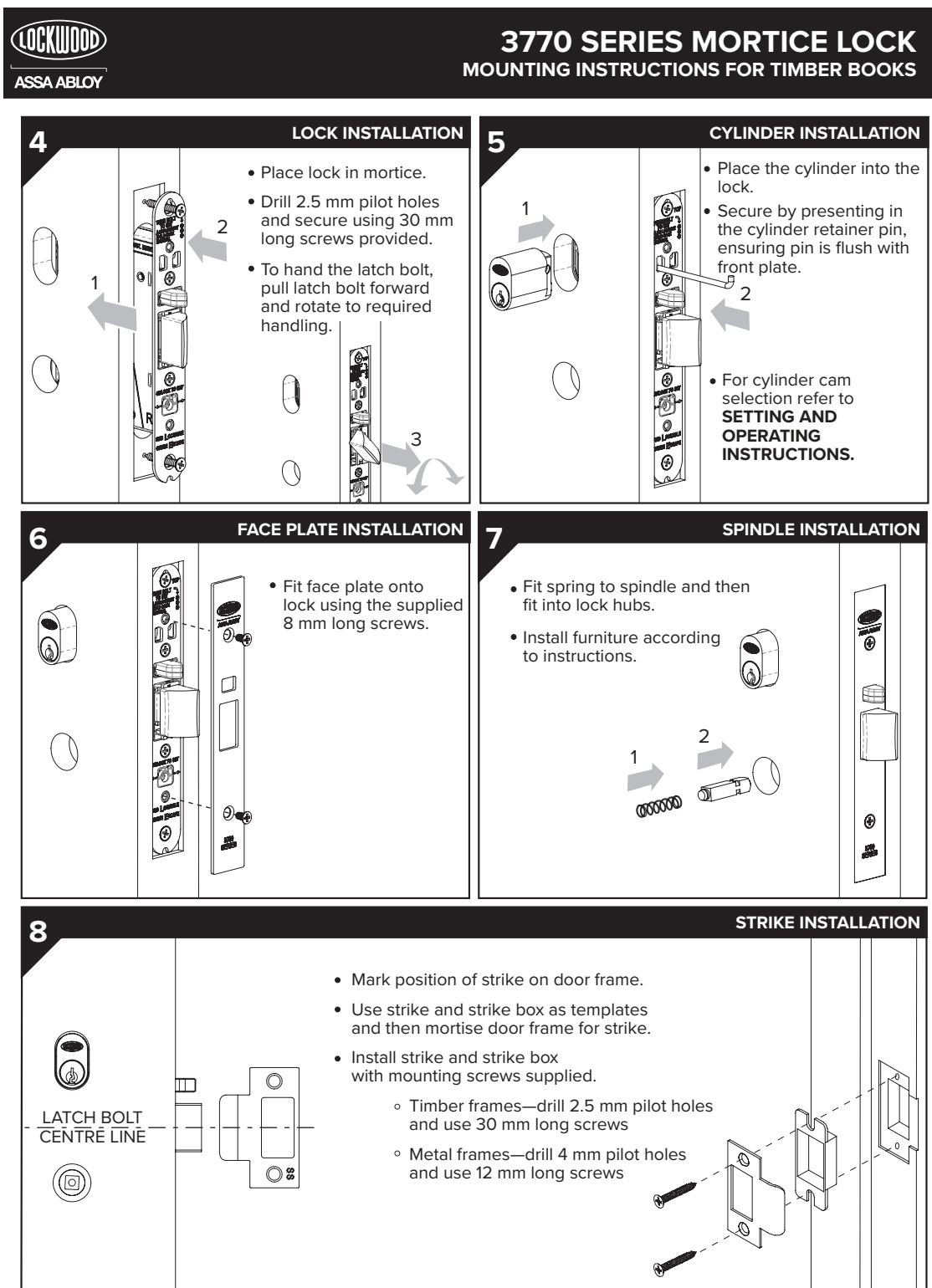


- Fit the lock into the mortise and mark using the face plate as a template.
- Remove lock and cut 4 mm deep recess for the face plate.



(continued)

Fig. 29.33 (b) Installation sequence of a mortise lock and passage set (continued)



CHECK YOUR UNDERSTANDING

5. List three types of door furniture.
6. Indicate in a sketch what distances must be measured from the top and bottom of a jamb so that the hinges can be correctly installed.

29.5 Install trims

29.5.1 Architraves

Architraves are mouldings used to frame the outline of doors and windows and to cover the joint between the frame and the structural members. Architraves are commonly 50 mm to 75 mm in width and 15 mm to 25 mm in thickness. They can be a variety of moulded profiles; some of the most used profiles are shown in Figure 29.34.

Note how some architraves may have a wide milling groove taken out of the back face. This makes them much easier to fit, as the groove will bridge any irregularities in the level of the wall sheeting while the edges will fit down tightly on the wall and frame.

The corners of architraves are mitred.

When fitting architraves to an opening, cut the side pieces and fix in position, allowing a *quirk*, approximately 3 mm, at the edge of the jamb. Cut and fit the head piece and fix the bottom edge to the jamb head (Fig. 29.35). Flush the mitred joint and secure with a nail through the top edge only (Fig. 29.36).

In the two top corners of the jamb mark the 3 mm quirk on the head and the stile. This intersection will give you the length of each piece of architrave to the short point of the mitre.

It is good practice to remove the arris (sharp edge) off the moulding prior to installing the architraves. This can be achieved using either a sharp block plane, which you can keep in your nail bag, or some abrasive paper (sandpaper). Select a paper with a grit of about 180 to avoid too rough a finish. Removing the arris from timber ensures that any finish to be applied, such as paint, stain, lacquer, etc., will

Fig. 29.34 Architrave profiles

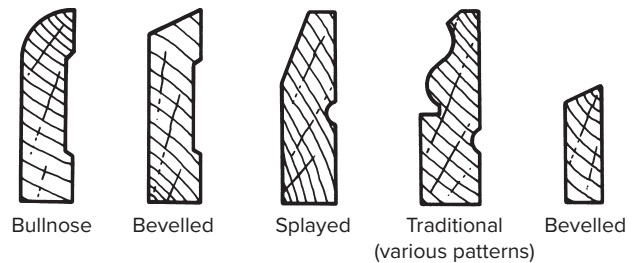


Fig. 29.35 Procedure for fixing architraves

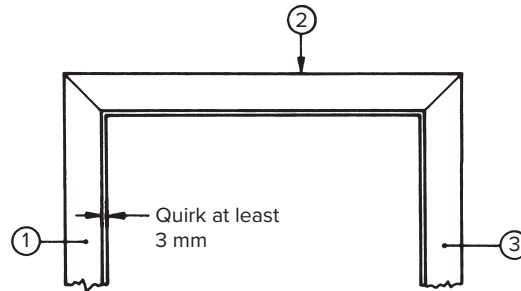
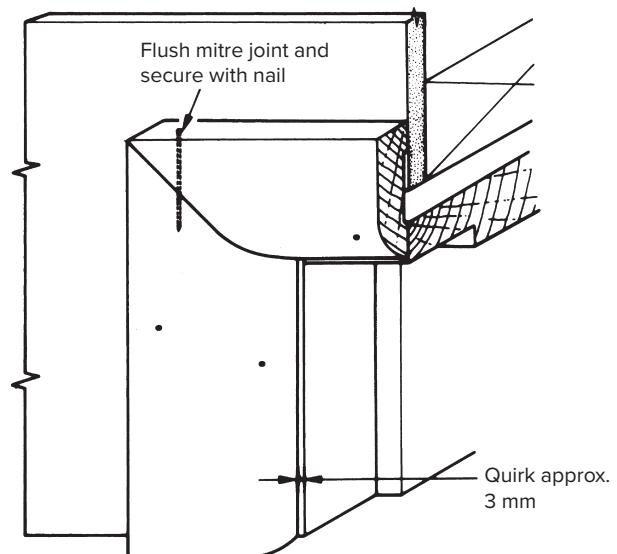


Fig. 29.36 Architrave mitre joint



stick (nothing sticks to a sharp edge). Removing the arris prior to installation also makes the task much easier. This step should be carried out prior to the installation of any finished timber work.

1. Starting from the left side, cut the mitre on the architrave and then cut to length and fix.
2. Cut the left-hand mitre on the head piece of architrave and fit. When this mitre fits well, cut the second mitre and fix.
3. Hold the right-side architrave on the jamb and mark off the length of the architrave. Cut the mitre and offer it up to see if the mitre joint fits well. There is scope for some adjustment on this cut, but only a small amount.
4. Once fitting well, fix and remove the arris off the back of the architrave with some sandpaper.

CHECK YOUR UNDERSTANDING

7. In what sequence should architraves around a door be installed?

WORKPLACE SCENARIO

It's always good practice to cut one piece of architrave at a time. Therefore, you are dealing with only one mitre at a time. I like to start from the left. If you want to, instead of measuring the length of the architrave, place the architrave where it's going to be installed and mark its length directly off the quirk line, which you would have marked at the top two corners of the jamb. Cut the architrave and install. Next, start with the head. Cut the left-hand mitre and offer it up to the first piece. At this point, the mitre can be adjusted so that it fits properly. Repeat the process, working on one cut at a time. If you don't do this, and precut your architraves, adjusting the mitres will be hard, as removing anything from them will decrease the length of the architrave, thus making it too short—meaning it won't sit on the floor.

29.5.2 Skirting

Skirting is located at the base of the internal walls and covers the joint between the wall and the floor, protecting the wall from damage (Fig. 29.37).

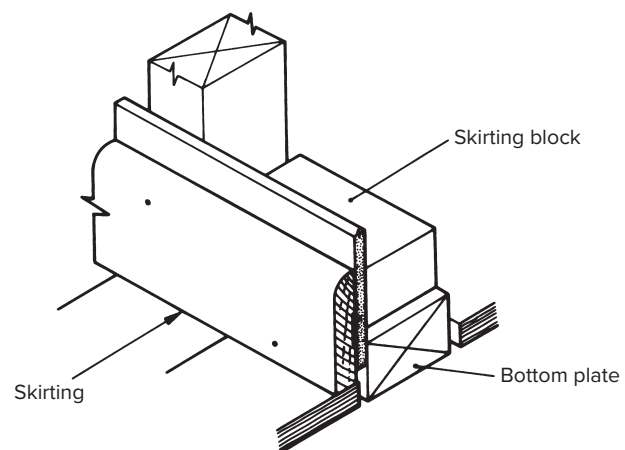
Moulded profiles for skirtings are similar to those for architraves except that skirtings can range in size from under 75 mm to 100 mm wide; in the restoration of old buildings, skirtings 150 mm to 200 mm wide, and occasionally more, may be used.

When fitting skirtings, scribed joints are used for internal corners, and external corners are mitred (Fig. 29.38).

29.5.2.1 Scribed joint

To make the scribed joint, the first piece *A* is cut off square and fixed in position. The second piece *B* is mitred at half the angle of intersection, usually 90° , as in this example, making the mitre angle 45° . The contour of the mould is then cut with a coping saw at the angle of intersection, in this case 90° (Fig. 29.39).

Fig. 29.37 Skirting and skirting blocking



The advantage of the scribed joint for internal corners is that piece *B* can be cut slightly long (say 2 mm, depending on length) and sprung into place, cramping the joint together. Thus, the joint will not be forced apart when nailed to the frame. Joints can at times open up due mainly to shrinkage of the structural framing and should be so arranged that a person will not be looking straight into the open joint from the most probable viewing positions.

Generally, the skirting opposite the door is fixed first and then work continues back towards the door, finally butting against the back of the architrave. A *pinch rod* can be used to measure the length of skirting quickly. This consists of two light laths of timber that are extended to measure the required lengths. Pinch them together and mark across them to ensure there is no movement as they are laid along the skirting and the length is marked from the rod (Fig. 29.40).

29.5.3 Fixing trim to window openings

Timber window frames are finished at the back of the sill with a window nosing and apron mould. Window nosings are milled from stock 50 mm or 75 mm × 38 mm and, when cut to length, are fitted around the window stud, and the mould returned on the ends. The nosing is drilled and fixed to the back of the sill using nails, which are so positioned that they will penetrate the window flashing close to its top edge only.

The apron mould covers the joint below the nosing and can be made up of various sections—bullnose, bevelled or scotia, for example. Great care must be exercised when nailing the apron mould to ensure no nails are allowed to penetrate the sill flashing.

The sides and head of the window opening are finished with an architrave in a manner similar to door openings, but depending on the thickness of the wall and the window frame used, an elbow lining may be necessary to cover the reveal from the frame to the face of the interior lining (Fig. 29.41).

Fig. 29.38 (a) Mitred joint; and (b) scribed joint

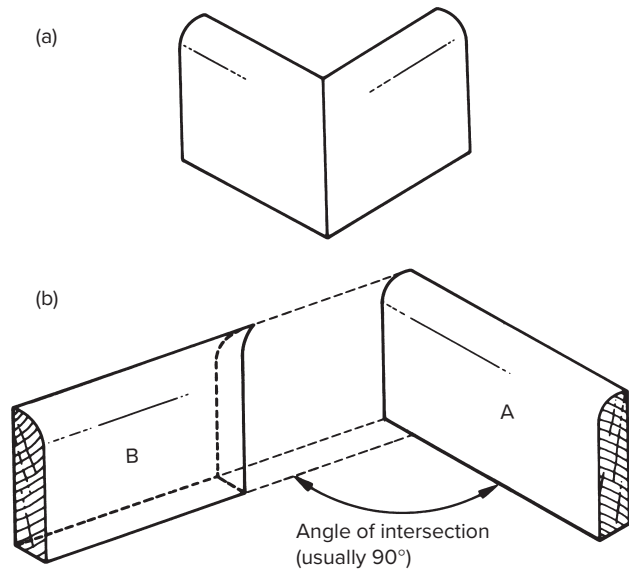


Fig. 29.39 (a) and (b) Making a scribed joint

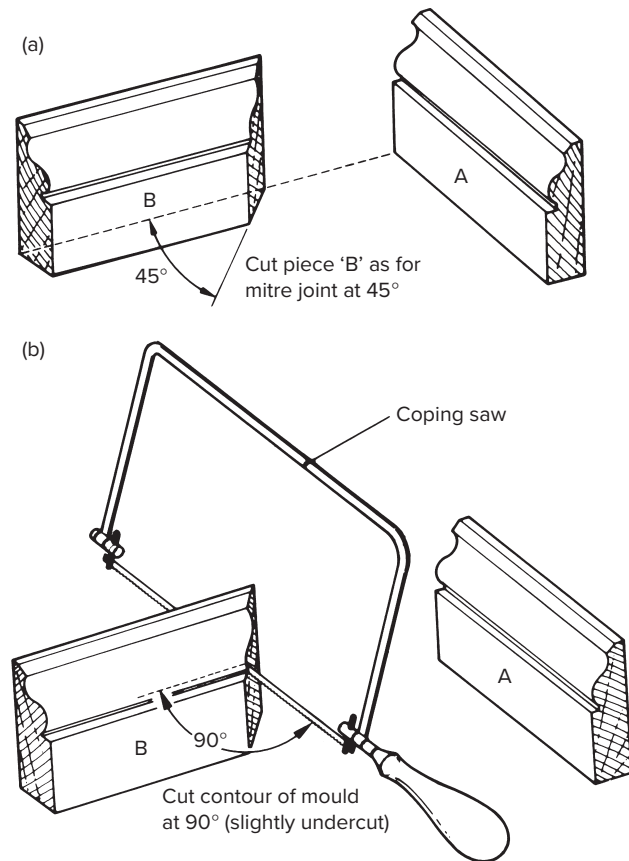


Fig. 29.40 Order of fixing skirting to a room

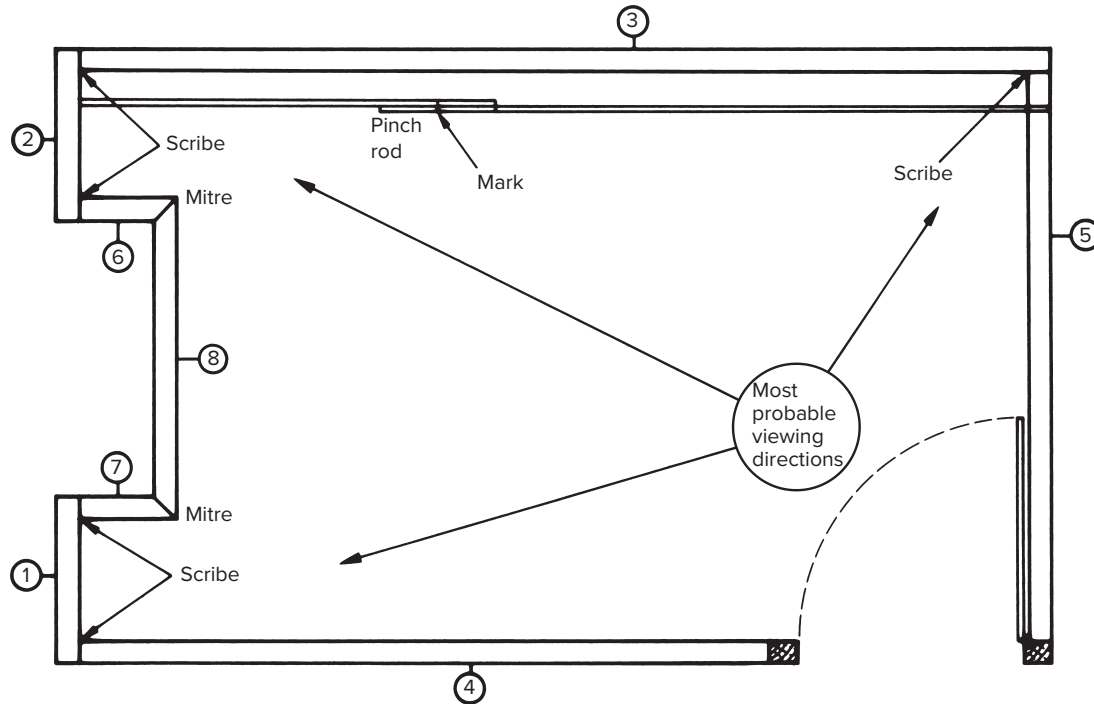
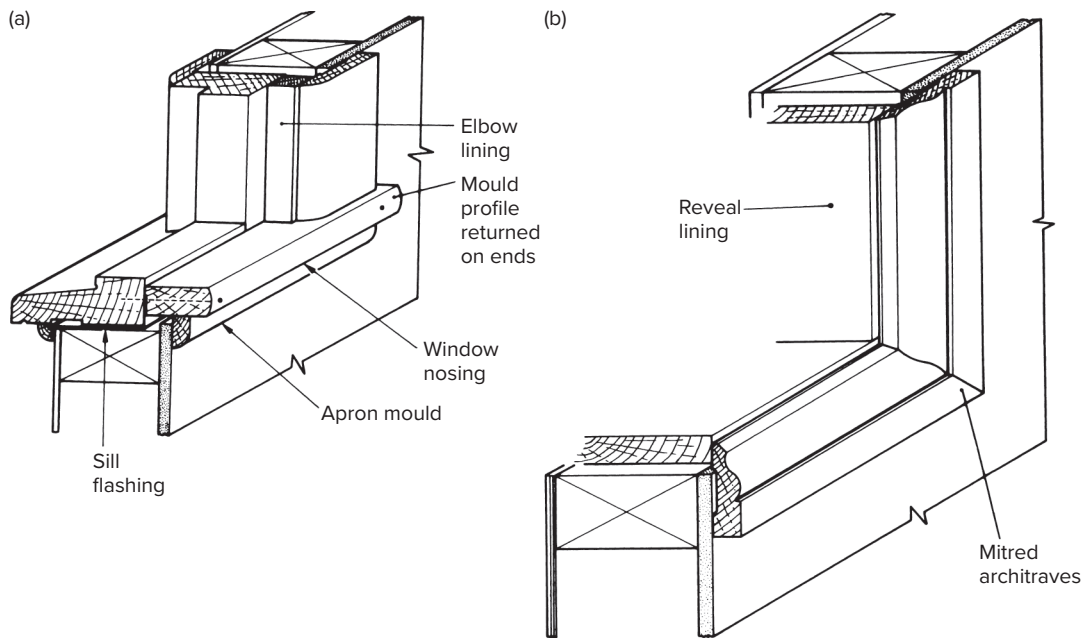


Fig. 29.41 Fixing of internal trim to window openings: (a) timber; and (b) aluminium



CHECK YOUR UNDERSTANDING

8. What general procedure should be adopted when fixing skirting boards to a room? Give an example.
9. Describe the joint you would use to join a skirting board at an internal corner.
10. What is the function of the following members when used to finish around a window opening?
 - a. Architrave
 - b. Nosing

29.5.4 Exterior door openings

Timber-framed buildings use a timber threshold to external doorways. This is milled from stock usually 175 mm × 38 mm of equivalent durable timber.

The threshold is made weather resistant by fixing it with a slope to the outside of, say 5 mm, which allows a strip of hardboard to be used as packing to the inner edge (Fig. 29.42).

The jambs are housed to the ends of the threshold, which is also cut around the face of the exterior sheeting to form a horn (Fig. 29.43). The front edge of the threshold can be fixed by nailing through the horn, but be sure to drill a hole with ample clearance to prevent splitting this close to the end: only the end of the jamb and housing should be painted before assembly.

TIP Thresholds can be manufactured with rebates to stop wind and rain from entering the house. There is also a wide range of weather strips available to make doors more draft and rain resistant.

Fig. 29.42 External door openings

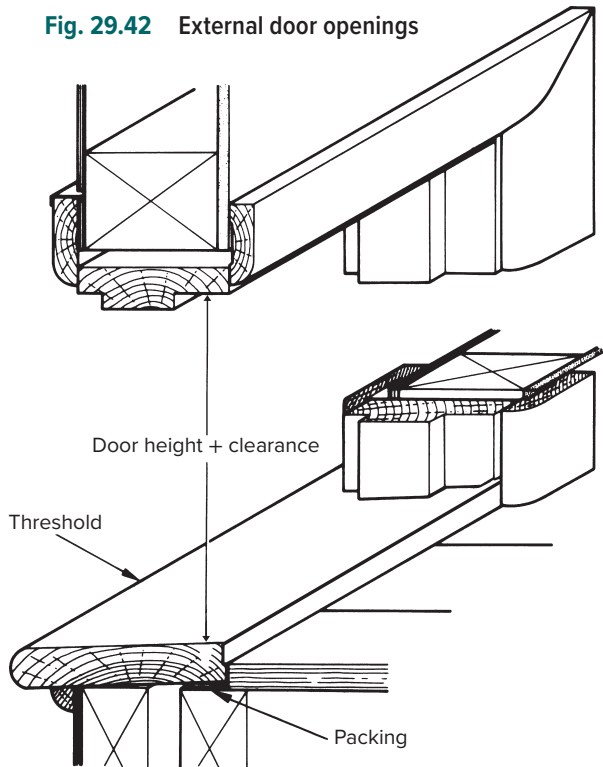
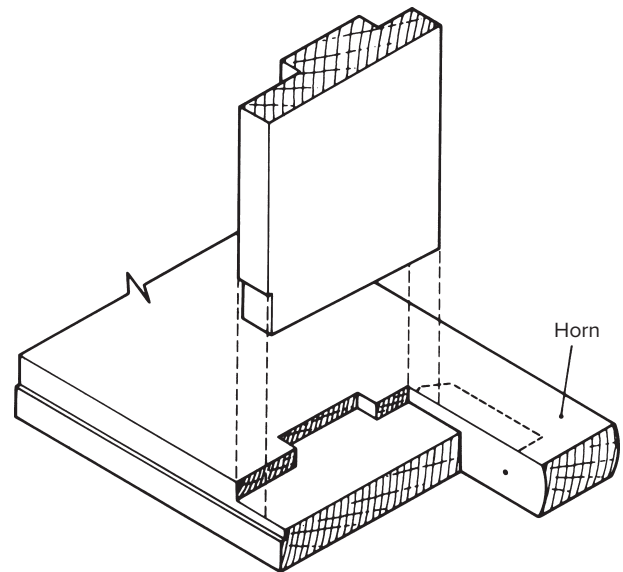


Fig. 29.43 External jamb lining housed into threshold



Student research

Research how many different types of hinges there are and their applications. Then practise letting in a butt hinge on a scrap piece of timber.

End-of-chapter activity

Research what materials other than those mentioned can be used to line the walls of a home.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1684—2010
Residential
timber-framed
construction

**National Construction
Code (NCC)**

**AS 4145—Locksets
and hardware for
doors and windows—
Mechanical locksets for
doors and windows in
buildings**

**AS 2688:2017—Timber
and composite doors**

**AS/NZS 2272:2006—
Plywood—Marine**

Tradie talk—Always scribe an internal mitre

Chapter 30

Erect and dismantle formwork for footings and slabs on the ground

Learning Objectives

LO 30.1 Plan and prepare

LO 30.2 Construct formwork

LO 30.3 Strip, clean and prepare formwork for re-use

LO 30.4 Clean and maintain tools and equipment for re-use

LO 30.5 Clean up and dispose of waste

Introduction

In this chapter you will learn about the legislative requirements with regard to planning and carrying out the construction and stripping of formwork for concrete slabs on the ground. This will include compliance with the National Construction Code, any relevant Australian Standards and codes of practice. You will also find out about compliance with work health and safety (WHS) regulations, environmental requirements and the need to follow the manufacturer's specifications, including any material safety data sheets (MSDS).

You will learn construction industry-related terminology for any works being conducted involving the construction and stripping of formwork for slabs on the ground. You will also learn about formwork construction for slabs on the ground in the building industry using different types of formwork materials and methods of construction, ensuring that the formwork is strong enough to hold the concrete as it is poured and as it sets.

Formwork construction requires special skills, and on many construction sites where formwork is being erected, the design and satisfactory performance of the formwork becomes the responsibility of the site manager or supervisor.

The specifications for the construction of any formwork, either from the formwork manufacturer, supplier or from the plans of the job, need to be closely followed as any shortcuts taken or incorrect

modifications to the formwork could cause the formwork to fail. If the formwork does fail, there will be a significant risk to any workers in the vicinity—severe injuries could occur. There will also be significant material costs through concrete loss, formwork, reinforcement or substrate repair or replacement if required, plant and equipment requirements, time and labour.

In this chapter, you will also learn how to strip the formwork correctly and safely from the concrete at the correct time after pouring. Cleaning and checking the formwork for any damage or faults and following the correct procedures to ensure any repairs to, or replacement of, the formwork components are carried out correctly is important. The correct procedures for storing the formwork for transporting or re-use will also be addressed.

The cleaning and maintenance of the formwork construction tools and equipment will also be addressed. As with the formwork components, all of the tools and equipment must be correctly cleaned and inspected for any damage or faults. If any repairs are to be made or tools or equipment replacement is required, the correct procedures for doing so must be followed.

Finally, you will learn about the correct procedures for the site clean-up and disposal of any waste materials according to any legislative procedures or specific worksite requirements.

Formwork is covered by AS 3610.1: 2018 Formwork for concrete.

30.1 Plan and prepare

30.1.1 Regulatory requirements, work instructions and sequencing of work

The construction of formwork for a concrete slab on the ground—whether it be a rebated slab for a typical brick veneer house or a square-set slab—needs to be carefully planned according to the requirements set out in any documentation providing instructions on how the task must be carried out. Such planning, as mentioned in Chapter 31, Concreting to simple forms, can include ensuring any legal requirements, regulations and safe work practices are met and addressed, such as WHS issues. This is best done by referencing any codes of practice available from the state or territory WorkSafe organisation. Any local government requirements, such as having the correct building applications, job plans, specifications and any other associated documents lodged and then obtaining and having the correct building permits in place for the work to proceed, must also be addressed.

It should be noted that formwork is only a temporary mould for concrete to be placed into. It is important that all documents, plans and specifications for the work should be developed with this, and the finished concreting job, in mind. Associated regulatory documents such as the National Construction Code, Australian Standards, codes of practice and any specific engineering requirements need to be understood and carefully adhered to as the formwork will create the finished shape of the concrete.

Even though the construction and stripping of formwork is not a large, time-consuming job in relation to the overall job time frames, it is vitally important that all regulatory requirements are met, that all plans and specifications are adhered to and that the work sequencing is such that the job will be accurately completed to the required specifications in the minimum time frame. This is because the concrete needs to be ordered well in advance of the formwork being completed, with a view to the formwork being ready to accept the concrete on the day and at the time it has been ordered for. In addition, the pre-pour inspection of reinforcement mesh and moisture barrier materials must be passed by a licensed building surveyor.

Once the concrete has been poured and set, the formwork will be stripped, cleaned and maintained and taken to the next job.

The concrete will remain as the permanent fixture, so it is of the utmost importance that the formwork is in the correct position, is sturdily constructed and is set to the correct height.

The position of the finished slab should be checked against the plans and the completed set-out on the existing profiles before any preparation work by other trades through to the construction of the formwork commences.

If it is detected before a pour that the formwork has, for example, been placed in the wrong position or at the wrong height or that it has not been adequately braced to withstand the force or pressure of the concrete when it is wet and being poured, all manner of problems will arise, with costly delays as the problems are rectified.

If it were to be discovered after a pour that the formwork had been positioned or constructed incorrectly, then the ramifications would be far worse. In all probability, the entire slab would need to be demolished and removed and all of the work up to that point would have to be redone in the correct position.

WORKPLACE SCENARIO

I recall I was working as a carpenter in rural Victoria and an extremely large subdivision had just been opened in a section of the city for a new housing development.

Construction had started on only a very few houses at that point, so any work was well isolated. No dividing fences had been constructed yet, so the only boundaries for the building allotments were the surveyors' pegs on the corners of each block.

Walking onto a vacant plot of land like this, it would take some time to clear the land, scrape or cut and fill to the correct height, set out the dwelling, excavate then set up the formwork for the house slab, and do all of the preparations for the house slab to be poured—which would also include the installation of all services by other trades such as plumbers and electricians—and then finally pour the slab, strip the formwork and commence construction of the house frame. The cost to get to this stage would be getting well into the cost of the entire build.

One such house in this new estate was exactly at that stage when the owners of the house under construction arrived back from their annual interstate holiday and decided to go and have a look at how their new house was progressing. Standing on the street and looking at the timber house frame on the concrete slab they sensed something was amiss so they immediately contacted the builder and asked them to send a representative around with the plans so they could discuss the concerns they had.

Once the building company representative arrived on-site with the plans for the house, they were able to establish that the setback from the side boundary on the site plan did not match the actual setback where the house had been positioned. Someone had misread the plan or made a mistake when measuring the setback when the initial set-out of the house was being done. This mistake was to prove very costly as the house had now encroached onto the vacant next-door lot by almost 2 metres. Once the set-out had been done, the measurements for the position of the house were never rechecked: not at the completion of the set-out stage; not while any of the services were being installed; not before or while the formwork was being constructed; and certainly not before the concrete pour went ahead. At no point had anyone on the site picked up this enormous mistake.

How was this mess going to be fixed?

Luckily for the builder and the concreter, who were responsible for the mistake, the new homeowners were forgiving people and said it was not anything but a mistake. Being the kind-hearted people they were, to save the building contractor and the concreter a lot of money and embarrassment, they purchased the plot of land next door, which at that stage was unsold.

After some negotiations with the local authorities to rectify the situation, with all costs being paid for by the builder, the house was completed to the highest of standards and handed over to the clients, who in typical country fashion were extremely impressed with their new home.

30.1.2 Site safety planning

The location and scope of the form work construction may produce a variety of hazards and associated risks that will need to be addressed and managed before any work commences. The person conducting the business or undertaking (PCBU) will be required to conduct a hazard identification and risk assessment of the entire job to meet any WHS obligations. The hazard identification and risk assessment may be carried out by conducting site and surrounding environment inspections.

Specific items considered can include such things as:

- entry/exit points to the site
- crossovers to public roadways
- traffic flow along adjoining roadways
- pedestrian traffic along adjoining footpaths
- site conditions such as cut and fill, deep excavations, terrain
- existing services and proposed service works
- inspections in the form of a job safety analysis (JSA) or, if the work is deemed high risk, a safe work method statement (SWMS).

The specific location and nature of the works being carried out will dictate the need for any barricading or signage (Fig. 30.1). Pedestrian and traffic management will have to be considered as the volume of traffic in and out of a construction site while site preparation, formwork construction and the concrete pour are taking place can be significantly higher than at other times in the construction process.

A lot of these requirements will already be in place on the construction site, before the construction of any formwork begins, so it may only be a case of ensuring that any formwork construction task-specific documentation is formulated to complement the already existing safety plans.

Other tasks that have already taken place which would require the same type of safety planning could include:

- site establishment
- site clearing
- site scraping
- setting out
- excavations (cut and fill, footings and piers, under-slab preparations)
- other trades or contractors (surveying, earth moving, plumbing, electrical, tree removal, to name a few).

30.1.3 Personal protective equipment (PPE)

Personal protective equipment (PPE) will be required to carry out the construction of formwork for slabs on the ground (Fig. 30.2). This will be similar to, if not the same as, the PPE required to carry out many of the above-mentioned tasks that take place in the early stages of construction, when there is no shelter from the elements and most of the work is carried out at ground level.

The required PPE could include such items as:

- protective clothing, including long work pants and a long-sleeved shirt or top
- hi-vis safety vest

Fig. 30.1 Site entrance signage covering emergency, PPE and COVID-19 information



Courtesy of Alister Ford

- gloves
- safety glasses
- steel-capped work boots
- hard hat
- protective sun hat
- sunscreen.

Any site-specific PPE will also be displayed on signage at the entrance to the construction site (Fig. 30.1), and any task-specific PPE will be listed on the accompanying SWMS or JSA. It is vitally important that these instructions regarding the wearing or use of PPE are always adhered to.

An additional requirement under the WHS Act is a material safety data sheet (MSDS) for all hazardous materials that are on-site. This information should be made available to all workers on-site. The MSDS/SDS is a document that describes the properties and uses of a substance. These include chemical and physical properties, health hazard information, precautions for use, first aid and safe handling information. The MSDS/SDS can be sourced on the internet by visiting the manufacturer's website.

An example of a required MSDS/SDS for the formwork stage of the construction job could be one for any release agents to be used on the formwork before the concrete pour.

30.1.4 Tools and equipment

The scope of the job will dictate the tools and equipment required to construct the formwork, but generally, for most on-the-ground slab formwork construction for rebated slabs or square-set slabs, timber, steel or plastic materials will be used to create the formwork and falsework.

The tools and equipment that carpenters would have in their tool trailer or back of their work ute would generally be adequate to construct the formwork for a slab on the ground.

These tools could include:

- levelling equipment (laser level, as in Figure 30.3, automatic level, spirit level)
- measuring equipment (100-metre tape, 30-metre tape, 8-metre tape, 1-metre four fold ruler)
- hammers (sledgehammer, mash hammer, claw hammer)
- saws (portable power saw, hand saw)
- drills and drivers with the correct bits for the fixings being used
- string lines.

The pegs used to hold the formwork in place can be steel or timber. If the pegs are steel, they will generally be star droppers (pickets), which have holes already in one leaf of the dropper. These are driven in to the desired height and the formwork can be fixed by screwing through the already-made holes, generally with hex head wood screws. When each star dropper is driven in and fixed, a high-visibility safety cap should be installed on the top.

If timber pegs are used, care should be taken when driving in the peg. A wayward strike to the peg with a heavy hammer can easily split the peg, rendering it useless. The ground around the peg may also be disturbed when removing the damaged peg, so much so that the new peg needs to be moved

Fig. 30.2 Gum boots are essential PPE when pouring large areas of concrete



Courtesy of Alister Ford

Fig. 30.3 Laser level set up for formwork construction and foundation preparation



Courtesy of Alister Ford

along to a more stable section of ground. This means that a gap between the pegs may create a section of formwork that could be unstable and susceptible to movement or even collapse when the concrete is being poured.

The formwork can be fixed to the pegs using hex head timber screws, as previously mentioned. Countersunk Phillips head screws can also be used. If nailing the formwork together, duplex nails are specifically manufactured for tasks such as formwork construction. As the name suggests, these nails have a double head. The nail is driven into the depth of the first head, leaving the second head protruding from the timber by approximately 10 mm. This means that when it comes to the time to strip the formwork, the duplex nail can be quickly and easily removed. Also, if the formwork is to be nailed, it is best to 'dolly' the formwork and pegs so as not to loosen the hold the peg has taken in the ground. Quite simply, to dolly means to hold a heavy hammer against the back of the materials being nailed together.

This will stop any movement of and loosening of the peg in the ground.

Required equipment could include:

- portable power generator and fuel
- power leads
- steel star droppers (pickets)
- steel dropper safety caps
- timber pickets
- fixings: nails (bullet head, flat head or duplex), screws (hex head or Phillips head timber or metal) and/or bolts if required
- release agent liquid
- brushes, rollers or a spray gun.

30.1.5 Formwork materials and quantities

30.1.5.1 Materials

Formwork holds the concrete in shape until it is set, and falsework holds or supports the formwork in position. Formwork must always be well constructed using materials that are suitable for the job and be able to withstand the associated pressures when the concrete is placed. It should be correctly joined, propped, pegged and braced and be of such strength that there is no chance of displacement or bulging.

The formwork needs to be constructed accurately according to the plans and specifications of the job. All joins in the formwork must be tight and properly connected to prevent any concrete escaping.

The formwork must also be constructed in such a way that it can be easily deconstructed and stripped without any damage being caused to the green concrete.

The materials used for the formwork and falsework will usually be selected at the discretion of the builder carrying out the construction. The builder's knowledge and experience will determine the suitability of any required materials.

Many builders will have their preferred formwork materials and equipment stored in their building yard ready for transport to the job site for use.

Generally, the formwork will consist mainly of timber or steel components, although formwork systems using plastic are becoming more common as it comes in a complete kit form.

Basic formwork materials can include the following materials. Also listed are some of the advantages and disadvantages of each material.

Timber:

- strong
- economical
- available in different section sizes and lengths
- easily cut to the required length
- easily fixed by nailing or screwing
- lightweight
- re-usable for some time.

Plywood or form ply:

- strong
- lightweight
- can be cut to different sizes or shapes
- can be worked to create curves
- comes in different thicknesses
- restricted in length of sheets
- re-usable for a limited time.

Steel:

- excellent for repeated use
- strong
- excellent finishing quality
- easily cleaned
- can be expensive to buy or replace.

Aluminium:

- excellent for repeated use
- strong
- lightweight
- easy to assemble and fix
- excellent finishing quality
- easily cleaned
- can be expensive to buy or replace.

Plastic:

- excellent for repeated use
- extremely light
- easy to handle and assemble
- highly flexible for creating curves or shapes
- easily cleaned
- available as a complete formwork system
- not suitable as falsework.

Particleboard:

- re-usable for a limited time
- can be cut to different sizes or shapes
- comes in different thicknesses
- must be properly treated to restrict moisture absorption
- not suitable as falsework.

30.1.5.2 Calculating quantities

Calculating the quantities of material for formwork and falsework can generally be done by looking at the plans and specifications for the job to determine the exact finished concrete sizes required.

Any mistakes made at this stage could prove costly and time-consuming to rectify.

A sound knowledge of the different types of construction and the relevant plans and specifications and how to read them to gather the correct information is essential. The size of the finished slab and the individual length of each section of the required formwork can be calculated by looking at the floor plan of the building. After calculating all of the individual lengths of formwork, with an overhang if required, the total lineal meterage can also be calculated for costing purposes if the formwork materials need to be purchased.

The finished floor levels and depth of the rebate will also be shown on the elevations or any details referring to the slab, so that the required depth of the formwork materials can be determined.

The lengths required will depend on the finished sizes. If possible, try not to cut the length of formwork as this will then limit the use of that particular length of formwork when it is required on the next job. It does not matter if the formwork protrudes past the adjoining piece of formwork. This '*under and over*' or '*in and out*' method can be applied as you move along and fit each section of formwork. Simply have one section of formwork project past the actual corner of the proposed slab, then the next piece of formwork is butted against the fixed section in the correct position and then itself fixed into position (Fig. 30.4).

This means that when the final piece of formwork is fixed into place, it can project past the first piece that was set up in position. The amount that the formwork '*flies past*' is not critical. If it were to extend a considerable distance, for example, up to 2 metres, it could still be pegged and fixed to provide extra strength and stability to the formwork structure.

In fixing the formwork this way, the only lengths of formwork that will need to be cut are those that form any internal corners or irregular-shaped areas of the slab.

Fig. 30.4 Simple '*under to over*' formwork construction



Courtesy of Alister Ford

If any long runs of timber formwork are required, the formwork timbers can simply be butt joined and spliced using timber shorts with screws or nails then braced accordingly. Other materials such as plastic, aluminium or steel may have special connector brackets or clips that come with the formwork system.

The formwork shown in Figure 30.4 was set up to pour a basic concrete slab that measured 5.6 m × 2 m. This slab was joined to an existing concrete slab using steel dowel starter bars. Only one long run of formwork for the outer run was required.

In ordering the lengths of timber for the form, it was determined that one 6 m length

and one 4.2 m length would be required, creating minimal waste. The two end boards would be fitted first and could be cut to their exact length out of the 4.2 m length of timber. The 6 m length was then used for the outer run of formwork, which allowed for a 200 mm over-run at each end, where the extra pegs could be positioned to hold the form well out of the way of the concrete screed as the concrete was being worked after pouring.

30.1.6 Site preparation

Before concrete can be poured, some important preparation tasks need to be undertaken. First, the slab must be set out according to the plan or known requirements.

Topsoil must be removed, and the foundation must be excavated to an established design level, by scraping or cutting and filling. The end result must be firm enough to support the slab to be laid.

Other preliminary works may need to be carried out by other trades, such as all plumbing and electrical installation for any services that need to penetrate through the slab (Fig. 30.5). Cast-in services may also need to be installed. For example, hold-down bolts for steelwork within the finished structure may have to be set in position. These can be suspended from the formwork after construction or tied to the mesh if practicable. Shower stalls may be required to be lower than the finished slab height. Timber or steel frames can be installed in the correct position and height for the pour and removed afterwards, leaving the void in the concrete slab (Fig. 30.6).

Compacted road base topped with compacted sand blinding to protect the plastic membrane may be required to raise the foundation to the design level of the underside of the slab.

A waterproof membrane or underlay is required to prevent water being drawn into the finished slab (Fig. 30.7). This is particularly important to combat rising ground salts.

Termite protection must also be installed around penetrations where specified.

Tools required to place and finish the concrete must be readily available and in good condition.

The quantity of concrete must be estimated and ordered at least one day before the work is to be carried out.

Fig. 30.5 Plumbing services cast in with the formwork construction for a waffle raft slab underway



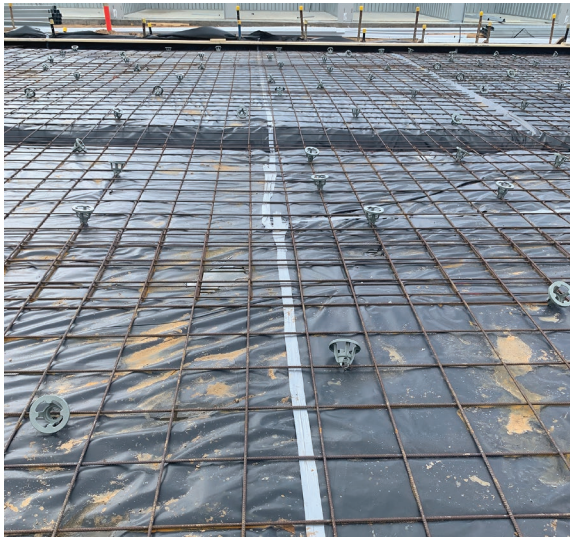
Courtesy of Alister Ford

Fig. 30.6 A simple timber-frame blockout for a rebated shower recess in a concrete slab



Courtesy of Alister Ford

Fig. 30.7 Waterproof plastic membrane overlapped and taped into position



Courtesy of Alister Ford

When the site has been fully prepared, the string lines to indicate the external edges of the finished footings and concrete slab need to be reset onto the existing profiles (Fig. 30.9). It is also important to recheck any setback measurements, the building for square, and any other measurements as the profiles can sometimes be knocked out of line or damaged during the course of any preliminary works taking place.

Ideally, the profiles and hurdles will be set at the finished height of the slab, which will make the construction of the formwork somewhat simpler as a visual height reference will be available for the entire construction phase. If not, it is not a major concern; the use of a properly set up laser level can make it quite easy to determine the correct heights as you go.

Fig. 30.8 Excavation of footings on a steep block (note the shutters in place to form up for the stepped footings)



Courtesy of Alister Ford

Fig. 30.9 String lines set up for formwork construction



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

1. Calculate the timber formwork requirements for the basic rectangular garage slab shown in Figure 30.10.
The slab measures 7 m × 6 m × 150 mm deep. Allow for an overhang of at least 300 mm at each corner.
2. Calculate the timber formwork quantities only to form up the stepped slab to be poured for the house shown in the plans in the Appendix. Allow for an overhang of at least 300 mm at each corner.

Fig. 30.10 A completed garage slab (note the blackout that has occurred for the roller door position)



Courtesy of Alister Ford

30.2 Construct formwork

Now that the site has been fully prepared, and the formwork can be constructed, we will look at the processes of first setting up timber formwork for a simple slab on the ground, followed by installing the formwork for a rebated slab. An important thing to note is that while constructing any formwork, it is especially important to keep checking that the construction is level, plumb and square. After the pegs have been installed, it is extremely hard to adjust the formwork without removing and refitting any pegs, which can destabilise the ground along any excavations. Extra bracing for stability and strength can be installed as you go or at the end of construction.

30.2.1 Formwork for a simple slab on the ground

1. Plumb down to the ground at each corner of the building and create a reference mark on the ground.
2. Lay the formwork boards out in position around the perimeter of the building, allowing for the extension of the boards to create the overhang at each corner.
As referenced earlier, this will keep the cutting of boards to a minimum, giving more scope to use the boards on the next job.

3. Select the first run to be erected, usually the longest straight run. Holding the first board in position, hammer in a peg on the outside of the board near each end. If the board is to be joined to continue along the run, remember to install the peg leaving enough of the board to install the fishplate for joining.

Fix the first board to the pegs at the correct height or just above so that the pegs can be tapped in a little more for an accurate adjustment.

Now that the first board is in place and pegged at each end, a string line can be attached so that the full board can be straightened, pegged and fixed into place. By fixing blocks of equal thickness to the inside of the board at each end and running the string line over these blocks, the board can now be measured accurately for straightness and a peg can be installed midway. Then the rest of the pegs can be installed at the required intervals (approximately 1 metre for good solid formwork planks) for support and fixed while ensuring that the formwork plank is fully secure and straight.

4. The corner can now be marked onto the installed formwork plank and the second plank installed against it to create the corner. Following the same procedure as with the first plank, install the pegs at each end, fit the formwork to height, fit the blocks and string line and straighten the board as the pegs are installed along its length.
5. The rest of the formwork can now be installed around the perimeter of the proposed concrete slab using this procedure, and not forgetting to install the safety caps on any exposed steel peg tops.

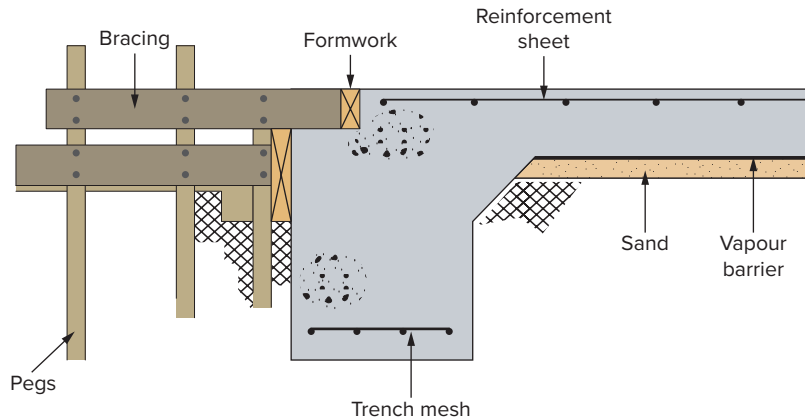
30.2.2 Formwork for a rebated slab on the ground

Constructing the upper section to form up the step with a 150 mm wide rebate, which is common practice in the construction of a brick veneer dwelling, can be done in several ways.

Following all the steps above as described for constructing formwork for a simple slab on the ground, but at a height below finished floor level to suit the depth of the required rebate, we now have the lower section of the stepped slab formwork constructed.

A. Using a braced, cantilevered ledger fixed over the lower formwork to fit the upper formboard

1. Starting at the first fitted lower edge board, install another peg, and fit a ledger in place just above the existing formwork to create a gap for the trowelling of the concrete. Make sure that when the top formboard is fixed to the ledger, a rebate of 150 mm will be created.

Fig. 30.11 Rebated slab, cantilevered formwork

2. Fit another ledger in place at the end of the first run, again ensuring that a 150 mm rebate will be formed.
3. Fit the rest of the pegs and ledgers along the first run and fix the first rebate formboard in place. Again, if the board overhangs, that is acceptable. There is no need to cut the boards on the top form shorter as they can also 'fly past' to ensure that they maintain their length for more scope of use on the next job.
4. Once the first top board is in place, the same process can be used to, again, work around the entire perimeter of the building, fitting each board in place to the fitted outriggers with the overhang of any board projecting and pegs at the ends for extra bracing and support if required, as shown in Figures 30.11 and 30.12.

B. Using rebate brackets fixed to the upper formwork to the lower formwork

Once again, following all of the steps as described for constructing formwork for

a simple slab on the ground, but at a height below finished floor level to suit the depth of the required rebate, we can construct the lower level of formwork. Once completed we can construct the upper section of formwork using rebate brackets to hold the formwork in place.

1. Starting again, along the first fitted lower run formwork board, screw the formwork brackets securely at the desired distance apart, so they are flat against the board and also vertical, ensuring an accurate, square rebate will be formed. If the brackets are sitting correctly and firmly, carry on around the perimeter of the formwork and fit the rest of the required brackets.
2. Fit the first board, ensuring that the board is sitting in place and level, on top of the bracket leaf (Fig. 30.13).
3. Fit the second board by butting and fixing to the first board, forming a square corner, then fit the second board securely to the brackets. Again, leave any overhang so that the formboards are not being cut.

Fig. 30.12 Extra pegs to support the overhanging formwork

Courtesy of Alister Ford

Fig. 30.13 Slab rebate formed using formwork brackets



Courtesy of Alister Ford

Fig. 30.14 Extra pegs and ledgers installed to help support bracketed formwork



Courtesy of Alister Ford

Fig. 30.15 Wider timber fitted to the inside of the formwork to create a blockout for an entrance door, plus narrower timber fitted to create a waterproof rebate for the metal external cladding to sit in



Courtesy of Alister Ford

4. Continue around the perimeter of the formwork and fix the rest of the formwork securely into place.
5. Once the formwork has been fitted, recheck it for level, height and stability. As the lower run of formwork has only pegs in the ground with no bracing to hold it, it is advisable to then install more pegs away from the formwork as in the first construction example and fit ledgers from these pegs back to the lower section of the formwork to hold it secure, guarding against any movement during the pour (Fig. 30.14).

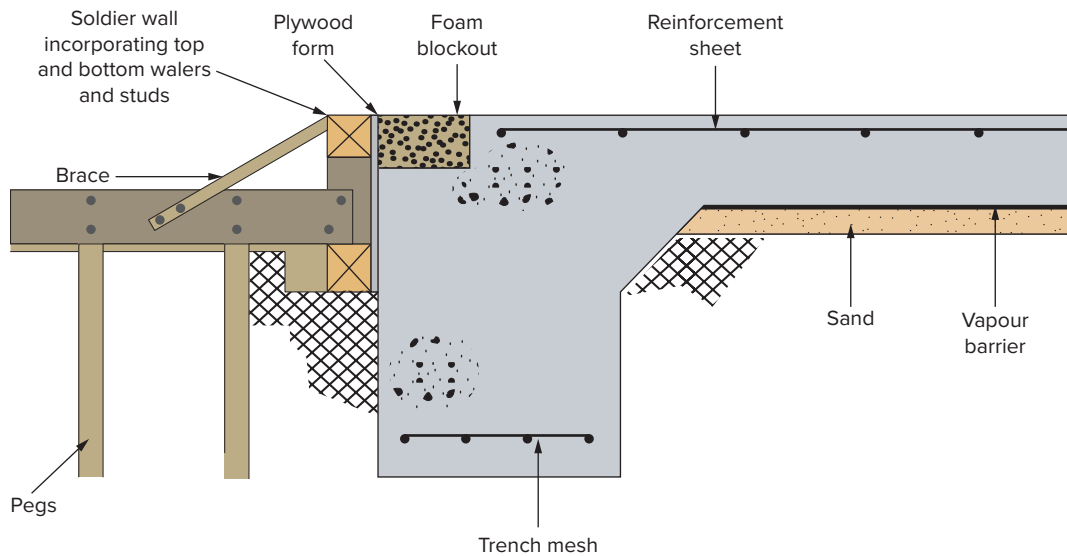
30.2.3 Formwork with solid blocking

At times, a rebate that is not specifically for a brick veneer construction may be required at the edge of the concrete slab. The rebate could be formed to accommodate other elements, such as the closing and waterproofing of roller or tilt doors, or different types of wall cladding that require a rebate for flashing and waterproofing purposes.

Solid blocking can be fixed in position to the face of the formwork to create the blockout to the required size. Generally, timber would be used, but other materials can be just as effective (Fig. 30.15).

More commonly, if a blockout such as this is required, the formwork would be constructed as a single edge form and the blocking fixed in the correct position through the existing form (Fig. 30.16).

Fig. 30.16 Rebated slab, foam blockout



30.2.4 Deep-edge formwork

Depending on the ground conditions when setting up formwork, sometimes deep-edge formwork may be required to accommodate the depth of the concrete slab.

Any formwork for a slab on the ground that is over 150 mm in depth should be treated as deep-edge formwork and constructed accordingly. This could mean the construction of soldier walls lined with form ply to accept the concrete or deep timbers that may be over 200 mm in width. Single timber forms should have a substantial thickness to avoid bowing under the weight of the concrete.

Soldier wall formwork or deep timber formwork should be set up initially in the same way as explained earlier in the chapter for a simple slab on the ground:

- string lines set up and corners plumbed to the ground and marked
- formboards laid out around the job
- pegs installed on the selected first run of formwork
- soldier wall fitted to the pegs and fixed at the correct height
- string line blocked out along the soldier wall and the remaining pegs fitted, ensuring the wall is straight
- continue on around the perimeter of the proposed slab and install the remaining soldier walls with an overhang so that extra bracing in the form of a strongback can be installed (Fig. 30.17).

Fig. 30.17 Extender soldier wall formwork with the corner pegged and braced for stability



Courtesy of Alister Ford

Once the soldier walls have been pegged and screwed or nailed into position, extra

bracing will need to be installed to prevent collapse as the force of impact and the weight of the concrete during the pour can be extremely high.

Extra pegs should now be installed back from the soldier wall in line with the existing pegs. A ledger can be fitted between the soldier wall stud or the inside peg to the outside peg.

A bracing timber should also be installed from the framework or inside peg near the top of the soldier wall and angled down to be fitted near the bottom of the outer peg. An example of this is shown in Figure 30.18.

Fig. 30.18 Soldier wall formwork pegged and braced from the top and bottom



Courtesy of Alister Ford

30.2.5 Release agents

Formwork release agents act just as their name suggests. When applied to the formwork they create a barrier so that the concrete will not bond to the formwork, which would significantly increase the likelihood of damage to the freshly poured concrete when the formwork is stripped.

Any formwork that is to have a release agent applied needs to be clean and free of any dirt, grease or splintered surfaces.

In some instances, the release agent may need to be applied before the section of formwork is put in place as any contact with the reinforcement material will prevent the concrete mix from adhering to the affected section of reinforcement. If at any stage the reinforcement does become contaminated by the release agent, it should be thoroughly cleaned before the concrete is placed.

The release agent will also work as a barrier to stop the formwork absorbing water from the freshly poured concrete.

Barrier release agents come in many forms such as:

- petroleum- or diesel-based products
- detergent- or soap-based products
- wax- or resin-based products.

Some release agents are known as reactive agents, which means that when they are applied and then come into contact with the concrete as it is being poured, they will have a chemical reaction with the lime products present in the concrete mix. A soapy film will develop, creating the barrier. This will dissolve and disappear as the reaction continues, leaving very little trace of the applied agent, which in turn can mean a much easier cleaning process. Common types of reactive agents can be oil- or fat-based products.

As mentioned, the formwork needs to be clean for the release agent to be applied. Application of release agents can be carried out in a number of ways depending on the product being used and the formwork to which it is being applied. Application methods can include:

- brushing
- using a roller
- spraying
- wiping
- dipping.

Any tools used in the application of release agents need to be thoroughly cleaned and stored afterwards to ensure they are ready for use on the next job.

CHECK YOUR UNDERSTANDING

3. What sort of slab is constructed to accommodate a brick veneer construction?
4. At what depth would formwork be considered deep-edge formwork?
5. Explain why release agent is used on formwork.

30.3 Strip, clean and prepare formwork for re-use

30.3.1 Stripping of formwork

The removal or 'stripping' of formwork is a simple form of deconstruction, which means the last piece installed will generally be the first piece taken out. Care needs to be taken when stripping the formwork as the freshly poured concrete will be 'green' and so can very easily be damaged as it will not reach its full strength for several weeks after being placed. Formwork should not be removed until the specified amount of time has elapsed for the concrete to gain enough strength to support itself without sagging or collapsing. This time frame will depend on the mix that was put in. Some of the factors that can influence this time frame include:

- megapascal (MPa) rating of the concrete
- moisture content of the concrete
- admixtures included for faster or slower setting
- cooler or warmer external air temperatures
- humidity
- concrete curing requirements and specifications.

Fig. 30.19 Falsework and brackets removed and first formboard carefully stripped



Courtesy of Alister Ford

An engineer may specify a certain time frame for the formwork to be left in place, but an experienced concreter will also be able to make an accurate judgement. Practically, the longer the better as this will help protect all of the edges and corners of the concrete, as other work may still be going on around the site.

As already mentioned, the formwork should be stripped in reverse order of construction. This being so, the falsework will be dismantled first followed by the formwork boards or soldier walls (Fig. 30.19).

Outriggers and/or rebate brackets and any strong backs holding the corners can be removed first, followed by the outer pegs that are away from the formwork. Once these falsework components have been put aside, a clear path is then in place around the perimeter of the slab.

If stripping a rebated slab, the top formboard that was held in place by the outriggers or rebate brackets can be removed. Care should be taken not to damage the concrete.

When the concrete is placed, even though a release agent may have been applied, the concrete may still grip the formwork rather than it being a

case of the formboard just falling away. Light tapping with a hammer should loosen the grip enough for the formboard to be carefully removed. Care should be taken to ensure the formboard does not fall and damage the concrete below. The board should be supported at both ends and carefully lifted clear and placed away from the work area for cleaning and stacking.

30.3.2 Denail, clean and prepare formwork for re-use

Formwork should be denailed, cleaned and maintained as the stripping proceeds so that no concrete residue is left to dry on the formwork, which might create a rough, uneven textured surface and render the formwork section unusable for any other job.

Any nails or screws still embedded in the formwork should be removed before the formwork is positioned for cleaning and maintenance.

A steel scraper can be used to remove any concrete residue as the formwork is removed and put to the side (Fig. 30.20). After the formwork has been stripped and scraped, a wash-down can remove any release agent residue or other concrete embedded in the formwork material. A high-pressure clean or a detergent-based scrub-down may be necessary for this task. This simple form of maintenance can prolong the life of the formwork materials considerably.

The formwork should be oiled if required, handled, stacked and transported carefully, ensuring that damage to the board edges does not occur.

Any damaged formwork should be set aside to be assessed. It may be the case that damaged formboard ends need only be trimmed off. Even though the board will now be shorter, it will still be usable in some way on the next job.

Any boards with long cracks or splits along the grain may need to be replaced as they may no longer be strong enough to support wet concrete.

A good tip to remember with formwork is that the care given to the cleaning, maintenance and handling of the formwork components on this job will make the next job run a lot more efficiently.

Fig. 30.20 A steel scraper ideal for cleaning formwork as it is stripped



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

6. In what order should formwork be stripped?

30.4 Clean and maintain tools and equipment for re-use

As is the case with any construction task, taking good care of the tools and equipment you use for the construction and stripping of formwork will ensure their longevity and performance is at a maximum.

Tools and equipment should be cleaned of any concrete residue by washing and wiping them down. Then, after being thoroughly dried, oil can be applied if required, to ensure no rust becomes evident.

Tools need to be checked for damage. Handles should be checked to ensure there are no splits or cracks. Any blades need to be kept sharp and also protected during storage.

Power tools should be checked to ensure blades are sharp and the safety guards and switches are in good working order, then they should be stored correctly.

Equipment such as steel pegs need to be well maintained. Make sure the ends are straight and well ground to shape after they have been hit with a heavy hammer. Over time the pegs can become severely damaged and the ends bent out of shape. This can lead to the protective caps not fitting properly and splitting or cracking when forced onto the peg.

Some maintenance with a hammer and angle grinder can return the pegs to a very usable condition with not much time taken.

A good approach to the care and maintenance of your tools and equipment can save money over time by avoiding the need to replace them and preventing lost time.

30.5 Clean up and dispose of waste

After the formwork has been completed, it is important to leave the site clean and tidy.

Any unused formwork or equipment needs to be stored well out of the way as reinforcement materials will have to be carried and placed in position. These reinforcement and trench mesh sheets are large and require more than one worker to safely manually handle them into position. Any scrap formwork, equipment, rubbish or tools left lying around can be an obstacle and cause problems for the workers who are trying to safely position the reinforcement into place.

Student research

1. Visit the Safe Work Australia website and download the *General guide for formwork and falsework* or obtain a copy from your instructor.
 - (a) From this document, prepare a report on 'How formwork and falsework risks can be managed'.
 - (b) List the four steps of risk management and report in detail how each step can be managed effectively.
2. Visit the Steel Reinforcement Institute of Australia website and download the *Ten steps to building a reinforced concrete slab-on-ground* or obtain a copy from your instructor. From this document, prepare a report listing the ten recommended steps with a detailed description of what is required for each step to be successfully carried out.

End-of-chapter activities

1. Using your drawing tools and equipment, neatly draw to scale an elevation of two alternative methods of setting up the formwork to create a rebated slab for a brick veneer house. See drawings earlier in the chapter.
Specifications:
 - scale 1:10
 - timber and plywood formwork, braces, and pegs; foam blockouts
 - footing size 400 mm wide × 500 mm deep
 - slab thickness 150 mm
 - reinforcing, trench mesh, sand blinding and vapour barrier to be shown in correct positions
 - sand blinding 50 mm thick
 - sheet reinforcement SL-82
 - trench mesh 4-L10TM
 - show correct hatching for earth, concrete and foam blockout.
2. Fill out a safe work method statement (SWMS) for the construction of only one of the rebated slab formwork systems that you have just drawn. The slab will be on a flat building site and everything is prepared and ready for the formwork to be constructed.

AUSTRALIAN BUILDING CODES AND STANDARDS

National
Construction
Code (NCC):
Building Code of
Australia, Part 3.2
Footings and
slabs

AS 2870:2011
Residential
slabs and footings

AS 3610.1:2010
Formwork
for concrete

AS 3610.1:2018
Formwork for
concrete, Part 1
Specifications

Safe Work
Australia:
General Guide for
Formwork and
Falsework

Steel
Reinforcement
Institute of Australia:
Ten steps
to building
a reinforced concrete
slab on ground

**Tradie Talk—Better to have too much bracing.
Formwork failure can be dangerous and costly**

Chapter 31

Concreting to simple forms

Learning Objectives

- LO 31.1 Plan and prepare to carry out concreting**
- LO 31.2 Consider WHS obligations for concreting**
- LO 31.3 Understand basic formwork for concreting**
- LO 31.4 Identify types of reinforcement materials**
- LO 31.5 Understand reinforced concrete footings**
- LO 31.6 Use concrete materials and ingredients**
- LO 31.7 Consider factors affecting concrete quality and strength**
- LO 31.8 Understand batching proportions for concrete**
- LO 31.9 Mix, place and finish concrete**
- LO 31.10 Cure concrete**
- LO 31.11 Understand the compressive strength and slump testing of concrete**

Introduction

Concrete is one of the most important structural components used in residential construction today. Together with timber and steel framing, structural steel and masonry, it is an important part of the structural fabric that supports the final external and internal finish. Many homes are built on reinforced concrete footing and slab systems, or subfloor systems incorporating concrete footings and piers, while concrete is also used in many of the available building finishes such as concrete driveways, concrete masonry, paving and exposed concrete floors, and walls and ceilings (Fig. 31.1).

Concreting is also a recognised trade under the Australian Qualifications Framework and is available as a Certificate III in Concreting. Closely allied trade qualifications include the Certificate III in Formwork/Falsework and the Certificate III in Steel Fixing.

Fig. 31.1 Steel stumps supporting a house—set on concrete pads and backfilled to ground level with more concrete



Courtesy of Alister Ford

Concrete that has no reinforcement is simply called plain concrete. It is used for simple poured piers or blob footings supporting brick piers, columns and posts.

In this chapter you will learn about planning and preparing to carry out concreting tasks. This may include organising and sequencing of work by reading and interpreting the plans and documents for the task, complying with laws and regulations according to the National Construction Code (NCC) and relevant Australian Standards, adhering to any environmental requirements, following the manufacturer's specifications via material safety data sheets (MSDS) or safe operating procedures (SOP) and the work health and safety (WHS) aspects of working with formwork, reinforcement materials, dry

Form workers create temporary moulds known as formwork into which concrete is poured to become a designed concrete structure. Steel fixers position and secure steel bars and/or steel mesh to engineered specifications, within the constructed formwork, to reinforce the completed concrete structure.

When concrete is poured with embedded reinforcing steel, it is called reinforced concrete; this is used in domestic housing construction, in such things as strip footings, slabs on the ground such as driveways and house and garage slabs, beams, columns and upper floors. Advanced concreting in commercial or industrial work will be especially engineered to accommodate the required formwork and concrete to the specific strength needed. This may require the concrete structure to be completed with what is known as pre- or post-tensioned concrete.

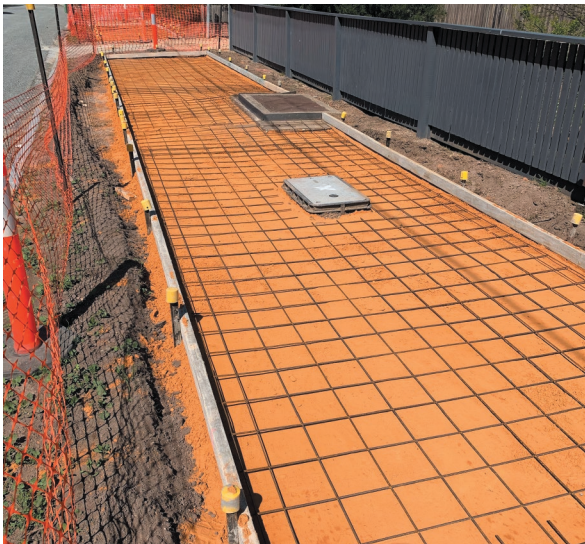
wet concrete, wet concrete and the required tools and equipment.

Basic formwork construction in the building industry using different types of formwork materials and methods of construction will be discussed.

You will also learn about the preparation of the site, vapour barriers, termite protection, steel reinforcement sheets, bars and accessories that are placed in concrete for strengthening purposes, the materials and additives that make up the concrete mix and the ratios that need to be applied when adding these materials so that the correct consistency and strength is achieved.

In addition, how to correctly and safely place, work, finish and cure the concrete. Finally you will learn about testing concrete will be explained to ensure that during the pour the concrete is at the required slump and when completed it will be at the required strength.

Fig. 31.2 Basic formwork for a footpath, with reinforcing mesh cut and fitted; bar chairs will be installed before the pour begins



Courtesy of Alister Ford

WORKPLACE SCENARIO

In 2008 I was teaching apprentice carpenters at the University of Ballarat TAFE division and one of my classes was due to complete the concreting unit, which is part of their apprenticeship training.

I was trying to think up a few ways to make a week of trade school learning about formwork, reinforcement, pouring and finishing concrete a bit more interesting and to find a real-time concreting example that the apprentices would not generally see on a domestic or commercial building site.

A major construction job being undertaken in the Central Highlands at this time was the Waubra wind farm, which is situated about 35 km from Ballarat. A total of 128 wind turbines were being constructed, with towers measuring 71.5 m high and blades approximately 40 m in length. These wind turbines would need a very substantial foundation and footing to serve this purpose over many years of service.

I contacted the principal construction company, introduced myself and explained that I wanted to show the apprentices some concrete work from preparation to finish of the likes that they had not seen before. The construction company representative was fantastic. She made all of the arrangements for us to visit the site and all we had to do was arrive at the main construction site offices at the given time on the day of our visit and we would be assigned a personal guide for the day.

Upon arrival, the 10 apprentices and myself were given a full site and company induction, before we went out into the field. All of the personal protective equipment was supplied: hi-vis reflective vests, safety glasses and hard hats. Then we got back into the minibus and followed our guide's four-wheel-drive dual cab out to the first tower site.

This site had been excavated and the workers were in the process of setting up the reinforcing steel in the excavation in readiness for the concrete pour in a few days' time. The excavation measured 15 m long $\times$ 15 m wide $\times$ 1.5 m deep. With the pedestal for the tower included on top of this huge block of concrete-to-be, this equated to approximately 360 cubic metres of concrete needed to construct the base.

The scope of this job meant that the two local concrete companies contracted to supply the concrete for these tower bases had actually set up their own concrete batching plants on-site rather than mixing in Ballarat and having a constant convoy of trucks continuously doing the 70 km round trip.

Inside each concrete foundation there was 32 tonnes of steel reinforcing that needed to be manually placed and tied or welded into position. Some of the steel bars, which were 70 mm in diameter and 15 m long, needed one worker per metre to carry and place them in the correct position.

Some of the apprentices started doing some calculations among themselves. Pretty soon the whole group was involved. Six cubic metres of concrete per truckload meant 60 full trucks would be required for a 360 cubic metre pour; 2400 kg per cubic metre equated to 864 000 kg or 864 tonnes of concrete. Add 32 tonnes of steel reinforcement and this meant the weight of each foundation would be 896 tonnes.

Considering a concrete slab for an average-sized house may be between 30 and 40 cubic metres of concrete, this would certainly be the biggest concrete pour they had ever seen. Out came the calculators again. Somewhere in the vicinity of 25 house slabs in each foundation multiplied by 128 towers equated to something like 3200 house slabs—enough houses to create a whole new town.

The second site we visited was a concrete pour in process. A steady stream of concrete trucks in and out of the site were placing the concrete into the concrete pumping truck chute and then placing it via the pump and pipe into the set excavation.

It felt like a truckload of concrete made absolutely no impression, considering the size of the hole in the ground that needed to be filled. The time to complete it would take anywhere from six to eight hours, with the workers rotating roles frequently for WHS reasons. Up to 10 truckloads per hour placed on a good weather day.

After watching the concrete pouring process, we headed back to the main site offices for an official debrief and question/answer session with the company representative, which we had to call to a close because of the amount of questions the apprentices kept asking. Seeing construction of this magnitude was certainly an eye-opener. It made a huge impression on these carpentry apprentices, and the field trip is often mentioned whenever I speak to any of them when our paths cross.

31.1 Plan and prepare to carry out concreting

Any concreting task needs to be carefully planned. This can include ensuring any legal requirements or regulations such as work health and safety (WHS) issues are addressed, as well as having the correct building applications and associated documents and plans lodged plus the correct permits in place from a local government perspective.

Plans and specifications should conform to all requirements of the National Construction Code (NCC) and any associated Australian Standards. As an example, the National Construction Code, Volume 2, Part 3.2, Footings and slabs, is divided into five sections listed as:

- 3.2.1 Application
- 3.2.2 Preparation
- 3.2.3 Concrete and reinforcing
- 3.2.4 Site classification
- 3.2.5 Footing and slab construction.

The information and guidance given in this section is the first point of reference for the design and construction of a concrete foundation and slab for any dwelling to be constructed in this way.

Further reference through this section is given via explanatory information boxes, which are highlighted throughout each section plus references to the relevant Australian Standards.

An example of an explanatory information box could be as taken from section 3.2.2 Preparation, subsection 3.2.2.7, Edge rebates: Explanatory information; see section 3.2.5.4 for minimum edge beam details. This gives a directive to refer to section 3.2.5.4 and read this in conjunction with section 3.2.2.7.

An example of the reference to Australian Standards could be as taken from section 3.2.2 Preparation, subsection 3.2.2.2, Filling under concrete slabs, Part (a) Item (i): Sand used in controlled fill or rolled fill must not contain any gravel-sized material and achieve a blow count of 7 or more per 300mm using the test method described in AS 1289, method 6.3.3.

Australian Standards and Technical Notes referenced in this section of the National Construction Code, which will need to be used at times for the planning and preparation of concreting work in domestic construction, include:

- AS 2870 Residential slabs and footings
- AS 2159 Piling—design and installation
- AS 1289 Methods of testing soils for engineering purposes
- AS 3600 Concrete structures
- AS 4100 Steel structures
- AS 1684.2 Residential timber-framed construction, Part 2: Non-cyclonic areas
- AS 1684.3 Residential timber-framed construction, Part 3: Cyclonic areas
- AS 1684.4 Residential timber-framed construction, Part 4: Simplified—non-cyclonic areas
- Cement, Concrete and Aggregates Australia, Technical Note 61—Articulated walling.

Once these points have been addressed and the correct paperwork is in place, the planning and sequencing of the work to be undertaken can be put in place.

31.2 Consider WHS obligations for concreting

31.2.1 Hazard and risk control

Depending on the scope and location of the concreting work, a variety of hazards may be encountered. To meet their WHS obligations, the person conducting the business or undertaking (PCBU) is required to conduct a risk assessment of the job. The risk assessment may be carried out in the form of a job safety analysis (JSA) or a safe work method statement (SWMS).

The location and nature of the concrete pour will dictate whether a job safety analysis (JSA) is required or if the work is considered high risk and a safe work method statement (SWMS) should be written. The importance of barricades, signage, traffic and pedestrian management and personal protective equipment (PPE) such as hi-vis clothing, hard hats, work boots, work pants, gloves, eyewear and hearing protection (Fig. 31.3) will be written into the aforementioned documents. The scope of the job will dictate the type of mechanical aids required for the pour. These may include pumps, chutes or kibbles, all of which introduce new hazards to the job. If the nature of the job changes by way of new equipment arriving, the safety plan should be revisited and adjusted to suit.

An additional requirement under the WHS Act is a material safety data sheet (MSDS) for all hazardous materials that are in use. This information should be made available to all workers on-site. The MSDS is a document that describes the properties and uses of a substance. These include chemical and physical properties, health hazard information, precautions for use, first aid and safe handling information.

The MSDS can be sourced on the internet by visiting the manufacturer's website.

31.2.2 Personal protective equipment

Common personal protective equipment (PPE) that may be required include:

- protective clothing
- safety vest
- gloves
- rubber boots
- safety glasses
- steel-capped work boots
- hard hat or protective sun hat.

31.2.3 Working with dry concrete

Concrete dust contains particles of crystalline silica, which, if small enough, can be inhaled into the lungs. The dust can be associated with the handling of dry cement powder or through dust generated by cutting, drilling or grinding. Exposure to this dust over a long period may result in the lungs being affected by damage and scarring, causing shortness of breath and silicosis.

Control of these hazards may require extraction systems, wet saws, wet sweeping, vacuums and/or dust masks and respirators.

Fig. 31.3 Concrete workers wearing correct PPE: hi-vis jackets, footwear and hard hats



Courtesy of Riviera Concrete

31.2.4 Working with wet concrete

Contact with wet concrete can cause irritation to the skin and eyes, resulting in skin conditions such as cement burns, cement dermatitis, dry skin and irritation to the eyes. Contact with wet cement should be managed through the correct use of PPE. Any contact with skin or eyes should be rinsed with clean water. Barrier creams can be useful for long-term exposure issues.

31.2.5 Site preparation

Before concrete can be poured, some important preparation tasks need to be undertaken:

- The slab must be set out according to a plan or known requirements.
- Topsoil must be removed and the foundation needs to be excavated to an established design level and must be firm enough to be able to support the slab to be laid.
- Road base may be required to raise the foundation to the design level of the underside of the slab.
- A waterproof membrane or underlay may be required to prevent water being drawn into the finished slab. This is particularly important to combat rising ground salts.
- Sand blinding may be required to protect the membrane.
- Tools required to place and finish the concrete must be available.
- The quantity of concrete must be estimated and ordered at least one day before the work is to be carried out.

TIP Have buckets of water available so that concreting tools can be cleaned regularly or dipped in water as the concrete is being poured and finished.

31.3 Understand basic formwork for concreting

31.3.1 What is formwork?

Formwork is the temporary mould used to encase fresh plastic concrete and create the desired shape. It represents a large part of the cost of any concrete structure. The erection of concrete formwork requires special skills, and on many routine jobs, the design and satisfactory performance of the formwork becomes the responsibility of the site manager or supervisor. The specifications for the construction of any formwork, either from the formwork manufacturer, supplier or from the plans of the job, need to be closely followed as any shortcuts taken or incorrect modifications to the formwork could have disastrous results. If the formwork fails, there will be a significant risk of injury to any workers in the vicinity. There will also be significant cost through concrete loss, formwork repair or replacement, plant and equipment requirements, time and labour.

Basic formwork materials can include:

Timber:

- strong
- very economical
- comes in many different sizes
- easily fixed in place and easily removed
- lightweight
- re-usable for a time.

Plywood or formply:

- strong
- lightweight

- can be cut to different sizes or shapes
- comes in different thicknesses
- re-usable for a time.

Steel:

- excellent for repeated use
- strong
- excellent finishing quality
- can be expensive to buy or replace.

Aluminium:

- excellent for repeated use
- strong
- lightweight
- easy to assemble and fix.

Plastic:

- excellent for repeated use
- extremely light
- easy to handle and assemble.

Particleboard:

- re-usable for a time
- can be cut to different sizes or shapes
- comes in different thicknesses
- must be properly treated to restrict moisture absorption.

Formwork is covered by AS 3610.1: 2010 Formwork for concrete.

At the time of writing, persons engaged in the erection of formwork require no special qualifications; however, a national qualification, the Certificate III in Formwork/Falsework, is available under the Australian Qualifications Framework. Concreters employed on a single dwelling residential construction can normally install the required formwork and reinforcing steel.

31.3.2 Formwork guide

Good formwork should be:

- accurate in size, shape and direction
- strong
- rigid and propped or pegged, braced and tied in all directions to prevent any bulging or displacement of forms
- tight-jointed to prevent the escape of the cement paste
- simple to install and dismantle and easy to handle
- cleaned immediately and checked for any damage upon stripping and dismantling. All nails and screws should be removed, and the formwork components neatly stacked ready for re-use or transport to the next job. Any detected faults need to be reported and then repaired or have the piece of formwork replaced. Arriving at the next job site with damaged, unusable formwork components will hinder the timelines of the job and cost unnecessary money in time and productivity.

To ensure that the formwork strips away easily from the semi-hardened concrete, the inside surfaces are coated with a form release agent that can be applied by brush, roller or spray equipment. This is best done before the formwork is erected or before any steel is placed in the forms, as the release agent must *not* come into contact with the steel reinforcement. Contact would destroy the bond between the steel and concrete, which is an essential factor if the reinforced concrete is to achieve its design strength.

Fig. 31.4 Using templates to maintain the shape of the concrete



Courtesy of Alister Ford

Fig. 31.5 Using curved concrete screeds to achieve the desired shape of the concrete



Courtesy of Alister Ford

31.3.3 Curved formwork

To form a curved edge for simple concreting tasks such as garden edging, pathways, driveways or verges, a flexible formwork material such as strips of form ply can be used. Where a sharp curve is required, it is necessary to place a series of shallow saw cuts almost halfway through the form material to allow it to be bent. The sharper the curve, the more closely spaced the saw cuts must be. The cut surface is placed on the outside of the formwork. Formwork may also be cut or shaped to form curved concrete surfaces. Templates cut the same shape as the external formwork can be fixed at intermediate points so that the desired shape of the concrete is maintained.

This can be seen in Figure 31.4. Curved concrete screeds can also be made to achieve the correct concrete shape, as seen in Figure 31.5.

31.3.4 Vapour barriers

If it is specified that a vapour barrier is to be installed under any concrete slab, it must be installed exactly as specified in the engineering plans or details, which should refer you to the National Construction Code Volume 2, section 3: Acceptable construction, Part 3.2: Footings and slabs, Part 3.2.2: Preparation, subsection 3.2.2.6: Vapour barriers. It should also refer you to any associated Australian Standards as mentioned in this section.

A vapour barrier must be made of polyethylene film with a nominal thickness of 0.2 mm. To put it in simple terms, this is black or orange plastic sheet branded as 0.2 mm thick and of medium-impact resistance.

All joins in the vapour barrier must be overlapped by at least 200 mm and securely taped and sealed. Any punctures must be sealed with additional plastic sheet and taped to prevent any moisture seeping through.

Penetrations for services must be taped or sealed with the specified sleeve for the job.

Any filling required under the slab before the vapour barrier is fitted must be installed according to subsection 3.2.2.2: Filling under concrete slabs, and any Australian Standards referred to in this subsection.

31.3.5 Tilt panel construction

Tilt panels are now a very popular form of construction in the commercial sector. The panels can be manufactured on the building site or at the manufacturer's factory then transported to the building site.

Tilt panels effectively make up the walls of a building. If they are made or 'cast' on the building site, this can be done on the existing concrete slab that will be the floor of the completed building or in cast beds constructed and placed specifically around the building site to enable the minimum distance of travel when the time comes to erect the panels.

The formwork for each panel in the building can be custom-designed and made as some panels will need block outs inserted in them for window and door openings. Any other inserts for footing, wall, roof attachments and lifting points are fixed in place. After the formwork is completed, the steel reinforcing sheets and deform bars to strengthen the wall panels are added and tied, and the concrete poured and finished.

When the concrete has set and hardened, another tilt panel can be poured on top. A bond breaker is placed in between the panels so that they easily lift away from the panel below. A stack of tilt panels can now be produced in the one cast.

31.4 Identify types of reinforcement materials

31.4.1 Steel mesh or fabric

Mesh is manufactured in flat sheets with bars up to 12 mm in diameter. The sheets are typically 6 metres by 2.4 metres. The fabric consists of a reinforcing bar welded in either a square or rectangular grid.

- Square mesh comprises bars of the same thickness, spaced 200 mm or 300 mm apart in both directions and is coded as SL82, which means square mesh, 8 mm main wire at 200 centres (Fig. 31.7).
- Rectangular mesh comprises longitudinal wires spaced at 100 mm centres, transverse at 200 mm (Fig. 31.8).

31.4.1.1 Trench mesh reinforcement

Trench mesh reinforcement consists of wires welded together to form narrow sheets ranging from 200 mm wide to 600 mm for footings. Common trench mesh strip widths are 200 mm (3 wires), 300 mm (4 wires) and 400 mm (5 wires). Trench mesh is coded by the number and size of the main

Fig. 31.6 (a–c) Preparation and concreting a slab for a free-standing steel garage shed: (a) sand blinding placed and compacted; (b) simple corner-lapped formwork, vapour barrier and reinforcement installed (note the section of formwork lying flat to allow easy access when barrowing the concrete in, plus the plastic bag of bar chairs ready to be installed when the pour begins, to lift the reinforcement to the correct height; (c) the completed concrete slab after the formwork has been carefully removed to avoid any damage to the edges

(a)



(b)

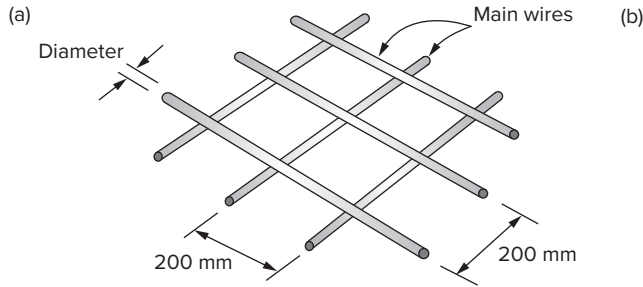


(c)



Courtesy of Alister Ford

Fig. 31.7(a) and (b) Square reinforcement mesh



Courtesy of Alister Ford

Fig. 31.8 Rectangular mesh

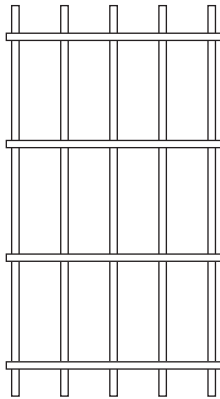
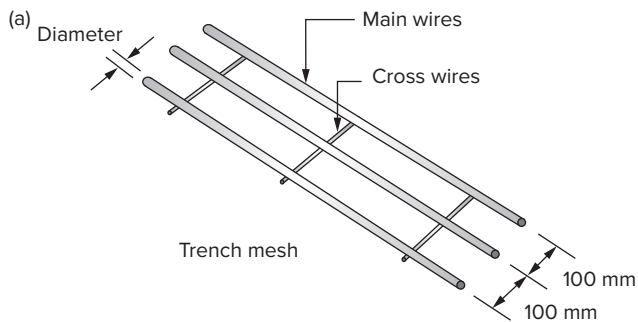


Fig. 31.9(a) and (b) Trench mesh reinforcement



Courtesy of Alister Ford

longitudinal wires. For example, 3-L10TM means the mesh has three main wires, each 10 mm in diameter, spaced at 100 mm apart (Fig. 31.9).

31.4.2 Steel bars

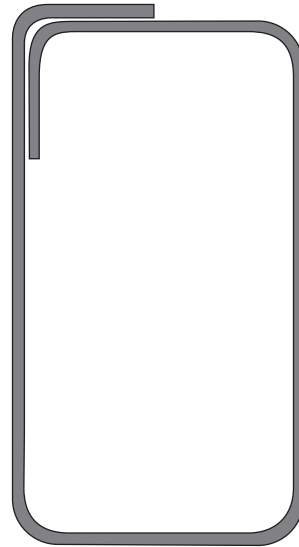
31.4.2.1 Deformed bar

A deformed bar, or N-bar, is used as the main structural reinforcement for suspended concrete floors, walls, beams and columns and for footing systems.

An N-bar has a yield stress of 500 megapascals (MPa) and is the most commonly specified

Fig. 31.10 Reinforcing cage out of deformed bar

© LuckyLife298/Shutterstock

Fig. 31.11 An elevation view of a round bar ligature or spacer

reinforcing steel for residential construction. An N-bar is sometimes mistakenly referred to as a Y-bar, which has not been manufactured since 1988.

31.4.2.2 Round bar

Round bar is commonly available in 6.5 mm and 10 mm diameter steel in 6 m lengths. It is used primarily for fitments (e.g. stirrups, spacers) to separate the top and bottom layers of trench mesh in footings and the fabrication of mesh reinforcement cages for columns and beams.

31.4.3 Reinforced concrete

Concrete is strong in compression but weak in tension, so steel rods are placed in concrete to carry the tensile stresses. The combination of steel and concrete is known as 'reinforced concrete'.

31.5 Understand reinforced concrete footings

Reinforced concrete footings generally have two layers of trench mesh or N-bars and are formed into a cage with stirrups or spacers out of round bar or N-bar. The cage is supported underneath by bar chairs spaced at 500 mm centres maximum. The top of the footing should be finished no higher than 150 mm below the existing ground height to ensure that the footing and first course of masonry are well covered. The reinforcing steel should be covered with concrete to the engineering specifications for the job. This means that the placement of the reinforcing steel to ensure the correct amount of cover is critical, and as the concrete is poured it should be vibrated to ensure the concrete achieves full strength and provides full protection for the reinforcing steel against corrosion.

Concrete strip footings have two layers of steel to resist the downward load of the building they support and to resist any upward movement of the foundation that the footings are placed on. Such

movement can occur when there are extended periods of rain and the ground swells.

Extended periods of dry weather may also cause clay foundations to shrink. The double layer of steel reinforcement in the concrete supports the footing beam between piers that are drilled down to a more stable foundation.

1. Support length of trench mesh or reinforcing bars on two saw horses or work platform.
2. Loop spacers onto trench mesh or reinforcing bars.
3. Tie off spacers to mesh or bars at spacings up to 900 mm between spacers and 100 mm between bars using annealed wire.
4. Place bottom layer of mesh or bars onto spacers and tie them off.
5. Run a length of wire diagonally from top to bottom on both sides of the cage as a brace.

31.5.1 Lapping of reinforcement

(See Figs 31.16–31.20.)

- Bars must be lapped at least 500 mm (Fig. 31.16).
- Trench mesh must be lapped at least 500 mm when lapping lengths and by the width of the trench mesh at corners and junctions. L-bars to external corner of L-shaped corners (Fig. 31.16).
- Mesh sheets must be lapped on their sides by the two outermost edge wires (Figs 31.17 and 31.19).
- The ends of mesh sheets must also be lapped by at least two main wires at the end of the sheet regardless of any overhanging longitudinal wire (Fig. 31.18).
- Two mesh sheets can be joined with a section of sheeting that laps and splices the two sheets together with at least two main wires (Fig. 31.20).

Fig. 31.12 Simple beam

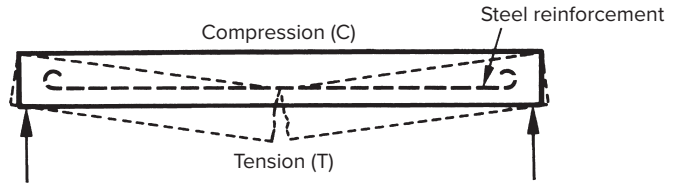


Fig. 31.13 Continuous beam

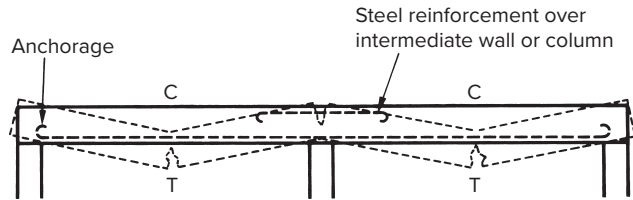


Fig. 31.14 Cantilever beam

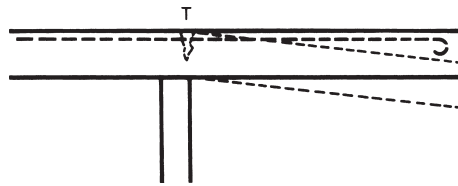


Fig. 31.15 Reinforcement cage 4-L10TM: (a) two layers with R8 coggled ties at 900 centres; (b) fixing reinforcement cages

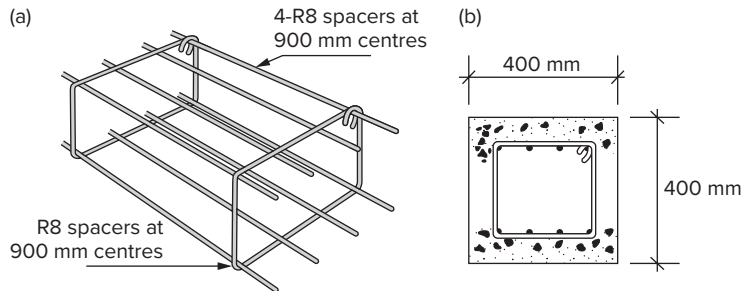
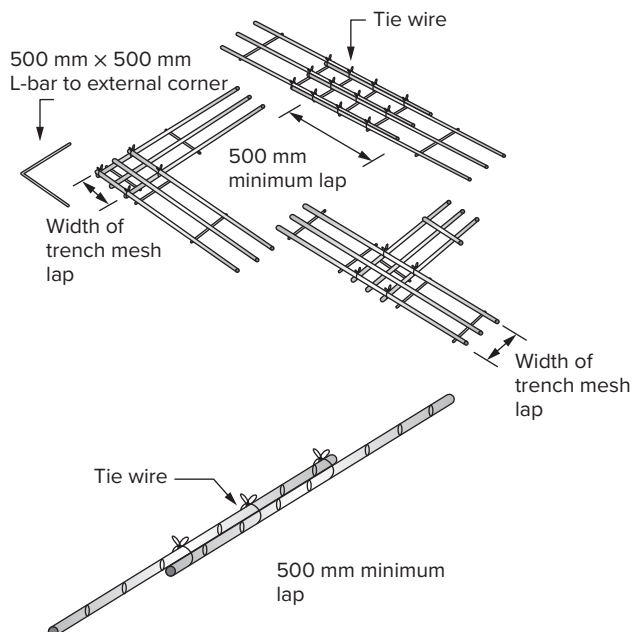


Fig. 31.16 Lapping of reinforcement



CHECK YOUR UNDERSTANDING

1. List the three main types of mesh reinforcement.
2. What is the purpose of placing steel rods in reinforced concrete? Provide two examples.
3. Why is steel reinforcing added to concrete?

31.6 Use concrete materials and ingredients

31.6.1 What is concrete?

Concrete is an artificial rock and is a combination of cement, fine aggregate, coarse aggregate and water. The raw materials are mixed to form a plastic material, which can then be poured or moulded into the required shape to harden by a chemical reaction. This chemical reaction is one of hydration, which specifically involves the action of water and cement. The resultant dense mass will be capable of carrying great loads.

Producing quality concrete requires an understanding of the process and careful control of all stages of production, from the selection of materials through to mixing, pouring, vibrating, levelling, finishing off and, finally, curing. If any of these steps is either missing or not carried out effectively, the desired results will not be attained.

31.6.2 Cement

Portland cement is so named because of its close resemblance to natural Portland stone in Britain. It is manufactured from suitable shale, limestone and smaller amounts of gypsum to control the setting times. The shale and the limestone are crushed separately and then mixed and burnt at a very high temperature of around 2000°C. The resulting clinker is crushed to form a fine powder. This powder is then bagged (packed in paper bags with a thin plastic liner) or transported in bulk containers.

1 bag of cement = 20 kg

108 bags of cement = 1 m³

1 bag of cement = 0.009 m³

Portland cement must comply with AS 3972: 2010 General purpose and blended cements, which classifies cement used in Australia as:

- *General purpose cement (Type GP)*. This ordinary Portland cement is the most commonly used cement for the manufacture of concrete, which is used for the majority of building construction for

Fig. 31.17 Two examples of lapping ends of two sheets

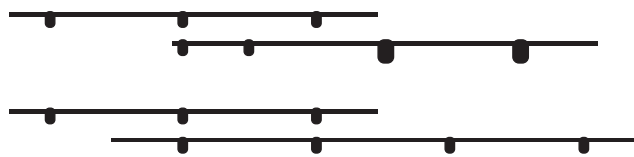


Fig. 31.18 Lapping sides of mesh sheets by at least two main edge wires

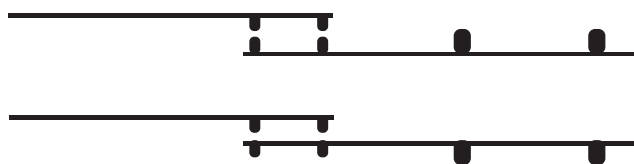


Fig. 31.19 Lapping two sheets of square mesh

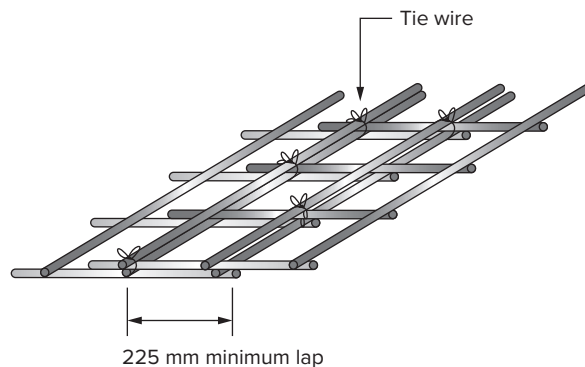


Fig. 31.20 Lap splice of two similar sheets



both concrete and mortars. Off-white cement is also a Type GP cement and is used where design requirements demand an off-white colour finish.

- *Blended cement (Type GB)*. This is used in all types of building and construction work. Early rates of strength gain may be lower than those of Type GP, and curing may be more critical for full-strength development.
- *General purpose limestone cement (Type GL)*. This cement has up to 7.5% of additional lime replacing the cement and has been developed to reduce the amount of cement manufacture in an effort to reduce carbon dioxide emissions in the manufacture of cement.

31.6.3 Special purpose cement

31.6.3.1 High early strength (HES)

High early strength (HES) cement gains its strength a little faster than Type GP, even though it sets in around the same time. However, its eventual strength will be little different from ordinary cement. Due to its rapid gaining of strength, HES cement also generates more heat in reacting, and so mixes made with it are more prone to cracking in uncontrolled conditions and when in large masses.

31.6.3.2 Low heat (LH)

During setting and early hardening, cement generates a considerable amount of heat, which is called *heat of hydration*. In large masses of concrete, this can cause damage. LH cement does not produce the same levels of heat as ordinary cement. For this reason, LH cement is useful in mass concrete to minimise the amount of heat generated. The gain in strength of LH cement is slower than ordinary cement, but the ultimate strength is the same.

31.6.3.3 Sulphate resisting (SR)

Sulphate resisting (SR) cement is similar to ordinary cement, with a greater resistance to sulphate attack, such as may occur where there is a high-salt content in the soil, or where there are high concentrations of industrial waste or in sewer applications. Sulphate attack causes the concrete to expand, which in turn causes cracking and softening of the concrete.

31.6.4 Aggregates

Aggregates for concrete should consist of clean, hard particles free from organic matter or other impurities that could affect the strength of the concrete.

31.6.4.1 Coarse aggregate

Coarse aggregate is usually produced from crushed granite, quartzite, dolerite or basalt, and is often known as 'blue metal' or crushed river gravel. The particles in a concrete aggregate should be graded in size so that the voids formed between the larger particles will be filled by smaller particles. For reinforced concrete, the maximum nominal size of aggregate is 20 mm, but up to half the total weight may be 10 mm gauge with a small proportion being even smaller in size. Common sizes are 7, 10, 14, 20, 30 and 40 mm.

31.6.4.2 Fine aggregate

Fine aggregate can pass through a 5 mm sieve and usually consists of natural sand, although it can also be produced from crushed stone. The sand must be clean and sharp and free of salt or organic matter. Rubbing a sample between the hands can be a rough test of its cleanliness: if the hands remain clean, the sand is probably satisfactory. Enquiries as to its source may indicate whether further

testing is warranted. Sand should also be screened for particle size as it should not contain more than 10% by volume of fine dust.

31.6.5 Water

Water for concrete and mortar should be clean and free of chemical impurities. Generally, water that is fit for drinking should be satisfactory. Avoid bore water as it may be high in sulphate or chloride salts.

31.6.6 Additives

Additives or admixtures are chemical-based and can be added to the concrete mix before or during the concrete mixing process.

There are five main classes of chemical admixtures:

- accelerating
- retarding
- water-reducing
- air-entraining
- plasticisers (super plasticisers).

Different admixtures will have varying reactions with the concrete, depending on the required modifications to the finished, hardened concrete.

Most commonly, admixtures can be used to accelerate the curing time of concrete, especially in colder climates where it can take a long time for the concrete to set. The concrete strength can be achieved much more quickly.

They can also work in the exact opposite, as a retarding agent—meaning that the curing time can be decelerated. This is especially useful in warmer climates, where the concrete can lose its workability very quickly.

Water-reducing additives can be used to reduce the amount of water by up to 10% required for the mixture. These allow the concrete mix to reach the required slump without using as much water, which means the concrete can reach a higher strength upon curing and hardening than concrete without the additive.

If an even higher water content reduction is required, a plasticiser or high-range water reducer can be used. These can reduce water content by as much as up to 30% and still create a high slump flowing concrete mix. The drawback with plasticisers is that they are effective for only a short period of time and the concrete can start to lose its workability in as little a time as 30 minutes. For this reason, plasticisers are generally added when the concrete arrives at the job site.

Sometimes, the mass of the finished concrete will need to be reduced and the workability improved. Air-entraining admixtures are used to form minute air bubbles in the concrete to achieve this. Some speciality admixtures are also used for varying applications such as concrete colouring, bonding, damp proofing, reinforcement corrosion inhibition, concrete shrinkage reduction and enhanced workability.

31.7 Consider the factors affecting concrete quality and strength

There are a number of factors that can affect the final quality of the concrete, the main four being:

- water/cement ratio
- cement-to-aggregate ratio
- compaction
- curing.

31.7.1 Water/cement ratio

After the concrete aggregates have been selected and graded to form a dense mass, they must be bonded together. This is done with the cement paste, which consists of cement and water. The strength of the cement paste is a critical factor affecting the final quality of the concrete.

The water/cement (W/C) ratio is the ratio between the amount of water and the amount of cement present in the concrete at the time of mixing and is expressed as the weight of water divided by the weight of cement. For example, if one cubic metre of concrete contains 150 kg of water and 300 kg cement, then the W/C ratio is equal to 150 divided by 300, or 0.5.

In some circumstances, the W/C ratio may be more conveniently expressed as litres of water per bag of cement. For example, one litre of water weighs 1 kg. One bag of cement weighs 20 kg. In the example above, the number of litres of water per bag of cement equals $0.5 \times 20 = 10$ litres.

31.7.2 Cement-to-aggregate ratio

The strength of the concrete can also be improved by increasing the proportion of cement to aggregate (shown in Table 31.1). A typical mix for high-strength concrete is 1:2:3—one part cement to five parts aggregate. This mix will make a dense, watertight finished product. Where general purpose concrete is required, a mix of 1:2.5:4, or one part cement to six-and-a-half parts aggregate, will provide concrete with lower compressive strength.

31.7.3 Compaction

By eliminating the air trapped in the concrete, its strength is significantly increased. This action allows the concrete to achieve its design strength. Compaction also provides good adhesion to reinforcing as well as ensuring that the concrete completely fills the forms, providing good off-form appearance.

Figure 31.21 represents the loss of strength as a result of air voids in the concrete. Air voids of 5% will cause a 30% reduction in the relative strength of the concrete.

The most common way to achieve compaction is through the use of vibration; this process reduces the friction between the aggregate, improving workability without the need to add additional water.

Compaction can be achieved through the use of:

- immersion (poker) vibrators
- surface vibrators (vibrating screeds)
- form (external) vibration
- tamping
- rodding.

31.8 Understand batching proportions and ratios for concrete

Concrete raw materials are proportioned by batching, either by mass or by volume.

31.8.1 Mass batching

Concrete may still be batched on remote construction sites where ready-mixed concrete is not available. In those cases, responsibility for the strength and quality of the concrete is entirely with the site contractor producing the concrete.

Fig. 31.21 The impact of air voids on concrete strength

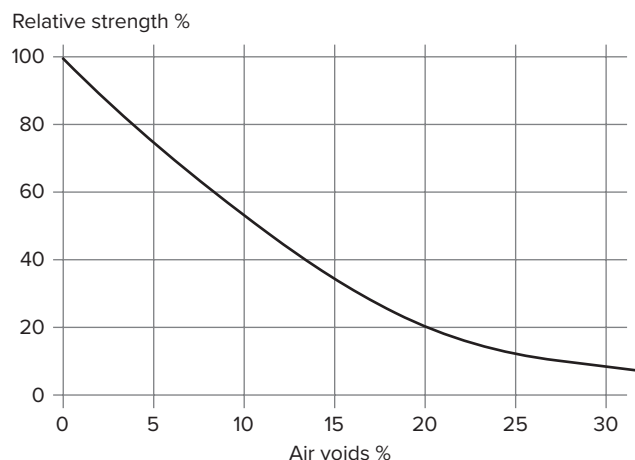


Fig. 31.22 Mobile site batching plant

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For large construction sites in major cities, a site concrete batching plant is often set up to reduce the need for heavily laden concrete trucks driving through traffic-choked streets and to ensure quality and availability of supply (Fig. 31.22). The raw materials are delivered outside peak traffic hours in bulk loads and the freshly batched concrete is delivered directly to where it is required on-site by pumps.

31.8.1.1 Ready-mixed concrete

Ready-mixed concrete is the most convenient and economical way of obtaining high-quality concrete that has been accurately proportioned by mass (weight) through a batching plant. Ready-mixed concrete is available in most areas. It is ordered by the cubic metre in increments of 0.2 m^3 . Trucks are available that can deliver up to 7 m^3 ; in some areas, mini-trucks will deliver loads of as little as 0.2 m^3 . The concreters must be ready to accept the concrete as it is delivered.

TIP When ordering ready-mixed concrete, indicate the strength of concrete required in MPa, as it is usually delivered with a slump not exceeding 80 mm and any departure from this amount must be specified when ordering.

Water should never be added to ready-mixed concrete to increase its workability unless the W/C ratio is maintained by also adding cement in the same proportion. The practice of 'wetting up' by adding water to the concrete in a concrete truck changes the W/C ratio and the design strength of the concrete, potentially resulting in concrete that has a lower MPa than required. If concrete with a lower slump is required because a concrete pump is being used, the concrete should be ordered with a higher slump.

31.8.2 Volume batching

Volume batching can be rather inaccurate due mainly to the bulking of materials, particularly sand, which when damp can bulk up to as much as 25%.

For the most accurate results, materials should be correctly proportioned by volume using consistently sized containers such as 10–15 L buckets, which can be picked up manually and emptied into a concrete mixer.

TIP A filled 20 L container is too heavy for one person to lift repeatedly and may cause injury.

Site mixing concrete using a concrete mixer:

1. Position mixer close to materials and stabilise the mixer to prevent it from moving.
2. Ensure all electrical leads are off the ground and elevated above the heads of workers. Connect electrical supply lead to an earth leakage detector and connect mixer lead to the earth leakage detector.
3. Wear relevant PPE. Avoid contact with your skin and concrete or cement powder and keep your hair, hands and body parts away from any moving parts. Don't fill buckets with more than 20 kg of material at any time (10–15 L of aggregate is approximately 20 kg).
4. Place all of the required water into the mixer for a full batch of concrete after the previous batch has been emptied.
5. Place one part of sand in the mixer and allow this to mix for a short period of time. This will clean the mixer.
6. Slowly add all of the cement required. Adding the cement now will allow the powder to thoroughly mix with the water while minimising the amount of dust created. Stand upwind from the mixer or use a protective dust mask.
7. Slowly add the remaining materials, alternating between fine and coarse aggregate.
8. If additional water is required, add a proportional amount of cement also based on the required W/C ratio.
9. Don't overfill the mixer! Smaller batches are better mixed and easier to handle in a wheelbarrow.

For volume-mixed concrete, the proportions shown in Table 31.1 can be used. Concrete should be mixed for at least three minutes and only clean water added sufficient to produce a slump not exceeding 80 mm.

31.8.3 Quantities of dry materials

In order to manufacture one cubic metre of wet concrete, approximately 1.45 m³ of dry materials will be required. A large amount of the fine aggregate will fill the voids between the coarse aggregate, with the cement filling some of the voids between the sand.

Fig. 31.23 Coarse and fine aggregate

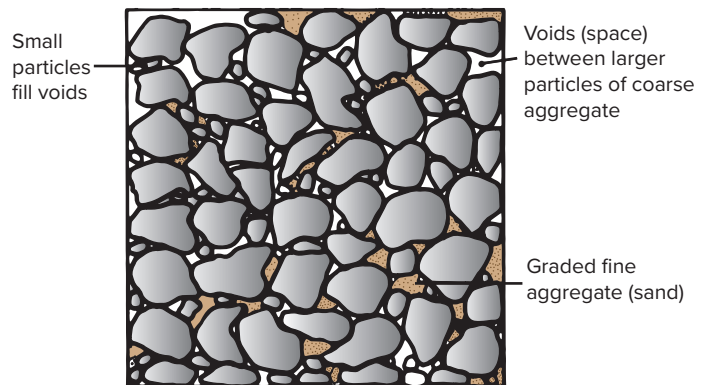


Table 31.1 Volume-mixed concrete proportions

Material	High strength	General use	Large mass
Cement (Portland)	1	1	1
Fine aggregate (sharp sand)	2	2.5	3
Coarse aggregate (20 mm)	3	4	5

31.8.3.1 Concrete mix estimating

To calculate dry mix quantities for high-strength concrete, we need to convert all of the units to m³. This means that although the cement is sold by weight (20 kg), we need to convert it to volume.

$$\begin{aligned}
 1 \text{ m}^3 \text{ of cement} &= 108 \text{ bags (20 kg)} = 2160 \text{ kg} \\
 1 \text{ bag} &= 0.009 \text{ m}^3 \\
 1.45 \text{ m}^3 \text{ of dry mix} &= 1 \text{ m}^3 \text{ finished concrete}
 \end{aligned}$$

The proportion for this batch of concrete, for 1 m³, will be:

$$\begin{aligned} \text{cement (1 part)} & 0.242 \text{ m}^3 \div 0.009 = 27 \text{ bags} \\ \text{sand (2 parts)} & 0.483 \text{ m}^3 \\ \text{aggregate (3 parts)} & 0.725 \text{ m}^3 \\ 6 \text{ parts} & = 1.45 \text{ m}^3 \\ 1 \text{ part} & = 1.45 \text{ m}^3 \div 6 = 0.242 \text{ m}^3 \end{aligned}$$

TIP Cement has a limited 'shelf life'; contact with air and moisture will cause the cement powder to begin setting. When ordering dry mix concrete, order only enough for the immediate task. If you do need to store the dry mix, ensure that it is kept off the ground and under cover in a dry location.

CHECK YOUR UNDERSTANDING

4. How does adding water to wet concrete affect its strength?
5. How many 20 kg bags of cement would you need to make 1.7 m³ of finished concrete using a 1:2:3 ratio mix?
6. Explain why batching by mass is preferable to volume batching in the production of high-quality concrete.

31.9 Mix, place and finish concrete

31.9.1 Transport and placing

After concrete has been mixed, it must be placed before it starts to stiffen. Generally, it will take four hours from when concrete is placed to when it initially sets. There is no appreciable stiffening for approximately 30 minutes, after which stiffening will accelerate at a rate depending on the concrete mix, the temperature of the concrete and weather conditions. High temperature accelerates stiffening and must be taken into account when determining how many people will be needed. In many cases, if the concrete must be moved by wheelbarrow over any distance, it may be more economical to hire a concrete pump.

TIP There are approximately 15 wheelbarrows of concrete for each cubic metre of concrete.

31.9.1.1 Segregation

Segregation in concrete refers to the separation of the coarse aggregate from the cement paste. This can occur during transporting and placing if unsuitable methods are used. This results in non-uniform concrete with weak and porous honeycomb patches.

Concrete should be proportioned in such a way as to give a cohesive concrete; harsh, overly wet mixes will segregate more readily. On smaller projects, avoid excessive vibration of the concrete by transporting it in rubber-tyred

Fig. 31.24 Site delivery chute



© Peter Righteous/Alamy Stock photo

barrows or dump trucks over smooth, prepared runways. Deposit the concrete directly over the final location.

When placing concrete, it should be shovelled into place and not allowed to flow over long distances. It must be well compacted by mechanical vibration but avoid over-vibration, which may also lead to segregation. In addition, concrete should not be dropped from a great height as this also leads to segregation. Where the drop exceeds 2 m, a drop chute may be necessary.

Immediately after placing, a screed (straight edge) is used to level off the concrete.

31.9.2 Ordering concrete

When ordering concrete, you must provide the following information:

- the name of the customer, contact mobile/phone and method of payment—normally the concrete supplier will need credit card details if you don't have an account
- the address and location of the site with any special instructions (e.g. 'number 90B Hill Street, near the corner of Hill Street and View Road, up the driveway and around the back; contact number 0230 910 245')
- the quantity in cubic metres (m^3) in increments of 0.2 m^3 ; orders less than 3 m^3 attract additional charges to cover delivery costs
- slump; for example, if a concrete pump is being used it is better to order concrete with a slump of 120 mm
- setting time required—concrete can be ordered with a guaranteed setting time for an additional charge (e.g. if the weather is forecast to be hot, concrete with a guaranteed setting time of four hours or more can provide extra time to place and finish the concrete)
- compressive strength in MPa (e.g. 25 MPa)
- day, date and time of delivery—allow time for workers to arrive and prepare, for formwork and steel to be checked; for the concrete pump to arrive and set up; and for traffic control to be set up
- rate of delivery or how many cubic metres per hour—for example, you can request two consecutive 6 m^3 truck loads, 45 minutes apart with a 'message'. When the second load is discharged from the truck, the driver will ask 'What's the message?'. Whereby, a quick check will show that another 1.5 m^3 is required, so the 'message' is 1.5 m^3 . Without the advice at the time of order that additional concrete may be needed you may have to wait until a concrete truck is available.

Charges apply to take excess concrete away, so it is best to attempt to accurately estimate the concrete order. Always have a plan to use or get rid of excess concrete (e.g. pour a small concrete pathway or slab; spread the concrete over the site or in one location so that it can be easily broken up before it sets and used later as fill; place it behind a retaining wall; fill any low areas that can be covered with soil).

31.9.3 Level control

When pouring slabs and footings, the finished height is critical to the successful completion of the project. The height is given as a reduced level (RL). This is usually given as a vertical height above or below a fixed known point, also known as a bench mark.

When slabs are being laid, height control can be achieved by setting the top edge of any formwork to the finished RL required. This can be achieved through the use of a laser level, an automatic level or, at a pinch, a water level.

Of all of these methods, the laser level is the most productive as it can be achieved by one person and has the added benefit of being able to provide spot readings over the entire slab surface as the pour is

being conducted (Fig. 31.25). This is particularly important when large areas are being laid, avoiding high or low spots in the slab.

When pouring footings, the finished height at the top of the footing should be fixed, by working back from the finished floor level stated on the plans. Before the pour commences, the finished height of the concrete can be marked by pushing a dowel into the side of the trench at the height required.

Fig. 31.25 Laser level monitoring depth of trench



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TIP On a sloping site, a stepped footing may be required. When pouring a stepped footing, the height of each step should correspond to brick courses. This would eliminate the need for the bricklayer to lay a course of split bricks.

31.9.4 Example: Pouring and finishing a simple reinforced concrete driveway

31.9.4.1 Planning procedure

1. Establish the finished height of the concrete and all grades and falls.
2. Estimate the concrete and reinforcing steel required.
3. Ensure there is enough formwork and it is in good condition and clean.
4. Install edge formwork.
5. Install waterproof membrane if required. Sand blinding may be required to prevent damage to the membrane.
6. Ensure the excavated area is clear of debris and any loose soil or rock.
7. Establish how many control joints or expansion/contraction joints are required and their spacing. Generally, these are up to 6 metres apart.
8. Install mesh reinforcement with bar chairs but only if the driveway can be easily accessed by a concrete truck or if a concrete pump is being used.

Fig. 31.26 A stepped footing excavation with mesh installed and timber block outs fixed at brick course height to create the steps



Courtesy of Alister Ford

Fig. 31.27 The poured stepped footing ready for work to proceed



Courtesy of Alister Ford

9. If you plan to drive the truck on the steel, do not install the bar chairs. The steel mesh must be lifted off the ground by at least 50 mm to provide 'cover' as the concrete is discharged using steel hooks or the hook on a concrete rake.
10. Order at least 25 MPa concrete for improved durability and workability.
11. Avoid pouring concrete during either extremely hot weather or when rain is forecast.
12. Ensure that you have enough workers to place the concrete and finish it within four hours of the first load arriving.
13. Do not attempt to pour concrete 'uphill' on steep driveways. Any minor grade can turn an easy job into a hard job if you have to drag and **screed** concrete 'uphill'. Consider using a concrete pump!
14. Finish concrete with a broom, cove trowel or wood float finish to improve traction.

TIP When colouring concrete, it is safer to order coloured concrete because the oxide used to colour the surface contains a hardener that is particularly hazardous. There is little cost difference.

31.9.4.2 Preparation of foundation

1. Remove all grass and topsoil to achieve a hard foundation for the driveway.
2. Fill any low spots and compact the fill by tamping with a piece of timber or with a mechanical compactor.
3. Compacted road base may need to be placed on top of the foundation or sub-grade to reduce the amount of concrete required and to provide the required level of the foundation (Fig. 31.28).

31.9.4.3 Placing concrete

1. The concrete should be placed where it is needed, working from one end and across the driveway, spreading it to an even specified depth or slightly more by using a concrete rake or shovel.

Fig. 31.28 Road base ready for final compaction before pouring



Courtesy of Alister Ford

2. As the concrete is spread, it should be compacted by tamping or using a mechanical vibrator to maintain durability and strength.
3. Screeding should commence immediately with another person assisting the person/people screeding by 'dragging' excess concrete away and adding additional concrete behind the screed as required. Screeding is progressed methodically from one end to the other (Fig. 31.29).
4. The concrete supplier allows 15 minutes per cubic metre for the concrete to be placed. Use that time to place the concrete where and when it is needed. That means the truck driver must understand when and where to discharge concrete and when to stop. Instructions must be clear with no indecisiveness.
5. Between loads of concrete, use the time to complete placement and screeding; collect and clean tools; and check the formwork for any movement.
6. Start to apply the initial edging finish as soon as possible. Unless the edging is started while the concrete is still plastic, it will be more difficult to finish the edging after the initial set.

Fig. 31.29 Screeding concrete

Courtesy of Riviera Concrete

Fig. 31.30 Vibrating screed

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31.9.4.4 Initial finish to concrete

1. Screed concrete to a consistent grade or level with no shallow spots or humps.
2. Initial edging finish is completed while concrete is wet to set up the aggregate along the edge form. A bull float can be applied over initial edge finish.
3. A bull float is applied when the screeding is completed. This will provide the initial finish. At this stage, the concrete is still too wet to apply the final finish (Fig. 31.31a and b).

Fig. 31.31(a) and (b) Bull float

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(continued)



Courtesy of Riviera Concrete

Fig. 31.32 Edging tool



Courtesy of Alister Ford

4. The final finishing can commence once the concrete is firm but still plastic and all excess water that bleeds to the surface has evaporated.

31.9.4.5 Final finish to concrete in two steps

1. While the concrete is still plastic but no excess water is on the surface, apply a hand or power trowel finish to prepare the surface for the final finish. Use hand trowels, such as a steel trowel, wood float or bull float.
2. Trowel edging for a second time and then apply final finish.

Fig. 31.33 Powered helicopter trowel



Courtesy of Alister Ford

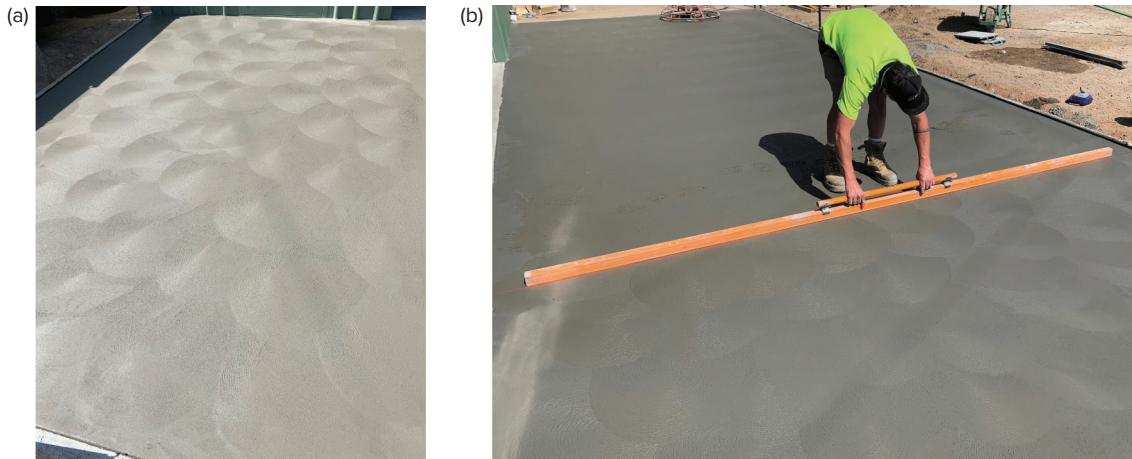
TIP Edging may be trowelled a third and final time if a different final finish is required for the edging.

31.9.4.6 Suitable slip-resistant finishes for a concrete driveway

Suitable slip-resistant finishes for a concrete driveway are:

- *Cove trowel finish.* Applied in same way as other hand trowels but leaves a raised or rippled surface finish. Edges may be finished with a smooth edge trowel or left as a cove finish (Fig. 31.34).
- *Wood float finish.* Applied in the same way as other hand trowels, but leaves a slightly sandy or slightly rough surface, which is ideal for pathways and driveways. The edges may be finished with a smooth edge trowel or left as a wood trowel finish.
- *Broom finish.* Applied with a special long-handled concrete finishing broom (Fig. 31.35). The technique requires the broom to be placed gently on a far edge just off the concrete. It is then drawn steadily back from the far edge towards the person applying the finish across the full width of the slab. The edges may be finished with a different trowel or left with a broom finish.

Fig. 31.34 (a) Cove trowel finish for non-slip pedestrian access; (b) marking the break for finishing; (c) smooth finish abutting cove trowel finish



Courtesy of Alister Ford



Courtesy of Alister Ford

Fig. 31.35 Broom finish



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31.9.4.7 Control joints

Control joints are used to prevent irregular or random cracking occurring after the concrete has set. They are either formed with a jointer when the concrete is wet or can be cut with a concrete saw between 4 and 12 hours after the concrete is poured. Control joints should be between 25 and 30 mm deep for a 100 mm slab and are spaced between 3 and 6 metres apart, depending on the size of the steel mesh bars. The larger the diameter of the steel bars, the greater the spacing between control joints.

31.9.4.8 Construction joints

Construction joints separate large sections of concrete and allow the concrete to expand or contract. The dowels, in this case, slide inside an outer casing on the other side of the plastic construction joint, which has a 'honeycomb' construction to allow contraction and expansion of the concrete. The dowels maintain the alignment of the two connecting slabs while allowing them to move independently.

31.9.5 Environmentally friendly waste management

Substantial fines are issued for contaminating stormwater channels with concrete waste. A waste management system should be established prior to work commencing. Tools and equipment should not be washed into the gutter. A washdown area should be established on-site where the run-off will not enter the stormwater system. After all tools and equipment have been thoroughly washed down, they should be inspected for any damage or faults and then, if not in need of repair or replacement, stored correctly in the appropriate area. Any tool or equipment repairs or replacements that need to take place before the next job should be documented then carried out as per company procedure so that all will be available in readiness for the next job to start on time.

Excess concrete should be poured into manageable piles on a plastic sheet. When dry, they can be broken up, recycled and used as road base or fill or disposed of in a rubbish skip as a last resort.

Ready-mixed concrete suppliers offer environmentally friendly waste management. This involves 'take back' of excess concrete delivered to site. This concrete is taken back to the batching plant and put through a process to recover the aggregates and waste water. This is not a free service and can be costly. This cost can be avoided by accurate quantity estimating.

Fig. 31.36 Sawn control joint



Courtesy of Alister Ford

Fig. 31.37 Dowelled construction joint placed every 18 metres



Courtesy of Riviera Concrete

Fig. 31.38 Dowelled construction joint between two separate concrete slabs



Courtesy of Riviera Concrete

Fig. 31.40 Excess and clean demolished concrete piled for recycling



Courtesy of Alister Ford

Fig. 31.39 Finished foam expansion joint



Courtesy of Alister Ford

Fig. 31.41 Recycling by machine



Courtesy of Alister Ford

31.9.5.1 Thermal mass of building materials

Thermal mass is the ability of a material to absorb heat energy. A lot of heat energy is required to change the temperature of high-density materials such as concrete, bricks and tiles. They are, therefore, said to have high thermal mass. Lightweight materials such as timber have low thermal mass.

In climates that have large fluctuations between day and night-time temperatures, high thermal mass can act as a thermal shock absorber. The building will heat up slowly during the day and hold that heat into the night, thereby

providing a more constant temperature inside the house. This process can be seen in places such as Coober Pedy where a lot of the population live underground. Despite extreme temperatures on the surface, the houses stay at a fairly constant 24 degrees.

It is not feasible to build all houses underground; however, the same principles can be applied by using high thermal mass concrete structures.

Fig. 31.42 Recycled concrete as road base



Courtesy of Alister Ford

Table 31.2 Volumetric heat capacity of common building materials

Material	Thermal mass kJ/m^3
Water	4186
Concrete	2060
Sandstone	1800
Rammed earth	1673
FC sheets	1530
Brick	1360
Earth wall	1300
AAC (Hebel)	550

CHECK YOUR UNDERSTANDING

7. What is the maximum height that concrete may be dropped in order to avoid segregation of concrete?
8. What is the difference between control joints and construction joints?
9. When placing a steep concrete driveway, what type of surface finish would you use? Why have you selected this finish?
10. List at least four precautions that must be taken to avoid the segregation of concrete during transporting and placing.

31.10 Cure concrete

When concrete begins to harden, the process of gaining strength will continue for some time provided that favourable conditions are maintained. This process is termed *curing* and two conditions are required: (1) the presence of moisture and (2) a favourable temperature.

Excessive evaporation of water from the concrete can cause the hydration process to stop.

On-site curing methods can include:

- spraying curing compounds over the surface, forming a liquid membrane that limits the evaporation of moisture
- covering the concrete with hessian or a layer of sand and keeping this moist by watering periodically
- covering the concrete with building paper or plastic sheeting to prevent loss of moisture.

TIP The curing process should continue for at least seven days. Concrete reaches 60% of its strength after seven days, and its final working strength when it is more than 28 days old.

31.11 Understand the compressive strength and slump testing of concrete

The compressive strength of concrete is a measure of its ability to resist crushing. The standard test for compressive strength is made when the concrete is 28 days old. It is measured in megapascals (MPa).

Test specimens are taken and prepared in concrete testing cylinders at various stages of the concrete pour and also from different areas within the pour. The time and location of each sample is recorded and they are then transported to the testing facility. These are cured under controlled conditions and at 28 days are subjected to a test procedure by crushing them to destruction to determine their compressive strength.

Standard grades of structural concrete are 15, 20, 25, 30, 40, 45 and 50 MPa. For domestic work, concrete of 20 to 32 MPa will meet most specifications. Concrete is designed to reach a specified strength by determining the W/C ratio. Examples of different concrete strengths and the required W/C ratios are shown in Table 31.3.

Fig. 31.43 Concrete testing cylinders filled and ready for transport



Courtesy of Alister Ford

Fig. 31.44 Compressive strength test cylinder

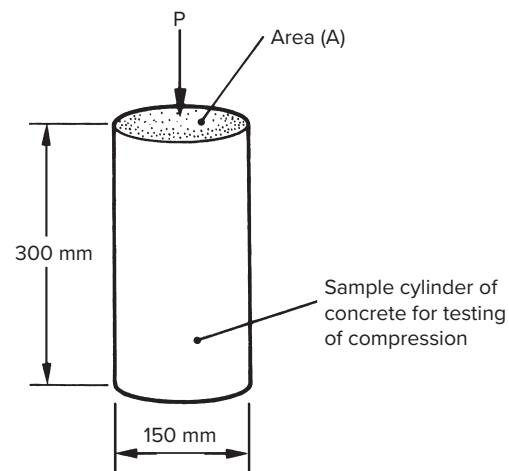


Table 31.3 Required W/C ratios

Compressive strength (MPa)	W/C ratio in kg	W/C ratio in litres per 20 kg bag of cement
15	0.7	14
20	0.6	12
25	0.55	11

TIP An allowance must be made in the amount of added water in order to compensate for the amount of water that may be present in the aggregates already, particularly damp or wet sand.

Concrete must be made sufficiently workable so that it will flow around any reinforcement and into the furthest corners of the formwork. When additional water is added to improve workability, an additional and proportional amount of cement must also be added to maintain the design strength.

31.11.1 Slump test

The workability of concrete is measured by the slump test and is made using a standard cone and tamping rod.

1. Stand the cone on a level surface and hold it firmly by placing feet on the foot rests.
2. Fill the cone with concrete in three layers of 100 mm each, tamping each layer evenly over its area 25 times with the tamping rod.

3. Strike level at the top. Lift the cone carefully but firmly straight up and then allow the concrete to subside.
4. Invert the cone and place it beside the sample.
5. Using the tamping rod and a rule, measure the slump, which is the difference in height between the cone and the concrete.

The recommended slump for differing applications and types of construction is shown in Table 31.4.

Fig. 31.46 A concrete slump test cone and tray ready to be used



Courtesy of Alister Ford

Fig. 31.45 Slump test equipment

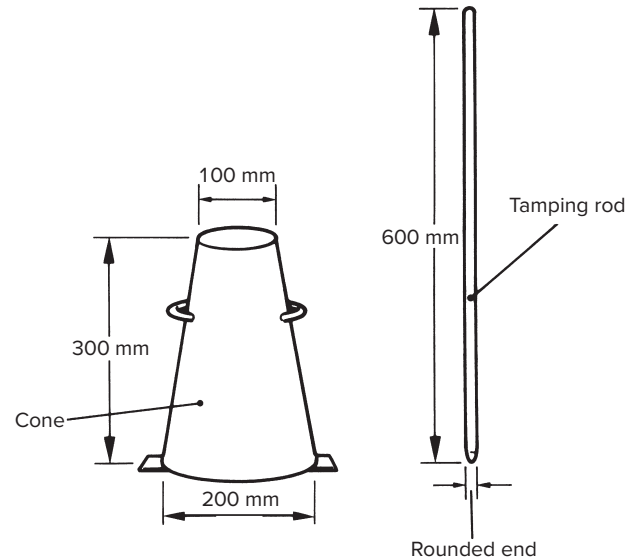


Fig. 31.47 Measuring concrete slump

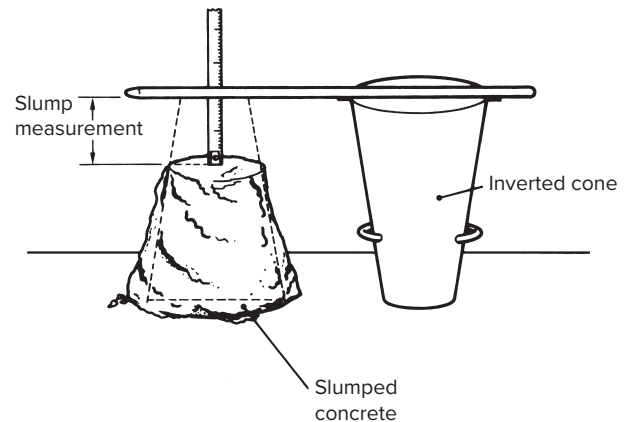


Table 31.4 Recommended slumps

Type of construction	Recommended slump (mm)	
	Minimum	Maximum
Pavements and slabs	50	80
Beams	50	100
Reinforced footings	50	100
Columns	50	100
Reinforced thin walls	80	120
Core fill for blocks	230	250

CHECK YOUR UNDERSTANDING

11. What are the four main components of concrete?
12. What are the benefits of compaction?
13. List six requirements of good formwork.
14. What items of PPE would you consider using when pouring a slab outdoors?
15. Why is it necessary to 'cure' concrete?

Student research

Search online for a MSDS for cement. Calculate the concrete and steel required for a reinforced concrete driveway.

Using the house plan provided in the Appendix, estimate the amount of concrete that should be ordered to pour the driveway from the front of the garage to the front boundary. Assume that the dimensions are 5.8 m wide × 8.0 m long. Allow 5% for waste for the concrete. Reinforcing steel will be standard sheet sizes using SL82 mesh and the driveway is 120 mm in thickness. Order concrete up to the nearest 0.2 of a cubic metre above your answer.

The following websites will provide detailed information in areas that go beyond the scope of this chapter:

- Cement Concrete & Aggregates Australia (CCAA): www.concrete.net.au
- Concrete Institute of Australia: www.concreteinstitute.com.au

Search online for 'laying concrete' to see more detail on concrete finishing.

End-of-chapter activity

Develop a detailed hazard assessment and then a safe work method statement (SWMS) for the construction of a new driveway as explained in the student research activity. The new driveway will need to be properly connected to the existing garage slab.

Include the clearing of, and preparation of, the base, the construction of the formwork, the fitting and placement of the reinforcement materials and the pouring and finishing of the concrete.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 3610.1: 2010
Formwork for
concrete

AS 3610.1: 2018
Formwork for
concrete. Part 1:
Specifications

AS 4671: 2001
Steel reinforcing
materials

AS 2870
Residential slabs
and footings

AS 2159
Piling—design and
installation

AS 1289
Methods of
testing soils for
engineering
purposes

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 3600
Concrete structures

AS 4100
Steel structures

AS 1684.2
Residential timber-framed construction,
Part 2: Non-cyclonic areas

AS 1684.3
Residential timber-framed construction, Part 3: Cyclonic areas

AS 1684.4
Residential timber-framed construction,
Part 4: Simplified—non-cyclonic areas
Cement, Concrete and Aggregates Australia,
Technical Note 61—Articulated walling

National Code of Practice: Pre-cast, tilt-up and concrete elements in building construction.
February 2008

WorkSafe Victoria
Industry Standard:
Precast and tilt-up concrete for buildings

Tradie talk—Too wet, too weak

Chapter 32

Formwork for stairs and ramps

Learning Objectives

- LO 32.1 Know about formwork standards**
- LO 32.2 Understand formwork materials**
- LO 32.3 Understand formwork design**
- LO 32.4 Construct formwork for concrete stairs**
- LO 32.5 Finish stair treads**
- LO 32.6 Build ramps**

Introduction

The ancient construction technique of formwork is still the most efficient and cost-effective way to keep structures stable during the construction process—and sometimes afterwards, in the case of permanent formwork. Formwork is traditionally constructed as a temporary structure used to hold concrete in place while it sets. As concrete is very heavy, formwork must be soundly constructed and firmly braced and supported.

Timber formwork (also known as 'shuttering') is made from a combination of timber and plywood and is typically the most affordable method of constructing forms. Formwork in construction is used for concrete projects of all sizes, from building residential foundations and slabs, walls, suspended slabs, stairs and ramps to constructing skyscrapers and civil engineering projects.

This chapter aims to provide enough information and knowledge to enable you to manufacture and construct:

- a flight of stairs, free-standing or against a wall, with a minimum rise of 1800 mm
- a ramp with a minimum rise of 400 mm and length of 5.6 m.

32.1 Know about formwork standards

32.1.1 Relevant legislation, standards and codes of practice

The installation of formwork is covered in AS 3610: 1995 Formwork for concrete and AS 3610 Supplement 2: 1996 Formwork for concrete—commentary (under revision).

Under the federal *Work Health and Safety Act 2011* and Safety Regulations 2011, formwork installation will often meet the criteria for classification as a high-risk activity requiring a discrete safe work method statement (SWMS), this being:

- work requiring temporary support of structural components
- the risk of falling more than 2 m.

The information that follows is from *Formwork and Falsework: Code of Practice* (Safe Work Australia, 2013) and AS 3610: 1995 Formwork for concrete.

Freshly poured concrete that is still fluid imposes forces on the supporting structure that can lead to **progressive collapse** if all elements, particularly the shoring system, are not properly installed. Failed formwork is a significant contributor to the annual death and injury statistics for building and construction workers. The mass of concrete is 2400 kg per cubic metre; this doesn't include the mass of the formwork.

The following critical points must be considered when installing formwork and pouring concrete for suspended slabs:

- Formwork should be erected only by a competent/qualified person (e.g. someone holding a Certificate III in Formwork/Falsework).
- A licensed scaffolder is required to work at heights of over 4 m.
- Safe access must be provided for workers installing formwork.
- Formwork frames must be erected progressively and safely.
- A safe **false deck** (scaffolding) must be provided for the erection of a formwork deck exceeding 2 m in height.
- Edge protection must be provided for formwork decks.
- The laying of formply must be planned so that a safe work platform is provided at all times.
- Cantilevers or 'traps' must be secured to prevent falls.
- Workers must be protected from falls through open penetrations such as stairwells.
- Barriers must be installed to prevent following trades from entering an active formwork zone.
- Placing loads onto active formwork decks must be planned and supervised to mitigate overloading and catastrophic collapse.
- Formwork must be inspected by an experienced structural designer/engineer before the concrete is poured.
- When concrete is poured, only one designated observer may be under the formwork.
- The pouring of concrete must stop when emergency repairs are required.
- Heavy equipment should not be placed on formwork unless the formwork has been designed for that purpose.
- Concrete should not be stripped until a competent person provides written confirmation that the formwork can be removed (e.g. a structural engineer).
- **Drop stripping** should not be undertaken.
- **Backpropping** must be supervised by a competent person and be designed to allow for any loads that may be placed on recently poured concrete.

TIP Each state and territory has its own code of practice for the erection and dismantling of formwork.

32.1.2 Workplace quality policies

Workplace quality policies and standards are developed from the NCC, Australian Standards and the Codes of Practice. They also take into account recommendations from the manufacturers of construction products on how materials are to be used, erected/constructed, installed, stored and handled safely.

Policies created by a business should be clear, simple statements of how the organisation intends to conduct its services, actions or business. They provide a set of guiding principles to help with a company's decision-making to maintain compliance with occupational health and safety (OHS) standards, the National Construction Code (NCC), Australian Standards (AS) and the Codes of Practice.

32.1.3 Safety

There are many dimensions to workplace safety, including:

- safety documents, such as: job safety analysis (JSA), safe work method statement (SWMS), material safety data sheet/safety data sheet (MSDS/SDS)
- plans (architectural and engineering) and specifications (manufacturer's specifications)
- quality requirements, including dimensions, tolerances, standards of work and material standards
- safe work procedures (SWP) related to the operation of small plant and equipment on construction sites
- verbal or written/graphic instructions
- signage
- work schedules/plans/specifications, work bulletins, charts and hand drawings, memos, and diagrams or sketches.

Safety is also about risk management and being risk averse. Some steps to help with risk management are:

- Observe the workspace to find out what could cause harm: is there interaction with traffic, the general public, other fixed structures or overhead powerlines? Take into consideration the other trades on-site and the ground conditions where you will be working. Make sure you have adequate communication with workers about any problems they encounter or anticipate at the workplace.
- Undertake a risk assessment to help you determine what action you should take to control the risk and how urgently the action needs to be taken.
- Take action to control the risk—if it is not reasonably practicable to completely eliminate the risk, consider one or more of the options from the hierarchy of risk control as far as is reasonably practicable: substitute—isolate—engineering—administrative—PPE (see Fig. 2.2 in Chapter 2, Construction work hazards and risk control strategies).
- Have regular reviews to ensure measures remain effective, that they take into consideration any changes, the nature and duration of the work and that the system is working as planned.
- Develop all safety requirements for the task of constructing, erecting and dismantling formwork for stairs and ramps with a JSA or a SWMS if the job falls within the description of high-risk construction work (HRCW).

For more information on the *General Guide for Formwork and Falsework*, see www.safeworkaustralia.gov.au, and check your state's safety governing body and Safe Work Australia.

CHECK YOUR UNDERSTANDING

1. List the current Australian Standards that apply to formwork.

32.2 Understand formwork materials

Materials used to construct formwork must be of good quality, free of defects that will seriously affect their strength and be sufficiently durable for the job.

32.2.1 Timber

Oregon (Douglas fir) is suitable for forms as it will retain its shape and with normal care can be reused many times. Specially designed, laminated veneer lumber (LVL) is also available as supporting timber for suspended formwork and for the edge boards for slab-on-ground construction. Whatever type of timber is used, its relative strength must be taken into account when designing the formwork.

32.2.2 Formply

Formply is widely used for formwork and is available in standard size sheets of 2400 mm × 1200 mm and 1800 mm × 1200 mm, and in 12 mm and 17 mm thicknesses, with stress grades F14 and F17 finished with a smooth plastic or a resin surface finish.

Plywood used as concrete formwork must comply with AS 6669: 2007 Plywood–formwork (which includes structural requirements of AS/NZS 2269: 2008 Plywood–structural) and be branded with a stress grade according to AS 6669: 2007, which outlines the class of off-form finish and bond type.

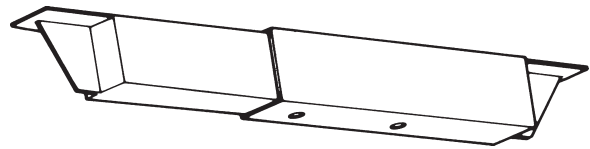
32.2.3 Fasteners

Hot-dipped galvanised stainless-steel or alloy nails and screws are recommended to prevent concrete staining for Class 2 and 3 finishes.

32.2.4 Steel and aluminium

Adjustable props, expanding beam centres (Fig. 32.1), supporting framework and circular or square columns are manufactured in steel and aluminium.

Fig. 32.1 Beam centre



32.2.5 Polyvinyl chloride, polystyrene and fibre cement

Polyvinyl chloride (PVC) and fibre cement (FC) fabrications are commonly used for circular columns, whereas polystyrene and PVC are used to form voids in waffle slabs. All three are used for concrete wall systems.

32.2.6 Formwork finish

There are five levels of surface finish for concrete to consider when designing formwork:

- Class 1—for monuments and other special finishes; not required for general building work
- Class 2—a high level of finish when viewed in close detail, e.g. facades and foyers
- Class 3—a high level of finish when viewed overall, e.g. internal and external facades
- Class 4—good alignment but concealed from general view with applied finishes
- Class 5—alignment and finish are not critical—totally concealed, e.g. footings.

32.2.7 Composite sheet building materials

Composite sheet building materials are highly processed natural materials. These include:

- composite boards
- plywoods—shuttering, standard, marine and laminated plywood variations

- chipboard and particleboards
- medium-density fibreboard (MDF)
- cement and wood fibreboards
- resins and VOCs
- mineral wools
- vermiculite and perlite
- plastics—PVC, foamed plastics, foamed sheets and elastomers.

Composite sheet products are high-embodied energy materials; however, they use low-grade or raw waste materials. Available in numerous varieties, sizes and thicknesses, they can be fitted to suit a project's requirements with minimal waste, which is one of their great advantages.

CHECK YOUR UNDERSTANDING

2. List three different types of materials used to manufacture formwork.

32.3 Understand formwork design

The proper sizes and spacing of components are subject to a number of variable factors; for example, the:

- volume of concrete to be contained in the form
- rate at which the concrete will be poured—rapid pouring means a greater head of liquid concrete, and requires stronger formwork
- temperature at the time of pouring the concrete—higher temperatures mean the concrete will begin to stiffen more rapidly and reduce the liquid head, also referred to as 'full fluid pressure'
- use of vibrators and heavy equipment, which requires stronger formwork—concrete additives are available that reduce the amount of vibration required
- strength and grade of the plywood, timber and other materials used—plywood formwork is generally stronger than solid timber and can lead to a reduction in the number of supporting members.

Safety must always be a factor in designing formwork. If in doubt, it is better to over-design it rather than risk movement in the formwork once pouring has commenced because at this stage it is almost impossible to correct any inadequacies.

CHECK YOUR UNDERSTANDING

3. List and explain three different formwork design considerations.

32.4 Construct formwork for concrete stairs

Many staircases are cast from concrete; the basic principles and proportions between treads and risers remain unchanged. However, formwork must be constructed that will conform to the stair design and retain the concrete (Figs 32.2 and 32.3).

The soffit decking is supported by joists and bearers in combination with props of adjustable tubular steel or of timber on folding wedges (Fig. 32.4).

Fig. 32.2 Formwork for concrete stairs

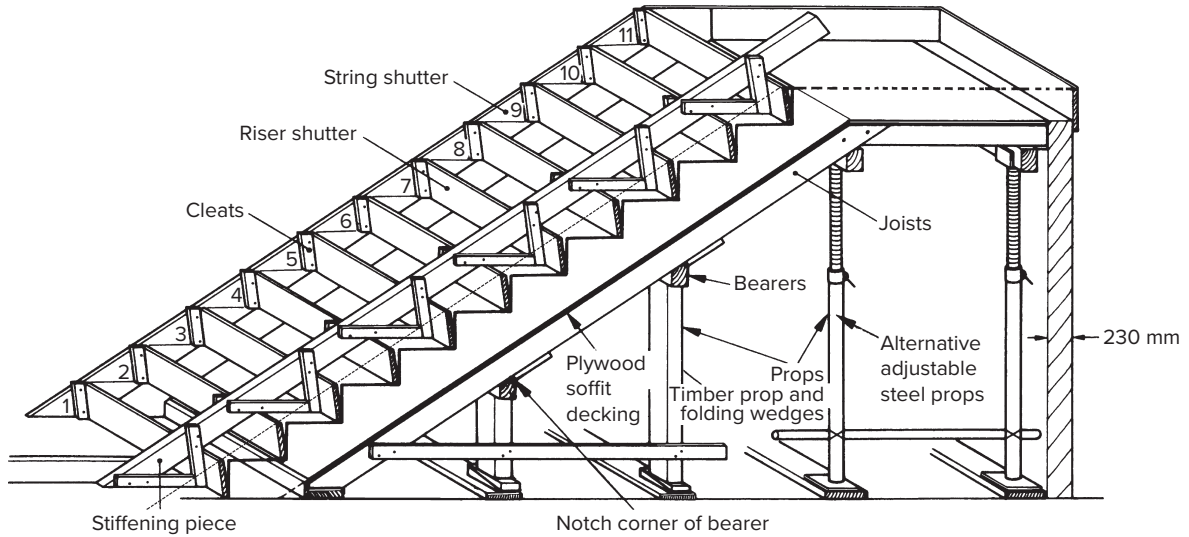
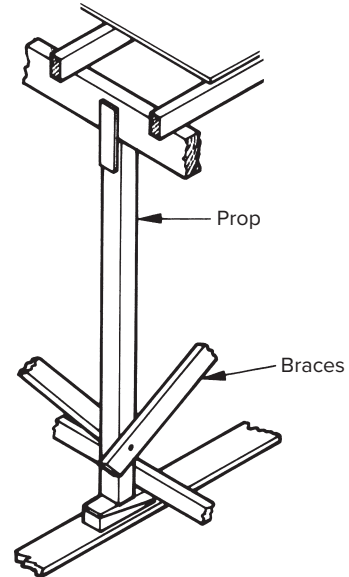


Fig. 32.3 Formed and poured concrete stairs



Courtesy of Graybuilt Pty Ltd

Fig. 32.4 Timber prop (stairs formwork)



32.4.1 Formwork stairs example

Figure 32.5 illustrates an example of a concrete stair. Assume that the floor-to-floor measurement (from one landing to the next level landing) is 1910 mm and the going of flight is restricted to no more than 2630 mm. Using the basic staircase regulations from Figure 32.6, we can calculate a suitable rise and going, taking into account the slope relationship.

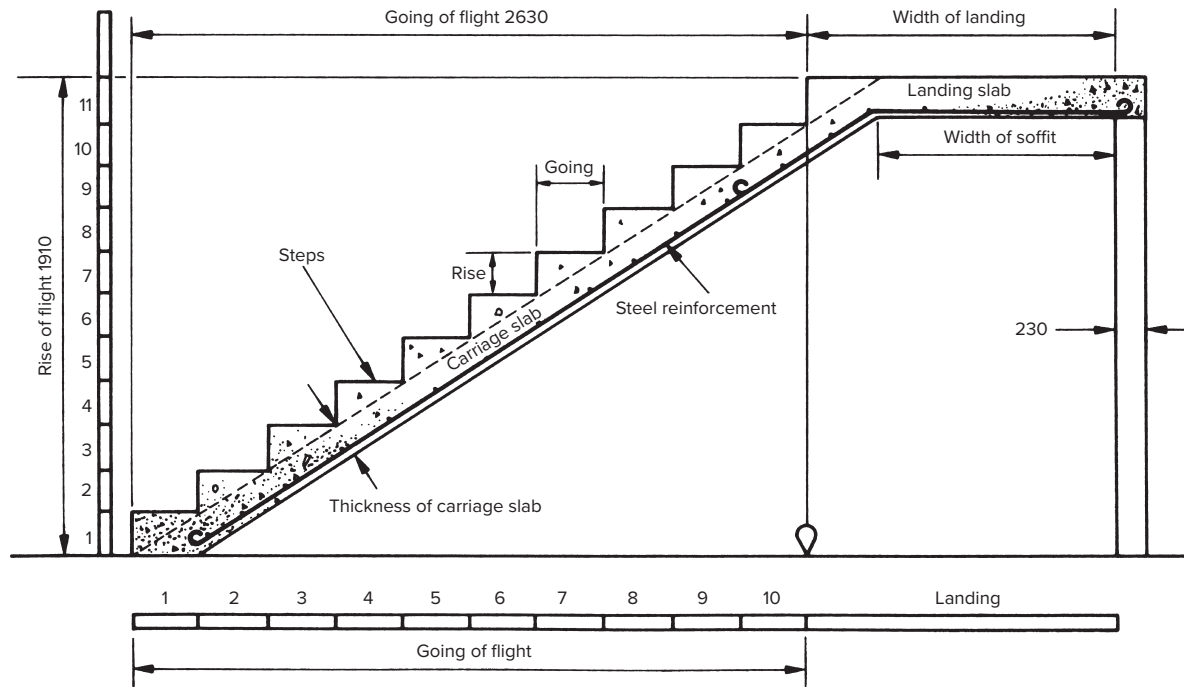
32.4.1.1 Rise

The easiest way to work out the rise of a staircase is to divide the overall height of the job, which is the floor-to-floor measurement, by the maximum rise regulation. This will give you the minimum amount of rise required for the job.

$1910 \text{ mm} \div 190 \text{ mm} = 10.05 \text{ mm}$ (you will need to round up to the next whole number, which is 11 risers)

$1910 \text{ mm} \div 11 = 173.6 \text{ mm}$ (you can round up to the nearest whole number, which is 174 mm)

We can continue this example and work out other suitable rises for this job:

Fig. 32.5 Concrete stairs**Fig. 32.6** Rise, going and slope relationship (NCC)

Stair type	Riser (R)		Going (G)		Slope relationship (2R + G)	
	Max.	Min.	Max.	Min.	Max.	Min.
Stairs (other than a spiral).	190 mm	115 mm	355 mm	240 mm (residential) 250 mm (commercial)	700 mm	550 mm
Spiral	220 mm	140 mm	370 mm	210 mm	680 mm	590 mm
Stairways serving non-habitable rooms used infrequently	225 mm	130 mm	355 mm	215 mm	700 mm	540 mm

1910 mm divided by:

10 risers = 191 mm (cannot use this rise as it does not fit within the NCC regulations)

11 risers = 174 mm

12 risers = 159 mm

13 risers = 150 mm

14 risers = 136 mm

15 risers = 127 mm

16 risers = 119 mm

17 risers = 112 mm (cannot use this rise as it does not fit within the NCC regulations)

Using the regulations, we would be able to use any of the risers above that fall between the NCC regulation of the minimum and maximum rise.

32.4.1.2 Going

The going in this example has been restricted to a maximum of 2630 mm from the starting point. Each staircase will have one less going than riser or one less step than riser. The easiest way to work out this calculation is to select a previously calculated rise such as 11 risers at 174 mm. This example would have 10 goings:

$$2630 \text{ mm} \div 10 = 263 \text{ mm}$$

We can continue this example and work out other suitable goings for the job:
2630 mm divided by

- 11 = 239 mm (cannot use this going as it does not fit within the NCC regulations)**
- 10 = 263 mm
- 9 = 292 mm
- 8 = 329 mm
- 7 = 376 mm (cannot use this going as it does not fit within the NCC regulations)**

Comparing the calculations from the rise and the going that we have completed, we can see that the only suitable going for the job (with a restricted going start point) is:

$$\text{Riser} = 11/174 \text{ mm}$$

$$\text{Going} = 10/263 \text{ mm}$$

The next step is to make sure our calculations are within the slope relationship formula (Fig. 32.6):

$$2R + G = 550 - 700 \text{ mm}$$

$$2 \times \text{riser} + \text{going} = \text{between } 550 \text{ and } 700 \text{ mm}$$

$$(2 \times 174 \text{ mm}) + 263 \text{ mm} = 611 \text{ mm}$$

Therefore, the rise and going are satisfactory as 611 mm falls between the minimum and maximum of the slope relationship regulation.

32.4.2 Carriage slab

The carriage slab is designed to support the mass of the stair, so it is important that this is made to the correct thickness. No encroachments into this thickness are allowed, e.g. through undercutting the risers or by using a riser shutter that is too wide. The carriage slab is reinforced with steel, which must be accurately placed in accordance with the engineer's drawings before the riser **shutters** are finally fixed in position.

See the steps below for setting out the string shutter (refer to timber external stairs on how to mark out stringers):

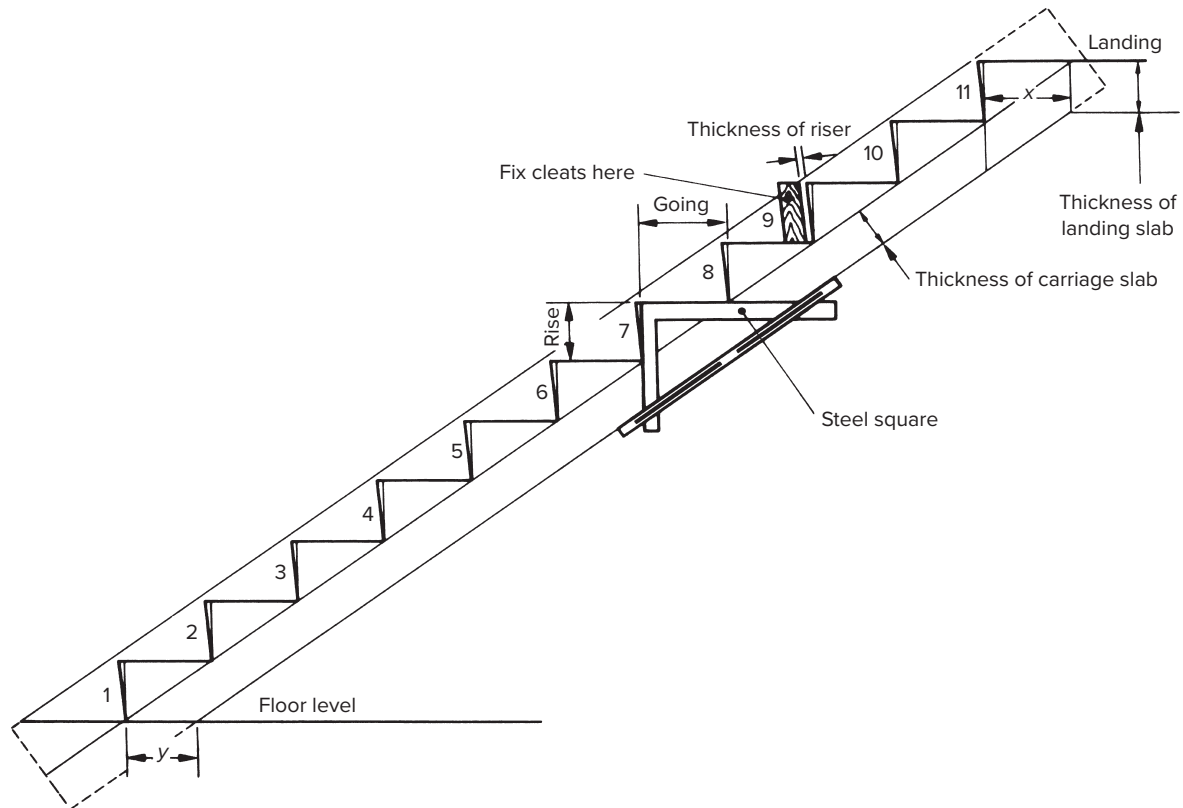
1. From the bottom of the string shutter, gauge a distance equal to the thickness of the carriage slab.
2. Lay the steel square on the shutter; from the line gauged for the top of the carriage slab, set off the going along the blade and the rise along the tongue. Fix the fence along the bottom edge of the shutter to this setting.
3. Commencing from rise 1 at floor level, set off accurately the number of rises (11 in this example). The last rise will establish the landing level.
4. It is common practice to add a splayed front to the face of the risers—a maximum of 25 mm is permitted. This can be treated in the same way as a nosing and, of course, the same splay must be made to each riser. From the face of the riser, allow for the thickness of the riser shutter and fix cleats to support the shutter (see rise 9, Fig. 32.7).
5. Set out the second string shutter by turning the steel square over and repeating the procedure to form a pair of shutters.
6. From the full-size set-out of the string, other useful dimensions can be measured off. For example, the distances shown as *x* and *y*, which will help to establish the width of the landing slab (*x*) and the run-out point (*y*) for the soffit decking, can be measured.

The completed formwork is seen in Figure 32.2. Note how the stringer is placed over the risers and brackets. Alternatively, blocks are fixed to prevent the shutters bulging in the centre. The stringer must then be made rigid by strutting back to a fixed point. The soffit decking is made wider than the stair to permit the string shutters to be fixed and braced back on the outside (Fig. 32.8).

CHECK YOUR UNDERSTANDING

4. What is the purpose of bracing the stringer?

Fig. 32.7 Set-out of the string shutter



32.5 Finish stair treads

After the structural concrete has been poured and cured, the stair treads can be finished off in a variety of ways. A common finish is cement render, approximately 15 mm thick. It is finished to a non-slip surface, sometimes with the addition of a coarse carborundum grit sprinkled in strips along the stair treads.

The important point to note is that the same thickness of topping must be applied to all treads and landings if the rise in all cases is to remain constant.

The situation can arise where a different thickness of finish is to be applied to the treads than to the landings; if the correct rise is to be maintained to the finished surface, some modification to the structural concrete is called for. Any error caused by a failure to do so usually occurs at the first and last rise.

To give an extreme and perhaps unlikely example, suppose the top and bottom landings to a stairway are to be finished with stone paving to a total thickness of 50 mm, whereas the stair treads are to be cement, rendered to a thickness of 15 mm.

Fig. 32.8 Bracing the string shutter

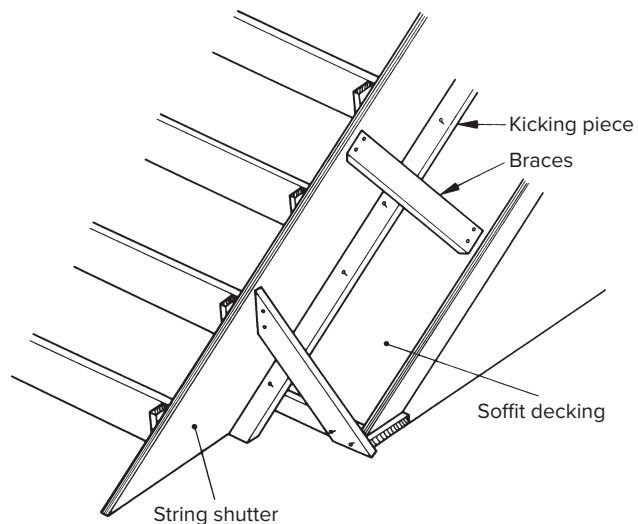
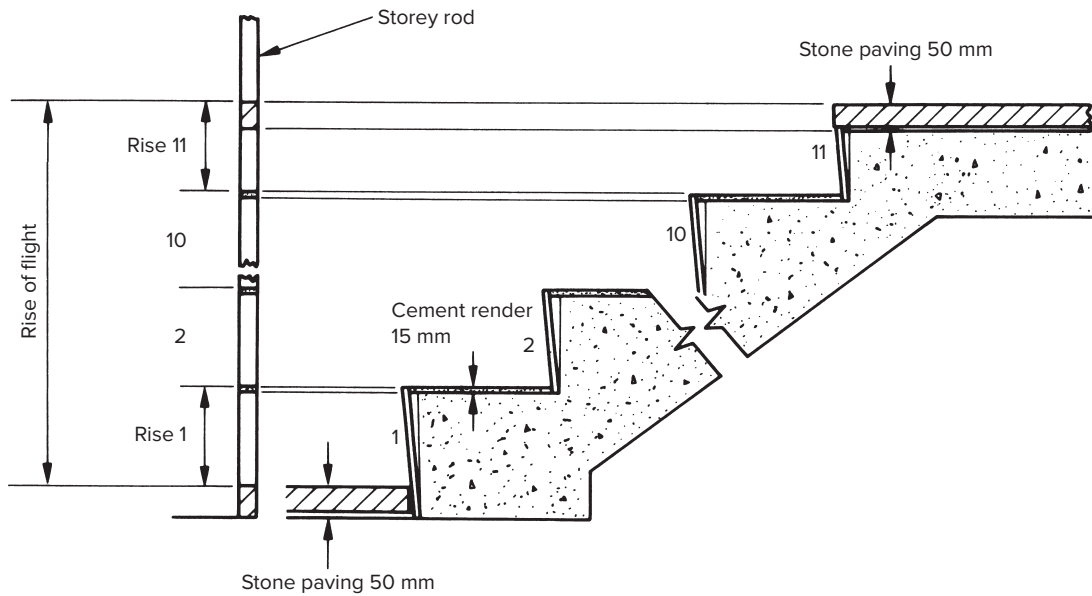


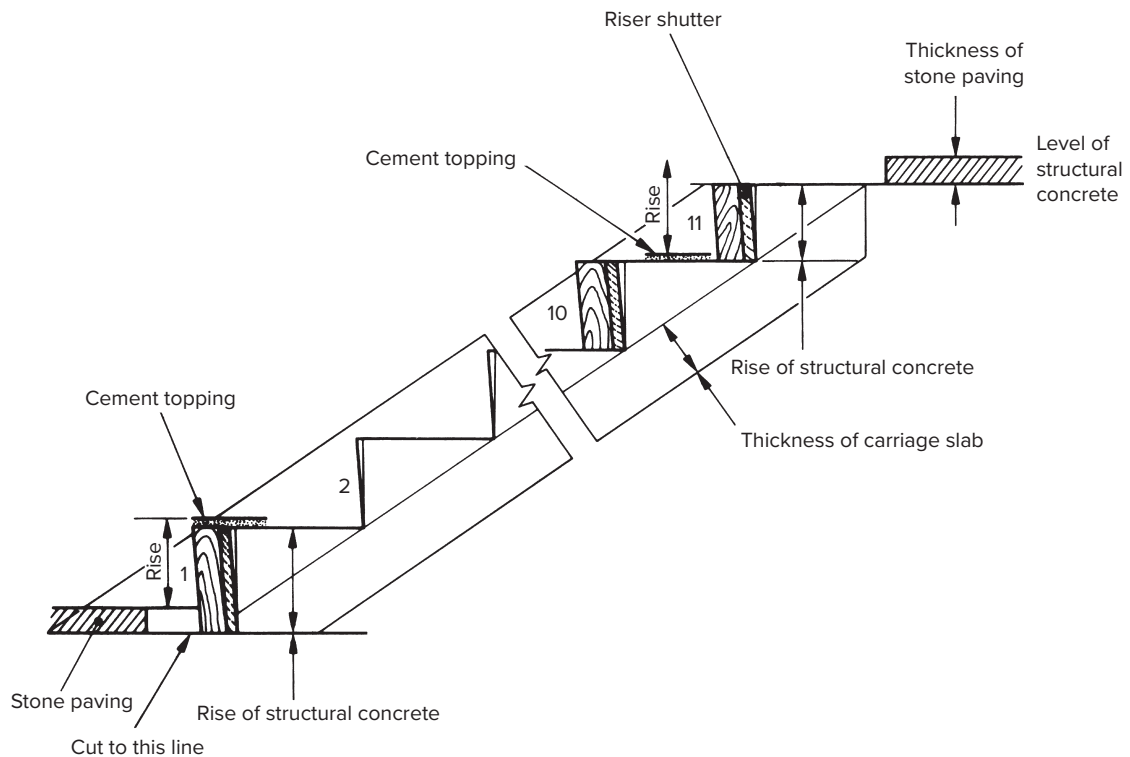
Figure 32.9 shows a vertical section through the first and last risers. Note how the thickness of the finish is shown on the storey rod and the rise of flight is between the finished surfaces.

Fig. 32.9 Finishes to treads and landings



The adjustment of the set-out of the string shutter is illustrated in Figure 32.10 and described below. First, set off the required number of rises and, if specified, add the splayed face; carry this out in a similar manner as previously described up to step 4 in the procedure for setting out the string shutter.

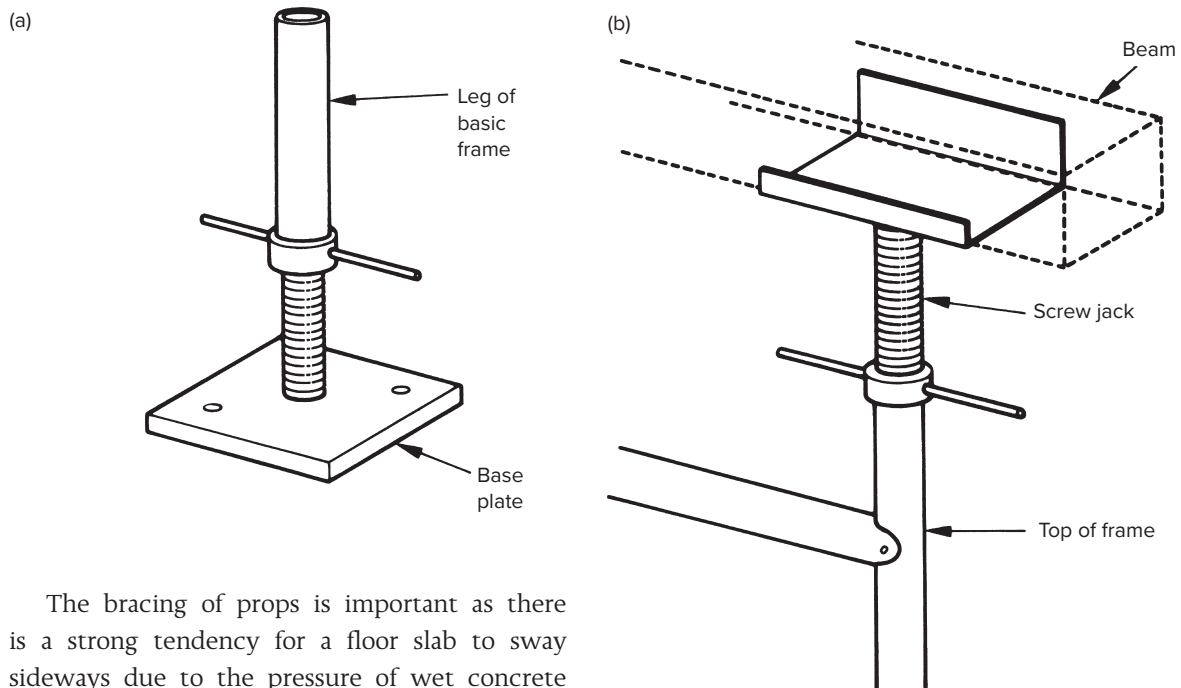
Fig. 32.10 Adjustment of the string shutter



At rise 1, add the thickness of topping to the tread. From this point, measure down the rise plus the thickness of the stone paving. This will establish the rise of the structural concrete and the line at which the shutter will be cut to length. At the last rise (rise 11 in this example), add the thickness of the topping to the last tread. From this point, measure up the rise and deduct the thickness of stone paving to establish the level of the structural concrete to the landing. Fix cleats to support the riser shutters.

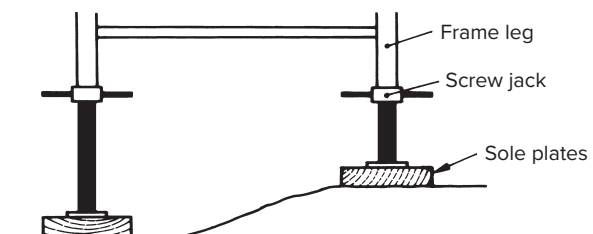
On firm surfaces such as a concrete floor, frames are supported on the base plates 200 mm × 200 mm, but on sloping ground it is necessary to level the frames through the use of screw jacks fitted into the legs (Figs 32.11 and 32.12). Set up the first screw jack on a solid sole plate at the highest part of the ground and adjust it to its lowest position, then level the frames by adjusting the other screw jacks. Frames can be coupled together with diagonal bracing to cover any area and to support bearers and joists. Set out to support plywood or timber decking panels.

Fig. 32.11 Adjustable screw jacks: (a) foot of basic frame; and (b) top of frame



The bracing of props is important as there is a strong tendency for a floor slab to sway sideways due to the pressure of wet concrete plus the movement caused by personnel and the equipment used to transport and place concrete. Newly erected masonry walls cannot be relied upon to provide lateral stability. Lateral bracing must be provided no more than 300 mm from the top and bottom of the props, and diagonal bracing must be provided in both directions, fixed as close as possible to the top or bottom of the props.

Fig. 32.12 Levelling base frames



CHECK YOUR UNDERSTANDING

5. What would be used on sloping ground to level the frames?

32.6 Build ramps

Access ramps may be formed in the same way as a suspended concrete slab or carriage slab for stairs with a sloping soffit, but there are standards to be applied from AS 1428 Design for access and mobility, with regard to the slope angle and the dimensions of ramps. The following notes apply to a concrete structure forming a ramp (see Figs 32.13, 32.14 and 32.15). For details on handrails and supporting posts and any other information on design for access and mobility, please refer to AS 1428.1: 2009 Design for access and mobility, Part 1 General requirements for access—new building work.

Fig. 32.13 Straight ramp with no change in direction

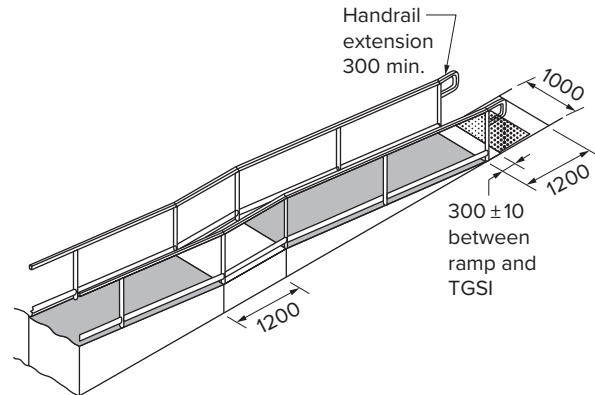


Fig. 32.14 Ramp with 90° return and an internal landing

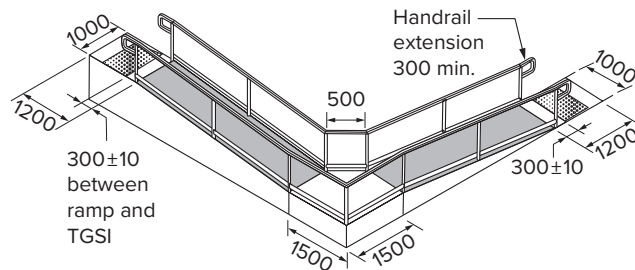
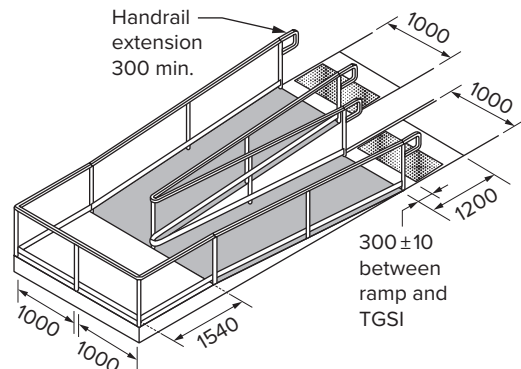


Fig. 32.15 Ramp with landing and 180° return



Ramps must meet the following requirements:

- Ramps that are more than 1900 mm long must have a maximum gradient of 1:14.
 - No section can be steeper than 1:14 and gradients must be constant with a maximum tolerance of 3%.
 - Landings must be incorporated at the bottom and top of a ramp with distances between landings not exceeding:
 - 9 m–1:14 grade
 - 15 m–1:20 grade
 Grades between 1:14 and 1:20—intervals are interpolated.
 - The angle of approach must be at 90° to the landing for the last 600 mm of the ramp length.
 - Ramp handrails on both sides must be between 865 mm and 1000 mm above the trafficable surface including transitions and must extend 300 mm into thresholds and landings (except where an inner handrail is continuous), finishing with a 180° bend.
 - Ramps must be set back at least 900 mm from property boundaries where a ramp enters a public walkway/thoroughfare so that the handrail and tactile ground surface indicators (TGSIs) don't extend into the thoroughfare.
 - Ramps must be set back at least 400 mm from the point where a ramp enters other walkways/thoroughfares so that the handrail doesn't extend into the thoroughfare.
- Where ramps include a concrete kerb wall, the following points apply:
- The kerb must be between 65 mm and 75 mm minimum above the finished floor level.
 - The kerb must not finish between 75 mm and 150 mm above the finished floor level.

- If the kerb wall finishes at a height greater than 150 mm, there can be no slots or gaps greater than 20 mm in the distance 75 mm to 150 mm above the finished floor.

32.6.1 Threshold ramps

Requirements for threshold ramps at doorways that connect with a ramp are:

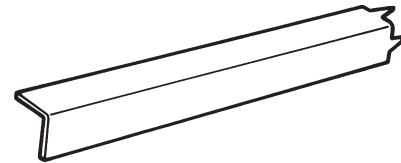
- maximum rise of 35 mm
- maximum length of 280 mm
- maximum gradient of 1:8
- must be located within 20 mm of the door leaf that it serves.

The edges of a threshold ramp are tapered or splayed at a minimum of 45° where the ramp isn't against a wall.

32.6.2 Form spacers

Form spacers are used to maintain the exact distances between forms or between forms and steelwork. Figure 32.16 shows a type of spacer made from galvanised steel. Spikes enable firm fixing to form timbers and can be obtained in lengths from 25 mm to 450 mm.

Fig. 32.16 Form spacers



32.6.3 Form ties

Form ties are used to tie concrete forms together in walls and beams so that they can resist the pressure of liquid concrete, which otherwise would tend to burst them apart. A tie rod with a galvanised pipe bolt sleeve, which also acts as a spacer (Fig. 32.17), is a simple arrangement. Alternatively, a plastic tube with a separate spacer could be adapted.

The disadvantage is that the pipe spacer remains in the concrete; in many situations, this may not be permitted. Besides the objectionable blemish made to the face of the concrete, the pipe spacer will corrode over time; it will also be a likely source of moisture, which will penetrate the concrete and corrode the steel reinforcement. A number of different wall tie systems are manufactured, many incorporating a plastic cone that can be removed from the concrete; the face can then be sealed to prevent the entry of corrosive elements.

Fig. 32.17 Wall tie (pipe spacer)

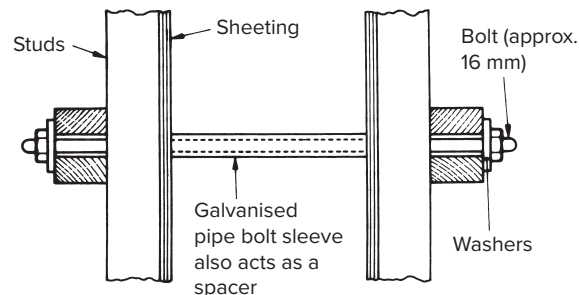
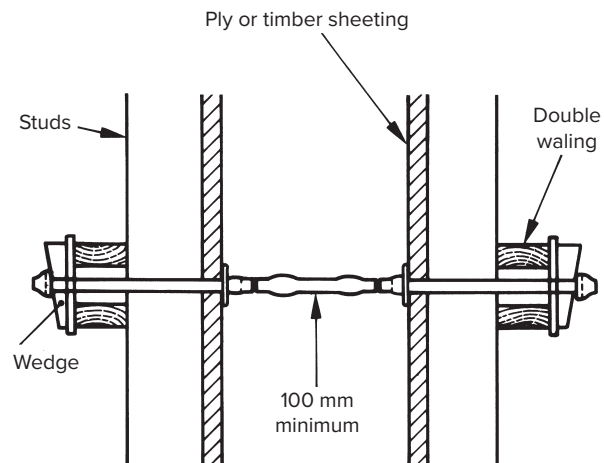


Fig. 32.18 Snap tie



32.6.4 Snap ties

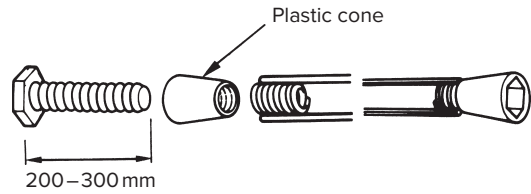
Snap ties are prefabricated from high-carbon wire and act as both ties and spacers (Fig. 32.18).

They are quick and easy to apply using a fast assembly wedge. After formwork is removed, the ties can be snapped off inside the concrete.

32.6.5 Coil ties

Coil ties (Fig. 32.19) are a system of form ties that provide strength, safety and speed. They can be obtained in a large range of sizes to meet the most complex situations.

Fig. 32.19 Coil tie



CHECK YOUR UNDERSTANDING

6. What is the maximum gradient for a ramp 20 m in length? How much does the ramp rise?

Student research

1. With reference to stair construction, define the following terms:
 - (a) rise of flight
 - (b) going
 - (c) stair string
 - (d) tread
 - (e) newel
 - (f) balustrade.
2. State a formula commonly adopted for calculating a suitable rise and going for a stair.
3. Investigate the licensing requirements for formwork installers for each state and territory. Do any still require a formwork licence or 'ticket'?

End-of-chapter activity

Construct, erect, strip and dismantle the formwork for:

- one flight of stairs, freestanding or against a wall with a minimum rise of 1800 mm
- one ramp with a minimum rise of 400 mm and 5.6 metres long.

AUSTRALIAN BUILDING CODES AND STANDARDS



Tradie talk—Time is money

Chapter 33

Construct timber external stairs

Learning Objectives

- LO 33.1 Understand staircase regulations**
- LO 33.2 Explain staircase terminology and components**
- LO 33.3 Describe general staircase design**
- LO 33.4 Understand the general layout of staircases**
- LO 33.5 Calculate the rise and going for a staircase**
- LO 33.6 Identify external staircase design**
- LO 33.7 Understand external open-riser staircase set-out**
- LO 33.8 Construct timber jigs and staircase components**
- LO 33.9 Explain the considerations when building in bushfire-prone areas**

Introduction

Staircases, often simply referred to as stairs, are a means of getting from one level to another. A staircase comprises a series of steps (usually referred to as a flight) that leads from one level to the next. Staircases are often a feature of residential homes or commercial buildings and can be constructed from a combination of materials such as timber, wrought-iron, steel, glass and concrete.

Staircase building has long been recognised as a specialist trade within the construction industry. These days, staircases will most likely be manufactured and installed by a company that specialises in staircase manufacturing rather than a site carpenter and joiner. Such companies will manufacture all of the staircase components off-site in a workshop or factory and then deliver the components to the site for assembly/installation.

A staircase can vary in design and construction, from simple stairs, such as straight flights or winders, to more complex constructions, for instance, a spiral or geometric staircase. The purpose of this chapter is to provide a practical approach to the manufacture, assembly and installation of a basic straight flight external timber staircase.

The material in this chapter complies with the Australian Standards for staircase materials, manufacture and installation as well as the National Construction Code (NCC). Each state and territory will also have its own clarifications of the Australian Standards and the NCC due to the state's climate, the availability of materials and the current information and recommendations from industry and forestry groups.

33.1 Understand staircase regulations

There are many factors governing stair design and construction. The key dimensions you will need to consider when you design stairs are specified in the National Construction Code (NCC) and the Australian Standards relevant to constructing, assembling and installing timber external stairs:

- AS 1657: 2018 Fixed platforms, walkways, stairways and ladders—design, construction and installation
- AS 2082 Timber—hardwood—visually stress-graded for structural purposes
- AS 2858 Timber—softwood—visually stress-graded for structural purposes
- AS 4586: 2013 Slip resistance classification of new pedestrian surface materials
- AS/NZS 1170.1 Structural design actions—permanent, imposed and other actions (general design requirements and loading on structures)
- AS 2796 Timber—hardwood—sawn and milled products
- AS 1786 Softwoods, joinery timber milled from Australian grown conifers (softwoods).

AS/NZS 1170.1 Structural design actions—permanent, imposed and other actions.

Balustrade and railings along with connectors that provide structural support must be able to resist the following factored limit state loads (residential private dwelling):

- 0.9 kN inward, outward and downward load at any point
- 0.53 kN horizontal or vertical
- 1.13 kN for external balconies, stairs and landings
- 0.75 kN for infills and balusters; they should be able to resist this force in any direction.

(1 kilonewton, 1 kN, is equivalent to 102.0 kgf, kilogram force)

National Construction Code (NCC):

- Part 3.9.1 Stairway and ramp construction
- D2.13 Going and rise
- D2.14 Landings
- D2.16 Barriers to prevent falls
- D2.17 Handrails

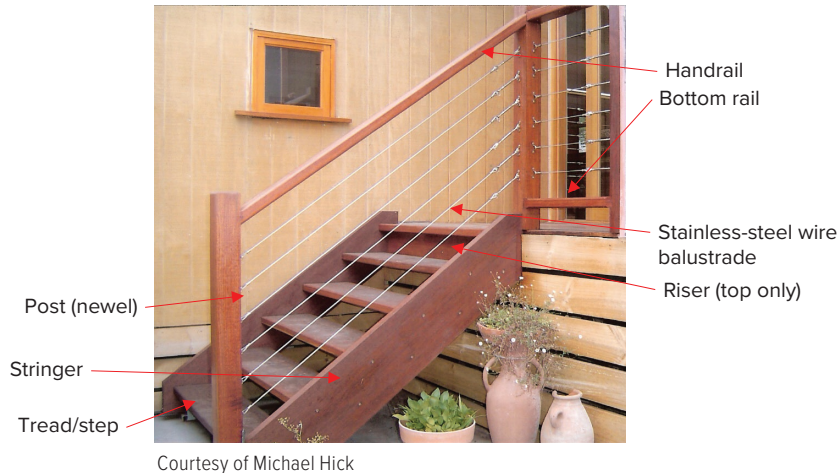
Understanding the regulations will help you determine the design, set-out and construction of your staircase. To be able to interpret the regulations, you need to understand some basic staircase terminology and components.

33.2 Explain staircase terminology and components

The following terms are generally used:

- **staircase:** the entire structure, comprising the steps, treads, risers, strings, balustrading, landings, etc.
- **stairway/stairwell:** the space/void provided for the stairs
- **tread:** the board forming the horizontal top/section of the step, also known as the face of the timber

- **riser:** the board forming the vertical face of the step
- **open stair:** where there are no boards enclosing the space for a riser board
- **staircase string:** the inclined board supporting the ends of the treads and risers; strings can be further sub-divided into closed strings, cut strings and wall strings
- **closed string:** a string that is parallel and housed on one side to support the ends of the treads and risers
- **margin line:** a line marked on the inside face of the string 38 to 50 mm parallel to the top edge; from this line the housings are usually positioned
- **horn/hook:** located at the top nosing on the stringer, this is where the floor meets the stringer. The hook is used to sit on top of the final top landing and supports the stringer during installation; a horn is created at the top of the stringer to sit on the final top landing to support the stringer during the set-up of the staircase—however, it will eventually be cut off and the stringer will be housed inside a post on the top landing
- **cut string (also known as a saw-tooth stringer):** a string cut on the upper edge with a square abutment to which the treads and risers are fixed
- **wall string:** the stringer of a staircase fixed flush with a wall
- **newel post/post:** posts can be located at the top and bottom of the staircase as well as at any change of direction or in the middle of the staircase for extra support. The posts are sometimes turned or carved as a decorative feature of the staircase
- **winders:** the triangular treads used to change the direction of a stair, usually around right-angled corners with a 90° or 180° change of direction
- **landing:** the flat platform usually located where a stair changes direction
- **nosing:** the shaped front edge of the stair tread
- **handrail:** the rail fixed parallel above the string to serve as a guard rail and to give assistance in ascending and descending the stairs, or on its own fixed to a wall with brackets
- **balusters/spindles:** upright members between the string and handrail
- **balustrade:** the combined framework between the handrail and stringer (rake) or handrail and the bottom rail (on a level section)
- **tie bolts:** bolts that prevent the strings from spreading apart, traditionally used on external staircases where the stringers are housed out from the back of the stringer to the front of the nosing for the step
- **nosing line:** the theoretical projection produced if a line is strung across the tip of each nose on the treads of a flight of stairs
- **handrail scroll:** the decorative handrail piece at the start of the stair that curls around and sits above usually the first/bottom step. The bottom step will be larger and protrudes past one side of the stringer (Fig. 33.11h later in the chapter). These steps are commonly referred to as bullnose treads or box treads
- **handrail wreaths:** the sections that curve around corners to form a continuous handrail
- **stanchions:** larger steel or stainless-steel posts at the start and at the corners of the stair which sometimes support glass panels
- **capping:** a section of timber that is fixed to the top of the stringer to form the base, to which balusters can be fixed to the raking balustrade
- **bottom rail:** the piece of timber that forms the edge or border for the carpet or other floor coverings, usually located at the edge of the floor on the upper level
- **geometric/curved staircase:** continuous stairs that turn or wind about a central well hole which has rounded corners or is circular or elliptical and that have the strings, capping and rails arranged upon geometric principles, and running continuously from top to bottom.

Fig. 33.1 External timber staircase with stainless-steel wire balustrade

As shown above, there are many industry-specific staircase building terms, most of which are used in the building and construction of internal staircases. External staircases share many of the same components, such as (Fig. 33.1):

- posts
- stringers
- treads/steps
- handrail
- bottom rail and capping
- balusters/spindles/stainless-steel wire.

Staircases are proportioned so that they can be negotiated safely by the average person, and the dimensions must fall within certain limits. The figures quoted in the following examples are taken from the NCC. The Australian Standards and the NCC regulations may be updated from time to time, so it is your responsibility to make sure you are following the current regulations for your state or territory, and for the municipal council where you are working.

When working on-site, make sure you have completed all relevant documents such as a job safety analysis (JSA) or safe work method statement (SWMS). Take the time to locate services and ensure the workspace in which you are working is free of hazards or that measures have been put in place for potential hazards. Signage may need to be displayed depending on the activity—for instance, if you are using an explosive power tool (EPT).

33.2.1 Head height clearance

The minimum head height clearance above a flight of stairs is 2000 mm, measured vertically from the nosing line, after all coverings have been fitted including carpet, tiles, etc.

33.2.2 Rise

The minimum rise (Fig. 33.2) for a staircase other than a spiral staircase is 115 mm and the maximum is 190 mm. The most important thing to ensure is that all risers in a flight are equal (always refer to the Standards for clarification). A spiral staircase can have a minimum rise of 140 mm and a maximum of 220 mm.

The maximum number of risers in a single continuous flight is 18. Beyond this, an intermediate landing of not less than 750 mm long must be provided.

Fig. 33.2 Rise, going and slope relationship (NCC)

Stair type	Rise (R)		Going (G)		Slope relationship (2R + G)	
	Max.	Min.	Max.	Min.	Max.	Min.
Stairs (other than a spiral)	190 mm	115 mm	355 mm	240 mm (residential) 250 mm (commercial)	700 mm	550 mm
Spiral	220 mm	140 mm	370 mm	210 mm	680 mm	590 mm
Stairways serving non-habitable rooms used infrequently	225 mm	130 mm	355 mm	215 mm	700 mm	540 mm

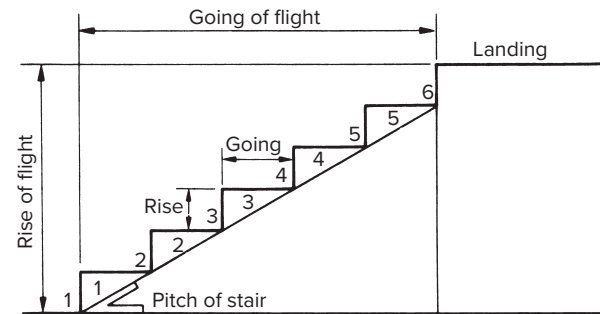
33.2.3 Going

The minimum going (Fig. 33.2) for a staircase other than a spiral stair is 240 mm and the maximum is 355 mm on a residential build. On a commercial build, the minimum going is 250 mm and the maximum is 355 mm. It is important to make sure that the going is consistent (always refer to the Standards for clarification). A spiral staircase can have a minimum going of 210 mm and a maximum of 370 mm.

33.2.4 Mark-out and pitch

The combination of the rise and the going is the pitch of the staircase (Fig. 33.3). The use of these two measurements together become the mark-out of the staircase. The NCC (AS 1657–4.1 Width and angle of slope) stipulates that the angle of pitch of a staircase shall be not less than 26.5° and not greater than 45° (45° is obtained with a spiral staircase).

Fig. 33.3 General layout of stairs



TIP Residential and commercial staircases will work to the minimum going and to the maximum rise. By doing this, the staircase will take up less space, use fewer construction materials and cost less.

33.2.5 Slope relationship

The formula to calculate slope relationship (Fig. 33.2) is twice the rise + going ($2R + G$) = maximum of 700 mm to a minimum of 550 mm, or $2R + G = 700$ mm to 550 mm.

The slope relationship for a spiral staircase has a maximum of 680 mm and a minimum of 590 mm. It also utilises the same formula: $2R + G$.

The combination of riser and going dimensions results in the pitch of the stairs. The maximum pitch for elderly people, young children and people with mobility impairments is recommended at between 33° and 35°. Pitch angles greater than 35° are less suitable for older people and people with disabilities.

The idea of a slope relationship was developed by the 17th-century French architect, engineer, diplomat and author François Blondel. He developed a formula that established the ideal ratio between a staircase riser and tread. Based on observations of people's gaits (a gait is a pattern of limb movements made during walking), the formula suggested that twice the riser height plus the tread depth should be between 610 mm and 635 mm. While there have been variations across countries in applying this formula, it has been widely adopted in stair building.

Australia has developed its own slope relationship based on this principle, using a minimum and maximum rise and going.

33.2.6 Handrails

There are many requirements for handrails and balustrades, and the regulations differ from residential to commercial and public buildings such as primary schools, aged care and healthcare buildings.

On a residential build, the external timber handrail on the flight of stairs (known as a rake or raking balustrade) will be fixed at a height of no less than 865 mm and is limited to a span of 3600 mm between supports (and must comply with AS 1170.1). This height is measured from the finished nosing of the staircase tread to the floor surface of the ramp or landing, and the rail must be continuous between stair flight landings (from one floor level to the next) and have no obstruction on or above it that will tend to break a hand-hold.

A level balustrade will be constructed to a minimum height of 1 m after coverings. 'After coverings' means that you will need to take into account the carpet, tiles and any flooring that is to be laid after the installation of the balustrade and before the completion of the build.

Fig. 33.4 Apprentice practice staircase and rake balustrade



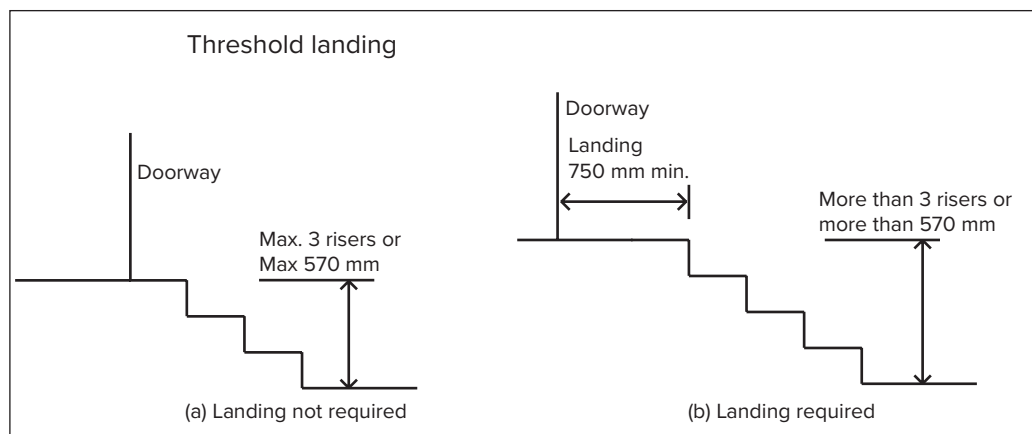
Courtesy of Michael Hick

The NCC also states that the maximum gap between the top of a tread and the underside of the next tread cannot exceed a 125 mm sphere. Similarly, the gap between balusters and other components (e.g. stainless-steel wire) is not to exceed a 125 mm sphere (Fig. 33.4). These rules exist for very good reasons; in this case it is to prevent a child's head becoming stuck. This measurement has been developed to ensure that a child's head cannot become stuck in the balustrade or between the treads—this is an example of child safety being considered as part of design.

Figure 33.4 shows a practice staircase created by apprentices. The staircase is a closed stringer (with treads and risers). The handrail has been set up to the regulation height and the balusters for the rake have been divided out evenly and within the maximum distance between balusters of 125 mm.

Threshold landings (Fig. 33.5) are cases where a landing is required at the threshold of a door. If the height from the ground to the sill of the doorway is less than 570 mm, then a landing is not required; however, if the measurement is over 570 mm, a landing will need to be constructed.

Fig. 33.5 Threshold landing regulations

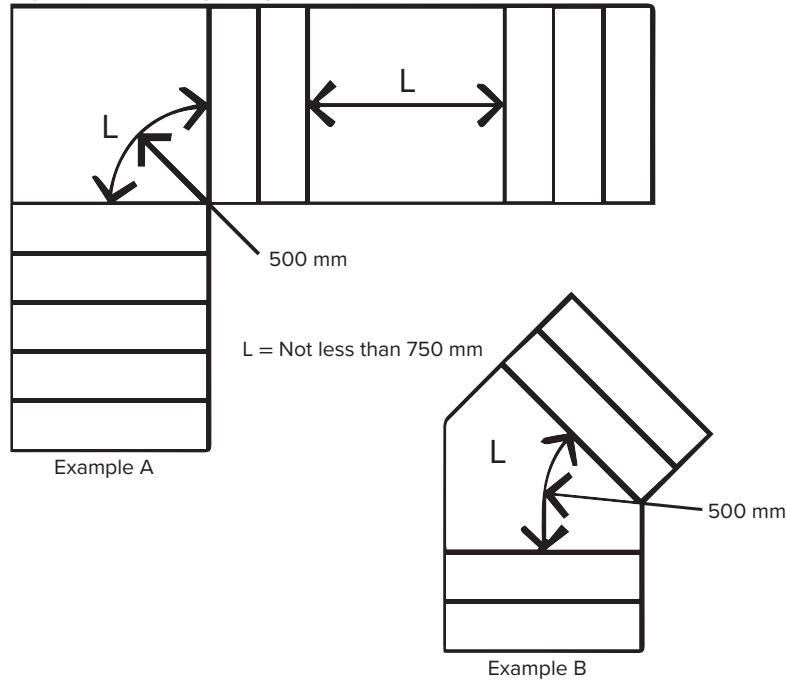


Where the threshold of a doorway is more than 230 mm above the adjoining surface, it must incorporate a step and two risers.

33.2.7 Landings

Landings must not be less than 750 mm long; where this involves a change in direction, the length is measured 500 mm from the inside edge of the landing (Fig. 33.6). The NCC does not prescribe minimum stair widths; however, the Australian Standards does for commercial premises.

Fig. 33.6 Landing design



33.2.8 External ramps

An external ramp serving an external doorway or a ramp within a building must be designed to take loading forces (AS/NZS 1170.1) and have a gradient not steeper than 1:8. Landings must be provided at the top and bottom of the ramp and at intervals not greater than 15 m.

33.2.9 Suitable external staircase timbers

Each state and territory may have its own set of standards for external staircase timbers that addresses issues of locally sourced timbers, materials and climate considerations. Examples of suitable external staircase materials include but are not limited to:

- Treated pine
- Cypress
- Merbau
- Jarrah
- Silvertop ash
- Tallowwood
- Ironbark.

33.2.10 Staircase tread spans

Fig. 33.7 A selection of timber stair tread sizes for external use

Timber type	Stair width (mm)				
	750	1000	1200	1500	1800
	Recommended thickness of tread (mm)				
Treated pine, cypress	40	46	54	70	–
Hardwoods	28	36	42	53	65
Merbau	28	34	40	50	60

33.2.11 Stringer spans

Fig. 33.8 A selection of timber stringer material sizes for external use

Timber sizes	Minimum section sizes (mm)	Staircase width (mm)				
		750	1000	1200	1500	1800
		Maximum number of risers				
Treated pine, cypress	190 × 35	10	8	8	7	6
	190 × 45	11	10	9	8	7
	240 × 35	12	11	10	9	8
	240 × 45	14	12	11	10	9
	290 × 35	15	13	12	11	10
	290 × 45	17	15	14	12	11
Hardwoods and merbau	190 × 35	13	12	11	10	10
	190 × 45	14	13	12	11	11
	240 × 35	16	15	14	13	12
	240 × 45	18	16	15	14	13
	290 × 35	18	18	17	16	15
	290 × 45	18	18	18	17	16

33.2.12 Handrail spans

Fig. 33.9 Handrail spans

Timber	Size/description (mm × mm)	Maximum span of handrail (mm)	
		Within or exclusively servicing one dwelling (excluding external balconies)	
		Timber on its flat	Timber on edge
Hardwood	65 × 65 (profiled)	3000	3000
	90 × 35	3600	3600
	70 × 45	3200	2700
	70 × 70	3500	3500
	90 × 70	3600	3600
Australian-grown softwood	65 × 65 (profiled)	2700	2700
	90 × 35	3200	1600
	70 × 45	2800	2000
	70 × 70	3200	3200
	90 × 70	3600	3400

The span tables in Figures 33.7, 33.8 and 33.9 give examples of a few suitable timbers that can be used for external staircases. When referencing timber member sizes, species and span for staircase stringers and treads, always refer to the AS, NCC and industry standards. Staircases need to be constructed

from durable timbers (AS 2082 and AS 2858). They usually have a solid timber tread; however, you can use a divided tread, with a 13 mm space between the boards. Having a divided tread means that rainwater can run off the divided treads more readily and they will not distort as much as wide boards.

Treated pine is a good alternative to hardwood for an external stair. However, ensure the fixings used in the construction of the stair are suitable for use with treated pine. Waste created from treated pine material that cannot be reused cannot be placed into recycling bins. It needs to be placed in the waste bins for shavings and dust, to be double bagged and disposed of.

CHECK YOUR UNDERSTANDING

1. What is the maximum number of risers allowed in a single continuous flight of stairs?
2. What is the minimum handrail height for a level section of void?

33.3 Describe general staircase design

Figure 33.10 demonstrates the main internal staircase designs from a plan view. Figure 33.11 shows a compilation of different types of stairs and balustrades. External timber staircases will usually comprise a straight flight with a half-space landing or quarter-space landing. Although the other shapes can be used for external staircases, such as the spiral and geometric, they would normally be constructed from metal or concrete.

Fig. 33.10 Internal staircase designs—plan view

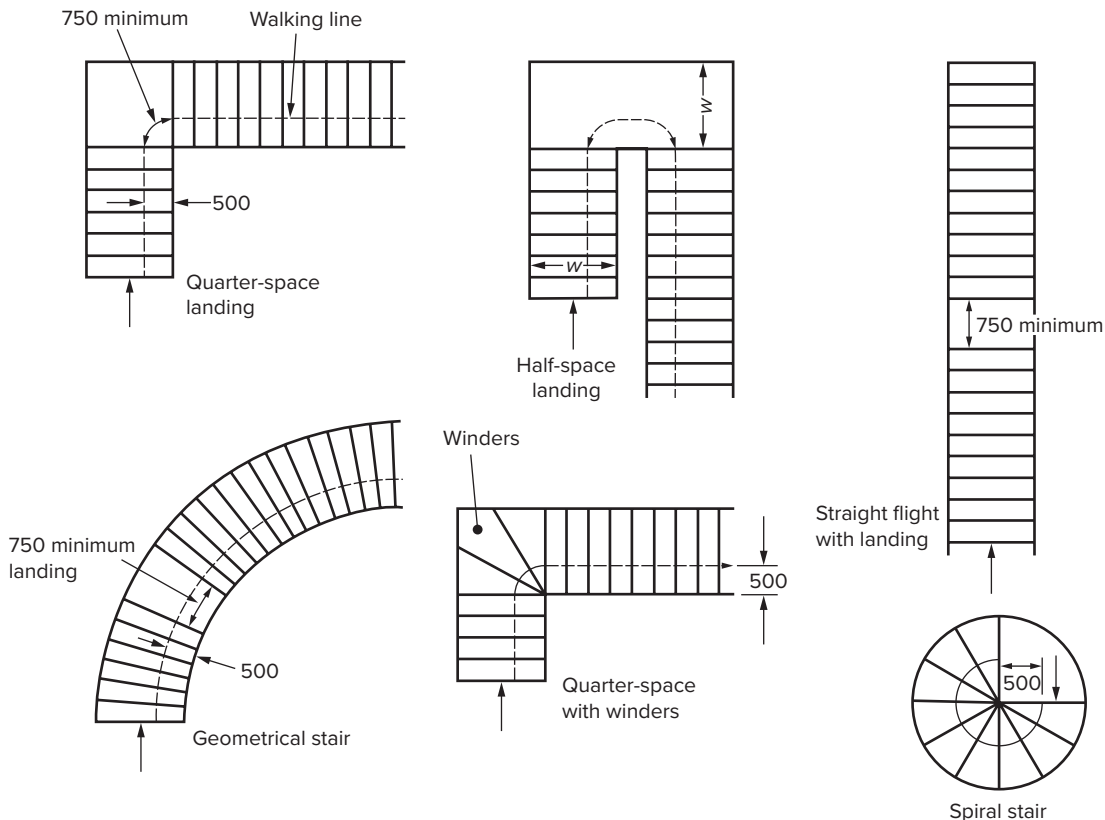


Fig. 33.11 Various staircase designs: (a) double sweeping staircase; (b) half-spaced landing; (c) glass balustrading; (d) quarter-space with three winders; (e) quarter-space with two winders; (f) half-space with six winders; (g) centre-beam staircase; (h) double rounded box treads; (i) wrought-iron balustrade; (j) straight open flight; (k) open flights with quarter-spaced winders; (l) centre beam with stainless-steel balustrade

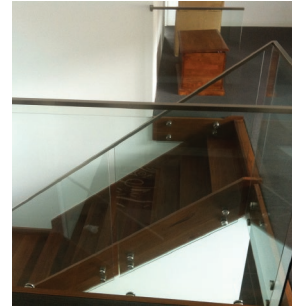
(a)



(b)



(c)



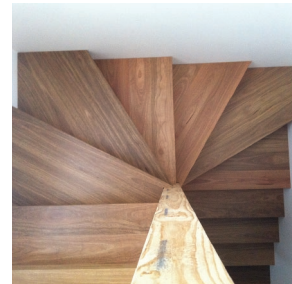
(d)



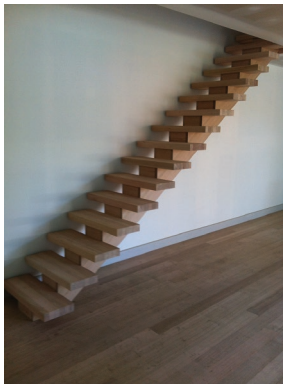
(e)



(f)



(g)



(h)



(i)



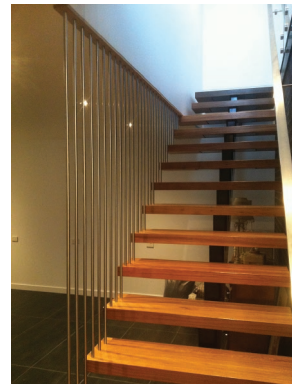
(j)



(k)



(l)



Courtesy of Michael Hick

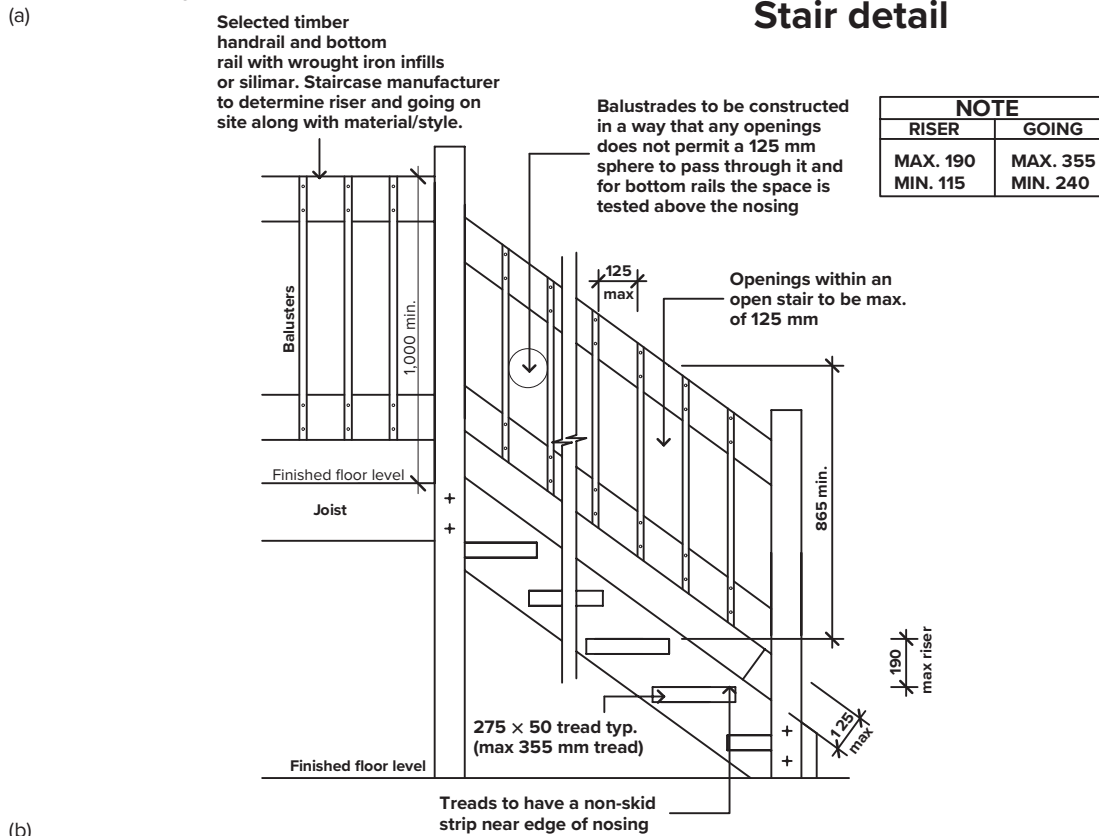
33.4 Understand the general layout of staircases

A stairway is composed of a number of individual steps. The horizontal distance covered by each step is termed the going and the vertical height of each step is the rise. When a number of steps are combined together, they form a flight of stairs. The total horizontal distance covered is the going of the flight and the total vertical distance is the rise of the flight (Fig. 33.3). There will always be one less going than the total number of rises. The angle formed by the rise and going is the pitch of the stair.

33.4.1 Plan reading for external stairs

Staircase design will often involve a discussion between the staircase builder and the client. Staircase details are taken from a set of plans; they can be very generic (Fig. 33.12a) and are drawn on the plans in a basic way that gives the general size and dimensions. A set of architectural plans will usually have a section on 'General Notes' detailing the basic staircase regulations (Fig. 33.12b).

Fig. 33.12 (a) Standard diagram of staircase detail, found in architectural plans; (b) general notes with basic staircase NCC regulations



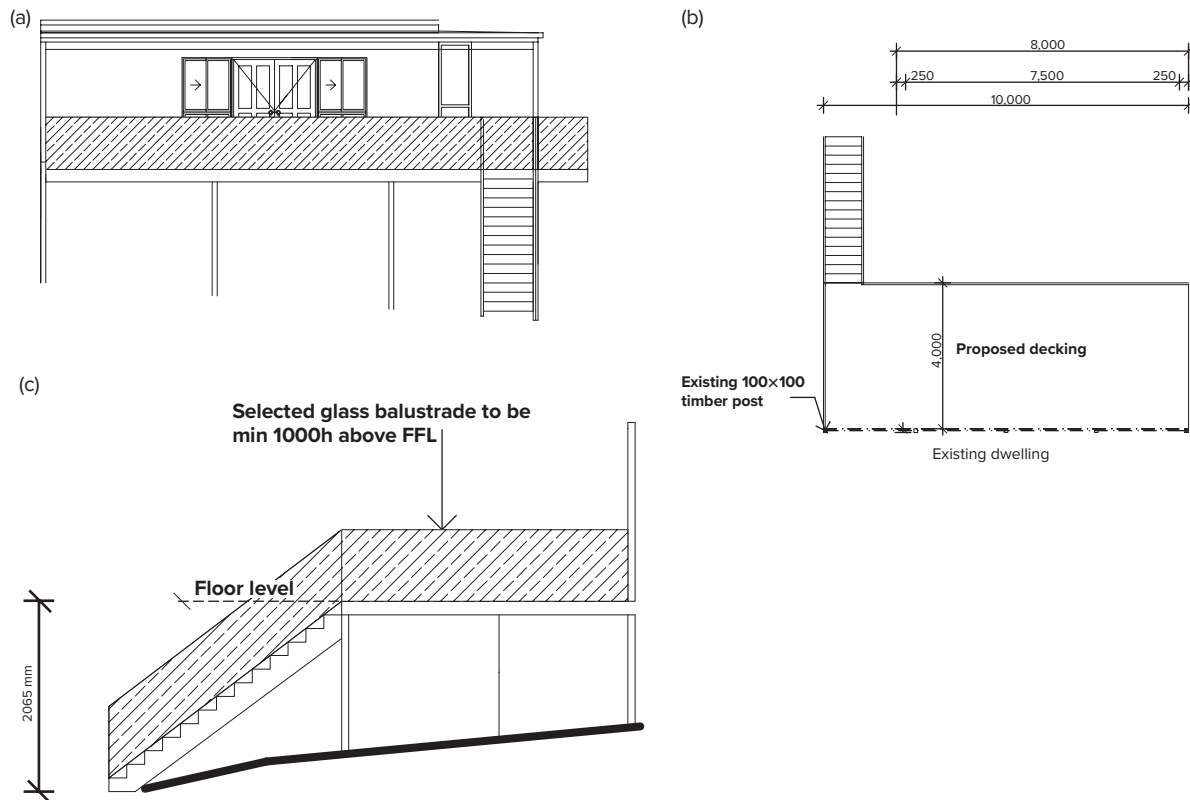
General Notes:

STAIR REQUIREMENTS (OTHER THAN SPIRAL STAIRS):

- RISERS—190 MM MAXIMUM, 115 MM MINIMUM
- GOING—355 MM MAXIMUM, 240 MM MINIMUM, PRIVATE STAIRS (AND 250 MM MIN. FOR PUBLIC STAIRS)
- RISERS AND TREADS TO BE CONSTANT IN SIZE THROUGHOUT FLIGHT. PROVIDE NON-SLIP FINISH OR SUITABLE NON-SKID STRIP NEAR EGDE OF NOSINGS
- ENSURE MAXIMUM GAP BETWEEN RISERS NOT TO EXCEED 125 MM OR USE CLOSED RISES
- PROVIDE CONTINUOUS HANDRAIL 1000 MM MIN.
- HEIGHT TO BALCONIES AND DECKS THAT ARE 1000 MM OR MORE ABOVE GROUND LEVEL: 865 MM MINIMUM HEIGHT HANDRAIL ABOVE STAIR NOSING AND LANDINGS
- MAXIMUM OPENING BETWEEN BALUSTERS NOT TO EXCEED 125 MM
- IF THE THRESHOLD SILL OF THE DOORWAY IS GREATER THAN 190 MM ABOVE THE FINISHED SURFACE OF THE GROUND TO WHICH THE DOORWAY OPENS, A LANDING SHALL BE PROVIDED NO LESS THAN THE WIDTH OF THE DOOR LEAF, OR 900 MM WIDE × 900 MM LONG, WHICHEVER IS GREATER

Figure 33.13a-c shows the position of a proposed staircase in relation to the proposed deck. There are minimum details available, apart from the glass balustrade and the general layout of the staircase. Later in this chapter we will see the actual staircase that was installed at this dwelling (a building in a bushfire-prone area).

Fig. 33.13 (a) South elevation of staircase; (b) east elevation of staircase; (c) plan view of staircase



33.5 Calculate the rise and going for a staircase

To determine the rise of a staircase, we first need to know what the floor-to-floor height is. Figure 33.3 demonstrates this as being from one level to the next landing, e.g. from the deck to the ground.

33.5.1 Calculating the rise

In the following example, the floor-to-floor for our staircase height will be 1500 mm.

To calculate the number of risers required for this floor-to-floor height of 1500 mm, we can use the maximum regulation for a rise, which is 190 mm.

$$1500 \text{ mm} \div 190 \text{ mm} = 7.89$$

This number will need to be rounded up to a whole number, so in this example we will need eight risers.

$$\begin{aligned} \text{To calculate the actual rise: } R &= 1500 \div 8 \\ &= 187.5 \text{ mm} \end{aligned}$$

Therefore, the rise is 187.5 mm.

In this example, you could also have used the following as these risers all fit within the minimum (115 mm) and maximum (190 mm) requirements for the rise regulations:

8 risers	= 187.5 mm
9 risers	= 167 mm
10 risers	= 150 mm
11 risers	= 136 mm
12 risers	= 125 mm
13 risers	= 115 mm

33.5.2 Calculating the going

Typically, when constructing staircases, the minimum going (240 mm) and the maximum rise (190 mm) are used, which creates a staircase that uses the least amount of materials, has the lowest costs and takes up the least space. However, a client or architect may want the staircase to start and finish in a particular position. In these instances, the going may need to be increased. Using our example of the floor-to-floor being 1500 mm, let's add the constraint that the staircase must have a starting point that is a distance of 2400 mm away from the top landing.

The easiest way to work this out is to take the starting point measurement of 2400 mm and divide this by the maximum going (355 mm).

$$2400 \text{ mm} \div 355 \text{ mm} = 6.76$$

Therefore, your staircase will require seven goings (seven steps will be needed); the actual going will need to be rounded up to a whole number.

$$2400 \text{ mm} \div 7 = 342.85 \text{ mm}$$

The actual going will be 343 mm (rounded up) to cover the distance of 2400 mm. However, we will need to check this against the slope ratio to check if it falls within regulation tolerances. Slope ratio formula: $2R + \text{going} = \text{between minimum 550 mm and maximum 700 mm}$ (150 is the difference).

$$\text{Floor-to-floor} = 1500 \text{ mm}$$

The rise we calculated was eight risers at 187.5 mm.

The going has been calculated at seven at 343 mm.

$$2 \times 187.5 \text{ mm} + 343 \text{ mm} = 718 \text{ mm}$$

From this calculation, we have determined that we are unable to use this mark-out combination of rise and going, as it does not fit in with the slope relationship regulation. We will need to add in another going, which will increase the number of risers from eight to nine (nine risers at 167 mm, as stated above).

As we have added another rise and going, the calculation will now be:

$$2400 \text{ mm} \div 8 = 300 \text{ mm}$$

The calculation will be eight goings at 300 mm with nine risers at 167 mm. Again we will need to check that this fits within the slope relationship regulations:

$$2 \times 167 \text{ mm} + 300 \text{ mm} = 634 \text{ mm}$$

This calculation fits within the minimum and maximum of the slope relationship and we will be able to use this for our example staircase.

An alternative way of calculating this example

An alternative way of working out which going to use to cover distance is to use the minimum regulation for a going (240 mm).

Use the example above with a floor-to-floor of 1500 mm and a distance of 2400 mm that needs to be covered by the staircase. We will use the original rise of eight risers at 187.5 mm and the slope relationship equation.

$$187.5 \text{ mm} \times 2 + 240 \text{ mm going} = 615 \text{ mm}$$

The difference from the 615 mm and the maximum slope ratio of 700 mm = 85 mm. This means that the maximum going you can use with the rise of 187.5 mm is:

$$240 \text{ mm} + 85 \text{ mm} = 325 \text{ mm}$$

Let's check if we will make the distance of 2400 mm for our example. Using the slope relationship and the maximum going that we determined we could use with our rise, the calculation will be:

$$2 \times 187.5 \text{ mm} + 325 \text{ mm} = 700 \text{ mm (max. slope ratio)}$$

Using a going of 325 mm, this stair will cover a distance of 2275 mm (7 steps $\times$ 325 mm going), so unfortunately this staircase falls short of the starting point.

We will need to increase the number of risers and goings to be able to make the 2400 mm distance that we need to cover. We will try the equation again with an increase to nine risers with eight goings.

This time, you can do the calculation differently by using the going:

$$2400 \text{ mm} \div 8 \text{ goings} = 300 \text{ mm}$$

Check it against the slope relationship regulations:

$$2 \times 167 \text{ mm} + 300 \text{ mm going} = 634 \text{ mm}$$

This calculation fits within the slope ratio regulations and can be used.

33.5.3 Calculating the pitch

Calculating the pitch of a staircase is important and part of making sure the staircase conforms to the standards and regulations. The NCC (AS 1657–4.1 Width and angle of slope) stipulates that the angle of pitch of a staircase shall be not less than 26.5° and not greater than 45° (45° is obtained with a spiral staircase).

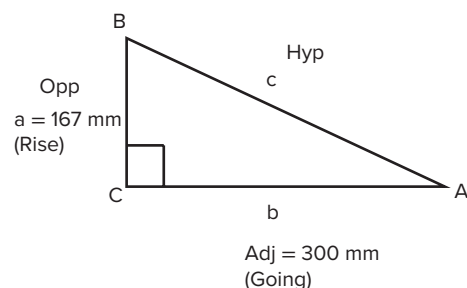
Using our example of a staircase that has a rise of 167 mm and a going of 300 mm, we can determine the pitch of the staircase using trigonometry (refer to Chapter 16, Construction calculations in carpentry work).

To work out angle 'A' (Fig. 33.14), we will need to create a calculation using the laws of trigonometry.

'SOH-CAH-TOA' is a way of remembering which function to use when working out the sides and angles of a triangle (sin = opposite over hypotenuse, cosine = adjacent over hypotenuse, tangent = opposite over adjacent).

To find angle 'A' we would use TOA, tangent = opposite over adjacent. Fig. 33.14 has been labelled with the example of the rise and going that we used previously. To achieve

Fig. 33.14 Labelled trigonometry triangle



this calculation, you will need to use a scientific calculator (most smartphones have this capability). Make sure your calculator is in the DEG(degrees) function and not RAD(radian).

The way that we would write this equation would be:

$$\tan A = \frac{167 \text{ mm}}{300 \text{ mm}}$$

As we are trying to find 'A', we will need to move the 'tan' to the other side of the equation. This will produce an inverse tan:

$$A = \tan^{-1}\left(\frac{167 \text{ mm}}{300 \text{ mm}}\right)$$

$$A = 0.5566$$

The next step is to press the $\tan^{-1}$ button on your calculator (this may be in the 2nd function section on your calculator):

$$A = 29.10^\circ$$

The pitch of our example staircase is 29.10° , which fits within the regulations and we will be able to construct this staircase.

The next step is to determine the length of stringers we will require to construct our example staircase:

Floor-to-floor	= 1500 mm
Rise	= 167 mm
Going	= 300 mm
Distance stair covers	= 2400 mm
Pitch of the staircase	= 29.10°

There are a couple of ways to determine the length of stringer that we will need. One way is to do a full-size set-out and the other is to calculate length using trigonometry or Pythagoras. Fig. 33.15 is a visual representation of the distance from the top of the floor-to-floor to the landing point of our staircase. Side 'c' (the hypotenuse) is the length of the stringer, and as we have two known sides we will be able to use Pythagoras' theorem: $a^2 + b^2 = c^2$ (Fig. 33.15).

To keep this equation simple, it is easiest to convert millimetres to metres:

$$a^2 = (1.5 \text{ m} \times 1.5 \text{ m}) + b^2(2.4 \text{ m} \times 2.4 \text{ m}) = c^2$$

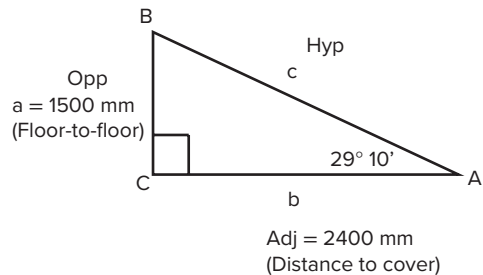
$$a^2(2.25 \text{ m}^2) + b^2(5.76 \text{ m}^2) = c^2$$

$$c^2 = 8.01 \text{ m}^2$$

$$c = \sqrt{8.01 \text{ m}^2}$$

$$c = 2.830 \text{ m or } 2830 \text{ mm}$$

Fig. 33.15 Stringer length using Pythagoras' theorem



The required stringer will need to have some allowances for splits at the ends of the timbers, floor cuts and hooks/horns, so an additional 300 mm should be added to this measurement.

$$2.830 \text{ m} + 300 \text{ mm} = 3.130 \text{ m (when ordering timber you will need to round up to the nearest 300 mm for pine and 100 mm for hardwoods)}$$

$$\text{Stringer length for hardwood} = 3.200 \text{ m}$$

$$\text{Stringer length for pine} = 3.300 \text{ m}$$

Tip Most residential staircases will work to the minimum going either 240 mm or 250 mm. To work out the timber stringer length for this standard minimum going you would multiply the total number of risers by 300 mm and add an extra 300 mm to the length. The extra 300 mm is for plumb cuts, floor cuts, hooks/horns.

CHECK YOUR UNDERSTANDING

3. What is the maximum going for a staircase?
4. What is the minimum rise for a staircase?

33.6 Identify external staircase design

33.6.1 Types of external stairs

As previously mentioned in this chapter, staircase building is a specialised trade and has been so for many years. However, with the trade and technologies changing, stair-building companies have embraced new techniques in staircase manufacture, such as using CNC (computer numerical control) machines. These machines can produce stairs faster and with a high degree of accuracy; as such, companies have expanded into selling staircases off the shelf. Many timber and hardware stores now sell external staircases direct to the DIY market. These types of staircases may be an alternative for a carpenter as they need only to be installed rather than having to be designed, manufactured and installed. Prefabricated stairs can be ordered with 1–17 steps.

33.6.1.1 Examples of prefabricated staircases

Figure 33.16 shows an example of an external powder-coated staircase that can be purchased from timber and hardware stores. It has been set up in a simulated work environment. The stringers come in pairs and are of a standard rise and going (bespoke stringers can be fabricated as a speciality order). This type of staircase is fixed to flat, level ground and comes with instructions to help you install the staircase to AS and NCC requirements. These types of stringers have a maximum set-up width; however, you can exceed the maximum width as long as you add another stringer in the middle. This middle stringer is called an undercarriage or carriage stringer. The wider the stair, the more carriage stringers you will have to install to carry the treads.

Figure 33.17 shows an example of an external galvanised stringer system. The top of the stringer fixes to the joist/wall at the top of the stair and the bottom of the staircase has an extension (Fig. 33.17d) post that is concreted into the ground. Treads are placed onto the plates (Fig. 33.17b) and fixed to

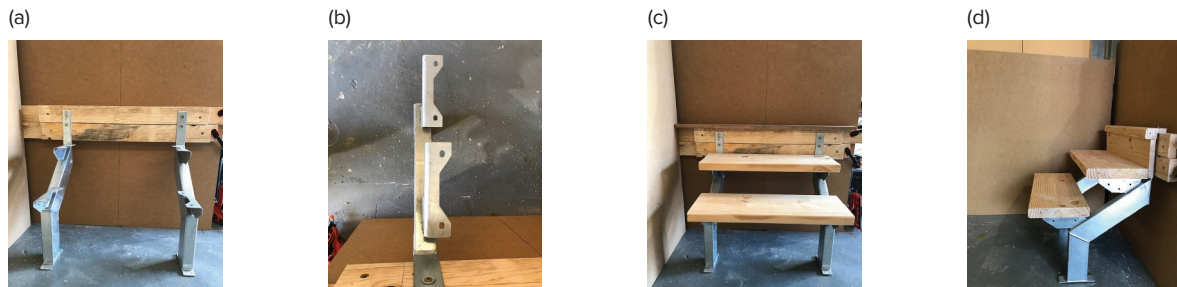
Fig. 33.16 Prefabricated powder-coated stringers: (a) levelling stringers; (b) stringer fixing points; (c) installed treads and top riser and nosing; (d) side view of installed staircase



Courtesy of Michael Hick

the stringer. This system comes in a standard rise and going; however, it can be ordered to a specific mark-out. The manufacturer includes information with all of the AS and NCC recommendations on installation, maximum widths of the staircase and tread thicknesses. Similar to the previous system, you can make the staircase wider as long as you install a carriage stringer that conforms to the AS and NCC.

Fig. 33.17 Prefabricated galvanised staircase: (a) galvanised stringers; (b) tread fixing points; (c) installed treads; (d) side view of galvanised stringers



Courtesy of Michael Hick

Timber staircases (Fig. 33.18) are also available in a kit. They come in a standard rise and going, but can also be made to order. Kits are usually manufactured from treated pine or merbau.

Fig. 33.18 Prefabricated staircase stringer



Courtesy of Michael Hick

33.6.2 Stair tread brackets

An alternative method to building stairs is to use galvanised tread brackets (Fig. 33.19a-d). With this method, you will be able to use the rise and going that you need for a particular job. These are quick to install and can be used with a variety of tread sizes. The brackets are particularly good for using on a carriage stringer (Fig. 33.45c and d later in the chapter).

There are many pros and cons to buying staircases off the shelf from a timber or hardware store. The following are some considerations to take into account when you are estimating the cost of a job.

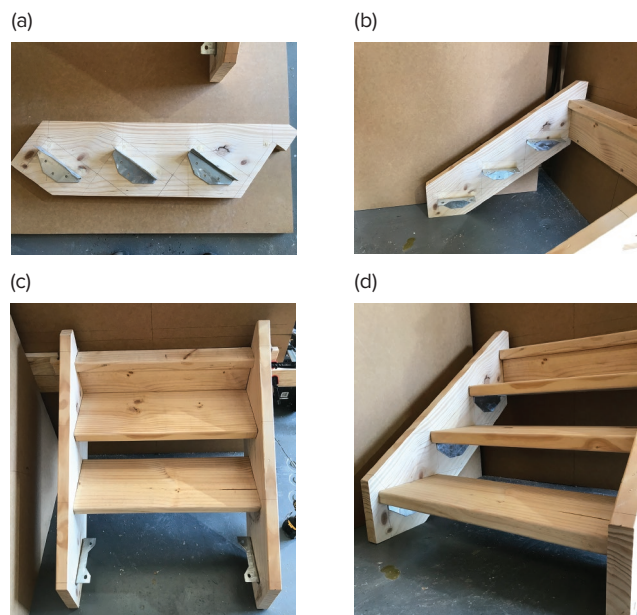
Pros:

- already manufactured to AS and NCC
- components are already machined to size
- saves time and money
- standard components are readily available.

Cons:

- rise and going are standard (so may not work for your job)
- increased price
- limited timber variety available.

Fig. 33.19 (a) Marked-out stringer with brackets; (b) stringer set-up; (c) installation of treads onto brackets; (d) completed staircase using galvanised tread brackets



Courtesy of Michael Hick

33.7 Understand external open-riser staircase set-out

33.7.1 Designing and manufacturing a timber external staircase

An external open-riser staircase is often used to provide access to a verandah or landing as shown in Figure 33.20. When designing an external staircase, there are some constraints and considerations that need to be taken into account. Always make sure you refer to the architectural plans for details of the dimensions of the staircase, the timber to be used, balustrade design, newel post and the starting and finishing point of the staircase.

When working out the levels for an external staircase, you will need to know the starting point and the finished ground level of the staircase. In some instances, the deck, pad or concrete path are already in place and you can simply level out to the finishing point with a level or long straight edge and measure an accurate floor-to-floor. Figure 33.20 shows an example of getting a floor-to-floor measurement from one deck to another.

However, sometimes the finished ground levels have not been completed and all you have to work with is a mark/peg in the ground that had been determined from the RL (reduced level—the height or elevation above the point adopted as the site datum for the purpose of establishing levels).

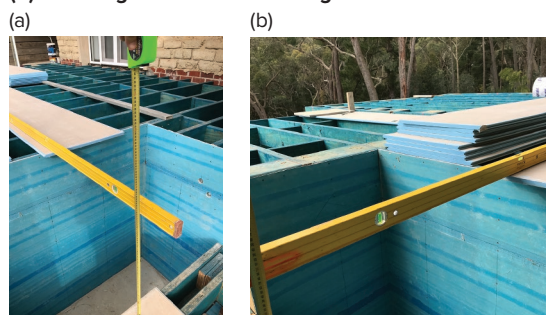
To achieve an accurate floor-to-floor, you will need to level out from the dwelling using a straight edge and a level and combine the two measurements together from point A and B (Fig. 33.21).

At times, the staircase may not have a designated ground finishing point and it will be up to the carpenter to determine the best fit for the staircase. One way of determining a ground point is to create a large pitch board with a comfortable rise and run (240 mm × 175 mm, for example). Place the pitch board against the house/wall/joist and string a line along the hypotenuse, then mark the ground with a peg to mark the finishing point of the stairs (Fig. 33.22). Then, using a straight edge and a level from the base of the dwelling, you will be able to plumb down from the straight edge to the peg. The combination of dwelling measurement A and measurement B will give you an accurate floor-to-floor to create a mark-out for your staircase.

33.7.2 Marking out stringers

There are a few ways of marking out stringers. A traditional method, still used today by carpenters who occasionally build stairs, involves a pitch board. A pitch board is prepared from a piece of plywood that has two edges at right angles to each other. On one edge the rise is marked and on the other edge the going is marked. Other information that can be placed onto the pitch board includes the margin line that has been developed. A timber cleat can be attached to the board to make it easier to move along the edge of the stringer and help increase accuracy (Fig. 33.23).

Fig. 33.20 (a) Measuring a floor-to-floor;
(b) levelling out to floor/landing



Courtesy of Michael Hick

Fig. 33.21 Determining floor-to-floor measurement from known RL

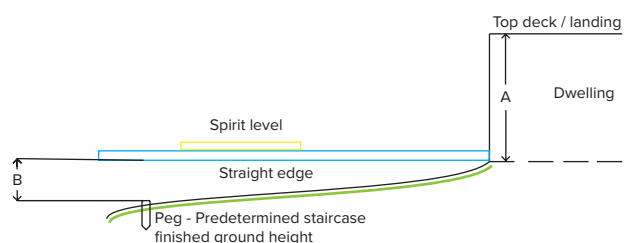


Fig. 33.22 Pitch board and string line

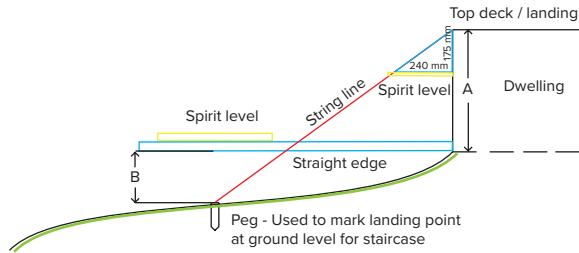
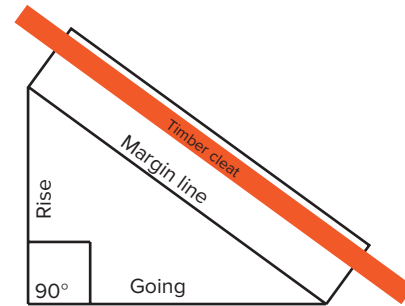


Fig. 33.23 Pitch board



The builder's square marking gauge is an alternative way to set out the string (Fig. 33.24-a-c). There is a direct relationship between the rise and the going, which are at right angles to each other, meaning you can use a builder's square to set up the pitch/angle of the stair. To set up the pitch, place the builder's square onto the stringer, and use the long blade of the square as the going and the short blade of the square as the rise. The relationship between these two numbers forms the pitch of the stair and will also be referred to as the mark-out of the staircase.

Fig. 33.24 (a) Angle gauges for builder's square; (b) builder's square with angle gauges; (c) marking gauge with timber cleat



Courtesy of Michael Hick

33.7.3 Chapter example staircase

The example staircase for this chapter will be constructed in a simulated work environment. We can use a simple job card to record the information for the staircase (Fig. 33.25). The job card will have key information to aid the manufacture of the staircase components and help with the installation. The card will have space to enter the type of timbers used, rise, going, floor-to-floor and space for a plan-view sketch of the job with all of the relevant information required for the installation. We will be making some estimations on the lengths of material needed. Using the information we developed for the stringer length, we can estimate the length of the stringers, handrails, capping and fillet for this example staircase (Fig. 33.26). The pitch of the staircase has been developed in Figure 33.27.

Figure 33.27 shows the trigonometry equation used to determine the pitch of the example staircase.

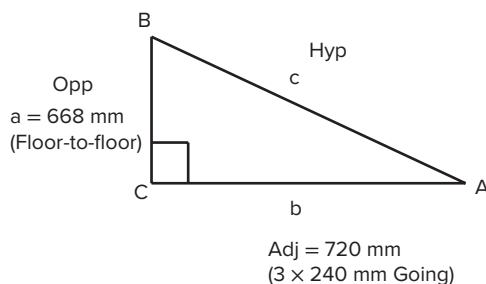
Fig. 33.25 Simple staircase job card internal/external

Client: _____		Quote number: _____		
Job Address: _____				
Contact: _____				
Phone Number: _____				

Stair details	Stair component	Materials	Materials sizes	Checked
	Stringers			
Floor to Floor	Treads			
	Risers			
Risers	Long post/s			
Mark out	Post/s			
	Winders			
Floor coverings top	Landing			
	Balustrade			
Floor coverings Bottom	Rake Balustrade			
	Handrail only			
Notes:	Nosing			
	Post caps			
	Fillet			
	Joists			
	Misc			

In Figure 33.26, we use the floor-to-floor measurement and the total goings to help determine the stringer length. As we calculated before, we will need to add another 300 mm to the answer to account for plumb cuts, floor cuts, hooks and horns.

$$\text{Stringer length} = 982.10 \text{ mm} + 300 \text{ mm} = 1282.10 \text{ mm}$$

Fig. 33.26 Example staircase stringer length

Pythagoras' theorem—stringer length

$$a^2 + b^2 = c^2$$

$$(0.668 \text{ m} \times 0.668 \text{ m}) + (0.72 \text{ m} \times 0.72 \text{ m}) = c^2$$

$$c^2 = 0.4462 \text{ m} + 0.5184 \text{ m}$$

$$c^2 = 0.964 \text{ m}$$

$$c = \sqrt{0.9646} \text{ m}$$

$$c = 982.10 \text{ mm}$$

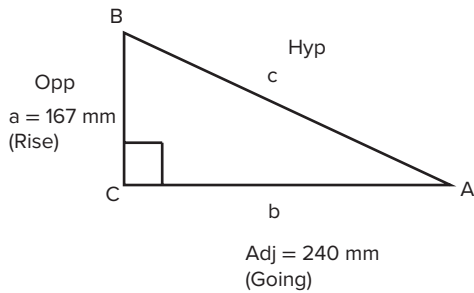
Staircase information:

Floor-to-floor: 668 mm

Rise: 167 mm

Going 240 mm

Pitch 34.83°

Fig. 33.27 Example staircase pitch**Quick calculations**

Trigonometry—pitch of staircase

$$\begin{aligned}\tan A &= \frac{167 \text{ mm}}{240 \text{ mm}} \\ A &= \tan^{-1}\left(\frac{167 \text{ mm}}{240 \text{ mm}}\right) \\ A &= 0.695833 \text{ rad} \\ A &= 34.83^\circ\end{aligned}$$

The nearest full-size treated pine stringer that we can order is 1.5 m. We will use this measurement to also order the handrail, capping and fillet at the same length.

The bottom post for this staircase will be supported by a post anchor and as such we will need only the minimum bottom post of 1200 mm. If the post was to be concreted into the ground, we would need to allow for the extra length. Balusters can be worked out to be two per step—the reason for this is that the staircase has a 240 going, so you can fit two of the 40 mm × 40 mm balusters within this going and not exceed the 125 mm balustrade regulation. As such, you can order two balusters per going and add an extra two balusters as a percentage of waste.

33.7.4 Manufacturing an external staircase

The tools used by a general carpenter to construct an external timber staircase would include the following:

- hand tools, e.g. hand saw, hammer, chisel
- builder's square
- router, drills, electric plane, belt sander/orbital sander
- power saw/drop saw
- hammer drill
- nail gun fixing/framing.

Always make sure your tools are well maintained and serviced. For each job, ensure you have completed all safety requirements such as a JSA and SWMS and you have referred to and adhered to the material safety data sheet (MSDS) regarding the products you are using, such as paints and finishes.

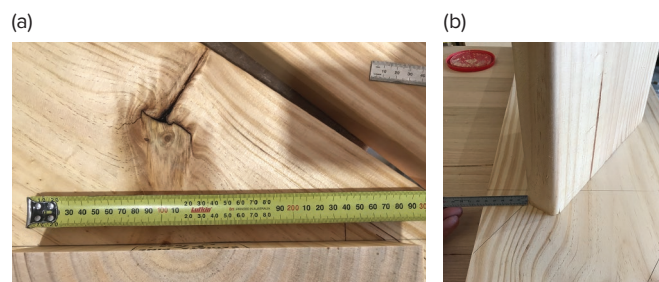
Once you have the floor-to-floor measurement, you will be able to start marking out your stringers. The following example staircase has been constructed in a simulated work environment, and has been developed and constructed using one type of staircase manufacturing method. There are various way of building staircases that will meet the AS and NCC standards.

When selecting timbers for stringers that have already been dressed all round (DAR), select the best lengths that you can—those that are straight. If there is excessive bowing in the timber along its edge, you may need to set up a straight edge and machine a straight parallel edge into the timbers.

The bows of the timber across its width will point in and the stair will be marked on this face. The reason for this is that as you are constructing the stair and installing each step, they will push the bow out of the timber.

Use your builder's square with the long side as the going and the shorter side as the rise.

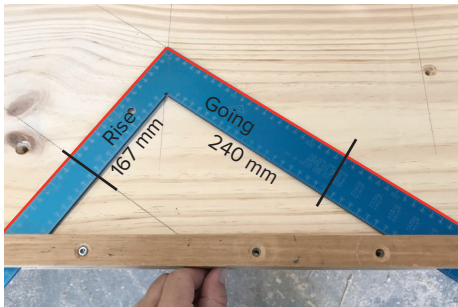
In Figure 33.28a, a mark-out line (going) has already been drawn onto the stringer and we will be using this line to help us determine a margin line. When creating a margin for your open-tread staircase, cut yourself a piece of timber that represents the size of the tread so you can see that you

Fig. 33.28 (a) Mark-out line; (b) checking the margin at the front is even

Courtesy of Michael Hick

Fig. 33.29 Setting up a marking gauge

Courtesy of Michael Hick

Fig. 33.30 Marking out with a builder's square and timber cleat

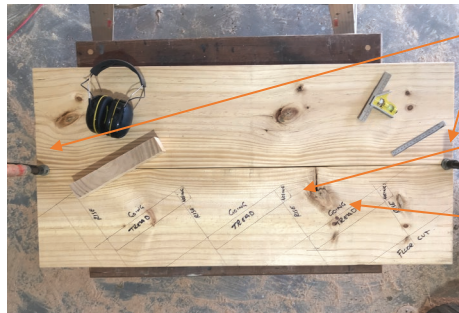
Courtesy of Michael Hick

where the rise and going are, as you then slide the marking gauge along to mark out the next rise and going. Where you have marked 240 mm, the marking gauge should intersect with the 167 mm rise on the marking gauge.

have an even margin at the front (Fig. 33.28b) and at the back of the tread if possible. In this example, we have been able to make the margin even at the front and back, so the staircase will still have all of its strength as well as an aesthetic balance.

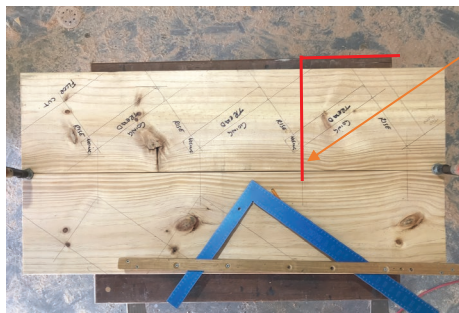
Using the measurements on the inside edges of the square, set the rise and the going on the edge of the stringer, e.g. 167 mm rise and 240 mm going. Draw this line on the stringer—once you have this line, it represents the pitch of the staircase (Fig. 33.29). You will now be able to set up your gauge to anywhere on the pitch line, taking into account your margin line.

The builder's square is held in position using either two angle gauges (Fig. 33.24a and b) or two cleats (Fig. 33.24c), one on either side of the builder's square. A handy tip is to screw these two cleats together with screws and wing nuts to help make it easy to adjust between different stair-building jobs. Place the cleat hard up against the edge of the timber and you can start marking out the job from one end of the stringer (usually you would start marking out from the bottom of the staircase). As shown in Figure 33.30, we mark in where the red line is, paying close attention to the rise of 167 mm and the going of 240 mm (in regards to this example). Put a mark

Fig. 33.31 Right-hand stringer marked out

Courtesy of Michael Hick

- To help keep the stringers straight, it can be a good idea to clamp them together.
- When marking out the stringers, take a moment to make sure the rise is correct.
- When you have marked out the stringer, take the time to mark in where the treads are located. That way you will avoid routing your housing joint out on the wrong side of the line.

Fig. 33.32 Marking out the left-hand stringer

Courtesy of Michael Hick

- When transferring guidelines from one stringer to the other, use a builder's square from the edge of the timber across the face of the timber. Square through the intersection of the rise and the going. When marking the other stringer, make sure you flip the marking gauge over—remember you are making a left-hand and a right-hand stringer.

Fig. 33.33 Checking that the left and right stringers line up

Courtesy of Michael Hick

- Once both stringers are marked out, double check that they are marked out as a mirror image of each other. One check is to see if all marking lines intersect. A common mistake is to mark out either two left-hand stringers or two right-hand stringers.

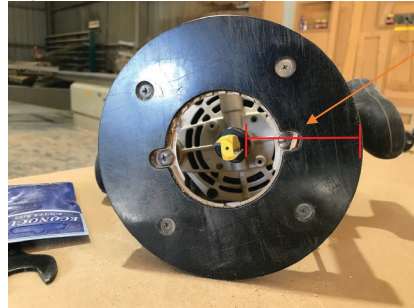
When marking out a stringer, make sure:

- you have enough space for the floor cut
- you have left on at least 50 mm in front of the bottom rise (to make sure the tread remains inside the stringer)
- at the top end of the stringer, you construct a hook (to sit on the top floor/landing) or horn (to be recessed/mortised into a post), to be cut out, as well as creating space for a top riser board to go in; the top riser board hides the joist as well as any visible fixings.

33.8 Construct timber jigs and staircase components

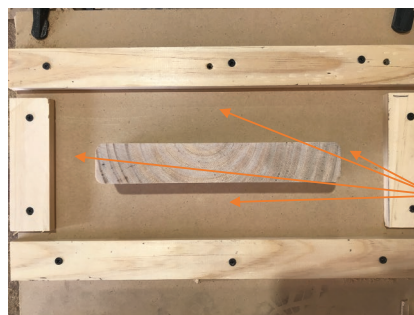
33.8.1 Construct a simple tread jig for stairs

There are a variety of ways to cut out the tread housing into the stringer; a simple way of achieving this is with a router and a simple timber jig (Figs 33.34–33.41).

Fig. 33.34 Determining the distance from the cutter to the outside of the base plate

Courtesy of Michael Hick

- Using a plunge router, you will need to determine the distance from the cutting edge of the blade and the outside edge of the router. In this example the distance is 71 mm.

Fig. 33.35 Timber step jig

Courtesy of Michael Hick

Using a scrap piece of ply, you can create a border for your router to run around. Using an offcut of the stair treads, measure out the distance of the router's cutting edge—in this example it is 71 mm. You should have the size of the tread plus a 71 mm gap all the way round.

- 71 mm gap all the way round the tread.

Fig. 33.36 Completed step jig ready for use



Courtesy of Michael Hick

The advantage to this type of jig is that you can see exactly where you are routing. You are able to place the jig directly on your mark-out lines.

Fig. 33.37 Routing-out steps



Courtesy of Michael Hick

Make sure you use the appropriate PPE, such as:

- work clothing
- safety glasses
- earmuffs/defenders
- dust mask.

Make sure the stringer and the jig are securely clamped in place.

Fig. 33.38 Routed left- and right-hand stringers



Courtesy of Michael Hick

- Hook—this part of the stringer will sit on the top floor/landing.
- The riser route has been placed at the top of the stringer to hide the joist and any staircase fixing that attaches to the joist.
- A completed pair of open-stair stringers, ready to be assembled.
- Additional 50 mm of material in front of the bottom rise and a floor cut.

Fig. 33.39 Assembly of stringers and treads



Courtesy of Michael Hick

- Predrill the stringer for four galvanised bugle screws per tread.

Fig. 33.40 Squaring staircase unit

Courtesy of Michael Hick

- Before you fix the stair together completely, it's a good idea to make sure the stair is square. You may need to use sash cramps to help pull the stair into square.

Fig. 33.41 Assembled and squared staircase unit

Courtesy of Michael Hick

- Completed open-rise staircase.

Finally, check that the gaps between the steps are less than a 125 mm sphere. If they are larger, you will need to install a timber cleat (Fig. 33.42) to reduce the size of the opening.

33.8.1.1 Alternative method of housing treads into the stringers

A traditional method, still used today by carpenters to create staircase housings into stringers on-site, is to fully cut out the back of the tread housing. This method has many advantages such as the ability to cut with a power saw, easy installation of treads once the stringers are set up in place, and easy replacement in years to come of treads that are weather affected. For this method, you will still mark out the stringers, as seen in Figure 33.33; however, instead of using a jig and router you can use a power saw to cut out the housings (a router may be needed to neaten up the nosing at the front of the housing). As an example, we will reuse the previous stringers to demonstrate this alternative method.

Figure 33.43a-f demonstrates the method of cutting out the tread housing and inserting the tread from the back of the stringer. Treads can be installed and fixed off with galvanised nails or galvanised bugle screws. (Bugle screws are a better method of fixing as they are easier to take out if you have to replace a tread.) Figure 33.43g-j demonstrates the location of the tie bolt, which is

Fig. 33.42 (a) Gap reduced by attachment of a cleat; (b) cleat is in line with the rise

(a)

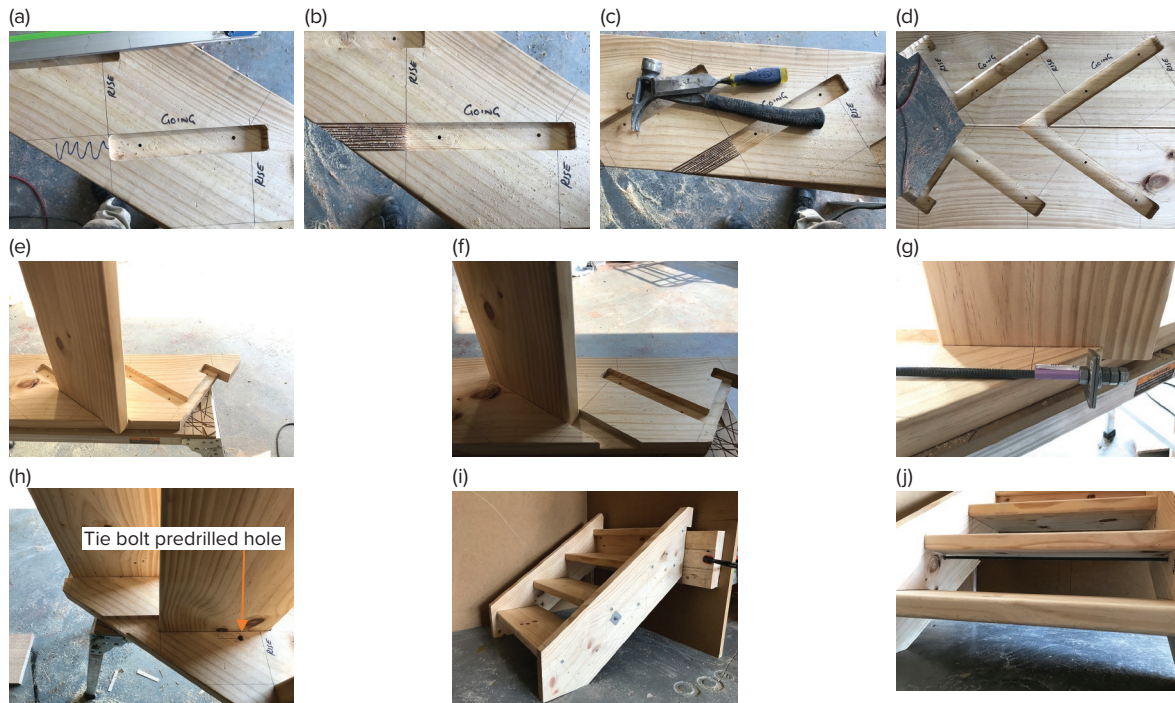


Courtesy of Michael Hick

(b)

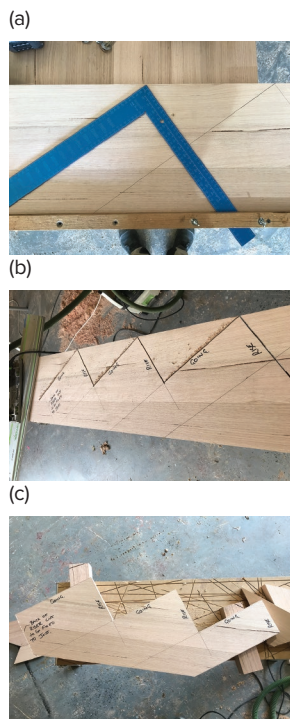


Fig. 33.43 (a) Marking back of tread; (b) cutting out back of housing using power saw; (c) using hand tools to clean up cut; (d) checking left and right stringer match; (e) checking fit of tread; (f) tread installed into housing; (g) tie bolt; (h) predrilled location for tie bolt; (i) tie bolt washer and nut; (j) tie bolt located under step



Courtesy of Michael Hick

Fig. 33.44 (a) Adjusted marking gauge; (b) cutting out carriage stringer; (c) cut-out carriage stringer



Courtesy of Michael Hick

placed under a tread, as close to the centre of the stringer as possible, and installed at a maximum of 1350 mm centres. The tie bolt will help to give rigidity to the staircase, keep the treads firmly in their housings and keep the staircase to its overall width.

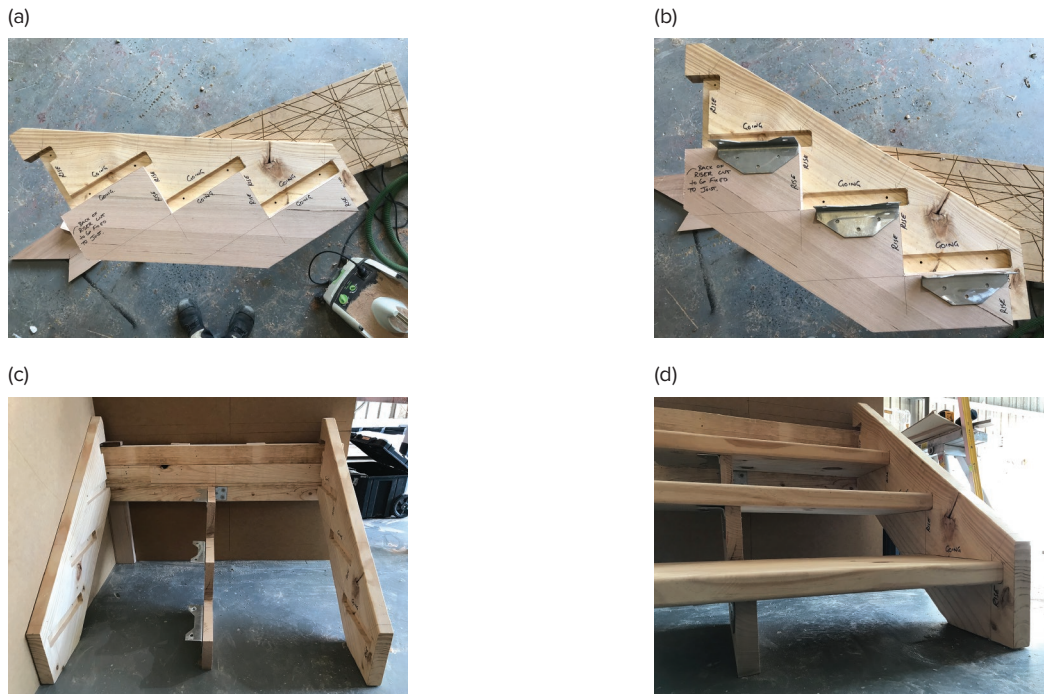
33.8.1.2 Undercarriage or carriage stringer

Staircase treads have a maximum recommended span (refer back to Fig. 33.7) and as such, if you want to make a wider staircase but are limited by the materials available, you can incorporate one or more undercarriages or carriage stringers. This stringer is a saw-tooth/cut stringer and will be marked out similarly to the open staircase. The main difference in marking out the stringer is that you don't want a large margin line, as you want to use as much of the stringer as possible. Adjust your marking gauge along the pitch line so that you are 5-10 mm from the top edge of the stringer (Fig. 33.44a). Make sure the timbers you are using for a carriage stringer conform to stringer timber guidelines (refer back to Fig. 33.8).

Using a power saw and a fence/track, you can cut out the tread and riser along the top lines of your mark-out (Fig. 33.44b). Give yourself an extra allowance at the top end of the stringer (Fig. 33.44c) to cut and fit the carriage stringer to the landing joist/wall. Check your carriage stringer against the open staircase stringer to make sure they line up together (Fig. 33.45a).

Carriage stringers are an excellent place to use galvanised tread brackets/plates (Fig. 33.45b) as you are able to fix the treads from underneath. When installing a carriage stringer at the top joist/landing (Fig. 33.45c), make sure it is level with the bottom of the top tread.

Fig. 33.45 (a) Checking the carriage stringer against the open stringer; (b) installation of galvanised tread brackets; (c) installation of carriage stringer; (d) carriage stringer is in line with the riser line



Courtesy of Michael Hick

Remember that we had made an allowance on the carriage stringer to be able to cut and fit it into place, making sure that it runs in line with the outside open stringers. Figure 33.45d demonstrates how the carriage stringer supports the tread.

In all of the examples of how to create a staircase stringer, we have used housing joints and galvanised brackets to support the treads. The best fixing is a combination of both a housing joint and a bracket. Figure 33.46 is a picture of a temporary site staircase that has failed. This demonstrates that there is not enough strength in butt jointing treads to the stringer and mechanically fixing with nails and screws alone.

To help with longevity, paint the ends of the treads and housings or use some other preservative treatment to help weatherproof the end grain of the treads. The treads will need to be sealed with a product that has an anti-slip rating of P4—ramps require a rating of P5. AS 4586: 2013 requires that stair treads have a slip-resistant finish or an anti-skid strip near the nose of the tread. A number of proprietary ‘paints’ and ‘strips’ are available to satisfy this requirement.

Fig. 33.46 Fixing failure



Courtesy of Michael Hick

33.8.1.3 Installation of post and raking balustrade

There are a variety of different types of balustrade on the market, from traditional federation-style balusters, plain square, stainless-steel wire (or nautical wire) and glass. Each type of baluster must conform to the AS and NCC as well as the BAL (Bushfire Attack Level). The BAL will determine what types of materials can be used in a bushfire-prone area.

The following example has been constructed in a simulated work environment. We will be using our example staircase to attach a post to the foot of the stringer and run the handrail and balustrading into the centre of an existing verandah post.

When installing a post at the foot of the staircase, you will need to consider the following:

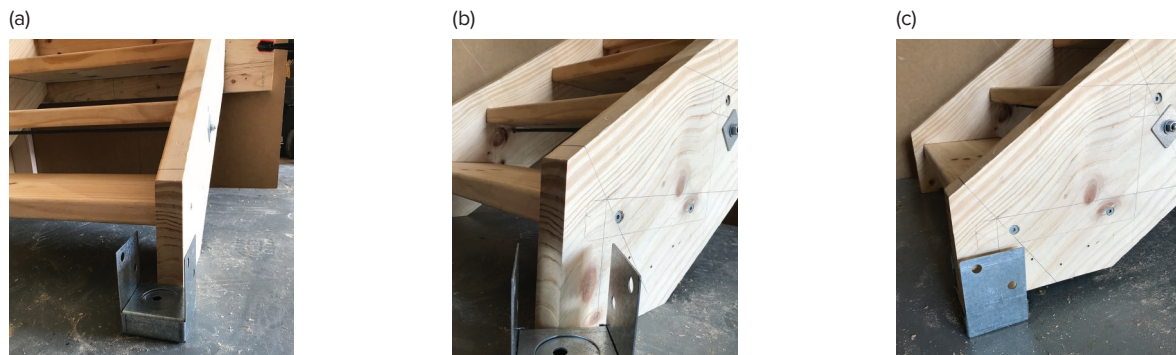
- Is the post being concreted into the ground?
- Is the post fixed into position by a stirrup or post anchor?
- Will the post be centred to the stringer?
- Will the post attach to the side of the stringer?

In our example, the staircase will be sitting on a concrete path and we will be using a bolt-down post anchor.

In Figure 33.47a–c we have scribed the foot of the staircase to accommodate the post anchor. The purpose of using the post anchor is to have the foot of the staircase off the ground and avoid it sitting in rainwater. In Figure 33.47c, the post has been pushed back to incorporate the nosing of the first tread and help keep the post square to the stringer. At this stage, with the foot of the staircase cut and the post anchor supporting the foot, we can now look at housing the top of the stringer into the verandah post (simulated post).

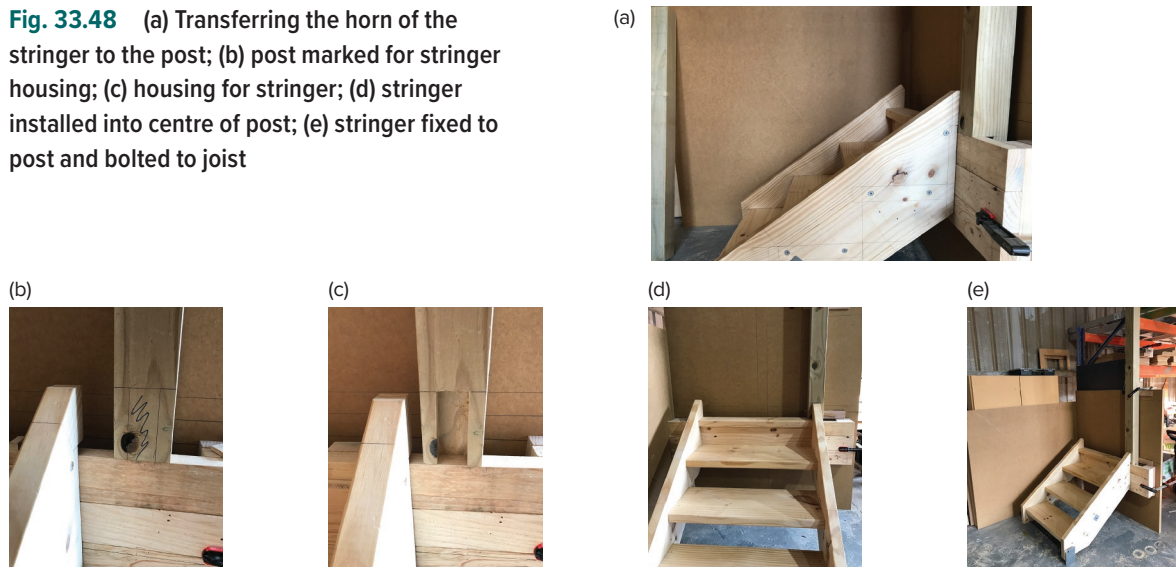
As the balustrading will be centred between the verandah post and the foot post, you will need to house the stringer (if possible) into the verandah post. Figure 33.48a–c shows how you can scribe and transfer where the stringer will need to be routed into the post. As the post is already fixed into position, you can use a drill and Forstner bit to make the housing for the stringer and clean up with a chisel. Figure 33.48d and e shows the stringer centred, fitted and secured into position.

Fig. 33.47 (a) Bolt-down post anchor; (b) marking stringer to cut foot down in size to accommodate bolt-down post anchor; (c) foot of staircase cut to suit post anchor



Courtesy of Michael Hick

Fig. 33.48 (a) Transferring the horn of the stringer to the post; (b) post marked for stringer housing; (c) housing for stringer; (d) stringer installed into centre of post; (e) stringer fixed to post and bolted to joist



Courtesy of Michael Hick

Fig. 33.49 (a) Setting up and marking position of post; (b) housing post to suit stringer; (c) marking tread nosing into post; (d) nosing routed into post; (e) post anchor installed and post attached to stringer; (f) plumbing post



Courtesy of Michael Hick

When setting up the post foot (Fig. 33.49a), you will need to make sure it is plumb when you are transferring scribe lines and measurements. Figure 33.49b-d shows the housing of the post that will fit over the stringer; the post also incorporates a nosing route that will help to ensure the post is square to the stringer once installed. Figure 33.49e and f shows the post fixed into position and has been plumbed.

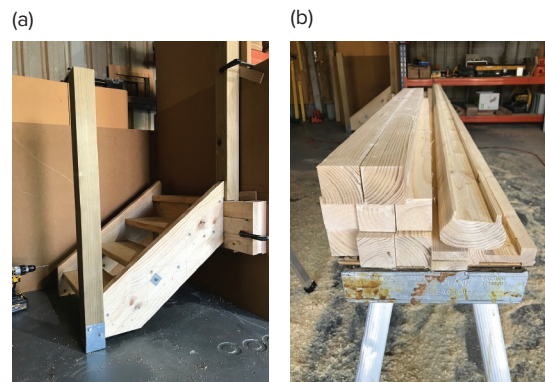
33.8.1.4 Setting up rake balustrading

When setting up the balustrade (Fig. 33.50a), it is important to take your time to make sure the posts are plumb and square to the stringer (Fig. 33.50b) as this will save you a lot of time in the long run. The regulations state that the minimum height of raking balustrade is 865 mm. If possible, give yourself room to move and add an extra 35 mm to the minimum. This will take into account any additions to the staircase such as an anti-slip nosing being installed over the nosings of the treads.

When measuring the height of the handrail, take the measurement from the nosing line of the treads. What this means is that if you were to place a straight edge that touched the nosing of all of the treads, this would form the nosing line and the datum from which the handrail would be set up from (Fig. 33.51).

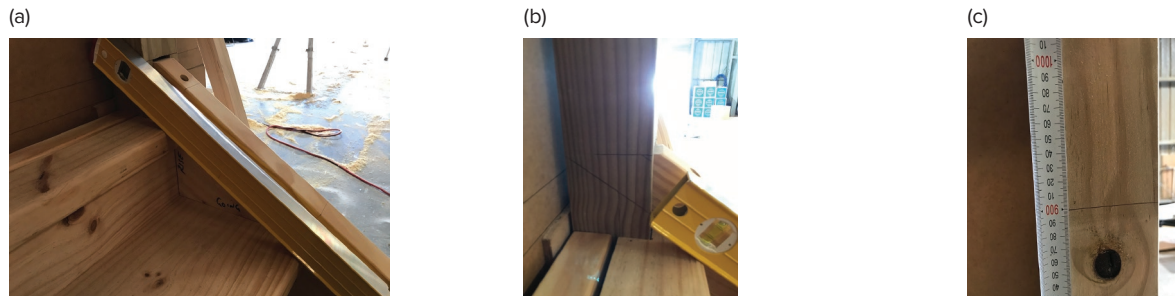
The nosing line (Fig. 33.51a) is continued through the verandah/top post (Fig. 33.51b) and becomes a line that you can plumb off to get your handrail height (Fig. 33.51c). On this example, we are making the handrail height at 900 mm.

Fig. 33.50 (a) Staircase post installed and plumb; (b) balustrade components



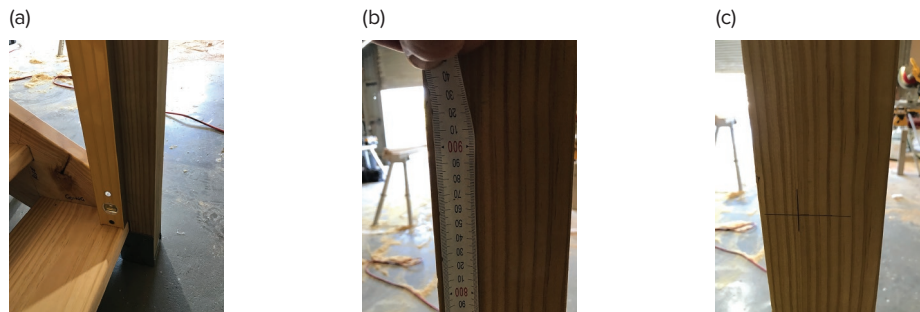
Courtesy of Michael Hick

Fig. 33.51 (a) Nosing line; (b) nosing line continued on top/verandah post; (c) verandah post handrail height from nosing line



Courtesy of Michael Hick

Fig. 33.52 (a) Plumbing from tread nosing; (b) measuring and marking the handrail height; (c) intersection of plumb line and handrail height



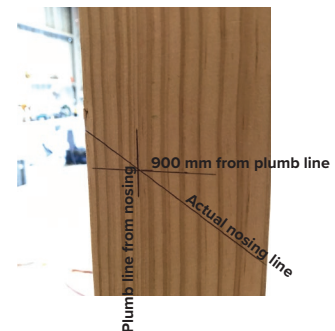
Courtesy of Michael Hick

As we have routed the nosing into the post, it is possible to plumb straight up (Fig. 33.52a) and mark the handrail height on the side of the post at 900 mm (Fig. 33.52b). The intersection (Fig. 33.52c) of these two lines can then have the nosing line (Fig. 33.53) added, so you are able to mark the back of the post with the correct handrail height.

The next step is to accurately set up the angle cuts of the balusters. If you have plumbed everything in properly then the angle cut on the end of the baluster, capping, handrail and fillet should be the pitch of the staircase.

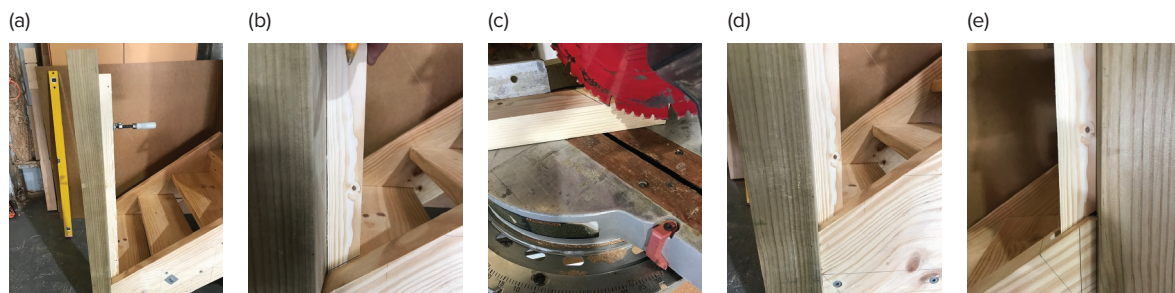
Figure 33.54a-e demonstrates a quick and practical way of working out the angle cuts for the handrails, balusters, capping and fillet. This cut should be the pitch of the staircase. Figure 33.54c shows that the angle cut on the baluster is 34.5° from the drop saw, which gives us a small difference from the calculation to the cut on the saw. This can simply be

Fig. 33.53 Nosing line intersection



Courtesy of Michael Hick

Fig. 33.54 (a) Setting up the blank baluster on the post; (b) scribing the stringer line to the baluster; (c) setting the saw and cutting the scribe line; (d) checking the scribe cut at the bottom post; (e) checking the scribe cut at the top/verandah post

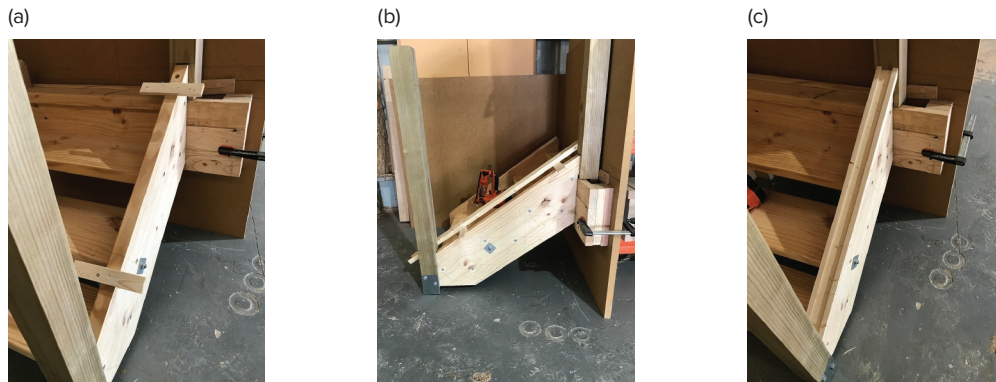


Courtesy of Michael Hick

because the saw hasn't been calibrated during its servicing or the staircase is out of level. The chances are that the staircase is probably less than 0.33° out of level. If there was a large discrepancy between the calculation angle and the saw cut, you would need to go back and check the staircase for level and plumb.

The first part of the balustrade to be cut in will be the capping. The capping sits over the top edge of the stringer and runs from the top post to the bottom post. A simple method of cutting the capping to the required size is to use a couple of offcuts and nail them across the stringer at the top and the bottom (Fig. 33.55a). Next place the capping on top of the offcut and against the posts and then scribe the capping at the point where they touch the edge of the posts (Fig. 33.55b). Once this is done, you simply cut the capping along the scribe lines (be sure not to cut the lines off as they were marked in-between the posts not on the outside of the posts) and check that it fits firmly between the top and bottom posts (Fig. 33.55c).

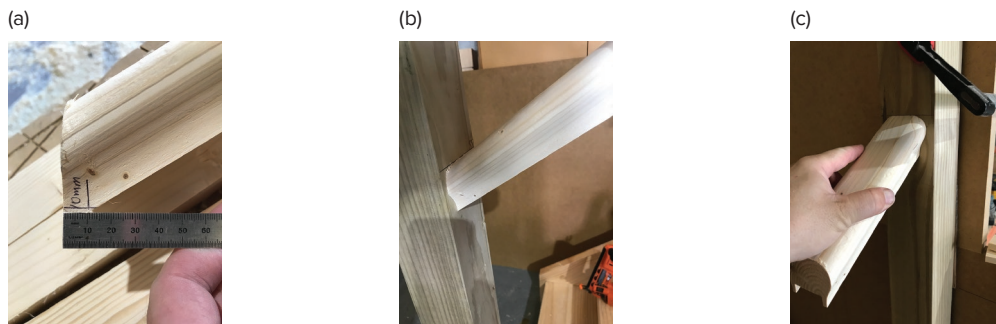
Fig. 33.55 (a) Setting up capping to be scribed; (b) scribing capping between the posts; (c) fitting capping



Courtesy of Michael Hick

At this point, simply sit the capping in place but do not fix it off as you still need to house the handrail and cut the balusters to size. The handrail will be housed into the post by 10 mm, which will make the handrail 20 mm longer than the capping. However, do not cut the handrail to size just yet. Cut yourself a short piece of handrail to be used as a pattern jig to mark out the handrail housings (Fig. 33.56a-c).

Fig. 33.56 (a) Pattern jig handrail; (b) marking handrail route in the bottom post; (c) marking handrail route in the top post



Courtesy of Michael Hick

When you have cut yourself a piece of handrail, you will need to take into account the angle of the handrail as it is housed into the post. This is so you don't have to cut into the post on the angle of the handrail as you will need to cut the bottom of the handrail off squarely (Fig. 33.56a) (the 10 mm is the depth of the post housing). The same will need to be done to the handrail that goes into the top post. However, instead of cutting the bottom off squarely, you will need to take it from the top of the handrail (Fig. 33.56c). Once you have drawn the handrail onto the post, you will be able to get

a measurement for the baluster lengths, as your drawing will have included the handrail rebate that houses the balusters (Fig. 33.57a and b).

From the handrail mark-outs on the post, you are now ready to cut your pattern baluster. The pattern baluster will be cut from the rebate in the capping to the rebate line marked on both posts.

The pattern baluster will confirm that your heights have been marked out correctly—if the pattern baluster does not sit on the drawn rebate line of both posts, you will need to go back and check your marking out. However, now that you have a pattern baluster, if your top handrail route is drawn in the wrong position, you can accurately redraw it using the handrail jig and the pattern baluster.

33.8.1.5 Working out how many balusters to use

You will need to know some specific information to work out the number of balusters required for this example staircase. As well as the length of the capping, you also need to know the length of the angle cut on the baluster, and you also need to factor in the 125 mm regulation for balustrade spacings.

The length of the capping is 910 mm (Fig. 33.58a); the balusters we are using are 40 mm × 40 mm and the length of the angle cut on the end of the baluster is 48 mm (Fig. 33.58b). The reason we need to know these measurements is that it is similar to marking out the joist, rafters and studs, as we want to know where the edge of the timber is and not the centre.

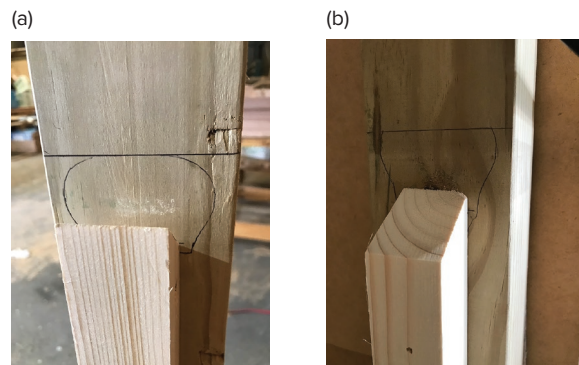
$$910 \text{ mm} + 48 \text{ mm} = 958 \text{ mm (capping and the baluster measurement on the } 34.5^\circ \text{ angle cut)}$$

The other piece of information we need to know is: what does 125 mm look like on the angle? We need to know this to make sure we don't go over the 125 mm regulation between balusters.

There is a mathematical way of checking this, as well as a practical method. Figure 33.59a shows the 125 mm regulation as measured level across from the post to the stringer.

From here, you can simply make a measurement of 125 mm

Fig. 33.57 (a) Handrail marked out, bottom post; (b) handrail marked out, top post/verandah post



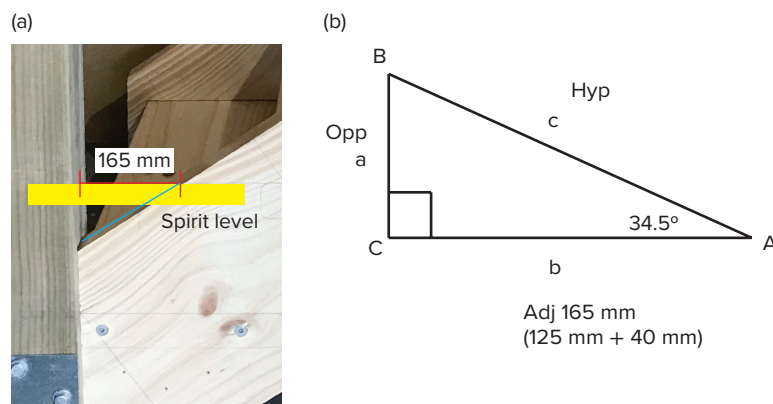
Courtesy of Michael Hick

Fig. 33.58 (a) The length of capping; (b) angle cut of the baluster



Courtesy of Michael Hick

Fig. 33.59 (a) Measurement of balustrade regulation from post to stringer; (b) trigonometry of the 125 mm regulation



Courtesy of Michael Hick

from the post and mark the top of the stringer, then to this add the thickness of the baluster that we are using (40 mm × 40 mm baluster) (Fig. 33.59a).

125 mm regulation + 40 mm baluster thickness = 165 mm (Fig. 33.59a marked in red.)

From there, measure from this mark back down along the stringer to the base of the post. The measurement on this example staircase is 198 mm (Fig. 33.59a marked in light blue).

We can also work this out mathematically.

In this trigonometry equation (Fig. 33.59b), you will be using cosine ($\cos = \frac{\text{Adjacent}}{\text{Hypotenuse}}$):

$$\cos 34.5^\circ = \frac{165 \text{ mm}}{\text{Hyp}}$$

In this calculation, you need to get the hypotenuse on its own; to do this, you need to multiply both sides of the equation by the hypotenuse:

$$(\cos 34.5^\circ) \times \text{Hyp} = \frac{165 \text{ mm}}{\text{Hyp}} \times \frac{\text{Hyp}}{1}$$

The Hyp will need to be written as a fraction $\frac{\text{Hyp}}{1}$; we can simplify this side of the equation as we have a common numerator and denominator, which is the Hyp. The two Hyps cancel each other out.

The equation will now read:

$$(\cos 34.5^\circ) \times \text{Hyp} = 165 \text{ mm}$$

The next step is to get the Hyp on its own so we will need to divide both sides by $\cos 34.5^\circ$:

$$\begin{aligned} \frac{\text{Hyp} \cos 34}{\cos 34} &= \frac{165 \text{ mm}}{\cos 34} \\ \text{Hyp} &= 165 \text{ mm} \div \cos 34.5 \\ \text{Hyp} &= 200.21 \text{ mm} \end{aligned}$$

The answer we will continue with is taken from the practical application, 198 mm. As we are marking out the balusters, we will be marking the front of each baluster—the 198 mm includes the baluster thickness and the regulation.

What this means is that when we divide up the 958 mm capping by 198 mm, this will tell us how many spacers there are and the number of balusters that we need for this example staircase:

$$958 \text{ mm} \div 198 \text{ mm} = 4.83 \text{ (rounded up to the nearest whole number 5. There will be 5 spaces and 4 balusters)}$$

Dividing:

$958 \div 5 = 191.6 \text{ mm}$. This fits within the maximum that we calculated. This measurement includes the 125 mm regulation and the thickness of the baluster. Let's see what the gap is between the balusters by working out the equation (Fig. 33.60).

The equation will be set out as cosine ($\cos = \frac{\text{Adjacent}}{\text{Hypotenuse}}$):

$$\cos 34.5^\circ = \frac{\text{Adj}}{191.6 \text{ mm}}$$

In this equation, you will need to get the Adj on its own.

The easiest way to do this is by multiplying both sides of the equation by the hypotenuse (191.6 mm).

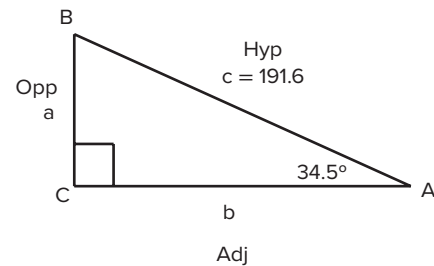
The equation will now read as:

$$191.6 \text{ mm} \times \cos 34.5^\circ = \text{Adj}$$

$$\text{Adj} = 157.90 \text{ mm}$$

This measurement of 157.90 is the combination of the baluster and the regulation levelled across rather than measured along the top of the stringer (pitch).

Fig. 33.60 Trigonometry equation to check baluster spacing



The actual gap between balusters will be:

$$157.90 - 40 \text{ mm (baluster thickness)} = 117.90 \text{ mm}$$

For the example staircase, it has been stipulated that we are to use five balusters and have six spacings.

As we are marking out the fronts of the balusters, we will be dividing the 958 mm measurement, which is the capping and the measurement of the baluster angle cut combined.

$$958 \text{ mm} \div 6 \text{ spacings} = 159.66 \text{ mm}$$

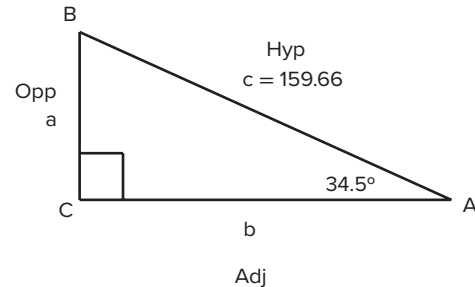
The actual gap between the balusters should be (Fig. 33.61):

$$\begin{aligned} \cos 34.5^\circ &= \frac{\text{Adj}}{159.66 \text{ mm}} \\ 159.66 \text{ mm} \times \cos 34.5^\circ &= \text{Adj} \\ \text{Adj} &= 131 \text{ mm} \end{aligned}$$

The actual gap between the balusters will be:

$$131 \text{ mm} - 40 \text{ mm (thickness of baluster)} = 91.58 \text{ mm.}$$

Fig. 33.61 Trigonometry used to work out the staircase gap between balusters in the example staircase



33.8.1.6 Marking out the capping

Now that you have the measurements for the baluster spacing, you can mark out the capping and install it. Remember that the markings show the fronts of the balusters not the centres as we have added on the size of a baluster (measured along the angle cut).

When marking out any balustrade or capping, you can use a pair of dividers to make the job easier. However, if you don't have a pair in your kit, it's just as easy to use a tape measure. So that you don't have any growth between the marks on your capping, use your calculator (most phones have one) to enter the mark-out—in this example it is 159.66 mm. Once you have entered this number into the calculator and have marked this measurement onto the capping, hit the + key twice on your calculator—this keeps adding the original number to itself every time you hit the '=' button. Or you can write down the measurements on a scrap piece of timber.

Spacings to be marked on capping (Fig. 33.62):

159.66 mm
319.32 mm
478.98 mm
638.64 mm
798.30 mm
957.96 mm

Remember that this final measurement will be the size of the baluster past the end of the capping as we are marking the fronts of the balusters not the centres.

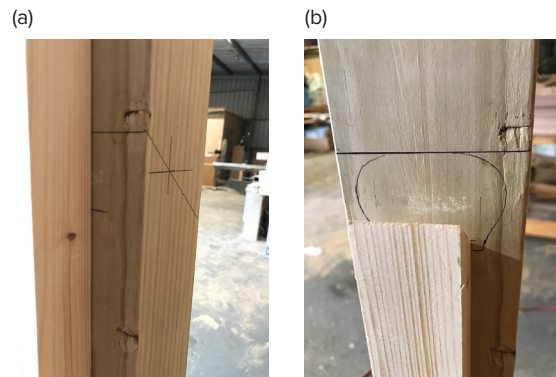
With the capping installed, you can now get an accurate measurement to cut your balusters to.

Fig. 33.62 Marking out the capping



Courtesy of Michael Hick

Fig. 33.63 (a) Developing the baluster length; (b) the baluster cut to length



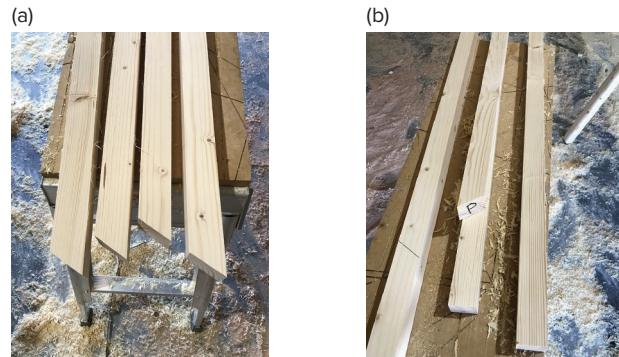
Courtesy of Michael Hick

placing a baluster that has a pitch cut on the bottom of the baluster, you can place this baluster into the rebate of the capping up against the bottom post (Fig. 33.63a) (use the bottom post as it is the post that we plumbed in).

Figure 33.63a shows the development lines of the top of the handrail and the rebate of the handrail. The next stage is to transfer the rebate line to the baluster and cut accordingly. Then, check that the baluster is cut to the correct height (Fig. 33.63b); if you are happy with the fit, then this baluster will become your 'pattern' baluster.

To begin, you will need to cut all of the balusters at one end (Fig. 33.64a), then if your drop saw has a workbench with a stop plate, you will need to set the stop plate up to the 'pattern' baluster. Accuracy is required to make sure all of the balusters are cut exactly the same. If you don't have a workbench with a stop plate, you can use your 'pattern' baluster and transfer the markings to each baluster to be cut out (Fig. 33.64b). Again accuracy is important, so take care.

Fig. 33.64 (a) Rake balusters cut at one end; (b) using a pattern baluster



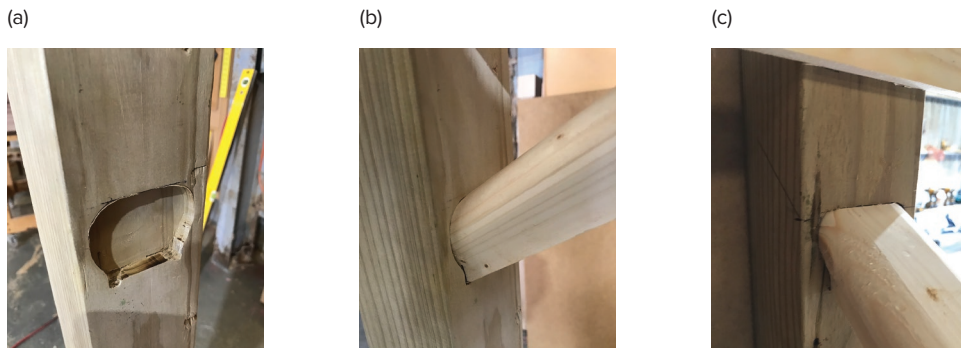
Courtesy of Michael Hick

33.8.1.7 Post handrail housing

There are a variety of ways to fix the handrails to the posts, such as housing and nails/screws/bolts, brackets, mortise and tenons. Always seek advice from the AS, NCC and your state's timber advisory centre for advice on the best method of fixing for your job.

In this example we are using the housing (Fig. 33.65a) and screw method. We have previously marked out the handrail profile onto the top and bottom posts. A trimmer router is an excellent tool to use for this particular exercise. Simple timber jigs can be made to help you with routing profile handrails or DAR (dressed all round) handrails. Take your time to fit the handrail to the housing joint as you are after a firm fit (Fig. 33.65b and c).

Fig. 33.65 (a) Routed-out housing for handrail; (b) housing in bottom post; (c) housing in top post

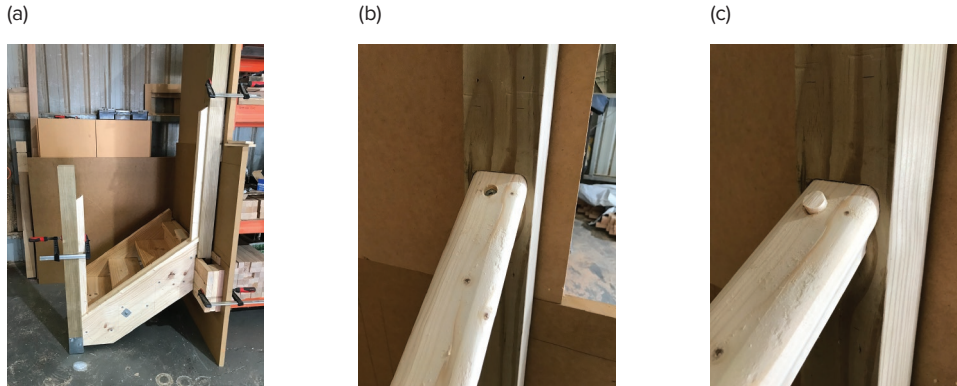


Courtesy of Michael Hick

To cut the handrail to size, clamp balusters to the side of the posts (Fig. 33.66a), with the baluster hanging past the post so you can get the edge of the handrail to sit onto the balusters. Scribe the line of the posts onto the handrail—note that this scribe line isn't the cut line—and make sure you add on the depth on the rebate to both ends.

Before you commit to cutting the handrail, take a moment to make some checks:

- Have you added the depth of the rebate to the cut?
- Is the handrail only the depth of the rebates bigger than the capping? If it's bigger/smaller, why?
- If it's a long handrail, are the bows in the timber giving inaccurate measurements?

Fig. 33.66 (a) Setting up the handrail; (b) screwing the handrail through the housing joint; (c) a timber plug

Courtesy of Michael Hick

Now that the handrail is cut to size, it can be fitted. Place the handrail into the housing joint in the bottom post first then do the same at the top. The handrail should go in with a little downward force to get it into the top housing joint. The handrail can now be screwed into the bottom post from under the handrail, through the handrail rebate, using a galvanised bugle screw. The handrail in the top post has been predrilled with a 16 mm spade bit, and a plug has been used to cover the bugle screw (Fig. 33.66b and c); this plug can later be sanded flush with the handrail.

Fig. 33.67 Temporarily positioned baluster to set up a handrail

Courtesy of Michael Hick

TIP If you have a long handrail that has a bow in it and it is affecting your ability to get an accurate handrail cut, what you can do is set up one or two balusters (Fig. 33.67) in position in the capping, evenly spread out. Plumb and nail the baluster at the base, and temporarily brace the balusters back to the stair. This will help to keep the handrail parallel to the stringer and make sure you haven't left it too long or cut it too short.

33.8.1.8 Installing the balusters and fillet

The first balusters that are installed and plumbed in should be in the middle (Fig. 33.68). This will ensure the handrail is running parallel with the capping. Once you have a few middle balusters plumbed in, the rest of the balusters can now be glued and nailed in as per the mark-out on the capping (Fig. 33.68a).

Figure 33.68b shows all of the balusters installed, glued and nailed off. Let's check to see if the gap between the balusters is as we had worked out previously—that is, 91.58 mm.

Our mathematical calculations for determining the gap between the balusters is correct. The measurement shows a gap of 92 mm (Fig. 33.69), which is well within the 125 mm maximum of the regulation.

The last piece of balustrading to go in is the fillet; the fillet timbers cover the rebate between the balusters.

Fig. 33.68 Capping mark-out

Courtesy of Michael Hick

Cut yourself enough fillet pieces to complete the job. Make sure that they are oversized and have the staircase angle cut already on at least one end (Fig. 33.70a). A tip is to number the fillet pieces and place them in-between the balusters. In a perfect world, all of the fillets should be the same size; however, you may have a 1 mm or so variation from baluster to baluster. Place the fillet up against the handrail/capping and balusters then scribe the fillet to suit (Fig. 33.70b). You can scribe all of the fillets at once and then do all of the cutting; because the fillets are all numbered you will know which fillet goes where. Figure 33.70c is a completed picture of all of the handrail fillets.

Fig. 33.70 (a) Oversized fillet timbers numbered; (b) scribing fillet; (c) installed fillet timbers



Courtesy of Michael Hick

Figure 33.71 is a picture of our simulated worksite with a completed example staircase and rake balustrade.

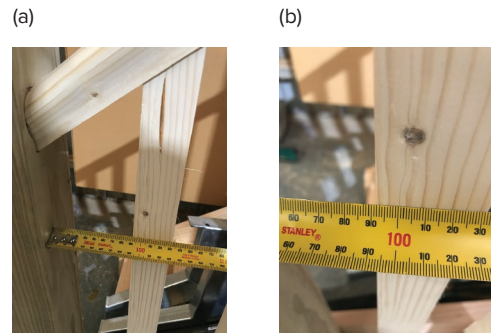
33.8.1.9 Level balustrade

A level balustrade for an external staircase will be located along the level sections of the staircase, on a landing that may separate two flights or along the void areas of a balcony or deck that are over 1 m in height above the ground (Fig. 33.72).

A level balustrade can be set up in a variety of ways and styles, using, for instance, timber, stainless-steel wire and glass. Each different type of balustrade will have its own regulations about spacing, tension, factored limit state loads and installation guides. You will need to check the AS, NCC, timber and forestry groups and industry governing bodies on the regulation surrounding these balustrade types and the best practice for installing these products.

In this chapter example, we used a timber balustrade for the rake balustrade, and the level balustrade can be installed in a similar fashion. The handrails and bottom rails will need to fit within the regulations and factored limit state loads for timbers. The handrails and bottom rails can be attached to the post/verandah post in a variety of ways, such as housed, mortise and tenon or brackets, and fixed off with the recommended bolts, screws or nails. The

Fig. 33.69 (a) Measuring the gap between balusters; (b) 92 mm gap between balusters

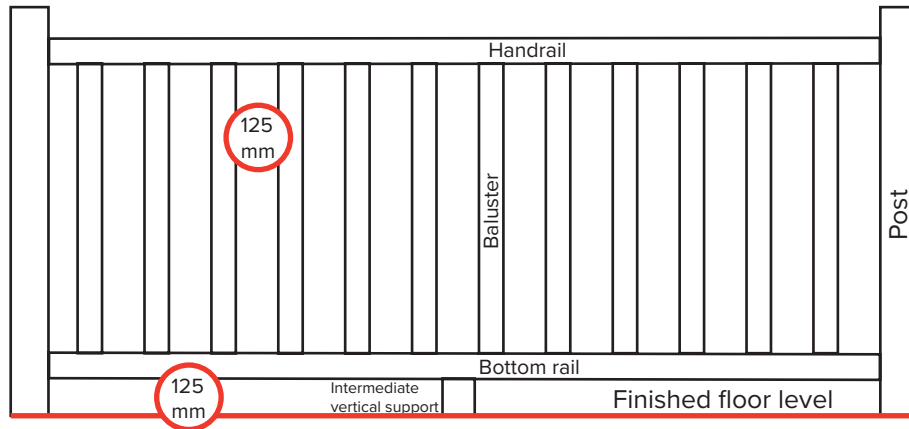


Courtesy of Michael Hick

Fig. 33.71 Completed external staircase and rake balustrade



Courtesy of Michael Hick

Fig. 33.72 Example of a level balustrade

balustrade will also need to conform to the 125 mm maximum between the balusters and between the finished floor level and the bottom rail (Fig. 33.72). A timber level balustrade is lifted up off the floor to allow water run-off, and, depending on the span, it may also need an intermediate vertical support.

Carpenters work in all different types of surroundings, from inner-city residential areas to rural builds as well as commercial and factory constructions. Each different type of construction project will have a BAL (Bushfire Attack Level) as part of the build, which will be printed on the architectural plans. The BAL will have an impact on the types of materials that can be used on a building—care needs to be taken to understand what this means for you and your trade.

33.9 Explain the considerations when building in bushfire-prone areas

BAL—Bushfire Attack Level

The Bushfire Attack Level (BAL), as defined in AS 3959, considers the type of surrounding vegetation, the distance of the vegetation from the site and the effective slope of the land under the classified vegetation. Once a site has been assessed for its BAL, the plans, building methods and materials need to take the requirements of that BAL into account.

The BAL has a range from BAL-LOW (low) to BAL-FZ (extreme). BAL-LOW allows for standard construction materials and methods, including timber framing and cladding materials, which can be used due to these sites having a low risk of bushfire attack.

The Standard has ratings from:

- BAL-LOW: Insufficient risk to warrant specific construction requirements
- BAL-12.5: Some possibility of ember attack
- BAL-19: Sites identified as having an increasing level of predicted ember attack
- BAL-29: Increasing level of chance of ember attack and burning debris ignited by wind-borne embers
- BAL-40: Further possibility of ember attack and burning debris ignited by wind-borne embers; likelihood of exposure to bushfire flames
- BAL-FZ: Extremely bushfire-prone, probably in a picturesque bushland setting; a home with this BAL has a predicted direct exposure risk to flames from a fire front, ember attack and a radiant heat flux greater than 40 kW/m².

This information is based on Appendix G of AS 3959.

The types of external staircases that can be installed in high-risk areas will be different from those that can be used in areas with a low BAL risk.

Most residential homes in built-up city areas will fall under the BAL-LOW category. These sites have no special requirements as there is such a low risk of bushfire attack (always refer to the building permits). In these areas, exposed timber staircases can be constructed using a variety of timbers such as treated pine, black butt and merbau (refer to AS 2082 and 2858 for advice on design and materials).

33.9.1 External staircase installation in a high-risk BAL zone

In this example, the location of the job is Hepburn Springs in Victoria (Figs 33.73 and 33.74). The land on which the house has been constructed has been zoned as BAL-40. This rating deems that the handrails and balustrading must be constructed from non-combustible materials and that the stairs and decks must be concrete or tiles.

The large deck that has been built is to be clad in 19 mm exterior cement sheets and the deck frame will be clad in cement sheet, while the floor and walls will be weather-tight and tiled.

The staircase will be constructed using a cut stringer/saw-tooth design and clad with 19 mm cement sheeting and tiled.

The personal protective equipment (PPE) used on this job includes:

- earmuffs
- safety glasses
- dust mask
- sunscreen
- work clothes and boots.

Fig. 33.73 Bushfire-prone location in Hepburn Springs, Victoria



Courtesy of Michael Hick

Fig. 33.74 BAL-40 zone in Hepburn Springs, Victoria



Courtesy of Michael Hick

SAFETY TIP When cutting cement sheet with a circular saw, make sure you use the correct blade and have the saw connected to a HEPA vacuum; also utilise a half-face or full-face respirator with N100 filters.

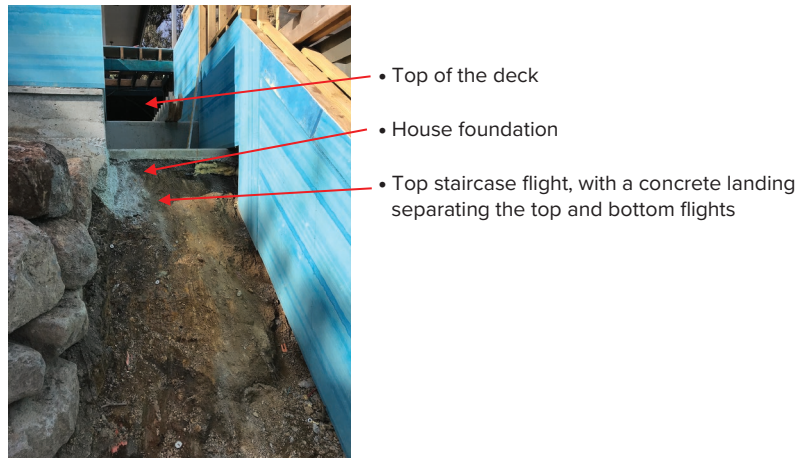
The staircase starts at the top of the deck and runs down the hill to a concrete path. Using a dumpy level, the floor-to-floor of the job was determined to be 4030 mm. The length of the stairwell is 6100 mm from top deck to the landing point on the concrete pathway at the bottom.

Approximately in the middle of the stairwell are two concrete slabs (Fig. 33.75); one of the slabs is a landing for the staircase, while the other is part of the house's foundation. Because the two flights are separated by a landing, this allows the two flights to have a different 'rise'. As you can see, this staircase and balustrade are different from the proposed staircase from the excerpt plans in Figure 33.13a-c. This is because of design factors, client involvement and the materials available for use in a high BAL area.

TIP In industry, the 'rise' is usually closest to the maximum and the 'going' is usually the minimum. The main reasons for this are that it enables you to use the smallest amount of materials and space, and it involves the lowest cost.

Constraints and considerations of staircase design are illustrated in Figure 33.75.

Fig. 33.75 Location of staircase from top landing to bottom garden path



Courtesy of Michael Hick

The cut stringers/saw-tooth stringers (Fig. 33.76) that have been used for this job were machined on a CNC (computer numerical control) machine for accuracy. The stair will be set out in a similar fashion as setting out joists. The carriage stringers will be divided in the stairwell space evenly, with no more than 450 mm centres. On this job the centres were 400 mm. The builder has nominated that all measurement and checking for square can come off this wall. Refer to Figures 33.76–33.85 for the set-up and installation process.

Fig. 33.76 Setting up cut/saw-tooth stringers



Courtesy of Michael Hick

Fig. 33.77 Setting up cleat for middle stringers (carriage stringers)



Courtesy of Michael Hick

- Once the first stringer is fixed into position, another stringer can be squared and fixed into position on the other wall.
- After working out the spacing between all of the stringers, a timber cleat can be fixed to the deck joist ready for the remaining stringers. The cleat sits at the same level as the first step on the stringer. By doing this, all stringers will be installed at the same height.

Fig. 33.78 Securing stringers into place



Courtesy of Michael Hick

- The stringers can also be fixed from behind; before you fix off the carriage stringers, also check that all stringers are level on the first/bottom step.

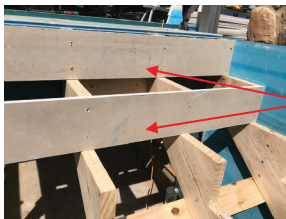
Fig. 33.79 Bracing and solid blocking stringers



Courtesy of Michael Hick

- Bracing and blocking can be used to shore up the stringers and keep the stringers evenly spaced.
- The wall stringers are secured into place by fixing them to the walls. A block needs to be secured to the ground so that the centre stringers can be fixed into position.

Fig. 33.80 Installing risers

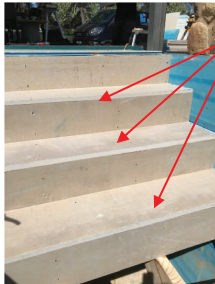


Courtesy of Michael Hick

Treads and risers are installed using liquid nails and galvanised fixings.

- The risers can now be installed (19 mm cement sheets).

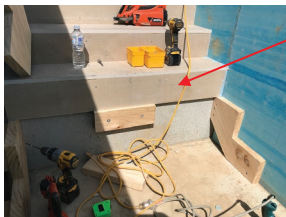
Fig. 33.81 Installation of treads and risers



Courtesy of Michael Hick

- After a few risers are installed, you can start to install the treads (19 mm cement sheet).

Fig. 33.82 Factors impacting staircase installation



Courtesy of Michael Hick

- The stair was set up to make sure this riser was flush to the front of the house foundation.

The bottom flight (Fig. 33.83) is set up the same as the top flight; however, due to the risk of sliding on the side of the hill, the risk was limited by having someone working at the top of the flight and someone at the bottom. Once the stringers were installed, the stair was constructed from the bottom up, which reduced the need to walk on the uneven ground.

Fig. 33.83 Installation of bottom flight



- Wall stringer is fixed to concrete wall.
- Wall stringer is fixed off and secured to studs.
- Solid blocking is being installed.
- Even though the stringers will be covered with cement sheeting and tiles, the stringers have been lifted off the ground and sit on top of 19 mm cement sheeting, in case of water seepage.
- Cleat block fixed to the ground and the middle stringers are fixed to it.

Courtesy of Michael Hick

Fig. 33.84 Completed bottom flight



- Treads and risers are installed.
- Cement sheet has been installed onto this stringer over its entire length as tiles will be installed at a later date.

Courtesy of Michael Hick

Fig. 33.85 Completed flight



Installed cut/saw-tooth staircase with 19 mm cement sheet treads and risers.

Courtesy of Michael Hick

Student research

Further research the timber external stair regulations in your state or territory. Locate information from timber and forestry advisory services for the spans of stringers, treads and handrails.

End-of-chapter activity

Design, manufacture and construct a timber staircase (in a simulated work environment or on-site) based on these specifications:

- The staircase will be an open-riser with housed stringers or metal brackets to accommodate treads. The unit can be free-standing or have one side against a wall.
- The timber staircase must be a minimum height from the ground level of 1100 mm and include a handrail and balustrade to the open side of the flight and landing.
- A JSA will need to be completed for the task and the tools/power tools being used.
- You will need to determine the rise, going and pitch of the staircase. The pitch will need to be mathematically determined with all workings out.
- You will need to calculate the stringer length, handrail and capping.
- You will also have to calculate the slope relationship to determine if the staircase meets the regulations.
- The balustrade will be manufactured using timber capping, handrail and timber balustrade (40 mm × 40 mm balusters depending on the availability of materials).
- The minimum number of balusters will be installed.
- The manufacture and installation of the staircase will meet all standards, NCC and state/territory requirements.

AUSTRALIAN BUILDING CODES AND STANDARDS

AS 1657: 2018
Fixed platforms,
walkways, stairways and
ladders—design,
construction and
installation

AS 3959:2018
Construction of buildings
in bushfire-prone areas

AS 1530.8.1: 2018
Methods for fire tests
on building materials,
components and structures:
tests on elements of construction
for buildings exposed to
simulated bushfire attack—
radiant heat and small
flaming sources

AS 2082
Timber—hardwood—
visually stress-graded
for structural
purposes

AS 2858
Timber—softwood—
visually stress-graded
for structural
purposes

AS/NZS 1716
Respiratory protective
devices

AS 4586: 2013
Slip resistance
classification of new
pedestrian surface
materials

**National Construction
Code (NCC)**

Chapter 34

Carry out demolition

Learning Objectives

- LO 34.1 Understand the safety aspects of demolition**
- LO 34.2 Plan for demolition work**
- LO 34.3 Prepare for demolition work**
- LO 34.4 Carry out demolition of minor building structures**
- LO 34.5 Carry out demolition of brickwork**
- LO 34.6 Re-use and recycle materials**
- LO 34.7 Carry out demolition site clean-up**

Introduction

Building and construction workers will at some stage be involved in the demolition of building structures. These structures will all be different in terms of their size, building materials and construction methods—making every demolition job unique in its own way.

It is important to note that even small-scale demolition projects may be difficult and expose workers to a wide range of hazards and risks. These hazards and risks need to be identified, then controlled or removed before the work commences.

Workers become qualified demolition practitioners by completing the required high-level demolition training. These are separate qualifications under the Australian Qualifications Framework that address demolition work.

Some construction workers specialise in large-scale demolition work, including the removal of multistory concrete, steel or timber-framed buildings or structures.

In this chapter you will learn about the safety aspects of demolition work, including your own personal safety and the safety of your fellow workers and members of the general public. You will also learn how to plan for, prepare and carry out the demolition of minor building structures, as well as how to identify and deal with potentially hazardous building materials and situations.

Other topics covered are the paperwork and permits required before the job commences, personal protective equipment (PPE) and how to fit and use it correctly, plus the tools and equipment required for the job. You will also learn how to identify and reclaim used building materials for re-use and recycling, followed by the clean-up procedures for the construction site and the correct disposal of demolition waste materials.

Fig. 34.1 PPE for demolition



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34.1 Understand the safety aspects of demolition

Workplace safety is the most important aspect of any job, as you cannot undo a workplace accident. When carrying out demolition work, you must be aware of any dangers that exist for that particular job and proceed in a manner that protects you and your workmates at all times.

Some important points to remember:

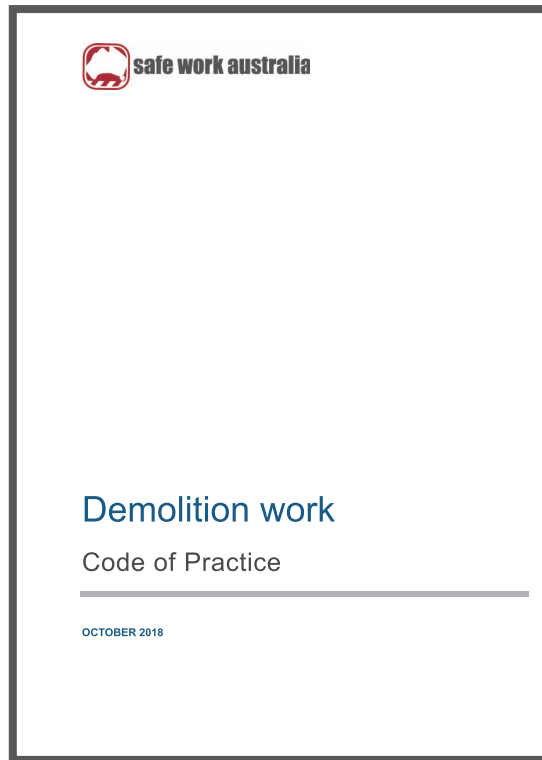
- Always have safe work method statements (SWMS) and demolition plans in place before starting work.
- Make sure you correctly select and fit any PPE (Fig. 34.1).
- Use safe manual handling procedures.
- De-nail as work proceeds.
- Do not work under any structure that is being demolished.
- Follow the Safe Work Australia Code of Practice for Demolition Work–October 2018 (Fig. 34.2).
- Follow the WorkSafe Victoria Demolition Compliance Code–Edition 1, May 2018.

WORKPLACE SCENARIO

Early in my apprenticeship, I was involved in the demolition of several brick tank stands on the top floor of a hospital boiler house. There were some old double timber doors on this floor and a steel gantry with a big steel pulley on the end installed above the doors. This was for getting water-pumping equipment in and out.

We had to get the bricks down from this fourth-story level somehow, so we sourced a length of thick rope that was probably a hundred metres or so long and rigged up some slings to hold the wheelbarrow level. We put the rope through the pulley then dropped it back down and tied it to the back of the hospital groundman's tractor. We then put the wheelbarrow in the slings and drove the tractor up the road.

This lifted the wheelbarrow up to the fourth floor with no problems. We loaded the barrow with bricks, the tractor reversed, bringing the wheelbarrow back down to ground level, and we went down and unloaded and stacked the bricks. A lot more barrowloads later, and all of the bricks were neatly stacked ready to be removed from the site. This method would not be acceptable under any circumstances by today's standards, and in hindsight I think we were very lucky to get the job completed without any incidents.

Fig. 34.2 Safe Work Australia, Demolition work, Code of Practice

Courtesy of Safe Work Australia CC BY-NC 4.0 <https://creativecommons.org/licenses/by-nc/4.0/>

34.1.1 Hazardous materials and chemicals

Hazardous materials and chemicals can be present in all types of buildings. Structures built many years ago are more likely to contain such materials as they were seen at the time to be hard-wearing. However, very little, if anything, was known then of the dangers that such materials would pose in later years. The most common hazardous materials are listed below.

34.1.1.1 Asbestos

What is asbestos? Asbestos is made up of naturally occurring minerals in our environment. When these minerals are mined, refined and then bonded, asbestos products can be manufactured. The substance was used in construction for many purposes because it was cheap, easy to use and very durable. However, it is a known health hazard and is associated with diseases such as mesothelioma and asbestosis.

Asbestos can be divided into two types: non-friable and friable.

- *Non-friable:* This type of asbestos is dry. It cannot be pulverised, crumbled or reduced to powder by hand pressure.
- *Friable:* This type of asbestos breaks, crumbles or turns to dust when handled.

Who can remove asbestos? This is one of the most commonly asked questions by apprentices and pre-apprentices because it is common on even the smallest demolition task to come across some type of asbestos containing building material.

There are three different asbestos removal levels: Class A licence; Class B licence; and no licence required.

- *Class A licence:* permits the removal of any amount of friable or non-friable asbestos, asbestos-containing material or asbestos-containing dust.

- *Class B licence:* allows the removal of any amount of non-friable asbestos, non-friable asbestos-containing material or non-friable asbestos-containing dust.
- *No asbestos removal licence required:* in these cases it is permissible to remove up to 10 m² of non-friable asbestos or non-friable asbestos-containing material. Asbestos-contaminated dust that is associated with the removal of less than 10 m² of non-friable asbestos or non-friable asbestos-containing material is considered to be only a minor contamination.

The total time for asbestos removal should not exceed one hour in any seven-day period (this time is cumulative for work carried out by all workers over a seven-day period). The workers must have been trained correctly in the safe removal of asbestos.

Examples of where you may encounter asbestos in demolition work include: external wall cladding on houses or buildings, corrugated sheets on roofs or fences, internal linings on walls and ceilings, particularly in bathrooms and laundries, spouting, guttering and downpipes, eave linings, splashbacks in wet areas, floor and wall tile underlay, carpet underlay, vinyl floor and wall linings (in both sheet and tile form), electrical meter box backing boards, pipe lagging (wrapped around water pipes, particularly hot water pipes), dust (in roof spaces and wall cavities where the covering is asbestos sheeting) (Fig. 34.3).

TIP A laundry or bathroom sized 1.8 m × 2.4 m with a 2.4 m ceiling height, a single door and a window has around 20 m² of wall and ceiling linings. Thus, most bathrooms and laundries will exceed the limit of 10 m² for non-specialist removal of asbestos and a licensed asbestos removal contractor must be used. The ceiling of a typical laundry or bathroom up to 2.4 m × 2.4 m will be around 6 m².

Bonded asbestos cement sheeting that is damaged and friable must be removed only by a licensed asbestos removal contractor.

Fig. 34.3 Specialised tools allow whole sheets of asbestos sheeting to be removed without breakage



© Logtnest/Shutterstock

34.1.1.2 Lead

Lead can be present in various construction materials and applications, such as:

- plumbing fittings, solders, sheets, pipes and flashings
- leadlight windows and glass
- lead-based paint.

If it is suspected that lead-based paint may be present, a test must be carried out to confirm its presence. Refer to AS 4361.1-1995, Guide to lead paint management—industrial applications, for more information and guidance.

When carrying out demolition that contains lead materials, some basic precautions can be taken:

- Continually clean the work area during the demolition process.
- As far as possible, minimise lead dust and fumes.
- Correctly select and fit your personal protective equipment (PPE).
- Thoroughly clean the work area upon completion of the task.
- Maintain good personal hygiene levels.

34.1.1.3 Synthetic mineral fibres

These are most commonly known as wall and ceiling insulation batts.

- Removal needs to be carried out carefully to avoid disturbing the fibres as they can cause skin and eye irritation.
- The fibres can also become airborne and may be inhaled into the lungs.
- Damping down can suppress the fibres and dust during removal.

34.1.1.4 Rogue services

It is vitally important to be aware of another hazard known as 'rogue services' when carrying out demolition work. These are services that have not been identified when all of the checks have been made and the reports finalised.

Rogue services most commonly occur in older buildings where renovations have been carried out, sometimes several times over many years. Most commonly, electrical cable or wiring is terminated in a wall cavity or roof space and capped off, leaving it attached to the switchboard and still live (Fig. 34.4). This can also be the case with gas and water services being capped and left as a branch from another known pipe that is connected to the mains.

Demolition saws and other demolition tools have been known to hit rogue services, sometimes with disastrous consequences.

Fig. 34.4 A near miss that could have been deadly: these wires were disconnected, taped and pushed back into the brickwork cavity during a previous renovation. The demolition saw was only millimetres away from cutting through them. A licensed electrician was immediately brought in to fix the situation



Courtesy of Alister Ford

CHECK YOUR UNDERSTANDING

1. List the items of PPE that would be required when undertaking demolition work.
2. What is the difference between bonded asbestos cement and friable asbestos?
3. What is the maximum amount of bonded asbestos cement sheeting that can be removed by a person who is not a licensed asbestos removalist?

34.2 Plan for demolition work

34.2.1 Plan well before any work takes place

The written plan will vary for demolition work—from very basic plans for small, uncomplicated work through to very detailed and comprehensive plans for large-scale demolition. But no matter the size or scope of the demolition, the plan must be easy to understand, effective, reviewed and clarified at nominated times or when work conditions change, then followed by all workers involved in the demolition job. Local government authorities have specific requirements relating to how demolition work should be carried out.

Before any demolition plan is developed or work is started, the local authorities should be consulted. Building plans should be lodged and approved, inspections should be conducted and permits to work obtained. Failure to do so can lead to heavy penalties being imposed.

Demolition is considered to be a high-risk work activity under current legislation. It is therefore a requirement to produce a safe work method statement (SWMS) to identify any hazards, and the risks created by these hazards, for anyone involved in the demolition task as well as the general public.

The SWMS will also detail how the identified hazards and risks will be controlled or eliminated, and who will be responsible for these actions. The SWMS will be used in conjunction with the demolition plan to ensure a safe, well-functioning work site.

Items that could be included in the demolition plan include:

- the address where the demolition will take place
- entry and exit points to the site
- the type of structure to be demolished
- the size of the structure
- protection of adjoining properties
- required signage, barricading, fencing and hoardings
- road or footpath closures and detours for any closures
- site plans, building plans and building specifications
- reports, which may include engineering, asbestos or environmental details, and which must be implemented and reviewed at appropriate times, and assessed in accordance with environmental plans and legislation associated with the demolition task
- location of services, whether underground, overhead or installed in the structure to be demolished
- methods of demolition for the specific job
- SWMS or JSA, including any work, health and safety review timelines and requirements.
- task and procedure review timelines and requirements
- the sequence of demolition and proposed timelines
- designated storage areas or bin placement for disposable materials, hazardous materials, recyclable materials or re-usable materials
- emergency plans, which could include: emergency services contact details (000), first-aid kits and first-aid areas in case of personal injury, rescue equipment in case of structure collapse, firefighting equipment, evacuation procedures, evacuation assembly points.

34.3 Prepare for demolition work

Once the planning for the demolition job has been completed, you can begin to prepare for the work using the plan as a guide. In other words, once all of the building plans have been submitted and approved, all permits have been obtained, testing for hazardous materials or substances has been completed and identified hazards have been professionally removed, preparation for the demolition work can now begin.

SAFETY TIP The correct personal protective equipment will need to be selected, fitted and used correctly.

An important point to remember is that you may not be the worker carrying out a specific task, but you may still be required to use the same PPE as that person because of close proximity.

Let's look at some of the specific PPE that you may be required to wear or use on a demolition task.

- *Eye protection:* safety glasses or a full-face shield. These should be clear with no damage, scratches or scuffs to impair your vision. Note: if you are working outside and some of the demolition is

at eye level or above, safety sunglasses may be a good option to reduce glare and give better vision.

- *Hearing protection:* ear muffs or ear plugs. Should be clean with no damage.
- *Head protection:* hard hat, hair nets and caps. All should be adjusted correctly and fitted so they won't fall off.
- *Hand protection:* leather gloves, fabric gloves, rubber gloves.
- *Foot protection:* steel-capped leather work boots.
- *Body protection:* overalls, coveralls, long-sleeve hi-vis work shirts, long work pants, hi-vis work jackets, disposable coveralls.
- *Respiratory protection (breathing, lungs):* disposable respirators, non-disposable respirators with changeable filters.

All of your PPE should be selected, correctly fitted and used in accordance with the relevant Australian Standard for that particular item.

An example of respiratory protection could be: P1 respirators, which filter hazardous dusts and asbestos particles; P2 respirators, which also filter smoke particles. The carbon in the mask shown in Figure 34.5 reduces the nuisance levels of organic fumes but will not filter hazardous fumes.

- Remember, your PPE is your own. Look after it. Replace anything that gets damaged immediately. Do not wait until the next job.
- For good health and hygiene, wear only your own PPE. Do not borrow from or loan your PPE to anyone else.
- Prepare access and egress points from the site.
- Identify and implement any footpath or road closures and detours.
- Identify, select, erect and position the correct signage so that it is in a prominent position and easily read without obstruction.
- Ensure barricading, hoardings or barriers are identified, erected and placed in the correct position and manner according to the manufacturer's or work instructions (Fig. 34.6).
- Set up protection for neighbouring properties.
- Set up areas for recyclable or re-usable or waste materials. These could be large bins or skips, trailers, pallets or areas on the ground for stacking and later removal.

Fig. 34.5 P2 respirator with valve and carbon filter



Courtesy of Alister Ford

Fig. 34.6 Sheet hoardings fixed onto the scaffolding for the building facade demolition process and rebuild



Courtesy of Alister Ford

34.3.1 Demolition tools and equipment

The tools and equipment used for carrying out general demolition can vary significantly depending on the nature and scope of the demolition work that needs to take place.

The tools and equipment used for demolishing timber-framed structures will differ from those used to demolish steel-framed structures and, again, from those used to demolish structures constructed from masonry, concrete or stone.

They can also be categorised into hand tools, battery-powered tools, power tools, plant and equipment.

Whatever the task, it is vitally important to select the correct tools and equipment and check them regularly for serviceability, ensuring that any faulty or damaged items are removed so that they cannot be used. Damaged or faulty tools or equipment should be reported immediately and rectified. If needs be, they should be sent out to be repaired correctly by an authorised repairer or, if they are irreparable, they should be replaced.

Hand and power tools that may be used to demolish a basic timber-framed structure could include any number of items from a carpenter's tools trailer. Some of the basic tools that will generally be used include:

- hammers (Fig. 34.7)
 - claw hammers
 - mash hammers
 - sledgehammers
- saws (Fig. 34.8)
 - hand saws
 - reciprocal saws
 - circular saws
- bars (Fig. 34.9)
 - pinch bars
 - wrecking bars
 - crowbars
- chisels
- screwdrivers or rattle guns
- bolt cutters.

Fig. 34.7 Hammers used for demolition work



Courtesy of Alister Ford

Fig. 34.8 Hand and power saws for demolition work



Courtesy of Alister Ford

Tools used for steel-framed demolition (Fig. 34.10) may differ from those used for timber-frame demolition and can include:

- angle grinders with metal cut-off blades
- reciprocal saws with metal blades
- oxyacetylene cutting equipment
- hacksaws
- tinsnips.

Demolishing concrete or masonry structures such as brick or block walls, retaining walls, concrete paths, slabs or footings (fence posts or outdoor structure posts) or removing ceramic tiles will require tools and equipment specific to the particular task.

These may include:

- air, electricity, or battery-powered jackhammers with a variety of conventional or flat chisels
- cold chisels, plugging chisels, bolsters (Fig. 34.11)
- sledgehammers or mash hammers
- ride-on, electric or hand-held tile scrapers/lifters.

Heavy machinery will often be required on larger or more dangerous demolition jobs. This machinery

Fig. 34.9 Bars used for demolition work



Courtesy of Alister Ford

Fig. 34.10 Tools used for the demolition of steel-framed walls



Courtesy of Alister Ford

Fig. 34.11 Cold chisel, bolster and plugging chisel for the removal of bricks



Courtesy of Alister Ford

must be operated by specially licensed operators. Often, if larger machinery is required, demolition contractors will be engaged, and the construction site will be open only to them for the duration of the demolition work taking place.

34.4 Carry out demolition of minor building structures

34.4.1 Typical small-scale demolition projects

In residential construction, demolition is not on the same scale as the demolition of high-rise office or industrial buildings. Many residential renovation projects require the demolition of small-scale structures

Fig. 34.12 Rotary hammer drill/jackhammer for ceramic tile removal or smaller concrete demolition work



Courtesy of Alister Ford

Fig. 34.14 Removal of ceramic floor tiles using a hand-held tile scraper



Courtesy of Alister Ford

Fig. 34.13 Kitchen renovation with partial concrete slab demolition. Note: the electric jackhammer, wet and dry vacuum system and all existing cabinetry are protected



Courtesy of Alister Ford

Fig. 34.15 An old house that through neglect has collapsed in on itself. Specialist demolition contractors and hazardous product removalists will need to be engaged to clean up the mess, as there could be any number of hazards present



Courtesy of Alister Ford



such as laundries or bathrooms, the removal of internal load-bearing or non-load-bearing walls to create open-plan living areas, the removal of external load-bearing wall sections so that an existing house can be extended and, occasionally, the demolition of a complete home (Figs 34.12–34.16).

Other residential projects can involve demolishing out-buildings such as verandahs, pergolas, decks, attached carports, patios, garages, free-standing carports, retaining walls, concrete paths, concrete driveways, tool sheds and workshops. Small tasks may also involve the demolition of fencing.

An important point to remember that will help you with any demolition task is 'Do not rush in and start to demolish'. Stand back and look at the structure that you are about to demolish and think about how it was constructed.

- Where did the builder start?
- What steps did they take to carry out the job?
- How did they fix things in place?

Demolition should be conducted in the opposite order to the construction. Remember: 'The last piece in is the first piece out.' This will create a safer work environment for you and your fellow workmates, and will minimise the risk of collapse or structural failure, which more often than not leads to workers being injured, sometimes critically.

Fig. 34.16 Typical flooring and subfloor of an older house under demolition



Courtesy of Alister Ford

34.4.1.1 Bathroom and laundry renovations

As it is classed as a domestic wet area, a bathroom or laundry in a house built before 1990 will most likely include asbestos cement sheeting as wall or ceiling lining, and perhaps tile or vinyl underlay on the floor. The vinyl tiles or sheeting used in these areas may also contain asbestos.

In full cavity (or double) brick homes, asbestos sheeting was used for bathroom and laundry ceilings only. In brick veneer or timber-framed houses with cladding, asbestos sheeting was used as both an internal wall lining and as a ceiling lining for bathrooms and laundries.

As discussed in the earlier section on demolition safety, asbestos cement sheeting that covers more than 10 m² must be removed by a licensed asbestos removalist. Besides the potential presence of airborne asbestos particles, when asbestos cement sheet ceilings or any ceiling linings are removed, abundance of dust is an issue. Filthy, black, sticky dust that contains many types of hazardous materials, including the remains of dead animals and bird excrement, must be handled with care.

The best method is to use an industrial exhaust fan with a length of ducting to remove all of the dust and move it outside into a collection point so that it can be safely and easily removed later (Fig. 34.17). Alternatively, the top of the ceiling can be cleaned with an industrial vacuum cleaner before the ceiling is removed.

Fig. 34.17 Industrial exhaust system for the removal of dust



Courtesy of Alister Ford

Another risk that construction workers and renovators face is the unknown condition and location of electrical wiring and the gas and water services. This should be established before demolition commences. Extreme care should be taken while demolition takes place in case rogue wires and water pipes exist in wet areas from previous renovation work.

Bathrooms are often located in an area that can be accessed only by walking through parts of the home. Large amounts of demolished materials must be moved manually from the bathroom or laundry and out through the house and into the specified area, depending on the plan for the demolished materials. Before work commences, the access walkway to the bathroom should be determined and plastic sheeting should be placed over floors, walls and ceiling to prevent damage to floor coverings and painted surfaces.

Entries into other parts of the home must be sealed to prevent dust travelling throughout the home. This can be done by closing the doors to other rooms and hanging plastic drop sheets from the top of the door-frame architraves and fitting them down onto the floor to prevent any dust penetration whatsoever. Placing protective covers over all exposed surfaces will result in a safe and efficient demolition that doesn't impact on the rest of the home. This also makes it easier and quicker to clean up after the work is completed.

Demolition plan for a bathroom renovation

Before demolition commences:

- inspect the ceiling space above the bathroom and identify any obstacles, fixed structures, and water, electrical and gas services
- inspect the bathroom and identify all services that have to be removed or relocated
- identify any potential asbestos and plan for this to be removed separately; asbestos removal should be conducted as a separate process and not in conjunction with the demolition of other structures forming the bathroom
- arrange for services to be relocated or removed before the demolition begins
- organise the correct signage and barrier tape
- organise waste, recyclable and re-usable storage areas for removed material.

During demolition:

- wear appropriate PPE
- install protective coverings to all surfaces in areas to be used as a walkway
- if the bathroom door or window is being retained, it will also need to be protected
- seal doors that open into the work area with tape to prevent any dust entering other parts of the home; secure these doors so they cannot be opened
- install signs and barrier tape (Fig. 34.18)
- shut down electrical, gas and water services at the main tap or switch and attach safety tags
- remove or temporarily move and shut down and secure all services—electrical, water and drainage, and gas
- isolate the bathroom work area from all services by shutting off power and capping other services to the bathroom

Fig. 34.18 Asbestos removal warning sign and barrier tape



Courtesy of Alister Ford

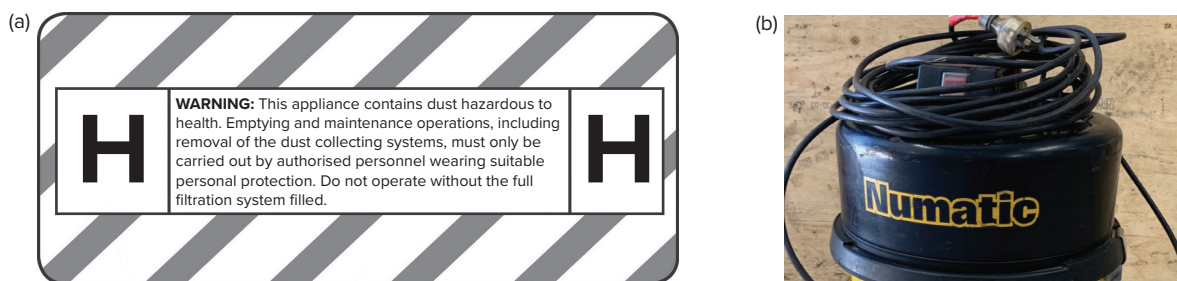
- identify and remove all prime-cost items, taps and other fixtures and fittings
- install a vacuum exhaust fan for dust removal and seal around exhaust ducting where it passes through the bathroom window
- remove the ceiling in accordance with the demolition plan in the next section
- remove wall tiles and the wall lining if it is to be removed
- remove floor tiles using appropriate demolition tools.

34.4.1.2 Demolition plan for removal of ceiling linings

- Turn power off at the mains and attach safety tags.
- Inspect the roof framing, supporting ceiling battens and the ceiling lining before commencing any demolition.
- Identify any insulation, obstacles or services that may have to be removed or moved temporarily.
- Identify any fixed structures that will interfere with the removal of the ceiling.
- Wear PPE: gloves, P1 or P2 mask or respirator, coverall clothing, safety glasses.
- Work from a raised work platform 600 to 900 mm above the floor placed inside the bathroom or laundry.
- Don't demolish the ceiling from inside the roof space.
- Ensure there are two workers on the job, to assist each other.
- Remove all dust from the top of the ceiling in the roof space using a class H vacuum cleaner.
- Cut ceiling lining into manageable pieces, e.g. 1.2 m × 1.2 m (four pieces for a 2.4 m × 2.4 m ceiling).
- Consider all identified obstacles, services and structures as the ceiling is cut.
- Select the right tools, which may include a cordless reciprocating saw, a cordless 100 mm grinder with cutting disc or a hand saw.
- Remove each piece separately but don't work underneath the piece being removed as you remove it.
- Remove each section from the demolition area as it is taken down.

TIP Vacuum cleaners used to remove asbestos fibres and friable asbestos must comply with Australian Standards and must display the high hazard (H) class symbol (Fig. 34.19) and contain warning information about dust in the vacuum cleaner collection system.

Fig. 34.19 (a) H-class label; (b) H-class vacuum cleaner with HEPA filter



34.4.1.3 Removal of external cladding and roofing

Removing external cladding and roofing requires the use of suitable scaffolding or work platforms. You may also be required to use a fall-prevention device such as safety harnesses attached to designated anchorage points. If the roofing or cladding is an asbestos-based product, it must be removed by a licensed asbestos removalist (Fig. 34.20).

Courtesy of Alister Ford

Insulation in wall cavities and roof spaces may also have to be removed.

Type P1 or P2 respirators or disposable masks must be used to prevent the inhalation of insulation products such as fibreglass and mineral wool. PPE such as safety gloves, safety glasses and disposable protective overalls should also be used to minimise skin irritation. Old insulation collects dust, which may contain unknown elements such as decayed dead animals and insects, and must be assumed to be hazardous.

Steel sheet roofing and clay and cement tiles can be recycled for re-use or conversion to other products. External cladding made from **fibre cement** (not asbestos cement) can be recycled, and timber cladding can be re-used if it is in good condition, otherwise it can be used as landfill.

Not all demolition jobs will be completed in one day. If roofing, exterior cladding, windows or doors are removed, it may be the case that the building needs to be made weatherproof overnight, or for a period of time. Large heavy tarpaulins are generally used for this task (Fig. 34.21). They must be spread evenly across the openings and tied down securely to ensure the weather and wind cannot penetrate to damage the inside of the building or lift the tarpaulin and blow it off the structure.

34.4.1.4 Removing load-bearing and non-load-bearing timber-frame walls

Internal walls may be removed to create larger open-plan living areas and improve access. These walls may be either **load-bearing** or **non-load-bearing**. Once the load that a wall was carrying has been directed to other points of the structure, the techniques for removal are similar for both.

It is not always a simple process to remove load-bearing walls—in fact, it can be very complicated. Many factors need to be considered and addressed with regard to the structural integrity of the building. Failure to do so can lead to some disastrous outcomes.

Redistributing the load that the soon-to-be-demolished wall was carrying is a vital part of the demolition process. No structural part of the wall can be removed until this has been done or at least

Fig. 34.20 Asbestos disposable plastic bags



Courtesy of Alister Ford

Fig. 34.21 Partial roof and ceiling frame demolition; tarpaulins will need to be fitted to ensure there is no damage from the outside elements



Courtesy of Alister Ford

until the load has been temporarily held up with props and toms, to be completed at a later stage. The redistribution of the load must be carefully planned and approved to ensure the new members that will take the load comprise the correct materials and are of adequate size and strength.

The load must also be redistributed through new point load positions that are deemed to be adequate to transfer the new load, as well as any previous load that this point was carrying. It is often necessary to add strength to remaining walls by way of adding extra studs into the frame to create new load points.

If the subfloor in the structure is of conventional bearer and joist design, it may also be necessary to add more timbers to the subfloor structure. The load will then be transferred through the remaining walls, onto the subflooring system and then to the footings of the structure. The risk of structural failure and accidents is lower when removing non-load-bearing walls.

Internal load-bearing timber-frame walls are designed to support many individual items in ceilings, conventionally pitched roofs and the upper story of two-story houses. These items can include:

In ceilings:

- ceiling joists
- ceiling trimmers
- hanging beams
- counter beams
- combined strutting/hanging beams
- combined strutting/counter beams
- ceiling lining materials
- ceiling insulation
- light fittings, ceiling fans, exhaust fans, surround-sound systems
- electrical cabling, gas and water pipes, air-conditioning ductwork
- hot water services.

In conventionally pitched roofs:

- common, jack, creeper, hip, valley rafters
- ridge boards
- underpurlins
- collar ties
- Barrup trusses
- struts
- strutting beams
- roof battens
- roof coverings
- television or communication aerials or dishes
- air-conditioning units.

In two-story constructions:

- upper-story bearer, joist and flooring systems (Fig. 34.22)
- upper-story deep joist and flooring systems
- in-floor cabling and piping
- upper-story floor coverings and underlays
- upper-story wall framing, insulation and linings
- ceiling and roof system as described above

Fig. 34.22 Temporary propping of floor joists in upper floor—note services



Viktor Ginić, B Design Engineering Services Inc.

- upper-story dead load—bathtubs (full), shower units, built-in cabinetry
- upper-story live load—moveable furniture, people, wardrobe and cupboard contents, paintings and wall hangings.

If the roof is constructed with a truss system, all ceiling loads and roof loads are transferred to the external walls. This allows *internal* non-load-bearing timber-frame walls (or masonry walls) to be removed without the need to support the roof framing temporarily. However, if the removal is for the purpose of creating a larger opening in an *external* wall, then the roof trusses must be temporarily supported.

When timber walls or roof framing is damaged by termites, the remaining structures that would normally be supported by the damaged framework must be temporarily propped while the damaged framework is removed and replaced.

Removing load-bearing and non-load-bearing steel-framed walls

Removing steel-framed walls, whether load-bearing or non-load-bearing, will follow the same principles as removing timber-framed walls. Any load-bearing points need to be propped to prevent collapse and any redistribution of loads through the remaining frame needs to be carefully planned, engineered and carried out before any temporary propping is removed. The tools and equipment used for demolishing steel-framed walls will differ from the tools and equipment used to demolish timber framing.

34.4.1.5 Demolition and replacement of timber decking

Homes built in the 1970s or 1980s and earlier often used unsuitable timber such as Oregon or Canada pine for external cantilevered joists. Timber decking was often a mixture of hardwoods with varying grades of durability. Decking was commonly used in highly-exposed situations or areas close to a marine environment. Bright steel nails were used to nail into untreated softwood floor joists through the hardwood decking. The steel nails would corrode and allow water to enter into the timber joists, causing them to rot over time.

Cantilevered balconies add another dimension to structural damage, with the real possibility of collapse as floor joists decay and finally fail, often resulting in sudden collapse when heavily loaded with people.

For the renovator or repairer, the first task in demolishing and replacing timber decking is to remove all of the structurally damaged materials. Working at height on a structurally unsound framework of timber floor joists that are cantilevered over steeply sloping land is a hazardous situation so a safe work platform must be used.

Sometimes cantilevered joists that run back for several metres as support under internal flooring must be removed and replaced (Fig. 34.23). If the floor framing joists below the upper floor can be easily accessed, the replacement of cantilevered floor joists is fairly simple, but if the lower floor area is another habitable room, then part of the ceiling lining below must be removed.

Fig. 34.23 Cantilevered timber balcony in the process of being demolished. The deep joists will be cut back to the building then correct propping will be installed for complete removal and replacement.



Courtesy of Alister Ford

34.5 Carry out demolition of brickwork

34.5.1 Demolition of brickwork to enlarge openings and install new doors and windows

The removal of existing masonry to form an opening for a door or window requires the use of temporary props. As masonry is removed, the work above that was previously supported must be re-supported.

The procedure involves the removal of one or two bricks to create small openings that continue across the full width of the wall plus the insertion of **needles** through these openings in the wall (Fig. 34.24a-c). The needles are then propped on each side and held up tight against the masonry above the small opening. Needles may be up to 1200 mm apart or further, subject to the strength of the mortar that was used originally to construct the brickwork.

Brickwork between the needles is removed, starting at the top of the proposed opening. As the brickwork is removed, an opening larger than the size of the door or window to be installed is created (Fig. 34.25a). The brickwork is **toothed** on the sides of the opening as bricks are removed to allow bricks to be re-laid alongside the newly installed window or door (Fig. 34.25b).

Once the brickwork has been re-laid up to the needle, the temporary props and the needles can be removed. However, before removing these props, the new lintel must be temporarily supported until the brickwork has set for at least seven days. The brickwork should be cured with occasional wetting to facilitate hydration.

Alternatively, an opening only slightly larger than the window or door to be installed can be cut out with a demolition saw. Normally this would be done only where the brickwork is not seen and is covered by solid plaster.

Fig. 34.24 (a)–(c) Conversion of a two-door garage into a one-door garage: (a) previous two-door garage; (b) brickwork removed and temporary props; and (c) new single garage door installed

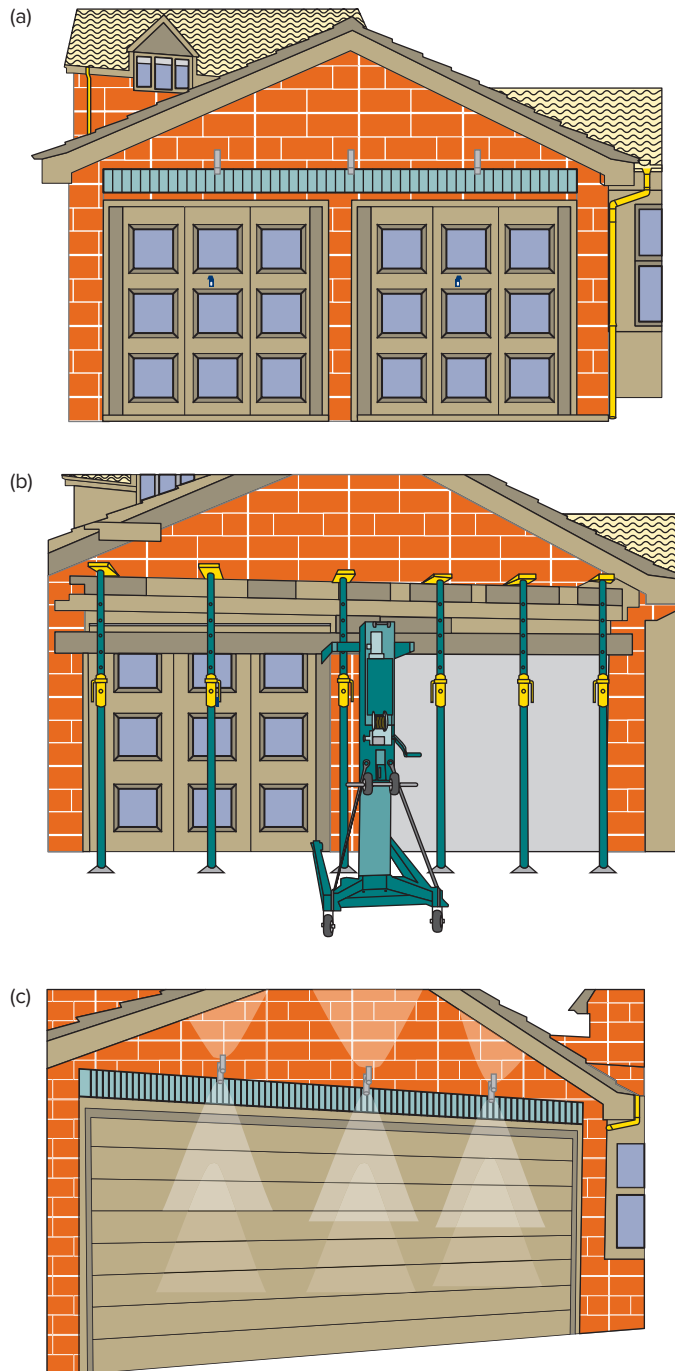
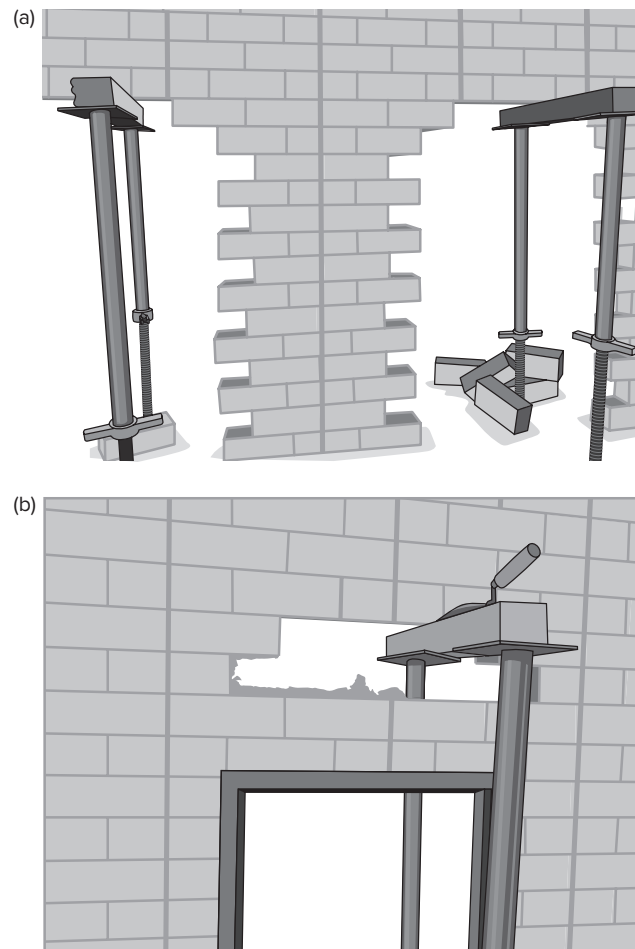


Fig. 34.25 (a) Brickwork removed and toothed; (b) door frame installed and bricks re-laid



Masonry walls are also often removed to open up connecting rooms and create one large room. Any structures supported by these walls should be temporarily propped until a new steel beam or lintel is installed over the new opening to support any masonry above the opening.

Any surplus bricks remaining after the opening is completed can be re-used or recycled for road base materials or decorative gravel.

CHECK YOUR UNDERSTANDING

4. Briefly describe a simple process to support brickwork when enlarging or creating an opening.
5. How would you undertake the installation of an opening in a non-load-bearing timber-frame wall? Take into account services such as water, gas and electricity.
6. Briefly describe how you would create a large opening in a load-bearing timber-frame wall.

34.6 Re-use and recycle materials

34.6.1 Reduce, re-use or recycle if you can

Construction waste is generated in considerable quantities on building sites. Finding a sustainable solution has become an urgent environmental problem. The crucial strategy to managing waste is to reduce, re-use or recycle materials.

One of the most important tasks during demolition is to sort demolished materials into separate categories.

Always remember the 'three Rs' of waste minimisation:

- reduce
- re-use
- recycle.

34.6.1.1 Reduce

We need to minimise the current amount of construction waste. This can be done through accurate ordering of materials and good site management. Excess packaging should be avoided, and suitable dry storage facilities provided on-site. Often the amount of new construction materials spilled or thrown away exceeds demolition waste: up to 20% of construction material on a commercial site may never be used.

34.6.1.2 Re-use

It is often more sustainable and cost-effective to re-use construction material rather than purchasing new ones. Re-using materials is frequently more energy-efficient because it eliminates the additional processes and energy involved in recycling. Timber, roofing tiles, bricks and blocks of low cement mortar are often re-used and are equal to, and sometimes better than, new.

Re-useable building materials can be sold or given away. Some money can be made by selling any re-usable materials. If something cannot be sold, it can often be given away. Second-hand building materials such as timber framing, timber flooring, timber lining and cladding, windows and window frames, doors and door frames, and cast-iron products are often highly sought after by home renovators, builders and furniture makers. These items sometimes cost more to buy than a new product to be used for the same purpose.

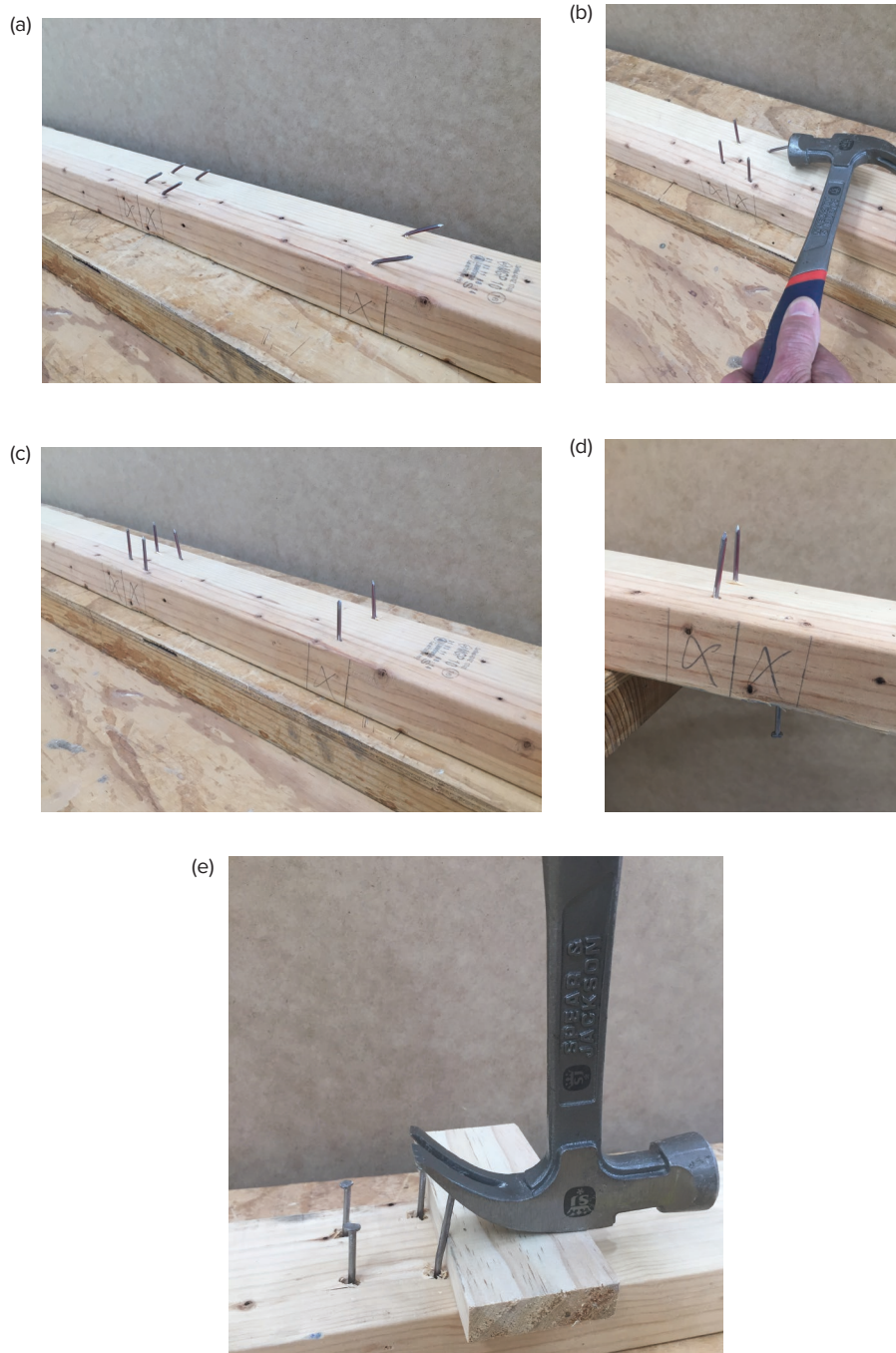
TIP Re-usable timber must be de-nailed before resale as any personal injuries that result from nails could result in litigation. There is also the risk of causing costly damage to woodworking machinery. Always use the correct PPE when handling materials from a demolition job.

As any demolition job proceeds, it is important to de-nail any timber as you go. This makes it much easier to stack, taking up less space as the job proceeds, which in the long run saves time and money. One way to check if the timber available for re-use has been properly de-nailed is to run a metal detector over the timber. It is quite easy to miss a nail—sometimes nails will snap off, leaving part of the nail in the timber unseen. Most second-hand timber yards will check any timber they purchase this way and if they detect any nails still present, they may lower the price substantially.

The process used to de-nail any re-usable timber is also very important. Timber can be ruined for its next purpose if it is not de-nailed correctly.

Timber-framing material will most probably be used for timber framing again. The process of de-nailing timber framing is a straightforward one (Fig. 34.26a–e).

- Straighten the nail at the back of the timber to its original position by hitting with your hammer or pulling it up straight with the claw of the hammer or a pinch bar.
- Place the timber on a solid support and hit the nail back through the timber with your hammer.
- Turn the timber back over, place a block under your hammer or pinch bar for extra leverage and pull the nail out.
- Throw the nail into a box or bucket for later disposal.

Fig. 34.26 (a–e) The correct way to de-nail timber framing

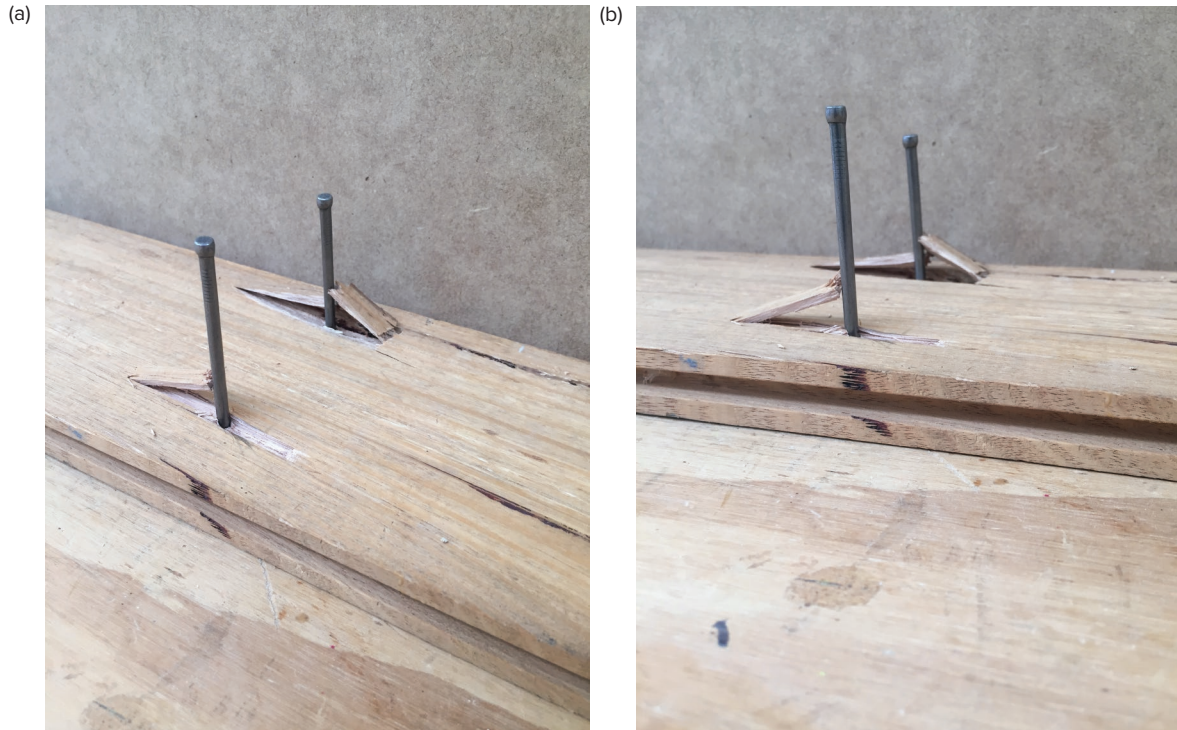
Courtesy of Alister Ford

It can be very costly to buy timber flooring and lining boards second-hand, so it is well worth the time and effort to remove them and de-nail them properly. De-nailing is a bit different here from normal framing timber because we do not want to damage the face edge of the board by 'exploding' the head of the nail back through the timber.

- Once the board has been carefully removed, lay it on a flat surface and bend the nail to about 45 degrees to the back surface of the board.
- Place a thin strip of timber under your pinch bar and place the claw of the pinch bar under the bent nail.

- Hit the pinch bar onto the nail until you feel the bar has securely grabbed the nail.
- Pull the nail through the timber, removing it from the back surface and leaving the face surface nice and clean with no nail removal damage.
- Throw the nail into a box or bucket for later disposal.

Fig. 34.27 (a) and (b) Timber flooring damaged by incorrect de-nailing process



Courtesy of Alister Ford

34.6.1.3 Recycle

Often, in reality, recycling in the building industry is actually 'down-cycling'. This is when a material is reduced to a lower-level use such as hardcore fill or landscaping bulk. Some recycling processes now produce materials that have equal properties to new, or natural, materials—for example, synthetic wood made from recycled rubber, plastic and sawdust (but at an energy cost).

Recyclable materials can often be given away at no cost to recycling yards. (Sometimes, however, there is a small fee for concrete and brick products, but it is far less than standard tip fees.)

Hard materials such as cement render, concrete, brickwork and tiles are recycled by being crushed down into different aggregate sizes to be used as road base or **hardcore** fill on new construction projects. Hard materials may also be suitable as clean fill on-site or may be used by others who require clean fill on vacant land to raise it above a flood level.

CHECK YOUR UNDERSTANDING

7. Explain why it is important to recycle demolished materials.
8. What products can be manufactured from recycled concrete?

34.7 Carry out demolition site clean-up

When a job has been completed and all re-usable and recyclable materials have been removed, the demolition site will need to be cleaned up and made good for the next phase of the construction process (Fig. 34.28a and b).

You may have a skip, waste-disposal bin, small tip truck, trailer or ute on-site to collect all of the disposable waste, ready for transport to the local tip or landfill site.

The whole demolition site needs to be inspected for rubbish; areas to be checked include:

- the place of demolition
- the designated paths from the demolition to the re-usable, recyclable and waste material areas
- the ground around these areas
- the entry and exit points of the job site
- the roadway leading to and from the site.

Rubbish may include:

- nails
- screws
- bolts
- timber
- tiles
- plaster
- glass
- rubble
- tin
- insulation
- anything that has unknowingly been dropped or been blown away during the transport of the demolished materials.

All waste must be properly secured for transport as heavy fines can be applied for unsecured loads. The slightest sign of asbestos cement materials mixed with landfill waste will result in all demolition materials being declared asbestos-contaminated and the cost of tipping will escalate dramatically. Asbestos-based materials must be wrapped in plastic and clearly labelled as 'hazardous asbestos material' and taken to specially designated landfill sites.

Once the demolition site has been thoroughly cleaned up and all materials disposed of, you will need to thoroughly check and pack away all of your tools and equipment. The nature of demolition work, with all sorts of building materials being pulled down, means that it can be quite easy to damage tools and equipment without realising it.

All hand and power tools should be checked and cleaned. Any faults such as damaged leads, guards, blades, casings or handles will need to be reported so they can be repaired.

SAFETY TIP If any tool or piece of equipment gets damaged while you are using it, stop using it immediately, isolate it and report it. You are not going to be in trouble for creating a safe work environment. Never try to hide anything away. The next person who picks up and uses the damaged tool or piece of equipment may get badly injured.

Fig. 34.28 (a) Reclaimed materials stacked and banded ready for removal from the demolition site;
(b) demolished brickwork being cleaned and stacked on pallets ready for removal from the demolition site
for re-use



Courtesy of Alister Ford

Student research

1. Visit Safe Work Australia: www.safeworkaustralia.gov.au, or any other state workers' safety authority (e.g. WorkSafe Victoria) and locate and review the Code of Practice for the Safe Removal of Asbestos and the Code of Practice for Demolition Work, or similar.
2. Search YouTube using the search term 'asbestos removal' and review the process of removing asbestos.
3. Search YouTube using the search terms 'house demolition' and 'building demolition', and compare the different processes.

End-of-chapter activities

1. Create a basic plan for the demolition of a small out-building such as an old free-standing garage.
Specifications:
 - 7 m long × 4.5 m wide × 2.7 m high
 - 1.2 m from the side boundary fence. The residence on the neighbouring property is 1.2 m from the same fence
 - unseasoned hardwood wall frames externally clad horizontally with hardwood weatherboards (nailed and painted)
 - unseasoned hardwood skillion roof frame externally clad with corrugated iron (nailed)
 - 125 mm thick concrete slab, reinforcement unknown
 - no internal linings
 - 2 × 1.5 m wide × 2 m high ledge and braced timber entry doors for vehicles
 - 1 × 0.8 m wide × 2 m high ledge and braced timber side door
 - 1 × 2 m wide × 1.2 m high fixed pane timber-framed side window
 - 1 × double fluorescent light fixed to the roof
 - 2 × double power points fixed to wall frames
 - 1 × garden tap plumbed and attached to the external side wall.
2. Fill out the SWMS template (Fig. 34.29) for the task of demolishing the same garage for which the demolition plan has been formulated.
3. Create a tools and equipment list for the small demolition task in Activity 1.
The list should include three sections:
 - (a) personal protective equipment (PPE)
 - (b) required tools
 - (c) required plant and equipment.
4. Create a detailed plan for the demolition of an external load-bearing wall in a brick veneer dwelling, for the purpose of extending the dwelling with an add-on, creating an open-plan living area.

Fig. 34.29 Work Safe SWMS template

APPENDIX A—SAMPLE SWMS TEMPLATE FOR HIGH RISK CONSTRUCTION WORK (HRCW)

DUTIES: 1) A SWMS must be prepared if proposed works involve any of the HRCW activities listed below and that work poses a risk to the health and safety of any person. 2) Affected employees and their HSRs must be consulted in the preparation of the SWMS. 3) Once a SWMS has been developed and implemented, the HRCW to which it relates must be performed in accordance with the SWMS. 4) Duty holders (builder and sub-contractor) must stop the HRCW immediately or as soon as it is safe to do so if the SWMS is not being complied with; the HRCW must not resume until the SWMS is complied with or reviewed and revised as necessary. 5) The SWMS must be reviewed and if necessary, revised whenever the HRCW changes, or after any incident that occurs during HRCW, or if there is any indication that risk control measures are not adequately controlling the risks. 6) An employer must retain a copy of the SWMS for the duration of the HRCW.			
Direct employer:		Principal contractor (PC) (Name and contact details)	
Work supervisor: (Name and contact details)		Date SWMS provided to PC:	
Work activity: (Job description)		Workplace and works location:	

High risk construction work:	☐ Where there is a risk of a person falling more than two metres.	☐ On or adjacent to roadways or railways used by road or rail traffic.	☐ In, over or adjacent to water or other liquids where there is a risk of drowning.
	☐ At workplaces where there is any movement of powered mobile plant.	☐ Structural alterations that require temporary support to prevent collapse.	☐ In an area where there are artificial extremes of temperature.
	☐ On or near energised electrical installations or services.	☐ Involving a trench or shaft if the excavated depth is more than 1.5 metres.	☐ On or near pressurised gas distribution mains or piping.
	☐ Involving demolition.	☐ Involving a confined space.	☐ On or near chemical, fuel or refrigerant lines.
	☐ Involving tilt-up or precast concrete.	☐ On telecommunications towers.	☐ Involving diving.
	☐ Involving removal or likely disturbance of asbestos (note: preparation of an asbestos control plan is taken to be preparation of a SWMS).	☐ In an area that may have a contaminated or flammable atmosphere.	☐ Involving the use of explosives.
			☐ Involving a tunnel.

Person responsible for ensuring compliance with SWMS:		Date SWMS received:	
What measures are in place to ensure compliance with the SWMS? (e.g. direct supervision, regular spot checks)			
Person responsible for reviewing SWMS control measures (e.g. PC's representative):		Date SWMS received by reviewer:	
How will the SWMS control measures be reviewed?			
Review date:		Reviewer's signature:	

Selecting risk controls:		More Effective
Any risk to health or safety must be eliminated, or if that is not reasonably practicable, reduced so far as is reasonably practicable by:	• implementing any mandated controls specified by law (e.g. the <i>OHS Regulations 2017</i>) • substituting a new activity, procedure, plant, process or substance (e.g. scaffold in preference to ladders) • isolating persons from the hazard (e.g. fence off areas for mobile plant operation) • using engineering controls (e.g. guard rails, trench shields)—or a combination of the above. If any risk to health or safety remains, it must be reduced by using: • administration controls (e.g. activity specific safety training, work instructions, warning signs) • PPE such as respiratory protection, hard hats, high-visibility clothing—or a combination of the above.	↓ Less Effective

[illegible]

Specifications and notes:

- the house is constructed as a brick veneer dwelling with steel-framed walls, steel-framed roof trusses and a concrete tile roof, fascias and guttering on a concrete slab
 - the section of wall for demolition does not have eaves
 - the internal walls and ceilings are 2.7 m high and are lined with 10 mm Gyproc plaster sheet with 70 mm coved plaster cornice
 - there are 65 mm × 19 mm MDF skirting boards and architraves
 - the section of steel-framed load-bearing wall to be demolished measures 3.6 m in length, is positioned between two internal/external wall junctions, and contains:
 - a 2.1 m high × 2.7 m wide aluminium sliding door assembly
 - an internal light switch for the external patio light on the outside brickwork to be demolished
 - back-to-back double power points—one internal, one external
 - fibreglass batt wall insulation
 - provisions to be made to protect against the elements after the wall section, and roof tiles above, have been removed.
5. Fill out a detailed safe work method statement (SWMS) for the demolition task in Activity 4.
 6. Create a tools and equipment list for the demolition task outlined in Activity 4.
The list should include four sections:
 - (a) personal protective equipment (PPE)
 - (b) required hand tools
 - (c) required power tools
 - (d) required plant and equipment.
 7. Correctly fit PPE, including eye protection, hearing protection, head protection, respiratory protection and hand protection.
 8. Undertake the correct removal of nails from timber framing and flooring as described in the chapter.
 9. Demolish a small timber structure, observing all the requirements listed in the chapter.
 10. Carry out the removal of an external timber or steel-framed wall to create an opening no less than 3 m wide, observing all the requirements listed in this chapter.

AUSTRALIAN BUILDING CODES AND STANDARDS

Safe Work
Australia,
Demolition work
Code of Practice—
October 2018

WorkSafe
Victoria,
Compliance code,
Demolition—Edition
1, May 2018

Safe Work
Australia,
How to safely
remove asbestos
Code of Practice—
October 2018

WorkSafe
Victoria,
Guidance notes,
Removing
asbestos—
October 2010

Tradie talk—The last piece in, is the first piece out

Chapter 35

Plan and organise work

Learning Objectives

- LO 35.1 Understand policies and standards for planning and organising work**
- LO 35.2 Understand safety when planning and organising work**
- LO 35.3 Identify environmental considerations**
- LO 35.4 Identify drawings and specifications for planning and organising work**
- LO 35.5 Identify types of planning**
- LO 35.6 Identify tools for planning**
- LO 35.7 Understand planning requirements**
- LO 35.8 Develop a plan**
- LO 35.9 Schedule a plan**
- LO 35.10 Identify considerations when planning and organising a basic construction task**
- LO 35.11 Problem solve plans and tasks**
- LO 35.12 Review plans and tasks**

Introduction

On industrial, commercial or residential projects, planning happens at all levels—from architects to project managers and along the line to tradespeople and construction workers. Regardless of the size of the project, whether it is a multistory city building or a residential home extension, planning must be done accurately and tasks identified before any construction work can begin.

Planning and organising work in the construction industry involves more than just working out the steps of a task. Planning and organising are essential skills that are necessary to achieve high-quality outcomes on construction projects, taking into consideration factors such as:

- workplace policies and standards (Australian Standards)
- environmental and workplace requirements

- workplace health and safety (WHS)
- requirements for work time, personnel, tools, equipment and machinery
- components, materials, fixings and adhesives
- scheduling of work, roles and responsibilities of team members.

Good planning helps to reduce expense, waste and time. Breaking a project down into tasks and steps allows:

- controls and contingencies
- efficiency of materials and labour
- communication between trades
- safety of the worksite and spaces
- quality.

Good planning also allows you to track the progression of your project and each of the tasks involved. Having this information will help you with scheduling and money management.

Poor planning or no planning, on the other hand, will increase the likelihood of:

- wasting materials/doubling up on materials
- not ordering enough materials and fixings
- having tradespeople waiting around or having to come back at another time or on a different day
- mistakes being made
- work health and safety (WHS) issues
- poor communication between architects, managers, tradespeople and contractors.

Construction projects that are well planned can potentially be completed faster and at less expense. As a direct result of this, a company or individual tradesperson can develop a good reputation within the construction industry, which can lead to more work and profit. The opposite is also possible: a poor reputation may result from poorly planned and overbudget jobs.

35.1 Understand policies and standards for planning and organising work

Consideration needs to be given to workplace policies and standards such as:

35.1.1 Legislation, regulations and Codes of Practice

The model WHS Act is the legislation governing all aspects of the building and construction industry and provides a balanced and nationally consistent framework to secure the health and safety of workers and workplaces. The regulations support the legislation, and are laws made by federal, state and territory governments covering all aspects of the construction industry, including working conditions, and quality and safety requirements. Codes of Practice provide practical advice on how the laws should be applied.

When you are planning and organising work, you will need to be aware of the regulations that apply to your state or territory. No matter the size and scope of the work, you will need to comply with the laws of the model WHS Act.

More information on the model WHS laws can be found at www.safeworkaustralia.gov.au.

35.1.2 Australian Standards

Standards are sets of nationally recognised documents establishing the minimum set of requirements that define quality and safety criteria within the building and construction industry. The Australian

Standards include specifications and procedures designed to ensure that products, services and systems are safe and reliable and that they consistently perform the way they are intended to.

35.1.3 Workplace policies and procedures

Workplace policies and procedures are developed in conjunction with the model WHS Act, the regulations and the Codes of Practice. These documents are developed by companies and worksites to let workers know how work should be done, the standard of work required, and what equipment and materials are needed. Workplace policies and procedures ensure company requirements are met, as well as meeting the requirements of the laws and regulations.

Policies and procedures may vary between companies and worksites, so it is essential to know what they are as this will affect your decisions in terms of planning and organising work, tasks and projects.

35.1.4 Manufacturer's specifications

Planning and organising must allow for any extra time that may be required to meet any specific quality requirements set out by the manufacturer. The manufacturer of a product will have a written set of specifications (available as a hard copy or online), instructions and recommendations detailing the applications its product can be used for.

Such specifications include but are not limited to:

- safe handling
- how the product is to be installed/erected
- assembly process
- fixings/adhesives
- storage
- how the product is to be maintained, repaired or dismantled.

If you do not follow the manufacturer's specifications, this may result in the failure of the product and void the manufacturer's warranties.

35.2 Understand safety when planning and organising work

Safety is a legal obligation and must be taken into consideration when planning and organising all aspects of building and construction tasks and projects. Safety considerations take into account all persons involved, all tasks and all potentially hazardous work and may include but are not limited to:

- personal protective equipment (PPE) such as earmuffs, safety glasses and harnesses
- barricades and signage
- first-aid equipment
- training on how to use new equipment or materials
- site induction/evacuation and emergency procedures
- working at heights/in confined spaces/trench works.

Safe planning will include the use of forms such as:

- job safety analysis/job safety and environmental analysis (JSA/JSEA)
- material safety data sheet/material data sheets (MSDS/MDS)
- safe work method statement (SWMS).

Developing a culture of safety will help increase efficiency through a reduction in costs associated with workers being injured and requiring days off. Major injuries on a worksite will have a significant impact on cost, workflow and schedules.

(For more information on safety and safety documents, refer to Chapter 1, Work health and safety.)

35.2.1 Quality requirements

Quality in terms of producing a product is the balance between cost and time, and making sure you comply with the industry standards and tolerances derived from:

- legislation, regulations and Codes of Practice
- Australian Standards
- workplace policies and procedures
- manufacturer's specifications.

Having quality controls in place will help ensure materials, components and products meet the necessary standards and the requirements of the order and contract. Quality controls should be embedded at each step of the production, manufacturing and installation process.

35.2.2 Housekeeping

Housekeeping is more than just sweeping the floor or dusting. It is crucial to ensure a safe workplace and can help prevent injuries and improve productivity. A written set of rules will help to prevent slips, trips and falls, eliminate fire hazards, and help control dust and clear clutter, as well as helping with tracking materials. By stacking and storing materials correctly, you can prevent falling objects and near-misses. It is also important to inspect personal protective equipment and tools to make sure they are in good working order.

Other safety equipment may include signs, barricades or guards to help keep the site clear for ease of access and movement for workers and equipment.

It is the responsibility of all construction workers to make sure they know the site policies and procedures for maintaining a tidy, organised and safe workplace. For further information, check on your state's Safe Work site.

35.3 Identify environmental considerations

Good planning and organising of construction work will take into consideration any factors that could affect the environment. Protecting the environment is a legal requirement and strategies need to be put into place to avoid or reduce the impact whenever possible.

Some examples of environmental considerations are:

- toxic liquids/fuels/chemicals: make sure these liquids are stored and used correctly according to the manufacturer's specifications and disposed of in compliance with the MSDS/SDS at the appropriate waste management facility
- road dust: on a large site, try to keep to one access road if possible; dirt roads will need to be sprayed down with water and, potentially, wind fences installed
- dust created from cutting materials: dust created by machining can be reduced by working with vacuums or working in designated cutting rooms
- litter/general rubbish: make sure the site has access to rubbish bins, and where possible separate skips for general waste, metals, clean soils, green waste and concrete. Some types of waste—for instance, asbestos—will need to be removed by a licensed contractor
- unused construction materials: where possible, these should be re-used and recycled
- trees: on some building sites, trees may have a protection notice and removal is not permitted. To protect these trees, fencing (Fig. 35.1) or hoarding will need to be erected around them
- noise/vibration: to reduce noise, make sure plant and equipment are serviced and working properly, and avoid using loud machines before or after designated times, especially in built-up areas
- water/waterways/drains: depending on the type of work taking place on-site, drains may need to be diverted or covered to avoid potentially harmful materials seeping or leaching into the drains system.

35.4 Identify drawings and specifications for planning and organising work

Sketches are often used to set down ideas for projects, proposing the sizes, locations and orientation of features. They are often used in conjunction with photos, magazines and internet sites that provide design ideas. These sketches are developed into architectural drawings and become the working drawings or construction drawings of the project. Such drawings contain a visual representation of a building or project.

Some of the information that can be found on working drawings are:

- site plan and orientation
- floor plan and elevation
- footings
- roof
- location of services, e.g. sewer, water, electrical
- bracing plan
- layout of room, windows and doors.

The main function of the working drawings is to convey the intentions of the architect or designer. The drawings must be clear, accurate and legible to everyone who needs to work from them. Working drawings should show the finalised design and the exact arrangement of spaces, the sizes, the construction materials and specific details that enable the building of a house. Figure 35.2 is an example of a plan view of a house. From the plan, we can get the overall dimensions of the house and where it sits on the property as well as all of the internal spaces.

Working drawings are also used in the tendering phase, when companies can make accurate estimations of the cost of the build and put in an expression of interest.

Specifications provide written information on the quality and type of materials and products to be used, and the standards for various building elements. The specifications will also include schedules for doors and windows, door furniture, finishes and other items.

Specifications are prepared to provide consistency and to instruct the builder and contractors on how the works are to be carried out, the quality of the work required and the methods of quality assurance on the construction. The specifications also reinforce to the builder and the contractors that they are required to conform to the Australian Standards and Codes of Practice.

The drawings and specifications work together to fully describe all of the materials and products that are required to construct a building project. The drawings and specifications are used to form part of the building contract, which is the legal agreement between the owner and builder.

35.5 Identify types of planning

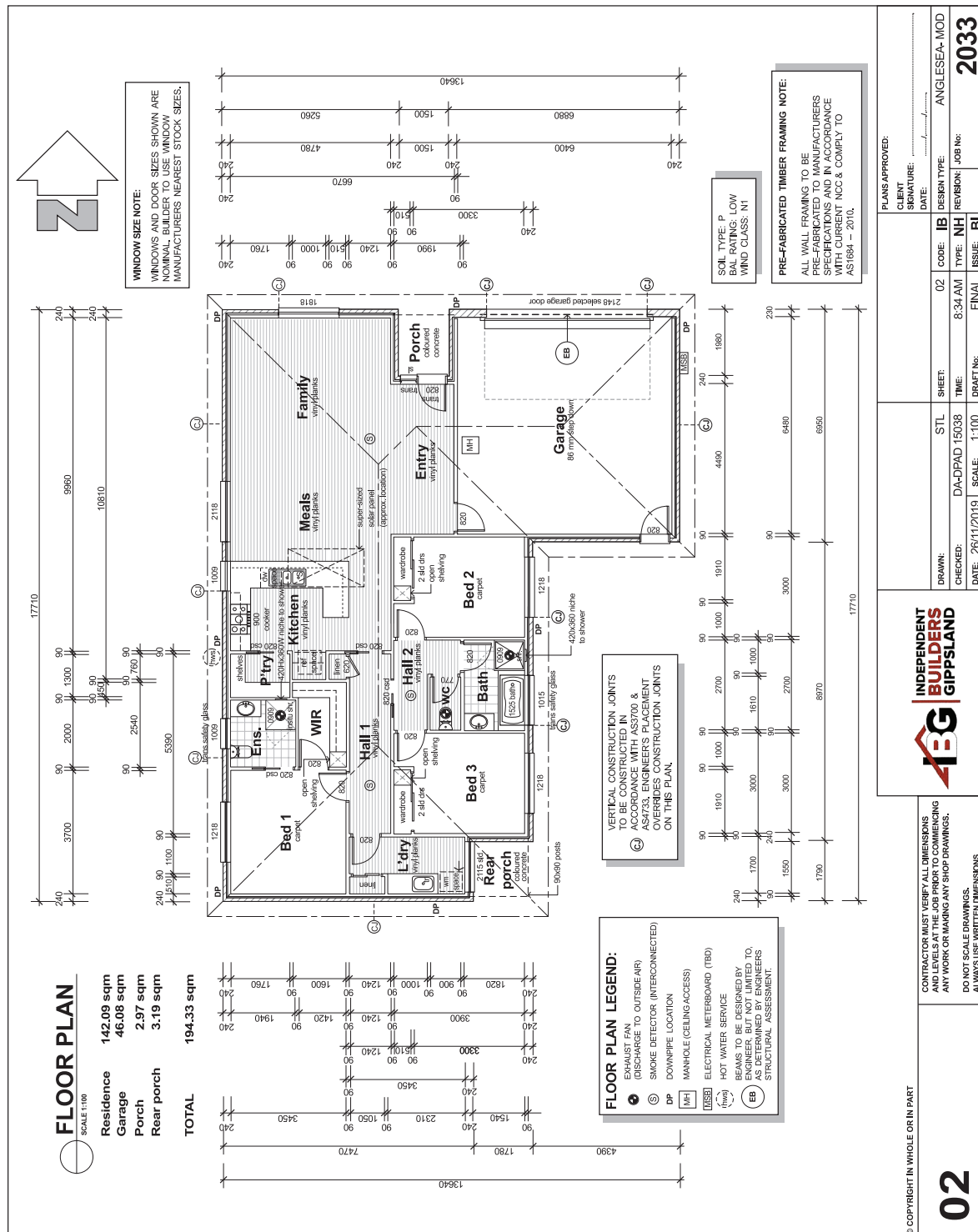
Businesses and organisations that work within the building and construction industry will use an assortment of types of plans. Planning helps to grow a business and its future outcomes. Businesses will use 'strategic plans', which are employed to help organisations with their long-term goals and future direction. Strategic plans will also provide guidelines about the required outcomes of subsequent plans at all other levels of the organisation.

Fig. 35.1 Fencing around a tree



Courtesy of Michael Hick

Fig. 35.2 Architectural plan view of a residential house



Short- and long-term goals are derived and developed from the strategic plan to help move the business in its preferred direction and towards its desired outcomes. Strategic, long-term and short-term planning are usually developed by senior management.

Operational plans provide details of what has to be done to achieve the specific objectives of a project. Although these plans relate to a specific job, they will still be connected to the short-term plans and the strategic plan.

Specific plans are used in the development of a specific task for a job, e.g. relating to the development of risk assessments or the training of staff.

Standing plans or ongoing plans are common plans used in the day-to-day running of a business, covering standard procedures and process.

Contingency plans are alternative plans that can be used if something unexpected occurs, such as extreme weather, materials being delayed or contractors being unavailable.

Most tradespeople will be primarily concerned with specific and contingency plans. Standing plans apply to all employees within the organisation. However, this doesn't stop a tradesperson or contractor from having their own long-term plans for their own careers and pathways.

35.6 Identify tools for planning

In the construction industry, many different types of work are being performed, from simple tasks to complicated projects. The more complicated the work, the more planned and organised you will need to be. There are many tools available to help you with your planning processes, some of which are outlined below.

35.6.1 Lists and checklists

Making a list is an excellent way of setting out the sequential steps involved in a task and the equipment, materials and tradespeople required. A checklist will help with the completion of each step as you can tick off the jobs/tasks as you go. A checklist may include sections for tools, equipment, stages in the timeline and who is responsible for each task.

35.6.2 Diaries and calendars

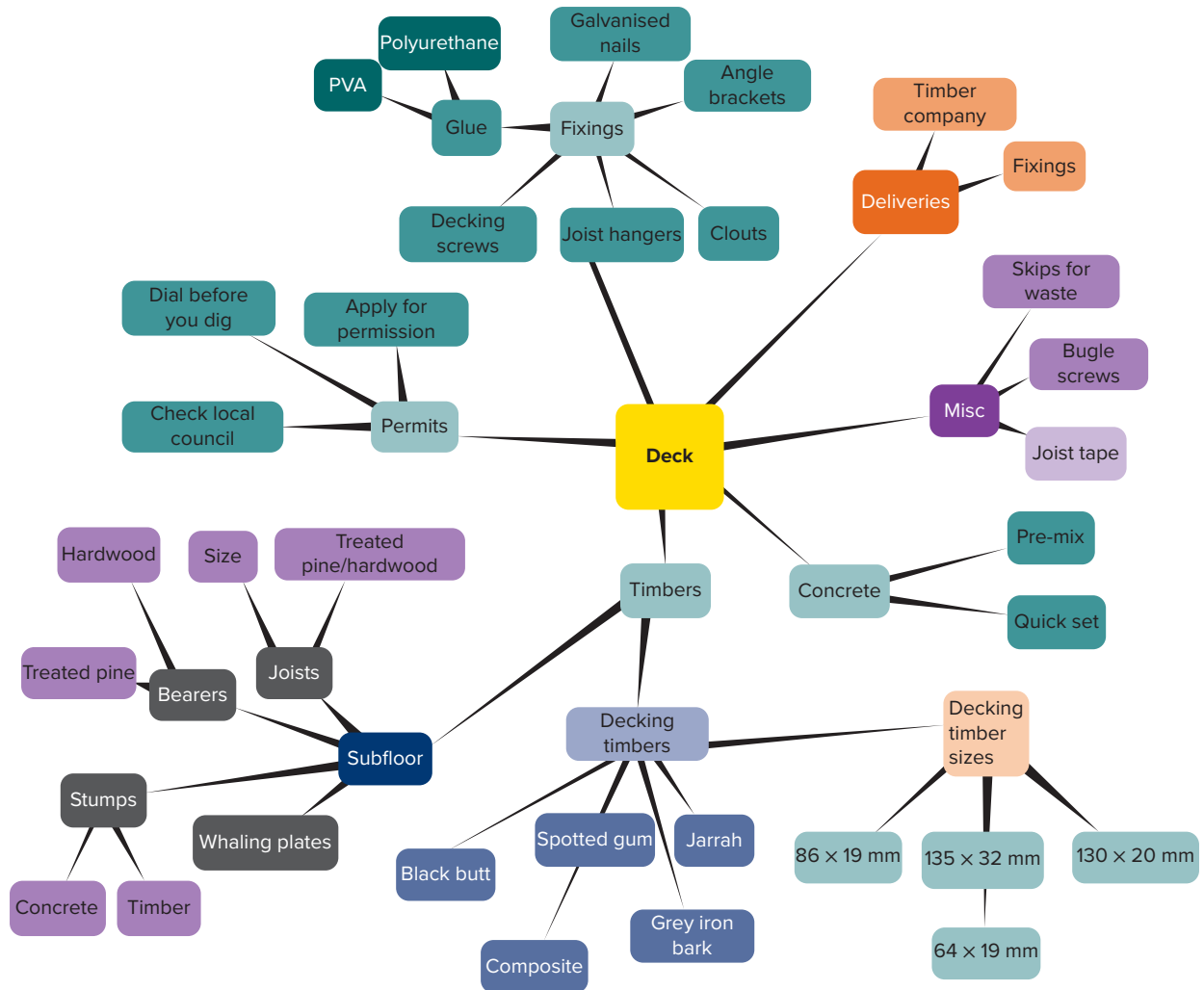
Diaries are a great way of keeping track of a particular job or an entire project. They are also a good place to record information and issues that have arisen on a job. Calendars also provide an excellent visual representation of a project or task timeline, and can be used to show the start, progression and projected end dates as well as when tradespeople have been booked in for works. Diaries and calendars may be in the form of a physical book, but these days most smartphones will have a calendar and diary function that enables you to set reminders and alerts when appointments/tasks are due.

35.6.3 Mind maps and spider charts

These types of visual aids are a great way to start a project, allowing you to write down all of the parts of the project and the associated tasks. The central project is in the middle of the chart, which has main branches and sub-branches for different aspects (Fig. 35.3). This is a helpful way to get all of your thoughts and ideas in relation to a project down on paper/onto a screen.

35.6.4 Flow charts, Gantt charts and spreadsheets

A flow chart is a type of diagram that represents a workflow or process. It can be used to express simple and complex information in a sequence of actions. A Gantt chart is a useful type of bar chart that illustrates a project schedule. In building and construction, a Gantt chart is a visual aid that shows the start and finish dates of each task and their relationships to one another, displaying which tasks can be completed at the same time and which tasks require prior tasks to be completed first before a certain task can begin.

Fig. 35.3 Mind map for a deck project

Spreadsheets are a great way of tracking many aspects of a project, including logging expenditure, employee work hours, estimating and accounting. Spreadsheets can be used over and over to calculate costs for varying quantities (Fig. 35.4) or suppliers and can be used to analyse a business's running costs, profit and loss.

35.6.5 Forms

Many companies use standard forms that have been developed to help with the running of projects. An example could be forms for quoting and estimating. These forms would have standard inclusions and exclusions, options for materials and finishes etc. to help with the costing of a job. Other standard forms that a company may use include risk assessment forms, JSA, SWMS etc.

35.6.6 Computer software

In today's modern world, computer software is available that has been developed to help businesses run smoothly. A variety of computer programs can be used to estimate the cost of an entire job or tasks, as well as the required materials and timelines. Even an everyday smartphone has a calendar, notes and apps that can be used to run entire businesses. These can also provide alerts and reminders, and help track and document projects. Some programs will develop complete cutting lists and costings.

Fig. 35.4 Example of a spreadsheet used for costings

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Client: Andrew Smith					Job no. 0001									
2	Job: Mill Park														
3	External deck from back door 4m x 1.7m overall size					Start date: 12/01/2021									
4	(refer to drawing)					Completion date: 14/01/2021									
5															
6	List of resources and materials														
7	Component	Material	Length	Width x thickness	\$ Cost	Supplier		Total including GST							
8	Whaling plates	Treated pine	1 / 4.2m	190 x 45mm	\$10.96 lm	Fords Lumber & Hardware		78.91							
9			1 / 3.0m												
10	Bearers	Treated Pine	2 / 4.2m	190 x 45mm	\$10.96 lm			124.94							
11			1 / 3.0m												
12	Joints	Treated Pine	12 / 3.0m	90 x 45mm	\$4.26 lm			153.36							
13															
14	Decking Timbers	Spotted Gum	186 l/m	86 x 19mm	\$7.00 lm			1302							
15															
16	Stumps	Treated pine	8 / 1.2m	90 x 90mm	\$18 per meter			172.8							
17															
18	Hardware					Sub Total		1832.01							
19	Clouts	Type	Size	Amount											
20	Decking screws	Galvanised	40mm	Box of 200	\$7.80	Fords Lumber & Hardware		79							
21	Joint hangers	Suitable for Hardwood	50mm	Box of 1000	\$79.00			11.8							
22	Bugle screws	Galvanised	180 x 45	4	\$2.95ea			22.5							
23	Masonry Bolts	Galvanised	100 mm	Box of 250	\$22.50			25							
24	Delivery cost	Galvanised	100 mm	Box of 20	\$25.00			60							
25								198.3							
26						Sub Total		396.6							
27						Total		2228.61							

*Prices are not accurate and have been used only as an example

35.7 Understand planning requirements

The first step in successful planning is to identify clearly what it is that you want to achieve and the preferred outcomes. Does the job have any special requirements? Are there restrictions on what you can and can't do in a particular state or council? Will you require any special planning permits and do you need to check in with other organisations before you commence work?

Information and instructions about the requirements for the job can come from many different sources. It is important you know how to access this information and ensure you have a clear understanding before you begin to make plans.

Planning starts with you asking these questions:

- who—who will be doing the work?
- what—what has to be done, what is the preferred outcome?
- when—when will it be done, what are the start and finish dates?
- where—where will the work be taking place, what state or council?
- how—how will the work be done?

There are many sources of information that can be accessed when you are identifying and clarifying the details of a project or job task. When preparing to plan for a task or quoting and estimating a job, you will need to gather as much information as you can on, for example:

- working plans, drawings and specifications
- timelines
- site measurements
- the intentions of the builder, architect and/or client
- permits required in certain councils in regards to parking, what times you can start and end work during the week
- documentation such as legislation, Australian Standards, policies and procedures and manufacturer's specifications.

It is important to be focused and pay attention to information that is being disseminated to you, to develop good active listening skills and ask as many clarifying questions as necessary to make sure you have all of the

information you need and that you understand what you have been told. A way of showing understanding is to paraphrase the information back to the person giving you it. To paraphrase simply means expressing the meaning of something written or spoken using your own words, which will help you achieve greater clarity. Summarising information can also help in making sure you understand the key points of a project or task.

After you have paraphrased and summarised the information, make sure you follow up by confirming the information. Confirming means you are checking the correctness of your understanding. This can be done verbally; however, it is always best practice to make sure confirmations are documented and signed off.

Clear and complete instructions need to be established in regards to the task you are going to be doing. If you are in any doubt about something, it is better to ask more questions and feel a little embarrassment rather than getting the job wrong—misunderstanding information and instructions can be costly and have serious consequences.

This gathering of information (Fig. 35.5) is essential for quoting and costing jobs and, if successful, the eventual scheduling of tasks, obtaining or preparing tools and equipment, and ordering materials and organising tradespeople and contractors.

Fig. 35.5 Collecting information for a deck project in a small backyard

Small deck project—collecting information

- Meet with clients and take the time to understand their vision for the decking project and develop a preferred outcome (provide at least three different options for the types of timber, finishes, direction of boards).
- Request permission and submit plans for the deck to your local council (councils will have standard forms that need to be filled out with details of how the deck will be constructed).
- Be aware that as the deck is to be constructed in a small back yard, the design must enhance the space and make it feel larger than what it is, also allowing smooth movement around the deck.
- Note that the overall size of the deck is 4 m × 2.7 m.
- Create an estimate for comparison between the different types of material/timbers available.
- Dial before you dig—make sure there are no pipes, sewerage or electrical services under the ground where stumps are to be installed.
- Determine all materials required.
- Provide a written quote and contract to be signed.

35.8 Develop a plan

Once you have gathered all of the necessary information for a project or task and you understand what you have to do, you can begin to plan the details of how to do it.

A plan will include:

- details of the task, broken down into individual steps
- sequencing of the steps—the steps will have to be organised in a logical order to ensure more tasks are completed in a time-efficient and cost-effective manner
- priorities to be assigned to each stage/step
- a schedule to ensure the task or project is completed within the agreed time frame.

As you break the task down, each step becomes simpler and more details are identified, making it easier to group some of the steps together and prioritise importance. Prioritising means deciding which tasks need to be done first, either because they are the most important to keep the project moving or the most urgent. When developing a plan, you will need to define which tasks have to be done immediately (urgent) and those that need to be done (important) but can be postponed if necessary.

Once you have been able to define which steps are either urgent or important, you can decide the order in which they should be done (sequencing). Sequencing ensures that people with different occupations who can work on a project at the same time—because they are able to work around each other and are not

dependent on whose job is completed first—can be on-site together. Some tradespeople can't be booked in together as there is a logical sequence to the order of work (Fig. 35.6). You couldn't have the roof tiler on-site at the same time as the carpenter, for instance, as the tiler can't work if the roof hasn't been constructed yet. Having them both there wouldn't be an efficient use of time and money. The next step, then, is to create a procedure for each of the tasks (Fig. 35.7) developed for your workers or contractors.

Fig. 35.6 Small deck project—tasks are broken down into a logical order

Small deck project—breaking it down into tasks

- Make sure you have obtained permission from the council.
- Order materials from your preferred timber yard to be delivered to site, noting the time/date.
- Note that access to the back yard is limited, so post holes will have to be hand dug.
- Note that dirt from the post holes is to be used as backfill, and excess dirt to be removed to the bin/skip.
- Set out site—stringline to square area and locate positions for stumps and height of bearers/joists.
- Install whaling plate attached to the house.
- Dig stump holes.
- Install stumps.
- Install weed matting.
- Install bearers and joists.
- Install decking timber—overhang the end of the joist to be cut back after all boards have been installed.
- Cut decking boards back to preferred overhang.
- Install decking fascia boards.
- Clean up.

Fig. 35.7 Small deck project—procedures for each task

Small deck project—assessing the tasks to determine what needs to be done and how it is to be done

- Make sure you have obtained permission from the council: council permission is approved and a time set for an inspector to come out and check the stump holes and fixing back to the house.
- Order materials from your preferred timber yard to be delivered to site: arrange a time/date for the materials and fixings to be delivered on-site for you to take delivery (preferably the day before you need them).
- Ensure excess dirt waste skip arrives on-site the day before.
- Note that access to the back yard is limited so post holes will have to be hand dug—excess dirt from the process will need to be wheelbarrowed out to the skip.
- Set out site—string line to square area and locate positions for stumps and height of bearers/joists. Use hurdles and site boundary fence.
- Install whaling plate attached to the house: heights are determined and the whaling plates can be attached to the house using masonry fixings.
- Dig stump holes: using the string line, mark the ground with spray paint to indicate where you need to dig the holes. Stump holes are 300 mm x 300 mm and a minimum depth of 600 mm. Some of the removed dirt will be used as backfill in the stump holes. Excess dirt will be placed in the designated skip.
- The inspector had been booked in to check stump hole depth at 12 pm.
- Install stumps: string lines have determined height of the stumps. Concrete has been prepared and poured. Stumps have been levelled and plumbed to string lines.
- Install weed matting: weed matt is installed over all exposed dirt under the deck line.
- Install bearers and joists: bearers are installed over stumps and secured, joists marked out and spaced at 450 mm centres and fixed off.
- Install decking timber—overhang the end of the joist to be cut back after all boards have been installed—4 mm gap between boards.
- Cut decking boards back to preferred overhang.
- Install decking fascia boards.
- Clean up site and construction rubbish.

35.9 Schedule a plan

Scheduling is a very important part of creating a plan for a construction project. It helps you to make the most efficient use of the time you have on a project (Fig. 35.8).

Fig. 35.8 Basic work plan schedule of works

Small deck project—schedule of works

In this example, the works are scheduled to be completed over two days. However, a contingency has been added, allowing three days in case of weather, materials not being on-site or certain tasks taking longer than expected.

Day 1: on a job of this size, a day will be approximately 6–8 hours, with an allowance for up to 10 hours (2 hours' overtime).

- Site set-out: 1 hour
- Cutting and installing whaling plates (2 people): 1 hour
- Digging 8 stumps, 15 minutes per stump (2 people): approx. 1.5 hours
- Installation of 8 stumps, levelling and plumbing (2 people): 1 hour (this should not be rushed—accuracy is key in the construction of a subfloor, and stumps may need to be braced into position)
- Installation of weed matting (1 person): 0.5 hour
- Cutting and installing bearers, 1 person cutting and the other installing and attaching joist hangers to the whaling plate plus joist tape: 1.5 hours
- Installation of joists, 1 person cutting, the other installing and fixing off plus joist tape: 1 hour.

Day 2

- Installation of decking timbers—2-person job: 6–8 hours, with an allowance for up to 10 hours (2 hours' overtime)
- Adding deck fascia boards—2 people, 1 cutting and assisting, the other installing and fixing off: 1–2 hours.

Notes:

- Timbers should be sorted into sizes. The deck is running at the shorter-length size (2.7 m, including overhang), which makes timbers of just over 2.7 m the longest length needed. Long lengths can be cut to just over 2.7 m and the short timbers may need to be butted together over a joist to create the required coverage. Need to ensure jointed timbers are staggered and separated by full-length timbers
- One person to be cutting timbers to the required lengths and assisting the other person in installing and fixing down the deck. This can be a time-consuming process involving countersinking, pilot holes and driving screws into timbers
- Clean-up—both people; clean-up of construction waste and packing up of tools.

Day 3

- Contingency day: 1 day has been allocated in case of weather, materials not being on-site or certain tasks taking longer than expected.

The schedule includes the following information:

- start and finish dates, progression stages
- logical order of the tasks to be completed (refer back to Fig. 35.6)
- date when each task will start and an estimated time of completion for the task (this estimation is usually worked out based on the best case scenario; however, contingencies will need to be adopted if there are any delays)
- connections, relationships and dependencies between tasks.

35.9.1 Deadlines and progression points

A deadline is the latest possible time by which a task or project can be completed. There are often consequences built into contracts if construction projects are not completed on time. Some reasons that a project may run overtime are:

- budgetary inaccuracies
- labour challenges

- approval times for permits and contracts
- subcontractor schedules and compliance/skills shortage
- lack of effective communication
- environmental factors such as poor weather.

There are significant extra costs if a project runs over time. On large projects, there may be many thousands of dollars in over-run costs and fines built into the contract for each day the project goes past the agreed completion date. On some jobs there are built-in bonuses if the project comes in under-budget and is completed before the deadline.

On a construction project, builders usually get paid at set progression stages. Common stages are:

- base
- frame
- lock-up
- fixing.

By planning well and therefore knowing when these stages will be completed, builders are able to control their cash flow.

35.9.2 Checking your plan

You should check and review your plans before you begin your task/project. Taking the time to check through your plans allows you to compare all the various documents you have created (materials lists, specialised machines, fixings, tools, trades etc.) and check for any errors or aspects that you may have overlooked. For example, you may find that although you have included a specialised machine on the schedule, you have not received confirmation of it being booked or available for the date that you want it.

35.10 Identify considerations when planning and organising a basic construction task

A lot of planning goes into organising a construction task/project, to ensure that everything runs smoothly, safely and efficiently. Good housekeeping is one factor that needs to be taken into consideration, while others are listed below.

35.10.1 Materials

Determining the materials for a task and making sure that they are delivered and on-site when they are needed is a major part of the construction task. Builders or contractors need to ensure they have the correct and up-to-date set of plans and specifications for the task/project. From the plans and specifications, you can determine the following:

- **Materials**—the plans and specifications may include the preferred type and brand of the materials that are to be used. They will also list the dimensions of the materials as well as any other crucial features such as fire resistance and quality requirements.
- **Costings**—materials will vary in price from supplier to supplier and you will need to get at least three different quotes to be able to compare cost and availability of the materials. There is no point going for the cheapest price if the materials are not available when you need them.

When ordering materials, you will also need to take into account the fact that with some products, such as flooring, you will not be able to purchase exact amounts. So you will need to factor in wastage from cutting the materials to odd sizes that you may not be able to use. Depending on the job (and

from your own experiences), you may add an extra 5–20% to the amount that you are ordering. This cost needs to be included in the costing of the job price.

Scheduling will help with the organising and delivery of material on-site. Materials should arrive on-site just before they are required and may need to be stored in a dry safe place. (Refer to Chapter 12, Handle carpentry materials, for information on the storage and safe handling and movement of materials on-site.)

Minimising waste is another advantage of good planning and organising. A reduction in waste will in turn save money by reducing the cost of disposing of waste materials—and is better for the environment.

35.10.2 Tools and equipment

Tools and equipment are required on every building and construction project. Tools need to be in good working order and fit for purpose. Planning may need to take into account the storage of tools and equipment in a dry, safe and locked space on-site. Some tasks on a project may require you to hire specialised equipment. As part of the planning process, you will need to make sure this equipment is available when you require it, so you will most likely need to book it in advance to ensure it is on-site when needed. Personal protective equipment (PPE) needs to be fit for purpose and in good working order. Equipment can include but is not limited to:

- earmuffs/ear defenders
- safety glasses/face shields
- work-specific clothing
- boots
- gloves
- respiratory equipment
- harness and fall protection equipment.

Checklists are a great way of keeping track of tools and equipment (Fig. 35.9).

35.10.3 Communicating with tradespeople, workers and contractors

As you are planning and organising a project, you will most likely need to communicate with other tradespeople and contractors. You will be negotiating aspects such as start and finish times, costings, payments and allowances. Sometimes, start dates and times will need to be negotiated with contractors and tradespeople to fit in with their schedules, as they may already have been booked in for other projects.

Good communication is essential when working with others to plan, organise or complete a task/project. This can be difficult at times because everyone is different (including in terms of backgrounds and abilities) and will vary in their communication style.

There can be a lot of pressure and stress involved with planning, organising and executing a project. Communication between contractors and tradespeople can be seriously affected if things don't go to plan.

A good communication strategy you can practise and use is 'active listening'. The key points of active listening are:

- building trust and establishing rapport
- demonstrating concern
- paraphrasing to show understanding
- using cues that show understanding, such as nodding and eye contact
- short verbal affirmations such as 'I see', 'I know', 'Sure', 'Thank you', or 'I understand'
- asking specific questions to seek clarification.

As with any of the relationships you have, if you lose trust and communication, the relationship is on a trajectory of failure. This technique takes time and practice.

Fig. 35.9 Example of a checklist

Checklist of required tools and equipment	Job: Mill Park	Client: Andrew Smith	
Job description: Deck	Notes	Checked	Signed
Task 1: Tools	All tools must be accounted for by 10/01/2021		
Shovel and post hole shovel		✓	Mick
Chisels		✓	Mick
Hand and powered saw		✓	Mick
Drill driver and impact drill—drill bits and drivers, hex, Phillips, decking screwdriver square		✓	Mick
Sockets, spanners and wrenches		✓	Mick
Measuring tape/folding ruler		✓	Mick
Hammer and sledgehammer		✓	Mick
Combination square/speed square		✓	Mick
String line		✓	Mick
Adjustable wrench		✓	Mick
Spirit level 800, 1200, 2000 and long straight edge 4 m		✓	Mick
Wooden and metal stakes		✓	Mick
Spray and mark paint		✓	Mick
External PVA glue		✓	Mick
Nail gun and framing gun (galvanised fixings)		✓	Mick
Fixings		✓	Mick
Task 2: Specialised tools			
N/A			
Task 3: PPE	All PPE must be accounted for by 10/01/2021		
N95 dust mask		✓	Dan
Earmuffs/ear defenders		✓	Dan
Safety glasses		✓	Dan
N95 mask for working in close proximity to others during the pandemic		✓	Dan
Gloves and N95 particulate respirator mask (for working with concrete)		✓	Dan
Sunscreen and hat		✓	Dan

35.10.4 Reporting and documentation

Keeping accurate records of a construction project is essential. Your records will be made up of the contract, lists of tasks, costings, schedule, required tools and equipment, tradespeople and contractors. The contract is a very important document as it is the agreement between two parties about the works, materials and timeline of a project. Any changes to the project must be agreed by both parties and an amendment must be made in the contract. Failure to record any changes in the contract may leave you open to liability if the owners have a change of mind and say they didn't sign off on the changes.

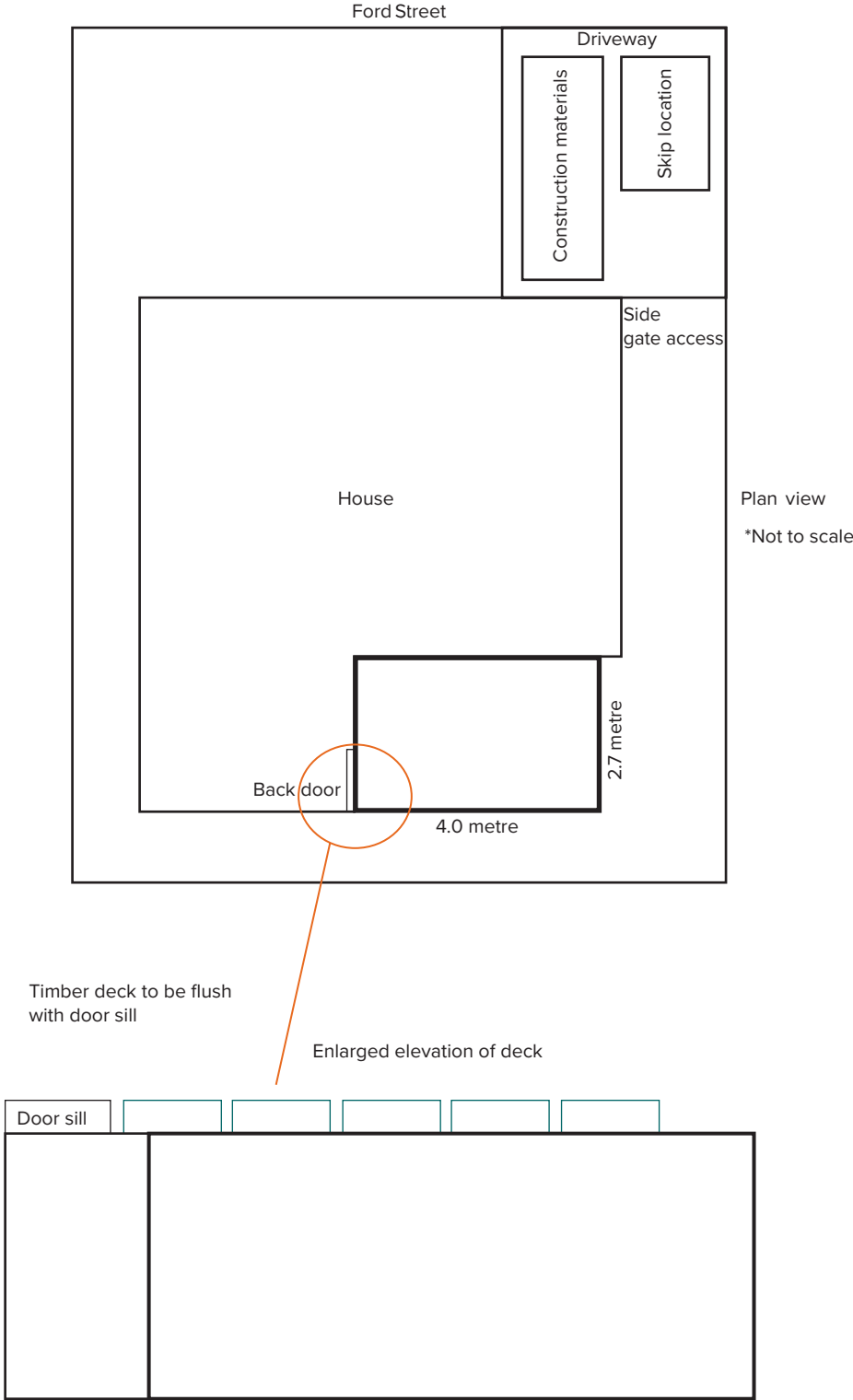
Standard documents that you will create when planning are:

- safety documents such as the JSA and SWMS
- quotes and estimating documents
- contracts
- task/work plans and drawings (Figs 35.10 and 35.11)

Fig. 35.10 Example of a written work plan of materials and resources

Job: Mill Park Client: Andrew Smith Start date: 12/01/2021 Completion date: 14/01/2021			Job no. 0001 External deck from back door 4 m × 2.7 m overall size Refer to drawing			
Task/step	Description	Materials	Tools and equipment	Safety equipment	Other information	Tradesperson(s)
1	String line Deck area and stump heights	String line	Hammer Hurdles/profiles	Weather-dependent Sunglasses and hat	8 stumps to be installed—refer to drawings	Mick and Dan
2	Whaling plates	Treated pine 190 × 45 Masonry fixings	Hammer drill Hammer Socket set/impact driver	Earmuffs Safety glasses Sun smart		Mick and Dan
3	Stump holes		Shovel/hole shovel	Gloves Sun smart		Mick and Dan
4	Installation of stumps	90 × 90 treated pine	Level	Gloves and N95 dust mask Sun smart	Use 3 bags of quick set per stump hole	Mick and Dan
5	Installation of bearers	Treated pine 190 × 45	Hammer Joist hangers Clouts	Earmuffs Safety glasses Sun smart		Mick and Dan
6	Installation of joists	Treated pine 90 × 45	Hammer	Earmuffs Safety glasses Sun smart		Mick and Dan
7	Installation of decking timbers	Spotted gum 86 × 19	Drills/impact driver Decking screws 50 mm	Earmuffs Safety glasses Sun smart	3 mm spacing	Mick and Dan
8	Installation of deck fascia boards					Mick and Dan
9	Clean-up	Spotted gum boards 86 × 19	Broom/vacuum		All rubbish to be placed in skip	Mick and Dan

Fig. 35.11 Basic work plan job drawing



- documents that provide information/direction to tradespeople, contractors, owners or others
- communication between yourself and tradespeople, contractors, owners or others, e.g. email correspondence
- documents for moderating and evaluating projects (costing, materials, profit etc.).

Formal planning documents that may need to be completed to comply with legislation, regulations and local councils are:

- planning permits
- building permits
- safety plans
- management plans for works that may require the closure of public footpaths and roads
- noise management plans
- permission to make construction noise outside of normal working hours
- parking permits.

Each council will have its own policies, procedures and restrictions, so you will need to investigate the processes for the specific council area you are working in. For example, some councils will allow construction work on Saturdays between 9 am and 3 pm and on Sundays only with a permit and at restricted times.

35.11 Problem solve plans and tasks

It doesn't matter how well you plan your project or job, there are just some factors that you cannot plan for and that will create delays and problems, for instance:

- tasks take longer than expected
- tradespeople are unavailable
- workers are away (sick or injured)
- extreme weather (hot, cold, storms, high winds etc.)
- materials are out of stock/unavailable or not delivered on time
- mistakes (e.g. cutting materials to the wrong size or placing them in the wrong position)
- faults or breakdowns with specialised tools and equipment
- products manufactured to the incorrect specifications
- too many tradespeople on-site at one time trying to access the same space (conflict can arise).

Problem solving is the process of determining what has gone wrong and finding a way and strategy to get the task or project back on track. The way that you deal with these setbacks and problems will determine the usefulness of your planning process.

Sometimes problems can have a knock-on effect, which means that one problem can inadvertently or directly cause another. Problems on a construction project need to be taken care of as soon as possible to reduce any knock-on effects—which may come in the form of extra time, money and materials.

Some simple problem-solving strategies include the following:

- Identify the issues: what is the problem? How did it occur? And work backwards from the result to what it is that you wanted to achieve.
- Understand everyone's interests: who is involved?
- List the possible solutions: brainstorm the problem with your team or coworkers, especially more experienced people.
- Evaluate the options: list the pros and cons of all possible solutions.
- Select the best option(s): what is the best solution to the problem?
- Document the agreement(s): write the solution(s) down—this will help you think through all of the details and implications of the option that you have selected. If it requires an alteration, make sure

the contact is updated and the changes have been signed off. Create and agree on new contingency plans so that there is a process in place to rectify it if this problem comes up again. And create a process to monitor and evaluate the outcomes.

Part of the planning process is to have contingency plans in place. Contingency plans are alternative plans that can be used if something unexpected occurs. You should have contingency plans in place for such things as:

- safety: a plan should be in place, and understood, detailing the action to be taken if there is an accident or incident on-site
- contactors and tradespeople: there should be a plan outlining what to do if your usual contractors are unavailable due to scheduling issues or other projects running over time (sick or injured)
- extreme weather: there should be a plan in place summarising what action to take if, for example, workers are working outside and the weather becomes too hot, ideally so that they can be moved onto other tasks located inside or under shade.

35.12 Review plans and tasks

To be a successful planner, it is essential that you are able to assess the effectiveness of your plan and recognise what worked and what didn't work, as well as any mistakes and oversights that you may have made. It is also imperative that you are able to manage unanticipated events and outcomes and have a set of contingency plans in place. With all plans, you also need to have a process in place to monitor, evaluate and review the effectiveness of your overall plan and make improvements to your planning processes.

Monitoring, evaluating and reviewing are parts of the improvement process. They help you to determine whether a project/task is on track, and whether changes need to be made and some areas adjusted.

Monitoring is the ongoing process of regularly collecting and analysing relevant information to make sure you are doing what you set out to do. Monitoring tends to happen continuously on a construction project for each task and stage. The process helps to identify potential problems and allows you to take the necessary corrective actions to ensure that the project remains within scope, on budget and on target to meet the specified deadlines.

Evaluating is when you assess the outcome of the task/project and assess whether the outcome was what you set out to do. Did you achieve all of the plan goals? Can you identify what went wrong and why? Was your planning process effective?

Reviewing is when you look at the results of an evaluation and decide whether something needs to be changed or improved upon. This information can then be used to make improvements to future plans and your planning process.

The review process will help you to identify areas of improvement such as:

- tasks that took longer than expected—was the time frame unrealistic?
- tasks that were not in the original plan—was this an oversight?
- materials that may not have performed in the way they were supposed to—are there better brands on the market?
- materials that were not cost effective for what they were used for—are there better alternatives?
- safety issues—did any issues arise that had not been taken into consideration?
- incidents—were there any accidents, injuries or near-misses that could have been avoided?
- estimating and timelines—was the plan within budget and on time and are there areas to improve in quoting and putting in tenders?

Working with team members to review the work plan can also help with:

- future planning of similar projects
- scheduling tasks to increase efficiency
- allocating roles and responsibilities of tasks
- providing feedback on any WHS issues with the project.

The review process can also include others who have worked on the project, scheduling meeting times with those who were involved, such as contractors and tradespeople, who can help identify where improvements could have been made and changes to be made to future plans.

Through planning and organising tasks and projects, you will gain knowledge and an understanding of how a project should under normal circumstances progress. The knowledge that you obtain through the experience of planning, from both the successes and the challenges, helps to make you better at planning and organising in the construction industry, enabling you to foresee potential problems, create contingencies and improve your processes and practices.

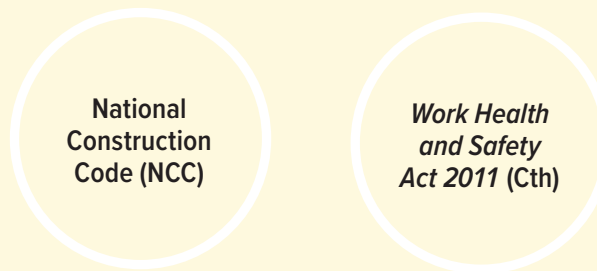
Student research

List the order in which a new residential house should be constructed. List the stages and tradespeople in the most logical order of works.

End-of-chapter activities

1. In a small group, discuss the implication and effects that poor communication between architects, managers, tradespeople and contractors have on a project that you have organised.
2. What environmental factors and considerations do you need to take into account in your planning?
3. In a small group, research and discuss the positive effects of reducing your waste on a construction project. Create a mind map with 'reduction of waste' as the central idea.

AUSTRALIAN BUILDING CODES AND STANDARDS



Tradie talk—If we fail to prepare, we prepare to fail

Appendix

Courtesy of Independent Builders Gippsland

Drawing 01: Site plan

Drawing 02: Floor plan

Drawing 03: East, south, north and west elevation

Drawing 04: Typical section and eaves detail

Drawing 05: Electrical plan

Drawing 06: General NCC notes

Drawing 07: Construction for bushfire attack level

SITE PLAN NOTE:

BUILDER TO VERIFY ALL BOUNDARY DIMENSIONS PRIOR TO SETTING OUT.

NO BUILDING WORKS ARE TO ENCR OACH OVER THE TITLE BOUNDARY INCLUSIVE OF ANY EQUIPMENT USED ON, OVER, UNDER OR IN AIR SPACE OF THE ADJOINING PROPERTIES WITHOUT OBTAINING ADJOINING OWNERS CONSENT VIA PROTECTION WORKS NOTICES PURSUANT TO PART 7 OF THE BUILDING ACT 1983 AND & BUILDING REGULATION 602.

DRAINER MUST REFER TO START WORK NOTICE FOR SEWER POINT LOCATION.

SEWERAGE AND SULLAGE TO CONNECT TO SEWERAGE MAIN AS DIRECTED BY LOCAL AUTHORITIES.

SITE TO BE SCRAPED LEVEL OVER PROPOSED BUILDING AREA WITH FINISHED GROUND TO BE GRADED AWAY FROM BUILDING.

BEFORE & DURING CARRYING OUT OF BUILDING WORK & EXCAVATIONS, THE ALLOTMENT SHOULD BE FENCED OR OTHERWISE GUARDED AGAINST BEING A DANGER TO LIFE OR PROPERTY.

THE MAXIMUM GRADIENT OF THE DRIVEWAY SHALL NOT EXCEED 1: 5.

STORMWATER DRAIN NOTE:

PROVIDE 90mm DIAMETER P.V.C STORMWATER PIPE WITH MINIMUM FALL OF 1: 100.

STORMWATER DRAIN LAYOUT IS INDICATIVE ONLY & WILL BE LAID AT THE DRAINERS' DISCRETION.

PROVIDE SELECTED DOWNPIPES AT 12.0m MAXIMUM CENTRES.

DISCHARGE TO LEGAL POINT OF DISCHARGE (LPD), UNABLE TO VERIFY EXACT LOCATION OF LPD, ASSUMED LOCATION SW CORNER. TO BE ADVISED.

CUT TO RL 9.500

CUT TO BE 1.0m MINIMUM FROM EDGE OF BUILDING AND BATTERED BACK AT 45° MAX. UNLESS OTHERWISE INDICATED.
CUT OUTSIDE HOUSE LINE TO FALL AWAY FROM HOUSE TO TOE OF BATTER BY 75mm MIN.

AG DRAIN TO BASE OF CUT AND CONNECTED TO SILT PIT = ⑤
SILT PIT TO BE CONNECTED TO STORMWATER.

CONSTRUCTION FOR BUSHFIRE ATTACK LEVEL LOW (BAL-LOW)

REF: AS3959-2009
• THIS STANDARD DOES NOT PROVIDE CONSTRUCTION REQUIREMENTS FOR BUILDINGS ASSESSED IN BUSHFIRE-PRONE AREAS IN ACCORDANCE WITH SECTION 2 AS BEING BAL-LOW.

NOTE: THERE IS A NUMBER OF STANDARDS THAT SPECIFY REQUIREMENTS FOR CONSTRUCTION; HOWEVER, WHERE THIS STANDARD DOES NOT PROVIDE CONSTRUCTION REQUIREMENTS FOR A PARTICULAR ELEMENT, THE OTHER STANDARDS APPLY.

• THE BUSHFIRE ATTACK LEVEL BAL-LOW IS BASED ON INSUFFICIENT RISK TO WARRANT SPECIFIC BUSHFIRE CONSTRUCTION REQUIREMENTS. IT IS PREDICATED ON LOW THREAT VEGETATION AND NON-VEGETATED AREAS (SEE CLAUSE 2.2.3.2).

SOIL TYPE: P
BAL RATING: LOW
WIND CLASS: N1

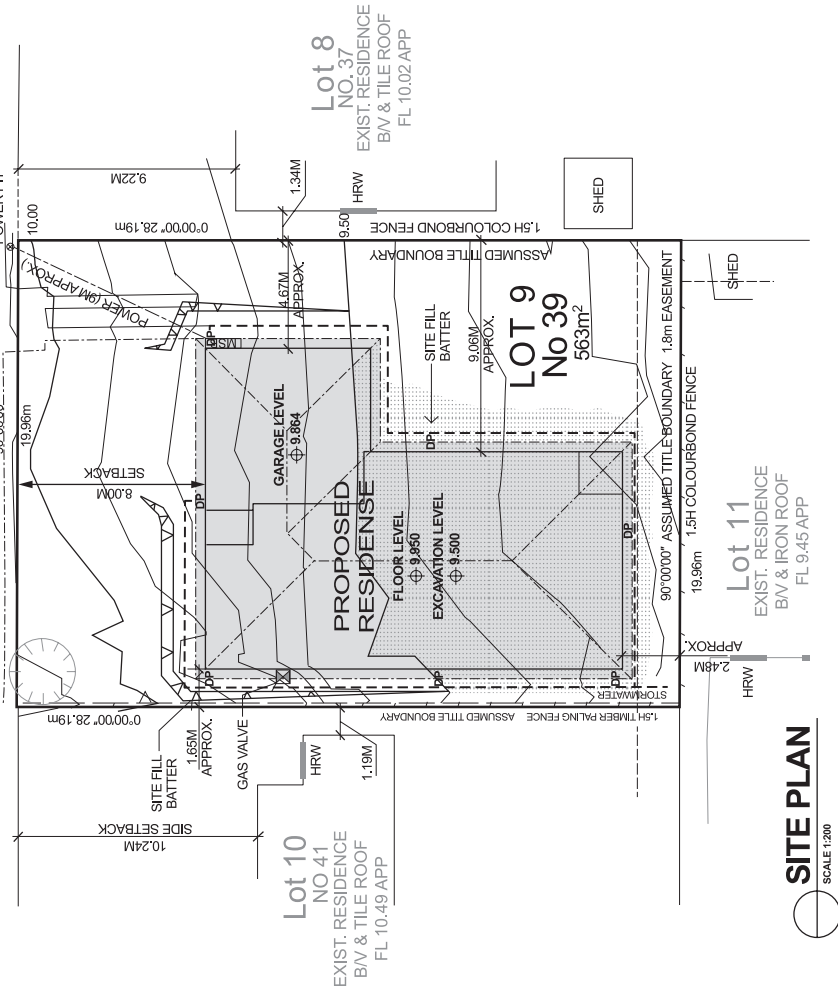
EDGE OF BITUMEN

EDGE OF GRAVEL

VEHICLE CROSSING

TBM 10.15 TOP OF TELECOM PIT

CONCRETE FOOTPATH



SITE PLAN

SCALE 1:200

SITE ANALYSIS:

SITE AREA: 563 sqm.
RESIDENCE: 142.09 sqm.
GARAGE: 46.08 sqm.
PORCH: 2.97 sqm.
REAR PORCH: 3.19 sqm.
HARD PAVING: 0 sqm. approx.
SITE COVERAGE: 184.33 sqm, 34.52%
PERMEABILITY: 368.67 sqm, 65.46%

BUILDING REGULATIONS:

Single Dwelling (Building Permit)

73 & 74. Setback.

Adjoining dwellings setback is 9.22m. Therefore the proposed 8.0m setback requires report & consent from local authority.

75. Building Height.

Building height is 5.25m which does not exceed the maximum standard of 9.0m.

76. Site Coverage.

Site coverage of 34.52% does not exceed the maximum standard of 60%.

77. Permeability.

Permeable area 65.46% exceeds the minimum standard of 20%.

78. Parking.

2 car spaces provided within allotment. Both within garage and meet the standard by existing car measurements of 6.0m deep by 5.5m wide.

79. Side and Rear Setbacks.

Proposed dwelling setbacks concur with minimum standard of 9.0m.

80. Walls on Boundaries.

No portion of the proposed dwelling to be constructed right on the title boundary, this requirement is not exceeded.

81. Daylight to Existing Windows.

All habitable room windows on existing dwellings is setback adequately. This allows 1.0m clear to sky to all habitable room windows.

82. North Facing Windows.

Adjoining properties setback adequately from proposed to have no affect on existing windows.

83. Overshadowing Open Spaces.

Single storey application. Not applicable.

84. Overlooking.

Proposed dwelling on slab and does not exceed 0.8m above the natural ground line, with fences min 1.8m high, therefore no overlooking issues.

85. Daylight to New Windows.

All internal living rooms are provided with windows that face open areas with natural daylight all with a min. of 3sqm and min 1.0m clear to sky to existing daylight.

86. Private Open Space.

Rear Private Open Space exceeds the minimum standard of 25sqm with a minimum of 1.8m high and 1.8m wide fences to be greater than 1.8m high and erect prior to occupancy of dwelling.

NOTE:

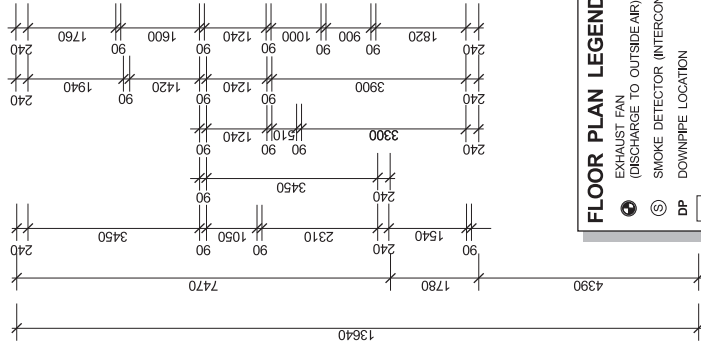
BUILDER TO CHECK EXCAVATION LEVELS ON SITE PRIOR TO COMMENCEMENT.

© COPYRIGHT IN WHOLE OR IN PART	CONTRACTOR MUST VERIFY ALL DIMENSIONS AND LEVELS AT THE JOB PRIOR TO COMMENCING ANY WORK OR MAKING ANY SHOP DRAWINGS. DO NOT SCALE DRAWINGS. ALWAYS USE WRITTEN DIMENSIONS.		INDEPENDENT BUILDERS GIPPSLAND		PLANS APPROVED:	
	01	2033	DA-DPAD 15038	STL	CLIENT SIGNATURE: _____ DATE: ____/____/____	DESIGN TYPE: ANGLESEA- MOD
DRAWN: _____		CHECKED: _____	DATE: 26/11/2019	SCALE: 1:200	DESIGN TYPE: IB	REVISION: JOB No: 2033
SHEET: _____		TIME: 8:34 AM	DRAFT No: _____	TYPE: NH	ISSUE: BI	
01		2033	DA-DPAD 15038	STL	CLIENT SIGNATURE: _____ DATE: ____/____/____	DESIGN TYPE: ANGLESEA- MOD

FLOOR PLAN

SCALE 1:100

Residence	142.09 sqm
Garage	46.08 sqm
Porch	2.97 sqm
Rear porch	3.19 sqm
TOTAL	194.33 sqm



WINDOW SIZE NOTE:
WINDOWS AND DOOR SIZES SHOWN ARE NOMINAL. BUILDER TO USE WINDOW MANUFACTURERS NEAREST STOCK SIZES.

SOIL TYPE: P
BAL RATING: LOW
WIND CLASS: N1

PRE-FABRICATED TIMBER FRAMING NOTE:
ALL WALL FRAMING TO BE PRE-FABRICATED TO MANUFACTURERS SPECIFICATIONS AND IN ACCORDANCE WITH CURRENT NCC & COMPLY TO AS1684 - 2010.

FLOOR PLAN LEGEND:

- EXHAUST FAN (DISCHARGE TO OUTSIDE AIR)
- SMOKE DETECTOR (INTERCONNECTED)
- DOWNPIPE LOCATION
- MANHOLE (CEILING ACCESS)
- ELECTRICAL METERBOARD (TBD)
- HOT WATER SERVICE
- BEAMS TO BE DESIGNED BY ENGINEER, BUT NOT LIMITED TO, AS DETERMINED BY ENGINEERS STRUCTURAL ASSESSMENT.

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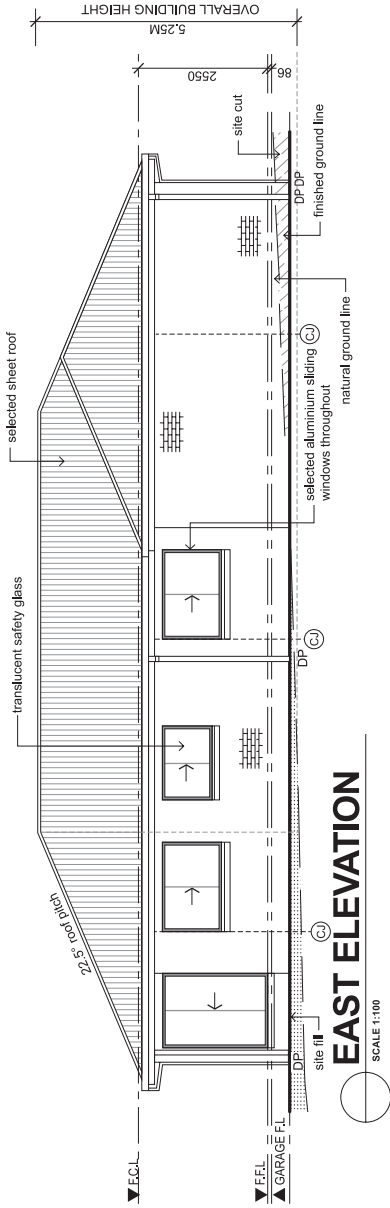
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CONTRACTOR MUST VERIFY ALL DIMENSIONS AND LEVELS AT THE JOB PRIOR TO COMMENCING ANY WORK OR MAKING ANY SHOP DRAWINGS.
DO NOT SCALE DRAWINGS.
ALWAYS USE WRITTEN DIMENSIONS.



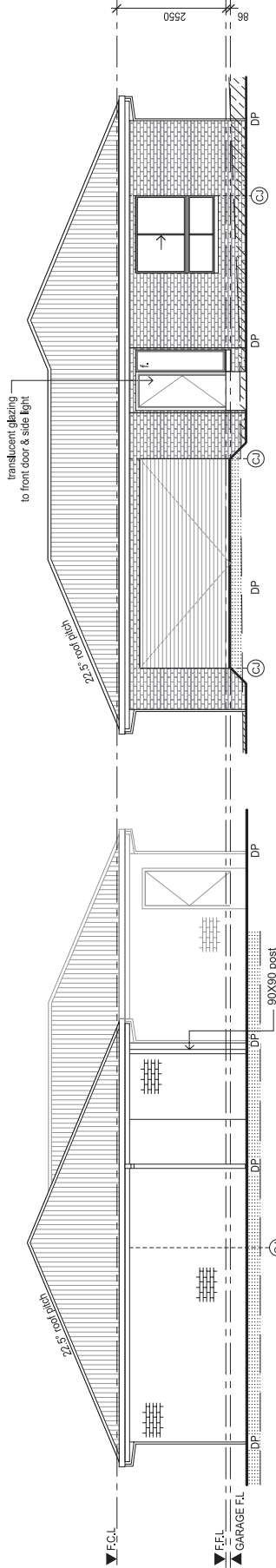
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DATE:	26/11/2019	SCALE:	1:100	REVISION:	NH
		DRAFT No:	FINAL	ISSUE:	BI
				JOB No:	2033

WINDOW SEZE NOTE:
WINDOWS AND DOOR SIZES SHOWN ARE NOMINAL. BUILDER TO USE WINDOW MANUFACTURERS NEAREST STOCK SIZES.



EAST ELEVATION

SCALE 1:100



SOUTH ELEVATION

SCALE 1:100

NORTH ELEVATION

SCALE 1:100

PRE-FABRICATED TIMBER FRAMING NOTE:
ALL WALL FRAMING TO BE PRE-FABRICATED TO MANUFACTURERS SPECIFICATIONS AND IN ACCORDANCE WITH CURRENT BCA & COMPLY TO AS1684 - 2010.

PROVIDE STRUCTURAL BRACING IN ACCORDANCE WITH AS1684 - 2010.

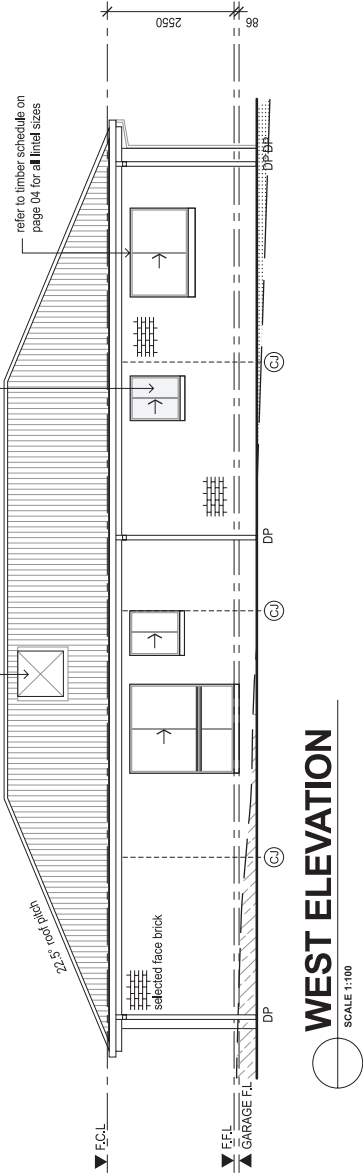
approx. location of roof solar panel

translucent safety glass

refer to timber schedule on page 04 for all final sizes

VERTICAL CONSTRUCTION JOINTS TO BE CONSTRUCTED IN ACCORDANCE WITH AS3700 & AS4733. ENGINEER'S PLACEMENT OVERRIDES CONSTRUCTION JOINTS ON THIS PLAN.

WEEP HOLES TO BRICKWORK MUST BE PROVIDED IN THE COURSE IMMEDIATELY ABOVE ANY DAMP PROOF COURSE OR FLASHING AT CTRS. NOT EXCEEDING 1.2m.



WEST ELEVATION

SCALE 1:100

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DATE: ____/____/____

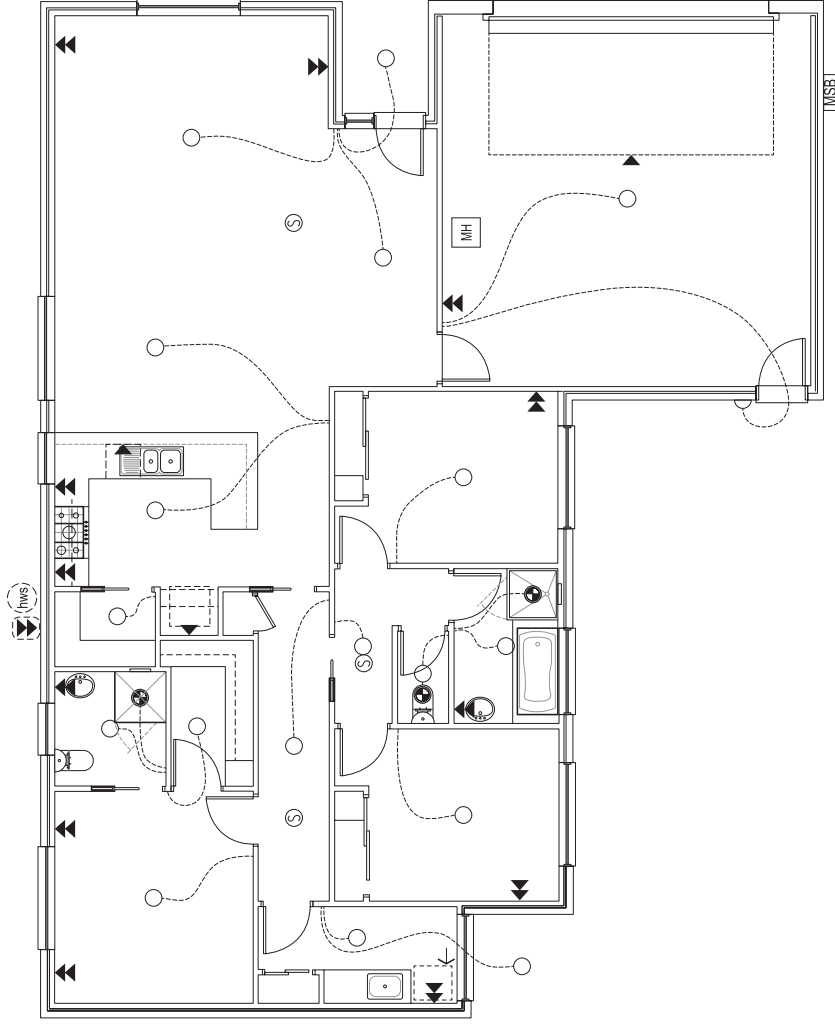
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DATE: 26/11/2019	SCALE: 1:100	DRAFT No: FINAL	ISSUE: BI

03

2033

ELECTRICAL LEGEND:

-  LIGHT POINT
-  DOWNLIGHT POINT
-  WALL MOUNTED LIGHT POINT
-  STAIR LIGHT 450MM ABOVE FFL
-  EX. FLOOD LIGHT POINT
-  PENDANT
-  FLUORESCENT LIGHT POINT
-  TRACK LIGHTING
-  MOVEMENT SENSOR FOR LIGHT
-  TASTIC COMBINATION
-  SINGLE POWER POINT
-  DOUBLE POWER POINT
-  EX. WEATHERPROOF DOUBLE POWER POINT
-  EX. WEATHERPROOF SINGLE POWER POINT
-  EXHAUST FAN
-  SMOKE DETECTOR INTERCONNECTED
-  DUCTED HEATING OUTLET (GUIDE ONLY)
-  DUCTED COOLING OUTLET (GUIDE ONLY)
-  MANHOLE (CEILING ACCESS POINT)
-  ELECTRICAL METERBOARD
-  TELEVISION POINT
-  TELECOMMUNICATIONS POINT
-  CEILING FAN
-  FAN & LIGHT COMBINATION
-  GARDEN TAP
-  WATER POINT
-  DATA POINT
-  HOT WATER SYSTEM
-  DOOR BELL
-  SPLIT SYSTEM
-  SPLIT SYSTEM CONDENSOR



ELECTRICAL PLAN

SCALE 1:100

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05



PLANS APPROVED:		CLIENT SIGNATURE: _____		DATE: ____/____/____	
DRAWN:	STL	SHEET:	05	CODE: IB	DESIGN TYPE: ANGLESEA-MOD
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GENERAL NCC NOTES

ALL MATERIALS AND WORK PRACTICES SHALL COMPLY WITH, BUT NOT LIMITED TO THE BUILDING REGULATIONS 2018, NATIONAL CONSTRUCTION CODE SERIES 2019, BUILDING CODE OF AUSTRALIA VOL 2 WIRE BARRIER CONSTRUCTION TO COMPLY WITH NCC PART 3.9.2.3 FOR CLASS 1 AND 10 BUILDINGS AND NCC 2019 BCA VOLUME 1 PART D2.16 FOR OTHER CLASSES OF BUILDINGS, OTHERWISE.

UNLESS OTHERWISE SPECIFIED, THE TERM BCA SHALL REFER TO NATIONAL CONSTRUCTION CODE SERIES 2019 BUILDING CODE OF AUSTRALIA VOLUME 2.

ALL MATERIALS AND CONSTRUCTION PRACTICE SHALL MEET THE PERFORMANCE REQUIREMENTS OF THE B.O.A. WHERE A PERFORMANCE SOLUTION IS PROPOSED THEN, PRIOR TO IMPLEMENTATION OR INSTALLATION, IT FIRST MUST BE ASSESSED AND APPROVED BY THE RELEVANT BUILDING SURVEYOR AS FOLLOWS:

THE BUILDER AND SUBCONTRACTORS SHALL CHECK AND VERIFY ALL DIMENSIONS, SETBACKS, LEVELS AND SPECIFICATIONS AND ALL OTHER RELEVANT DOCUMENTATION PRIOR TO THE COMMENCEMENT OF ANY WORKS. REPORT ALL DISCREPANCIES TO THIS OFFICE FOR CLARIFICATION.

CONCRETE STUMPS:

THAT ARE LOCATED WITHIN A PERMITTED DEVELOPMENT AREA SHALL BE REMOVED AND REPLACED WITH A TERMINAL PILE FOUNDATION SYSTEM.

ALL WORKS SHALL COMPLY TO THE FOLLOWING AUSTRALIAN STANDARDS;

- 180TMM TO 3000MM LONG TO BE 125MM X 125MM(2 NO. HD. WIRES)

- | | |
|--|---|
| | <p>THE BUILDER AND SUBCONTRACTOR SHALL ENSURE THAT ALL STORMWATER DRAINS, SEWER PIPES AND THE LIKE ARE LOCATED AT A SUFFICIENT DISTANCE FROM ANY BUILDINGS FOOTING AND/or SLAB EDGE BEAMS SO AS TO PREVENT GENERAL MOISTURE PENETRATION, DAMPNESS, WEAKENING AND UNDERMINING OF ANY BUILDING AND ITS FOOTING SYSTEM.</p> <p>THESE PLANS HAVE BEEN PREPARED FOR THE EXCLUSIVE USE BY THE CLIENT OF 'SKETCH BUILDING DESIGN' (THE DESIGNER) FOR THE PURPOSE EXPRESSLY NOTIFIED TO THE DESIGNER, ANY OTHER PERSON WHO USES OR RELIES ON THESE PLANS WITHOUT THE DESIGNER'S WRITTEN CONSENT DOES SO AT THEIR OWN RISK AND NO RESPONSIBILITY IS ACCEPTED BY THE DESIGNER FOR SUCH USE AND/OR RELIANCE.</p> <p>THE CLIENT AND/OR THE CLIENT'S BUILDER SHALL NOT MODIFY OR AMEND THE PLANS WITHOUT THE KNOWLEDGE AND CONSENT OF 'SKETCH BUILDING DESIGN' EXCEPT WHERE A REGISTERED BUILDING SURVEYOR MAKES MINOR NECESSARY CHANGES TO FACILITATE THE BUILDING PERMIT APPLICATION AND THAT SUCH CHANGES ARE PROMPTLY REPORTED BACK TO 'SKETCH BUILDING DESIGN'.</p> |
| 100MM X 100MM STUMPS EXCEEDING 1200MM ABOVE GROUND LEVEL TO BE BRACED WHERE NO PERIMETER BASE BRICKWORK PROVIDED. | |
| TOILET DOORS: | |
| TOILET DOORS ARE TO BE FITTED WITH REMOVABLE HINGES, OR ARE TO SWING OUT, OR BE SLIDING WHERE THE HINGE SIDE OF DOORWAY IS WITHIN 1200MM OF THE PAN. | |
| SMOKE ALARMS: | |
| SMOKE ALARMS TO BE INSTALLED IN ACCORDANCE WITH B.C.A PART 3.7.2. SMOKE ALARMS MUST BE CONNECTED DIRECTLY TO MAINS POWERS AND INTERCONNECTED | |
| MECHANICAL VENTILATION: | |
| MECHANICAL VENTILATION MUST BE DUCTED TO THE EXHAUST TO THE OUTSIDE OF THE BUILDING TO COMPLY WITH PART 3.8.5 OF THE BCA & AS1688.2 | |

GLAZING: GLAZING, INCLUDING SAFETY GLAZING, SHALL BE INSTALLED TO A SIZE, TYPE AND THICKNESS SO AS TO COMPLY WITH:

MASONRY: BUILDINGS IN MARINE OR OTHER EXPOSURE ENVIRONMENTS SHALL HAVE MASONRY UNITS, MORTAR AND ALL BUILT-UP COMPONENTS AND THE LIKE COMPLYING WITH THE DURABILITY REQUIREMENTS OF TABLE 4.1 OF AS 4773.1:2010, MASONRY IN SMALL BUILDINGS: PART 1, DESIGN.

THE APPROVAL BY THIS OFFICE OF A SUBSTITUTE MATERIAL, WORK PRACTICE, VARIATION OR THE LIKE IS NOT AN AUTHORIZATION FOR ITS USE OR A CONTRACT VARIATION. ALL VARIATIONS MUST BE

DESIGN

- BCA PART 3.6 FOR CLASS 1 AND 10 BUILDINGS WITHIN A DESIGN WIND SPEED OF NOT MORE THAN 103/AND
- BCA PART 3.6 FOR CLASS 1 AND 10 BUILDINGS WITHIN A DESIGN WIND SPEED OF NOT MORE THAN 103/AND
- STORMWATER:**
- ALL STORMWATER TO BE TAKEN TO THE LEGAL POINT OF DISCHARGE TO THE RELEVANT AUTHORITIES APPROVAL)
- ACCEPTED BY ALL PARTIES TO THE AGREEMENT AND WHERE APPLICABLE THE RELEVANT BUILDING SURVEYOR PRIOR TO IMPLEMENTING ANY VARIATION.

CLASS 6 UPVC STORMWATER LINE LAID TO A MINIMUM GRADE OF 1:100 AND CONNECTED TO THE LEGAL MANUFACTURER, WINDOWS TO BE FLASHED ALL AROUND.

WET AREAS: WATERPROOFING OF WET AREAS, BEING BATHROOMS, SHOWERS, SHOWER ROOMS, LAUNDRIES, SANITARY COMPARTMENTS AND THE LIKE SHALL BE PROVIDED IN ACCORDANCE WITH AS 3745-2010: WATERPROOFING OF DOMESTIC WET AREAS.

CHANGE OF DIRECTION. THE COVER TO UNDERGROUND STORMWATER DRAINS SHALL BE NOT LESS THAN:

- 100MM UNDER SOIL.

PROVIDE IMPERVIOUS FLOOR & WALL FINISHES TO ALL WET AREAS IN ACCORDANCE WITH BCA PART 3.8.1.2.

- 100MM UNDER UNREINFORCED CONCRETE OR PAVED DRIVEWAYS
- 75MM UNDER REINFORCED CONCRETE DRIVEWAYS

THESE DRAWINGS SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT STRUCTURAL AND ALL OTHER ENERGY RATING REPORT:

ENERGY RATING REPORT: THESE DRAWINGS SHALL BE READ IN CONJUNCTION WITH ANY HOUSE ENERGY RATING (HERS) REPORT AND SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE STAMPED PLANS ENDORSED BY THE ACCREDITED THERMAL PERFORMANCE ASSESSOR WITHOUT ALTERATION.

STAIRS & BARRIERS:
SITE BUSHFIRE ATTACK ASSESSMENT (SIMPLIFIED METHOD) REFERENCE DOCUMENT 'AS 3959-2009

STAIRS & BARRIERS.

STEP SIZES OTHER THAN FOR SPIRAL STAIRS) TO BE:

- RISERS (R) 190MM MAXIMUM AND 115MM MINIMUM
- GOING (G) 355MM MAXIMUM AND 240MM MINIMUM
- 2R + 1G = 700MM MAXIMUM AND 550MM MINIMUM
- WITH LESS THAN 125MM GAP BETWEEN OPEN TREADS

CORROSION PROTECTION OF BUILT-IN STRUCTURAL MEMBERS:
ALL TREADS, LANDINGS AND THE LIKE TO HAVE A SLP-RESISTANCE CLASSIFICATION OF P3 OR R10 FOR DRY SURFACE CONDITIONS AND P4 OR R11 FOR WET SURFACE CONDITIONS. OR ANOSING STRIP WITH A SLP-RESISTANCE CLASSIFICATION OF P3 FOR DRY SURFACE CONDITIONS AND P4 FOR WET SURFACE CONDITIONS. PROVIDE CORROSION PROTECTION OF BUILT-IN STRUCTURAL STEEL MEMBERS SUCH AS STEEL LINTELS, SHELF ANGLES, CONNECTORS, ACCESSORIES (OTHER THAN WALL TIES) IN ACCORDANCE WITH TABLE 4.1

PROVIDE BARRIERS WHERE CHANGE IN LEVEL EXCEEDS 1000MM ABOVE THE SURFACE BENEATH LANDINGS, RAMPS AND/OR TREADS, BARRIERS (OTHER THAN TENSIONED WIRE BARRIERS) TO BE: CLASSIFICATION.

- 1000MM MIN. ABOVE FINISHED SURFACE LEVEL OF BALCONIES, LANDINGS OR THE LIKE, AND
- 855MM MIN. ABOVE FINISHED SURFACE LEVEL OF STAIR NOSING OR RAMP, AND
 - VERTICAL WITH LESS THAN 125MM GAP BETWEEN AND
 - ANY HORIZONTAL ELEMENT WITHIN THE BARRIER BETWEEN 150MM AND 750MM ABOVE THE FLOOR
- MUST NOT FACILITATE CLIMBING WHERE CHANGES IN LEVEL EXCEEDS 4000MM ABOVE THE SURFACE BENEATH LANDINGS, RAMPS AND/OR TREADS.
- SITE CLASSIFICATION:**
- REFER TO SOIL REPORT PROVIDED BY LICENSED SOIL ENGINEER FOR SITE CLASSIFICATION.
- PROVIDE CORROSION PROTECTION FOR SHEET ROOFING IN ACCORDANCE WITH BCA TABLE 3.5.1.1A SUITABLE FOR THE ENVIRONMENT CLASSIFICATION OF

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[illegible]

DO NOT SCALE DRAWINGS.

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CONSTRUCTION FOR BUSHFIRE ATTACK LEVEL LOW (BAL-LOW) REF: AS3959-2009

- THIS STANDARD DOES NOT PROVIDE CONSTRUCTION REQUIREMENTS FOR BUILDINGS ASSESSED IN BUSHFIRE-PRONE AREAS IN ACCORDANCE WITH SECTION 2 AS BEING BAL-LOW.

NOTE: THERE IS A NUMBER OF STANDARDS THAT SPECIFY REQUIREMENTS FOR CONSTRUCTION. HOWEVER, WHERE THIS STANDARD DOES NOT PROVIDE CONSTRUCTION REQUIREMENTS FOR A PARTICULAR ELEMENT, THE OTHER STANDARDS APPLY.

- THE BUSHFIRE ATTACK LEVEL BAL-LOW IS BASED ON INSUFFICIENT RISK TO WARRANT SPECIFIC BUSHFIRE CONSTRUCTION REQUIREMENTS. IT IS PREDICATED ON LOW THREAT VEGETATION AND NON-VEGETATED AREAS (SEE CLAUSE 2.2.3.2).

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07

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DRAWN: STL	
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Glossary

A

abutments the jambs of the wall or pier supporting the arch

access bay a bay of scaffold that gives access to the scaffold work platform by means of ladders or stairs

aluminium oxide synthetic abrasive made into stones, wheels or abrasive paper for sharpening tools

angle of repose the angle to the horizontal at which a given soil type will rest in situ or when stockpiled, and not crumble or otherwise fall away

asbestosis a disease of the lungs caused by an accumulation of asbestos in the lungs that reduces a person's ability to breathe

Australian Standard approved standard for material, equipment, technique or procedure as set down by the Standards Association of Australia (SAA)

autoclaved aerated concrete (AAC) lightweight concrete manufactured with a mix of sand, lime and cement with water and aluminium paste which causes a chemical reaction to form gas bubbles. The liquid mix is placed in forms and, as the gas bubbles expand and increase, the mixture rises creating a lightweight concrete product. Common applications include blocks and reinforced panels for building construction

awning sash top pivoted sash

B

backblocking technique applied to reinforce the joints between sheets of plaster by fixing smaller pieces of plasterboard behind the finished surface but over joints between the plasterboard sheets

backpropping after formwork has been dismantled, all concrete previously supported by the formwork is stripped and temporary props are installed underneath it to allow work to continue on the new floor above

barefaced mortise-and-tenon joint a mortise and tenon that has only one shoulder

base material the material into which the fastener shaft is driven

battering form the face, side or wall of an excavation to an angle, usually less than the natural angle of repose, to prevent earth slippage

bay the horizontal distance/length between any two adjacent standards

belt sander a powered machine where an abrasive belt revolves over rollers

benching the horizontal stepping of the face, side or wall of an excavation

bevel an angle formed between two straight lines meeting at an angle other than 90°

bit an interchangeable cutting tool inserted into the chuck of a drilling machine

blinding layer a 50 mm layer of coarse sand (washed river sand) laid over the top of filling or road base under a concrete slab that allows water to drain through and also prevents puncturing of the waterproof slab underlay

blob footings plain concrete footings poured into a square or round hole. Often called pad footings and used to support brick piers or timber or steel posts that support the floor framing for a suspended timber floor; load-bearing concrete elements

blocking short lengths of timber used to support the ends of hanging beams, etc.

bolection moulding moulding that finishes higher than the framing

bond beam a course or courses of blockwork that are core filled with concrete poured around reinforcing steel to form a reinforced concrete beam. The beam may support roof framing and may also tie a series of vertical core-filled blocks together to form a concrete framed structure

bonded asbestos cement asbestos fibres bonded together with cement and formed into sheeting and other products including sheet roofing and cladding

bond strength the strength of the bond of mortar onto bricks and between bricks and the ability of mortar to hold masonry units together

bore diameter of centre hole in a circular saw blade

bottom plate a horizontal member forming the bottom side of wall framing

building drawings the site plan showing the location and dimensions of the building site; the floor plan or view looking down on the building at floor level; four external elevations for each aspect and cross-sections through the building that indicate internal details or specific construction requirements

building line a line established by the local council which is the minimum distance that must be maintained from the building to the site boundary

bullnose step the curve to the first riser in a flight of stairs

butter a term used to describe how a trowel or a similar tool is used to apply an adhesive or mortar coating in a swiping motion to materials to be laid or fixed in place

butt hinge hinge commonly used for fitted doors

butt joint a joint between two pieces of timber in which the two members abut without lapping two flat surfaces brought into contact and secured with nails, screws or adhesives

C

cantilevered where a structural element (e.g. a beam) is anchored and supported at one end and unsupported at the other

carcase the basic unit of furniture and fitments

carcinogenic cancer causing

casement sash side-hinged window sashes

ceiling joist structural member which binds the wall and roof framing together and carries the mass of the ceiling sheeting

ceiling joist hangers metal product designed to connect the ceiling joist to the hanging beam

ceiling ties devices used to strengthen the joint between hanging beams and ceiling joists

centring rafters pair of rafters located at the end of the ridge in a hipped roof running at 90° to the ridge of the wall plates

chuck the part of a drilling machine that grips the drill bit

cladding outer covering applied to the external walls of a framed building

cleaning eyes every third or fourth brick is left out at ground level or on top of the DPC/flashing for a raft slab to facilitate cleaning of the cavity in cavity wall construction. This is undertaken regularly as work progresses using a hose, timber battens, trowels or chains to remove excess mortar that has squeezed out from masonry units as they are laid. The hose is used to flush out the excess mortar and to clean the cavity

cleats small pieces of timber used to join pieces of timber

clenching when nails longer than what is required are used to secure two or more pieces of timber together and the protruding point is bent over and hit into the timber parallel to the grain, thus pulling the timber together tightly

codes of practice practical guides to achieving the health, safety and welfare standards required under WHS legislation. They represent the lower tier of the WHS hierarchy which includes the Act, the Regulation and codes of practice. They must be approved as a code of practice and are admissible in court proceedings. Compliance with an approved code of practice is considered to demonstrate compliance with WHS legislation

collar a circular steel disc that clamps each side of a saw blade

collar tie a roof framing member that ties the two rafters together, usually halfway between the ridge and the wall plate

common rafter a rafter that is continuous from the fascia to the ridge

compressive strength in concrete measured in MPas, the ability of concrete to withstand pressure. The greater the amount of cement in concrete, the greater its ability to withstand pressure. Concrete is naturally strong in compression

compressive strength of masonry measured in MPas, the ability of masonry units and mortar to withstand pressure

computer-aided design (CAD) using computer programs to design whole buildings or individual rooms, as well as any of the fitments to be installed in the building

concentrated load a force applied at a single point on a beam or structure

construction energy the amount of energy used on a building site during construction

construction work defined in the Model Regulations as any work carried out in connection with the construction, alteration, conversion, fitting out, commissioning, renovation, repair, maintenance, refurbishment, demolition, decommissioning or dismantling of a structure

continuous span a beam supported at three or more points

contour line a line drawn on a site plan joining points of the same ground level

control measure an action taken to as far as is reasonably practicable eliminate or minimise health and safety risks

conventional fixing method the conventional method of fixing plasterboard sheets is to fix around the perimeter of the plasterboard sheet with screws or nails while the internal area of the board is laid against adhesive placed onto metal or timber framing that is to be 'plastered or lined'

coreboard plywood type with central core of timber strips bonded together; also known as blockboard

countersink a tapered recess, cut around a pilot hole for a screw, to receive the head of the screw

cover the actual distance a board will cover in width after milling; notably in flooring, weatherboards and lining boards

crane chaser or dogman a worker who places slings in position around loads of materials and then attaches the slings to a crane hook ready to lift the material

creeper cuts the bricks cut into the extrados of an arch

creeper rafter a rafter running from wall plate to hip rafter

cross cutting cutting timber across the grain

crown the upper half of the arch

crown end assembly the junction of ridge, hip rafter, crown end rafter and centring rafters

crown end rafter a rafter running from the end of the ridge to the wall plate

curing of concrete maintaining sufficient moisture in the concrete to allow the process of hydration to be completed

cutters blades and bits used with power tools

cutting an open cut excavation having a single wall or face

D

damp-proof coursing (DPC) a layer of impervious material including lead, copper, stainless steel, aluminium, embossed polyethylene or chemicals added to mortar. Often placed between brick or masonry courses to prevent rising damp or used vertically to create a damp-proof barrier between an external damp wall and an internal dry wall where there is no cavity

datum a horizontal plane of known height to which the elevation of different points can be referred

daylight line the edge of daylight seen through a window

dead load permanent load due to weight of materials

deformed bar round steel bar with lugs, or deformations, rolled into the surface of the bar during manufacturing. These deformations create a mechanical bond between the concrete and steel. Deformed steel bar is designated as N-bar and has a yield strength of 500 MPa

diagonal brace oblique framing member securing wall framing laterally in vertical position

direct load situation where roof rafters are placed directly over wall studs

door (flush) smooth-faced door

door (hollow core) a door with infill of expanded cardboard

door (solid core) a door with blockboard infill

doorset door plus frame (jamb)

double-hung sash vertically sliding window sashes

double log cabin pattern of timber siding

double mortise-and-tenon a joint used where a rail is much wider than the stile

dovetailed tee halved joint a halved joint where one half is dovetailed into the other

dowel borer horizontal boring machine for dowelling

dowelled joints framing and carcase joints using dowels fitting into mating holes

dowelling jig a metal guide to boring dowel holes

draw boring preparing holes for draw pin, where one is slightly offset to draw a joint together

draw pin a wooden peg used to draw a joint together after draw boring

dressed rusticated pattern of timber siding

drop stripping a high-risk practice that does not comply with the formwork code of practice. Formwork is partially dismantled and then dropped as a single item rather than a section at a time

dummy level an optical levelling instrument

durability a measure of the ability of mortar or concrete to resist the long-term effects of weather and environment on their surface

duty of care a reasonable and responsible person is expected to act cautiously and with foresight and logic while being attentive to the potential for damage or injury to others. To act otherwise would be considered negligent

E

easement a section of the building site that must be left clear of construction so that services such as sewer and stormwater drains can be provided

eave soffit underside of eaves

elevations scaled drawings showing what a building looks like when viewed from one side

end grain a cross-cut section of timber, e.g. at right angles to the grain

engineers detailed drawings drawings that convey specific information on how a building is to be constructed so that it is structurally sound, e.g. reinforced concrete strip footings or a raft slab with details of reinforcement dimensions and location of reinforcement in concrete

excavation to remove soil, earth, rock or rubble to create a hollow, hole, pit, trench, dam, pool, pond or similar

exclusion zone an area from which all non-essential persons are excluded from excavation work (also called a no go zone)

exposure grade bricks bricks that are capable of resisting salt attack

extrados the external circumference of an arch

F

face an exposed sloping or vertical surface resulting from the excavation of material

face work first quality masonry work—bricks or blocks—that is finished with a clean ‘face’ free of mortar smears and the joints are properly finished, e.g. round iron finish. Face work masonry is the final finish. There are no surface coatings and the masonry is seen. The face side of a brick or block is the side that is laid level and plumb

false deck the extension of a formwork platform of deck beyond the formwork that will actually support poured concrete and is used as a scaffolding or work platform

fanlight a sash placed over a door opening

feather a tongue used to join timber

fence guide for running tool or material along an edge

fibre wood tissue mainly for support of wood

fibre cement the modern alternative to asbestos cement.

Cellulose fibre is combined with cement to produce a range of fibre cement products including compressed sheet flooring, cladding and roofing, and circular hollow columns for use as formwork and drainage pipes

fish plate a plate of steel or timber nailed or bolted over a butt joint in timber, used to extend timber in length

flashing a layer of impervious material including lead, copper, stainless steel, aluminium, zincalume or embossed polyethylene. Used to prevent the ingress of rain by covering or ‘capping’ a gap or joint between two building elements; to prevent moisture crossing between walls in a cavity wall and to redirect water to an outside wall to prevent entry into a wall cavity. Often placed above and below openings in walls, such as windows and doors

floor (fitted) flooring fitted between interior wall frames

floor (platform) a construction system where all frames are fixed on top of the flooring

footing a structural building element that distributes the load of the building through the foundation. Located at the base of a wall or pier, it is usually a concrete strip or pad, supporting the mass of the building

foundation the ground on which a building is built and that supports the mass of the building

fox wedges wedges concealed in a stump mortise-and-tenon joint

framed and panelled door a frame-type door with panels fitted to grooves or rebates

framed ledge door a framed door sheeted with vertical boards

franking projection on stile in a sash joint

friable asbestos asbestos in the form of small particles or that can be easily crumbled, pulverised or reduced to small particles by hand pressure, e.g. asbestos lagging, sprayed

insulation, millboard, felt, woven asbestos matting and bonded asbestos that has been damaged

furring channels U-shaped sections of light gauge steel that are fixed to the underside of a floor so that suspended plasterboard ceilings can be fixed to them and supported

G

gable vertical triangular area formed at the end of a roof between the top plate and two sloping roof surfaces

gable stud stud enclosing the gable

galvanised a sacrificial zinc coating used on steel to prevent rusting

glazing fitting of glass to sashes

glazing bar bar dividing glazing in sashes into small sections

going the horizontal distance covered by a step

going of flight the total horizontal distance covered by a flight of stairs

green blocks concrete masonry blocks are made by placing wet concrete into a mould. After the initial set the concrete block is released from the mould and cured in a heated chamber. Freshly moulded blocks are given the term 'green'. The same term applies to masonry walls after they have been laid and the mortar has not properly set. Wet, partly set mortar or concrete has a dark-green appearance

green hardwood timber that has been milled and sold without being seasoned/dried. The timber has high moisture content

H

half-lapped joint a joint in woodwork where two members are halved in thickness and joined by lapping

half span the run of a rafter (half the width of the building)

hammer drill a portable drilling machine which exerts hammer blows to the head of the drill as it rotates for drilling masonry materials

handrail bolt a heavy duty joiner of timber in length

hanging beam a beam placed on edge over ceiling joists to prevent them sagging over long spans

hanging door fixing a door and its hardware into its frame

hardboard timber sheet product manufactured of compressed wood fibre

hardcore a hard sub-base material around 40 mm diameter with a small amount of fines that is compacted in layers as a sub-base for less coarse base material such as road base

harmonisation a process applied by the state, territory and federal governments to provide consistency in the implementation of legislation across different state and territory and commonwealth jurisdictions. With WHS this has meant the development of model legislation by the Commonwealth to be adopted by the states and territories

haunch the portion of tenon left near shoulder to prevent rail from twisting in stile; part of arch from springing line to crown

haunched mortise-and-tenon framing joint to ends of stile

hazard anything that has the potential to cause harm to a person; this can be a physical hazard, such as machinery, tools and chemicals, or a situation which might include bullying, physical violence or repetitive work

head top horizontal member of door jamb

head trimmer (head) beam supporting load over a window or door opening in wall framing

hierarchy of control a system of controls written in descending order and used to minimise or eliminate exposure to hazards

high-risk construction work hazardous construction work that has the potential to harm the health and safety of people or to damage plant and equipment. Specific activities that are defined in the regulations require a relevant SWMS

hipped roof a roof shape where the sloping surfaces are pitched on all sides of the building

hip rafter a rafter that runs from the end of the ridge to an external corner and forms the junction of two sloping roof surfaces

hopper sash bottom-pivoted sashes

horizontal line a line at a tangent to the curvature of the earth's surface, e.g. at any given point it is parallel with the surface of still water

horn waste left on stile while joint is being worked

hydration in concrete a chemical reaction caused by the addition of water to cement. The cement compounds form chemical bonds with water molecules and become hydrates or hydration products

I

inlay moulding moulding that finishes below the level of the framing

intrados or soffit the internal circumference or underside of an arch

J

jack stud a short stud above and below a window or door opening

jamb lining milled to fit into door opening and rebated to accept door

jamb stud the stud supporting the ends of lintels at door and window openings

job safety analysis (JSA) a document that outlines the steps required to safely complete a specific work task on a given day or days, as long as the task is not classed as high-risk work

K

kerf a cut made by a saw

key the central voussoir in masonry arches; it is often decorated in a distinctive way

knockdown fitting a clamping device for assembly of carcase framing

L

level bevel an angle used on rafters; equals pitch of roof

lift the vertical distance between levels of a scaffold at which a platform can be constructed

lightweight truss common timber domestic-type truss

lintel a structural member or beam carrying loads over an opening

live load load to the use of an area

load bearing structural elements such as walls that support other structural or non-structural building elements

long and short shoulder mortise-and-tenon a joint where the shoulders are of different lengths

long point correction allowance when measuring length of creeper rafters for thickness of the rafter

low angle of incidence a reference to the low angle of a light source that lights a finished surface area, such as painted plasterboard. The lower the angle of incidence, the more likely that shadows will highlight surface imperfections

M

machine gauged structural members that have been passed through a machine to reduce them to a uniform width and thickness

managing risk a process set out in WHS regulations to eliminate health and safety risks as far as is reasonably practicable

mandatory construction induction training general safety training that must be provided to construction workers before they commence work in the construction industry

manual excavation an excavation created by the use of basic hand tools

masonry bricks, blocks or panels made from natural stone or man-made products, such as concrete, burnt clay or cement, and fibre stabilised clay (mud bricks) that are bound together by mortar

masonry veneer a building system that incorporates an external loadbearing frame of timber or steel with an external cladding of masonry that is tied to the frame for stability

material safety data sheet (MSDS) a document that contains information on potential hazards and how to work safely with a product or substance

may notes an optional course of action

mechanical excavation an excavation created by the use of a machine such as a scraper, backhoe, bulldozer, excavator or similar

mechanical handling devices equipment used for the movement, storage, control and protection of materials, goods and products

medium-density fibreboard (MDF) a manufactured timber board made from very fine timber particles that are bonded together with glue and compressed into square sheets

megapascals (MPa) a measurement of the pressure that can be withstood by concrete before it fails. It is determined by a calculation using the mass of a load or building element, the rate of acceleration of gravity and the area the pressure is applied to. MPa is also used to measure internal pressure, stress and tensile strength

mesothelioma a cancer caused by asbestos fibres that become embedded in the lining between the lungs and the diaphragm

mitre saw circular saw which can rotate on a swivel base for cutting timber at angles up to 45°

mortise-and-tenon joint framing joint for stiles and rails

mortise board a holding device on a bench for timber being mortised or chopped

mortise gauge a marking tool with two spurs to mark out mortises

mouldings timber ornamentation

mullion vertical divide between sash of window

muntin vertical frame members dividing door panels into smaller sections

musculoskeletal disorder (MSD) an injury to, or disease of, the musculoskeletal system, such as sprains and strains of muscles, ligaments, tendons and joints; one of the most common work-related injuries, MSD can have long-term costly impacts for companies and workers

must notes that a legal requirement exists that has to be observed

mutually recognised where states and territories agree to recognise licences and training delivered by different states

N

nap a reference to the length of the pile on a paint roller

NATSPEC (National Building Specification) Construction Information an impartial, national, not-for-profit organisation with the objective of improving the construction, productivity and quality of the Australian built environment

needles used as horizontal support members in vertical shoring to provide temporary support for materials that are removed and replaced with a new element

nogging horizontal blocking fitted between studs to hold studs straight and for fixing linings

non-load bearing non-structural elements that only support their own mass, e.g. internal partition walls

nosing the front edge of the tread

O

1/3 fixing method a method of fixing plasterboard ceiling sheets where extra fixings are placed at 1/3 spacings across a plasterboard sheet together with adhesive spaced between these fixings

open excavation an excavation where the width is equal to or greater than the depth

orbital sander a powered machine where a sheet of abrasive paper attached to a plate revolves in a circular motion

overlaid door a cabinet door fitted over carcass

overlay hinge hinges for overlaid doors

P

panelling fixing of plywood sheets to walls

particleboard manufactured material formed by bonding together flakes of wood and pressing them into a dense sheet

person conducting a business or undertaking (PCBU) can include a company, unincorporated body or association, sole trader or self-employed person

personal protective equipment (PPE) any clothing or equipment a worker uses for protection

piano hinge a continuous hinge

pilot hole a hole drilled to receive a nail or screw

pit a hole or cavity in the earth

pitch the angle formed between the sloping roof surface and a horizontal surface

plain concrete concrete that has no reinforcement; commonly used to support downward or compressive loads only

plan view a drawing that shows the details of a house or building when viewed from above

plasterboard a layer of set gypsum or plaster between two layers of heavy duty paper to form a board which is used to line wall and ceiling framing

platform construction building construction where the floor is fitted with wall framing applied over finished 'platform'

platform floors provide a convenient and safe working platform during the construction process

pneumatic nailer a machine tool for driving nails

pneumoconiosis an occupational lung disease that is very restrictive, caused by the inhalation of dust

post hole a hole for erecting posts in

Pozidrive a type of slot formed in the head of screws providing a very positive grip for the screwdriver

practical completion a point in time when a building is ready for occupation, although there may still be minor defects to be rectified

principal contractor a person who has management or control of a workplace where construction work is undertaken. Under WHS legislation they have specific responsibilities. Additional responsibilities are applied once the value of the construction work reaches \$250 000

Procore Construction Management a cloud-based platform that offers complete management of specific construction stages

profile frame set up on a building site on which is indicated the position of the building

progressive collapse the effect of formwork collapsing from one point through to another with the mass of collapsing concrete, reinforcing and wet concrete causing damage to adjacent formwork structures and causing those to also fail

R

rafter a sloping roof member supporting the roof covering

rafter boat a jig which generally contains the rafter plumb cut, birdsmouth and rafter side cut of the roof being constructed. It is used in place of a pattern rafter

rail horizontal member connecting stiles

random loading where roof rafters are spaced without reference to location of the wall studs and exceed the limits of direct loading

random orbital sander a powered machine fitted with a velcro pad to sand timber and produce a fine flat finish

reactive soils soils or foundations that respond to different moisture levels by expanding and contracting. Reactive clay soils are common in Australia, requiring double layered reinforcement in concrete and the use of piling systems that transfer the loads placed on footing systems down to a stable foundation

reinforced concrete when reinforcing steel is placed inside concrete, the tensile strength qualities of the steel and the bonding of concrete to the steel result in a structural element that has the compressive strength of concrete and the tensile strength of steel

reinforced concrete footings generally have a top and bottom layer of reinforcing steel to withstand tensile stress on the bottom of the footing caused by building loads or upward forces caused by soils that expand when affected by groundwater causing tensile stress on the top of the footing

reinforced concrete masonry contains embedded reinforcing steel that imparts the strength and characteristics of reinforced concrete. In the case of hollow masonry blocks that are core-filled, the blockwork acts as a formwork

residual current device (RCD) sometimes referred to as a *safety switch*, this is mandatory on all building sites and protects workers from being electrocuted by monitoring the current flowing in the active and neutral wires supplying equipment

ripping sawing timber in the direction of the grain

rise the vertical height of the arch from the centre of the springing line to the underside of the crown. Also, the vertical distance covered by a step

rise of flight the total vertical distance covered by a flight of stairs

rise/run ratio the ratio that exists between the rise of a roof rafter and its run

riser the board forming the vertical face of the step

riser shutter the board retaining the concrete for the rise of the stair

risk the possibility that harm (death, injury or illness) may occur when exposed to a hazard

roof load width (RLW) used as an indicator of the loading carried by some roof members as well as load-bearing wall frame members and supporting substructure

roof pitch the angle formed between a sloping roof surface and a horizontal line

roof rise the height of a roof from its base to the apex

roof span the distance overall between the wall plates supporting the roof

rough-in 'the rough-in' of gas, water, drainage and electrical services is the initial installation of these services before the final fittings are connected and the services are commissioned

router a powered machine mainly used for cutting grooves and trimming edges

run the horizontal distance covered by a sloping roof member

S

safe operating procedures (SOP) a sequence of logical steps that describe how to safely operate an item of plant or how to use a specific hand or power operated tool; also known as a standard operating procedure

safety tags tags attached to switches or valves as a warning not to open or turn on a service, such as electricity, or to start up an item of equipment. This is done to ensure the safety of any workers required to work in areas where such services or equipment would be a hazard if they were made operational or reconnected. Normally used to isolate or shutdown services and equipment during maintenance repairs or when hazardous work such as demolition is undertaken

safe work method statement (SWMS) a document that identifies the risks associated with high-risk work and that develops a step-by-step process that mitigates or removes the risk altogether

safe work procedure (SWP) usually developed alongside the SOP, the SWP also covers the work environment around the machine, its intended use and who can use the machine

salt attack damage that occurs in areas where ground salts in solution are drawn into masonry in contact with the ground by capillary action. The solution evaporates on the masonry surface leaving salt crystals growing below which damage either the mortar or the masonry units, causing spalling or erosion

sarking a reflective foil laminate (RFL) that contributes to radiant and convective insulation and also provides a condensation barrier

sash cramp a cramp for cramping wide joinery items

sash joint a modified mortise-and-tenon joint for stiles and rails

saw kerfing a method of bending timber by a series of close saw cuts

sawn splayed a pattern of timber siding

screed levelling a layer of concrete with a straight edge using a back-and-forth motion

screw gauge a number indicating the diameter of the shank of a woodscrew

scribed joint a joint where mouldings intersect, where one member is fixed and the other mitred at half the angle of intersection and then cut out by coping saw to the contour formed

sealant group of non-hardening materials used to seal joints against penetration of moisture

shaft lock a lever operated locking device which, when operated, prevents the spindle of a tool from rotating

shiplap timber milled for one member to overlap the next

shoring the provision of support for excavated face(s) to prevent the movement of soil and ground collapse

should notes a recommended action

shoulder line the line on rail where it meets the face of the stile

shutter normally a reference to the 'plywood' used to form the internal mould and finish of formed concrete

silicon mastic a waterproof adhesive type sealant used for sealing off gaps and thus preventing water penetration

sill trimmer the horizontal member supporting the window frame in a wall frame

simulated panel door solid door where design is routed into panel

single leaf construction a single load-bearing masonry wall with no cavity to prevent moisture entering a building. The wall supports the roof framing and must be waterproofed with an external coating to prevent internal dampness

single span a beam supported at two points only

site safety audit a methodical process of identifying and listing all potential work hazards in a workplace and then identifying appropriate risk management strategies that have been or need to be applied

site safety management plan a management plan developed and administered by the head contractor on a construction site where the contracted work is valued at \$250 000 or more

site-specific induction training safety training provided to all workers when first entering a new worksite. This training identifies specific site hazards, site rules and site amenities

skewbacks the immediate sloped masonry that supports the bricks of a segmental arch

skew nail a nail driven at an oblique angle through a piece of timber and into the receiving piece. Usually in opposite pairs

skillion a roof shape consisting of a single sloping surface

skirting moulding to cover the joint between floor and wall lining

sleeper pier a pier supporting floor framing at points not attached to dwarf walls

slip-tongue joint a joint used for joining segments in curved work

slope of roof the angle formed between the slope of the roof surface and the horizontal line

slump test a test to measure the water content and workability of concrete

soffit underside of eaves

soffit decking formwork in contact with the underside of the stair and landing

solid plaster a 10 mm coating of cement mortar placed onto masonry units and finished with a smooth sandy texture ready for painting. Surface may also be finished with a thin 2 mm coat of plaster leaving a smooth texture-free finish

spalling the process of layers of masonry being damaged by the growth of salt crystals below the surface of masonry units; the growing salt crystals cause small layers of masonry to be fractured and forced off the face of the masonry unit

span the horizontal distance between the abutments

specifications a document that details exactly what materials and systems are to be used to construct a building and includes both structural elements such as the footings and non-structural building elements such as a prescribed paint system. Specifications take precedence over building drawings if there is conflicting information

splayed weatherboards a pattern of timber siding

springing line the horizontal line from which the arch commences; the points at each end of the spring line are referred to as the springing points

starter bars steel reinforcing bars that are left protruding above finished concrete or core-filled concrete masonry. They allow different phases of work to be completed at different times. As a new section of work is started the starter bars overlap and connect with the steel reinforcement in the new section to structurally connect two different phases of concrete or reinforced concrete masonry

stile vertical side member of a frame

stopped housed joint a joint where the housing is stopped short at face edge

straight edge a length of timber that is made straight and parallel, and used during levelling operations or setting up a number of points to a straight line

stress grade visual or mechanical grading of whole lengths of timber into working stress categories, based on resistance to bending

stretcher bond bonding in masonry is the lap of one block or brick over another to strengthen the wall. When the lap is equal to half the length of the masonry units being used it is termed 'stretcher bond' or 'half bond'

stringer a member laid over the top of the formwork which supports brackets that prevent the riser shutter bulging in the centre

string shutter provides fixing at each end for the riser shutter and retains the concrete at the sides of the stair

strutting beam a beam used over large rooms to support struts where no internal walls are available

stud a vertical member in wall framing

stump a vertical member of timber, pre-cast concrete or steel sunk into the ground for the support of a floor or wall framework

subfloor a loadbearing timber or metal structure which the flooring material is secured to. The subfloor sits upon the stumps or piers

substrate underlying layer that a surface finish, such as paint, plasterboard or ceramic tiles, is applied or fixed to

sustainability the ability to continue activities without exhausting the available resources or degrading the environment

sustainable development a development or building project that meets the needs of the present without adversely affecting the ability of future generations to meet their needs

T

tensile stress in concrete the response of concrete when loads are applied causing it to bend and resulting in a tendency to split or tear along the convex surface of the concrete element. Plain concrete has a low tensile strength

tension bracing bracing, usually galvanised hoop iron. It is effective in tension only and must be fixed in two directions

termite barrier the traditional termite barrier for Australian construction systems has been galvanised steel or zincalume sheeting placed as a continuous layer between timber framing and supporting subfloor masonry or posts. Today they include granular granite or recycled glass, chemically impregnated sheeting, stainless steel micromesh sheeting and the use of termite resistant structural building elements

timber siding boards specially milled to function as an effective wall cladding to timber-framed buildings; also known as weatherboard

tongue and groove jointing system for timber boards where one side is grooved to allow the insertion of a tongue from the adjacent board

tongued and trenched joint a joint where a tongue on one piece engages a trench in the other

toolbox meeting short informal meetings used to convey important information to workers on a construction site. Safety requirements for new work activities are generally the focus but work systems updates may also be topics for discussion

toothed (brickwork) refers to the practice of removing bricks or leaving bricks out as work progresses so that the brickwork steps in and out vertically in line with the bond or overlap of bricks. Forms a vertical 'tooth-like' appearance

top plate horizontal member forming top side of wall framing

traffic control plan for the construction industry, a traffic control plan documents the steps to be taken to minimise the risk of motor vehicle related accidents and interruption of traffic flow adjacent to where building or construction work is being undertaken

transom a horizontal member dividing doors or sashes in window or door frames

traversing planing diagonally across a board

trench an excavation having a length that exceeds its width, measured at the bottom

twin mortise-and-tenon a joint used where rails and stile are very thick

U

underpurlin roof member running the length of the roof supporting rafters; also known as a prop or tom

unreinforced concrete masonry masonry that has no embedded reinforcing steel to increase the tensile strength of the masonry but may have embedded joint reinforcement to stop joint cracking

V

vermin wire a layer of 12 mm steel mesh that is fixed to the bottom plate of wall framing at 200 mm centres and turned down onto a course of masonry in masonry veneer construction. The mesh prevents the entry of rats and other vermin into the wall cavity from the subfloor area and through into the roof space

vertical line a line at right angles to a horizontal line

vibrating screed comprises a length of straight steel or aluminium with a mechanical vibrator mounted on top that is drawn along by the operator. Levels and compacts the concrete

voussoirs the arch bricks forming the arch; voussoirs are supported by mutual pressure from their neighbours; the joints in voussoirs should always be normal to the curve of the arch

W

waffle raft slab a two-way reinforced concrete slab system with integral beams in two directions beneath it which forms a slab with a waffle-like appearance underneath. Polystyrene or plastic forms are placed directly on a prepared and levelled foundation with the slab underlay on top of the foundation

waterproof membrane or slab underlay a continuous layer of polyethylene sheeting placed under a reinforced concrete slab to prevent ground moisture and ground salts in solution rising into the slab. The underlay is lapped 300 mm and taped when lengths are joined. High impact underlay should always be used to prevent puncturing of the membrane

wedge allowance space provided for wedges, as in mortise-and-tenon joints

weepholes unfilled perpendicular joints or gaps left between masonry units to allow moisture to drain from a cavity where flashing crosses the cavity. They also provide cavity

ventilation. Proprietary inserts have a mesh cover to prevent entry of insects and vermin. In bushfire areas the mesh is stainless steel to prevent entry of flying embers or sparks

wet area(s) a room in a building which houses water-using fixtures or appliances

wind brace diagonal members bracing ridge to prevent rafters toppling sideways due to wind load

wind load load due to wind action

work activity training training that must be provided by an employer to ensure that employees are able to undertake work, of which they have no prior experience, safely and competently

work health and safety (WHS) managing risks to the health and safety of everyone in the workplace

work method statement a document that identifies the risks associated with high-risk work and that develops a step-by-step process that mitigates or removes the risk altogether

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