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Foundations & Concrete Work



EDITORS OF **Fine Homebuilding**

Foundations & Concrete Work



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FROM THE EDITORS OF
FineHomebuilding



The Taunton Press

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The Taunton Press
Inspiration for hands-on living®

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introduction

Around the perimeter of my basement floor, about 4 ft. underground, are some big rectangular footings that spread the weight of the house over the soil to keep it from shifting or sinking. The footings are made of concrete reinforced with rebar. Around my sink and adjacent to my stove, I have a beautiful, durable countertop. It too is made of concrete reinforced with rebar. I did not form and pour the footings; my house was built before I was born. I did, however, make my countertop, and I have poured deck piers and concrete steps for a landscape project in my yard.

Concrete is strong, versatile, durable, and fun to work with. I would recommend that anyone interested in a small project like my countertop go for it. The materials are available and relatively inexpensive. Pouring footings, foundation walls, or a slab is another story. Once the ready-mix truck is en route, you own the concrete, so you better be prepared. A form blowout can be disastrous. And the window of time for finishing the concrete closes quickly.

That's what this book is all about: making sure you are armed and ready with all the information you need from the professionals who have seen it all, time and again. Taken from the pages of *Fine Homebuilding* magazine, this book is a complete guide to concrete—from pouring a foundation to pouring a walkway, from waterproofing to repair. You can trust the pros who wrote this book. I do. If I ever get the opportunity to build a house from the ground up, I will probably pour all the concrete myself—but not before I reread all of the articles you'll find here, because knowing what can go wrong is a great way to make sure everything goes right.

—Brian Pontolilo
Editor, *Fine Homebuilding*

Foundations and Concrete Basics

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Understanding Building Loads

BY ROB MUNACH

A house is more than an assembly of studs, joists, and rafters clad in materials like drywall, tile, paint, carpet, concrete, and asphalt shingles. When built well, a house protects its inhabitants from relentless physical forces.

It is important, then, before sinking a nail into the first piece of framing lumber, to understand how a house frame and foundation perform. To begin, you need to know what a building load is. Here's how it works.

Understanding Loads Improves Framing and Design Skills

A building load is simply a force that a house frame needs to resist. The frame must be designed to withstand eight of these loads—including wind, earth, and snow—without catastrophic stress on the structure. Although not every load consideration is applicable to every geographic region, or even every home within a region, having a collective understanding of building loads will strengthen your view of framing as a general system. That's an asset when designing, building, or remodeling any home, anywhere.

1. THE LOAD: DEAD

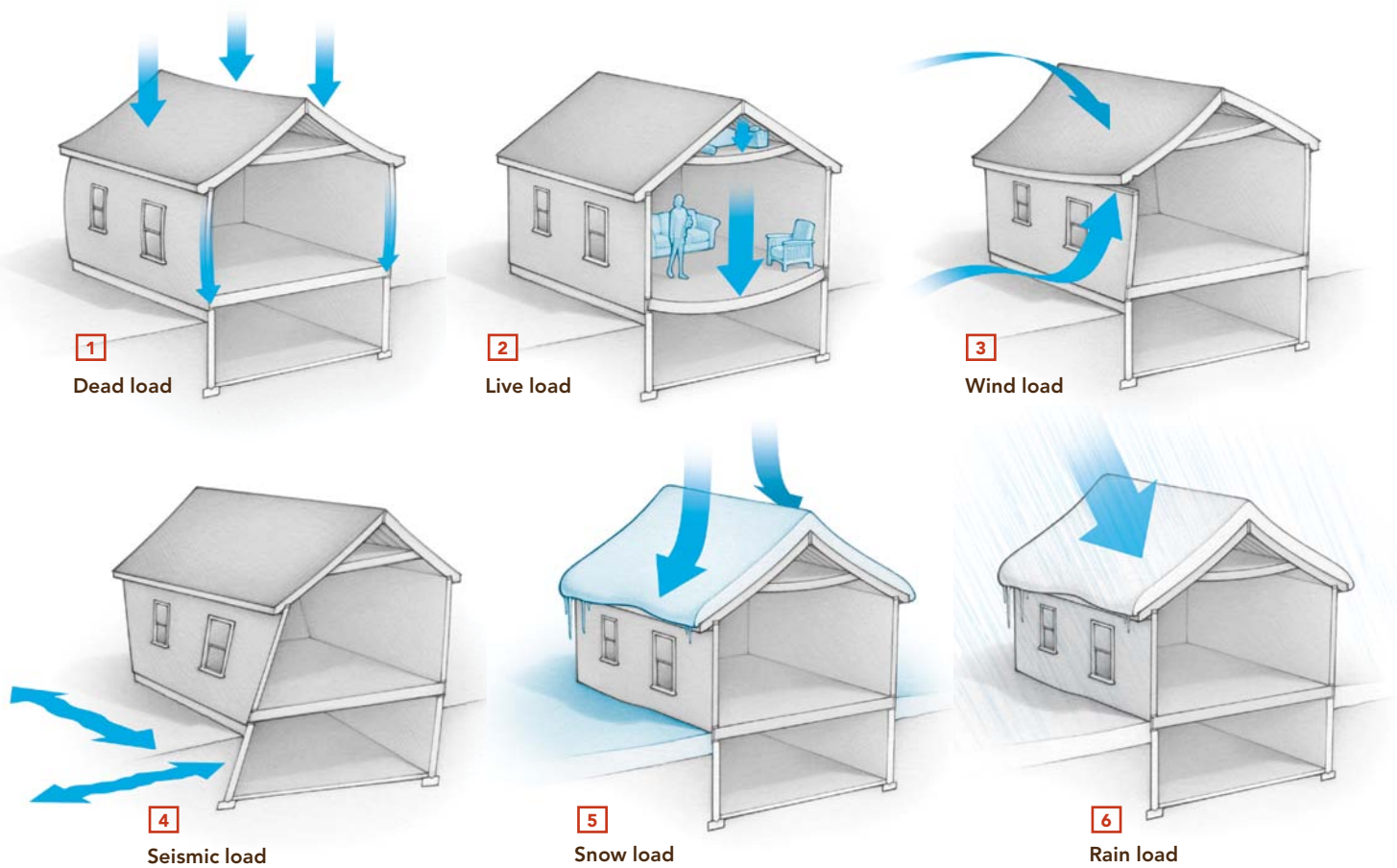
- **What it means:** Dead loads are the forces incurred due to the weight of all the materials used in the

construction of a home. Dead loads can vary greatly depending on the type of construction and the interior finishes. For example, carpet, sheet vinyl, trussed roofs, 25-year shingles, and vinyl siding are relatively light in weight. Tiled floors, suspended concrete slabs, 40-year shingles, built-in cabinetry, granite counters, plaster walls, fiber-cement siding, and veneered masonry are relatively heavy.

- **What it affects:** Dead loads have an effect on all structural members of a house. The loads are a constant over the life of the structure, and they have a big impact on the long-term deflection or creep of framing members.

2. THE LOAD: LIVE

- **What it means:** Live loads are produced by the users of a home. These loads include the weight of people, their furniture, and their storage items. A live load is most applicable to floors, but it can apply to roofs during repair projects due to the weight of workers and their materials.
- **What it affects:** Live loads exert force on almost all of a house's framing components. The goal is to design floor systems that limit deflection and vibration.



3. THE LOAD: WIND

- **What it means:** Wind loads are the positive or negative pressures exerted on a house when it obstructs the flow of moving air. Wind loads generally act perpendicular to the surfaces of the house.
- **What it affects:** The significance of the load depends on the geographic location of the house, its height, and its roof pitch. Wind loads have the most significant impact on roof framing, overhangs, and large openings, especially those near building corners. On a larger scale, shear-resisting elements, such as the roof, floor framing, and sheathed wall segments (shear walls), are affected by wind loads.

4. THE LOAD: SEISMIC

- **What it means:** Seismic loads are the inertial forces acting on a house due to earthquake-induced ground motions. These forces generally act horizontally on each element of the structure and are proportional to their mass. As such, heavier houses are more susceptible to seismic loads.

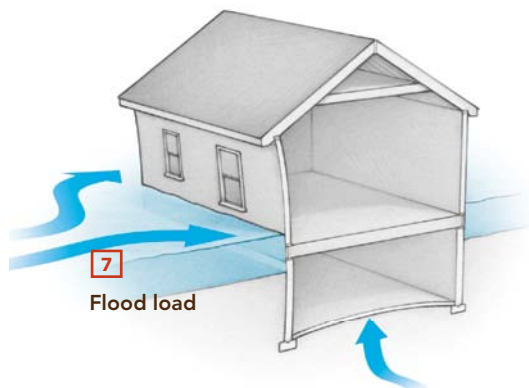
- **What it affects:** While all components of a frame feel the effect of seismic loads, shear-resisting elements (see wind loads) that provide stability are most affected.

5. THE LOAD: SNOW

- **What it means:** Snow load is the weight of snow uniformly distributed on the roof or piled into drifts. Snow that slides from an upper roof onto a lower roof can also add significantly to snow load.
- **What it affects:** Roof and wall framing is generally responsible for resisting snow loads. Floor joists and girders also may be affected, depending on the framing configuration.

6. THE LOAD: RAIN

- **What it means:** Rain load is the weight of rainwater that accumulates on a roof. This type of load is typically an issue only on very low slope roofs. In addition, rain can add to snow loads on low-slope roofs.
- **What it affects:** The framing members that support snow loads also resist the forces of rain loads.



7
Flood load



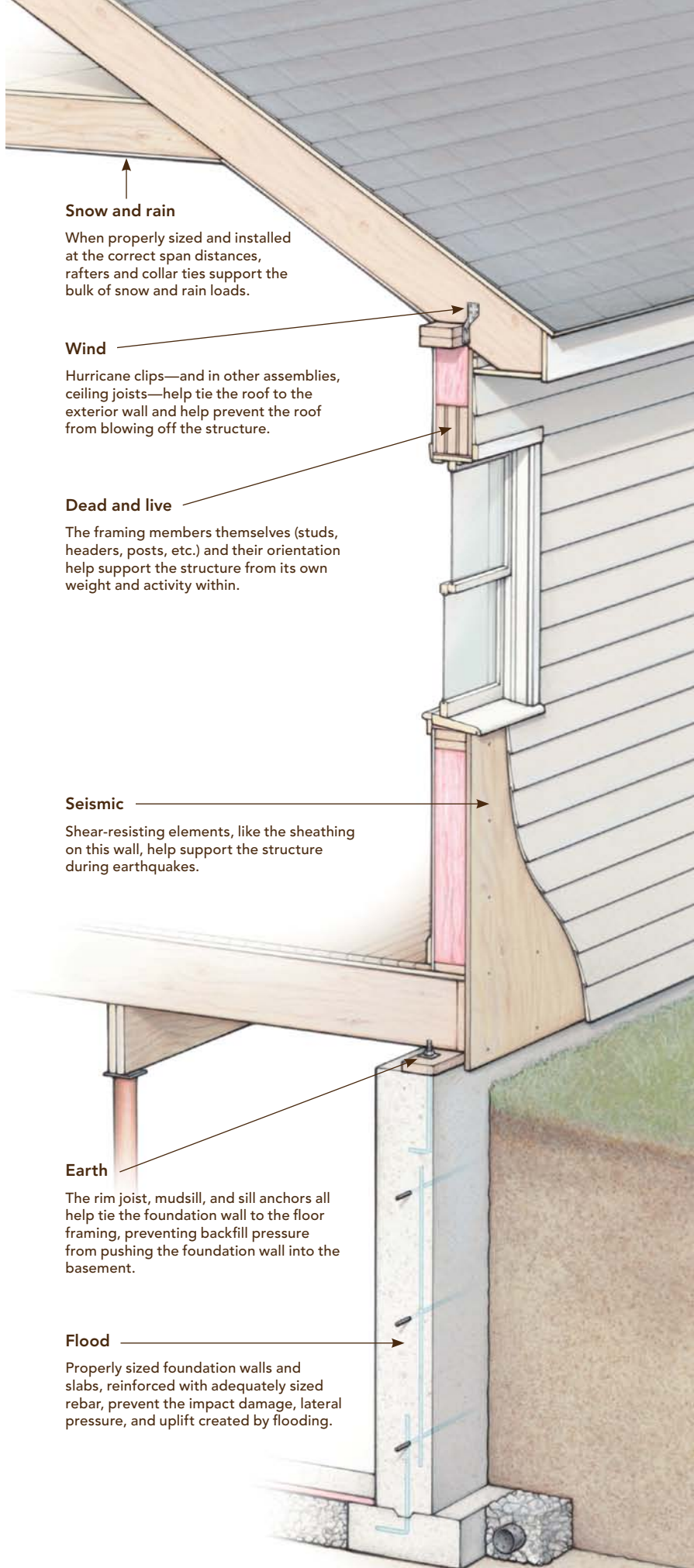
8
Earth load

7. THE LOAD: FLOOD

- **What it means:** Flood load is the pressure exerted on a house when it obstructs the flow of moving water.
- **What it affects:** Foundations must be designed adequately to resist these forces as well as impact forces from moving debris. Also included are hydrostatic loads due to the difference in elevation between the water inside and outside the structure, which can cause uplift on slabs and floor systems.

8. THE LOAD: EARTH

- **What it means:** Earth load is the lateral pressure on the foundation wall due to the height of the backfill.
- **What it affects:** Foundation walls and their attachment to mudsills and floor joists must be designed properly to withstand this load. Floor diaphragms and lower-level shear walls are also affected; they must resist racking due to the overall pressure of the earth on the structure.



Snow and rain

When properly sized and installed at the correct span distances, rafters and collar ties support the bulk of snow and rain loads.

Wind

Hurricane clips—and in other assemblies, ceiling joists—help tie the roof to the exterior wall and help prevent the roof from blowing off the structure.

Dead and live

The framing members themselves (studs, headers, posts, etc.) and their orientation help support the structure from its own weight and activity within.

Seismic

Shear-resisting elements, like the sheathing on this wall, help support the structure during earthquakes.

Earth

The rim joist, mudsill, and sill anchors all help tie the foundation wall to the floor framing, preventing backfill pressure from pushing the foundation wall into the basement.

Flood

Properly sized foundation walls and slabs, reinforced with adequately sized rebar, prevent the impact damage, lateral pressure, and uplift created by flooding.

Soil: The Other Half of the Foundation

BY ROBERT M. FELTON

Most builders and architects are familiar with the problem of building settlement: the chimney that won't stop going down, the wall cracks that keep opening up, the older home that suddenly begins to exhibit movement for no apparent reason. Everyone in the building industry has a story about a fix that "shoulda done it," but didn't.

Preventing settlement problems begins with the recognition that the soil a foundation rests on is part of the foundation system; it's a building material, just like the 2×4 studs that frame the house. The fact that you can't go to a lumberyard and select this building material—that in most cases you're simply going to use whatever you happen to have—makes it especially important that you recognize differences among soil types, know something of the way soils respond to building loads, and be able to identify potential problems.

Differential Settlement Is the Real Enemy

A few things need to be understood about settlement. First, all houses settle. The amount may be so small as to be undetectable or may be so uniform as to leave no signs, but it unquestionably happens. Second, because of the natural and construction-

related variations in soil properties, not every point on a foundation settles the same amount.

To avoid problems with entrances and utility connections, total settlement must be minimized. To avoid racking door frames and cracking walls, you must prevent differential settlement, the difference in settlement between various points on the foundation. The distinction between total and differential settlement is important. The Palace of Fine Arts in Mexico City, for instance, has settled several meters without significant distress to the structure and remains in service because the settlement has been uniform. The Leaning Tower of Pisa, on the other hand, is useless for anything but the Kodak® moments of tourists.

Elementary Research Can Dig Up Most Problems

Fortunately for homebuilders, the loads involved in most residential construction are relatively light. Following time-proven procedures and steering clear of some common misconceptions will keep you out of trouble in most cases.

For starters, you can learn a lot about soil conditions on your site by taking advantage of public-sector resources. The U.S. Department of Agricul-



FINDING OUT WHAT'S DOWN THERE. Taking samples from a series of drillings enables engineers to determine subsurface soil characteristics.

Understanding the stuff the house sits on may prevent cost overruns, callbacks, and neighborhood gossip.

ture (USDA) has prepared soil maps for most of the country. Available at no cost at any local USDA branch office, these maps superimpose soil-type delineations over aerial photographs (see “Two Ways to Look at the Same Piece of Land” on p. 10). By studying these maps and the soil descriptions that accompany them, you can find out information such as whether your site might have a high groundwater table or whether problematic soils—for example, shrink/swell-susceptible clays—might lurk beneath the surface.

Having been taken 40 years ago or more, aerial photos often reveal evidence of unsuspected devel-

opment or manipulation of the site. An even better source for this type of information is a topographic map from the U.S. Geological Survey. This map may reveal abandoned cemeteries, farm ponds, or wells or even the long-forgotten town dump. A topographic map may be purchased for a few dollars at outdoor-sporting-goods stores or downloaded at no cost (www.trails.com).

Don't forget to check with your community's building and engineering departments; they often have a wealth of local information and experience, which they are usually happy to share. Developers who have built close by and homeowners on adjoining lots are other good sources of information.

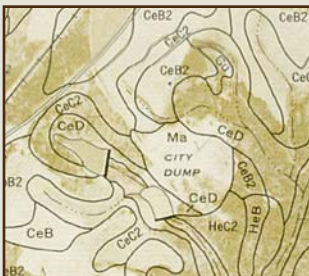
Virgin Soil Is Not Always Virtuous

If your research unearths potential problems, then it's time to bite the bullet and consult an expert (see

two ways to look at the same piece of land

Soil maps from the U.S. Department of Agriculture (USDA) are actually aerial photographs with soil types superimposed on them (see the drawings below left). They can alert builders to problem soil conditions before they start digging.

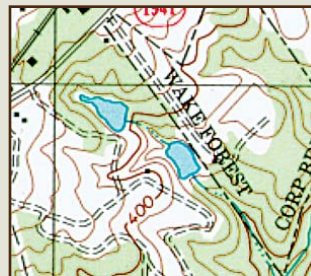
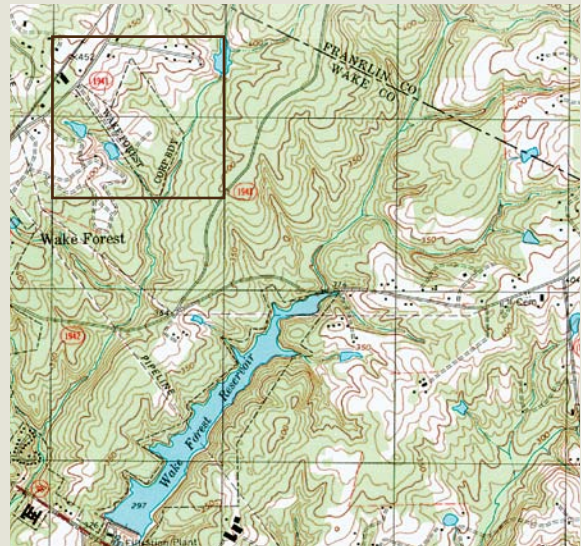
USDA SOIL MAP



CITY DUMP? The soil descriptions that accompany this map indicate that except for the suspicious area in the center (*Ma* signifies man-made soil), all the soils delineated in this close-up are builder friendly sand. The two straight, bold lines to the left of the dump represent dammed lakes.

Topographic maps from the U.S. Geological Survey (USGS) can reveal wetlands or intermittent streams (see the drawings below right). Serving as snapshots in time, both maps provide valuable insight into human activity that has taken place on the land.

USGS TOPOGRAPHIC MAP



WHAT CITY DUMP? Although a topographic map is generally the better indicator of previous development, a builder who relied on only a topo map in this case would not be able to tell that the lakes were man-made and, more important, would have no idea that his or her dream land was once the city dump.

“When Should You Call in a Soils Engineer?” on p. 12). If you uncover no history of activity that may have left behind problems, that’s probably good news, but there may still be things that need attention. “Virgin soil” isn’t inherently problem free. Muck (decomposed organic material), for instance, may have been undisturbed since Mother Nature deposited it, but building on it is always a bad idea.

Clay can also be troublesome. The strength of clay soils varies inversely with changes in moisture content: The greater the moisture, the weaker the soil. If clay materials underlie your site, the site plan must provide for positive drainage that will direct surface water away from the structure and paved areas; otherwise, water may penetrate and weaken the supporting soil. This is, in fact, a common cause of postconstruction settlement problems. If site constraints make it impossible to direct runoff away from the driveway, you should plan to provide lateral drains alongside the drive to prevent water from accumulating beneath the pavement. Foundation drains must also be carefully designed to carry groundwater well away from the structure. These measures aren’t cheap, but they cost less than repairs, ill will, and neighborhood gossip.

Bridging the Gaps

What if there’s a wet, loose, soft, low, or mucky spot on the site? Can you bridge it with fill? Geotechnical engineers like me have a couple of easy rules of thumb that we refer to when called to a site and asked what to do. After that, it gets complicated.

- **Rule one:** Never fill a low spot with surface strip-pings, shrubs, or woody debris, no matter how much clean fill will be placed on top of it. It might take years, but the organic material will inevitably decompose and cause settlement.
- **Rule two:** Muck must be removed. Although it’s possible to force sand and gravel fill into the muck and create a stable mixture, that’s not a reliable solution. What usually happens is that pockets of weak material become scattered throughout the

reworked material, and those areas slowly compress over the years.

To control settlement problems, soils engineers want the foundation to rest on stable, compacted material that extends at least half of the influence depth, the distance beneath the footing that its weight is still “felt” by soil particles (see “The Other Half of the Foundation” on p. 13).

Square foundations (such as those beneath a Lally column) stress the soil to a depth equal to about 2 times the foundation width. A 2-ft. by 2-ft. pedestal, for example, is felt by soil particles to a depth of about 4 ft. below the foundation.

A strip foundation, one whose length is 10 or more times greater than the width (for example, a wall foundation), stresses the soil to a depth equal to about 4 times the foundation width. Thus an 18-in.-wide foundation is felt by soil particles as much as 6 ft. below the foundation. The maximum stress for either type of foundation occurs at a depth of about one-quarter of the influence depth.

What all this means to the builder is that for the pedestal I just described, you must provide at least 2 ft. of competent support; for the strip, you must provide at least 3 ft. If that can’t be done with the existing soil, you should plan to remove and replace the undesirable material and restore the site to grade with engineered fill.

Self-Compacting Soil Has Not Been Invented Yet

One of the misconceptions I often encounter is the belief that soil will densify and strengthen if it’s merely dumped on a site and left undisturbed for several months—that fill dumped in a low area in the fall will be ready to support construction in the spring without any compaction. To this opinion, I always respond: “’Fraid not.” To understand why, think back to your high-school physics class: “An object at rest tends to remain at rest unless acted on by an outside force.” Loosely dumped soil does not densify and strengthen by itself.

when should you call in a soils engineer?

Many builders and architects are reluctant to hire engineers to perform subsurface investigations, and that's easy to understand: The cost of a house can go up a few thousand dollars. Despite the cost, there are circumstances in which consulting a soils engineer is a wise investment.

- If you're wondering how on earth (to belabor the point) you're supposed to build a house on a lot with a steep slope, then you need an engineer to determine the soil properties and to evaluate the stability of the incline.
- Evidence of previous earthwork at the site, especially filling, requires careful investigation. The site may host buried organic materials such as muck, debris such as demolition rubble or abandoned vehicles, or simply dumped fill. Any of these things can cause severe settlement problems.
- A local history of the presence of clay soils that are susceptible to shrinking and swelling with changes in moisture content also requires careful investigation and, usually, specialized design services and the use of an out-of-the-ordinary foundation.
- Encountering groundwater or weak soil while excavating for foundations may indicate a potential for future settlement or instability. The problem area should be carefully delineated by an expert and remedied after close consultation.
- Consult your experience. If you're crossing your fingers and hoping the soil conditions won't cause a problem, you're probably right to be uneasy. Call in a specialist.

To locate an engineer in your area, contact the American Society of Civil Engineers (www.asce.org) at (800) 548-2723.



NOT EXACTLY WINE TASTING. Soils engineers inspect core samples they've taken using the split-barrel sampler on the left.

Failure to compact is what leads to cracking sidewalks and uneven driveways.

It is particularly important that fill be placed in thin layers so that the densification effect of the compaction equipment is felt all the way to the bottom of each layer (see “Proper Fill Placement” on p. 14). The maximum thickness for each layer depends on soil type: Ordinarily about 12 in. for sand and 6 in. to 8 in. for clay. The required degree

of densification is usually set forth by the local building code and specified as some percentage of maximum dry density as determined by one of several standard methods.

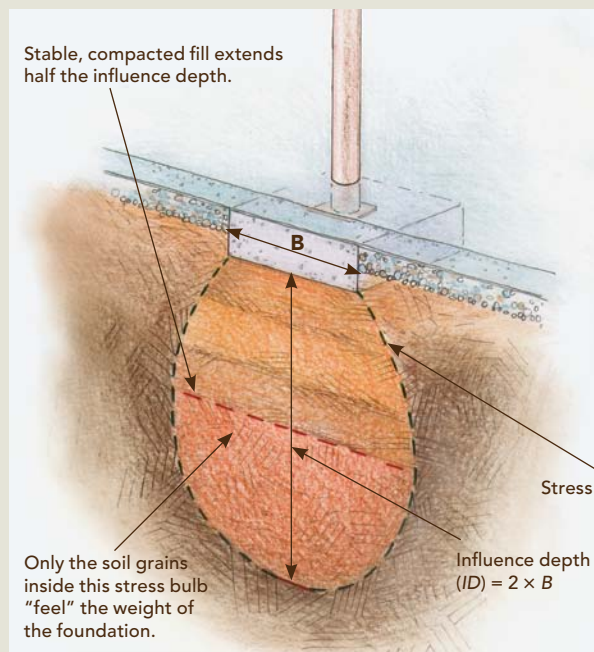
The moisture content of the fill material must also be controlled. If the moisture is too low, it is difficult for individual soil grains to realign themselves into the densest configuration; adding moisture lubricates the grains and makes realignment easier. But if there is too much moisture, the soil becomes unstable under the influence of compaction equipment because a portion of the compactive effort will be borne by the water between the soil grains and result

the other half of the foundation

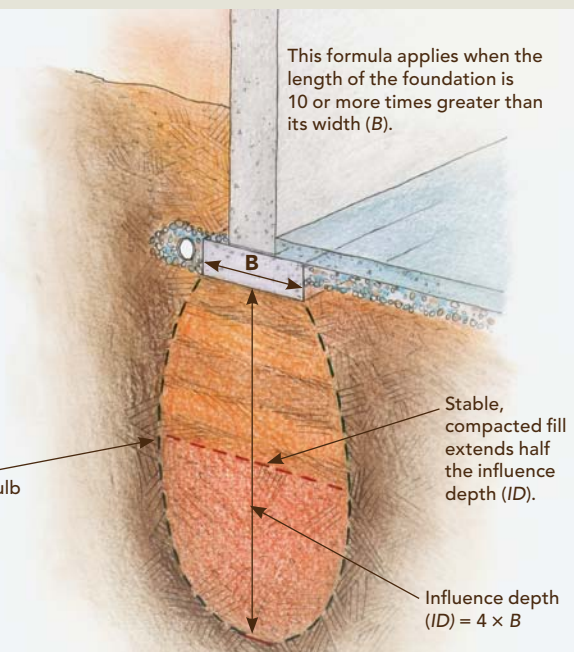
To prevent settlement problems, soil that is stable and compacted must extend at least half the distance from the base of the footing to the influence depth (the farthest distance beneath the footing that its weight is felt by soil particles). Strip

foundations (such as the wall in the drawing below right) stress the soil more than square foundations (such as the pedestal in the drawing below left) and thus have greater influence depths.

Square foundation



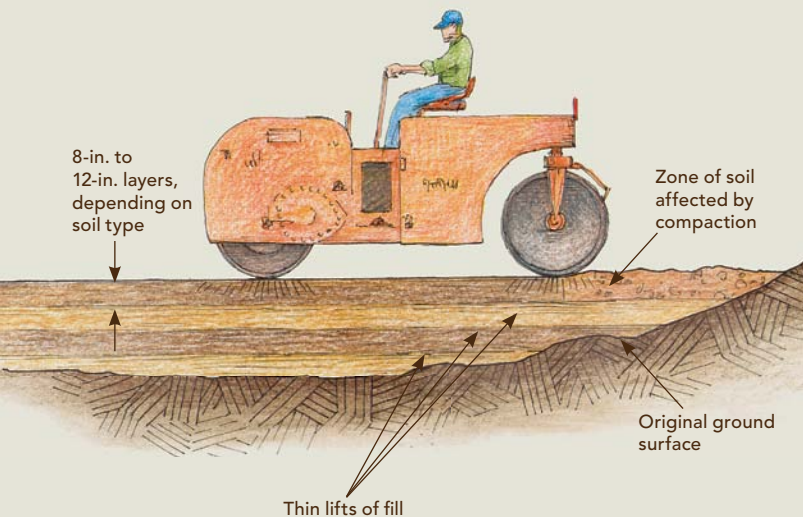
Strip foundation



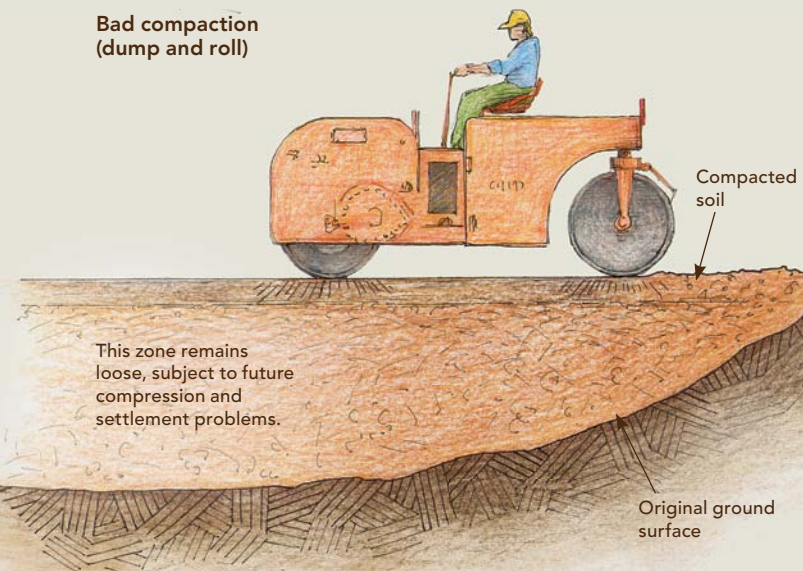
proper fill placement

To minimize settlement and to ensure that the foundation is properly supported, fill must be placed in thin layers, and each layer must be individually compacted.

Good compaction



Bad compaction (dump and roll)



in a water-bed-like rolling of the soil. Granular soils such as sand are most desirable for use as fill because their moisture content can be easily tweaked.

Keep Heavy Equipment away from Foundation Walls

Compacting soil against below-grade walls also requires special care, lest the horizontal load imposed by the compaction equipment damage the walls. A good rule of thumb is to keep heavy equipment away from the wall a distance of at least two-thirds the unbalanced height of the fill (see “Compacting Soil against Foundation Walls Takes Care” on the facing page). In other words, if the fill on the outside of the wall is 6 ft. higher than the fill on the inside, the big rollers should be kept at least 4 ft. away from the wall.

The strip of ground adjoining the wall should be compacted using small, hand-operated equipment. But make no mistake: It should be compacted; failure to compact is what leads to cracking sidewalks and uneven driveways. It is equally important to ensure that fill placed in utility-line excavations be properly placed and compacted. Improper placement of fill by the plumbing contractor, for instance, not only causes drain problems but frequently leads to exterior-wall settlement and cracking over buried drain lines.

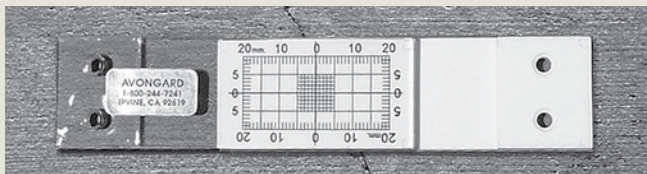
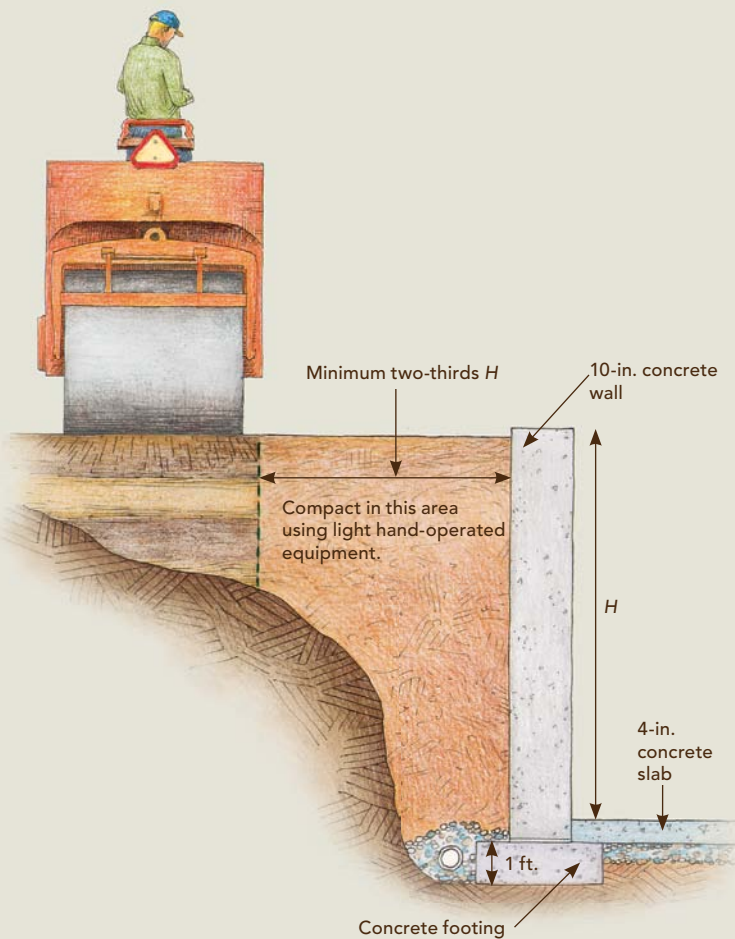
Troubleshooting

In spite of your best efforts, what if the new homeowners call your office and demand that you come over right away to inspect a crack they’ve just noticed? You have not only a public-relations problem, because previously unnoticed hairline cracks suddenly become subjects of concern to the buyer, but a real technical problem too: You’ve got to figure out what has happened.

Most cracks are minor and insignificant, a consequence of the settlement and shifting that all houses undergo. In these cases, you need to explain a few things to the homeowners. Ideally, you would have prepared them for these possibilities beforehand:

compacting soil against foundation walls takes care

To avoid damage from the horizontal loads imposed by compaction, heavy equipment should be kept away from the wall a distance of at least two-thirds the unbalanced height of the fill.



HAIRLINE CRACK OR STRUCTURAL DISASTER? A crack monitor is used to track crack movement over a period of time. The pattern of movement enables an engineer to determine when and what remedial action may be necessary.

- The act of building the house changed the local groundwater conditions. In particular, the shallow soil zone beneath the house is drying. The minor settlement that results can be enough to cause hairline cracking.
- When you painted the house, it was empty. When the owner took possession and brought in the home gym, water bed, and baby grand, this stress caused flexing of virtually all the structural members. This too can cause hairline cracking.

Of course, there may be times when simple explanations don't suffice, when something strange seems to be happening. The best way to identify the cause of the problem is to install a crack monitor (Avongard Products; www.avongard.com; 800-244-7241), a two-piece, specialized ruler that is mounted over a crack (see the photo at left). Using a crack monitor spares you the work of trying to decide by eye and memory whether a crack has grown or changed. If it appears you've got a real problem, the data will be invaluable to whoever is trying to figure out what's causing the crack and what ought to be done because different settlement mechanisms leave distinctive signatures, which become apparent when the data are graphed.

The correction of foundation problems requires thorough investigation by experts. You should not hire a grouting contractor to mud-jack (pump concrete beneath a distressed area) until the cause of the distress has been positively identified. If a house corner is settling due to the presence of buried, compressible organic material, for example, pumping a yard or two of concrete into the soil immediately beneath the foundation will increase the load over the soft material and thus *increase* settlement. The wall may look fine when the contractor cleans up the job site and leaves, but more irate-homeowner phone calls are inevitable.

When making repairs, just as when beginning a project, you should be guided by a single rule: The best defense against future problems is doing it right the first time.

Working with Rebar

BY HOWARD STEIN

Why should you have a spare tire in the bed of your truck? It's not required by law, and the truck will run just fine without it. Using essentially the same logic, some people might ask why we use rebar in our residential foundations. Many houses are built without it (East Coast building codes don't require it), and if a house is built with rebar, building inspectors often don't inspect its placement.

The simple answer is that rebar is cheap insurance against the potential problems that can develop after concrete is poured or, worse, after the foundation has been backfilled. A foundation that has gone wrong is extremely expensive to repair. Just to be safe, my crew and I reinforce concrete in footings and walls, in piers and columns, and in structural slabs, and we also use rebar to tie new work to old.

Concrete used in residential construction is usually specified in a range of compressive strength in 500-lb. increments between 2,500 psi and 4,000 psi. It's obvious that concrete can support phenomenal compression loading. However, when it is under tension or shear forces, concrete has lower values compared with other common construction materials. If the underlying soils are of uneven densities, differential settling beneath the foundation can cause large cracks in the walls. Concrete is also subject

to shrinkage cracks, especially when poured with a high water to cement ratio. When properly sized and embedded in concrete, rebar partially compensates for these deficiencies. (Remember that excess water produces lower-pounds-per-square-inch concrete, which is weaker and more prone to shrinkage. Even reinforced with rebar, concrete with a high water to cement ratio shouldn't be used.)

Sizes and Grades of Rebar

Rebar comes in many sizes and grades (see "Know Your Rebar" on p. 18). In residential work, we mostly use bar sizes #3, #4, and #5. These sizes translate to the diameter of the stock, measured in 1/8-in. increments; #3 bars are 3/8 in. in dia., #4 bars are 1/2 in. (1/2 in.), and #5 bars are 5/8 in. The grades 40 and 60 refer to the yield (tensile) strength (40,000 psi and 60,000 psi, respectively). Grade 60 is harder to cut and bend. Both grades are priced the same. The designer usually specifies which one to use for a particular purpose. If the grade is not specified, I buy the softer grade 40 for short lengths and bends, and grade 60 for long straight runs with few or no bends.



CUTTING AND BENDING REBAR is a matter of leverage and muscle. The cutter/bender's head provides a lever and fulcrum that makes simple bends; more complex bends can be made from individual pieces lapped together.

Make Sure the Rebar Is Delivered Where You Want It

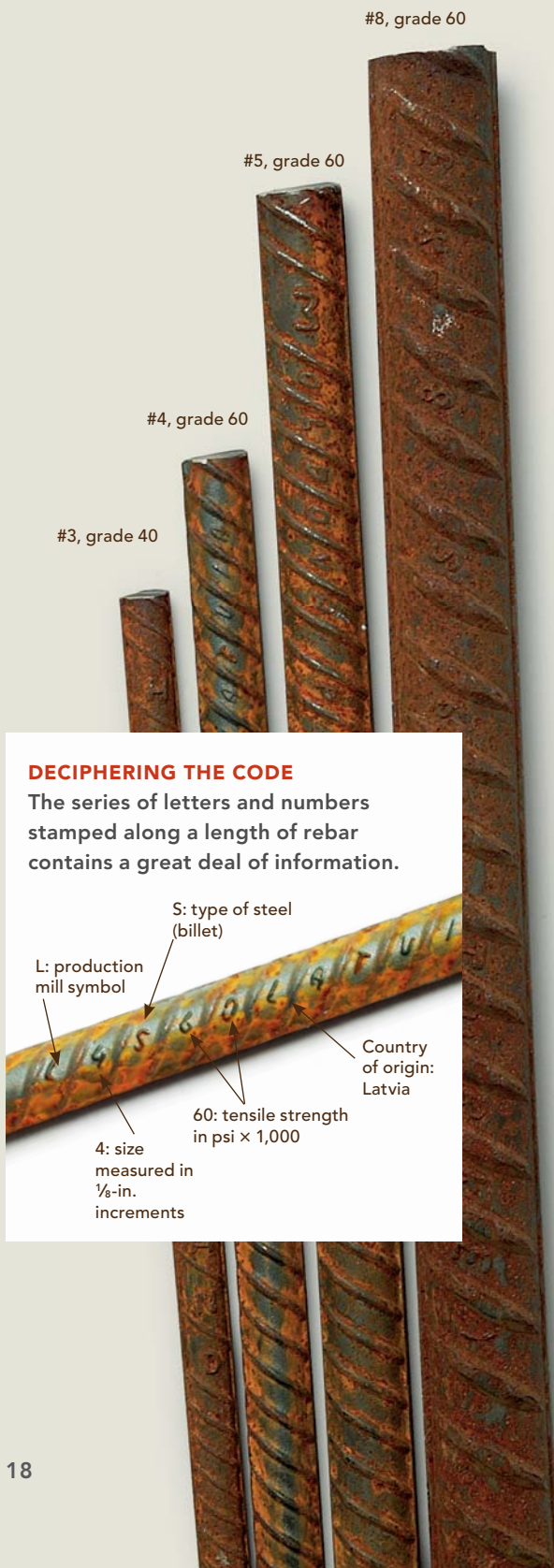
Rebar is available at some lumberyards and from most masonry suppliers. However, 9 times out of 10, I order it from a steelyard that stocks both grades, that always has #5 bars, and that delivers to the site. If the site has good access and if we have an excavating machine available during the delivery, the machine can lift the rebar from the truck with a chain sling. If we don't have equipment on site, I let my suppliers know so that they can deliver my order on the outside edge of the truck bed, where it can be levered off and onto the ground.

If the delivery is early or late or if the machine is unavailable, we drop the bundles off the side of the truck onto blocks of wood; it's easier to maneuver the chain and slip hooks under the load when we



ALTHOUGH CHOPSAWS OR TORCHES can make quick work of cutting rebar, at a site without electricity, the stock can be cut with the cutter/bender.

know your rebar



DECIPHERING THE CODE

The series of letters and numbers stamped along a length of rebar contains a great deal of information.

L: production mill symbol
S: type of steel (billet)
4: size measured in 1/8-in. increments
60: tensile strength in psi × 1,000
Country of origin: Latvia

are ready to move it to the foundation area. We also store the rebar off the ground at its staging area so that it doesn't get muddy or sit in puddles. Dirty rebar must be cleaned before use.

The Concrete Reinforcing Steel Institute (CRSI; www.crsi.org; 847-517-1200) has something to say about clean rebar in its manual *Placing Reinforcing Bars*: "The surface condition of reinforcing bars may affect the strength of the bars in bond. The main factors affecting bond are the presence of scale, rust, oil and mud." Scale is caused by the manufacturing process; loose scale usually falls off when the bar is handled or bent. Tight scale and light rust are acceptable and actually enhance the bond with concrete because they add more surface area. Too much form oil on rebar can adversely affect the bond, according to the CRSI manual.

The Grunt Work of Cutting and Bending Rebar

If there's power on site, steel can be cut using a circular saw outfitted with a metal abrasive wheel or a 14-in. chopsaw with the same blade. The latter cuts the bar more easily, but we need to bring the steel to the saw. Using either saw, we can cut three to six pieces of rebar to common lengths simultaneously. Incidentally, wearing goggles and earplugs is a must when cutting steel with a saw.

Without electricity, rebar can be cut to length with an oxyacetylene torch or a cutter/bender (see the bottom photo on p. 17). Lacking a torch, we use the slower cutter/bender, mounted on a 2×8 for stability, and cut one piece at a time. Available from masonry-supply houses and some tool catalogs, cutter/benders have cast-steel heads, feature replaceable cutters and cost \$250 to \$300. Many cutters have a 52-in.-long handle that gives you plenty of leverage. Even so, the process is slow, and if we're cutting #5, grade-60 bar, we really have to throw our weight into it.

We've found that the best way to mark steel for cutting is with a quick shot of spray paint (see the photo on p. 21) from a can designed to work upside down. With anything else, the marks can be pretty

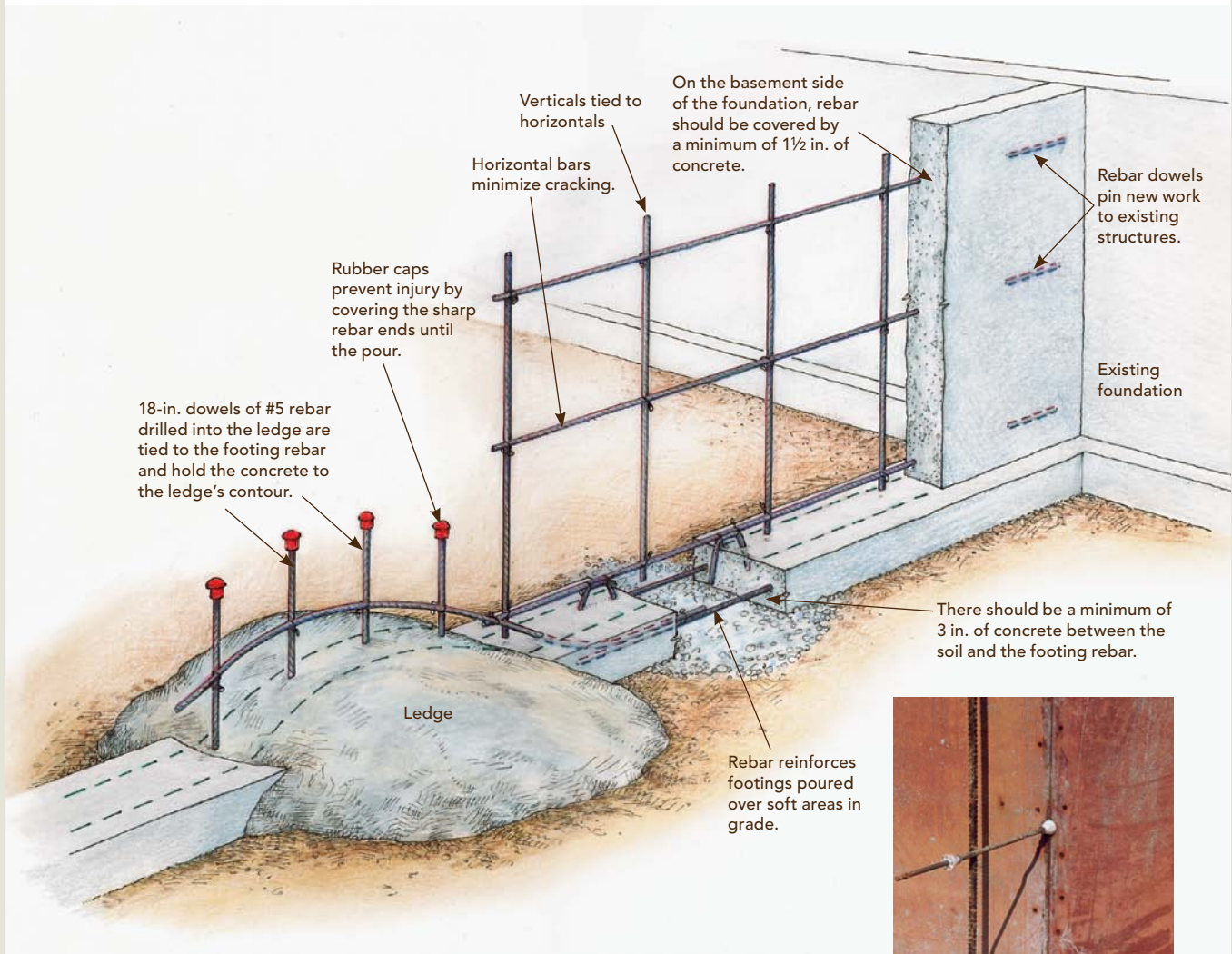
twisted wire holds the rebar in place

Prelooped wire ties are twisted around the junction of two pieces of rebar to hold them in place until the concrete is poured. The wooden-handled hook (see photos below left), known as a twister, speeds up the process. On longer runs or in place of multiple bends, rebar can be lapped. The overlap should be a minimum of 36 bar diameters and tied together with wire in two places (see right photo).

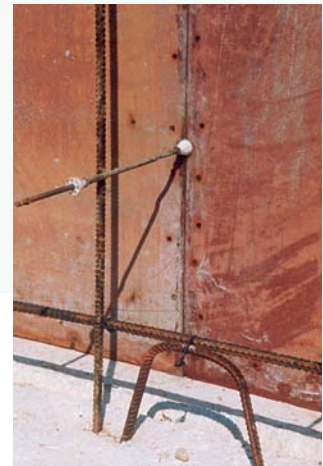


rebar makes the average foundation better

In a typical situation, rebar is placed in a foundation wall to prevent cracking and to strengthen the wall. The exact type and placement of the rebar varies from job to job and is always determined by the structural engineer.



**U-SHAPED DOWELS
REPLACE KEY WAYS.**
Planted on 4-ft. centers,
the dowels help anchor
the footings to the walls
and to the rebar.





SPRAY PAINT MARKS THE SPOT. A spray can that's made to shoot upside down marks the position of bends or cuts on a piece of rebar. The mark is waterproof, easy to read, and nearly indelible.

hard to see. Exact length is seldom critical with rebar. Because it's designed to overlap, if you're off by 1 in., it usually doesn't matter.

The easiest way to bend rebar is with the cutter/bender (see the top photo on p. 17). After measuring and marking bends with paint, we lay the stock under the head and lever it into shape, using the tool head as a fulcrum. The stock has to be in a straight line when bent. Although some of the newer models have stops at 90° and 180°, we just eyeball the bend and adjust as needed. We're careful not to overbend an angle, though, because you can't use the bender to bend it back and because it's hard to do using your hands and feet. To save time, we'll often bend corners while we're waiting for the forms to be completed. If we need more than one bend in a piece of rebar, we've found it's easier to lap with another bent

bar; it's awkward to make multiple bends on site, especially with long lengths. In a pinch (such as when we don't have the cutter/bender), we have bent bars around the pintle on my truck's hitch plate, but I wouldn't want to do more than a few bends this way.

Wiring the Rebar Together until the Pour

To lap or cross rebar, we use prelooped wire ties (see "Twisted Wire Holds the Rebar in Place" on p. 19). Commonly available in lengths of 6 in. and 8 in., the latter are handy for tying together pairs of #4 or #5 bars. A bag of 5,000 8-in. ties costs about \$45 and will last for several residential-size foundations. Wire is also available on spools, but we find that less convenient.

The simplest tie requires merely bending it diagonally over the bars and, using a tool called a twister, hooking the loops and spinning the wire. Over-twisting the wire will simply break it. (The wire adds no strength or integrity once the concrete has been placed.) The twisted wire is then wrapped around the bar so that it doesn't extend toward the exterior surface of the concrete. The wire might rust if it remains exposed to the elements or could lead water into the embedded rebar if exposed below grade. Incidentally, spools of wire are also handy for hanging the rebar at a consistent height in the footings (see the photo at right on p. 24). Because the footing is covered later by the waterproofed foundation wall, the wire is never exposed to the elements.

Rebar Maintains Control of Concrete Shrinkage

In addition to solving problems related to shear or tension, rebar is also specified for shrinkage control of concrete (see "Rebar Makes the Average Foundation Better" on the facing page). Because the water in poured concrete is lost by evaporation as it cures, concrete shrinks in volume. Rebar doesn't prevent shrinkage but binds both sides of the eventual cracks into a single wall plane.

welded-wire mesh vs. rebar: what's the difference?

Concrete has great strength under compression. Under tension, however, concrete doesn't fare so well. For example, as concrete cures, it loses water, which causes it to shrink and crack. Similar cracks open as concrete endures the rigors of changing seasons. Reinforcing concrete ensures that the cracks that do develop don't go far, thus preventing substantial failure.

To reinforce concrete, you can use rebar or welded-wire mesh. Either material can be engineered to work in almost any application. With a few exceptions, there is no difference in the tensile strength of the materials as long as they're installed correctly. Choosing the reinforcement becomes a matter of the job-site conditions, the availability of the product, and the way you prefer to work.

REBAR

Rebar is nothing more than common steel rods that come in sizes ranging from #3 ($\frac{3}{8}$ in. dia.) to #18 ($2\frac{1}{4}$ in. dia.). For residential use, #6 rebar is usually the largest size used.

Rebar's use depends on its application. In a sidewalk, driveway, or slab, rebar is wire-tied into a grid pattern, usually 12 in. or 18 in. on center, then is supported above grade on small piers so that it ends up in the center of the slab. Building codes dictate what size rebar should be used for which job as well as the appropriate grid spacing.

In walls, rebar specifications also are determined by code. In some areas and uses, you need to install a grid pattern over the entire wall; in others, you need only a few lengths of rebar.

Rebar clearly outperforms welded-wire mesh in one application: When reinforcing piers or columns, rebar offers superior strength and maneuverability.

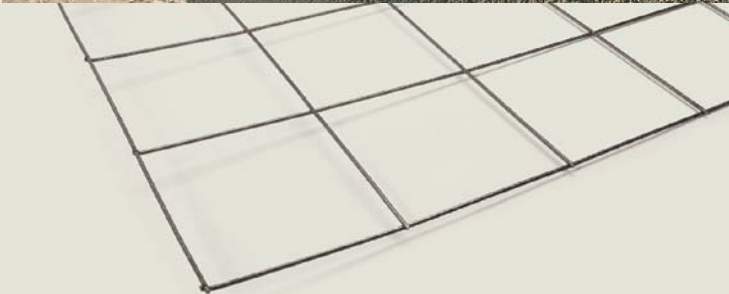
WELDED-WIRE MESH

Welded-wire mesh is a steel grid that can be used in many of the same applications as rebar. Because welded-wire mesh is usually made of lighter-gauge steel, the grid patterns have to be much tighter than with rebar. Mesh can be purchased in either rolls or sheets, but sheets are commonly available only in heavier gauges for commercial work and might not be readily available.

For slab work, mesh performs in much the same way as an assembled grid of rebar. The mesh is unrolled and fixed in place—using small piers—so that it stays in the center of the finished slab. The upside of using mesh is that it's less labor intensive because the grid is already welded together; no wire-tying is required. The downside of using rolled mesh is that it tends to curl back up, so controlling its location in the slab can be a challenge. Also, because it's not as heavy, it's easy to pull it up with rakes during the pour, so it could end up being in the wrong position in the slab.

In most wall applications, two mats can be used to prevent long cracks, but if structural reinforcement is required, mesh might not be an option because it doesn't come in large enough diameters to provide the needed rigidity. That said, manufacturers will soon release a mesh that is the equivalent of #6 rebar.

—Matthew Teague, contributing writer



According to Val Prest, a structural engineer from Harvard, Massachusetts, “This shrinkage will result in $\frac{1}{16}$ -in. to $\frac{1}{8}$ -in. cracks at about every 20 ft. at the top of an unreinforced wall. Add more water to the concrete, and you get more shrinkage—cracks that are perhaps every 10 ft. to 15 ft.—and the concrete is weaker. Horizontal bars will minimize the cracking by causing multiple fine line cracks instead.”

Prest also says, “Temperature- and shrinkage-designed steel for the average 10-in.-thick residential foundation is commonly spaced on 12-in. centers, or every 10 in. horizontally for #4 bars and every 15 in. for #5 bars.” For horizontal placement in wall forms, we almost always tie rebar to the tie rods (or form ties) that hold the outer and inner concrete formwork together. After the concrete subcontractor sets up the outer wall and pushes the tie rods through, we place the steel on these tie rods and wire the rebar to them (see the drawing on p. 20). The verticals are tied to the horizontal bar and to U-shaped dowels in the footing (see the photo on p. 20).

Although steel is specified for its temperature and shrinkage control, Prest says, “99% of the time, steel is designed for shrinkage, not temperature.” Some exceptions are bridges, concrete roadbeds, and large retaining walls built on highways exposed to direct sun.

That said, there are some general rules about placing rebar that can be applied to most situations:

- In footings and walls below grade, rebar should be covered with at least 3 in. of concrete to protect it from groundwater and soil.
- Inside a wall, rebar is positioned on the tension or inner (basement) side with approximately $1\frac{1}{2}$ in. of concrete cover.
- The horizontal shrinkage-control steel is placed in the wall first, followed by shorter vertical bars placed to the inner unrestrained side of the wall.

One note: If there is a dense mat of steel in a slab or wall, it may be necessary to vibrate the concrete with a pencil vibrator to consolidate the concrete without leaving voids.

keeping rebar at a consistent height

Rebar placed in footings should always be above grade. To prevent the bars from sinking in the wet concrete, foundation crews often suspend rebar from strapping that spans the tops of the forms (see photo at right). Any exposed wire is trimmed after the concrete sets up and is covered by the foundation wall. Manufactured supports known as chairs offer another option for locating rebar (see photos below). Available in different sizes, chairs are usually made of plastic or heavy-gauge wire; plastic feet help insulate the wire from corrosion that results from ground contact.



Start with Batter Boards

BY JIM BLODGETT

You're finally ready to build that new deck, porch, patio, or addition. With a permit in your pocket, money in the bank, and a shovel in your hand, it hits you: Now what? How do you make the transition from concept to concrete? Batter boards. Batter boards are like bookmarks. They're placeholders for string lines that describe the dimensions of a structure. You can use batter boards as a job progresses to reduce compounding error.

Build with Screws, Brace with Stakes, and Walk Away

To keep batter boards accurate, place them safely away from construction traffic, and build them sturdily. Use braces. I usually place batter boards within a couple of feet of the foundation and discourage the flow of foot traffic with strategically placed piles of demolition debris, dirt, or lumber.

I use two types of batter boards for most small projects: a three-legged freestanding type for outside corners, and a single 2×4 screwed horizontally (and level) to the side of the existing house. Rather than nails, I use screws so that I don't loosen the braces on freestanding batter boards, which lessens accuracy. Deck screws are great for this, but drywall screws are fine.



ENSURE A SQUARE AND LEVEL building project right from the get-go with strings and a few scraps of wood.

Use a Builder's Level Once, Then Leave It in Its Case

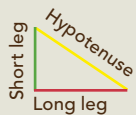
Installing batter boards that are level with each other allows me to use a level string line to set the grade on excavations, footings, and foundations. I generally use an elevation higher than where the top of the foundation will be. I level batter boards with a water level or a builder's level.

five steps to squaring success

One goal of batter boards is to define a footprint with square corners. Most people use the Pythagorean theorem ($a^2 + b^2 = c^2$) to check that the corners are square. They do so by measuring 3 ft. along one side, 4 ft. along the other, and checking for a 5-ft. diagonal (or hypotenuse)

between those two points. But those dimensions (3–4–5) are too small to square up a larger corner accurately. It's better to use multiples of 3–4–5 (see the chart below left) that define a right triangle that's close to your building's dimensions.

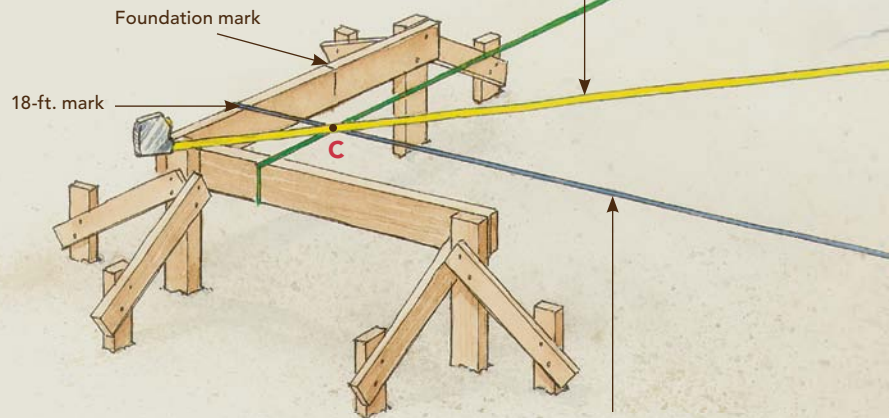
Step 1: Choose your triangle from the chart of multiples (below). Select the triangle nearest to your project's footprint; bigger is better.



SHORT	LONG	HYPOTENUSE
3	4	5
6	8	10
9	12	15
12	16	20
15	20	25
18	24	30
21	28	35
24	32	40
27	36	45
30	40	50

Step 4: Measure the hypotenuse.

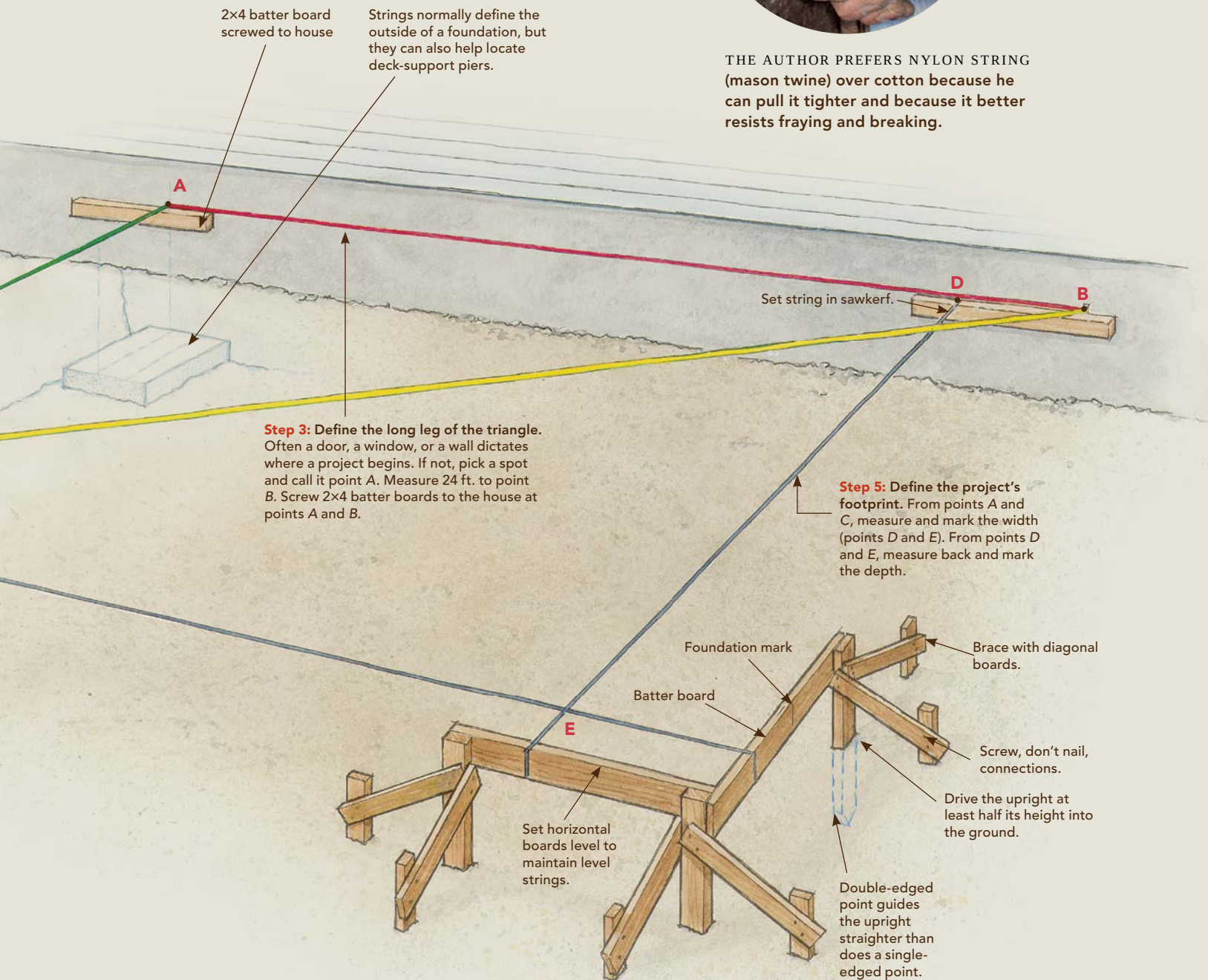
Pull a tape measure from point B, and find where the 30-ft. mark intersects the reference string line (mark this point with ink). Now run a string from point A through this mark and fasten the string to the batter board.



Step 2: Set a reference string line parallel to the house at a distance equal to the triangle's short leg (18 ft.).



THE AUTHOR PREFERS NYLON STRING (mason twine) over cotton because he can pull it tighter and because it better resists fraying and breaking.



After the building lines and levels are determined and double-checked (and verified and triple-checked), I use a handsaw to score just deep enough through the top edge of the batter board to hold the string. No matter how many marks, arrows, offsets, or elevation notes are written on the batter boards (and over the course of a job, there can be a lot), I can find the building lines quickly.

I take all measurements from these sawkerfs, and I mark them on the batter boards. In addition to the inside and outside faces of the footing and foundation walls, I lay out offsets from the building lines so that I can set up a parallel string quickly. These offset lines allow me to climb in and out of the excavation without doing the limbo to avoid lines all day.

quick-release knot holds string tight



LOOP STRING AROUND ONE FINGER, **twisting that finger several times as you pull your hands apart.**



PLACE THE LOOP OVER A NAIL, **pulling on the free end of the line while feeding the fixed end toward the nail.**



WHEN THE STRING IS BANJO-TIGHT, **pull the free end back toward the nail. The twists will ball up into a knot. To loosen, pull the free end in the opposite direction.**

Mix Concrete by the Bag

BY SCOTT GRICE

Some people might assume that mixing concrete is an obvious task: Buy a bag of premix, dump it in a wheelbarrow with some water, and mix it up. Sounds simple, right? As a fence and deck contractor, I have learned otherwise. I often have to mix 5 bags to 10 bags in an afternoon, and then have to push around wheelbarrow loads of wet concrete. This chore was a strong motivator for me to come up with an efficient, reliable mixing system.

The first step to smarter concrete mixing is to use my truck's tailgate as a platform for emptying the concrete premix into the wheelbarrow. This setup limits the number of times I have to move the bags of concrete and keeps them at a comfortable working height. Second, I put the water in the wheelbarrow before the concrete. This step helps keep down the dust and prevents dry pockets in the mix. Third, I use a stiff rake to mix the concrete. A rake mixes more efficiently and is easier to work with than a hoe or a shovel. Finally, to keep from straining the operator (me), I mix only one 90-lb. bag at a time. I don't think mixing two bags at once is any faster, and I know it tires me out sooner.

After I've finished, I pour any excess concrete into a compact lump to be removed once it hardens. Then I wash out the wheelbarrow so that it's ready to work another day.



a common garden rake is the ideal tool for mixing small batches of concrete.

sturdy, stable, and sized right

When it comes to wheelbarrows, bigger is not always better. A medium-size 6-cu.-ft. tray is large enough to hold as much wet concrete or rock as I can move comfortably but is not so big that it's unwieldy. I prefer a tray made of heavy-gauge steel that, unlike plastic, is not affected by UV-rays and won't crack if the temperature dips into single digits. Nice extras on any wheelbarrow are solid hardwood handles for easy gripping and anti-tilt-back supports on the feet to reduce the chance that I'll end up with a load of concrete exactly where I don't want it. All this adds up to a wheelbarrow that can take the abuse of a full-time professional. For information about the Jackson® wheelbarrow, visit www.jacksonprofessional.com.



mixing concrete:

COMBINE WATER AND CONCRETE AT THE TRUCK



1 put in the water first. For this size wheelbarrow, add water to a depth of about 1 in. Too little water is better than too much. You always can add more later.



2 ADD THE CONCRETE. Place the unopened bag in the water. Then use a utility knife to open the bag with a single cut along the end. Grab the bottom of the bag and tip it up so that the concrete slides out rather than pours out. This technique minimizes dust.



3 MOVE THE MIX TO WHERE IT'S NEEDED. To maneuver through tight areas without hanging up the rake, put the working end of the rake in the wheelbarrow with the handle pointing ahead.

step by step

MAKE A LAGOON IN THE ISLAND OF CONCRETE



4 STAND IN FRONT TO MIX. Pull the concrete to the front, and water will flow in behind it. Because I'm standing at the front of the wheelbarrow, I now can work the concrete without having the wheelbarrow move as I push back and forth. Let the water flow in after each push-and-pull stroke. Keep mixing until most of the water is absorbed.



5 ADD WATER IN SMALL AMOUNTS. Too much will weaken the concrete, so add a little water at a time, then mix. Aim for the texture of dry cottage cheese.



6 THE FINAL TEST. I'm done when all the concrete is wet and I've scraped the rake along the bottom and sides to remove any dry pockets. The mix passes my personal slump test when it's all wet but still firm enough for the rake's furrows to hold their shape.

Avoiding Common Mistakes in Concrete and Masonry

BY THOR MATTESON

At the engineering firm where I work, the past few years have brought us about a dozen jobs retrofitting designs for relatively new buildings that were structurally deficient or failing for one reason or another. Typical was the work we did on a poorly designed office building. Improperly placed rebar substantially reduced the strength of a critical grade beam. After a good deal of excavation, we epoxied dowels into the old grade beam and reinforced it with 10 yd. of new concrete.

Now I notice structural problems everywhere I look. I can't even go to the supermarket without wincing ever so slightly at the shrinkage cracks in its concrete-block walls (see the photo on the facing page). Although these problems are how I make a living, many of them could have been avoided.

Concrete Strength Relies on the Right Mix and Reinforcement

Reinforced concrete is barely 100 years old, and engineers are still refining their assumptions of its properties. Yet some contractors (even large governmental agencies) have not changed their methods in the past 40 years or 50 years.

Concrete alone lacks appreciable tensile strength. Steel reinforcing, or rebar, used in concrete cannot withstand compressive force by itself. Combining

the strengths of concrete and steel produces the required structural properties (see “More About Concrete Reinforcement” on p. 42).

Anyone who works with concrete knows that steel reinforcement provides tensile strength. But even experienced builders and designers commonly overlook an obvious consequence of this fact. Rebar must extend into concrete deep enough to develop that tensile strength. Instead of pulling out of the concrete, the bars will start to stretch.

Problems commonly arise at points where rebar changes direction and at intersections. Take, for example, a corner in a footing that has two horizontal rebars. Workers often place the outer bar wrapping around the outside of the corner, which is correct. But then they wrap the inside bar around the inside of the corner, losing a few essential inches of development length. Inside bars at corners should cross, run past each other, and extend toward the far side of the footing (see the drawings on p. 34).

Rebar Has to Go Deep Enough to Do the Job

Straight reinforcing bars can develop sufficient bond if they extend far enough into the concrete. When you don't have thick enough concrete (such as at a wall corner or at a T-intersection), a hook at



THIS WALL MADE ITS OWN CONTRACTION JOINT. **Quarter-inch contraction joints made of a high-grade elastomeric sealant allow a block wall to shrink, instead of crack, as water dissipates from the grout. This wall should have had these control joints every 15 ft. to 20 ft.**

the bar's end may substitute for the lack of available embedment. If a perpendicular bar is placed inside the hook, it spreads the force to a greater area of concrete. (Usually there is a whole row of hooked bars, and a single bar can run through all of the hooks.) We like to see a bar inside the bend at any change in bar direction.

Sometimes the tail of a hook may not fit where it's shown on the plans. Usually you can rotate the tail of the hook to clear obstacles. As long as the hook extends into concrete to develop sufficient anchorage, it's doing its job. You should check with the designer first, though. Sometimes hook tails need to lap with other bars.

Less Water Means Less Shrinkage, More Strength

Nuisance cracking in concrete has two major causes: shrinkage during the curing process and thermal expansion or contraction due to temperature swings. Generally, shrinkage is caused as the water in the concrete gradually dissipates. As much as one-third of the water, or 5% of the total volume of the concrete, can dissipate.

The strongest concrete uses only enough water to hydrate all of the cement in the mix. Excess water leaves space in the concrete when it evaporates, making the concrete less dense and therefore weaker. (Lost water affects the concrete's structure on a molecular level, unlike the tiny bubbles that are left in air-entrained concrete.) But strong concrete is worthless if you can't place it, and getting good workability requires more water.

Good workability means that you can consolidate the concrete around reinforcement and into corners by vibration. It does not mean that the concrete flows there by itself. If I overhear concrete workers complaining about how hard it is to work the mix, I know it's good concrete.

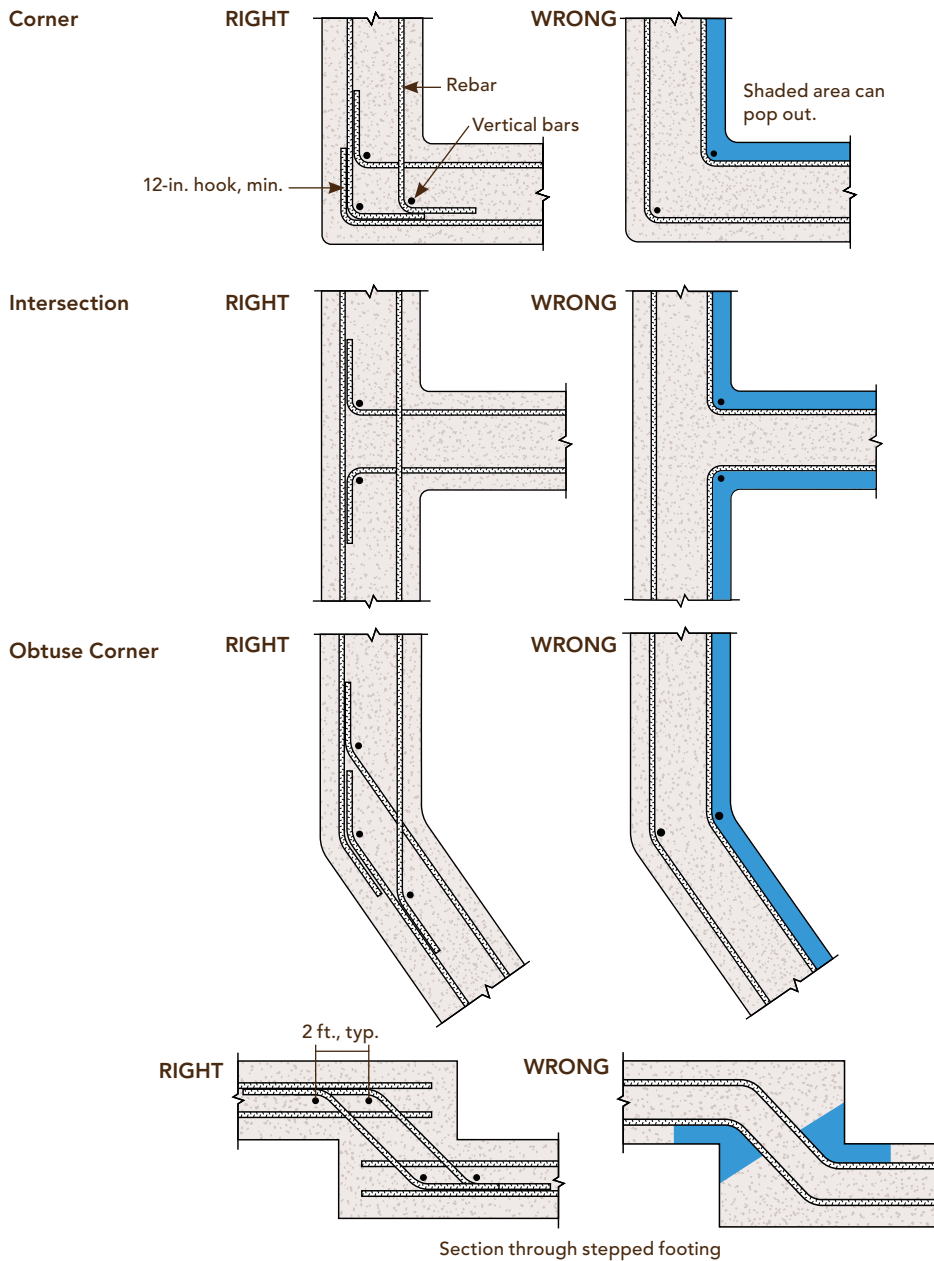
Reducing the amount of water in the mix also makes the cured concrete less permeable to air, water, and salts. Although air seems harmless, the carbon dioxide it carries can react with water in a process called carbonation. In carbonation, water and carbon dioxide combine to form carbonic acid, a weak acid. Over time, enough acid lowers the concrete's alkalinity to the point where steel corrodes much more readily. Using a drier mix and consolidating it well can forestall carbonation for a long time.

Reducing the amount of sand makes concrete harder to work, but it also means fewer shrinkage cracks.

rebar must be detailed carefully at corners

At intersections and corners of concrete footings and walls, problems can arise if reinforcement is improperly placed. Steel bars must overlap the correct length and should hook around perpendicular reinforcing. At corners,

inside bars should cross, run past each other, and extend to the far side of the footing. Otherwise, the inside bar in the corner lacks sufficient embedment, and the concrete may then pop out. The drawings below are plan views of footings.



Substituting Pea Gravel for Sand Can Reduce Problems

Using a high proportion of sand makes concrete easier to finish, but it causes problems, including increased shrinkage and reduced strength. A mix with as little sand as possible helps ease these problems.

Reducing the amount of sand makes concrete harder to work, but it also means fewer shrinkage cracks. Here's why: To make concrete workable, water must coat the surfaces of all of the aggregate. For a given weight of aggregate, large pieces will have considerably less surface area than small grains, and thus require less water to provide lubrication. Substituting pea gravel for some of the sand in the mix allows you to reduce the amount of water needed for workability. Less water is left free to evaporate, and the concrete will crack less.

When you order a load of concrete, you can specify less sand and more gravel. Your local batch plant should have various mix designs on file so that you can specify a 60-40 or 65-35 mix (the ratio of gravel to sand).

Less water also reduces potential reactive aggregate problems. Some aggregates will gradually react with the alkaline cement and expand slightly in the process. When this situation happens, the concrete's own ingredients break it apart, and it gradually disintegrates. Although coarse reactive aggregates can be sorted out economically, a similar process does not exist for sand, so the less sand the better.

Special Considerations for Slabs on Grade

Concrete slabs need to have a firm, even, well-compacted substrate, which begins with properly prepared original ground. Remove all sod, stumps, roots, other organic matter, large rocks, and wet, mushy soil. The soil must be compacted thoroughly and evenly. If you have unstable soil, plan on hiring an engineer or ending up with a cracked, buckled slab.

Moisture intrusion through slabs varies greatly in different regions of the country. In most cases, the American Concrete Institute® recommends not

using vapor barriers. This subject creates great debate between all involved. Recent building code changes may require vapor barriers to prevent radon infiltration.

Current recommendations suggest using *crusher-run* rock (also called *road base*) underneath slabs on grade. Sand does not perform as well as road base. If local codes or conditions mandate the use of a vapor barrier, it should usually be placed on top of the layer of crusher-run rock. Also, depending on local conditions, you may need to install 4 in. to 6 in. of clean gravel to prevent groundwater from wicking up under the slab. The need for insulation varies with region as well.

Rebar Performs Better Than Wire Mesh in Slabs

Steel rebar and wire mesh both serve the same function: They add structural reinforcement to the concrete. Rebar is only slightly more expensive than mesh but easier to keep centered in the slab. If mesh is properly placed, it should do just as good a job of strengthening the concrete as rebar.

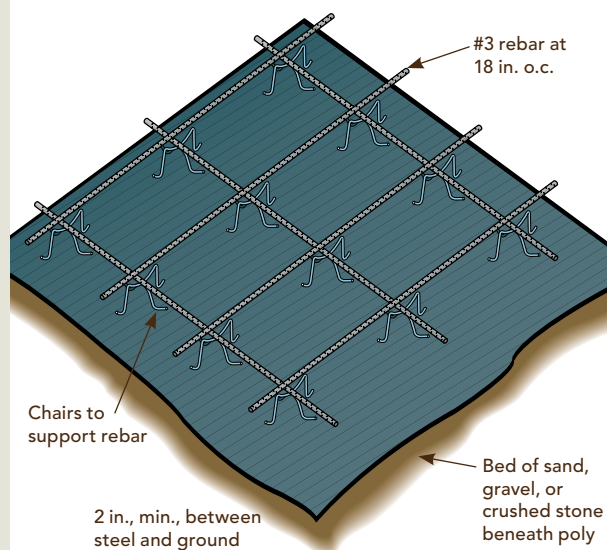
Reinforcement should stay centered in the slab and not trip concrete workers as they move about. However, if the reinforcement is wire mesh, there's no way to avoid trampling it while placing the concrete. So the mesh gets embedded in the crusher-run rock beneath the slab. Although it's not impossible to keep the mesh centered uniformly in the slab (see the photo on p. 36), it is difficult.

Placing a grid of #3 rebar at 18-in. centers provides adequate slab reinforcement and places for nimble feet to step. Supporting the bars on metal *high chairs* or precast concrete cubes ("dobies" where I live) keeps them in the proper position as concrete is poured over them. The cost difference between mesh and rebar is almost negligible, and the reinforcement ends up where it belongs.

Reinforcement falls into two main categories: structural and shrinkage/temperature. Structural reinforcement provides strength to resist bending, compression, and tensile loads. Shrinkage/temperature reinforcement reduces the concrete's tendency

rebar on chairs stays in center of slab

In concrete slabs, steel-bar reinforcement works better than wire-mesh reinforcement because it stays where it's put. It's also important to have a firm, even bed beneath the slab and to cover the substrate with a plastic vapor barrier.



WIRE MESH CAN END UP AT THE BOTTOM OF THE SLAB. This core sample of a wire-mesh reinforced concrete slab illustrates what happens when concrete is poured over the mesh. Rather than staying in the middle of the slab, where it strengthens the concrete, the mesh gets pushed to the bottom, where it does little good.



to crack as it dries or as it contracts or expands due to temperature changes.

For the latter, chopped fibers of polypropylene, nylon, steel, glass, or the like may be added to the concrete mixture. Because the fibers are automatically distributed throughout the concrete during mixing, there are no concerns about proper placement. For most slabs on grade that require no structural reinforcement, fiber reinforcing can be placed in the mix at the batch plant. Fibers do affect the finishing characteristics of the slab: Using a power trowel can collect fibers into little "pills" on the surface.

Tips on Placing and Working Concrete

Concrete-form construction is beyond the scope of this chapter. But when you build forms, build them stronger than necessary. Brace them well; expect to climb all over them while carrying an ornery vibrator.

Secure anchor bolts and other inserts to the forms in their proper locations before the pour. (Poking bolts into wet concrete disturbs the aggregate and gives a weaker bond than pouring the mix around the bolt.) If you use a form-release agent, apply it to the form boards only, not to the reinforcement.

Always place concrete as close to its final position as possible. When concrete comes out of the chute or the pump hose, it should not free-fall more than 4 ft. or clatter off the rebar or forms (see "The Right Way and the Wrong Way to Place Concrete" on p. 39). Either of these conditions can cause the coarse aggregate to separate from the rest of the mix, resulting in concrete that's not uniform. Preventing this condition in tall walls or columns usually requires that a concrete pumper dispense the concrete from a hose, which can maneuver close to the bottom of the forms.

Building codes require consolidating all structural concrete to eliminate voids. The most effective way to do this is with a concrete vibrator. Turn the vibrator on and insert it into the concrete as quickly as possible. To vibrate the first lift poured, insert the

vibrator all the way to the bottom for 10 seconds. Then withdraw it slowly, about 3 in. per second. (This works out to about 15 seconds for every 4 ft., which is much slower than most workers are used to.) The goal is to allow all of the trapped air bubbles to get out of the concrete. The bubbles move up slowly; if the vibrator head moves faster than they do, they will remain trapped. Vibrate any additional lifts the same way, but extend the end of the vibrator about 6 in. into the previous lift.

The vibrator influences a circular area of concrete, whose size depends on the power of the tool. These circles of influence should overlap. Use a regular pattern and consolidate the concrete. Do not insert the vibrator at haphazard angles or use it to move concrete in the forms.

Keep the Concrete Wet and Warm

Builders always want to hurry to strip the forms, but leaving them in place a few days holds the moisture in the concrete. A week of wet curing would make any engineer happy. Keep the concrete wet with spray from a fog nozzle, or by covering it with plastic or wet burlap. Very thin “painter’s plastic” clings well to damp concrete. Curing compounds that seal in moisture when sprayed on concrete are available. Some of these methods will leave permanent patterns on the concrete, which could be a concern.

Rapid drying or freezing severely reduces concrete’s strength and results in weak slab surfaces. A little time invested in proper curing protects the finished product you worked hard for.

For further information, the American Concrete Institute (810-848-3700) publishes several references; the most relevant one is ACI 302.1, *Guide for Concrete Floor and Slab Construction*. Hanley Wood, LLC (<http://hanleywood.com>) offers several publications and references intended for contractors and builders. *Design and Control of Concrete Mixtures* by the Portland Cement Association (www.cement.org; 847-966-6200) addresses mixing, placing, finishing, testing, and more.

control joints help control cracking

Shrinkage cracks appear in any slab. But you can keep them small and govern where they appear by building in control joints. A control joint works like perforations in a piece of paper. The joint is a line of weakness in the slab that eventually becomes a crack.

If you place the joints at 10-ft. to 15-ft. intervals, most cracking occurs along the joints. For large industrial or commercial slabs, control joints usually are sawn into the concrete. On smaller jobs it may not be worthwhile to bring a concrete saw on site. In such cases, long pieces of plastic extruded in T-shaped cross section can form the joints. Concrete finishers force the stem of the T into the slab. To ensure that cracks occur at the control joints, their depth should be at least one-quarter of the slab’s thickness.

Understanding the Principles of Concrete-Block Construction

Reinforced concrete-block construction can produce strong, durable walls efficiently. But too few masons really understand the principles involved in the trade. In this type of construction, three components form the structural system: the blocks and the mortar that holds them together; the reinforcement; and the grout, which is used to fill in the cores in the concrete block.

Grout is a mix of fine gravel, sand, cement, and water. In some areas (not California), mortar is used instead of grout in block cores. However, grout contains coarser aggregate than mortar, which makes it stronger. The building code requires each cell that contains reinforcement to be filled with grout. In earthquake-prone areas (almost all of California

and the West Coast), this rule means filling at least every sixth vertical cell (every 4 ft.) and grouting a bond beam at the bottom, middle, and top of an 8-ft. wall (see the drawing on p. 40). (Bond-beam blocks are made with space for horizontal rebar to lay in them; a course of these blocks, when reinforced with steel and filled with grout, forms a bond beam.) Additional bars at openings, or where required by the designer, often decrease the spacing to 32 in. or even 24 in. Grouting all of the cells is usually easier than trying to block off the cells where grout is not required, so most walls we see are solid-grouted. In essence, concrete blocks or withes of brick just serve as the forms for a fine-aggregate concrete (grout) wall. Your wall should solidly attach to the footing and act as a monolithic unit, not a stack of separate blocks. Also, cores should be grouted after the wall is built, not as you go, which would mean cold joints.

Cleanouts Ensure that the Wall Bonds to the Footing

Openings at the base of cells that receive grout allow you to remove construction debris before pouring (see the drawing on p. 40). When all of the blocks are laid, you can remove the mortar droppings, the nails, the tape measures, the cell phones, and the like that have fallen to the bottom of each cell. (Initially pouring an inch or so of sand at the base of the cleanout prevents fresh mortar from sticking to the footing. Mortar droppings decrease the bond between the grout and the footing.) Then, seal the footings before pouring the grout, and let the mortar set a few days (to prevent blowouts) before the grout is poured. The code requires cleanouts in cells containing reinforcement if a grout pour will be more than 5 ft. high. For shorter lifts, you can suck debris out with a shop vacuum, although you may have trouble winding past all of those bars.

Ladder-Type Joint Reinforcement Is Better than Truss Type

Joint reinforcement can be used instead of bond-beam units that contain horizontal bars. This type

of reinforcement consists of two horizontal, parallel wire rods connected by cross ties (see the drawing on p. 40). The reinforcement is placed between courses of block or brick, and the side rods get embedded in the mortar. The cross ties may go straight across or zigzag; these cross ties are called ladder type and truss type, respectively.

The cross ties of ladder reinforcement should preferably align vertically with the webs of the blocks. Truss-type or zigzag-type wire reinforcement is even more difficult to align. We don't recommend using this reinforcement in concrete-block walls because the diagonal reinforcement can block the open cell and make it difficult to insert the vibrator.

Use Pairs of Horizontal Rebar to Make Room for a Vibrator

Rather than using single horizontal bars in bond beams, which lie in the middle of the wall cavity, use pairs of horizontal bars (either smaller bars or the same size at greater spacing). This process leaves more room for the vibrator head. Designers should consider this idea, but if yours hasn't, ask about it before proceeding. In straight runs of wall, open-end units allow grout to flow more easily through the block cavities. Using standard units forms air gaps between blocks at head joints.

Admixture Increases Grout Bond to Block

Certain compounds react with grout ingredients to produce a gas. The gas expands, forcing the grout into the porous surface of the block cells. Several brands of admixture are available; most use powdered aluminum as the active ingredient (for more information, visit www.basf-admixtures.com).

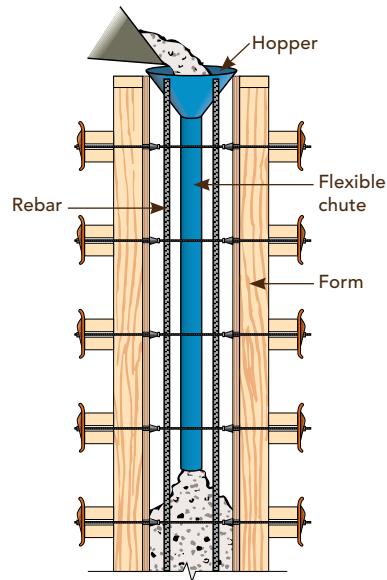
Most masons add the admixture once the grout arrives at the site because its working time is limited to about 1 hour. Although the powder may be added straight into the truck, we require it first to be thoroughly mixed with water. If clumps of powder get pumped into the wall, they can generate enough gas pressure to pop the block apart.

the right way and the wrong way to place concrete

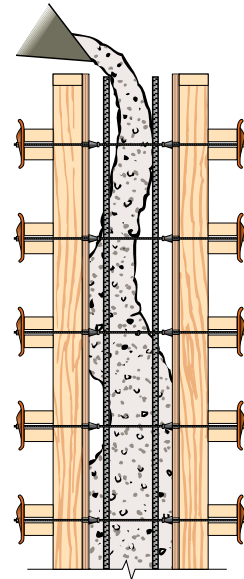
If concrete is dropped from a height greater than 4 ft. into a form or permitted to fall freely over reinforcement, the aggregate can separate from the concrete or honeycomb

at the bottom. When filling forms from a chute, use a hopper to deliver concrete to the bottom of the forms. When using a pump, feed the hose to the bottom of the form.

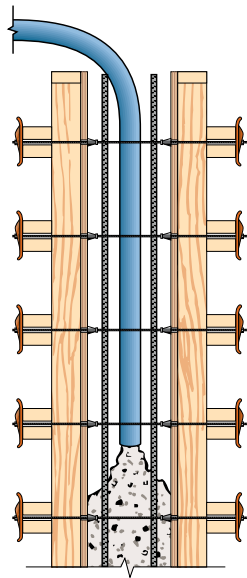
RIGHT



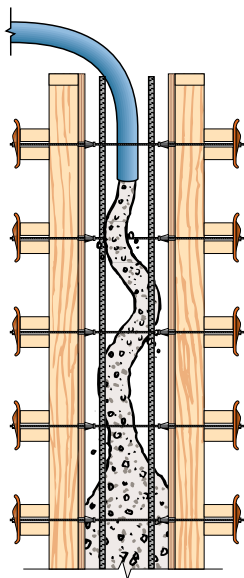
WRONG



RIGHT

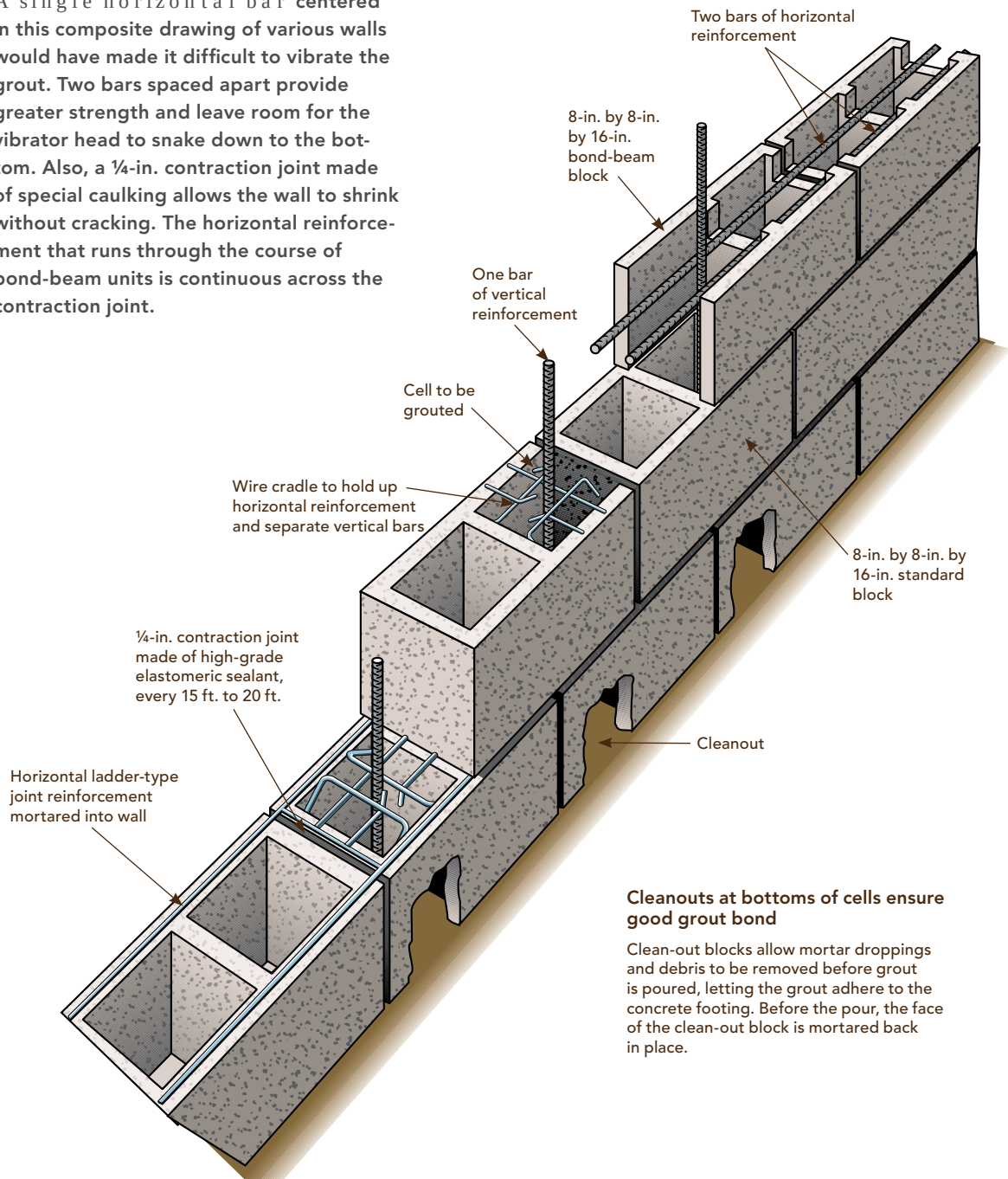


WRONG



ample reinforcement leaves room for vibrating and has built-in joints

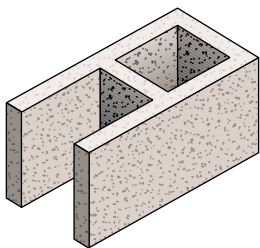
A single horizontal bar centered in this composite drawing of various walls would have made it difficult to vibrate the grout. Two bars spaced apart provide greater strength and leave room for the vibrator head to snake down to the bottom. Also, a ¼-in. contraction joint made of special caulking allows the wall to shrink without cracking. The horizontal reinforcement that runs through the course of bond-beam units is continuous across the contraction joint.



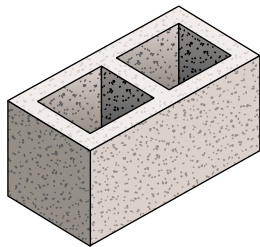
STANDARD TYPES OF CONCRETE BLOCK

Here are a few of the standard types of concrete block. There are many other blocks made for a variety of different functions and in a variety of different sizes, configurations, and textures.

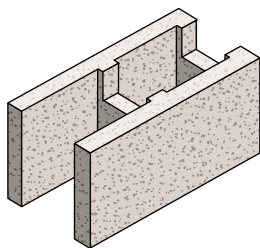
8-in. by 8-in. by 16-in.
open end



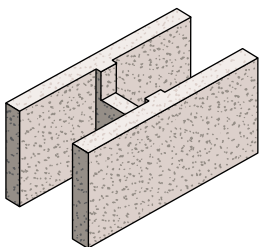
Normal, or standard,
block



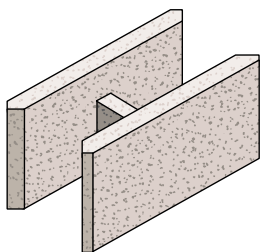
8-in. by 8-in. by 16-in.
open-end bond beam



8-in. by 8-in. by 16-in.
double-open-end
bond beam



8-in. by 8-in. by 16-in.
mortarless head joint
or speed block



Vibrate Grout Twice

For grout to flow into all of the crevices in a wall, it needs to be as fluid as possible. This wet grout is poured into dry masonry and vibrated immediately. The masonry soaks up excess water. As this soaking occurs, the grout loses volume. The grout may actually shrink away from one side of the grout space. The UBC requires reconsolidating the grout with a second vibrating. Vibrating a second time settles the grout fully into the cavities.

I have seen the level of a 4-ft. grout lift (the maximum height allowed) drop by 2 in. during revibration. It's important to wait at least 20 minutes before revibrating so that excess water has time to soak into the masonry. But do not wait so long that the expanding admixture reacts completely or that the grout begins to set up. In mild weather, revibrate within 45 minutes to 1 hour of placing the grout.

Vertical Contraction Joints Reduce Cracks in Long Walls

Masonry walls shrink in length and height as excess water in them dissipates. It may seem as if you're weakening the wall, but if you don't provide contraction joints to accommodate this shrinkage, the wall makes its own—in the form of cracks. To avoid shrinkage, build long walls in segments no more than 12 ft. to 16 ft. long.

Build each segment as if it were an individual wall. Separate the wall segments about $\frac{1}{4}$ in. Instead of a mortar joint between them, fill the gap with a high-grade elastomeric sealant, such as Sonolastic (www.saudi-basf.com; 800-433-9517) or Sikaflex® (Sika Corp.; usa.sika.com; 800-933-7452). Joints can break up a wall's appearance, but they look better than cracks.

Using some or all of these tips will make your work easier and stronger. For further information, the National Concrete Masonry Association (www.ncma.org; 703-713-1900) publishes its TEK briefs on a wealth of masonry topics.

more about concrete reinforcement

A common gauge of steel's strength is its yield stress. When you apply stress below the yield stress and then release it, the steel returns to its original shape. But when you apply stress greater than the yield stress, the steel begins to deform permanently. The yield stress of reinforcing steel is indicated by its grade. Grade 40 means the yield stress is 40,000 psi. Most reinforcing bars are either grade 40 or grade 60.

U.S. steel mills produce reinforcing bars in 11 sizes, which are denoted by numbers (see the chart below). Those numbers represent the bar's nominal diameter in $\frac{1}{8}$ -in. increments. So a #4 bar has a $\frac{1}{2}$ in. dia. and a #18 bar has a $2\frac{1}{4}$ in. dia. (Note that bars are appearing increasingly often marked in millimeter sizes; see chart.)

Multiplying the bar's yield stress by its cross-sectional area gives its strength. For example, a #4 bar of grade 40 steel will withstand 8,000 lb. of force ($0.2 \text{ sq. in.} \times 40,000 \text{ psi}$).

A bar's size and grade are stamped along its length, appearing in a column of symbols, letters, and numbers. The first number to appear is the bar size. For some reason, the steel grade is more deeply hidden. Grade-40 bars have no special or additional marks. Bars of grade-60 steel have the number 60 stamped as the last symbol in the column, or they have an additional rib in their deformed pattern.

For the strength of a bar to be realized, it has to be held in a tight grip by the concrete. This bond strength comes from the bond between the concrete and the rebar, and it depends mostly on the concrete's strength and the holding ability of the rebar. The combination of concrete strength and holding ability of rebar is known as *development length*. For a #4 grade-40 rebar, the correct development length is the distance the rebar must be embedded into the concrete so that when you pull on it with 8,000 lb. of force, the rebar stretches rather than pulls out of the concrete.

The American Concrete Institute's (ACI) model code gives the development length for small bars (#7 and smaller, typically) as 0.03 times the rebar's diameter in inches times its yield stress in psi divided by the square root of the concrete's compressive strength (in psi) at 28 days, the final result ending up in inches.

For more information on rebar, contact the Concrete Reinforcing Steel Institute (www.crsi.org; 847-517-1200).

standard reinforcing-bar sizes

TO DETERMINE THE STRENGTH OF A GIVEN SIZE OF REBAR, MULTIPLY ITS YIELD STRESS (40,000 PSI AND 60,000 PSI FOR GRADES 40 AND 60) TIMES ITS CROSS-SECTIONAL AREA.

BAR SIZE		WEIGHT PER FT.		DIAMETER		CROSS-SECTIONAL AREA	
US	MM	LB.	KG	IN.	CM	SQ. IN.	SQ. CM.
#3	10	0.376	0.171	0.375	0.953	0.11	0.71
#4	13	0.668	0.303	0.500	1.270	0.20	1.29
#5	16	1.043	0.473	0.625	1.588	0.31	2.00
#6	19	1.502	0.681	0.750	1.905	0.44	2.84
#7	22	2.044	0.927	0.875	2.223	0.60	3.87
#8	25	2.670	1.211	1.000	2.540	0.79	5.10
#9	29	3.400	1.542	1.128	2.865	1.00	6.45
#10	32	4.303	1.952	1.270	3.226	1.27	8.19
#11	36	5.313	2.410	1.410	3.581	1.56	10.07
#14	43	7.650	3.470	1.693	4.300	2.25	14.52
#18	57	13.600	6.169	2.257	5.733	4.00	25.81
#11	36	5.313	2.410	1.410	3.581	1.56	10.07
#14	43	7.650	3.470	1.693	4.300	2.25	14.52
#18	57	13.600	6.169	2.257	5.733	4.00	25.81

A Solid Deck Begins with Concrete Piers

BY RICK ARNOLD

Dig a hole and fill it with concrete. How hard can that be? I've seen old decks built on top of little more than a shovelful of concrete, cinder blocks up on end, and even 8-in. by 12-in. patio blocks. I've also seen old decks—not to mention a couple of new ones—sink and pull away from a house, heave up with the same results, and even both sink and heave from one end to the other.

An insufficient design or a bad installation of this simple foundation system can have disastrous consequences in terms of safety, aesthetics, and a builder's reputation. That's why I approach piers with the same care as I do a house or addition foundation.

Determining Pier Size and Spacing

Because piers perform the same job for the deck that the foundation does for the house, it's critical to size and space them properly (see "How Many and What Size?" on p. 47). I begin by figuring out how many piers I'm going to need. This decision depends mostly on deck design. For this project, I was building a simple 12-ft. by 16-ft. rectangular deck with a double rim joist to act as a beam that could span about 8 ft., with posts running down from the beam to the piers. In this type of application, I start with two piers on the corners and divide the 16-ft.

double-rim joist until I get a figure of 6 ft. or less. Here, I found that dividing the rim joist into three sections gave me a span of roughly 5 ft. 4 in., which came out to four piers. Even though my double-rim joist could span 8 ft., I chose to use a 5-ft. 4-in. pier spacing to minimize the pier diameter.

After calculating the number of piers I need, I determine the size they need to be. The size of builder's tube dictates the size of the bottom of the pier, which is the area that will be in contact with soil at the bottom of the excavation. To figure this out, I calculate the maximum weight each pier must be designed to bear (by code). For the deck in this chapter, I figured a 1,600-lb. load on each of the two inside piers (see "How Many and What Size?"). Then I compared that to the bearing capacity of the soil at the bottom of the hole. I was building on hard-packed gravel, which easily has a bearing capacity of more than 3,000 lb. per sq. ft. (psf).

The bearing capacity of a 10-in.-dia. tube in 3,000 psf soil is 1,650 psf ($0.55 \times 3,000$). The design load of each inside pier is 1,600 lb., so a 10-in. tube will work. However, by jumping up to a 12-in. tube, the bearing capacity becomes 2,370 psf ($0.79 \times 3,000$), which can carry the 1,600-lb. load more easily. For just a bit more concrete, I ensure the pier is well designed. I typically ignore the pier



BEING ACCURATE WHEN PLACING PIERS and inserting anchor bolts ensures a safe, long-lasting, and professional-looking deck.

weight because there is enough fat in these calculations to justify this simplification.

The two outside-corner piers are required to bear only half the weight, but to simplify the work process, I use the same-size tubes for all four of the piers.

The depth you set the piers at depends a lot on the region of the country you're working in. In climates where frost is an issue, the minimum depth is established by code. For this project, the bottoms of the piers have to be 36 in. below finished grade.

Wherever you live, it is important to dig past soil that contains organic matter (topsoil) and any uncompacted fill. Organic matter decomposes over time and settles; loose fill also settles over time. In most cases, the depth of undisturbed soil is not known until the excavation is well under way.

Begin Layout with Deck Dimensions

Once I know the size and the number of piers I'm going to use, the next step is to lay them out on site. If the deck details aren't drawn on the plans, I sketch the outside deck framing to determine exactly where the center of the supporting posts are in relation to the outside dimensions of the deck. Then I use those locations to form a layout rectangle. I use batter boards and string to locate the exact center of the post, which is also the location for the anchor bolts that hold the post hardware in place.

Once the post locations are identified and marked with surveyor's paint, I remove the strings and dig the pier holes. When the holes are deep enough, I rough-cut the builder's tubes, drop them in, and replace the string lines. I keep the tubes centered on the string lines while they are backfilled, and I double-check the measurements with a tape measure.

piers transfer the deck's weight to the soil

To effectively transfer the weight, the piers need to be sized and spaced according to the deck's design load and the soil's bearing capacity (see "How Many and What Size?" on p. 47). In cold climates, piers should always sit below the frost line to prevent frost heaves. Check your local code for pier-depth requirements.

FOOTINGS SPREAD THE WEIGHT OVER A LARGER AREA

If the piers will be used in soil with poor bearing capacity or if the deck has a heavy design load, use a spread footing to distribute the load over a greater surface area. The more expensive, labor-intensive way to do this requires a relatively large excavation for each pier. After forming and pouring the footings, you have to install the tubes and backfill around them, then complete a second pour for the piers. But plastic footing forms bring this process down to just one pour.

For most of these systems, a builder's tube is fastened to the top of the form; then the assembly is lowered into the hole, backfilled, and poured in one shot. See the manufacturer's Web site for sizing and load requirements.

SQUARE FOOT®

www.sqfoot.com

Available from 22 in. dia. to 32 in. dia.

BIGFOOT SYSTEMS®

www.bigfootsystems.com

Available from 20 in. dia. to 36 in. dia.

THE FOOTING TUBE

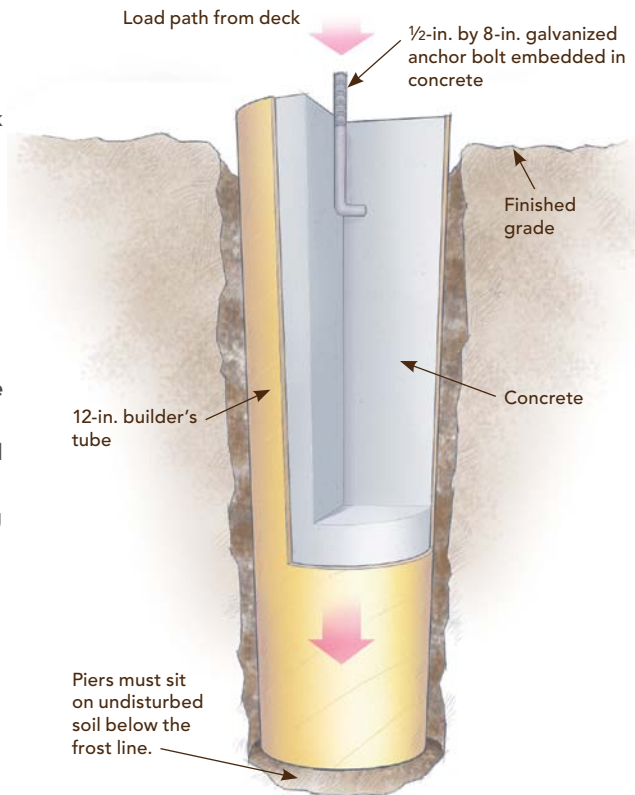
www.foottube.com

A builder's tube and spread footing in one. Top diameter sizes range from 6 in. to 12 in.

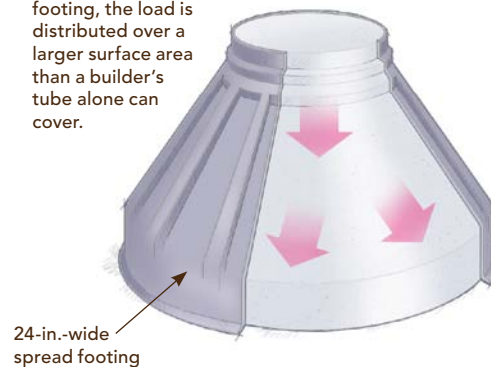
REDIBASE®

www.redibase-form.com

Available in 24 in. dia.



When using a spread footing, the load is distributed over a larger surface area than a builder's tube alone can cover.



everything you need

A few tools, even fewer materials, and a little sweat will get most deck foundations out of the ground in less than a day.

- Builder's tubes
- 80-lb. bags of ready-mix concrete
- Garden hose
- Foundation spikes
- Batter boards
- 1/2-in. by 8-in. anchor bolts, nuts, and washers
- Adjustable post bases
- Post-hole digger
- Digging bar
- Electric concrete mixer
- Stabila® plate level



Rather than try to cut tubes to the exact height, I leave them long and pour concrete to the desired height inside the tube. In most cases, I like the pour to come a couple of inches above the finished grade. If the piers are on a pitched elevation, the tops of the piers won't be level with each other. On this job, the finished grade was level, so I used a long level to carry the elevation across the piers.

After marking each pier with a small nail pushed through at the right height, I again remove the string lines so that I can pour the concrete into the tubes. Once they're filled to the right height, I float the concrete smooth with a scrap of wood. Then I replace the string, and using a slight up-and-down motion to prevent air from becoming trapped, I insert the anchor bolts in their proper locations.

how much concrete do i need

To pour the piers for an average-size deck, I use 80-lb. bags of concrete and an electric mixer, which rents for about \$45 a day or sells for \$250 or so.

For major pours, I have a concrete truck deliver a 2,500-lb. mix. Either way, the basic formulas below will help you estimate the number of bags or cubic yards of concrete required based on pier size and depth.

EXAMPLE

- Size of tubes: 8 in.
- Number of tubes: 8
- Average depth per tube: 4 ft.
- $0.53 (8 \times 4) = 17$ bags

TUBE SIZE	NUMBER OF 80-LB. BAGS PER FOOT	CUBIC YARDS PER FOOT
8 in.	0.53	0.13
10 in.	0.8	0.02
12 in.	1.2	0.03
14 in.	1.6	0.04

how many and what size?

Three things affect the number and the size of piers you use: the way you frame the deck, the weight the deck is designed for, and the load-bearing capacity of the soil. For the deck I'm building, I chose to support the double-rim joist with piers instead of a cantilevered approach that uses piers beneath a beam. I use the design load for decks suggested by the International Residential Code® (IRC), which is 50 lb. per sq. ft. (psf) (40 psf live load, 10 psf dead load). Different soils have different bearing capacities (measured in psf); consult Table 401.4.1 of the IRC for the bearing capacities of different soil types.

STEP 1. SPACE PIERS EVENLY BENEATH THE DOUBLE-RIM JOIST

Because I'm using a double-rim joist to support the floor joists, I support this 16-ft. deck with four piers.

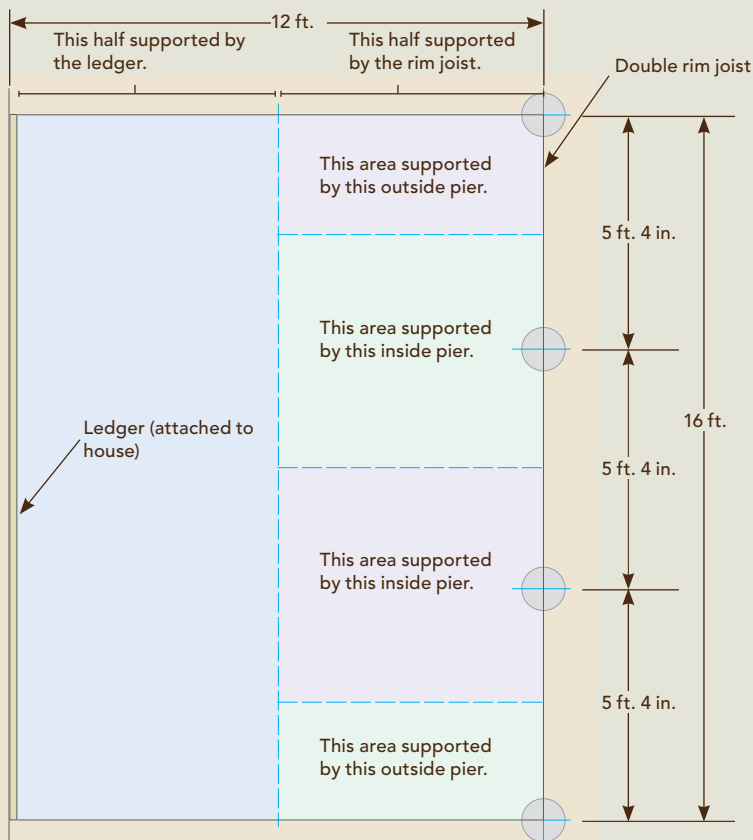
STEP 2. DISTRIBUTE THE DECK'S WEIGHT ONTO THE PIERS

A 12-ft. by 16-ft. deck is 192 sq. ft. Multiply by 50 psf to determine the design load, 9,600 lb. Half of that weight (4,800) is carried by the ledger; the other half is carried by the piers. Because the corner piers carry only half the weight that the inside piers carry, dividing 4,800 lb. by three tells me the two inside piers must each bear 1,600 lb.

STEP 3. TRANSFER THE WEIGHT TO THE SOIL

For this project, I was working in hard-packed gravel, which I estimate to have a bearing capacity of 3,000 psf. Using the chart below, I multiply the square-foot equivalent of each tube by 3,000 psf to find one that will work in this soil. A 10-in. tube will bear 1,650 psf, which is close, but I chose to bump up to 12-in. piers for peace of mind. To keep things simple, I made the corner piers the same size.

Tube diameter	8 in.	10 in.	12 in.	14 in.
Square feet	0.35	0.55	0.79	1.1



use two lines for a dead-on layout

With the ledger location transferred to grade level, I can measure out from the house foundation and run a string line to represent the center point of the piers. A single line parallel to the house intersecting a line perpendicular to the house locates the center of the far-corner pier. Measurements for the rest of the piers are taken from this intersecting point. Batter boards help set the lines accurately ("Tool Tip," below).



TOOL TIP

Rousseau makes a reusable batter-board system that is easy to install with foundation spikes and allows for horizontal, vertical, rough, and precision adjustments of the string line with a couple of thumbscrews. Cost for a set of four: \$64. www.rousseauco.com



1 PLUMB DOWN FROM A HIGH LEDGER. With a Stabila plate level (www.stabila.com), I carry one end of the ledger down to the grade. I drive a stake into the ground here to anchor a line that will run perpendicular to the house.



2 THE PIER CENTERLINE RUNS PARALLEL TO THE HOUSE. The batter boards I use make it easy to adjust the string line until it's exactly the right distance from the house foundation. I set the batter boards a couple of feet beyond the corner-pier locations so that the boards won't be disturbed when holes are dug.



3 $A^2 + B^2 = C^2$. Pulled diagonally from the foundation, my tape forms the hypotenuse of a right triangle. A helper shifts the line that extends from the house to intersect with the right measurement, identifying the center of the far-corner pier.



4 MARK PIERS WITH PAINT. Measure the remaining piers from the far-corner pier. A dot marks the center point, and a rough circle highlights where to dig. Pull the string lines and prepare to dig, but keep the batter boards in place.



5 THE BEST HOLES HAVE NO ROCKS. But just in case you encounter a few, make sure to have a long digging bar in addition to a post-hole digger. Take care not to disturb the batter boards or their settings because you'll have to reattach the string lines later. Dig down deep enough so that the bottom of the pier rests on undisturbed soil below the frost line.

TOOL TIP

If excavating multiple holes, consider renting a gas-powered auger. A one-person auger, shown here, costs about \$50 a day. The two-person version rents for about \$70.



fine-tune the layout before and after the pour

Once the holes are dug, put the string lines back on the batter boards. When setting each builder's tube, use the lines and a tape measure to center them according to layout, adjusting the hole locations as needed. Take the time to check the tube locations often as you backfill to keep them on layout. After all the fill is in place and the final layout check is made, fill the tubes with concrete, and insert the anchor bolts.



1 BACKFILL WITH MEASURING TAPE AND SHOVEL. I cut the builder's tubes so that they stick out a few inches above grade when placed in the hole. To make sure a tube is placed precisely, I hold it on its layout while a helper backfills. Pack the soil around the tube every so often as you go.



2 DOUBLE-CHECK THE CORNERS. I spend a little extra time checking the location of the final corner pier to make sure that it's in the right spot because I won't get a chance to move it once the concrete is poured. Use a nail to mark the finished height of the piers, keeping it a couple of inches above the finished grade. If you need to have piers all at the same height, use a long level or a transit to locate their finished height.



TOOL TIP

A mixer does the most difficult work of mixing the concrete. Just dump in the mix, turn it on, then add water.

3 A SHOVEL MAKES UP FOR BAD AIM. Fill the tubes with concrete until it reaches the nail. The concrete should be just slightly on the wet side, about the consistency of thick oatmeal. As the concrete is poured into the tube, a helper uses a shovel to agitate the mix every 8 in. to 10 in. to work out air pockets.



4 PLACE ANCHOR BOLTS ACCURATELY. Once all the piers are poured, I go back and insert anchor bolts in the center of the piers. I measure from the line running perpendicular to the house to set anchor bolts accurately. Be sure to leave the threads high enough so that a post base, washer, and nut can be added later.



5 ADJUSTABLE POST BASES ALLOW FOR FINAL TWEAKS. After the concrete is cured completely, I attach adjustable post bases. I like to use Simpson® ABA-style bases because they allow me to fine-tune the post location after the post is attached.

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Pouring Concrete Slabs

BY CARL HAGSTROM

Liquid stone. It's an image you might think describes placing concrete, and to some extent, it does. But there's more to it than backing up the ready-mix truck, opening the spigot and letting the concrete flow out until the forms are full.

The applications of concrete are almost limitless, but here I'll focus on residential slabs. About half of the new homes currently built in the United States start with full-basement foundations, and virtually all of these basements have concrete floors. For the most part, these floors consist of 4 in. of concrete placed over 4 in. or more of crushed stone. Concrete floors in garages are similar, except they are sometimes reinforced with wire mesh or steel. But whether it's a basement or a garage slab, the way you place the concrete is the same.

Ordering Concrete

Concrete is sold by the cubic yard, and calculating the amount you need is simple: length times width times depth (in feet) divided by 27 equals cubic yards. Most concrete trucks max out at 9 yd., and if your floor will require more than nine (the average floor uses about 19 yd.), tell your supplier to allow 1 hour to 1½ hour per truckload so that all the trucks don't arrive at once.

But a word of caution. Running out of concrete is like running out of champagne at a wedding: If you can't get more real soon, you're headed for trouble. Don't be stingy with your concrete estimate. You're a lot better off with half a yard left over than a quarter yard short.

Once you've told your concrete supplier how much concrete, you'll have to tell them what kind. Concrete is made up of four basic ingredients: cement, sand, stone, and water. Depending on the proportions of the ingredients, the strength can vary considerably. Compressive strength, measured in pounds per square inch (psi), is the method used to evaluate the performance of a given mix. Generally speaking, the higher the cement content, the higher the compressive strength. Most residential concrete has a compressive strength between 2,000 psi and 3,500 psi.

You'll also need to specify the slump, or the wetness, of the mix. A slump of 4 to 5 is about right for slabs, whereas a slump of about 2 to 3 is normal for piers, which don't need to be worked, so the concrete can be stiffer.

Placing the Slab

Arrive early on the day of the pour and use a water level or a transit to snap chalklines on the founda-



USING A SCREED RAIL. Two workers use a magnesium straightedge, or screed rail, to level freshly placed concrete. The ends of the rail glide over previously leveled concrete strips, called wet screeds. A third worker rakes the concrete behind the screed rail to adjust for high and low spots.

tion wall at finish-floor height (usually 4 in. higher than the stone). The lines help you level the concrete along the walls.

You should also lay out the vapor barrier at this time. Six-mil polyethylene works well, but if you're concerned about punctures from traffic during the pour, a puncture-resistant, cross-laminated product is available, called Tu-Tuf® (Sto-Cote Products, Inc., 888-786-2683).

If you elect to use wire-mesh reinforcement, this is also the time to lay it out. Wire mesh doesn't prevent cracking, but it will help keep hairline cracks tight, even as the temperature varies. Typically, a basement slab isn't subjected to wide temperature swings. Therefore, a basement slab placed over a properly prepared stone base doesn't require wire mesh. Garage slabs, on the other hand, typically experience harsher weather conditions, and wire mesh

may be used as temperature reinforcement. But wire mesh won't be effective unless it's placed midway in the thickness of the slab, so be sure to use wire high chairs, which hold the reinforcement up off the stone during the pour.

The ready-mix truck arrives, and the driver asks, "How wet do you want it, Mac?" Drivers routinely ask about adding water to soften the mix. When a mix is too stiff, it's physically difficult to work and presents problems when it's time to float and finish the slab. To get a smooth, hard, dense finish on top of the slab, the mix has to be workable. As mentioned earlier, however, the wetness was determined when you specified the slump of the mix. And as any structural engineer will tell you, when you add water to concrete, you lower the final strength. The issue of water content in concrete is critical; many concrete



FIRST MUD. With the vapor barrier in place and the chalklines snapped, the first load of concrete is dumped in the far corner of the foundation. The mason dumps the concrete away from the wall so that he won't cover the chalkline.

Running out of concrete is like running out of champagne at a wedding: If you can't get more real soon, you're headed for trouble.



ESTABLISHING A PERIMETER SCREED. A magnesium hand float is used to push the concrete up to the chalkline. This strip of wet concrete, placed along the foundation walls, is a perimeter screed.

be prepared for the pour

Be prepared for the day the concrete is scheduled to arrive by first surveying your situation.

Do you have a grade-level door or will you need to chute the concrete through a basement window? Will the ready-mix truck be able to get next to the house, and if not, will the manpower be available to transport the concrete in wheelbarrows? Pushing one wheelbarrow full of concrete uphill is possible for some, but making 30 trips uphill is a job for the John Henry type. It never hurts to have more help than you might need because concrete is always a rugged day's work.

A little rain the night before can turn a dry approach into a muddy nightmare. I call my supplier several days in advance and say that I'm shooting for next Thursday, for example, but that I'll call first thing Thursday to confirm. If conditions are terrible, I reschedule.

Remember, concrete waits for no one. From the minute it leaves the plant, it has a finite time before it sets up, and just about any builder can come up with a horror story describing a pour that got away.

companies require that you sign off on the delivery slip when requesting additional water so that they have a record of your compromising the rated strength of the mix.

If the first few wheelbarrows of concrete are difficult to work, have the driver add water to it—but in small amounts. You can always soften the mix by adding water, but you can never dry it if it becomes too wet.

Leveling with Wet Screeds

There are many ways to place a basement slab. If you've never placed one, ask some masons about the

techniques they use. If you have placed a few slabs, don't be afraid to try a different method; you may discover a system that you're more comfortable with. But whatever approach you take, follow a logical progression: Don't trap yourself in a corner. I prefer to use wet screeds as guides to level the slab (see the photo on p. 54)

Wet screeds are wet strips of concrete that are leveled off at finish-floor height and used to guide a straightedge, or screed rail, as you level the slab. If you've ever watched a sidewalk being placed, you've seen concrete placed between two wood forms, a screed rail placed on top of those forms and sawed back and forth to strike the wet concrete down to the level of the forms. Wet screeds guide the screed rail in places where there are no wood forms, such as against an existing concrete wall or in the middle of a slab.

Where you start with your wet screeds depends on the layout of the slab. In a typical rectangular basement with the walls already in place, a wet screed is placed around the perimeter of the foundation, and a second wet screed is placed down the center of the foundation (see the photo on the facing page), parallel to the longer dimension of the foundation. On a bigger slab you might need more wet screeds; the determining factor is the length of the screed rail you'll be using.

Placing the wet screeds around the perimeter of the foundation is simple. Use the chalkline you snapped at finish-floor height as a guide to level the concrete at the wall (see the bottom photo on p. 55.) As the concrete is placed, either from a wheelbarrow or directly from the chute, use a magnesium hand float to push and level the concrete to the line. Be sure you don't cover up your chalkline as you place the concrete. Dump it near the wall and bring it up to the line with the float (see the top photo on p. 55).

Establishing the level of the center screed requires that you drive pins about 8 ft. apart at the level of the finish floor; 16-in. lengths of ½-in. rebar work well. Try to set these pins immediately before the pour, using a transit or a string line, and cover them with



RAKER'S ROLE. As the screed rail levels concrete between the perimeter screed (right) and the center screed (left), the raker pulls away excess concrete or fills low spots. A rebar spike set at finish-floor height and subsequently driven below the concrete's surface establishes the center screed's level.

TIP: If you're pouring a garage slab, you'll probably use wire mesh as temperature reinforcement. Be sure to use wire high chairs during the pour to hold the reinforcement up off the stone.

upturned buckets so that no one trips on the pins. Place and level a pad of concrete around each pin, then fill in the area between the pads with concrete and use a screed rail, guided by the pads, to level the

area between them. As you complete each portion of this center screed, drive the pins a few inches below the surface with a hammer and fill the resulting holes with a little concrete.

Raking and Striking

To fill in the areas between screeds, place and rake the concrete as close as possible to finish level before striking with a screed rail. Placing too much material makes it difficult to pull the excess concrete with the screed rail as you strike off, and the weight of



OPERATING A BULL FLOAT. After the concrete is screeded, a bull float pushes stones down and brings up the fines—sand and cement—that make a smooth, finished surface. To use a bull float, lower its handle as you push it away, and lift the handle as you pull it back.

the excess concrete can distort a wooden screed rail. If you starve the area between the screeds, you'll constantly be backtracking through freshly placed concrete, filling in low spots and rescreeding.

Using a screed rail, strike off the concrete with the perimeter screed and the center screed as guides. Your path of escape will determine the placement and the size of your screeds, but generally speaking, you progress in about 10-ft. or 12-ft. sections of slab.

The person raking the concrete can make or break the pour. As the wheelbarrows are dumped, the raker should nudge the concrete to the plane of the finish floor, eyeing the placed concrete like a golfer lining up a putt, and noting any mounds or valleys that will create problems as the screed rail works across. As the concrete is struck off, an alert rake person will pull away any excess concrete accumu-

Teamwork is the name of the game. Establish each person's role well ahead of the pour, and do your best to stick to the plan.

lating ahead of the screed rail (see the photo on p. 57) and push concrete into any low spots.

At this stage of the pour, with five or more people working, teamwork is the name of the game. Establish each person's role well ahead of the pour, and do your best to stick to the plan.

Striking off the concrete with the screed rail is the last step in placing the concrete and the first step in finishing it. A good, straight 2×4 will work well, but magnesium screed rails, available in a variety of



CEMENT SHOES. Knee boards—pieces of plywood with strips of wood on one edge—allow you to move around on fresh concrete without sinking in because the boards distribute weight over a large surface area. Concrete finishing is done from knee boards while the concrete is in a plastic state, meaning it's neither liquid nor solid.

lengths, will perform better. No matter which you choose, working a straightedge back and forth is a lot like running a two-man saw. The work is done on the pull stroke, and you have to be aware of your partner's progress. Wear rubber boots because, standing alongside the wet screeds, you'll often be wading through concrete. (For anyone tempted by the prospect of a barefoot frolic in concrete, be warned that concrete is caustic and will corrode your skin.)

As you saw the screed rail back and forth, let it float on top of the wet screeds, keeping an eye open for low spots and stopping when excess concrete dams up ahead of the screed rail so that the raker can pull off the excess.

Bull Floating

As the pour progresses, it's necessary to smooth the surface of the leveled concrete with a magnesium bull float (see the photo on the facing page). When you bull float is determined by the length of the tool's handle and how comfortable you are operating the tool. For example, a bull float with an 18-ft. handle will easily float a 10-ft. or 12-ft. section of a slab. Bull floating levels the ridges created by the screed rail, but more important, it brings cement and sand to the surface of the slab and pushes stones lower.

Water is the lightest ingredient in concrete and quickly finds its way to the surface as you jostle the mix around with a bull float. As the water rises to the surface, it also brings some cement and sand with it. These are the fines (sometimes called fat or cream) that provide a stone-free medium for troweling to a smooth finish.

Although its size is intimidating, a bull float works about the same as a hand trowel. The trick is to keep the leading edge of the bull float inclined above the surface of the slab by lowering the bull float's handle as you push it away and raising the handle as you pull it back. Some masons jiggle the handle as they move it out and back to jostle more fines to the surface. The ease of final troweling depends on how well the slab has been bull floated.

Floating from Knee Boards

Once the bleed water has evaporated, work the slab. Some slabs (in crawl spaces, for example) are acceptable with just a coarse, bull-floated finish. But these finishes tend to dust over time; that is, concrete particles come loose from the coarse slab surface whenever it's swept. Additional finishing compacts the surface so that the slab won't dust.

You may have seen professionals using a power trowel to float and finish larger slabs. A power trowel works like a lawn mower without wheels. It rides on rotating blades that smooth the surface of the concrete. If you're inexperienced, however, or if the slab is small, you're better off finishing it by hand. And

hurry up and wait

Once the slab is placed and bull floated, it's time to sit and wait. The first stage will be the evaporation of the bleed water, water that rises to the surface as the slab sets up. Depending on the weather conditions and the consistency of the mix, this time can vary from 1 hour on a hot, dry day to 10 hours on a cool, damp day.

But keep in mind that when concrete starts to set, it waits for no one. There is a small window of opportunity in which you can work the slab, and if you happen to be out for coffee when the concrete starts to set up, you'll learn an expensive lesson. Unless you're a veteran finisher, don't ever leave the pour; you may return to a problem whose only solution is a jackhammer.

even professionals still use hand floats and trowels at the edges of the slab and around projections because a power trowel will finish only to within a few inches of these spots.

Hand finishing is commonly done from knee boards, which are like snow shoes for the still-wet slab (see the photo on p. 59). They let you move around on the slab without sinking. To make a simple pair of knee boards, cut two pieces of $\frac{3}{4}$ -in. plywood 2 ft. square, and tack a 2×2 strip at one edge of each piece.

It's difficult to describe just when the slab is ready for hand floating, but it may help to think of the slab as drying from the bottom up. If you set a knee board on the slab, and it sinks $\frac{3}{4}$ in. when you step on it, you're too early; if it fails to leave a mark, you're too late. As soon as you can easily smooth over the tracks the knee boards leave behind, the slab is ready for the first hand floating.

Test the concrete at the area where the pour started because it tends to be ready first. If any areas of the slab are in direct sunlight, you can bet they'll be ready long before the shaded areas are. At any rate, your first pass will be with a magnesium hand float (see the top left photo on p. 62).

Like a bull float, a magnesium hand float works the fines to the surface, and you fill in any low spots or knock down any high spots during this pass. The goal when using the magnesium float is to level the concrete, preparing a surface that is ready for smoothing with the steel trowel. You can generally work the entire slab with the magnesium float before it's time to trowel with steel.

The difference between a magnesium float and a steel trowel is easy to recognize on the slab. You can work the slab all day long with magnesium, but you'll never get beyond a level, grainy surface. But when the slab is ready, and you lay a steel trowel to it, the results are impressive.

Hit the Slab with Steel

Keeping the image in your mind of the slab drying from the bottom up, picture the top $\frac{1}{8}$ in. of the concrete, which is all cement, sand, and water. While the top section is in a plastic state—neither liquid nor solid—the steel trowel will smooth this layer and compact it into a dense, hard finish. Now the preparatory work pays off; if the concrete was placed and leveled accurately, the final finish goes quickly.

Obtaining an exceptionally smooth finish is a practiced technique that takes years to develop. The steeper the angle of the trowel to the slab, the more trowel marks will occur. If you hold the trowel at an extremely slight angle, you're liable to catch the slab and tear out the surface.

Your troweling technique will be dictated by how loose or tight the surface of the slab is. When the surface is wet, you can hold your trowel fairly flat, but as the fines tighten up, you'll have to increase both the angle and pressure of your trowel. As the slab dries you might have to use both hands on the trowel to muscle some fines to the surface

tips for pouring in the weather

Temperamental is an apt description of concrete. Temperature, along with humidity, influences the pour more than any other factor.

HOT-WEATHER POURS

When it's hot, and the humidity is low, every minute is important. If you spend time fussing around, when the last wheelbarrow of concrete is finally off the truck, the first section of floor you placed will probably be hard enough to walk on.

HERE ARE SOME STRATEGIES THAT HELP IN HOT WEATHER:

- Even if a polyethylene vapor barrier is not required, use one. It blocks the moisture from dropping through the subgravel.
- Have lots of help available. The sooner you get the truck unloaded and the concrete leveled, the better your chances will be of getting a good finish.
- Have two finishers working the slab: one with a magnesium float, and another following behind with a steel trowel.
- Although it compromises compressive strength, consider using a wetter mix to buy a little more working time.
- If more than one truckload is needed, coordinate the arrival times carefully. If a fresh truckload of concrete has to sit and wait 1 hour while you finish unloading the first truck, you may find that concrete from the second truckload will set up before you're ready for it.
- Areas that receive direct sunlight set up much more quickly than shaded areas.
- Start wetting down the slab as soon as the final finish has set. Few things will weaken concrete as much as a "flash" set, by which the concrete dries too quickly.

COOL-WEATHER POURS

When the temperature is cool, concrete initially reacts in slow motion. After the slab is placed, and the bleed water slowly evaporates, you'll wait hours for the slab to tighten up enough to start hand troweling. When it's finally ready to be troweled, you'd better be there because that window of opportunity for finishing doesn't stay open much longer on a cool day than it does on a warm day.

HERE ARE A FEW COOL-WEATHER TIPS:

- Don't wet the mix any more than necessary.
- If a polyethylene vapor barrier isn't required, don't use one. Any moisture that drains out of the slab will speed the set.
- Pour as early as possible to avoid finishing the slab after dark.

COLD-WEATHER POURS

When the temperature is cold, a whole new set of rules comes into play. Concrete cannot be allowed to freeze. That tender, finely finished surface you just troweled on the slab will turn to mush if it's allowed to freeze. Fortunately, the chemical reaction that takes place when concrete hardens generates heat.

HERE ARE SOME STRATEGIES THAT HELP IN A COLD-WEATHER POUR:

- Ask your concrete supplier about using warm mixing water to prevent problems during transit on days when the temperature is well below freezing.
- Having the supplier add calcium to the mix accelerates the initial set of the concrete, and the concrete achieves the strength to resist freeze/thaw stress faster. The amount of calcium is measured as a percentage of the cement content and ranges from ½% to 2%. Talk to a veteran concrete finisher before deciding when and how much calcium to add to the mix. Too much calcium produces the same problems as hot, dry weather. It's important to note that calcium is corrosive to steel and should never be used in steel-reinforced concrete.
- Always be sure that all components of the sub-base are frost free.
- Provide supplemental heat to keep the building above freezing.
- Cover the slab with polyethylene and then spread an insulating layer of straw or hay at least 4 in. thick on top, or use an insulating tarp.
- The best strategy: Pour when cold temperatures are not an issue.



START WITH A MAG; FINISH WITH STEEL. After bull floating, use a magnesium float (left) to smooth out bumps and fill in low spots. The resulting finish will be coarse. Later, use a steel trowel (right) to get a smooth, dense finish that won't crumble when it's swept.



TWO HANDS! TWO HANDS! As the concrete sets up, working it with a steel trowel may require the strength of two hands. The back of the trowel is angled up as you push it away (left), and the front of the trowel is angled up as you pull it toward you (right).

(see the bottom photos above). Once the fines have emerged, switch back to one hand and polish the area with your trowel (see the top right photo above). If you've waited too long, and you're losing the slab, sprinkle water on its surface to buy a little more finishing time. After that, there isn't enough angle, pressure or water anywhere on earth to bring a lost slab back to life. If it's important that the final finish be first rate, consider hiring a professional. Remember, you get only one try.

Curing the Finished Slab

While it's true that you can walk on the floor the day after it's placed, concrete actually hardens very slowly. The initial set represents about a quarter of the total strength; it takes about a month for con-

crete to cure fully. The goal during this period is to have the concrete cure as slowly as possible.

Keeping the slab soaked with water for 4 days or 5 days will keep it from drying too quickly, but continual hosing down involves a lot of time and effort. Slabs can require a soaking every half hour in the heat of summer. A masonry sealer applied the day after the pour will keep the slab from drying too quickly and protect the floor from stains that might otherwise wick into the slab.

When you consider that the material cost of a basement slab is less than \$1 per sq. ft., it's difficult to imagine a more economical finished floor system. But when you consider the cost of removing and replacing an improperly finished concrete floor, the importance of knowing how to handle two or three truckloads of concrete becomes apparent.

Laying Up Concrete Block

BY JOHN CARROLL

Masons work from the ground up. You're probably not surprised to hear that. As simple as this principle sounds, however, it's also a bit misleading. Masons build from the ground up, but they measure from the top down, which means the real starting point of a masonry job is the top line.

From this line, masons measure down, marking in equal increments what will be the top of each course of brick or block. By working to these marks, masons arrive with evenly spaced courses at the tops of foundations, the bottoms of windowsills or other predetermined landing places.

Even when I'm using basic techniques for planning and laying up a simple concrete-block foundation, I return again and again to the same starting point: the top line.

Planning and Laying Out a Block Structure

Before any mud is slung or any blocks are buttered—indeed, before any dirt is dug or any concrete footings are poured—the finished dimensions of a block structure should be established. These dimensions are length and width—along with any variations in the basic rectangle—and exact height.



THE BASIC TOOLS FOR WORKING WITH CONCRETE BLOCK. **To get started laying up block requires a trowel, a pointing tool, line blocks, and string (mason twine).** Also helpful are line stretchers (left) and twigs, shown next to the string.

When I build a foundation, for instance, the first thing I do is see if any small dimension adjustments might allow the masonry units to fit without being cut. Say this foundation is 12 ft. by 13 ft. I try to change the 13-ft. dimension to 13 ft. 4 in. so that it works out to an even number of blocks.

Unlike the foundation for a freestanding building, where a difference of 1 in. or 2 in. in the final height usually isn't too important, the height of the founda-



GET EVENLY SPACED COURSES and consistent mortar joints by using the proper layout, mortar consistency, and troweling techniques.

tion for an addition must be right on the money. To get to this point, the first thing I do is to mark the height of the existing finished floor on the outside wall of the house. For this, I set up my laser level, shoot the elevation of the floor through an open door or window, and then transfer that elevation to the outside wall.

Next, I find out exactly what will be used in the addition as floor covering, subfloor, joists, and sills. On the foundation project shown here, these included carpet and pad ($\frac{3}{4}$ in.), tongue-and-groove plywood ($\frac{3}{4}$ in.), 2×10 joists ($9\frac{1}{4}$ in.), and 2×8 sills ($1\frac{1}{2}$ in.). By measuring down a total of these depths— $12\frac{1}{4}$ in.—from the mark I made on the outside wall, I arrived at the correct height for the top of the foundation. Using my laser level, I made marks at this elevation at both ends of the planned addition, and I snapped a line on the house to represent the top of the new foundation.

Establishing the Entire Top-of-Foundation Line

The project pictured here is a 16-ft. by 24-ft. foundation for an addition. Here's how it began. After I snapped a line on the house to represent the top of the foundation, I marked the beginning and end of the foundation on this chalkline, which served as a reference to lay out the rest of the foundation.

My next step was to set up a line that would represent the top of the outside foundation wall. This line had to be 16 ft. from—and parallel to—the house and at the same level as the chalkline. To hold the string, I set up a pair of batter boards. First, I drove a pair of 2×4 stakes into the ground several feet outside the corners of the planned foundation (I could judge this by eye by looking at the corner marks on the chalkline marked on the house).

I set the stakes in line, 14 ft. and 18 ft. out from the house so that they would straddle the planned 16-ft. line. After driving in the 2×4s, I used my laser level to transfer the top-of-foundation elevation, represented by the chalkline, to the stakes. Then I attached a horizontal batter board to each pair of

stakes, keeping the top edge even with the top-of-foundation marks. Once the batter boards were attached, I stretched a line from one batter board to the other. To hold the line in place, I used mason's line blocks, which I could slide along the batter board. By methodically measuring and adjusting the work I was doing, I was able to get the line exactly parallel to and 16 ft. away from the house. This string line represented the top outside edge of the foundation wall.

I now turned to the task of laying out the two sidewalls. These walls would run perpendicular to the house and would begin at the corners marked on the chalkline. To do this, I calculated the hypotenuse of a right triangle with sides of 16 ft. and 24 ft. This works out to 28 ft. $10\frac{1}{8}$ in. I pulled this dimension diagonally across the planned foundation from one of the corner marks on the house to the string line. Using a felt-tipped pen, I marked where 28 ft. $10\frac{1}{8}$ in. intersected the string line. This dot represented the third corner of the foundation. Pulling this dimension diagonally in the other direction, I marked the fourth corner. To check my work, I measured from dot to dot along the string line. Seeing that it was exactly 24 ft., I knew my layout was correct.

After the third and fourth corners were marked on the string line, I set up two more pairs of batter boards. To represent the top of each wall, I stretched a string from the corner mark on the house, through the mark on the string line, to the new batter board. I now had string lines outlining the top outside edge of the entire foundation.

A Story Pole Aligns the Courses and the Corners

The top of the footing should be a set number of block courses below the top-of-foundation line. In the example that I'm using, the footing was exactly 80 in., or 10 block courses, below the top line.

After the footings are poured, it's good to recheck the position of the top-of-foundation lines. After seeing that my top-of-foundation line hadn't moved,

buckets are better than shovels when mixing mortar

Block work is mainly a physical skill that takes a lot of practice. The best training is to have at it, ideally alongside an experienced mason.

The first thing a novice should learn is how to make good, consistent mortar. I've found that this cannot be done using ready-mix mortar. The material that comes already mixed with sand has poor plasticity and contains coarse sand.

You can rent electric mortar mixers by the day, but most novices are laying block so slowly that they'd be just as well off mixing it in a wheelbarrow by hand. They're not using mortar fast enough to justify the cost of renting a machine.

MORTAR MIX

Mortar is made up of portland cement mixed either with lime or any of several proprietary ingredients. One part of this mixture is combined with 2½ parts to 3 parts sand, and water is added to get the right consistency. Cement/lime mortars often come in separate bags and have to be mixed on the job. Masonry cement mortars (those with the proprietary ingredients) come ready to be mixed with sand.



Masons often count 18 shovels of sand for every bag of mortar, but the size of a shovel is inexact. I measure the ingredients by filling a drywall bucket with dry mortar and three other drywall buckets with sand. I put all this in a mixer and add water until I get the right consistency.

It's hard to describe the right consistency. As opposed to concrete, which should be kept as stiff as possible, mortar should be made as wet as possible, yet still be workable. The primary role of mortar is to bond masonry units together. Wet mortar spread on dry units is absorbed deep into the pores and crevices of the units, producing a tenacious bond. A mixture that is too wet, however, is almost impossible to work with and makes a mess of the job. Good mortar is almost fluffy; some masons call mortar that's just right *fat mortar*.

The best way to learn how to make good, wet, workable mortar is by actually making it and using it. Even perfect mortar doesn't stay that way for long. On hot days, you often have to "shake up" the mortar by mixing in a little water. Enthusiastic novices invariably mix too much mortar. The longer mortar sits, the harder it is to work. After 2 hours, it should be disposed of, usually into the cells of the block wall.

I try to make about an hour's worth of mortar at a time. Usually one bucket of mortar and three buckets of sand last me about 1 hour; however, a novice may want to start by mixing a half batch. And before I mix the material, I make sure I have everything ready. To estimate what you'll need, figure three bags of mortar for every 100 blocks plus 9 cu. ft. of sand, or about fourteen 5-gal. buckets (a 5-gal. bucket is 0.668 cu. ft.).

NOT TOO MUSHY AND NOT TOO STIFF. Mortar should be as wet as possible, yet still be workable. Mortar should have some body, but it still should be mushy.



A GRINDER MAKES A CLEAN CUT. To avoid ragged edges in cut blocks, use a grinder equipped with a diamond blade, and give the block a tap with the hammer to get a clean split. This procedure is messy, however, so a respirator and eye protection are important.



I dropped a plumb bob from the intersection of the lines to mark the outside corners of the block courses. At each outside corner, I attached a story pole of 2-in. tubular steel to the footing. The story poles I use have two L-shaped brackets welded to their bottoms. To attach the story poles, I nail through holes in the brackets with case-hardened, fluted masonry nails into the concrete footing. Then I set the story pole plumb and clamped 1×4 braces to the pole and to the batter boards (see the photo on p. 68).

At the corners that engage the house, I affixed 1×4 story poles. Next, I marked down all the story poles in 8-in. increments from the top-of-foundation line and was ready to lay block.

Avoid Unnecessary Cuts

Blocks are difficult and expensive to cut, and when they are cut, they can detract from the appearance of the job. So it's wise to avoid unnecessary cuts.

Cutting units lengthwise (the masonry equivalent of ripping) is referred to as splitting. Cutting units to length (the masonry equivalent of crosscutting) is simply called cutting. Split blocks not only interrupt the orderly progression of horizontal courses—and look bad—but they're also a scourge of productivity. It comes as no surprise that masons do their utmost to avoid split units. Units cut to length are a different matter. Because every house has windows, doors, and corners, blocks inevitably have to be cut to length.



MEASURE FROM THE TOP DOWN. Steel story poles at the outside corners of the block foundation are nailed to the footings, held in place with 1×4 braces, and mark the corners of the foundation and the courses of block. String lines between the house and the poles mark the foundation height.

When I have to cut block, I avoid masonry hammers or chisels. I've never liked the ragged edges these tools leave. Instead, I use a 4-in. grinder equipped with a diamond blade (see the left photo on p. 67). You can also use an abrasive blade in a circular saw. After cutting as far into the block as I can, I give it a good tap with a hammer, and it breaks easily (see the right photo on p. 67).

Keep Mortar Joints Consistent

Masons adjust the height or length of courses by altering the thickness of mortar joints. This is a basic part of masonry. It allows masons to make up for inconsistencies in the size of the units and to fit whole units into a given space (between windows, for instance). But this device is easily overused. Fat joints and abrupt changes in the thickness of joints look terrible.

Joints that are thicker than $\frac{3}{4}$ in. can shrink excessively, which sometime results in leaky hairline cracks. And because masons tend to use a stiff mix when making thick joints, the bond is often poor, resulting in both leakage and structural compromise. For optimal appearance and performance, joints should be between $\frac{5}{16}$ in. and $\frac{1}{2}$ in. thick, and they should be as consistent as possible.

To attain evenly spaced courses with consistent mortar joints, masons lay out courses in standard modules based on the size of the block used. The height increments for concrete blocks are typically 8 in. or 4 in. Like lumber, blocks are smaller than their nominal size; an 8-in. block is actually $7\frac{5}{8}$ in., and a 4-in. block is $3\frac{5}{8}$ in. A block with a $\frac{3}{8}$ -in. bed joint, then, measures an even 8 in. or 4 in.

Getting Started with the First Course

After stretching string lines for the first course in both directions from the corner pole, I lay my first block, a corner block. The top of this block fits snugly to the intersection of the string lines.

After getting this block even with both strings, I start laying blocks in from the corner along one of the lines. After laying all or part of this line, I work down the other line, working from the corner in.

After running all or part of this line, I move both lines up to the next mark on the story pole and start the second course. Like the first block I laid in the previous course, the first one here fits snugly into the intersection of the lines at the story pole. This block, however, crosses to the corner block in the first course and thus begins the familiar bond pattern associated with most block walls.

At this point in the job, I have the option of either laying the entire length of each course or laying just far enough down the line to build up the corner. Usually, there's no need to build a corner lead. I often build entire small foundations straight off the story poles. On congested sites, however, it's often best to build the corner first so that you can get the story pole and braces out of the way as soon as pos-



TAP THE BLOCK GENTLY TO GET IT PLUMB AND LEVEL. This block was set into about 1 in. of mortar and gently tapped with the butt of the trowel until it was level and plumb. The layout line remains a fraction of an inch above the block to keep the string from snagging on the block.

sible. To set up a line for laying the rest of the wall, just hook the line block directly to the corner you've built.

The ability to set up a line quickly and securely is an important masonry skill. The two most common tools for doing this are line blocks and twigs (see the photo on p. 63), which masonry-supply houses traditionally supply for free. To use a line block, wrap the string over and around the block a couple of times and hook it on either the outside corner of the masonry or on a corner pole.

Twigs fasten to the string, and a brick or a piece of block holds it on the top edge of the block. One of the advantages of using a twig is that the string

keep the blocks dry

An important consideration in block work is keeping the blocks dry. Although dry and absorbent brick sometimes needs to be dampened before it is laid, blocks should always be kept dry before they are installed. Wet blocks don't bond well and are difficult to lay, so it's prudent to cover blocks as soon as they're delivered. At the end of the day, it's also smart to cover the top of the wall, both to protect the bond of the day's work and to make sure the top course is dry when you return to lay blocks on top of it.



YOU CAN FEEL IF A BLOCK IS ALIGNED WITH THE REST. Place the palm of your hand on the new block and your fingers across the joint between blocks to feel if the new block is even.



CLEAN THE JOINT OF EXCESS MORTAR. After a block is set in place, use the trowel to cut the mortar that has bulged out. Then give the trowel a shake and butter the end of the block with the remaining mortar.

can be pulled taut without exerting pressure on the masonry just laid. Sometimes, instead of hooking a line block on a corner I've laid, I attach the line to a stake or a block beyond the corner and use a twig to hold the line even with the top edge of the unit.

A third tool that is sometimes used to affix lines to the inside corners is the line stretcher. After the corner has been built, the string is wrapped around the line stretcher, and the stretcher is placed across the top of the first unit of the course being laid. The stretcher is held in place by tension on the line. All these tools are available from a good masonry-supply company.

While you're pulling together the tools and materials you need to get started, you should also consider lightweight block instead of standard block. Lightweight block is made with special lightweight

aggregates rather than crushed stone. A standard 8-in. by 8-in. by 16-in. block weighs 32 lb. to 38 lb. A lightweight block weighs only 22 lb. to 27 lb., but it's weight that really adds up after a day of lifting. Lightweight block also costs up to 25% more than normal-weight block.

Troweling Techniques: To Sling or to Butter

There are two techniques for spreading the bed joints, or horizontal joints, of a block wall. In the first, load your trowel, hold it above the top edge of the lower block and shake some mortar loose from the trowel. Then, as you move the trowel down the line toward yourself, shake more of the mortar loose and let it fall in a line along the block. After about a third of the mortar is laid down like this, simultane-

ously turn your wrist downward and pull the trowel quickly toward yourself, slinging the rest of the mortar in a nice line on top of the block.

In the second technique, load your trowel and give it a good shake (a hard shake makes the mortar stick to the trowel). Then, in a downward, pulling stroke, butter the top edge of the block by sliding the trowel blade down and across the block.

There are also two methods for buttering the head joints of blocks. Some masons butter the ends of the block before they pick it up and set it in the wall. Others butter the ends of the block after they set it in the wall. Either way, you need to apply it

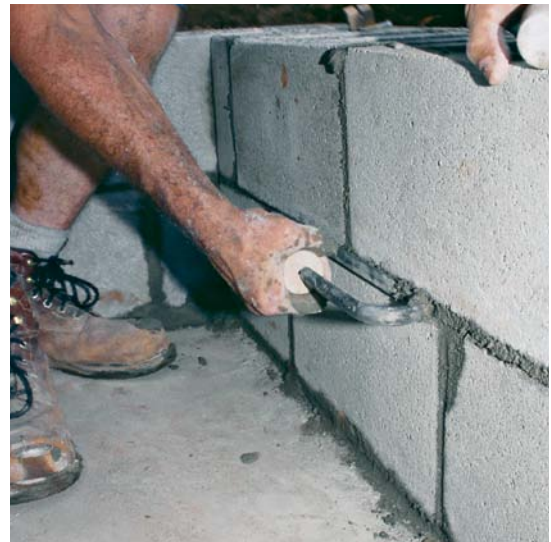
with some oomph so that the mortar hits the surface hard and sticks.

Finally, a few words on the trowel, which is the most basic tool in masonry. For me, the size of the trowel is analogous to the size of a hammer. Some carpenters use a 24-oz. hammer, and some masons use a 13-in. trowel. A small trowel is 10½ in., and a large trowel is 13 in. My suggestion is to use whatever is most comfortable in your hand. I use a small hammer and a small trowel because I have tendinitis. So whatever you use depends on how much weight you want to handle.



LADDER REINFORCEMENT EQUALS LATERAL STRENGTH. Ladder-type wire reinforcement can be added to the bed joints of a block wall as it's laid up. In this example, the ladder reinforcements were added at every other course.

Good mortar is almost fluffy; some masons call mortar that's just right *fat mortar*.



TOOLING THE JOINTS FOR A NEAT LOOK. When the mortar is as stiff as putty and beginning to pull away slightly from the edges of the blocks, it's ready for tooling.

the best jointer for the job

There are many different jointers on the market. I own several different types. But for laying block, the S-shape jointer is a standard. You don't get into much variation in jointers until you get into brickwork. The S-shape jointer has two different-size jointers, with one at each end. Use whichever end looks best. I usually use the wider one so that it doesn't cut the joint too deeply.

Get into a Rhythm

Once I get going, the basic rhythm of masonry is to spread a bed of mortar an inch or so high, then gently push or tap the block until it's even with the line.

I like to keep about a $\frac{1}{16}$ -in. space between the line and the block because if the block touches the line, it can push it out and throw off a course (see the left photo on p. 69). I almost always set the line up on the far side of the wall so that I don't have to lift blocks over it all day. As I set each block in the wall, I use the heel of my left hand (I'm right-handed) to feel when the top of the block is even with the preceding block (see the right photo on p. 69). I get this corner even by feel and, looking straight down over the line, push or tap the outside of the block even with both the string line and the block below it. At the same time, I push the block horizontally against the buttered ends of the preceding block until the joint size looks right.

Using the trowel in my right hand, I cut the mortar that has bulged out from the joints (see the left photo on p. 70) and, giving my trowel a good shake, butter the end of the block I just laid (see the right

photo on p. 70). I do any minor adjustments immediately. After the blocks have set for a while, they should not be disturbed. Tapping blocks laterally after the initial set of the mortar breaks the bond and weakens the wall.

To finish off the wall of the foundation, I install anchor bolts at every corner and at each door and window jamb, as the local code requires. I also installed bolts at least every 6 ft. between these points. To anchor the sills, I drop broken bits of block or brick into the cores to provide support for the grout, which I make out of concrete or a portland cement-sand mix, which is stronger than mortar.

As for tooling the joints, it's necessary to wait until the mortar is thumbprint hard before tooling begins. When the joints are ready, they are usually about as stiff as putty and starting to pull away slightly from the edges of the blocks. Using a jointing tool, I tool the vertical joints first, then do the horizontal joints (see the right photo on p. 71). Wherever the joints need a bit of mortar, I push a lump into the joint with my jointer.

Reinforcing a Block Wall

There are several ways to reinforce a unit masonry wall. The wall can be thickened by switching from 8-in. to 10-in. or 12-in. blocks. Ladder-type wire reinforcement can be added in the bed joints as the blocks are laid up (see the left photo on p. 71). You can apply stucco reinforced with fibers to the outside of the wall after it's built. Or you can reinforce the wall with rebar and concrete grout.

To design a reinforced-block wall, it's best to hire a structural engineer for the project. You can also get an idea of what works in the area where you live by talking to other builders and to your local building inspector. In addition, you can see what doesn't work by carefully looking in your area at foundations and retaining walls that have failed.

BY RICK ARNOLD AND
MIKE GUERTIN

Forming and Pouring Footings

Over the years, we've built homes on almost every type of foundation imaginable. However, a concrete foundation always seemed to provide the best base for a home built in Rhode Island, our part of the country. In 1996, Rick bought a concrete-forms company, and our firsthand knowledge of footings and foundations increased exponentially.

With every project, we do everything in our power to keep the house and its foundation from settling and cracking, which can cause problems ranging from drywall cracks and sloping floors to doors that won't close. The best preventive medicine is putting the foundation on top of poured-concrete footings (see "Why Footings?" on p. 75).

The price for this medicine is usually reasonable. On a 26-ft. by 38-ft. house, footings add only about \$800 to \$950 to the cost of the house. Prospective homeowners will spend that much in a blink to upgrade a kitchen. We figure that it makes more sense to upgrade the whole house by adding footings to ensure that the new kitchen stays put.

Laying Out the Footings

Most of the footings called for in our work are 1 ft. high and 2 ft. wide. We normally reinforce footings with a double row of ½-in. (#4) steel rebar unless

plans specify otherwise. For the project featured here, the soil at the bottom of the excavated hole was like beach sand, so footings were a must. We went with standard-size footings to support the 10-in. wide by 8-ft. high foundation walls that would be poured on top.

But before we can think about footings, we have to lay out the location of the foundation. We begin by establishing two starting points, the corners at both ends of one foundation wall. With most houses, there are a couple of surveyor stakes (photo 1 on p. 76) outside the hole with the offsets (the distance to the edge of the foundation wall) written on them.

For most jobs we find corner points by running a string line between the stakes. We measure in the offset amount and then drop a couple of plumb lines to the floor of the foundation hole.

We drive stakes (usually foundation-form rods) into the ground at the two points; the measurement between the two rods should be the length of the wall as indicated on the plans (photo 2 on p. 76). If the points are off an inch or so, we adjust them until the measurement is correct. If there is a large gap between our measurement and the plan, we call the surveyor back. For the house shown here, setbacks were tight, so the surveyor set two exact foundation corner points on the floor of the hole.



FILL UP A TRENCH WITH CONCRETE—WHAT'S TO KNOW? If a house is going to stand on those little sidewalks, they'd better be straight, level, and correctly placed.

ON THE DIAGONAL

The best way to locate the rest of the corners or points from the two reference points is to use diagonal measurements, just like we learned in high-school math. Unlike in high school, however, we depend on a calculator to do the math.

Before jumping into the hole, we sit down with the blueprints and the calculator. In about 10 minutes we figure out our diagonals so that every corner on the plans has two reference measurements. Then it's just a matter of measuring those distances from the original two points to find the other foundation corners. The quickest method is to have two crew members hold tapes at the original reference points. A third crew member pulls the tapes tight and crosses them, moving the tapes until the calculated measurements from the corners meet each other

We always double-check our measurements between the corners to make sure the foundation dimensions are right on.

(photo 3 on p. 76). A stake is then driven into the ground to mark the point. We always double-check our measurements between the corners to make sure the foundation dimensions are right on.

The project house has a garage with a connecting breezeway that meets the house at an angle. To locate the corners of the breezeway, we triangulate from the foundation corners we've just found for the

main body of the house. Again, we double-check all our dimensions to be sure they gibe with the plan. Once stakes have been driven at every corner, we run a string line from one to the other, sort of like a giant connect-the-dots game. The result is an outline of the entire foundation.

Setting Up the Forms

With the outline in place, we're ready to start setting forms. We use 2×12s connected by steel form brackets that hold the inside and outside forms exactly 2 ft. apart (photo 5 on p. 77). Rick had these brackets custom made.

We locate the forms so that the foundation walls will be centered on the footings. The foundation walls for this house were 10 in. wide, so we subtracted 10 in. from the footing width of 24 in. To leave equal amounts of footing on both sides of the foundation wall, we divided the remaining 14 in. in half to give us 7 in. of exposed footing on both sides of the walls.

Because the string line we've set indicates the outside of the foundation wall, we start by nailing two 2×12s together to form an outside corner. We then set our corner 7 in. away from the string line (photo 4 on p. 77). A form bracket locks the inside form plank at the proper width (photo 5 on p. 77). We continue this process around the perimeter of the foundation. Form brackets are dropped every 4 ft. or so. Where two planks butt, we toenail the tops together and put form brackets on both sides of the butt joint.

We keep many different lengths of form stock on hand, so we rarely need to cut a piece. When we come to a small jog, such as the inside corner of the angled breezeway, we simply form the whole area off. The extra concrete used is negligible. When two planks don't quite meet, we bridge the gap with a short piece, and if a plank is a little long, we just run it by the adjacent plank and tack the two together. Forming footings is forgiving because the finished product is buried. The major concern with footings is strength and function, not how they look.

why footings?

Trudging through 2 ft. of snow can be a real nuisance. Strap on a pair of skis, though, and nuisance becomes recreation. The extra surface area of the skis distributes your weight over a greater area so that you don't sink into the snow. The same principle of load distribution is why we put footings under house foundations.

Footings are reinforced-concrete platforms at least twice as wide as the foundation they support and usually a foot deep. They are required by most local codes, especially if an area has soils with questionable bearing capacity, such as loose sand, silt, or clay. A wet site is another prime candidate for footings.

When we need a footing that is wider than 2 ft. or if we're forming a large area such as a bulkhead pad, we secure the forms in a different manner. We run ¾-in.-wide perforated-steel strapping beneath the planks across the bottom of the footing. The strapping is run up the outside of the form planks and nailed to keep the bottoms of the planks from spreading. The tops are then held at the proper width with a length of 1×3 nailed between the two planks.

Setting the Footing Height

Once all the forms are in place, we backfill against potential weak points such as butt joints or the larger areas where we couldn't use form brackets. Backfilling prevents the concrete from getting underneath the planks and lifting them up during the pour. At this point we transfer the foundation lines to the tops of the forms for future reference. The string line is removed, but the stakes are left in the ground as a visual reference to make sure that the forms don't shift during the pour.



SURVEYOR STAKES INDICATE WALL LOCATION.

1 Measurements are taken from surveyors' stakes and transferred to the floor of the excavated hole to locate one foundation wall. **2** The ends of the wall are then located precisely with a measuring tape.

3 DIAGONAL MEASUREMENTS LOCATE THE OTHER WALLS. All other corners are located by triangular measurements from those points. Three people and two tapes make the process go quicker.





The major concern with footings is strength and function, not how they look.

Next, using a builder's transit, we set the grade to make sure the top of the footing is poured to the same level. First, we find the lowest point on the forms by checking the height of the planks at every corner and at several points in between. The low point becomes the grade for the footing. We mark a yardstick to the measurement at the low point on the forms. Then we work our way back around the footing, installing grade nails every few feet on the inside of the forms. To mark the grade, we hold a 6d nail against the bottom of the yardstick and move it up or down until it's at the right height. The nail is then hammered in about halfway.



4 OUTSIDE FORMS ARE SET UP FIRST. Starting at one corner, the outside forms are set at a given distance off the foundation line.

5 BRACKETS SET THE FOOTING WIDTH. Brackets are then slipped over the forms that keep the inside form exactly 2 ft. away from the outside. The footing height is then set with a transit and marked on the inside of the form.

summer vs. winter concrete mixtures: what's the difference?

When it's slightly overcast and temperatures are consistently in the 70s, pouring concrete comes with few surprises. That's seldom the case when the truck backs down the driveway and the temperature is below freezing or in the high 80s. Different seasons demand a little extra planning and work. Understanding the differences in each type of concrete mixture ensures that your slab, patio, or walkway cures correctly.



KEEP HOT CONCRETE WET

Concrete needs water to cure properly, and the slower it cures, the better. But on hot summer days, the water in the mix begins evaporating as soon as it comes off the truck, causing concrete to dry too quickly. Admixtures such as water reducers or superplasticizers can be added to help retard the cure and reduce water demand, and both types increase workability and strength. Once the concrete is set and finished, keeping it wet is the best way to strengthen the curing process. A lawn sprinkler set to go off at regular intervals can help ensure that the concrete doesn't dry too quickly.



KEEP COLD CONCRETE FROM FREEZING

Cold weather creates an opposite set of problems. The amount of water in the cement mix is greatly reduced, which in turn reduces the setting time and gain of strength. If concrete freezes, it can become damaged.

The best way to increase the setup time of concrete is to add hot rather than cold water to the mix. While most companies switch to hot water automatically when it's below 40°F, it's a good idea to double-check. Another option is to use a finer cement, type III, which generates more heat and has a higher early strength. Admixtures like calcium chloride (salt) also work as accelerators with reinforced concrete.

Concrete generates heat as it cures, which works to your advantage in the winter. However, you may still need to cover the work with thermal curing blankets to retain heat. A layer of plastic and straw also works.

—Matthew Teague, contributing writer



6 REBAR IS INSERTED INTO THE WET CONCRETE. The footing forms are filled to grade, and the concrete is worked with the flat side of a shovel until the footings are level. Then ½-in. rebar is pushed down into the fresh concrete.



7 THE TOP IS TROWELED SMOOTH, and **8** a keyway is formed by dragging a 2x4 down the center of the footing.

The excavators we work with usually leave the foundation hole less than 2 in. out of level. But if we see that some parts of the footing are too shallow because the bottom of the hole is too high after we shoot the grade, we dig out inside the forms until the proper depth is reached. If we undermine the planks in the process, we backfill the outside of the form. We also spray a light coat of form-release oil on the inside of the 2xs.

Pouring the Footings

Now we're ready for the concrete. The best foundation holes have clear access for the cement trucks all the way around the hole. Good access makes the pour go more quickly because the truck can shoot

concrete into the forms without our having to drag it with shovels. If access is a problem, we usually start the pour at the most difficult spot for the truck to reach and work our way out.

The concrete chute is moved slowly along the forms, allowing the concrete to fill up to the grade nails. For sections that can't be reached with the truck's chute, we drag the concrete along the forms until those areas are filled. When the pour is finished, we begin installing a double row of ½-in. steel rebar around the footing (photo 6, above).

Although rebar is not required for residential footings here in the Northeast, we believe that its added strength is cheap insurance. For commercial footings that are required to take many times the load of



9 FOUNDATION CORNERS ARE MARKED ON TOP. While the concrete is still green, the corner of the foundation is marked on the footing.

a typical house, we wire the rebar together and set it on chairs that keep it at a specific height during the pour. However, the additional cost of the labor and the materials usually rules out this option when we're doing residential projects.

Instead, rebar is placed atop the wet concrete about 6 in. in from each form. For angles or 90° corners, we bend the rebar around a knee until it's at the desired angle. Rebar is then inserted under the brackets and pushed down about 8 in. into the concrete, using the shovel as a gauge. As rebar is pushed in, we jiggle it with the shovel to remove any trapped air.

We level the concrete by vigorously pushing it with the flat of the shovel until the concrete is at finish grade. We add or remove a shovelful of concrete to adjust the level and to rework the concrete until the grade nails are exactly half-exposed.

After the concrete is leveled to the grade nails, we gently lift up all the form brackets a couple of inches, which makes our last two jobs easier. The first job is troweling the top of the footing (photo 7 on p. 79) to

provide a smooth surface for snapping chalklines for the foundation walls. The smooth surface also makes it easier to sweep off the dirt that always gets on the footing while the forms are being stripped.

A 2×4 CUTS THE KEYWAY

The final part of the pour is making a keyway, centered on top of the footing, that will lock the foundation walls in place. We usually make our keyway 1½ in. deep and 3½ in. wide, or the size of a 2×4 laid flat. We simply press a short piece of 2×4 into the concrete and drag it down the center of the footing (photo 8 on p. 79). By now the concrete should have cured enough for the 2×4 to leave a significant depression.

Cutting a keyway this way causes a slight buildup of displaced concrete, and we've found that concrete built up in the corners can interfere with setting the foundation forms plumb. To avoid this problem, we end the keyway short of each corner or angle in the foundation. Because corners and angles are the strongest parts of a foundation wall, we aren't worried about compromising integrity at these points.

Before stripping the forms, we square off the foundation-line marks on the forms and mark the foundation corners in the green concrete (photo 9, above). A long steel bar makes short work of popping the brackets, and with the duplex nails, removing the forms is a breeze.

BY RICK ARNOLD AND
MIKE GUERTIN

Forming and Pouring Foundations

The lime green neon sign flashed “Learn your future today.” Our crew, skeptics all, filed in through the purple door in the tiny storefront and listened expressionless as the gypsy inside delivered eerily detailed portraits of each of us as well as glimpses into what was in store for our lives. Rick shrugged off her bizarre prophecy that his future would involve “packaging the earth.” Then, a couple of years later, he decided to buy a concrete-form business from a friend. On hearing the news, Rick’s wife said, “My God, Rick, that lady was right: You are going to be packaging the earth.”

There are over a dozen different types of forming systems for poured-concrete walls, but the basic concepts of laying out, squaring, leveling, pouring, and finishing are common to any good foundation job. So whether you’re pouring a foundation yourself or paying someone to do it for you, it’s important to understand the process because things can go wrong in both subtle and dramatic ways.

The Foundation Hole Must Be Level

The key to raising foundation forms quickly and securely is having a good base to set them on. We always prefer to put a foundation on concrete footings (see “Forming and Pouring Footings” on p. 73) as

we did for the job featured here. The footing surface is flat and level, so the forms go up as quickly as we can move them.

The alternative to using footings is setting the forms on a gravel or crushed-stone base on the floor of the foundation hole. A good foundation hole is usually within 2 in. of level. Any more than that means a lot of labor for us scratching down or filling up to level as we set the form panels.

The excavator is also responsible for the amount of overdig, or the area that is dug beyond the actual perimeter of the foundation. Ideally, there should be 4 ft. to 5 ft. left between the forms and the hole sides to give us the room we need to handle the forms and to work on the outside of the walls. For safety’s sake, the sides of the hole should not be excavated vertically or undercut. Instead, there should be some sort of slope or pitch to the hole walls.

Another critical duty of the excavator is making sure the concrete trucks have good access to the foundation (see the photo on p. 82). If they don’t have access, we end up having to push the concrete by hand along the forms, sometimes 40 ft. or more. Some conditions require a concrete pump truck, to the tune of an extra \$700 to \$800. Once the hole is satisfactory and the footings are ready, we give the tops of the footings a final sweep before layout.



THIS FORM SYSTEM, preferred by the authors, includes form panels that can be reused many times, depending on how they are handled.

Laying Out the Foundation Walls

We plot out the foundation walls the same way we did the footings. The goal is to pinpoint every corner and angle on the outside face of the foundation wall. Before we stripped the footing forms, we had scribed the corner points of the longest foundation wall on top in the concrete from points that had been marked on the forms. We double-check the distance between these points as well as the distances from the surveyor's stakes.

When we laid out the footings, we figured out all the diagonal measurements to find the location of the other corners and jogs in the foundation. Those same calculations are used again on top of the

footings for the foundation (photo 1 on the facing page). When all our points have been established, we take diagonal measurements to be sure the layout is square (photo 2). We then snap lines between the points that represent the outside face of the foundation walls to give us a guide to follow as we set the forms (photo 3).

Assembling the Forms

As a couple of crew members work on the layout, the rest distribute forms around the perimeter of the hole, sliding them down along the sides of the hole in pairs. By the time the layout is done, enough



1



2



3

1 LOCATE THE FOUNDATION CORNERS. Working on the floor of the foundation hole or on top of the footings, you first have to find the outside point for every corner or jog in the foundation.

CHECK THE LAYOUT FOR SQUARE. **2** Diagonal measurements are then taken to check for square, and **3** chalklines are snapped for lining up the forms.



4 FORMING STARTS IN A CORNER that uses a right-angle form for the inside and special brackets for the outside.



forms are in the hole, and the layout crew can begin setting them up.

The forming starts in one corner. We use 90° forms for inside corners, but for outside corners we have special brackets that join two standard forms at a right angle (photo 4). Once the corner forms are set up, we tweak them until they're exactly plumb, using shims if necessary. Plumbing each corner precisely simplifies the later job of squaring the top of the foundation.

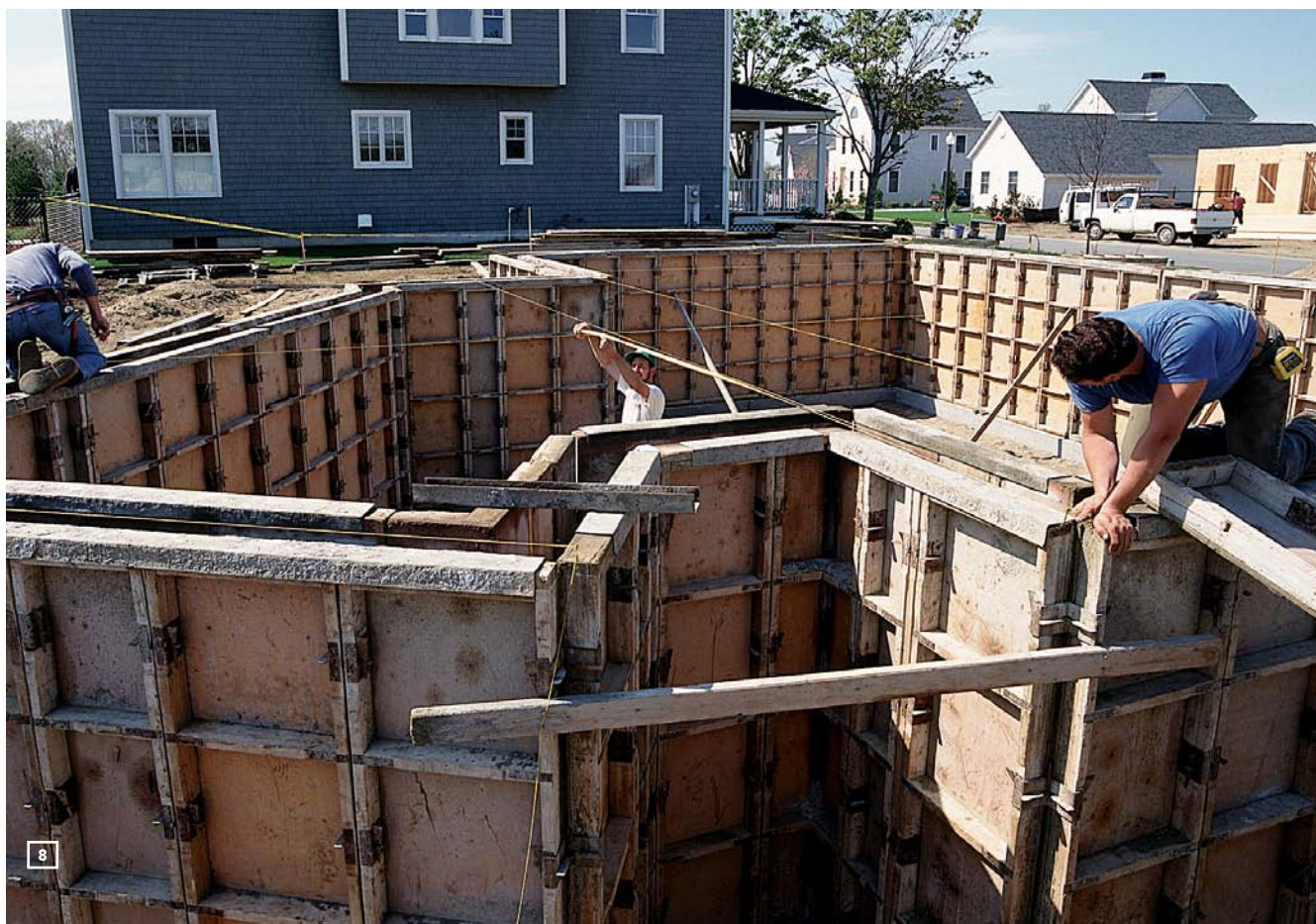
When a corner has been set, crew members each take a direction and begin setting up the standard-size (2-ft.-wide) forms. To join our forms together, metal Ts are slipped through reinforced holes in the side rails of the form that is already set up. Then flat, slotted foundation rods are slipped over the ends of the Ts, locking the inside and outside panels at the specified width for the foundation wall, in this case 10 in. (photo 5). Foundation rods not only determine the width of the wall but also—along with the Ts—keep the forms from spreading during the pour.

The next panels, one inside and one out, are placed close enough to the previous ones to feed the ends of the Ts into the matching holes. Then the forms are pushed hard against each other, and a flat, tapered pin, or wedge, is slid into the slot on the end of the T (photo 6), locking the two panels together. At this point, the wedges are left loose in the slot until the walls have been squared and straightened.

5 SLOTTED RODS THAT SLIP OVER TS hold the forms apart at the right wall width.

6 TAPERED PINS, OR WEDGES, through the Ts hold adjacent panels together.

7 BRACING KEEPS THE WALLS plumb during the setup and pour.



8 BEFORE THE CONCRETE TRUCKS ARRIVE, string lines are stretched as guides for straightening the walls.

Our forms come in 2-in.-wide increments from 2 in. to 24 in., so it's easy to anticipate what we'll need for each wall. A 30-ft. 2-in. wall will use thirty 24-in. panels plus a pair of 2-in. fillers. If a wall is 41 ft. long, we use forty 24-in. panels and a pair of 12-in. panels. If a wall length is specified to an odd inch or to a fraction (we just love those), we simply nail a spacer made of $\frac{3}{4}$ -in.-thick furring or the appropriate-size plywood to the ends of an inside and an outside panel to make up the difference. The panels with spacers are then locked to neighboring panels with longer Ts.

Besides 90° corners, the most common angle we're asked to form is 45°. We have forms and brackets similar to our 90° system to create 45° walls. However, for other angles, we usually build forms on site.

The house featured here had sections offset from the main body of the house at 30° and 60°. We formed these angles by locking smaller-size panels together with perforated-steel strapping. The inside panels are connected to the outside panels with $\frac{1}{4}$ -in. steel rod (called pencil rod). We bolt clamps onto the pencil rod to hold the panels at the 10-in. wall width. Voids between the forms are filled with rigid-foam insulation that we cut and insert.

9 THE TOP OF THE FOUNDATION is found with a transit, and **10** chalklines are snapped at that level.

11 BASEMENT WINDOW FRAMES ARE INSERTED and tacked to the forms, **12** and form-release oil is applied to the inside of the forms.





WHEN THE PREP WORK IS DONE, the forms are filled with concrete. ¹³ The backside of a shovel floats the top of the concrete until it's halfway through the grade nails. ¹⁴ The top is then screeded with a 2x4 to smooth it out.

TIP: If a wall length is specified to an odd inch or to a fraction, nail a spacer made of 3/4-in.-thick furring or the appropriate-size plywood to the ends of an inside and an outside panel to make up the difference.



15 ANCHOR BOLTS ARE INSERTED while the concrete is still soft.

Straightening and Squaring the Walls

As the forms go up, we brace both the inside and outside sections with 2× bracing every 8 ft. to 10 ft. (photo 7 on p. 85) to keep forms from racking and falling over. When all the panels are up and the job is closed in, we slip steel channel over the tops of the forms. The channel fits tightly, locking the panels into alignment with each other.

Next we string the whole job to straighten and square the foundation (photo 8 on p. 86). Mason's twine is stretched from one corner to the other; the

string line is kept lined up exactly with the face of the outside corner panels. Then a crew member walks along the top of the forms, telling two other crew members who are on the ground (one inside, one out) which way to adjust the 2× braces to straighten the wall. Braces are not nailed; instead, they are wedged under a horizontal member of the form.

The next job is squaring the foundation by measuring diagonally between the corners just as we did when laying out the foundation on the footings. If need be, we shift a corner or two until our diagonal measurements are equal. When the entire job is squared, we once more straighten the tops of the walls and tighten the bracing.

Next we check and tighten all the hardware, the easiest but probably most crucial job of the process. Each foundation rod is checked methodically inside and outside to make sure that it is properly engaged by a T. If a T misses the slot in the rod, it can cause the wall to blow out from the weight and pressure of wet concrete. As the rods are checked, each wedge is driven home to tighten the joints between the forms.

Final Prep before the Pour

We're now ready to shoot the grade, or the height of the foundation wall (photo 9 on p. 87). Because we're on footings, we shouldn't have any high or low spots to factor in. Unless otherwise specified, the grade is established at 93 in. from the bottom of the form, and a 6d grade nail is driven at that elevation. (Our forms are 96 in. tall; our alignment channels are 2½ in. deep. A pour height of 93 in. keeps the concrete off the channel.) A yardstick is then placed on top of that grade, and the height is read through our transit.

The crew member with the yardstick works his or her way around the foundation, setting grade nails at each corner on the outside form at the height indicated by the crew member at the transit. If a wall is longer than 24 ft., we set a grade nail in the middle of the wall. Lines are snapped between the grade nails (photo 10 on p. 87), and then extra nails are set in the snapped line about every 4 ft.

concrete has to be the right mix

When we order concrete, we specify the strength of the mix and the slump, or stiffness of the mix. A 2,500-psi mix provides sufficient strength for most house foundations, and most mixes arrive at a slump of around 4, a medium number that flows readily. Occasionally, we ask the drivers to add a little water and spin the load if it seems too stiff. However, too much water can weaken the concrete, so we're careful to add only a small amount to make the concrete easier to manage without diminishing its strength.

Before the channel went on, we'd slipped the basement window frames down between the forms (photo 11 on p. 87). At this point, the frames are brought up to the grade line and tacked to the inside of the forms. We also locate and nail in metal forms for the beam pockets. These forms leave a small shelf inside the wall to hold the end of the main beam. If the foundation requires a sewer chase or a chase for any other purpose, we slide a Styrofoam® block between the forms and secure it at the proper location with 16d duplex nails driven from the outside. These blocks are made on site to the required dimension and fit tightly between the forms.

The inside faces of the forms have to be coated with form-release oil to prevent the forms from sticking to the concrete as it cures. We usually apply the oil just before or as the trucks arrive (photo 12 on p. 87). There are many types of form oil and release agents. Motor oil and diesel fuel used in the old days have been replaced with more environmentally friendly nontoxic mixtures. Many places require the use of these newer products, and we've had good luck with paraffin and vegetable-oil-based

release agents. We use a handheld pump sprayer with a wand to apply a light coat on the panel faces.

Filling the Forms

Because concrete starts to cure within 2 hours, we begin the pour with the most time-consuming or hard-to-reach areas of the foundation and work our way around the foundation from there. This strategy keeps any of the walls from curing before the other walls can be poured.

During the pour, we keep a constant watch for blowouts or shifting panels. We stop the pour as needed to rebrace walls, keeping the forms aligned and plumb. When the concrete nears grade, we slow the pour rate a little and move the chutes to keep from overfilling the forms.

Once the walls are topped off, we check the string lines again to make sure the walls stayed straight, adjusting the forms if necessary. Our concrete mix is generally loose enough that we don't have a problem with voids from pockets of trapped air. But if a real stiff mix is specified for a job, we tap the forms with a rubber mallet, and in extreme cases we use a vibrator to remove trapped air from the mix.

With the forms filled, we grade the top surface by floating the backside of a shovel on the concrete and working it to level the surface (photo 13 on p. 88). At this point, we also add or remove a touch of concrete until half of each grade nail is exposed.

A crew member then follows along, screeding the surface with a length of 2×4 (photo 14 on p. 88). The edge of the 2×4 is pushed vigorously up and down, forward and back, to bring water up to the surface, making it smooth and level. The final step is inserting ½-in. anchor bolts into the top of the wet concrete (photo 15 on p. 89). Some local codes may require that the bolts be in position before the concrete is poured to ensure proper aggregate consolidation around the bolts. But our building officials allow us to insert the bolts directly into wet concrete, moving them up and down slightly to make sure there is no trapped air around them. When we poured this job, CABO code required bolts every 6 ft. Here in Rhode Island, that



16 FORMS ARE STRIPPED and carried to the truck. After the concrete has cured overnight, the crew strips off the forms and takes them to the truck to be stacked.



17 AS EACH FORM IS REMOVED, excess concrete along the top is scraped off.



18 THE ENDS OF THE FOUNDATION RODS are then broken off with a hammer.

requirement has since been upgraded to anchor bolts every 4 ft.

Stripping Forms: Setup in Reverse

The concrete is allowed to set up overnight, and the next morning, we're back at the site to strip the forms. Stripping is basically the setup process in reverse. First, we remove the string and the channel from the tops of the forms. Then the Ts, wedges, and any other removable hardware come off.

If the form oil has done its job, the panels should pop away from the walls easily (photo 16 on p. 91). The excess concrete that built up at the grade line is scraped off the forms (photo 17 on p. 91), which are brought to the truck.

After the forms have been stripped, we snap off the ends of all the foundation rods that held the forms together and that now project beyond the foundation (photo 18 on p. 91). The rods are scored so that they break off safely below the surface of the foundation wall. We remove the rods to make the job site safer for the rest of the subcontractors and to allow the exterior of the foundation walls to be damp-proofed.

It's best to let the concrete cure before backfilling the foundation. Concrete doesn't reach its full compressive strength for 28 days or so, but 5 days to 7 days is usually sufficient curing time for the concrete walls to withstand backfill pressure. Still, it's always a good precaution to brace the inside of any green walls that are long and straight before backfilling against them.

Frost-Protected Shallow Foundations

BY MARTIN HOLLADAY

The footings of most foundations are placed below the frost depth. In colder areas of the United States, this can mean excavating and pouring concrete 4 ft. or more below grade. If you include enough rigid-foam insulation around a founda-

tion, however, you can keep the soil under the house warm enough to permit shallow excavations, which can be 12 in. or 16 in. deep, even in northern areas.

So-called frost-protected shallow foundations usually consist of a monolithic (thick-edged) slab

pros and a few caveats

Frost-protected shallow foundations have the following advantages over deeper conventional foundations.

- They require less excavation, so smaller equipment and less labor are involved.
- Less concrete is consumed.
- Monolithic slabs are formed and poured in one shot, speeding the work schedule.
- They typically cost 15% to 21% less than a conventional foundation, according to a study by the NAHB Research Center.

Frost-protected shallow foundations don't make sense everywhere, though.

- If you live where frost depths are already shallow, don't expect any savings in labor or material, although an insulated foundation may save energy dollars later.

- Frost-protected shallow foundations aren't appropriate for steeply sloped sites or sites with permafrost.
- In areas that are heavily infested with termites, including the southeastern United States and most of California, the use of below-grade rigid-foam insulation is not necessarily a good idea.
- Deep-rooted perennial plants shouldn't be planted above the shallow wing insulation that surrounds a house with a frost-protected shallow foundation.
- The above-grade portions of the vertical foam insulation surrounding a shallow foundation need to be protected with a durable finish material, such as Protecto Bond® insulation wrap (www.protectowrap.com), or stucco over metal or fiberglass lath.

wrapped with vertical and horizontal rigid-foam insulation. Although the International Residential Code (IRC) does not require a shallow foundation to have insulation below the slab, omitting the subslab insulation is not a good idea. After all, the more insulation you have under the slab, the less heat will leak out of your house into the soil below. Fortunately, these shallow foundations don't depend on leaking building heat to keep the soil warm. Instead, horizontal wing insulation extending from the bottom edge of the slab helps retain the natural warmth of the earth.

Either extruded-polystyrene (XPS) or denser types of expanded-polystyrene (EPS) insulation may be used to insulate a frost-protected shallow foundation. To account for the possible performance degradation of foam insulation that remains buried for years, designers "derate" the presumed R-value of XPS from its nominal value of R-5 per inch to R-4.5 per inch. The amount of insulation you'll

need depends on the air-freezing index in your area. Coincidentally, because of existing energy code requirements, you may already be insulating your foundation walls enough to achieve the necessary R-value for a shallow foundation.

Let's say you're building a frost-protected shallow foundation in a Minnesota town with an air-freezing index of 2,500. According to code requirements for frost-protected shallow foundations found in Table R403.3 of the IRC, the minimum R-value of the vertical insulation at the perimeter of the slab is R-6.7 (about 1½ in. of XPS). Ironically, the energy section of the IRC, which applies to all types of slabs, not just those that are frost-protected, requires more slab-edge insulation, R-10, for slabs commonly built with full-depth footings in this climate zone.

The R-value for the horizontal wing insulation in this example is R-4.9. Table R403.3 also specifies the minimum width and configuration of the wings.

DIG LESS, INSULATE MORE

Because most rigid insulation is either 24 in. wide or 48 in. wide, it makes sense to design a frost-protected shallow foundation to be 24 in. deep at the perimeter, with 16 in. below grade and 8 in. above grade.

Metal flashing with ¼-in. drip leg

Protective covering applied to above-grade rigid foam

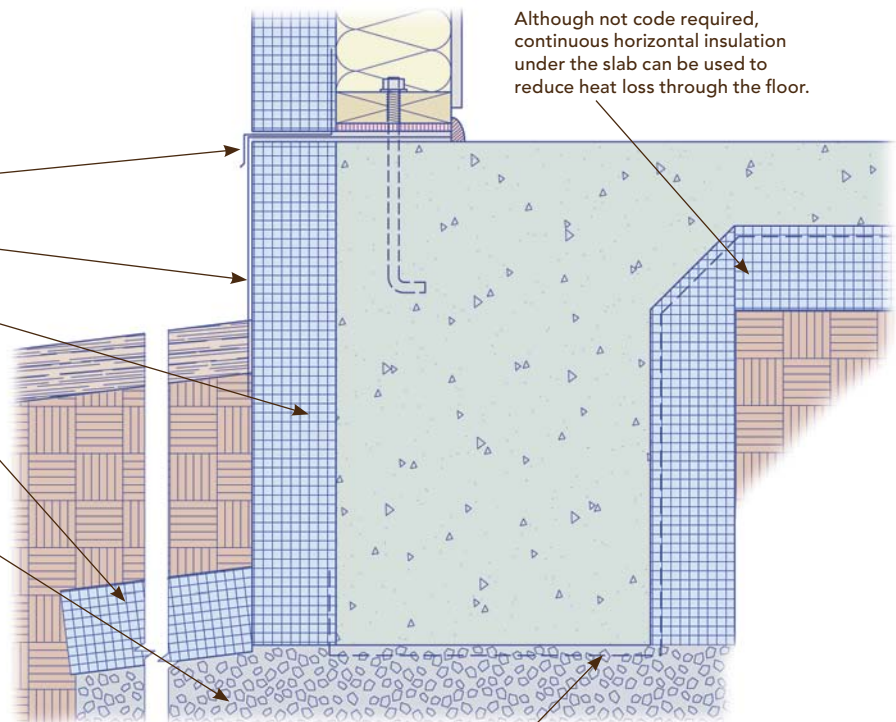
Around the perimeter of the slab, vertical rigid foam insulates the foundation.

Horizontal wing insulation extends out from the bottom edge of the foundation, at least 12 in. below grade, to retain heat in the soil near the building. It can be sloped slightly away from the foundation for drainage.

Footing drains are not necessary, but the slab and horizontal insulation should sit on a 4-in.-thick compacted layer of crushed stone, and the site must be properly graded.

Builder's tip

Monolithic-slab foundations require a perimeter trench. If vertical insulation is installed inside the formwork before the pour, the trench and the foam board can act as the lower section of the form.



Although not code required, continuous horizontal insulation under the slab can be used to reduce heat loss through the floor.

6-mil polyethylene under slab

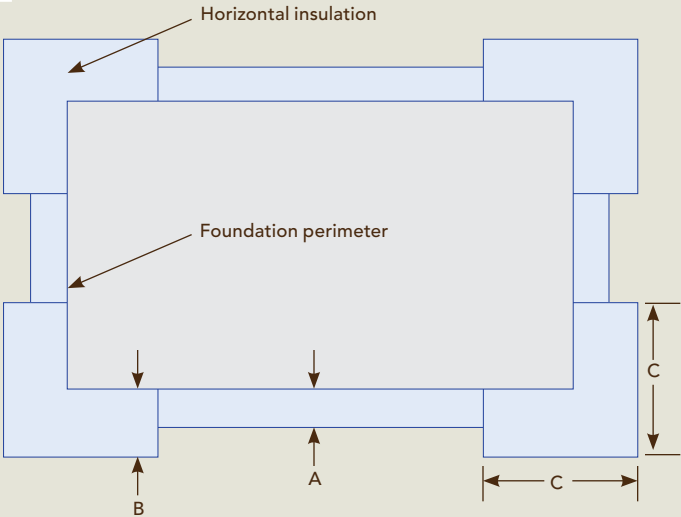
Now that minimum energy code requirements for slab insulation have overtaken the design requirements for a frost-protected shallow foundation, the line between a conventional slab-on-grade foundation and a frost-protected shallow foundation has been blurred. As a result, almost any monolithic slab complying with energy code requirements can be

turned into a frost-protected shallow foundation by adding the required wing insulation.

For more information, see the U.S. Department of Housing and Urban Development’s *Revised Builder’s Guide to Frost Protected Shallow Foundations* (www.toolbase.org/PDF/DesignGuides/revisedFPS-Fguide.pdf).

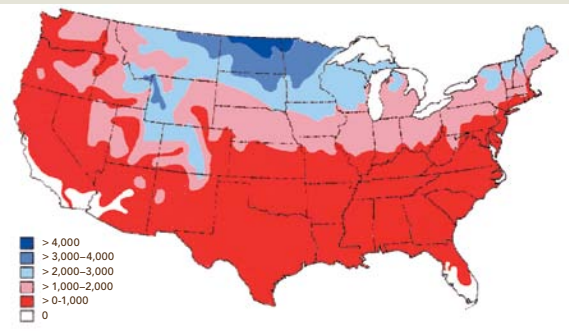
air-freezing index determines r-value

To calculate the necessary R-value of the foam needed for a frost-protected shallow foundation, most designers look up the air-freezing index for the area in which they are building. The higher the index, the colder the climate. Design guidelines for frost-protected shallow foundations can be found in an American Society of Civil Engineers publication, *Design and Construction of Frost-Protected Shallow Foundations* (ASCE 32-01). However, most residential builders will probably find it easier to follow the prescriptive requirements for these foundations in section R403.3 of the IRC, also shown in the chart below right.



Air-Freezing Index
(°F days)

A simplified analysis of the 100-year return period



The amount of insulation needed to protect a building foundation is determined by the air-freezing index.

AIR-FREEZING INDEX	VERTICAL INSULATION	HORIZONTAL INSULATION				
		At Walls	At Corners	A	B	C
< 1,500	R-4.5	NR	NR	NR	NR	NR
2,000	R-5.6	NR	NR	NR	NR	NR
2,500	R-6.7	R-1.7	R-4.9	12 in.	24 in.	40 in.
3,000	R-7.8	R-6.5	R-8.6	12 in.	24 in.	40 in.
3,500	R-9	R-8	R-11.2	24 in.	30 in.	60 in.
4,000	R-10.1	R-10.5	R-13.1	24 in.	36 in.	60 in.
4,500	R-12	R-12	R-15	36 in.	48 in.	80 in.

An Energy-Smart Foundation in Two Days

BY TIM ROBINSON

We all know that time is money. That's why waiting for the footings and foundation to go in can be one of the most frustrating aspects of any home-building project. Trying to get a house out of the ground in the winter is even more challenging.

One time-saving solution I've come to like involves the installation of insulated, precast concrete panels to construct a building's foundation. I use a system from Superior Walls® (www.superiorwalls.com), but the same benefits are available from other companies in different parts of the country (see "Sources" on p. 101). In most cases, after a site is excavated, I can install the whole system in two days: one day for prep and one day to set walls. Because these panels sit on a compacted gravel footing, my crew can do the prep work.

Not only are the panels quick to install, but they're also insulated with 2½ in. of foam (R-12.5). The foam is visible on the inside surface of each panel; so are steel studs punched with holes for wiring and plumbing, making this type of foundation easy to finish inside. The outer concrete face is mixed at 5,000-psi, vs. the 2,500-psi concrete in standard poured walls, so the prefab walls are practically bulletproof and waterproof. (For the record, the manufacturer says these panels are "damp-proof"

and makes no claim about bullet resistance.) On this project, I elected to waterproof the foundation with a sprayed-on sealant and a dimple drain; the cost is minimal for the peace of mind gained.

Drainage Matters for All Foundations

Because no concrete footing is used, the code governing wood foundations applies (International Residential Code section R402), specifically, ½-in. compacted gravel. The depth of the stone (4 in., in this case) depends on soil type and the combined load per lineal foot (dead load + live load + wind/snow load = combined load; see p. 5 for more on building loads).

Drainage is important for all foundations, perimeter drains being the most common. Although code allows exceptions, Superior Walls does not. The perimeter drain's gravel must extend below the frost line, so if you have a wall with no backfill against it, you need to dig a trench and fill it with gravel to set the wall on (see the top left photo on p. 100). This trench requires its own drain. The width and depth of the trench vary depending on your location.

The overall excavation should be at least 2 ft. larger than the foundation on all sides so that there's ample room for the perimeter drain and room for



INSTALLING AN INSULATED, PREFABRICATED FOUNDATION costs about the same as installing and insulating a conventional foundation—but it takes a lot less time!

the installers to work. If you decide to waterproof (required in some areas), you'll need this room. It's also a safety issue (required by the Occupational Safety and Health Administration [OSHA]) to have at least 2 ft. of space from a foundation to the edge of the trench. On a simple rectangular foundation, we locate the two back corners first to ensure that we have this 2 ft. of working space behind the wall. Next, we pull the correct measurement perpendicular to this line and make a 3-ft. to 4-ft. arc in the gravel. After calculating the diagonal measurement of the building, I measure from the back pins to where that measurement intersects the arc to find the other two corners.

Spreading the Gravel

With the rental of a skid steer and a compactor, we can place and pack the gravel in less than a day. To keep the gravel bed even, I set up a builder's level in an out-of-the-way corner and measure off the level to set grade pegs throughout the footprint roughly 8 ft. to 10 ft. apart. Working from back to front, we fill in the gravel, raking it to the height of the grade stakes. Two carpenters easily can keep ahead of one skid steer, and working back to front like this, I never have to drive the skid steer on a finished area.

After the gravel is leveled, we tamp the entire area, reshoot grade, and fill in the low spots. The tolerances aren't exactly rocket science; the installation crew requires that the gravel be within only 1 in. of

THE DENSE CONCRETE SHELL HAS INSULATION AND METAL STUDS BUILT IN

Using a compacted gravel footing and preformed panels means the foundation goes up fast. But it's also warm, water resistant, and ready for drywall because the panels have foam insulation and steel studs with holes drilled for wiring and plumbing. The floor system secures the top of the foundation walls, and a concrete slab at the bottom resists the pressure of backfilling.

Floor framing anchors the top of the walls.

Holes punched for mudsill bolts

2-in.-wide galvanized-steel studs at 24 in. o.c.

1-in. EPS foam

2½-in. XPS foam

Add a dimple drain or spray-on membrane for additional waterproofing.

At 1¾-in. thick, the concrete face provides strength and water resistance.

Screw pressure-treated 1x4 to studs for screed board

½-in.-dia. rebar inside each stud.

A 4-in.-thick concrete slab anchors the bottom of the walls.

Compacted gravel base

Perimeter drain

½-in.-dia. rebar inside top and bottom beams

level. They'll compact it and level it again before setting the walls.

Factory Crew Sets the Walls

The walls are trucked to the site in sections that fit together nicely. Stainless-steel bolts hold the panels together, and urethane sealant keeps the joints water-tight. Because the walls are precast and square, the gravel base must be perfectly flat and level. That's why the installers reshoot grade, repack the gravel, and re-level it all. The project featured here is a cabin on top of a mountain accessed by narrow roads, so the walls had to be transferred from a semi-truck to a couple of smaller dump trucks that could navigate the hill.

Starting in a corner, a crane lifts the walls into place. The installers plumb and brace the wall; then the rest of the panels slide into place quickly, with no additional bracing required. I hope that my block mason isn't reading this because I've never had a masonry wall turn out as well or as fast. At the end of the day, the diagonal measurement was within 1/4 in. of square.

Reinforcing the Foundation

Because this foundation is composed of sections, it's possible that the joint between each panel could fold like a hinge under the pressure of backfilling, so the tops and bottoms of the walls need to be reinforced. A slab locks the bottom of the wall, and the floor framing secures the top (see the drawing on the facing page).

Blocking details in the floor framing resist inward force on walls parallel to the floor joists; they're explained and illustrated in the "Builder Guide-line Booklet" from Superior Walls. Longer walls might require shear walls to provide extra bracing, depending on how tall the walls are and how much backfill will be placed against them.

Superior Walls panels come in three standard heights: 8 ft. 2 in., 9 ft., and 10 ft. You also can order custom heights; however, the cost advantage begins to diminish for crawl space and irregular foundation details. For this project, the manufacturer needed

prefab vs. poured or block foundation

The prefab foundation for this project cost \$12,400 in 2006. By comparison, the estimated cost for a block foundation framed with 2×4s was about \$11,000. However, when you account for the cost of insulating a block foundation with 2½ in. of foam, the price difference is a wash.

But there's more: I saved about a week of work, and job site cleanup was nothing but a trash bag full of empty urethane-sealant caulk tubes; no piles of broken block, empty soda cans, candy wrappers, or leftover concrete block to deal with.

A prefab foundation is best used where there is a full basement with a consistent sill height. Different wall heights slow the process, minimizing the cost benefit. Although a prefab system might not be the best choice all of the time, it makes a lot of sense some of the time.

3 weeks to 4 weeks of lead time after the plans were finalized, but that can vary depending on complexity, location, and time of year. The blueprints must be accurate, showing all point loads, window and door positions, and partition walls. Although you can change the backing for interior partition walls pretty easily in the field, point loads must be engineered into the wall panels.

Precast foundation systems probably won't become my standard operating procedure anytime soon, but I use them whenever I can. The speed, quality, and price are hard to beat. Two days after the hole is dug, I'm framing a floor. To me, that's priceless.



GRAVEL DEPTH VARIES DEPENDING ON SOIL TYPE. In this case, the gravel footing is 4 in. thick. A perimeter drain is buried in the footing to direct groundwater away from the foundation. The pipe extends to the steep drop-off at the right edge of the photo.



A GAS-POWERED COMPACTOR is used along the perimeter of the foundation line. Because the foundation crew does the fine-tuning, the gravel needs to be within only 1 in. of level.



STARTING IN A CORNER, the crew aligns the first panel with a string line and then braces it plumb. No additional braces are needed because the corners stabilize the walls. Additional panels are set to the string and bolted together top and bottom.



ALL JOINTS ARE SEALED WITH URETHANE. Corner panels are mitered; the others butt together. The crew uses Bostik Chem-Calk® polyurethane sealant (www.bostik-us.com) on all panel joints before bolting them together.



SO FAR, SO GOOD. After three corners are set, the crew checks the work. As it turned out, the dimensions of the house were within $\frac{1}{8}$ in.



A CONCRETE SLAB ANCHORS THE BOTTOM OF THE WALLS. To brace the walls before backfilling, a slab is poured inside the walls; the floor framing secures the top. A pressure-treated 1x4 fastened around the inside perimeter acts as a screed and keeps concrete out of the wall cavities.

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Building a House of Insulated Concrete Block

BY FRED LEADBEATER

Stick-frame construction is all but dead in Europe, and for good reason. Wood is too scarce and too expensive to use as a hidden structural element as it is in U.S. residential construction. Instead, European builders use wood primarily for decorative details. Masonry construction is standard, as I learned in years of job-related travel that took me to Europe. When I moved to Montana a few years ago and built a house, the technologies I had seen in Europe made more sense than standard wood-frame construction.

Weather conditions in the mountains of southwestern Montana are brutal: scouring winds, 90°F summers, and -40°F winters. The climate seemed ideal for one of the best European products I had seen, an insulated concrete block called Rastra. Developed in Austria, the block is a type of insulated concrete form that is dry-stacked, reinforced with steel, and then filled with concrete. About 85% of the material's volume is recycled polystyrene, which is shredded into beads and mixed in forms with cement to make the block. Once completed, walls resist fire, earthquake, wind, water, and insects. A 10-in. Rastra wall has an effective R-value of 19 to 24 according to tests done at the U.S. Department of Energy's Oakridge National Laboratory. Houses built this way are unbelievably comfortable summer

and winter, and pleasing to the eye to boot (see the photo on p. 109).

I am not a builder by trade. But my budget was tight, so I joined the construction crew that consisted of architect-builder Matthew Beardsley of the Baukunst Company in Bozeman and one other person. We used block from a now-defunct company called Ener-Grid to build my house. It seems identical to the block manufactured by Rastra (866-272-7872; www.rastra.com). Techniques we used to build my house should work with block from other companies.

Working with the Blocks

Ener-Grid blocks were available in widths of 8 in., 10 in., and 12 in., and 15 in. or 30 in. high. Each block was 10 ft. long (sizes may vary, depending on which manufacturer you buy from). For all their bulk, however, blocks were relatively light. The 10-in.-deep, 15-in.-high blocks that we used weighed 160 lb. each. To move them, we used a rented farm tractor equipped with a simple clamp (see the right photo on p. 105). Once we were on the second floor, we also used a portable aluminum hoist.

The material is easily cut with a chainsaw or hand-saw (see the left photo on p. 105). It can be routed, drilled, sanded, rasped, shaped, and set into curves.



SOLID AS A ROCK. Insulated-block walls reinforced with concrete keep the weather extremes of southwestern Montana at bay while offering protection from insect damage, fire, and earthquake.

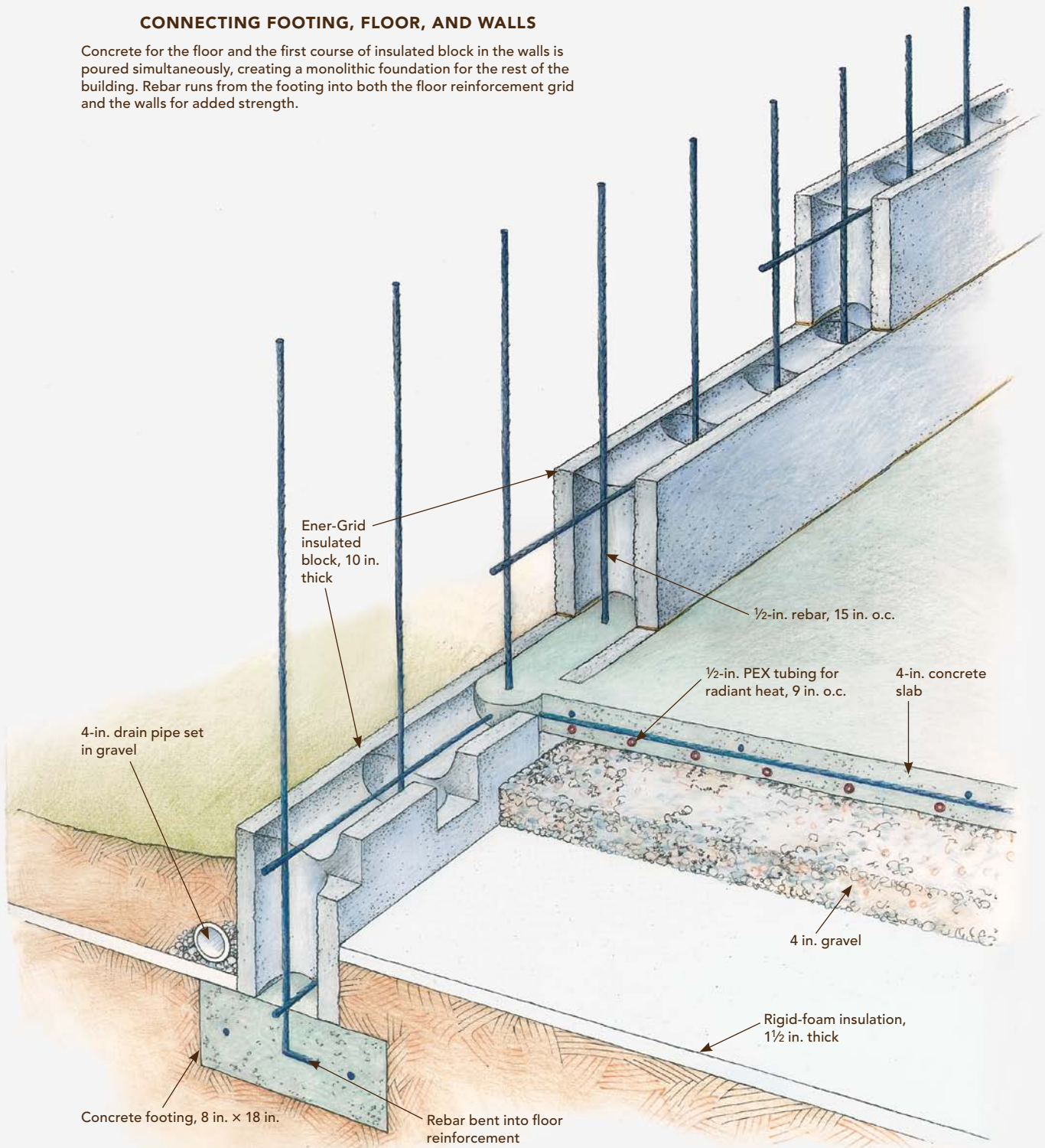
That's the real beauty of the material: Its applications are limited only by your imagination. Running through the block, both horizontally and vertically, are 6-in.-dia. cores 15 in. o.c., where steel-reinforcing bar and, ultimately, concrete are placed. Once filled, the blocks form a continuous, reinforced grid of incredible strength.

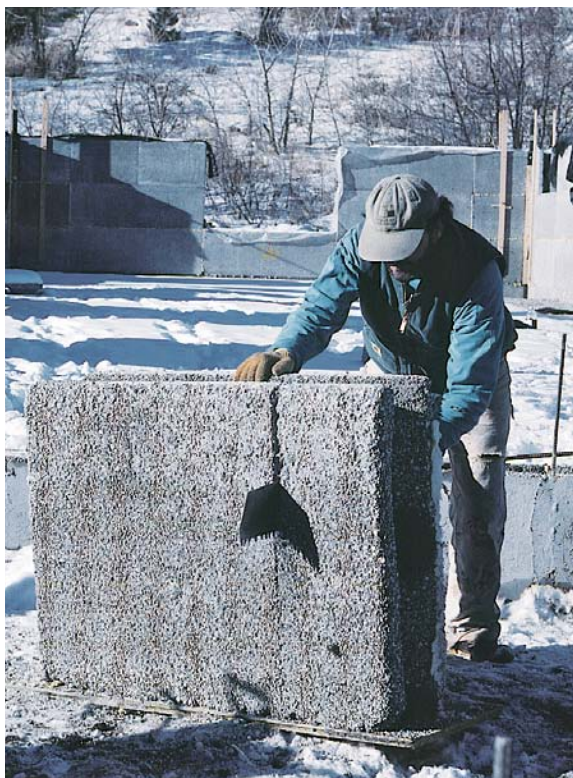
Before starting this project, Matthew had compared the cost of a well-insulated stick-frame house with Ener-Grid block and found that costs were comparable. Performance of the block, however, is superior to conventional construction in almost every way.

Houses built this way are unbelievably comfortable summer and winter, and pleasing to the eye to boot.

CONNECTING FOOTING, FLOOR, AND WALLS

Concrete for the floor and the first course of insulated block in the walls is poured simultaneously, creating a monolithic foundation for the rest of the building. Rebar runs from the footing into both the floor reinforcement grid and the walls for added strength.





BLOCK IS EASY TO CUT AND MOVE AROUND THE SITE. Made of concrete mixed with recycled polystyrene, the block is easily cut with a chainsaw or a handsaw. A tractor and a pair of tongs provide the muscle to move block on the ground. But at about 160 lb., this 10-ft.-long block can be hoisted into place by hand.

Building the Block Walls

There's nothing unusual in the way these walls start: Our first step was to pour a concrete footing 18 in. wide and 8 in. deep (we used a frost-protected shallow foundation). Blocks are stacked directly on the footing. For a solid connection, we set lengths of #4 rebar into the concrete that would run up through the first few courses of block. When the blocks reached the level of the poured floor, Matthew used a chainsaw to cut notches on the inside face of the wall. Some of the rebar cast into the footing was bent 90° and tied to the steel reinforcement for the floor (see the drawing on the facing page). When the floor was poured, walls and floor were connected in a monolithic structure. Radiant-floor heat is perfect with this technology.

Wall block is simply stacked up and temporarily glued in place with polyurethane foam. We used rebar both vertically and horizontally, running the steel into each hollow core after the walls were stacked. One of the beauties of working with the material is that holes can be easily patched with foam. So we could run horizontal rebar right through the side of the block into the core, and then patch the hole with foam.

Outside corners are formed with 30-in.-high blocks mitered lengthwise at 45° and set into place on end. That created a neat, straight joint. The blocks were easy to cut with a circular saw set to a 45° angle. Matthew cut one face, flipped the block to cut the other face and finished the cut with a handsaw.



ONE FLOOR AT A TIME. When the first-floor block is filled with concrete, a ledger to carry second-floor framing can be bolted into place. Bolts should be set before the concrete is poured.



SNAP TIES REINFORCE BLOCK. Standard snap ties run through the 2×4 blocking will help keep the block courses aligned when the concrete is poured. These second-floor walls need only modest bracing.

Windows, Doors, and Floors Require Special Planning

At window and door openings, we cut back the cores of the block to accommodate a 2×6 buck, or frame, whose faces were flush with the outer edge of the block (see “Setting Doors and Windows in Place” on the facing page). These bucks prevent concrete from spilling out of the block as the walls are poured, and they make a nailable foundation for installing doors and windows later. Bolts inserted through the 2×6 bucks and into the hollow cores of the block make for a solid connection once the concrete has been poured.

We ran Ener-Grid block all the way up the gable-end walls, then snapped a line at the same angle as



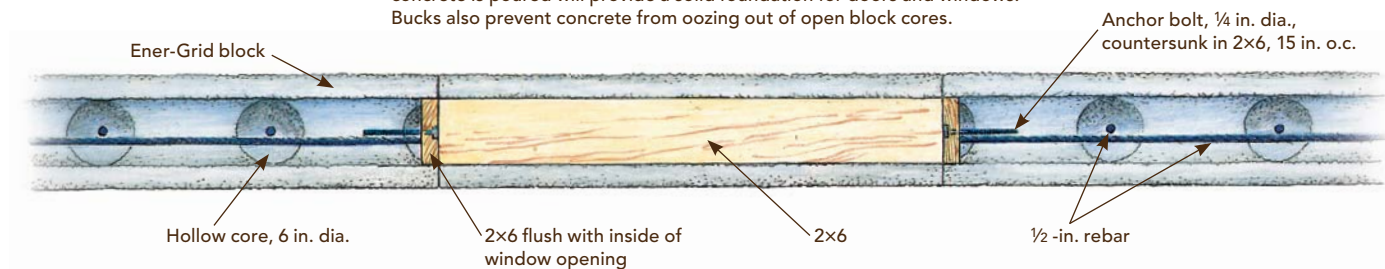
WIRES AND BOXES ARE SET INTO CARVED RECESSES. Because the block is relatively soft, many tools, including a keyhole saw, can be used to make electrical channels.



A PUMP TRUCK SAVES A WORLD OF TROUBLE. A soupy mix of concrete is placed efficiently with a 5-in.-dia. line. Anchor bolts set in the concrete at the top of the wall will be used to fasten a 2× top plate for conventional roof framing.

SETTING DOORS AND WINDOWS IN PLACE

Bucks, or frames, made from 2×6 material and anchored to walls before concrete is poured will provide a solid foundation for doors and windows. Bucks also prevent concrete from oozing out of open block cores.



the roof pitch. Matthew cut to the line with a chain-saw, leaving core openings on an angle. We worried that the concrete would quickly drain out of these openings. But by making the concrete somewhat stiffer for those areas, we avoided a problem.

Floors can be hung at any height. Once the block walls were erected but before they were poured, we pushed anchor bolts through the block wall and into the open cores. Later, we drilled corresponding holes in the wood I-joists that were used as ledgers for the second-floor framing and bolted them firmly to the walls (see the top left photo on p. 106). We used spacer blocks to fill spaces between chords and webs. Although we could have used solid 2× ledgers here, Matthew had already determined the floor framing would be I-joists, and keeping joists and ledgers the same made it much easier to hang drywall ceilings down the road. Anchor bolts also are set into the top course of blocks so that a plate can be attached at the top of the wall for the roof framing.

Walls are reinforced with a combination of conventional snap ties and threaded rod bolted through 2× blocking (see the top right photo on p. 106). We added bracing where we thought it would be most needed—at doors and windows, for example, or where the block was cut. All in all, bracing was on roughly 8-ft. centers and was used to straighten walls before the pour as much as it was for strength.

A Pump Makes Placing Concrete Faster and Easier

With this kind of construction, the nail biting comes when the concrete truck arrives. There are a lot of passages for concrete to fill, so we used grout with a slump of 8. That's roughly twice as fluid as standard ready-mix concrete. Matthew specified a seven-sack mix with 40% of the aggregate $\frac{3}{8}$ in. or less and the balance sand, which should yield concrete with a compressive strength of 4,200 psi. We also used a concrete pump truck, which simplified the pour (see the photo on p. 107). We placed the concrete with a 5-in.-dia. hose with an S-curve at the end. The curve

It is important to plan utilities from the start so that conduit and water supply lines can be located correctly in the concrete floor.

is important because it slows down the concrete as it leaves the hose. A gate on the S-curve allowed the person handling the hose to shut off the flow of concrete quickly.

Walls for the house were formed and poured in stages. We placed block for the first floor, poured concrete to that height and then added the second-floor deck. This process provided a solid platform for forming the remainder of the walls. Although Matthew has placed concrete in walls as tall as 17 ft. in one shot, a lower wall height reduces the risk of a blowout during the pour.

Any time wall height exceeds 8 ft., it's a good idea to place the concrete in two passes, or lifts. By the time you get back to the starting point, the concrete placed on the first pass will have stiffened somewhat. Because this concrete had such a high slump, we did not need to use any mechanical vibration to consolidate it. We used a total of 30 cu. yd. of concrete for my 3,000-sq.-ft. house.

Installing Utilities

Plumbing and wiring are not as difficult as you might think. It is important to plan utilities from the start so that conduit and water supply lines can be located correctly in the concrete floor. From there, electrical and plumbing lines are run mostly through interior partitions. You do need receptacles on the outside walls, and this is where you will be thankful that the block is easy to work with.

A channel can simply be gouged out of the wall to create enough room for standard plastic-coated



SNUG AND COMFORTABLE. Dyed concrete floors that conceal a radiant-floor heating system and interior trim of vertical-grain Douglas fir help give the house an earthy, low-tech appeal.

cable. Just about any tool—router, keyhole saw, chainsaw tip—will do the job. Boxes are set in their own cavities (see the bottom photo on p. 106) and then foamed into place. When the cable has been run, the wire and channel are simply plastered over. We didn't think metal conduit was necessary.

When it came time to apply interior and exterior finishes, we rasped the rough block joints smooth with a thick piece of expanded metal lath attached to a handle. The material can be shaped easily. You can plaster or tile directly to the insulated block. Hanging pictures and other light objects from block walls is easy with a plastic anchor and screw. Heavier

objects require more support. The best way is to plan by inserting bolts into the hollow cores before the concrete is placed.

Almost any siding can be used on the block. We used stucco on the exterior walls up to the gable ends. From there, we hung cedar siding from furring strips routed into the block and screwed into the concrete core.

Waterproofing

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a curtain drain
- 146 sealing a crawl space

Details for a Dry Foundation

BY WILLIAM B. ROSE

As a research architect at the Building Research Council of the University of Illinois, I am paid to solve some of the more nagging problems that houses have. Frequently, I visit troubled houses, and the most common problem I encounter is poor drainage away from the foundation. This problem became worse as wetlands were developed; I know what to expect when the name of the development is Frog Hollow.

I was once asked to look at a house that had settling problems. An addition, built over a crawl space was moving down relative to the main house. The dirt floor of the crawl space was even with the bottom of the footing. The soil along the edge of the footing was in small clumps, unlike the grainy, gritty surface of the rest of the floor. I dug away at the clumps, and my fingers hit air. I dug a little more and found a space that reminded me of a prison escape tunnel. In all, 10 ft. of the footing was undermined.

Water from a downspout draining too near the corner of the house and the addition was the culprit. The water was taking the path of least resistance to the footing drain and sump pump in the basement of the main part of the house. That path happened to be under the addition's footing. By following that path, the runoff had washed away the ground under the footing and caused the addition to settle.

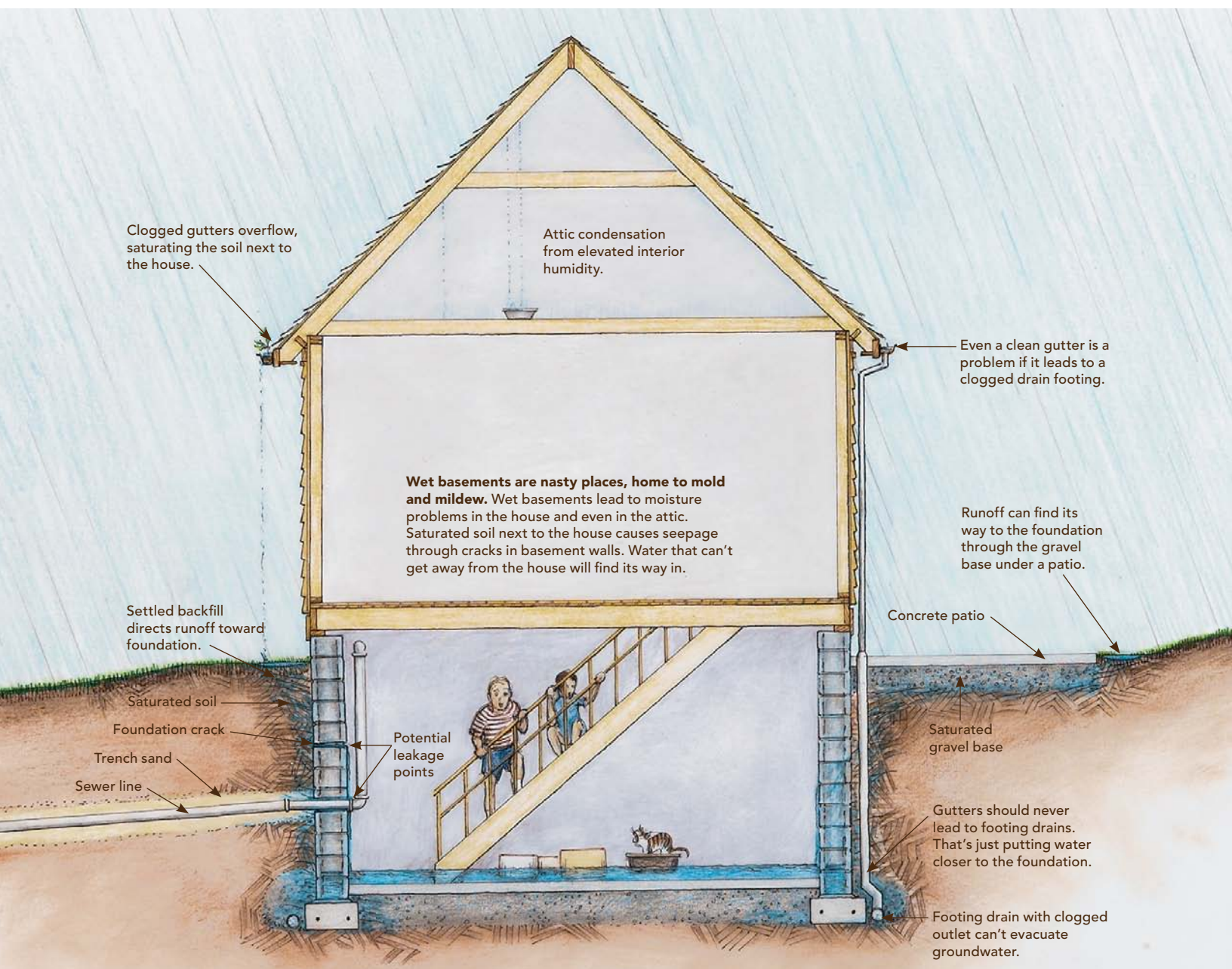
Bad Drainage Can Cause a Raft of Problems

I call my studies of the zone where the house meets the ground *building periodontics*. Proper preventative care of this area can avoid a variety of problems, some less obvious and a lot more serious than a damp cellar.

For example, a common problem in basements, particularly those with block walls, is inward buckling. This usually shows up as a horizontal crack one or two blocks below grade, or at windowsills, stepping up or down at the corners. A study I did with the Illinois State Geological Survey revealed the cause. Clay soils shrink during dry spells, forming a crevice between the soil and the foundation wall. Wind and light rains carry dirt into this crevice. Then, when seasonal rains come, the soil swells back to its original dimension, plus the increment of added soil. Over time, the wall is ratcheted inward and eventually buckles. You avoid this problem by keeping the soil next to the foundation dry.

Slabs suffer from water problems, too. Garage floors, for example, commonly crack at outside corners near where gutters drain. This cracking may be due to upward expansion of water directly below the corner. It can also be due to adhesion lifting of the perimeter wall, a situation occurring when saturated

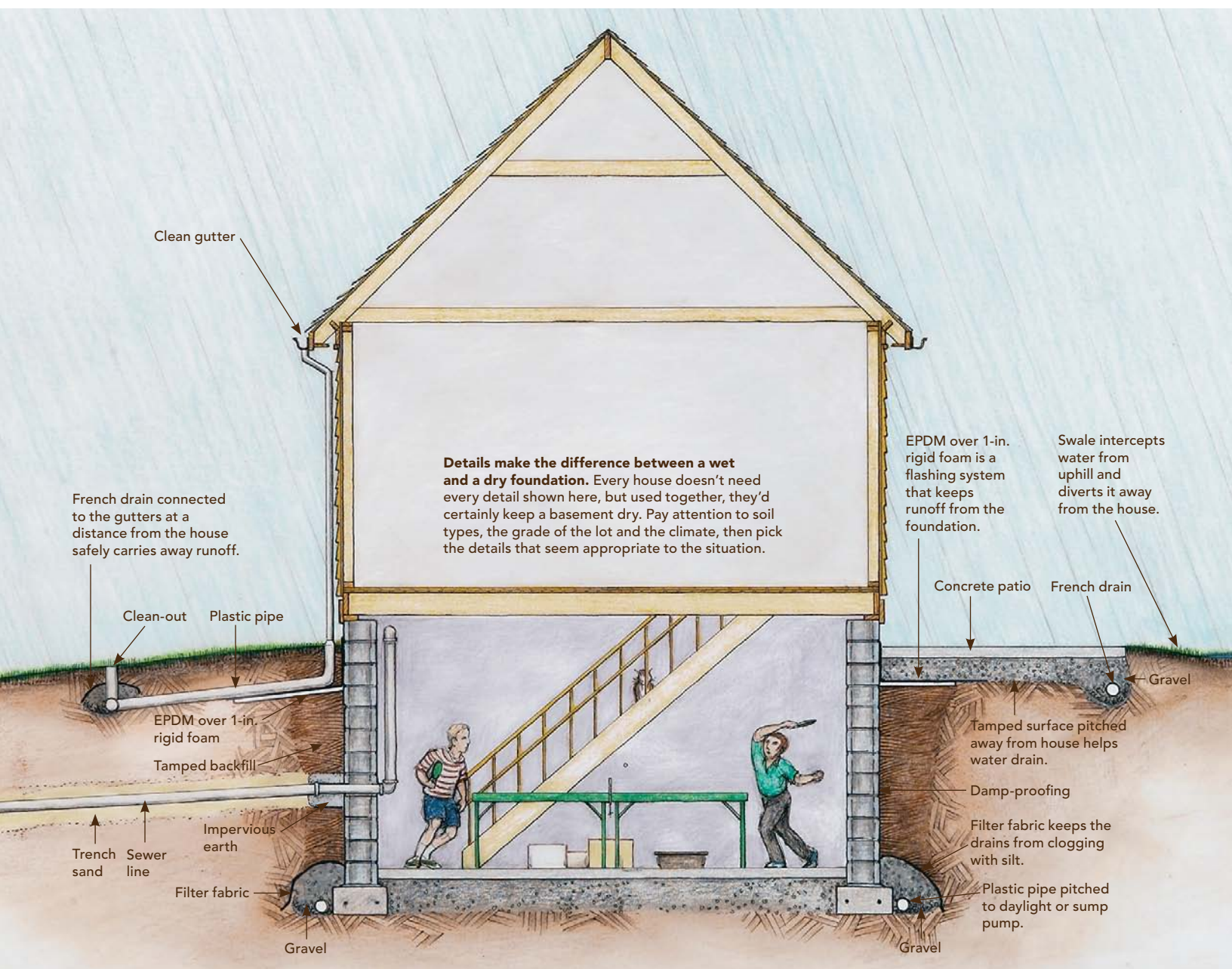
THE PROBLEMS



soil freezes fast to the foundation wall (see “Saturated Soil Leads to Frost Heaving” on p. 115). The soil nearest the surface is the first to freeze, and as the cold weather continues, deeper soil freezes. This saturated soil expands by 8% as it freezes, exerting a tremendous force that lifts the soil frozen to the wall above. The wall lifts and cracks the slab.

Moisture damage around foundations isn’t limited to masonry problems. In 1947, Ralph Britton, the government researcher whose work led to the current attic-ventilation standards, showed that water vapor traveling upward from damp foundations caused most attic moisture problems. He concluded that if attics were isolated from wet

THE SOLUTIONS



foundations, the standard 1:300 venting ratio could be reduced to 1:3,000.

First, Pinpoint the Trouble Spots

Let's take a walk around an imaginary house and study the sources of its foundation water problems (see "The Problems" on the facing page). We eas-

ily spot the first one: The front gutters are clogged. Been clogged for so long, in fact, that saplings are sprouting in the composted leaves. Rainwater overflows these gutters, causing the ground below to settle. A small crater has developed, and its contents have nowhere to drain but down and into the cellar.

The gutters at the back of the house, however, are clean. The leader feeds into an underground drain that goes . . . where? Walking downhill, we find an outlet pipe at about the right elevation to be a footing drain. Composting leaves and granules from asphalt shingles clog the corrugated pipe. Might the water that should flow from this pipe be ending up in the basement?

A concrete patio, probably poured on a sand or gravel base, extends off the back of the house. A shallow depression next to the patio's edge collects a pool of runoff. This collected water will drain down the path of least resistance—through the gravel, under the patio and down the foundation wall.

Going into the basement, we find leaks in places that confirm our observations. There is also a leak where the sewer line exits the house, indicating that water is flowing into the house through the sand in which the sewer line is laid.

Timing can provide clues to the source of leaks. If they occur in a matter of hours after a rain, the problem is surface water. If leaks follow a day or so after a rain, a rising water table is likely the cause.

Know Your Soil

As I write this, I am sitting in the middle of the Midwest. The soil here is Drummer silty clay loam, great for agriculture, murder on construction. The available water capacity is about 20%. This means that if I had 5 cu. in. of dry soil, adding 1 cu. in. of water would saturate it. Being clay, the soil will swell as I add water. The permeability is about 1 in./hour. This means that any layer of rain will need an hour to get through a horizontal layer of soil 1 in. thick. That's really slow. From these numbers, I can estimate that a 1-in. rain will saturate 5 in. of soil and take 5 hours for full penetration.

That's useful information. It is from the U. S. Department of Agriculture's county soil survey, available from your county cooperative extension service agent. It allows a builder to estimate how much vertical water penetration there will be and how much of the rain runoff must be treated as sheet

flow on the surface. This information matters a lot more on flat lots than on sloped ones, but it can still be important on the uphill side of sloping sites.

The perc test for septic systems is also a good predictor of how well the soil drains. If your soils have a good percolation rate, say, 10 in./hour to 15 in./hour, to below the bottom of your footings, you may not have to do much to ensure a dry foundation. Install gutters and downspouts and make sure the first 10 ft. of ground around your house slopes away at something like 1 ft. in 10.

First Lines of Defense

What if your percolation rate is considerably less than 10 in./hour? First, don't build on the lowest part of the lot, because that is where the water will go. Gutters and downspouts are at the heart of rain-water management, the heart of moisture control in buildings. Deposit rainwater from gutters onto splash blocks and onto undisturbed soil so that the water runs away from the house.

Most modern houses are damp-proofed; that is, the exterior of the basement wall receives a bitumen coating. This provides a considerable amount of water protection. But water can enter through cracks resulting from utility penetrations, concrete curing, settlement, swelling soils, seismic activity or other causes. Think of damp-proofing as a secondary defense against water.

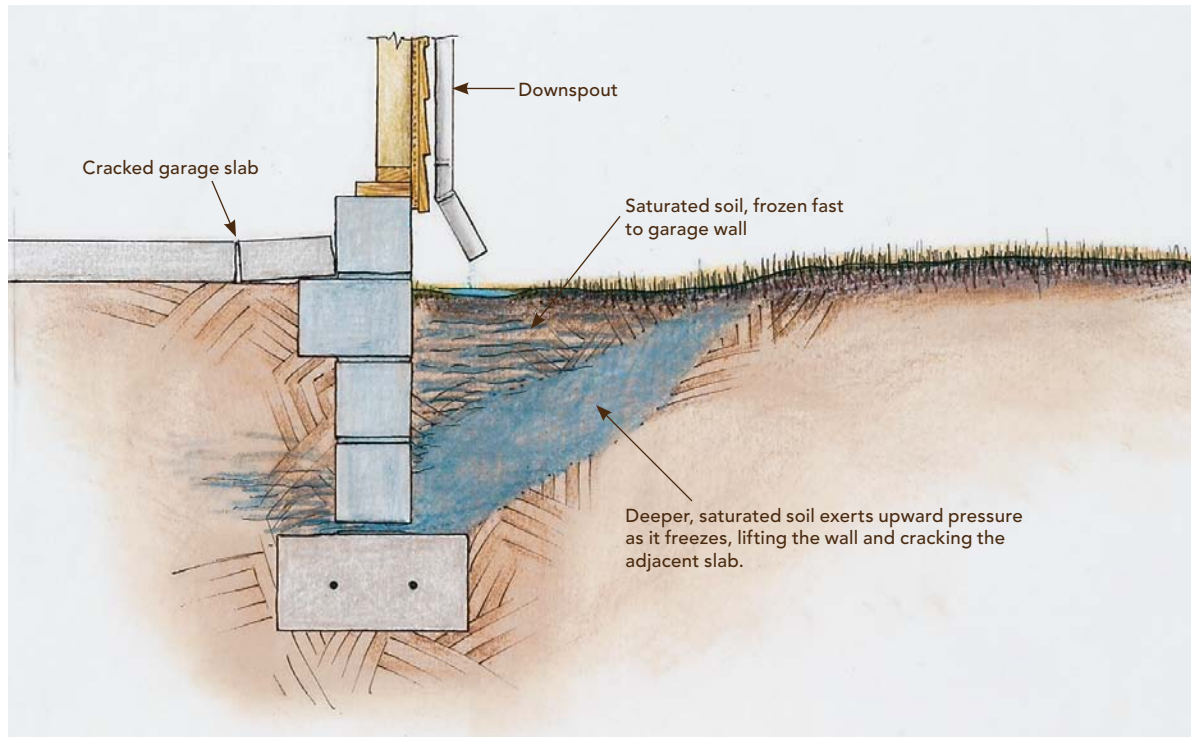
Dealing with a Rising Water Table

Footing drains have been used for decades to intercept rising groundwater. Rising groundwater usually isn't the major problem for foundations. Surface water is much more likely to cause trouble if it isn't led away from the foundation. Still, footing drains should be installed. They don't cost much when you're excavating, anyway, and they're the devil to retrofit if you find later that you have a high water table.

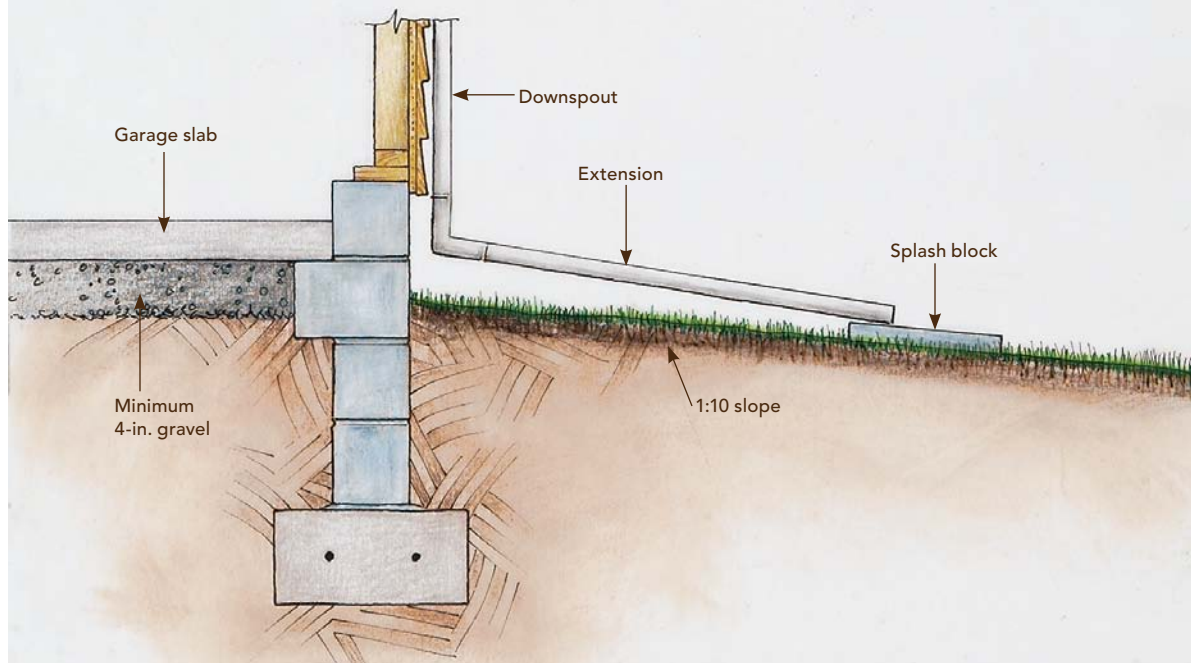
Footing drains should consist of a foot or so of gravel around the outside of the foundation. Use a filter fabric over the gravel to keep it from clogging

SATURATED SOIL LEADS TO FROST HEAVING

In a common scenario, water from downspouts has nowhere to go but next to the foundation. This results in damage to a garage slab from soil freezing.

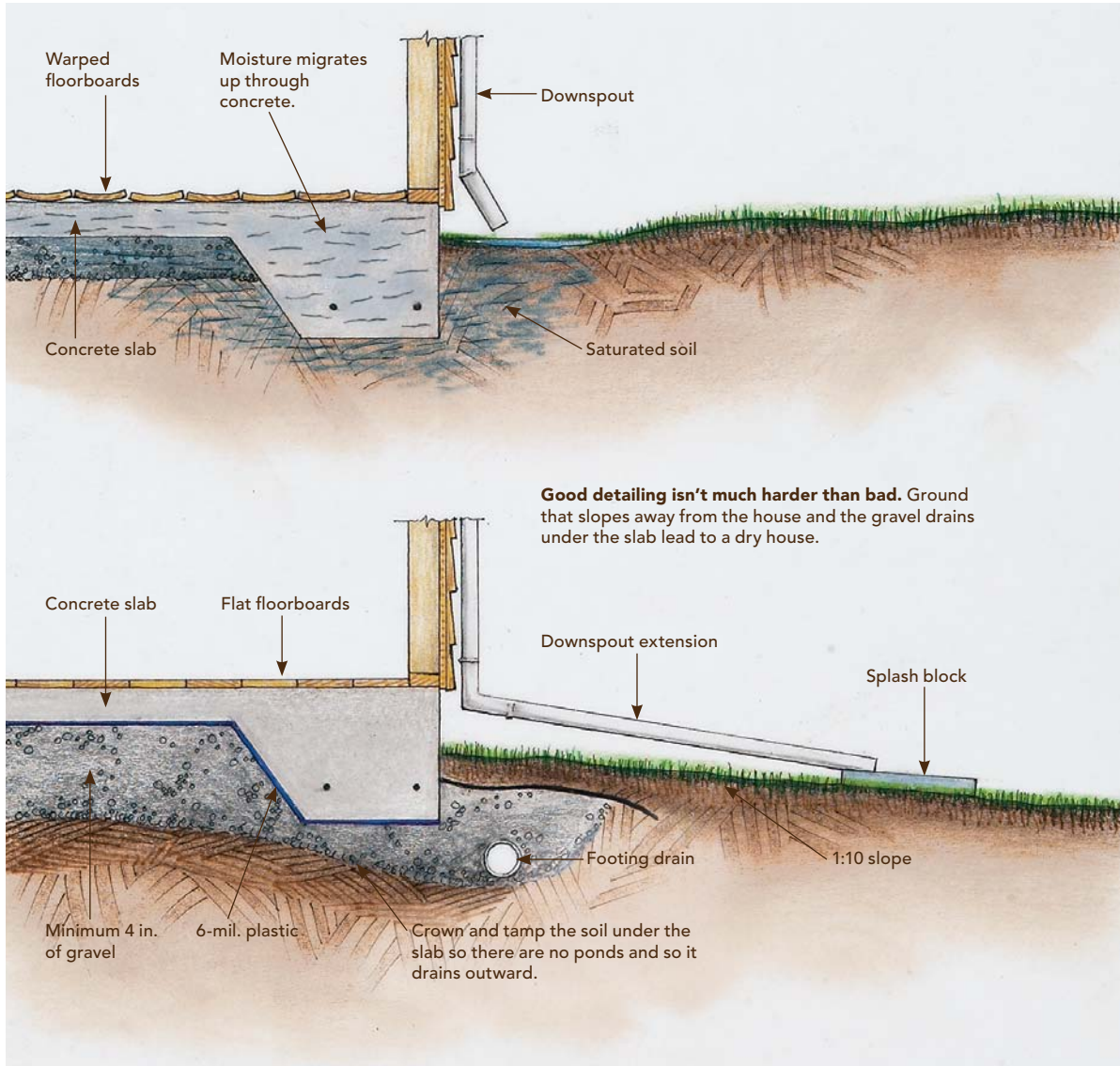


Keeping water away is the solution. Proper detailing can be as simple as sloping the ground away from the house and using downspout extensions to deposit runoff away from the backfill onto undisturbed soil.



MOISTURE IN THE GROUND LEADS TO MOISTURE IN THE HOUSE

Ground sloping to the house and no capillary break between the slab and the earth give water nowhere to go but up. Moisture from saturated soils will diffuse upward and warp floorboards, cause peeling paint, and possibly rot the framing.



with silt. Filter fabric comes in several weights; the lightest is just fine for residential use. Footing drains can have 4-in. perforated plastic pipe with the holes pointing down. They must lead to a sump pump or a gravity drain consisting of solid pipe leading to daylight. If you use pipe (as opposed to just gravel) in a footing drain, it should be slightly pitched

toward the outlet, or at least not pitched backward. It should have surface clean-outs every 50 ft. Discharge by gravity flow is preferable to a sump pump. Sump pumps are a weak link, likely to fail when most needed, but a gravity drain may not be possible if the footing drains are deeper than any possible discharge point.

Gutters and downspouts are at the heart of rain-water management, the heart of moisture control in buildings.

Gravel alone is probably just as good as gravel with pipes in it. A continuous gravel base that leads to a sump pump or to a daylight drain of solid 4-in. plastic pipe will handle most rising groundwater. The gravel is the main water route, so pipe used as a collector is not critical. In fact, I believe that most pipe is placed by people who don't really know what water is supposed to go where. Drainpipe here symbolizes good practice while making a doubtful contribution.

Never connect the downspouts to the footing drains, even if the drains run to daylight and not to a sump pump. Putting that volume of water closer to the footings makes no sense at all in light of my opening story. I'm trying to solve problems here, not create them.

Good Backfilling and Grading Are Crucial

Proper backfill procedures go a long way toward eliminating water problems. At the risk of sounding simplistic, be sure the ground slopes away from the house. You'd be amazed how many builders get this wrong. I recommend a slope of 12 in. in the first 10 ft. as a minimum (see "Moisture in the Ground Leads to Moisture in the House" on the facing page). Builders commonly don't allow enough extra soil for settling, and they almost never compact the backfill. Lightly compacted backfill may settle 5% of its height or more, often resulting in a situation in which the grade pitches toward the house. When backfilling, include a correction for settlement. There really aren't any hard-and-fast rules. Deep, lightly compacted backfill needs a big correction. Shallow, well-compacted fill might require none.

slabs need good detailing

Getting water away from slab foundations is just as critical as with basements or crawl spaces. Remember, there are retrofit draining and venting options that can, to a degree, rescue a damp basement or crawl space. There is none that works on slabs.

Good preparation of the ground surface is critical before slab placement. Level the center, slope down to the excavation for the thickened edge of the slab, and compact the soil well. Pour the slab on 6-mil polyethylene over at least a 4-in. tamped gravel base. This base serves as a capillary break between the soil and the underside of the slab. Extend the gravel base to a footing drain to carry water away. It is important to remember that a capillary break works only as long as it remains unflooded.

Remember, too much slope near the house doesn't create water problems; too little does.

Compact the backfill as tightly as possible without damaging the foundation walls. Brace them well, using trusslike assemblies of heavy framing lumber spanning from wall to wall. Have the first-floor deck on, and fill all sides evenly. Block walls require more caution than poured concrete. Compact the backfill in 1-ft. lifts using a hand compactor, commonly called a jitterbug, or careful pressure from a backhoe. Because intersecting walls brace each other, the soil at outside corners can be compacted with less risk than in the middle of a long wall. For a minimum, compact these corners well, and be sure that all the downspouts drain near them.

Utility lines are frequently laid in sand that provides a direct path for water to reach the foundation.

Take special care where utility lines enter the house. They are frequently laid in sand that provides a direct path for water to reach the foundation. Be sure the soil under the utilities is well compacted, and cement and damp-proof the utility penetrations. Then use an impervious earth such as clay soil, or mix a bag of portland cement with the soil you have, to fill around the utility penetration. Tamp well.

Swales and French Drains

Other means of transporting water away from the house besides sheet flow (when the surface is effectively running water) are the swale and the French drain. A swale is a small valley formed by two sloped soil surfaces. Swales must be pitched, or they become ponds. A swale should be located away from the building, and it is often used to divert sheet flow coming from uphill (see “The Solutions” on p. 113).

A French drain is a trench filled with rock or gravel that collects water and transports it laterally (see “French Drains Collect and Transport Water” on the facing page). I prepare the bottom of the trench so that it is smooth and carefully pitched toward the outlet. Mix dry cement with the soil in the bottom of the trench to make it less permeable, and fill the trench with whatever clean gravel is locally available. I hesitate to use road stone, a blend of gravel and stone dust, because water passes through it slowly. If the gravel is to be exposed, I try to cap it with an attractive rounded stone. If the drain is to be covered, I provide graduated layers of smaller stone toward the surface, then perhaps filter fabric before the sod covering.

I sometimes use 4-in. smooth-wall perforated plastic pipe in a French drain, particularly if I expect it to carry a big volume of water, say runoff from the

gutters. There are fittings that connect downspouts directly into this pipe. If you do this, install clean-outs at least every 50 ft. and keep the gutters clean. Otherwise, the pipe can become clogged with leaves. I don't use corrugated pipe for drainage because it is more difficult to ensure smooth, straight runs. It clogs more easily and is more difficult to clean out.

Concrete patios, stoops, driveways, and sidewalks abutting the foundation present problems. It is important to design them so that the gravel base beneath drains outward, a perfect use for a French drain. You may find that the driveway is one of the most convenient sites for a French drain. Driveways usually pitch away from the house, and a French drain can be integrated with the driveway so that it will not call attention to itself.

Where Should the Water Go?

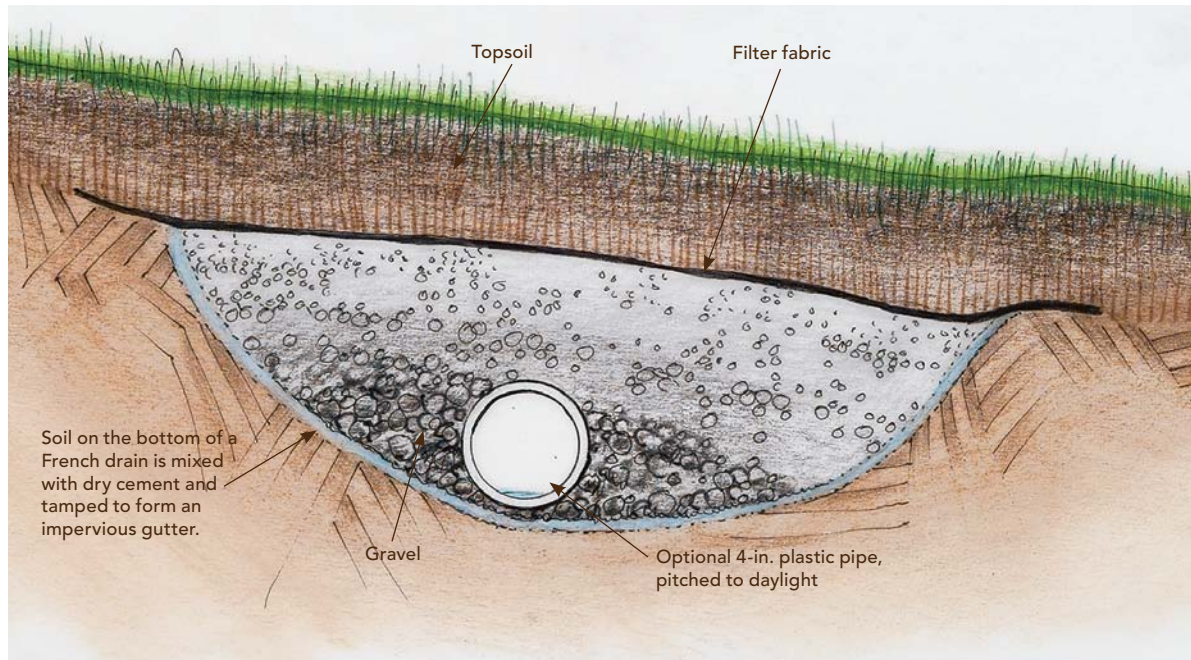
To my knowledge, municipalities no longer provide storm-sewer service for new residential runoff. In my area, they do not receive the output from sump pumps. They receive and treat storm water to keep streets open, and that's about it.

If there isn't enough elevation difference between the house and a point on the lot where a pitched drain can come to daylight, then another solution is needed. Theoretically, if the pipe never pitches back, you don't need more than the diameter of the pipe in elevation difference. Practically, more is better, and ¼ in. per foot is a good number to shoot for.

But say you don't have even that much pitch. For hundreds of years, cisterns and dry wells collected water below grade. Often, there was an overflow toward a leach field. Such design is still feasible, and indeed it is useful for garden irrigation where fresh water is scarce. Some municipalities require new subdivisions to handle runoff with on-site dry wells, rather than feeding it to a common detention basin. Usually a 1,000-gal. precast-concrete dry well (see “Dry Wells Avoid Draining Runoff on the Surface” on the facing page) or commercially available plastic drainage structures are buried somewhere on site.

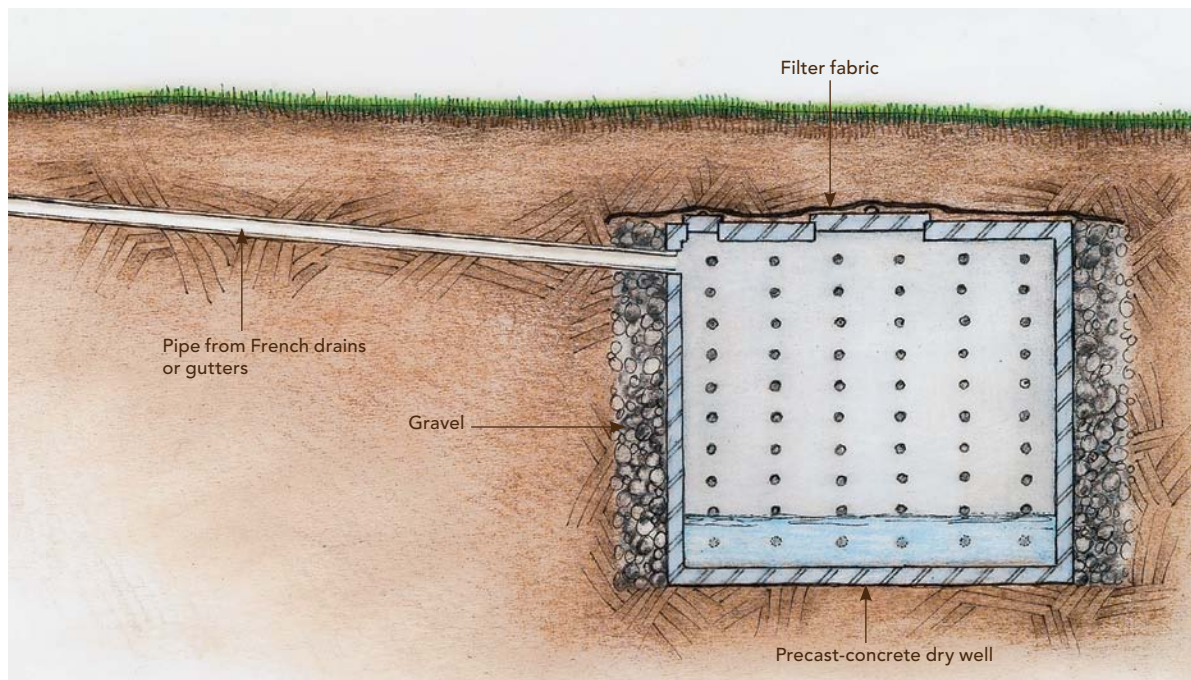
FRENCH DRAINS COLLECT AND TRANSPORT WATER

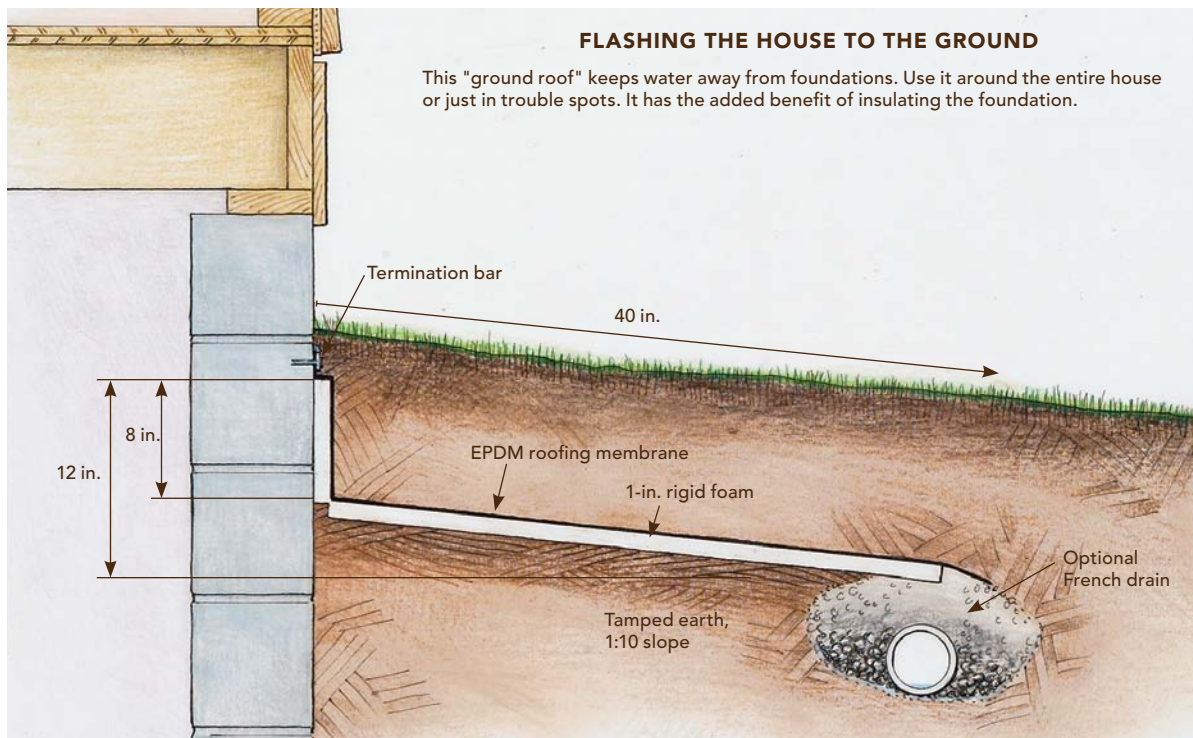
A French drain can play an important role in draining slabs, gutters, and ground-roof systems of water.



DRY WELLS AVOID DRAINING RUNOFF ON THE SURFACE

Required in some municipalities, dry wells give runoff time to soak into the ground. Their success depends highly on how well the surrounding soil drains.



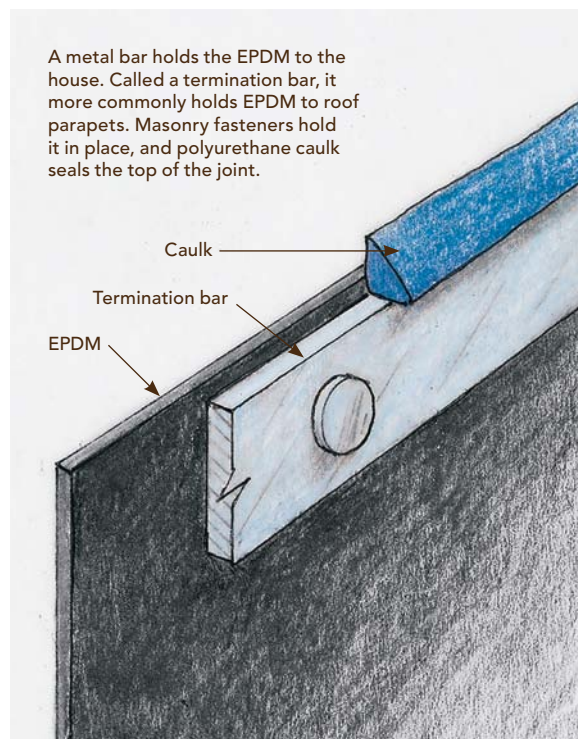


Water from the gutters is piped in and stored until it can soak into the surrounding soil. The likelihood of success with either one of these systems depends on the perc rate of the soil and sufficient storage capacity to handle the maximum likely runoff. It also depends on how big the design rainfall is.

If you are not required to treat runoff in a specific manner, then take advantage of natural drainage courses on your lot. Get the water away from the house responsibly. If several downspouts connect to a French drain, enough water may flow from it to cause erosion problems. Place rocks under the end of the pipe and in the outwash area to spread the flow out and reduce erosion. Don't flood the neighbors' basements to spare your own.

Flashing the Intersection of the Ground and the Foundation

I call that zone where the house meets the soil the *ground roof* because the soil surface must shed rain-water away from the foundation and the soil below.



During dry spells, I commonly see a ½-in. crevice between the soil and the foundation. If that gap appeared on a roof, wouldn't we flash it? In severe cases or in old houses with hopelessly porous foundations, I have flashed this gap in the ground roof with EPDM roofing membrane (see "Flashing the House to the Ground" on the facing page). Polyethylene sheets and bitumen membranes would work, but they degrade more easily when backfilled.

Ideally, I would flash a house as it was being built. In reality, I've done it only as a retrofit. A frost-protected shallow footing (see p. 93) would lend itself well to a ground-flashing system. I dig down 8 in. at the foundation wall and extend outward 40 in., sloping the excavation 1 in. in 10. The hard work is the digging. Having done it, I should get as much benefit as possible, so I take this opportunity to insulate the foundation. Slice through one side of a 4x8 sheet of 1-in. rigid foam, 8 in. from the edge, and fold along the cut. The resulting piece fits neatly into the 8-in. by 40-in. excavation. In the South I suggest high-density mineral wool because it is less hospitable than foam to termites. In new construction, compact the backfill under the flashing well. Otherwise, settling could tear the EPDM from the wall or cause it to pitch toward the house.

After placing the insulation, I roll out the EPDM, letting it hang over the end of the foam. A metal strip called a termination bar, more commonly used to attach EPDM to roof parapets, clamps the membrane to the foundation at grade level. I attach the termination bar to the foundation with expanding nail-in fasteners: alloy or plastic sleeves that slide into holes drilled into the foundation and then expand as a nail is driven in. I run a bead of cutoff mastic, a high-quality polyurethane caulk used for waterproofing termination bars on roofs, on this joint and backfill.

The flashing could extend farther outward from the building at the downspout locations. In existing buildings, you can often get away with flashing only the trouble spots, usually inside corners with down-

consider your site and plan accordingly

There are so many soil classifications, foundation types, and climate variables that assembling general rules is challenging. If there is a general rule, it is this one: Design the soil surface that goes around the building to act as a roof. The overall aim is preventing the soil that is in contact with the building from being saturated with water. This ground roof should ensure that rainwater moves quickly and effectively away from the building. Downspout discharge, grading, flashing, drains, and soil treatment at the surface all play major roles in keeping the ground in contact with the building dry.

Basements, crawl spaces, and slabs all have their own peculiarities. With thoughtful design of the area where the house and the ground intersect, any foundation can be dry. Well, maybe any foundation that doesn't have provisions for boat docking.

spouts. The ground roof need not be as watertight as a house roof. After all, moisture control in soils is always a matter of playing the percentages.

In soils with an average percolation rate, flashing by itself is enough to keep the water away from the foundation. If your perc rate is slow, install a French drain near the outboard edge of the flashing. Shallow plantings can go right on top of the EPDM.

Keeping a Basement Dry

BY LARRY JANESKY

I was standing in water a quarter-inch deep that covered an entire basement floor. The homeowner asked me in a surprisingly calm voice, “Is there any reason the basement of a brand-new million-dollar home should leak?” “Even if your house cost \$100,000, it still shouldn’t leak,” I answered. I also told her that she had lots of company in her misery: A recent survey of 33,000 new-home owners revealed that 44% had leaky, wet basements. It was my guess that most of the basement problems were the result of a builder’s neglect or efforts to cut costs.

As a basement-waterproofing contractor, I fix the mistakes of others. Having been a builder myself, I can empathize with the emotional struggle to “spend more and be safe” vs. “spend less, make a profit, we should be okay.” However, no matter how much you spend, you shouldn’t end up with a basement that seeps water like a cave; it’s not good for the house or its occupants. Remember that it’s much easier (and cheaper) to build it right the first time than to dig it up later with a jackhammer. To that end, I like to seal foundation walls, drain water away from the foundation’s exterior, and expel the water that does manage to leak into a house’s basement.

Sealing Foundation Walls

When water saturates the soil surrounding a foundation, it essentially creates a column of water whose cumulative weight increases as it rises in the backfill. This force pressing down is known as *hydrostatic pressure*; it drives water through joints, cracks, form ties, and other foundation imperfections. The first line of defense is some sort of exterior coating on the foundation walls.

These sealants are categorized into two groups: dampproof and waterproof coatings. Dampproof coatings are typically thin asphalt-based solutions that are sprayed or painted onto the foundation’s exterior. The asphalt reduces the porosity of the concrete, but over time, it emulsifies in water and won’t seal cracks. Some contractors mix fiberglass fibers with the asphalt to strengthen the mix but still offer only a one-year warranty. The low cost of dampproofing makes it attractive to many builders, but the brief or nonexistent warranties (usually only a year) should make consumers wary.

Waterproof coatings, on the other hand, are a mixture of rubber and asphalt or all rubber (sometimes called *elastomeric*) and can cost three times as much. Like dampproof coatings, waterproof coatings are sprayed onto the foundation (see the top photo on the facing page), but the material must



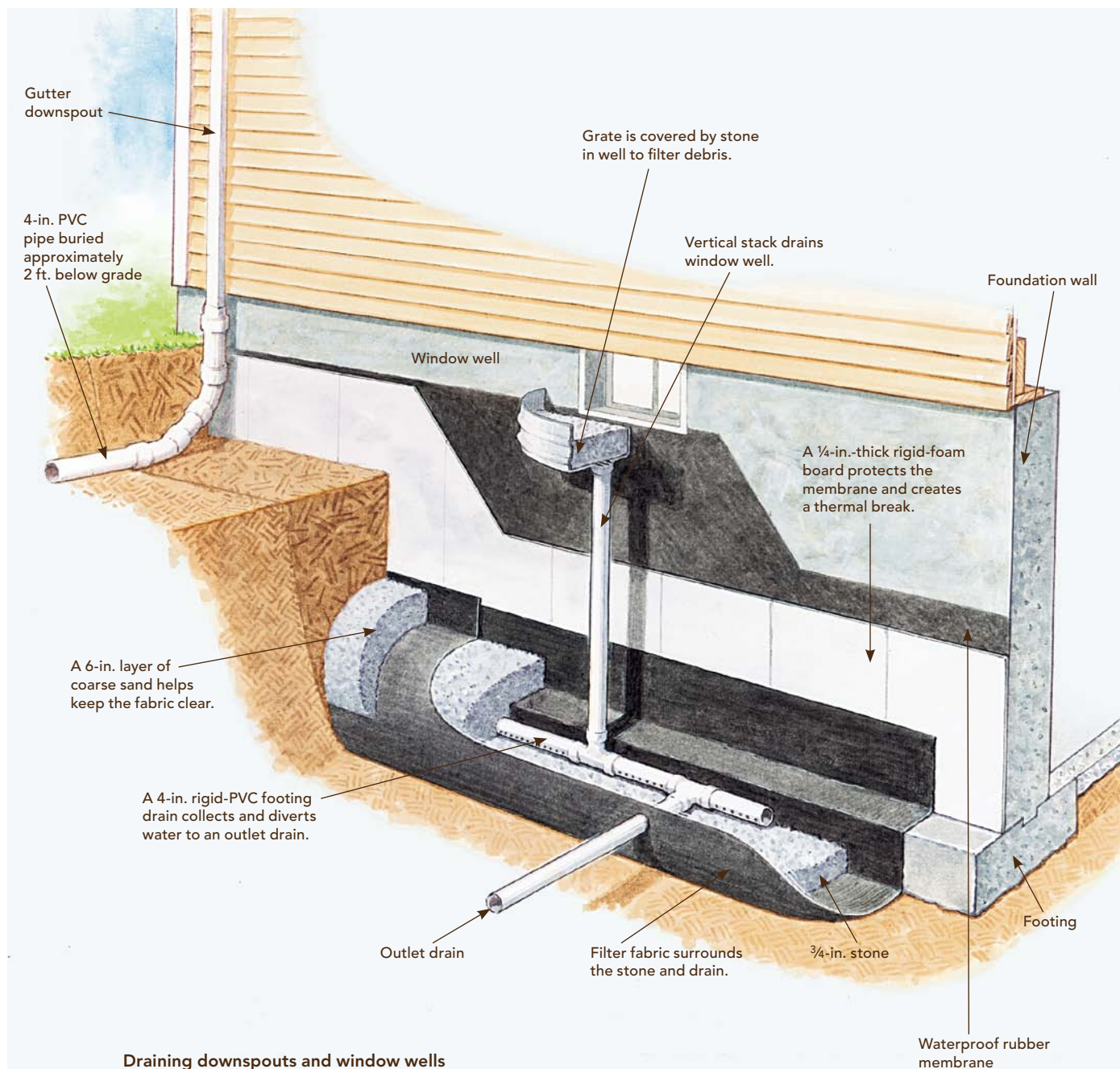
WATERPROOFING, NOT DAMPPROOFING, seals the foundation walls. More expensive than asphalt-based mixtures, a rubber-based membrane sprayed onto foundation walls remains flexible and waterproof.

RIGID-FOAM PROTECTION BOARD shields the membrane from backfill damage. Applied while the waterproofing is still tacky, the ¼-in. foam panels also provide a thermal break between the foundation and the backfill.



MAKING THE FOUNDATION'S EXTERIOR IMPERVIOUS TO WATER

Because most water problems come from saturated backfill, it's important to seal foundation walls. An elastic rubber membrane sprayed onto the concrete seals small cracks, holes, and other imperfections. A PVC drain laid along the footing carries excess water away from the house. A multistage filter of stone, filter fabric, and coarse sand keeps the drain from clogging with silt.



Draining downspouts and window wells

If left unattended, rainwater that drains off the roof will end up in the basement. Gutter downspouts can be connected to 4-in. drain lines that run to daylight, away from the house. To keep window wells from leaking into the basement, a 4-in. vertical pipe run from a T in the footing drain can divert any water that collects there.



CLOGGED FOOTING DRAINS CAN'T DO THE JOB. Water draining into the pipe carries silt that eventually fills the pipe. To avoid replacing a clogged footing drain, the author surrounds the pipe with a layered filter that stops sediment.

be heated before application; it's also applied in a thicker coat and is elastic enough to bridge $\frac{1}{16}$ -in.-wide cracks and small holes. The key to the waterproofing's performance is the amount of rubber in the mixture; more rubber means better performance and higher costs.

To protect any coatings' integrity when the foundation is backfilled, many contractors cover the sealed concrete with what is known as protection board: sheets of fiberglass, rock wool, or extruded polystyrene foam. I use a $\frac{1}{4}$ -in.-thick foam board that adheres to the fresh layer of waterproofing (see bottom photo on p. 123); at the very least, it provides a thermal break between the backfill and the foundation. A number of waterproofing manufacturers such as Rub-R-Wall® (800-860-7721; www.rpcinfo.com) and ElastiKote™ (800-992-1053; elastikote.com) produce an extremely resilient coating that doesn't need protection board. But I still like to have the extra insulation provided by the foam.

When applying waterproofing, I make sure the joint between the footing and the wall is sealed. This means the top of the footing has to be clean before the wall is sprayed. Form ties should be knocked off both inside and out before spraying. It's also a good idea to determine the finish-grade height and spray

TIP: The black coiled, slotted pipe often used as a foundation's drainage system can be difficult to keep straight. Any dips in the pipe cause poor flow and clogs. Try 4-in.-dia. rigid PVC pipe instead.

to that line. If this elevation is miscalculated, 6 in. or more of untreated wall can end up beneath the backfill, causing leaks when the inevitable shrinkage cracks begin to appear in the foundation.

A popular alternative to waterproofing is waterproof drainage mats. The dimpled polyethylene sheets are unrolled and nailed onto the foundation wall, caulked at the top and left open at the bottom. The mat's dimpled shape creates an airspace between the wall and the soil, so if water does leak in at the top or through a joint, it can drain to the bottom.

The problem with these drainage mats is that they must have an open footing drain below. If (or when) the footing drain clogs, hydrostatic pressure forces water up between the matting and the wall. Because the wall was never waterproofed, every crack and form-tie hole is vulnerable to easy water entry. In contrast, if a footing drain fails along a wall that was waterproofed, the form ties, wall cracks, and footing/wall joint are sealed and protected. However, even the best waterproofing guarantees only that water won't penetrate walls and doesn't prevent water from coming up around the footings and floor.

Keeping Footing Drains Clear

To keep a basement dry, you need to channel water away from the house with footing drains. Although most building codes say that foundations must have a drainage system of drainage tile, gravel, or perforated pipe, I always use 4-in.-dia. rigid PVC pipe. (I've found that the black coiled, slotted pipe often used is difficult to keep straight; any dips in the pipe cause poor flow and clogs.) Two rows of



INTERIOR PERIMETER DRAINS ARE GOOD INSURANCE in new construction or retrofits. Plastic drains on top of the footing collect water that leaks in through the walls and channel it to the sump pump. The entire drain is to be covered with concrete, except the opening facing the wall.

As long as the lot's grade allows it, the exterior footing drains should always be run to daylight, pitched at $\frac{1}{4}$ in. per ft. or more, if possible.

$\frac{1}{2}$ -in. holes drilled at the 4 and 8 o'clock positions keep the pipe's sediment intake to a minimum; slots will clog much faster than holes in most soil conditions. To make sure the pipe doesn't become clogged (see the photo on p. 125), I wrap the pipe with a succession of filters that resembles a giant burrito.

I start by cleaning the excavation to the bottom of the footing, usually with a shovel; a half-buried footing causes poor drainage. Next I unroll 6-ft.-wide filter fabric along the footing, spreading excess on the ground away from the foundation and up the sidewalls of the excavation (see "Making the Foundation's Exterior Impervious to Water" on p. 124). I then dump 3 in. of $\frac{3}{4}$ -in. stone on top of

the fabric, level it off by hand, then set the PVC pipe so that at worst, it's level around the entire foundation. Because the footings are mostly level, I'm happy if I can gain a few inches of pitch to the outlet. During this stage of the project, it's convenient to tie the drains below each window well to the footing drains. Vertical risers made of solid 4-in.-dia. pipe run up from the footing drains under the window wells and terminate with a grate about 4 in. below the windowsill. The well can be filled later with stone so that leaves won't clog the grate.

I backfill over the footing pipe with more $\frac{3}{4}$ -in. stone to an elevation of 8 in. above the top of the footing. As a rule of thumb, 1 yd. of aggregate will cover 12 lin. ft. of exterior footing drain; therefore, a house with 150 ft. of foundation will require a little more than 12.5 yd. of aggregate. I pull the filter fabric up over the top of the stone and against the wall, using shovelfuls of sand or stones to hold it in place. If the fabric is not long enough to reach the wall, I add another course, overlapping by at least 12 in. Now the burrito is nearly complete. Because the filter fabric will eventually clog, I put about 6 in. of coarse sand on top of it. This progression of materials will keep the drain clear longer than any other practical way I know. The fabric protects the stone, the sand protects the fabric, and the soil won't wash into the sand.

As long as the lot's grade allows it, the exterior footing drains should always be run to daylight, pitched at $\frac{1}{4}$ in. per ft. or more, if possible. If the drains are servicing more than 200 lin. ft. of foundation, you might want to consider added measures. For example, you could put two outlets to daylight or increase the diameter of the outlet pipe from 4 in. to 6 in.

If there isn't considerable pitch on the lot or a handy storm sewer, the footing drains must run inside to a sump pump. A single 6-in. pipe that connects the exterior drain to the pump should be cast through the footing at the sump location and should give the drain as short a run as possible.

sump pumps for interior drainage

Any drainage technique is dependent on one thing: a good sump pump. After installing more than 10,000 pumps myself, I have some criteria for choosing a pump. First, it should have a cast-iron body; second, it should be able to pump $\frac{1}{2}$ -in.-dia. solids; and third, it should have a mechanical float switch (a float riding up and down on a rod), not a pressure switch or a "ball on a wire" design that often hangs up. A Zoeller M-53 (Zoeller® Pump Co.; 800-928-7867; www.zoeller.com) fits the bill perfectly and pumps 2,600 gal. per hour.

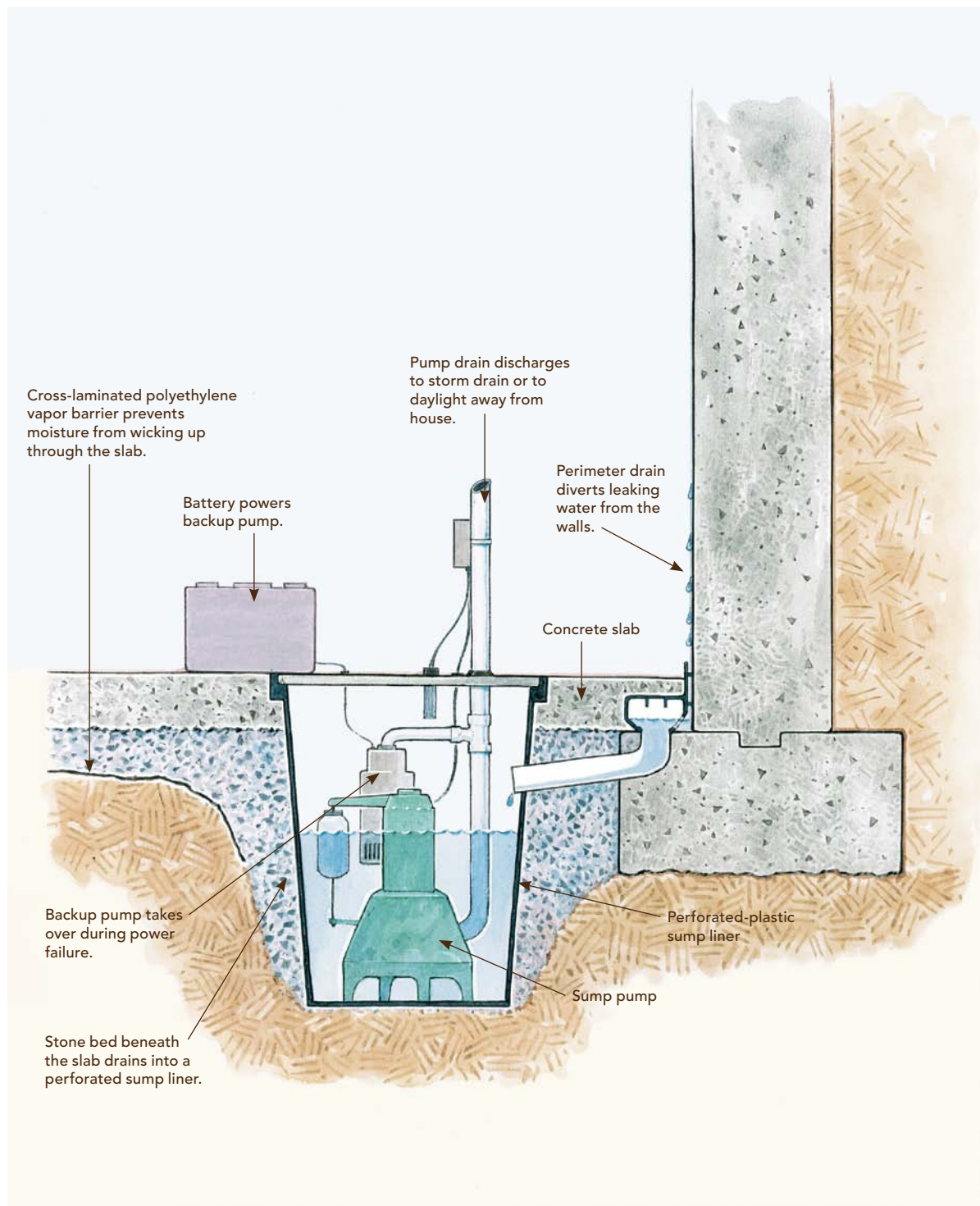
The pump sits inside a plastic bucket called a liner that collects water and separates it from the surrounding dirt so that the pump can push it out. The liner should be perforated and set in a bed of aggregate. Any drainage system that feeds water to the sump should have a pipe cut through the sidewall of the liner. The liner should have an airtight lid that will keep moisture from evaporating into the basement; it also keeps objects from falling into the sump hole that could interfere with the switch operation.

Relying on a lone sump pump to keep the basement dry is risky. It's all too common for a storm to knock out the power and flood the basement all in one night. A battery-operated backup pump provides insurance and often is equipped with an alarm that announces a pump failure. The backup can usually be installed in the same sump hole as the primary pump and use the same discharge line. The best backup systems use pumps that sit up off the sump floor, have float switches and use matched chargers and batteries made specifically for long-term standby use. This last item is critical. Many backup units don't provide a battery; if the battery and charger aren't matched, the system won't charge properly.

Discharge from the sump pump should be piped to a storm drain if one is available or to the exterior, where it will flow away. The discharge line should be installed so that it doesn't freeze during the winter.

KEEPING THE INTERIOR DRY WITH A SYSTEM OF DRAINS AND PUMPS

To handle any leakage through foundation walls and to ensure a dry floor, an interior perimeter drain collects water from the walls and channels it to the sump pump. On sites where exterior drainage is poor, the pump can also be connected to the exterior footing drains.





It's worth mentioning that it's never a good idea to connect an interior footing drain with a cross-over pipe in the footing to an exterior footing drain that drains outside the house. The probability of failure on an exterior component of the system is high, while the probability of a failure to the interior system is low. If and when the exterior footing drain fails, the water will back up into the interior footing drain and flood the basement.

Drain the Gutters Far Away from the House

It may seem obvious, but many houses don't have adequate drainage for gutters and downspouts. Rather than carry water away with splash blocks, it's more efficient to connect the downspouts to a 4-in.-dia. PVC pipe (see "Making the Foundation's



A TOUGH VAPOR BARRIER KEEPS THE BASEMENT SLAB DRY. Made of 2-ply high-density polyethylene, the vapor barrier can be installed under or over the gravel base and keeps moisture from wicking up through the slab.



DRAINAGE FLASHING IS A SIMPLER, LESS-EXPENSIVE INTERIOR DRAIN. Installed at the junction of wall and footing, this flashing has a dimpled profile that allows any water from the walls to flow beneath the slab and into the sump pump. Obviously, it's important to keep the top of the flashing clear when pouring the slab (left).

Exterior Impervious to Water” on p. 124). Starting at about a 2-ft. depth at the house, the pipe should be pitched toward daylight as steeply as possible so that it can flush out the dead leaves and sticks that always accumulate.

Because gutters collect debris, it's a good idea to enlarge the downspouts to 3 in. by 4 in. instead of the usual 2 in. by 3 in.; this will also drain the gutter twice as fast in a heavy rain. The underground drain itself can be enlarged to a 6-in. dia. if necessary. In

the drain, it's best to avoid 90° bends, which trap leaves and gunk, and use 45° bends instead. If there's a long run of gutter, give it two outlets. Finally, never connect the gutter drains to the footing drains, no matter how far downstream. Gutter drains are always voted “most likely to clog” and will back up the footing drains, too.

interior vs. exterior foundation drains

When an existing home has a wet basement, there are two basic approaches to solving the problem: an interior or an exterior drainage system. Several things should be addressed, however, before any system is installed. First, make sure the grade is pitched away from the house to drain away surface water effectively. The grade should not be any closer to the siding than 6 in. because of rot and termite concerns. Next, extend the outlets of the downspouts away from the house, and keep gutters free of debris to help keep water away from the foundation. Although these two steps nearly always help, they rarely keep a wet basement completely dry, and a drainage system should be considered.

EXTERIOR DRAINAGE SYSTEMS

The installation of an exterior system requires the excavation of soil around the entire house down to the bottom of the foundation footing. This process can be disruptive because landscaping, driveways, sidewalks, porches, decks, and so on, have to be removed and replaced. In addition, the soil taken out of the hole has to be stored in the yard temporarily, which is usually a huge mess. Once excavation is done, the footing drain can be installed. The system then has to drain to a sump pump inside the house or by gravity to daylight if the grade permits, which would require an additional trench.

Exterior drainage systems are not easily serviced. If something goes wrong, it's tough to find and fix the problem easily. Last but not least, the cost of an exterior system can be many times greater than that of an interior system. For all these reasons—cost, mess, difficulty in servicing—I do not recommend exterior drainage systems on existing houses, except in extreme cases.

INTERIOR DRAINAGE SYSTEMS

Interior footing drains are the best solution for most wet basements. With this type of system, the edges of the slab are removed. Next, a trench is dug around the perimeter of the foundation. Perforated pipe (usually 4 in. dia.) is placed in the trench and covered with crushed stone. Then concrete is poured over the trench.

Usually, interior systems drain to a sump pump, but in rare cases, they can be run to daylight. Sump pumps have come a long way. Some super systems feature sealed lids with built-in floor drains, alarm systems, and a host of other features. I also recommend a battery backup to keep the system working should the power fail.

Other hybrid interior systems that I recommend are less prone to clogging and are less disruptive than a round-pipe system. These systems also take water from along the walls, which can be crucial if a wall cracks, a pipe penetration leaks, or a window well floods unexpectedly. Whatever system you choose, put drainage around the entire basement, even if only part of the basement seems to be leaking. If fixing your basement isn't a project that you're comfortable doing, call a basement-waterproofing professional.

Getting Rid of Water in Basements

Although installing interior basement drains in new construction is a good idea, they're usually installed to fix problems in existing construction. Typical strategies include the use of interior perimeter drains that collect water from foundation walls, a vapor barrier below the slab that prevents water and vapor from wicking up through the concrete, and a good sump pump that will eject any water that collects in the drains and under the slab. In new construction, these methods all start with a new basement floor.

Under the slab, I like to lay 8 in. to 10 in. of clean ½-in. to ¾-in. stone. This stone allows the entire subslab area to drain and makes a good base for the slab. Once the gravel is laid, I always like to install a puncture-resistant vapor barrier (see the photos on p. 129). The strongest material is a 4-mil cross-laminated high-density polyethylene such as Tu-Tuff (Sto-Cote Products, Inc.; 888-786-2683). It comes in 20-ft. by 100-ft. rolls. I overlap adjoining pieces at least 18 in. and seal the lap with housewrap tape. The concrete guys aren't crazy about the barrier because it doesn't allow the water in the mix to settle out, making the finishing process longer, but a 3-in. bed of sand laid over the barrier will alleviate the problem. (You can also lay down the barrier before the gravel is brought in.) Either way, the long-term benefits of an unbroken barrier under the floor are well worth the temporary inconvenience of installation.

Because water usually comes into the basement through the walls and the footing/wall joint, the best place to capture and channel the water is at the junction of the floor and wall (see "Keeping the Interior Dry with a System of Drains and Pumps" on p. 128). The most efficient method is to install a plastic perimeter drain that sits on top of the footing and below the slab (see the photo on p. 126); this perimeter drain collects any water that seeps in through the walls. In retrofit jobs, the first 6 in. of slab perimeter is cut away to expose the footing; once the drain is installed, the slab is patched. There are many manufacturers' variations on this theme; I use a drain that I designed and now manufacture. Rectangular in cross section, it has a slotted opening facing the wall that channels water down and out toward the pump. The interior footing drain costs \$30 to \$40 per ft. in a retrofit. A less-expensive version of this system for new construction is known generically as a draining floor edging (see the photos on p. 130). It's a 6-in. by 4-in. L-shaped plastic flashing with a dimpled design. The dimples are laid against the wall and footing side and allow water to pass into the gravel below the slab, where it can be pumped out. You can find versions of these products through your local waterproofing contractor, or you can contact my company, Basement Systems®, at (800) 541-0487; www.basementsystems.com.

Foundation Drainage

BY DAVID BENAROYA HELFANT

In a hillside community of homes I once inspected, I found an interior stairway that rested on a “floating” concrete slab-on-grade. The owners of the house complained about the constant repairs needed to patch the drywall and baseboards that were connected to this stair. It seems that every time it rained, the stair would move up relative to the rest of the house. When the ground dried out, the stair sunk.

The problem was that the stemwall foundation around the house was poorly drained, resulting in an inconsistent moisture content in the soil under the footings and allowing runoff to migrate beneath the slab some distance from the exterior stemwall. The slab was placed atop the undrained clay-laden soil, and there was negligible weight on the slab. Every time it rained, the clay expanded, taking the stairway for a short ride upward, tearing the drywall joints, and wracking the baseboards, railings, and casings out of alignment. The remedy to the situation was the placement of a drain uphill from the slab that diverted the water away from it.

The objective in designing and installing drainage systems around the perimeter of a foundation is to keep water from soaking into the soil and moving under the footings. Water initiates the undermining of a foundation by causing erosion beneath it, literally carrying away the soil on which the footing

If your house is on a hillside made up of soils that drain poorly, such as clay, subsurface drains can be essential to the long-term well-being of the structure.

bears. Often this is the prelude to building settlement. If the soils have a high clay content, poorly drained foundations can be cracked or rotated by forces exerted by the wet clay as it expands (see the photo on p. 134).

If the grade around a house is well sloped, you may not need a subsurface drainage system. But if your house is on a hillside made up of soils that drain poorly, such as clay, subsurface drains can be essential to the long-term well-being of the structure.

In most cases, a structure won't be threatened with a terminal illness brought on by bad drainage, but it can suffer an abundance of minor maladies. A damp crawl space can cause mustiness, mold, and mildew in a house, and fungus wood rot and termites thrive in this kind of environment. Soils under foundations that undergo dry/soggy cycles can bring on the familiar phenomenon of sticking doors and



GOOD DRAINAGE IS ESSENTIAL for foundations built on heavy clay soils to avoid cracking and rotating.

windows. While good site drainage may not solve all moisture problems (such as condensation), it can be effective in combatting cyclical changes, such as the floating-slab phenomenon described earlier.

System Basics

An effective drainage system consists of two distinct systems: a subsurface drain to carry away the flow of ground, or subsurface, water and a surface drain

to convey rain or snowmelt away from the building (see “Section through Drain Lines” on the facing page). The core of any subsurface drainage system is a network of perforated pipes laid at the bottom of trenches next to or near the foundations, and sloped to drain toward a suitable receptacle. The pipe is laid with the perforations pointing down, so that water seeping into the trench from below will rise into the pipe and be carried off. Above the perforated pipe is

a run of unperforated pipe that is used to transport runoff from roofs, patios, walkways, and other paved surfaces (see the photo on p. 136). Typically, these pipes will lead to a dumping site 10 ft. to 20 ft. downhill from the house (more on this later).

You may ask, Why can't I just run my downspouts into the subsurface drain and do away with the surface drain? Don't do it. Combining the two increases the potential for a clogged line, and it defeats the purpose of a subdrain by injecting water into the ground.

HOW MUCH FLOW WILL DETERMINE THE TYPE OF PIPE TO INSTALL

For most residential drain lines—both surface and subsurface—we use 3-in.-dia. pipes. But if we're working on a hillside where we expect heavy flows, we'll install 4-in. subsurface lines. If a large roof area is draining into a single downspout, we'll play it safe and install a 4-in. surface drain line to carry the runoff.

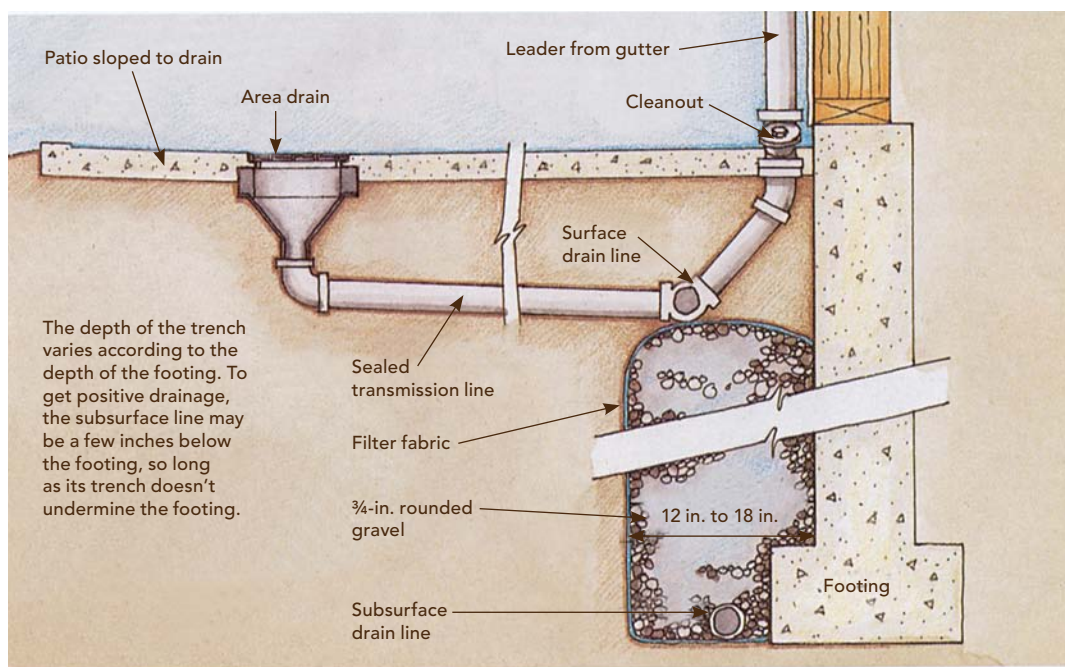
Pipes and fittings for drain lines are quite similar to those used for drain, waste, and vent (DWV) work, but the fittings don't come in as many con-

figurations and the pipes aren't as heavy. They also cost less—40% to 50% of what corresponding DWV materials cost.

We prefer to use smooth-wall pipe and fittings made of polyethylene plastic for subsurface and surface lines. This is a fairly rigid pipe that can be cleaned by an electric snake without being diced up from the inside out. We specify pipe that is rated at 2,000 lb. of crushing weight. This is important because subsurface pipes are often buried well

An effective drainage system consists of two distinct systems: a subsurface drain to carry away the flow of ground, or subsurface, water and a surface drain to convey rain or snowmelt away from the building.

SECTION THROUGH DRAIN LINES





TWO PIPES. To drain a structure, remove subsurface water moving through the soil as well as runoff. The perforated pipe at the bottom of the trench (holes oriented downward) carries off the former. The top pipe carries away surface runoff from downspouts and drains. The pipe stub projecting above the tamped earth will attach to an area drain.

beneath the surface, and we usually compact the earth above them. Where the line passes under a sidewalk or a portion of a driveway that will carry traffic, we switch to cast-iron pipe and link the two materials with no-hub couplings.

When we can't get the polyethylene pipe, we use polystyrene pipe instead. But this material is brittle, which makes it tougher to assemble the fittings and pipe sections. We never use clay-tile pipe, which comes in 12-in. to 16-in. sections that butt against each other. There are too many opportunities for sections to move differentially. Nor do we use the thin,

corrugated polyethylene pipe, because an electric snake can rip it apart if a line needs augering to clear a blockage. Its weak walls make it suspect for deep trenches, and its fittings do not seem to seal well.

In deep systems where it is necessary to carry large volumes of water, corrugated galvanized-steel or thick-walled ABS or PVC pipe may be preferable. Under these conditions, you should consult a geotechnical engineer for specific recommendations regarding dimensions and types of pipe.

INCLUDE CLEANOUTS FOR EASY CLEANING

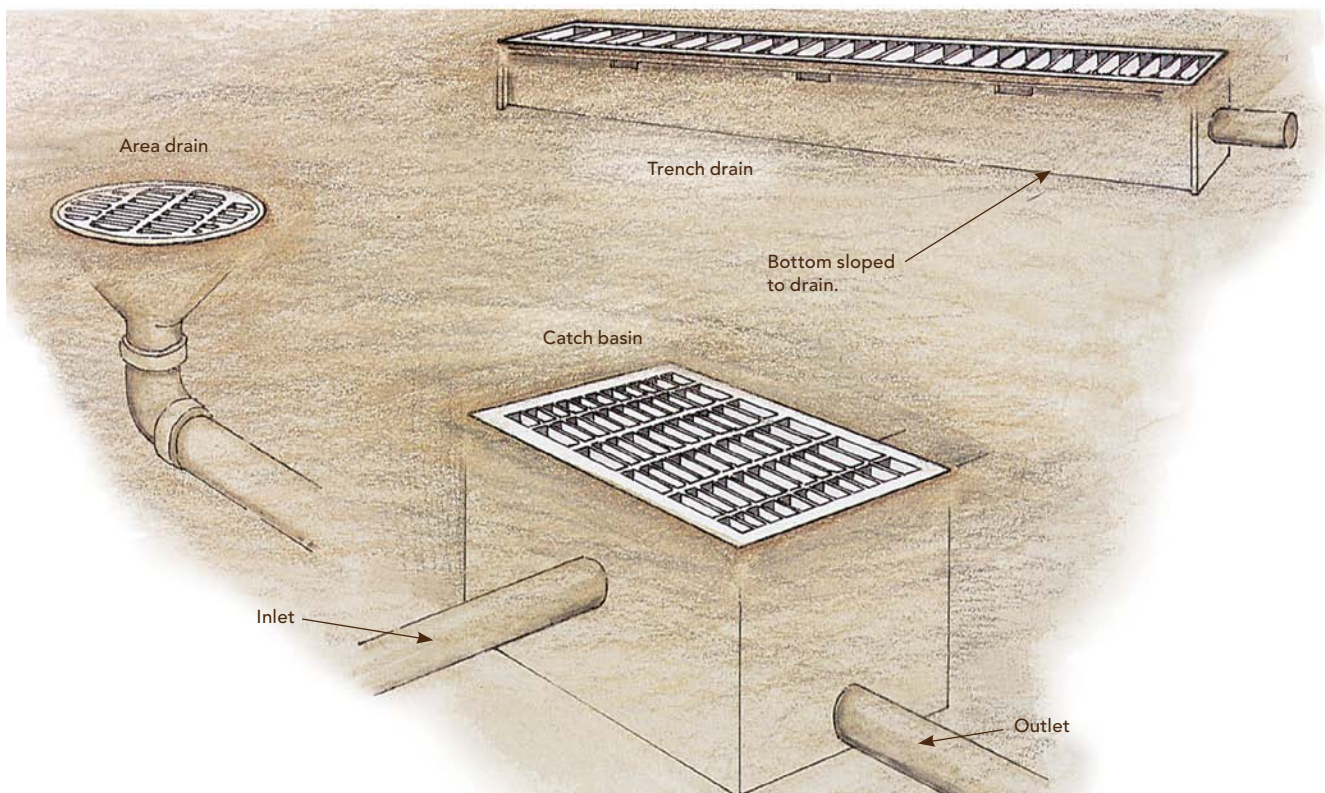
All of our drainage systems are designed with cleanouts, similar to conventional waste-line plumbing systems, so that the system can be cleaned with an electric snake. We put them at 30-ft. to 40-ft. intervals on straight runs and at strategic locations elsewhere: major bends, intersections with other lines, and the point at which downspouts enter the surface-water drain system (a prime target for a leaf clog). We always cap the cleanout with a plug so that it does not collect debris.

We handle surface-drain flow either with an area drain, a catch basin, or a trench drain (see the drawing below). The first two are concrete, alloy, or plastic boxes that have metal grills to keep debris out of the systems. The area drain is connected to a leader that ties into the surface drain line (see the drawing). A catch basin collects water from several surface drains and feeds it into a single outlet. A catch basin is also deep enough to allow sand and soil to fall to

the bottom, where they collect without interrupting the water flow. These “fines” settle into a sludge that should be removed periodically. Trench drains are long, narrow steel, plastic, or fiberglass boxes with grills on them. You see them at the base of driveways, where they catch the water before it inundates a garage that’s downhill from the street. We usually install the ones made by Polydrain® (ABT,® Inc.)

Tools of the drainage trade are neither mysterious nor high-tech. They include picks and shovels as well as pneumatic and electrical demolition and digging tools to break up the earth. Good wheelbarrows are essential. We recently acquired a Takeuchi® tractor, which has a backhoe and an auger attachment. It speeds up excavation considerably, but in some cases, even a little tractor like this is tough to maneuver. Therefore, drainage work on steep hillside tends to be labor-intensive and impossible without a conscientious crew.

SURFACE DRAINS



Putting It in the Ground

Naturally it's best to think about controlling subsurface water in the planning phases of a new construction project. The pipes can be installed alongside the new footings before the trenches are backfilled. But I can assure you, plenty of houses have been built with inadequate systems for controlling ground water, if any at all. The methods for assembling a system during new construction are the same as that for a retrofit—it's just a lot easier to do it before the foundation trenches are backfilled and the landscaping has taken root. We find that it costs two to three times more to install a drainage system around an established house than it does to add drainage around a new house. The photos illustrating this chapter show a couple of typical retrofit installations.

BEGIN WITH A TRENCH

When we can get the tractor into place, we begin a job by trenching alongside the foundation (see the photo on the facing page) until we've reached the base of the footing without undermining it. In the project shown in the photos on p. 140, the house was cut into the hillside to create space for a garage, and the cast-concrete foundation and the stairs to the side yard were gradually being shoved east by the swelling of the clay-laden soils. When this house was built in the 1920s, the builders had included foundation drain lines. But they were cast-iron pipes installed a foot or so below grade. When we found them, they were rusted out, clogged with mud, and totally useless. We also found lines as we trenched along the back of the house and hit water at about 5 ft., which was 4 ft. above the level of the garage slab.

USE FILTER FABRIC TO PREVENT CLOGGED PIPES

Before we laid pipe in our trenches, we lined the trenches with geotextile fabric. Also known as filter fabric, this material is made of either woven or spun-bonded polyester or polypropylene fibers. The purpose of the fabric is to keep the fines in the soil from

It costs two to three times more to install a drainage system around an established house than it does to add drainage around a new house.

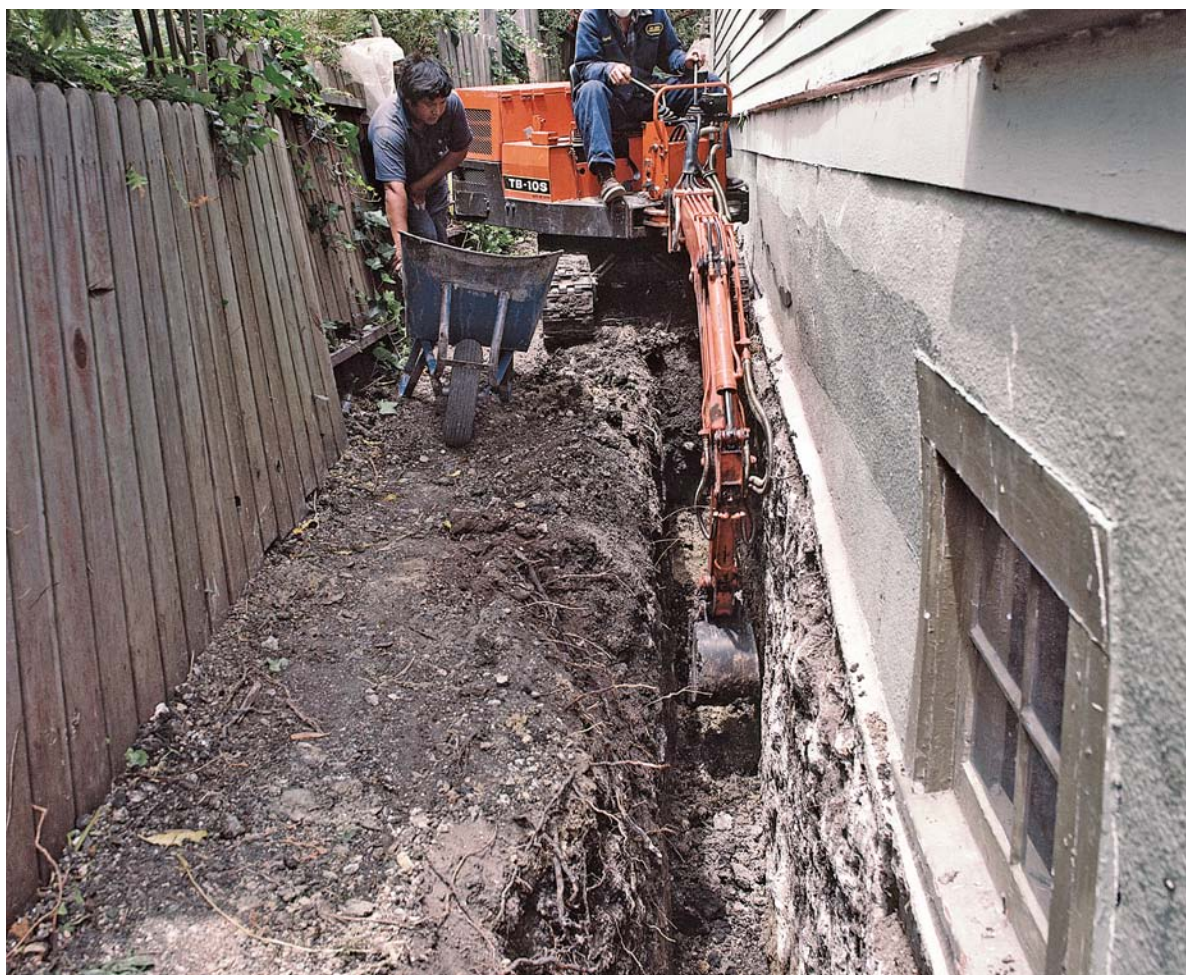
migrating into the gravel backfill, which eventually would clog the drain line. We use a 4-oz.-per-yard, spun-bonded fabric designed for soils that don't have a lot of silt in them. Under some conditions, soils that have high sand and silt contents can clog filter fabrics, so if you're in doubt about the makeup of the soil, have a soils lab test its constituents so you can choose a fabric accordingly. Filter fabric is remarkably tough stuff. To cut it, we use sharp sheet-metal shears, but a sharp razor knife will work. We buy the fabric from a local vendor that supplies products related to concrete work. If you can't find filter fabric locally, two companies that make it are Mirafi® and Hoechst Celanese Corp.

Before the fabric is down, we sometimes add a thin layer of sand to smooth out the bottom of the trench. This keeps the pipes from getting flattened at the high spots when the gravel backfill is placed. But if the bottom of the trench is pretty uniform, we skip the sand.

LAY THE PIPES

The pipes have to be sloped at a minimum of $\frac{1}{8}$ in. per ft. For shallow trenches that have relatively short runs—say 40 ft.—we'll use a 4-ft. level with gradations on the bubble that read slopes of $\frac{1}{8}$ in., $\frac{1}{4}$ in., and $\frac{3}{8}$ in. For longer runs, or deeper trenches, we use a transit and a rod to check the slope.

We cut pipes with a hacksaw, and for the most part, we rely on press-fitting the parts because they usually go together with a satisfying snugness. If so, we don't bother gluing them. But if they seem loose, we swab them with the glue supplied by our vendor



RETROFIT DRAINAGE WORK begins with excavation of a 12-in.- to 18-in.-wide trench to the base of the footing.

for the particular kind of pipe and wrap them with duct tape as a further hedge against separation during backfilling.

USE CLEAN GRAVEL TO FILL THE TRENCH

When all the subsurface lines are in place and their cleanouts have been extended above grade, we fill the trench with gravel to within a foot of grade. This gravel should be clean $\frac{3}{4}$ -in. material. If you are applying polyethylene sheeting to the foundation as a moisture barrier, use rounded rock. Crushed rock has sharp edges that will damage the poly. Otherwise, crushed rock is usable and probably cheaper. Don't use road-bed mix, though, because it has too

many fines in it. Gravel in place, we wrap the fabric over the top like a big burrito.

Atop all this goes the unperforated surface runoff lines. While we usually position them about a foot below grade, they can be placed lower, if necessary, for positive drainage or to protect them from the gardener's shovel. The surface runoff lines are sloped at least $\frac{1}{8}$ in. to a foot. Leaders from the rain gutters are connected to the surface lines by way of plastic fittings that are square on one end to accept the leader, and round on the other. At each leader entry, we place a wye fitting for a cleanout, and at the highest elevation of the surface drain line we position a pair of cleanouts (see the right photo on p. 140).



YOU KNOW YOU'VE GOT A SUBSURFACE WATER PROBLEM when your basement is 9 ft. below grade, water is 5 ft. below grade, and the remains of your drain line are 1 ft. below grade. It can be seen in the center of the photo, on the trench's right bank.

Usually the surface line and the subsurface line will drain to daylight at different places, but we sometimes combine the two if we need to go under a sidewalk with a line. In this case we make sure the intersection is at least 20 ft. downhill from the structure to minimize the chance of a blockage that would cause water to back up into the subsurface line. And we include a cleanout.



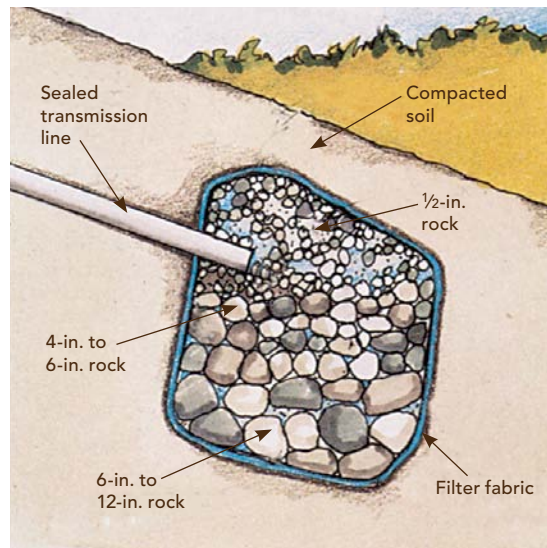
AT THE HIGH END OF THE SYSTEM, cleanouts should be installed allowing access in both directions. Shown here is the subsurface line—the surface line will also need cleanouts.

FINISH THE JOB

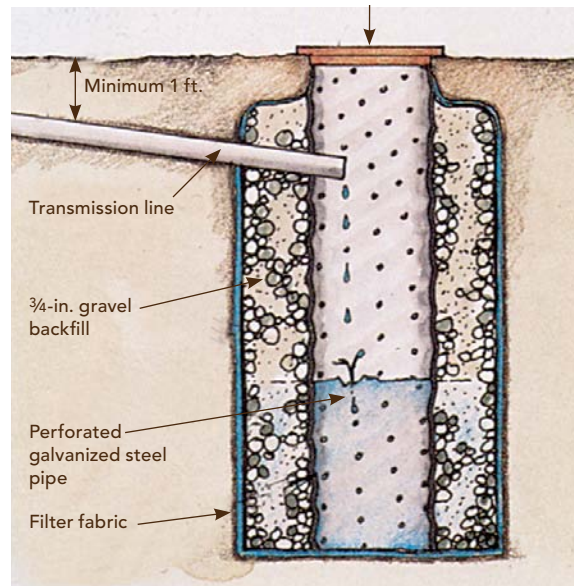
To finish the job, we will either compact a layer of soil on top of the buried lines or cover them with more gravel if the surface is likely to get heavy run-off. Road base is usable here. It's probably overkill, but I think it's best to top the system with some type of paving—either a poured-concrete cap or individual pavers that direct the water away from the building.

OPTIONS FOR RUNOFF DRAINAGE

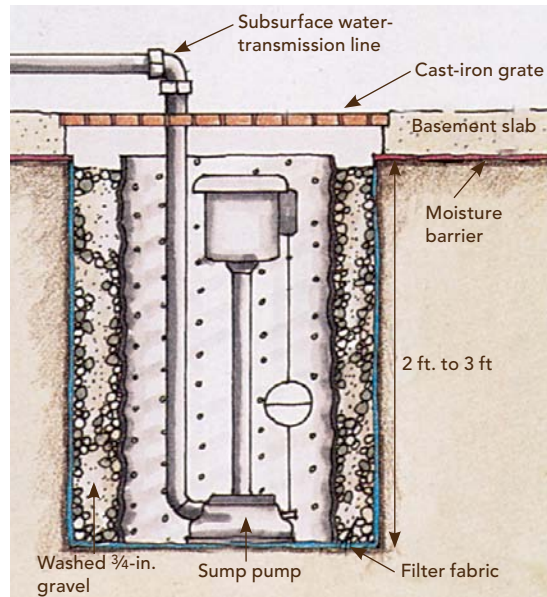
Energy-dissipation basin



Dry well



Sump pump



If you're unsure about the stability of the soils at a likely water-dump site, you should consult a soils engineer.

put your storm drainage on your neighbor's property. In the latter case when you're on a hill, sometimes the only appropriate solution is to secure an easement for a drain line that will discharge below both properties.

What to Do with the Water

The final phase in drainage work is doing something with all the water once you've got a system for collecting and rerouting it. Two guidelines are important to follow. First, if bad drainage is causing your property to deteriorate, then it's important to make sure that your depository doesn't cause the same problems, albeit in a different location. Second, don't

CONNECT DRAINAGE TO AN ESTABLISHED SEWER SYSTEM

In many places storm drainage must be put into established sewer systems dedicated to carrying runoff. Local jurisdictions vary on the hookups required. In some cities you simply daylight the drain lines at the curb sending the water to the storm sewers via the gutters, while other jurisdictions require a sealed hookup. Some will let you dump runoff into effluent sewer lines, but I've

found this to be the exception. Given the differing approaches, make sure you check with your local building department to verify local practices.

OTHER OPTIONS

If there isn't a municipal storm sewer to carry away the water that is collected, things get more complicated. Leach fields, energy-dissipation basins, and dry wells are three approaches to allowing the runoff to continue draining slowly, in a manner less likely to cause erosion and other related problems. But these strategies can concentrate an abnormal amount of water in one place. So if you're unsure about the stability of the soils at a likely water-dump site, you should consult a soils engineer.

If you have an open area with suitable soil, a leach field can be used to distribute the water back into the ground. Like a septic leach field, this requires a manifold of perforated pipes buried below grade. You run a sealed transmission line into one end, and the water will dribble back into the soil over a large area.

An energy-dissipation basin takes less space than a leach field. It usually consists of an excavation lined with filter fabric and filled with rock graded by size (see "Options for Runoff Drainage" on p. 141). The ones that we've done have been about 5 ft. square and 4 ft. deep. The graded rock is arranged so that the big ones are on the bottom where they can get a good bite into the hillside. A sealed line enters the basin, and its end should be buried in about 2 cu. ft. of ½-in. rock. Recently we had to convey a load of 4-in.- to 12-in.-dia. rocks 200 ft. down a hillside. We made staging areas at 60-ft. intervals and rolled rocks to them through taped-together Sonotubes®. The crew loved it.

Covered with a layer of native soil, an energy-dissipation basin can be made that will virtually blend into the landscape. But make sure you compact the soil before landscaping to avoid the inevitable settling that will occur.

If there is insufficient grade for positive drainage away from the building, a dry well (called a stand-pipe in the Midwest) could be your solution (see the drawing on p. 141). It is usually placed 15 ft. to 20 ft. from the house. When constructing one of these, we use an 18-in.- to 24-in.-dia. corrugated and perforated galvanized-steel pipe set vertically into an excavation roughly 4 ft. in dia. and 8 ft. to 10 ft. deep. The hole is lined with filter fabric, the pipe goes in the middle, and a collar of ¾-in. drain rock fills the space between them. A sealed transmission line from the drainage system sloped at ¼ in. per foot enters the dry well. It should be at least 1 ft. deep to protect it from shovels or a rototiller.

A dry well should be capped with a heavy, tight-fitting lid that is impervious to youngsters. I hasten to add, however, that dry wells are not appropriate alternatives in all situations. Installed on slopes, they may concentrate water where you don't want it, and could even create an unstable slope condition that might result in a landslide.

As a last resort, you can use a sump pump (see the drawing on p. 141) to lift water out of an undrainable situation. The sump pump goes in the deepest part of the basement and needs a reliable source of power. Two essential characteristics make sump-pump systems less-than-ideal solutions. For one, if they are installed within the home's footprint, water is still getting in or under the building. And two, they rely on manufactured energy, which is vulnerable to outages that typically occur precisely when you need the pump the most. But in some cases, a sump pump is the only way to get the water to an acceptable distribution system. Regardless of which system you elect to install, it's a recommended practice to keep good records showing the details (size, depth, location, cleanouts) of the system.

Keep Your Basement Dry with a Curtain Drain

BY ERIC NELSON

When it comes to unwanted moisture in the basement, an ounce of prevention is worth many gallons of cure. That's why I start solving basement water problems by looking at grade, gutters, and foundation cracks. Grade should be pitched away from the house. Gutters should be clean and should channel water away from the house. Foundation cracks should be repaired with mortar or masonry sealant. If you still have water problems, think about where the water is coming from: groundwater seeping up or surface water seeping down. For high water tables, an internal drain with a sump pump could be the answer. For runoff, a curtain drain is a great low-tech solution.

A curtain drain is a trench filled with gravel and a perforated pipe to channel water away from the house; line the ditch with filter fabric to increase its longevity. I avoid generic landscape weed-blocking fabrics, opting instead for a high-quality product such as Typar® landscape fabric (www.typarlandscape.com). Don't overlap the ends of the fabric close to the pipe. Instead, line the ditch sides with fabric, then fold the fabric over the gravel a few inches below the surface. Fine aggregate, such as silt, will be prevented from sifting down deep into the curtain drain and eventually clogging the pipe.

As long as you're digging up the yard, consider laying gutter drains in the same ditch, but don't connect gutter drains to the perforated pipe. Instead, run gutter pipe alongside the curtain drain. And don't gamble with your safety; call 811® (www.call811.com) before you dig to find out where utilities lines are buried.

It's Like a Gutter for the Foundation

When installed correctly, a curtain drain can intercept surface runoff and groundwater before it gets to the foundation. The water flows into a gravel-filled ditch that contains a perforated pipe pitched to promote good drainage. The ditch should be 18 in. to 24 in. deep and slope downhill. Terminate the drain in an area where flowing water won't create problems. Lining the ditch with filter fabric helps keep the pipe clean so that the drain works maintenance free for a long time.

Rigid 4-in. PVC perforated pipe is available in 10-ft. lengths; the straight and bell ends are glued together with PVC primer and cement, and laid with the bell end facing uphill. The 3,000-lb. crush strength meets almost all needs. For under-road or under-driveway applications, use SDR-35 sewer pipe.

cleanouts can prevent a big headache

It's a good idea to think ahead to the day when the drainpipe becomes clogged with some type of debris. If you use sanitary tees in the corners and add wye fittings in long runs (and mark them or photograph them), you'll be able to blast the system out with a power snake, which saves a lot of digging and pipe replacement.



Wye fitting



Sanitary tee

Flexible black plastic is less expensive than rigid PVC. Available in rolls with specialized fittings, flexible pipe is easy to work with, but not as tough as PVC. Be careful not to crush the pipe with rocks while backfilling. If you use flexible black-plastic pipe, don't clear clogs with a power snake or you could destroy the pipe.



Rigid PVC



Flexible black plastic



USE A LEVEL TO MAKE SURE THE TRENCH ISN'T. The trench should slope away from the center point to prevent puddling. Don't overdig because backfilling with uncompacted soil causes settling and low spots.



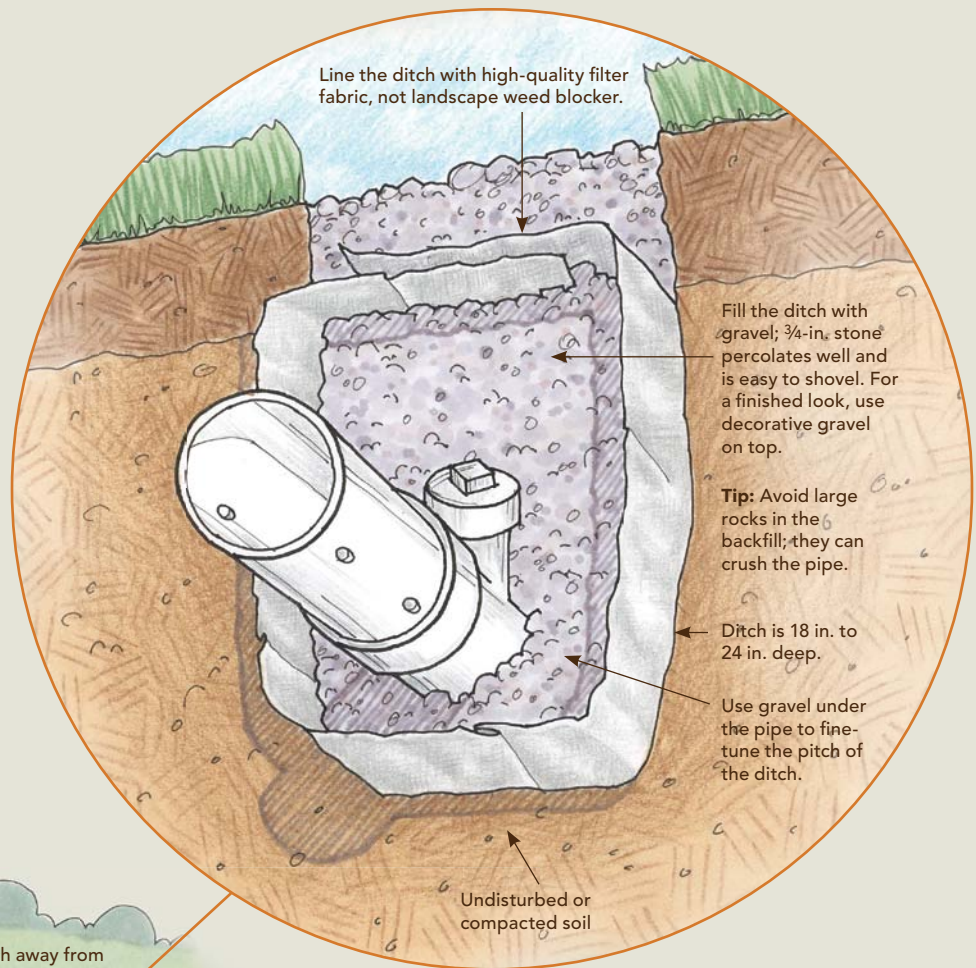
SET THE PIPE IN A BED OF GRAVEL. Filter fabric lines the trench to keep silty sediment from clogging the pipe. You can adjust the pitch of the ditch before laying the pipe by varying the thickness of the gravel layer.



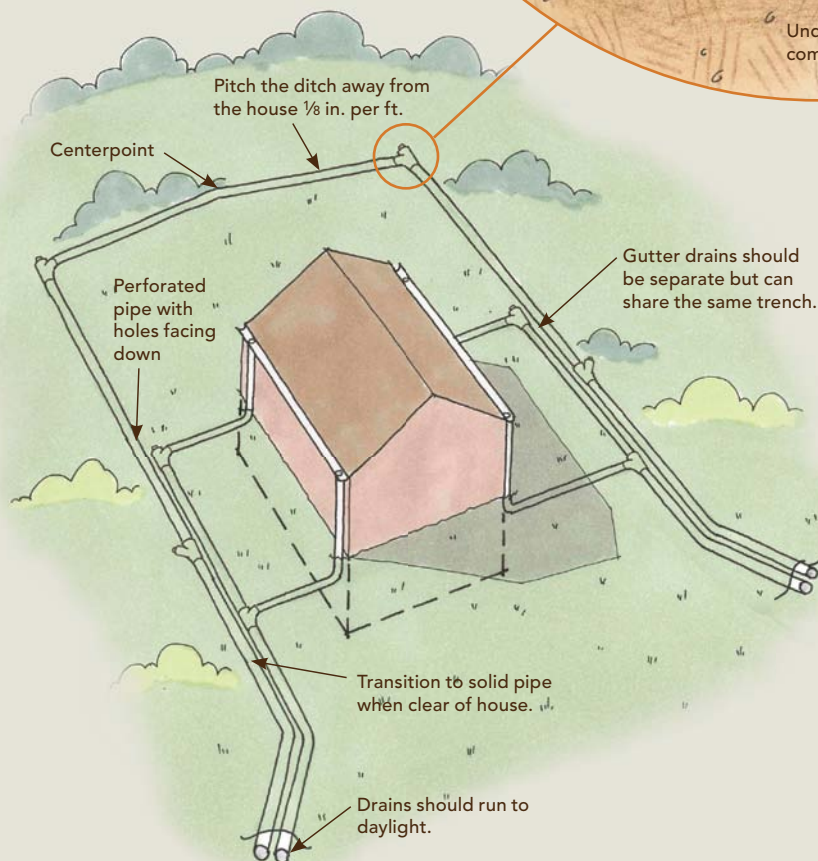
KEEP THE FABRIC NEAR THE SURFACE. The top layer of filter fabric eventually clogs. If that top layer is close to the pipe, you'll have to do a lot of digging to fix the problem. By folding the fabric over the gravel a few inches below the surface, you leave it accessible.



TOP THE TRENCH WITH GRAVEL. For a better look, you can buy decorative gravel that matches the landscape for the top layer. Where the underlying pipe is nonperforated (beyond the curtain drain and into the bulk-water removal), you can skip the top layer of gravel and plant grass.



CURTAIN-DRAIN PLAN



Sealing a Crawl Space

BY LARRY JANESKY

Dirt crawl spaces are never-ending sources of moisture. Even if the dirt's surface is dry, digging down a little bit reveals moist earth. Moisture ruins houses by providing a hospitable environment for the fungi, mold, and insects that destroy wood framing. Moisture in a crawl space affects not only the floor system directly above it but also the entire house. Warm air in a heated building rises. As it rises, replacement air is sucked from the lowest part of a house. This natural air movement, called the stack effect, is how chimneys work. Consequently, whatever is in the air at the lowest point eventually flows through the upper sections of living space (see the left drawing on p. 148). If mold spores and radon are present in the crawl space, you can bet they're in the living space as well.

Separate the House from the Earth

With little headroom, light, and habitability, the crawl space may not seem to be an important part of the house. In fact, it's very important. Moist crawl spaces may be a bigger problem than wet basements (see "Keeping a Basement Dry" on p. 122) because they can produce an unseen moisture stream through the building envelope.

To avoid moisture's negative effects, a crawl space should be fully sealed and isolated from the ground and the outside. Part of my technique involves placing a 20-mil, 7-ply sandwich of high- and low-density polyethylene with polyester-cord reinforcement on the dirt floor and up the walls. I have this pool-liner-like sheeting made specially for my system (www.basementsystems.com; 800-541-0487). It is easily strong enough to crawl on and to store materials on. Its bright white color makes the crawl space a light, relatively pleasant place to be (see the top photo on the facing page). A vapor barrier such as Tu-Tuf (Sto-Cote Products Inc.; 888-786-2683) also could be used, but it offers less durability, UV-resistance, and fire-resistance. Some contractors solve the problem of moist crawl spaces by pumping in concrete. But for this method to work, the concrete needs a vapor barrier. Even with a vapor barrier, this alternative doesn't address water-vapor diffusion through the walls. If the vapor barrier is doing all the work, then why use expensive concrete?

Despite what the building code says, many colleagues and I believe that venting crawl spaces is a bad idea. Code requires 1 sq. ft. of ventilation for every 150 sq. ft. of dirt floor. Using a vapor barrier over the dirt floor reduces the ventilation require-



Close the vents and let a heavy-duty vapor barrier keep moisture, mold, and radon out of the living space.

DRAMATIC TRANSFORMATION. Proper detailing changed this crawl space from a spelunker's nightmare (bottom photo) into a bright, clean, dry storage space (top photo).

if it's in your crawl space, it's in your house

As warm air rises inside the house, replacement air enters from the lowest part, often the crawl space. Properly sealing the crawl space and channeling rainwater away from the house can provide mold-free and radon-free living spaces.

PROBLEMS

A. Roof runoff and improper grading allow water to collect, where it can enter the crawl space through cracks in the foundation walls.

B. Humid summer air enters the crawl space through foundation vents and condenses.

Crawl space dampness can breed mold in living spaces.

C. Radon rises through the soil, into the crawl space and ultimately into the living space.

SOLUTIONS

A. Roof runoff is directed away from the house with gutters and proper grading.

B. Sealing foundation vents keeps humid air out of the crawl space.

Dry crawl space discourages mold growth in living spaces.

C. A sealed crawl space keeps moisture from the ground out and passively mitigates radon. In tough cases, a PVC pipe and inline fan exhaust radon outside.

ment to 1 ft. per 1,500 sq. ft. of floor space. The intent is to vent out the humidity that the exposed earth lets in.

But venting creates its own problems. In winter, there's an energy penalty: cold floors and higher heating costs. In summer, vents actually admit moisture in the form of warm, humid air. Warm air can hold more moisture than cool air. Warm air entering a cool crawl space can reach its dew point and give up its moisture as condensation. Relative humidity, dew point and the stack effect combine to make crawl space vents more likely to compound a moisture problem than to alleviate it.

For these reasons, I close the vents outside and seal them from the inside with 2-in.-thick foam insulation and polyurethane caulk. And yes, I sleep well at night because I am doing the right thing for my clients.

Wet Crawl Spaces Need Drainage

In addition to water vapor, many crawl spaces leak groundwater. Such cases require a drainage system appropriate to the details of the crawl space. Outside, I make sure downspouts are directed away from the house. Inside, I grade to one corner and install a sump and a pump with a sealed lid. Groundwater that leaks in can make its way from the dirt floor into the sump and be pumped out (see "Got Water? Pump It Out" on p. 150).

If a lot of water is leaking in, I create a swale in the dirt at the perimeter to channel water into the sump more directly. As another option, I can trench in a perforated pipe around the perimeter pitched to the sump. To prevent the pipe from clogging with silt, I slip a filter-fabric sleeve over it. Except in cases where there's extreme flooding or where a concrete floor will be poured, I avoid using crushed stone on perimeter drains because it's heavy and it's hard to lug through small openings.

I do one more thing before installing the liner: clean the dirt. All sharp or large rocks are buried when I re-grade, thrown around the sump liner or removed along with any wood or other organic material.

Installing and Sealing the Liner

Once the crawl space is cleaned out and drainage issues are solved, I install the liner. The liner material comes in a 24-ft. by 50-ft. accordion-folded roll. It's much easier to handle the 105-lb. roll outside than in the crawl space, so I roll it out on the driveway to cut it to size (see the left photo on p. 151). I then fold and roll up the liner like a carpet, black side out, and bring it into the crawl space.

I start with a piece of liner wide enough to cover the floor from the center row of piers to the perimeter, and up to the top of the wall. Next, I cover the other three walls, making sure the liner is long enough to overlap the floor by about 1 ft. Then I cut the remaining floor piece. After I roll out the liner, I take off my boots for the rest of the job to keep the liner clean.

Now, I turn back to the walls. I cut the liner 2 in. from the top of the wall (see the top left photo on p. 152) and fasten it with nylon expansion fasteners (Outwater Plastics; www.outwater.com) that press in ¼-in. holes that I drill every 3 ft. or 4 ft. along the top edge (see the bottom left photo on p. 152). I install the fasteners 3 in. down from the top of the liner (see the top right photo on p. 152) so that I can pull down the liner to seal it to the wall with polyurethane caulk (see the photo on p. 153). Polyurethane caulk is the only caulk I use on my projects; it sticks to anything and lasts for ages. I use Bostik 916 (www.bostik-us.com; 800-726-7845) or Vulkem® 116 (www.tremcosealants.com; 800-321-7906).

I never seal the liner to the sill plate because doing so gives water vapor a path to the wood and can be a route for termites and other insects to get to the house framing. Leaving the liner 2 in. down from the top of the wall allows for a routine termite inspection.

At wood posts, I lift the weight with a hydraulic jack, if possible, and slide the liner under. If I can lift the post only a bit, I slide a piece of aluminum flashing under the post and seal the liner to the edges of the flashing with caulk. At masonry piers or columns, I cut slits and wrap the liner up 6 in. or so,

got water? pump it out

If gutters and exterior grading **won't** stop water from coming in, a trench, perforated drainpipe, and a sump pump may be required to move it out. A water-removal strategy could be one of the following scenarios.

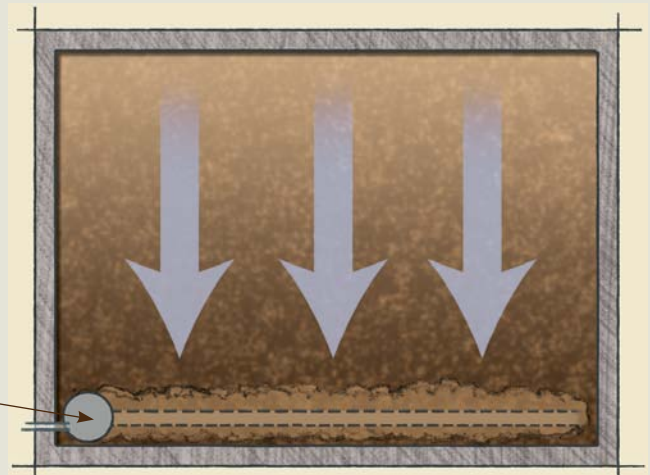
IF THE GROUND SLOPES TO ONE CORNER, install a sump in the lowest corner.



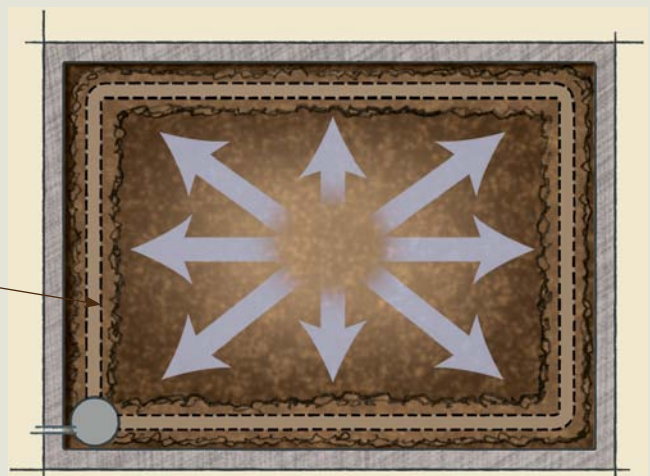
PLAN VIEWS

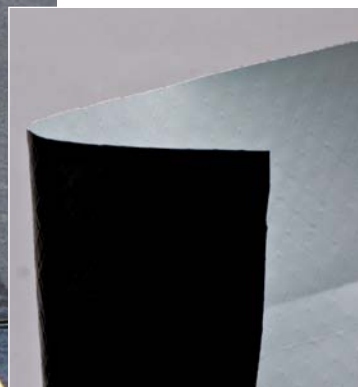


IF THE GROUND SLOPES TO ONE SIDE, dig a trench to channel water to the sump.



IF THE GROUND SLOPES MORE THAN ONE WAY, trench in a perforated pipe around the perimeter to carry water to the sump.





PLASTIC LINER IS MORE EASILY HANDLED IN THE DRIVEWAY. **After** the plastic is cut to size and rolled up, it can be installed in sections in the crawl space. The author has liner material custom-made, but lighter plastic such as Tu-Tuf also can work.

then caulk. At seams, I caulk under the overlap and use a 4-in.-wide peel-and-stick tape made from a matching material, which makes the seams disappear. A high-quality builders' tape such as Tyvek® tape (www2.dupont.com; 800-448-9835) also would work.

The finished system looks fantastic. My customers are pleasantly shocked when they see the end product. The white color reflects light, and it's clean and mold free. Indoor-air quality is improved, and the crawl space can be used for storage.



TO KEEP WATER AND INSECTS AWAY from floor framing, the liner is cut in place 2 in. below the top of the wall.



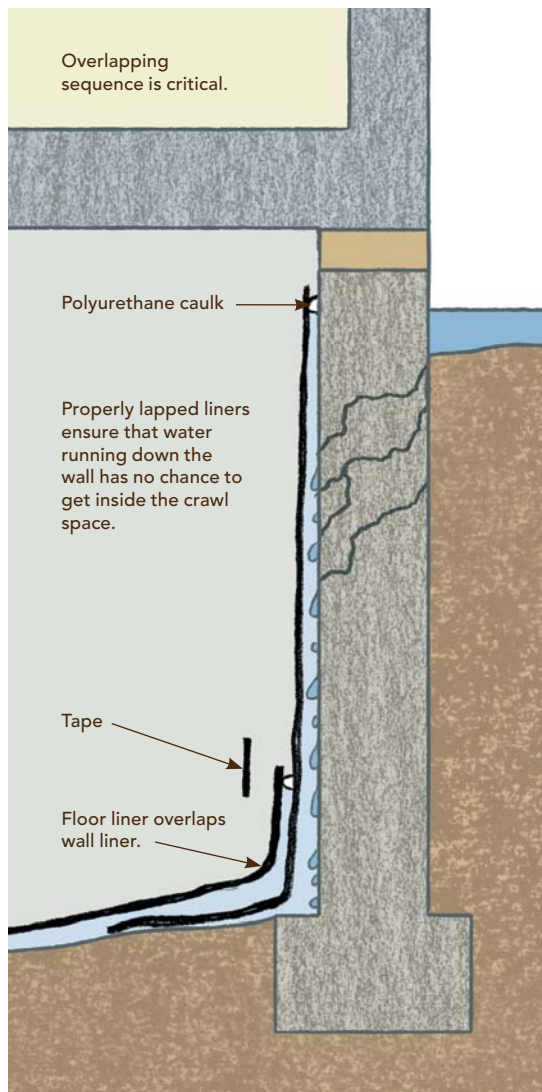
HOLES ARE DRILLED THROUGH THE LINER into the foundation (above), and nylon expansion fasteners are driven into the holes (top right).



SEEMS LIKE A SINGLE SHEET, BUT IT'S NOT. Overlapping seams of the liner sections are sealed with caulk and matching tape for a seamless barrier.



POLYURETHANE CAULK AND PLASTIC TAPE SEAL THE DEAL



damp crawl spaces can make your living room moldy

Almost weekly, we see news stories about mold spores. Molds and individual tolerances to mold species vary. Some mold has little effect other than an unpleasant odor, but some can be toxic (most notably *Stachybotrys chartarum*).

Mold needs organic material, moderate temperatures, and moisture to grow. Remove one factor, and mold can't grow. Of these factors, moisture is the easiest to control. Mold thrives in damp environments. Using a hygrometer, we routinely find humidity readings well above 50% in dirt crawl spaces. Some are as high as 80%. This is compared with readings around 27% in conditioned space. According to the Environmental Protection Agency (EPA), relative humidity should be kept below 60% (ideally between 30% and 50%) to control mold. Properly sealing a damp crawl space lowers relative humidity to within these levels.

For more information on mold prevention, contact the EPA Indoor Air Quality Information Clearinghouse (www.epa.gov/mold/index.html).



SEAL THE LINER to the
foundation with polyure-
thane caulk.

Retrofits and Add-Ons

- 155 retrofitting a foundation
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- 186 the stay-dry, no-mold finished basement
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Retrofitting a Foundation

BY BRIAN BROPHY

Replacing a house's foundation can be a daunting task, but the work can restore a home's structural integrity and make it last for another century or more. After having retrofitted several foundations, I've settled on doing as much of the work as I can. I've found the work to be easier than expected, and the more I do myself, the more I profit. That said, when the work exceeds my expertise or comfort level, I sub it out. In the end, a handful of subs work on each project, including an engineer, an HVAC contractor, and a house-lifting company. The contractor's job is to keep the job site safe and the work moving by hiring quality subs and communicating clearly with them.

Make the Choice to Retrofit

Most people would rather repair a foundation than replace it. However, certain situations call for a complete retrofit. In my experience, foundations fail mostly because they were not engineered properly for the soil conditions around the house. Common sources of failure include weak bearing soil, which is

RETROFITTING A FOUNDATION **begins with the disconnection of all utilities and the installation of steel I-beams, upon which the house will rest when lifted from the old foundation.**



project at a glance

This farmhouse sat in a 300-acre vineyard two hours east of San Francisco for more than 100 years. It had been passed down through generations of grape growers. The original brick foundation finally reached critical failure. The brick itself was in decent shape, but all the mortar had disintegrated.

- Location: Lockeford, Calif.
- Foundation length: 140 lin. ft.
- Foundation height: 6 ft.
- Type: Concrete replacing brick
- Project length: 15 days
- Project cost: \$45,000 (2011 prices)

GENERAL COST BREAKDOWN

- Engineer: 9% (\$4,050)
- HVAC/plumbing sub: 5% (\$2,250)
- Machinery rental: 10% (\$4,500)
- Material: 10% (\$4,500)
- House lift: 15% (\$6,750)
- Crew labor: 20% (\$9,000)
- Net income: 31% (\$13,950)



THE BEAMS ROLLED UNDER THIS HOUSE were lifted with individual 30-ton jacks. Some outfits use a unified hydraulic-jack system that raises and lowers the house evenly in one shot. Those systems require less labor, but the individual jacks that were used on this job work well, too.

Project Journal

My greatest strengths as a contractor are my own crew and the relationships I have with my subs. Here is an outline of who completed each step of the project and when they were on site. A job of this scale hinges on a variety of site-specific factors, but by implementing a similar schedule in your own foundation-retrofit project, you will be more apt to stay on deadline and within your budget.

DAY 1

Disconnect all the ductwork tied to the furnace and air-conditioning units.

- *Who's responsible:* HVAC subcontractor
- *What to look for:* Be sure that the subcontractor temporarily seals all the ductwork openings before demo. This will keep the ducts—and the house—free of dirt, dust, and debris. In older homes, this is also a good opportunity to analyze the performance of the heating and cooling elements and to replace them with more efficient models.

Disconnect electrical and plumbing runs to the main floor.

not capable of properly supporting the weight of the house, or poor soil compaction, which creates voids. (For more on soil problems and solutions, see “Soil: The Other Half of the Foundation” on p. 8.)

It is also important to pay attention to the foundation material itself. For instance, brick can deteriorate through a process known as spalling, and concrete can suffer sulfate attack, which can reduce its cohesion and strength.

Most of these failures can be detected visually, but I find it best to consult with an engineer whenever possible. An engineer can provide critical feedback that will steer the course of the work.

- *Who's responsible:* Contractor's crew (electrical), plumbing subcontractor
- *What to look for:* All the plumbing lines and electrical runs should be disconnected and secured so that they will not be damaged and so that they will not hinder the work under the house. If need be, remove any plumbing that will interfere with getting the beams in place. Plan to replace the gas and septic lines when the foundation is removed. It is unlikely that there will ever be better access to these lines again, so take advantage of the opportunity to do the work. There will be lots of activity on the job during this phase of the project. The order in which the subs are called doesn't matter much, but be sure they're scheduled so they're not forced to interrupt each other's workflow.

Build the cribbing necessary to support the structure, and install the steel I-beams with a crane. Lift the house with jacks, and stabilize it on cribbing.

- *Who's responsible:* House lifters



WE CREATE A TRENCH WIDE ENOUGH, about 6 ft., to allow the Bobcat to drive down to the grade of the slab. This makes removing the old foundation material a lot easier. It also creates a large, safe working zone for those building the new footings and foundation walls.

- *What to look for:* Be sure that the beams are placed in the correct position and that the load-bearing points of the structure are well supported. If the engineer has offered recommendations on beam placement, be sure that the house lifters' installation is in sync with that plan.

DAY 2

Begin the excavation work around the house.

- *Who's responsible:* Contractor's crew
- *What to look for:* Crew members should be comfortable with and capable of operating a rented Bobcat® and mini-excavator. Someone should dig by hand around critical elements like gas and sewer lines. Create enough space between the foundation and the edge of the trench to work safely. Take measures to reduce erosion and prevent rainstorms washing dirt into the basement. Move excess soil away from the trench and place silt fence around each dirt pile.

DAY 3

Excavation work continues.



consult an engineer

I always consult an engineer before I start foundation retrofit work. It would be easy enough to let local codes dictate the details of a project, but the codes in my part of the country are rather lax. I want to be sure that my job is done right and that my work reflects the specific demands of the site. An engineer helps me do that. My engineer offers guidance on everything from the temporary support-beam placement and footing construction to rebar and anchor-bolt placement.

Choosing the right engineer is imperative, but unfortunately, there isn't a formula to follow when deciding who is best. I've worked with the same engineer on every project, and the only recommendation I can offer is to find someone who has worked on house lifts before and whom you trust.

DAY 4

Begin foundation removal after all excavation is complete.

- *Who's responsible:* Contractor's crew
- *What to look for:* Use the bucket on the mini-excavator to pull down large sections. Use the Bobcat to haul away all the material and to make room for the new footings. Work carefully around any existing gas lines and sewer lines. Remove the bricks in these locations by hand with sledgehammers and wrecking bars, never with machinery.

DAY 5

Foundation removal continues.

DAY 6

Finish foundation removal and final cleanup of debris.

- *Who's responsible:* Contractor's crew
- *What to look for:* The job site should be clear of brick and any construction debris to make room for forming new footings.



IDEALLY, DAY 8 OF THE PROJECT WILL FALL ON A FRIDAY, as it did on this job, so that the footings can cure through the weekend.



ON THIS PROJECT, WE BUILT 140 LIN. FT. OF FORM using 2×4s for walers, 1½-in. plywood, and snap ties. You can certainly sub out this work, but building forms goes quickly. I've found that building forms costs less than hiring a concrete subcontractor to do the work.

DAY 7

Dig and form the new footings for the foundation stemwalls.

- *Who's responsible:* Contractor's crew
- *What to look for:* Be sure that the overall dimensions of the footings are code compliant and in tune with the engineer's recommendations. These footings are 24 in. wide by 24 in. deep and are reinforced with ½-in. rebar placed horizontally 3 in. from the top and bottom of the forms and vertically every 18 in.

For more information on building square and level footings and walls, click the "Site Work and Foundations" link under the "How-to" tab at Fine-Homebuilding.com.

DAY 8

Pour new footings.

- *Who's responsible:* Contractor's crew
- *What to look for:* The grade of the footings is determined and marked with a transit and chalkline when the forms are built. Be sure that the crew is following the proper grade. Also be sure that all the rebar is well supported; otherwise, it will sink

to the bottom of the form when concrete is poured and reduce the strength of the footing. Rebar can be set atop metal chairs or dobies or be suspended from above by wrapping the rebar with wire and attaching the wire to a furring strip nailed to each side of the form.

DAY 9

Build the forms for the foundation stemwalls.

- *Who's responsible:* Contractor's crew
- *What to look for:* Check to be sure that all the walls are plumb, square, and level. All the rebar should be in place in accordance with the engineer's recommendations. Before the concrete truck's arrival, new anchor bolts should be hung from the mudsills by attaching a nut to each bolt.

DAY 10

Formwork continues.

DAY 11

Pour foundation stemwalls.

- *Who's responsible:* Contractor's crew



I SPECIFY THE DRIEST CONCRETE MIX **that my plant will supply for optimum strength and that will cure properly in my climate, which usually demands the use of additives.** Drier concrete, however, sometimes leads to small voids in the wall after the forms are stripped.

- **What to look for:** The concrete truck should have clear access to the foundation. Concrete trucks weigh a lot and have the ability to cause substantial damage to driveways, buried sewer pipes, and septic tanks. Keep the truck on solid ground. Spray all the forms with a release agent. Minimize voids in the wall by ensuring that the concrete hose is at the bottom of the form, and by filling the form from the bottom up instead of letting concrete fall from the top. During the pour, shake the forms with a vibrating rod to help settle the concrete.

DAY 12

Strip the forms, and fill voids.

- **Who's responsible:** Contractor's crew
- **What to look for:** Use a trowel and masonry mortar to fill any honeycombing, or small voids between the aggregate. If larger voids form, patch them with a 3,000-psi concrete mix. The holes in the foundation that are left for beam removal will be patched later with a similar mix.

DAY 13

Lower the house onto the new foundation walls.

- **Who's responsible:** House lifters
- **What to look for:** The most critical error that can occur when retrofitting a foundation is having the



THIS WALL WAS DAMPPROOFED using a spray-on product called Pene-Krete® (www.super-krete.com). If using a dampproofing membrane, stop it 4 in. below final grade. Reduce installation errors by snapping a chalkline on the foundation wall at this height.

house lifters transfer the weight of the house from the beams to the new foundation too quickly. Let the foundation cure properly before the house is lowered, which may demand supplemental wetting over the course of a week if admixtures weren't used.

DAY 14

Patch access holes and reconnect all the mechanical, plumbing, and electrical systems.

- **Who's responsible:** HVAC subcontractor and contractor's crew
- **What to look for:** Assess the condition of all ductwork, plumbing lines, and electrical wires. This is the time to replace any damaged, dated, or questionable materials.

DAY 15

Backfill, compact, and regrade the soil surrounding the new foundation.

- **Who's responsible:** Contractor's crew
- **What to look for:** The final grade of the site should slope down and away from the new foundation. This ensures that surface water will drain away from the foundation instead of settling alongside it.

Replace a Rotten Lally Column

BY EMANUEL SILVA

As a restoration and remodeling carpenter in and around Boston, I get to work on a lot of old homes. The years have not been good to many of these old structures. Over the past 15 years, I've been called to address sagging floor joists and their support beams so often that shoring them up has almost become routine. Many of these older floor systems were supported by inferior, hollow Lally columns—steel pipes typically filled with concrete for increased durability and load-bearing capacity—temporary jack posts, and even tree trunks. To make matters worse, they were typically set atop equally inferior footings or on no footing at all.

By temporarily supporting and jacking up the beam just enough to loosen the existing column, I can create enough workspace to install a proper footing and Lally column. I don't attempt to fix sagging or otherwise unlevel floors (see "Why Shouldn't I Level the Beam?" on p. 165). My goal is simply to prevent further settling.

The house shown here has moisture problems as well, thanks to surrounding properties that channel rainwater toward its foundation. While the concrete Lally columns will likely survive occasional flooding, I decided to anchor them atop small piers for longevity. The process is roughly the same whether you want columns raised or set flush to the slab.



SAGGING FLOORS may be due to a failing column or the lack of a proper footing. In either case, you must temporarily support the beam and remove the old column.



A PROPER FOOTING AND POST add floor support that will never fail again.

Build Cribbing to Support Temporary Posts

When removing an existing column, it's imperative that the temporary supports are as strong as the new columns being installed. Because most of the homes I work on have slabs that are in poor condition, I try to spread the load by building cribbing. The cribbing serves as a strong, level base in which I can place screw jacks. With the jacks in place, I can use 4x4 pressure-treated posts to raise the beam safely. It's best to install these supports roughly 1½ ft. from the location of the new footing. This lends the support you need and allows comfortable working room.



START LEVEL, STAY STRAIGHT. Use small scraps of lumber to bring two 3-ft.-long 4x4 pieces of pressure-treated lumber to level. The next two pieces are stacked perpendicular to the first two. The top layer then is screwed to the bottom.

TWIST TO LIFT. Before cranking on the jacks, plumb the post and secure it to the beam with toenailed screws. If someone accidentally bumps into a post, it will stay put. Raise the jacks to relieve enough pressure on the old posts so they can be removed easily, but no higher.





MEASURE OUT, PLUMB DOWN, AND DIG. According to code, there must be a support column along this beam every 8 ft. Take measurements from the foundation wall, and mark them in the center of the beam. Then plumb down from each mark to locate the center of the footings. From this point on the slab, measure 1 ft. out in four directions. With a framing square, connect the points to create a 2-ft. by 2-ft. square. Use a cold chisel to score the perimeter line, and then use a jackhammer or a sledgehammer to break through the slab. Dig down 1 ft.

Punch a Square Hole in the Old Slab

This slab was in bad shape and, at 2½ in. thick, it was thinner than the slabs poured nowadays. From my experience, I knew that if a footing existed, it would be little more than stones thrown in a hole. I was right. Not all footings have to be rebuilt, though. Assess the condition of the slab, and look for signs that the home was built to high standards. When in complete doubt, dig.



why shouldn't i level the beam?

Wood, drywall, and plaster are viscoelastic. (Think of Silly Putty® as an extreme case.) They act elastically under short-duration loads and act plastically under sustained, long-term loads. As such, it is difficult to jack all of the sag out of a beam that has crept over the years unless it is done slowly over time.

Although it may be possible to bring a beam back to level, the question of whether sag should be jacked out of a beam is difficult to answer. It depends largely on the framing above the floor. If there are plaster or drywall walls above, then it may be possible to remove only a small amount of sag from the beam. Drywall and plaster creep over time and do not like to be moved. I have seen contractors literally jack a house off its foundation before getting any sag out of a beam.

If the beam is in an open expanse of floor, then raising it is an easier proposition. I have even recommended that contractors kerf stub-born beams in several locations. The beam, and subsequently the floor, then can be raised easily. The beam itself can be sistered up with additional lumber to restore its integrity.

—Rob Munach is a professional engineer in Carrboro, N.C.





Pour a Bombproof Footing

Because we wanted to elevate the new column's base above the slab, I incorporated a builder's tube into the footing to create a pier. I reinforced the pier with six pieces of #4 rebar. You can bypass this step if you'd like and install the posts so they're flush with the slab. To do that, simply lay a grid of rebar 3 in. from the bottom of the footing, and install another grid 3 in. from the top of the footing.

ADD CONCRETE. Make sure the soil is compacted. Then cover the bottom of the hole with 3 in. of concrete rated for 4,000 psi. Place two pieces of rebar parallel to each other on top of the wet concrete and 6 in. from each wall of the hole.



CREATE THE PIER SUPPORT. Into the wet concrete, set a 16-in.-long, 12-in.-wide builder's tube fitted with two pieces of rebar that protrude 6 in. from each side, and level it. The exposed rebar, which sits a few inches below the height of the slab surface, helps tie the pier to the rest of the footing.



FILL IT UP, AND SCREED IT AWAY. Pour concrete in and around the builder's tube until the concrete is slightly proud of the slab and the lip of the builder's tube. Push two 16-in.-long pieces of rebar into the pier—so that their top end is 2 in. to 3 in. below the finished concrete—before screeding off the excess concrete and feathering the surrounding concrete into the slab. During the pour, make sure you're maintaining center by checking the pier location with a plumb bob.

Install the New Column

I like to use 3½-in. concrete-filled Lally columns. Manufacturers say that the color—red or gray—is no indication of performance or application differences. A variety of cap and base plates is available. I use the standard plates that come with the columns from the lumberyard.

TIP: Hang a retractable plumb bob, such as this one made by Tajima (www.tajimatool.com), from the beam to mark the center of the footing. It can be raised when it gets in the way and lowered regularly to check center.



TAP IT INTO PLACE. After cutting the column to length (be sure to consider the thickness of the plates when measuring for length), place the column on the bottom plate. Add the top plate to the column, and tap the assembly into place with a sledgehammer. Check to be sure the column is plumb.





SECURE THE PLATES. Drill pilot holes through the screw holes of the bottom plate, and secure the plate with 3-in. Tapcon® screws or concrete anchors. Attach the top plate to the beam with 2½-in. lags, never with nails.



FINISH THE PIER. Remove the exposed builder's tube by scoring it with a utility knife where it meets the slab. Masonry caulk, such as Quikrete® Concrete Repair (www.quikrete.com), cleans up and protects the seam.

TIP: You can cut a lally column with a specialty column cutter. However, I find it easier to hold the column in place with a large pipe wrench and cut it with a pipe cutter that has the capacity to cut 4-in. pipe. I clean up the cut edge by chipping away any concrete with a cold chisel.



When Block Foundations Go Bad

BY DONALD V. COHEN

When people ask me what kind of house foundation I prefer—poured concrete or concrete block—I tell them to take a look at the Yellow Pages under “Waterproofing Contractors.” Here in southeast Wisconsin, where I work as a building inspector and engineer, such a search will turn up more than 50 companies specializing in repairing cracks and stopping water seepage in concrete-block foundations.

This is not to say that concrete-block foundations are always a bad idea. They can perform well with proper drainage and appropriate reinforcement, but these conditions are not always present. Gradually, time and the elements can undermine the health of a block foundation, even a well-built one, a fact I am reminded of when doing inspections for prospective home buyers. I constantly see wet basements, or foundation walls that have cracked, buckled, tipped, and sometimes even collapsed (see the photo on p. 170).

Soil Pressure Works against the Foundation

Most problems associated with concrete-block foundations can be traced to two related factors: improper drainage and the seasonal expansion and contraction of soil, which puts pressure on founda-

Concrete-block foundations can perform well with proper drainage and appropriate reinforcement.

tion walls (see “Soil Pressure Can Push a Block Wall off Its Footings” on p. 171).

Water seepage is the most common problem I see, but water-soaked soil around the foundation also imperils the structural integrity of the walls. When the ground freezes and thaws, pressure builds against the walls. Common failures are horizontal cracks along mortar joints where the wall has been forced in due to soil pressure. I usually find cracks like this between the third, fourth, or fifth courses from the top in a typical 10- or 11-course wall, which corresponds to the frost line. Often accompanying these cracks are other signs of failure: vertical shear cracks in the corners, step cracks following the mortar joints, and walls pushed off the mortar joint between the first and second courses of block. Unrestrained walls sometimes slide under the joists in response to soil pressure, tipping the wall out of plumb.



POOR DRAINAGE can lead to foundation walls that crack, bubble, or even collapse.

Water and soil cause other problems, too. Consolidation or settling of subsoil due to heavy rains, or a substantial loss of moisture in the soil, can undermine the foundation from below. This settlement may allow footings to drop, causing vertical and step cracks as well as tipped and cracked concrete floors. In some cases, this kind of settlement causes the walls to tip outward.

Look for Problems outside the Foundation

The first approach to fixing a wet basement is to correct the grades around the foundation so that water flows away from the walls. Make sure downspout drains, sump-pump discharge pipes, and storm sewers convey roof and surface water away from the

house. Low spots around the foundation are likely to collect water, so any depressions should be filled.

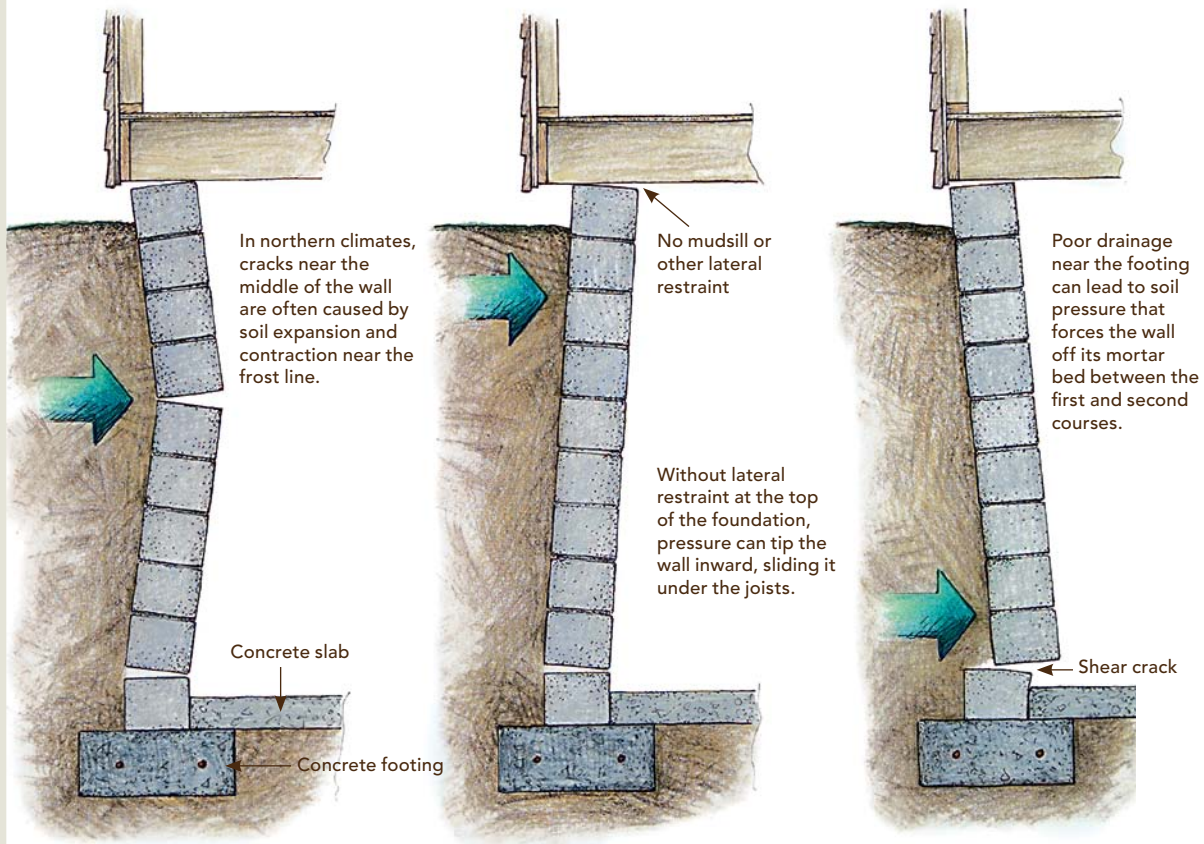
A wet basement may have a deeper source: the absence or failure of a foundation drainage system. For older homes with chronic water problems and no drainage system, the only solution may be to excavate the walls and install a perimeter drain. Clues that might indicate the absence of a drainage system are wet walls, lack of a sump pump, and no evidence of interior drainage or exterior discharge pipe.

Most foundations today, however, are required to have a drainage system that channels water away from foundation walls. (Residential foundation-drainage systems are generally required by code if seasonal groundwater levels are less than 6 ft. below the surface.) The drainage system—usually concrete tiles, perforated plastic pipe or tubing 3 in. to 4 in.

soil pressure can push a block wall off its footings

Without proper drainage, water gathers in the soil surrounding foundation walls, often finding its way into the basement. Sometimes disaster is unavoidable, as in the photo on the facing page, shot after a storm dumped 6 in. of rain in three hours. Other times, pressure builds slowly, particularly dur-

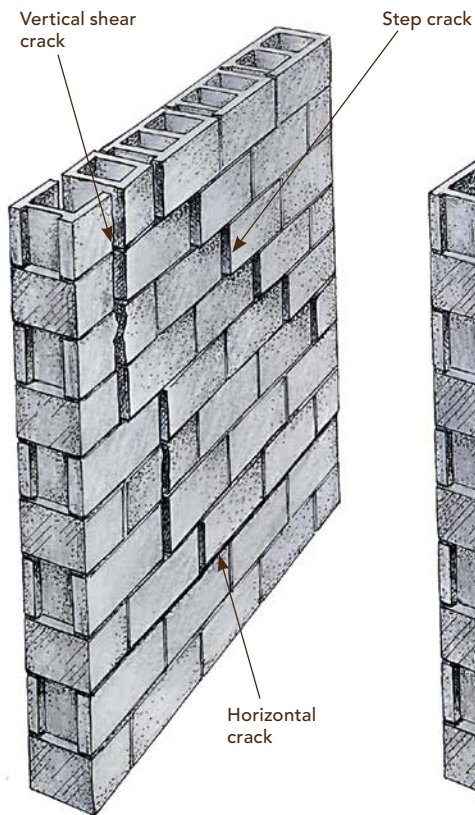
ing freeze-thaw cycles. The drawings below demonstrate how soil pressure can tip foundation walls inward, cracking the mortar joints. Any wall displaced more than 1 in. from a plumb position must be excavated. Walls displaced less than 1 in. can be braced from inside.



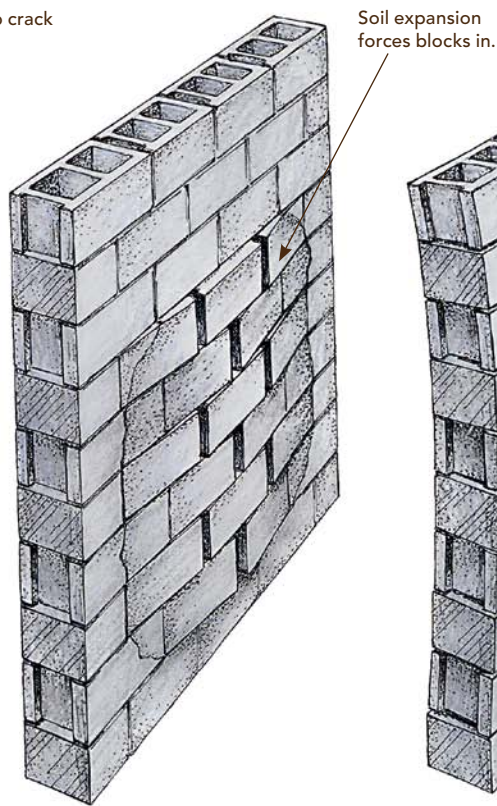
common failures in concrete-block foundations

Water accumulation and the seasonal expansion and contraction of the soil put lateral pressure on foundation walls. Without proper drainage, the pressure against a concrete-block foundation wall can create failures along mortar joints and cracks in the blocks themselves.

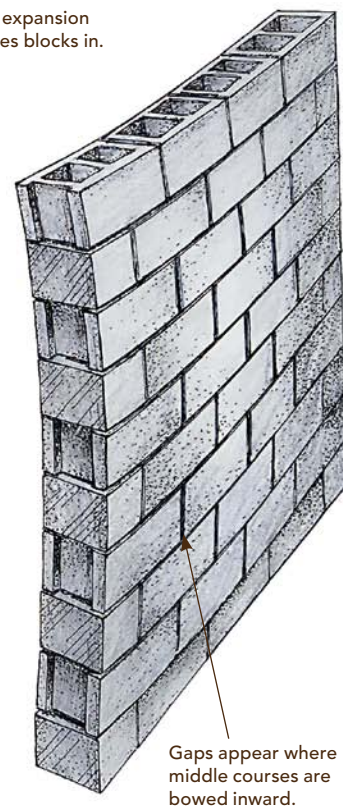
CRACKED WALL



BULGED WALL



BOWED WALL





IT'S EXPENSIVE, but sometimes excavating the foundation is the only way to fix chronic water problems and severely damaged walls.

in diameter—is placed along the perimeter footings and covered with crushed stone. The outlet of the drain system can be external (run to daylight somewhere on the lot) or internal (to a sump pump inside the basement). Many modern drainage systems use cross bleeders through the footings from exterior drainage pipes to interior perimeter drains underneath the concrete slab. The cross bleeders are usually spaced 8 ft. apart, starting 4 ft. in from a corner.

If you suspect a blockage in the drainage system (wet walls along the lower courses, for example), the repair can be as simple as breaking open the concrete floor in the corners and at the midpoints of each wall and flushing the drain tiles. If that doesn't work, you may have to cut open the floor around the perimeter of the basement and replace all the drain

tiles and flush all the cross bleeders. If water appears to be trapped inside the concrete-block core, drill a 1-in. hole through the face of the block along the top of the footing to allow any trapped water to seep into the opened drain tile. After the repair, cover the exposed tile with a 1-in. deep layer of stone, and replace the concrete level with the floor.

Bracing with Concrete and Rebar

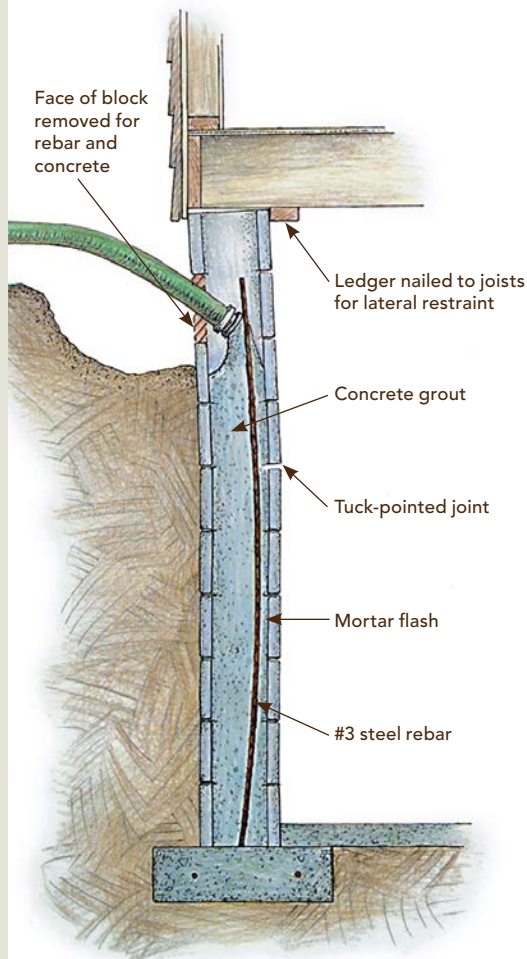
In addition to leakage problems, concrete-block foundation walls often display cracks, the early signs of failure. If the walls are fairly dry and if they have not been displaced more than 1 in. from plumb, it is possible to brace the walls without having to excavate the foundation. (The bracing must be designed by a licensed engineer.)

if you catch a problem early, you can brace walls without digging

Walls that are cracked but are displaced less than 1 in. can be braced against further movement. Two common bracing techniques are filling the cores with rebar and concrete and fastening steel columns to the floor joists and slab.

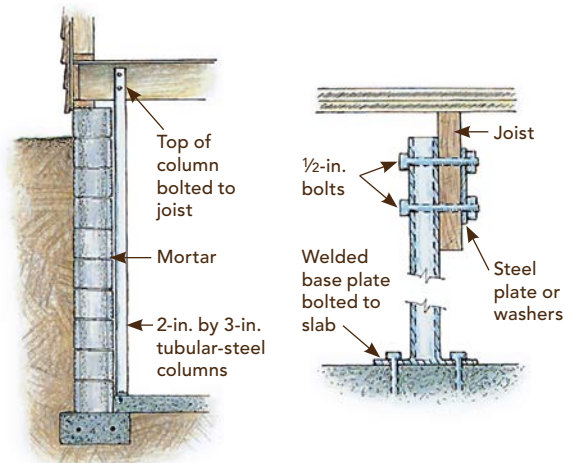
Reinforcing a wall with concrete and rebar

In this repair, rebar is threaded into the block cores, which are filled with concrete. A ledger strip nailed to the underside of the joists prevents the top of the wall from moving.



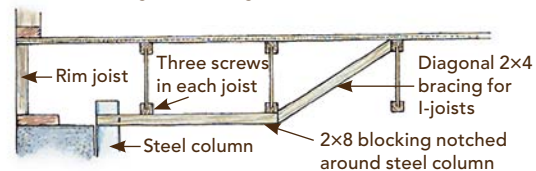
Steel columns provide bracing on the inside

Tubular-steel columns (spaced 32 in. to 48 in. o.c.) are bolted to the joists and slab to hold a cracked wall in check.



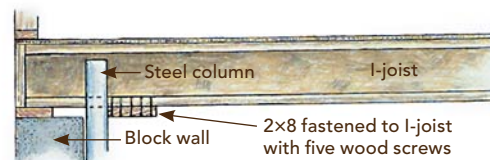
I-joists may need additional bracing

If the joists are parallel to the foundation wall, the blocking must be braced as shown below. I-joists require the addition of diagonal bracing.



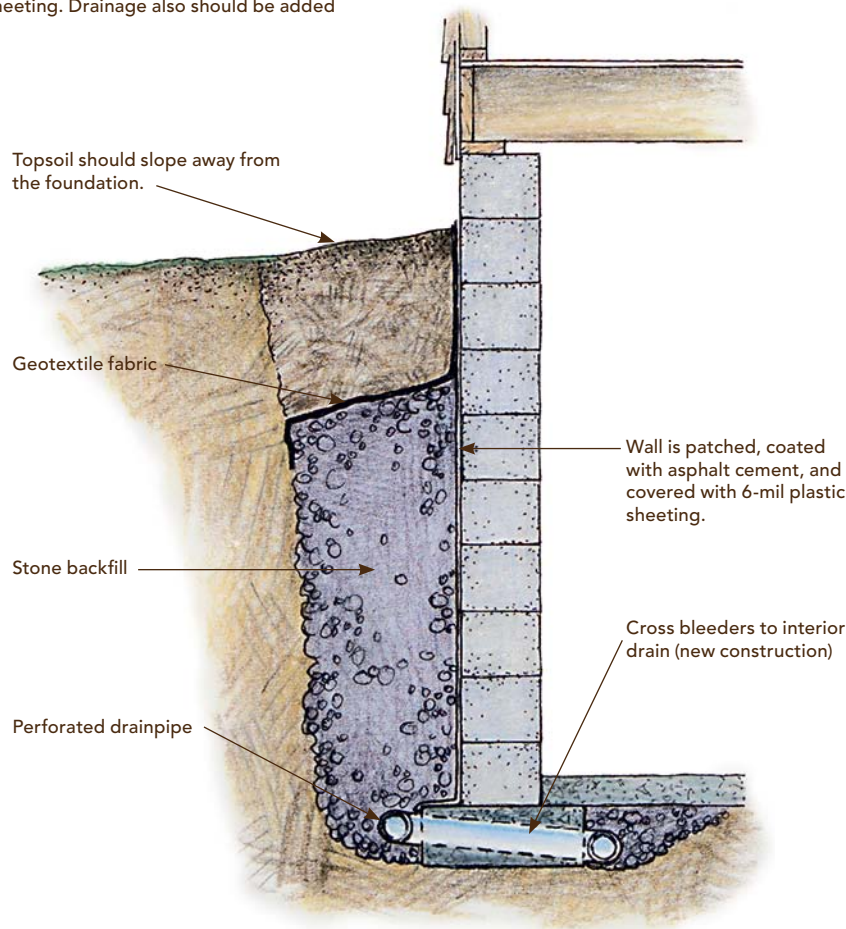
I-joists take braces instead of bolts

Wood I-joists require 2x8 blocking fastened to the underside of the I-joists to lock the steel columns in place.



EXCAVATION IS THE LAST RESORT

After the walls are replumbed and braced, and before backfilling, the exterior of the wall should be coated with fibrated asphalt cement, then covered with 6-mil plastic sheeting. Drainage also should be added at the footing if none exists.



There are two common bracing systems: (1) filling the core of the block with rebar and concrete and (2) installing steel tubing vertically from the floor joists to the concrete slab. Both methods help the wall resist soil pressure, sometimes (but not always) checking further movement.

The first method requires removing the exterior faces of concrete blocks near the grade line (not at the top), inserting #3 steel rebar into the block cores, and pushing it down to the footing (see “If You Catch a Problem Early, You Can Brace Walls without Digging” on p. 174). This can be done in every core or as much as 48 in. apart (I have seen it done both ways). The cores are then filled with a concrete slurry mix.

Keep in mind that this repair will not restrain the wall at the top and the bottom. The concrete slab—if it was poured without expansion felt—will provide support at the bottom. In new construction, a mudsill anchored to the wall (required by code) will provide lateral support at the top. But if there is no mudsill, as in many older homes, a ledger must be installed next to the wall and nailed into the underside of the joists.

Filling a block wall with concrete and rebar is fairly simple, but it has some drawbacks. The concrete tends to hang up on mortar flash inside the block cores, leaving voids in the wall. Another problem is threading 6-ft. long rebar into the core

through the open face of a block. I have seen workers cut the bar and drop the short pieces into the core as the concrete goes in, a method that compromises the strength of the repair.

Filling the core with concrete also causes problems if the wall fails again (if too few cores were filled, for example). A second failure may result in cracked or broken blocks, making it impossible to push the wall plumb. Sometimes, a repaired wall has to be excavated and rebuilt.

Steel Columns Reinforce Walls from Within

Another way to brace cracked walls is to install steel columns inside the basement that span the wall vertically between the footings and floor joists (see “If You Catch a Problem Early, You Can Brace Walls without Digging” on p. 174). This method is generally a cheaper alternative but does have one drawback: The columns will interrupt any smooth stretches of wall.

The steel columns should be at least 2 in. wide, 3 in. deep, with a $\frac{5}{16}$ -in. wall thickness and can be 32 in. or 48 in. apart for a standard 11-course basement. If joists run perpendicular to the foundation wall, the column is fastened to one side of the joist with $\frac{1}{2}$ -in. bolts through a steel plate or washers on the other side of the joist. (Wood I-joists require 2×8 blocking fastened to the underside of the I-joist to lock the column in place.)

If the joists run parallel to the foundation wall, the columns can be held in place with 2×8 blocking notched around the column and pressed firmly to the wall. The blocking should span at least two joist bays to provide lateral restraint. Again, wood I-joists require additional bracing.

For lateral support at the bottom of the wall, each column should have a welded-steel plate, which is bolted into the concrete slab or footing. Any spaces between the wall and column can be filled with a mortar grout. If there are pipes or conduit on the walls, they can be accommodated by notching the face of the column to fit over the obstruction,

although the notch should be limited to a depth of 1 in. Ductwork along the basement ceiling can be bypassed by welding a horizontal leg to the top of the column at the wall, and then a vertical piece to fit alongside the joist beyond the duct.

Excavated and Replumbing Walls

If water problems go unchecked, the accompanying seasonal expansion and contraction of soil can wreak havoc on foundation walls, sometimes causing severe displacement. Building-code officials here in Wisconsin require any foundation wall displaced 1 in. or more to be excavated and jacked back to plumb (see the photo on p. 173).

After the wall is excavated but before it is jacked or pushed back in place, cracked joints must be cleared of mortar to release the joint and to straighten the wall. With the wall replumbed, the joints must be filled with new mortar. It's important to remember that excavating a finished wall is not enough. Any wall that has been excavated and repaired must be braced or reinforced to prevent future failure. Once the excavated wall has been repaired and before it is backfilled, it's also a good idea to add a drainage system or to repair the existing one (see the drawing on p. 175).

Excavation can be an expensive repair. If there is a judgment call as to whether a wall needs to be excavated, as an engineer my decision depends on the extent of the cracking, the amount of moisture in the wall, the distribution of the building load and the character of the subsoil. Old brick-masonry walls 12 in. thick can bulge inward 2 in. and support a building. Concrete block, on the other hand, tends to fail under similar conditions.

In cases in which the wall was constructed out of plumb, a displacement of more than 1 in. might be acceptable, as long as there are no stress cracks. If the same wall is wet, however, excavation might be necessary to repair a drainage problem that might cause a more serious failure in the future.

a reinforced-concrete grade beam braces walls after excavation

For severely displaced walls, a Milwaukee-area contractor has developed, and patented, an alternative to traditional concrete-block foundation repairs. The repair involves excavating the foundation, inserting steel rebar into the core of the wall, and attaching the rebar to a horizontal, reinforced-concrete grade beam (as shown in the drawing below). The grade beam is designed to brace a damaged wall to prevent failure in the future.

The process is straightforward: After the wall is excavated and pushed back to plumb, exterior faces in the fourth course from the top are removed at 4-ft. intervals along the length of the wall. The bottom block below the top opening is also opened, and steel rebar is worked up and down inside the core to clear mortar flash at the joints. Debris can be removed from the opening in the bottom block.

With the block cores cleared of obstructions, steel rebar is placed in the cores. The rebar projects

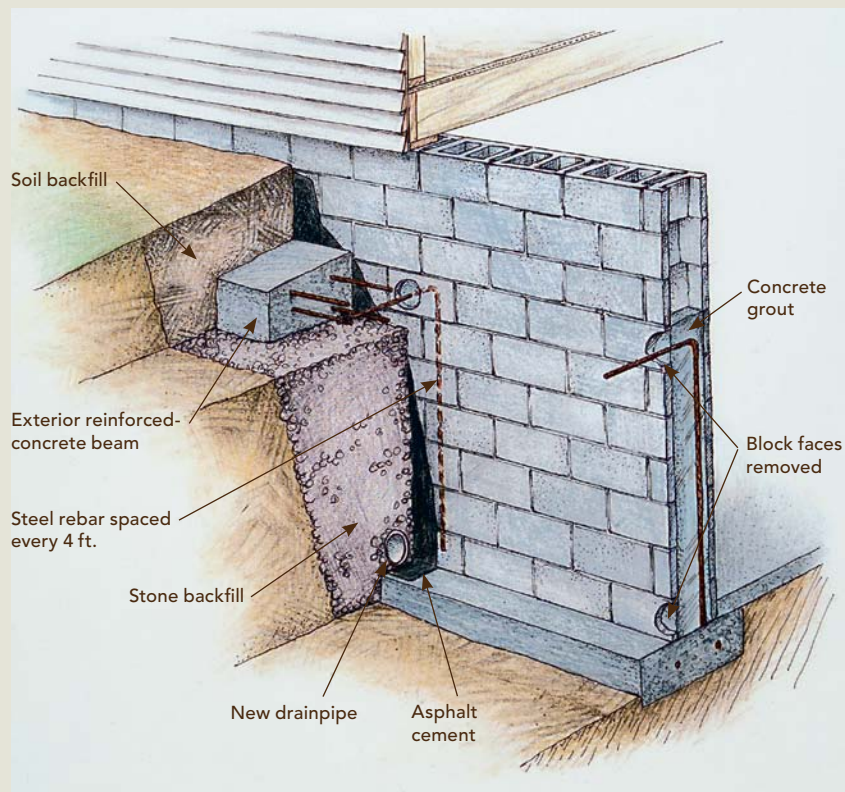
out of the block at the top opening perpendicular to the wall, where it intersects a reinforced-concrete grade beam running parallel to the wall. The cores are then filled with concrete, after which the foundation wall can be tuck-pointed and waterproofed, and new drain tile can be added.

Crushed stone is then added to within 6 in. of the projecting rebar. Then the 12-in.-high concrete grade beam is formed on top of the stone fill, sloped away from the foundation wall. (The width of the beam can be determined by an engineer but is never less than 12 in.) Soil fill can be placed over the beam to restore the surface to its original condition.

Although this is an extreme measure, the cost of this repair is competitive with other bracing methods. The benefits of a concrete grade beam are its strength and the fact that it does not disrupt the walls inside the foundation.

Patented Grade-Beam Repair

A displaced wall that has been excavated and repaired must be reinforced against future failure. One method is to excavate and install a concrete grade beam. The beam is connected to concrete and to rebar placed inside the block cores.



Protect Your Home with a Basic Seismic Retrofit

BY THOR MATTESON

Geologists estimate that the Hayward Fault that runs through the East Bay of San Francisco is due to give way at any moment. When it hits, the earthquake is projected to cause significant loss of life, to cause nearly \$165 billion worth of damage, and to leave hundreds of thousands homeless. The last major Hayward Fault earthquake was in 1868. Research shows that five major quakes have occurred along the fault—on average, every 140 years dating back to 1315. The 140th anniversary of the 1868 quake was four years ago.

As a structural engineer in the San Francisco Bay area, I specialize in helping prepare homes for seismic events. While I work to shore up homes in a very distinct region of the country, the basic lessons that you'll learn here—how to reinforce the floor framing, properly attach a house to its foundation, and construct site-built shear walls—are broadly applicable.

Keep the House on the Foundation

A seismic retrofit does not make your house earthquake-proof, but it does minimize potential damage to the house.

First, it keeps your house from sliding off its foundation. This is accomplished by using specialty

hardware to reinforce the transition between the foundation and the floor framing or wall framing. Many older homes are not bolted to their foundation adequately, and many floor systems aren't attached to the walls beneath them securely enough.

Second, a seismic retrofit prevents cripple walls—sometimes referred to as pony walls or kneewalls—under the home from collapsing. Most homes in my region are built atop cripple walls. In other seismic zones, like the Pacific Northwest, cripple walls aren't as common, so retrofits predominantly focus on strengthening floor connections to the foundation.

Site-built shear walls strengthen cripple walls and make them far less likely to collapse when the ground beneath them shakes back and forth.

In no way do these measures constitute a comprehensive retrofit for all types of structures. They are merely a starting point for creating a safer home. Brick chimneys, for example, pose a threat in many houses. Thousands of relatively new chimneys failed in the 1994 Northridge earthquake, despite having met code requirements in force at the time of construction. There is no economical way to strengthen a masonry chimney. The best solution is to remove the chimney and fireplace entirely. Gas water heaters in older homes should be secured with



STRENGTHENING A HOME in earthquake country means anchoring it to its foundation and adding site-built shear walls.

connect mudsills to the foundation



BORE. Use a 1/2-in. spade bit to bore a hole through the mudsill. With a rotary hammer and a masonry bit, drill a 1/2-in. hole 5 in. deep into the concrete foundation.



TAP. Hammer a 1/2-in. by 7-in. steel wedge anchor into the hole. The bolt should be fit with a 1/4-in.-thick, 3-in. by 3-in. plate washer.

HARDWARE. Hilti®: 1/2-in. by 7-in. Kwik Bolt; Simpson: 1/2-in. by 7-in. Wedge-All® and BP1/2-3 plate washer.



TIGHTEN. Use an impact driver or wrench to tighten the bolt. Wedge anchors have shear ratings of roughly 700 lb. in wood and perform well. Epoxy anchors are better but are needed only when the concrete is porous or deteriorated.

strapping (it's code for new homes), and automatic gas-shutoff valves should be installed to help prevent gas leaks and fire outbreaks after a big shake. Garage-door openings are a notorious weak point in a structure, especially when there is living space above them. Reinforcement of these large openings should be completed with the consultation of an engineer who can draft a site-specific approach, which may demand the integration of structural steel members.

Homeowners Beware

Knowledgeable engineers are invaluable in helping fine-tune retrofit measures to specific structures. Comprehensive retrofit methods are currently under development by volunteer groups of engineers and other retrofit experts. Until they are available, the only nationwide building code applicable to seismic-retrofit work is Appendix Chapter A3 of the International Existing Building Code® (IEBC). The IEBC has roughly eight details showing methods to brace cripple walls and connect them to footings or foundations. These same details have been repeated



WHEN SPACE IS TIGHT. Bolt a plate to the foundation wall and the edge of the bottom plate to prevent the floor system from moving along the foundation wall or footing. This particular plate has a shear rating of roughly 1,300 lb. *Hardware: Simpson: UFP10; KC Metals: RFA138.*

in several regional guidelines, with occasional diversification. The variety of existing framing conditions found in houses far exceeds the scope of these details. Also, some of the methods shown in these documents require precise installation to work.

To add to the problem, California has no specific licensing requirements or subdiscipline for earthquake-retrofit contractors. The Association of Bay Area Governments (ABAG) has offered training sessions on seismic retrofitting for contractors (or other interested parties), but current budget problems mean there is a backlog of people waiting for training. Given the scant selection of details in the IEBC, there is not enough training material to offer comprehensive instruction. The results, unfortunately, can be well-meaning contractors implementing retrofit strategies that may do nothing to strengthen your house during an earthquake

(see “Three Retrofit Methods That Don’t Work” on p. 183). The techniques presented here, however, are widely accepted practices and have been proven to protect houses during earthquakes.

Cost and Effectiveness

For the basic underfloor strengthening described here, installation costs in the Bay Area generally fall in the range of 1% to 3% of the value of the home (roughly \$3,000 to \$8,000 in 2011). In the Pacific Northwest, where retrofits are often simpler, a home can be strengthened for as little as \$2,000. Costs vary depending on the shape of the house, the height of the workspace, the number of obstructions to the installation, and other factors. Sometimes other concerns come to light during the retrofit that require additional work, such as deteriorated foundations, insect or rot damage, and water intrusion under the house.



SECURE FLOOR JOISTS to cripple wall top plates with shear-rated framing connectors and 8d nails. A positive-placement pneumatic nailer makes hardware installation fast. *Hardware:* KC Metals: HT10R; Simpson: H10R; United Steel Products: RT16A.

APA-The Engineered Wood Association cites a real-life comparison of an original versus a retrofitted house as a barometer of retrofit performance. An architect purchased two identical Victorian houses in Santa Cruz in the 1980s. He intended to strengthen both of them. Unfortunately, the 1989 Loma Prieta earthquake occurred when he had completed seismic-retrofit work on only one house. The retrofitted house needed roughly \$5,000 in repairs. The other house, whose collapsed cripple walls caused it to fall off its foundation, needed \$260,000 in repairs.

As earthquakes occur, we learn more about how various strengthening methods perform. Improvements likely will be found, but in the meantime, it's a safe bet to put yourself in the category of homeowners who strengthen their homes properly rather than the control group that does nothing or that employs ineffective retrofit measures.



CONNECT RIM JOISTS to wall top plates with shear-rated framing connectors. A palm nailer is an indispensable tool when securing hardware in hard-to-reach areas.

HARDWARE. KC Metals: CA50, CA70, CA90; Simpson: L50, L70, L90; United Steel Products: AC5, AC7, AC9.



Connect Mudsills to the Foundation

Dated building practices mean that older homes are the most susceptible to earthquake damage. For example, the Uniform Building Code did not require connecting the wood framing of a house to its foundation until 1946. Houses without good connections to their foundations can simply slide off them under the force of an earthquake. Newer homes also should be inspected to ensure that they are bolted down correctly. (See the photos on pp. 180–181.)

three retrofit methods that don't work

Until the 1989 and 1994 earthquakes in California, there was not much hardware specifically marketed for earthquake-retrofitting purposes. Until recently, contractors, homeowners, and even engineers had to invent their own techniques. Sometimes these methods are effective, but more often, they give only a false sense of security.

1 HOMEMADE HARDWARE

- **Retrofit:** Using angle iron to prevent wall from sliding off foundation.
- **Problem:** Custom-made connectors require costly custom engineering. This piece of angle iron will act like a lever when the wall moves and will shear off the bolts.
- **Solution:** Simpson's UFP10 hardware or anchor bolts are better suited for this application.



2 EXPENSIVE CONNECTIONS THAT DO LITTLE GOOD

- **Retrofit:** Attaching posts to girders with gussets or specialty hardware.
- **Problem:** For this connection to come loose, the floor framing would have to move quite a bit, which simply means you should have spent more effort strengthening the building perimeter.
- **Solution:** It's much more cost-effective to construct shear walls and to strengthen connections around the perimeter of the house to keep it in place than it is to spend money on expensive hardware connections between posts and girders in a crawl space.



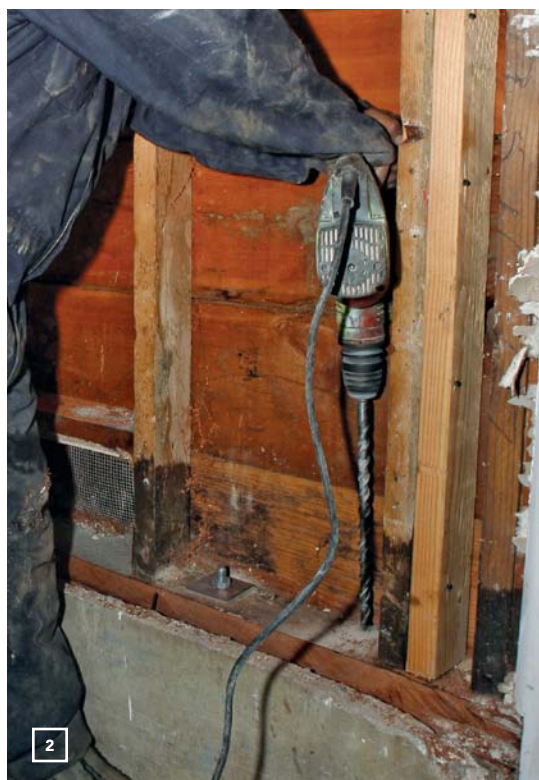
3 STOCK HARDWARE USED IMPROPERLY

- **Retrofit:** Using hardware that resists uplift in situations in which shear is the main concern.
- **Problem:** Hardware developed for hurricanes is often misused in seismic retrofits. The straps shown here have a rated lateral load of 185 lb. That's not strong enough.
- **Solution:** The UFP10 has a lateral load rating over seven times greater than each of these straps.

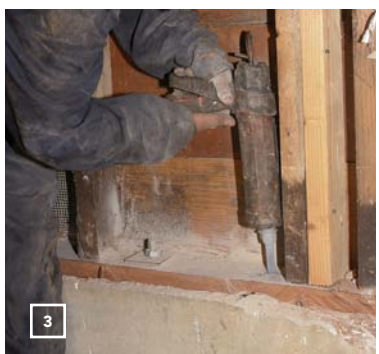
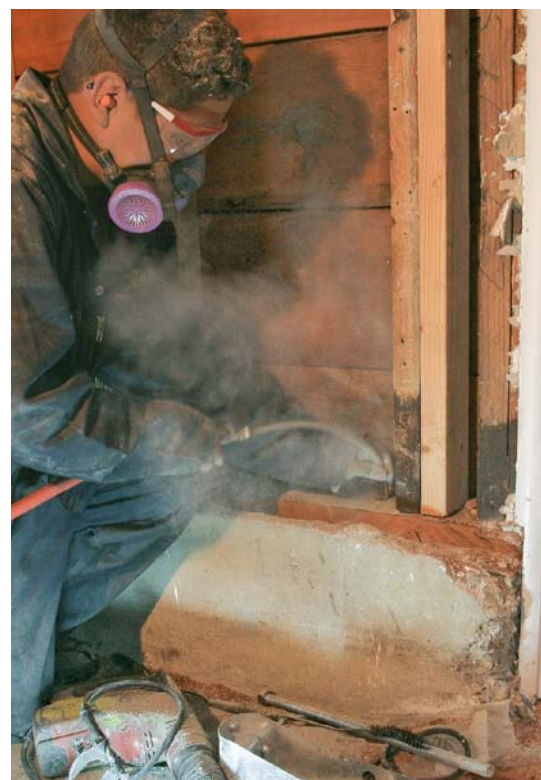




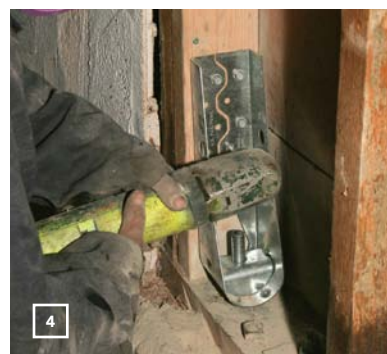
CUT THE MUDDSILL FLUSH WITH THE STUDS. This allows the plywood to be edge-nailed against an even surface. This is best accomplished with a tool like the CloseCut™ saw by Clemenson Enterprises Inc. The photo shows a saw modified with the FlusSa™ attachment.



DRILL AND PREP HOLES FOR HOLD-DOWNS. With a rotary hammer drill and masonry bit, drill an 1¹/₁₆-in. hole at least 12 in. deep (left photo). To ensure a proper bond between the epoxy and the threaded rods, plunge each hole with a bottlebrush, then blow compressed air into the hole to remove masonry dust. Repeat this process three to four times before dispensing epoxy into the hole (right photo).



SET THE RODS. After filling the holes with epoxy, set the 5/8-in. all-thread rods. Twist the rods to ensure the epoxy finds its way between each thread. The epoxy used is quick setting, and the nut will be ready to tighten within an hour.



SECURE THE HOLD-DOWNS IN PLACE. When the epoxy for each rod is set, attach the hold-down to the stud with screws before placing the nut on the threaded rod and bolting the assembly to the mudsill. *Hardware:* Simpson: HDU2, HDU4, HDU5; United Steel Products: PHD2A, PHD4A, PHD5A.

Secure Floors to the Top of Walls

Most floor systems aren't adequately attached to the top plates of the walls beneath them. As a house shifts back and forth under the forces of an earthquake, the critical joist-to-plate and rim-to-plate connections can fail and cause the floor to slide off the top of the cripple wall or floor joists to slide off mudsills. Readily available framing connectors and blocking between joists create a positive connection between floor systems and walls. Framing connectors have different shear ratings depending on the manufacturer, so choose hardware carefully. (See the photos on p. 182.)

Build Shear Walls

The most crucial element in a seismic retrofit in homes with cripple walls is installing plywood shear panels. Shear panels are built on site with plywood, hold-down hardware when needed, and properly sized nails. An engineer can determine where shear walls should be placed, or you may be able to follow a plan in a regional guideline. Shear walls need to be added only to one side of the cripple wall, so it's very likely that you can fit these panels into place without disturbing the exterior. Some shear walls demand hold-down hardware to be installed. Typically, when shear walls are taller than they are wide, they risk overturning during earthquakes. Hold-down hardware installed in the shear wall keeps the wall in place. (See the photos on these two pages.)

ATTACH THE PLYWOOD. With all the hardware in place, attach ½-in. five-ply structural grade 1 plywood to the studs with 8d nails spaced every 3 in. Nailing schedules vary based on engineered plan.



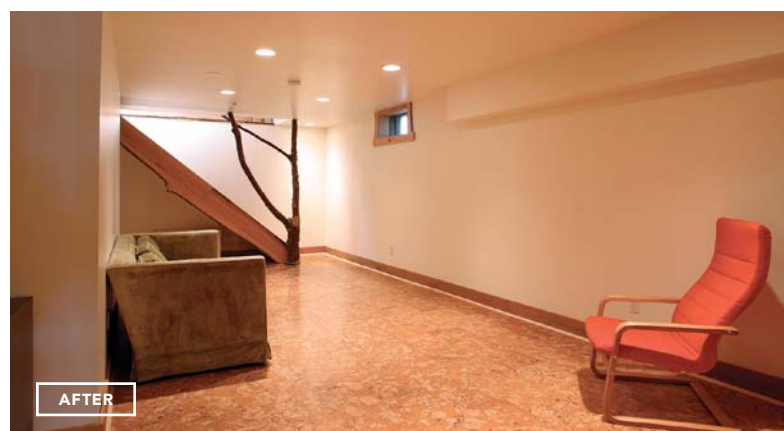
The Stay-Dry, No-Mold Finished Basement

BY ANDY ENGEL

Finished-basement projects usually begin with visions of a game room for the kids or of a secluded spot for Dad to watch Sunday football games with his cronies. Just about as frequently, these projects end badly with black spots of mold, crumbling drywall, and a smell reminiscent of a dungeon. What goes wrong? In most cases, water becomes trapped behind a wood wall or floor and nurtures a bloom of rot.

However, it probably isn't a flood that causes the problem. Yes, bulk water, the kind that flows across the floor, needs to be eliminated before an attempt is made to finish a basement. (Some common measures include exterior waterproofing, functioning gutters, and/or an internal drain system.) But even if your basement looks dry, you easily can have problems when you enclose the concrete with a framed wall. The real villain here is water vapor, the invisible moisture that keeps concrete damp and makes cold-water pipes drip with condensation in the summer. This water is always present. To reduce mold growth, water's contact with cellulose (paper, wood, etc.) has to be limited, and the water has to be allowed to escape.

Through research published by Building Science Corporation (see "Sources" on p. 193), I've found
(Continued on p. 193)



A REC ROOM THAT WILL LAST. Built with conventional wall framing, a plywood subfloor, and rigid-foam insulation, this basement remodel doesn't trap moisture that can cause problems later. (By the way, the stair railing isn't finished.)

understanding the nature of basements and water

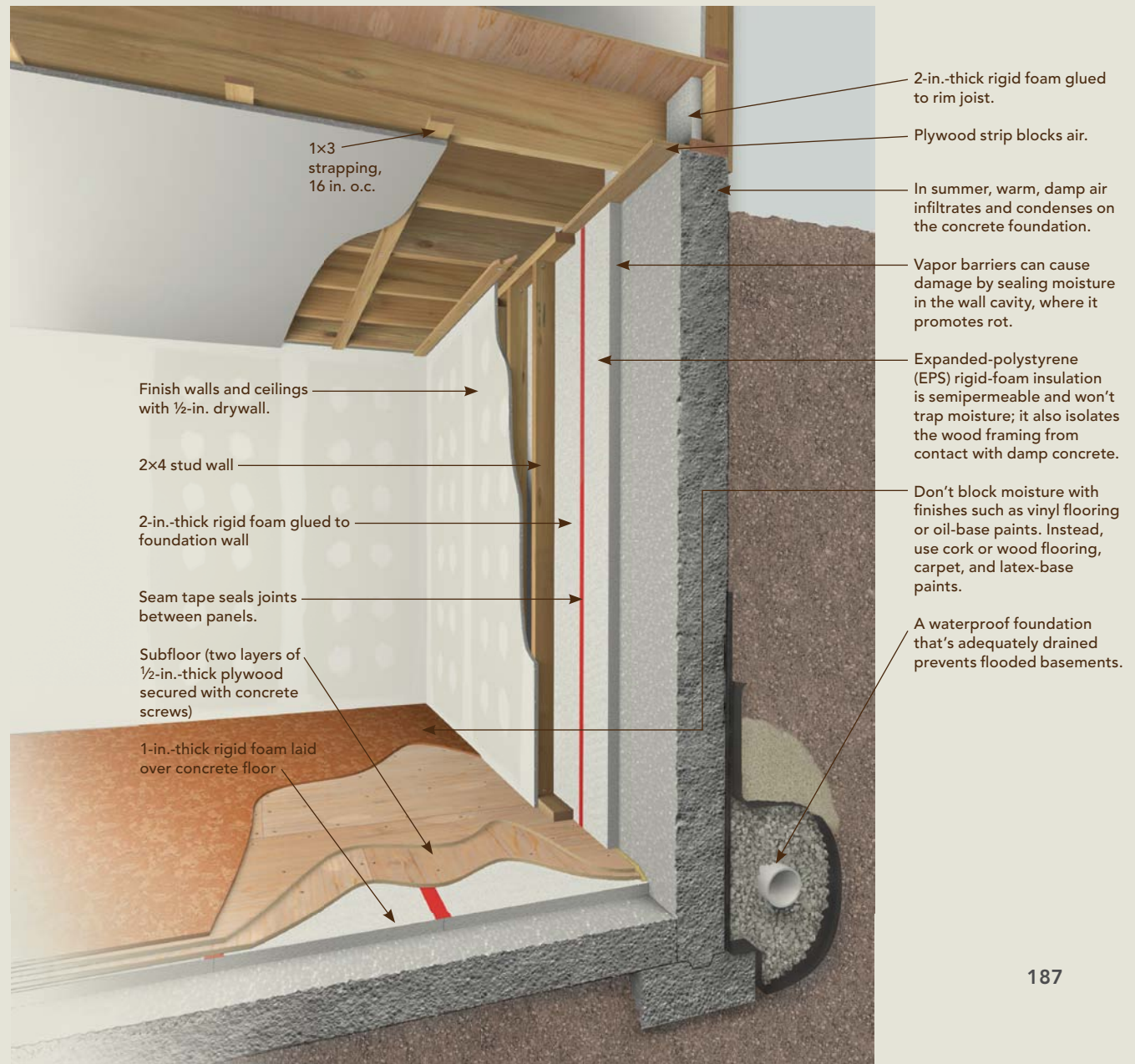
Moisture moves from wet to dry and from warm to cool. In the summer, damp soils and warm air outside make the moisture drive mostly inward. Humid outside air enters the basement and condenses on anything below its dew point: cold-water pipes, concrete walls, and floors. In particular, carpeted concrete floors can be a problem because they easily can become wet enough to support mold and dust mites.

Most basements dry out only in the winter when interior heat sucks the available moisture out of the basement and drives some moisture outward

through the exposed portion of the foundation.

There's also some drive-out through the foundation itself because the basement is warmer than the surrounding soil. The trouble is that the soil tends to be wet, and so has a limited capacity for drying.

There's a significant energy cost in moving this water through the foundation. The traditional response has been to frame walls next to the foundation, fill them with fiberglass, and seal them with a plastic vapor barrier. But a basement vapor barrier can trap moisture and promote rot. Basement floors built with a similar system fare no better.



plywood subfloor is supported and insulated with rigid foam

USE RIGID FOAM INSTEAD OF WOOD FOR SLEEPERS

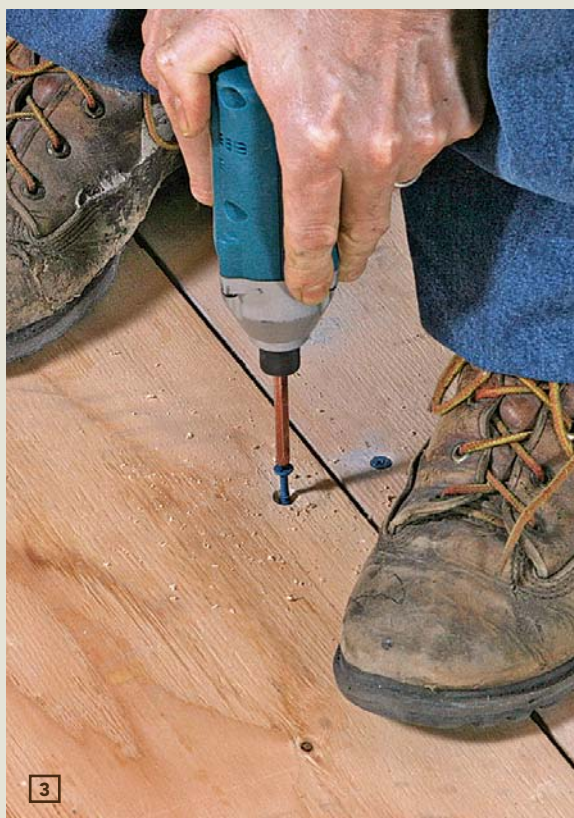
To isolate the wood from moisture in the concrete, full sheets of EPS are laid on the concrete floor. Seam tape and expanding foam seal the seams against the infiltration of moist air.



TWO LAYERS OF PLYWOOD GO DOWN WITH SCREWS

After drilling and countersinking pilot holes **1**, the author attaches the first layer of 1/2-in.-thick plywood with 2 1/2-in.-long concrete screws **3**. To allow for expansion, 1/8-in. gaps are left between each sheet and around the room's perimeter. Laid at right angles to the first layer, a second layer of plywood is fastened with 1 5/8-in. drywall screws and spans the joints between sheets to make a stronger floor **4**.





framed walls are isolated from the foundation's moisture

AN INSULATED BAND JOIST STOPS THERMAL BRIDGING

Insulating the joist bays with 2-in.-thick EPS will keep air leaks and cold spots to a minimum. Minimal amounts of expanding foam applied around the edges of each piece act as both a sealant and an adhesive.



BLOCKING AIR INFILTRATION

A strip of plywood is screwed to the underside of the floor joists (photo below). Extending from the edge of the mudsill to the inside of the wall plate, this plywood creates an air barrier. Gaps are filled with expanding foam.

MAKE THE FOAM ON THE WALLS AS TIGHT AS POSSIBLE

After the floor is done, the walls are insulated with EPS sheets trimmed for a friction fit and glued to the foundation with expanding foam [1](#) [2](#). Seams and gaps are filled with the foam and taped. Plywood scraps keep the sheets in place until the glue sets [3](#). Unlike furring strips, a stud wall goes in plumb and straight, and allows room to run any utilities in the usual manner [4](#).





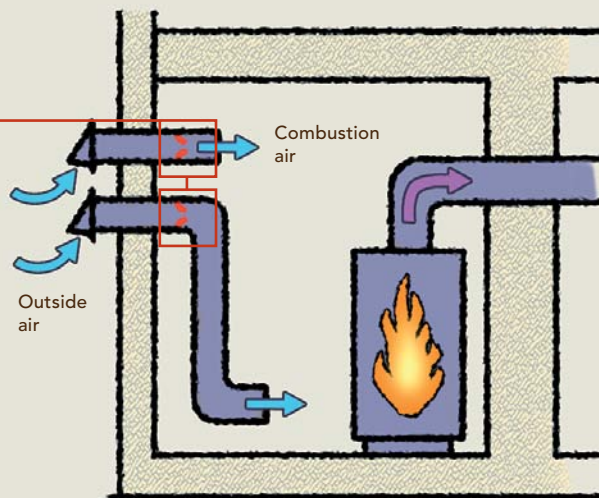
air quality and fire safety in the basement

One of the effects of finishing a basement is to cut off leaks that may have been supplying combustion air for the boiler, furnace, or water heater. Failure to replace this air supply could contribute to backdrafting and the possible buildup of lethal amounts of carbon monoxide.

Unless the appliance manufacturer provides specs that say otherwise, the rule of thumb is to provide makeup-air ducts leading to the outside that are twice the size of the combined flues. In this basement, the boiler and water heater share a 6-in.-dia. flue. I provided two 6-in. supplies, one that ended at the ceiling level and one that ended near the floor in the mechanical room. To prevent these ducts from chimneying nice warm air to the

outside, they were fitted with fabric dampers made for this low-pressure application (see the bottom photo below and "Sources" on the facing page).

One other safety consideration is basement egress. Most building codes require habitable basements to have two exits in case of fire. This basement already had two doors, so that requirement wasn't an issue. Lacking the second door, I'd have had to provide a code-approved egress window (a 5.2-sq.-ft. opening within 44 in. of the floor, leading to a 36-in. by 36-in. well with ladder rungs leading to grade). Last, if your home isn't already so equipped, install hard-wired smoke and carbon-monoxide detectors in the basement.



Fabric damper

that rigid-foam insulation both thermally protects the basement and breaks the contact between framing and concrete. To avoid trapping moisture, I never install a vapor barrier. Instead, I use materials and finishes that allow moisture to diffuse. You can get rid of this diffused water by installing a dehumidifier or by extending the air-conditioning ductwork into the basement. I'm no expert in this area, so let an HVAC contractor figure out the specifics.

Isolate and Insulate the Concrete

I use 2-in.-thick expanded-polystyrene foam (EPS, or Styrofoam) on the walls and 1-in.-thick EPS below the plywood subfloor. This rigid-foam insulation is sufficient to make a noticeable temperature difference in the basement without crowding in the walls or the ceiling height. EPS is cheap, effective, and vapor permeable. Believe it or not, it also has the compressive strength to support a two-layer plywood subfloor without the use of sleepers.

After insulating the rim joist, I cover the floor with a layer of 1-in.-thick EPS. On top of this, I lay the subfloor, then build a regular stud wall against the foam on the walls.

Keeping wood from contacting concrete is critical. Fail here, and you're inviting water in through capillary action. You could use pressure-treated plywood and framing lumber, but I think that's false security and an unnecessary expense. If you've got enough moisture in the wall or the floor to cause rot, then you've also got the right conditions for mold growth, something that pressure-treated lumber won't prevent.

It's also possible to skip the stud wall and to screw furring strips to the concrete through the foam, but I don't like that approach for two reasons. First, I haven't seen many basement walls that are as plumb or as straight as I can build a stud wall. Unless you want to spend days playing with shims, the furring strips will mimic the defects of the foundation. Second, furring strips don't have the depth that allows easy installation of electrical boxes.

SOURCES

The foam gun, canisters of expanding-foam sealant, seam tape, and low-pressure dampers are available from The Energy Federation Inc. (800-379-4121; www.efi.org).

Expanded-polystyrene (EPS) rigid foam is available at most lumberyards and home centers.

Much of the information in this article was obtained from the consulting firm Building Science Corporation; its Web site (www.buildingscience.com) has a wealth of information on building technology.

A Fast Foundation for an Addition

BY RICK ARNOLD

A few years ago, a builder asked me to form and pour a crawl-space foundation for a small addition using insulating concrete forms (ICFs). I had never worked with ICFs before. He was a good customer, though, so I rolled my eyes and agreed. I grabbed my friend and fellow contributing editor Mike Guertin, figuring we could muddle our way through just about anything. Less than two hours later, we were ready to pour, and I was sold.

Since then, I have used ICFs to form everything from full basements to two-story houses. Along the way, I've discovered many benefits of building with ICFs (see "Building with ICFs" on p. 196), but I especially like them for small-addition foundations, like the 18-ft. by 18-ft. foundation featured here, because they can be installed so quickly. In fact, I've talked contractors and homeowners through the process over the phone.

Because ICFs are so easy to install, I can save a lot of money in labor by doing the job myself rather than paying a subcontractor. For instance, this job cost a bit more than \$1,400: \$900 for the blocks, and about \$550 for the 7½ yd. of concrete (2005 prices). ICFs are available in several styles, each suited for different types of walls. I prefer the flat-wall type, even though it requires more concrete than other styles, because it emulates the more familiar poured-concrete wall.

My ICF of choice is called iForm® (www.reward-walls.com; see the bottom photo on the facing page). The best thing about this ICF system is that, because there is no top or bottom, the blocks can be installed in any direction; even corner blocks can be flipped to fit a right or left corner.

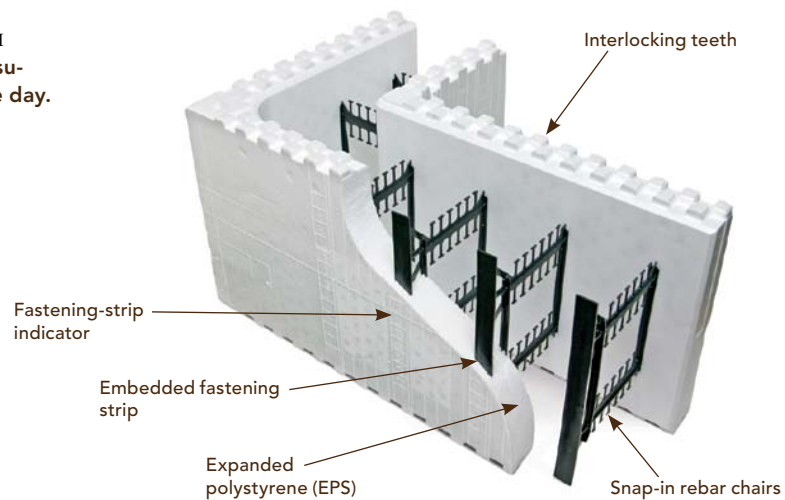
To estimate the number of blocks needed for a job, I start by dividing the length of each wall by the length of a single block. When added together, this tells me how many blocks I need in each course. Next, I divide the required height of the wall by the height of one block; this tells me how many courses I will need. When multiplied together, these two numbers give me the total blocks needed. I also like to add one extra block for each side of the foundation in case I run into problems.

Establish a Dead-Level First Course

To start, I sweep the standard concrete footing clean and snap chalklines representing the outside perimeter of the foundation (see "Forming and Pouring Footings" on p. 73). Next, I cut 2½-in. light-gauge steel-stud track to length and fasten it along the chalklines with masonry nails (see the top photo on p. 197). The metal track, which normally is sold as top and bottom plates for steel-stud wall systems,



THANKS TO INTERLOCKING FOAM FORMS, you can form, pour, and insulate any small foundation in a single day.



building with ICFs

PROS

- Unlike conventional concrete foundations, ICFs require no special tools or training. Basic carpentry skills are about all that is needed.
- The expanded-polystyrene (EPS) blocks are light, easy to cut and place, and permanent.
- There is no hassle of stripping forms after the pour.
- Fabrication around difficult areas like live sewer pipes and electrical conduit is easy.
- When concrete is poured inside ICF blocks, a negligible amount of water evaporation occurs, which is crucial to proper curing. Most contractors strip conventional forms a day or two after the pour, which increases evaporation and interferes with the curing process.
- Pouring concrete in cold weather is not a problem because the curing concrete generates heat that's retained by the insulation.
- If a conditioned crawl space is part of the building-envelope strategy, the ICFs provide a well-insulated and air-sealed barrier.
- Basements built with ICFs are less prone to moisture problems than are poured-concrete walls.

CONS

- Exposed exteriors require a protective finish. I use an exterior insulation and finish system (EIFS) coating called Dryvit® (www.dryvit.com) or 1/4-in. cementitious panels (www.jameshardie.com).
- The outer 2½ in. of the finished foundation is not load bearing, so I use a larger sill plate (2×8 instead of 2×6); I always double the plate anyway.
- Building officials may require the inside wall of an ICF crawl space to be covered with a fire-retardant material.
- ICFs offer no means of visual inspection for insects. Some brands of ICFs are treated for insects, but termite shields and ground treatment are good ideas.

just happens to be the right width to hold the iForm blocks firmly in place.

Before I start installing the blocks, I check the footing for level. The key to a quick, accurate installation is a dead-level first course. If the footing is more than ¼ in. out of level, I have some adjusting to do. This can be done by trimming the bottom of the blocks or by lifting them with shims, and later filling in any gaps with expanding foam.

Because each block is 16 in. tall and the overall foundation height often isn't a multiple of 16, I usually have to trim one course to get the correct finished height. If this is the case, I prefer to cut the bottom of the first course so that the top course is a full-height block. The blocks can be cut quickly to a uniform height on the tablesaw, using the rip fence as a guide.

Corners Come First

Because the corners are the weakest points in the foundation, they are the first blocks to be installed on each course. This ensures that I won't have to compromise their strength by cutting them to fit the rest of the blocks. After I lay the corners, I fill in with straight blocks.

As I work my way out of each corner, I usually have to trim one block on each side of the foundation to get the right fit. The iForm blocks have vertical lines at 1-in. increments on the sides, so I can take my jigsaw and cut by eye, using the nearest inch line as a guide. It's best to cut a little short rather than a little long; any extra length will push the corners out of square.

Block by block, I work my way toward the existing foundation. Butting the ICFs against a flat surface (poured concrete or concrete block) simply involves cutting the last blocks to the correct length and inserting rebar into the existing wall. But on this job, the existing foundation was fieldstone that had a very irregular surface. Thanks to the easy-working properties of the ICFs, I was able to scribe the blocks to fit against the old foundation (see the

the first course is most important



Anchor the first course of ICF blocks by fastening steel track along the chalklines with 1-in. masonry nails spaced 2 ft. to 3 ft. o.c. (left). I set the corners of each course first to eliminate any need to cut, and thereby weaken, this structurally vital part of the foundation (below).



ZIP TIES SECURE THE CORNERS.
Because the corners are the weakest points in the form assembly, it's important to secure corner blocks to adjacent straight blocks with plastic zip ties.

rebar strengthens the concrete

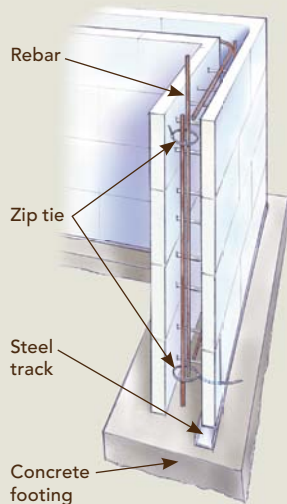
Plastic zip ties and internal webbing hold vertical and horizontal rebar in place.



AFTER THE FIRST COURSE HAS BEEN LAID, SLICE THE SIDE OF one block and loop a zip tie around the vertical rebar that extends from the footing. Pull the tail end of the zip tie through the slot so that it's accessible from outside the form.



WHEN THE AUTHOR DROPS IN ANOTHER LENGTH OF VERTICAL REBAR from above, it is carefully threaded into the looped zip tie, which then is pulled tight with a pair of pliers to tie the rebar together.



left photo on the facing page). I didn't need any rebar anchoring the new wall to the old because the rough fieldstone offers a strong bonding surface, which poured-concrete and block walls do not.

Reinforce the Forms with Plastic and Steel

Once the first course is laid, I reinforce the corners by securing the corner blocks to adjacent straight blocks with zip ties (see the bottom photo on p. 197). Available at any hardware store, zip ties are thin plastic straps used for bundling cables and wires. I also use zip ties to tie together the two blocks that form the vertical seam. Then I snap in a row of 1/2-in. rebar and overlap it by at least 18 in. in the corners. The rebar chairs of the block I use are formed to allow two pieces of rebar (up to 5/8 in. dia. each) to be snapped together, one on top of the other, eliminating the need for wire ties. That's a real time-saver.

On the next course, I flip the corner blocks end for end so that the seams will stagger. I build up the corners pyramid style, making sure to attach the corner blocks to adjacent straight blocks with zip ties before stacking the next unit.

After measuring the diagonals of the foundation to make sure it's still square, I lay the rest of the straight blocks in place, reinforce the vertical seams, and scribe the ends as before. Staggering the cut seams in successive courses is not an option because ICFs with interlocking teeth almost never line up correctly; therefore, one of the two rows of teeth would have to be cut off to get the forms to seat properly.

Handling Vents and Openings

To create a hole for crawl-space access, I build a permanent frame using pressure-treated lumber. The bottom of the frame is separated into two halves with a gap in the middle so that I can watch for voids underneath during the pour.

When I use steel vents meant for poured-concrete walls, I run into two problems. The first is that traditional vents are made for 12-in.-wide walls, but the ICF walls I use are 13 in. wide. This means the

vent has to be recessed 1 in. on the inside of the crawl space. Also, there is no easy way to secure vents during the pour. I've managed to solve this problem by placing a heavy rock on top until the pour is finished.

Getting Ready for the Pour

I straighten the top of the walls with steel track, which keeps the interlocking teeth from clogging with concrete. I also string up a dry line 1 in. to 2 in. above the outside perimeter of the walls. After snapping in the top row of rebar, I reinforce the vertical cut seams in the blocks by gluing them together with

foam and screwing plywood scabs into the embedded fastening strips across both sides (see the right photo below).

It doesn't take much concrete to move an unbraced wall, but it doesn't take much time to brace it either. As concrete is poured into the wall, it tends to push the blocks away from the existing foundation. To prevent this, I brace the ends of the wall opposite the existing foundation. Because the blocks I use lock together so tightly, bracing the sides of the foundation isn't necessary. However, if you use another brand of ICFs, check the instructions.

tie up loose ends before the pour

Even though the ICF foundation is strong and stable, I always reinforce large seams with a combination of plywood and foam, and I brace the outside corners to ensure a trouble-free pour.



FOAM FILLS THE GAPS. Expanding foam can be used to seal seams, plug holes, and tighten rough scribe work.



THERE'S NO SUCH THING AS TOO MUCH BRACING. It may be overkill, but always brace the corners securely to prevent the blocks from pushing away from the existing foundation.



PLYWOOD BANDAGES. After gluing large vertical seams with foam, reinforce them with plywood scabs screwed to the embedded fastening strips found on both sides of the seams.

pour the concrete

The pour requires close attention. It's best to pour the walls in 2-ft.- to 3-ft.-high sections called "lifts." Start with the corners before proceeding to the straight sections, making sure to watch carefully for a void-free pour. I use rocks to hold down the vents, and a dry line lets me double-check that the walls stay true.



SMOOTH THE SURFACE. Once the walls have been topped off, use steel track as a guide to remove excess concrete and to smooth out the surface before inserting anchor bolts.

The Pour Is the Trickiest Part

Most ICF manufacturers list how many blocks can be filled by 1 cu. yd. of concrete. For instance, 1 cu. yd. of concrete fills seven and a half 13-in.-wide iForm blocks. So I simply count the number of blocks in the foundation, divide it by $7\frac{1}{2}$, then round up to the nearest half yard.

The design and engineering of ICF blocks are based on a 3,000-psi concrete strength, but double-check your local code and the ICF manufacturer's specs to make sure you pour the right type of concrete in the foundation. I usually order 3,000-psi concrete with $\frac{1}{4}$ -in. to $\frac{3}{8}$ -in. peastone aggregate. I've found that concrete with aggregate larger than $\frac{3}{8}$ in. is difficult to pour and consolidate in the ICFs.

Pouring the concrete is the trickiest part of the process. Because the concrete needs to flow between the webbing of each ICF block, the consistency of the concrete is important. The lower the slump, the less water is mixed with the concrete, and the stiffer it will be. But a higher slump of 6 or 7 may result in substandard strength.

As with all three-wall foundations, I first anchor the corner blocks by filling them about halfway with concrete. Keeping the concrete at a 4 slump, I continue pouring the rest of the walls to the half-way mark. Then I have the truck driver loosen the concrete to about a 5 slump, start back at the corners again, and continue with the top half of the pour.

During the pour I constantly watch for voids forming, walls bowing, or gaps and seams opening up between the forms. I just use a stick to poke the concrete beneath the vents because I don't like to use a vibrator unless absolutely necessary. If gaps or seams open up, I stop the pour and reinforce the area with plywood scabs. Then I give the concrete a little time to set up, usually by continuing the pour in another area.

sources

Founded in 1995, the Insulating Concrete Form Association (ICFA) is a growing group of professionals ranging from manufacturers to ready-mix suppliers, all focused on educating builders about the benefits of ICFs. Visit them online at www.forms.org.

Visit www.concretehomes.org for a list of ICF manufacturers and distributors in your area.

The International Residential Code (IRC) has a section covering ICFs, complete with rebar tables. The source document for the code is "The Prescriptive Method for Insulating Concrete Forms in Residential Construction," published by the Department of Housing and Urban Development (www.hud.gov).

Once the wall has been topped off, I float it level with a trowel, using the steel track as a guide (see the bottom photo on the facing page). Then I install the anchor bolts. One last adjustment can be made simply by pushing or leaning on the wall to tweak it straight—and my foundation is formed, insulated, and poured in record time.

Footing and Foundation in One Pour

BY JIM BLODGETT

We have been pouring foundations pretty much the same way that our grandfathers taught us: Build the forms for the footings, pour the concrete, strip the forms. Build the forms for the foundation, pour the concrete, strip the forms again.

This time-tested approach to footing and foundation construction works fine for big jobs, but it's not the best way to tackle a small job. You pay a pretty stiff upcharge when you order a short load of concrete (less than 4 cu. yd.), and small projects usually call for short loads. Pouring the footing and foundation at the same time can convert two short loads into one regular load.

When pouring footings and foundation walls separately, there's a built-in safety net: If the footings aren't perfectly square, you can correct mistakes when you form the walls. Not so with a monolithic pour; you need to be more careful when laying out and setting up the forms.

Batter boards guide string lines, which in turn guide the placement of the footings. Specialized metal straps and brackets position the wall forms on the footings (see "Straps and Brackets Support the Wall Forms" on p. 204).

Build Forms to Disassemble Easily

Another important thing to remember when building forms is that you will have to strip them. Poorly thought-out joints can make stripping forms a nightmare.

Forms with outside corners are generally easy to strip because pressure from the concrete tends to push the joints apart. Inside corners, however, are pushed together. When building forms, I follow a couple of simple rules for inside corners. If a form board butts existing concrete (the house's foundation), I butt the opposite end into wood by reversing the lap of the corner; and I use two short boards joined with a plywood bracket instead of one long board.

Keep Concrete Where It Belongs: In the Forms

If placing forms accurately is one difficulty encountered in a monolithic pour, keeping the concrete in the forms is another.

On small jobs, space is usually tight. Getting concrete to the forms may require a pumper or a wheelbarrow. But even distributing concrete within the forms can be tricky on a tight lot. If you don't have room to dump the wheelbarrow every couple



FOR SMALL JOBS, you can save time and money by pouring the footings and foundation at the same time—but there are some pitfalls to be aware of.

straps and brackets support the wall forms

The metal straps are nailed across the footings, and then the bracket locations are set by plumbing down from the string lines (see the left photo below). Don't cap off the footing because pressure from the concrete will lift it out of the ground. Instead, pour the wall in lifts.



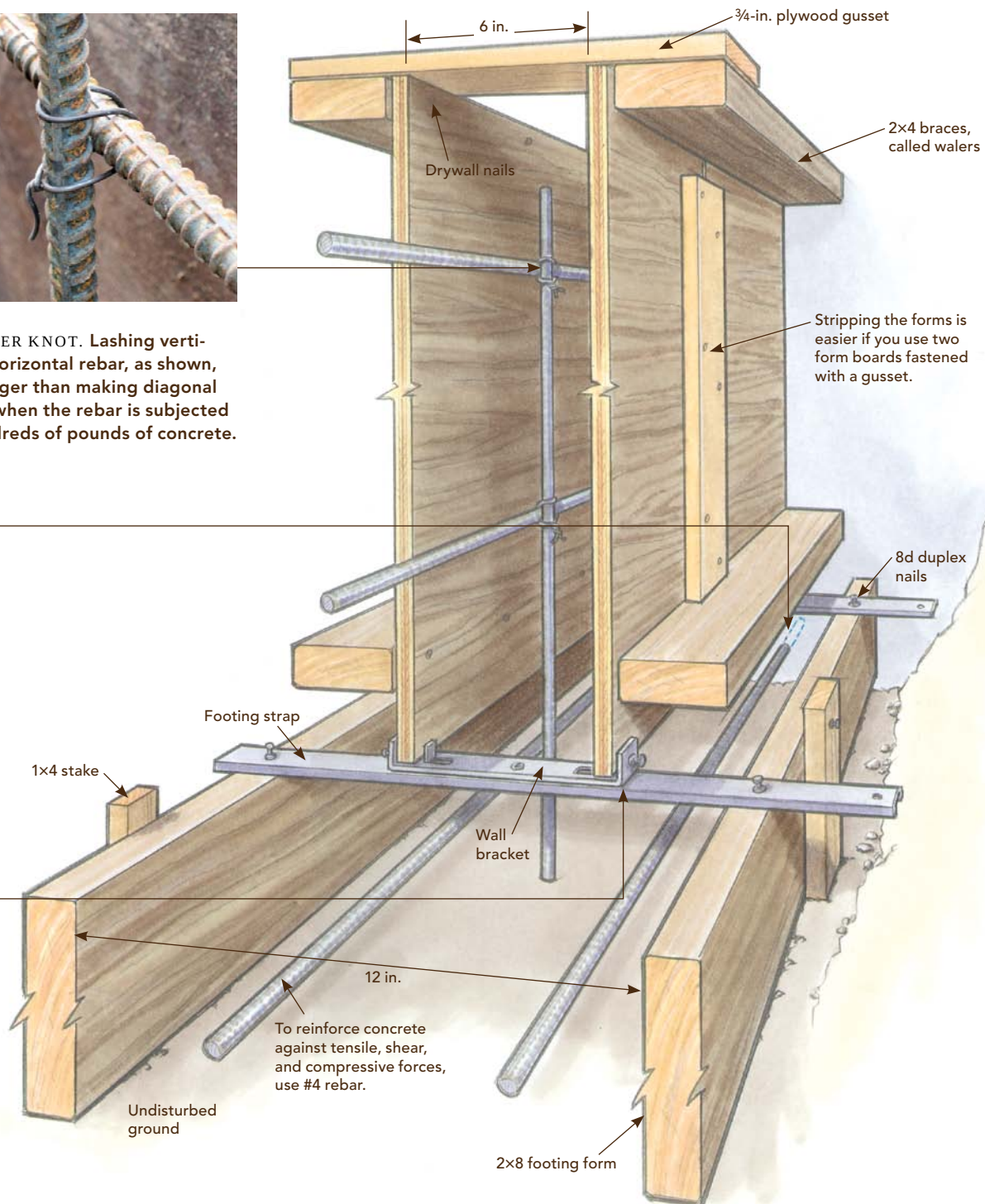
EPOXY ANCHORS THE REBAR. Fasten the new foundation to the old by drilling 4-in. to 6-in. holes and gluing the rebar ends in place with epoxy.



SPECIALIZED HARDWARE MAKES IT EASY. Footing straps have pre-punched holes for different-width footings. Wall brackets allow some wiggle room in locating the walls. The straps and brackets cost about \$1 each (www.awardmetals.com; 800-228-3676).



A BETTER KNOT. Lashing vertical to horizontal rebar, as shown, is stronger than making diagonal wraps when the rebar is subjected to hundreds of pounds of concrete.

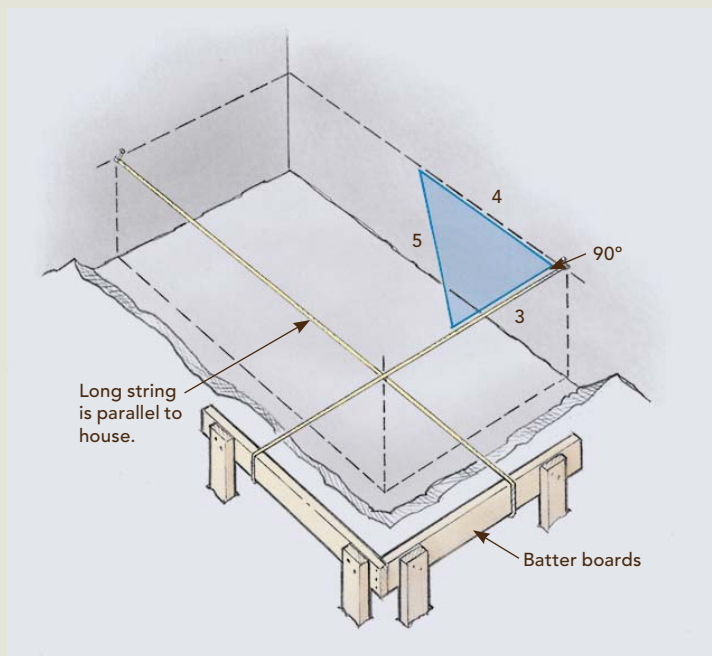


batter boards and strings align the forms

Locating the forms for this L-shaped foundation wall can be done by stringing lines between batter boards and the walls of the house.

Set the long string by measuring equally off the house at two points. Then set the shorter string square to the house by applying the 3-4-5 triangle rule. A triangle with these side lengths contains a 90° corner. Because the strings are for reference, they don't have to be at any particular height, but they should be level.

Some people establish a level grade line inside the foundation forms and pour to the line, but setting the top of the form to the finished height of the wall makes the whole process easier.



of feet along the forms, an electric vibrator can be helpful. I rent an electric vibrator to move concrete within the forms and to reduce air and rock pockets (honeycombing). The vibrator is a wonderful tool, but it has drawbacks; specifically, vibration adds pressure to the forms, notably at the bottom and on corners, which can cause the forms to break. Anyone who has poured concrete has learned about this hydrostatic pressure the hard way.

In monolithic pours, you have the additional challenge of controlling a lavalike mud flow from the open top of the footing. You can't contain the concrete by sealing this opening, so don't try. The same hydraulic pressure that lifts concrete over the top of the form can lift sealed forms out of the ground—stakes and all—leaving you with a monolithic mess.

The key step is keeping an eye on the opening while you pour and vibrate. If concrete starts to ooze over the top of the footing, move to another spot and let the concrete stiffen before you add more weight on top of it. When you come back to it, vibrate the two pours together enough to ensure a good joint, but not enough to lift the forms.



BUGGY POURING IS EASIER WITH A HELPER. A strategically placed helper with a splash board gets the mud inside the forms with fewer spills. If you can't persuade your daughter to help you, brace and nail the splash board in place.



CLEAN THE FORMS WHILE THE CONCRETE IS WET. Stripping goes more quickly if you don't have to chip away hardened concrete to find the nails. Another way to make stripping easier is to use two short boards rather than one long board when building the forms. This reduces the effect of pressure exerted by concrete on the inside-corner joints.



OUTSIDE CORNERS STRIP EASILY. The pressure of the concrete doesn't act to tighten the joints in the form boards on outside corners as it does on inside corners. When stripping outside corners, the author starts at one end and works his way to the other. Inside corners should be formed so that a central section can be pulled away and stripping can proceed in both directions.

tight corners are easy to bend

Using two lengths of black pipe, I get excellent results without an expensive rebar bender.



Put one pipe's opening at a corner.



Slide the second pipe over.



Bend to the desired angle.



Voilà!

a vibrator strengthens and smooths concrete

TO GET A SMOOTH FINISH ON A CONCRETE WALL, I vibrate the concrete as I pour it. Vibration also adds strength because it removes air pockets and eliminates the cold joints between successive pours. I use a series of plunges into the concrete instead of constant vibration, which would create too much pressure on the forms and make the concrete soupy. At about \$50 a day, a $\frac{3}{4}$ -in.-dia. vibrator is worth renting.



crack prevention for an add-on slab

When adding on to a home built on a slab, where the addition will also be built on a slab, first check with your local building department. Local code might require that you tie the old slab to the new one. This typically is done by epoxying short lengths of rebar to the edge of the old slab, as shown in the left photo below. Use a hammer drill to bore a $\frac{5}{8}$ -in.-dia. hole at least 6 in. deep every 16 in. Clean all dust from the hole before filling it with epoxy and a 16-in. length of #4 ($\frac{1}{2}$ -in.) rebar, which can be tied to the reinforcement in the new slab.

To reduce cracking in the new slab, use a grid of #4 rebar. John Gibson, a friend of mine who builds

houses in California, routinely installs a 16-in.-sq. grid of #4 rebar in his slabs; it's a code requirement in many areas. The rebar grid is held together with standard tie wire and is elevated on 2-in.-tall concrete spacers, which we call dobies.

Although this approach adds \$250 or so to the construction cost, it provides excellent insurance against cracking. When a slab is being poured and the mud is being pushed and prodded into place, standard welded-wire mesh often is trampled to the bottom of the concrete layer. In contrast, the #4 rebar grid stays put, springing back into place after it's stepped on. This is another reason why upgrading to rebar makes sense.

—Larry Haun is the author of *A Carpenter's Life* (The Taunton Press, 2011).



ANCHOR THE NEW SLAB TO THE OLD ONE. Use epoxy to set rebar stubs into the existing slab, and tie them to the rebar grid of the new slab.



A REBAR GRID WORKS BETTER than steel mesh to prevent cracks. Held together with tie wire, a rebar grid set on 2-in.-tall concrete spacers stays put during the pour and the screeding. Wire mesh often ends up at the bottom of the slab, where it can't provide structural support.

Concrete in the Landscape

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Four Retaining Wall Choices

BY ERIC NELSON

A homeowner once approached me as I stood, hammer in hand, working on a stone retaining wall, and asked, “Is that it? You just knock the rocks into place?” I wish it were that simple. Stacking natural stone or concrete pavers or spiking together timbers may look easy, but I’ve replaced or rebuilt enough walls to know how often it is done incorrectly. The trick is to pick the material that best suits your landscape, your budget, and your ability (if you plan to tackle the project yourself).

I usually build fieldstone or timber walls because they are the most popular materials in my area, but modular-block and poured-concrete (or concrete-block) walls also are excellent options. Each type of wall requires a different set of tools and building skills. For instance, timber landscape ties are a good, inexpensive material for someone comfortable building with wood. A poured-concrete wall is likely the strongest choice, but the installation is probably best left to professionals.

Choosing the most appropriate material is the first decision you need to make when starting a retaining-wall project. Before you begin building a wall, you also need to consider the elevations of the new finished grades, the appropriate base and backfill, and the question of whether an engineer should design the wall.

Modular Block

If you want the look of a natural-stone wall but lack the skill to build one, a modular-block wall might be the answer. These wall systems come in a variety of styles, patterns, and colors. There are tumbled blocks of uniform size that simulate the look of quarried granite, blocks of varying sizes that form patterns to look like natural stone, and split-faced blocks that look like what they are: concrete. In fact, these blocks are made from really strong concrete; most have a compressive strength of 5,000 psi.

Modular-block retaining-wall systems are available from a number of manufacturers. Prices vary between manufacturers and styles. Each company—sometimes each style—has its own building system. Most systems are made up of a few different components, including the basic wall blocks, corner blocks, and cap pieces. The good news is that none of the systems is too complicated, and the walls go up quickly.

The trick is to get the first course level. Then it is mostly a matter of stacking blocks and backfilling. Many systems even incorporate a setback into the design so that as you build up, the wall automatically pitches back into the retained earth behind. It is hard to avoid cutting blocks, but the only specialty tools you’ll need are a masonry or diamond blade for your circular saw and a mason’s chisel.

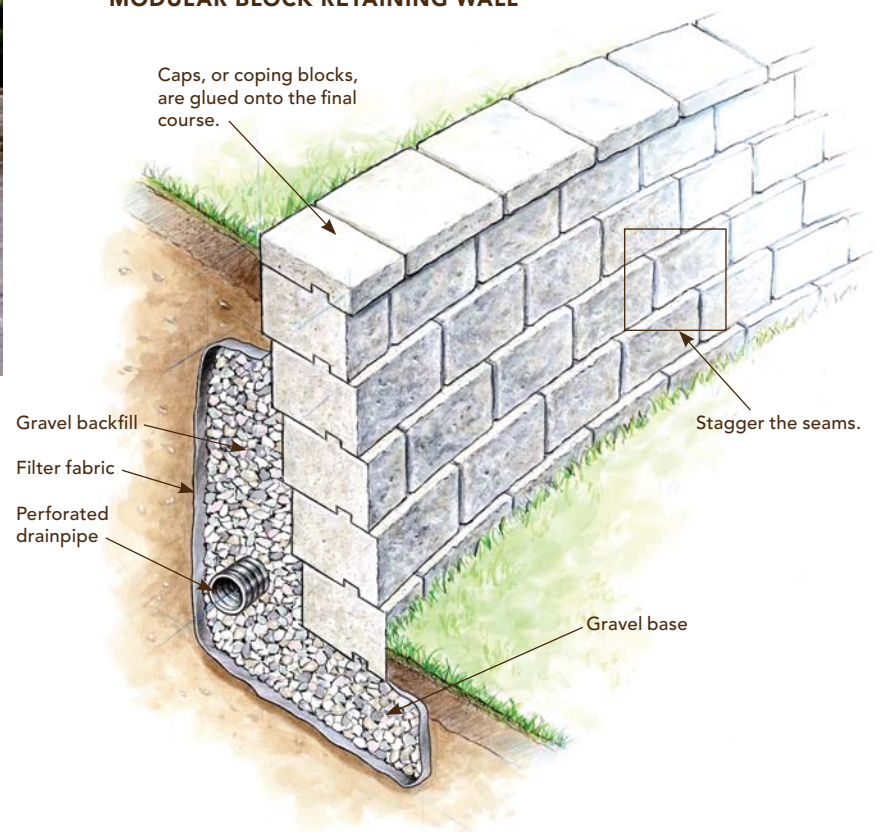


MODULAR BLOCK is versatile in design and interlocks for strength.



RANDOM PATTERNS LOOK NATURAL. Allan Block's Ashlar Blend™ is a combination of three different blocks that can be mixed and matched (www.allanblock.com; 952-835-5309).

MODULAR BLOCK RETAINING WALL



interlocking blocks

With pins or ridges, blocks lock together for strength.



UNILOCK ROMAN PISA. A ridge on the top of one course fits into a groove on the bottom of the next (www.unilock.com; 800-864-5625).



VERSA-LOK® MOSAIC. A top-down pinning system lets you push a pin through a hole in one course and into a groove in the course below (www.versa-lok.com; 800-770-4525).



KEYSTONE® COUNTRY MANOR®. Pins are placed into the top of one course, and the next course is positioned on the protruding pins (www.keystonewalls.com; 800-747-8971).

These interlocking systems are versatile enough for most designs. Curved walls can be built, and matching steps and walks can be incorporated. Some manufacturers will send a representative to help you figure out just what you need for your project.

Concrete

Poured-concrete and concrete-block, or concrete-masonry-unit (CMU), walls are the most complicated, most expensive, and least attractive retaining walls. If they're engineered well, though, they're probably the strongest. And veneers can take the curse off how they look.

These heavy walls always should be designed by a professional who will test the soil conditions and draw plans for the project. Because they demand extensive excavation for the footing and mate-

rial to build the forms, the pour is also best left to professionals. CMU walls require a footing engineered similarly to poured-concrete walls, and their strength depends on the right mortar mix and reinforcement. If you need retaining walls near a house under construction, consider having them poured at the same time as the foundation.

Laying up veneer can be tackled by a first-timer. Although the process is slow and the materials expensive, the wall's structural integrity won't be threatened by mistakes.

There are a variety of veneer materials to choose from. Natural stone is popular, but thin stone veneer is more expensive than most wall stone. Cultured, or artificial, stone is less expensive and has the advantage of uniform thickness. Of course, in the right landscape, brick veneer and stucco are good choices, too.

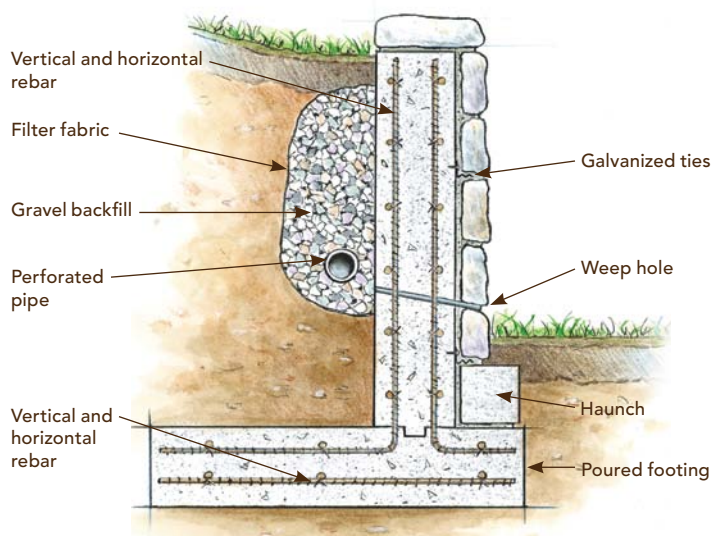


CONCRETE is a strong material with many looks.



CONCRETE WALLS TAKE ON THE LOOK of the surface treatment: here, stucco (left) and brick (right).

CONCRETE RETAINING WALL



consider terracing

Even the most attractive retaining wall can lose its charm if the wall is too massive for its surroundings. If there is enough area to divide the change in grade into multiple stepped walls, a series of small walls might be more visually appealing. Terraced walls also may avoid the need for permits, engineers, and complicated construction details. The area between terraced retaining walls does not have to be level and can be used for lawn or gardens.

Building two or more small walls also may be easier on your back because you don't have to lift the stone, block, or timbers too high, or set up staging. If you decide to build a terraced retaining wall, start with the lowest wall: You'll create flat areas to stand on while working on the upper walls, and you can incorporate steps, which have to be built from the bottom up.



TIMBER IS LESS DURABLE, **but easy to build.**

Timber

For most folks, timber retaining walls are the easiest type to build. And in most cases, they are the least expensive option (8-ft. pressure-treated 6×6s start at \$16). If you are comfortable with basic carpentry, you shouldn't have a problem building a timber retaining wall. In a dry area, a timber wall can be built without a base or tricky backfill. Steps can be made by joining two 6×6 timbers and are incorporated easily into these walls. It is simple to make 90° and 45° corners, though curves are tricky.

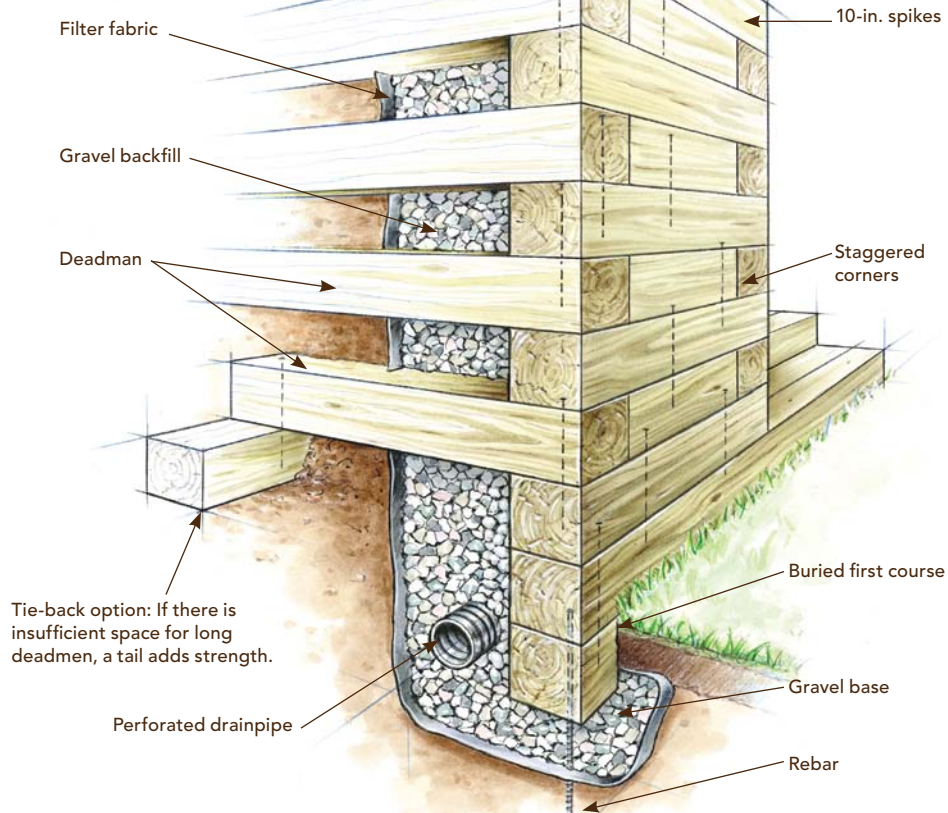
Timbers range from used railroad ties to planed lumber. If you can find them, used railroad ties are fairly inexpensive, but they're often treated with creosote. They also may be inconsistent in dimension and not very straight. This combination can make for tricky building.

The most commonly used material is pressure-treated 6×6 landscape timbers. You can use a rough-sawn, dimensional 6×6 for a rustic look, or a planed 6×6 (actually 5½ in.) for a more-finished look. For shorter walls, a 4×6 timber also can be used.

The length of the ties also varies. A 12-ft. or 16-ft. tie can cover a lot of ground but is difficult to handle alone. An 8-ft. tie is more manageable for one person.

The obvious drawback to timber walls is that they eventually rot. Pressure-treated timbers will last longer than untreated timbers, but be aware that the manufacturer's warranty on new pressure-treated timbers may not be honored if the tie is cut.

TIMBER RETAINING WALL



the basic steps of timber-wall construction



Cut timbers with a chainsaw, or with a circular saw and a handsaw.



Drill pilot holes so that spikes or rebar can be driven easily, with less chance of splitting.



Tie courses together by driving spikes with a 12-lb. hammer or 20-lb. sledgehammer

Stone

Stone walls may be the best choice for a natural-looking landscape. Natural stone offers limitless design possibilities, including curves, and stone walls can be built to follow a sloping grade. Steps can be incorporated into stone walls, though stone treads often are too heavy to handle without a machine. The price, type, and availability of stone vary from one area to the next, but natural stone is almost always one of the more expensive retaining-wall materials.

Along with pricey material costs, stone walls bring high labor costs. It takes practice to learn to build with the irregularities of natural stone, and even for an experienced mason, building a stone wall takes longer than building the same wall with another material. Still, stone walls can be a rewarding project for patient first-timers. In most areas, you can have pallets of stone delivered. And a few inexpensive tools, such as a mason's hammer, will make the work go more smoothly.



STONE WALLS CAN BE DECEIVING. From a distance, this stone retaining wall appears dry-stacked. A closer look reveals that the stones actually are mortared. Mortared backfill is a good idea for taller walls or walls that will be walked on or sat on.





THE MANY FACES OF NATURAL STONE. The availability and type of stone vary from one area to the next. Fieldstone is easy to find in the Northeast (facing page). Quarried Niagara boulders (left) and limestone (above) are common in the Midwest.

Stone walls can be stacked dry using stone and rubble for backfill. Dry walls are built on a base of compacted gravel. It's important for hidden backfill stones to be stacked just as securely as visible "face" stones. All voids inside the wall should be filled with rubble.

Another option is to stack the face stones dry, then backfill with stone and mortar. This type of construction requires a deeper (24 in.) compacted-gravel base. Finally, you can mortar the joints between stones. These walls should be built on a

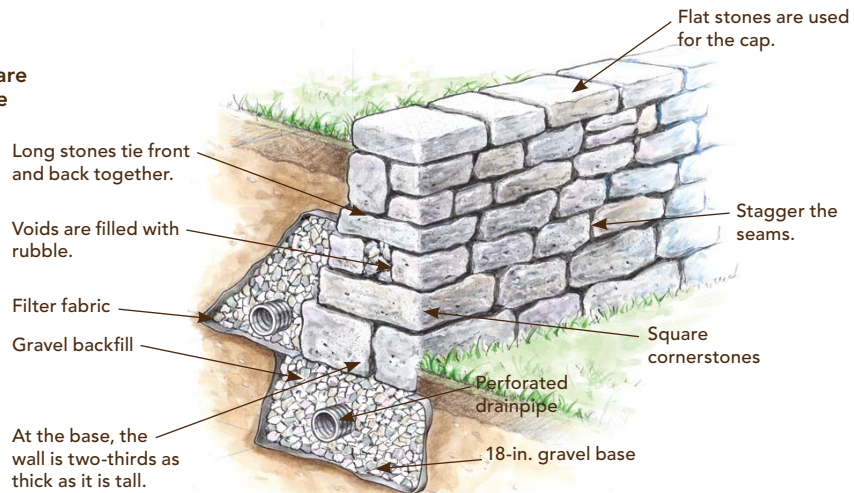
poured-concrete footing with rebar placed horizontally in the footing and vertically to extend through the wall as it is built up. All "wet" walls need a drain in the backfill or weep holes to relieve pressure from water that seeps behind the wall.

Base and Backfill

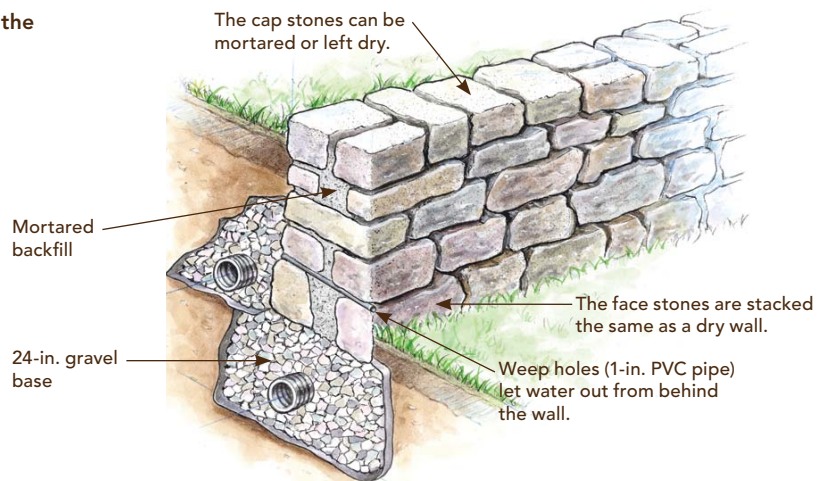
One truth about all retaining walls is that they are only as good as the base they are built on. The right depth and type of base depends on the material and the landscape. The base and backfill in the drawings

three ways to stack a stone retaining wall

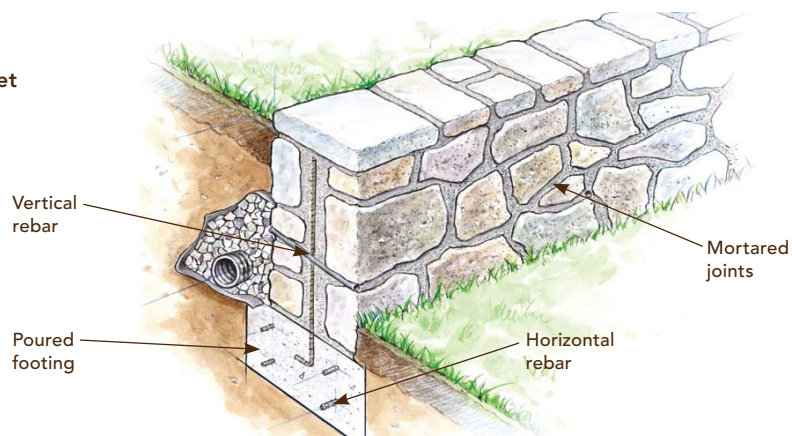
1. Dry-stacked walls are backfilled with rubble



2. The dry look, with the strength of cement



3. Poured-concrete footing to prevent wet walls from cracking



shown here represent best practices. In other words, this is how I would build each of these walls in wet or uncertain conditions. In dry areas, I build timber walls right on the ground. And although I always build stone and modular-block walls on at least an 18-in. gravel base, I put a drain in the base only in wet areas. Any time a perforated pipe is used in the base, the gravel must be separated from the earth with filter fabric.

Backfill is equally important. Dry-laid stone walls usually are backfilled with large stones, and the voids are filled with rubble. If the wall is separated from the earth with filter fabric, drainage behind the wall often is unnecessary. Modular-block walls should be backfilled with gravel and a perforated drainpipe and separated from the earth with filter fabric. This method also can be used for a timber wall in a wet area, a wet-stacked stone wall, or a poured-concrete wall. Weep holes are another option for poured-concrete walls and wet stone walls.

For some projects, excavating for the base and backfill is the most laborious part of the job. If this is the case, it might be worthwhile to hire an excavator or to rent a backhoe for a day.

The last thing I do before I begin a wall is to determine the height of the top of the wall and the finished grade at the bottom of the wall. This way, I can make sure the top of the base is set a few inches below the finish grade (lawn or garden) to keep it hidden when the project is complete. Don't trust your eye when determining elevations. Use a site level to avoid mistakes.

when do you need an engineer?

You'll have to check with your local building department to find out if you need a permit and engineer's approval to build a retaining wall. The International Residential Code regulates the construction of walls more than 4 ft. tall. Likewise, most manufacturers of modular-block wall systems recommend that any wall over 4 ft. be designed, or at least approved, by a professional engineer. I agree that there is little danger in a homeowner or contractor tackling a project less than 4 ft. tall. I also agree that it is a good idea to speak with an expert before attempting to build a retaining wall over 5 ft., even if your local code doesn't require that you do. In many cases, two small walls look better than one tall wall anyway.

Dress Up a Block Wall with a Rock Wall

BY CODY MACFIE

In the old days, foundations of rock or brick were the norm. They looked good and were fairly easy to build. Nowadays, concrete block or poured concrete is the foundation method of choice because they're much faster to build. This newfound speed, however, comes at an aesthetic cost: Concrete is ugly. But you can make a plain-looking block wall into a great-looking rock wall by veneering it with field-stone. The tools and materials needed are few, and the payoff is huge.

The techniques for veneering are the same for block, poured concrete, or even a wood-frame wall, as are the requirements. Make sure you have sufficient support below the stone (a solid footing), and attach the veneer to the wall with wall ties. If the veneer is a retrofit, you may need to pour an additional footing, usually about 6 in. wide. And for wood-frame walls, you need to add a moisture barrier, such as peel-and-stick roofing membrane or #30 felt paper, to the wood. Wall ties are easy to install if you're laying up a new block wall. For concrete walls or existing block walls, the ties can be attached with a powder-actuated nail gun or with masonry screws.

Although veneering an entire house is best left to a professional, a short foundation veneer, such as the one featured here, is certainly bite-size enough for a non-mason to attempt.

Tight-Fitting, Yet Natural

There are as many varieties of stonework as there are stonemasons, but most can be lumped into a few patterns (see "Rubble Patterns" on the facing page). Much of my work is in a style called dry stack, which resembles a traditional no-mortar rock wall. When veneered in the dry-stack style, mortar is packed behind the stones as well as in a thin layer around the stones, but the mortar is not visible. While dry-stack veneer looks rough and tumble, it's rather precise. The stones fit together tightly yet do not look manipulated. With jointed-style stonework, you don't have to be as particular because the visible mortar around the stones absorbs the bumps and irregularities.

Good-looking dry-stack veneer is all about tight joints that look natural. You can close gaps between stones by chipping away bumps, by using plugs, or by manipulating the shape of the stone with a hammer and a blunt chisel. Large gaps not only look unnatural but also can allow stones to shift, which creates a weak spot in the wall.

The Most Important Tool Is Space

Being able to look at all the stones to choose the best size, shape, or face for each particular spot—especially the corners—is critical. Because stonework

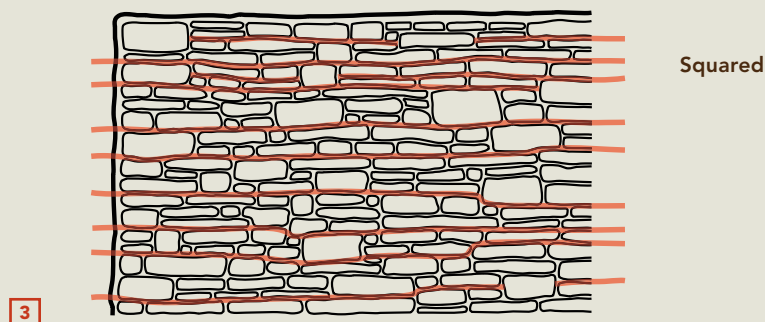
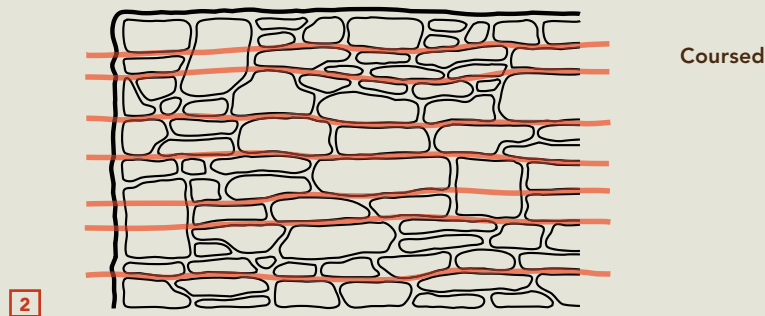
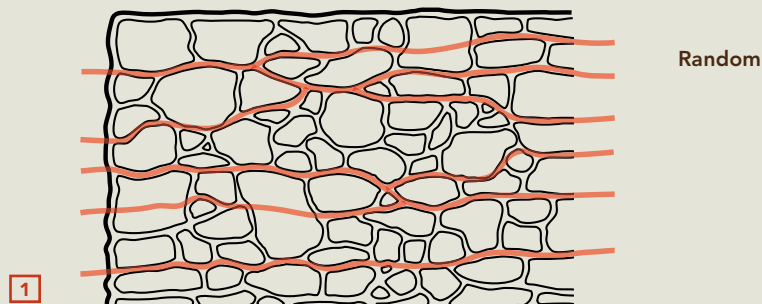
rubble patterns

Rubble patterns refer to stonework that doesn't look manipulated (cut or chiseled). Whether the mortar is visible or not, there are a few common patterns for laying up stone.

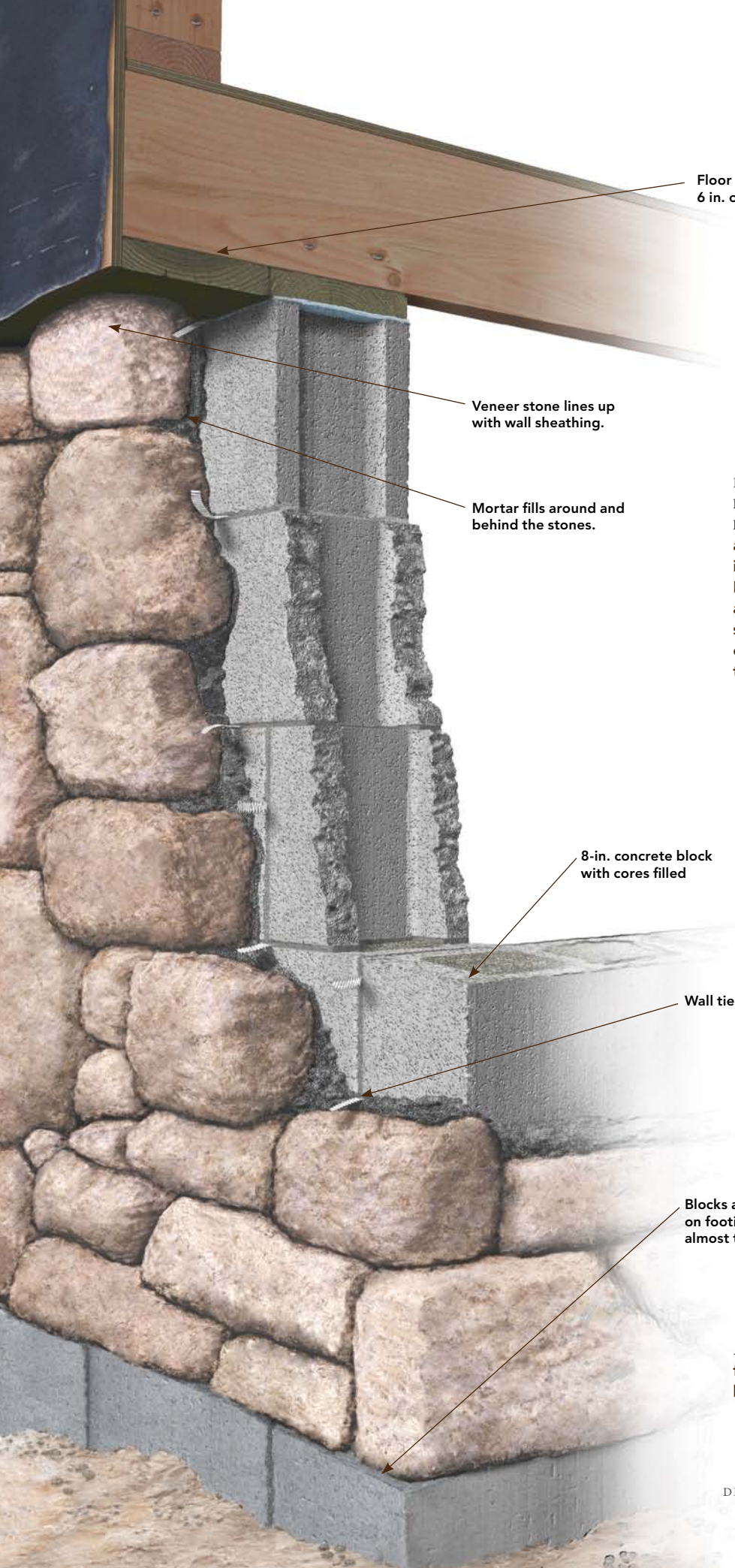
1 Random rubble has no visible continuous course or bed lines. The stones may fit together tightly but randomly, as featured in the photo on p. 224.

2 Coursed rubble has a somewhat level bed line with every course. The stones are of varying sizes, but each large stone defines a level bed line.

3 Squared rubble has a level bed line every third or fourth course.







Floor framing is cantilevered
6 in. over foundation wall.

Veneer stone lines up
with wall sheathing.

Mortar fills around and
behind the stones.

IF YOU OVERHANG THE FLOOR FRAMING, STONE VENEER CAN LOOK STRUCTURAL. Stone veneers are different from stone foundations in that they don't support the house. But they're still heavy, so they require a footing. Rather than burying your stonework, though, build up the existing footing with concrete block to grade.

8-in. concrete block
with cores filled

Wall ties

Blocks are set
on footing
almost to grade.

A DRY-STACK, RUBBLE PATTERN,
fieldstone veneer greatly enhanced the
block foundation of this house.

is a mixture of art and grunt labor, plenty of space allows you to take inventory and set aside key stones, such as corners and caps, so that you won't have to switch gears as often. Stopping the process of laying up stone to haul another load can be frustrating.

Start by dumping the stone into a large space near the work area, and shuttle small piles to the wall in a wheelbarrow. The other tools you'll need are a square shovel, a pointing trowel, a mason's trowel, a 4-ft. level, a brick hammer, a 4-lb. rock hammer, a blunt chisel, a plumb bob, a tape measure, and a garden sprayer. If the job is large, rent a cement mixer.

Before You Start, Look Up and Down

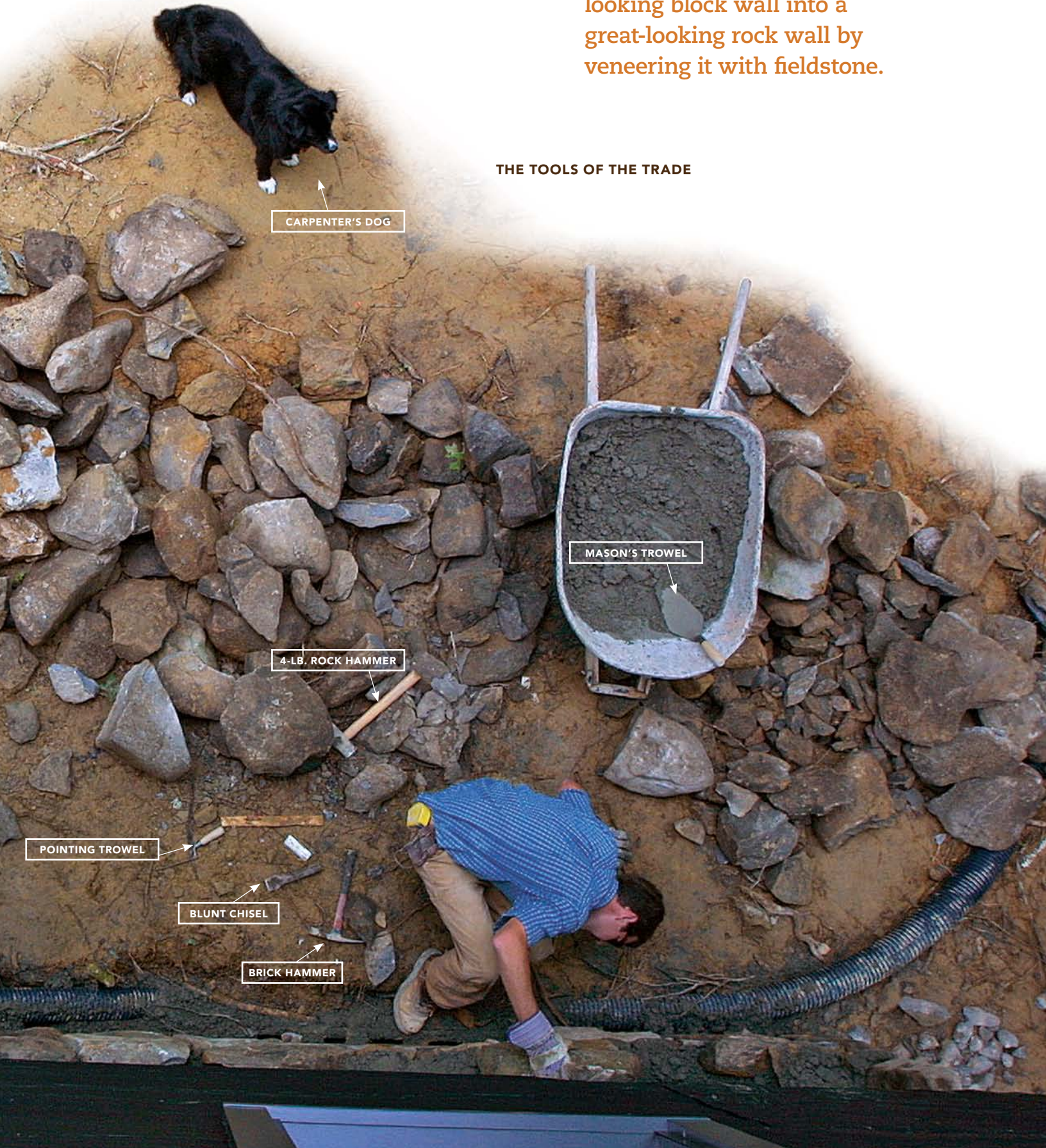
Although stone veneer doesn't support weight, a footing must support it. Because the footing is below final grade, stacking 6-in. or 8-in. concrete blocks to just below the final grade line and laying stones on the blocks makes sense. Blocks need to be secure to make a solid seat for the first course of stones, so set them in mortar. If dirt has covered the footing, dig it out until the footing is exposed.

Verify that the wall to which you are veneering is plumb. A plumb wall speeds the veneering process because you can simply measure the same distance from the wall to the face of the stone as you lay them. If the wall is not plumb, then use a level to make sure the stone faces are plumb.



You can make a plain-looking block wall into a great-looking rock wall by veneering it with fieldstone.

THE TOOLS OF THE TRADE



CARPENTER'S DOG

MASON'S TROWEL

4-LB. ROCK HAMMER

POINTING TROWEL

BLUNT CHISEL

BRICK HAMMER

mortar binds the wall

Lay stone on a bed of mortar and pack more behind. The unseen mortar below, beside, and behind the stone holds the wall together, but visible mortar in front will be scratched out.



USE SHIMS TO SET THE STONES MORE SECURELY. The rock-fragment shims can be used in one of two ways: either as temporary shims until the mortar sets up or as permanent plugs to fill gaps between stones, giving a tighter appearance.



TRIM ROCK WITH A BLUNT HAMMER. Break bumps off the back and bottom to improve fit and to reduce the chances that the stone will move as rocks are piled on top of each other.



PACK MORTAR BEHIND THE STONES. Mortar holds the stone in place, and wall ties embedded into the mortar tie the stone veneer to the block wall. Lay a mortar bed on top of each stone course for the next course.

Mortar Holds the Stone Together

I measure mortar in batches, or the amount that my mixer can mix, that my wheelbarrow can hold, and that I can maneuver around the site. A full batch fills my mixer. I mix either a full batch or a half batch depending on the weather, my crew size, and proximity to quittin' time. Regardless of whether you use a mixer or a wheelbarrow, the recipe is the same: a 3-to-1 mixture of sand to portland cement. A full batch in my mixer is a half bag of portland cement and 14 shovelfuls of sand. If you mix in a wheelbarrow, small batches make the mixing much easier. Whether mixer or wheelbarrow, mix the dry ingredients well before adding the water.

Dry-stack mortar can be mixed a bit wetter than jointed style; it should be slightly sticky. To test, take a handful, form it into a loose ball, and throw it into the air. If it stays in a ball, you're ready to go. If it crumbles and doesn't stay in a ball, slowly add water. Be conservative. There is probably more water in the mix than you realize, and if the mix becomes too soupy, you'll need to add more sand and cement. On hot days, mix the mortar a little wet because it tends to dry quickly, especially when sitting in the sun.

A fast-drying variation of this 3-to-1 recipe is to change the cement mix from 100% portland to half portland and half type S. Type-S cement is stickier and sets up faster. I use this recipe when I need to be able to build a wall higher than 4 ft. or 5 ft. in a single day. The stickier mortar adheres well to the stone, and it dries within a couple of hours.

TIP: I never build more than 4 ft. or 5 ft. high in one day without using fast-setting (type S) mortar. Portland cement-based mortar won't cure fast enough to hold the weight.

The Craft of Stonework: Cutting and Shaping

The difference between a good-looking wall and a monster has a lot to do with your ability to manipulate a rock. The tighter the stones fit together, the neater the overall wall will look. Good masons know how and where to hit a stone, then where to place it.

To trim the edges of large stones, use a blunt chisel; keep the brick hammer sharp for trimming the edges of smaller stones. If you are unhappy with how the stone looks on the wall, take it down and trim it the way you want it, or simply find another stone.

For a rustic look, minimize surface chiseling; don't trim the textured faces you want exposed. On this job, the homeowners wanted an organic, native stone with a lot of texture, natural weathered color, rigid lines, and shadowed indentations, so I left the faces alone. The sides and tops of the rocks, however, aren't exposed, so I was fairly liberal in trimming around the edges.

Without surface chiseling, the face of the wall will vary somewhat. I set the face of each stone roughly 6 in. from the block wall. Some surface lumps or dimples will be closer or farther. The main body of the stone aligns, and the surface irregularities provide texture.

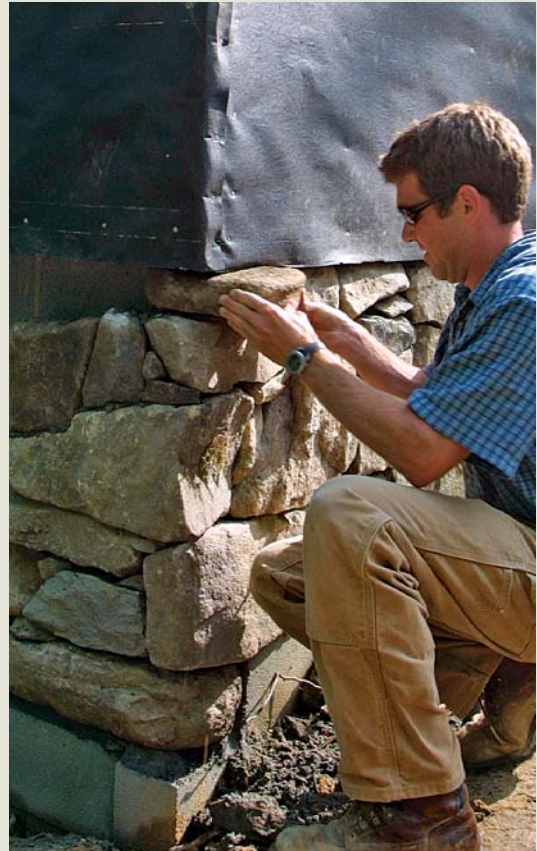
Because cornerstones have two exposed faces, it's a good idea to choose them first. And because the corners dictate the course lines, that's where I start. After setting a couple of alternating cornerstones, I lay a long base of horizontal stones before building up. I never build more than 4 ft. or 5 ft. high in one day without using fast-setting (type S) mortar. Portland cement-based mortar won't cure enough to hold the weight. When placing each stone, orient it so that the thickest part is on the bottom, which keeps it from kicking out when weight is stacked on top. Make sure the stone doesn't shift before you fill in with cement. And don't trim rocks while they are resting on the wall; trimming can loosen surrounding stones before they are set.

alternate the cornerstones

Because cornerstones have two faces exposed, pick them carefully. To make a corner strong, the stones should alternate directions. Build up the corners, then work sideways into the field.



KEEP THE ROCKS PLUMB. Regardless of how thick the rocks are, the faces should be in the same plane. If the foundation wall is plumb, you can measure to the face of the rocks consistently.



THE CAPSTONE TAKES A LITTLE PLANNING. Select the capstones before you place the preceding course. Because the siding will hang down an inch or so, there's some wiggle room that can be filled with mortar.



RAKE OUT THE SEMIDRY MORTAR. After a few hours, the mortar is dry enough to remove all that is visible. Use a pointing trowel and go deep. There should be no visible mortar in a dry-stack veneer wall.

Long Stones Make the Wall Look Stronger

Stones often are packaged in similar shapes: long horizontal stones, nuggets, rounded fieldstones, etc. A pattern that I like is a mixture of 20% to 40% fieldstones and 60% to 80% horizontal stones, but the final pattern depends somewhat on how the stone yard packages the stone. For this job, I bought the stone for the project in bulk to get a more random selection of rock shapes because the homeowners didn't want the wall to have a formal pattern. Even for a random pattern, though, I follow a couple of rules.

- **Rule #1:** Always bridge vertical joints with the stones in the next course. Running vertical joints are not pleasing to the eye and eventually can crack if the foundation settles or shifts.
- **Rule #2:** Alternate corners to the left and right as you set each course. Even with a rustic pattern such as this one, structure demands that the quoins, or large cornerstones, alternate. Although I didn't pull strings from the wall ends for a straight corner, I did take care to choose cornerstones with faces at right angles to one another.

Cap the Wall

Because this veneering project tucks under cantilevered framing, a perfect cap isn't as critical. However, if a veneer projects beyond the siding, a flat cap with the same type of stone gives the wall a finished look and allows it to shed water.

If you know the veneer will need a finished cap, make sure you leave enough room for it. Up to 2 in. more than the thickness of the capstones is enough

TIP: Don't trim rocks while they are resting on the wall; trimming can loosen surrounding stones before they are set.

space to angle the stone away from the house to shed water. Tap capstones with a rubber mallet to set them in position. Make sure the capstones are level. One easy way is to snap a chalkline across the wall before you set the last course of stone.

Finish with a Brush and a Sealer

As you lay the stones, packing mortar behind them to set each one and to hold the wall ties, some mortar will make its way to the surface cracks. After allowing a couple of hours for it to cure, scrape away this excess with a small pointing trowel. The mortar should crumble and fall out. Scraping too soon may smear cement on the edges of the stones or compromise the integral structure of the hidden mortar bed. With dry-stack veneering, you don't need to finish the joints, so after scraping out excess mortar, brush the joints with a small broom.

After a few days, the mortar should be cured fully and ready for a waterproofing sealer. I like Sure Klean® Weather Seal Siloxane PD (www.prosoco.com; 800-255-4255). Waterproofing keeps moisture out of the basement and also prevents efflorescence. Apply sealant to the stone with a garden sprayer. The most important place to seal is the top of the wall (the cap) because this spot gets the most water.

Placing a Concrete Driveway

BY ROCKY R. GEANS

A few years back, we had just finished a driveway at a house in South Bend, Ind. We were about to call it a day when the homeowners' dog got loose, burst into the garage, and used our freshly placed concrete drive as his escape route. When the dog heard us holler, he stopped in the middle of the driveway. Then we tried to get him back inside, which made him scamper back and forth on top of the concrete, making a bad situation worse. We ended up refinishing the whole driveway and giving that dog a scrubbing he'll never forget.

What Lies Beneath

We've been putting in concrete driveways for 30 years, and a crucial part of proper driveway design is making sure the materials below the concrete are adequate (see "Soils Support the Driveway" on p. 234). The first 6 in. to 8 in. of material directly below the concrete is the base. The subbase is the soil 8 in. to 12 in. below the base, and the subgrade is usually the native or naturally occurring soil below the subbase. The design thickness of each layer depends on the soil being built on. Acceptable natural soils such as sand and gravel let moisture drain. If the subgrade consists of this type of soil, then it



RECYCLED CONCRETE FORMS THE SUBBASE. Coarsely crushed concrete is compacted to provide a drainage layer and a capillary break to prevent moisture from wicking up.



AN ATTRACTIVE, LONG-LASTING ALTERNATIVE TO ASPHALT. **Properly installed, a concrete driveway will stand up to a lifetime of vehicular traffic with minimal maintenance.**

can be compacted to serve as the base and subbase, and more excavating and filling are unnecessary.

However, if the subgrade is clay, peat, or fine-grained silty soil that holds moisture and drains poorly, removal of up to 20 in. of subgrade soil might be necessary, depending on the support value of the soil. If you have doubts about the soil characteristics in your case, it's worth hiring a soils engineer to do an evaluation.

Establish Driveway Elevations Early for Proper Drainage

Before excavating and backfilling, the exact elevation of the top of the drive should be established. Then, as earthwork is being done, base grades can be brought up with equipment usually to within 1 in. of their required height, which saves on hand-grading later. For the best drainage, we try to drop the driveway at least $\frac{1}{4}$ in. per running foot away from the house.

Some situations prevent proper drainage, such as an area of concrete that is locked between a house and a garage. In these cases a catch basin may have to be installed as part of the driveway's drainage system.

The best way to remove water from a catch basin is to use a drainpipe at least 4 in. in dia. that returns to daylight or to a storm sewer that is located safely away from the house. A second method is to connect the catch basin to a dry well. In the most extreme cases, a sump pump is installed to pump collected water to a safe place. The last solution is the most costly and probably should be used only with the recommendation of an engineer.

A Compact Base

I check soil compaction initially by walking over the area to get a feel for firmness. In addition, I shove a ¼-in.- to ½-in.-dia. smooth steel rod into the soil in several places to check the resistance. If the soils are

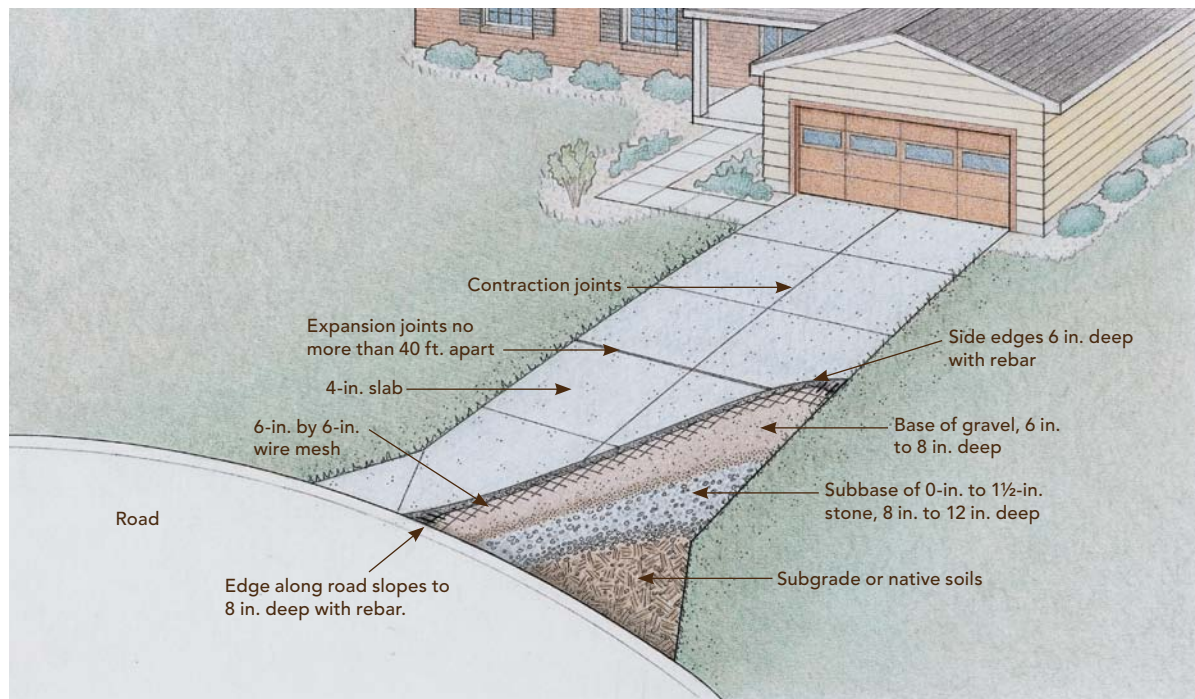
Planning for contraction and expansion joints is a crucial part of the driveway layout.

properly compacted, the rod should encounter firm, even resistance over 2 ft. to 3 ft. However, if the rod meets resistance, say, in the first 6 in. and then can be pushed farther into the soil with ease, it's a sure indication that only the top 6 in. of soil is compacted and that the lower layers of soil are loose. Over time, loose, uncompacted soils will settle as storm water drains through them. Soil settling leaves voids that greatly increase the odds for driveway cracking, sinking or even collapsing in certain areas.

If testing reveals uncompacted soil layers below a top layer that is compacted, then the top soils need

SOILS SUPPORT THE DRIVEWAY

A concrete driveway begins with well-drained soil compacted in layers. Wire mesh stabilizes the slab, and the concrete along the edges is thicker with rebar reinforcement. Expansion and contraction joints give the driveway freedom to move with soil and temperature changes without compromising the strength of the concrete.



to be removed and lower levels compacted properly before the base layers are replaced. In many instances the top 12 in. may be properly compacted while the next 3 ft. to 4 ft. are loose. Ideally, the soils should be excavated down to solid native soil (usually no more than 4 ft.). The soil is then replaced and compacted in 6-in. layers, called *lifts*.

In new construction where excavation has occurred for a foundation, soils should be backfilled and compacted in 6-in. lifts all of the way to final grade. Otherwise, concrete work such as driveways, sidewalks, and patios will settle over time and slope or fall inward toward the house. If there are doubts about compaction in any situation, hire a company to perform an on-site compaction test, a minor investment that can buy peace of mind.

In addition to being properly compacted, the subbase and base need to be made out of materials that will form a capillary break. A capillary break is a layer of soils large and coarse enough to pre-

vent water from being drawn up into them through capillary action the way lamp oil is drawn through a wick. Moisture allowed to wick up and accumulate in soils beneath the driveway slab will freeze, expand, and create frost heaves in the slab. Use 0-in. to 1½-in. stone or recycled concrete for a subbase because it compacts well and creates a good capillary break (see the photo on p. 232).

The Forms Determine the Final Grade of the Driveway

After the soils have been layered and compacted satisfactorily and the proper grades established, the driveway forms can be laid out and installed. We usually make our forms out of 2×4s if the driveway is to get a 4-in. slab or 2×6s for a 6-in. slab. The forms need to be staked strongly enough to hold the concrete and to withstand screeding without movement, so we drive our stakes every few feet. Wooden stakes are okay, but they don't hold up well

the importance of expansion joints

Expansion joints serve several functions in a concrete driveway. First, the expansion joint provides relief between slab sections as the concrete expands and contracts with temperature changes. This movement is horizontal, and the joints that serve this function should be placed no more than 40 ft. apart in any direction. To facilitate this horizontal movement, the base that rests below the slab has to be smooth and well compacted, with no obstructions such as rocks or holes, which can fill with concrete and restrict movement.

The concrete slab needs to be able to slide back and forth over the base. Any restriction of this movement will contribute to cracking. Even the

thickened edge at the roadside is designed with a gradual slope from 4 in. to 8 in. rather than having an abrupt 90° excavation that would restrict slab movement.

Expansion joints also serve as a buffer between the driveway slab and the adjoining rigid structures, in this case the sidewalk and the garage. Movement at these points is vertical; the driveway moves in reaction to changes in the soils beneath the slab. An example is the soil swelling that occurs when moisture in the slab freezes. Without the aid of the expansion joint, the slab would chip or crack as it slid by slight imperfections in the abutting concrete.



THE BASE LAYER IS GRADED TO THE PROPER HEIGHT. The laser level in the background is used to set the forms to the correct height. The crew then grades the base to the forms, and the base gets compacted one last time.



EXPANSION JOINTS GET A PLASTIC CAP FOR INSTALLATION. Expansion joints act as buffers between driveway sections. After the concrete has cured, the plastic cap is removed, and sealer fills the joint to keep out moisture and light.



WIRE MESH IS PULLED UP ON TOP OF A THIN LAYER OF CONCRETE. A crew member pulls the wire-mesh reinforcement up to the proper height with a rebar hook. A bead of concrete laid first supports the mesh during placement.

to being driven and generally can be used only once. On most jobs we use commercially available round metal stakes with predrilled holes for nailing the stake to the form.

The driveway featured here was placed on a nice, gently sloping lot. We began by setting the forms to the natural grade along one side. On the opposite side we ran a string at the exact width of the finished slab. We staked the forms for this side along the string line at roughly the correct height. Next, we leveled from one side to the other to set the exact height of the opposite forms, driving the stakes deeper or pulling them up to adjust the height. We've found that a laser level is the quickest and easiest tool for setting the height of our forms, although a transit or even a water level can be used.



SCREEDING CUTS CONCRETE TO THE RIGHT HEIGHT. A long, straight 2×4 or aluminum box beam is pulled across the surface of the concrete while it is moved in a side-to-side motion. Screeding brings the level of the concrete down to the top of the forms and consolidates it at the same time.

Our forms usually receive a coating of release agent (a special oil available from concrete-supply houses) to provide better consolidation of the adjacent concrete and to make removal easier. After the forms are set, we grade the base layer of soil to its exact elevation and run the compactor over it one last time (see the top photo on the facing page). Then we dig the edges of the driveway down a couple of inches. The thicker concrete along the perimeter provides additional support as well as protects against erosion of the soils next to the drive. We also incorporate a double run of rebar along the edges for additional support.

Adding Expansion Joints

Another crucial part of the driveway layout is planning for contraction and expansion joints. Contraction joints are added during placement, so I'll discuss them later. Expansion joints, installed before concrete placement, allow the driveway to move both horizontally and vertically. Most people think concrete is solid and unmoving. However, concrete

not only moves in relation to other solid structures, such as foundations and roadways, but it also expands and contracts with temperature changes and moves as soil conditions beneath the slab change.

Expansion joints provide a full division between different sections of concrete placement. For the driveway featured here, expansion joints were placed between the driveway and the sidewalk to the front door, between the driveway and the garage apron, and between the two main-driveway slabs that were placed or poured separately. We didn't need an expansion joint between the driveway and the asphalt roadway, but a joint is required if the roadway is concrete. An expansion joint consists of a thin layer of energy-absorbing material such as asphalt-impregnated fiberboard, plastic foam, wood, cork, or rubber. For most driveways, we use ½-in.-thick fiberboard installed with a plastic cap strip on top, flush with the finished height of the slab (see the middle photo on the facing page). After the concrete has set up, the cap strip is removed, and we fill the top of the joint with a joint sealant, Sonolastic® SL 1™ ([PLACING A CONCRETE DRIVEWAY 237](http://www.build-</p>
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order the right concrete mix

Concrete mixes vary depending on the application. But for most driveways, we use a six-bag limestone mix (4,000 psi) with approximately 6% air entrainment. Air entrainment is the incorporation of microscopic air bubbles throughout concrete to help prevent scaling, the flaking or peeling that occurs on cured-concrete surfaces.

The mix order should also include the slump requirement, or the wetness of the concrete when it's delivered. Slump is measured on a scale of 1 to 12, with 1 being the driest mix. For most driveways, we request a slump of 4 to 5, which is easy to spread but can be worked shortly after it is poured. After a mix has been prepared to specifications, adding water can weaken it. The concrete supplier is responsible for the slump as well as the strength of the mix, and the concrete should arrive as ordered. If concrete arrives too wet, it can be sent back.

ingsystems.basf.com), which protects the joint from moisture penetration and UV-degradation. The joint sealant also matches the color of the concrete to add a more pleasing look to the joint.

Another way we restrict vertical movement is by drilling and installing steel dowels into adjoining rigid cement work, such as a foundation just below the driveway slab. A $\frac{3}{8}$ -in. by 12-in. dowel works well in most situations.

The foundation, which is bearing on a footing below frost level, should not move. However, the driveway, which rests on soils only 4 in. to 6 in. below grade, will almost certainly experience some degree of movement. We want to give the drive the freedom to move up but not to drop any lower than the dowel.

We also use dowels to maintain alignment between the driveway and existing flat work, such as sidewalks. The dowel should be smooth and installed parallel to the concrete, not at an angle. Rebar can be used for this application, but it won't work as well because of its rough texture. We drill a hole into the existing flat work slightly larger than the diameter of the dowel, which allows for expansion and contraction. These dowels should be installed a minimum of 2 ft. o.c.

Wire Mesh Is the Best Reinforcement Option

Next we place the reinforcement. We use 6-in. by 6-in. wire mesh throughout the slab as reinforcement. Wire mesh is not designed to prevent concrete from cracking. However, it does prevent widening or horizontal separation of cracks that form.

There are many claims that cracking can be eliminated by mixing nylon or steel fibers with the concrete. I've used fiber mesh on a couple of large parking lots, and I have mixed feelings about the long-term results. I still think that wire-mesh reinforcement installed correctly is best.

In most cases wire mesh is pulled up into the wet concrete while it's being poured, ideally 1 in. to 1½ in. above the bottom of the driveway slab. We have the concrete truck place a bead of concrete at a uniform height that supports the wire mesh while the rest of the concrete is being poured (see the bottom photo on p. 236). Another method that I prefer (although it's probably more time-consuming) is setting the wire mesh on 1½-in. chairs that keep the wire at a more consistent height.

When the wire mesh is in place, I make sure everything has been prepared properly and that every tool needed for finishing the slab is on hand. The next step is ordering the concrete.

Screeding Creates the Level of the Slab

Trucks in our area are able to distribute concrete pretty evenly by controlling the flow of material and the direction of the chute. We work the concrete



A BULL FLOAT SMOOTHS THE CONCRETE AND FILLS VOIDS. As the crew member in the foreground pulls the wide blade of the bull float over the concrete, surface tension is created, bringing water to the surface and filling in imperfections from screeding.

along the edges to consolidate it and to remove any voids. Then the concrete is raked to a rough elevation just slightly higher than the forms and expansion joints. We make sure we never get too far ahead of the screeding process so that any excess can be easily raked down to areas waiting for concrete.

Screeding cuts in the grade of the slab and consolidates the concrete before bull floating (see the photo on p. 237). It's usually done with a long, straight 2×4 (we sometimes use an aluminum box beam screed rail), slightly longer than the width of the driveway. The 2×4 or screed rail that rides on the forms is pulled across the wet concrete with a side-to-side reciprocating motion.

After 2 yd. or 3 yd. have been placed, the edges should be hand-floated and cut in with an edging tool (see the photo at right). The screeded concrete can now be bull-floated (see the photo above). A bull float is a wide, flat metal float mounted on the end



WORKING THE EDGES. A crew member with a flanged edging tool works along the perimeter of the slab to consolidate material and to rough-cut the rounded edge.



A SPECIAL TOOL CUTS THE CONTRACTION JOINTS. Contraction joints score the slab so that cracking from the curing process occurs at these points rather than at random.



KNEE BOARDS KEEP THE MIDDLE MAN from sinking in the concrete. The crew works the surface for the last time, going over it first with magnesium floats and then doing a final smoothing with flat-bladed trowels. The crew member in the middle works on plywood boards that distribute his weight and keep him from sinking into the slab.

of a long handle. As the float is pushed and pulled over the screeded concrete, the leading edge must be elevated to keep from digging in. If the float is mounted on the handle at a fixed angle, bull-floating can be a real workout. The best bull floats have a blade that rotates back and forth by simply twisting the handle; this design allows the operator to keep the handle at a constant, comfortable angle. As the bull float rides over the concrete, it creates surface tension that brings water to the top, which smooths the slab and fills in minor voids at the same time.

After bull-floating, the concrete should be left alone until all bleed water on top of the wet concrete has evaporated. At this point the concrete should be strong enough to support a crew member on knee boards (described later) and is ready for finishing. Finishing

the concrete too early can trap water and create a weak surface with a high water to cement ratio.

Cutting Contraction Joints

The first part of the finishing process is laying out and cutting the contraction or control joints (see the left photo above). Contraction joints act as score marks in the concrete; they create weak points and encourage any cracks that might develop to occur at the joints. To understand how contraction joints work, I need to explain why concrete cracks.

Concrete begins to crack before receiving any loads whatsoever. As the concrete cures and dries, water is absorbed into base materials and evaporates through the surface, which causes the concrete to shrink or contract. Cracks form in the concrete as a



result. Contraction joints provide the relief needed so that these cracks form along a joint instead of randomly in the surface of the slab.

Maximum spacing of contraction joints should follow this rule of thumb. Multiply the thickness of the slab by $2\frac{1}{2}$, and that number represents the maximum distance in feet between joints in any direction. The slab for this driveway was 4 in. thick, so the maximum distance between the joints is 10 ft. ($4 \times 2.5 = 10$).

The depth of the joint should be no less than one-quarter of the thickness of the slab and should be cut in either during the finishing process or immediately afterward. For this driveway we cut the joints with special tools called groovers. We begin by stretching a string between our layout lines and snapping it to leave an impression in the wet concrete. We work the groovers along straightedges to cut in the joints. Thicker slabs require deeper joints that are cut with saws equipped with blades designed to handle fresh, or green, concrete.



A BROOM FINISH PROVIDES TRACTION. A broom finish is applied to the still-wet concrete after it is troweled. A wide, fine-bristled broom is dragged slowly in parallel strokes from the middle of the slab out and is cleaned with water between strokes.

Working from Knee Boards

After bull-floating, all of the steps in finishing concrete, including cutting in the contraction joints, require a crew member to work in the middle of the slab on top of the uncured concrete (see the right photo on p. 240). To keep from sinking into the fresh concrete, the crew member works on a pair of knee boards. We make our knee boards out of ½-in. plywood about 24 in. long and 16 in. wide. We cut the corners off to keep them from digging into the fresh concrete, and we put a handle on one end, which helps a lot when the crew member is moving the board around on the slab.

After the contraction joints have been cut, the crew works the surface of the slab one last time. For most driveways one crew member works the center of the slab while two work the edges. First they go over the surface with an aluminum or magnesium hand float with a thick blade (slightly round in section). This process, known as magging, releases air that might be trapped in the concrete from bull-floating and leaves a smooth, open texture on the uncured concrete.

As a final step, a trowel with a thin, broad metal blade is passed over the surface in large circular strokes. Troweling should leave the surface of the slab smooth and flat. If any slurry from the magging gets into the contraction joints, it will be necessary to go back over them with the groover and blend the edges of the groove into the rest of the slab with a trowel.

Broom Finishing

We give most of our exterior flat work, including driveways and sidewalks, a broom finish for traction. Right after troweling, a crew member drags a wide broom over the slab in smooth, parallel strokes (see the photo on p. 241). We use a fine-bristled broom made either of nylon or of horsehair. A coarse broom will dig into the surface too deeply and dislodge the aggregate. Because this driveway was double wide, the crew member started at the middle and dragged the broom to the outer edge for each side of the slab. The broom should be cleaned by dipping it in water after each stroke to keep excess concrete from building up in the bristles and changing the texture.

Right after we finish, we spray on Sonneborn® Kure-N-Seal™ (www.buildingsystems.basf.com), a combination curing and sealing compound. Used to prevent water from evaporating too rapidly, curing compounds form a membrane on the surface of a slab. Application of curing compound effectively slows the curing rate, and the longer concrete takes to cure, the stronger it becomes. Concrete treated with curing compound also has better resistance to scaling. Sealing compounds prohibit moisture from getting into the concrete once the concrete has cured. Because the concrete's curing takes several days, we recommend not allowing vehicular traffic on the slab for a week.

Build a Sturdy Stone Sitting Wall

BY BRENDAN MOSTECKI

I used to get annoyed when I heard people compare building a stone wall to assembling a jigsaw puzzle. Stone walls have no precut pieces, and they certainly don't come with a picture. Then one day I sat down with my two sons to put together a jigsaw puzzle. As these things often go, they quickly ran off with the box, and I was left with a pile of pieces but no road map. That's when I realized that a stone wall wasn't so different from a puzzle after all. I start each wall by emptying and sorting a pallet of stone into four categories: base pieces, face pieces, corner-stones, and caps. I lay out the first row, establish the corners, then work in toward the middle, just like a puzzle but without the picture, of course.

I could write an entire book about different ways to build stone walls. They can be dry stack or wet-tack (set in mortar with or without visible joints) and built either freestanding or with stone applied to the face of concrete blocks. The stones can be round or flat, natural or chiseled, rough or smooth, and random or uniform.

For the project shown here, my crew and I built a small retaining wall that doubles as extra seating around the perimeter of a patio. Sitting walls can be topped with large flat stones that match the face of the wall but I prefer to cap these walls with custom slabs, in this case bluestone.

Size the Base, and Consider the Drainage

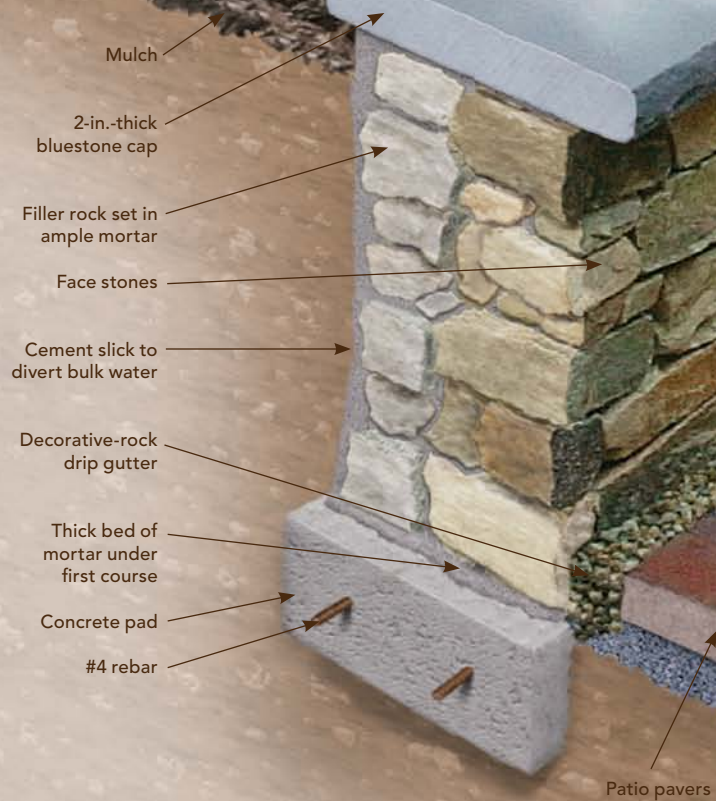
Stone walls can be built atop a well-compacted gravel base or atop a poured concrete footing. Personally, the only time I choose a gravel base is if I'm building a dry-stack farmer's wall. For most situations, substituting the gravel base with a rebar-reinforced concrete pad allows you to cut the base depth in half. A concrete pad also helps unify the assembly, allowing the wall to rise and fall as one unit when the ground freezes and thaws.

In most cases, a poured footing can be formed just by digging a trench, adding rebar, pouring the concrete, and letting everything set. Straight footings are the easiest, but curved footings aren't much extra work. Once I have the area cleared and leveled, I scribe the curve in the dirt, playing around with the layout until I'm happy with the shape and the flow of the wall. Then digging can begin.

If patio pavers are going to abut the stone wall, I like to form the edges of the footing with ¼-in. or ½-in. plywood, which I remove once the wall is built. This creates a smoother surface so that in winter months, the patio pavers will be less likely to collide with the wall footing and heave; it's the same principle as using cardboard Sonotubes for pier footings.

DRY-STACK, BUT WET IN BACK

Although it has a classic dry-stack look, each stone in this wall is actually set in mortar. Because the back of the wall is hidden, it is built with inexpensive rock and coated with a slick of cement to provide strength and to help control drainage.



Drainage and hydraulic pressure are also concerns when I'm designing a wall. I wish there were a rule of thumb for this issue, but every installation is different. The stone wall featured here was set at the foot of a short hill; the soil both below it and behind it had lots of gravel mixed in to provide excellent natural drainage. In this case, no other drainpipes were necessary, but if a retaining wall is at the bottom of a long downward-sloping hill and doesn't have at least a perforated drainpipe set similar to a typical footing drain on a house, the buildup of water behind the stone will force the wall forward (see "Tall Walls Need Drainage" at right). It's also sometimes necessary to install small-diameter PVC pipes through the wall to allow water to drain from behind the stones. If you are unsure of your site conditions, I suggest calling a qualified contractor to help you assess the soil, drainage, and other factors. The same is true if you are building a wall that will be taller than 4 ft. or that will support a structure or a driveway; consult a structural engineer. These walls often need additional reinforcement and are best left to professionals.

The First Course Is the Easiest

Once the footings have cured, I like to spread the pallets out and pick through all the stone to find cornerstones and, if necessary, capstones. Cornerstones should have at least one 90° angle; capstones should be relatively large and flat on one side. When I find a stone that looks appropriate for the face of the wall, I use my bricklayer's hammer to chip off unwanted tapers and nonusable corners until the stone is ready to go. Doing this work at the pallet also keeps most of the waste away from the wall, which makes it easier to work.

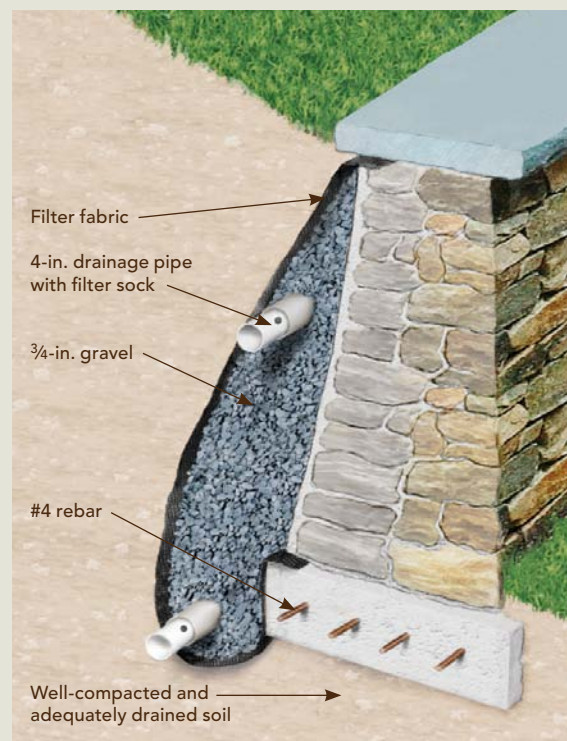
I put the usable stones in a wheelbarrow and move them to the working area near the wall. I place the undesirable stones and broken leftovers in buckets to be used as backfill, as shims to prop up the main stones during installation, and later as chinking to fill gaps.

tall walls need drainage

Because the wall in this project was only about 2 ft. tall and was surrounded by soil with a high gravel content and lots of thirsty vegetation, we didn't need a massive amount of reinforcement or additional drainage behind it. Extra drainage is, however, a good idea for walls that are taller, built over clay soil, or located in an area that sees lots of runoff. If you are unsure, don't wing it. Contact a qualified contractor or mason to help assess the site conditions.

The standard approach to drainage is a perforated drainpipe set at the bottom edge of the concrete pad and surrounded by free-draining gravel, with the whole assembly wrapped in filter fabric. Short lengths of 1-in.-dia. PVC pipe also can be placed among the stones to let out water from behind the wall.

If the wall is taller than 4 ft., it's often a good idea to incorporate drainage at the footing and at the upper part of the wall as well (see the drawing below). I also like to pitch tall walls backward about $\frac{3}{4}$ in. for every 3 ft. of vertical rise.



laying the first courses

The concrete pad will be wider than the finished wall, so it's important to double-check that the wall sits at the right spot on the pad by dry-laying the first course. Once I'm happy with the curve, I trace a line along the front face of the stones **1**, then pick up the stones one at a time and set them in a thick bed of mortar.

Using the first course of stones as a guide, I drive wooden stakes into the ground at each corner and transition point, and I tie and level guide strings tautly to each stake **2**. I prefer to tie the strings with loops so I can move the string up as work on the wall progresses.

The flat surface of cornerstones makes it easier to stack courses neatly and ensures that the end of the wall is both strong and attractive **3**. I like to establish the corners early because they require stones with at

least two flat faces that are square to each other, and finding these stones takes time.

Once the first course is set, I place the rest of the stones, keeping the mortar toward the back where it won't be visible **4**.

Stone walls set on top of stepped pads are a bit less forgiving in terms of layout. Almost as important as setting the corners, the height changes must be laid out carefully to keep subsequent courses level **5**.



The first course sets the curve of the wall.



Keep it in line with string.



Corners anchor the wall.



Aim for a dry-stack look.



Pay attention to changes in height.

The first course of stones in this type of wall is actually the easiest because you don't have to think about the bottom of each stone; you need to worry only about the sides and the top because a healthy bed of mortar evens out the bottom. For this first course, I choose stones that vary in height and size, but I make sure they are flat on top. Any stones that have a flare or a slope will be difficult to build on top of, so make sure to put that side of the stone face-down. I like to lay out the whole first course before applying any mortar, which allows me to double-check my work. After adjusting any stones I'm not happy with, I mix the mortar and set the first course.

String Lines Help Guide the Installation

String lines (mason twine) are essential for helping me keep each course of stone level and plumb. The string line should be set even with the front face of the first course of stones and moved up on the wooden stakes as the courses progress. I periodically check that the wall is plumb by standing above the string line and looking down toward the base of the wall (see the photo 2 on the facing page). This string-sighting method doesn't work as well on curved walls as it does on straight walls, so make sure also to check the curved sections with a level as the wall is built.

With the string lines in place, I begin work on the corners and transition points of the wall, building them up to the desired finish height, then filling in toward the middle.

My last piece of advice: Don't work in one spot on the wall. Instead, grab one stone at a time, and bring it to an appropriate spot on the wall. The stones might need to be tweaked with a few blows from a bricklayer's hammer before being placed on the wall, but if you pick up a stone, install it somewhere.

After all the courses have been set, the capstones can be fabricated and installed. I prefer to leave backfilling and landscaping until after the capstones have set up completely. This allows me to run the backfill right up to the back edge of the bluestone for a smooth transition.

match the mix to the task

The basic ingredients in a batch of mortar are portland cement, hydrated lime (typically labeled as type-S or type-N mortar), and sand mixed with water. I vary the mix proportions depending on the task. Here are the different mixes I used for this stone wall.



FACE/FILLER STONES

- 1 bag type-2 portland cement
- ½ bag type-N or type-S mortar
- 18 to 20 shovelfuls of sand
- About 5 gal. of water
- Adjust amount of sand until the mix looks smooth and fluffy.



CAPSTONE AND SLICK ON BACK SIDE OF WALL

- ½ bag type-2 portland cement
- ½ bag type-N or type-S mortar
- 14 shovelfuls of sand
- 3 gal. to 4 gal. of water
- Mix to a thick, peanut butter-like consistency.

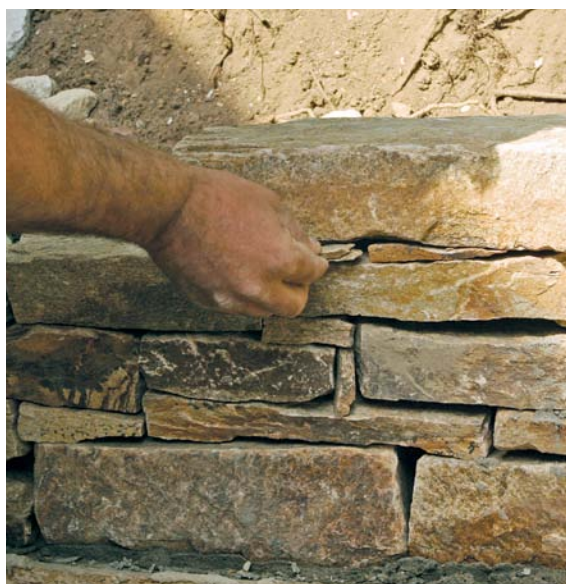




BUILD UP THE BACK SIDE. After setting a few courses of stone on the face of the wall, the author builds up the back side with less expensive blasted ledge stone set in plenty of mortar.

Customize the Cap with a Rock and Thermal Finish

Because this wall borders a patio and is meant to be a place to sit, I chose an 18-in.-deep bluestone cap. To dress up the edges, I did a “rock and thermal” finish. These finished caps can be ordered from a masonry supplier, but this service is not cheap, especially on curved caps, which require some additional steps. I prefer to do the work myself, starting with 24-in.-wide by 4-ft.-long slabs. I recommend practicing the cutting, chiseling, and torch work on a scrap before taking on the full slabs; each type of stone behaves differently. Also this work involves lots of dust, heat, and flying shards of rock, so wear a respirator when making cuts, safety glasses when chiseling, and a full face mask and gloves when using the torch.



GAPS GET SCRAPS. To help create a true dry-stack look, the crew uses the chipped-off chunks and slivers from the rock hammering to fill the spaces between stones. Ideally, these small stones will slide in deep enough to be held in place by the mortar. If not, we add a bit of mortar before inserting.

STEP 1

After I've laid out the slabs and cut the joints with a diamond-blade wet saw, I decide on an appropriate overhang for the front edge, typically 1¼ in. to 1½ in. so that water running off the cap won't drip onto the face of the wall. Next, I use a flexible piece of vinyl molding to transfer the curve of the wall to the capstone.

STEP 2

After making a shallow cut along the line with my angle grinder and a diamond blade, I then transfer the curve to the back of the capstones and cut both edges using a wet saw. If the curve is too tight for the saw, get close, then finish with an angle grinder. Don't worry if your cuts aren't perfect; just make sure they are square and not tapered in or out vertically.



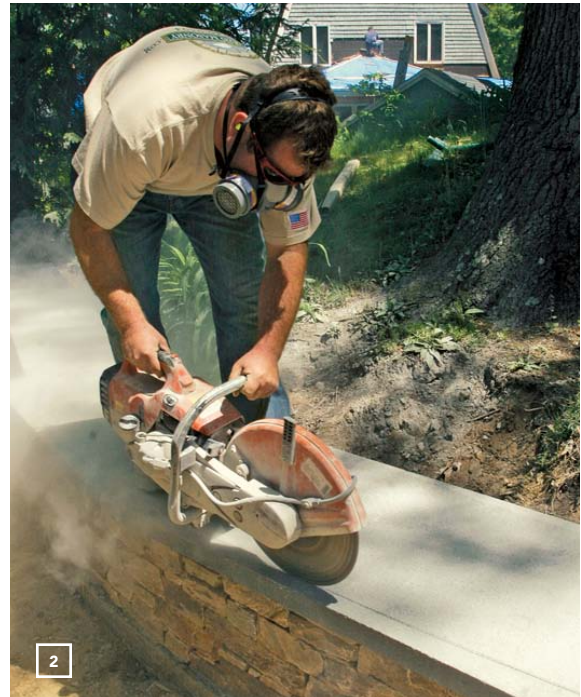
Determine the overhang.

STEP 3

The chisel work, also known as “rocking,” comes next. I set one of the slabs in a bed of sand, making sure that it's fully supported to prevent cracks from the force of the chisel and hammer. I scribe a guide-line about ¼ in. from the outside edge of the stone, place a chisel on the line, then strike it with the sledge in a firm outward motion. I move the chisel over, and repeat. Once all the edges are rocked, I place the slabs back on the wall, using cutoffs as shims to keep them level front to back.

STEP 4

I complete the look by “thermaling” the chiseled edge of the stone to make it appear natural. First, I soak the edge of the slab with water, and then follow along with a torch to make the surface pop off. I prefer to use an oxygen-propane torch with a



Cut the curve.

rosebud tip and grade-T hose (www.airgas.com). A small propane torch kit (www.bernzomatic.com) can also be used for small jobs, but don't expect to get much run time out of these smaller cylinders. The key is the right amount of heat. The torch should be hot enough that you hear the surface of the stone pop off within seconds of being touched with the tip of the flame.

To set the caps, I pour a crumbly, dry mixture of mortar on the top course of the wall, and then brush a thick, gooey mixture of mortar and water on the

back side of each slab before placing it on the wall. This combination of wet and dry mortar forms a durable bond. After the cap has set for 24 hours, the joints between each slab can be cut to the desired width and taped off with painters tape in preparation for jointing. Mortar is a good choice for joints in masonry surfaces that will see lots of foot traffic, but a sitting wall won't get much traffic. The wall I built for this project will be fully exposed to the harsh New England ice and snow, so I used a flexible silicone sealant.



Chisel the outside edge.



Torch the chiseled edge.

Creating a Curved Concrete Walkway

BY RICK ARNOLD

While the work might seem intimidating, installing a curved concrete sidewalk is a surprisingly easy project that most anyone with a few friends and a day of good weather can handle.

The first step is preparing the base. In general, the base needs to be free of organic material, well compacted, and free draining. For this walk, I excavated the topsoil, then placed and tamped down a layer of gravel and dirt so that the top of the base material was 4 in. below the final elevation of the walkway.

I also pitched the section near the house about $\frac{1}{8}$ in. per ft. to direct water away from the house. Although the minimum width of a sidewalk is 3 ft., I made this walk 4 ft., which is more comfortable to use. Because this walk needed to turn 90° toward the house, I included a curve for extra interest.

Plan the Path

If you're working around established landscaping, you can stretch out a garden hose or two to visualize the path. Because this simple design was built on bare soil, I outlined one side of the path with a can of marking paint and then used a 4-ft. stick to space and mark the other side evenly. With conventional $\frac{3}{8}$ -in. plywood forms, a 2-ft. radius is the tightest turn you can make, but tighter turns are possible

with plastic forms, which are available at concrete-supply houses.

Reinforcement Is a Must

All concrete needs reinforcement to prevent cracks. For this sidewalk, I used 6-in. wire mesh and #3 ($\frac{3}{8}$ -in.-thick) rebar. To bend the rebar to fit the curves, have a helper lift up the end while you walk down its length. When placing it, be sure to overlap the bars by at least 12 in., and secure the joint with tie wire (or plastic zip ties) in two places. The steel should be near the middle of the concrete depth (about 2 in. from the bottom). You can either place the reinforcement on supports (called *chairs*), or you can pull it up as the concrete is being placed.

Order Concrete Like a Pro

Place your order two or three days ahead of time for a better chance of getting the concrete when you want it. Be prepared to give the dispatcher directions to the job and answers to the questions below. When you're done placing the order, ask the dispatcher to read back the specs and to give the total price. The total should include the price per yard as well as any extras for fuel, Saturday deliveries, or small loads. Ask about the standard unload time. Some suppliers charge extra when their trucks are on site longer than normal.



FORMING, POURING, AND STAMPING a concrete walkway creates an inviting path to any front door.

WHAT STRENGTH AND SLUMP?

Residential concrete is generally rated from 2,000 psi to 3,000 psi. Used for exterior flat work, a 2,500-psi air-entrained mix is common in sidewalks and patios, but check with your building inspector for local requirements. Measured on a scale from 1 in. to 10 in., slump describes the stiffness of wet concrete. The lower the number, the stiffer the mix. Walks and patios should be placed at a 5-in. slump, whereas steps should be at a 3-in. slump. Water weakens the mix, so place concrete as stiff as possible.

HOW MANY CUBIC YARDS?

Dispatchers often help you figure out how much concrete you need, but this should be a way to double-check a figure you've already come up with. For sidewalks, multiply length by width (in feet)

by thickness (4 in. = 0.33 ft.), and divide by 27.

For curving walks, use a 50-ft. or 100-ft. measure (they're more flexible) to follow one side of the walk's curving formwork. Double-check your math, and add 10% to compensate for spillage and an uneven grade.

HOW MUCH TIME BETWEEN TRUCKS?

If your order requires multiple loads (a full-size mixer holds between 9 yd. and 11 yd.), consider how long you need to empty each truck. Because the concrete will start to cure, you don't want a truck waiting, and you'll also have less time to pour and finish. If you're using a wheelbarrow to move wet concrete, plan to have three or more going at once.

(continued on p. 260)

lay out and form

A curving walkway starts with a stable subgrade of well-compacted, free-draining material. The design is planned either with a garden hose or by eye and is transferred to the soil with marking paint. Curving forms are made from 4-in. strips of $\frac{3}{8}$ -in. plywood screwed to stakes so that the tops of the plywood and the stakes are flush. Straight forms made from 2× stock are placed similarly. Inside the forms, a grid of reinforcement helps prevent cracks and control shrinkage.





DRIVE THE STAKES. Space the stakes every 1 ft. in the curved sections and every 2 ft. in straight sections. Then, using a rotary laser equipped with a receiver (a water or spirit level works, too), mark the stakes no less than 4 in. above finished grade. Once they're marked, cut them off with a circular or reciprocating saw so that the screed board can pass easily.



ADD REINFORCEMENT. Place sections of reinforcing mesh so that the panels overlap by 6 in., and cut away the excess so that the wire is about 2 in. away from the sides of the form. Then put in rows of $\frac{3}{8}$ -in. rebar spaced about 1 ft. apart. Overlap the bars by 1 ft. and tie them together at both ends of the overlap.



WET THE GROUND. Concrete needs adequate water to cure properly. Prevent water from being drawn out of the concrete by thoroughly wetting the ground just before you start pouring.

pour and finish

The main worker screeds the concrete level with the forms while helpers rake out the concrete and raise the reinforcement so that it's in the center of the slab. Finishing starts with a magnesium bull float to bring up bleed water and force the aggregate into the mix. After the bleed water has evaporated, start troweling, first with a magnesium float, then with a steel finishing trowel.



PULL UP THE REINFORCEMENT. You can place rebar and reinforcing mesh on small metal stands, called chairs, ahead of time or you can raise them as you spread the wet concrete.



BULL FLOAT FIRST. Take two or three passes with a magnesium bull float to level the surface and to push the aggregate into the mix. Raising the leading edge of the float will prevent it from digging into the surface. Additional handle sections provide extra reach on large pours.



BRING UP THE CREAM. A smaller float made of magnesium, aluminum, or wood brings cement particles and fine aggregate to the surface. The resulting cream fills small voids and smooths the surface.



EDGE THE CORNERS. After mag floating, use an edging tool on the slab corners. Rounded edges resist weather better than do sharp corners.



FINISH WITH A STEEL TROWEL. The final finishing tool is a large steel trowel, which forces the cream back down into the surface for a smooth, durable finish. Trowels with curved corners are less likely to leave tracks.

stamp the surface

After finishing with a steel trowel, cover the surface with a powdered release agent (www.advancedsurfaces.com), which allows the stamp mats to be removed without damaging the textured surface. Arrange the mats in running-bond

pattern, and start stamping. At first, stamping is easy, but it gets more difficult as the concrete firms up. Stamp mats are expensive, costing between \$100 to \$200 each, but they can be rented at many concrete-supply yards.



TRANSITION AT CURVES. A stripe with a simple contrasting pattern provides a convenient place to hide control joints and to eliminate odd transitions where the walk changes direction.



APPLY RELEASE AGENT. Before stamping, cover the entire surface with a release agent. Shaking it on with a broom is fast and easy, but be careful not to hit the wet concrete with the bristles.



ARRANGE THE STAMPS. Place the first row of stamp mats parallel to the form's end board, and stagger subsequent rows to create a running-bond look. Tamp the form straight down. Be careful not to overstamp, or you may leave small cracks in the surface. You may have to vary the order you stamp, depending on the pattern.



six tips for keeping up with concrete

1. PLAN FOR THE WEATHER

Hot, dry, and windy conditions mean the slab will set up more quickly. In cool, damp conditions, it may take hours for the slab to firm up. In either case, start early and have extra help to finish the job.

2. USE A MINIMUM OF WATER

Although wet concrete is easier to work, it also has less strength and shrinks more, leading to cracks. Get extra help instead of relying on soupy concrete to make the job easier.

3. DON'T LEAVE THE SLAB

It may be tempting to run for lunch while the bleed water evaporates, but don't do it. You could return to a slab that's too hard to finish. Have a helper get lunch while you keep an eye on things.

4. A SLOW CURE IS BEST

Few things weaken concrete as much as having it set too quickly. Cure finished concrete slowly by spraying on a curing compound or by covering the surface with wet burlap or straw. Don't use plastic because it can discolor the surface.

5. START FINISHING RIGHT AWAY

You can start finishing fresh concrete when you step on the wet surface and your boot leaves a ¼-in.-deep depression. Wait longer, and you'll have less time to do the job.

6. CLEAN YOUR TOOLS

Wash your tools as soon as you're done using them. Dirty tools leave a rough finish, and cleaning off crusty residue is a pain.

IS THIS A FIRM ORDER?

When the weather is iffy, some suppliers take a will-call order, meaning that the concrete will be sent only if you call ahead of time (usually 2 hours) to confirm. This contrasts with a firm order, which means that your concrete will be delivered at the agreed-on time unless you cancel. If you need to postpone, call the dispatcher right away.

Get Extra Help for the Pour

When it's time to place the concrete, it helps to have at least three people on hand. The most important job is getting the concrete flat with a screed board. A screed board is a 2×4 long enough to span the formboards on both sides of the walkway. It scrapes away excess concrete and highlights low spots so that the forms are filled to the perfect level. You also need people with rakes to move the concrete around. Their job is to place the right amount of concrete in front of the screed and to lift the wire and rebar into the middle of the concrete as the pour progresses.

Concrete has a limited working time. When temperatures are in the high 70s or warmer, you may have only 30 minutes before the concrete is too hard to finish and stamp, but in cooler temperatures, especially below 65°F, you may have to wait an extra hour or two before you can start finishing. Note: projects in direct sun will set up faster than those in shady areas.

As you stamp the concrete, it will get harder. But be careful not to pound too heavily, which will create small cracks in the surface. Once you've finished stamping, check the edges and transitions for any places that need to be touched up.

Apply a Sealer

After about 24 hours, wash off the release agent with a garden hose. Once the surface is dry, apply a good sealer with a thick-nap paint roller or a garden sprayer. I like to use Renew-Crete® sealer (www.renewcrete.com) because it usually covers in a single application. A walk like this costs about \$8 per sq. ft. in my area, which is a bargain compared to the \$12 per sq. ft. a walk with real cobbles would cost.

contributor list

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Front cover: Daniel S. Morrison (FHB). Back cover: John Ross (FHB).

The articles in this book appeared in the following issues of *Fine Homebuilding*:

pp. 5-7: Understanding Building Loads by Rob Munach, issue 212. Drawings by Chris Mills (FHB).

pp. 8-15: Soil: The Other Half of the Foundation by Robert M. Felton, issue 136. Photo p. 9 by Tim O'Brien (FHB), photo p. 12 courtesy of S&ME, Raleigh, NC, photo p. 15 courtesy of Avongard. Maps p. 10 U. S. Dept. of Agriculture (left), U.S. Geological Survey (right). Drawings by Christopher Clapp (FHB).

pp. 16-24: Working with Rebar by Howard Stein, issue 137. Photos by Charles Bickford (FHB), except bottom photo p. 17 and photo p. 21 by Howard Stein, product photos p. 23 by Dan Thornton, top photo p. 23 by Roe A. Osborn. Drawing by Christopher Clapp (FHB).

pp. 25-28: Start with Batter Boards by Jim Blodgett, issue 169. Photos by Hugh Lentz. Drawing by Dan Thornton (FHB).

pp. 29-31: Mix Concrete by the Bag by Scott Grice, issue 186. Photos by John Ross, except left photo p. 30 courtesy of Jackson Professional Tools.

pp. 32-42: Avoiding Common Mistakes in Concrete and Masonry by Thor Matteson, issue 103. Photos by Thor Matteson. Drawings by Mark Hannon.

pp. 43-51: A Solid Deck Begins with Concrete Piers by Rick Arnold, issue 180. Photos by Christopher Ermides (FHB), except bottom right photo p. 49 courtesy of Ardisam Inc. Drawings by Dan Thornton (FHB).

pp. 53-62: Pouring Concrete Slabs by Carl Hagstrom, issue 83. Photos by Rich Ziegner (FHB).

pp. 63-72: Laying Up Concrete Block by John Carroll, issue 111. Photos by Steve Culpepper (FHB), except p. 63 by Scott Phillips (FHB).

pp. 73-80: Forming and Pouring Foundations by Rick Arnold and Mike Guertin, issue

119. Photos by Roe A. Osborn (FHB) except photos p. 78 by Justin Fink (FHB).

pp. 81-92: Forming and Pouring Footings by Rick Arnold and Mike Guertin, issue 120. Photos by Roe A. Osborn (FHB).

pp. 93-95: Frost-Protected Shallow Foundations by Martin Holladay, issue 216. Drawings by Dan Thornton (FHB), except p. 94 by Steve Baczek.

pp. 96-101: An Energy-Smart Foundation in Two Days by Tim Robinson, issue 186. Photos by Daniel S. Morrison (FHB), except bottom right photo p. 101 by Anna Robinson. Drawing by Don Mannes.

pp. 102-109: Building a House of Insulated Concrete Block by Fred Leadbeater, issue 132. Photos by Fred Leadbeater, except photos p. 103 and p. 109 by Scott Gibson (FHB). Drawings by Christopher Clapp (FHB).

pp. 111-121: Details for a Dry Foundation by William B. Rose, issue 111. Drawings by Christopher Clapp (FHB).

pp. 122-132: Keeping a Basement Dry by Larry Janesky, issue 140. Photos by Tom O'Brien (FHB), except photo p. 125 by Larry Janesky and photos p. 130 by Harold Shapiro. Drawings by Rick Daskam.

pp. 133-142: Foundation Drainage by David Benaroya Helfant, issue 50. Photos by Charles Miller (FHB). Drawings by Frances B. Ashforth.

pp. 143-145: Keep Your Basement Dry with a Curtain Drain by Eric Nelson, issue 189. Photos by Eric Nelson, except for product photos p. 144 by Krysta S. Doerfler (FHB). Drawings by Martha Garstang Hill (FHB).

pp. 146-153: Sealing a Crawl Space by Larry Janesky, issue 153. Photos Harold Shapiro, except for fastener photo p. 152 by Roe A. Osborn (FHB). Drawings by Mark Hannon.

pp. 155-160: Retrofitting a Foundation by Brian Brophy, issue 217. Photos by Brian Brophy, except photo p. 155 and left photo p. 157 by Rob Yagid (FHB) and photos p. 160 by Rick Arnold.

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