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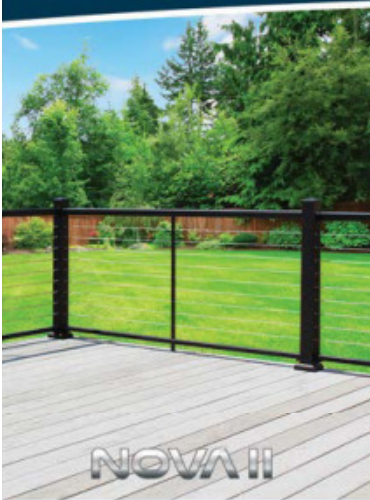
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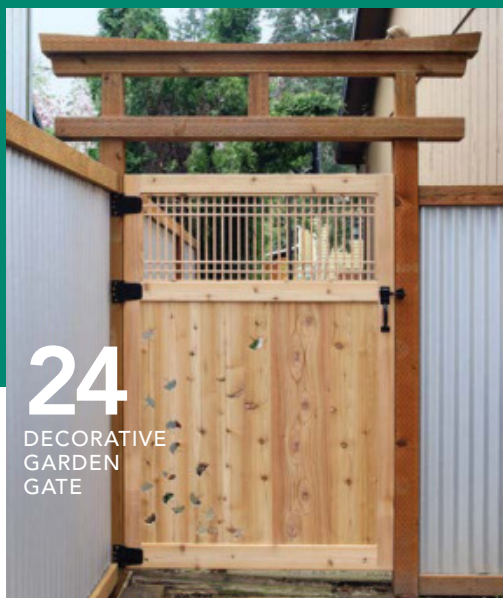
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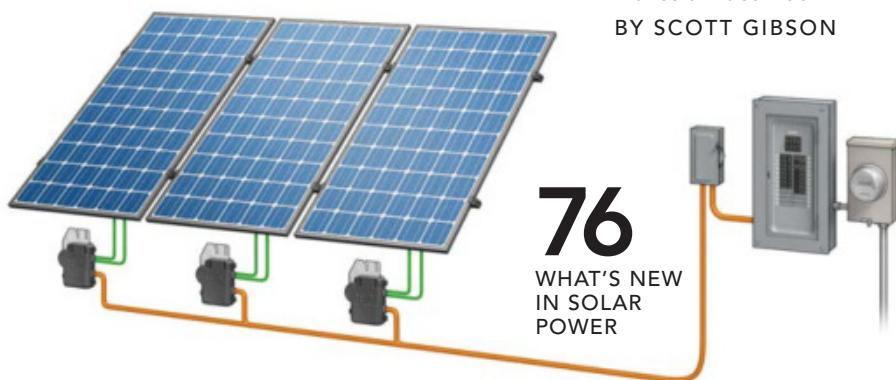
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Everything you need to tackle your deck project with confidence

The world of deck building is constantly evolving, with new materials, new techniques, and new codes to follow. In this comprehensive project guide, over 40 deck-building pros share their expertise, leading you every step of the way from design to finish.

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Build or renovate a porch

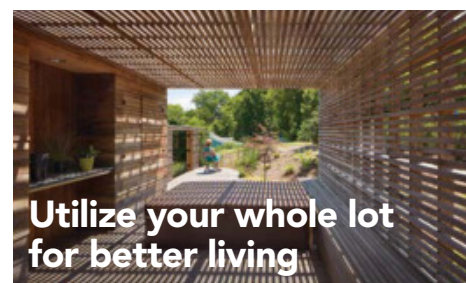
Find the information you need to build or restore this outdoor part of a home and ensure it can stand up to the elements year-round.

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Guide to building sheds

We've compiled our favorite articles and videos to help you build your own shed, from setting the foundation to roofing, and everything in between. [FineHomebuilding.com/shed-build](https://finehomebuilding.com/shed-build)



Utilize your whole lot for better living

Architect Tina Govan shows how simple modifications can better enhance the relationship between the interior and exterior of a home. [FineHomebuilding.com/whole-lot](https://finehomebuilding.com/whole-lot)

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THE VOICES OF EXPERIENCE



DAVID HORNSTEIN ("Durable and Good-Looking Traditional Gutters," pp. 42-47) is the principal of Light House Design. He got his start building geodesic domes in the 1970s, then worked for a variety of design-build companies before starting his own Boston-based practice in 1980. David's son Doug recently joined the company and brought his carpentry and computer-modeling skills to the practice. Every component of Light House Design's projects is computer modeled, including framing and mechanicals.

In 2002, after trying out some less satisfying occupations, **MARIA KLEMPERER-JOHNSON** ("Scribing Rails to a Round Column," pp. 31-35) followed her passion to become a builder. In 2013, she founded Hammerstone School of Carpentry for Women to share that passion with other nontraditional builders. She now teaches residential construction at SUNY Delhi, and during her summers continues to build and teach carpentry for women in Trumansburg, N.Y.



KEVIN MANNING ("Rock-Solid Deck Stairs," pp. 20-23) is a project manager at Red House Design Build in Providence, R.I. He has been working in the field for 18 years, tackling a variety of roles from painting to roofing, and working his way up the ranks in carpentry. Recently promoted from lead carpenter, Kevin's role as project manager has him hanging up his tool belt to take on the supervision of multiple projects at a time, managing budgets, schedules, Red House carpenters, and trade partners.

write an article

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Creating a greater outdoors

It's more important now than ever to think about how the environment outside your home affects the one inside your home. If the last few years are any indication, having a space where you can enjoy the weather, gather with friends and family, and decompress after a day at the (home) office is vital to your health and happiness. Sometimes, an old chair and a spot on the deck is everything the doctor ordered. Thinking more broadly about the outdoors, it's clear that weather patterns are changing, and weather events are becoming more drastic. Increased exposure to extreme weather conditions means that building resilience into our landscape and our homes is vital to long-term health and survival.

If you're looking for a great outdoor project that teaches you some new skills and gives you a place to enjoy and show off the fruits of your labor, I can't think of a better place to start than a deck. You'll learn about framing and footings, deck boards and railings, and one of the most confounding subjects for first-time builders: stairs (pp. 20-23). With a generous time line and good weather, building deck stairs is just the right combination of mathematical calculation and fun with tools. If your deck is in tip-top shape and you're looking to flex your building skills on a project that'll impress the neighbors, the Japanese-style garden gate on pp. 24-30 will be right up your alley. Combining detail-oriented woodworking with resilient materials results in a statement piece that'll last for years to come.

One of the joys of being a homeowner is seeing the effects of the outdoors on your house, and figuring out how to fix it. Water can be one of the most destructive forces a house sees, so durable gutters are a must. The architectural aluminum gutters featured on pp. 42-47 offer a combination of pleasing aesthetics and protection from the elements. And if you have a brick chimney, you can keep it in good shape, both aesthetically and functionally, by learning about repointing—a task that's more tedious than complicated—on pp. 48-53.

If your eyes are on the future, there are plenty of progressive outdoor upgrades to ponder, including one of today's hottest topics: solar power. Not only are solar panels more affordable than ever, it's clear that power outages are going to be more common for much of the country while electrical infrastructure is modernized. Take a peek at "The Steady Surge in Solar Power" (pp. 76-81) and "Solar Energy Storage" (pp. 82-85) for a thorough primer on collecting and storing your own energy. Being prepared is half the battle, and choosing the right generator (pp. 86-90) can give you peace of mind when the unexpected happens.

So whether you're making a spot to relax or making your house better suited for the future, here's to good weather and great building.

—ANDREW ZOELLNER

editorial director

Placing a small concrete slab

Although the amount of concrete used is small, the forming and finishing techniques for a slab such as a deck-stair landing—or in this case, a propane-tank pad—aren't much different from those used for larger slabs. First and foremost is subgrade preparation. Get that wrong, and the slab will crack. The underlying ground needs to be compacted evenly. In most cases, slabs shouldn't be placed next to new buildings until the backfill around them has settled for several years. After digging out the slab location, compact the soil directly below so that there's no loose dirt.

Use a gravel base

One step that's called for but rarely done on small jobs is to place gravel between the slab and the subgrade. The usual explanation is that the gravel provides drainage to prevent soil saturation and the resulting frost heaving. But unless you drain that gravel somewhere with pipes, where's the water going to go?

There are two reasons to use gravel. First, concrete moves because of thermal expansion and contraction. Restricting this movement will crack the concrete. A gravel base allows the slab to move freely. Second, slabs need a flat base to ensure uniform thickness, and gravel is easier to grade than many soils.

Choosing concrete

For a slab that's 40 sq. ft. or more (about 1/2 cu. yd. of concrete for a typical 4-in.-thick slab), it's easiest to order truck-mixed concrete. This 3-ft.-sq. slab was small enough that mixing bagged concrete by hand

STEP BY STEP



1 Prepare the subgrade. Dig 6 in. beyond where you want the slab edges and 8 in. deeper than where you want the top of the slab. Make sure the subgrade pitches away from the building, and tamp down loose soil.



2 Grade the gravel. Fill the excavation with 4 in. of gravel. Rake it flat, and use a level to make sure it's pitched about 1/4 in. per ft. so that the slab, which will parallel the base, drains water.



3 Make and set the form. Most 4-in. slabs are actually the 3 1/2-in. depth of standard 2x4s. Nail the corners together, and place the form on the graded gravel, making sure it doesn't rock. Drive 12-in. lengths of rebar to just below the top of the form to keep it from moving.



4 Mix the concrete. Dump two 80-lb. bags of mix in a wheelbarrow for each batch. Add 3 qt. of water per bag, and mix thoroughly with a hoe. Add small amounts of water as needed to bring the concrete to a consistency that's about the same as thick cake batter.



5 Settle the concrete. After dumping the mixed concrete in the form, jab into it all along the edges with a shovel. This helps to ensure that the mix fills the form without leaving voids.



6 Tap the sides of the form. Lightly hammer the form all around the slab until you see bubbles rising from the concrete. This step makes for a smoother slab edge that won't collect water, which can freeze and spall the concrete.



7 Screed the slab. Flatten the concrete using a straight 2x4 that's about 1 ft. longer than the form width. Move the board forward with a back-and-forth sawing motion while keeping it on the form.

made sense. At 9 sq. ft. and 4 in. thick, the project called for 3 cu. ft. of concrete. An 80-lb. bag of concrete mix makes $\frac{3}{5}$ cu. ft., so this slab took five bags.

I used a crack-control concrete, which includes reinforcing fibers. The slab was small enough that no steel reinforcement was needed, but that little extra strength from the fibers only cost me \$5. Larger slabs, say 5x5 and up, will benefit from reinforcement with rebar or wire mesh to control cracking.

Concrete needs moisture to cure. After finishing the slab, cover it with plastic and keep it damp for at least a day. A week is better, and 28 days ensures the best cure.

Andy Engel is a contributing editor.
Photos by Patrick McCombe, except where noted.

Concrete tools

MAG FLOAT Used in the initial tooling to bring up a creamy mix that's easy to finish. As a final finishing tool, it leaves a coarse, slip-resistant surface that's good for exterior slabs.



STEEL FLOAT A finishing tool that leaves a smooth, compacted surface that repels water but that also can be slippery when wet.



EDGER Rounds over the exposed edges of slabs, leaving a surface that's more resistant to chipping than a simple square edge would be.



STEP BY STEP



8 **Tamp the surface with a rake.** Gently tamp the entire surface of the slab. The rake pushes down the gravel that's part of the concrete mix, and brings up a mixture of cement and sand that's easier to smooth.



9 **Smooth the rake marks with a mag float.** Keep the leading edge of the float up. When the surface water dissipates, float the slab again. This is the final finish for exterior slabs. For a smooth interior slab, work it again with a steel float when the surface begins to lose its wet sheen.



10 **Round the corners.** This leaves smooth, friendly edges that are less likely to chip. Use an edger once after each mag floating; on interior slabs with exposed edges, use it after the steel float. After the slab hardens for a day or more, pry the joints apart and remove the form.



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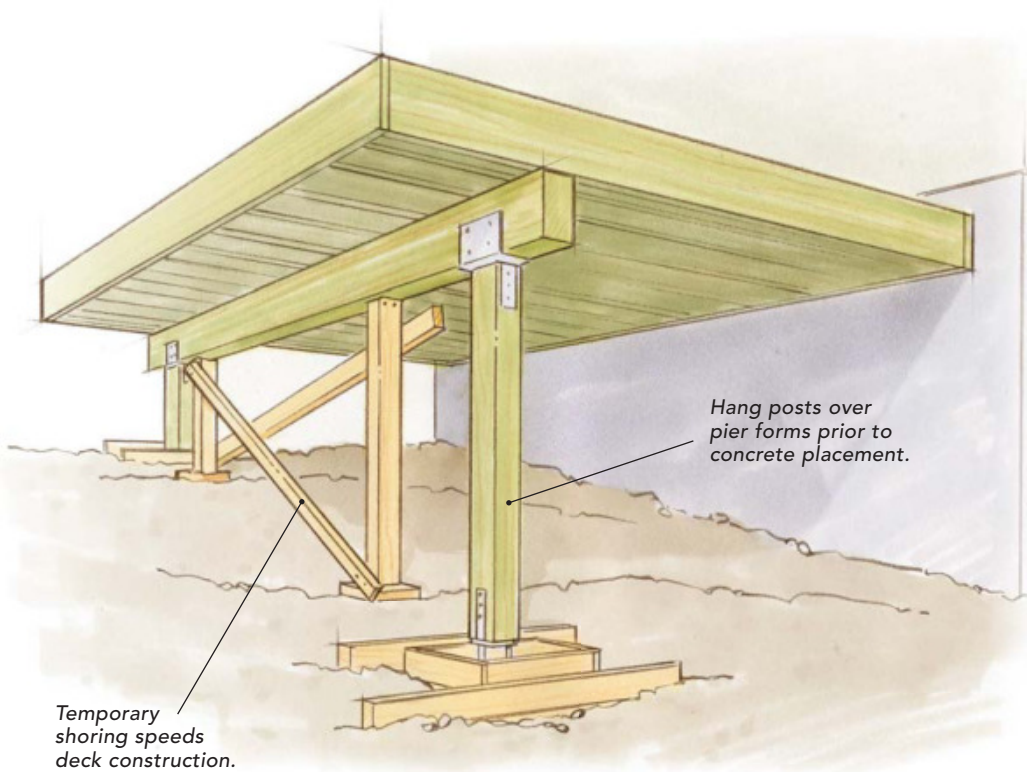
9 Tips for Building a Better Deck

Field-tested strategies for saving money, time, and energy on your next project

COMPILED BY ANDREW ZOELLNER

Building a deck is a fantastic project for a homeowner, and a great way to add outdoor space for family and friends to enjoy. It's also a basic project to learn the ins and outs of building. Part of the battle is understanding what problems could pop up and how to deal with them. With that in mind, here is some of our best advice for building a deck that will last and look great. □

Andrew Zoellner is *Fine Homebuilding's* editorial director.
Drawings by Dan Thornton.

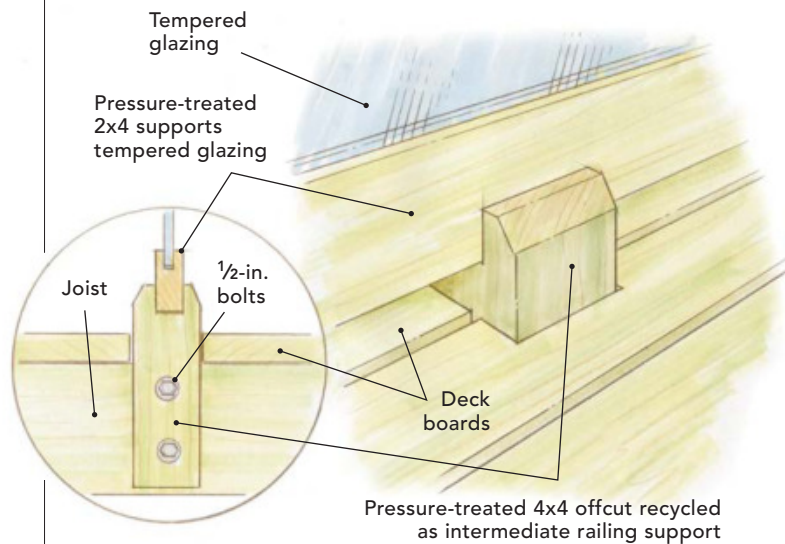


LABOR-SAVING DECK-BUILDING STRATEGY

The temporary beam support shown in the drawing saved us money and a full day of time. Here's how it worked. A typical deck project begins by digging the holes for the footings, getting them inspected, and then placing the concrete. We tweaked this sequence by putting the forms in place on day one and by continuing with our framing by supporting the beam with the temporary braces shown in the drawing. The posts are measured and cut to fit, and are hung from the beam with the base and cap hardware already attached. Using this method, we framed the entire 12-ft.-sq. deck on day one. On day two, we had our footing inspection, poured the concrete piers with quick-set concrete, and installed the decking and railing. We were done in two long days. —Brian Brophy, Lockeford, Calif.

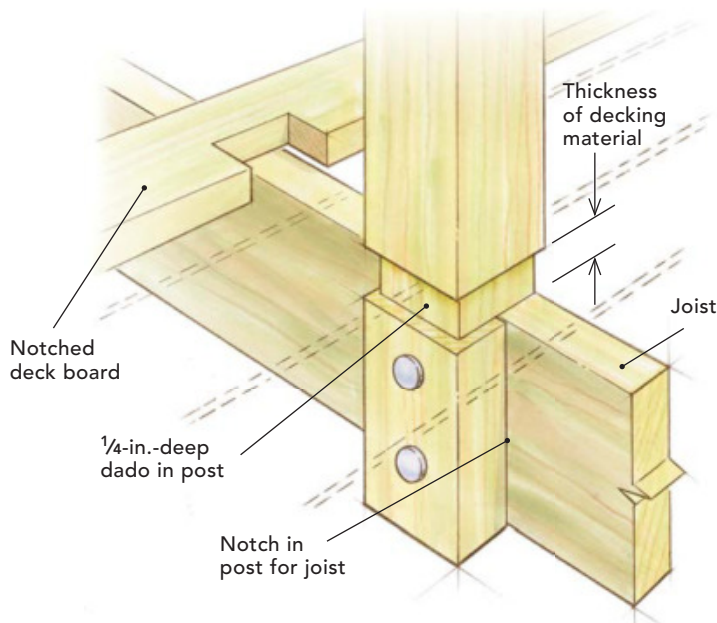
PRECISION-FIT DECK POSTS

I have long been frustrated trying to get a decent fit while installing decking around deck posts. The drawing shows how I finally solved the problem. Before installing the posts, I simply cut a 1/4-in.-deep dado around the post. The width of the dado is equal to the thickness of the decking, and the bottom of the dado is flush with the tops of the deck joists. I cut the dado by making multiple kerfs with my circular saw. Then I clean up the stray bits with a chisel. Installing the decking is now a matter of loosely fitting the deck boards to the bottom of the dado. This method saves time and frustration, and best of all, the posts look as though they grew there. —Mike Nolin, Brewster, Mass.



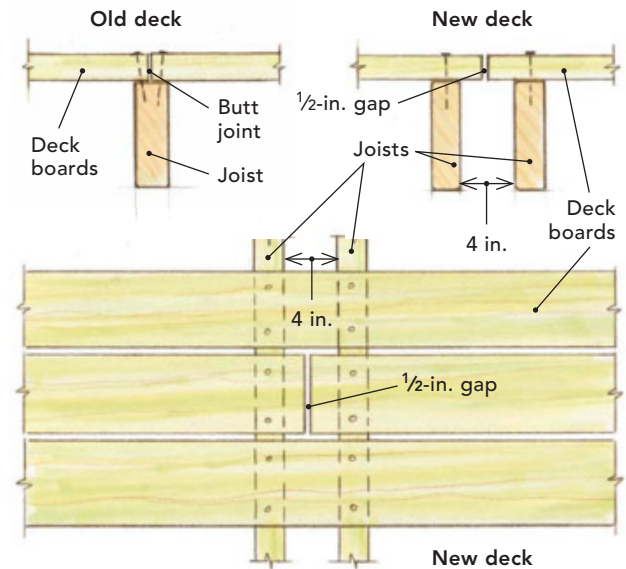
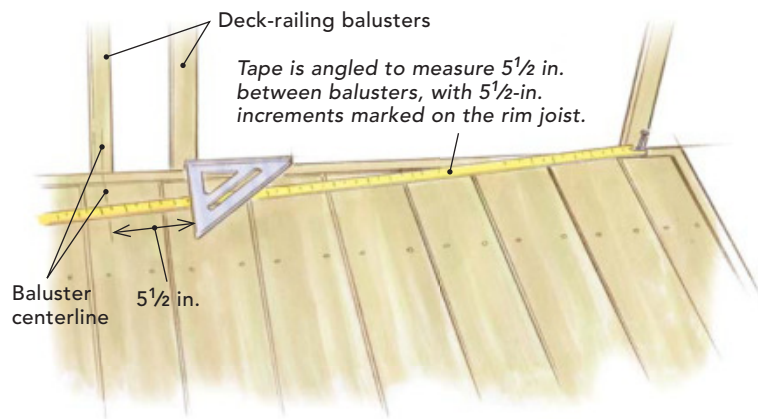
USING LEFTOVER PRESSURE-TREATED LUMBER

When building my deck, I had some short 4x4 pressure-treated offcuts. To help reduce waste and alleviate environmental concerns when disposing of pressure-treated lumber, I found the short 4x4s made excellent intermediate supports for the tempered-glass balustrade. I notched the ends to receive the frames and cut chamfers on the edges to make strong and attractive deck elements that saved the cost of buying commercially made brackets. —Robert Gunn, Mississauga, Ont., Canada



SPACING DECK-RAILING BALUSTERS

I have struggled many a time in the past to create equal, code-approved spacing between deck balusters. The method I've come to rely on—the slant-rule technique—has taken all the frustration out of the problem. With one baluster installed at each end of the railing, I start by measuring the distance between their centers. Next, I divide this number by the desired spacing between the centers of the balusters. Around here, the space can be no more than 4 in. With 2x2 balusters, I divide the railing length by 5½ in. That's because 5½-in. centers on 2x2 balusters results in a 4-in. space between them. Let's say, for example, the length is 158¾ in. I divide it by 5½, which equals about 28¾. I round up to the next highest whole number: 29. Now I multiply 5½ by 29, which equals 159½. At one end of the deck, I drive a nail into the center of the first baluster. At the other end of the deck, I place my framing square with the long blade parallel to the rim joist and the short blade aligned with center of the last baluster. With my tape hooked to the nail, I find the point on the short blade of the square where 159½ in. falls. The tape is now at a slight angle to the rim joist, and I can measure off 5½-in. increments with my framing square and mark them on the rim joist to locate the center of each baluster. It helps if you have a calculator that has an add-on function to speed the layout sequence. Once I began using this method, I was surprised by how fast and effortless it is. With a little ingenuity, I think this technique could be applied to a staircase as well. —Mike Hoffman, Portland, Ore.



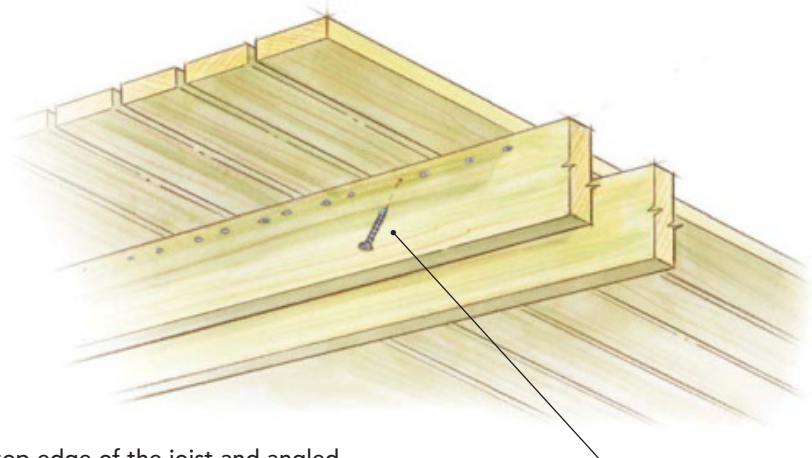
DOUBLE DECKING

When our house was built in 1958, the plan included large decks on two sides. They were built conventionally: 2x8 joists covered with 2x6 planks set on 6-in. centers. By 1980 I had to replace the decking, primarily because of rot that started wherever two 2x6s butted each other over a joist. My design involved doubling up the joists as shown in the drawing. This simple change accomplishes the following: no tight butts in planking, no butts over joists, no split 2x6s from nailing them at their ends, and the entire structure can now “breathe.” The deck has a width of 15 2x6s. With careful layout using lengths up to 20 ft., I have no more than four joints at any station, minimizing waste. I used pressure-treated southern yellow pine. At the time, all the lumber cost about \$1000, and only \$64 was added by doubling up on the 2x8s. —James B. French, Portsmouth, R.I.

A LOW-COST ALTERNATIVE TO HIDDEN DECK FASTENERS

When I built my own deck, I wanted to conceal the fasteners for aesthetic reasons as well as for function (not catching something on a protruding fastener) and durability (not creating an entry point for moisture to penetrate the decking). I looked at all the edgemount and bottom-mount systems, and was turned off by their tediousness and taken aback by their price. Instead of investing in one of these proprietary systems, I used GRK R4 Multi-Purpose Screws to affix each deck board to its joist from below. As shown in the drawing, I used two 8-in. by 2½-in. screws per board at each joist.

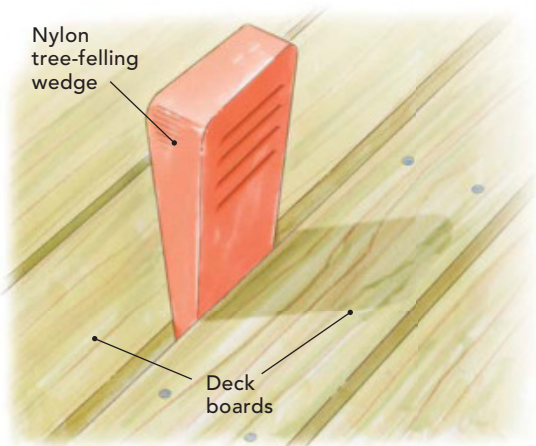
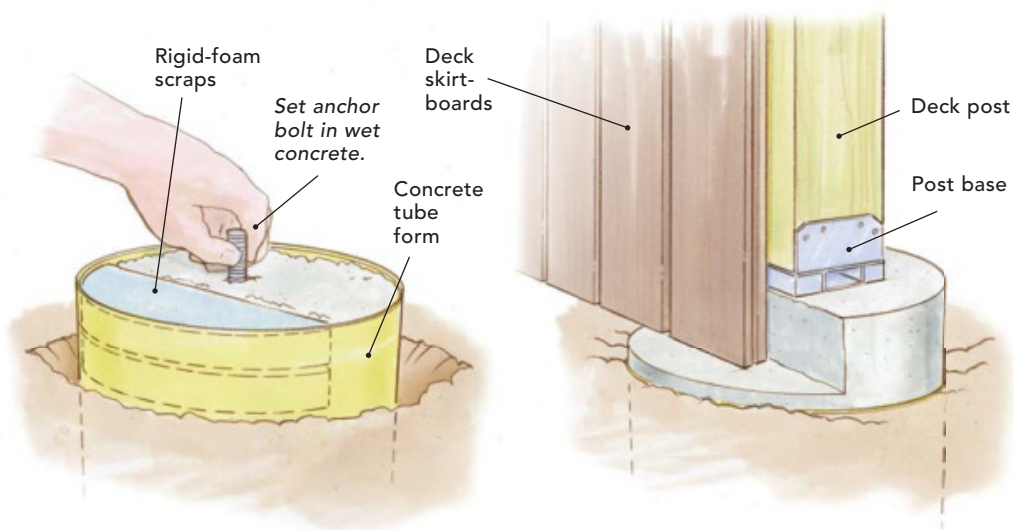
Working from below, I started the screws about 1½ in. from the top edge of the joist and angled them at about 30°. That put about ¾ in. of each screw into the 5/4 deck boards. The sharp “zip-tip” points of the screws eliminated the need to drill pilot holes. It has been a couple of years since I installed the decking, and it looks great. The decking is solid as a rock without a single squeak, and I saved about \$1500 on mounting gizmos. —Steve Carle, Edina, Minn.



PLANNING AHEAD FOR SKIRTBOARDS

If you're pouring piers for a deck that extends above the grade—and that deck calls for decorative skirting to hide the underside of the deck—you could install those skirtboards right up to the pier and then have to notch them over the ugly protruding concrete, but there's a better way. By using some scrap rigid foam and wet-setting the anchor bolts, you can create a template that helps you easily avoid this eyesore from the start when pouring concrete piers.

—Kevin Ireton, New Milford, Conn.



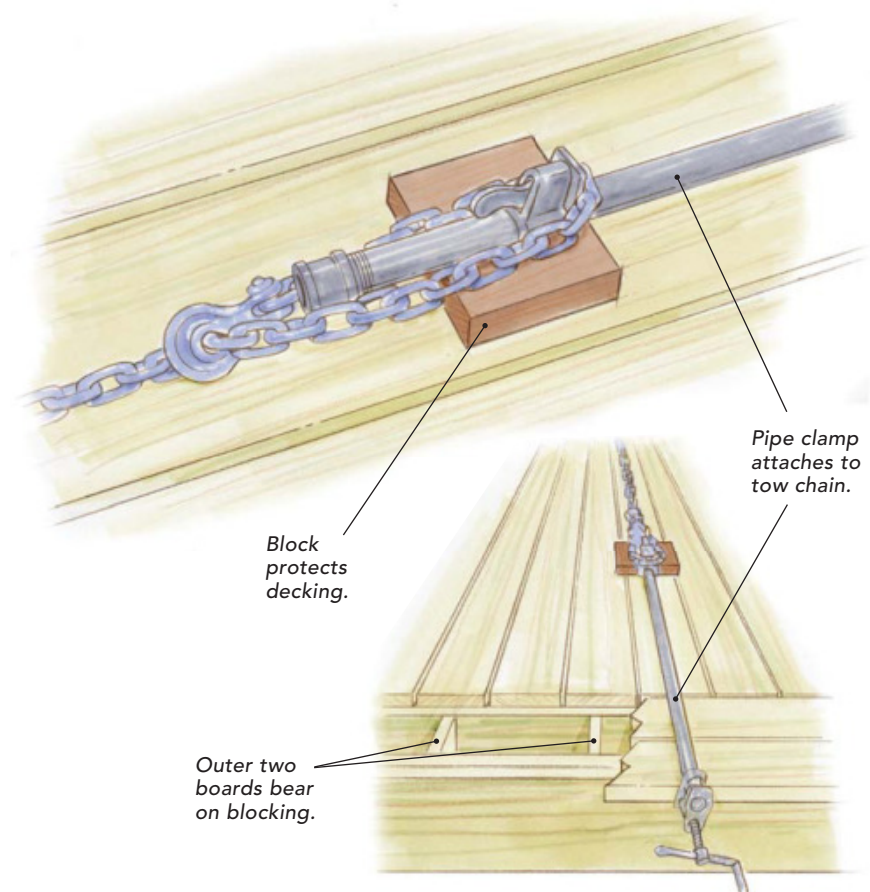
SPACING DECK BOARDS WITH A WEDGE

My company builds a fair number of decks, and we spend a lot of time trying to straighten boards and adjust the gaps between them. Most of our decks are made of cedar, which mars easily, so we've tried just about every technique in the book to coax the deck boards into alignment without damaging them. The results have always been mixed. One day we had a nylon felling wedge on site, and a crew member used it to separate a couple of deck boards that were too close (see drawing). We all became instant converts. Nylon felling wedges are available at any store that sells chainsaws and related equipment. The wedges sell for only a few dollars. A felling wedge tapers to a good, sharp edge, and it is extremely tough. If you pick one with smooth sides, the wedge will not mar even the softest of woods. Best of all, felling wedges are typically bright orange, and therefore they are nearly impossible to lose. —Grant Johnson, Heriot Bay, B.C., Canada

A TOW CHAIN MEETS A PIPE CLAMP

On a deck made of a Brazilian hardwood called Tigerwood, I was able to force all boards into place using a tip from a past issue in which a pipe clamp is anchored against a pry bar inserted between previously installed boards. This deck, however, has two outside rows of deck boards oriented perpendicular to the field boards and parallel to the main floor joists. I had no desire to purchase 20 ft. of $\frac{3}{4}$ -in. pipe for my pipe clamps to span the width of the deck. Instead, I placed a pipe clamp on each side of the deck and then joined them together using a length of tow chain with grab hooks at each end. I placed a block under each of these intersections to prevent damage to the beautiful wood.

—Stephen Beese, Winston-Salem, N.C.





Rock-Solid Deck Stairs

A simple solution to framing new stairs to an out-of-level, 100-year-old patio

BY KEVIN MANNING

Historic remodels often present challenges that involve plumb, square, and level. On this house, floors and ceilings were out of level up to 4 in. in some areas. When adding a new deck to the back of the house, we also encountered similar issues typical of a home that's over 100 years old—for example, the visibly sloping brick patio where the stairs would land.

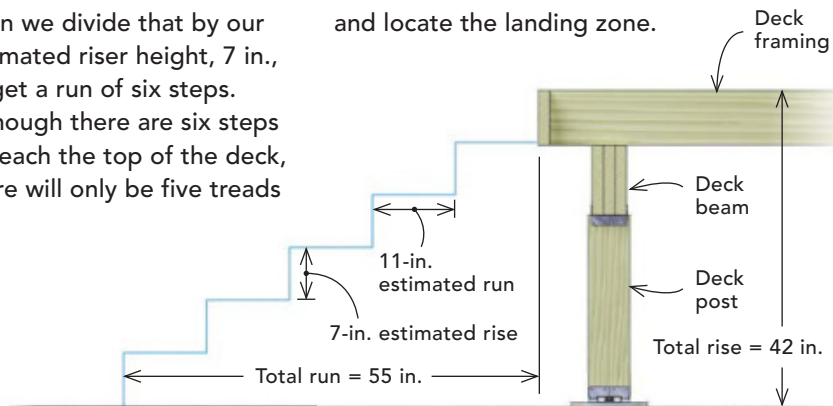
Typically, leveling the landing zone would be a straightforward process: Pull up some bricks, pour a level pad, then reintegrate bricks around the pad. But the clients didn't want to disturb the historic, moss-covered patio—they wanted the stairs to land on the bricks as if they had always been there. For us, that meant incorporating the slope into our stringer calculation during framing. □

Kevin Manning is project manager for Red House Design Build in Providence, R.I. Photos by Colin Russell.

DETERMINE THE RISE AND RUN

To locate where the stringers will land, we make an initial calculation based off a central stringer position at the deck frame. Measuring from the top of the frame to the grade below, we establish a rise of 42 in. Then we divide that by our estimated riser height, 7 in., to get a run of six steps. Although there are six steps to reach the top of the deck, there will only be five treads

because the rim joist acts as the top riser. To determine how far out the stringers will project, we multiply five treads by 11 in., our estimated tread depth, to get 55 in. At that location we can measure the overall rise and locate the landing zone.

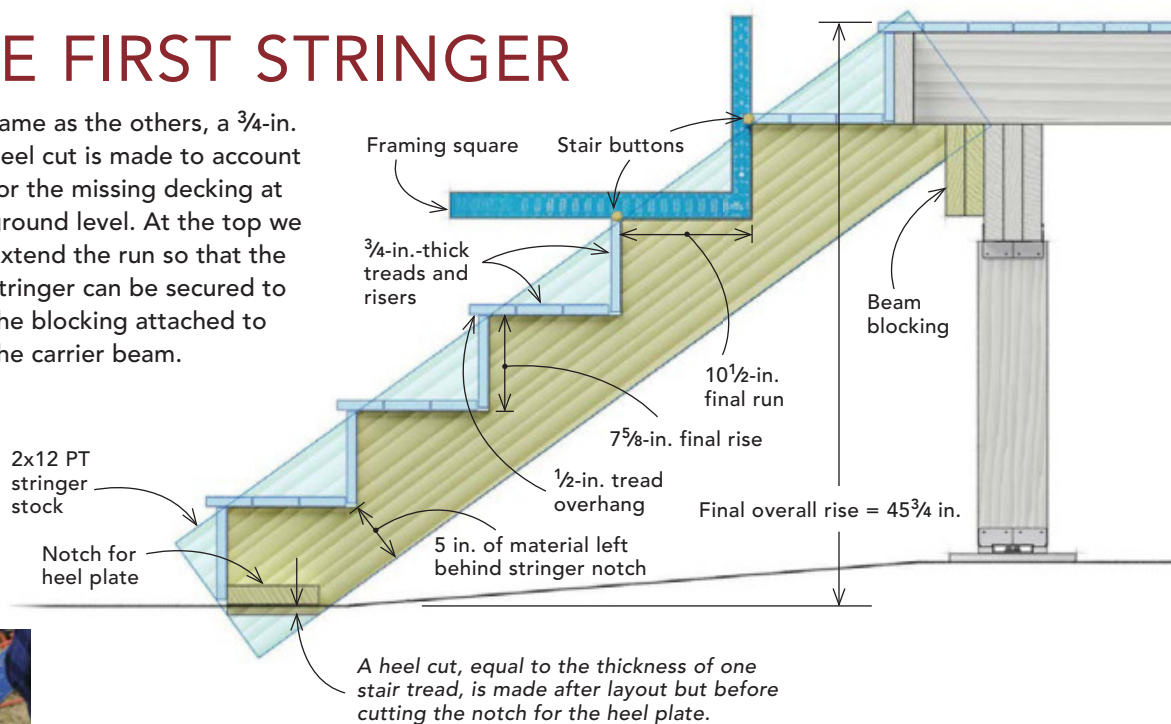


Find the overall rise. At a central location across the deck frame, we used a level to extend the deck height outward 55 in. At this point we found the grade 3 in. lower than at the edge of the 42-in.-high deck frame, for an overall rise of 45 in.

LAY OUT THE FIRST STRINGER

The total rise is the distance from the patio surface to the deck, so we add the decking thickness, $\frac{3}{4}$ in., to our overall rise, 45 in., and divide by six steps. This results in a final riser height of $7\frac{5}{8}$ in. For the run, the 11-in. treads will have a $\frac{1}{2}$ -in. overhang, so the stringer's tread depth will be marked and cut at 10 $\frac{1}{2}$ in. Except for the bottom landing, every tread has $\frac{3}{4}$ -in. decking; to keep the rise at the bottom the

same as the others, a $\frac{3}{4}$ -in. heel cut is made to account for the missing decking at ground level. At the top we extend the run so that the stringer can be secured to the blocking attached to the carrier beam.



A heel cut, equal to the thickness of one stair tread, is made after layout but before cutting the notch for the heel plate.



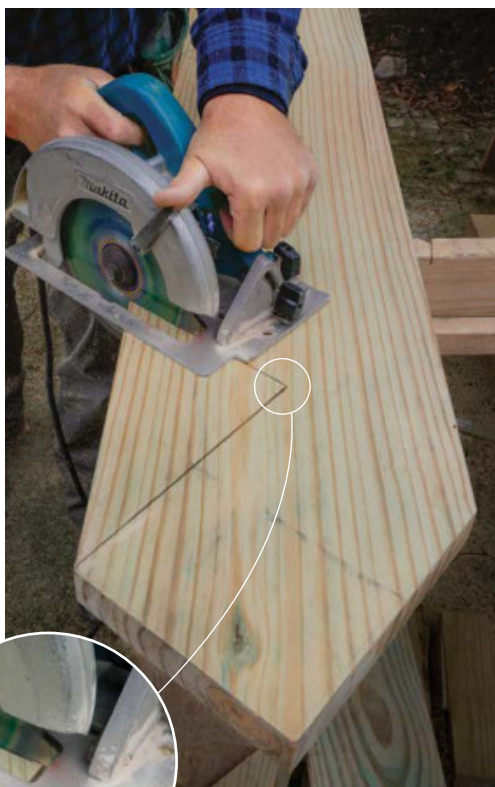
Buttressed in. Stair buttons fastened to a framing square at the rise and run dimensions make accurate layout a breeze.



Squared off at the top and bottom. The bottom of the stringer is squared off at the riser height before the heel cut is marked. The run at the top of the stringer is extended to reach the blocking on the carrier beam.

CUT THE FIRST STRINGER

When it comes to cutting stringers, being precise is a time-saver later. This deck will be wrapped in mahogany hardwood, so to get the finished details right, we need to spend less time battling framing. When cutting stringers, we make initial cuts right up to the line with a circular saw, and complete the cuts with a jigsaw. We use the first stringer as a template for the remaining stringers. We leave the heel cuts for last so that there's enough material to dial them in one at a time to compensate for the patio's slope from left to right.



FIT THE FIRST STRINGER



Use the first stringer as a template. Align the straight edge of the template to the new stock, and hold it firmly in position. Use a sharp pencil to transfer the layout.



Cut the heel and check the fit. The first heel cut matches the thickness of the decking. Make the cut, then position the stringer so that it's tight against the carrier beam and snug to the band joist above. Use a torpedo level to ensure treads are level.



Notch the heel to fit the plate. Use a circular saw followed by a jigsaw to cut an accurate notch for receiving the 2x10 plate that will tie the assembly together. Dry fit both pieces, and check that the treads are still level.





DIAL IN THE HEEL CUTS

Now that the first stringer is fit, we can address the out-of-level base. All we need to do is find the riser height for the first step of each stringer so we can trim the stringers individually. Because the patio slopes from left to right, that means we'll be taking more material off on the left and less on the right.



Incorporate the slope. Extend a level across the first step of the first stringer. Measure the distance to the plate at the location of each additional stringer, add the plate thickness, and cut the heel before notching for the heel plate.



Toenail in place. Position and toenail the stringers into the carrier beam to hold each in position. Then toenail the heel of the stringer to the bottom plate.

Secure the stringers to the frame. Fasten the stringers to the blocking attached to the carrier beam using structural connectors and compatible screws to make the final connection.



Lock down the heel plate. Use a mason's bit to drill holes through the plate and into the brick. Concrete screws, two between each stringer, lock the plate into position.

Build a Japanese-Style Garden Gate

Versatile assembly can be adapted to any gate design

BY ASA CHRISTIANA

When we moved west and bought a fixer-upper in Portland, Ore., one of my first to-do items was replacing a broken-down fence with one of my own design. I hired pros to set the posts, but did everything else myself, including building a Japanese-style arch over the gate opening. The plan was to cook up an eye-catching gate in a similar style.

I've learned not to rush the design stage, so I visited the excellent Portland Japanese Garden, took pictures of every door and gate I found there, and did some digging online. This gate, with falling ginkgo leaves pierced through the lower panel and traditional Japanese gridwork at the top, is the result.

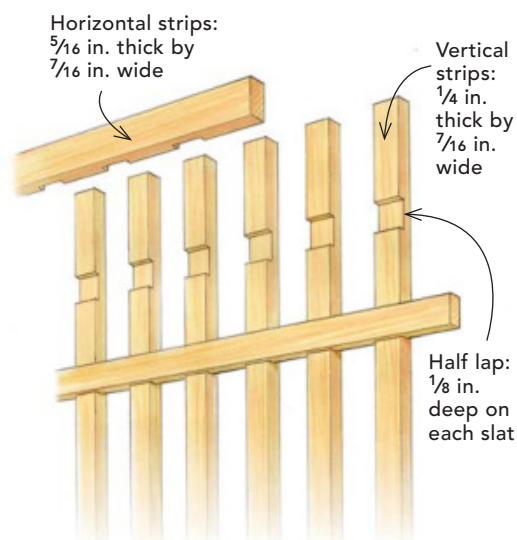
Water, weather, and weight are tough on gates, and over the years they tend to sag. The usual solution is a diagonal rod, surface-mounted and tightened with a turnbuckle. But in my research, I didn't see any Japanese carpenters resorting to such contrivances, so I didn't plan to either. Like them, I relied on the right materials and robust joints to keep the gate square and swinging smoothly. After more than a year, it hasn't sagged a centimeter in its 4-ft. opening. Better yet, the gate is obviously custom-made, and never fails to grab visitors' attention.

Sturdy frame for gates of any size

The first step in the engineering was to choose the wood, which was easy. Widely

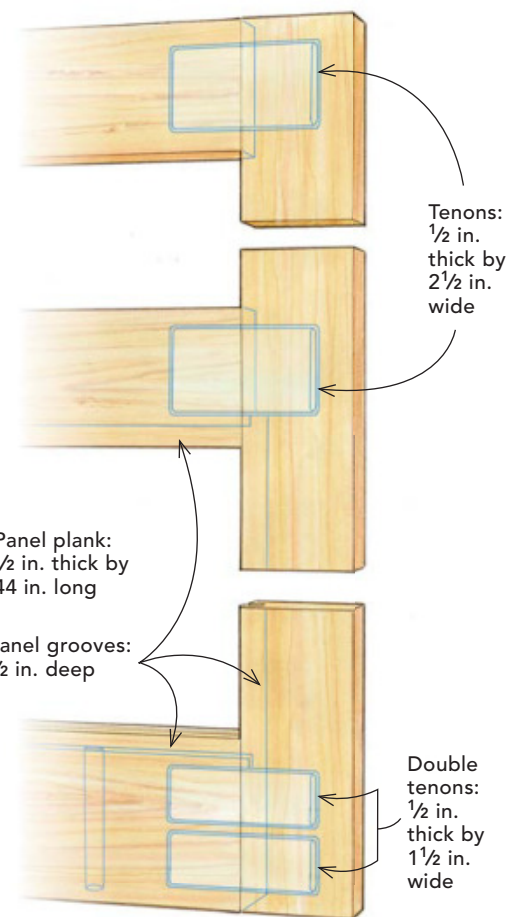


Pretty path to the backyard. This cedar gate is more like a big passage door, with deep tenons to keep it square and sag-free.



SAG-RESISTANT ASSEMBLY

I dimensioned the parts to look good and weigh as little as possible while accommodating deep tenons. The lower tenons are doubled up because seasonal wood movement will wreak less havoc on two smaller tenons than one very wide one. The lower panel boards are held in grooves while the upper gridwork is held by strips similar to glass stops. You can adapt the anatomy to almost any gate design you like.



DEEP TENONS MADE SIMPLE

This simple jig, combined with a router bushing installed in the router base and a long upcut spiral router bit, creates matching mortises in the rails and stiles of this frame. The jig shown below is used for the double mortises in the bottom rail. Follow the same approach to make a jig for the single mortises in the upper rails.

1 BUILD THE JIG

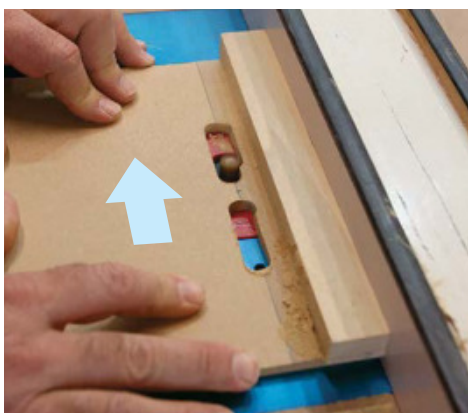


Nail on the plate. It can be difficult to get the wood fence flush with the $\frac{1}{4}$ -in. MDF. Instead, attach it so that it sticks out a little from the plate. Because the jig's fence will ride the router fence when you cut the slot, the slot will be perfectly parallel to the jig fence, which is what matters.



Get ready to rout. This jig needs two mortise slots. Lay out the slots, marking the centerline and ends of each slot, and then drill $\frac{3}{4}$ -in.-dia. holes at the left end of each slot. For the middle and top rails, make a similar jig with one slot for the single tenons in those joints.

Head to the router table. Each slot can be routed in a single pass with a $\frac{3}{4}$ -in. bit, but it's safer to make two passes with a $\frac{1}{2}$ -in. bit. Drop one of the drilled holes over the bit to help you set the fence accurately to one edge of the hole. Hold down the jig, turn on the router, and make a pass on each slot, using the pencil lines as guides. Then turn off the router, adjust the fence, and take a second pass on each slot to widen them to the full $\frac{3}{4}$ in.



available and affordable, western red cedar offers an excellent combination of strength, weight, and weather resistance. I started by picking very straight, $1\frac{1}{2}$ -in.-thick decking boards out of the lumberyard pile, and milled them down to $1\frac{1}{4}$ in. using my thickness planer. This gave me boards that are thick enough to resist warping and bowing, and to accommodate the $\frac{1}{2}$ -in.-thick tenons I was planning, without being an ounce heavier than they needed to be.

When using a softer wood like cedar, the walls of the mortises should be at least $\frac{3}{8}$ in. thick to have enough strength to resist flex-

ing out when the tenons are inserted. A word of advice: Avoid boards that have sections of cream-colored sapwood in them. That part of a cedar log is far more prone to rot.

As for the deep tenons, I used slip-tenon (or loose-tenon) joinery, an approach that makes a traditional joint much simpler. Rather than being integral parts of the rails, the tenons are made from other stock, ripped and shaped on the tablesaw and router table to fit into matching 2-in.-deep mortises in the frame pieces.

The beauty of this approach is that the tenons are completely separate pieces, so you

can simply run them through your planer to achieve a perfect fit. I have a slick way to rout the matching mortises, too, borrowed from Gary Rogowski in the pages of *Fine Woodworking* magazine ("Arts and Crafts Bed," *FWW* #156). I went 2 in. deep into both sides because that's the maximum depth possible with a standard $\frac{1}{2}$ -in.-diameter spiral router bit.

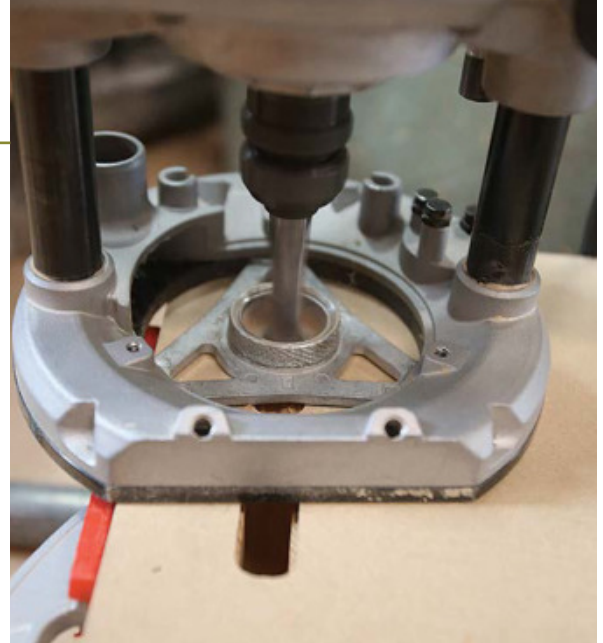
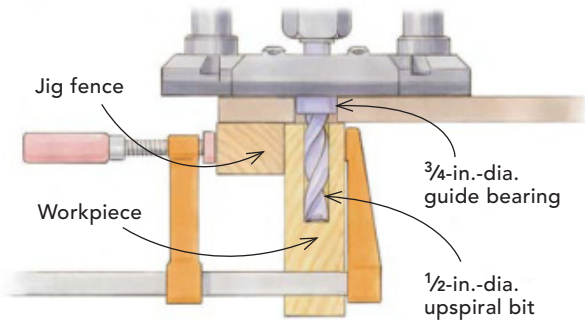
I designed the bottom rail wider than the two upper rails. The upper rails each get single wide tenons, while the extra width of the bottom rail accommodates two narrower tenons, adding to the strength. A wider bot-



2 ROUT THE STILES AND RAILS



Mortise the stiles. Measure to determine where the center of the jig goes, then clamp it on the edge of the workpiece. Set your router to use the bit's full cutting depth (around 2 in.) and rout each mortise with a series of shallow passes. Upcut spiral bits remove some of the chips; stop and vacuum the chips out if they get packed in. A $\frac{3}{4}$ -in. guide bearing keeps the $\frac{1}{2}$ -in. bit centered in the jig and on the workpiece, leaving $\frac{3}{8}$ in. of material on either side of each mortise.



Mortise the rails. As with the stiles, measure and mark where the center of the jig goes, and clamp the jig on the workpiece. Use the same router setup used to mortise the stiles to mortise the rails, again making a series of shallow passes. Be mindful that the top rails each get one mortise per end, while the bottom rail gets two mortises per end.



Foolproof results. Vacuum out the last of the wood chips, and the mortises are done. Note the long clamps used to hold the workpiece vertically against the edge of the workbench.



Matching mortises. It's critical to make the mortises in the correct locations on each piece to keep the gate square. The jig's job is to ensure that the mortises match.

3 MILL PERFECT-FITTING TENONS



Plane a board to a snug fit. Run a board through your planer until it will slip into the mortises with hand pressure.



Rip and rout. Rip the board on the tablesaw to just narrower than the width of the mortises, then use a $\frac{1}{4}$ -in. roundover bit to rout all four edges.



Chop and bevel. Cut the tenons a little short to leave room at the bottom of the mortises for the glue that will be pushed down there during assembly. Then bevel the ends a little to make it easier to insert the tenons.



DOOR DECORATION

The ginkgo leaf is featured prominently in Japanese design and culture, so I decided to cut a series of those shapes into the lower panel boards.



Arrange by eye. After printing ginkgo leaves on paper, glue them to cardboard and cut them out to use as templates. With the panel boards all laid out, play around with the templates until you find the windblown effect that looks right to your eye. There will likely be some erasing involved, but it's easier to erase pencil lines than a hole in the wrong spot.



Jigsaw does the job. Drill holes inside the perimeter of each leaf outline to make a place to start each cutout. Then put a curve-cutting blade in your jigsaw (I used a Bosch T119BO blade), and get to sawing and sanding.

tom rail also just looks good in a frame-and-panel assembly, grounding it.

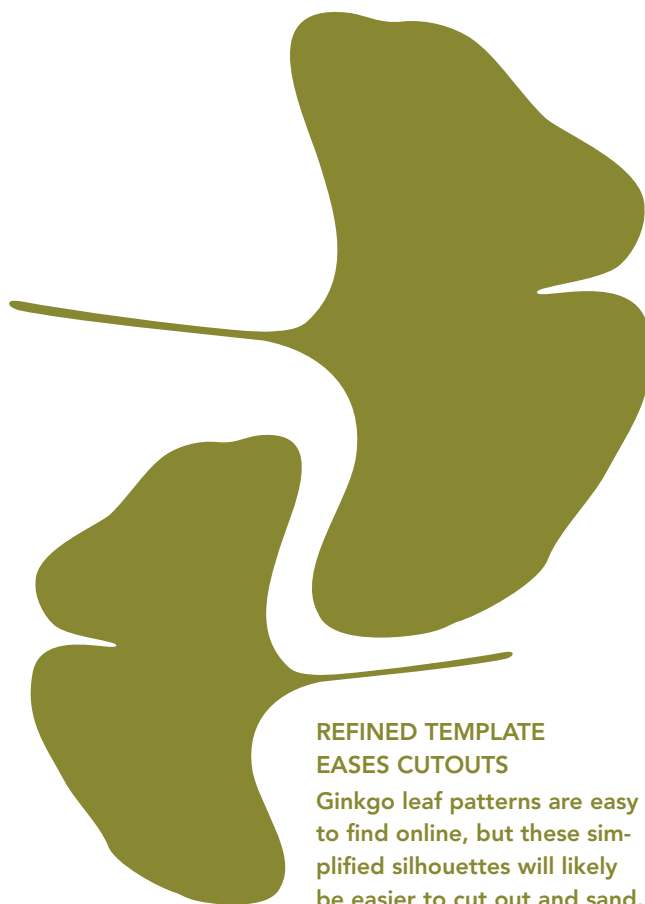
Altogether, that adds up to eight deep, thick mortises and tenons, four down each side—enough to keep this wide gate square for the long haul.

I added one more detail to increase the gate's longevity: To prevent water from pooling in the groove of the bottom rail, I

drilled $\frac{3}{8}$ -in.-diameter holes, spaced about 6 in. apart, down through it before assembly.

The details are up to you

Once you know how to make a big, sturdy frame like this, you can design any gate you like. In my case, I filled the lower frame with $\frac{1}{2}$ -in.-thick cedar boards, and the upper one with Japanese-style gridwork.



REFINED TEMPLATE EASES CUTOUTS

Ginkgo leaf patterns are easy to find online, but these simplified silhouettes will likely be easier to cut out and sand.

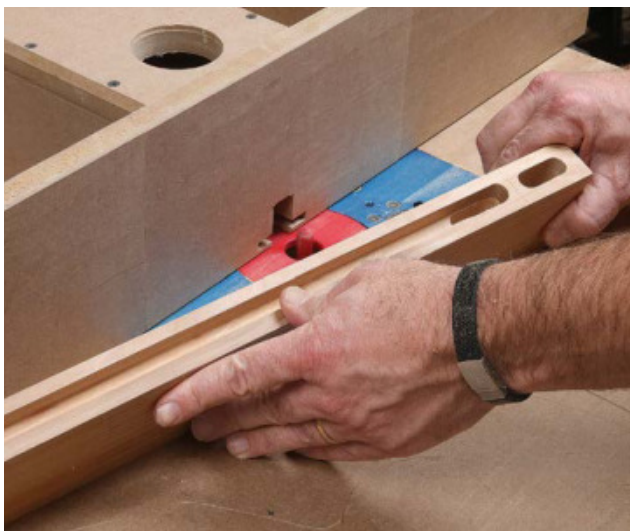


Smooth the shapes. Wrap 80-grit sandpaper around a dowel and smooth away the bumps and wood whiskers.

The thin lower boards are lightweight and so were easy to pierce with the ginkgo leaf shapes I had planned. To prevent big gaps from appearing between the boards as they shrink and expand over the years, I fired a single brad through the rail into the ends of each board, both top and bottom. This allows the wood to shrink and expand without splitting, and will prevent the boards

ASSEMBLY TIME

I recommend Titebond III wood glue, which is waterproof for outdoor use and allows ample time for assembly before it starts to cure and seize up.



Don't forget the grooves. Cut all the panel grooves on the router table with a 1/2-in. bit, using two passes to reach the full depth. To groove the lower sections of the vertical frame parts, start the bit in one of the mortises, and rout until you reach the next one. The grooves on the rails run straight through, so they are even easier.



Always do a dry fit first. Once you're sure all of the joints will close nicely, take the opportunity to round all the inside corners with a router.



Assemble in stages. Start by inserting the panel boards into the lower and middle rail, with no glue—but fire a single brad through the rail into each board to keep it roughly in place. Then apply glue to all of the mortises and tenons and add the top rail and stiles. I used bar clamps to draw the joints home, as they get pretty snug once glue is on them.



Glue goes on mortises and tenons. Put most of the glue in the mortises, using a brush to spread it around. Glue on the tenons tends to get scraped off and squeezed out during assembly, so use only a light coat there.



GRIDWORK

The gridwork jig is two pieces of 1/2-in. or 3/4-in. plywood or MDF screwed together at 90°, along with a “key” made from a length of the grid material. You can clamp it to your miter-gauge fence as shown, or screw through the back of the miter fence into the jig fence to attach it.



Grid magic. After cutting the gridwork strips to fit the opening, cut half-lap joints with a stacked dado set. A jig assures even notch spacing; just bump the tip of the workpiece against the key for the first notch, and hold it securely to the jig to make the cut. The rest index off the previous notch.



Get ready for the gridwork. Use 1/4-in.-thick strips behind and in front of the gridwork to secure it in place. L-shaped stops help correctly locate the back strips, and shooting 18-ga. brads through the strips locks them in place.

from moving relative to one another in the frame.

For the Japanese gridwork up top, the key is to drop it in separately after the gate is assembled. I cut the pieces to fit the opening, and then used a tablesaw jig (pictured above) to make the little interlocking notches I needed to join them together. To install the gridwork, I simply nailed thin wood strips



Locking in the grid. After gluing up the entire grid at once, put a dab of glue at each joint, let it dry (with weights on it to hold it flat), and then place it in the opening. Then nail in the front strips to lock it in place. If it ever gets damaged, you can always pull it out and repair or remake it.

on both sides of it, like glass stops. If the gridwork ever gets damaged, it will be a cinch to pop it out and repair or replace it.

As for the finish, I didn't use any. My feeling on outdoor projects is choose the right woods and then let them weather naturally. The cedar will eventually turn gray, as will the pressure-treated wood, blending with the color of the galvanized panels over time.

Before hanging the door, I trimmed its outside edges a little for a perfect fit in the opening. For hardware, I used a self-closing gate kit from Everbilt, which included adjustable, spring-loaded hinges and a matching latch. □

Asa Christiana is a contributing writer based in Portland, Ore. Photos by the author, except where noted.



Scribing Rails to a Round Column

Create a smooth transition for this tricky porch post-to-rail connection

BY MARIA KLEMPERER-JOHNSON

When I was approached to rebuild a porch in the Fall Creek neighborhood of Ithaca, N.Y., I knew it would be a rewarding project. The clients—both landscape architects—care about aesthetics and construction details. Their porch was barely hanging on, but its original character was visible beneath the peeling paint and rotting boards.

The most gratifying part of the project was designing and building the railing—the original was undersized both in terms of code and appearance, and the connections to the columns were a cobbled mess of rusty toe screws and brackets. The challenge lay with cleanly attaching the railings—particularly the sloped stair rails—to three tapered round columns.

I've seen myriad awkward solutions to this tricky detail. Sometimes the column is “flattened” with an applied block; other times handrails are hung off brackets on the side of the column, or they land on an extra newel post. I wanted a more elegant connection, so I built a jig that allowed me to cut the curve of the column on the sloped handrail. I started by making a radial template sized for the diameter of the columns—this took care of the level railings. Then I built a scaffold to hold that template at the slope of the stair. It turned out to be a lot of work that I didn't anticipate when bidding the job. But the fun of solving a challenging carpentry problem made it worthwhile. □

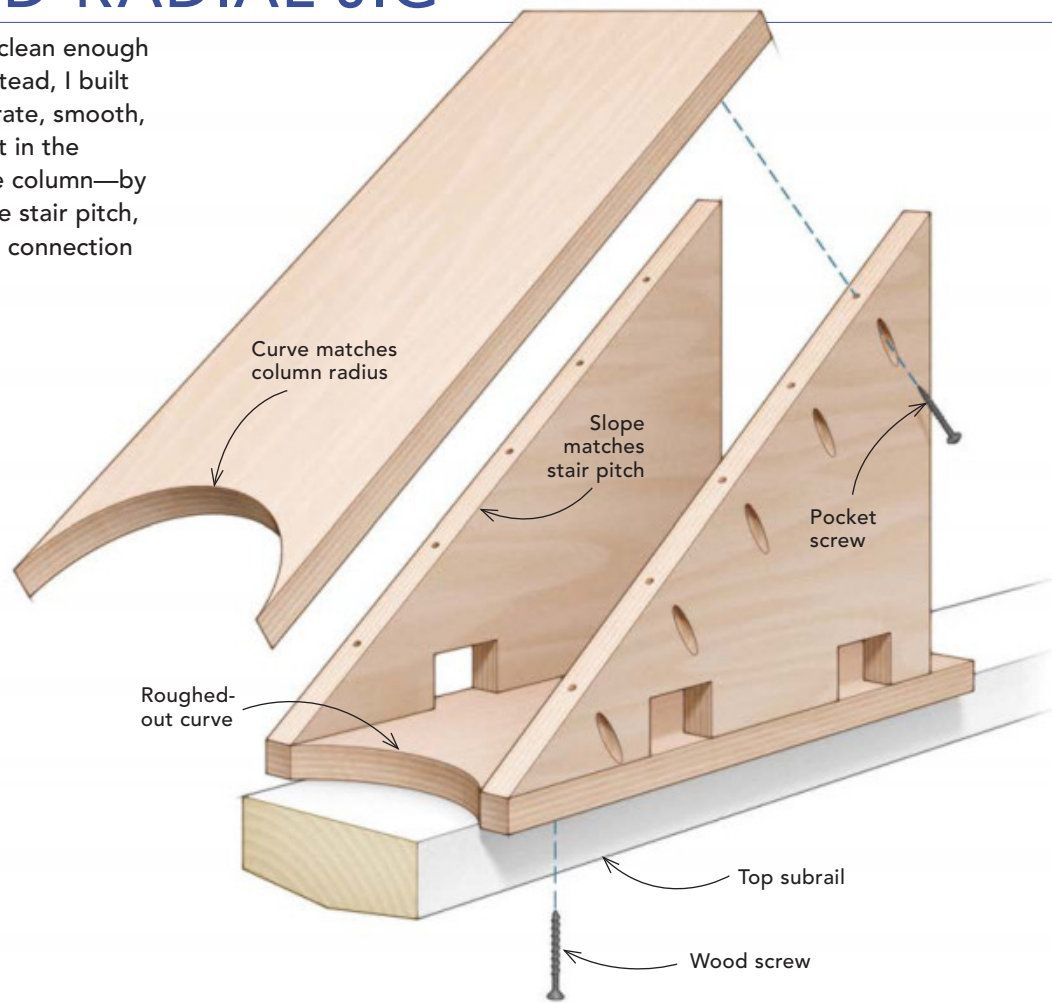
Maria Klemperer-Johnson is a carpenter and residential-construction instructor at SUNY Delhi. Photos by Kiley Jacques, except where noted.

BUILD A SLOPED RADIAL JIG

Even a steady hand won't produce curves clean enough for such a visible location as a stair rail. Instead, I built a router jig, which allowed me to get accurate, smooth, repeatable results. The radius of the cutout in the sloped top piece matches the radius of the column—by setting that piece on an angle matching the stair pitch, that radius is elongated, creating a perfect connection from sloped rail to plumb column.



Get the radius. Measure the diameter of the column at the railing connection using a pair of framing squares. Where the tongue and the blade of the squares meet is the diameter of the column; divide that number in half to establish the radius.



Transfer the radius. Use a compass to mark the curve on a piece of plywood from a pivot point located 1 in. in from the edge (this will be the top board of the jig). Secure the board to your bench with countersunk screws on both sides of the curve to be sure all parts of the piece remain immobile as they are cut free.



Add the pivot pin. To cut the curve, I use my router's edge guide as a trammel (my router's guide has a pivot point built in; you can also build a trammel jig). Drive a 1/4-in. drill bit into the pivot point on the board and into the support below, and leave the bit in place to act as the pivot pin.



Cut and trim. Slide the edge guide onto the pivot pin and cut the radius, starting the router off the board and moving in a clockwise motion. After cutting the curve, trim the extra width at the tablesaw so the board is only as wide as the curve.



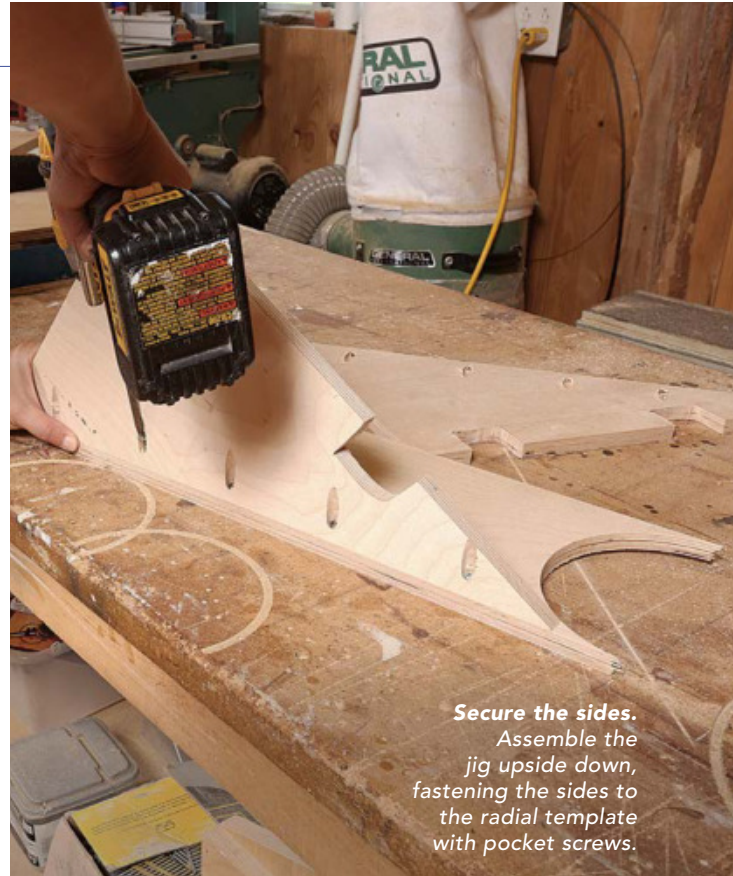
Test it out. Check the fit against the column. This radial template can be used alone to copy the curve onto the horizontal railings before it's incorporated into the sloped jig to make the cuts for the pitched handrail.



Measure and cut jig sides. The pitch of the jig should match the angle of the stairs. For stairs with 7-in. risers and 10-in. treads, lay out two 7:10 triangles on a piece of plywood and cut them with a track saw.



Make space for clamps. Cut clearance notches in the runs (bottom legs) of these triangles to make room for clamps to hold the jig to the railing stock.



Secure the sides. Assemble the jig upside down, fastening the sides to the radial template with pocket screws.



Add the base. With the jig right-side up, add a piece of plywood to the base. Use the curve cutout on the top piece to transfer the arc to this bottom piece, then rough out the curve with a jigsaw (this will keep it out of the way of the router bit).



Finish the assembly. Realign the bottom piece, lay the jig face down, and face-screw the bottom piece to the sides.

CUT THE RAILS

The curved cut is made using a pattern bit. Because of the jig's slope, there will be a varying depth of cut across the arc. You could start with a 1-in. bit, or even a 1/2-in. bit, then switch to a longer bit in as many increments as you want. But that's time-consuming. You could use a longer bit, but that would make too deep a cut



at the edges where the router enters the workpiece. Plus, a single bearing would force you to make the whole cut in a single pass, which is aggressive. I prefer to stack a few extra bearings on a 1-in.-long top-bearing flush-cut bit and make multiple light passes, lowering the bit incrementally.

Whiteside 3020 template bit, \$34;
B19 ball bearings, \$14 each

Trace the arc. Using centerlines, place the jig square on the end of the railing stock and trace where the router will cut.



Rough-cut the rail. Use a jigsaw to rough out the curve, then realign and clamp the jig. Even though the jigsaw cuts square to the face of the stock and the router will cut at an angle, it's helpful to get this material out of the way.



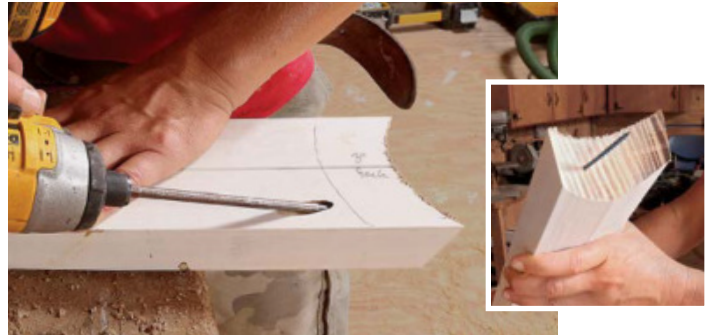
Take the plunge. Use a plunge router to make the cut in multiple passes. The bit's bearing will ride along the jig's curve for the first few passes (photo above), but as the cut goes deeper, the router will bottom out. To finish the last few passes, slide the jig back on the railing stock a few inches so the leading corners of the cut are just below the top surface of the jig, then use the previously cut surface of the workpiece as a guide for the bearing (photo left).

CONNECT THE RAILS TO THE COLUMN

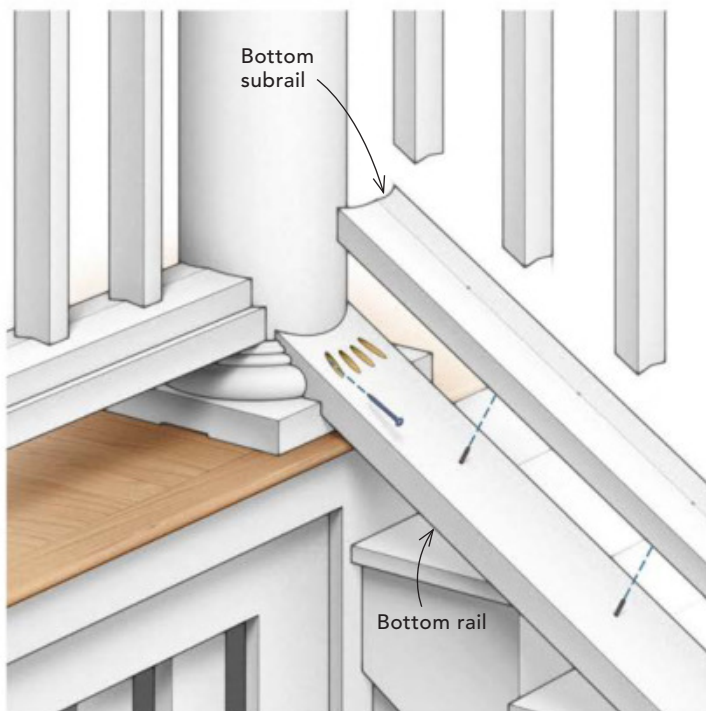
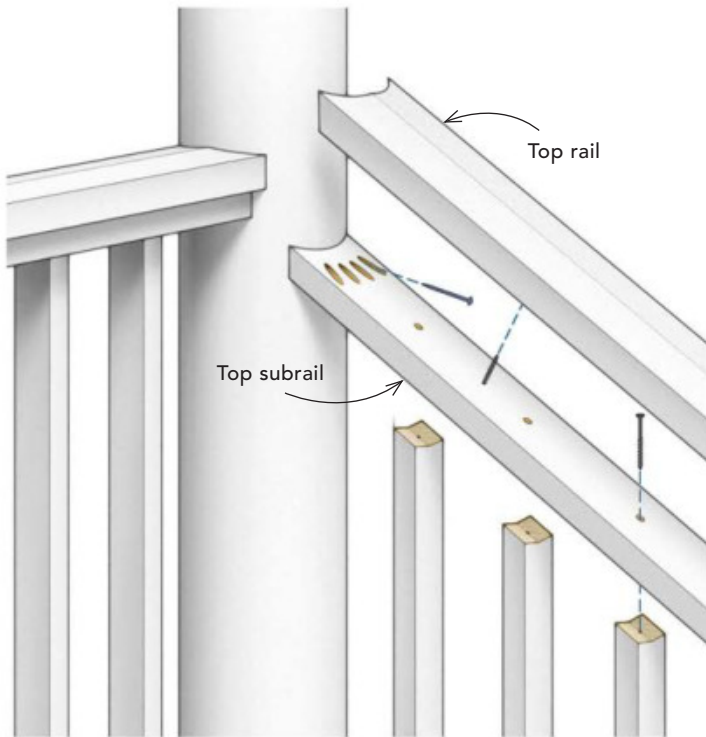
Part of the beauty of this railing design is the hidden connections. On this project, I notched out the column base molding to receive the bottom rail, which is then pocket-screwed from the top into the column. The bottom subrail is set on top, and hides the connection. The top rail works the same way—the top subrail is pocket-screwed from above, and the top rail hides the column connection as well as the screws that connect that subrail to each baluster.



Position pocket holes. Lay out lines where the pocket-hole jig should sit, then secure the jig to the railing stock with a quick-release clamp. The jig should be positioned so the screws will fan toward the middle of the curve (this angle can be eyeballed).



Test a screw. Drill a test pocket hole and drive a test screw to be sure it emerges at approximately the midpoint, thickness-wise, of the workpiece end. Then drill four pocket holes and drive four 2½-in. exterior-grade pocket screws through the top subrail and the bottom rail into the columns.





Replacing a Basement Door

Steps for preparing, installing, and flashing long-lasting bulkhead doors

BY MIKE GUERTIN

On this house, the existing basement bulkhead door was its second. The original was made from wood and became too difficult for the elderly owners to lift, so they had this steel one with torsion springs installed in the 1960s. But after 50-plus years of service—and several poor paint jobs—it had rusted through in a few spots and was peeling constantly.

It's not a surprising situation. Sloped basement doors receive a lot of punishment. Children play on

them, owners walk on them to reach the wall above, and they're exposed to the elements. They're also close to the ground and prone to damage from lawn equipment such as grass trimmers. Whether site-built out of wood, or manufactured from steel or plastic, they can deteriorate to the point where replacement makes more sense than a repair. □

Mike Guertin (@mike_guertin) is editorial advisor. Photos by Colin Russell.

OUT WITH THE OLD

Basement doors are most easily removed piece by piece, just as they're assembled. The doors and hardware come off first, then the frame is disassembled and removed in parts.



DOORS AND HARDWARE FIRST

Start by removing the pins or bolts from the hardware to release the doors.



REMOVE FASTENERS

A pry bar often makes quick work of removing the anchors or screws fastening the side panels and sill to the foundation. If a pry bar won't work, a reciprocating saw and metal-cutting blade are in order.



DISASSEMBLE THE DOOR FRAME

After unbolting the sill and header sections from the side panels, remove the sill to free the side panels, fold the panels in toward the stair opening until they disengage, and then pry the header piece down from under the siding.

ASSEMBLE THE NEW DOOR

To make assembly easier, I unbox the new door components and preassemble them on a flat surface rather than try to do it in place on the foundation.



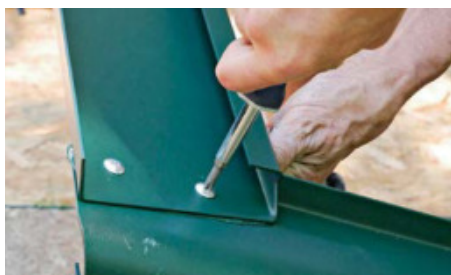
SET UP FOR SUCCESS

A couple pieces of sheathing are all you need to make a temporary flat work surface to assemble the new door. I use clamps as a second set of hands to hold the side panels upright.



SEAL THE CONNECTIONS

At the header, apply high-quality, clear exterior sealant (I used OSI Quad Invisible) to the joints on both sides before bringing the parts together.



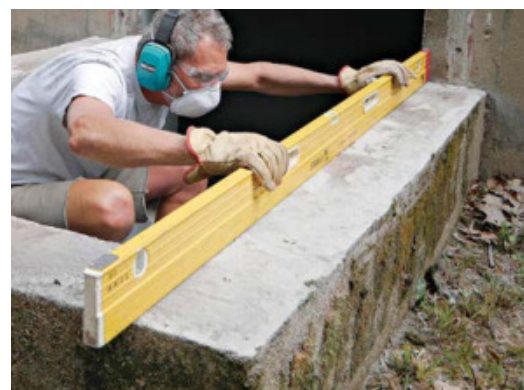
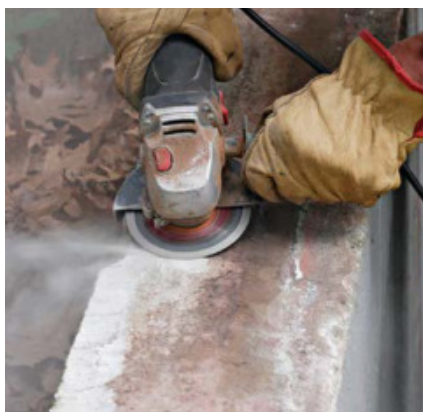
INSTALL THE HEADER

Position the header piece between the side panels and fasten using the supplied bolts. Then set the sill piece into place and fasten.



PREPARE THE FOUNDATION

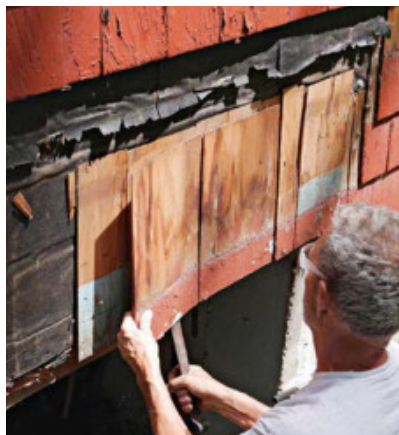
With the old door removed, this is the chance to address any deficiencies in the concrete foundation. Here, the previous installer had put sloped mortar around the metal door to keep out water, but it actually held water against the steel and led to corrosion, so it needed to be chiseled and ground away.



CHECK FOR LEVEL Before installing the new door, use a long level to check the foundation for level in all directions. If needed, apply a concrete resurfacer to level out low areas, or use a grinder to level out high spots.

PREPARE THE WALL

The new door-frame header and walls need a flat surface to seal against. This means some adjustments may need to be made when the wall sheathing and underlying framing is on a different plane than the exposed foundation wall below. The wall sheathing can be cut back if it's proud of the foundation wall, or pressure-treated furring strips can be installed over the foundation wall to pad it flush with the sheathing above.

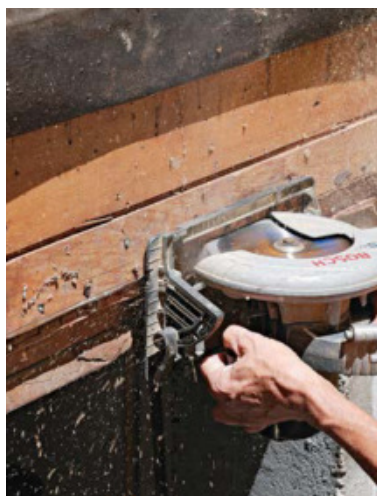


REMOVE SIDING

Strip away enough siding from the wall so the door-frame flange can be placed against the sheathing. Here, I removed three courses of cedar shingles to reveal the sheathing and make it easier to slide in replacement shingles after the door is installed.



DRY-FIT THE FRAME Center the frame on the foundation and check the seal against the house. Here the $\frac{3}{4}$ -in. sheathing was about $\frac{3}{8}$ in. proud of the concrete, so I traced the flange on the wall for a cutline.



TRIM THE SHEATHING Use a circular saw with the blade set at the depth to be removed to cut along the flange mark, and follow up with a chisel to remove the remaining material to recess the flange.



CAP THE FOUNDATION

For a clean, finished appearance, cut and install metal accessory plates over the top of the old foundation walls. Like the door unit, these foundation plates are powder-coated on all sides.



CUT TO FIT I cut the plates with a tungsten carbide metal-cutting blade in a circular saw; an angle grinder with a cutoff wheel can also be used. Prime and paint all cut edges.



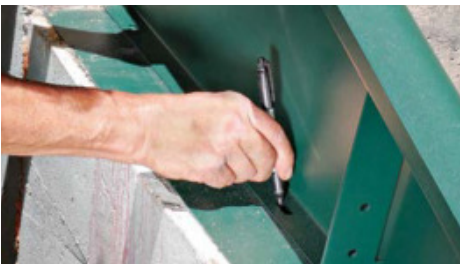
INSTALL THE PLATES Apply a thick bead of high-quality sealant to the top of the clean foundation before installing the plates.

INSTALL THE FRAME

The most accurate way to locate the mounting holes for the door is to set the door in place, and get it plumb and square.



PLUMB AND SQUARE Dry-fit the door tight against the house and centered on the foundation plates. Measure diagonals to verify that the unit is square, adjusting as necessary.



PREPARE FOR DRILLING Locate and mark the mounting holes on the foundation and walls.



THROUGH THE METAL AND INTO THE MASONRY Start the holes in the foundation plates with a metal-drilling bit, then switch to a masonry drill and bit to finish boring through the thin remaining metal and into the concrete.

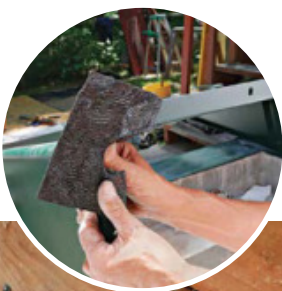


POSITION, SHIM, AND SEAL Shim the whole unit about 1 in. above the foundation and apply a bead of sealant along the foundation and walls for the new door frame to bed into.



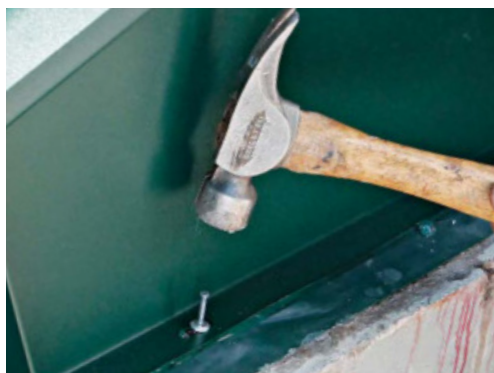
BED THE FRAME After applying sealant, slide out the shims one at a time and lower the frame, backfilling the areas where the shims were located with sealant.

FLASH THE FLANGE As added insurance against water, install self-adhering flashing tape at the top corners of the door frame where the side panels meet the header flange to help prevent leaks.



FASTEN FRAME TO FOUNDATION

To permanently attach the frame to the concrete, install hammer-drive anchors around the entire perimeter.



FLASH AND FINISH

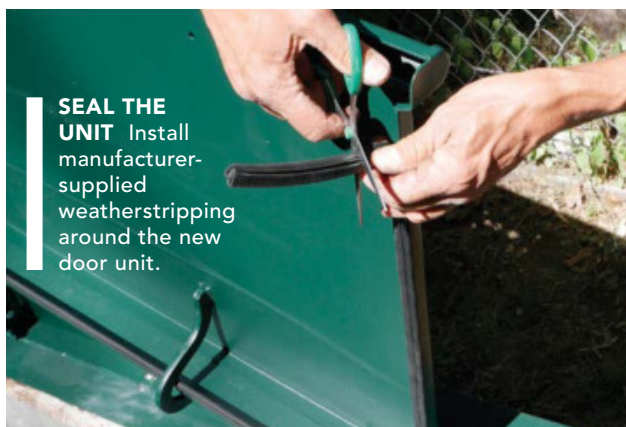
With the door in place, complete the installation by flashing the unit to prevent water entry, and installing or replacing the siding.



MANAGE WATER Apply self-adhered flashing tape over the header flange of the door, tucking it beneath the water-resistant barrier on the wall.

SEAL THE UNIT

Install manufacturer-supplied weatherstripping around the new door unit.



PATCH THE SIDING Install new shingles above and around the door frame and flange, leaving a 1/4-in. space above the header as a capillary break.



Durable and Good-Looking Traditional Gutters

An extruded-aluminum gutter and matching rake trim recreate a classic detail without leaks and rot

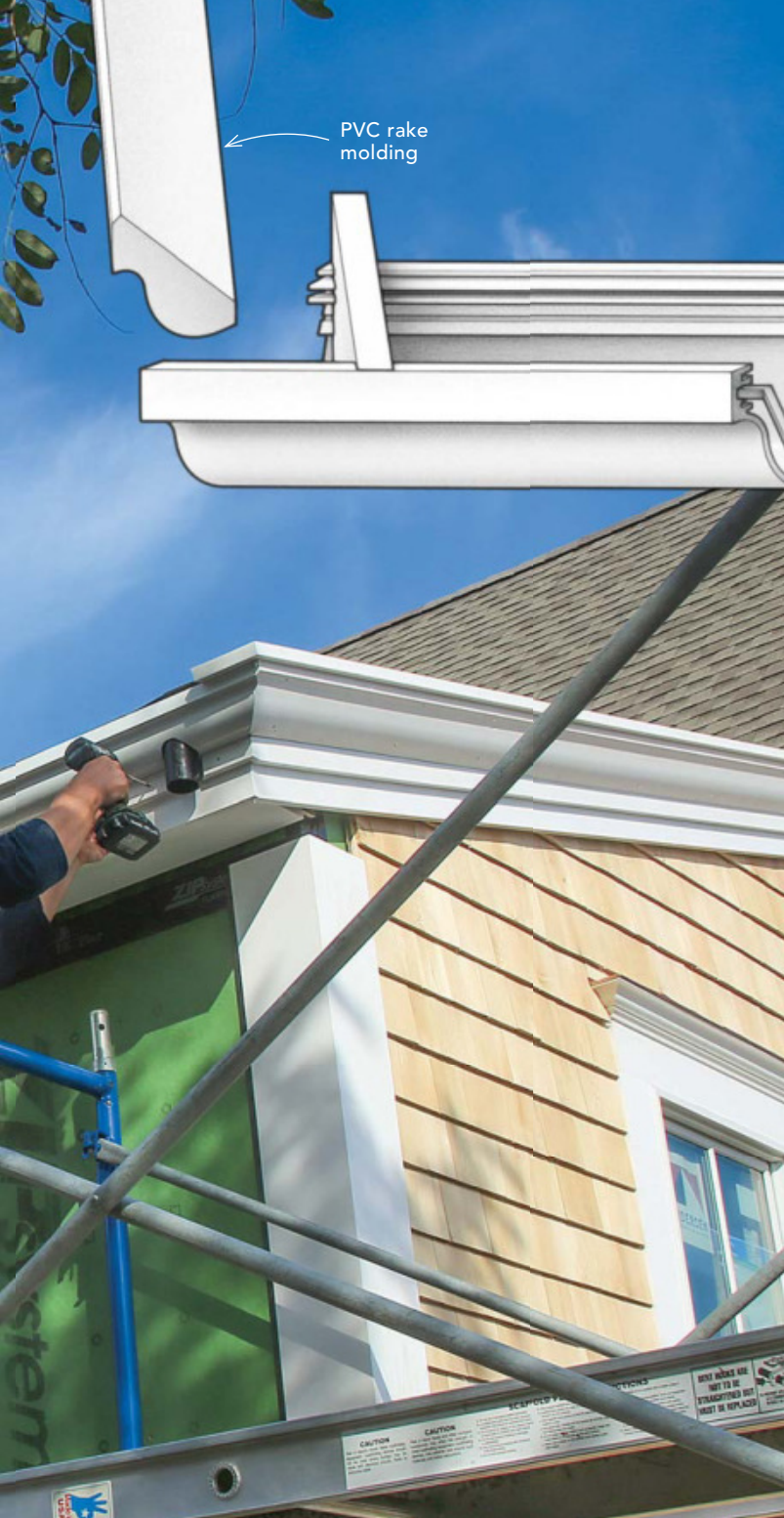
BY DAVID HORNSTEIN

One of the great things about living in New England is seeing the traditional architectural details on old houses, and that includes the gutters. Gutters used to be fully integrated into the overall trim scheme of a home. From modest bungalows to extravagant Victorians, gutters were a key architectural element, treated as moldings that defined the roofline and created a visually seamless continuity with other trim elements. But there were seams—and that was part of their demise. Now known locally as the Boston pattern, a standardized gutter and rake trim first appeared around 1880 and was developed to simplify and

standardize the process of putting on gutters and cornices. Its defining feature is the seamless transition from a beautiful wood gutter at the eave to a matching rake trim with the same profile. With the new system, lumberyards could sell a single gutter and rake profile that worked for a variety of roof pitches and overhang details.

Gutters and rakes made to match

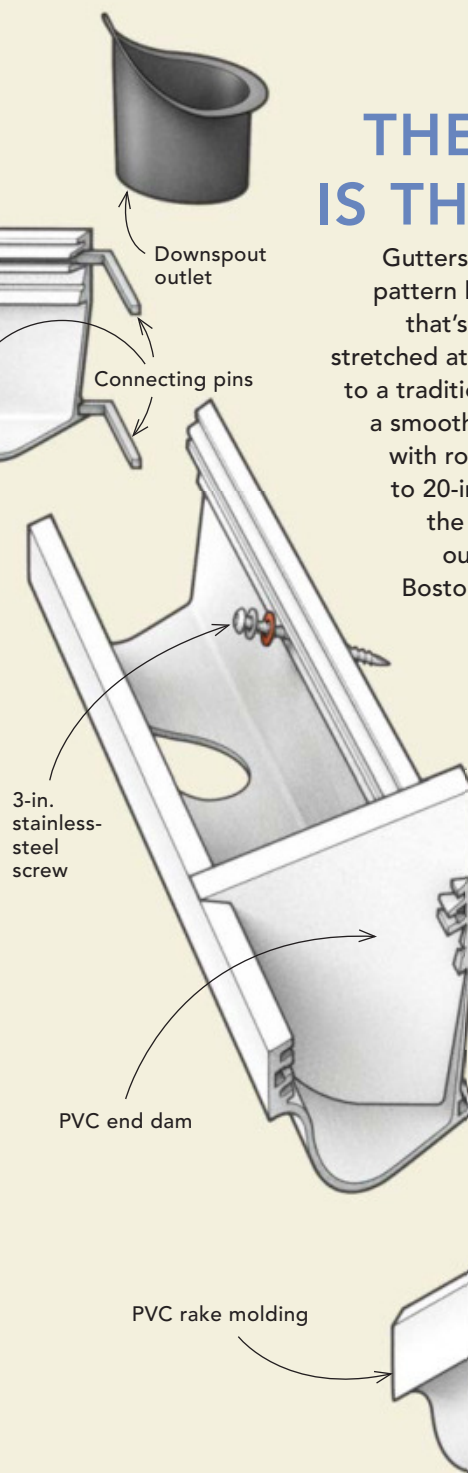
The sloping rake must mate up to the level gutter at roof corners, but their cross sections are different because one is horizontal and the other slopes. To get the two parts to line up at the miter, carpenters



THE SECRET IS THE SHAPE

Gutters made with the Boston pattern have a concave section that's smaller at the top and stretched at the bottom compared to a traditional ogee, allowing for a smooth eave-to-rake transition with roof pitches from 3-in-12 to 20-in-12. Duragutter OG is the same ogee profile and outside dimension as the Boston pattern wood gutter, but because aluminum is much thinner than wood, it holds twice the volume of water.

Like the original Boston pattern gutter, it can be attached directly to the rafter tails or mounted to a fascia board underneath it or behind it. The gutter is available in 8-ft. and 29-ft. lengths.



employ a number of strategies. You can use a gutter and rake with different widths. You can also adjust the spring angles to align the parts. The mill owners who introduced the Boston pattern figured out a brilliant solution to getting the two different cross sections to fit together. They modified the traditional ogee, making the top concave section smaller and extending the bottom section. This pleasing shape allows rake profiles to work with common roof pitches from 3-in-12 to 20-in-12 with a minimum of fitting at the rake miter. These gutter and rake profiles were used extensively, even during the Queen Anne era when rooflines had varied pitches and eccentric designs.

Aluminum ends the Boston pattern

The joints, transitions, and downspout outlets on wood gutters were made watertight by carving out a recess on the inside for lead or copper flashing. Given the movement of wood, these joints would fail over time, leading to leaks and rot. Repairs required skilled carpenters and roofers, so when inexpensive, maintenance-free aluminum gutters came on the scene in the 1950s, wood gutters were quickly replaced.

There was one big problem, architecturally speaking: The profiles of aluminum gutters were different than wood gutters, so the

Continued on p. 46

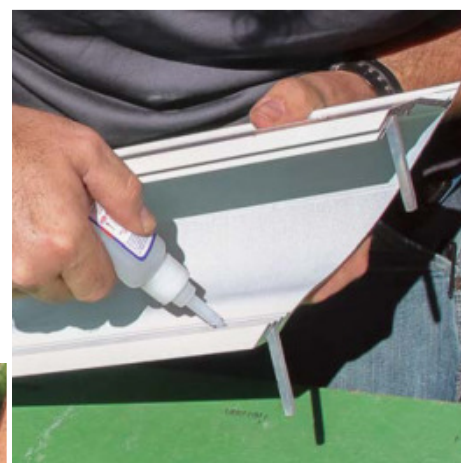
BUILD AND HANG THE GUTTER

The overflow lip of the gutter lines up with the top surface of the roof sheathing, following the slope. This sets the rake at the right height so that it just touches the underside of the roofing. A pitch toward the downspout at $\frac{1}{16}$ in. per ft. is essential with wood gutters, but unnecessary with these aluminum gutters.



Make cuts and drill for drops. The heavy-duty extruded-aluminum gutter is cut with a carbide-tipped blade on the miter saw with the gutter upside down on the sawtable, using a supplied block to raise the front edge. Holes for the outlet are made with a 2½-in. bimetal hole saw. The drill must be held parallel to the gutter's back to prevent an elongated hole.

Join corners. The gutter extrusion has three channels that receive aluminum connecting pins for butt joints and miters. CA glue holds components together.



Activator speeds the bond. CA glue activator is sprayed on the glue joint and connecting pins, which hold the separate pieces together.



Tape seals the deal. Butyl tape is cut and fit at joints and corners. The small pieces of tape are supplied precut for easier assembly.



Install end dams. Plastic blocks are fit near rake transitions and sealed so water never reaches the mitered joint where the gutter meets the rake board. The blocks are angle-cut in the field to match the roof pitch.



Glue the tube. CA glue is placed around the flange at the top of the downspout outlet. The outlets are ABS plastic, which is durable in warm and cold temperatures and UV-stable.



Make the opening. The top of the downspout outlet is sealed with pieces of butyl tape that are rolled with a small roller for a strong bond. Then the downspout opening is cut with a knife.



Hang assembled sections. With the outlets installed and the inside corner assembled, this section of gutter is ready for hanging.

Fasten with screws. Three-inch stainless-steel structural screws are used to hang the gutter, with one screw per rafter. The screws have a T30 torx head and include a flat washer and a flexible sealing washer.

CUT AND FIT THE RAKE

When joining the gutter to the rake at a miter at a gable end, the gutter is always cut at a 45° angle regardless of the roof pitch. When doing an in-line rake miter (at a cross gable in the middle of a straight run), we reverse the miter and make it a 45° inside corner. In both configurations (gable end and cross gable) the special angles occur on the rake molding only, and these angles vary by pitch and are the same angle for inside and outside corners.

Traditionally, carpenters wouldn't know or calculate complex rake angles because they would cut a 45° angle on the gutter/cornice first and then cut the angle on the rake molding by holding it in place. Following the roof pitch and the 45° cut on the gutter, they'd cut the rake miter by eye using a handsaw. Unfortunately, today's carpenters aren't trained to cut freehand compound angles this way.



Install blocking. Two-by blocking with a beveled edge is fastened to the subfascia with 3-in. nails to reinforce the rake molding and provide for nailing. The sloping PVC 1x stock is in the same plane as the roof sheathing. This house will get a new roof as part of the renovation.

Add fascia and fillet. A 1³/₄-in.-wide fillet strip is installed on top of a 3¹/₂-in.-wide fascia board. The boards are fastened with FastenMaster Cortex screws and plugs. The PVC plugs are made to match the grain of the various brands of PVC stock.



Continued from p. 43

new gutter could no longer integrate into the rake trim common to New England architecture. This led to some hideous hacking away of original details, compromising the integrity of many fine homes. Over time, many architects and builders forgot the historical details and developed new, “economized” versions that could be built with available materials. A few builders and design die-hards still insist on using authentic wood gutters, but unfortunately redwood and cypress have been replaced by less-durable cedar and fir.

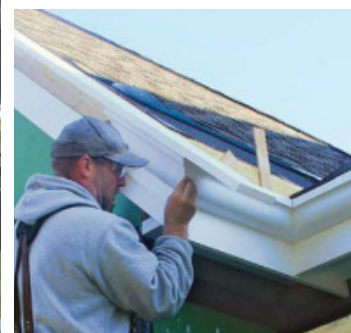
Modern materials, less maintenance

It killed me to see botched gutter jobs on otherwise beautiful homes, and I was inspired to find a better solution. I ended up manufactur-

ing my own, seen in the project in this article. It's an extruded aluminum gutter with a profile identical to the Boston pattern, called Durragutter. It enables designers and builders to replicate traditional details with low-maintenance materials. There is also a square profile designed for contemporary homes, as well as a flat-bottom version.

This article showcases a Cape undergoing a complete renovation and gutter installation. It was designed by Chatham, Mass., architect Leslie Schneeberger of SV Design and built by Duffany Builders. □

David Hornstein is a principal at Light House Design. Special thanks to John Moriarty of J. P. Moriarty & CO., Restoration Millwork in Somerville, Mass., for explaining the history of the Boston pattern. Photos by Patrick McCombe.

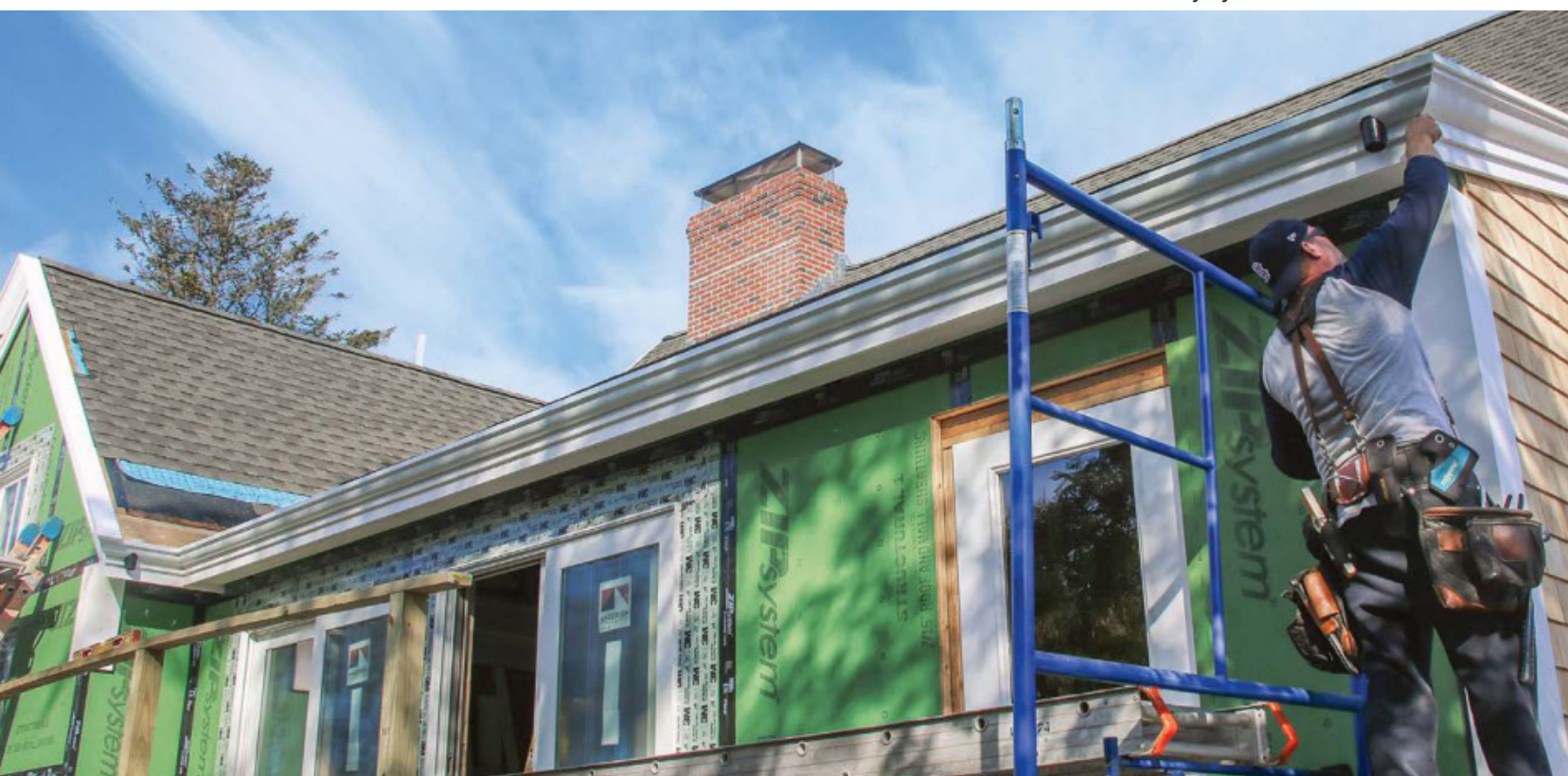


Fit and fasten the rake. Figuring out the rake miter angles is series of trial-and-error cuts at the miter saw. We use a small piece of stock to try the various miter and bevel angles and we minimize the number of trips from the saw to the roof with a mockup used to approximate the fit where the gutter meets the rake.



Trim the top. The trimboard that covers the rake's projection is run long initially and trimmed on the roof. This board is in plane with the roof sheathing and finishes the roof's edge on the underside, which is visible from the ground. After trimming, the end of the board is sanded smooth.

Timeless look. The completed gutter and rake trim make seamless turns at roof corners and intersecting gables without any eyesore transitions.





Repointing a Brick Chimney

Extend your chimney's life by tackling this tedious task

BY MATTHEW MILLHAM

A well-built brick chimney can last for centuries or longer, but it's unlikely to make it to old age without some routine maintenance. It's just a fact that brickwork needs to be repointed from time to time to maintain its weathertightness and keep it from falling apart. This involves carefully removing some of the old mortar and replacing it with new. It can be painfully tedious work, requiring at least as much patience as skill.

The first priority when repointing is to do no harm. It's probably obvious that you don't want to break any bricks in the process, but you also want to avoid even small chips. The fire skin on the surface of a brick protects a more porous and softer interior, and it's especially thin on older bricks made before the development of modern kilns and firing techniques. If the skin is broken, the brick will succumb to the processes of weathering much more quickly. Protecting that skin while clearing out the joints is easier if the chimney was built correctly with mortar that's softer than the brick. If the mortar is harder than the brick, as it was in this case, extra care is needed.

When the mortar is harder than the brick, it can cause the brick to spall and crack just through normal expansion and contraction—as you can see below, some of the bricks in this chimney were nearly pulverized, and the hard mortar is the likely culprit. Chiseling out old, hard mortar can cause the same damage even more quickly, as the energy



from hammer blows transfers through the chisel, into the hard mortar, and out through the path of least resistance—the soft brick.

In this case, it was already too late to save some of the bricks. Fortunately, the damage was confined to the southern and western exposures above the roofline—the parts that

see the most sun and accompanying thermal expansion and contraction. When the damage is relatively limited like this, it can be a tough call whether to just tear down that part and rebuild or remove and replace what's broken. If I can find bricks that match the originals, tearing down and rebuilding is my preference. Here, I was limited to 10 decent bricks that were left over from when the chimney was built—they were used as edging in a nearby flowerbed. I decided to take the less-destructive path, and removed and replaced the bricks in the worst shape.

Repointing is messy work. All the dust and debris from removing old mortar and drops from new mortar can damage or stain the roofing material, so protecting it is critical. On shingled roofs of moderate pitches like this, I use a moving blanket to cover the shingles in the working area. This allows me to keep a good grip on the roof while protecting it. A 2x4 or some bricks wrapped into the bottom of the blanket create a dam to keep debris from rolling down the roof. □

Matthew Millham is a contributing editor. Photos by the author.

REMOVING OLD MORTAR

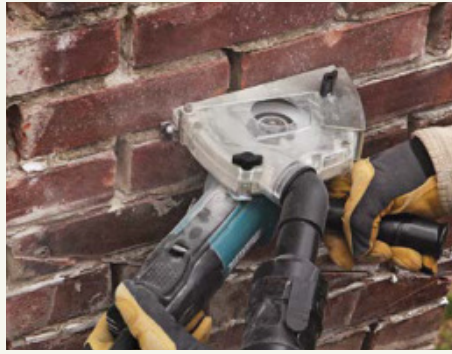
Removing the old mortar is by far the most time-consuming part of repointing, and a step that can't be skipped. The good news is you only need to remove some of the mortar, not all. A good rule of thumb is to cut back the mortar to a depth that's twice the height of the joint. So if the joints are $\frac{3}{8}$ in., remove $\frac{3}{4}$ in. of mortar, plus any loose or crumbling stuff behind that—the deeper mortar is often a bit crumbly. Don't go beyond one-third of the joint's total depth or you risk destabilizing the brick.

The face of the excavated joint should be square to the brick and as flat as you can get it so it can be easily refilled without leaving voids. New mortar won't bond well to old mortar, so exposing a decent amount of brick and removing all debris is essential for the job to last.

I take what could be called an escalation-of-force approach to mortar removal. If the mortar is soft, a heavy hammer and an assortment of chisels will do the trick. If the mortar is hard, chiseling alone can spall the brick, so I pull out my grinder with a thin, segmented diamond blade and cut a kerf in the bed (horizontal) joints. These are essentially relief cuts that redirect the energy from hammer blows away from the faces of the bricks. Then I continue on with chisels. Never use a grinder on head (vertical) joints—you're sure to nick the bricks above and below them.

A heavy hammer may seem antithetical, but it gives you more control over your strokes. Light hammers deliver relatively little energy to the chisel as they're swung, encouraging you to swing harder and raising the risk of accidental damage. A heavy hammer, paired with light taps on the chisel, gets the job done better with less effort.

For chisels, go with something at least $\frac{1}{16}$ in. narrower than the joint you're trying to clear out. If the side of the chisel makes even slight contact with soft brick as it's struck, the brick can chip. Angle the chisel as far away from 90° as possible while still getting purchase (around 45°), aim toward an area that's already been cleared, and take only small bites— $\frac{1}{4}$ in. to $\frac{1}{2}$ in. of material at a time.



Kerf it. Use care when grinding not to hit the bricks. A dust-collection shroud hooked to a vacuum keeps the work visible. This shroud has a sight to make alignment easy, allows you to set the cut depth, and keeps the grinder wheel square to the surface.



Plug it. Use plugging chisels—specifically designed for repointing—to remove soft mortar, keeping the chisel angled at about 45° to the surface. Don't start in the middle; always start at one end of a bed joint and work across it.



Clear the beds, then the heads. It's always best to chisel toward a void; it prevents the brick from spalling and, like chiseling wood, it's easier to pare from an edge. Clear kerfed and hard-mortar joints with masonry chisels, angling the cut toward previously cleared parts of the joint. Once a bed joint is clear, chisel out the head joints next to it, angling toward the empty bed.



Remove the debris. Scrape out any loose bits of mortar (here I'm using a rock hammer, but a 5-in-1 tool or something similar also works), then remove any dust with a vacuum or compressed air.

REPLACING BRICKS

Often, if a brick's surface is only slightly damaged, it can be worth it to carefully remove it, spin it around, and mortar it back in. I started to do that here, but the two bricks I removed were laid with that particular face out for a reason—the hidden faces were already beat up. Fortunately, I had some bricks to replace the most compromised ones in the chimney.

Breaking out broken bricks still takes care. A slip of a chisel or an over-deep thrust with a hammer drill can easily damage nearby bricks or the masonry flue. After each whack with a hammer and chisel or plunge of a hammer drill, remove what bits you can by hand.



Crushed corner. Broken bricks on outside corners can be easily removed with a hammer and chisel rather than resorting to power tools. Hand tools alone generally take too long for field bricks, though.

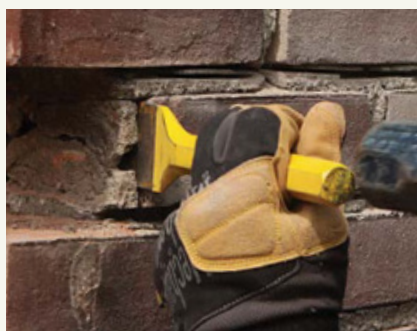


Slice and dice. When removing field bricks, break the brick vertically into 1-in. pieces using a hammer drill chucked with a 1-in. chisel. Only go about as deep as the joints are excavated around the brick to avoid putting pressure on the surrounding bricks. Then break the vertical slices in half horizontally, leaving a grid of small pieces.



Chisel 'em out. Use a hammer and wide masonry chisel to slice out the pieces of broken brick. Removing the top half of the broken-up brick first provides room and relief to easily remove the bottom half without pressuring and possibly breaking the surrounding brick.

Soft power. Remove old mortar from bricks with a hammer drill and chisel set to hammer, angling as shallow as possible to the face of the brick. Barely pull the trigger. It often doesn't take much for unconfined mortar to separate from the brick face.



Clean the old. After removing a brick, the remaining mortar typically comes out easily. A steeply-angled chisel and a few light taps are often enough to break its bond with the brick.



Reason for care. Many chimneys are only one-wythe thick, with the masonry flue right behind it. Be extremely careful not to damage flues, especially if they're in active use.



Wet it down. After clearing away all dust and debris, wet the surrounding brick to prevent it from sucking the moisture out of the new mortar and interfering with proper curing. Don't move on to mortar until any standing water is absorbed or evaporated.



Prep the void. Apply mortar to the bottom and sides of the opening, tapering the sides toward the front and slightly overfilling the bottom. Don't apply mortar to the top.



Butter the brick. Fill manufacturer stamps with mortar to prevent voids and ensure a good bond between the brick and mortar.



Push it in. Carefully insert the brick into the hole, keeping it centered side-to-side, then wiggle it down into the bed mortar.



Level it. Slide a margin trowel into the open top joint and use another trowel to tap down on the brick and level it both side to side and front to back.

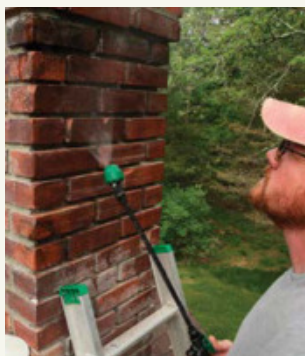


Plane it. Use a short length of 2x4 to help push the brick flush with its neighbors on all sides and check for general flatness.

REPOINTING DONE RIGHT

The primary tools for repointing are tuck-pointing trowels to fill the joints, and something to hold the mortar while working—I use a mortar hawk, though some prefer to use rectangular finishing trowels. I use a margin trowel or brick trowel to move mortar from the bucket to the hawk, and to flatten it into a pancake about the same thickness as the joints. This makes it easy to get just the right amount of material on the tuck pointer.

Fill joints starting from the top down so material that drops doesn't mar your completed work, and fill the head joints before the bed joints as you progress down. Add material in 1/4-in. lifts. For bed joints, start at one side and work toward the other (for righties, that generally means working from right to left), and add lifts until the joint is slightly over-full. This helps ensure no air gets trapped in the joint, which can weaken it. When replacing bricks without repointing, use the same techniques to fill and finish the top and side joints.



Wet it first. Moisten the brick so it doesn't absorb water from the mortar and inhibit proper curing. Don't be afraid to soak it; just make sure there's no standing water before proceeding.



Heads before beds. To fill head joints, take a small slice of mortar from the hawk, put the tip of the tuck pointer onto the brick below, tip it into place, and smear it firmly into the back of the joint. Repeat until the joint is full.



Small slices. To fill bed joints, lean the edge of the hawk below the joint and simply push small slices of mortar into it, pushing it far back and raking across the joint to pack it in tight.

MIXING MORTAR



Small-batch goodness. Mix repointing mortar in small batches in a bucket, using a mixer or hand tools. Add water only a little at a time and mix thoroughly until the mortar can be formed into a ball that holds together and keeps its shape.

If you've never repointed before, it's surprising how little mortar it takes to fill in those joints you just took hours or days chiseling out. A 3/8-in. joint excavated 3/4 in. deep requires about one 80-lb. bag of mortar per 40 sq. ft. of surface area. On this project, I had roughly half that much area to refill with mortar.

Because the volume of mortar needed is so small, it makes sense to mix in small batches. I can't say this enough: Always use a mortar that is softer than the brick.

There are three main types commonly available—from hardest to softest they are M, S, and N. All of these contain Portland cement, hydrated lime, and sand. Both Portland and lime are binders, but they have different characteristics. Portland cement increases the mortar's compressive strength, but can make it brittle and unyielding. Lime produces lower compressive strength, but increases bond strength and flexibility, and it can self-heal small cracks. Type M typically has three times more Portland than lime, while type

N has equal parts Portland and lime.

Don't use Type M or S mortars for repointing. Type N mortar is usually the recommendation for American brickwork built after 1900. It's softer than most, if not all, modern brick. For older brickwork and historical buildings, you likely need even softer mortar—Type O, which has only a small amount of Portland, or lime mortar without any Portland at all. Typically, these are mixed from raw ingredients on-site and aren't available bagged.



Test for hardness. When the mortar has set up hard enough that it can hold a thumbprint, it's time to tool the joints. Check regularly; depending on the weather and mortar type, this could happen in minutes or hours.



Tool the joints. There are various methods, styles, and reasons for using particular joints. Here, I used a joint raker to create clean, flat joints recessed about $\frac{3}{16}$ in. from the brick surface.



Final consolidation. After raking, use a brush to clean up the joints, and then tool the joint faces to consolidate them.

Mix mortar in a clean bucket. If using a bagged mix, measure out the amount needed into the bucket, add just a small amount of water, and begin mixing—you can use a margin or brick trowel to mix, but I prefer to use a right-angle drill with an eggbeater drywall mixer. Add water a little at a time, mixing until the mortar can be formed into a ball that holds its shape. Follow the directions on the bag if they vary from this, and make sure to pay attention to guidance on mixing and wait times. Mixing guidelines differ, but

some bagged mortars require a wetting and waiting period to allow the lime and cement to fully hydrate. Once a bagged mortar is wet, there's a limited amount of time before it has to be used. Don't mix more than you can use within the working limits printed on the bag.

Here I mixed my own lime mortar from mason's sand and Type S mason's lime, which is a dry, bagged, hydrated product. I measured out the dry ingredients carefully—my mix is two parts sand to one part lime. I mix the dry ingredients together, then add small

amounts of water and mix for at least 10 minutes. When I can form the mortar into a ball that doesn't fall apart, I cover it and let it sit in the bucket for anywhere from a couple hours to a couple days—as long as air can't get to it, it won't harden (another benefit of this mortar). When I'm ready to use it, I check the consistency and add a little more water if needed. It should be just wet and tacky enough to stick to the tuck pointer so I can easily transfer it to the vertical joints without dropping it, but no wetter or it will smear the brick.



Cover and keep. Covering the chimney with a tarp after repointing and lightly spraying it daily for a week helps the lime mortar remain damp—a requirement for proper curing.

Flat-Roof

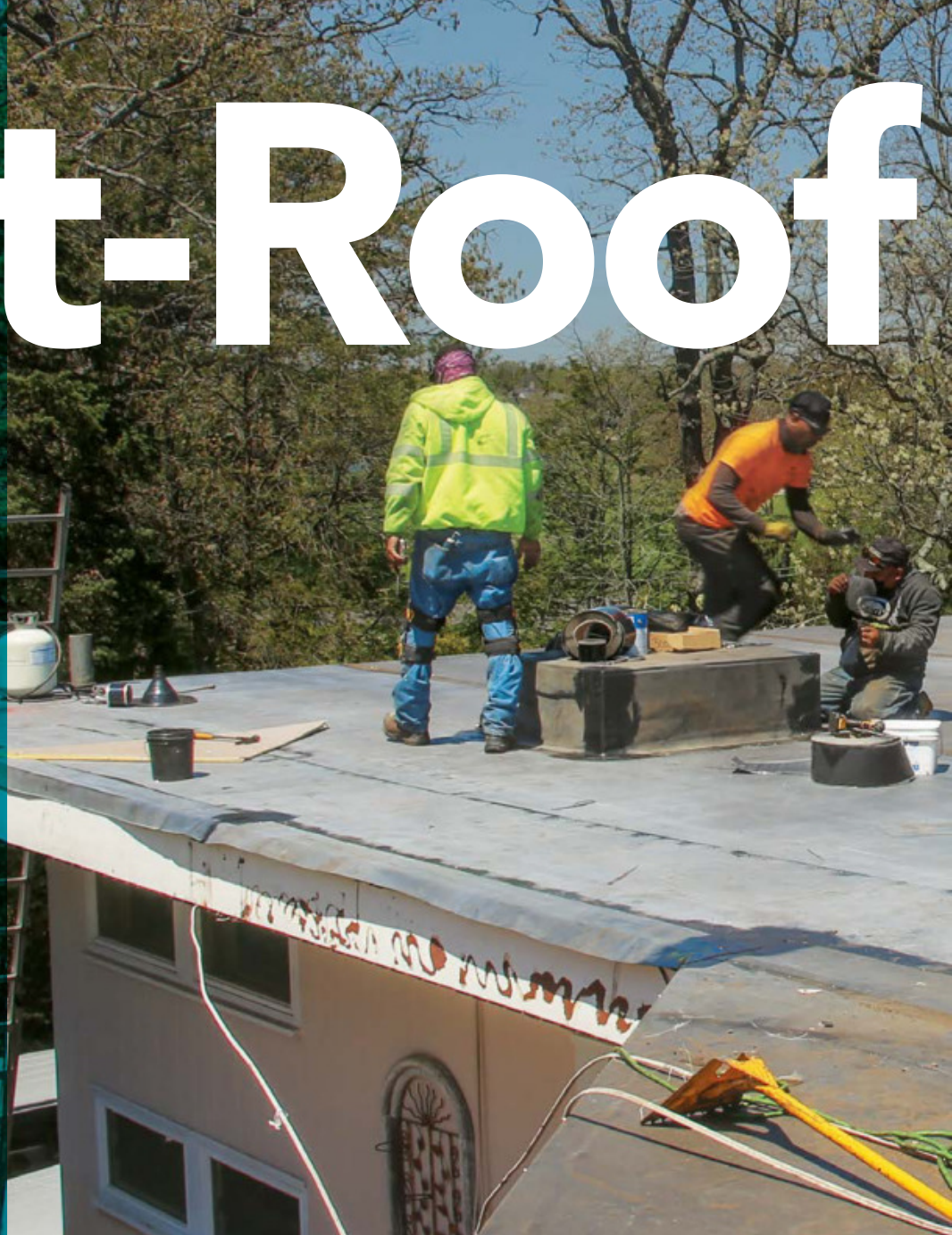
Removing the asphalt shingles and adding a rubber membrane prepares a roof for any weather

BY DYAMI PLOTKE

The PVC roof on my clients' midcentury-modern home was decades old and well past its useful life. The patches that seal the fasteners were split and part of a system abandoned by its manufacturer years ago. The homeowners had a local roofer attempt to fix the leaking fastener patches with a fluid-applied waterproofing, but when this didn't stop the leaks, they began to do their own research and contacted Carlisle, a commercial roofing manufacturer. As one of their premier installers, we were put in touch.

I met with the homeowners and reviewed the condition of the roof. The existing PVC was in such bad condition—and the underlying insulation and original roof were so wet—that the existing roof had to be removed, and we replaced it with an EPDM (ethylene propylene diene monomer, a type of synthetic rubber) membrane roof. The process involved hundreds of hours and several days of work, but the end result is a roof finally suited for home's modern architecture and ready to stand up to the elements. □

Dyami Plotke is project manager for Roof Services in Deer Park, N.Y. Photos by Patrick McCombe.



OFF WITH THE OLD

The existing roof had two roofing systems on top of the sheathing. First was the original hot-mopped asphalt roof. On top of that was a PVC membrane roof, likely added when the original roof started to leak. Under the hot-mop roof was a layer of wood-fiber insulation. Under the PVC was a layer of Perlite insulation. It all added up to 210 yards of debris that we tossed into seven 30-yard dumpsters.



Cut and peel. We cut the screw covers with a utility knife and back out the screws that hold the PVC to the roof sheathing. Then we cut the PVC into manageable pieces and roll them up for disposal.

Rescue



A roof is a system. Sheathing, insulation, roof membrane, and flashings all work together to keep a low-slope roof watertight. The products must be compatible with each other and the crew must be trained to install them correctly.



Make a mess. The wood-fiber insulation, asphalt felt, gravel, and Perlite insulation must be broken up and shoveled into contractor bags or carted to the roof edge in wheelbarrows before being tossed into the dumpster. It's hard, messy work.



Patch the holes. A leaky roof generally leads to some rotted sheathing. We used $\frac{3}{4}$ -in. CDX plywood, the same sheathing material as the rest of the roof, to patch two rotted sections.

INSTALL INSULATION AND MEMBRANE

Membrane roofs are almost always installed over a continuous insulation layer. Combined with the 6-in. batts in the rafters, the roughly R-8 polyiso layer will make this roof R-28. The clients opted not to spend more for additional insulation. The EPDM rubber membrane is glued to the insulation and is completely watertight when complete—unlike an asphalt-shingle roof, which is described by roofers as “water-shedding.”



1 **Prep the edges.** Roof edges are vulnerable to high winds, which can cause the insulation and membrane to lift and lead to a failure. 2x6s around the roof perimeter provide a secure point of attachment for the edge metal, which helps hold the roof down. The metal parts that secure and finish the edges will be installed later.



2 **Fit and fasten the insulation.** We fit the 4x8 sheets of 1½-in. polyisocyanurate insulation with the seams staggered. Then we fasten them to the sheathing with 3-in. roofing screws and 3-in. insulation plates using a 24-in.-on-center spacing.



3 **Prep for drains.** We connect the new drains to new 4x6-in. downspouts before we cut holes into the sheathing. The bottom half of the drains are installed before the insulation and EPDM layers.



4 **Clean up.** We thoroughly sweep the insulation layer and blow away all debris before we install the EPDM membrane. This ensures proper adhesion and prevents lumps and damage to the roofing.





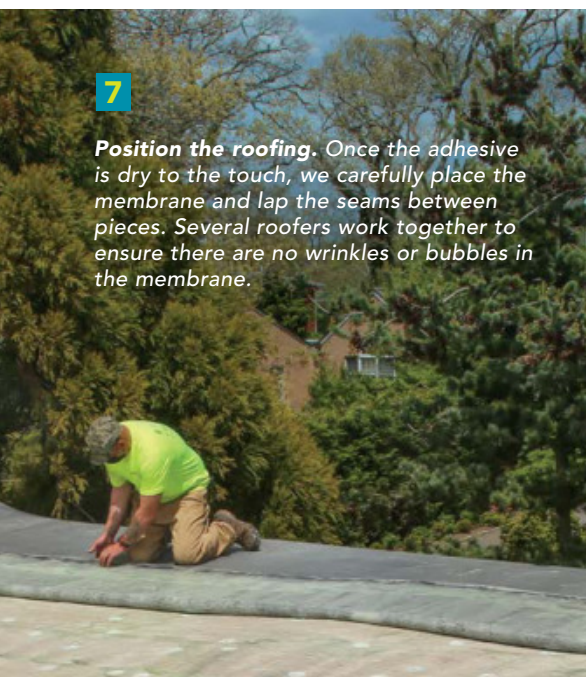
5

Cut to length. We roll out and cut the 10-ft. by 100-ft. rolls of EPDM roofing with scissors.



6

Apply adhesive. With the piece of membrane folded in half, we spray EPDM adhesive onto the insulation and the membrane and allow it to tack up for a few minutes. Waiting a few minutes allows the solvent to evaporate to prevent bubbles. The hotter the weather, the faster the solvent evaporates.



7

Position the roofing. Once the adhesive is dry to the touch, we carefully place the membrane and lap the seams between pieces. Several roofers work together to ensure there are no wrinkles or bubbles in the membrane.



8

Broom it down. We use a broom in long strokes over the entire piece of EPDM to ensure the membrane is fully bonded to the insulation layer.



9

Seal the seams. We wipe the seams where the pieces of EPDM meet with a membrane cleaner using paper rags, and then coat them with seam primer, before positioning and rolling the tape.



10

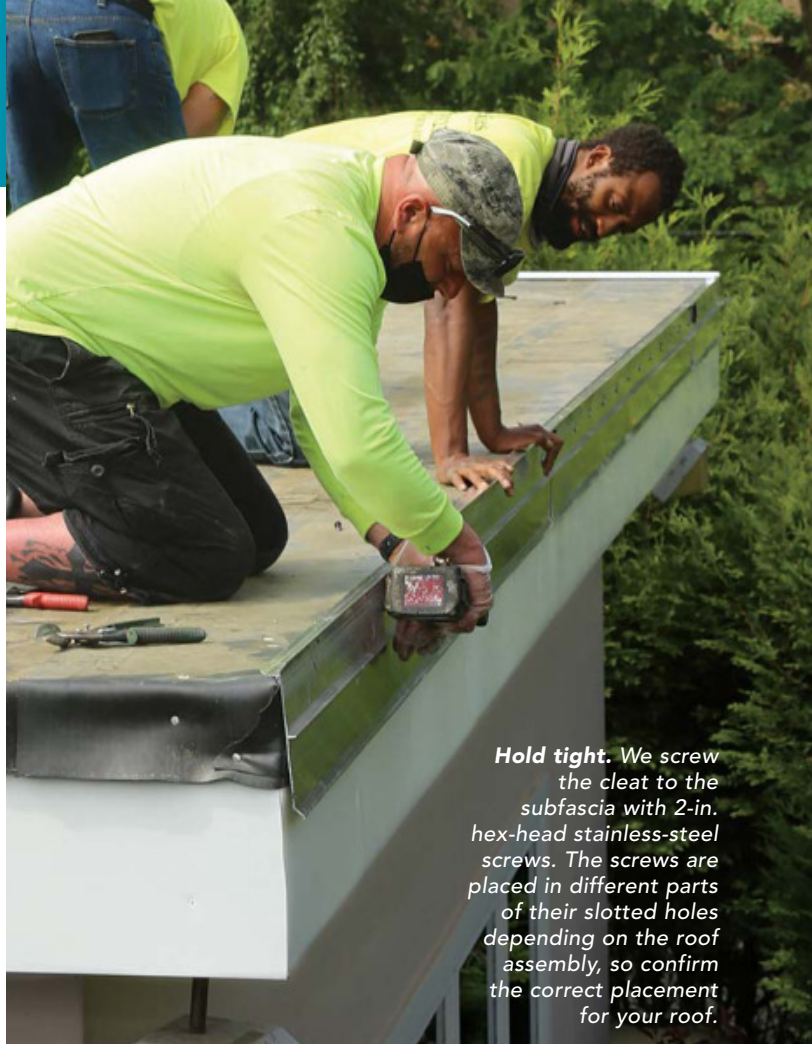
Roll it again. After the tape is rolled, we position the EPDM over the tape and then roll the seam again, both parallel and perpendicular to the seam along its entire length and width.

TRIMMING THE EDGE

The edges of this low-slope roof have a detail common to commercial roofs—a two-part edge metal with an extruded aluminum cleat and a powder-coated cover; this one is Anchor-Tite by Metal-Era. The metal keeps the roof edges from lifting in high winds. The manufacturer provides several options that can be used with different thicknesses and types of roofing.

Make it stick.

An adhesive strip on the cleat seals the edge metal to the roof.



Hold tight. We screw the cleat to the subfascia with 2-in. hex-head stainless-steel screws. The screws are placed in different parts of their slotted holes depending on the roof assembly, so confirm the correct placement for your roof.



Fit the fascia. We cut the 0.04-in.-thick aluminum cover with aviation snips and form the corners with hand seamers. This work will be visible from the ground, so it requires care and precision by the roofer.



Snap on the fascia. The Anchor-Tite fascia cover is snapped onto the cleat with pieces overlapping 3 in. When installed correctly on commercial projects, the manufacturer provides a 215-mph-winds warranty. Residential roofs are not warrantied because of a lack of training and certification for residential roofers.

CLEVER FIX FOR A FLAWED GUTTER

The trickiest part of this roof was the existing Yankee gutter. It was 128 ft. long, starting on the home's north side and curving to the front, over the front entrance. It had 3500 sq. ft. of roof draining into a 2-in.-deep trough framed into the roof, providing a volume of about 10 cu. ft., and it would overflow almost every time it rained. A roof this size really needs a gutter with several times the volume. With both a hanging box and a K-style gutter as aesthetic nonstarters given the home's architecture, we raised the roof edge, filled in the old system, and designed a much larger gutter that won't overflow, even with heavy rain.



Fill the trough. We filled in the existing Yankee gutter with 2 in. of polyiso and built up the outside edge to match the inside edge of the original gutter. We flashed the edge with EPDM before installing the new gutter.



Make a new gutter. The new gutter is made from 5.2-in. Eliminailer-T (see below), which creates a dam along the roof perimeter. The heavy-gauge aluminum pieces are best cut with a metal-cutting circular saw or grinder.

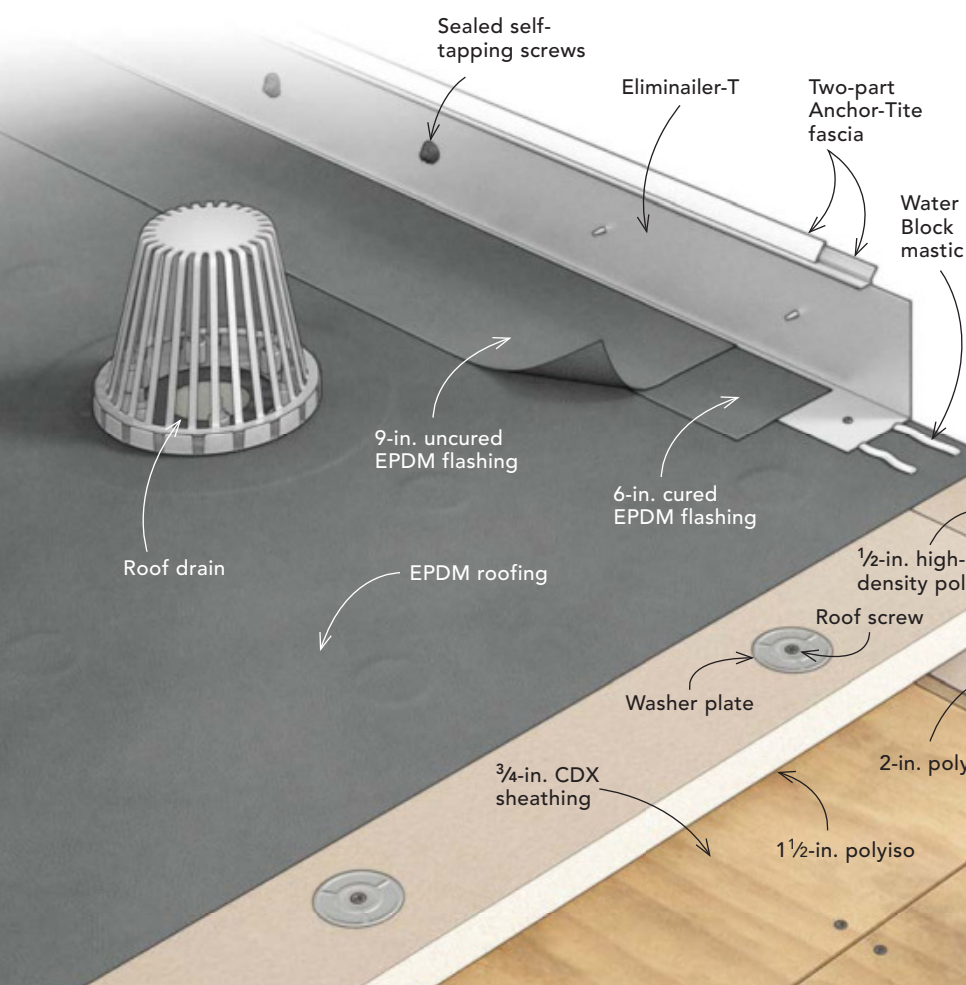


Gutter must go. The roof's existing gutter was framed into the roof and was a source of frustration for the 20-plus years the homeowners have lived in this house. The overflowing roof water left debris on the fascia and dripped on anyone who used the front door during a storm.



Cover conceals the gutter. The new gutter is hidden from the ground with an aluminum cover that matches the covers on the other roof edges.

It snaps on so it can expand and contract with temperature changes.



BUILD A BETTER GUTTER

Metal-Era's Eliminailer-T is an extruded aluminum angle commonly used to replace wood blocking on the edge of flat roofs. It's designed to accommodate 5.2 in. of insulation (R-30), which is local code for flat roofs on commercial buildings. In this case, we did not put any insulation behind the Eliminailer, so it projected 5.2 in. above the finished roof. We sealed the Eliminailer with EPDM and detailed it into a watertight dam that holds the water until it drains into the downspouts.

MAKE PENETRATIONS WATERTIGHT

Commercial roofing systems have tested methods for sealing common roof penetrations like pipes, ducts, chimneys, and skylights. In addition to multiple skylights—including a 6-ft. round one—this roof had plumbing and mechanical penetrations and an 8-ft.-wide masonry chimney with leaky flashing. Methods vary for dealing with penetrations, but a skilled roofer should be able to solve most problems with tested assemblies. Detail drawings are often available from the roofing manufacturer.



Heal the cut. The EPDM membrane may need to be cut over penetrations. We wipe the area around the cut with membrane cleaner and coat it with primer before adding a patch of cured flashing tape.



Prevent lift-off. We clip the corners of the self-adhering flashing tape patch in order to prevent them from lifting and creating a toehold for a leak.



Roll the patch. The flashing tape has a pressure-sensitive adhesive that must be rolled for a strong bond. We roll the entire patch in both directions.



Prime for the boot. We wipe the area under the pipe flashing with membrane cleaner and then prime it with adhesive primer.



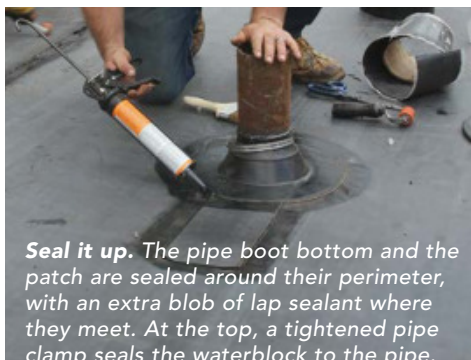
Bead at the top. Before installing the flashing, we add a bead of Water Block around the pipe, placed so that it will align with the top seal of the flashing boot when the seal is slipped over the pipe.



Fit the flashing. The flashing is molded to accommodate pipes from 1 in. to 6 in. in 1/2-in. increments and is trimmed to be just smaller than the pipe diameter, creating a tight seal.



Stick the bottom. The pipe flashing has pressure-sensitive adhesive that's rolled like flashing tape for a strong bond. Notice the bead of Water Block at the top of the boot.



Seal it up. The pipe boot bottom and the patch are sealed around their perimeter, with an extra blob of lap sealant where they meet. At the top, a tightened pipe clamp seals the waterblock to the pipe.

Cross your "T"s.

We cover spots where patches and membrane seams intersect with T-joint covers made by the roofing manufacturer as a second line of defense against water. These are also rolled and their edges sealed with lap sealant.





Fix a leaky chimney. The chimney can't be seen from the ground, so it made sense to insulate it and cover it with EPDM so it could be more reliably flashed and in order to reduce thermal bridging. The insulation is held to the masonry with concrete screws. Drive anchors hold the termination bars.



Flash the top. Once the termination bars are in place, we prime the areas around them and cover them with uncured flashing tape, which is more flexible but not as long-lasting as the cured version. It must be rolled like other seams and transitions. The skinny roller in the foreground is for corners.

Why EPDM?

While there are other options, for me, choosing EPDM for a low-slope roof is an easy decision. It's cost-effective and low maintenance, and makes for an incredibly long-lasting and reliable roof. That's why, when we install it on a commercial building, the manufacturer will provide a 20-year full-system warranty (unfortunately, it's not available for single-family homes.) Because it's UV-stable, EPDM won't dry and crack like this home's previous roof, and it does not require any coating on the seams. The tape used on the seams makes the joints between pieces almost as strong as the membrane, resistant to opening and resultant leaks. The whole insulation and roofing system installs with fasteners and adhesive, eliminating the high-power torches that used to be an everyday part of commercial roof systems and a huge fire risk for a wood-framed home. Another big plus is that the flashings used with Calrlisle's EPDM membrane call for a primer and tape from the same manufacturer's system, make them relatively easy to install and more reliable.

—D.P.



- + The most UV-stable roofing membrane available
- + Strong seams, every 10 ft.
- + Clean installations with no fire risk
- + Moderately tolerant of standing water

EPDM

- * Only available through commercial distribution, in minimum 500-sq.-ft. rolls
- * Requires skilled, experienced installers
- * Installed price can be expensive
- * Black color can be an aesthetic issue



- + Readily available from big-box stores to commercial-roofing distributors
- + Often inexpensive

ASPHALT ROLL ROOFING

- * Weak seams, every 3 ft.
- * Not UV-stable (requires granules or aluminum paint)
- * Fire risk (if torch-applied)
- * Because of wide availability, often installed by inexperienced crews
- * Not tolerant of standing water
- * Requires 2 plies (layers) for long-term performance

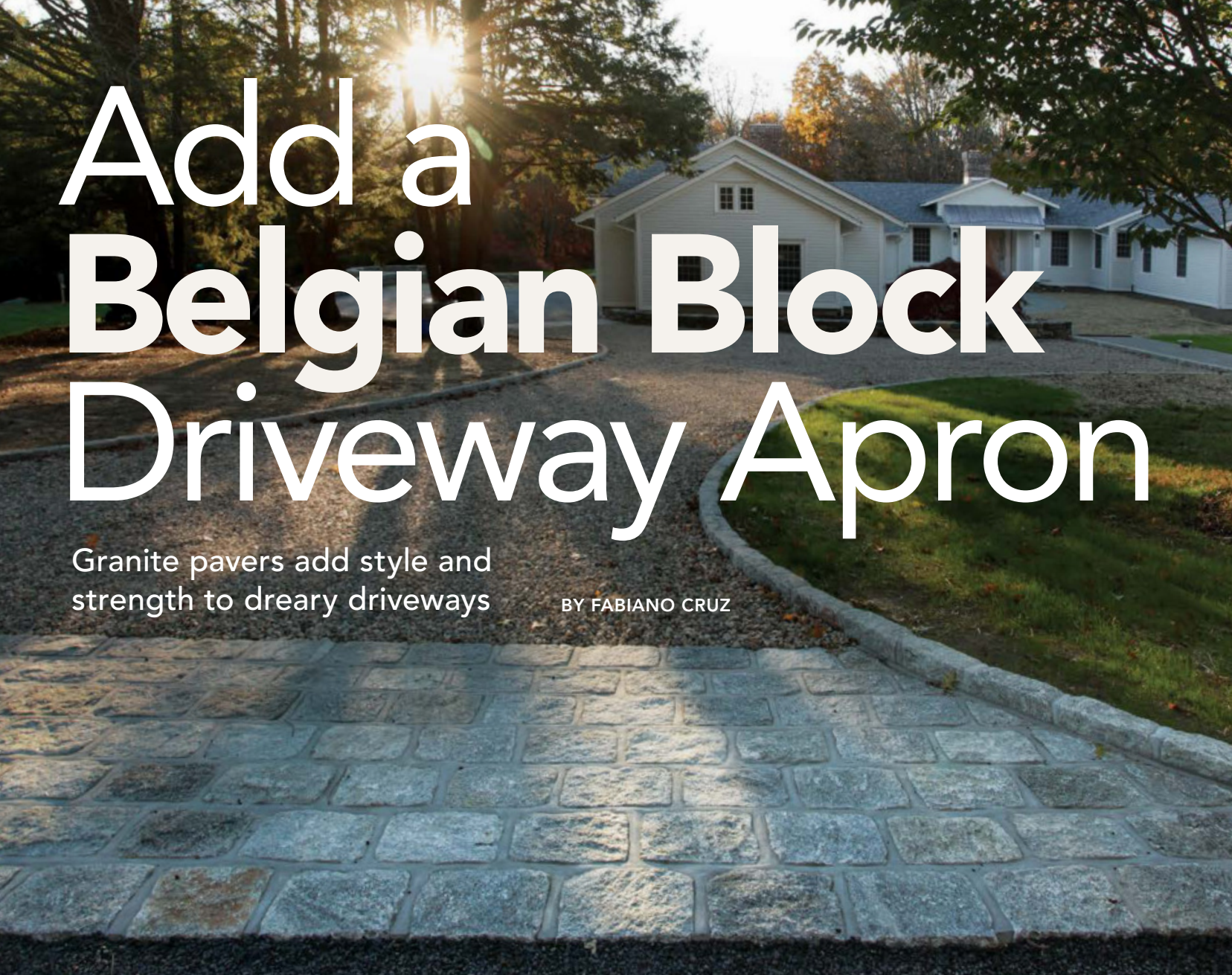


- + Moderate UV stability
- + Seams stronger than EPDM, every 10 ft.
- + Clean installation with no fire risk
- + Very tolerant of standing water
- + Very reflective

THERMOPLASTIC POLYOLEFIN (TPO)

- * Only available through commercial distribution, comes in minimum 500-sq.-ft. rolls
- * Requires skilled, experienced installers with specialized equipment
- * The installed price can be expensive
- * The white color can be an aesthetic issue
- * Very slippery





Add a Belgian Block Driveway Apron

Granite pavers add style and strength to dreary driveways

BY FABIANO CRUZ

Back in the horse-and-buggy days, it was common to see Belgian blocks paving American city streets. There's a lot of sketchy scholarship about where these granite blocks came from and how they got their name, but this much is true: They can take a pounding and look good doing it. Despite these advantages, they were pretty much done for when cheaper and easier concrete and asphalt pavements came on the scene.

Still, Belgian blocks are a popular go-to when cities or homeowners want to dress up a space. You probably see them most often in curbs along streets and paths. In the part of Connecticut where I live, a lot of driveways have Belgian-block aprons. These aprons add more than style; they also pro-

vide a visual transition from the blacktop of the residential streets to the (usually) gravel driveways, and they keep the small stones from spilling into the road. At this house, a second apron also provides a transition from the gravel drive to a blacktop parking area by the garage.

Because these aprons are so common in this area, a lot of masons are asked to build them, and often they're treated like a cast-paver installation. I've seen many that have gone bad. If Belgian blocks are laid on a base of gravel and sand—common practice for some segmental pavements—they'll rut and shift. Belgian blocks don't interlock like concrete or clay pavers, so they need a solid base and hard joints to handle vehicle traffic. Get those details right and Belgian-block aprons

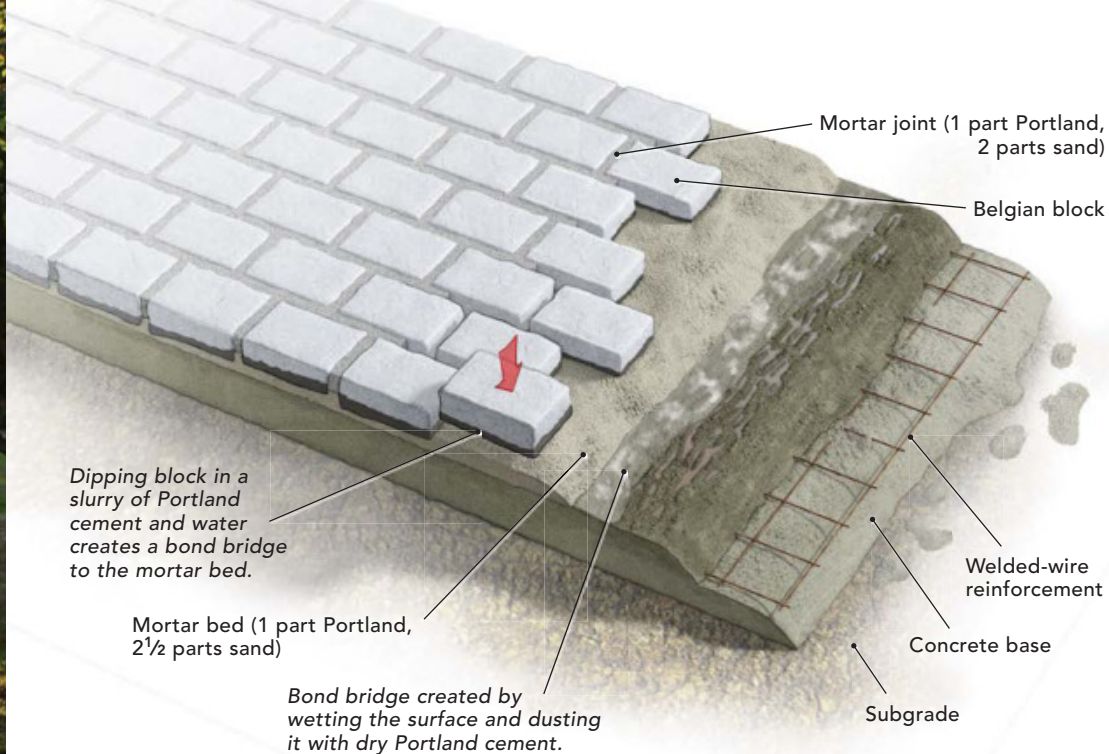
(or entire driveways, for that matter) will stay where you put them and last a lifetime.

Build the base

To stand up to heavy loads, these aprons should be constructed in three layers: a reinforced concrete base, a mortar bed, and the mortar-jointed Belgian blocks on top. The whole assembly is about 1 ft. thick and should be built on undisturbed soil.

The concrete base is 6 in. thick, but it doesn't require the precision of a normal slab. Here we set a stringline on one edge and measure down to check our concrete depth along that side, and use a 2x8 form board as reference on the other (photos facing page).

We place half the concrete, lay-in welded-wire reinforcement, place the rest of the con-



THREE-LAYERED APRON

Unlike in a common paver patio, Belgian blocks for a driveway apron are set in a mortar bed laid atop a 6-in.-thick reinforced concrete base. Because the blocks aren't uniform in any dimension, the thickness of the mortar underneath each block varies, but averages about 2 in. A bond bridge of Portland cement and water binds the layers together.

SET THE BASE

Reinforce the slab. The edges of the excavation typically make sufficient forms for the concrete. Place and rake flat half of the concrete, then lay the welded-wire fabric followed by the rest of the concrete.



Bond bridge. After the slab has set, wet it thoroughly and dust with cement to create a bond bridge for the mortar bed.



Place the bed. Mix and place enough bedding mortar to keep pace with block laying so the mortar doesn't dry out or set prematurely.



Compact and tooth. Compact the concrete with the faces of the rakes, and leave the impressions to key into the bed mortar for a stronger bond.



CUTTING BLOCK

Blocks will have to be cut to fit at the ends of the apron, often at angles. A hand tracer (a type of chisel) and hammer can do the job, but a gas-powered masonry saw can do it quicker.



Mark the cut. For angled cuts, measure the distance from the corner of the block to the edge of the curb, then transfer that measurement to the other edge of the block, and trace a line from that point back to the corner you measured from.



Cut partway. When cutting blocks with a powered masonry saw, cut about one-half to three-quarters of the way through.



Break it off. Use a rock hammer or engineer's hammer to break the block on the cutline.



Rough it up. Use light to medium hammer blows to roughen the clean-cut edge for a more natural or tumbled look.



Place and pound. Set the cut block, leaving joint space for mortar along curbs. Hammer down until the top edge is aligned with the stringline, keeping one hand on the block to keep it from shifting.

crete, rake it roughly flat, and compact it with the faces of the rakes. We leave the toothed rake impressions on the surface to give the mortar bed a better surface for bonding. In 24 hours, it's ready for the next layers.

Make the bed

Taking any slope into account, we mark the final elevation of the Belgian block onto curbing, if it's included, or use a stringline if there are no curbs. Another stringline establishes the front edge and elevation of the first course (photos p. 63).

I like to use Type II Portland cement in all the mixes for the aprons. The mortar used for the bed is one part Portland to two-and-a-half parts sand, with just enough water to activate the Portland. It looks and feels almost like plain sand, but will be as tough as concrete once the blocks are hammered down into it and it sets. Before laying down the mortar, thoroughly wet the concrete base and dust it with cement to create a bond bridge between the slab and the mortar bed.

Helpers mix enough bedding mortar to stay ahead of the block layers. Because the blocks vary, the actual thickness of the bedding layer varies, but it averages roughly 2 in. We put down mortar only in the areas we're laying at the time.

Lay the block

Belgian blocks aren't uniform like bricks, so it takes more work to make everything look tidy. Lay each block with the flattest face up and keep the widths of individual courses consistent to maintain straight lines. Sorting the blocks into piles or rows of similar widths makes them easier to pick through.

How and where to start laying depends on the situation. On narrower aprons, we typically lay full blocks for each course at both ends to start, use stringlines along the width to set the courses straight and level, and use levels to check that the blocks are in plane across the depth. This apron was wide—more than 30 ft.—so we laid the full first course and the first few blocks for the rest of the courses at one end at the same time. We add and subtract mortar below each block as necessary to get them to the right elevation and then drive them into the mortar with rock hammers (photos facing page).

The blocks aren't set at this point; this part of the process is about establishing the slope and elevation, and making sure the courses start parallel to one another.

Once that work is done, setting begins. We remove the blocks one by one, coat them in a slurry of Portland cement and water—mixed to the consistency of thin pancake batter—place

LAYING BLOCK

Working with Belgian blocks is more art than science, but levels and stringlines are crucial to keep everything straight and in plane.



Follow the line. Only one edge of the blocks will follow a line while the other runs ragged. Using blocks of similar widths in individual courses helps keep the joints consistent.



It ain't brick. Expect huge variation in every dimension when picking through a pallet of Belgian blocks.



Adjust the bed. Add or subtract bedding mortar as necessary so each block can be firmly hammered into the bed to the proper elevation.



Check the plane. Use a level to check that the blocks are in plane front to back. The level should touch the face of each block in any direction.

SETTING BLOCK

Belgian blocks won't stick to the mortar bed without help. A slurry of Portland cement and water mixed to the consistency of thin pancake batter provides a bond bridge between layers.

Dip it. After a block is hammered to the right position, remove it and dip it in a slurry of Portland cement and water, which creates a bond bridge between the granite and the bedding mortar.



Replace and hammer. Replace slurry-dipped blocks in the same orientation as you picked them up, and then hammer them home for a secure bond.



Check your work. When setting a stringline for a new course, set a level across existing courses and the stringline to check for plane.



Smooth it out. Dampen the edges of the mortar bed and trowel them flat to finish them off. The edge along the first course should be troweled flat after that course is set.

them back, and hammer them to the line. Once these initial blocks are set, the rest go relatively quickly. Working from one end to the other, one or two courses at a time, each block is positioned, hammered to or near its final depth, removed, dipped in the Portland cement slurry, replaced in the same orientation, and hammered home.

Since the blocks' surfaces aren't flat, you have to split the difference when driving them down to the stringlines. The edges usually aren't parallel either, so the joints between blocks inevitably vary. I try to keep all the joints between $\frac{3}{4}$ in. and 1 in. wide. While the stringline is placed on the front edge for the first course, it's aligned with the back edge of subsequent courses.

Some blocks have to be cut to fit at the ends. This can be done with a hammer and chisel, but we usually use a masonry saw to cut one-half to three-quarters of the way through the block, then use a hammer to break it on the cutline and roughen the cut edge for a more natural look (photos p. 64).

Once all the blocks are set, we dampen the edges of the mortar bed with sprinkles of water and trowel it flat (photo above).

Fill the joints

The mix for the joints is one part Portland cement to two parts sand; the richer mix helps it flow out of the grout bag. It should be thick enough that it won't run out of the joints, but thin enough to easily squeeze out of the bag.

Slightly overfill the joints from the bottom up. When the mortar has set up a little, strike the joints with a flat slicker (a type of brick jointer) to squeeze out the excess, but don't remove it. Let it set up a bit more (to the consistency of cookie dough) so the waste doesn't stick to and stain the faces of the blocks.

After flicking off the excess, I like to tool the joints so they're slightly convex, then hit them with a single sweep of a masonry brush to give them some texture. After three days of curing, it's safe to drive on the apron and finish off the rest of the driveway. □

Fabiano Cruz is the owner of Keystone Masonry in Bridgeport, Conn. Photos by Matthew Millham.

JOINTING BLOCK

The jointing mix is one part Portland cement to two parts sand, with enough water to achieve the consistency of a thick milkshake. The mortar should easily squeeze out of the grout bag, but not run out of the joints.



Mix and remix. Start the mortar in a mixer, then transfer to a wheelbarrow and add water slowly to creep up on the right consistency.



Fill 'er up. Slightly overfill the joints from the bottom up.



Joint and flick. Let the joint mortar firm up a bit before tooling or removing excess mortar, then use a flat slicker to flatten the joints and squeeze out the excess. Let it firm up some more, then flick off the excess and finish tooling the joint so the mortar is slightly below the block face.



Blow it away. Use a leaf blower, not a broom, to remove the flicked-off mortar so it doesn't smear and stain the block.



Brush it out. Hit each joint once with a masonry brush for a clean finish.



Long-Lasting Gravel Driveways

Get the drainage and base right, and gravel can be an economical alternative to asphalt

BY DAVID CROSBY

When John Denver sang, “Country roads, take me home,” he probably wasn’t singing about paved roads. There’s a certain charm to an unpaved road or driveway that you just can’t get with asphalt. Of course, it doesn’t hurt that gravel is also far less expensive up front and over time, and that if you ever have to remove or realign a gravel driveway, you can just rip it up, rake it out, and re-vegetate.

Because many people opt for a gravel driveway as a cost-saving measure, it tends to be used as an excuse for poor site prep and installation. But that’s a missed opportunity, because site prep and installation mean the difference between a job so good you never notice it and a hassle that you live with because you can’t afford to fix it.

Like any unpaved road, a properly built gravel driveway is as much art as science. It’s not just dirt and rocks; it’s a built structure. The right approach may vary not only from state to state



Top layer
¾-in. crushed aggregate spread to a thin layer (about 1 or 2 stones thick)

Subgrade
Minimum of 4 in. to 6 in. of tightly compacted aggregate base course (ABC)

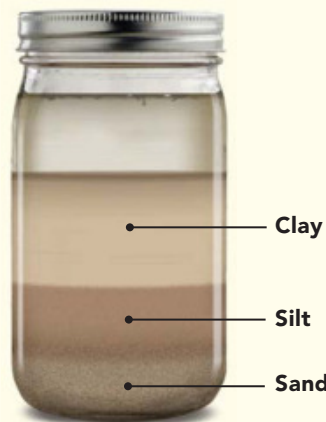
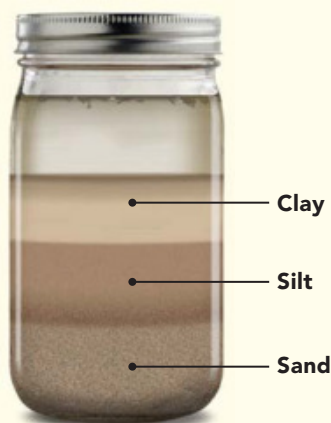
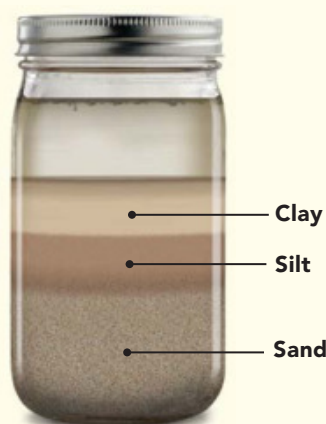
Base layer
At least 6 in. of soil—existing, supplemented, or brought to the site—blended to optimal moisture content and compacted

Undisturbed native soil

GET TO KNOW YOUR SOIL

The first step is to assess your existing subgrade. The ideal soil is a balanced mix of gravel, coarse sand, fine sand, silt, and clay. The acceptable range of mixtures is wide, but you might need to add material to get the desired results.

After digging past the topsoil, fill part of a jar with soil from which you've removed all of the rocks. Fill the jar with clean water, leaving a little room at the top, then close it and shake the contents. When you stop, the soil will begin to settle into layers. What settles immediately is sand. What settles in a few minutes is silt. What settles in a few hours is clay. What floats is organic.



Take the glass-jar test

Test results: If your soil is about two-thirds sand and one-third silt and clay, it will work well as a subgrade. Sand and gravel of various sizes is ideal. If you don't have enough fines to hold the soil together under load, it will still work as a subgrade, but plan on importing material for the last couple of lifts.

Next steps: Get the grade you want; compact it as you go; establish your ditches, turnouts, and water bars; and top it with the best material that is available locally.

Test results: If your soil is between one-quarter and one-half sand, with the rest silt or clay, then it is going to be prone to heaving, mushing out from under the load that is applied (so-called displacement failures), and settling. It generally will be a muddy mess.

Next steps: This is the soil you need to compact tightly to increase the bearing strength and to reduce the chances of water saturating the subgrade. Consider bringing in gravel and blending it with the existing soil as you work it.

Test results: If you have mostly clay and silt, including fine sand but very little coarse sand, you're at risk of the driveway behaving in a plastic manner when it gets wet. To determine the risk here, do a follow-up test: Take a small clump of the soil, wet it slightly so it is moldable, and roll it between your palms or fingers. If it rolls out into a long thin shape like a worm without breaking, you have problem soil.

Next steps: The smartest thing you can do is hire a good equipment operator. If that isn't an option, consider bringing in some pit-run gravel, which will reduce the chances of heaving and settling.

or climate to climate, but possibly from one end of your property to the other. Depending on where you are, the available materials will differ, as will the site conditions, drainage, and existing soil types.

I've built unpaved roads in mountains, deserts, forests, coastal regions, and swamps, and they all have held up well. Every job was unique, but there were always basic principles to apply and common mistakes to

avoid. In my experience, most problems with unpaved driveways can be traced back to one or more of these three things: bad design, moisture, or unsuitable soils.

Well-graded works best

Compared to the scholarly works that have been published on the subject of structural fill and road base, what is offered here is a gross oversimplification. Still, the principle

remains: A good subgrade for an unpaved road is analogous to the foundation of any other structure. To achieve the desired strength and stability, the subgrade should be well graded, meaning that a mixture of stone, gravel, coarse and fine sands, silt, and clay exists in the right proportions (see "Get to know your soil," above).

The idea is that the stone and coarse gravel provide a lot of the bearing capacity, the sand

Moisture and compaction

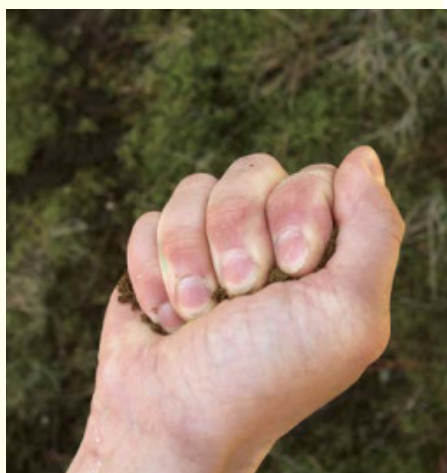
Soil reaches its maximum density for any given compaction effort at what's called optimum moisture content. In some parts of the country, the existing moisture content of the soil already will be optimal; in other regions, however, you will need to haul in water or get rid of it.

You can hire a geotechnical engineer to determine optimum moisture content, but a simple test will give an idea of where you stand: Compress a handful of dirt into a baseball-size clump, squeezing it as hard as you can. If you have liquid on your hands, the soil is too wet. You need to rip (scarify) the subgrade of the proposed driveway to let the soil dry, and possibly even flip it a few times.

If there is no liquid on your hands and the clump stays together, then the next test is to drop it from shoulder height. If you drop the clump and it splats, it is too wet, and you may have high-plasticity soil, which requires further investigation. If it crumbles or shatters, the dirt is too dry and must be scarified, wet down, allowed to sit, and possibly turned over a few times before compacting. If it cracks into several pieces but more or less stays together rather than splats, the moisture content is acceptable. That amount of water in the soil will help the particles slide past each other without turning to mud and will enable you to work the voids out of the soil efficiently.

fills in the different-size spaces between the stone and gravel and helps with drainage, and the fines (silt and clay) bind everything together. That's in a perfect world. In the real world, where money matters and sometimes we have to use whatever is available, it's still possible to build a good driveway.

If after you remove the layer of organic soil the native soil seems dense and well graded, you might not have to do anything



more to this layer of the driveway. Often, though, it needs some attention. Be on the lookout for poorly graded, loose, highly plastic soil. If the soil has too high a moisture content to properly compact, it will need to be flipped and possibly augmented before smoothing it out and recompacting (see "Moisture and compaction," above). You also might need to bring in granular material to help with drainage, such as

How hard is it to do a gravel driveway?

People often ask me if the installation and maintenance of a gravel driveway are within reach of a nonprofessional. I encourage anyone who is so inclined to do this work themselves. Machinery can be rented, local quarries are a wealth of knowledge when it comes to working with local soils, and lots of high-quality information is available in print and online. One of my favorite resources is *The Massachusetts Unpaved Roads BMP Manual*, a free PDF available at berkshireplanning.org. It's packed with information, and although it was written with a New England bent, it has been the gold standard nationwide for many years.

A skid-steer loader and a mini-excavator or a small backhoe are all the rental equipment needed for most residential work. On driveways that are longer than about 50 yards, a small motor grader is handy but not essential.

A plate compactor or static roller are the two common options for compacting, but be mindful of the damage you can cause to nearby structures with vibratory compaction equipment. It's surprisingly easy to crack plaster or drywall. If there's any doubt at all, you're better off static rolling or wheel rolling in thin lifts.

As the machine operator, it's your responsibility to locate utilities before you dig, to learn basic operations of the machine, and to know typical safety guidelines. Understand where your blind spots are, don't let children or pets anywhere near the work area, and instruct anyone helping you not to walk behind the machine or approach until they have made eye contact and received positive acknowledgment from you.

Finally, don't force the machine out of its operating capacity. You can make a much bigger mess in a few minutes with one of these machines than you can clean up by hand in a weekend, so go easy, and take your time.

DURABILITY DEPENDS

Bad drainage is the main ingredient in just about every recipe for driveway failure. Ideally, the drainage issue is addressed by laying out the driveway to follow the natural terrain. But that's often not possible, so you must also incorporate drainage strategies.

Build ditches. If the native soil isn't too rocky or gooey, building ditches along one or both sides of the driveway gives you material to work with when crowning the driving surface. The ditches also provide a way to drain runoff from the driveway, and they offer another means for diverting the path of overland flow. You often can cut earth away on the high side to create the ditch, and then use it as fill on the low side. On relatively flat sites, or where you are forced to cross contour lines, you may need ditches on both sides.



CUT

ON DRAINAGE



Take advantage of the existing terrain. When possible, avoid steep areas, as these contribute to erosion, accelerated wear, and spinning tires. They also are safety hazards when accelerating or braking. Avoid areas that are below the elevation of the surrounding terrain, as they will be difficult to drain, resulting in mud and frost heaves. For driveway width, 10 ft. is very tight, 12 ft. to 14 ft. is comfortable, and 16 ft. allows cars to pass each other.

Use water bars to divert flow. Sometimes no matter what you do, water still wants to run across the driveway, which leads to erosion and a constant maintenance headache. A solution is one or more water bars—pairs of shallow ditches and berms that run 30° to the direction of travel. The angle ensures that you won't have two wheels in the low spot or on the high spot at any time, making for a more comfortable ride and minimizing driveway damage.

Raise and crown the road. How far to elevate the roadbed above the ditches or the surrounding terrain is a judgment call. There's only one rule: Make it high enough so that it doesn't get wet and turn to mud or heave. In general, well-graded granular soils on a firm, well-drained subgrade require less elevation than soils that are more clay or silt, and a slope of between ½ in. and ¾ in. per ft. of road width is a good balance of driving comfort and drainage.

FILL

3-in.-minus gravel, which is a mixture of rocks sized from a maximum of 3 in. down to dust. In some cases, you might need to import all of the material for this layer.

On top of this subgrade layer, my favorite options are a state-spec aggregate base course (usually called ABC) or a screened and blended product. Unprocessed gravel—usually sold as pit-run or bank-run gravel—can be an excellent and inexpensive amendment to soils that would otherwise be unsuitable in wet weather. It's important not to use too much, though, because without enough fines to hold it together, it will be unstable.

Finishing up and maintaining

You may or may not want a topping, and it often comes down to budget. A top layer of clean stone gives a finished appearance, wears better, is a little stronger, and mostly eliminates mud in wet weather. It's a nice touch if you can afford it.

On my company's premium work, we topped the last 8-in. lift of aggregate base course with no more than an inch of ¾-in. crushed aggregate. That stone topping should be just one or two rocks thick; otherwise, you start sliding around in it as you drive. The crushed part is important, too. People seem to like the way round rock looks, but it is slippery to drive on and rarely wears well or stays in place.

Anybody with a gravel driveway will tell you that maintenance is essential. Normal driving wears the particles on the surface smaller and smaller until wind and water carry them away; ruts can appear with rainstorms; a "washboard" surface appears wherever speed, acceleration, or braking is excessive; surface material gets shoved to the outside of curves; and as the original profile changes, the driveway gets muddy.

Once the driveway starts becoming unpleasant to travel on, running a grader over it and re-establishing the crown may be all that's required. But the worse it gets, the faster it gets worse, so timely maintenance pays. If the soils in your area have high plasticity—that is, they get muddy and slippery when wet, you might need to import sand, gravel, or ABC from time to time. □

David Crosby has worked in various aspects of construction for almost four decades. Most recently, he ran an excavation business in Santa Fe, N.M.

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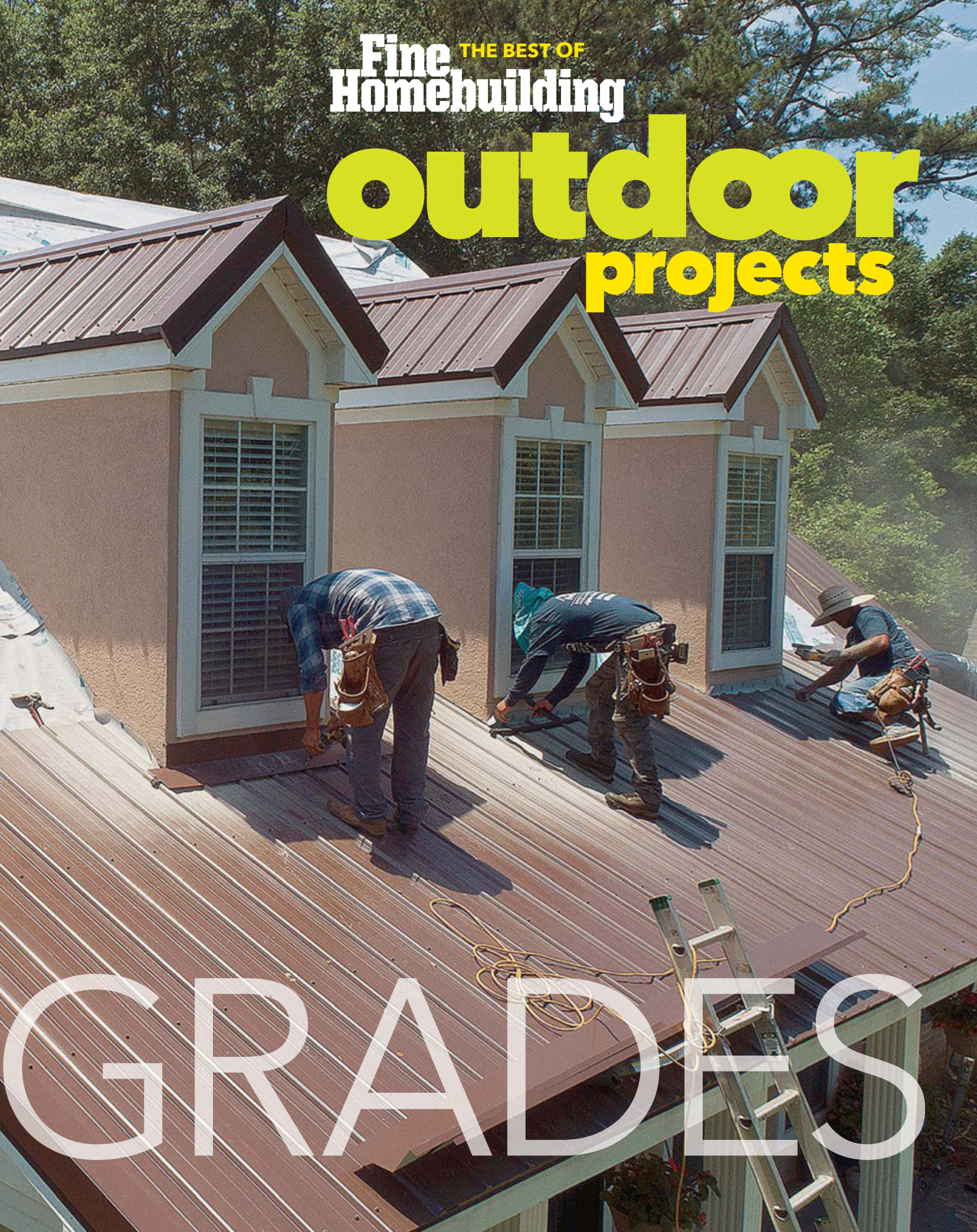


UP

Fine THE BEST OF
Homebuilding

outdoor projects

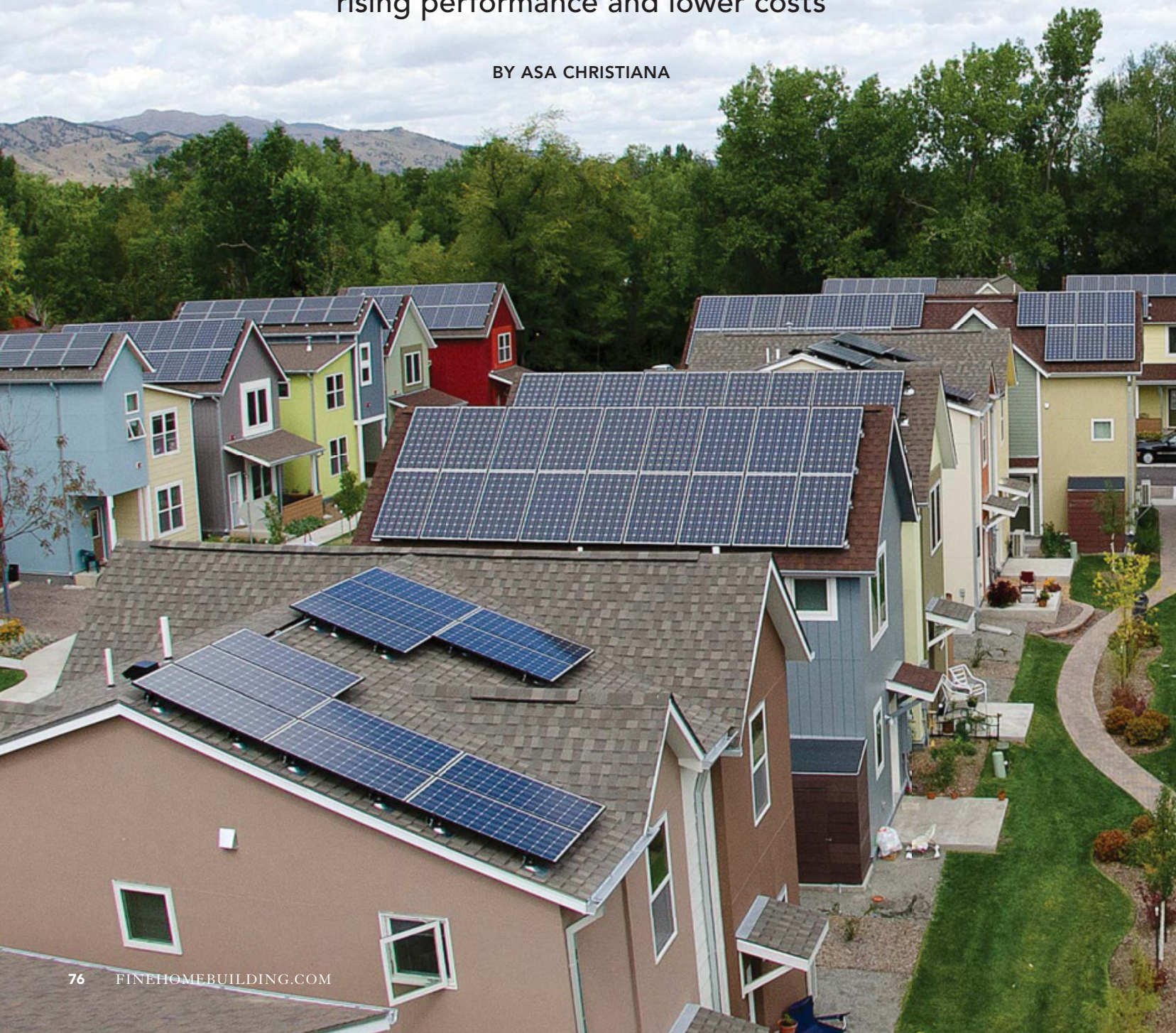
GRADES

A photograph of three construction workers installing a brown metal roof on a house. The house has three gabled dormers with white trim and multi-paned windows. The workers are wearing hard hats, tool belts, and work clothes. One worker is in the foreground, another in the middle, and a third further back. A ladder is leaning against the side of the house. The background shows green trees and a clear sky.

The Steady Surge in Solar Power

Improving technology delivers
rising performance and lower costs

BY ASA CHRISTIANA



Solar accounted for 43% of all new electricity-generating capacity added in the United States in 2020, topping all other technologies for the second year running. The curve promises to continue upward. According to the Solar Energy Industries Association (SEIA), solar capacity will quadruple over the next 10 years.

In response, the U.S. Congress has once again extended the solar investment tax credit (ITC)—through 2022 this time, with a reduction in 2023 unless extended again. The credit allows residential solar customers to deduct 26% of the cost of their system from their taxes owed to the IRS. For the average \$27,000 solar installation, for example, the credit takes \$7000 off the bill. And it has no limit, so the rebate can be two or three times more for more expensive systems with battery backup. State incentives, where available, can subtract thousands more. Overall, payoff periods are averaging eight to

12 years—depending mostly on local electricity rates—for an energy-producing system that will deliver clean power for 30 to 50 years.

By all estimates, the big tax incentives won't last forever. State programs have dwindled somewhat, and the federal credit is down a bit from the 30% of a few years ago. However, despite the drop-off in credits and incentives and the increasing cost of skilled labor, prices per watt delivered have dropped steadily. At the same time, looks and reliability have improved, making photovoltaic (PV) power more attractive than ever.

"We've learned so much since incentives came in 15 years ago," says Sara Peavey, a PV designer for Mayfield Renewables in Corvallis, Ore. "We have tons of data on what works well and what failed. While some incentives have gone away, they forced companies to make solar more affordable."

What's new in PV panels

Rooftop modules have steadily improved in every way— aesthetics, performance, and cost—and the trend is expected to continue until



the limits of physics are reached. But the changes at this point will be incremental and not worth waiting for.

Whenever you decide to say yes to solar panels, you'll be getting a better deal than ever. Instead of the old polycrystalline panels with silver stripes running through them and silver frames on the outside, you'll likely get a set of monocrystalline modules that are uniformly dark, with black frames and dark-blue cells, giving the panels a sleek, seamless look. A white background is also available for those who prefer that aesthetic. With each module operating independently, regardless of shade sources, panel arrays tend to be large, uniform rectangles, adding to the elegant look.

John Grieser is co-owner of Elemental Energy, a solar-energy company that installs five to eight residential systems a week in Oregon and Washington. Like many in the industry, Grieser counsels against delay, explaining that the sooner you start paying off a system, the closer you'll be to free energy. "In rainy Portland, half of our clients—with an average house and average electric bill—can get to net-zero. So incremental improvements in PV technology don't really matter at this point."

To further reduce costs per watt, manufacturers are also increasing panel size, packing in more cells and effectively reducing the amount of frames and electronics—the priciest parts of a panel. However, for historical homes with more complex roofs, smaller panels might make more sense.

While SunPower is still considered the leading innovator in PV panels, many of its patents have expired, inviting manufacturers from around the world to take advantage of the latest technology. SunPower, LG, REC, and Panasonic tend to offer the best combination of performance, price, and warranty, according to installers I spoke with as well as reviews by EnergySage.com, a resource for unbiased information and competitive quotes.

While experts generally agree that it's hard to make a bad equipment choice these days, they caution against products with anything less than a 25-year warranty on parts, the labor required to replace them, and energy production, with the best guaranteeing a less-than-10% drop-off over the warranty period.

New technology changes the game

One big reason behind solar's exponential growth and improving prices is the panels themselves—or modules, as they are known in the trade—which have improved steadily in efficiency vs. size and

cost. Holding down the modules are mounts, rails, and clamps called "racking." Refined over a few decades now, racking systems are extremely reliable, with flashed mounts that connect to rafters, and rails and clamps engineered for local weather conditions, such as wind and snow. Available for all roofing types, these components have also become easier to install over the decades. "If the system is spec'd and installed correctly, you'll have no leaks and no problems," Grieser says.

Today's racking systems are also less obtrusive, so the newer dark, seamless panels—installed in clean, rectangular arrays—look even more sleek and elegant. Most systems offer black anodized rails to match the new aesthetics, and SunPower's InvisiMount frames hide clamps from sight completely.



RACKING IS VERY RELIABLE

"Racking" is the industry term for the mounting systems that attach solar panels to roofs. When chosen and installed correctly, these mounts, rails, and clamps are extremely reliable and will not adversely affect the performance of the roof.

Improvements to the electronics have also made panels more efficient in more locations. PV panels produce DC current, which must be converted to AC for residential use. Today, module-level power electronics (MLPEs) are innovating this process. The biggest advantage of MLPEs is optimization of the output from each module, regardless of sun and shade conditions. Contrast that with older arrays, which would shut down altogether if a single panel was shaded. MLPEs allow solar arrays to be installed in more places on a roof and on multiple planes, regardless of trees and chimneys, allowing much more output for a given location. The widespread adoption of MLPEs means a price break for consumers too.

"When I started out 10 years ago, a solar install was \$78 per watt," Peavey recalls. According to the most recent market report from EnergySage.com, state-by-state costs for solar range between \$2.30 and \$3.15 per watt before credits and incentives. "That's because we can install anywhere on the roof at any angle, all optimized, and shade doesn't matter," Peavey says.

"You get lots more flexibility, and a better-quality product as well."

MLPEs also have built-in monitoring, so you can see exactly what each panel is producing and also pinpoint any problems or equipment failures. "What other appliance gives you that level of granularity?" Grieser asks. "For HVAC or minisplits, you can't always tell if refrigerant lines were pressurized properly or filters are dirty, which can have a huge impact on performance. With solar, you know if your appliance is working at all times, and you can compare numbers with what a salesman promised, year to year, as trees grow in the way, etc."

MLPEs meet the latest National Electrical Code (NEC) requirements for module-level rapid shutdown, designed to protect fire-

MICROINVERTERS vs. DC OPTIMIZERS

Conventional solar arrays do not include module-level power electronics (MLPEs). As a result, they can't optimize panel output in shaded conditions, nor do they allow power to be shut down at the panel itself in emergencies. While these arrays are still allowed in some regions, the latest National Electrical Code requires MLPEs at each panel, and local codes will soon follow suit.

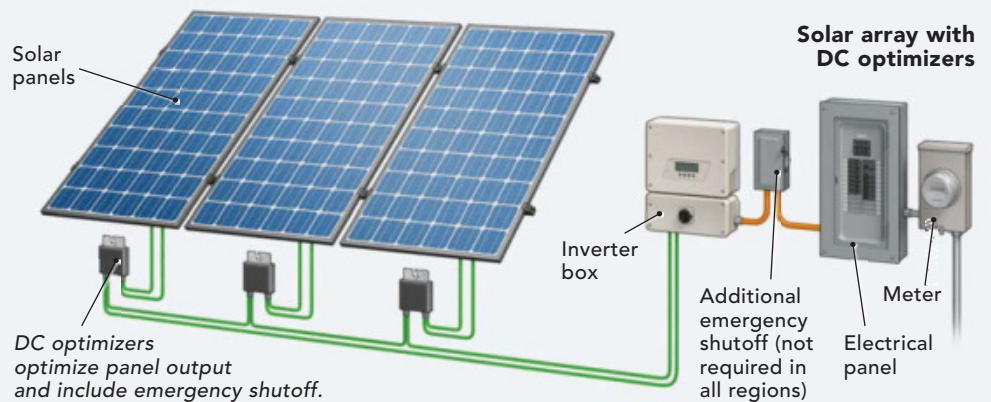
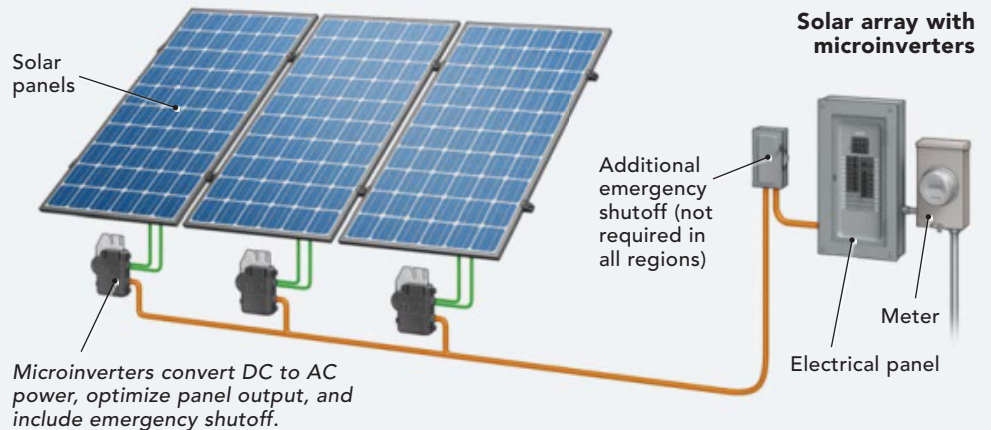
MLPEs break down into two equally popular and reliable types, creating a Coke vs. Pepsi situation with Enphase's microinverters and SolarEdge's line of power DC optimizers. (These two companies dominate the marketplace for MLPEs.) Affinity for one or the other is as likely to be attributable to regional familiarity as it is to the actual technical differences between them.

Microinverters are clean and easy

Microinverters (MEs) convert the DC current produced by PV cells into AC power right at the panel. This lets electricians run normal nonmetallic cable down to the meter, following the AC code they are most familiar with and making it easy to hide the wires inside the home. "We can cut drywall and pull cable through walls a lot easier than pulling metal-clad wiring or running metal conduit up an exterior wall," says John Grieser, co-owner of Elemental Energy, a residential system installer. MEs eliminate a bulky inverter box and are more conveniently installed near the home's main electrical panel. As an MLPE, microinverters also optimize the performance of each panel.

While early Enphase MEs were dogged by high failure rates, the engineering has been worked out, with the latest generation (the IQ series) offering the same 25-year warranty as the best PV panels. Installers across the United States have expressed very little hesitation about today's MEs, even in areas with extreme weather. "The temperature swing on a roof in New England is 20°F below to 140°F, but the equipment is engineered for it," says Brandon Bernard of ReVision Energy.

In general, MEs are more expensive than DC optimizers, but the difference is somewhat offset by faster, more straightforward installation.



DC optimizers are robust and less expensive

The other type of MLPE is the DC power optimizer, which includes the optimization and monitoring capabilities of any MLPE, but unlike MEs it doesn't convert DC to AC. That still requires a central inverter. While DC optimizers are simpler electronically, making them more resilient historically in the tough roof environment, they require a very high amount of DC voltage to be carried down the wall and/or through the house to a central inverter box, with code requiring shielded steel conduit that is more likely to be run down an exterior wall, a wiring method that is likely less familiar and more time-consuming. Proponents of MEs also point to a DC optimizer's central inverter box as a single point of potential failure that will disable an entire PV system until it is repaired or replaced.

In the end, the differences between MEs and DC optimizers matter less than choosing skilled, reputable installers who are very knowledgeable about the system they prefer using, if not both.

fighters, tradespeople, and others from encountering dangerous voltage levels of DC power anywhere between the modules and the meter. A 2014 NEC change required that rapid shutdown be installed somewhere in the system, and the 2017 NEC pushed that capability to the individual modules themselves. If your state hasn't yet adopted the latest NEC, it will. If your system predates the NEC changes, your state might require you to retrofit MLPEs at each module, but there are affordable products for that.

A number of manufacturers now offer AC modules, or "smart modules," with an MLPE inverter integrated into the back of the panel, offering a single plug-and-play connection on each unit, which makes installation faster and easier, with fewer wires to potentially rub on the roof or be nibbled by rodents. These panels are pricier but easy to install, so they generally save customers a bit on installation costs.

Another new module is the "bi-facial" panel, with a transparent back that allows light to reach the underside of the cells, intended to produce some energy from a reflective deck or patio, for example. The experts I interviewed, however, were unable to measure a significant increase in production from the lower side of these panels.

A system for energy storage

A "grid-tied" system trades energy back and forth with your utility company. When your modules are producing more energy than your home is consuming at any given moment, the excess is back-fed into the electric power grid. The meter keeps track, and when the sun goes down, the grid feeds your home what it needs.

At the end of the year, you pay only for the net energy used. In the design of any given solar array, the goal is to get that number as close as possible to zero without producing much of an annual surplus, which most utilities won't pay you for. Led by Tesla's popular Powerwall units, battery storage can replace the grid during power

outages, backing up your whole home or just a few essential circuits, just like a generator. In fact, generators and battery backup can be used together to handle extended outages.

Although pricey enough to double, triple, or even quadruple the installed price of a typical system, depending on storage capacity, battery backup is increasingly popular, largely due to the increase in catastrophic weather events. Today, almost every manufacturer of solar components is jumping into the game to compete with the Powerwall, with each of the major manufacturers aiming to be a one-stop shop for residential solar components.

Generac's approach, though, is unique. Known for its traditional standby generators, Generac recently launched its own components for power transfer, optimization, rapid shutdown, and battery storage. Including everything but the rooftop modules, the fully integrated system is called PWRcell and promises to emerge as a strong competitor to the stand-alone MLPEs from Enphase and SolarEdge. (For the rest of the story on Generac's new approach to solar, check the follow-up article on solar-energy storage on pp. 82-85.)

Beyond the standard roof panels

While the standard rooftop installation is still king, there are other ways to mount panels, and other places to put them. The most-hyped innovation might be Tesla's PV roof tiles, called Solar Roof, announced in 2016 to much fanfare. Although the company has been taking orders for some time, experts say that the practical reality is a long way off, and the real cost has nearly doubled from the original.

For homeowners with a big sunny field on their property, a ground-mounted array can be a fantastic option. Space is potentially unlimited, panels can be pointed and tilted for optimal production, and snow and debris can be cleared manually. Ground-mounted systems comprise 10% of residential installations for ReVision Energy, and

the New England-based company recently dedicated a crew to installing the helical piles that attach these arrays to the ground.

Compared to a roof installation, says ReVision's Brandon Bernard, the up-front costs for ground-mounted arrays are a bit higher, due to the larger racking systems and the trench that carries the power to the home. "But the overall economics are great," he adds. "The payback period is similar because you can optimize the panel angle and array."

Carports, pergolas, patio covers, and other shade structures offer additional sky-facing purchase for PV modules, but experts issue an important caveat. "These structures are often underengineered for solar," says long-time residential installer Jim Bakhaus, now project manager at Denver-based Resort Energy Ventures. "You need to see if it is engineered for the increased weight loads, wind loads, and uplift." □



A FEW OTHER BOXES

Other than the rooftop panels, all that most systems will add to your home is a small inverter box (right in photo) mounted on an exterior wall. If you've opted for a battery storage system, that larger unit can be placed inside the home or garage or even outside, as shown here.

Asa Christiana is a contributing editor to *Fine Homebuilding*. Photos by Topher Donahue, except where noted.



AN ARRAY OF OPTIONS

Solar panels can go almost anywhere. If engineered properly for the increased weight and wind loads, pergolas and carports can be great places to mount panels, and homeowners with sun-exposed fields can install large ground-mounted arrays.



Solar Energy Storage

Extreme weather and aging power grids heat up the market for battery backup

BY ASA CHRISTIANA





The combination of extreme weather events, aging power grids, and more people working from home is driving an overall trend toward energy resiliency. Collecting clean solar energy is part of the solution, but only when storage is added. “There’s a basic misunderstanding,” says Zach Snyder, program manager at Solar Oregon, a nonprofit solar advocacy group. “People think they can rely on solar when the grid goes down, but you need battery storage to keep the power on.”

As I pointed out in the previous article on pp. 76-81, which focused on the components that collect solar energy, increasing efficiency and falling prices are turning more and more homes into candidates for photovoltaic (PV) power, and a big federal incentive program has been extended to promote the PV path to clean, green energy—which is ultimately free for consumers after a relatively short payoff period, considering the 30- to 50-year working life of most solar arrays.

This article focuses on the other end of the equation, battery storage, which offers its own array of increasingly attractive benefits. Led by Tesla’s popular Powerwalls, battery storage can replace the grid during power outages, backing up your whole home or just a few essential circuits, like a generator does—but without the noise, carbon footprint, and long-term cost of fuel and maintenance.

Battery storage is trending

Battery-based backup systems are pricey enough to double, triple, or even quadruple the installed price of a typical PV power system, depending on storage capacity, how many circuits you want to back up, and the home’s overall energy demands. So while up to 50% of new solar customers inquire about batteries, the actual “attachment” rate is closer to 20% for new customers across the United States, according to EnergySage.com, a resource for up-to-date information on residential solar as well as price quotes from local installers. That rate is growing, however, and is up from just 10% a few years ago.

One hot spot for storage is California, where long outages are increasingly common. Another driver in the Golden State and other states with utilities that raise electricity rates during periods of peak use is “rate-shaving.” This is done by filling up the batteries earlier in the day when the sun is strong but rates are relatively lower, and releasing that backup power in the afternoon and evening when rates increase. All battery systems can be programmed for rate-shaving, keeping batteries topped off and healthy.

Backup systems are also popular in areas with very hot summers (to keep the AC running) and very cold winters (to keep pipes from freezing).

Another reason to consider battery backup is the federal Solar Investment Tax Credit (ITC), which

allows residential solar customers to deduct 26% of the cost of their system from their taxes owed to the IRS. For the average \$27,000 solar installation, for example, the credit takes \$7000 off the bill. And it has no limit, so the rebate can be two or three times more for systems with battery backup. State incentives, where available, can subtract thousands more.

While the U.S. Congress has extended the ITC through 2022, with a reduction planned for 2023, state programs have dwindled somewhat, so there are no future guarantees. On the other hand, more and more companies are jumping into the battery-backup game, which is likely to lower prices per watt, just as it has for the components that collect solar energy.

Tesla dominates, but competitors are charging

While battery backup systems include suitcase-size units that can keep just the fridge and/or essential life support going, the most popular choice for residential solar customers is a larger bank of batteries, often installed in the garage and able to back up critical circuits, if not the whole home, for days at a time.

While there are a number of battery systems for residential solar energy, Tesla’s modular Powerwall system, based on the same batteries that go in its cars, has grabbed a dominant position in the U.S. market with an unmatched combination of price and storage capacity. But long lead times and rising prices for Powerwall batteries have opened the door to competitors, and now almost every major solar manufacturer is offering a battery system of its own in an effort to capitalize on the increasing demand. “While the collection side is consolidating, and pretty steady-state right now, the battery side is a Wild West,” says Jim Bakhaus, a longtime residential installer and now a project manager at Denver-based Resort Energy Ventures.

Most customers choose to install a single Powerwall, which adds \$10,000 to \$15,000 to a typical solar installation. It offers 13.5 kilowatt-hours (kwh) of storage capacity on a single charge, enough to back up essential circuits for a few days or more. Each additional Powerwall adds \$10,000 or more each, with three to four needed for whole-home backup.

Powerwall models will accept either AC or DC power from the PV array, meaning they will work with either optimizers or microinverters for all new PV systems and all retrofits—and transfer power in any direction, to and from the grid, and back into the home.

The downside of the popular Powerwall is the long lead times—reported to be nine months or more in some cases. To keep them in stock and eliminate delays, larger companies like ReVision Energy can preorder and buy in bulk, but that isn’t an option for

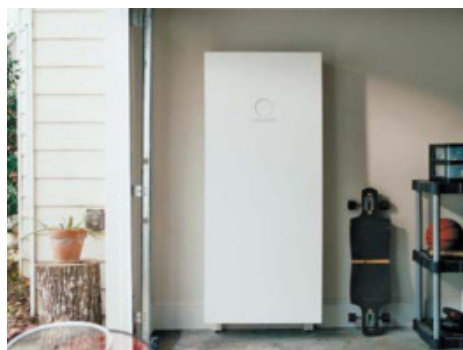
SOLAR STORAGE COMES IN MANY SIZES

Technology is constantly changing, and prices are dependent on local installation costs and tax credits, but here is a snapshot of the choices right now.



JUST THE BASICS

A small battery-based power station like Goal Zero's Yeti models will keep your energy green and maintenance-free. Output is significantly less than that from a traditional generator, though—just enough to power a life-support system or a fridge and phone charger for a few days. These systems are small enough to fit into a closet and come in sizes from 150 watt hours (0.15 kwh) up to 6 kwh, with prices ranging from \$200 to over \$5000.



A SINGLE BATTERY DOES THE TRICK

A single full-size battery packs 10 kwh to 13 kwh of energy in a single charge, enough to keep the fridge and furnace running, the lights on, and electronic devices powered for days. Generac, Enphase, and Sonnen, among others, make battery backup systems like these, designed to be paired with solar panels. A single battery will add \$12,000 to \$15,000 to a typical solar installation, with additional batteries available at \$10,000 each for full-home backup.



MULTIPLE BATTERIES POWER IT ALL

If you're looking for enough backup to power your whole house, then you want multiple big batteries from the same manufacturer. You can stack as many as you need; three to four batteries power all of the circuits in a typical home, driving prices up to \$35,000 or more. For complete energy freedom and a potentially lower price tag, consider combining a single full-size battery with a full-size generator, which can recharge the battery during extended outages.

most companies. "Powerwalls are still better in every way," says John Grieser, co-owner of Elemental Energy, "so if customers are willing to wait, they get more bang for the buck."

Other battery systems are more readily available but cost relatively more per kwh of storage capacity. They also tend to be compatible with either AC or DC power from the solar array, but not both. Enphase designed its AC-coupled Encharge storage system to work seamlessly with its microinverters, while SolarEdge's Energy Hub inverter is DC-coupled, designed to connect its optimizers efficiently to DC-coupled batteries, such as those from LG and Sonnen. (Each time DC is converted to AC, or vice-versa, the inverter takes a bite out of efficiency.)

SolarEdge is also in the process of making its Energy Hub inverter compatible with a traditional backup generator, as Generac has done recently (see more below), allowing unlimited, whole-home backup for extended outages.

The technical details can be confusing to work out, but your local installer will help you find the best storage solution for your budget and installation.

Generac jumps in with a splash

The big player in traditional standby generators recently entered the renewable-energy space with an integrated suite of solar components called PWRcell, which includes a modular, scalable battery system that can be backed up by a new, specialized generator, ushering in true energy independence for indefinite power outages.

Called PWRgenerator, the specialized backup generator can be powered by propane or natural gas, and it feeds DC power into the PWRcell batteries, making the entire Generac system DC-coupled for maximum efficiency. PWRgenerator means that customers won't need as big a PWRcell battery array to create true whole-home backup, with the gas-powered generator kicking in only when needed. Generac also claims that its unique, fuel-injected DC generator is more efficient and (at 60 db.) quieter than others, and that it runs at slower rpms, doubling the interval between required service.

Whether you buy PWRcell batteries only or the integrated suite that includes PWRgenerator, the system is controlled by Generac's new user-friendly load-management device, PWRmanager, which budgets backup power according to user-defined parameters, controlled by an intuitive smartphone app. Unlike third-party load-management devices, PWRmanager is designed specifically for the DC-coupled PWRcell system, with plug-and-play connections that make installation quick and easy.

Manufacturing everything but the solar panels themselves, Generac is aiming to be a one-stop shop for solar customers and installers. Rounding out the company's integrated suite of products and components is a new family of microinverters, called PWRmicros, designed to work seamlessly with the rest of the system.

Generac is confident that its big bet on renewable energy will pay off. "Everything is heading toward energy independence," says Generac's marketing manager for clean energy, Jeremy Niles.

Small solutions have their place

At the other end of the cost spectrum is a range of smaller backup solutions, starting with a traditional generator. “For less than \$5000, you can buy a small generator for critical loads,” Bakhaus says, acknowledging that it can be noisy and require more maintenance.

For a moderate amount of clean, quiet energy—more than enough to keep phones and laptops charged and life support or a fridge running for a few days—there is a range of portable power stations. Falling somewhere between a phone charger and a Powerwall, they range in price from a few hundred bucks to \$5000.

Goal Zero offers a great line of lithium-ion power stations, with its top-end Yeti 6000X model (\$5400) packing 6 kwh of juice into a rolling unit that can hide in the bottom of a closet, and its best-selling Yeti 1500X offering 1.5 kwh of capacity (and a \$2000 price tag). Compare that to the Powerwall’s 13.5 kwh and you’ll see how these portable home batteries offer a relatively affordable solution for short outages. You’ll find a longer list and wider range at greenchange.net/actions/batteries.

Bidirectional chargers are the new frontier

Sitting under the hoods of electric vehicles (EVs) and hybrids is a bank of batteries equivalent to a whole row of Powerwalls. These powerful battery arrays are an untapped resource for home-backup power. Moving electricity in and out of those batteries requires a bidirectional charger, which allows you to both charge your car at home and discharge it to power your home. Already established in Asia, the technology is emerging rapidly in the United States, promising to usher in a new reality for renewable energy.

In addition to a bidirectional charger, you need a car that is compatible with it. At the time of writing, there were only a few vehicles capable of acting as a storage system for home backup. The latest and greatest is the 2022 Ford F-150 Lightning pickup truck, which packs up to 155 kwh of stored power into its “extended range” batteries, according to most estimates, or 115 kwh in its “standard range” batteries. The truck offers up to 11 AC outlets onboard, including one 240A outlet. Home backup requires Ford’s 80-amp Charge Station Pro bidirectional car charger—which can pump 9.6 kwh at a time back into the home and works only with this Ford battery.

A few other electric vehicles and hybrids are bidirectionally enabled (although they don’t yet have bidirectional car chargers yet), but many others are as little as months away, including vehicles from Audi, Hyundai, Tesla, and Volkswagen.

The first residential bidirectional chargers that will work with any enabled EV on the horizon is Wallbox’s Quasar 2, which debuted in the U.K. in 2020 and is expected in North America in late 2022. Others are on the way, promising to usher in the full potential of vehicle-to-grid charging.

Companies such as Virginia-based Fermata Energy are already preparing to create cooperative associations of EV owners that will sell their storage capacity to utility companies, who will use it to back up the entire grid during peak periods. Fermata CEO David Slutzky predicts that bidirectional chargers will allow EV and hybrid vehicle owners to earn thousands of dollars per year from utility companies, ultimately making these vehicles much more affordable and attractive. “At minimum, you’ll get a free car charger and start paying off your car,” he says.

While it may seem counterintuitive, Slutzky suggests that a bidirectional charger will not shorten battery life. “An EV needs to be driven,” he explains. “With a properly managed charger keeping the batteries at a healthy level, you will extend the life of the car, not degrade it.”

Fermata’s bet on vehicle-to-grid charging is backed up by existing programs that pay battery owners for access. For example, Vermont’s Green Mountain Power offers two programs. One is a lease program that makes Powerwall batteries more affordable. The other is a “bring your own device” program that works with any battery system and pays customers cash dividends based on how much power they share with the grid. In exchange for the benefits of these programs, customers give Green Mountain Power access to their batteries during peak-use periods, which lowers costs for all customers.

These promising new programs are just the beginning. As solar capacity and storage continue to grow, so do the implications for clean energy and a brighter future. □

Asa Christiana is a contributing editor at *Fine Homebuilding*.



A DIFFERENT STYLE OF STORAGE

A bidirectional charger allows you not only to charge your car’s battery but also to discharge the battery to power your house. The Ford F-150 (left) provides home backup with the company’s charger; bidirectional chargers that work with any electric car, such as the Quasar 2 by Wallbox (above), are expected to reach the market soon.

Get the Right **GENERATOR**

Standby generators are quieter than portable options and start up automatically when the power goes out

BY PATRICK McCOMBE



My family and I moved into our southwestern Connecticut home in 2010. It's a cute little place, but it's thirsty for electricity. Its drilled well has a 1-hp pump for domestic water. There's an electric water heater and an electric range, and our furnace needs electricity for its blower and burner. When our power goes out, life gets difficult. Not only are we without heat and lights, but there is no water—hot or cold. Since moving here, we've had five prolonged outages ranging from four to 11 days. Fortunately, we only lost power once during the winter. That eight-day episode forced us to use a propane space heater to keep the pipes from freezing.

During the most recent outage, my wife, Carol, asked, "Can we please get a generator?" We'd had this discussion in past outages, but I resisted because of the noise, the expense, and the firm belief that if we ever bought a generator, we would never have a power outage again. Carol is a kind, patient woman not known for extravagances of any kind. Her pained look from days of flushing the toilet with a bucket of stream water, taking lukewarm sponge baths, and rummaging for soggy food in an ice chest showed there was only one answer to her question if I wanted to stay married.

There are two choices when it comes to generators: portables and standbys. Portable generators can be easier to set up; installing a standby generator is not something you can do quickly, even when a marriage is at risk. There are a bunch of steps and the process can take weeks or months, especially after widespread outages when the misery of being without power has people flooding dealers for installations. But portable generators have significant drawbacks as well.

Standby vs. portable generators

Portable generators are like those you see on construction sites. You put gas in them, start them up, and plug tools or appliances directly into their on-board outlets. Bigger models have wheels and handles so you can move them around; small ones you can carry like a suitcase. Instead of plugging directly into the generator, you can also connect a portable generator safely to your home's electrical system with a transfer switch that prevents back-feeding power into the electrical grid, an electrocution hazard for line workers.

The downside to a portable generator is that you have to drag it out of the garage, connect it to the transfer switch, and get its small engine going before it can be of any help. That's a big problem if the power goes out while you're on vacation. You could come home to burst pipes or a freezer full of spoiled food. And because portable generators can go for long periods unused, another big problem is old gasoline. According to Jake Thomas of Generac, "People don't

use gas stabilizer. Gas goes bad after sitting for a month or two and when they need the generator, it won't start."

The alternative to a portable generator is a standby generator with an automatic transfer switch. A setup like this monitors utility power and when there's an interruption, the generator starts and transfers selected circuits to generator power automatically. There's a slight delay, usually 10 to 30 seconds, before the generator takes over—to get the engine running and to allow for very brief outages. When utility power is restored, the transfer switch goes back to utility power and the generator's engine shuts off after a cooldown period. Another benefit of a standby generator is that they are quieter than large portables.

I debated for a few weeks about which type of generator to get, and then the pandemic hit. I suddenly felt like I couldn't wait any longer. The prospect of being without power and having no place else to go to shower or wash clothes made me pull the trigger on a portable generator from an equipment dealer on Amazon. I bought a Yamaha EF7200 for just under \$2000 and it was delivered a few days later.

Although large standby generators can be fueled by diesel, most residential units are powered by natural gas or liquid propane (LP). If you have natural gas service, connecting a standby generator to your home's gas service seems like a no-brainer, but recent winter storms in Texas and other places unaccustomed to freezing conditions show that utility gas service can be interrupted by unusual conditions. You should also keep in mind that the most-visible specs on generator output found on product literature are based on using propane, which is more energy dense than gas. It's common that models designed to be field-switchable from gas to propane will have less output when powered by natural gas.

If you don't have gas, you'll be running your generator on propane. Manufacturers have fuel requirements spelled out on their website, but commonly sized units from 10kw to 24kw use about 2 gal. of propane per hour at half-load. Thomas told me that most installers and propane dealers recommend at least a 250-gal. propane tank, which holds 200 gal. of propane, so you don't run out during a days-long outage. If you use propane for your home's heating system or other appli-

ances, you'll want to make sure your supplier fills the tanks before expected storms or you risk running out when the power is off.

My portable generator runs on gasoline. One of our past outages was a localized windstorm that knocked out the power for days. At the time, none of the gas stations around my house had power and therefore no gas. By the time I found an open station 15 miles from home, there was a line of cars filling gas cans. Though I didn't have a

THE PROBLEM WITH PORTABLES



SOME ASSEMBLY REQUIRED

Portable generators have on-board outlets for plugging in extension cords and devices. Portables set up for connection to a transfer switch have an outlet on the house that connects to the generator's 30-amp "shore-power" outlet with a heavy-duty cord. The problem is that to use it, you have to be at home, have fuel, and know how to get it going.



A transfer switch allows the generator to power selected household circuits when utility power is interrupted. It also prevents back-feeding to the grid, which is an electrocution risk for utility workers. Transfer switches can be manual, where you physically change the switch positions, or automatic. Automatic transfer switches automatically switch to generator power when there's a utility interruption.



GENERATOR-READY

Some electrical panels have generator capability built in. This 200-amp whole-house transfer switch from Kohler can also be a home's main electrical panel. A generator-ready panel can save money in new builds when a generator is planned.

Kohler RDT-CFNC-200ASE
RDT Series 200-amp ATS

STRATEGIC LOAD MANAGEMENT

Load-management modules like this one from Champion allow the generator to switch what it's powering based on available output, like shutting off the air conditioning temporarily when a water heater calls for power. Low-tech versions use a timer to turn the air conditioning back on. Others monitor available power and switch as electrical demands change. Some allow you to change power priorities from a smartphone.



Champion 100868
50-amp LMM

generator at the time, that experience showed me that when you need a generator, you also need to have fuel on hand.

Ready for all weather

A standby generator is of no value if it doesn't start when you need it. To keep things working, standby generators start themselves about once a week to exercise the engine and electrical components. You can choose how often it exercises and the day and time to minimize the disturbance from noise. Some models exercise at a slower-than-normal engine rpm to minimize noise.

Getting a generator's small engine to start in cold weather can be a challenge, but running the heating system to prevent frozen pipes is one of the most common reasons to have a standby generator, especially in rural areas with less-reliable power. To make a standby generator's engine easier to start, "Many have a block heater that sucks electricity to keep the engine warm in cold weather," says Doug Horgan, vice president of best practices for BOWA in McLean, Va. "These things use a ton of electricity. The control system uses some power in standby too."

David Duffield, director of sales for Champion's standby generators, told me that his company uses a 24v starting system. The higher voltage allows the company to eliminate engine heaters, even in cold climates. If your system does have a heater, make sure its thermostat is working, so the system shuts off when you don't need it.

This concern can be alleviated with a portable—my generator stays warm in my workshop, which is a conditioned space. I don't like storing gas engines inside, even in a garage or outbuilding, but leaving them outside is worse. Not only will it be hard to start in winter, but mice and other critters like nesting in the cozy cavities found in power equipment. Their gnawing and urine can also cause damage and keep the generator from working when you need it.

Load management prioritizes power

Although you can get a generator big enough to power everything in the house at once, it will be costly and you'll seldom, if ever, need its maximum output. A far more cost-effective strategy is to get a smaller generator and rely on some form of load management, the industry term for switching circuits on and off so the generator isn't overloaded. Load management can be manual, meaning you have to physically turn on and off circuits, like turning off your central air conditioning or water heater while you're using the oven.

More sophisticated systems manage loads automatically, turning off high-draw loads when more critical circuits call for power. Also described as load-shedding, a common example is turning off the central air conditioning when the water heater or well pump calls for power. After about 30 minutes, the transfer switch will try turning the air conditioning back on. If the water heater or other appliance is finished using electricity, the air conditioning will kick back in. If not, the switch will try again in another 30 minutes.

The most sophisticated transfer switches are current-sensing, meaning they shed and reconnect designated loads by monitoring their current draw and available power from the generator. Unlike timer-based controls, they can tell when the water heater has shut off and can turn the air conditioning back on without a wait.

The most high-tech systems allow you to change the settings in your load-management strategy from your smartphone. Becky Fellows, marketing manager for standby generators at Briggs & Stratton, said



SIZING A STANDBY

Determining which model of generator to get depends on what you're trying to power. Generator manufacturers have calculators on their websites to help size a generator and they are good for getting you in the ballpark, but a more reliable way is to have an electrician or a generator dealer figure out the exact loads with an ammeter and by checking motor and appliance rating plates.

Resistance elements for cooking, heating, and domestic hot water use a lot of power, as do electric motors for HVAC equipment and pumps. When you add up the wattage required, you may decide that not everything on your generator wish list will make it, because bigger generators cost more to buy and run than smaller ones. Even models described as "whole-house" generally can't power everything at the same time, so you need to figure out the critical circuits, add up all their wattage, and then select a generator that can deliver what's required.

Prices start at \$3000 for the smallest models (7000w) and go up \$30,000 or more for 125kw. Keep in mind that these prices are for the generator only. You'll also need a transfer switch, wiring, fuel connections, and installation, which often doubles the final cost. I have to power a large well pump, which pulls between 4000w and 5000w at startup, combined with the furnace and a few receptacles and lights. For this reason I chose 7200w, which most people would consider a large portable.

COMMON APPLIANCE WATTAGE		
Must-haves	Start-up (w)	In use (w)
Home oxygen concentrator	300-600	300-600
Central heat pump or AC	7200	5400
Well, sewage, and sump pumps	2000-4000	150-2000
Refrigerators and freezers	750-2000	500
Electric garage door openers	1400	600
General lighting	500-1000	500-1000
Kitchen and dining area receptacles	1000-3000	1000-3000

INSTALLATION CONSIDERATIONS

Fire-protection rules require standby generators be kept at least 5 ft. from any opening, including windows, doors, and exhaust and intake vents. They must also be installed on a sturdy composite or concrete pad above flood levels.



Briggs and Stratton 040590
12kw \$3300



Champion 100237
14kw \$3800



Kohler 14RESA
14kw \$4045



Winco PSS8B2W/H
8kw \$5210

Are batteries the future?

We've probably installed over fifty generators, from 5kw to 150kw. Most are 20kw to 40kw. If you want to see a client get mad, have a power outage when their generator won't start. It's often because it hasn't been maintained, but I still get the call. We've also had trouble with sensitive electronics. One house with a gigantic whole-house generator is especially memorable: Sometimes at switchover, it freaked out the security and HVAC systems. The alarm wouldn't stop sounding and all the thermostats turned themselves off. We also put in a bunch of generators with an English-made gas engine. They proved less reliable than a Jaguar.

We've also put in big battery bank systems, similar to Tesla's Powerwall. They're reliable, they're silent, and they work better with sensitive electronics. But big battery systems are expensive, and their power is limited. If you have batteries and PV panels, you may be able to ride out a prolonged outage. If you do run out of battery power, you can use a backup generator to recharge. See more on battery storage on pp. 82-85.

—Doug Horgan, VP of best practices for BOWA in McLean, Va.



that these features are appreciated by second-home owners. “They can keep the home’s critical systems energized when they’re not there, but they can change priorities when they’re using the house,” she said. Everyone I spoke with agreed that advances in load management have made standby generators more useful and affordable.

My load-management strategy is pretty simple. My transfer switch has two 240v circuits: one for the well pump and another for the water heater. I can’t run them at the same time, so when I need hot water, I turn off the pump and turn on the water heater. During this period, we have to ration water. About 45 minutes later and I can turn on the pump again. I have to go to the basement to switch circuits.

Installation considerations

Even a small standby generator weighs several hundred pounds, so you need to consider how the installer will get it to where it needs to go. Fellows mentioned the concept of a “generator-friendly home” for new builds. Keeping the utilities close together or roughing-in pipes or cable to make the house generator-ready can significantly reduce installation costs. Part of my reasoning for a portable generator over a standby unit is that I don’t have natural gas service available and the house doesn’t currently have LP. Filling a propane tank and connecting a standby would cost at least \$1000.

A generator installation is complicated. Skilled tradespeople and advanced do-it-yourselfers may have the skills necessary for an installation, but if problems arise, manufacturers can decline war-

ranty coverage if the unit was installed by someone outside their dealer network.

Duffield said, “I would want an electrician who’s installed generators before, but if they haven’t, be sure the installation complies with the manufacturer’s instructions and NFPA 37”—the National Fire Prevention Association standard for permanently installed internal-combustion engines.

Properly sized standby units should be using about half the maximum wattage most of the time for the best balance of fuel efficiency and longevity. Units that are undersized can wear out prematurely from running at full capacity all the time.

By this point you must be wondering what I think about my portable generator purchase. In short, I made a big mistake. It is a complete hassle wheeling it into position and connecting it. I spent about \$2500 on the generator and other components. Ironically, my house is small, and I have a basement—the ideal scenario for a standby unit. I’m told that I could have a similar-size standby professionally installed for between \$5000 and \$6000, and I wouldn’t have to deal with storing and buying gas. And unlike my portable, it would turn itself on when it’s needed, even when I’m not I’m there. It would also manage loads automatically, and in an outage, the family and I would be comfortably riding out a storm instead of dragging a 250-lb. generator through the yard. □

Patrick McCombe is a senior editor.

Protect Your Outdoor Outlets

What you need to know when selecting weatherproof boxes and covers

BY MATTHEW MILLHAM

If you ever need to plug in a saw or compressor for an outdoor building project, having a receptacle available outside, rather than running an extension cord into the house or garage, is a great convenience. It's also safer, so model building and electrical codes require receptacles outside of new homes. But because codes are constantly changing, many older receptacles are not up to current standards. If you want to replace one that's broken or outdated or add more, you can't rely on what's there as a template for what right looks like.

My house is a great example. My wife and I bought it a few years ago, not long after the previous owners added a new deck. The deck had a code-required receptacle with a ground-fault circuit interrupter (GFCI), but it wasn't a weather-resistant type. On top of that, it had the wrong kind of cover installed in the wrong orientation, so water had probably been streaming in from day one. The receptacle never had a chance.

That this happened isn't particularly surprising. For a novice, figuring out the right boxes and covers for outdoor electrical outlets can be a head-scratcher, which explains why many jurisdictions require that electrical

work be left to the pros. With that in mind, what we're discussing in this article is meant to provide an understanding of what goes into selecting boxes and covers for outdoor receptacles, and is not a substitute for local code requirements.

Before getting into specifics, it's important to understand the intent of the National Electrical Code (NEC) with regard to outdoor receptacles. The two biggest threats to the safety of outdoor electrical installations are water and physical damage. To stand up to them, code and common sense require that exposed boxes and covers be sturdy and able to shed water. But these installations don't need to be totally waterproof; like the rest of the house, they just need to be weatherproof. The NEC defines this as: "Constructed or protected so that exposure to the weather will not interfere with successful operation." What's required to achieve that intent varies depending on where you put the device.

Yes, the rules are complicated, but they make things safer and longer-lasting so that power is there when you need it. □

Matthew Millham is contributing editor. Photos by Melinda Vazquez.



BOXES ON THE WALL, OR IN IT?



SURFACE MOUNTED

Surface-mounting, as the name implies, means attaching the box to the surface, which leaves it exposed. This requires the use of listed weatherproof boxes, which are labeled to indicate their weathertightness, often with the words “suitable for wet locations” somewhere on the box. In addition, weatherproof covers are needed to keep water from getting in through the front.

Surface-mounted boxes are typically screwed to the siding or trim through external lugs that are either cast or molded into the boxes or screwed on prior to installation. Additionally, some metallic boxes have “knockouts” in the back that can be drilled through to mount the box without visible fasteners, though there are caveats to this approach. First, any holes other than approved weep holes must be waterproofed. Second, these may not pass muster in some jurisdictions because the holes fundamentally compromise the weatherproof integrity of the box—even the best sealants can fail. And just because the knockouts—or what look like knockouts—are there doesn’t mean the manufacturer intends for them to be used. Many nonmetallic boxes, for example, have what look like knockouts molded in, but metal fasteners are generally prohibited in these boxes. Check the printed instructions or call the manufacturer to find out what they allow.

FLUSH MOUNTED

Flush-mounted installations are a different animal. A hole is cut so the box can be recessed, leaving the front of the box flush with the surface. Because it’s protected, a flush-mount box doesn’t need to be weatherproof itself if it’s in a location that would be dry but for the hole cut for the box; only the covers must be weatherproof and must seal against the finished surface to keep water out. In these kinds of installations, it’s common to use the same kind of box that’s used inside the house, but that’s not always a great idea. Interior boxes tend to leak a lot of air and are difficult if not impossible to properly integrate with water and air control layers on exterior walls, particularly when there’s an air gap behind the siding. Luckily, there are purpose-built exterior flush-mount boxes that are far easier to integrate and seal.

Purpose-built flush-mount boxes

Purpose-built flush-mount boxes are in a class all their own. The versions I’m familiar with—from Arlington Industries and TayMac—are superior to the type of flush-mount installations mentioned above because they can easily be flashed to integrate with water-resistive barriers on exterior walls. While they seem expensive compared to the standard way of doing things, they include integral in-use covers, so there’s one less thing to buy and separately install.

Arlington has a wider selection for a range of conditions, including exterior rigid foam, but both companies’ products work with various exterior claddings and wall systems, and can be used in new work or retrofit applications. Most of these boxes are made entirely of UV-resistant plastic, though Arlington makes versions with metal inserts for compatibility with metallic conduit.



Better flush-mount boxes. Preventing air and water infiltration is key to any wall’s performance. Purpose-built boxes like this one are easy to flash and seal to keep out the elements, while also protecting electrical devices.

WEATHERPROOF-BOX BASICS

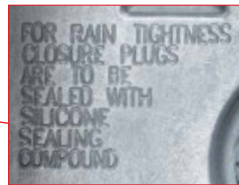
Weatherproof boxes—the type required for surface-mounting—come in both metallic and nonmetallic versions, in a range of colors, depths, materials, and gang sizes—gang number being the industry term for how many devices the box can hold. A one-gang rectangular box can hold a single device, such as a duplex receptacle. The limiting factor

in the number of gangs for rectangular boxes serving outdoor locations is often the cover. While you can find three- and four-gang boxes, weatherproof covers for anything bigger than two-gang is usually a custom order. Round boxes are typically 4 in. in diameter and, while generally used for lighting, can also serve as receptacle boxes with the use of adapter plates.

All of these boxes have hubs—the equivalent of knockouts on metallic boxes used indoors—to attach conduit and run wires or cables. Most of these hubs are threaded to accept various fittings and conduit, but there are also PVC boxes with smooth hubs designed to be cemented to PVC conduit or fittings.



Weatherproof metallic boxes typically come with a **GROUND SCREW** either preinstalled or in the package.



Many weatherproof boxes and covers include sealing instructions that must be followed for code compliance.

Sigma Electric
14251-5
Metal Box
\$6

Don't use Teflon tape on metal conduit; seal on the outside with silicone, or use conductive sealants to maintain bonding.

METALLIC VS. NONMETALLIC

An important difference between metallic and nonmetallic boxes is their compatibility with conduit, which is required for some outdoor wiring projects (and indoors in some jurisdictions). With rare exceptions, metallic conduit can only connect to metallic boxes; nonmetallic conduit can be used with either metallic or nonmetallic boxes. Metallic boxes also need to be grounded, while nonmetallic boxes, which aren't electrically conductive, don't.

Compatibility with existing wiring is another issue, especially in retrofits. If the new outdoor box is tapped into an existing circuit, it's generally simpler to use a box that easily integrates with what's already there. If the house is wired with armored or metal-clad cable, metallic boxes will make the job easier; if the wiring is nonmetallic sheathed cable, nonmetallic boxes will require fewer fittings and less time to install. Cables and wires rated for interior use can't be used in conduit, but they can enter through the back of weatherproof boxes attached to walls.



PVC boxes with smooth hubs are designed to be cemented to PVC conduit and fittings.

Carlton
E982DFN
PVC Box
\$5

TAP AN EXISTING CIRCUIT, OR ADD A NEW ONE?

If you're running a new circuit to power your outdoor electrical installation, your options for where to put a new exterior receptacle, switch, or light are almost endless. A new circuit is optimal if you plan to plug in power-hungry tools, but probably isn't necessary for lower-draw electronics like radios and battery chargers. In many cases, you may be able to tap an existing circuit with unused capacity rather than run a whole new cable back to the service panel. There are some circuits you cannot tap into, though: Circuits serving kitchens and bathrooms, and dedicated circuits for single appliances, are all off limits. Any new cables and receptacles that tap into existing interior outlet boxes should have the same gauge and ampere ratings as the cables and receptacles already on that circuit.

If you tap into an existing receptacle at the end of a circuit, there should be enough room inside the box to bring a cable to feed the new outdoor receptacle. However, if there are already two cables in the box—incoming and outgoing—you may need to replace the existing box with a larger one.

Weatherproof cover

Gasket

Incoming cable (from power source)

New cable to outdoor receptacle

GFCI receptacles are larger than standard duplex receptacles, so there may not be enough room in a single-gang box if you also need to splice an outgoing cable to feed another outdoor outlet downstream. In that case, install a deep box or an extension to the single-gang box.

GROUND-FAULT PROTECTION

Receptacles installed outdoors must be rated for weather resistance (listed and labeled as "WR"), and have ground-fault-circuit-interrupter (GFCI) protection. GFCIs monitor current on the hot and neutral legs of the circuit for imbalances that may be caused by contact with water. When they sense such an imbalance, they trip, shutting off the power.

There are a few different ways to get GFCI protection for receptacles. The first is to use a GFCI breaker in the service panel. This provides GFCI protection to the entire circuit, and can be a good option when all of the receptacles on that circuit require GFCI protection, such as a circuit dedicated to an outdoor deck or patio. But they're more expensive than GFCI receptacles, and they need to be reset at the panel when they trip.

The second option is to use GFCI receptacles where GFCI protection is needed. The nice thing about GFCI receptacles is they can be reset individually, and they can be wired to provide GFCI protection to all devices connected downstream on the same circuit, including regular receptacles. A single GFCI receptacle installed first in line on the circuit can provide the same whole-circuit protection as a GFCI breaker at a fraction of the cost.

It's worth noting that most receptacles inside and outside homes are nonlocking, with two slots to receive the blades and, in grounded versions, a round hole to receive the ground pin of standard plug caps. In most cases, these receptacles must be tamper resistant as a safeguard to protect children, both inside and outside the home.



A remedy for old outlets. Standard weather-resistant receptacles can get GFCI protection from GFCI devices—either breakers or receptacles—upstream.



GE THQL1115GFTP
15-amp GFCI breaker
\$64



Legrand 1597TRW
15-amp GFCI receptacle
\$24

COVERS WEATHERPROOF VS. IN-USE

All outdoor outlets need some kind of weatherproof cover. There are two main classes of these: weatherproof, and weatherproof while-in-use. Covers that are simply weatherproof keep water out only when there's nothing plugged into the receptacle and the cover is closed. Weatherproof while-in-use covers (commonly called "in-use covers") are able to close and keep water out even when an electrical cord is plugged into the receptacle.

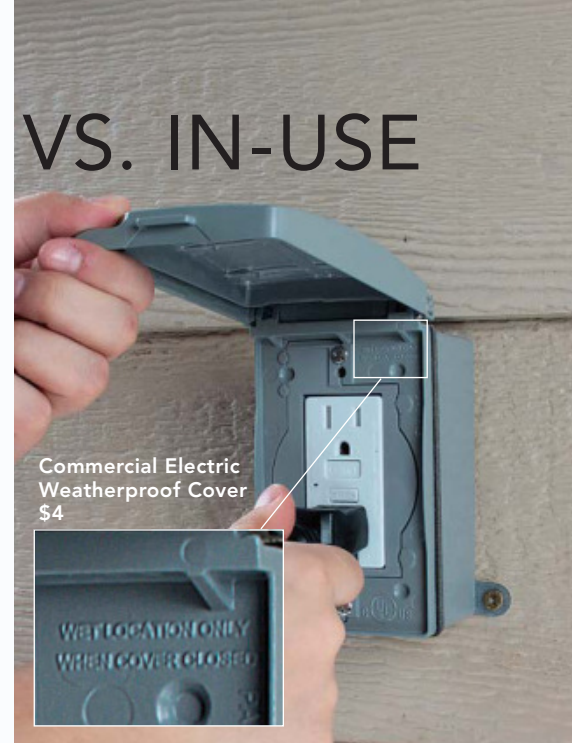
The type of cover you need depends on whether the location is considered "damp" or "wet." Everything outdoors falls into one of those categories. If you're unsure whether the location you're installing a receptacle in is wet or just damp, err on the side of wet. Anything that's good enough for a wet location is suitable for damp locations as well.

Damp locations are those that are exposed to moderate amounts of moisture—say from fog or morning dew—but are protected from the weather and aren't subject to beating rain or runoff, such as under the protection of a porch roof. In damp locations, a weatherproof cover is generally all that's required. These usually have little spring-loaded doors that snap tight over the receptacles when there's nothing plugged into them, but are open when the receptacle is in use.

Wet locations are places likely to get saturated with water or other liquids and typically have no protection from the weather, such as on decks, walkways, or pergolas. With one exception, receptacles in wet locations must have in-use covers. There are some boxes, like the Arlington IN BOX shown at the bottom of p. 92, that include integral in-use covers. But the most common type is an in-use outlet box hood, also known as a bubble cover (photo above, left), and these covers must be labeled "Extra Duty."

As for the exception mentioned earlier: Receptacles in areas routinely subjected to high-pressure spray-washing (and thus considered "wet") are exempt from the Extra Duty in-use cover requirement. Here, a cover that's weatherproof when closed is permitted, so long as it's actually closed when spray-washing occurs.

In-use and standard weatherproof covers are available in both metallic and



Two levels of protection. Weatherproof while-in-use covers (left) can be closed even when something is plugged into them to protect outdoor outlets from precipitation, and are generally required in wet locations. Weatherproof covers that remain open when something is plugged into them (right) are mostly for damp areas.

nonmetallic versions, and either can be used with either metallic or nonmetallic boxes. All have hinged lids that should be installed so they open upward. Many in-use covers have removable inserts to make space for electrical cords when they're in use and keep critters out when they're not.

This should go without saying, but for flush-mount installations, the covers should sit flat on the surface, not bridge courses of siding or other irregularities. And while covers typically come with gaskets to help seal them to whatever they're attached to, they need backup (see below).

SEALING BOXES AND COVERS

Sealants are almost always needed to truly weatherproof outdoor receptacles. Most weatherproof boxes and covers note this in their instructions, which need to be followed for a code-compliant installation. Still, some instructions lack enough detail to do the job right. For surface-mounted boxes that don't come with explicit instructions to the contrary, cap all unused threaded hubs with closure plugs, and use nonhardening silicone to seal the joints around them. Use the same sealant around the top and sides of surface-mounted boxes where they meet the surface, but leave the bottoms unsealed so water that does get back there can drain out. Covers should also be installed with non-hardening silicone applied around the entire perimeter of the gasket to prevent water from wicking behind it through capillary action. The gaskets included with these covers can bridge only tiny irregularities.



Second line of defense. Even when installed on weatherproof boxes, a bead of nonhardening silicone is good insurance to back up the wafer-thin gaskets that come with weatherproof and in-use covers.

All About Garage

Buyers have a wide range of options for architectural style, material, and price



BY SCOTT GIBSON

The 1940s-era garage tucked behind our house is barely big enough for one car, and only part of the garage door is visible from the street. That's not an uncommon arrangement in my neighborhood, but a far cry from more contemporary house designs that have two or more oversized garage doors facing the street. Garage doors have become an important architectural feature, not just a way to get to the lawn mower.

In 2019, roughly 650,000 new single-family homes in the United States came with a one- or two-car garage, and industry experts suspect the replacement-door market is even bigger. That's a lot of doors. The most common variety is a door divided into a number of

horizontal panels that slide on a pair of steel tracks. These “upward-acting sectional doors” can be traced back to at least 1921, according to the Overhead Door Corp., and possibly as far back as 1906 with the introduction of a horizontal folding door sold by the Variety Manufacturing Co. of Chicago.

Sliding sectional doors solved several problems that homeowners had with traditional outward-swinging carriage doors. For one, the door is stored overhead when open, out of the way and safe from damage. Homeowners no longer had to shovel snow out of the way to open the door. And with the addition of counterbalancing springs, a heavy garage door was almost effortless to open and close. The

Doors



Aluminum and Glass

Aluminum frames work well for doors full of glass. You can choose the finish for the metal, as well as the opacity of the windows for light or privacy.

MATERIAL MATTERS

Garage doors have come a long way. Not only are there many materials available, from inexpensive steel to luxe custom wood, but you also can select pretty much any style in your chosen material.



Steel

Steel is strong and durable, but it doesn't have to look old-fashioned. These carriage-house-style doors are steel with faux-wood composite cladding.



Vinyl

Typically available in light colors, vinyl is resistant to salt and humidity, so it works well in coastal areas.



Wood

Custom wood doors give you exactly what you want, but they can be expensive and need regular maintenance.

introduction of the electric door opener in 1926 simply sweetened the pot.

The Door & Access Systems Manufacturers Association, a trade group, lists dozens of manufacturers at its website. Online catalogs of big manufacturers, such as Clopay, Amarr, and Wayne Dalton, list dozens of choices in a range of styles. Doors can be faced in painted steel, wood, plastic composite, or fiberglass, or made with aluminum frames and glass panels. Manufacturers also offer two kinds of insulated doors and reinforced garage doors for high-wind areas.

Sectional doors are the most common type, but buyers also may find traditional swing-out doors, roll-up doors (more common in com-



Wayne Dalton
Model 9800
insulated fiberglass

KEEP OUT THE COLD

Garage doors are available with and without insulation. Insulated versions have a polyurethane or polystyrene core. Insulation layers come in thicknesses of up to 2 in. and some versions include thermal breaks to enhance efficiency. R-values depend on the type of insulation and how thick it is. In addition to protecting the garage from heat and cold, insulated doors can offer benefits such as quiet operation and durability.



Polyurethane foam

Polyurethane foam injected between inside and outside faces of the door gives the highest insulating value while increasing strength.



EPS panels

Polystyrene bonded to the inside face of the door is protected by a vinyl backer. R-values are lower, but so are prices.



No insulation

A basic one-layer door comes at the lowest price, but without insulation the door is more prone to dents because of the lack of reinforcement.

mercial and industrial settings), and single-piece tilt-up doors. Prices vary considerably, from less than \$300 for a single-layer, no-frills steel door from a big box store to several thousand for an insulated high-end door in a custom color.

Steel dominates the market

Steel is far and away the most common choice for garage doors, says Mike Fisher, the executive director of the International Door Association. Steel covers the widest range of design, color, and price. At one end of the spectrum are doors consisting of a single layer of steel—what the industry calls a “pan door.” A midrange door would have two layers of steel with insulation in between. At the high end are four- and five-layer designs with custom paint, windows, and as much as 2 in. of insulation. These doors may include a composite overlay that looks like wood over a steel skin along with polyurethane or polystyrene foam.

The steel door with an embossed raised-panel design is the plain-Jane standard in the industry, but that popularity is declining in favor of the carriage-house or Shaker design that looks like an older-style carriage-house door that would swing open. Also gaining popularity is a smooth door reminiscent of a midcentury design you might have seen on *The Brady Bunch*.

Finishes typically consist of a galvanizing layer over the bare steel followed by a primer and a top coat. Higher-end finishes allow color-matching with house colors and

GARAGE DOORS*

Amarr
amarr.com

C.H.I. Overhead Doors
chiohd.com

Clopay
clopaydoor.com

Garaga
garaga.com

General Doors Corporation
general-doors.com

Haas Door
haasdoor.com

Midland Garage Door
midlandgaragedoor.com

Raynor
raynor.com

Wayne Dalton
wayne-dalton.com

GARAGE-DOOR OPENERS

Chamberlain
chamberlain.com

Genie
geniecompany.com

LiftMaster
liftmaster.com

Skylink
skylinkhome.com

*The Door & Access Systems Manufacturers Association, a trade group representing garage-door manufacturers, maintains a list of member companies at its website dasma.com.

SOURCE BOX

industrial-grade topcoats with multiyear warranties. Manufacturers typically offer hundreds of paint colors in addition to custom color-matching.

Doors also can be ordered with a plastic composite or fiberglass facing that's made to look like one of several species of wood. Unlike wood, composites won't rot, and they can be stained or painted.

For an upgrade, steel doors can be ordered with two types of insulation: polyurethane foam or expanded polystyrene (EPS). Polyurethane offers higher R-values, and like spray-foam used in houses, it fills irregularities inside the door cavity more effectively than sheet foam, in effect gluing the inner and outer steel layers together. Builders or homeowners worried about the high global-warming potential of chemicals used in polyurethane foam may want to check with the manufacturer to see if they've switched to a low-GWP blowing agent, or opt for EPS.

According to Clopay, in addition to protecting the garage from temperature extremes, insulated doors are quieter as they go up and down and also better at muffling the sound of an impact. But some builders might argue that an insulated door is not worth the extra cost (see sidebar, below). Expect to pay about \$1000 for a midrange three-layer insulated door, not including installation.

Windows are another consideration. They lower the overall R-value of an insulated door, but insulated glazing is an option, as is tinted and tempered glass. Windows are a traditional feature of carriage doors, and the glass

Is an insulated door worth the extra cost?

It depends on where you live and whether you use the garage for anything other than parking a car, says Mike Guertin, *FHB's* editorial advisor and a Rhode Island builder.

Guertin installed an R-12 garage door on his drive-under garage 25 years ago and says that even in very cold weather, with temperatures dipping as low as 0°F, the garage stays at about

45°F. That's without any source of heat in the garage. "That sounds cold," he says, "but compared to 20°F or 14°F, it's comfortable."

When he built a detached garage six years ago, Guertin installed an R-16 door. The garage has a layer of rigid polyiso insulation on the outside of the building, but no cavity insulation. With no heat source, the garage stays 15°F or so above what

the outside temperature is. If he's going to work in the garage, Guertin fires up a woodstove. The space heats up nicely and seems to retain heat fairly well.

Both the house and the detached garage are well-air-sealed. Even if the garage doors are not perfectly sealed, Guertin suspects there's not much of a stack effect in either building. Very little cold air is being drawn

into the garage because not much air is escaping through leaks in the building enclosure.

If he didn't care about temperatures in the garage being moderated, or if he weren't using the garage occasionally as a shop, Guertin said he would not spend the extra money for an insulated door. He'd just opt for a door that had adequate bracing for stiffness.

allows light into the space, enhancing visibility during the day. Adding windows typically adds about \$500 to the cost of a door.

Wood, aluminum, and vinyl

Garage doors made of wood have been a staple in the Northeast for many years, and many homeowner's associations still require them. These are rail-and-stile doors with thin plywood panels that come with or without a row of windows along the top of the door. But more stylish versions made to look like carriage-house doors that swing open are becoming increasingly available. The 7400 Series from Wayne Dalton, for example, is available in T1-11 plywood, hemlock, western red cedar, mahogany, and knotty cedar. These doors can be ordered with arched or square tops, windows, and one of many panel styles, including several with the characteristic X-brace reminiscent of a barn door.

Truly custom doors also are widely available for buyers set on a certain species of wood, panel design, and finish. This is the top of the market, where prices may hit \$10,000 or more for a one-off design bound for a celebrity mansion.

Wood is traditional, charming, and stylish, but it's also prone to a familiar list of disadvantages, including its tendency to decay if left in the weather too long without attention. Buyers should count on periodic refinishing, just as they would with any exterior wood components.

Aluminum is another material choice, typically as the frame material for doors made mostly of glass. Available in many styles, glass doors have a much more contemporary flavor than traditional styles like the carriage-house door. Frames can be ordered with a powder-coated or anodized finish and with a number of clear or opaque glazing options, and several choices for shades of tinted glass. Acrylic panels and insulated glass also are available. Aluminum and glass doors are significantly more expensive than basic one-layer steel doors.

Some but not all manufacturers also make vinyl-faced garage doors. They're available in a limited palette of light colors (no dark shades) and appear to be marketed for coastal areas because of PVC's resistance to corrosive salt air.

Doors for high-wind areas

Garage doors make houses in hurricane-prone areas vulnerable to catastrophic



Design on the fly. Upgrading your garage door is easy with an interactive website. Just take a photo of your existing door, upload it to the site, and have fun playing with different looks.

damage, a potential that is leading to more stringent code requirements for their assembly. In a report published by FEMA after Hurricane Andrew ravaged parts of Florida in 1992, the agency found that when garage doors collapse in high winds, the entire house could become pressurized, causing "partial or complete blowouts of major structural systems such as walls and roofs."

FEMA called for design improvements to garage doors, such as wind-resistant locks, stronger track assemblies, and reinforcements to make door sections more robust. Codes and standards in Florida were subsequently updated, with new provisions for wind-pressure ratings and impact protection from airborne debris. According to Fisher, Florida's response changed the door industry and helped set the stage for basic requirements nationwide. The 2021 International Residential Code (IRC) requires that all garage doors be labeled for wind-load ratings, although it will be up to individual states whether to adopt the 2021 IRC or modify it to suit local conditions.

Doors are rated for particular air pressures based on predicted wind speeds. The first step in choosing a door is to check with local building officials to find out what the code

requirements are, and then to choose a door that has been labeled to show it meets a particular wind rating. Impact-resistance ratings or other protection may also be required in areas where there is a risk of damage from windborne debris.

Sizing and ordering

Stock sizes for single-car garage doors are 8 ft. or 9 ft. wide and 7 ft. or 8 ft. tall. Double doors are typically 16 ft. or 18 ft. wide. Doors also can be ordered in custom sizes, in 2-in. increments for width and 3-in. increments for height.

Ordering a custom size may mean a slightly higher cost, but the industry has become more flexible over time. "Back in the day you'd have an inventory of garage doors because they were all white and they all had that same panel style," Justin Evans, Clopay's residential product manager, said. "Today there are so many colors, so many designs, so many window choices. There are really not a lot of stock items; pretty much everything is custom-made. Even when you order a standard size, I'd say eight times out of 10 it's made to order."

Interactive websites offered by a number of manufacturers give buyers a chance to virtually try out a wide range of door styles before making a decision and placing an order. At the Raynor website, for example, uploading a photo of your garage opens the door to a menu of choices for the style of door, window type, panel shape, decorative hardware, and color. When you find the door you want, you can save the file, email it to someone, and request a quote from a local dealer.

Because most manufacturers work through a network of local dealers who take care of installation, there's no instant price quote for the door you've chosen. Nor is there immediate feedback on how design choices affect the final price—for example, does the price go up or down, and by how much, when decorative hardware is added? Even so, these tools are a great first step in visualizing various types of doors on your own garage rather than a generic building pulled from a collection of stock photos.

I used the Raynor online app, submitted the design, and had a follow-up call from a local installer within a couple of days. □

Scott Gibson is a contributing writer for *Fine Homebuilding* and Green Building Advisor.



Simplicity and style. Quieter and with less hardware, wall-mounted openers leave more room for storage, but they are pricier than the typical ceiling-mounted options.

OPENER OPTIONS

Garage-door openers (or “operators,” as they also are called) look increasingly like many other internet-connected devices around the house. In addition to making the door go up and down on command, they also allow homeowners to monitor the inside of the garage remotely with a camera, open and close the door for a delivery driver or a neighbor, and lock up even when no one is at home.

The most inexpensive openers have basic safety features, no internet connectivity, and AC motors rated at ½ hp that are suitable for relatively light doors. Midpriced openers add features such as smartphone controls, motion-activated lighting, and dual-lens lights, says Gregory Martell, senior product manager at Chamberlain, a door-opener manufacturer. Top-end openers can lift heavier doors with motors rated at 1 hp or more, have battery backup, and use a belt-driven or wall-mounted lifting mechanism for less noise.

Installed prices range from about \$300 to \$900. If you want to do the installation yourself, models are available for under \$150. Here are some features to consider:

- **Belt drive, chain drive, or screw drive.** Chain drives are inexpensive and reliable but noisy. Replacing the chain with a steel-reinforced belt will make the system much quieter, Martell says. In addition to belt- and chain-driven openers, Genie, another manufacturer, also offers a direct screw-drive mechanism designed for heavy doors.
- **Overhead or wall mounted.** Standard openers include a ceiling-mounted motor that powers a chain-driven traveler to open and close the door. A wall-mounted unit is attached directly to the shaft of the opener, which both saves space and makes less noise.
- **AC or DC motor.** According to Martell, some openers have built-in inverters that allow the motor to run on direct current. These typically make less noise than AC models and are often found on openers with greater lifting capacity.
- **Battery backup.** Openers with an integral battery are required in California but are available anywhere in the U.S. A battery is mounted inside the unit and remains charged. When the power goes out, the door can still be opened and closed a number of times. (Doors also have pull cords that disengage the door from the drive mechanism so they can be opened without electricity.)
- **Lighting.** If high-intensity lighting is a priority, look for a model with integrated LEDs. Although homeowners can replace incandescent bulbs with off-the-shelf LEDs, Martell says these standard bulbs will interfere with the operation of the remote or reduce the distance at which the remote works. Integrated LEDs don't have that problem.

Door openers are designed to overcome the “moment of inertia” and get the door moving. Once that happens, the springs should do all or most of the work. Choosing the correct opener means matching the power of the motor with the weight of the door, Martell says, rather than trying to calculate how much horsepower the motor should have. Basic openers are designed to lift doors of up to 330 lb., according to Martell, but more powerful units with wall-mounted drive mechanisms will get an 850-lb. door going in the right direction.



Traditional system, smart technology. Ceiling-mounted openers are budget-friendly, and some can connect to WiFi so you can operate them from a smartphone.



McElroy
Metal
Meridian

The Rise of Metal Roofing

Long-lasting,
lightweight, and
resistant to hail
and fire, metal
makes an ideal roof

BY SCOTT GIBSON

Metal roofing has a long history in the U.S., but until 20 years ago it was a bit player in residential construction, with just a 3.6% share of the reroofing market. That number has roughly quadrupled since then, according to an industry trade group.

What happened? Metal roofing is now available in a range of styles—from standing seam to a variety of stamped metal shingles that look like slate, clay tile, and even asphalt. Paint and stone coatings are more sophisti-

cated and durable, giving metal roofing a long service life while appealing to homeowners with a variety of aesthetic preferences.

The industry is also working harder to win over consumers who once thought that metal roofing was too hot, too heavy, noisy, or prone to rust, says Dick Bus, president of ATAS International and head of the Metal Roofing Alliance. “Those myths are gone, and people want to reroof with something that has some permanence to it,” he said. Metal roofing may never catch up to asphalt

Endless choices. Metal roofing is available in hundreds of styles, from traditional profiles like standing seam to modular panels that can look like slate, tile, and even asphalt shingles.



Classic
Metal
Roofing
Systems
Country
Manor
Shake

in the residential arena simply because of sticker shock. A standing-seam or metal-tile roof can be two or three times the initial cost of asphalt. But its longevity, recyclability, high fire resistance, and low maintenance has increased its acceptance.

Select a base metal

Steel and aluminum are the two most common and least expensive metals used for residential roofing. "On about 80% of all homes, either metal will work just fine," says Todd

Miller, president of Isaiah Industries, a manufacturer of a wide range of metal roofing products. "On the other 20%, it tends to be driven by climate in that area."

Steel's weakness is its potential for rust. One way to prevent it is to galvanize it by adding a coat of zinc to the surface before painting. The amount of zinc is key. A G-100 coating (1 oz. of zinc per sq. ft.) makes a long-lasting substrate for roofing, says Ken Gieseke, vice president of marketing at McElroy Metal, a Louisiana-based manufacturer. Galvalume

Testing for tough conditions

Roofing faces a variety of environmental challenges, but hail, high winds, and wildfire are certainly among the most difficult tests. For a rundown on the various rating standards for roofing, I turned to Stephen Knight, a professional engineer and engineering manager for McElroy Metal.

HAIL

The standard test for resistance to hail damage is UL 2218. Steel balls in four different diameters are dropped from increasingly greater heights to simulate a hailstorm. A roofing sample fails if there is any surface tearing, splitting, or fracturing. Class 4 is the best rating, meaning the roof can withstand a 2-in. ball dropped from 20 ft.

WILDFIRE

Fire resistance is determined by UL 790. This includes three parts: application of an intermittent flame, a flame-spread test with a continuous flame, and a brand test, designed to test how a roof will react when a flaming ember or branch falls on it. Class A is the highest rating, "effective against severe fire test exposure."

HIGH WINDS

There are several standard tests for wind. One major question to be answered is, at what wind pressure (not wind speed) will the roofing blow off? Results are described in wind uplift in pounds per square foot (psf). For example, when the specs list wind uplift as Class 90 (UL 580), this means that the roof will resist an uplift of 90 psf. Uplift pressures at any given wind speed are affected by a number of factors, including roof configuration, building height, and any openings in the building. The calculations are complex, but many manufacturers offer free engineering services to help with design. Tighter fastener spacing, narrower panel profiles, and using mechanically seamed panels all increase wind resistance.

is another, and widely regarded as better, option. In this process, bare steel is coated with an alloy of zinc and aluminum (generically, this coating is referred to as an AL-Zn alloy) before it's painted or clear-coated. The treatment is especially useful in harsh weather conditions. McElroy cites a side-by-side comparison in which Galvalume-coated panels were two to four times as durable as galvanized steel after 23 years of weather exposure.

Bus prefers aluminum as the base metal over steel (his company manufactures both types). In "aggressive" environments—along the coast or in regions with highly acidic rain—aluminum is less likely to corrode, and if the surface is scratched, the panel won't rust. Aluminum is slightly more expensive—7% more than the steel roofing leaving his plant.

There are several other choices, all of them more expensive but also extremely durable. The best known is probably copper, with installed costs around \$2000 per 100 sq. ft.

Zinc is another option with an extremely long service life—hundreds of years, according to Bus—but it's never been as popular as copper in the U.S. Metal thickness ranges from about 0.014 in. to 0.05 in., depending on the profile and the type of metal. Manufacturers may use the metal's gauge as a measurement—the lower the number, the thicker the material.

Select the finish coat

Treated steel and aluminum roofing substrates also get a topcoat. The most durable finish is polyvinylidene fluoride (PVDF); two of the most popular brands are Kynar 500 and Hylar 5000. These coatings resist fading and chalking much better than silicone-modified polyester (SMP) and polyester finishes. They also are more expensive. On a typical residential reroofing job, Kynar 500 may add a couple of hundred dollars to the cost, but SMP surfaces can begin to fade in less than 10 years.

"The technology is real," Gieseke says of PVDF coatings. "It's not a marketing gimmick. It's really the best-performing system out there."

Stone-coated steel is another finish option that some manufacturers offer. In a process that Boral says was developed in the 1950s, tiles start with Galvalume-protected steel, followed by an acrylic primer, then an acrylic resin binder to which the ceramic granules are bonded. The granules provide color and UV resistance.

While stone-coated roofing can be just as durable as any other type of metal roofing, Renee Ramey, the executive director of the Metal Roofing Alliance, suggests buyers discuss product specs with their installers. "The U.S. is experiencing an issue with subpar products being imported," Ramey said. Dealing with MRA-member manufacturers is one way of avoiding a problem with substandard base metals and coatings that can shorten product life.

Both paint and stone-coated surfaces can be engineered so they reflect heat from the sun for cooler roofs and reduced cooling loads. The Cool Roof Rating Council describes a cool roof as one that reflects solar energy that hits the surface (solar reflectance) and radiates heat that is absorbed (thermal emittance). These properties are measured and described by a number between 0 and 1—the higher the number, the cooler the roof. In general, white and light-colored roofs will reflect more solar energy than black or charcoal-colored roofs, but even darker shades are now available with cool roof coat-

3 MATERIALS

Although metal roofing can be made from zinc, stainless steel, and even lead-coated copper, steel, aluminum, and (to a lesser extent) natural copper dominate the market. Steel and aluminum are generally painted, so it may be hard to tell the difference between the two after installation. Copper is uncoated, and turns green with age.

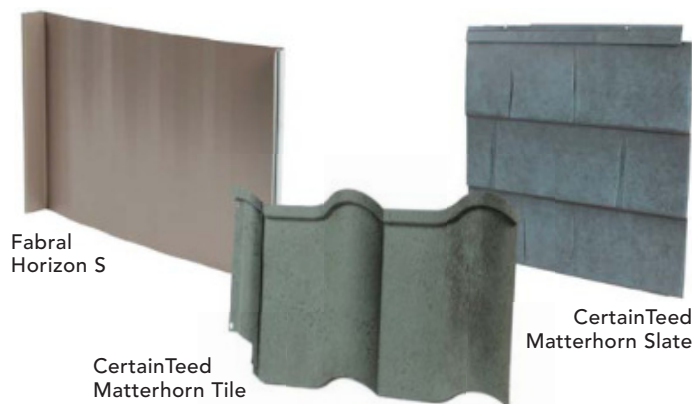


Protective coating. Stone-coated shingle panels have a layer of granules on top of the pressed-steel panels that help them stand up to sun, hail, and fire.

STEEL

Steel is the strongest metal roofing material and is often used in commercial buildings with long spans between structural elements for this reason. It's available in through-fastened, standing-seam, and modular panels, and offered in styles to mimic shakes, shingles, and tile.

- Most economical metal roofing option
- Can be galvanized or protected with a Galvalume coating before it's painted; if choosing a galvanized substrate, coating should be a minimum of G-90
- Better crush resistance than aluminum in areas where severe hail and very heavy snowfalls are a threat
- Prone to rust if surface is damaged to expose bare metal



LEAD THE PACK



ATAS
Techno Tile

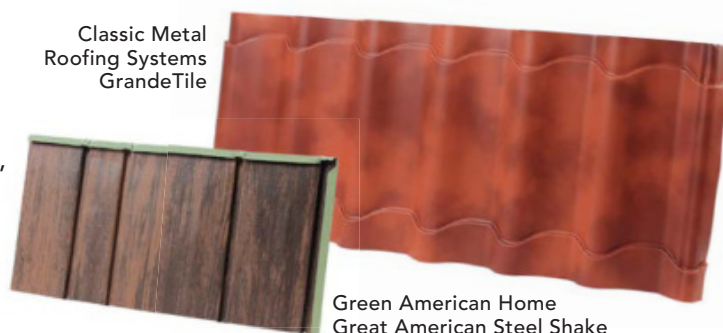
Weather permitting.
Resistant to corrosion and wind, modular aluminum panels are a good fit for coastal areas.

ALUMINUM

Aluminum roofing is painted with high-performance coatings to further resist corrosion. It is available in modular and standing-seam panels, and less often as through-fastened panels. Like steel, the panels come in styles to mimic shakes, shingles, and tile.

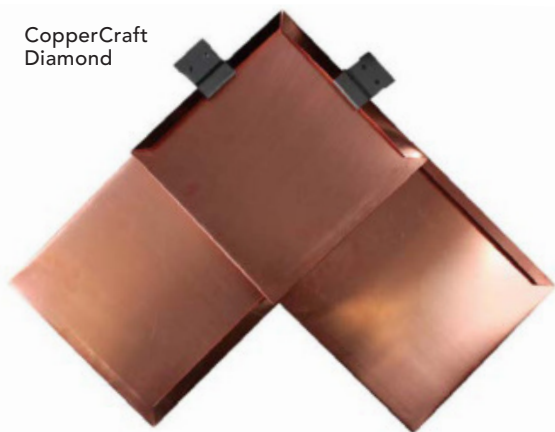
- Slightly higher cost than steel
- Higher rate of thermal expansion and contraction than steel
- Outlasts steel in marine and acid-rain environments

Classic Metal
Roofing Systems
GrandeTile



Green American Home
Great American Steel Shake

CopperCraft
Diamond



COPPER

Copper has been installed on roofs for centuries; today's copper roofs are available in standing-seam and modular panels. The uneven verdigris color is tough to replicate with coatings, but copper roofing can leave green stains on siding and flatwork.

- Extremely durable
- Ages to natural patina
- Most expensive common metal option

CopperCraft
Classic Standing Seam



Made to last.
Copper roofs last indefinitely, but their higher cost makes them a distant third in terms of overall popularity.

ings. (For a product directory, check the Cool Roof Rating Council's website.)

A variety of panel and tile choices

The most basic type of metal roofing is corrugated, galvanized panels roughly 3 ft. wide that run from eave to ridge. They are attached to the roof deck (or strapping) with screws that remain exposed when the roof is installed. Gaskets or washers between the screw head and the panel are designed to keep water out. These "through-fastened" roofing panels go up quickly, particularly on a simple gable roof.

Standing-seam (or concealed fastener) roofing consists of a number of individual panels whose seams are joined either with an interlocking snap-lock profile or mechanically with a special crimping tool that installers take with them onto the roof. A crimped-seam roof is watertight on roofs with slopes as low as 1-in-12, but when the roof pitch increases to 3-in-12 or more, the snap-lock panels will keep water out about as well, Bus says. Wind resistance is another consideration (for more on that, see "Testing for tough conditions," p. 103).

Standing-seam panels are a step up in performance from through-fastened roofs, and also a step up in cost. Bus estimates that these concealed-fastener roofs typically cost between \$8 and \$9 per sq. ft. installed (remember that roof geometry, local labor rates, roofing profiles, and metal and finish choices all affect the price). Concealed-fastener roofing panels come in a wide range of profiles and colors.

Finally, there are metal roofing shingles (also called "modular panels"), a diverse category that includes products manufactured to look like clay roofing tiles, wooden shakes, slate, and even asphalt. "Asphalt?" you might ask. This design is for homeowners who may not be able to get the OK from a homeowners' association for a metal roof, or those who don't want to rock the boat in a neighborhood full of asphalt roofs. Like other forms of metal roofing, shingles have a very long service life, and high hail and fire ratings.

What do designers prefer?

A metal roof is more expensive than asphalt, but the architects and designers I contacted prefer metal over asphalt and other roofing options. They cite a number of reasons: high recycled content, durability, and compatibility with rooftop solar panels. Typical of the responses was this from Ann Edminster, a California-based architect and green building consultant. "It's extremely durable and of course usually has recycled content, and it's infinitely recyclable," she said. "The finishes on metal tend to be pretty benign and long lasting. It's inherently reflective; metal just comes that way. The water coming off of it is clean because it's not laden with volatile hydrocarbons and things like that.

"It's really high in embodied carbon," she adds, "but so is all roofing. And so it's basically a contest between other attributes and metal. Metal stacks up better across all of those attributes."

One final note from Miller: Don't minimize the role of the installer. With skilled labor increasingly difficult to find, it's more important than ever to find an installer who knows what he's doing. Miller suggests contacting the manufacturer of the roofing you've selected and asking for the names of experienced installers in your area. "Proper installation is more important than product," he says. □

Scott Gibson is a contributing writer from Portland, Maine.

3 WAYS TO SKIN

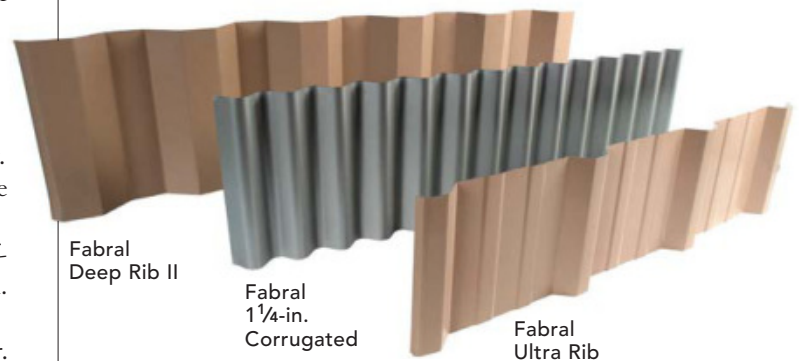
Metal roofing comes in a wide range of colors, textures, and profiles. There are three basic panel types: standing seam (concealed fastener), through-fastened (exposed fastener), and modular (shingle-style). Metals other than aluminum and steel are chiefly available as standing-seam and modular roofs. Type of metal, the profile, local labor rates, and roof complexity all affect cost.



THROUGH-FASTENED

Through-fastened panels are the least expensive metal roofing option and they install quickly, especially on simple roof designs. Follow manufacturer instructions on screw placement (it varies) to ensure warranty coverage.

- Panels attach to roof deck or purlins with screws along edges and field of panels
- Fastener heads seal with a gasket but remain visible after installation is complete



PROS Wide sheets speed installation and lower labor costs

CONS Some panels are very thin; potential for leaks around fasteners

COST Starting at about \$5 per sq. ft. installed

A ROOF

MODULAR

Shingle panels are installed over solid sheathing or wood battens. Installation instructions are product-specific, and must be followed carefully to ensure long-term durability and weathertightness.

- Shingles install separately, much like an asphalt shingle or wood shake
- Fasteners fully concealed when installation is complete
- Can be made to mimic many roofing materials, including tile and asphalt

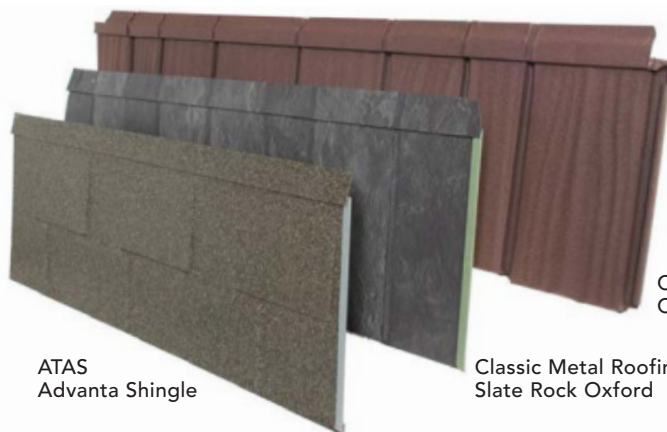
PROS Wide range of colors and textures; asphalt lookalikes may be enough to win over homeowners' associations and neighbors

CONS Higher labor costs than standing-seam or exposed-fastener panels

COST \$9 to \$20 per sq. ft. installed



Easy on. Shingle panels are easier to install on complex and cut-up roofs than standing-seam and through-fastened panels. They have excellent wind, hail, and fire resistance.



ATAS
Advanta Shingle

Classic Metal Roofing Systems
Slate Rock Oxford

Classic Metal Roofing Systems
Country Manor Shake

STANDING SEAM

Standing-seam panels can be installed over solid or skip sheathing (skip sheathing requires a thicker panel). Installation is often faster than modular panels, but slower than through-fastened panels, because standing-seam panels are generally narrower.

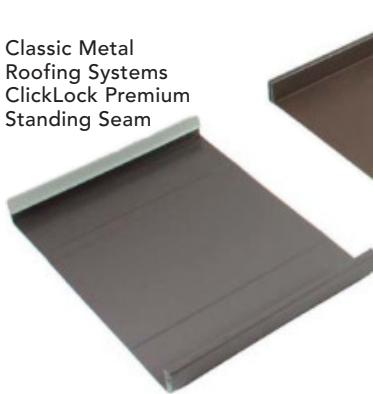
- Vertical panels attach to roof deck or purlins with screws through clips or prepunched holes along panel edges
- Fasteners fully concealed after installation is complete
- Seams join with a snap-lock profile or with a portable seaming tool

PROS Abundant choices for type of metal, panel profile, and finish

CONS More expensive than through-fastened panels.

COST \$8 to \$9 per sq. ft. installed (depending on metal, roof profile, and local labor rates), but may be \$20 per sq. ft. for copper and even more for zinc.

Classic Metal
Roofing Systems
ClickLock Premium
Standing Seam

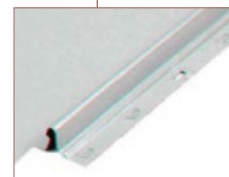


ATAS
Dutch Seam

Classic Metal
Roofing Systems
Universal Standing Seam



Clips... Some panels use hidden clips screwed to the roof deck to hold the panels in place and allow for expansion and contraction with changes in temperature.



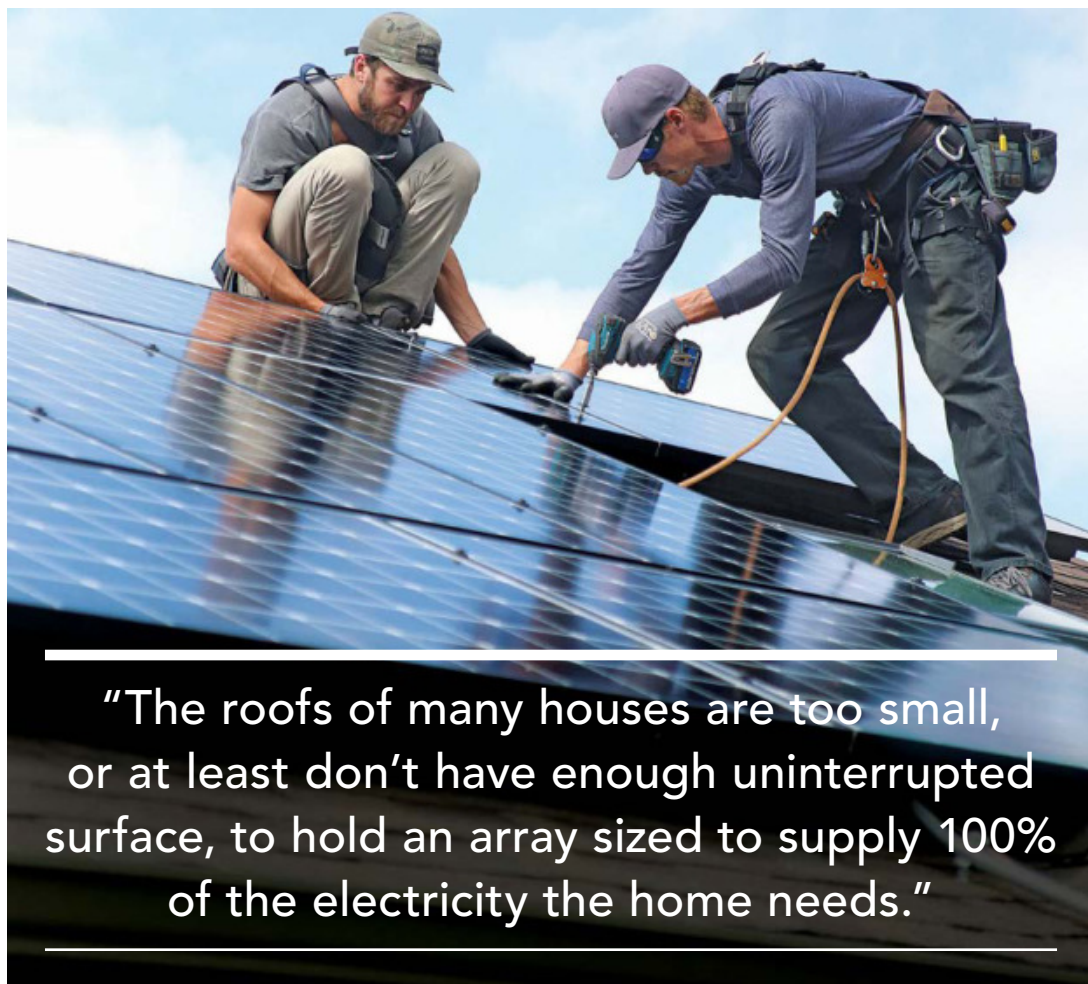
...and no clips. Some panels have a prepunched flange for screws. This doesn't allow as much movement, so is more common on steel panels, which expand less than aluminum.

Planning for solar panels

It's been interesting to watch the evolution of solar power over the last three decades—so many advances; a few stubborn hurdles. One thing that remains a constant is the importance of the right roof for the job. Too often, it seems, solar photovoltaic (PV) arrays are not part of the initial design plan but rather tacked on long after the fact. In his recent article, “Thinking Like a Roofer,” Martin Holladay writes, “Most architects lack a roofer’s eye. While a roofer delights in the sight of a simple uninterrupted gable, architects entertain flights of fancy: They come up with butterfly roofs, or flat roofs surrounded by parapets and scuppers, or complicated roofs interrupted by multiple valleys and dormers.” Therein lies the PV challenge.

According to Bill Brooks of Brooks Engineering, which does engineering consulting work for the solar industry, common problems associated with solar panels include: insufficient conductor ampacity and insulation, excessive voltage drop, unsafe wiring methods, lack of or improper placement of overcurrent protection and disconnect devices, use of unlisted or improper application of listed equipment (e.g., AC in DC use), lack of or improper equipment or system grounding, and unsafe installation and use of batteries.

But before all of that, there's the roof itself.



“The roofs of many houses are too small, or at least don’t have enough uninterrupted surface, to hold an array sized to supply 100% of the electricity the home needs.”

Design drivers

The roofs of many houses are too small, or at least don't have enough uninterrupted surface, to hold an array sized to supply 100% of the electricity the home needs. According to the team at ReVision Energy, a renewable-energy contractor that serves parts of New England, it takes about 75 sq. ft. of roof space for every 1kw of output from a solar array, and

about 5kw of output is required to supply all the electrical needs of the average home in their service area. That translates to about 375 sq. ft. of roof space needed to mount an array of sufficient size to meet all of the home's needs.

Many homeowners approach the sizing of a new PV array based on budget. With that in mind, the strategic architect will steer clients in the direction

of energy-efficient appliances as the starting point, as it is generally cheaper to install efficient appliances and a small PV array than it is to go with conventional appliances and a larger array sized to handle those electrical loads. Of course, heating and cooling loads, plug loads, and the domestic hot water system need to be hammered out before designing for a PV array.

The price of solar panels has

come down considerably over the last decade, and now hovers somewhere between \$3.18 to \$3.34 per watt, including installation and other fees. Myriad factors can make those numbers go up or down; regardless, factoring solar panels into the roof design has cost-savings potential.

"It's frustrating when providing a good solar roof is an afterthought," says solar design specialist Thomas Tutor of ReVision Energy, "especially when there are plans from the beginning for a home to be net-zero." Tutor advises designing an uninterrupted south-facing rectangular space devoid of dormers, vent pipes, chimneys, or other obstructions. It should match the geometry of the panels to allow for one clean plane with few gaps and little exposed roof. Once you start breaking up the array and spreading panels around, the system becomes less efficient, more expensive, and visually disruptive.

The optimal pitch for a PV array is the same as the location's latitude, though in general, Tutor says anywhere from 20° to 45° is a good pitch. While arrays typically produce more electricity in the summer due to the longer days, this output can be boosted further in those months on flatter-pitched roofs, since the sun is higher in the sky. That isn't optimal for winter electricity production, but in markets that have net-metering, which provides credit for excess energy generation, PV users can bank the credits to use in the colder months.

In addition to pitch, two other factors affect solar performance: orientation and shade. Orienting the panels to face south—180°—is optimal, though plus or minus a few degrees of that is still very good, as you are los-

ing just a few percentage points of production. But if the panels are in the shade, their pitch and orientation won't matter much.

"Many people are focused on the tilt and orientation," Tutor notes, "but the reality is, if you have a shade-free roof, then solar is going to be a good investment no matter the tilt and orientation."

Potential obstacles to optimal solar design also include vent pipes, which are not commonly drawn on new construction plans, so when plumbers come on board, they follow the path of least resistance, putting vent pipes wherever that might be. Sometimes that's on the south-facing roof.

"It's always disappointing when our team gets to the site to install the system and finds obstructions in the solar roof," says Tutor. "It means we need to redesign that system and it usually loses some output and performance."

Simple is sage

Ann Edminster, founder of the consultancy Design AVenues and a leading international expert on zero-energy homes, describes the roof as "an interesting element for architects," noting how it gets manipulated to "create interest." The problem, of course, is that those manipulations have implications. The introduction of additional corners, plane changes, angles, and difficult details drives up costs and results in thermal- and moisture-control-related compromises. "My biggest message is to simplify," she says, adding that designers should start with the end in mind. Factors such as a supertight building envelope and energy-efficient appliances that make it easiest to achieve

net-zero-energy performance need to be included in the early stages of a solar design. Like Tutor, Edminster makes the point that people get hung up on the idea of net-zero. "I think close is great—it's not a sin if you don't make it to zero."

Location impacts numbers

Assuming PV-panel systems have the same solar efficiency, the efficacy of a system is directly related to the amount of sun hours a geographical area gets during the year. The amount of solar radiation per day is measured in kilowatt-hours per square meter per day (kwh/m²/day). On average, northern regions of the U.S. get less than 4kwh/m²/day, whereas southern regions receive more than 5.75kwh/m²/day. In the southwest, where the air is dryer and there is less cloud coverage, more solar radiation makes it to the Earth's surface. On a 5000-sq.-ft. house, which is the average size of architect Armando Cobo's projects, he uses a 10kw system—between 30 and 34 3x5 panels—that's at least 450 sq. ft. needed for the panels alone, in addition to space for clearances, which might result in up to a total of 900 sq. ft. needed to accommodate the system.

Codes require clear roof space around panels and pathways up the roof for firefighter access, as well as space between the panels and other roof penetrations or features like skylights and plumbing vents—all of which Cobo accounts for in the design; he also specifies no-vent zones. And like all designers should, he plans around the requirement that panels not be installed in such a way as to reflect onto neighbors' fenestration or cladding.

Roofing material matters

For its energy efficiency, sturdiness, and durability, standing-seam metal is the most compatible roofing material for PV installations. It allows for an array to be mounted to the seams without any roof penetrations, and the clamps used are less expensive than the mounting hardware for an asphalt-shingle roof. However, metal is not always in keeping with the architectural style, and it's expensive.

Asphalt shingles are significantly less expensive, but they require many penetrations—typically one penetration every 4 ft. along the rail system on which the panels are mounted. That increases the likelihood of premature leaks, shortening the life of the roof. Plus, asphalt-shingle roofs have a lifespan of 15 to 20 years, which is shorter than that of most PV systems.

Mounting arrays on clay, slate, and concrete tile roofs is difficult because the materials are brittle and subject to breakage. Plus, in order to properly secure the panels, the installer needs to bolt the feet of the racking equipment directly to the roof, which requires removing the tiles. Cobo prefers to use standing-seam metal roofing where he wants to mount the array, and he will finish the rest of the roof in the chosen tile. He refers to this method as a "strip-and-go" installation.

It seems fair to surmise that all three designers are in favor of preconstruction planning, uncomplicated roof shapes, and solar-compatible roofing materials as key to the cost-efficiency and functionality of a good solar design.

Kiley Jacques is senior editor at Green Building Advisor.

KeepCraftAlive

CELEBRATING PASSION FOR BUILDING

Eleven years ago, Josh Ford took a pay cut to work for Namasté Solar. He had been remodeling houses, but that work wasn't doing anything for the planet. "With all the crap going on in the world," he says, "I wanted to feel like I was working for a better tomorrow."

Namasté Solar was founded in 2005 by three friends in Boulder, Colo. They started out delivering solar panels to job sites on bicycles. Today, 175 people work for the company, and nearly half of them are co-owners, including Ford.

The work—installing PV panels on existing homes—is dangerous, thanks to steep roofs and extreme weather. The first thing Ford and his crew do when they arrive at a job, before they even say "good morning" to the customer, is talk safety. They walk around the house and identify hazards, from overhead power lines to aggressive dogs. "We do this on every single job," he says. "We're not just clocking in, clocking out, and getting our paychecks. We all look out for each other. It's part of the culture."

Ford has been working with his hands since he was little. "My dad was always at work. So I was Mr. Fixit at six years old. It's in my blood." Now, he says, "I couldn't stand an office job. I love being outside, working with my hands and making customers happy."

"Going beyond what the customer wants, that's craftsmanship to me," Ford says. He wants people to look at the conduit he ran on the side of a house and know he cared. He wants them to say, "Wow, that guy really knew how to run that pipe."

— Kevin Ireton, editor at large

**"I want to
do something
that actually
makes a
difference."**

JOSH FORD
PV INSTALLER
BOULDER, COLO.



Keep Craft Alive is our campaign celebrating those who have chosen to passionately pursue a career in design, building, and remodeling. Find out more and show your support by visiting KeepCraftAlive.org, and use #KeepCraftAlive to share your passion for the cause.

FHB PRO TALK LIVE

Performance Building & Design

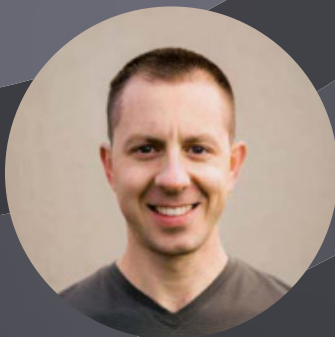
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