A Builder's Guide to

Smart Framing and Solid Subfloors

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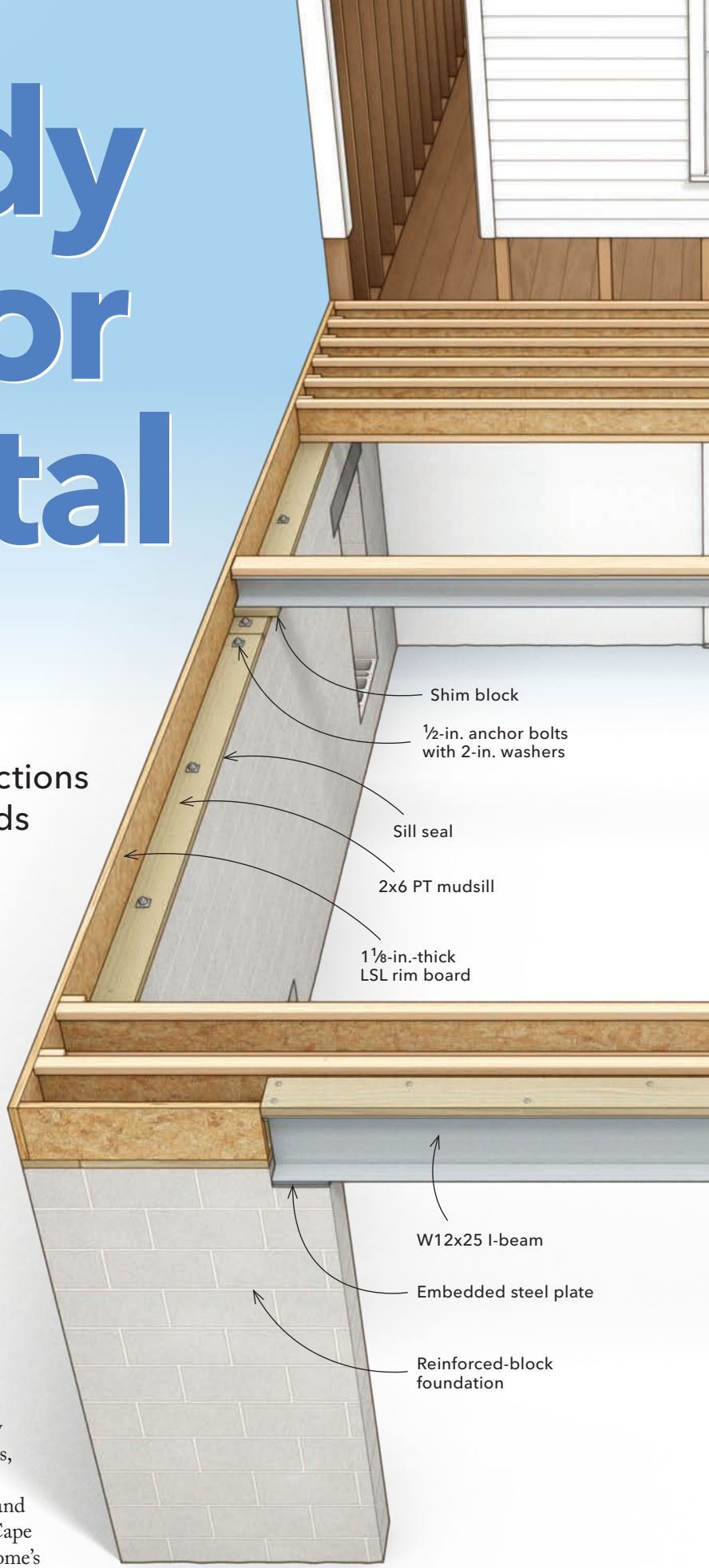
A Sturdy Floor for a Coastal Home

Structural steel and strong connections help a raised floor resist high winds and water

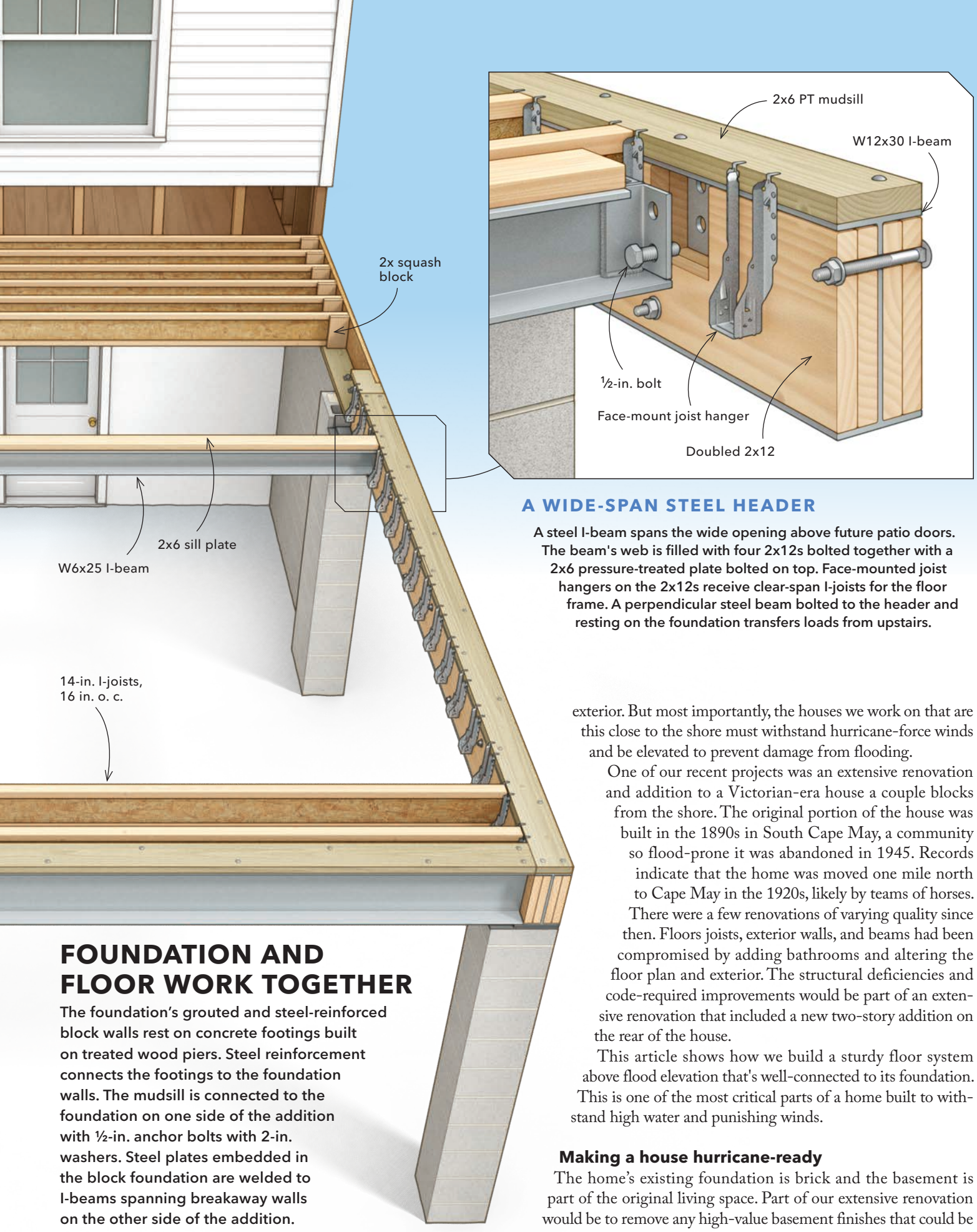
BY NATE ELDON

Cape May in New Jersey is the country's oldest seaside resort, hosting vacationers from Philadelphia and the surrounding area starting in the mid-18th century. Despite decades of coastal storms, much of the Victorian architecture is still here, making Cape May second only to San Francisco for its collection of highly ornate wood-frame buildings from the 1800s. My firm does a lot of renovation work on these old houses, which usually involves adding on to the original structure in the form of dormers, add-a-levels, and rear additions.

Even though the houses we work on are old, anything new (and much of the old) must comply with modern building codes and Cape May's strict zoning rules, which regulate any work that alters a home's



Drawing: Christopher Mills



A WIDE-SPAN STEEL HEADER

A steel I-beam spans the wide opening above future patio doors. The beam's web is filled with four 2x12s bolted together with a 2x6 pressure-treated plate bolted on top. Face-mounted joist hangers on the 2x12s receive clear-span I-joists for the floor frame. A perpendicular steel beam bolted to the header and resting on the foundation transfers loads from upstairs.

FOUNDATION AND FLOOR WORK TOGETHER

The foundation's grouted and steel-reinforced block walls rest on concrete footings built on treated wood piers. Steel reinforcement connects the footings to the foundation walls. The mudsill is connected to the foundation on one side of the addition with ½-in. anchor bolts with 2-in. washers. Steel plates embedded in the block foundation are welded to I-beams spanning breakaway walls on the other side of the addition.

exterior. But most importantly, the houses we work on that are this close to the shore must withstand hurricane-force winds and be elevated to prevent damage from flooding.

One of our recent projects was an extensive renovation and addition to a Victorian-era house a couple blocks from the shore. The original portion of the house was built in the 1890s in South Cape May, a community so flood-prone it was abandoned in 1945. Records indicate that the home was moved one mile north to Cape May in the 1920s, likely by teams of horses. There were a few renovations of varying quality since then. Floors joists, exterior walls, and beams had been compromised by adding bathrooms and altering the floor plan and exterior. The structural deficiencies and code-required improvements would be part of an extensive renovation that included a new two-story addition on the rear of the house.

This article shows how we build a sturdy floor system above flood elevation that's well-connected to its foundation. This is one of the most critical parts of a home built to withstand high water and punishing winds.

Making a house hurricane-ready

The home's existing foundation is brick and the basement is part of the original living space. Part of our extensive renovation would be to remove any high-value basement finishes that could be

A FOUNDATION BUILT FOR FLOODS

The rear addition's foundation has steel-reinforced 8-in. block walls and piers built on reinforced concrete footings on top of treated-wood piers driven into the sand. The sections of framed walls between the block masonry are designed to give way during flooding. This equalizes water pressure on the inside and outside to keep the house standing during floods. Flood vents in the older parts of the house work similarly.

1 • TRANSITION TO STEEL

The steel I-beams are connected to the foundation with steel plates, called embed plates. The 8-in. by 8-in. plates have steel legs welded to the underside that are grouted into the block walls by the masons who lay the block. The I-beams will be welded to the plates later.

2 • CHECK THE HEIGHT

The 2x6 mudsill plate that will sit on top of the steel I-beam is designed to be flush with the top of the floor joists to receive the floor sheathing. Steel shims welded on top of the embed plates will bring the sill plate flush with the top of the floor joists and allow the sill to be leveled.

damaged from flooding and replace them with more water-resistant materials. The basement would be a convenient and expansive space in which to store bikes, beach gear, and outdoor furniture.

We also had to raise electrical service and mechanical equipment above the design flood elevation (DFE), which is meant to keep HVAC and electrical components—and the floor system—above water during a severe flood. For this house and much of Cape May, the DFE is 10½ ft., which is 2½ ft. above the base flood elevation (BFE) of 8 ft. Flood maps assume that there's a 1% chance of a flood equaling or exceeding the BFE in a given year. The BFE for different areas can be found on FEMA's website (fema.gov). DFE is determined by the municipality and is higher than BFE to minimize damage from flooding. Flood elevations are based on historical record, but they've been raised in recent years to compensate for the greater regularity of severe coastal storms. Local officials can help determine the DFE where you're building.

Steel solves problems

In both our renovation and new-construction projects, structural steel is increasingly common for beams and headers for several reasons. Steel is much stronger than wood or engineered lumber of the same depth, allowing us to tuck flush beams into shallow assemblies and still carry big loads. It also lets us span longer distances for expansive rooms and extrawide window and door openings. In areas with height

3 • PREP FOR PLATES

Drilling holes in heavy steel on-site is time consuming, so instead we have the metal fabricator drill the components. This allows us to more easily attach wood plates and nailers to the steel I-beams and columns.

4 • BUILD BEAMS ON THE GROUND

The steel I-beam that recieves the joists has a web about 11½ in. tall. We pad out the predrilled web by bolting a pair of 2x12s to both sides, and then attach the face-mount I-joist hangers at 16 in. on-center with a connector nailer.

5 • FIELD-MODIFY

When we went to pad out the I-beam's steel web with lumber for hangers, we realized the fabricator had made the beam too long. Instead of sending it back to the shop, the installation crew used an oxy-acetylene torch to trim the beam on-site.

STEEL SPANS THE GAPS

The steel I-beams that span the large openings in the foundation walls restrain the tops of the walls to keep them from toppling in a flood and also carry the load from the floor system, walls, and roof above to the foundation. An additional steel I-beam near the center of the floor continues a load path from the upstairs.

1 • SET ONE SIDE OF A CORNER

A telehandler or crane is needed for lifting the steel components. We use a telehandler to help the steel fabricators set and level the steel I-beam that sits parallel to the floor joists. This 12-ft. 8-in. beam weighs more than 300 lb.

2 • MARK THE MUDSILL

Pressure-treated mudsills connect the floor joists to the block foundation. While the steel crew prepares to lift and place the beam that receives the floor joists on the opposite side, we drill the mudsills for the ½-in. anchor bolts and lay out the joists.

3 • SET THE OTHER SIDE

With the beam's web padded with lumber, the top flange plated, and the face-mounted hangers installed, the beam is lifted and guided in place by workers on both ends. Fully prepped, this beam weighs between 700 lb. and 750 lb.

4 • CHECK THE HEIGHT

The top of the beam must be flush with the top of the floor framing. We check the height and then calculate the amount of steel shims needed to raise the beam so it will be flush with the top of the joists. The shimmed connection will be welded later.

restrictions and an amazing water view like Cape May, designers and clients want to maximize a home's interior volume, and the thinner steel beams are less intrusive on views and living spaces. In addition, our projects sometimes use steel moment frames, which are basically steel rectangles or "U" shapes bolted together to help the building resist wind and shear loads.

In our new-home builds and renovations, the project architect works with an engineer to specify the steel- and wood-frame assemblies as part of their plan set. As GC, I work with a steel fabrication shop to have the parts made and assembled on-site. Generally it takes a few weeks for them to make the parts and schedule the job-site installation. Depending on the complexity, it may take a few hours to a few days to install a home's steel work. Setting the steel beams and connecting them took a few hours on this project. It took a few hours more for my crew and me to frame and sheathe the I-joist floor.

Steel design and fabrication

The architectural firm that designed this renovation project has their own engineering team that specified all of the steel-beam sizes, shear nailing, and structural connections. Other architects in my market use separate engineering firms for the same work. There doesn't seem to be a big advantage to either arrangement, but in-house teams can usually answer questions and make changes with less back and forth

5 • BRING IN CONNECTING BEAMS

This steel beam parallel to the floor joists supports the first- and second-floor bedroom walls. Beam-to-beam connections are often bolted. The crew will hand-tighten the bolts on this end and then level the beam by shimming the other end.

7 • MARK A LEVEL LINE

We use a rotating laser to establish a level reference line around the foundation. We measure from our reference line to the top of the beam and shim it to match the height of the bolted connection on the other end.

6 • MAKE IT SQUARE

Once the steel components are in place, the corner is squared using the previously squared mudsills for reference before the I-joists are installed. Often brute force can move a beam, but sometimes one may need to be lifted slightly with a crane or all-terrain forklift.

8 • SHIM TO MATCH

The height of steel components is often different from standard sizes of sawn lumber and engineered joists. The discrepancy may require adding shims, plates, or both to level the wood and steel elements.

STRONG CONNECTIONS TIE IT TOGETHER

Sturdy connections where different parts of the house come together are critical for the house to withstand the stress of high winds and water. The engineer and architect specify the connection details. The steel subcontractor and our framing crew build to the plans, and the local inspector checks the work as part of the framing inspection.

1 • SECURE THE MUDSILLS

The anchor bolts have 2-in.-square washers to prevent the bolts from pulling through the mudsill with high winds or flood water. This foundation was within ⅛ in. of square and level, so we were able to bolt the mudsills to the foundation without shims.

3 • MAKE WELDED CONNECTIONS

The I-beams and any shims under the beams are welded to the embed plates by the steel crew using an arc welder. Once welded, the joints are cleaned of welding slag and then sprayed with a corrosion-resistant primer to prevent rust.

4 • INSTALL JOISTS

14-in.-deep I-joists span a little over 16 ft. from the masonry wall to the I-beam that receives them. The joists are nailed with 2½-in. nails through the bottom flange into the mudsill. The engineered rim board and wall sheathing will add additional strength to the connection of exterior walls, floor system, and mudsill.

2 • MAKE BOLTED CONNECTIONS

When the steel beams are in their final position, the bolts connecting steel components are fully tightened. Once a bolt is sufficiently tight, the electric wrench snaps off the end of the bolt as a visual indicator that the bolt has been tightened.

between the architecture and engineering professionals. Once you've worked with a specific design professional a few times, you start to notice their favorite structural solutions and connection details. The experience helps us more accurately estimate build time and cost.

Around here steel fabricators familiar with residential wood-frame construction are pretty common, but if you can educate yourself as to how steel construction works, everything will go a bit smoother. I recommend first learning how to interpret the steel descriptions in plans and catalogs so you can determine the dimensions of any specified beam, column, or channel. A basic understanding of how the components are bolted and welded together is also helpful. The steel fabrication shops I've worked with can drill and make other provisions for fastening wood components to the steel. Take advantage of these options, which make integrating steel beams and columns into typical wood-frame construction much easier.

If you're a builder or designer hesitant to use steel because of a lack of experience, I'd say give it a try, as it's not as different from engineered lumber as you might imagine. The big difference is that steel beams are smaller, making them easier to integrate into the rest of the building. I would also encourage anyone interested in ornate old buildings to come to Cape May for a visit. □

Nate Eldon is the owner of Eldon Builders in Stone Harbor, N.J. Photos by Patrick McCombe.

5 • ADD SQUASH BLOCKS

Short pieces of 2x6, often called squash blocks, transfer loads from roofs, floors, and walls around the floor system to the mudsill. The blocks are nailed to the top and bottom flanges with 8d common or 10d box nails.

6 • SNAP A LAYOUT LINE

We mark 4 ft. in from the outside edge of the engineered rim board on both ends of the addition and then snap a chalkline between the marks. The snapped line is where we align the interior edge of the subfloor.

7 • APPLY ADHESIVE

High-quality subfloor adhesive prevents squeaks and is critical for the floor's strength, making it part of the floor system's instructions. Using a ⅜-in. bead, we apply enough adhesive for a sheet or two of subfloor. Adhesive that has partially dried (skinned over) will compromise the bond.

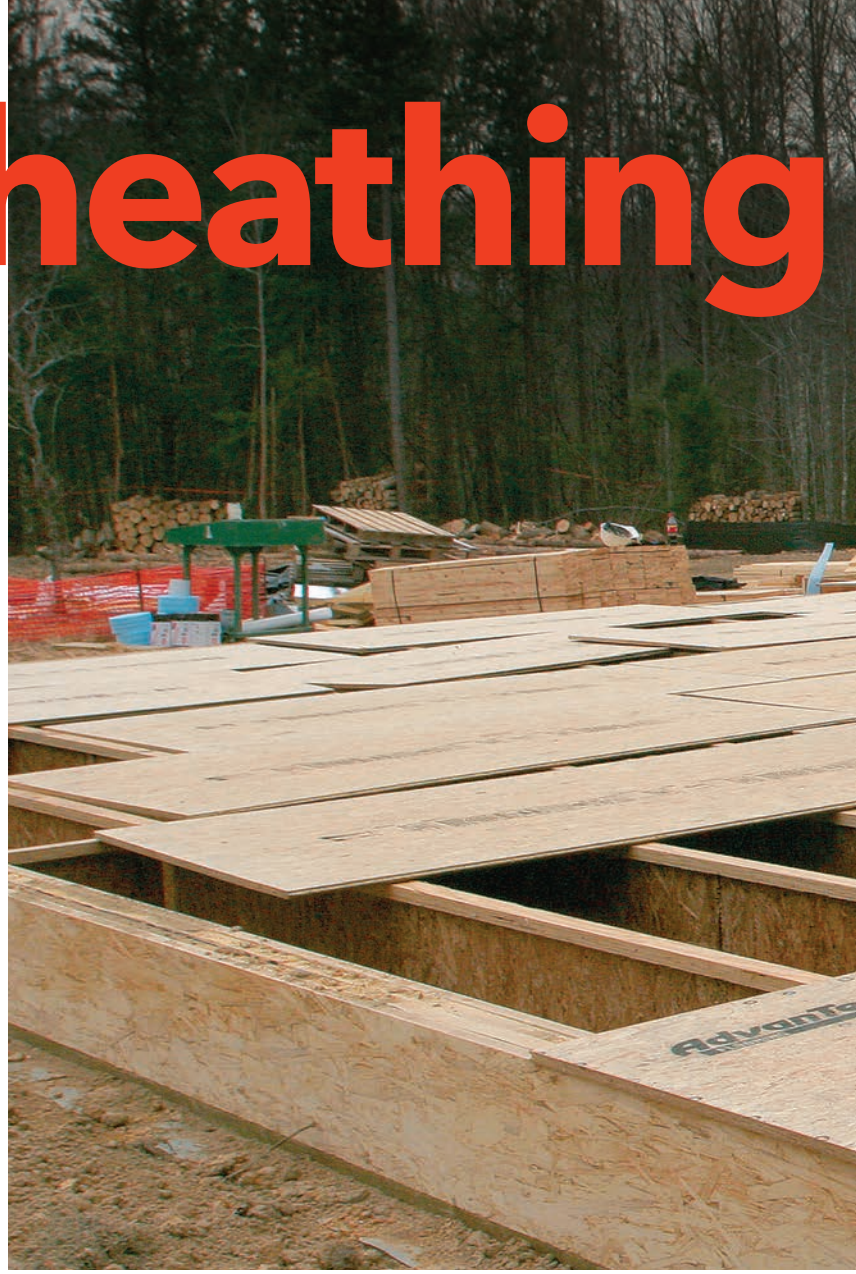
8 • INSTALL THE SUBFLOOR

Starting at the outside corner with the subfloor tongue toward the exterior, we install the subfloor in rows, working toward the other side of the addition. We stagger the seams by 4 ft. and nail the subfloor with 2-in. ring-shank nails every 8 in.

Floor Sheathing

Working together, a four-person crew finishes a subfloor in an hour

BY DANNY KELLY



As a carpenter turned general contractor, I'm always happy when we start installing the subfloor on the first level of a new house. Floor sheathing means that we can finally stop slogging around in the mud and will soon have a nice level surface for setting up tools and ladders. Sheathing a floor like the 1800-sq.-ft. one shown here can take all day with an inexperienced crew, but the crew I work with was able to bang out this floor in a little under an hour.

On most houses, the longest exterior wall perpendicular to the floor joists is the place to start sheathing a floor. With a four-person crew, two carpenters move and cut panels, and two place and nail the sheets to the joists.

We cut the sheets to length after they've been nailed in place; this is faster and eliminates layout and measuring mistakes. We're careful to cut floor sheathing flush with the band joist. Otherwise, overhanging pieces will prevent the wall sheathing from fitting tight to the band joist. To get the sheets to fall on the center of the floor joists, subtract ¾ in. from the first joist cavity. Then the first sheet can start flush with the band joist without any waste. □

Danny Kelly of Kelly McArdle Construction is a home builder and remodeling contractor in Charlotte, N.C.

HOW TO PUT DOWN A SUBFLOOR FAST

Two carpenters move panels and make cuts while two position, glue, and nail the sheets. While one sheet is nailed, another is dragged into place.

Line up the edge of one sheet with the previous sheet, making sure that all the tongues and all the grooves are facing the same direction. (The author's crew starts with a tongue toward the outside wall.) Don't drag the panels through the adhesive.

Drop the panel onto the joists as close to its final position as possible; otherwise, you'll mess up the subfloor adhesive when you slide the panel into place. It doesn't matter whether you drop the tongue or the groove edge.

Photos: Patrick McCombe

Done Right

LAY DOWN A WORKSURFACE

It's too dangerous to walk on the tops of joists while sheathing a subfloor, so create a worksurface by covering the floor joists with as many sheets of tongue-and-groove sheathing as you need to move around safely. Arrange the panels so that all the tongues and all the grooves are oriented consistently. Start with a full sheet on the corner of the longest exterior wall perpendicular to the joists. The next row starts with a half-sheet. One pair of carpenters should keep laying and nailing down full sheets while another pair stocks the floor with full sheets, and cuts and places partial sheets. Alternate full sheets and half-sheets to start each row (photo right). Some sheathing (left) has marks indicating common on-center spacings.

One carpenter moves the sheet so that its leading edge is lined up with the adjacent sheet. The nail-gun operator tacks the corner with a single nail, then pauses while a teammate moves the other end into position.

With the sheet in position, the nail-gun operator drives a nail or two to lock the sheet in its final position and then nails the rest of the sheet. With an experienced team, positioning and tacking take seconds. Panels overhanging the edge of the band joist will be cut in place later.

RUN WILD!

Save time, and eliminate layout and measuring mistakes by cutting odd-shaped panels in place. The first piece in a row will be a full sheet or a half-sheet, but the last piece at the opposite end likely will be an odd-width offcut.

Measure from underneath; snap lines on top. *Feed a tape measure under the panel until it hits the band joist. Transfer the measurement to the top of the panel, and snap chalklines to guide a circular saw. Set the blade so that it just cuts through the subfloor and doesn't damage the band joist.*

Put off cutting when you can. *When possible, save the job of cutting unusually sized panels like the ones around this crawlspace opening until you've finished laying all the sheets. Cutting odd-shaped panels is a good job for less experienced carpenters while the more senior carpenters move on to snapping lines and laying out plates for wall framing.*

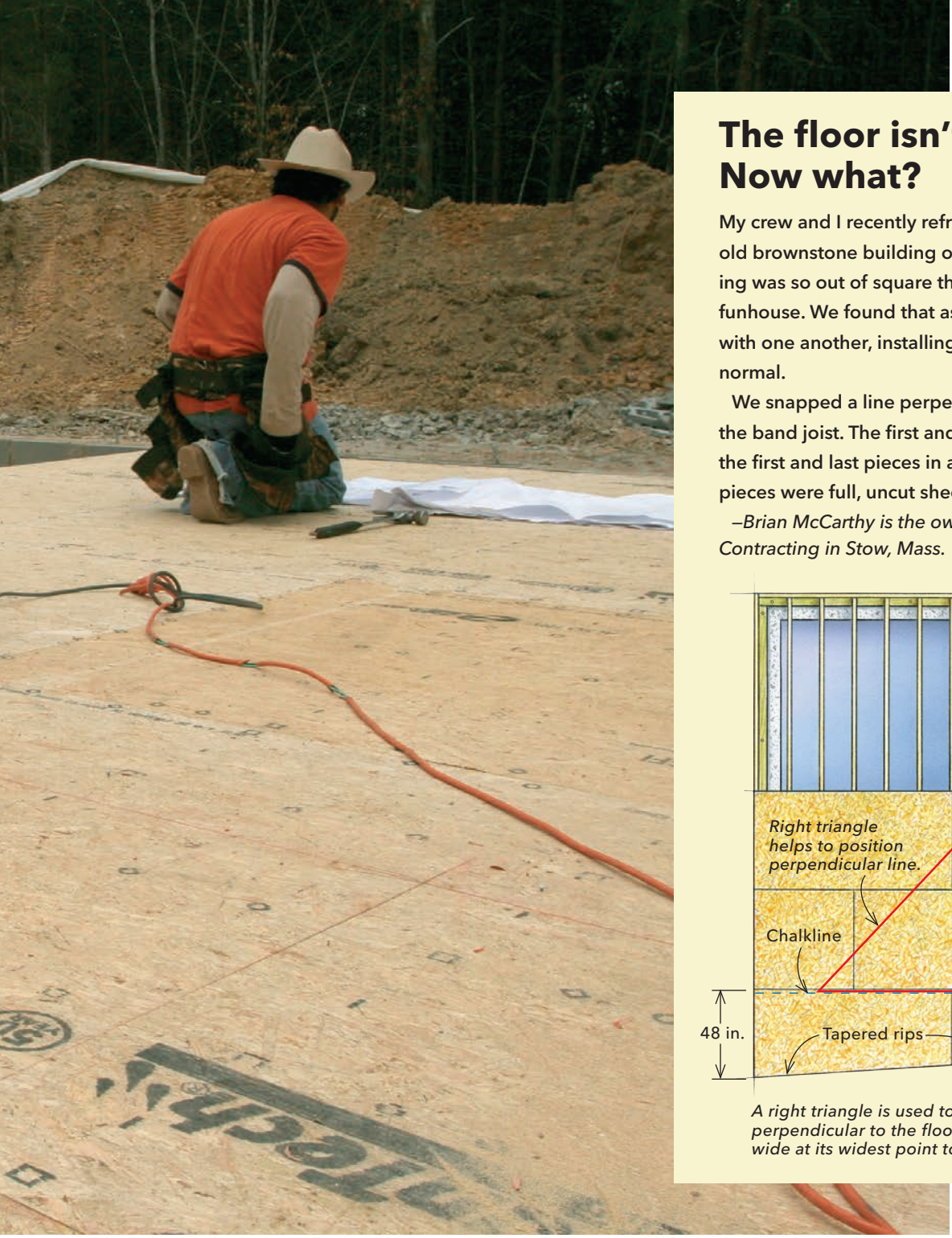
DOS AND DON'TS

Do use a sledge sparingly. *The tongues and grooves on subflooring are designed to gap panels properly, so the panels shouldn't be beaten together except when the tongue has been damaged by rough handling. When that's the case, use a sledgehammer to get the sheets to meet up. A board prevents the hammer from doing additional damage.*

Don't mess up the glue. *To prevent smearing the subfloor adhesive, stand the sheet on edge in the proper spot, and let it drop into the glue. A well-timed pull with your foot helps keep the panel edge close to the previous row.*

Do check the joist spacing. *Warped joists don't necessarily line up with on-center spacing, so check the spacing before nailing, then use a hammer to coax joists into the proper position. Subflooring with spacing marks saves time.*

Drawing: Don Mannes



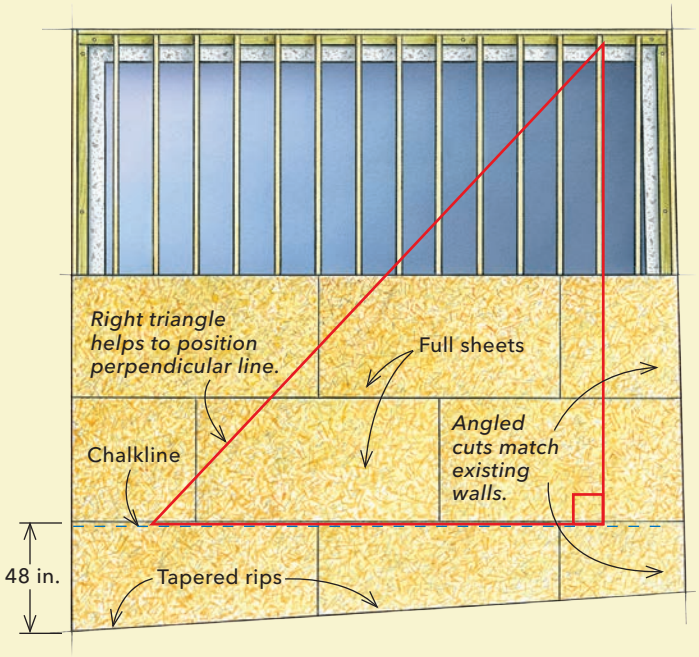
The floor isn't square. Now what?

By Brian McCarthy

My crew and I recently reframed the interior of a 100-year-old brownstone building on Beacon Hill in Boston. The building was so out of square that it was like building in a carnival funhouse. We found that as long as the joists were parallel with one another, installing the subfloor could proceed as normal.

We snapped a line perpendicular to the joists 48 in. from the band joist. The first and last rows were tapered rips, and the first and last pieces in a row were angled. All the field pieces were full, uncut sheets.

–Brian McCarthy is the owner of McCarthy General Contracting in Stow, Mass.



A right triangle is used to create a reference line perpendicular to the floor joists. The line should be 48 in. wide at its widest point to match the panel width.

Don't let the glue dry. *Apply only as much glue as can be covered with sheathing quickly. Save time by cutting the plastic nozzles on the glue tubes all at once. (An inner seal keeps the opened tubes from drying.) Water-based adhesives, which are more environmentally friendly, work better than they used to, but solvent-based adhesives are still more forgiving in wet weather.*

Do use enough nails. *Nail subfloor panels every 12 in. in the field and every 6 in. along panel edges. Keep fasteners ⅜ in. from panel edges for maximum hold. For ¾-in.-thick sheets, use 8d (2½ in.) common nails or gun nails approved by local code. The author uses ring-shank nails and adds screws once the house is dried in.*

Fast, Accurate

A rear addition provides a small-scale example of how to frame efficiently

BY NATE ELDON

My construction company specializes in custom homes and major renovations in and around Cape May, N.J., one of America's oldest seaside resorts. The area is renowned for its Victorian architecture, much of which is preserved in the original downtown. It will come as no surprise to builders specializing in custom homes for discerning clients that interiors must have tight-fitting trim and casework, and that hardwood flooring and tile must be straight and square to walls and interior elements. Properly aligned siding and trim is a similar requirement on the outside.

All of these things require walls that are straight, square, and plumb. It's easy to make such walls if you have unlimited time, but we have to frame efficiently to be

Wall Framing

SET THE STAGE

The lead carpenter generates a list of cut parts early in the process so that the crew can get right to work without a wait. Before framing begins, the lead figures out the order in which the walls will be raised so that walls already standing won't interfere with raising the next ones. After snapping lines showing wall locations, the lead cuts top and bottom plates and arranges them in their final locations on the subfloor.

CUT TOP AND BOTTOM PLATES Before we start framing walls, we cut all the top and bottom plates for the exterior and interior walls and place them on the subfloor in their final location. This ensures the walls will fit correctly once framed.

CUT FROM THE STACK
Whenever space allows, we use our forklift to bring framing to where it's being used, saving a lot of time. We make sure delivered material is kept off the ground so we can get the forks underneath.

QUALITY CHECK
Once the plates are cut and arranged, check that their length matches the closet and room dimensions in the plans. Also, confirm that interior plates match the wall thickness. Plumbing walls and those with pocket doors may require 2x6s instead of 2x4s.

MAINTAIN ACCURATE SPACING When the 16 in. on-center layout doesn't start at the end of a plate because of an opening or abutting wall, Doug finds the first stud location and drives a nail to hook his tape on. From here he can mark stud layout as usual.

MARK THE LAYOUT
While Doug lays out the plates, other carpenters cut jack studs, cripples, and headers for doors and windows. They also nail together corners and built-up posts for point loads.

FRAME OPENINGS FIRST

The correct location of windows and doors is critical, so the lead carpenter locates headers according to the plans and has the rest of the crew complete the opening.

FASTEN THE HEADER We start by attaching headers to the top plate. On this wall, each header is a doubled 7¼-in. LVL with a 2x6 on the bottom. With a double top plate, this places the opening about 12 in. from the ceiling.

NAIL ON KINGS With the top plate upside-down, we nail the king studs to the ends of the headers for all of the wall's openings.

CONNECT TOP AND BOTTOM PLATES We nail the plates to the corners, king studs, and any posts connecting load paths through the wall.

NAIL ON JACKS With the king studs fastened to the bottom and the header, we install the jack studs that support the header. These small windows only need one jack; wider openings will need additional jacks.

INSTALL CRIPPLES AND ROUGH SILLS Cripples and rough sills are cut and nailed in place last. When possible, we make blocking and cripple studs from offcuts to reduce waste. A second subsill provides nailing for a wide apron or casing.

DOUBLE THE TOP PLATE Whenever possible, we nail on sections of double top plate while the wall is on the floor. We leave a gap at corners and at intersecting walls where the double plate overlaps the joint, strengthening the connection where walls meet.

QUALITY CHECK
Talk to clients and designers about their plans for window treatments and future decorating. It's easy to add blocking as walls are framed but increasingly difficult as the build progresses.

Drawing: Christopher Mills

competitive in our market of skilled builders. Our framing crew is led by Doug Hicks, a production framer who has worked here in New Jersey, in Arizona, and in various spots on the West Coast. I started out as a production framer myself right after college, during the building boom of the early 2000s. The things Doug and I learned on production crews help us to be efficient, while our focus on quality is what satisfies clients and designers and makes the rest of a custom-home build easier.

Before we begin

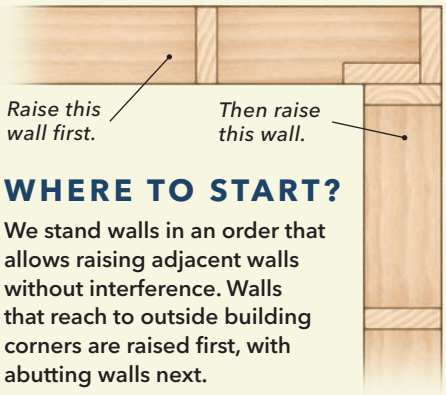
For me, the single most important factor in framing efficiency is eliminating rework. I'm not talking about client changes; those are nearly impossible to control. I'm talking about redoing steps or fixing mistakes later. Simply put, it's much faster to get it right the first time. To make sure that happens, our lead carpenters check over the plans a couple times leading up to the framing project.

The first check involves developing a materials list for the framing project to make sure everything will be delivered in sufficient quantities and on time. For a lead carpenter, like Doug, this is often the best way to get familiar with the project. Lumberyards and some suppliers can produce decent takeoffs, but at the end of the day, it's the crew leader's responsibility to make sure that the material is correct and there's enough of it. Calculating what's needed for a day of framing work requires thinking through all the steps and the material needed to complete them. Once the order is delivered, he makes sure every-

RAISE THE FIRST WALL

We often sheathe walls before raising them, but because of limited space on this project, we decided to sheathe later as part of framing the roof and building the overhangs.

ADD BLOCKING The best time to install blocking for panel edges and finishes is when the wall is lying down. We also nail scraps to the band joist to prevent the wall from sliding as it's raised.



WHERE TO START?

We stand walls in an order that allows raising adjacent walls without interference. Walls that reach to outside building corners are raised first, with abutting walls next.

RAISE THE WALL We lift the wall enough to get a pair of blocks under the top plate so we can get our hands around the top of the wall. We lift the wall until it's vertical, and then we hold it there while it is braced.

BRACE IT PLUMB Diagonal braces on both ends hold the wall upright while we build and raise the other exterior walls that form the room addition. We don't plumb it fully at this point–just enough to keep it upright. We'll plumb and straighten the walls when they've all been raised.

NAIL THE BOTTOM PLATE Gable walls like this one are nailed to the band joist through the bottom plate. Eave walls are nailed to the band joist and the floor joists with pairs of nails for added strength.

QUALITY CHECK
Have a quick look at the wall to see if window openings and studs look straight and match the elevations. Check that blocking, posts for point loads, partition pockets, and corners are in place.

FRAME THE SECOND WALL

The second wall we frame is perpendicular to the first. Raising a pair of exterior walls in an L-shaped arrangement makes the walls largely self-bracing and keeps them out of the way for subsequent framing.

LAP PLATES ON HEADERS For longer walls, we like to splice top plates on top of headers, which makes a sturdier connection than landing on a single or double stud.

FRAME OPENINGS FIRST Like the first wall, we frame the openings first. We attach the headers to the plate and then nail on king studs before laying the wall back down to fasten the bottom plate.

QUALITY CHECK Check that studs and wood components are in the same plane and that components are fully nailed. Any framing cavities that will be inaccessible after walls are standing should be air-sealed and insulated.

FILL IN THE STUDS One carpenter lays the studs near the layout marks while two others line up the studs and nail them in place. Experienced crew leaders are always thinking about next steps to keep the work moving without slowdowns.

FIX IT NOW, NOT LATER Doug takes a few minutes to pull nails and correct this misaligned jack stud. With the nails out, he uses his hammer to lever it into the same plane as the rest of the wall. Compared to time spent on fixes later, this is time well spent.

FILL IN THE TOP PLATE Once the wall is raised, we fill in the missing sections of double top plate, tying the corner and intersecting walls together.

thing is there before scheduling the work with our crew.

The second check comes a day or two before framing begins, when Doug decides in what corner of the building the floor, wall, or roof layout will start and in what order the work will progress. Spending a half-hour making these decisions on the day kills morale and costs a lot of money when the whole crew is waiting to work. Generally, we start with the longest exterior wall and then build the second wall to form a corner on one of its ends. But if starting with the longest wall prevents access with our all-terrain forklift, we'll start with another wall, like we did on this project. In any case, we always build the first two walls in an L-shape for stability.

Inside and outside corners are arranged so walls that are already raised don't interfere with raising and placing the others. For example, on this project, we first raised the gable end, which fully reaches to the building corners. The eave walls butt into the gable wall, so they are raised after the gable is up (see "Where to start?," p. 18).

Have a plan

Every lead goes about this a little differently, but when it's time to start framing, whoever is running the show should be ready and organized. For wall framing, in addition to knowing where to begin and the order the walls will be raised, the lead should have cut lists with dimensions and quantities for headers, jacks, and cripples for window and door openings.

OPENINGS FIRST, ONCE AGAIN This wall has patio doors and windows that look out on an elevated deck. We frame the openings first and then fill in the studs around them, using the same methods as the other two exterior walls.

FRAME THE FINAL WALL

We left this wall for last because of its location; it was easier and faster to pull studs from our forklift while building the other walls.

LOOK FOR WANE Framing lumber with wane is cut from a part of the tree that's resistant to twist, making these studs perfect for use around window and door openings. Orient the wane so that it faces another stud to prevent the missing corner from affecting trim and finishes.

RAISE THE LAST WALL With the framing complete and blocking for sheathing edges in place, we lift the wall, creating the three-sided exterior of the home's rear addition. It's nailed to the adjacent wall and to the band joist and floor joists.

QUALITY CHECK
Check that all walls are on their layout lines. Headers, posts, and other wood-framed load-path elements should be in place before standing interior walls. Install hardware and metal connectors where interior walls will prevent easy access later.

FRAME INTERIOR WALLS

Once we start standing interior walls, the space quickly becomes too small for framing, so we build most or all of the interior walls before we start raising them.

PLATES PREVIOUSLY CUT While we framed the exterior walls, we put the plates for the interior walls aside. Doug pulls them back out and marks the layout while the crew puts away the 2x6 exterior studs and gets a load of 2x4s for the partition walls.

FRAME LONG WALLS FIRST We frame partitions and interior bearing walls on 16-in. centers using methods similar to those used for the exterior walls. A partition pocket framed with a 2x6 and 2x4s on their sides will receive an interior 2x6 plumbing wall.

FRAME SHORT WALLS LATER Even short walls take up a surprising amount of space, so we frame them close to where they will stand, sometimes on top of longer walls.

LONG GRAIN FOR SHORT CRIPPLES Short cripples above openings tend to split when nails are driven into both ends. We cut cripples that will be 5½ in. or less from rips of framing stock so the nails are going against the grain, which reduces splitting.

DON'T GET BOXED IN We try to stand all the long walls first and then connect shorter perpendicular walls to the longer walls for stability.

QUALITY CHECK Make sure all walls are framed to the right thickness (2x4, 2x6, or otherwise) and are on their layout lines. Confirm interior walls have load-path elements and correctly sized openings.

There should also be accurate counts on how many two-stud (California) corners, built-up posts, and U-shaped partition pockets are needed. With this information ready, crew members can cut and assemble those parts while the lead focuses on layout.

The project shown here is a rear kitchen addition to a Victorian home built in the early part of the 20th century. You can see how we framed the elevated floor system in "A Sturdy Floor for a Coastal Home" (p. 3). We framed the floor square and straight, which also helped to make the walls and roof straight and square. This isn't a big addition, but we used the same steps and methods to frame this kitchen and two bedrooms that we use on a whole-house build.

The photos here show us building three exterior walls. The fourth wall of this addition is the former rear wall of the existing structure, with a new larger opening connecting the new and old parts of the house. An expansive opening in an old house is a subject for another article, but as you'll notice, the new and old floors don't line up. The kitchen addition includes a step up so that you can stand up in the storage area below.

Framing the 8-ft.-tall interior and exterior walls for the first floor of this two-story addition took a little more than half a day. All the finishes looked great at the end of the project, with nothing to fix or change later—all because the frame is straight and square. □

Nate Eldon owns Eldon Builders in Cape May, N.J. Photos by Patrick McCombe.

PLUMB EXTERIOR WALLS We attach one end of a diagonal brace before using a spring brace and a 12-in. cat's paw hooked over a nail to push the top of the wall over to make it plumb. Once the wall is plumb, we nail the diagonal bracing into several studs to hold it straight.

STRAIGHTEN AND BRACE

Once all the walls are nailed to the floor and adjacent walls are tacked together, we plumb and straighten the exterior walls, which helps to plumb the interior walls connected to them.

SPRING-BRACE SOLUTION Spring braces are nailed at the top of the wall between the top plate and double top plate. The brace is sprung with an upward curve to move the wall in or with a downward curve to push the wall out. Once the wall is in the correct position, the brace is nailed to the floor to hold the wall in place.

STRAIGHTEN EXTERIOR WALLS With the corners plumb, we sight along the tops of the walls to ensure they're straight, making adjustments with braces. We use a string for longer walls, but a discerning eye is faster and accurate for walls around 20 ft. or less.

PLUMB AND STRAIGHTEN INTERIOR WALLS Interior walls are straightened much like exterior walls, starting with the longest ones. We use a plate level to check for plumb and spring braces to move resistant walls into the correct position. Diagonal bracing holds them plumb while we build the floor or roof on top.

QUALITY CHECK After plumbing and straightening, check that all connections are complete. Fully fasten corners and intersecting walls. Check that bottom plates are securely nailed to the floor system, and that all double top plates are in place and nailed.

6 Ways to Stiffen a Bouncy Floor

Minor floor deflection absorbs the impact of your steps, but too much movement can be troublesome

BY MIKE GUERTIN AND DAVID GRANDPRÉ

If you haven't fallen into the basement of your house already, don't worry; your bouncy floor is probably not an indication of a disaster waiting to happen. Floor deflection is common in older homes because the floor joists often are smaller or are spaced farther apart than the joists in modern homes.

Of course, new homes also can have bouncy floors if the joists are approaching the maximum spanning distance for the weight they are supporting. Long-span joists may meet design criteria and the building code, yet still feel uncomfortable.

Some deflection in floors is good

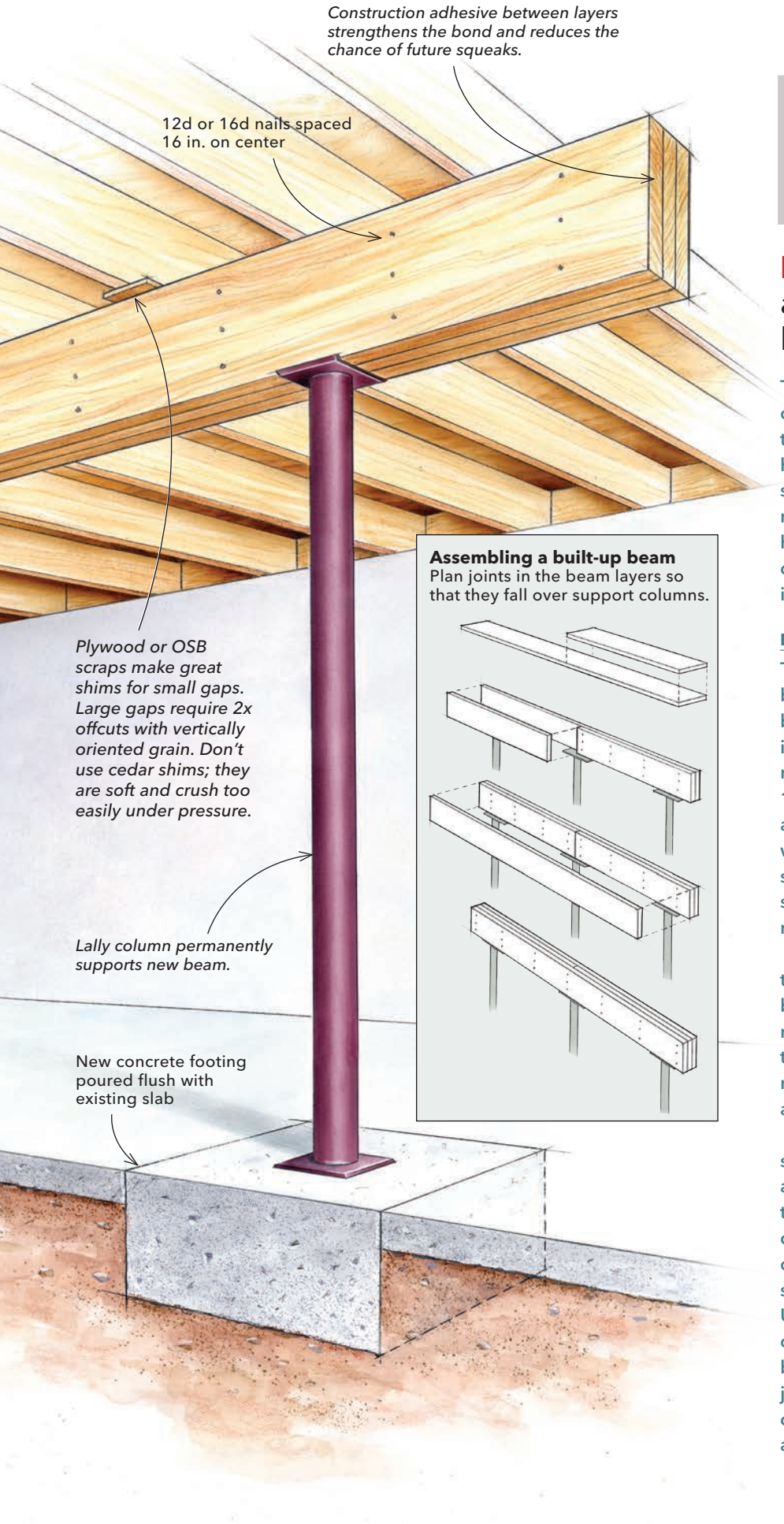
A well-designed wood floor feels stiff as you walk on it but still gives slightly under foot, absorbing some of the impact of your steps. Too much bounce, though, can make the china cabinet wobble. You can shore up floor joists and reduce the bounce in a number of ways, but the six methods outlined here represent a mix of common and not-so-common solutions. The best choice depends on access to the joists, obstructions in the floor system, or current remodeling plans; one technique or a combination may be your most practical solution.

It's important to make these improvements carefully. If existing joists have been weakened due to rot or insect damage, glue and fasteners won't hold well, and your work may be ineffective. Loose blocking or an underfastened subfloor won't bring any benefit, so take extra time and care during installation. Also, you can use jacks to relieve the load on joists while the work is being done. Jacks improve the effectiveness of your floor-stiffening work. □

Long post-shore jacks *are useful for several of these suggested stiffening strategies. They vary in price, depending on lifting capacity; prices start around $25 apiece (www.ablebuilders.com).*

Mike Guertin is a builder, remodeler, and contributing editor to *Fine Homebuilding* from East Greenwich, R.I. David Grandpré is a professional engineer Photos by Mike Guertin, except where noted.

Drawings: Don Mannes. Photos facing page: Daniel S. Morrison.



Assembling a built-up beam
Plan joints in the beam layers so that they fall over support columns.

[1]

Built-up beams are rock solid but reduce headroom

This solution works best in crawlspaces where you aren't too concerned about limiting headroom or cluttering the space with columns. If you don't mind the obstructions or loss of headroom, though, beams and columns certainly can be added in basements, too.

DETAILS

The important thing to remember when adding a support beam is also to add proper footings to support each column. In most instances, a 2-ft.-square, 1-ft.-deep footing provides adequate support. However, when you're installing LVL or steel beams with wider column spacing, larger footings may be necessary to support the load.

The beam size depends on the load and span of the beam between columns. Also, keep in mind that the closer you space the footings and columns, the more rigid the new beam will be and the stiffer the floor will feel.

To make a new footing, cut the slab, dig out the earth beneath, and pour concrete flush with the top of the slab. Next, snap a chalkline across the underside of the joists in the middle of the span to help align the new beam. Use post shore jacks, screw jacks, or hydraulic jacks to lift the new beam into position beneath the joists. Finally, cut and install new columns to fit between the beam and the new footing.

Steel or LVL beams *can be used in lieu of dimensional lumber. Their added strength will allow for wider column spacing, but larger footings may be required to carry the load.*

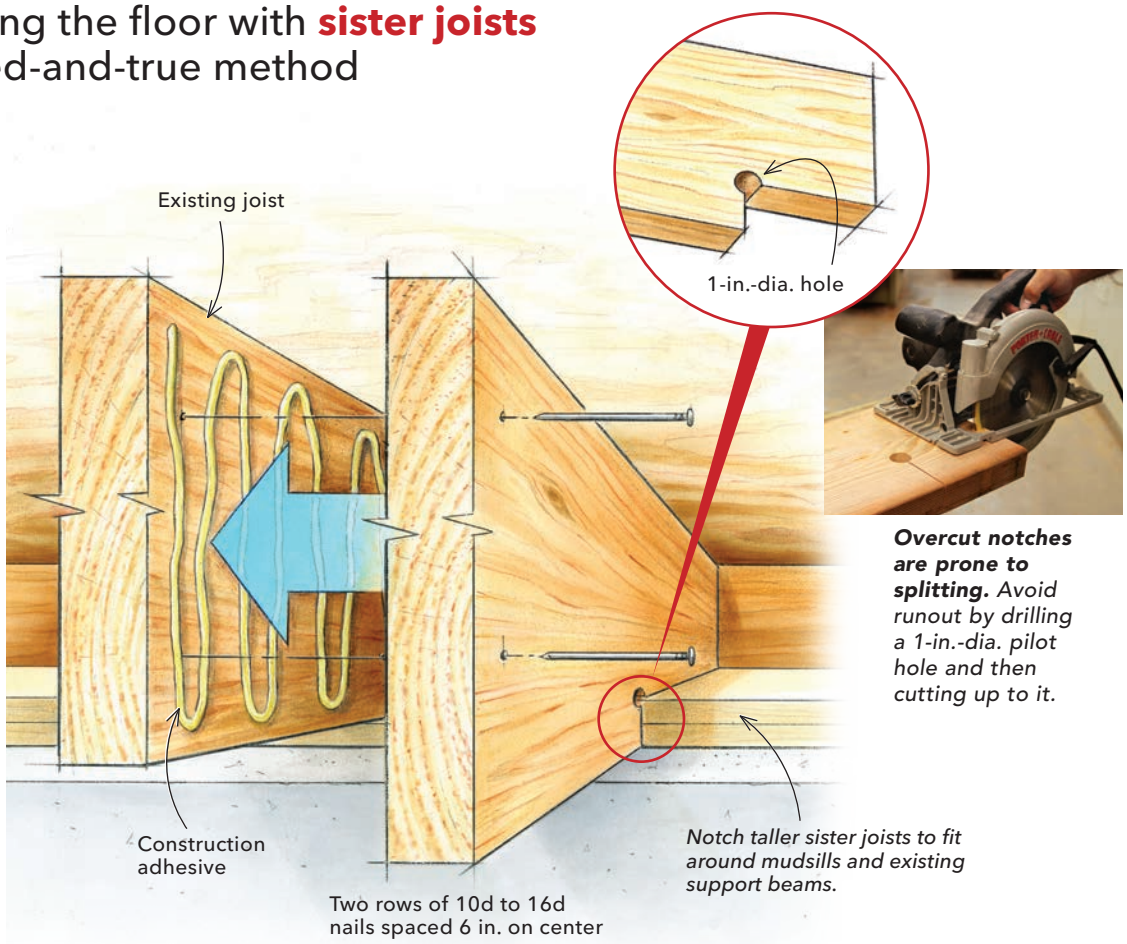
Steel beam

Laminated-veneer lumber (LVL)

[2] Stiffening the floor with **sister joists** is a tried-and-true method

Adding a second joist of the same size alongside each existing joist, also known as sistering the joists, stiffens a floor. When headroom permits, sistering with taller joists provides more bang for the buck than sistering with same-size joists. Even though taller joists need to be notched to fit existing mudsills and support beams (photo right), the added depth along the middle of the span provides extra support and further reduces bounce.

Engineered lumber—LVLs, for example—also can be used as sister joists and adds more stiffness to a floor than dimensional lumber.



Overcut notches are prone to splitting. *Avoid runout by drilling a 1-in.-dia. pilot hole and then cutting up to it.*

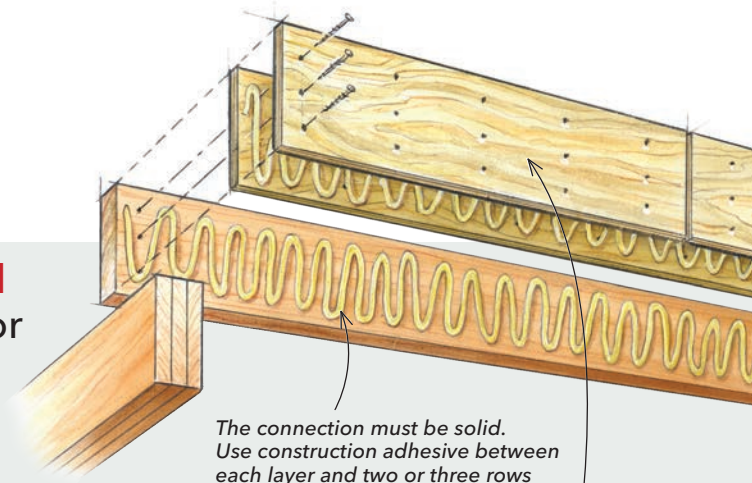
DETAILS

If the existing floor joists are bowed downward noticeably, they might need to be jacked up slightly to make installing the new joists easier.

To minimize future squeaks, spread construction adhesive onto both the existing joist and the new joist. Position the top of the new joist alongside the top of the existing joist. Use a sledgehammer or a pry bar to force the bottom of the new joist along the mudsill and center support beam of the floor system (or the opposite mudsill on short spans) until it's flat against the existing joist. Nail the new joist to the existing joist with two rows of 10d to 16d nails spaced 6 in. on center. For additional stiffness, sister joists can be applied to both sides of a joist.

[3] Flexible **plywood strips** are great for tight quarters

An alternative to adding full-length sister joists is to apply two layers of plywood to one side of the bouncy joists. Shorter, lighter, more flexible plywood strips often are easier to install in tight quarters than full-size dimensional lumber.



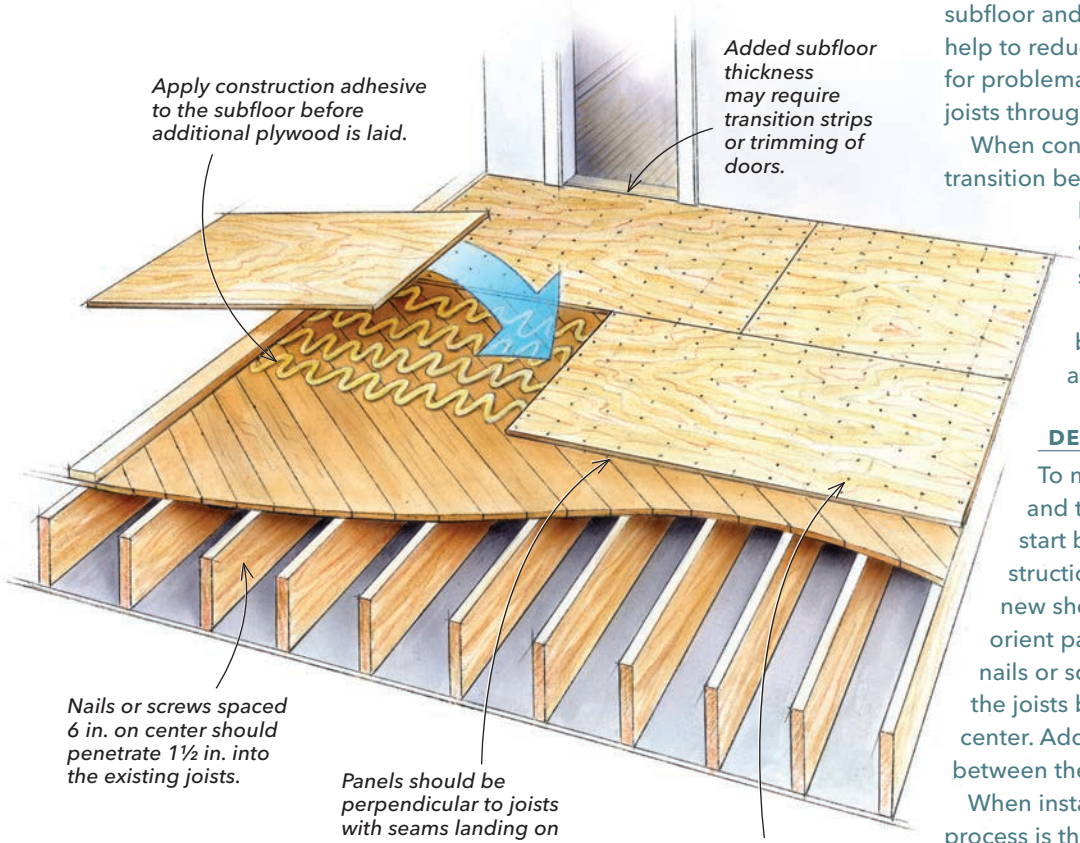
Top photo: Justin Fink

[4] Weakened planks and second-floor bounces are best fixed with a **new layer of plywood**

Floors in older homes often are decked with diagonally laid 1x planks instead of plywood or OSB (oriented strand board). If you're planning to remodel or just add new flooring to a room, consider adding a layer of ¾-in. plywood subfloor sheathing over the lumber decking. When nailed through the old subfloor and into the joists, the new subfloor can help to reduce floor bounce. This solution also works for problematic second floors, where accessing the joists through the first-floor ceiling isn't a possibility.

When considering this option, think about the transition between old floor heights and new floor heights at doorways. You may need to add thresholds and cut doors. Also consider the loss of headroom.

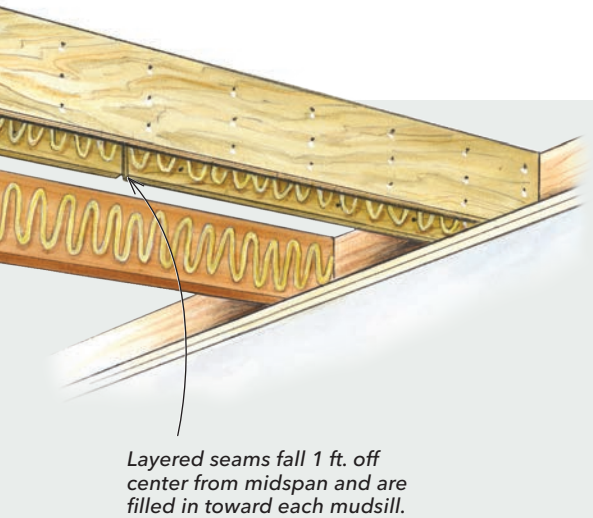
Sheathing also can be applied to the bottom of the floor joists instead of or in addition to being installed on top.



DETAILS

To minimize the chance of future squeaks and to help secure the new floor sheathing, start by spreading a generous amount of construction adhesive over the old planks. Lay the new sheets perpendicular to the floor joists, and orient panel ends over joists. Choose ring-shank nails or screws that are long enough to penetrate the joists by 1½ in., and space them every 6 in. on center. Add an additional row of fasteners midway between the joists to pull the layers tightly together.

When installing on the underside of the joists, the process is the same. You can apply sheathing to the underside of floor joists only if the bottom edges are at the same level. If the joist level varies by more than ½ in., you can't use this method.

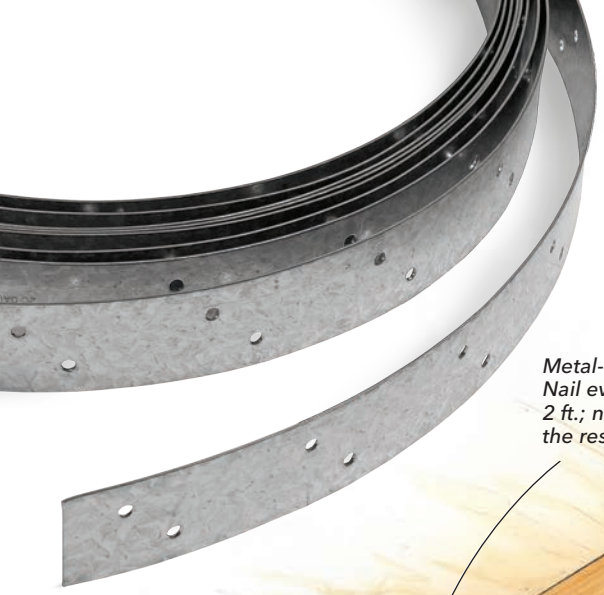


DETAILS

Rip ¾-in. plywood into 8-ft.-long strips equal to the height of the existing joists. Use a combination of construction adhesive and nails or screws to fasten two layers of strips to the existing joist, spanning from the mudsill to the center support beam or opposite mudsill. Place the first 8-ft.-long strip 1 ft. off center from midspan, and fill toward the ends with pieces. Then glue and fasten a second layer of plywood starting with a full strip 2 ft. off center from the first layer.

When fastening to joists less than 8 in. tall, drive two rows of 8d nails or 2-in. wood screws 6 in. on center into each layer of plywood. If the joists are taller than 8 in., add a third row of fasteners.

This system relies on good workmanship for success. Be generous with adhesive and fasteners; and make sure that the existing joists are solid and not deteriorated. If the connection between the two plywood layers and the existing joists isn't solid, you don't maximize the benefit of using this technique.



Perforated steel strap
(Simpson Strong-Tie CS20;
www.strongtie.com)

Metal-connector nails: Nail every hole on first 2 ft.; nail every 6 in. along the rest of the strap.

Hammer-bend the strap crisply around the bottom of the joist.

Existing center support beam

Use temporary jacks set about 1 ft. from midspan to lift the joists slightly during installation.

Chalkline marks midspan on the existing joists.

A 6x6 beam on top of the jacks spreads lifting force to several joists at once.

[5]

Metal straps are deceptively effective and simple to install

Tim Brigham of Koloa, Kauai, Hawaii, suggested the use of continuous steel straps to stiffen joists in a past issue of Fine Homebuilding. Wrap the joists from the top of one end, around the bottom at midpoint, and back to the top of the opposite end. When a load is applied to the middle third of the joists, the steel strap transfers the force of the weight to the nails along the length of the joist, particularly along the ends where the joist is more rigid.

DETAILS

To begin, lift up the joists with jacks and a temporary beam about 1 ft. from midspan of the joists. Raising the joists slightly (anywhere from ⅛ in. to ½ in., depending on the span and on the conditions) before installing this system helps to ensure that the straps are nice and tight when the jacks are removed.

Starting above the mudsill on one side of the joist, sink metal-connector nails through every hole along the first 2 ft. of strap. With the first 2 ft. fastened securely, the strap then should be fastened every 6 in. and folded with crisp bends around the bottom of the joist and onto the opposite side. Nail the strap to the opposite side of the joist the same way as the first side. For additional support, straps can be installed on both sides of the joists and cross-lapped at the center. Once all the joists are strapped, remove the temporary beam.

[6] **Solid blocking** ties the floor together but takes time to install correctly

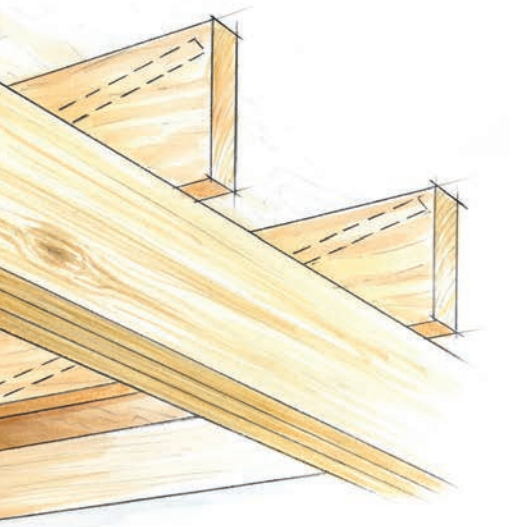
Properly installed solid-wood blocking helps to transfer weight to adjacent joists so that the floor acts as a stronger unified system. If you already have blocking or bridging installed between joists, it may be ineffective because it's not tight. Metal and wood cross-bridging are both prone to loosening over time as wood expands and contracts. Solid blocking is susceptible to shrinkage, but it typi-cally works better than using the cross-bridging method.

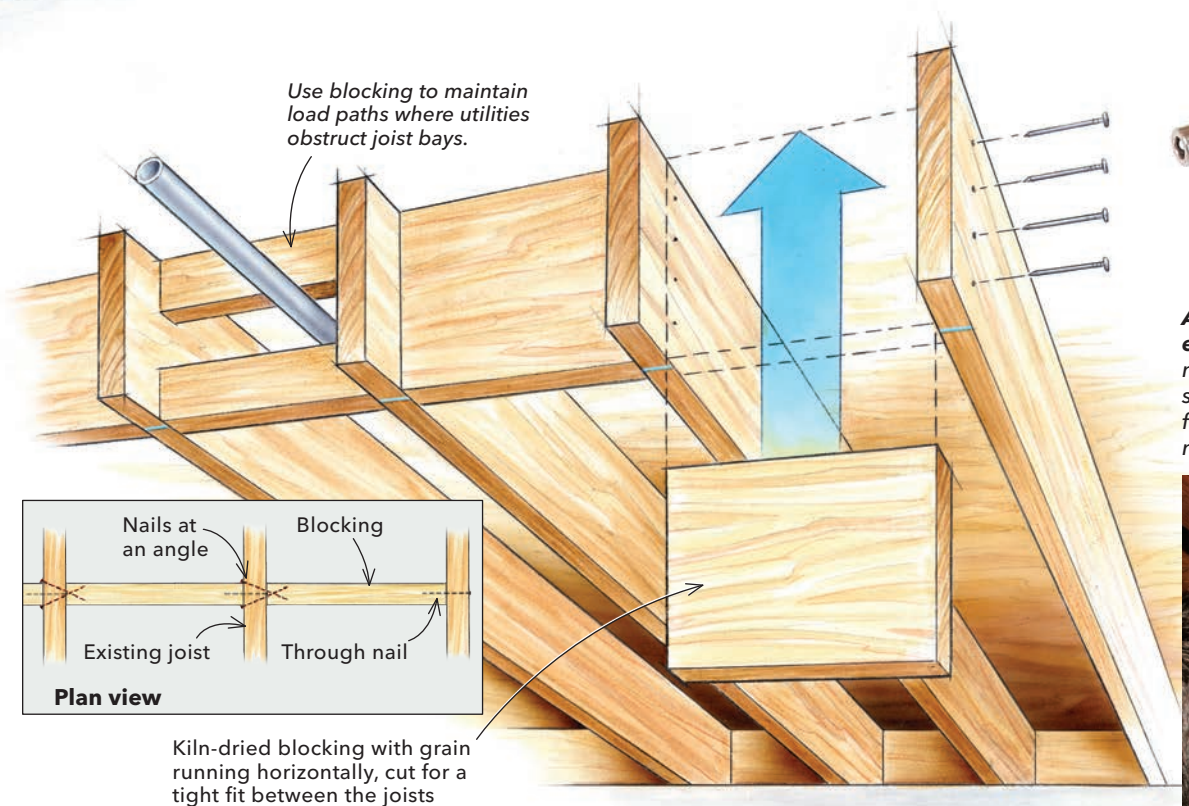
DETAILS

This method works best if joists are dry, so it's a good idea to wait until late winter or early spring when the heating season is coming to an end and the moisture content of the joists likely will be at its lowest. Start by snapping a chalkline at the middle span of the floor running perpendicular to the joists. Using dry dimensional lumber, cut blocks just a whisker longer than the space between joists, and pound them into place so that they are tight. Blocks that aren't tight will end up causing squeaks.

It may be tempting to install this type of blocking in a staggered line because it's easier to fasten. But solid blocking is meant to work as a system, so keep the blocks in line. If you need to get around pipes or ductwork, use split blocks (a pair of 2x4s, for instance) on top and bottom to maintain the path.

Through-nail into the end of each block using three or four 16d spikes or 3½-in.-long wood screws. Pneumatic palm nailers work great for driving nails in these tight situations (photo below). For added support, you also can install two or three rows of blocking spaced equally apart.





***A pneumatic palm nailer** is great for driving nails in spaces where swinging a hammer or fitting a full-size framing nailer isn't convenient.*

Photos this page, facing page: Krysta S. Doerfler

Frame an I-Joist Roof

Engineered rafters are lighter, straighter, and often have more room for insulation than dimensional lumber

BY ANDREW STEELE

There are many choices for roof framing: dimensional lumber, trusses, or engineered lumber such as laminated veneer lumber (LVL) and I-joists. All have advantages and drawbacks. On a recent project, an accessory dwelling behind an in-town bungalow, I was tasked with building a 16-ft. clear-span monoslope roof with a soaring cathedral ceiling on the underside. The logical choice was to use 14-in. I-joist rafters.

Advantages of I-joists

I-joists are great for roofs because of their consistent dimensions. And because they're very straight, they create a dead-flat ceiling. I've had 2x12s range from 11⅛ in. to 11⅝ in. in the same delivery, which can cause waviness that shows up on the finished ceiling or the roof, likely both. LVL or LSL (laminated strand lumber) are also options, but they are more expensive and heavier than I-joists.

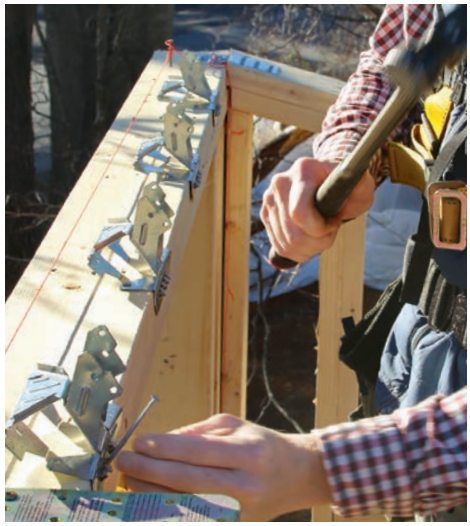
I-joists come in longer lengths than readily available dimensional lumber, which is great for roof spans. They also come in many depths and flange widths to accommodate snow loads and design considerations. Their

LAY OUT THE ROOF

Rafters are spaced 16 in. on center and positioned 1¾ in. away from the edge of the wall plate at the ridge to allow for a continuous LVL that transfers the roof load around the large south-facing windows.

Eyeball the wall. *Use a stringline to check and adjust the wall framing until the wall is straight.*

Mark the layout. *Lay out the rafter locations 16 in. on center with a tape measure, and extend the marks using a square. Here, to prevent creating a rafter cavity too small to insulate easily, we spaced the second rafter 12 in. from the first, ensuring the last rafter cavity would be large enough.*



Nail on connectors. *Simpson VPA Variable-Pitch Connectors secure the I-joist rafters at the ridge end. They're fastened with eight 3-in. common nails.*

extra depth means they can meet insulation requirements for even the coldest parts of the country with less-expensive fibrous insulation rather than foam.

For this project, we needed stock longer than 16 ft. In my area right now, dimensional lumber longer than 16 ft. is a special order with a very long lead time, but I was able to get 18-ft., 14-in.-deep I-joists in just a few days through a local lumberyard. Most good lumberyards have someone who can help with I-joist engineering and design, and manufacturers have approved installation methods for common overhangs and ridges, as well as hip and valley details.

Approaching eaves and ridges

I-joist roofs have specific details for eave and ridge connections, and you have to follow the details provided by the specific manufacturer. Generally, there are several ways to deal with the bird's mouths. The first is to avoid them completely with beveled top plates on the exterior walls. This works well if you are building with 2x4 walls, but not 2x6 walls; job-site tablesaws can't rip a full-width bevel on a 2x6. You can bevel a 2x6 using a sled with a lunchbox planer, but it takes forever. I know—I've tried it.

Another option is to hang the rafters from a rim board with an adjustable face-mount hanger like Simpson's LSSR. If you use this hanger, you have to pad out the web of the I-joist with 3-in.-wide pieces of plywood or OSB of a thickness that matches the width of the flanges. I attached the ridge end of my rafters with Simpson VPA Variable-Pitch Connectors (about $8 each), which can accommodate roof pitches from 3:12 to 12:12.

In order to create an uninterrupted taped-sheathing air barrier, we cut the "seat" portion of a bird's mouth on the lower end of the joists but then trimmed them off flush with the wall framing. We installed the overhang later. To help the roof resist uplift, there are Simpson H2.5AZ connectors on every rafter on the inside. The I-joist webs are padded out for this connection.

Details for blocking and venting

To prevent the rafters from rolling over under load, I used a manufacturer detail

(Continued on p. 35)

PREP THE RAFTERS

The rafters are cut and prepped on the ground on sawhorses before they're lifted onto the roof. They should be stored banded together and lifted from both ends to prevent damage.

Make a test. *Cut a test rafter to length. Here, both ends have plumb cuts for a 4:12 pitch, and the eave end has a seat cut that sits on the top plate.*

Check the fit. *Lift the test rafter onto the roof. Checking the length and angle of the cuts on the test rafter prevents making a roof's worth of incorrect rafters.*

Stiffen the web. *Place 5/8-in.-thick web stiffeners on both sides of the test rafter, and fasten them with 8d nails. Bend over the nails on the other side.*

Make the rest. *Once you have confirmed the test rafter fit, scribe and cut the rest of the rafters using the test rafter as a template.*

SET THE RAFTERS

While a crew of two cuts and preps rafters, two other workers start nailing rafters in place, starting with the second rafter. The first and the last rafters that form the gable ends will be nailed in place later.

Nail the eave. *Nail the eave through the flange with 8d nails at least 1½ in. from the end of the I-joists. Here, the nailer is angled because of the web stiffener.*

Bend the connector. *It is easier to bend the metal connectors before attaching the I-joists because you need less pounding on the top of the I-joist to match the hanger to the slope.*

Nail the ridge. *Attach the I-joists to the connectors with a pair of 1½-in. nails. Bend the small tabs on the connector over the bottom flange and fasten through them with a connector nailer.*

Have a look. *Once a few rafters are in place, look down their ends to ensure that they are lined up and that the wall hasn't moved since it was straightened.*

Keep it moving. *Working across the roof, place and fasten the rafters one at a time. Every few rafters, check the layout at the top and bottom of the roof to ensure that it's straight and that the rafters are spaced correctly.*

SHEATHE THE ROOF

Fill in gable webs. *Fill the webs of the rafters on the gable end with 5/8-in.-thick sheathing nailed and glued with construction adhesive. This additional layer allows the wall sheathing to be attached to the entire rafter for extra uplift resistance.*

Install gable rafters. *The gable-end rafters are attached like the common rafters. We could have started with a gable rafter on this build, but had to wait for a wall sheathing delivery.*

Lift and fasten a heavy header. *A single piece of 14-in. LVL spans the ridge. It's toenailed to the top plate and fastened into the rafter ends at the top and bottom flange. We rented an all-terrain forklift for a day to lift this header and the roof sheathing.*

The roof and the tops of the walls are sheathed together. Here, the top course was left off of the wall sheathing so that the crew could tie the wall sheathing into the roof system for greater uplift resistance in high winds.

Connect the walls and roof. *Attach the wall sheathing with 8d nails spaced about 6 in. on center and fastened into the studs and rafters.*

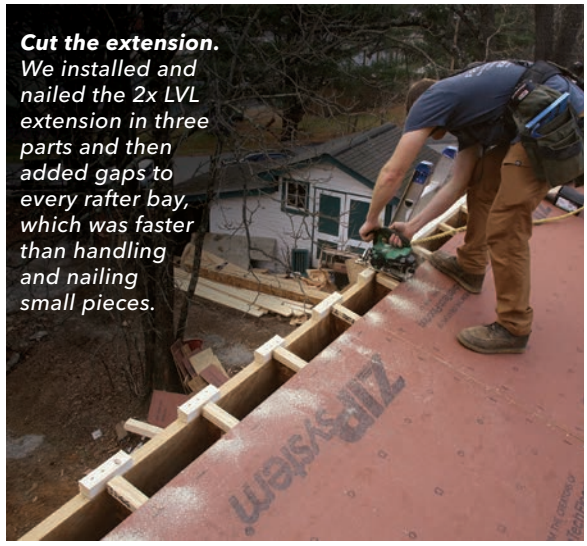
Line it up. *Snap a line 4 ft. up from the eave to mark the edge of the first row of roof sheathing.*

Sheathe out and up. *The first step in sheathing the roof is to create a safe work area near the edge from which to pull the sheets from the forklift. After that, work away from the unloading area, staggering the seams by a half-sheet and fastening with 8d nails 6 in. on center at edges and 12 in. o.c. in the field.*

PLAN FOR VENTING

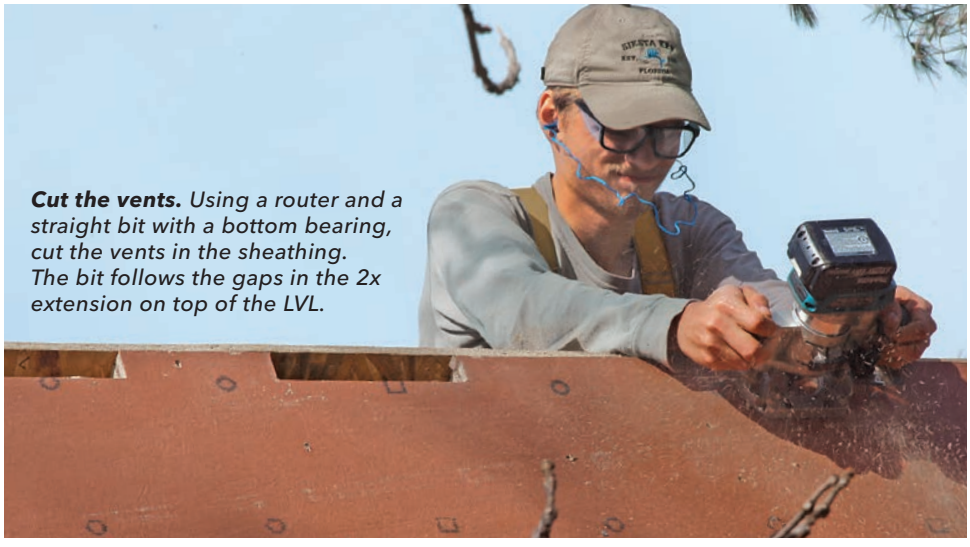
With I-joist roof framing you can attach rigid insulation to the bottom of the top flange to create a space for a vented roof. The ridge and eave are treated differently when it comes to venting.

Stretch the LVL. *We were not able to get a 16-in. LVL to match the length of the plumb cut. The LVL had to be extended with a 2x ripped to width, with a bevel to match the roof pitch.*



Cut the extension. *We installed and nailed the 2x LVL extension in three parts and then added gaps to every rafter bay, which was faster than handling and nailing small pieces.*

Finish the sheathing. *Install the last row of wall sheathing from above after the roof sheathing is complete.*



Cut the vents. *Using a router and a straight bit with a bottom bearing, cut the vents in the sheathing. The bit follows the gaps in the 2x extension on top of the LVL.*

(Continued from p. 31)

with blocking between each rafter on the low end of the roof using LSL rim board. (The blocking is also the attachment point for the applied rafter tails that will be installed later.) I waited to install this blocking until sheathing the roof and taping the seams so that I'd have a dry place for priming and painting exterior trim on rainy days. If I had to do it again, I would install the blocking before the roof sheathing, because fitting the blocking tight to the rafters is more difficult with the sheathing in place.

Creating a cathedral ceiling with an air space for venting is easy with I-joists. We used the top flange of the I-joist as a mounting point for ¾-in. XPS foam. The space above the foam is the vent channel, and there's still enough room for R-38 fiberglass insulation below the foam, the code minimum for a sloping ceiling in my climate zone.

The XPS foam was nailed to the underside of the flange using a roofing nailer, and the edges were sealed with canned spray from. On the lower end we drilled a series of ¾-in. holes through the sheathing to connect the vent space to the outside. On the ridge end we cut holes in every bay with a router.

Addressing overhangs

The design called for exposed rafter tails with exposed tongue-and-groove roof sheathing that could be seen from the ground. Obviously an exposed I-joist would look bad and rot quickly. Since we had a solid LVL spanning the front of the building on the upper end of the roof and solid blocking on the lower end, we were able to build applied rafter tails to attach at these locations.

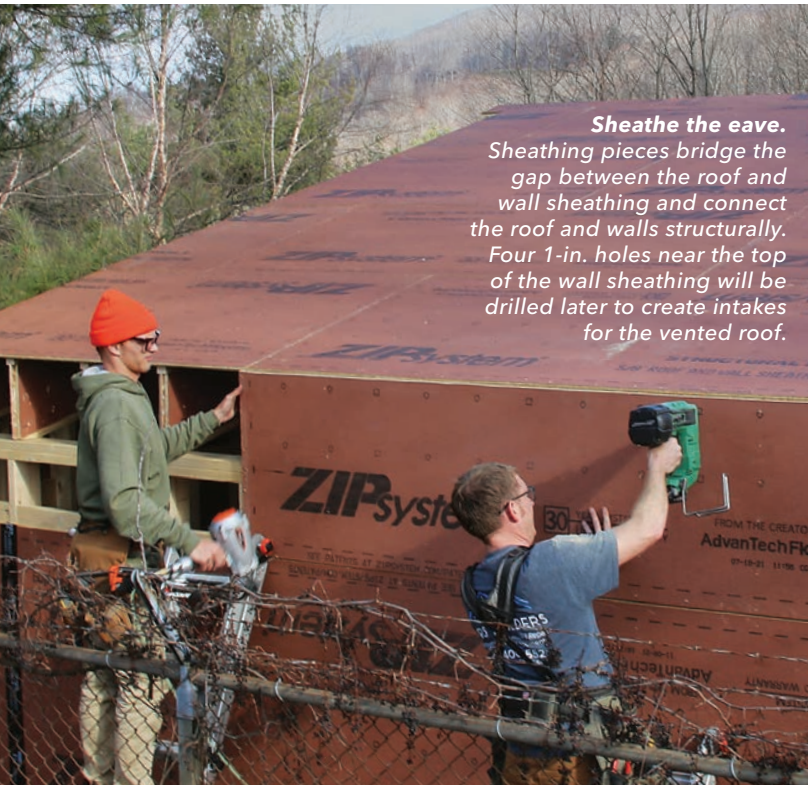
I-joist-framed roofs have some fussy details, but the long, straight engineered lumber solved a number of problems on this build. First off, I could find light, one-piece, freespan rafters, and I was able to get them onto the roof without heavy equipment. For another, they simplified the roof-venting strategy. And last but certainly not least, they were available when I needed them. □

Andrew Steele is the owner of FRS Builders in Purlear, N.C. Photos by Patrick McCombe.

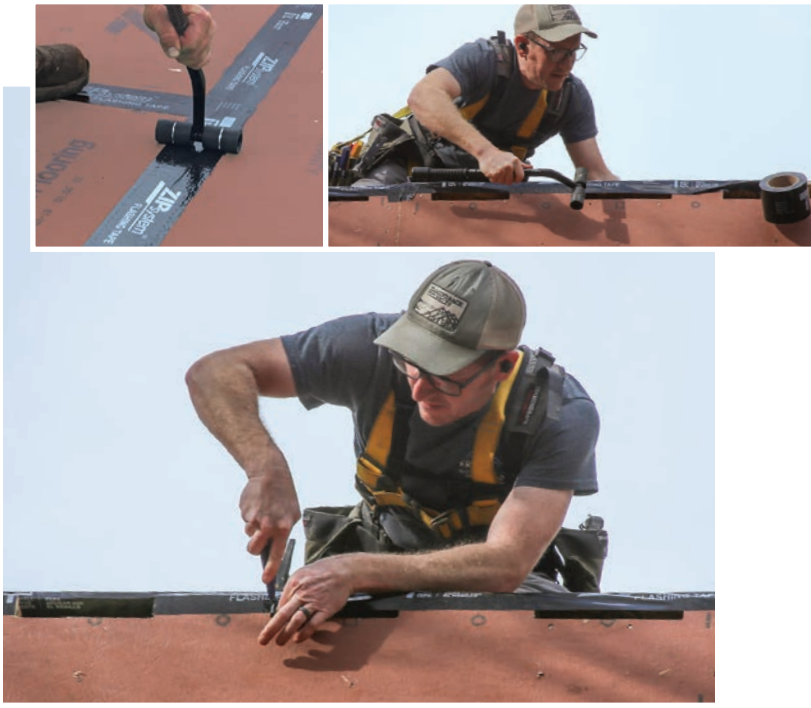
MAKE IT AIR- AND WATERTIGHT

The taped sheathing on this house is its primary air and water barrier. Like the other walls, the eave wall is tied to the roof system for uplift resistance.

Add blocking. *LSL blocks help the rafters resist lateral loads that could overturn them. The blocks must fit tight on all sides.*



Sheathe the eave. *Sheathing pieces bridge the gap between the roof and wall sheathing and connect the roof and walls structurally. Four 1-in. holes near the top of the wall sheathing will be drilled later to create intakes for the vented roof.*



Tape the seams. *With flashing and seam tape sealing any gaps in the sheathing, the structure is kept dry throughout the rest of the construction. Cut the tape around the vent openings.*

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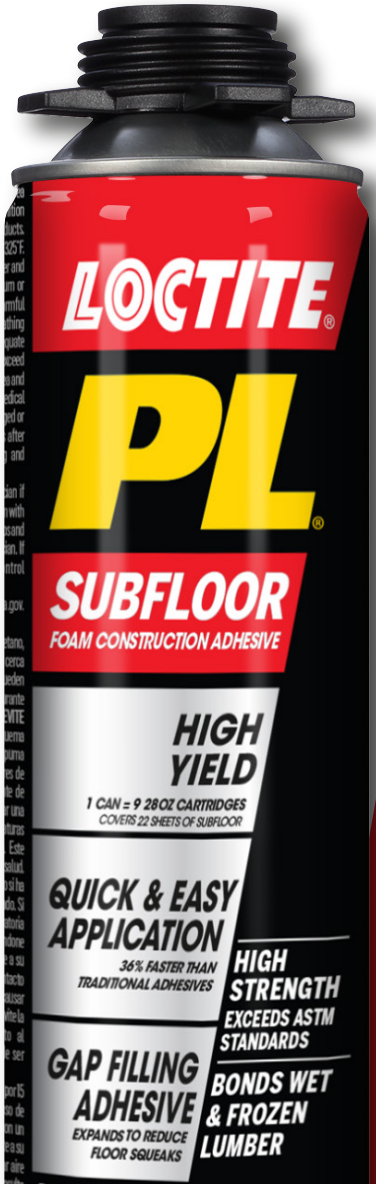

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