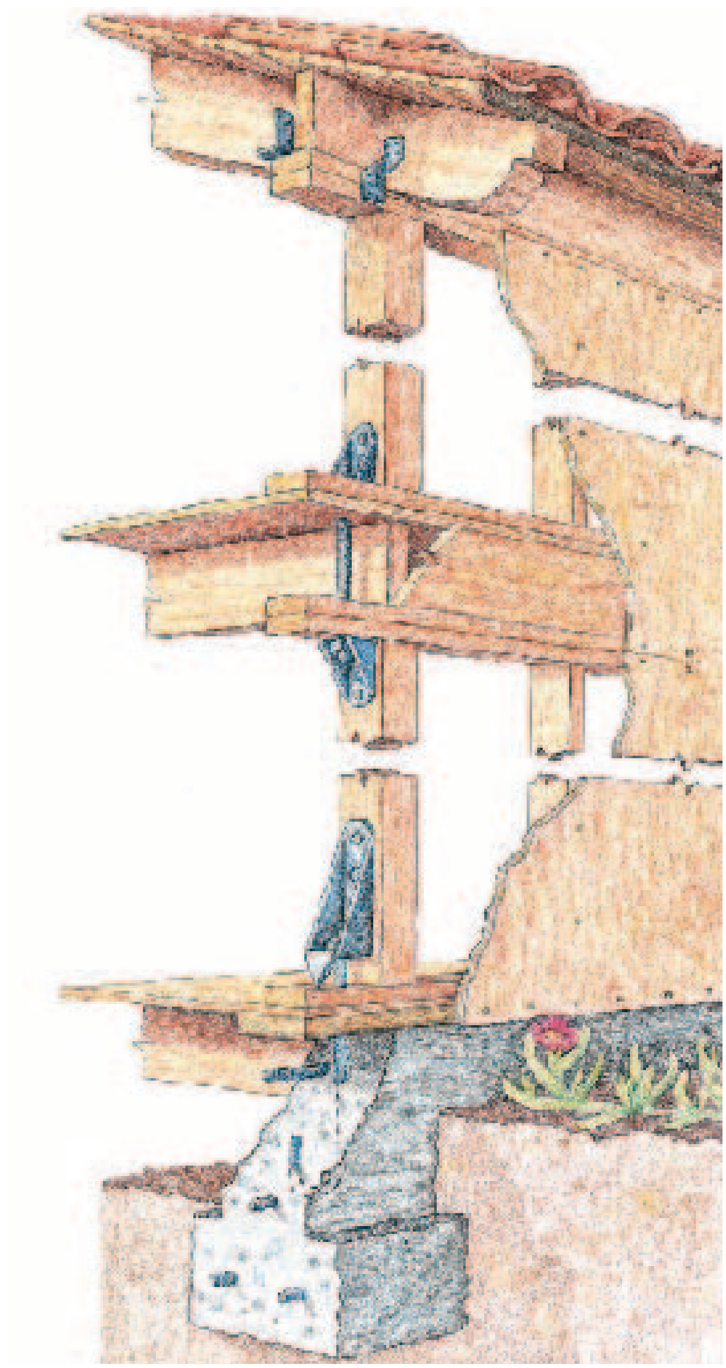
Tying Down the House

Properly installed hold-down hardware can keep a house from shaking or blowing apart


LENA SAVAGE

To keep houses from shaking apart in earthquakes or being blown away in hurricanes, engineers and architects specify hold-downs, metal framing connectors, and plywood shear paneling. The idea is to use metal connectors and plywood to create a continuous "hold-down path" that ties the structural wooden frame together from foundation to roof peak. In California, where I live and work, every set of house plans addresses the issue of tying the structure to the foundation.

by John Scoggins

Scan the Plan

Every piece of hold-down hardware, whether it's a simple 1/2-inch J-bolt or a custom metal clip, will be marked on the foundation plan and in the structural details. When reviewing a set of plans, I use a colored marker to highlight every hold-down and shear panel anchor bolt. As I mark each one, I keep a running count of each type and famil-

Scanning the Plans

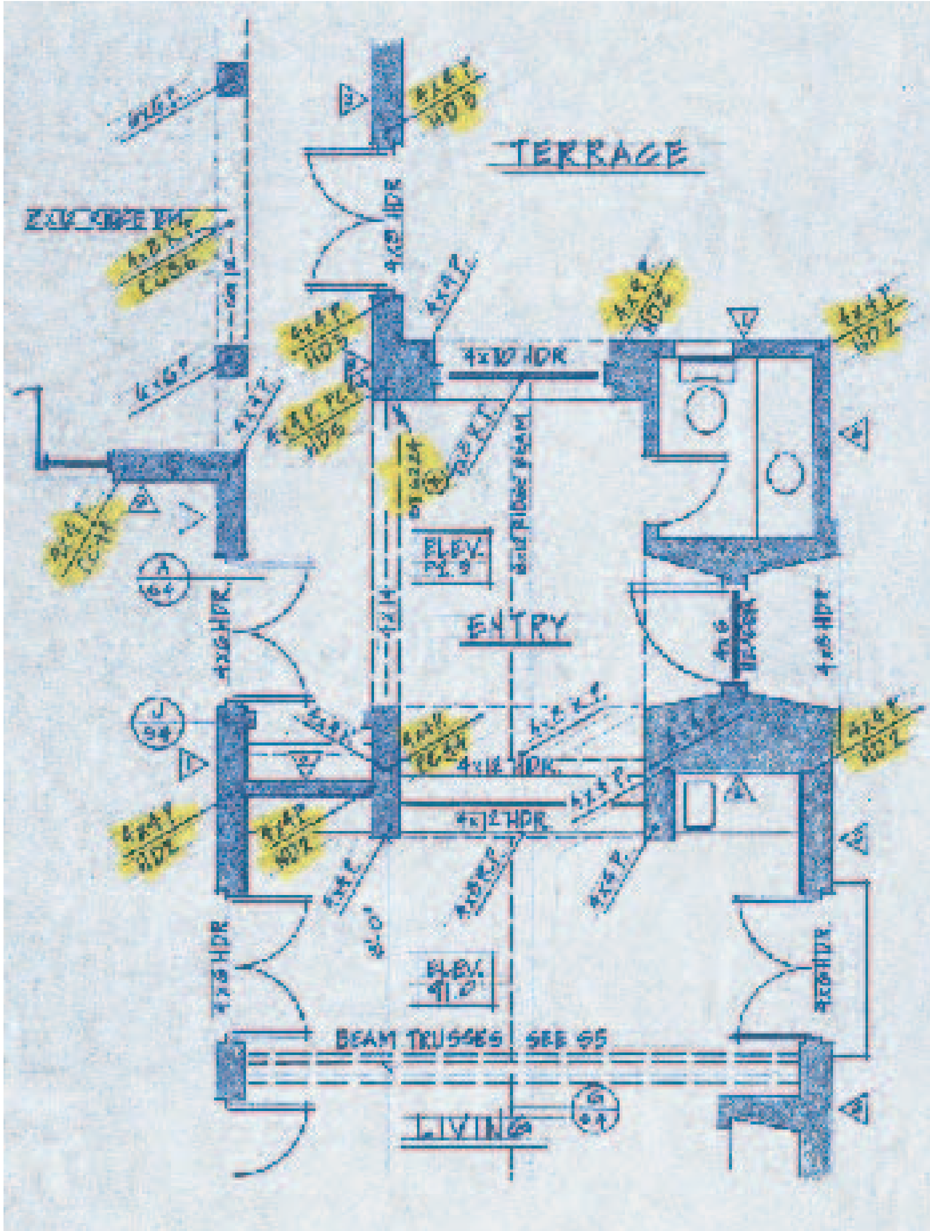


Figure 1. Hold-down installation begins with a careful review of the plans. An overlooked hold-down bolt or embedded strap can turn into a costly retrofit once the slab is poured. The author uses colored highlighters to locate every piece of hardware specified by the engineer.

iarize myself with their locations. Hold-downs are typically called for in pairs, located, for instance, at each end of a shear wall or on both sides of a window or door where the shear wall is interrupted by the opening (see Figure 1). With experience, it's pretty easy to find (and even memorize) the location of the hold-downs.

Although we usually keep an extra supply of the most popular clips in the storage shed, it's expensive to go back and do a special installation of an omitted hold-down, especially for the larger, more costly anchors. So if you are new to these kinds of anchor systems, be prepared to do a close examination of the plans to avoid a costly retrofit installation. Nevertheless, this is a common problem, especially on a complicated set of plans. If you do omit a hold-down, ask your structural engineer for a solution. For example, a common fix for a missing foundation anchor is to drill into the foundation or footing and install a retrofit bolt or a length of threaded rod, secured with epoxy.

The plans I get from architects are very specific, and it's my job to locate the foundation hardware and to see how it will connect to the shear walls, and to the door and window openings. I look for places where some other building component, such as waterlines or power conduits, might interfere with the installation of the hardware. If the house has a second story, I'm careful to note any connection called out between floors so that my framer can adjust the stud and post layout to accommodate the connecting hardware.

I then turn to the roof framing plan and note how the engineer has created a hold-down path up to the roof diaphragm. These systems can be complicated, so if anything is unclear I notify the engineer and ask for guidance. To avoid confusion between subs, I meet with our lead framer and foundation foreman to discuss the plan and to note any changes.

In our area it is usually the contractual responsibility of the framer to supply and install the hold-down hardware. The hardware is often a mix of inexpensive off-the-shelf sizes and expensive custom-order styles. The custom pieces sometimes take weeks to deliver and can't be sent back, so it is important not to miss any on the plans.

Layout at the Foundation

After the foundation forms are in place, I lay out the centerline of every door and window opening directly on the formwork. Next, I figure backwards and mark the exact locations of rough openings, trimmers, and posts. We work off the actual, not nominal, post sizes to determine the setback (offset distance from the edge of the actual post) for the centerline of the hold-down bolt. For example, the hold-down shown in Figure 2, uses a $^{7}/_{8}$-inch anchor bolt (the hole is drilled $^{1}/_{16}$ inch larger), and has a centerline $2^{1}/_{16}$ inches from the face of the post. It's possible to simply measure the distances, but often the bolts are on site before the rest of the hardware is delivered, so to be accurate we look up the centerline dimension of each style and size of hold-down in the hardware catalog.

At the same time, I also mark the location of all the shear wall anchors and other hold-downs, such as strap ties and post anchors. I do this layout jointly with the lead framer so that we are both in agreement.

Anchoring the Anchors

Hold-down bolts and hold-down straps must be securely fixed in place both laterally and vertically (Figure 3). If they move sideways during the pour, they'll miss the structural member that they are supposed to anchor. If a bolt moves up, it won't embed into the concrete enough. If it moves down, it gets embedded too deep into the concrete and there won't be enough exposed thread to make a connection. (If a bolt happens to sink into the concrete during the pour, a threaded union and a piece of all-thread the same diameter as the bolt can be used to lengthen the exposed shank.)

The inspectors in our area require that all hold-down bolts be in place before the pour. Using the color highlights on the plans for reference, I spray paint the matching locations on the formwork to make the job easier for the inspector. Then we install plywood templates and jigs to lock the bolts in their proper locations during the concrete pour. When we require extreme accuracy, we use the Simpson MKP (monkey paw anchor bolt holders) to help secure bolts prior to concrete placement.

After a hold-down inspection of both numbers and locations by the job superintendent and approval by the inspector, the concrete can be placed. Make sure you comply with the engineered design mix and that the concrete is mechanically vibrated into place to eliminate concrete honeycombing or voids that could compromise its strength, especially around the hold-downs. At the same time, make sure the vibrator does not come in contact with hold-downs and preset anchors or it may move them. After placing the concrete and while it is still wet, check the hold-down locations a final time, and make any necessary adjustments.

Figure 2. Bolts for hold-downs like the type in the photo above, left, have to be precisely located with respect to the framing when the foundation is poured, as do post anchors (above). Embedded straps (left) are somewhat more forgiving.

Framing Around Hold-Downs

The hold-down hardware in the walls will have to line up with the anchor bolts in the concrete when the walls are tilted up. So before any framing begins, the layout man needs to accurately note the location of key structural members such as bearing posts, window and door trimmers, and king stud assemblies, so that they match the location of the hold-down hardware. In some cases — at inside corners or near a window or door, for instance — it may be necessary to predrill a structural member or leave out the adjacent stud in order to have access to the nuts and bolts.

At the foundation, a typical hold-down consists of an embedded anchor bolt connected to a metal bracket with a nut and washer. The metal bracket is

Shear Basics

The plywood sheathing on the walls of a house does double duty. First, it provides resistance against racking — the tendency for a row of studs to collapse like dominoes along the length of the wall. Second, when lapped across the wood members and nailed properly, plywood ties the pieces of the framing together.

A good example of this is the joint between a first and second story. If the plywood sheathing spans from the lower to the upper floor and is properly nailed into the first-floor studs and top plates, the second-floor rim joist (or blocking), and the second-story studs and plate, the plywood ties the two floors together.

Typically in residential construction, 1/2-inch Structural #1 (called “struc one”) plywood is specified for shear paneling. Plywood ratings call out the veneer grades, adhesives, and the structural span of the plywood. Do not substitute a different grade of plywood for the specified grade without the engineer’s approval.

Plywood shear panels should be placed and nailed so that they connect the sole plate or bottom plate of the wall to the vertical framing members. Shear walls should also be blocked between studs at the top of each sheet of plywood to accept edge nailing. The plywood sheet must be nailed so that all four edges have framing members behind them to allow for full perimeter nailing.

All our plans have a shear nailing schedule that specifies the spacing and size of nails to be used (See sample schedule, below). For instance, a schedule that calls for a 4- and 12-inch nailing pattern refers to a 4-inch nail spacing along the plywood perimeter and a 12-inch spacing in the rest of the sheet.

Shear paneling should be installed so that the joints are staggered. The shear plywood should continue to the top plate of the wall and in two-story construction should tie the first and second floors together. It is critically important that sheets are gapped 1/8 inch at the joints (we use 16d nails as spacers.) This allows the sheets to expand and contract with moisture and temperature changes without buckling.

— J.S.

Shear Wall Schedule

Symbol	Wall Sheathing	Sill Connection
1	3/8” ply. str II, blocked w/8d @ 6” o.c. E.N. & 12” o.c. F.N.	A34 @ 24” o.c. 16d @ 6” o.c.
2	3/8” Ply str II, blocked w/8d @ 4” o.c. E. N. & 12” o.c. F.N.	A34 @ 24” o.c. 16d @ 6” o.c.
3	3/8” Ply str II, blocked w/8d @ 3” o.c. E.N. & 12” o.c. F.N.	A34 @ 16” o.c. 16d @ 3” o.c.
4	1/2” Ply str I, blocked w/10d @ 3” o.c. E.N. & 12” o.c. F.N.	A34 @ 8” o.c. 16d @ 3” o.c.
5	5/8” G.W.B blocked w/6d cooler nails @ 4” o.c. E.N. & F.N.	A34 @ 48” o.c. 16d @ 8” o.c.
6	7/8” stucco over paper backed lath w/16 GA. staples @ 6” o.c. top & bottom & E.N. & F.N.	A34 @ 32” o.c. 16d @ 8” o.c.

Diaphragm Schedule

Roof: 1/2” CDX plywood 24/0 W/8d @ 4”, 6”, 12”
Floor 5/8” Str I plywood, blocked, W/10d @ 4”, 6”, 10”. Glue plywood to floor joist.

This typical shear wall schedule specifies plywood size and type as well as edge-nailing (EN) and field-nailing (FN) size and spacing.

then attached to a structural member such as a trimmer, with a set of horizontal bolts. Tolerances of plus or minus 1/8 inch must be met to make installation go smoothly. Otherwise, it takes a pretty big hammer to bend the steel into submission.

All hold-downs must be installed with the bottom hole at least seven bolt diameters from the end of the post. This prevents the horizontal bolt from passing through the post too near the post end, where it could tear out under load. It used to be that some of the smaller hold-downs had to be held up a certain distance — the "standoff" distance — when installed. But now Simpson Strong-Tie, the hardware manufacturer I use, has built this standoff distance into all of its hold-downs. The HDA series installs flat against the sill and the bottom hole is automatically seven bolt diameters up. The heavier-duty HD series has a folded down "ear" that presets the distance (Figure 4).

Hold-downs are installed with commonly used tools, such as a 1/2-inch or 3/4-inch drill and auger bit, open-end wrenches, a deep-socket set, and, occasionally, a pneumatic impact wrench. Once the plywood shear paneling has been installed, access to the hold-down bolts is restricted. So we usually connect and tighten the hardware after the walls have been plumbed and lined, but before the plywood shear paneling is installed. Sometimes the plywood has to be nailed before the hold-downs are connected. In this case, we use ratchets and pneumatic impact wrenches to get into tight spots. It's occasionally necessary to preinstall hold-downs to king post assemblies before framing the king post into the wall.

Hold-downs can also be used to connect two floors together (Figure 5). In this application, one hold-down is installed upside down at the top of a structural framing member. We drill a hole in the top plate with the correct offset, then install another hold-down at the base of the second floor framing directly over the upside-down one below it. The holes can't be more than 1/2 inch

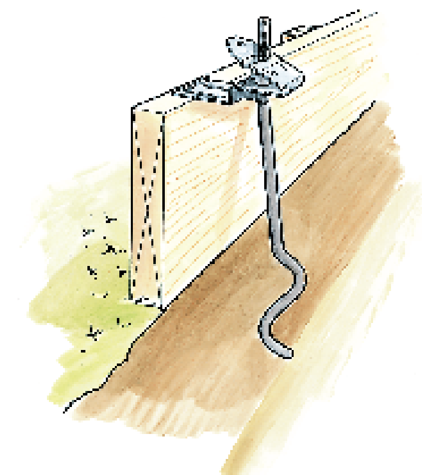


Figure 3. The author uses plywood templates (photo, above) or Simpson "Monkey Paws" (drawing) to secure hold-down bolts to foundation form boards. Embedded strap anchors are tacked into place, while post anchors (left) are temporarily secured to a scrap of framing lumber of the correct width.

Figure 4. Some hold-downs, depending on the manufacturer, have to be held up a specified "standoff" distance from the plate, to ensure that the horizontal bolts don't tear out the end grain of the post under load.

Tying Stories Together

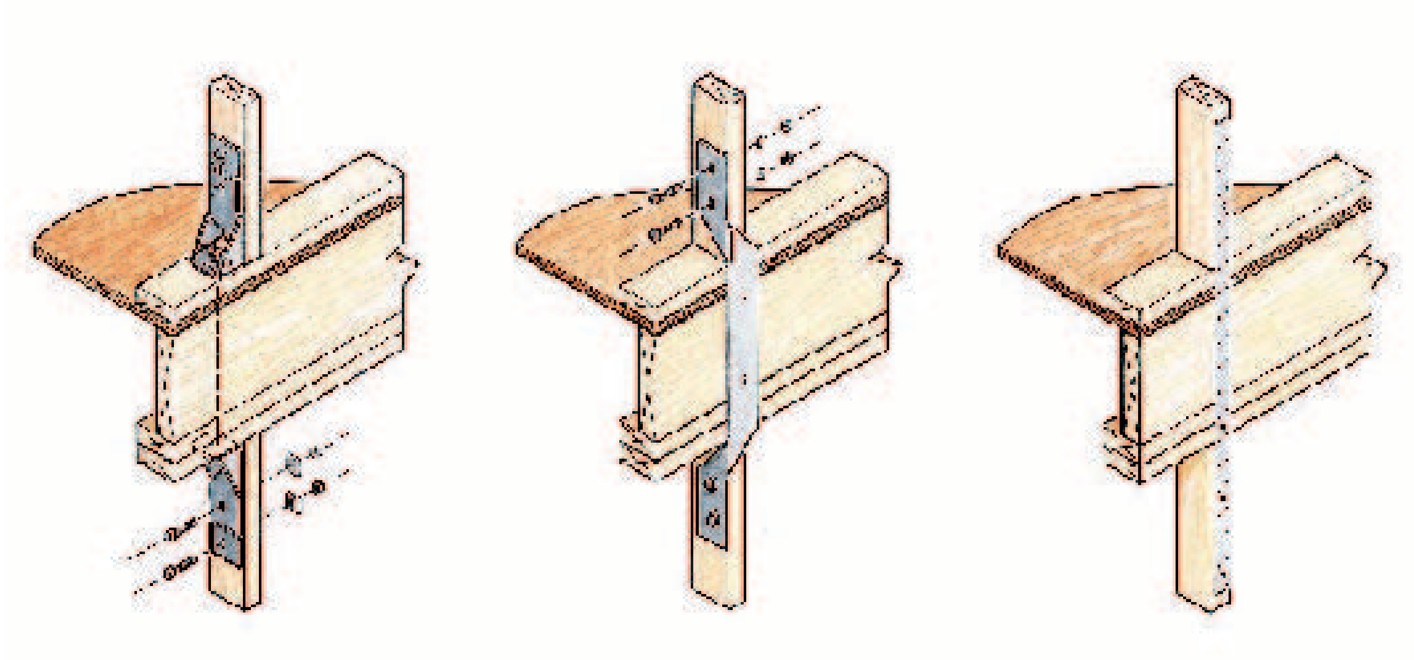


Figure 5. To provide a secure load path between stories, engineers specify bolted hold-downs, with the lower one turned upside down (left), or straps like the Simpson FTA (middle) or MST (right).

out of alignment or the threaded rod will bind. In the real world, of course, we often have to "correct" an offset with a hammer to make the rods line up. We then cut a piece of threaded rod to slide through one hold-down, the floor framing, and into the second hold-down. Finally we install and tighten the nuts at each hold-down, making the first to second floor connection.

Hold-downs are not the only way to tie together the framing between floors. In fact, engineers are beginning to specify Simpson MST straps or FTA floor ties because they are cheaper and easier to install (Figure 5). These are flat steel straps that span between the two floors with either nails or bolts to attach them. With strap connections between floors, the framing members such as studs or posts need to be exactly in line with each other vertically.

Figure 6. Here, Simpson A35F clips tie eaves blocking to the ceiling diaphragm below.

Tying to the Roof

To ensure that the plywood extends (and ties) all the way up to the top plate, we install the rafters after nailing the shear panels flush with the top of the double top plate. Blocking is nailed into place between rafters and A35F clips are installed on 16-inch centers to tie the blocking to the top plate (Figure 6). In cases where roof overhangs are large and wind uplift is an issue, we use H-series or hurricane offset straps to tie the rafter to the top plate.

Roof sheathing. The building code requires us to stagger the joints of the roof plywood. For added strength, we are often required to block between rafters along plywood edges or to use tongue-and-groove plywood. We also nail the sheathing to the perimeter blocking installed between rafters. This allows the transfer of shear stress from the roof to the walls and down the hold-down path to the foundation.

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