Shear Nonsense

by Scott McVicker, S.E.

Building shear walls is an everyday affair out here in California, where I work. Shear walls are one of the main design elements engineers use to help wood-frame buildings resist the lateral loads imposed by earthquakes. Shear walls are also becoming increasingly common in coastal zones throughout the U.S., where new high-wind codes often require them. For the carpenter, shear walls require some changes to standard wall framing. The most obvious is that the plywood sheathing gets installed with a lot more nails, especially around the edges. That's the easy part. There are also heftier framing members that have to be included — typically 4x4 posts at the shear wall ends. And there are the hold-downs, those bothersome pieces of hardware that have to be embedded in the concrete foundation and connected to the posts, creating another level of layout and coordination for the framer to worry about.

Forces in a Shear Wall

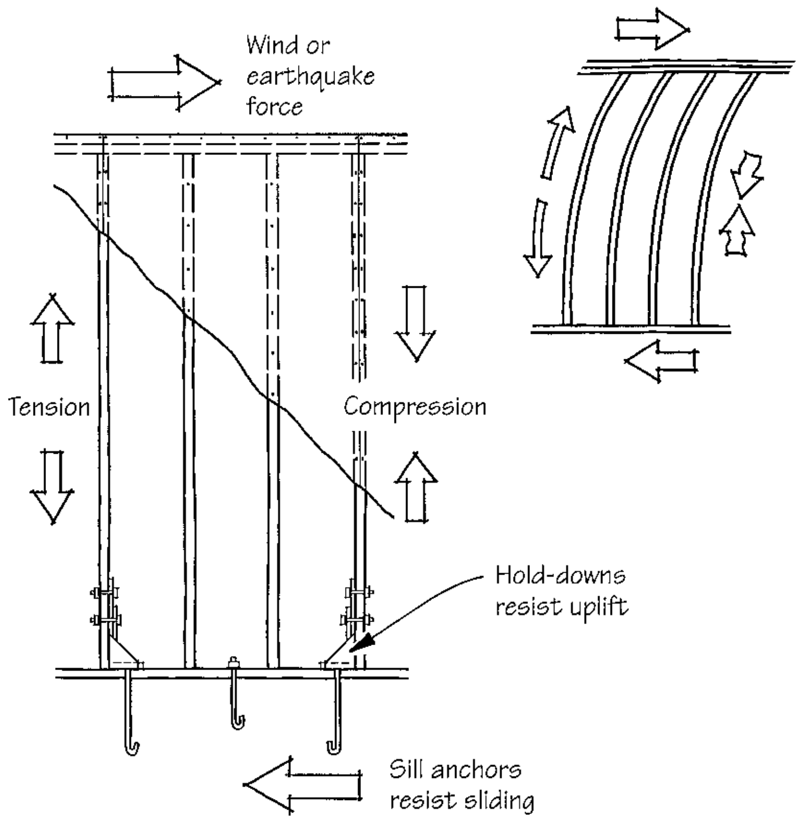

Figure 1. When wind or an earthquake exerts a force, the load is delivered to the top of the shear wall, along the plates. As the shear wall resists the load, one edge is put in tension, the other in compression.

Nailing off plywood shear panels is easy enough to do right, but hold-downs are a little trickier. In this article, I'll look at some hold-down installations that were muffed for one reason or another. But before discussing what's wrong with these installations, let's review how a shear wall is supposed to work.

Shear Basics

When the wind pushes a house or an earthquake shakes it, the force is delivered to the top of the shear wall (see Figure 1). At the bottom, where the wall is attached, there is an equal resisting force in the opposite direction. The "overturning moment" (a moment is a force times a distance) equals the force at the top of the wall times the height of the wall.

So that the shear wall does not overturn, there has to be another counterbalancing pair of forces. This is provided by the hold-down and tension post on one side and the compression post on the other side. (When an earthquake shakes a building back and forth, there is a cycle — first one post is in tension, then in compression, then in tension, and so forth.) With the counterbalancing pair of forces applied, the shear wall remains stationary.

For the shear wall to work, the hold-down must be correctly sized to handle the tension force generated. Any additional force, and the wall will begin to overturn. The hold-down must also be installed so that it transfers the force into other parts of the building — such as a slab foundation, for instance.

The Good

With those basics in mind, let's look at some actual installations. Figure 2 shows a reasonably good installation.

The hold-down is slightly off-center on the post because of the foundation anchor bolt's position, but not enough to be a problem. The bolt positions were carefully marked on the 4x4 post to ensure accurate drilling and thus equal bearing at each bolt.

Note the coupler nut used to extend the anchor bolt. Is this a sign of trouble? The coupler nut itself is not a problem, but its presence where a nut for a standard sill bolt would go makes me question whether this is an ordinary sill anchor that has been modified for use as a hold-down anchor. Hold-down bolts are typically longer than sill anchors — the deeper embedment allows the uplift forces to be distributed more widely in the slab footing or stem wall.

It's a good idea to mark hold-down bolts with spray paint or colored cap nuts before concrete placement begins: This will help ensure the right bolts are used at shear wall locations.

The Bad

Figure 3, shows an outside corner, with two hold-downs bolted through the end studs into the same post beyond. The two shear walls are sharing the post, which in itself is not a problem. But a dangerous assumption has been made — that the two hold-downs can act together to resist uplift forces.

First, the positions of the hold-downs relative to the direction of overturning will affect their relative degree of stress: The one farthest away from the compression end of the wall will see the maximum force. Second, we must expect some variation in the workman's skill in drilling the two pairs of holes. In an earthquake, the bolts in the hold-down that feel the load first will receive the total force. Only after some yielding occurs will the other hold-down's bolts achieve maximum bearing. The solution, when sharing a post between shear walls, is to use only one larger connector, with adequate anchorage to the foundation.

A Collision of Purposes

The shear wall in Figure 4 has several strikes against it. The most obvious is the way the stem wall, sill, and sole plate have been butchered to make way for a radiant heat feed. Given the size of the notch, the bolts don't have enough end distance (relative to the cutout), so their lateral shear capacities must be reduced.

Beyond that, the length of this shear wall is a problem. Under the 1997 *Uniform Building Code*, a shear wall must have a maximum height-to-length ratio of 2:1. But even under the former rule of 4:1, it's doubtful this wall would have passed. The contribution that such a short wall can make to resisting overturning forces is very small, but something about the design of the building forced the engineer to use every bit of wall to resist lateral forces. It gets even more interesting if you consider that this particular wall section is at the other end of the header shown in Figure 5.

The Ugly

Of greatest concern in Figure 5 (next page) is the hold-down on the left. Where is the tension force supposed to go? The threaded rod doesn't even have a properly sized bearing washer on the bottom face of the header. If tension does act to pull the rod upwards, the small washer and nut, acting as a wedge, could fracture the header. But even if it holds, it is doubtful that the few nails in the 16-inch cripple studs above will transfer force to the 4x4 post. Notice also the way the header is nailed to the post with four

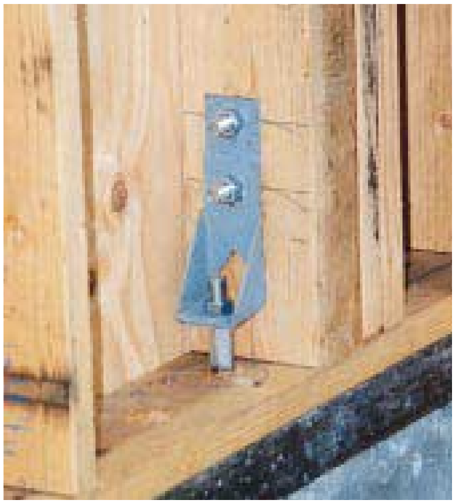

Figure 2. Assuming the anchor bolt is properly embedded, this hold-down is correctly installed.

Figure 3. It's a mistake to attach two hold-downs to a single post. The two shear walls meeting at this corner should have been properly connected with nails, and one correctly sized hold-down attached.

Figure 4. This shear wall is not long enough (plate length) to meet code, and the plate has been so badly mangled by the hvac sub that its lateral strength is compromised.

Figure 5. The window opening at the bottom left of the photo was enlarged, pushing the first-story hold-down post out of line with the second-story post. In a quake, the uplift forces will likely rip the long threaded rod through the header or pull the header out of position.

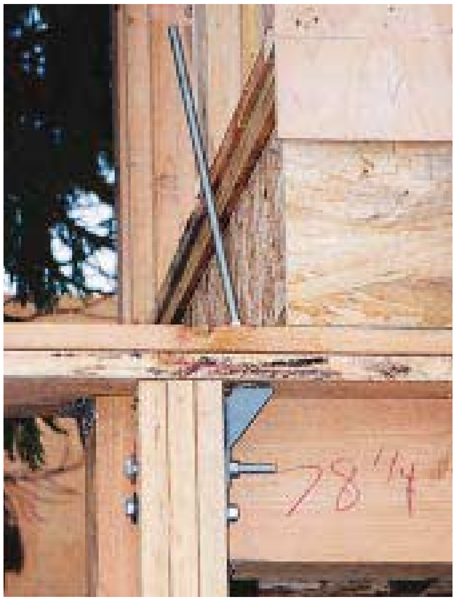

Figure 6. A triple-2x4 post makes it difficult for the carpenter to know where to place the perimeter nailing. The author recommends nailing off all three studs with the edge nailing schedule.

bent-over nails — not much good against uplift.

There's another issue here: The engineered rim board is not strong enough to handle the kind of compression forces that may be exerted by the posts in the event of a quake. Nor are there any floor joists coming in perpendicular on the other side to provide this support.

So Close

Besides the problem the hold-down in Figure 6 will have in mating with a hold-down above, this installation also illustrates some of the challenges of working with engineered lumber in shear wall construction. Just as in Figure 4, neither the engineered rim board nor the wood I-joists that meet it are strong enough in compression to handle the forces that will be transferred through the hold-down and post. The framer must either bring the post above all the way down onto the top plate (which would interrupt the second floor sole plate and require notching the subflooring), or use triple pony studs between the floors to give solid bearing between the posts. Using solid blocking with the grain oriented parallel with the plates would be a mistake, since the shrinkage relative to the engineered lumber floor system would leave a gap in the load path.

One final note: Using multiple studs instead of a post at hold-downs can make plywood nailing confusing for the carpenter, since there is no one stud taking the uplift and downward shear force at the wall boundary. I recommend following the perimeter nailing schedule at each stud in this case.

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