Protect Your Home With a Basic Seismic Retrofit

Strengthening a home in earthquake country means anchoring it to its foundation and adding site-built shear walls

BY THOR MATTESON

Geologists estimate that the Hayward Fault that runs through the East Bay of San Francisco is due to give way at any moment. When it hits, the earthquake is projected to cause significant loss of life, to cause nearly $165 billion worth of damage, and to leave hundreds of thousands homeless. The last major Hayward Fault earthquake was in 1868. Research shows that five major quakes have occurred along the fault—on average, every 140 years dating back to 1315. The 140th anniversary of the 1868 quake was three years ago.

As a structural engineer in the San Francisco Bay area, I specialize in helping to prepare homes for seismic events. While I work to shore up homes in a very distinct region of the country, the basic lessons that you'll learn here—how to reinforce the floor framing, properly attach a house to its foundation, and construct site-built shear walls—are broadly applicable.

Keep the house on the foundation

A seismic retrofit does not make your house earthquakeproof, but it does minimize potential damage to the house.

First, it keeps your house from sliding off its foundation. This is accomplished by using specialty hardware to reinforce the transition between the foundation and the floor fram-

ing or wall framing. Many older homes are not bolted to their foundation adequately, and many floor systems aren't attached to the walls beneath them securely enough.

Second, a seismic retrofit prevents cripple walls—sometimes referred to as pony walls or kneewalls—under the home from collapsing. Most homes in my region are built atop cripple walls. In other seismic zones, like the Pacific Northwest, cripple walls aren't as common, so retrofits predominantly focus on strengthening floor connections to the foundation.

Site-built shear walls strengthen cripple walls and make them far less likely to collapse when the ground beneath them shakes back and forth.

In no way do these measures constitute a comprehensive retrofit for all types of structures. They are merely a starting point for creating a safer home.

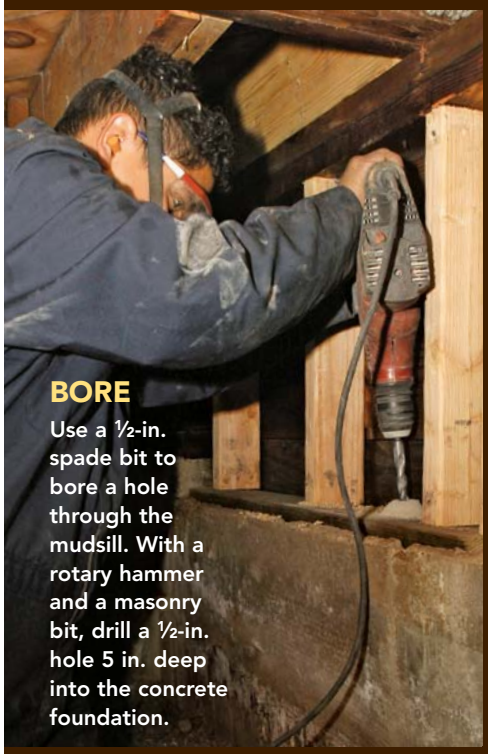
Brick chimneys, for example, pose a threat in many houses. Thousands of relatively new chimneys failed in the 1994 Northridge earthquake, despite having met code requirements in force at the time of construction. There is no economical way to strengthen a masonry chimney. The best solution is to remove the chimney and fireplace entirely. Gas water heaters in older homes should be secured with strapping (it's code for new homes), and automatic gas-shutoff valves should be installed to help prevent gas leaks and fire outbreaks after a big shake. Garage-door openings are a notorious weak point in a structure, especially when there is living space above them. Reinforcement of these large openings should be completed with the consultation of an engineer who can draft a site-specific approach, which may demand the integration of structural steel members.

Homeowners beware

Knowledgeable engineers are invaluable in helping to fine-tune retrofit measures to specific structures. Comprehensive retrofit methods are currently under development by volunteer groups of engineers and other retrofit experts. Until they are available, the only nationwide building code applicable to seismic-retrofit work is Appendix Chapter A3 of the International Existing Building Code (IEBC). The IEBC has roughly eight details showing methods to brace cripple walls and connect them to footings or foundations. These same details have been

CONNECT MUDSILLS TO THE FOUNDATION

Dated building practices mean that older homes are the most susceptible to earthquake damage. For example, the Uniform Building Code did not require connecting the wood framing of a house to its foundation until 1946. Houses without good connections to their foundations can simply slide off them under the force of an earthquake. Newer homes also should be inspected to ensure that they are bolted down correctly.



BORE

Use a ½-in. spade bit to bore a hole through the mudsill. With a rotary hammer and a masonry bit, drill a ½-in. hole 5 in. deep into the concrete foundation.

TAP

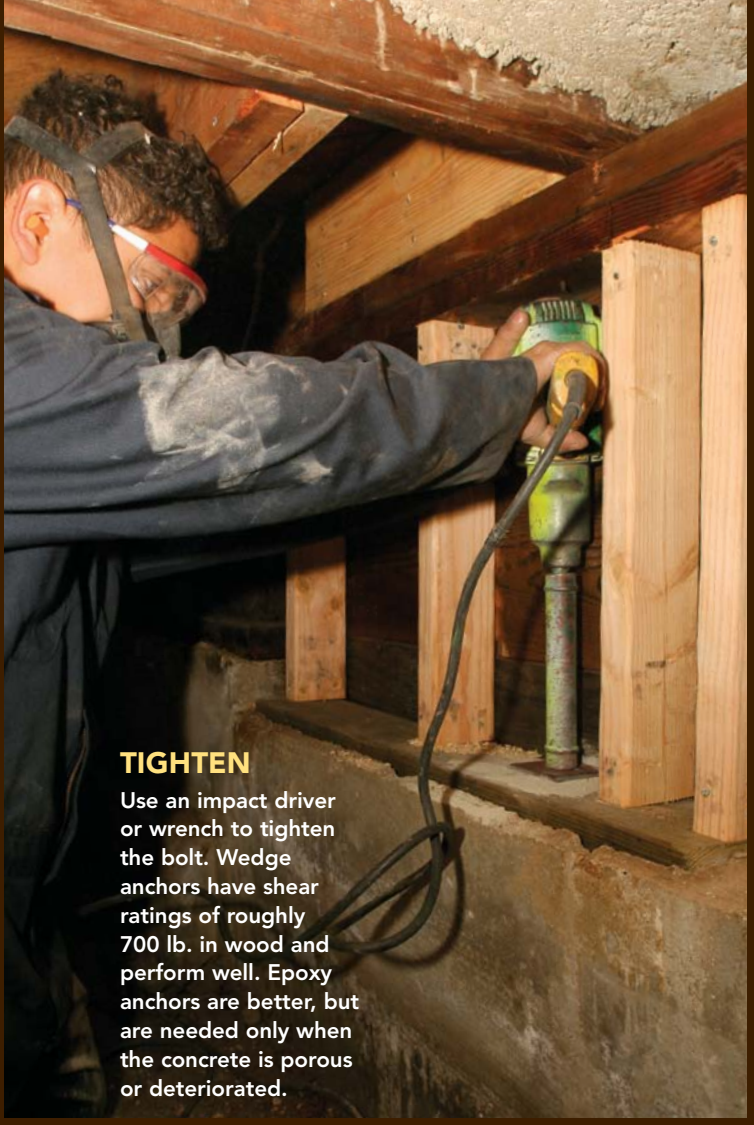
Hammer a ½-in. by 7-in. steel wedge anchor into the hole. The bolt should be fit with a ¼-in.-thick, 3-in. by 3-in. plate washer.

HARDWARE

Hilti: ½-in. by 7-in. Kwik Bolt
Simpson: ½-in. by 7-in. Wedge-All and BP½-3 plate washer

SECURE FLOORS TO THE TOP OF WALLS

Most floor systems aren't adequately attached to the top plates of the walls beneath them. As a house shifts back and forth under the forces of an earthquake, the critical joist-to-plate and rim-to-plate connections can fail and cause the floor to slide off the top of the cripple wall or floor joists to slide off mudsills. Readily available framing connectors and blocking between joists create a positive connection between floor systems and walls. Framing connectors have different shear ratings depending on the manufacturer, so choose hardware carefully.



TIGHTEN

Use an impact driver or wrench to tighten the bolt. Wedge anchors have shear ratings of roughly 700 lb. in wood and perform well. Epoxy anchors are better, but are needed only when the concrete is porous or deteriorated.

WHEN SPACE IS TIGHT

Bolt a plate to the foundation wall and the edge of the bottom plate to prevent the floor system from moving along the foundation wall or footing. This particular plate has a shear rating of roughly 1300 lb.

HARDWARE
Simpson: UFP10
KC Metals: RFA138

SECURE FLOOR JOISTS to cripple wall top plates with shear-rated framing connectors and 8d nails. A positive-placement pneumatic nailer makes hardware installation fast.

HARDWARE
KC Metals: HT10R
Simpson: H10R
United Steel Products: RT16A

HARDWARE
KC Metals: CA50, CA70, CA90
Simpson: L50, L70, L90
United Steel Products: AC5, AC7, AC9

CONNECT RIM JOISTS to wall top plates with shear-rated framing connectors. A palm nailer is an indispensable tool when securing hardware in hard-to-reach areas.

BUILD SHEAR WALLS

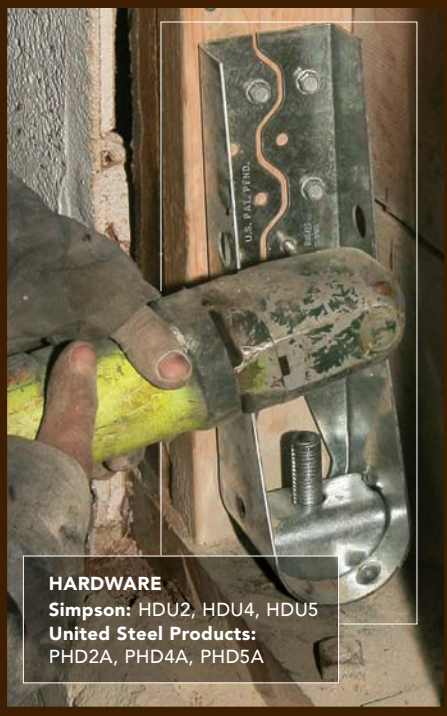
The most crucial element in a seismic retrofit in homes with cripple walls is installing plywood shear panels. Shear panels are built on site with plywood, hold-down hardware when needed, and properly sized nails. An engineer can determine where shear walls should be placed, or you may be able to follow a plan in a regional guideline. Shear walls need to be added only to one side of the cripple wall, so it's very likely that you can fit these panels into place without disturbing the exterior. Some shear walls demand hold-down hardware to be installed. Typically, when shear walls are taller than they are wide, they risk overturning during earthquakes. Hold-down hardware installed in the shear wall keeps the wall in place.

1 ***Cut the mudsill flush with the studs.*** *This allows the plywood to be edge nailed against an even surface. This is best accomplished with a tool like the Closecut saw by Clemenson Enterprises Inc. This photo shows a saw modified with the FlusSa attachment.*

2 ***Drill and prep holes for hold-downs.*** *With a rotary hammer drill and masonry bit, drill an 1 1/16-in. hole at least 12 in. deep. To ensure a proper bond between the epoxy and the threaded rods, plunge each hole with a bottle brush, then blow compressed air into the hole to remove masonry dust. Repeat this process three to four times before dispensing epoxy into the hole.*

HARDWARE
Hilti: HY 150 Epoxy, HAS Anchor Rod

3 ***Set the rods.*** *After filling the holes with epoxy, set the 5/8-in. all-thread rods. Twist the rods to ensure the epoxy finds it way between each thread. The epoxy used is quick setting, and the nut will be ready to tighten within an hour.*



HARDWARE
Simpson: HDU2, HDU4, HDU5
United Steel Products: PHD2A, PHD4A, PHD5A

4 ***Secure the hold-downs in place.*** *When the epoxy for each rod is set, attach the hold-down to the stud with screws before placing the nut on the threaded rod and bolting the assembly to the mudsill.*

repeated in several regional guidelines with occasional diversification. The variety of existing framing conditions that are found in houses far exceeds the scope of these details. Also, some of the methods shown in these documents require precise installation to work.

To add to the problem, California has no specific licensing requirements or subdiscipline for earthquake-retrofit contractors. The Association of Bay Area Governments (ABAG) has offered training sessions on seismic retrofitting for contractors (or other interested parties), but current budget problems mean there is a backlog of people waiting for training. Given the scant selection of details in the IEBC, there is not enough training material to offer comprehensive instruction. The results, unfortunately, can be well-meaning contractors implementing retrofit strategies that may do nothing to strengthen your house during an earthquake (sidebar facing page). The techniques presented here, however, are widely accepted practices and have been proven to protect houses during earthquakes.

Cost and effectiveness

For the basic underfloor strengthening described here, installation costs in the Bay Area generally fall in the range of 1% to 3% of the value of the home (roughly $3000 to $8000). In the Pacific Northwest, where retrofits are often simpler, a home can be strengthened for as little as $2000. Costs vary depending on the shape of the house, the height

Photos facing page: top, bottom, Paul Rude; center, Thor Matteson.

For more on shear walls, see "How It Works" on pp. 18-19.

5 ***Attach the plywood.*** *With all the hardware in place, attach ½-in. five-ply structural grade 1 plywood to the studs with 8d nails spaced every 3 in. Nailing schedules vary based on engineered plan.*

3 retrofit methods that don't work

Until the 1989 and 1994 earthquakes in California, there was not much hardware specifically marketed for earthquake-retrofitting purposes. Until recently, contractors, homeowners, and even engineers had to invent their own techniques. Sometimes these methods are effective, but more often, they give only a false sense of security.

Homemade hardware

Retrofit: Using angle iron to prevent wall from sliding off foundation

Problem: Custom-made connectors require costly custom engineering. This piece of angle iron will act like a lever when the wall moves and will shear off the bolts.

Solution: Simpson's UFP10 hardware or anchor bolts are better suited for this application.

Expensive connections that do little good

Retrofit: Attaching posts to girders with gussets or specialty hardware

Problem: For this connection to come loose, the floor framing would have to move quite a bit—which simply means you should have spent more effort strengthening the building perimeter.

Solution: It's much more cost-effective to construct shear walls and to strengthen connections around the perimeter of the house to keep it in place than it is to spend money on expensive hardware connections between posts and girders in a crawlspace.

Stock hardware used improperly

Retrofit: Using hardware that resists uplift in situations where shear is the main concern

Problem: Hardware developed for hurricanes is often misused in seismic retrofits. The straps shown here have a rated lateral load of 185 lb. That's not strong enough.

Solution: The UFP10 has a lateral load rating over seven times greater than each of these straps.

of the workspace, the number of obstructions to the installation, and other factors. Sometimes other concerns come to light during the retrofit that require additional work, such as deteriorated foundations, insect or rot damage, or water intrusion under the house.

APA-The Engineered Wood Association cites a real-life comparison of an original versus a retrofitted house as a barometer of retrofit performance. An architect purchased two identical Victorian houses in Santa Cruz in the 1980s. He intended to strengthen both of them. Unfortunately, the 1989 Loma Prieta earthquake occurred when he had completed seismic-retrofit work on only one house. The retrofitted house needed roughly $5000 in repairs. The other house, whose collapsed cripple walls caused it to fall off its foundation, needed $260,000 in repairs.

As earthquakes occur, we learn more about how various strengthening methods perform. Improvements likely will be found, but in the meantime, it's a safe bet to put yourself in the category of homeowners who strengthen their homes properly rather than the control group that does nothing, or that employs ineffective retrofit measures. □

Thor Matteson is a structural engineer in Berkeley, Calif., and author of *Wood-Framed Shear Wall Construction: An Illustrated Guide* (ICC, 2004). Structural engineer Joshua Kardon and Michael Wieber of Northwest Seismic contributed technical support. Photos by Rob Yagid, except where noted.