STRUCTURE

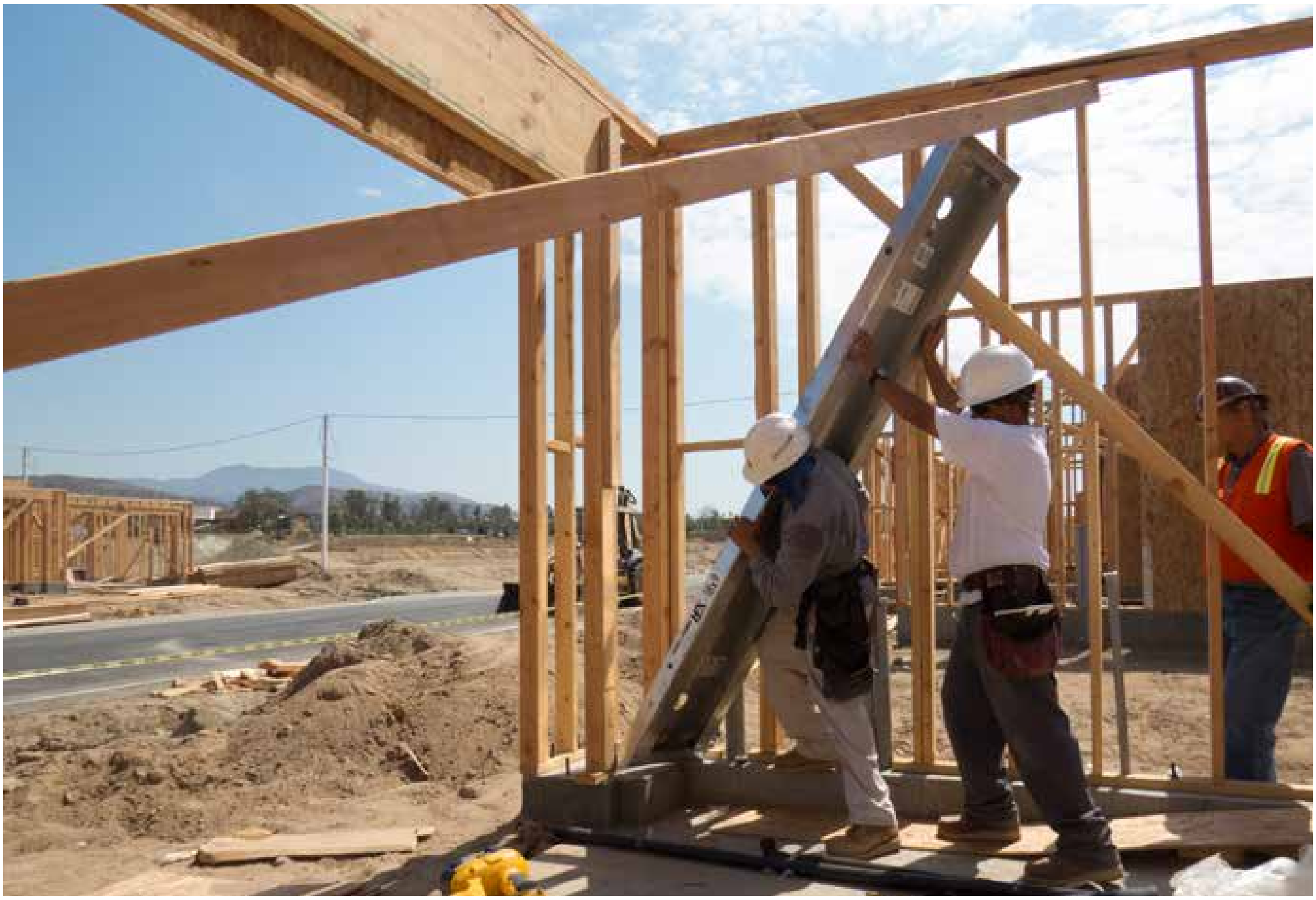
Photo: Isaiah Cushman

Manufactured Shear-Wall Components

When you need to handle seismic or wind loads with a narrow wall section, these products supply the solution

BY TED CUSHMAN

Some houses are simple. You have a shoebox shape to work with, there aren't too many big window or door openings, and you're not in a seismic zone or high-wind area. But some builders work in seismic zones, and some builders work in hurricane country. In those regions, any structure—high-rise or house—has to be designed for lateral loads, the sideways force of wind pressure or earthquake action.

Whether it's of a Florida beach, a Los Angeles hillside, or a Colorado mountaintop, homeowners love a beautiful view, and designs often call for high ceilings, walls full of windows, and large open rooms; and, of course, there's always the garage door. The result is structural situations where an extreme wind or seismic load has to be handled by a very small amount of solid wall. Facing that challenge, a typical stud-and-plywood wall—or even a site-built shear wall— can't always do the work.

If that's your situation, your engineer is likely to specify manufactured shear walls and moment frames—most likely supplied either by Hardy Frames (Panel or Brace Frame components and

SIMPSON STRONG-TIE

The company (strongtie.com) offers designers a range of solutions. Its wood Strong-Wall was its first entry into the field. Made with 2x4 or 2x6 studs and OSB faces, the components come in a range of widths (18, 24, 32, and 48 inches), and at heights suitable for framing an 8-foot, a 9-foot, a 10-foot, or a 12-foot wall, taking plate thicknesses into account.

For greater strength with a narrower wall, Simpson developed the steel Strong-Wall, substituting a corrugated steel panel for the OSB shear panel of the wood version. Available widths are 12, 15, 18, 21, and 24 inches, and there are eight available heights: 80, 85 ½, 93 ¼, 105 ¼, 117 ¼, 129 ¼, 141 ¼, and 151 ¼ inches.

Falling between the wood Strong-Wall and the steel Strong-Wall—in width, structural capacity, and price—is the Strong-Wall SB Shearwall, originally developed by Trus Joist and formerly marketed as the Trus Joist TJ Shear Brace. Simpson Strong-Tie purchased the product line from Weyerhaeuser in February 2013 and is launching the rebranded component into the market this fall. Based on a laminated strand lumber (LSL) column, the Shear Brace comes in widths of 12, 18, and 24 inches, and in heights ranging from 7 feet up to 20 feet high. Conveniently, the Shear Brace is field-trimmable to custom heights—just order the next greater size and cut the top to fit.

Simpson Strong-Tie also offers two types of prefabricated steel moment frames: the Ordinary Moment Frame and the Special Moment Frame. Moment frames cost more than prefab shear-wall panels but supply the greatest structural capacity, as well as the narrowest wall profile. The Ordinary Moment Frame has rigid corners and is well-suited to hurricane situations, where it's expected to stay stiff while standing up to the wind pressure on the house. The Special Moment Frame, introduced by Simpson just a year ago, was developed to address earthquake situations. A special ductile connection tab at the frame corners will yield under stress to protect the frame's main members from damage and allow for a quick post-earthquake repair in place.

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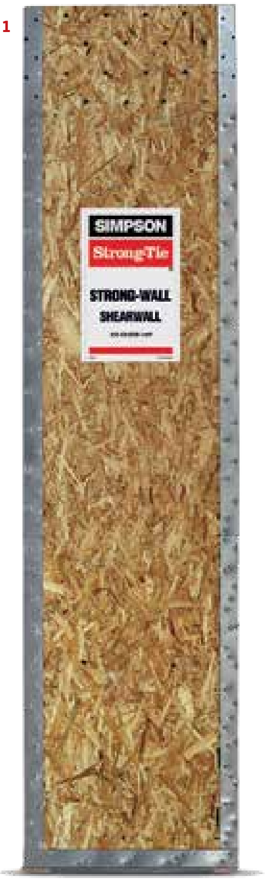

engineered Moment Frames; hardyframe.com), Simpson Strong-Tie (Strong-Wall panels and Ordinary Moment Frame or Special Moment Frame assemblies; strong-tie.com), or, in parts of the western U.S., Shearmax (the Shearmax panel system; shearmax.com).

"I kind of see manufactured components as a necessity now, to design what people actually want and to give them the structural integrity that they need," says Santa Barbara, Calif., framing contractor Don Gordon. "You've got an ocean view and you need a big window, but that only leaves you room for 8 feet of plywood. Well, in 4 feet, these things can give you the equivalent of 16-feet worth of site-built shear wall."

In this story we'll survey the whole field—wood shear-wall components, steel shear-wall components, and steel moment-frame assemblies. We'll look at how the products are the same and how they're different, and take a look at the issues you'll want to be aware of when you frame with them. We'll also discuss which product type is best suited for which situations, including both new construction and retrofits of existing structures.

UNDERSTANDING LATERAL LOADS

When the ground moves in an earthquake or the wind blows against the walls in a hurricane, houses in seismic or wind zones experience a "lateral force." To remain standing, walls have to withstand this force and transmit it into the foundation. The fine points of wall performance vary depending on whether the design accounts for wind, earthquakes, or both (see Seismic Versus Wind, page 56). But in general, engineers look at four issues: Shear—will the wall rack? Overturning—will the wall topple? Sliding—will the wall slip sideways? And uplift—will the anchors pull out?

The narrower the wall involved, the more problematic these forces become. A narrow wall has less material available to pick up the shear load, and fewer locations for anchoring to the foundation to prevent sliding. And as walls become narrower, the "aspect ratio"—the ratio of height to width—becomes higher, which increases the risk of overturning. That, in turn, creates greater leverage at the base of the wall, which applies a greater uplift force to the wall anchors.

Photo: courtesy Simpson Strong-Tie

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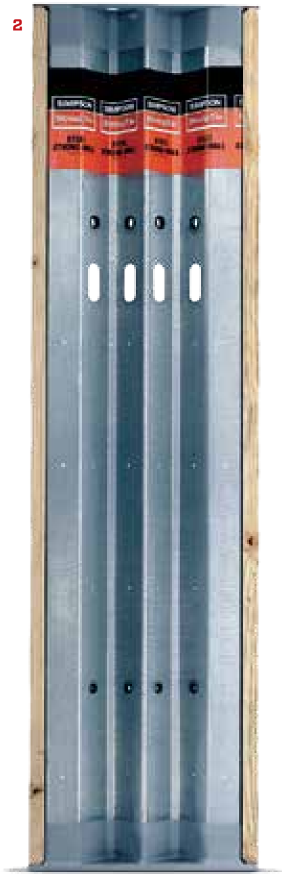

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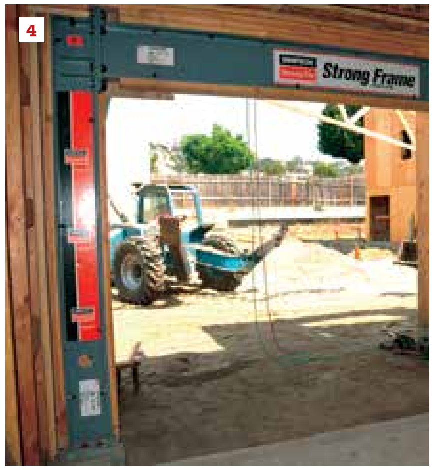


Simpson Strong-Tie's wood Strong-Wall **(1)** was the company's first entry into the market. The steel Strong-Wall **(2)** offers greater capacity in a narrower form, with simpler base attachments.

The Strong-Wall SB Shear wall **(3)** is made of laminated strand lumber (LSL) and is field-trimmable.

Simpson Strong-Tie's Ordinary Moment Frame **(4)** holds the frame stiff in a windstorm. In an earthquake, the steel column and frame bend to absorb the quake's energy, saving the building, but ruining the moment frame. Simpson's new Special Moment Frame (not shown) has a "fusible" connection between the columns and beam that is designed to yield in an earthquake, preserving the main members of the frame.

Photos: left, top right, courtesy Simpson Strong-Tie; bottom right, Ray Castillo/Gordon-Fiano

David Lopp, who handles product support for Hardy Frames, explains: "As a panel gets narrower, the uplift on the hold-down bolt, and the compression on the other corner of the panel—that overturning force goes up. If you put a panel in the wall that is 12 inches wide, or you put a Brace Frame in the wall that is 44 inches wide, when you push with the same force at the top, the uplift on the narrow panel is going to be much greater than it is on the wider frame."

All the big suppliers offer a variety of pre-built panels and frames, in a range of widths. And because the narrower components need to do more work and be more securely anchored, the narrower the component, the more it is likely to cost.

THE MAKERS

Most of the manufactured-shear-wall industry is made up of two top companies: Simpson Strong-Tie, headquartered in Pleasanton, Calif., and Hardy Frames, based in Ventura, Calif. Both of these big players ship components nationwide and offer extensive design and technical support. Simpson Strong-Tie also manufactures hangers and connectors; and Hardy Frames has been acquired by a larger company, MiTek, which also owns United Steel Products Co., the makers of USP Structural Connectors. So both Simpson and Hardy Frames can help engineers specify a complete solution for a home's structural load path, tying together roofs, walls, floors, and foundations to resist all the applied loads.

Shearmax, a much smaller company, is important in the California market and also ships panels to Utah and some other western states. Like Hardy Frames, Shearmax started out life as a framing company in Southern California; company engineer Tim Timmerman II (son of the founder, Tim Timmerman Sr.), credits that background for the company's emphasis on making a user-friendly panel.

Hardy Frames' Lopp makes the same argument for his company: "We started out as a production framer. You have to be efficient, you have to be effective, and you have to be the low price. And there

HARDY FRAMES

There are two flavors of manufactured shear wall offered by Hardy Frames (hardyframe .com): a "Panel" version made with continuous sheet steel; and a "Brace Frame" version made with steel vertical members and a diagonal cross-brace.

The Brace Frame, offered in widths of 32 and 44 inches, is the lower-cost and lower-capacity alternative for situations where wall length allows a wider component; the higher-strength, narrower Hardy Frames Panel is available in widths of 9, 12, 18, and 24 inches.

Hardy Frames' Moment Frame, made of steel I-beams, was the first prefab moment frame to gain a code listing. Standard sizes are available for opening widths from 1 foot up to 23 feet wide, and various opening heights (non-standard sizes require a special order).

SHEARMAX

The wood-based Shearmax panel is Shearmax's (shearmax .com) one flagship product. The product's unique design gives it a relatively high capacity for a wood panel: The OSB panel is set into a routed rabbet on the inside edge of the Doug fir 4x4 frame, so that wood-to-wood contact supplements the strength of the nails attaching the sheathing element to the frame. Light-gauge steel flanges around the perimeter of the frame add strength but maintain the "ductility," or capacity to yield, that allows the panels to function well, even at very high aspect ratios. Shearmax also developed an outside-mounted bracket with a small offset, which company engineer Tim Timmerman says transmits forces more efficiently from the foundation to the frame.

Shearmax panels come in nine standard widths (16, 18, 21, 24, 28, 32, 36, 42, and 48 inches), and the company can produce custom lengths up to 20 feet at no extra charge (odd widths are also available as a special order, but cost more). The panels can be custom cut in the field, either square or, if necessary, at an angle to match a roof rake.

are a lot of things we know how to do that will save money in the framing while still using these high-capacity panels."

Making the panels cost-effective and easy to use is on Simpson Strong-Tie's radar as well. For example, after acquiring the Trus Joist TJ Shear Brace system (a laminated strand lumber shear-wall component) from Weyerhaeuser this year, Simpson started addressing complaints from the field about the product's anchoring method. The system, re-branded by Simpson as the Strong-Wall® SB Shearwall, allows framers to make top cuts in the field to fit a roof height and rake angle. But accessing its attachment hardware at the bottom can be awkward.

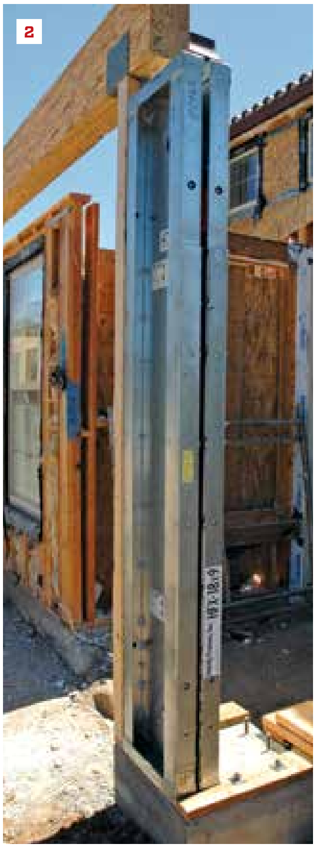
Competition among the top suppliers is keen. As a result, every year brings improvements to product lines, and companies put a lot of energy into technical support for their products—on site, as well as over the phone. For the smaller companies, it's personal: Hardy Frames' Lopp says, "If somebody calls with a question, they can talk to me." And California builder David Moore says that when he got into trouble with a Shearmax installation, Shearmax president John Jenkins came out to the site to help him set panels. "He figured out what to do in a half hour," Moore says. "It would have taken me half a day."

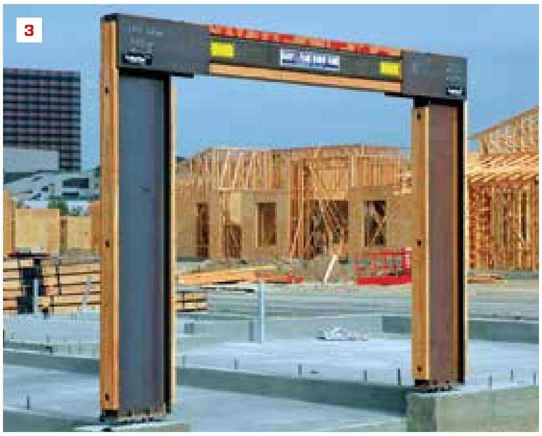
CHOICES AND CHALLENGES

All the products in the market are designed to do the same job—strengthen the building against lateral loads. And their code listings, based on verified testing, are evidence that you can rely on all of them to perform as advertised (as long as you follow the directions when you install them).

Depending on the situation, a framer might prefer working with one or the other. Unfortunately, however, framers—or even builders—who are working in high seismic zones aren't usually the ones choosing which product to use. Bay Area builder and remodeler Jeff Kerr says, "It depends on the engineer who's actually specifying it, based on the seismic requirements. The architect draws his plans, which are basically a wish list. Then he sends the plans to an engineer who determines the loads and specifies the

Photo: courtesy Hard Frames





Hardy Frames offers two flavors of shear wall: the Panel, made of sheet steel; and the Brace Frame, an open stud frame with a diagonal brace. Shown here are two Brace Frames **(1)** on an outside corner, and two Hardy Frames Panels **(2)** installed back to back for a doubled capacity.

Hardy Moment Frames **(3)** come in widths up to 23 feet. Custom sizes and two-story frame assemblies can be special-ordered.

Shearmax panels, a versatile solution for high-end custom work, are available in a wide range of widths and custom heights (but only in the California market). Shown here **(4)** are tall panels combined into four-sided box columns to support a high roof over open walls.

Photos: left, top right, courtesy Hardy Frames; bottom right, courtesy Shearmax

products. Our job is just to price it out and install it."

Typically, framers set the shear-wall panels directly on the concrete foundation or on the first-floor frame before they start stick-framing the surrounding walls. Kerr describes the installation process: "You form for your concrete (we do most of our own concrete work), you get all your rebar in, and you get a set of drawings from your engineer. All the panels come with a template, and you attach the template to the forms. Then from the template, you hang off your threaded rod or your anchor that is going to get embedded in the concrete in the forms. You just have to follow the instructions. … Once we've poured it, it only takes two guys a couple of hours and they're in. Then you just frame around the thing and attach it."

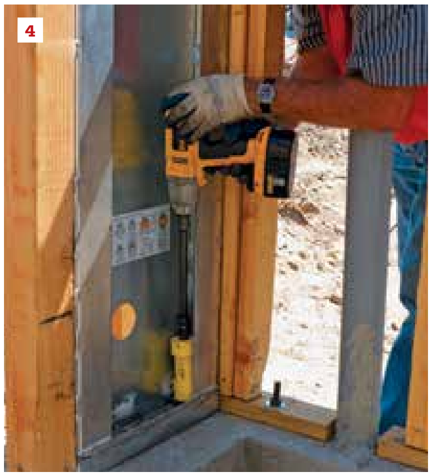
Sometimes, however, because of delivery issues or job schedules, wall framing is completed before the panels are installed. You can set a shear-wall panel into an already framed wood wall, but it may be a little fussier and slower (see photos, next page), so framers usually prefer to set the panels first.

"Probably the most critical thing is to get the bolts in the right spot to start with," Gordon says. "You have to use the templates. We've had bolts misplaced a couple of times, to where the panel is sitting outside of the wall."

Kerr agrees. "You better do your layout carefully, and be sure you've looked at all your framing members so that you've given it enough space to fit, you've put it in the right spot, you've set the template just so, and you've set the right bolts and hardware in place. If you blow it there, you can take care of it, but that's only going to cost you time and money. If you missed a bolt, you have to drill a new bolt and epoxy it in. If you've got something in the wrong spot, well, you might be chopping the whole thing out."

That happened more when the products were new and unfamiliar, says Simpson Strong-Tie's Don Simon, a trainer who helps manage the company's builder education outreach. "In the early days, we had guys in the field all the time helping builders fix mistakes," he says. But these days, it's old hat, at least on the West Coast.

Carpenters have one good reason to like Simpson Strong-Tie or



Framers typically set panels before they stick-frame the surrounding walls; here **(1)**, panels stand alone on a slab waiting for walls. But you can also set panels into an existing wall **(2)**. Accurately locating bolts during layout is a key step—and even with a good layout, panels may have to be persuaded into place **(3)**. Fortunately, this steel Hardy Panel offers easy access for tightening down mounting nuts **(4)**.

Hardy Frames moment frames, Gordon notes: It puts the ball in their court. "It becomes my work, not the structural-steel guy's work," the framing contractor says. "So I buy the $2,000 moment frame, charge profit on the materials, and then charge labor to install it."

But shear-wall panels aren't that expensive, Kerr says: "I just priced a pair out for a master bedroom addition with a large patio door. They were $330 apiece, plus tax."

Where a builder does have control over design and product specification, there's a lot of variety to choose from—and what you select depends on what you care about. If you want to be able to trim panels in the field, you have two options: Simpson's Strong-Wall SB Shearwall or Shearmax. If you need the maximum wall opening possible, you'll have to choose a moment frame. If you have a lot of wall area to work with, you can use a less expensive and wider component, such as a wood Simpson Strong-Tie Strong-Wall or a Hardy Frame Brace Frame.

What you don't have to worry about—if you install the panels right—is performance. Consulting engineer Zeno Martin says, "They've all been engineered to do what they say they can do. You've taken engineering out of the equation. So for a builder, I think it all comes down to cost and lead time. How much am I going to have to pay for it, and how long is it going to take me to get it?"

FIXING EXISTING BUILDINGS

New construction is one thing, but in the years to come, contractors will face a much more complicated challenge: plugging shear-wall and moment-frame components into existing buildings.

Investigators in California noticed a common mode of failure in many buildings after the Loma Prieta (1989) and Northridge (1994) earthquakes: A "soft story" on the building's first floor buckled and failed, and the building's upper stories fell to the ground. According to Dan Friedman, who was in L.A. just weeks after the Northridge earthquake (see "Eight-Penny News: Earthquake Aftermath: On-Site

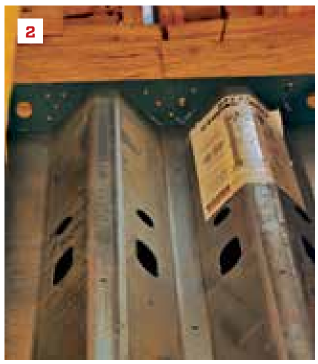
Photos: Isaiah Cushman

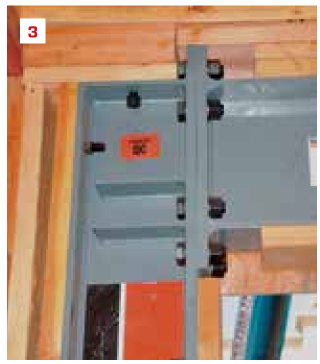
MOMENT FRAMES AND UPLIFT CONNECTIONS

Unlike a shear-wall assembly, where the anchor points between the wall base and the foundation are assumed to pick up an overturning load on the shear wall, moment frames do their work in the upper corners of the frame. There they resist the "moment"—the force of bending or rotation—with a rigid connection at the joint between the column and beam, rather than relying on the joint between the base of the column and the foundation it rests on.

In terms of overturning, a moment frame is analyzed like a single large shape. Its two narrow columns aren't considered to be overturning independently; instead, the entire frame around a garage door or large window may be trying to overturn as a 9- by 20-foot unit. If the weight of an upper story is resting on the header beam, the uplift on either column from the overturning motion could be completely outweighed by the gravity load on the whole structure. This means that, in total, the uplift stress on the bolted connections between each column and its concrete base is less problematic than is the case with narrow shear walls, even though each of the frame's two columns may be quite narrow.

This difference is reflected in the connection details of the various systems. The Simpson steel Strong-Wall at right, for example, has heavy bolts tying it to the foundation at its base, where the overturning and uplift forces could be extreme **(1)**. At the top of the panel **(2)**, by contrast, the connection consists only of Simpson SDS screws—lighter-duty fasteners. But in the upper corner of a Simpson Ordinary Moment Frame **(3)**, heavy-duty bolting is required to hold the joint stiff.





Report," April/94), "Collapsing second stories reduced parking areas and, in some cases, first-floor apartments to as little as a few inches in height, resulting in a record number of deaths."

Years later, federal, state, and local governments are getting serious about addressing the "soft story" problem. San Francisco passed a city ordinance on April 18 this year (the anniversary of the 1906 earthquake) requiring mandatory retrofits of thousands of buildings in the city to strengthen "soft story" first floors. San Francisco's new law will apply only to buildings with five or more apartments built before 1978. But that's still a lot of work.

Simpson Strong-Tie engineers say their new Special Moment Frame is tailor-made to address the problem. Unlike earlier types of steel moment frames, the Special Moment Frame is connected at column-to-beam joints with a tab of softer steel that is designed to bend and give in a way that will absorb the energy of an earthquake without subjecting the frame's main members to the quake's full force. Standard steel moment frames, says Simpson engineer Steve Pryor, absorb the energy in the main beam of the frame instead. "When the steel in the beam starts yielding, it becomes soft throughout its whole depth," Pryor says. "So you have to hang onto it so that it doesn't buckle and move sideways. ... That stability bracing is critically important in a seismic event."

But this bracing is a problem when retrofitting wood structures. "When you're putting steel frames in wood buildings," Pryor says, "you cannot anchor your brace into the wood floor next to the beam strongly enough to stop that twisting and buckling. So the Special Moment Frame technology that we have developed is a game changer because the special fusible links, top and bottom, do all the bending, instead of the rest of the frame. You don't have to worry about this twisting and buckling problem."

Ted Cushman is a freelance writer based in Peaks Island, Maine. He is editor of the Coastal Contractor newsletter and has been a regular contributor to JLC since 1993.

Photos: Ray Castillo/Gordon-Fiano

Seismic Versus Wind

Shear walls and moment frames are the standard solutions for handling lateral forces on building walls in both seismic and high-wind zones. But the ways in which earthquakes and hurricanes act on a building differ, so the job that shear walls or moment frames do varies depending on whether they're facing a seismic load, a wind load, or—to make things a bit more complicated—both.

Engineer Steven Pryor, a Simpson Strong-Tie expert on designing for lateral loads, gave *JLC* some insight into that topic in a September interview.

"When you design for hurricane forces, you have a force applied to your building for a long time in the same direction ... The wind can keep pushing on you for 15 or 20 minutes; the building has to tough it out for as long as it takes. So for wind, we design for strength."

SEISMIC IS DIFFERENT

Unlike wind, "the earthquake doesn't apply a force directly to your building," Pryor points out. "The foundations just move, laterally and up and down." Pryor focuses on the lateral movement because good gravity design will handle the up-and-down motion, which is in the same direction that gravitational forces work.

The building's inertia tends to keep it stationary, so shear walls and moment frames are designed to help the building keep up with the motion of the foundation. Without them, Pryor says, "you find a situation where the foundation is in one spot and the mass of the building is in another spot. If the difference gets too big, the weight of the building and gravity will just drive that building down. We call that 'pancake' or 'collapse'—and that's what you see in the 'soft story' buildings in Loma Prieta in 1989 and Northridge in 1994" (see "Eight-Penny News," April/94).

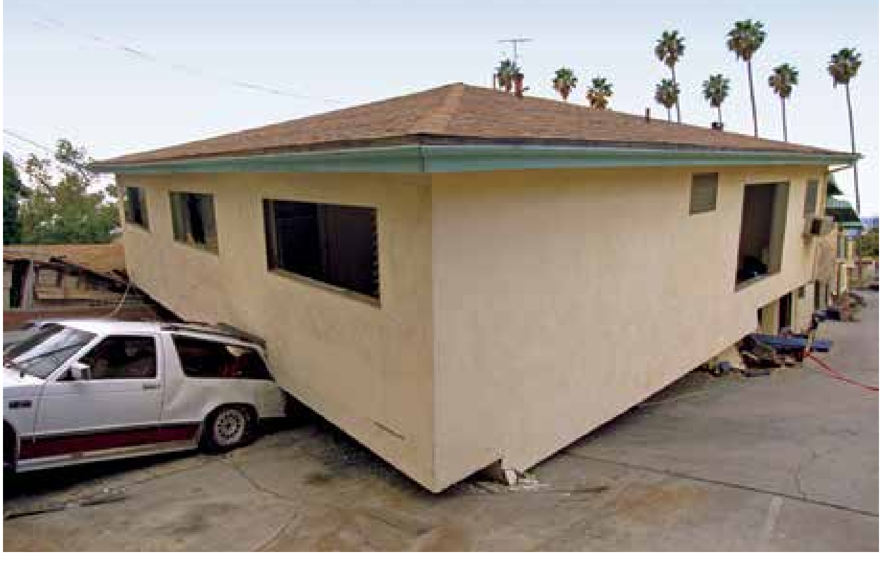
Earthquakes are more powerful than wind, and it's too expensive to fully resist their lateral forces. So engineers compromise. "Unlike a hurricane that blows in one direction for 20 minutes, an earthquake creates ground motion that goes to the left for half a second, then back to the right," Pryor says. "If you let the beam and column connections yield, you can design for a force that is one-sixth to one-eighth the force that you would need to keep that building strong enough to not yield at all."

The good news is that if the design works, the building won't fall down and kill somebody. The bad news, Pryor says: "Your building is getting damaged. We accept limited damage to the building, as long as the building doesn't collapse. Your home may get red-tagged after the event, but nobody got killed."

WIND AND SEISMIC TOGETHER

The trickiest cases, Pryor says, are those rare situations where wind and seismic rules both apply. Engineers use the "R factor," or "reduction factor," for building assemblies that yield in an earthquake. The R factor for wood-frame construction is 6.5, which means that, for calculation purposes, the earthquake load is considered as one-sixth the equivalent wind load because the building is designed to yield and deform, soaking up and dissipating the energy of the motion. If the building were designed to stay stiff throughout the movement, the forces would be much higher.

Combining wind design with seismic design can be confusing, but the key is always to detail the structure for a seismic event, even if the wind forces are higher. The allowable reduction factor is based on an assumption that the building's connections will yield and absorb the shaking energy of the quake. If the house were built instead with stiff details that wouldn't yield, the connections would perform well in a windstorm, but in an earthquake some components could experience actual forces that were many times the design shear, leading to failure and collapse. —*T.C.*



In an earthquake, shear walls help upper stories stay connected to the foundation, which moves rapidly back and forth. Without them, the movement gets too far out of sync, and the building "pancakes," as in this 1994 photo from Northridge, Calif.

Photo: FEMA/Andrea Booher