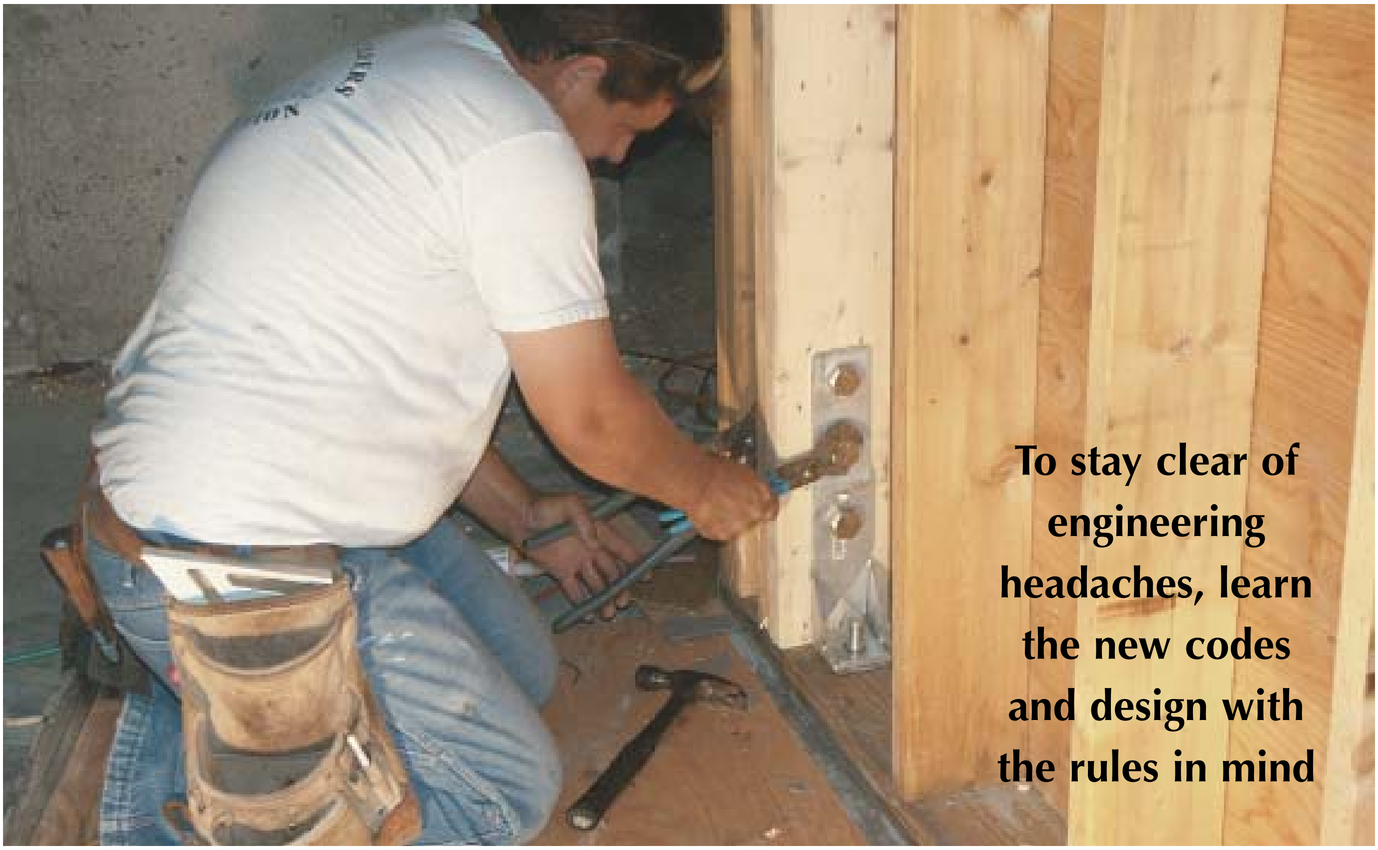
Shearwalls for Coastal Homes



As a design-build contractor specializing in custom homes near the water, I have to take wind loads into account on every project.

by Andrew P. DiGiammo

The New England coastline where I work has been hit by hurricanes before and no doubt will be again; homes here are supposed to be ready to handle a storm.

I've been using wind-resistant design and construction details for as long as I've been a builder, but this year I've been making some adjustments. That's because I face the same situation as many builders in other coastal states: Rhode Island and Massachusetts, where I work, are moving to the 2000 *International Residential Code* (*IRC*) and the *International Building Code* (*IBC*). The International Codes contain provisions for wind-resistant construction that are quite a bit tougher and more detailed than the rules we used to have.

Even for builders like myself who have long experience with wind-resistant details, now is a good time to review our approach to wind-resistant construction. If you don't know much about wind issues, and you plan to build near the coast, doing some homework will help you stay out of trouble.

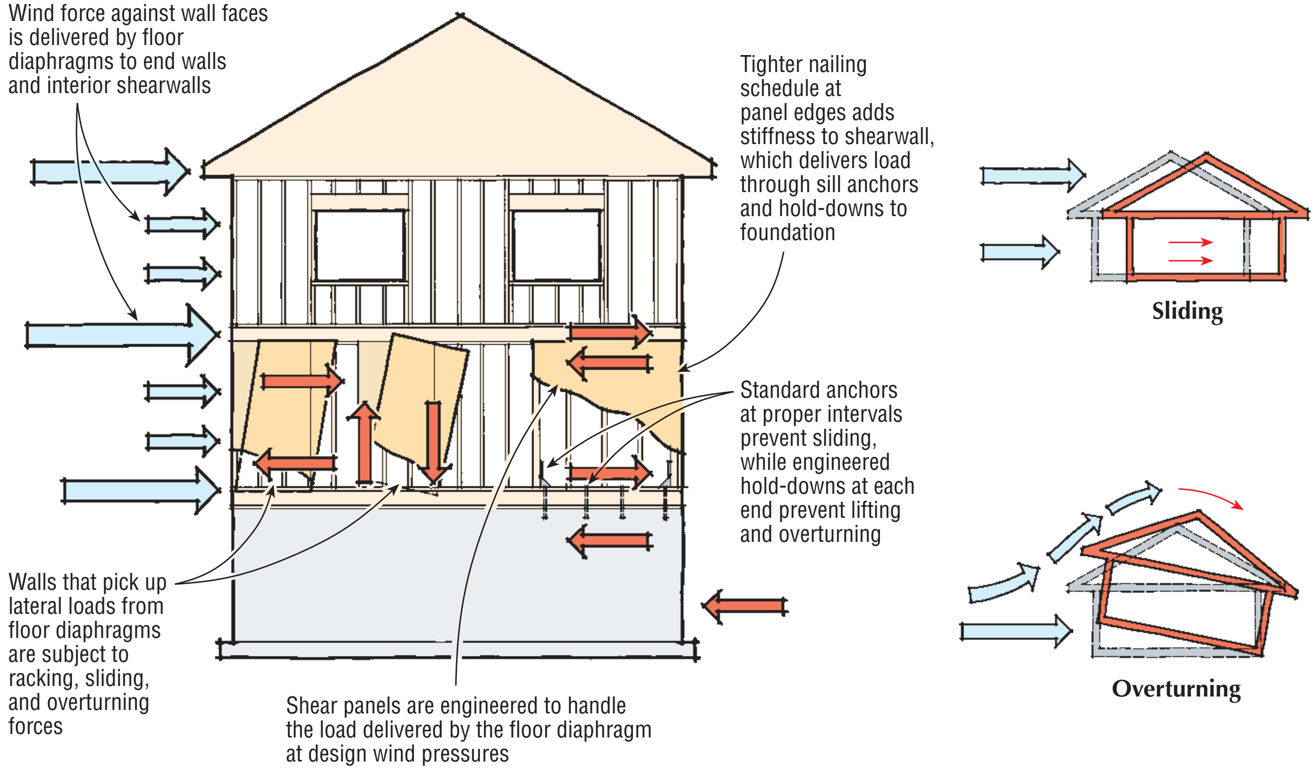
The new rules cover a whole range of complicated issues, including the way houses are anchored to foundations and the way components and claddings are attached to the structure. There's also a new set of requirements for windows. That's too much to cover all at once, so in this article I'll focus on one aspect of a wind-resistant building: shearwalls.

Understanding Wind Loads

Every framer has an instinctive awareness of gravity loads: Common sense says that your walls have to hold up the floors and the roof. Lateral loads aren't so obvious, but near the coast they are important: Wind applies a sideways force to your building that can be stronger than the gravity loads on the floors and roofs. The Rhode Island waterfront house shown in this article, for example, had design wind pressures of 35 psf on the building. That house needed several beefy interior shearwalls to pick up the load.

Wind basics. Wind acts on a building's structure in several primary ways. Uplift, the suction force that could tear the roof off or lift the building off its foundation, is important to consider, but it's not central to this discussion.

How Shearwalls Resist Lateral Loads



Conventional structurally sheathed exterior walls withstand some of the lateral force exerted by high winds but are not strong enough in 110- and 120-mph zones. By contrast, shear panels, which can be incorporated into standard frame walls, are engineered specifically to handle all sliding and overturning forces without relying on other elements of the frame.

What matters more here are the racking, sliding, and overturning effects: When winds try to roll the house over or slide it horizontally, floor diaphragms and shearwalls come into play (see illustration, above).

In reality, the force of wind is variable and unpredictable, and there is no way to define it exactly. To get numbers we can use for design loads, we have to oversimplify. In the code, it comes down to wind speed zones: The higher the wind speed zone, the greater the pressure. There are also exposure categories: If you're building right on the water where wind has a clear shot, you use a higher-design wind load than if your site is protected by woods, rough terrain, or other buildings.

Shearwalls at Work

How do shearwalls handle wind? The easiest way to understand wind is to think of it as a constant load pushing against a wall face. It loads the wall the way furniture and people load a floor, only horizontally rather than up and down. Wall sheathing collects the wind pressure and delivers it to the studs, which in turn carry the load to the top and bottom of the wall and apply a force to the floor systems. Next, the plywood-sheathed floor picks up the force, acting like a deep, thin, sideways beam, and carries the load over to the shearwalls. The shearwalls, in their turn, restrain the floor diaphragm and carry the load to the foundation and into the earth. On larger buildings, end shearwalls typically need help from interior shearwalls.

To do their part, the shearwalls have to be stiff enough to resist racking, and they must also be anchored against sliding and overturning. The stiffness comes from plywood or OSB sheathing (I use plywood). To pin the wall in place, the easy choice is a manufactured hold-down like Simpson Strong-Tie's HD5 series, which I used on my current Rhode Island project. You could design your own connector if you could find an engineer to okay it, but in my experience it's so convenient to work with Simpson products that I don't bother looking for an alternative.

Stud and plywood framing isn't the only way to build a shearwall. In commercial construction, engineers might call for a steel moment frame or a reinforced masonry shearwall to pick up lateral loads. But steel and masonry aren't easy to mix with wood framing; they interfere with wiring, insulation, flashing, and everything else. In houses, wood-framed shearwalls make more sense.

Even without special detailing, a stud wall with plywood or OSB sheathing has a lot of shear capacity. A "braced wall section" that will satisfy the *IRC* prescriptive path is just like a normal sheathed wall. It's permitted in lower-wind-speed zones. But it's not an engineered solution — code acceptance of braced wall sections is based on tradition and experience.

To get an actual shearwall with predictable strength, you don't change much: It's still 16-inch on-center stud framing with a single shoe and double top plate, typically sheathed with a $^{1}/_{2}$-inch panel (or thereabouts), using 8d nails. But you need hold-downs of some sort at both ends of the wall — concrete anchors, or a floor-to-floor connector in the case of a second-floor shearwall. The hold-downs need to connect to a double stud, or sometimes even a single 4x4 member.

To strengthen the basic shearwall, you can increase the perimeter nailing, use thicker plywood, or go up to 10d nails — or some combination of all three. If the wall has to handle a bigger load, it may also need beefier hold-downs. Specifications that match nail size, spacing, and panel thickness to shearwall allowable capacity are available from APA–The Engineered Wood Association at www.apawood.org.

New Codes, New Loads

While design and construction of shearwalls have not changed, the codes that tell you where and when you need a shearwall have. Based on the lessons of hurricane damage in the 1990s, the *IRC* and *IBC* have incorporated a number of important changes. One is that the map of wind-speed zones has been modified to reflect new data collected by modern instruments. The new map is published in *ASCE-7*, the American Society of Civil Engineers handbook that governs wind and seismic building design.

The *IBC* now requires houses in wind speed zones greater than 110 mph to be designed according to *ASCE-7*, or according to one of the documents based on it (see "For More Information," page 8). If your house is exposed to a wind speed of less than 110 mph, you can use the prescriptive methods given in the *IRC*, and for speeds of less than 100 mph, the prescriptive methods give you more leeway. Below 90 mph, conventional construction is allowed.

Of course, states that adopt the *IRC* and *IBC* can (and do) amend them, adding their own special rules and compliance paths. In Rhode Island, for example, the state has tried to simplify even the prescriptive wind provisions in the *IRC*. In place of the *IRC*'s extensive section on "braced wall" options, Rhode Island's "Appendix L" just calls for a 4-foot-wide shearwall at every building corner and at least every 25 feet — blocked at panel edges, nailed at 6 inches on-center, and with an anchor and doubled studs at each end. (Alternatively, a window opening may occur as close as 2 feet from the corner, but only if the shearwall section is made 8 feet wide instead of 4.) It's simple, but if you deviate from it, you need an engineer to review and approve the change.

I don't particularly like the limits on window location or the prescriptive tables they replaced. I never use the prescriptive methods, even if I'm in a zone where they apply, because I know that at some point I'm going to want a window or something where the rules don't allow it. So I just get an engineer on board from the beginning and assume that he'll be reviewing the plans. That way I can control both the appearance and the structure of the house.

Designing Around Shearwalls

Near the water, I like to use the shingle style, a tradition that includes a lot of jogs and bays. The corners and short wall sections add rigidity to the structure.

I always identify the shearwall requirements at the beginning, before I start to make decisions about the floor plan. When I see that I'm going to need interior shearwalls, I can place walls that define the shapes of rooms in the house in a way that lets me use those same walls for shearwalls and also as bearing walls for the roof and floor gravity loads. It simplifies both the engineering analysis and the construction of the house, eliminating a lot of aggravation and expense.

To simplify the structural analysis, it's helpful to locate a few wall areas in each structure that can be left without windows. That way I don't have to analyze walls with openings ("perforated" shearwalls). Instead, I have the freedom to slide windows around any way I please in all the other walls.

Case Study

My current project illustrates how I incorporate these structural solutions into my design concept from the outset (see "A House by the Water," next page). The main house is based on a traditional colonial rectangular shape but with several polygon bays. The bays gather in sunlight and air but are also stronger elements than flat faces that have to be reinforced.

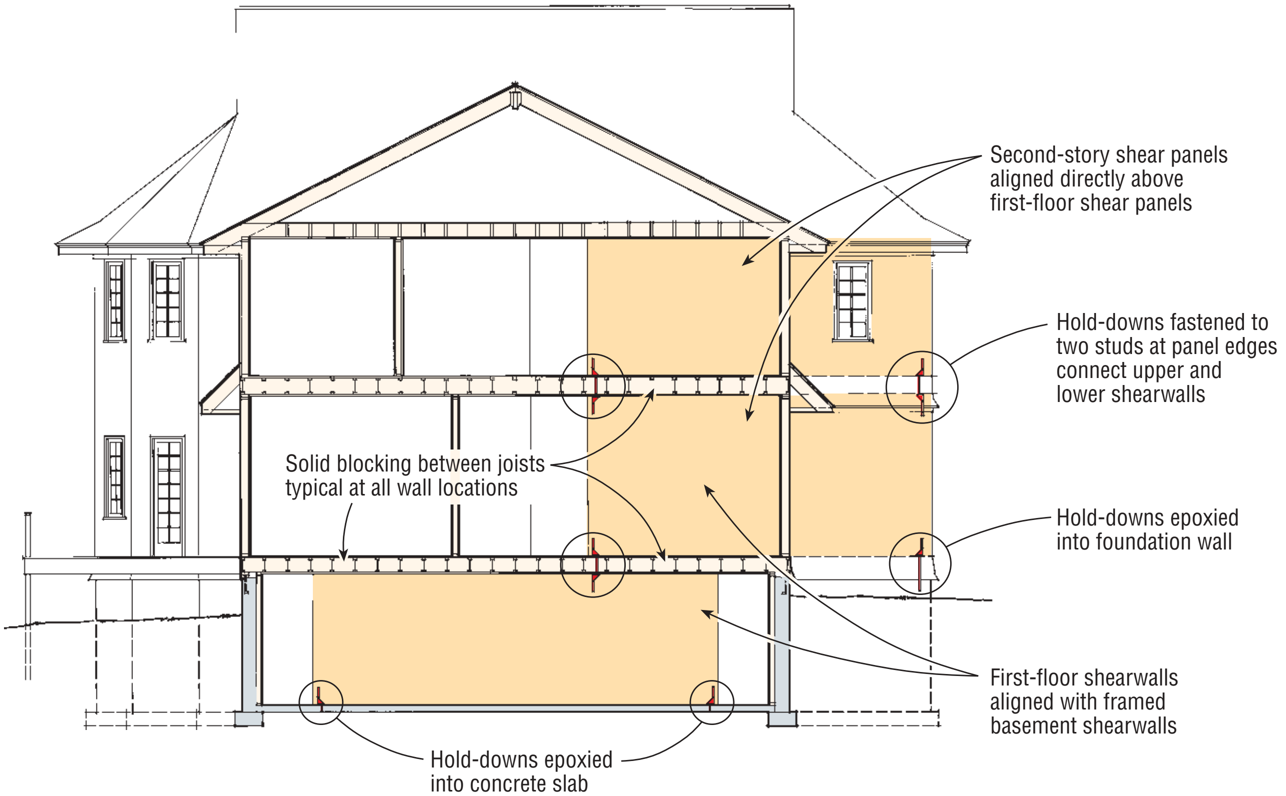
For framing efficiency, I used full-length 40-foot wood I-joists for the first floor, running them from end to end of the house. They are supported on the two end walls and on three framed walls built on their own footings in the basement.

Two of the cross-basement walls also act as shearwalls, anchoring the first-floor diaphragm. Stacked directly above them is a pair of first-story shearwalls, which carry their share of the second floor's live and dead loads and also serve to handle any lateral load carried into the house by the second-floor diaphragm. Above those two walls I set a third pair, which support the second-floor ceiling (the attic floor) and lock the floor and ceiling

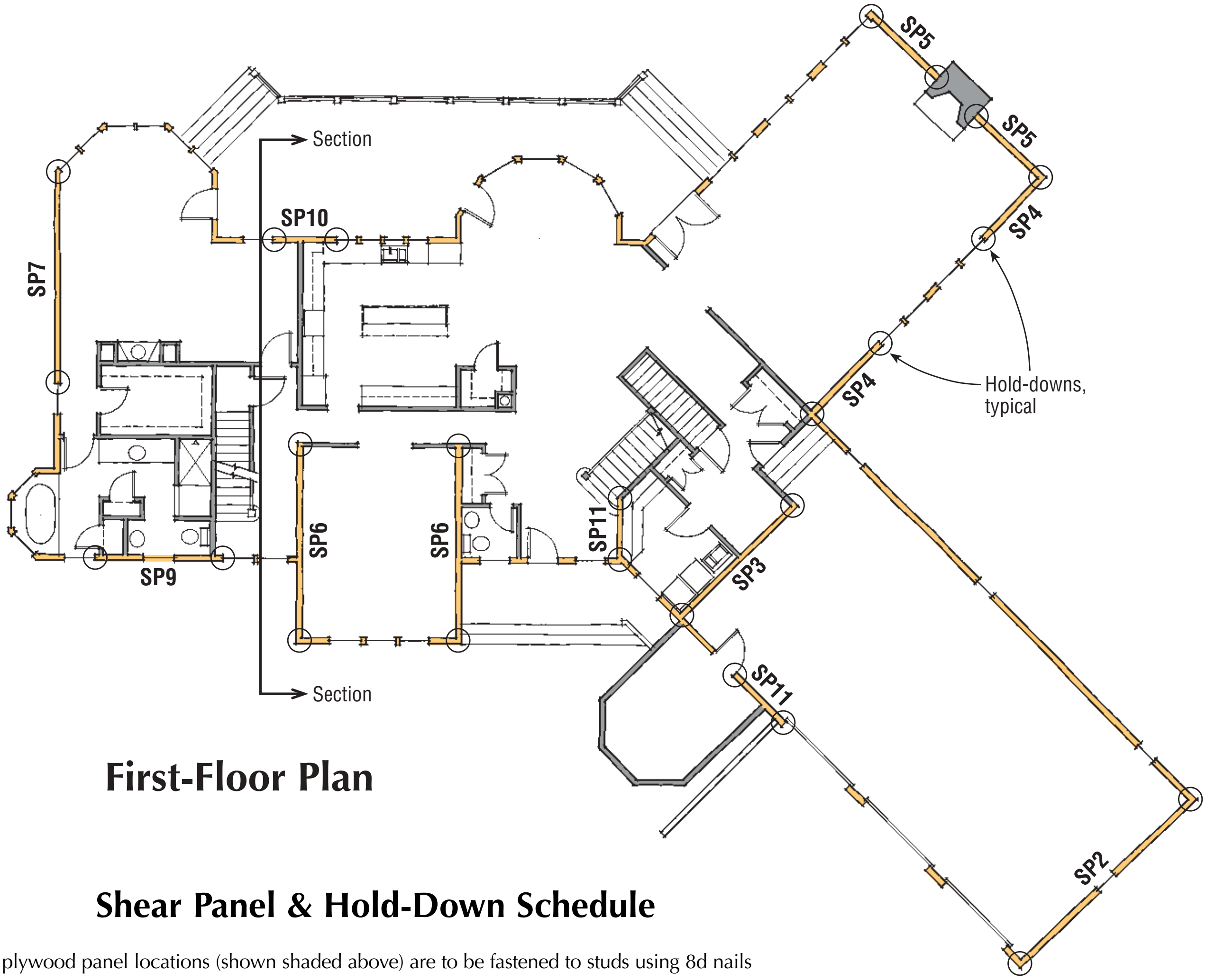
A House by the Water

The author designed this oceanfront home with code shearwall requirements uppermost in his mind from the concept stage. Working with an engineer, he stacked two primary first-story and second-story shear panels directly above basement-level shearwalls (section, below). In this way, he was able to accommodate most of the wind loads from the long axis of the house without cramping the generous space desired in ocean-facing rooms (floor plan, next page). The unbroken expanse of the north-facing end wall also contributes (top photo). This wall was left windowless intentionally because it faces the neighboring house on the narrow lot. While the east-facing wall has many windows, the polygonal jogs provide lateral strength through geometry — the same way right-angle jogs in a long foundation wall do.

Proper shear panel nailing and hold-down placement are critical, so the engineer prepares a separate plan sheet and fastener schedule for this purpose. The schedule lists the hold-down spec and plywood nail size and spacing for each shear panel location (next page, bottom).



Building Section



First-Floor Plan

Shear Panel & Hold-Down Schedule

All plywood panel locations (shown shaded above) are to be fastened to studs using 8d nails spaced at 6" on-center at all plywood edges and at 12" o.c. at all intermediate members except for the specially designated shear panel types indicated below.

Mark	Force	Height	Length	Shear	Hold-Down	Plywood Attachment	Hold-Down Connector
SP1	7680	8	20	384	3072	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD5A into (2) studs
SP2	12408	10	24	517	5170	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs
SP3	9040	9	16	565	5085	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs
SP4	4032	9	7	576	5184	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs
SP5	3552	9	9	395	3552	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD5A into (2) studs
SP6	13760	9	20	688	6192	Glued with 8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs
SP7	8256	9	21	393	3538	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD5A into (2) studs
SP8	6144	8	12	512	4096	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD6A into (2) studs
SP9	6885	9	13	530	4767	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs
SP10	3090	9	6	515	4635	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs
SP11	1650	9	6	275	2475	8d nails at 6" o.c. at edges, 12" o.c. intermediate	Simpson HD5A into (2) studs
SP12	13760	8	24	573	4587	8d nails at 4" o.c. at edges, 12" o.c. intermediate	Simpson HD8A into (2) studs

- All designated shear panels are to have solid blocking installed between studs along plywood edges.
- All Simpson hold-down connectors at the second-floor level are to be fastened through to the shear panel below.
- All Simpson hold-down connectors at the first-floor level are to be fastened into the foundation wall or supporting beam.

diaphragms for that story into the whole-house assembly.

Nuts and Bolts of Hold-Downs

For shearwalls to work, it's critical to block and nail the plywood panels to the framing according to the engineer's nailing schedule. It is also vital to properly install all hold-downs in the specified locations. The well-fastened plywood gives the wall enough strength to resist racking forces from the applied lateral loads, while the hold-downs keep the wall from lifting, rotating, or sliding.

For the house shown, my engineer specified 1/2-inch plywood on one face of each shearwall, nailed at 4 inches on-center on the perimeter with 8d common nails. He called for Simpson HD-type hold-downs at both ends of each wall (there are several

To link stacked shearwalls through the wood floor, a carpenter drills a tight hole from upstairs (above left), using the bracket to locate the hole and a torpedo level to stay plumb. He hammers the rod through (above right) and sets the brackets, then drills holes into the studs (right) for lag screws. In the basement, he hammer-drills holes in the concrete, then anchors the threaded rod into the hole using high-strength epoxy (below, left and right).

varieties of the HD and similar connectors, suited for use in different situations).

To secure the basement shearwalls to the slabs and footings they rest on, we first drilled a hole through the wall plate and into the concrete, using a masonry drill and bit. Then we placed threaded rod in the hole using an epoxy formula supplied by Simpson Strong-Tie.

Neither my engineer nor I recommend placing anchors in the concrete during the pour. The anchors have to be placed accurately, and it is much easier to drill a hole in the plate and footing than it is to locate a rod in the right place during concrete work. And epoxy is actually stronger than a concrete bond anyway, as long as you are sure to blow out all the dust with compressed air before you put the adhesive in the hole.

Epoxy used to be a hassle, back in the old days, with two tubes to mix by hand. But the new systems use a mixing nozzle attached to the tube — you squeeze the epoxy out just as if you were applying caulking or subfloor adhesive. Nothing could be easier — and now my local lumberyard even stocks the adhesive, so I can pick it up whenever I need some.

The epoxy has to set up before the nuts and bolts can be torqued down. You can put the nuts on finger tight about a half hour after setting the rod into the epoxy, but you should wait a day before tightening down the fasteners to the specified torque.

To tie together wood-framed shearwalls on different stories, we install one bracket above and one below, linked by a length of threaded rod long enough to get through the floor system and both wall plates. You set the bracket in place, mark the spot, then take the bracket away for a moment to drill the hole. Holes should be snug enough that it takes some force to send the rod through — there's no wiggle room allowed when you're fastening down a shearwall. As with the concrete-set hold-downs, the nuts need to be tightened to the supplier's specifications, but since there's no epoxy involved, you don't have to wait.

Hold-downs are not cheap, and they take time to install, so I like to use them efficiently. With the walls stacked one above the other as they are in this design, I needed just six of these standard fasteners for each foundation-to-attic shearwall stack. The system is easy to inspect and understand as well as to build — a plus when I get inspected by the building official.

Finding the Right Engineer

Many of the projects I build are large and elaborate, and I know from the outset that I'll need a lot of engineering help. But even for smaller jobs, I like to get an engineer involved. Near the coast, I consider an engineer to be an indispensable part of the team.

One big reason is to handle surprises. There's always a chance that you'll hit a snag with the building department about some structural element. The inspector might come to check the framing and say, "That beam wasn't called out in the plan. It's fine that it's there, but prove to me that it works." If you call an engineer cold at that point, he might get back to you in six weeks — or never. For $150, why should he involve his professional license in some stranger's project that he hasn't followed from the outset? If something else goes wrong, he's at risk, though he took no part. The relationship is important: I bring the engineer on board from the beginning so there will be someone I can call up on a Thursday morning and say, "I need help figuring something out" and get an answer that week.

For coastal houses, selecting an appropriate person is important. You're looking for an engineer who specializes in this field, or is at least experienced with wood frame platform construction. I've had disappointing results with some engineers, who were very skilled but didn't know this kind of framing — they specified connectors that were not available, for instance. You need your engineer to come up with a solution that works well with both the design and the process of your specific building.

And he can do that only if he wants to. In my experience, some of the larger firms don't want to bother with homes — they won't give you their real attention. If they take the work, they'll think of it as something they can do between big jobs when they have time on their hands. They may give you a solution that covers their rear end but leave you with a logistical problem — you end up with something that will work the way they drew it but will be a hassle to get in place. You need someone who knows how to specify the wood members and connectors you typically work with.

Good engineers will do as much or as little for you as you need them to. I like to bring my plans to the engineer as if I were ready to go to the building inspector for a permit. I'll have the footprint, all the elevations, and the floor plan laid out, and I'll know how I intend to frame. If I've already planned for the lateral loads, at least in principle, everything is easier: He will calculate what I need for sheathing, nailing, and hold-downs, but he'll be working with my framing concept, not telling me how to lay out the building.

The engineer then supplies me with a plan overlay showing where all the shearwalls are. He calls out all the connections I need between those shearwalls and the foundation, the floor system, or the walls below, and he specifies the plywood and the nailing. He can also provide a letter that you can take to the building department with wording like, "At your request I have reviewed the construction documents for your project. My review includes an analysis and design of the main structural support beams, a general overview of the typical framing systems, and a wind analysis." Most of the time, such a letter with the engineer's stamp and signature is enough to satisfy building inspectors — it saves your time and theirs, because you don't have to go over your plans with them page by page.

— A.D.

Because the floor joists ran the length of the house, they couldn't be used to tie the ends of the rafters. So the author used a supported ridge, posted down to the foundation.

The frame was simple to analyze, efficient to build, and economical, to boot. There was no need to build and set a center girder down the long axis of the basement, and using the full-length I-joists saved labor, even though we had to block between the joists above the shearwalls.

Because they run the long way, I couldn't use the attic floor joists to tie the rafters together. Instead, I used a supported ridge, which I was able to post straight down through my shearwall assemblies to the basement footing — a strong, direct, efficient load path (see photos at left).

This setup gives me several long rooms that span the width of the house from ocean side to landward side. The bays function to open up those spaces and make them broad as well as long.

As a result, the structurally critical shearwalls support, rather than interfere with, the other functions of the building.

We've ended up with a structure that meets or exceeds the capacity required by code. The engineer's analysis includes just the walls we designated as shearwalls. Of course, all the other elements in the house contribute some degree of strength. So although we have designed for a wind between 110 and 120 mph, in a severe exposure category, I'm comfortable that this house could handle an even rougher storm. That's okay — the extra capacity will add stiffness and solidity to the structure and security to the owner's life and well-being.

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For More Information

Standards referenced in the International Codes (available from the International Code Council at 888/699-0541, www.iccsafe.org/e/catalog.html):

Minimum Design Loads for Buildings and Other Structures (ASCE Standard No. 7-02), $98.00.

The Wood Frame Construction Manual for One- and Two-Family Dwellings, 1995 SBC High-Wind Edition, $30.00. Referenced by the 2000 *International Residential Code*.

The Wood Frame Construction Manual for One- and Two-Family Dwellings, 2001 Edition. Referenced by the 2003 *International Residential Code*.

SSTD 10-99 *Standard for Hurricane Resistant Construction*, $33.00.