

Preventing Wind Failures

by David Wickersheimer, P.E.

Prevent construction blow-downs with adequate bracing and proper sequencing

Builder Steve Drake had been in business ten years, built over 600 homes, and had never had a problem with wind. Drake's crew was within six feet of finishing off a roof on a large custom home in Champaign, Ill., when a sudden rain squall moved through the area. The crew scrambled down from the roof to the first floor to wait for the sky to clear. Minutes later, a gust of wind shook the building. The crew narrowly escaped out the doorway as the wind blew the house apart.

No one was injured, and the losses were largely covered by insurance. But many builders are not so lucky.

Bob Mairs, a spokesperson for St. Paul's, the nation's largest builder's-risk insurer, says blow downs are far more common than builders realize. Wind damage is responsible for 30% of his company's losses, and "houses under construction are twice as likely to suffer damage as completed houses."

Blow downs during construction can threaten the lives of the crew and provide an embarrassing front-page story for the builder.

Unfortunately, the model codes provide no guidance on how to protect buildings during the construction. The codes are designed to protect finished buildings and do not address the question of "open buildings" or the sequence of construction.

Code officials say they rely on the competence of the contractor; howev-

er, wind design, the seismic design, is more in the realm of the engineer than the general contractor. Here are some of the highlights from a recent presentation on wind resistance that was given to Fairfax County, Va. In this article, I'll point out some ways to reduce your risk of wind damage during construction and meet the wind-load requirements of the model codes.

Blow Down Lessons

I've found that winds normally considered harmless, 35 to 50 mph, can cause structural collapse. Two collapses of homes under construction in Fairfax County, Va., prompted code officials to begin strict enforcement of the wind-load requirements of the CABO code. I visited one of the houses that collapsed soon after the incident.

The house had occupied a corner lot at the edge of a subdivision where it was exposed to wind on two sides. The house had been roofed and sheathed, but it did not have windows or doors installed. Ironically, the black paper was undisturbed, but wind had lifted the roof off the house and pushed the walls in. The roof sheathing held the roof together (in fact the dormers were still neatly perched on top), but the sheathed roof had acted as a sail as wind blew in the open windows and doors.

Around the perimeter of the house, you could see where studs had been



Terry Swift

Strong winds blew through the open gable end of this partially sheathed house (inset). Minutes later, the house looked like pick-up sticks. A nearby airport clocked the wind speed at 40mph, but the builder estimated gusts near the house were much higher.



Champaign-Urbana News Gazette

Figure 1. Wind uplift pulled these studs away from the bottom plate. End-nailing alone offers little resistance to tensile forces.



Figure 2. Shear-wall sheathing and a diagonal T-brace held some walls together, but they still pulled away from the platform.



David Wieschehner

pulled off the bottom plate. This end-nail withdrawal is typical of wind-damaged buildings (see Figure 1).

I visited Steve Drake's job shortly after it blew down. There, the wind suction had pulled the shear walls away from the platform (see Figure 2). The walls that had been sheathed with flakeboard were still square, and I could see the diagonal tension ties, used to keep the wall from racking, running at a 45° angle to the studs. But the face-nailing that had held the shear wall to the floor had simply pulled apart.

What Causes Blow Downs?

Wind failure follows a typical pattern. If uplift forces are strong enough, they will pull a building apart vertically. The codes figure that on finished buildings, wind can get under the eaves, pushing up, while suction forces on the leeward (downwind) side of the building pull on the roof. But buildings that are under construction are even more vulnerable because the wind can sweep through the building, pushing from the inside while simultaneously pulling on the roof from the outside. Typically, any joint that is end-nailed will pull apart, as nails withdraw from the end grain. The most common place for failure to occur is at the top plate or the bottom plate.

Rafters or trusses toe-nailed to the top plate with two 8d nails are also likely locations for wind failure. The 8d nails are really just tacks; they're good for positioning the rafters or trusses, but in all likelihood, some of the wood has split during nailing, and split wood has no holding power. If rafters and ceiling joists are nailed together, or if you've used trusses, chances are the roof will maintain its triangular shape, but it will still separate from the walls.

Wind also applies horizontal pressure to buildings; some walls and roof surfaces experience a pushing (direct) force and others a pulling (suction) force. These forces tend to make the building slide along its foundation or the walls tilt into a parallelogram. Sometimes, the wind's forces are strong enough to tip a building over, but this would generally only occur if the building did not have much dead load, or it were in an extremely windy area.

The microclimate has a lot to do with wind exposure. If you're building on an infill lot where the streets are lined with large old trees, you'll be less exposed than if you were building on a corner lot in a subdivision bordering flat farmland during a particularly windy spring. But on any given day, wind can strike areas that are not normally considered hazardous.

To prevent problems during construction and after, you want to tie the roof to the walls, keep the wall plates from separating, and stiffen the walls so they don't rack, slide, or tip over. Finally, you want to anchor the walls to the foundation. How much protection you provide depends on the wind speed in your area (see "Codes and Wind," next page.)

Tying Down the Roof

During construction, you can protect the roof by bracing the trusses according to the recommendations of the Truss Plate Institute (see "Fast Framing With Trusses" JLC, 5/89). It's also important not to place additional loads on unfinished buildings. For example, don't stack sheathing or bundles of shingles on a partially sheathed roof. This could add stress and make the building more vulnerable to wind damage.

To safeguard buildings under construction or in high-wind areas, many builders use hurricane braces in the attic. These are diagonal braces that tie rafters or trusses to a center-bearing wall. Where wind loads are likely to be high during the building season, you should use additional bracing in the attic until the building is fully enclosed.

The piece of hardware I would like to see builders use routinely is a light-gauge metal "tie-down," called hurricane or storm anchors in some parts of the country (see Figure 3). These anchors should go on every rafter or truss. Even though the CABO codes does not require this level of protection in Zone 1 or 2, (see map, next page) tie-downs provide cheap insurance (at 20¢ to 40¢ per anchor) for the builder. Simpson and TECO make many anchors for this purpose; the best tie is one that nails to the rafter, the double top plate, and the stud. The natural way to work this into the construction sequence is to set the trusses, then go back and nail on the storm anchors.

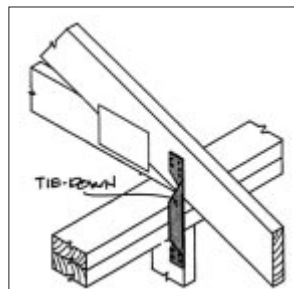
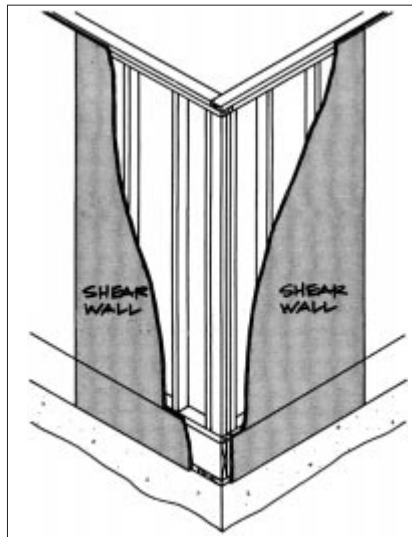


Figure 3. Tie downs should be nailed to the roof framing, the top plates, and the studs.

Figure 4. Structural sheathing at the corners functions as a shear wall, keeping the building from racking. One panel at each corner may suffice for one-story houses.



In very high wind zones, where the uplift forces warrant it, you may have to use straight straps to tie the studs to the second-story box sill or to tie the box or mud sill to the foundation. An architect or engineer can help you decide if you need this level of protection. Your local building codes may have requirements more stringent than the CABO code if you are in a known high wind area.

Bracing Walls

Once you have taken care of the uplift problem, take a look at the code requirements for horizontal wind loads. Wind-load resistance for horizontal force is provided by stiff walls, called "shear" or "x-braced" walls. When wind strikes the roof planes and upper walls, these walls transfer the wind load down to the foundation. Stiff walls can help reduce the risk of wind failure during construction, but you can still have wind failure until the building is fully enclosed.

Shear walls. The best way to stiffen a wall is to provide a shear wall. A shear wall is a wall that is sheathed with plywood, flakeboard, or OSB, but not fiberboard or rigid insulation (see Figure 4). Builders trying to reduce heat loss through the studs may be tempted to use only one 4-foot panel width on corners, but that may not be enough shear wall for two- or three-story houses, large complex houses, or houses in severe wind zones. On a small one-story house, engineering calculations usually show that one vertical 4x8 piece of sheathing at all four corners of the building is sufficient. These houses require thicker plywood and usually need more than one panel width at the corners.

The way you install the sheathing is just as important as the proportion of the wall it occupies. I've seen jobs where they plywood stopped short of the top plate by a foot or where it failed to reach the mud sill. The purpose of the plywood is to transfer building loads from the top plate down to the mud sill, so unless you get one continuous panel, your plywood won't do the job.

Since this is one of the easiest upgrades you can make, it's worthwhile to spend some time on the finer details of the installation. If you possibly can, use 9-foot pieces of OSB and install them vertically. (these may cost about 15% more than the standard sheets, and they aren't stocked in every yard.)

If you're forced to use 8-foot sheets, you'll probably want to set them vertically so they split the bottom plate, placing your joint along a chalk line at the midpoint of the bottom plate. A narrow

strip of sheathing fills in from the bottom of the mud sill to the mid-point of the bottom plate (see Figure 5).

If you're going up another story, you'll have to jockey the plywood down and inch or so. You always want the plywood pieces to join at the midpoint of the plate or 3/4-inch into the band joist, because this keeps wind uplift from pulling your wall apart vertically. Repeat the process you used earlier, and make sure the filler strip falls at the midpoint of the second-floor plate. The top sheet of plywood should end up within 3/8-inch of the top of your top plate.

Another issue that also comes up at the band-joint area is energy efficiency.

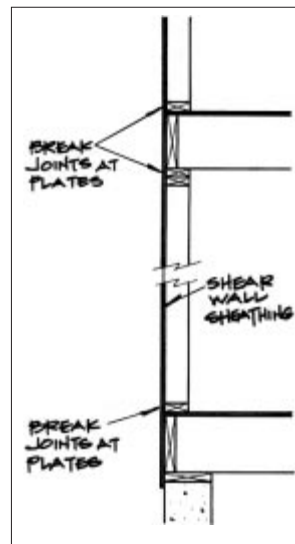


Figure 5. Break the joints between shear-wall panel sections over the plates. This ties the shear-wall to the mudsill and foundation.

If the band joist gets cold, condensation may eventually cause it to rot. Many builders have been using plywood sheathing between wall plates, but they fill in the band joist area with rigid insulation. If this is the strategy you choose, you should use flat light-gauge metal straps, also made by TECO and Simpson, particularly in Wind Zones 2 or greater.

If you prefer to start your shear wall with an 8-foot sheet, you can line up your sheet with the bottom of the mud sill. You'll end up short of the top plate, and you will have to use another whole sheet plus a filler strip if you're going up

another story. In areas where wind forces are high, or in Seismic Zones 2 and up, you will need to use horizontal blocking behind any horizontal free edges. In other areas it is still good practice to use blocking on the first floor of the house because it gives the house much greater wind resistance. Breaking your stud spaces with blocking may be a problem for your insulation contractor, however.

Before you nail off the shear panels,

make sure your nailing schedule is the one required for your wind zone. Each nail carries a portion of the load, and the size and spacing of the nails is extremely important to the shear wall's strength.

Cross bracing. An alternate way to stiffen a wall, especially one where you'd like to use rigid foam sheathing, is to use metal bracing (also called T-bracing) or diagonal 1x4 "let-in" bracing. To install the metal, you snap a

quick diagonal chalk line down the studs, saw-cut the studs to the depths of the "T," and drop the T-brace into the slot.

Again, you'll have to pay attention to the details, or the T-brace won't be effective in transferring wind loads down to the foundation. The brace must run continuously from the top plate down to the bottom plate. And it should be placed at a 45° angle; 60° is the maximum angle. If you install the T-brace 3 or 4 inches below the top plate, or if you install it at a 75° or 80° angle, you might as well leave it out (see Figure 6). If you're short one brace, don't try to butt-join scraps in the middle of a run. Unless you bolt them together, they won't be structurally effective. The T-brace must be nailed to each stud and to the top and bottom plate with 10d nails.

Sequence of construction. The T-brace is easy to drop in place while you're framing the wall, and it keeps the wall square while you're tilting the walls up and bracing them. Until you put the sheathing on, the walls are open and the wind can pass safely through. If you're close to the end of the day, you should brace the walls by running several diagonal 2x4s between the studs and deck, nailing the braces securely with 16d nails at both ends. Hold off on sheathing until you return to work the following day.

Many builders use both T-bracing and structural sheathing—the "belt and suspenders" approach. This makes good sense when you think about the sequence of construction. Here's why.

strong gust blew in beneath it.

You're going to have to make some judgments about what constitutes an adequate level of temporary bracing. Just having shear walls in place can't completely protect the building. The erected portion may be torsionally weak and easily racked.

Anchoring to Ground

Foundation anchorage is the final step in assuring a building's wind resistance. While shear walls are used to keep the building from racking, wind can also cause the building to slide along the foundation. In extreme cases, wind tends to top the shear walls over. Foundation bolts tie the building to the foundation and prevent sliding. In high wind areas, you may also need tension hold-downs to keep the building from tipping. Where uplift forces are high (winds 50 mph and up), you're probably also going to need to provide additional vertical anchorage.

Foundation anchors. Think of the mud sill as the last link connecting the ship to the anchor. Use washers, and center the anchors in the foundation wall. Take the time to get them positioned correctly while the mortar or concrete is still plastic. If the anchors are more than 2 inches from the end of the mud sill, you less likely to split the wood as you're tightening the bolt; with splits, the holding capacity plummets.

Most builders will find that the standard CABO requirements will provide adequate anchorage against sliding. The CABO code calls for you to place

Codes and Wind

Because of two recent wind failures, Fairfax County's Building Department now requires builders to submit wind load calculations that have been sealed by a registered structural engineer or architect. These calculations are based on a Wind Probability Map (see below that appears in Appendix A of the CABO One- & Two-Family Dwelling Code, the code most commonly used in residential construction in the U.S.).

The Wind Probability Map shows wind design loads for horizontal and uplift forces on the roof. Note that uplift forces have to be taken into account in Zones III and IV and in the cross-hatched "Special Wind Regions." The design values increase by 16% for building with roof heights between 30 and 50 feet, not uncommon in large custom homes.

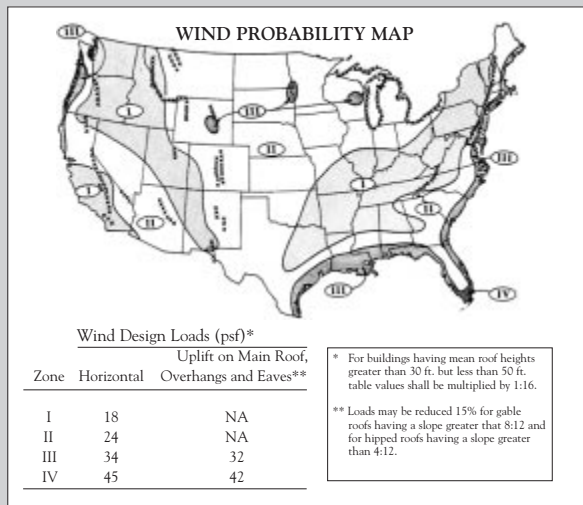
If you are building in Zone III or IV, your local code may already require additional protection to resist wind damage. But even buildings in Zone II can collapse because of the strong wind effects in open buildings.

To make sure your buildings are meeting the code's minimum requirements, you should talk with a structural engineer. It's important to talk with an engineer because the code does not spell out exactly how you are to meet its wind-load requirements.

While the CABO code is prescriptive in some areas—it tells you just exactly how to pace your foundation bolts—it is performance-oriented in other areas. The code sets guidelines telling you how it expects the building to perform, but it leaves the details up to you. The code gives the designer and builder flexibility in selecting a method to tie the rafters and walls together, based on section R-402.3, but it does not expect that you will ignore the issue altogether. A good engineer can go one step beyond the code and help you establish a construction sequence to protect your building. Once you have found a system that works for your crew, you can use it on every job.

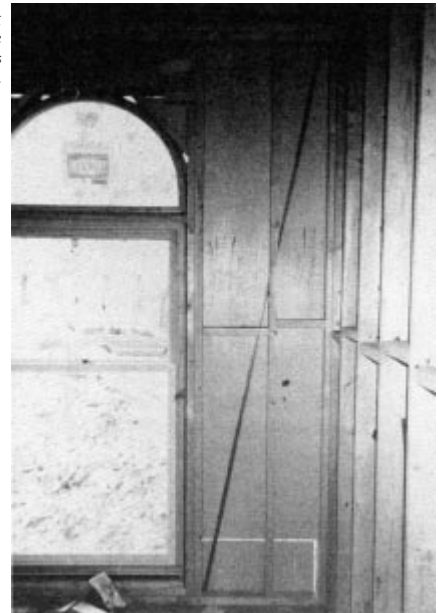
An architect or engineer designing a home has the option of building according to the prescriptive CABO code or building according to the requirements of the local governing code—BOCA, ICBO (UBC), or SBCCI. All these codes are very performance-oriented and use language that is foreign to most contractors. For instance, the code talks about "tributary width" and "withdrawal loading"—terms more familiar to engineers.

Many buildings are not designed by architects or engineers, however. One of the "performance" codes the Southern Building Code Congress International (SBCCI), has found it helpful to provide a more specific description of what its code calls for. This information is contained in the Deemed to Comply Manual that shows a builder exactly what should be done to comply with the SBCCI code. If you build according to the document, you will be meeting the intent of the code. This document is helpful because it shows you how to build in high wind areas—90-, 100-, or 110-mph winds. The document cost \$23 plus tax and is available from SBCCI, 900 Montclair Rd., Birmingham, AL 35213-1206; 205/591-1853.—D.W.



The Wind Probability Map from the CABO One- & Two-Family Dwelling Code shows four Wind zones. The cross-hatched areas are special wind regions where winds can be extremely strong.

Figure 6. Cross bracing must run at a 45-degree angle to be effective. This one isn't doing the job.



As soon as you begin to put the exterior sheathing on, the risk of wind failure increases. Rigid insulation and fiberboard don't give you any shear strength, so it's best if you nail on your tie-downs to connect the roof to the walls. Then, immediately after this step, get the structural sheathing in place. Once you've completed the corners, you can fill in with insulation or fiberboard.

If you're building a two-story house, put your shear-wall panels on the first floor before you frame the second floor. If you intend to nail off the floor platform on the second floor, it's best to immediately use extra bracing on the first floor. Otherwise the second-story deck could be subject to uplift if a

1/2-inch foundation bolts near the corner of each elevation, spacing them a maximum of 6 feet on-center along the wall.

The anchor bolts assure that you engage the foundation-wall dead load to resist overturning and sliding, as well as uplift. If the foundation is unreinforced concrete block, you'll need to use longer anchor bolts that go at least 1 1/2 block courses down. Grout the top two block courses. Follow the American concrete Institute's residential concrete recommendations for horizontal and vertical reinforcing. In high wind zones or high seismic zones, consult and engineer.

Tension hold-downs. The other type of anchorage you're likely to see in high

Figure 7. Hold-downs are used at the corners of shear walls in high wind zones.

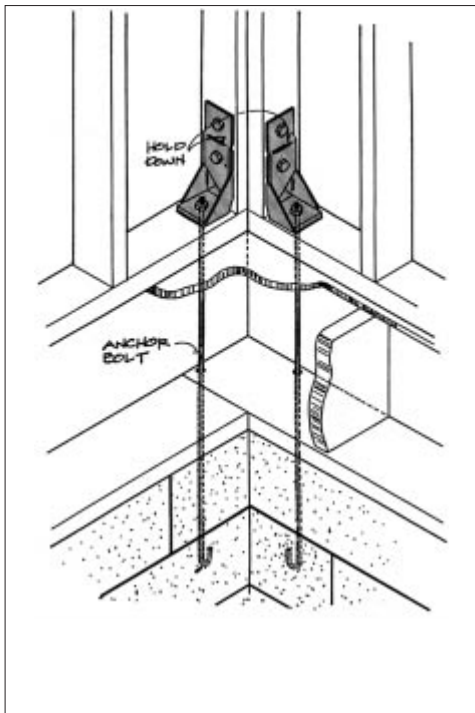
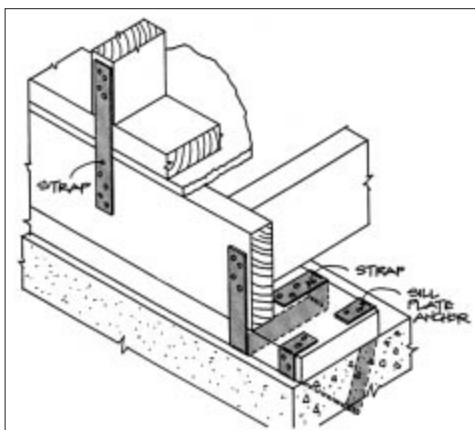


Figure 8. In high wind zones, you may need additional anchors to prevent nail withdrawal at the sill area.



wind areas is a tension "hold-down" at the ends of shear or x-braced walls (see Figure 7). At the foundation level, tension hold-downs are bolted to threaded rod embedded deep in the foundation. The hold-down itself is like stiff angle iron; the bottom part of the angle is bolted to the threaded rod and the vertical part of the hold-down bolts through the corner studs.

Tension hold-downs are becoming more common in seismic-risk zones, and engineers are calling for them in extreme wind areas and for buildings over two stories that do not have enough dead load. You may even need them to anchor the first and second stories together.

Vertical anchors. To meet wind uplift requirements in Zone IV, you

may need some additional hardware. TECO and Simpson both make hardware to fasten anything to anything. You may need straps that are embedded in the foundation and that wrap around the mud sill, or you may need straps to tie the band joist and studs together (see Figure 8). But again, you'll only need them if the engineer's calculations show they're necessary.

Careful attention to the construction sequence and using the right details improves the building's chance of survival in high winds, both during and after construction. ■

David Wickersheimer, P.E., is president of Wickersheimer Engineers, Champaign, Ill., and professor of architecture at the University of Illinois.

For More Information

Additional information on wind resistance can be found in the following:

- *Houses Can Resist Hurricanes*, U.S. Forest Service Research Paper FP133. The publication number is PB 174 3465. Send \$15.95 plus \$3 for handling to: NTIS, Springfield, VA 22161; FAX# 703/321-8547.
- *How to Build Storm Resistant Structures*, Catalog #120. Order from Southern Forest Products Assn., Box 52468, New Orleans, LA 70152. Send 70¢ plus postage.