Building Two-Story Window Walls

by Christopher DeBlois

Tall walls full of windows will flex and rack too much unless you stiffen them with full-height studs and shear panels

CAROLYN BATES

Great rooms with high ceilings and walls full of windows have become popular in contemporary house design. But for the unprepared builder, a 16-foot-high wall can spell big headaches. When a strong wind hits an underdesigned wall, excessive flexing and racking may cause problems ranging from cracked plaster and stucco to cracked or rattling glass.

To prevent these headaches you need to understand how structures react to wind loads (see Figure 1). All walls have to resist three types of forces: *flexing,* which acts perpendicular to the wall, pushing or pulling it in or out; *shear,* which acts in the plane of the wall to cause racking; and normal *gravity* loads.

Most builders are familiar with gravity loads. In this article I'll look at ways to resist flexing and shear in two-story walls. Throughout, I'll assume a typical design wind load. In much of the country and in the Atlanta area, where I work, that's 75 mph, although the great plains and coastal areas face even stronger winds. Building in hurricane-prone areas is a different subject and won't be covered here.

Stiffening Tall Walls

Wind blowing perpendicular to a wall causes it to flex. To resist flexing, a wall should be stiff enough to limit the mid-height deflection under the design wind load to $1/240$ of the overall wall height (about $3/4$ inch for a 16-foot-high wall). In planning such a wall, there are four basic variables to consider:

- **Design wind speed:** The higher this is, the stiffer the wall must be.
- **Height of the wall:** With all things equal except height, a 12-foot-high wall is five times more flexible than an 8-foot-high wall; a 16-foot-high wall is 16 times more flexible than the 8-foot-high wall.
- **Thickness of the framing:** 2x6s are stiffer than 2x4s.
- **The number of studs** you have room for: This depends a lot on how the windows are laid out.

Window layout. Figure 2 shows three window layouts, ranging from worst design to best. A regular pattern of windows leaves more room for more structural studs and beams than does an irregular pattern or one with enormous windows. If your mullions are narrow, you can fit more full-height studs into them by supporting any lower headers (which are nonstructural) on steel joist hangers rather than jack studs, as in Figure 3.

Balloon framing. In general, two-story walls should be balloon-framed. In a platform-framed wall, the hinge created by the horizontal plates adds too much flexibility. A common exception to the balloon-framing rule is a narrow two-story wall that's

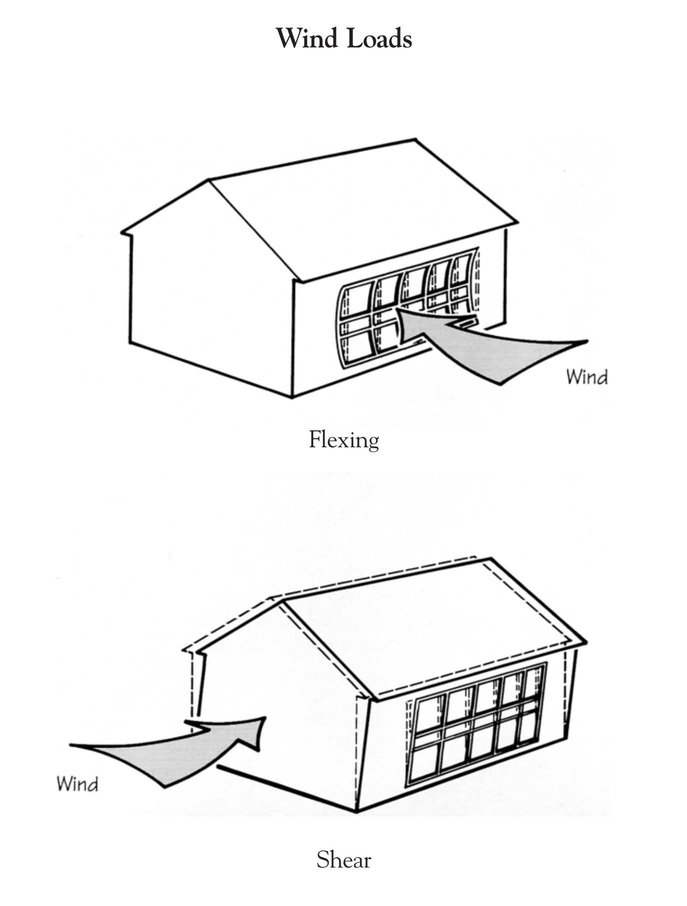


Figure 1. ***Tall window walls*** *must be able to resist wind loads in two ways: flexing, caused by wind blowing perpendicular to the window wall, and shear, from wind blowing parallel to the wall.*

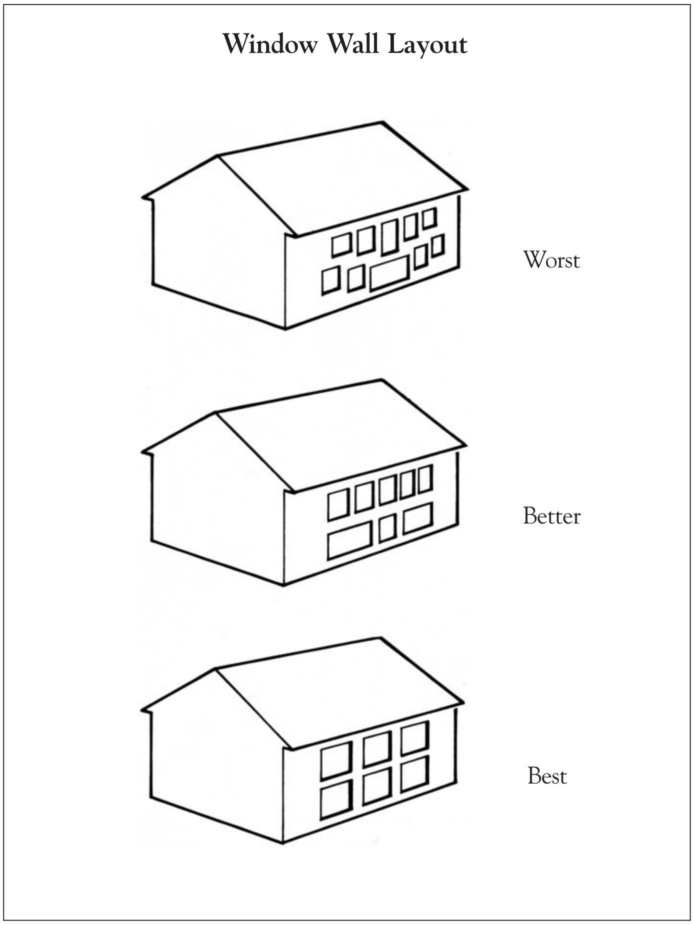


Figure 2. ***A regular pattern of windows*** *makes for stronger walls because it leaves room for more full-height structural studs and connecting beams than does an irregular pattern.*

almost completely filled with glass (I see this most often in entry foyers), leaving insufficient room for full-height studs. Since the wall can't be balloon-framed, you may have to stiffen it with a horizontal beam placed at mid-height.

Steel channels. There will be times when none of these variables are working in your favor. If that's the case you may need something even stiffer than 2x6s. One option is to use steel channels (Figure 4, page 43). These are structural steel members with U-shaped cross-sections that are bolted to the wide face of wood studs between the top and bottom wall plates. They're available in 3-, 4-, and 5-inch widths.

Steel channels are good for retrofitting flexible walls. Because they cover the wide face of the stud, however, they require you to remove the existing wiring, plumbing, and insulation. An alternative technique is to nail new studs flatwise to the $1^1/_2$-inch face of the existing studs. The resulting T-shaped members will increase both stiffness and strength without any internal changes to the existing wall. The design for either of these approaches should be handled by your structural engineer.

Using a Design Table

One way to make sure your wall will be stiff enough is with a design table (see "Design Table," next page). I've developed this table for use in Atlanta, in a wall framed with southern pine.

The table only covers walls that support fairly light loads. You can't support more than 1,000 pounds with a southern pine 2x6 stud and also expect it to have enough strength left to resist flexing. The issue is even more critical for 2x4s. Building codes don't let you use 2x4 studs longer than 14 feet 7 inches to hold up gravity loads. Beyond that height, the stud's capacity falls too rapidly. Finally, to keep them from buckling, codes require that tall studs be properly braced in the plane of the wall. You can satisfy this requirement with horizontal fireblocking or let-in steel straps spaced 6 feet on-center.

Resisting Shear

An even trickier problem presents itself when a two-story wall must resist shear, or racking forces. Unfortunately, the options for resisting shear are limited. The best solution, when possible, is a diaphragm of OSB or plywood shear panels. You can use shear panels in a two-story wall where the windows don't take up the full width of the house. In this case, you flank the windows with shear

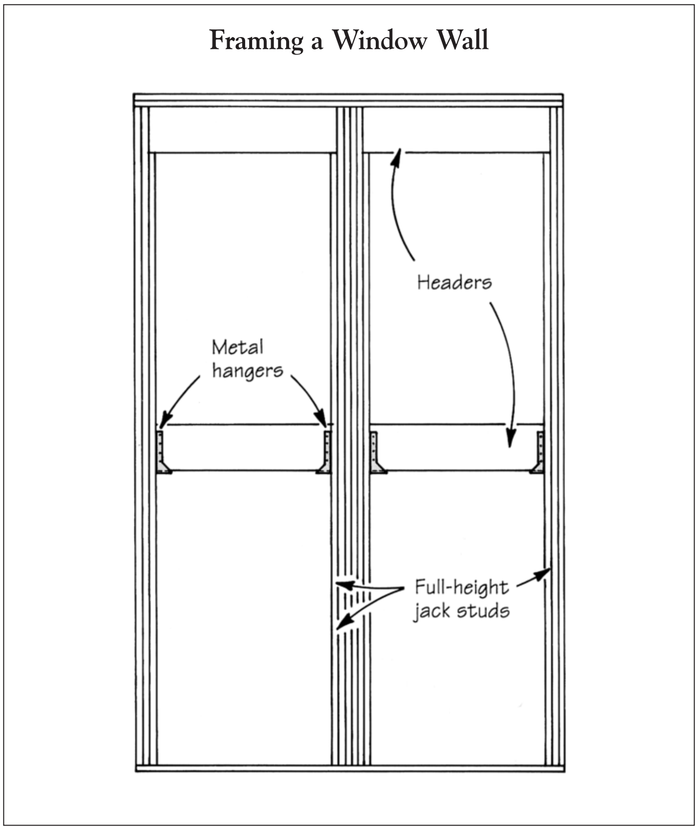


Figure 3. ***The more studs in a wall,*** *the stiffer it will be. You can get two extra studs into a mullion by using joist hangers rather than jack studs to support the lower headers. In the example shown, this raises the number of studs from four to six, increasing stiffness by 50%.*

Design Table for Tall Window Walls

		Wall Height								
		14'	15'	16'	17'	18'	19'	20'	21'	22'
Stud Type	Stud So. Pine 2x4	5.7	4.6	3.7	3.1	2.6	2.2	1.9	1.6	–
	Stud So. Pine 2x6	21.9	17.7	14.5	12.1	10.1	8.6	7.3	6.3	5.5
	#2 So. Pine 2x6	25.1	20.3	16.6	13.8	11.6	9.8	8.4	7.2	6.3

Note: *This design table gives the stud spacing for a solid wall, which you can then use to determine how many studs are needed between windows in a tall window wall. This table was developed by the author for the Atlanta area, with a design wind speed of 75 mph and southern pine framing lumber. A structural engineer can develop an appropriate table for your area.*

To use the table:

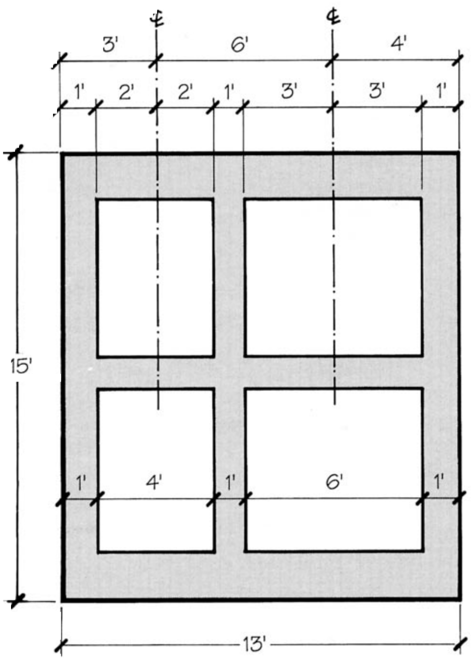
(1) Find the window wall height along the horizontal axis and the stud type along the vertical axis. The intersection gives you the wall length in inches (measured parallel to the plate) that each stud can support. In Example A, a 15-foot-high wall framed with stud-grade 2x6s needs one stud for every 17.7 inches of wall.

(2) Now divide the window wall into sections that vertically bisect each bank of windows. Each section should enclose one window mullion and half of any adjoining windows. In Example A, that gives 3-, 6-, and 4-foot sections (36, 72, and 48 inches).

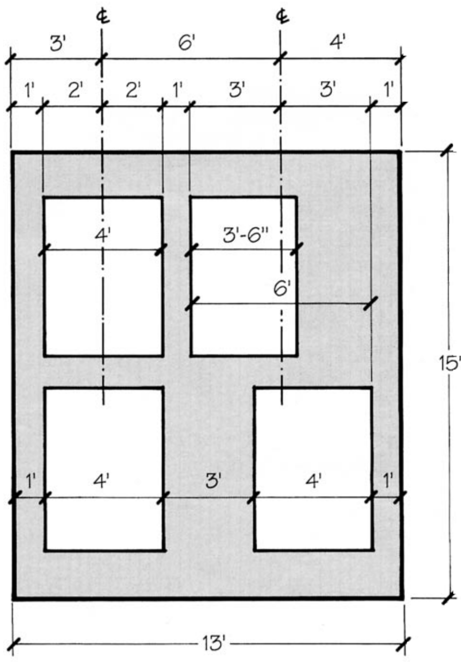
(3) Divide the width of each section in inches by the number from the table to get the approximate number of studs required in each mullion. Round the answers to the nearest whole number. In Example A, that's two studs for the 36-inch section on the left (36 ÷ 17.7 = 2.03), four studs in the middle (72 ÷ 17.7 = 4.07), and three studs on the right (48 ÷ 17.7 = 2.71).

If upper and lower windows don't line up, but overlap in such a way that you can't fit any studs between them, then you must treat them as a single bank of windows. In Example B, the overlapping windows on the right are treated as one 6-foot-wide window. The walls in Examples A and B are identical from a structural perspective.

Example A



Example B



Stiffness of Wood Studs vs. Steel Channels

Channel	Specifications	Compared to No. 2 Southern Pine 2x6	Compared to Stud Grade Southern Pine 2x4
C3x6	3 in. deep 6 lbs./lin. ft.	1.8 times as stiff	8 times as stiff
C5x9	5 in. deep 9 lbs./lin. ft.	7.8 times as stiff	35 times as stiff

Figure 4. ***One retrofit option*** *for flexible walls is steel channels bolted to the wide faces of the studs. As the table shows, adding a 3-inch-deep channel to a 2x4 stud makes it as stiff as nailing eight additional studs to it. A disadvantage of channels is that they may require you to reroute the existing wiring and plumbing.*

panels. If the two-story wall is at the end of an addition, there may be room for panels at the intersection of the addition and the main house (Figure 5).

One crucial dimension is the shear diaphragm's height-to-width ratio. An 8-foot or 9-foot wall can get by with one shear panel at each corner, but the same isn't true for a very tall wall. A shear panel is just not effective against racking — and the building codes won't accept it — if its height exceeds three and a half times its width. A 4-foot-wide strip of sheathing won't meet the code requirements for shear for any wall over 14 feet tall.

The concept behind this becomes clear if you look at the plywood as a simple way to provide X-bracing. The part of the panel doing most of the work is an X from corner to corner; the taller and more slender the X becomes, the less effectively it will resist racking. I like to add a margin of safety by limiting the height of the shear panel to three times its width: If there isn't room for a 6-foot-wide strip of plywood at each corner of an 18-foot wall, it's time to rethink the house design. One obvious solution is not to let windows take up the entire width of one wall.

Engineered solutions. If you can't change the window layout, another alternative is to frame an interior wall parallel to the window wall and to sheathe it with OSB or plywood shear panels. Unfortunately, you can't use rules of thumb to find the required distance from the end wall to the interior shear wall; you will need a structural engineer.

If the design prohibits any type of shear wall, you may want to consider another engineered solution, a structural-steel frame known as a moment frame. "Moment" is bending in a structural member created by an applied load or force, and a moment frame is a structural frame that resists bending moments by using rigid joints. The difference between the joints in a moment frame and those in a standard wood frame is the difference between a framing square and a door hinge — one is rigid, the other isn't.

A moment frame is usually made from welded steel, whether I-beam, channel, or rectangular tube (for a comparison of steel types and sizes see "Steelwork in Wood Frames," 4/92). The material you choose will depend on the amount of racking the wall must resist, as well as on the interior and exterior finishes. For instance, the flat face of a rectangular tube is an easy surface to shoot strapping into. Whatever your choice, a steel fabricator can turn an engineer's design into the moment frame you need.

I've been asked from time to time if a moment frame can be made from wood with steel connectors. The short answer is no. It's theoretically possible by bolting heavy-gauge T plates to the face of each joint. But the size of the plates and framing members, as well as the number of bolts needed, would make the extra effort and expense greater than that required for a steel frame.

How Much Is Too Much?

One final piece of advice is to make two-story walls stiffer than you think necessary. This may raise costs, but it will also keep you out of trouble. One builder I've worked with in Atlanta learned that lesson the hard way. About five years ago, he framed a two-story window wall with 2x4 studs. It seemed stiff enough to him, especially after the interior finishes went on.

Unfortunately, the owners didn't agree. Because of visible flexing, the old wall came down and a 2x6 wall went up — at the builder's expense. Now he won't build tall walls with anything less than 2x6s. If he doesn't have room for a comfortable number of studs, he asks me to check out the design in advance. He's learned that tall walls are like that old oil filter ad: You can pay now or you can pay later. ■

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Shear Wall Solutions

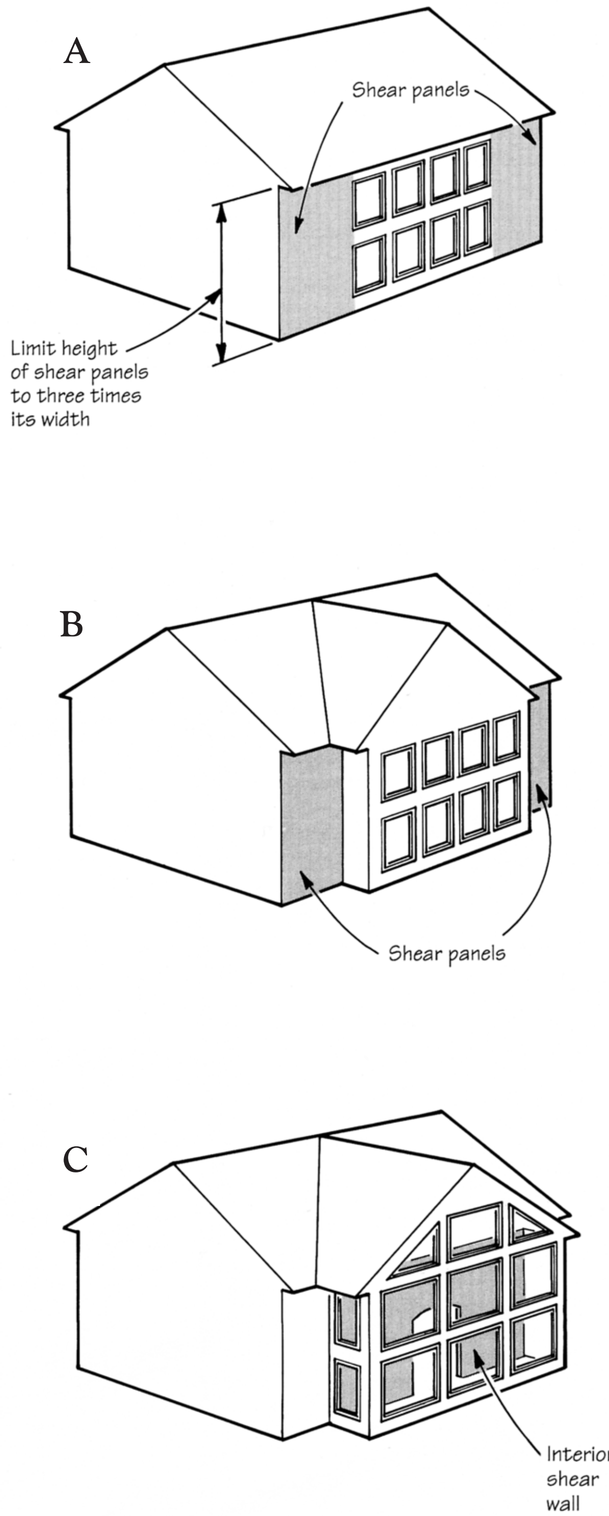

Figure 5. ***Using shear panels:*** *A window wall can be braced with shear panels on each side (A). With an addition that is not too long (B), shear panels on the main wall at each side of the addition may work. In some cases, an interior shear wall (C) is the best way to prevent racking.*