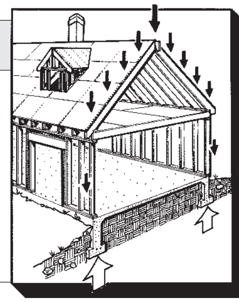

Resisting the Wind

by Harris Hyman, P.E.

Out in the rural areas and suburban fringes, there's a great way to get a little extra money to pay off the mortgage: build a two-car garage with an apartment over it. But while it looks like a complete winner, this project has a whole bunch of problems in a whole bunch of areas. In this column, I'll just hint that there are financial and zoning problems and stick to some of the engineering difficulties. The size of the garage footprint is pretty well dictated by the size of vehicles and available garage doors — usually 24 feet wide by 24 to 30 feet long. It can vary a little, but it's a pretty simple building.

Your major design concerns are probably the need to keep an open floor plan in the garage, and sizing the headers over the wide doors. These are usually solved by a main girder down the center and by big headers. You may need a couple of pieces of steel, but there's really nothing serious to worry about here. If you check the tables or do a few simple calculations, resolving all of the gravity loads is pretty straightforward. Then you're ready to build a strong, serviceable, economical building, right?

Not so fast. The obvious, self-evident structural solution won't always do the job. We've been working with only one dimension of the building. But there are loads other than gravity, in other directions beside down. One of these other loads is wind, which acts sideways and sometimes up.

Wind Loading

Wind loading can be a big problem with a garage. As an example, I'll use the conditions in eastern Oregon, where 80-mph gusts are not uncommon. A wind like that exerts a load of 15 psf on the sides of the building. When the wind blows parallel to the ridge, it strikes the gable end. A typical garage with living space above rises up about 18 feet to the eaves, and then another 8 feet to the ridge. This gives a gable end area of 528 square feet, for a total wind load of 7,920 pounds (see Figure 1).

Fortunately, on the gable end, there are no large unsupported areas. The bottom is fixed to the ground, the sides are supported by the eaves walls, and the top is supported by the roof pitches. In addition, the second-story floor deck acts as a large stiffener across the middle.

We have a different situation with the wind blowing across the ridge. The load is a little bigger because there is more total surface facing the wind: the side walls plus half of the roof area. Calculating the load as we did for the gable gives a 9,360-pound total load exerted by wind blowing against the side of the building.

But the real design difficulty comes from there being so little support in the gable end at the garage door openings. The exterior sheathing, which gives a frame wall its strength against racking forces, is interrupted and greatly reduced around the doors. The small area at the top of the door is simply not strong enough to resist a sideways force. This gable gives no support for the eaves side, and if a high gust strikes the side of the building, the whole building will twist and move (Figure 2, next page). The occupants of the apartment will get a very uneasy feeling as the building jumps around an apparent 1/2 inch or so during severe gusts of wind. (Actually, the movement will be less, but some sensory mechanism in our Old Lizard Brain makes it feel like a whole lot more.) In any case, it may be enough movement to make the occupants of the apartment complain … or move out (and there goes that mortgage payment).

Three Solutions

Well, what do we do about it? Engineering is not just calculations, it's also finding a solution. I have worked with three designs that stiffen

Calculating Wind Loads

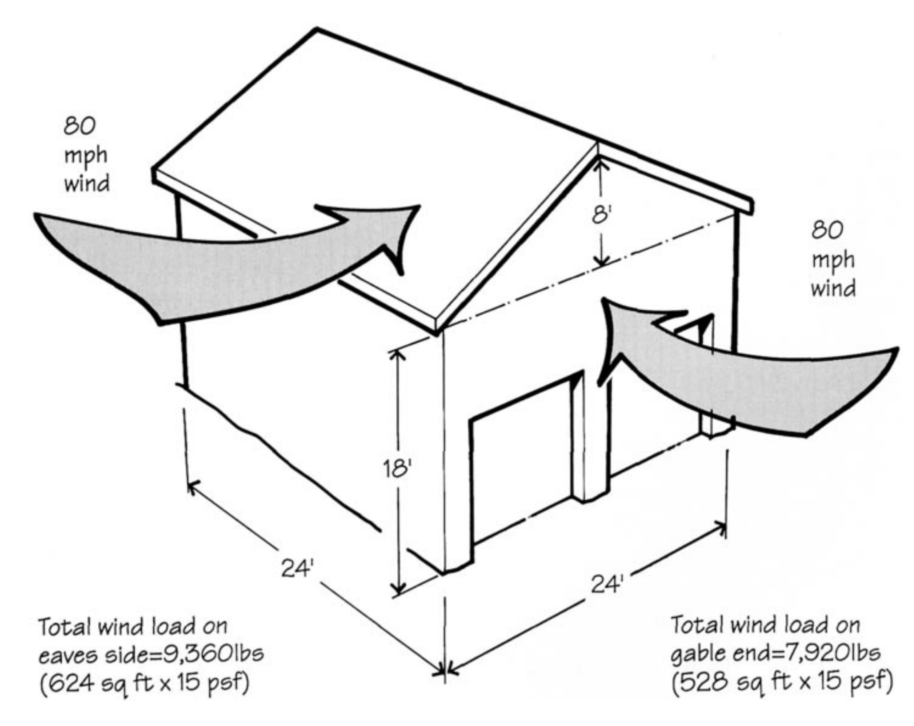

Figure 1. *An 80-mph wind exerts a 15-psf load against a building. For the building shown, this would mean a total load of 7,920 lb. for a wind blowing against the gable, or 9,360 lb. against the eaves side.*

the building in the racking dimension: angle braces, steel stiffeners, and diaphragm sheathing (Figure 3).

Braces. Angle braces cut across the corners of the doors at or close to a 45-degree angle. When the door is framed and sheathed and trimmed out it creates an appearance that a lot of people like, and it is easy to build. I designed this once for a barn in Vermont. About a year later, a neighbor who saw the chamfered corners thought it was neat and wanted chamfered corners on his building. It became sort of a fad and a bunch of buildings in central Vermont all have angle braces on doors and windows, whether they need them or not.

Racking Under Wind Load

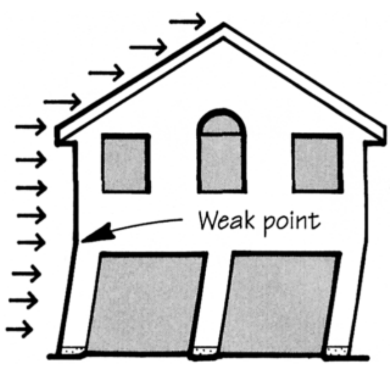

Figure 2. *A typical garage with living space above will rack under heavy wind loads if the gable end is not adequately braced.*

A messy calculation that I won't repeat here (really, I looked it up in a table) shows that for adequate strength, the brace should be about 30% of the way down the upright. On a standard 7-foot-high door this is $25\frac{1}{4}$ inches. The centerline length of the brace is $35\frac{5}{8}$ inches. This says cut the braces out of 41-inch-long sticks. I suggest a double 2x6, spiked together with plenty of 10d nails. A 4x4 or a 4x6 might be tempting, but the brace must be free from checks and splits. This might be hard to find in a 4x6; 4x4s are usually better, but cull for a good piece.

Because this detail steals some of the clear height from the door openings, it might be preferable to use 8-foot-high doors for the extra headroom they provide.

Steel. Ninety-degree steel stiffeners preserve the square appearance of the doorway. They should be about $\frac{3}{8}$ inch thick by 3 inches wide by 2 feet long on each leg. Bolt through the jamb and header framing with at least four $\frac{3}{4}$-inch bolts in each leg. The framing details have to be worked out for each situation. This looks like a huge piece of steel, but it's really not: To have the same effect as the angle brace, it has to cover the same 30% of the door height.

Diaphragm sheathing. For those builders who want the square openings and prefer not to work with steel, there is diaphragm sheathing. This consists of two layers of plywood or OSB that overlap 16 to 24 inches, screwed to the framing. This is my favorite; the wall is exceptionally stiff against racking, and I don't particularly like the chamfered corners of the bracing. The paneling should be $\frac{3}{8}$ or $\frac{1}{2}$ inch thick. The panels should also be relatively free from delaminations and voids. This is sometimes hard to find in CDX plywood; most OSB is usually okay.

The inner layer goes up with $1\frac{3}{8}$-inch drywall screws on 6-inch centers; the outer layer needs $1\frac{3}{4}$-inch screws, also on 6-inch centers. The screws should go solidly into the framing.

For the diaphragm to work properly, the exterior jambs of the garage doors must be at least 24 inches wide, as indicated in Figure 3. The diaphragm is actually a whole lot stronger than necessary, but thinner plywood is inadequate for sheathing.

I find this problem interesting because it vividly illustrates that structural design is not simply resistance to vertical loads. Over the years, I've gone through this explanation a dozen times with real structures, both at the design stage and after the fact when the building had problems. One couple who came to me had actually had their entire house built over the garage — which made for a literally shaky foundation. Fixing it was an expensive mess on all fronts: contractual, emotional, and legal.

Try not to forget that there are several dimensions to building loading conditions. They all must be checked out for a safe and serviceable structure. ■

Bracing the Gable End

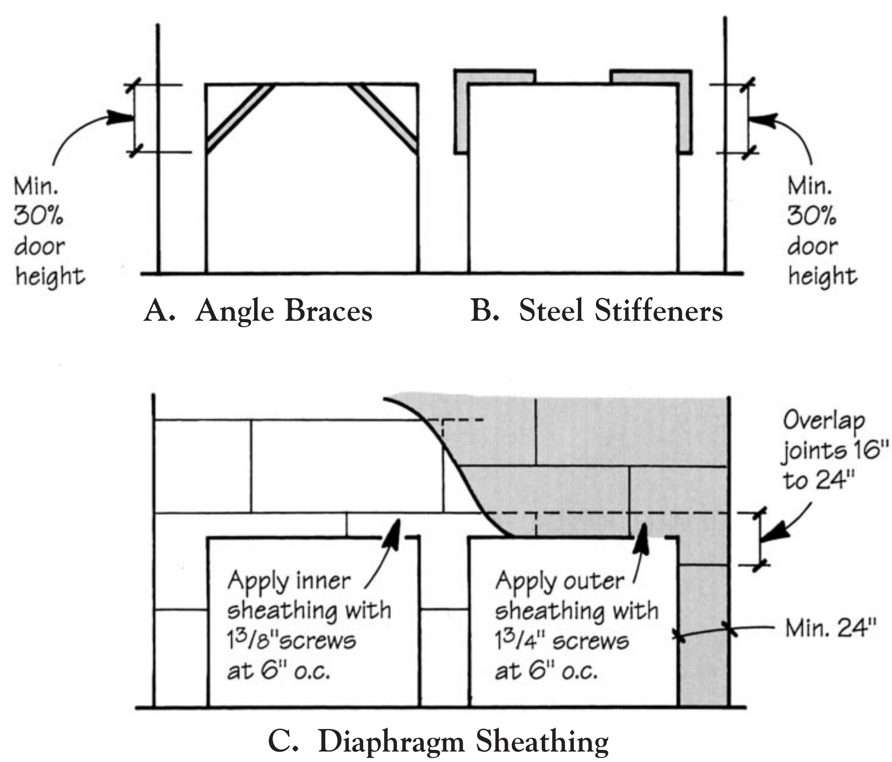

Figure 3. *Solutions for resisting wind loads include angle braces (A) and welded plate-steel stiffeners (B). Diaphragm sheathing (C), consisting of two layers of $\frac{3}{8}$- or $\frac{1}{2}$-inch plywood or OSB, provides the strongest wall.*

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