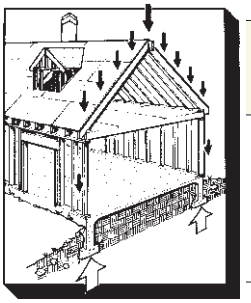


Holding the Roof Up

by Robert Randall, P.E.

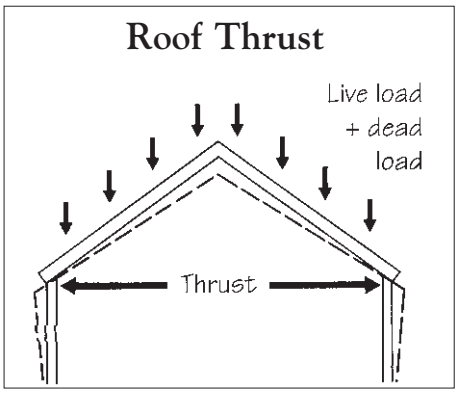


Figure 1. *In a typical roof with no structural ridge, the loads push out on the exterior walls. These forces must be resisted by nails or bolts at the joist-rafter connections and at the midspan splices in the joists.*

The morning following a recent heavy snowstorm, I got an emergency call about a roof collapse. It was, in fact, an example of what we engineers call "catastrophic failure" — a classic case of underdesigned (or undesigned?) eaves tie connections. Although these things don't occur often, such a collapse serves as a reminder of what might happen if connections are not properly designed and executed in the field.

This old, solidly built structural-brick building had full-size 3x8 attic floor joists at 16 inches on-center, with full 1-inch-thick plank flooring. (As it turned out, the sturdy attic floor saved the day, halting the fall of the roof assembly and preventing damage to the walls and ceilings below.) The roof was framed with full-cut 3x6 rafters at 24 inches on-center, which meant that only every fourth floor joist aligned with a rafter and could serve as an eaves tie.

The calculated load at this connection is 1,680 pounds, obviously more than the four or five toe-nails provided were capable of carrying. The building had stood for over a hundred years with no apparent problem until this sudden and very dramatic failure.

Eaves Ties Explained

Any peaked roof that does not have a structural ridge capable of carrying the vertical loads of the entire center half of the roof will inevitably develop lateral thrust, usually at the eaves (see Figure 1). This thrust is a horizontal force tending to spread the top of supporting walls and is usually resisted by eaves ties, also known as ceiling joists or attic floor joists. Regardless of what you call them, these members carry a lot of force in

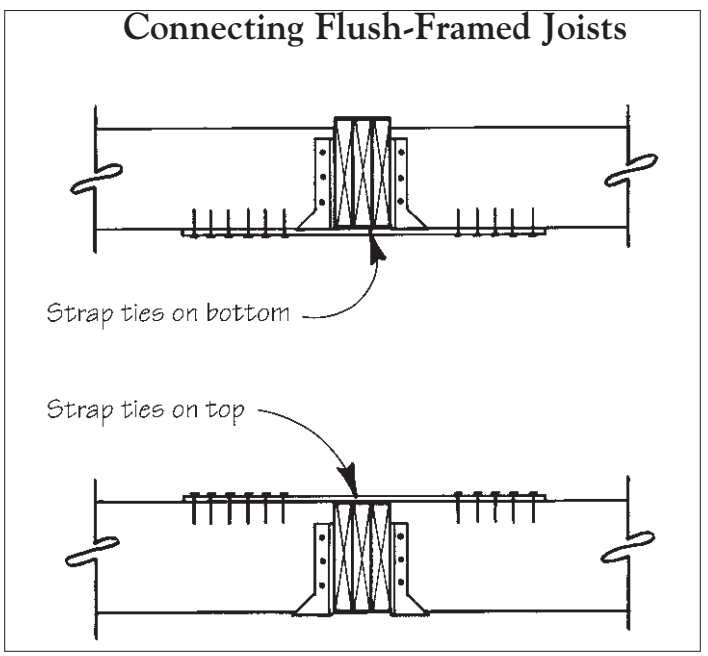
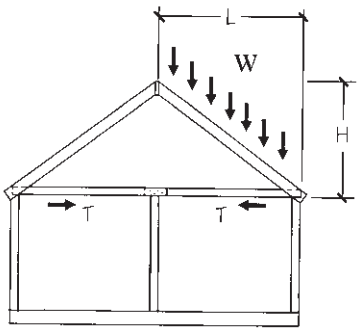


Figure 2. *When a flush-framed header or girder interrupts the ceiling joists at midspan, use strap ties to connect the joists and carry the tension created by the roof load.*

Nailing & Bolting Schedule for Eaves Tie Connections



W = L (ft) x rafter spacing (ft) x roof design load (L.L. + D.L. in psf)

$$T = \frac{W \times L}{2H}$$

Roof Pitch	Building Width (2L) 20'	24'	30'	36'
3/12	T = 1,064 lb. 11 nails or 3 bolts	T = 1,276 lb. 13 nails or 4 bolts	T = 1,596 lb. 16 nails or 4 bolts	T = 1,915 lb. 20 nails or 5 bolts
4/12	T = 798 lb. 8 nails or 2 bolts	T = 958 lb. 10 nails or 3 bolts	T = 1,197 lb. 12 nails or 3 bolts	T = 1,437 lb. 15 nails or 4 bolts
6/12	T = 532 lb. 6 nails or 2 bolts	T = 638 lb. 7 nails or 2 bolts	T = 798 lb. 8 nails or 2 bolts	T = 957 lb. 10 nails or 3 bolts
9/12	T = 355 lb. 4 nails or 1 bolt	T = 425 lb. 5 nails or 2 bolts	T = 532 lb. 6 nails or 2 bolts	T = 638 lb. 7 nails or 2 bolts
12/12	T = 266 lb. 3 nails or 1 bolt	T = 319 lb. 4 nails or 1 bolt	T = 399 lb. 4 nails or 1 bolt	T = 479 lb. 5 nails or 2 bolts

Note: *This table is based on 30-pound psf live load plus 10-pound psf dead load. Nails are assumed to be 16d, at 100-pound capacity each; bolts are 1/2 inch, at 400-pound capacity each. Rafters are 16 inches on-center.*

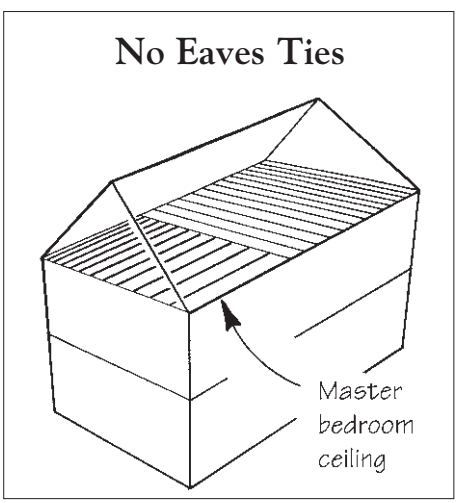


Figure 3. *Whenever ceiling joists are turned parallel to the ridge, as in this second-story master bedroom design, there is no eaves tie effect. A structural ridge must be used for this section of the roof to prevent sagging.*

tension and must be designed accordingly. The weak link is usually in the connections, both at the eaves and at center splices, which may be overlooked as significant structural connections.

The table above shows how dramatic the variation of this thrust can be with varying roof pitch. The low-pitched roofs, 3:12 and 4:12, need ten and more nails per connection, a nailing schedule seldom seen in practice. When the number of nails required reaches ten or more, I usually specify bolts instead and hope that there will be two or three nails as well.

In most parts of the country, you don't need to look very far to see a roof with noticeable sagging of the ridge line. When you get into the attic and investigate, which is often part of my job, you frequently find eaves tie connections that have too few fasteners. Over the years, the result is a sagging ridge and cracked ceilings below, especially the flush ceilings between a living room and dining room common in ranch-style homes.

Weak Center Splices

Ceiling cracks near the center of the building occur when ceiling joists are not adequately spliced. The center splices should have the same number of nails or bolts as the connection to the rafters. When a flush-framed header or girder is installed to support ceiling joists, you should use at least 16-gauge steel strap ties to bridge across the header and connect the joists, which are interrupted by the header (Figure 2). Use the same number of nails in the strap (usually 10-penny) as for the rafter-joist connection. I typically recommend Simpson-brand strap ties, because they're load-rated and the catalog specifies the required nailing.

Another common eaves tie deficiency I see is in two-story homes where the master bedroom extends from the front to the rear of the house and the ceiling joists have been rotated to run parallel with the ridge to create a flush ceiling (Figure 3). Without eaves ties or a structural ridge, the only thing left to keep this roof standing is the shear diaphragm action of plywood sheathing, which is often not adequate.

Not a Collar Tie

Eaves ties, as discussed here, are not the same as collar ties, which may be used to stiffen roof rafters. In some cases, eaves ties may be raised above the wall plates to resemble collar ties, but when this is done, careful analysis is needed to avoid overloading the rafters with bending moment. I'll look at this in a future column.

Fortunately, most roof failures occur progressively, and visible cracks and sagging provide advance warning of trouble developing. The best strategy for a builder, of course, is to take care to prevent problems by using a few extra nails or, for low-pitched roofs, using bolts. And when in doubt, consult an engineer. ■

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