Everything You Always Wanted to Know About REMOVING COLLAR TIES

by Harris Hyman

Can you add attic headroom and still comply with the codes? Maybe.

With the downturn in new construction, we're getting into a lot of remodeling jobs. One type of project that comes up again and again is the conversion of the attic space into a real room. Inevitably, the space is full of collar ties. Should we raise them a couple of feet, the way the owner wants? Or cut them away altogether? We may alter them and give our client a big confident smile, but later we begin to worry.

What Do Collar Ties Do, Anyway?

Collar ties are peculiar items. Their job is pretty simple but their loading can be deceptively large. Basically, they keep the rafters from spreading. Just that. Unlike trusses, collar ties do not stiffen rafters or help carry loads.

Roof loads are transferred to the wall structure through the rafters, *in the direction of the rafter.* At the eaves, rafters push both down and outward. The collar ties help handle the outward forces; the wall studs handle the vertical loads.

However, collar ties do get in the way when you want to use the attic space. And everyone knows somebody who has just sawn them out and done a pretty nice-looking conversion. The idea of doing the job this way doesn't feel quite right, though. Should we repeat this ourselves?

I'll look at two common situations where you might want to move or remove collar ties to get more headroom in an attic. In the first case, the rafters come right down to the attic floor; the second case has the rafters resting on top of half-walls.

The Easy Situations

Rafter-to-joist connections are critical. If the rafters end at the attic floor (Figure 1), they can be fastened in and the collar ties removed *with no real effect.* As an example, on a 24-foot span with 12:12 rafters 24 inches on-center, the necessary restraining force at the bottom of the rafter is 600 pounds under a 50 psf code load. Ties are available to handle this.

Attaching Rafters to Joists

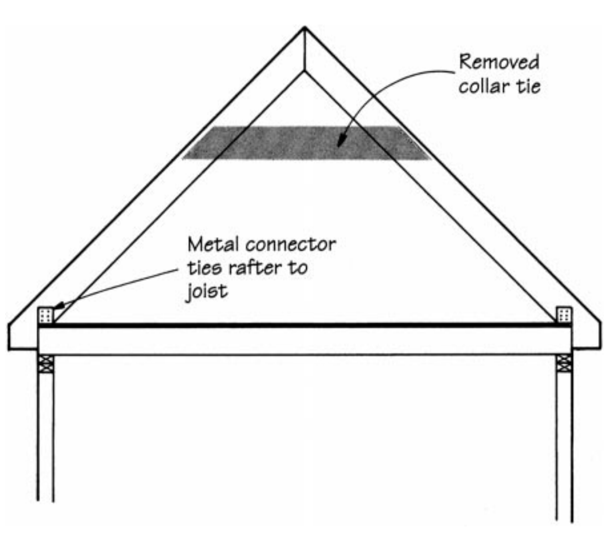


Figure 1. *In a typical gable roof, collar ties can be removed with no real effect, as long as the rafter ends are securely fastened to the floor joists. The author recommends metal connectors for restraining roof thrust.*

The best fastenings are metal strap ties, such as those Teco makes. There are a variety of ties available to fit various situations, and they are described in the catalogs, along with their load capacity. There is a good collection of catalogs in the Sweet's collection, which your neighborhood architect will probably let you scan. You should always check the catalog specs for the strength of the fastener you want to use. The counter person down at the lumberyard may be real friendly and helpful, but he has no liability for your projects.

Do not depend on toenailing, which, even when carefully done, is exceptionally weak. Toenailing should only be used to hold sticks in place until a firmer fastening method can be applied.

If the rafters are face-nailed to the joist ends, a common practice in attic spaces, you may want to beef up the connection before removing the collar ties. A workable rule of thumb for nail strength says that 10-penny, 12-penny, or 16-penny nails in 2x spruce hold about 100 pounds per nail in shear, or 60 pounds against withdrawal. Nails can be clustered about a dozen diameters apart — about 1¾ inches for 12-penny nails — without splitting construction softwoods.

Kneewalls an option. If it's not possible to make a strong enough connection between joists and rafters, another option is to build a

Kneewalls

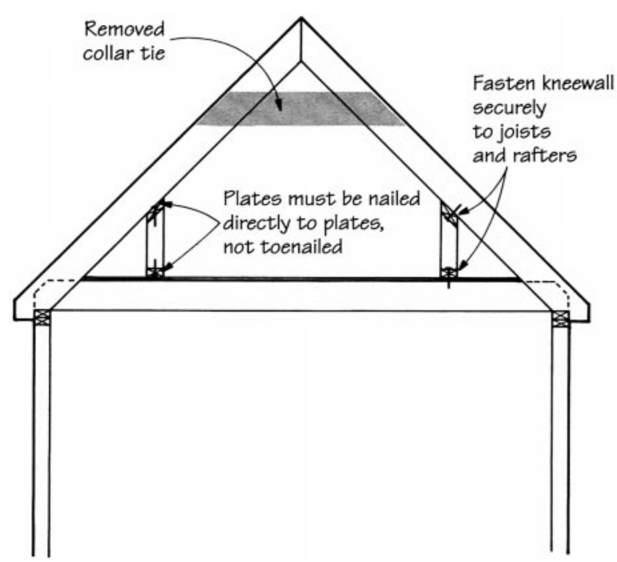


Figure 2. *Kneewalls close to the eaves can also serve to make a strong rafter-to-joist connection. The kneewall must be carefully built and securely fastened to joists and rafters.*

Raising Collar Ties

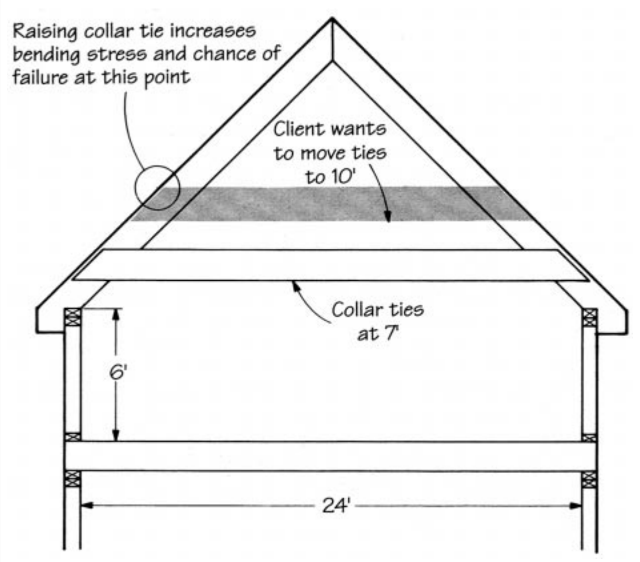


Figure 4. *Raising collar ties to create more headroom can raise the tension in the tie so high that the tie cannot easily be fastened to the rafter. The raised tie also adds bending stress to the rafter.*

Half-Walls

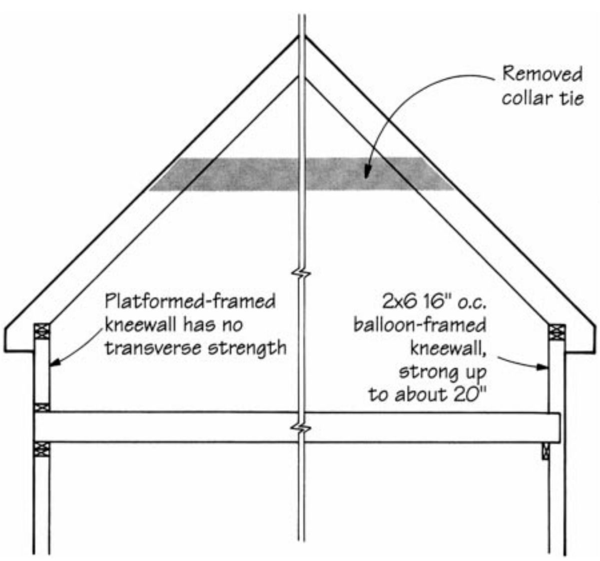


Figure 3. *With story-and-a-half structures, you must be extremely careful about removing collar ties. Platform-framed half-walls (like the one at left) have no strength to resist the thrust of the rafters, so the collar ties must remain in place. With balloon-framed 2x6 half-walls, with studs 16 inches on-center (at right), collar ties can be removed if the half-wall is less than 20 inches high.*

kneewall. A short wall a few feet inside of the eaves line shifts some of the load to the deck (see Figure 2). The triangle formed by the floor, the rafters, and the kneewall acts as a buttress. This contains the outward thrust, and reduces it some by reducing the actual span of the rafters. The rafter loads are carried to the floor, which becomes a massive tie.

Kneewalls are often good architectural solutions, since they trap off some messy, unusable space at the bottom corner of the roof pitch and allow the space to be filled with insulation. If the wall is a little higher, say 5 feet, and further in from the eaves, it creates some storage space.

Kneewalls must be built carefully, and securely fastened to both the rafters and the floor joists. The plates must be nailed directly to the studs, not toenailed. For adequate strength and stability, the upper plate of the kneewall must be nailed directly to the rafters, and the lower plate must be nailed directly to the floor joists. No special sheathing is needed on kneewalls; ordinary drywall is generally strong enough.

With kneewalls, vertical loads are transferred to the ceiling joists, but the kneewalls are usually close enough to the eaves that the joists are not overstressed.

Half-Walls

A messier situation exists when the rafters rest on a short wall extending above the deck (Figure 3). If the building is old enough or new enough to have been balloon-framed, the wall can handle the push of the rafters if it isn't too high — about 20 inches under code loads for 2x6 studs 16 inches on-center.

Where the rafters rest on platform-framed half-walls, however, *there is no transverse strength at all.* In this case, the collar ties are resisting the outward thrust of the roof, and should not be removed. But can you move them higher?

Figure 4 shows a hypothetical situation: a 24-foot cape with 6-foot platform-framed half-walls, a 12:12 roof with rafters 24 inches on-center, and collar ties at 7 feet off the attic floor. The owner wants to raise the ties to 10 feet! Can you do it?

You definitely crank up the tension when you do this. Under the 50 psf load specified in some model codes, the original tension in the tie is 655 pounds. Raising the tie to 10 feet pushes the tension up about

Code Vs. Reality, or Why Most Things Don't Fall Down

A reasonable technical analysis of collar ties suggests that they should *never* be removed, at least not in snow country. This "reasonable analysis" is based on building-code roof loads of 35 to 55 pounds per square foot. However, for the most part, in the typical house where the attic is to be converted to a room, actual loads are rarely above 10 pounds per square foot.

Just writing this makes me cringe a little, as I picture my liability insurance agent's face turning to chalk when she reads it, and as I try to frame answers to the letters from responsible engineers. Still, let's look at the physical world (not to be confused with the "real world," where lawyers exist).

In reality, attic conversions are almost always done on steep roofs, 9:12 or steeper. In most cases, a shallower roof is simply unsuitable for adding living space. And a little observation shows that snow usually doesn't pile up for long on a 10:12 or 12:12 roof. The lower 3 or 4 feet might accumulate an inch or two of ice. This looks frightening, but an inch of ice weighs only about 5 pounds per square foot. Added to this external load is the typical roof structure and shingles, in the neighborhood of 5 or 6 pounds per square foot. A design load of 15 or 20 psf is actually reasonably conservative.

Now, I am not enough of a fool to stamp designs to this criterion, but the information is offered to help explain why some have gotten away with cutting out the collar ties. It's like a stop sign on a road with no traffic: I can say the road is empty, but it's irresponsible to advocate that you ignore the stop sign. *I strongly encourage you not to neglect the building codes.*

As an example, consider a 24-foot span under a 12:12 roof, with the rafters 24 inches on-center and the collar ties 7 feet above the top plate (see illustration). Engineers make a common assumption for analysis: The bottom ends of the rafters are held up by the walls, but are unsupported against spreading — as if they were resting on short, platform-framed half-walls. So under a code load of 50 psf, an engineer's calculation finds a tension in each of these collar ties of 1,440 pounds.

Don't get tricked into thinking that half the tension can be carried by each end — a small but unforgivable violation of Newton's First Law. The total tension in the collar tie must be held on both ends. The tension must also be supported in the middle of the tie with wood. Construction softwoods have a tension design stress of about 300 psi, so a 2x8, which has 5.3 square inches of cross-section area, willhandle the 1,440 pounds.

If that sounds like a lot of force, it is. And the really difficult problem becomes how to fasten the ends of the ties to the rafters to withstand such tension. You could do it with a pair of $2^1/_2$-inch split-ring connectors, or a dozen 3-inch screws, if you can find space for them! Bolts are unsuitable because there just isn't room for three 1-inch bolts with washers. Although smaller bolts would never break, the larger bolts are required to spread the load and avoid crushing the wood fibers.

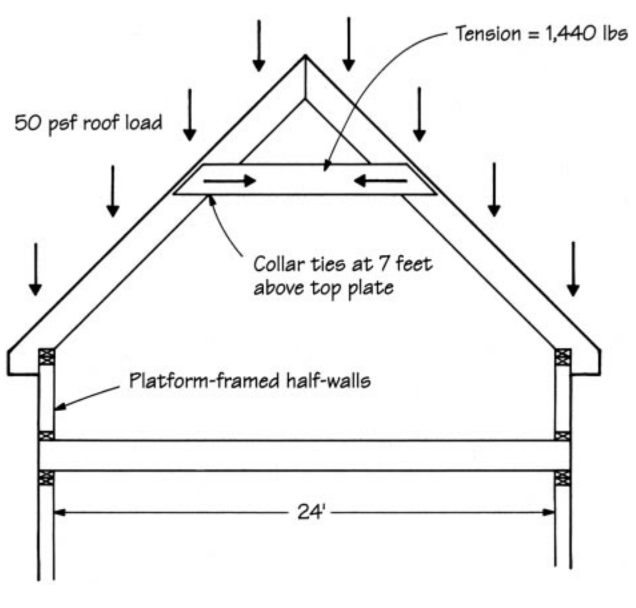
In reality, of course, we expect a roof load more like 15 psf. In that case the tension is reduced to 432 pounds, which can be supported by five 12-penny nails. And we may also find some support provided where the rafters tie in at the eaves, which helps to explain why a couple of nails banged into each tie seem to have held.

This issue comes about because of the gap between physical reality and the codes. Perhaps the right way to approach it is to advocate change in the code, but our working world is not that of the code-making official. We have to expand the attic space, and tomorrow's revised building code will not get today's job done.

One piece of advice: If the only thing involved is a little money, play it conservatively.

— *H. H.*

Collar Tie Tension



The higher the collar tie, the greater the tension. In the example above, using a design load of 50 psf, the tension in the collar tie is 1,440 pounds. The problem for the builder is not the strength of the wood, but finding a practical fastener to withstand that kind of force.

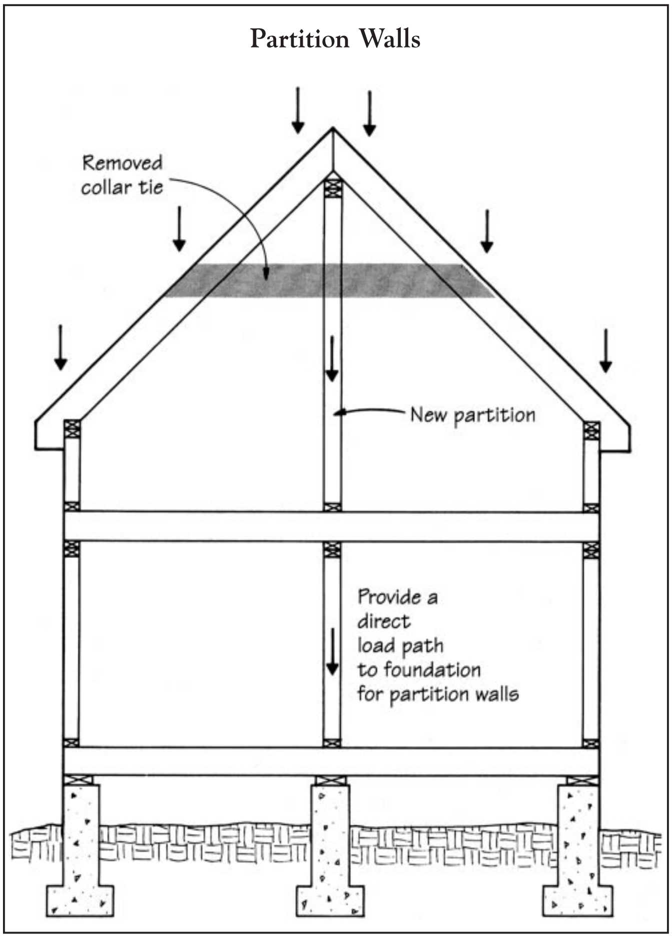


Figure 5. *Load-bearing partitions can remove the roof's outward thrust, but you must be sure you have a direct load path to the foundation.*

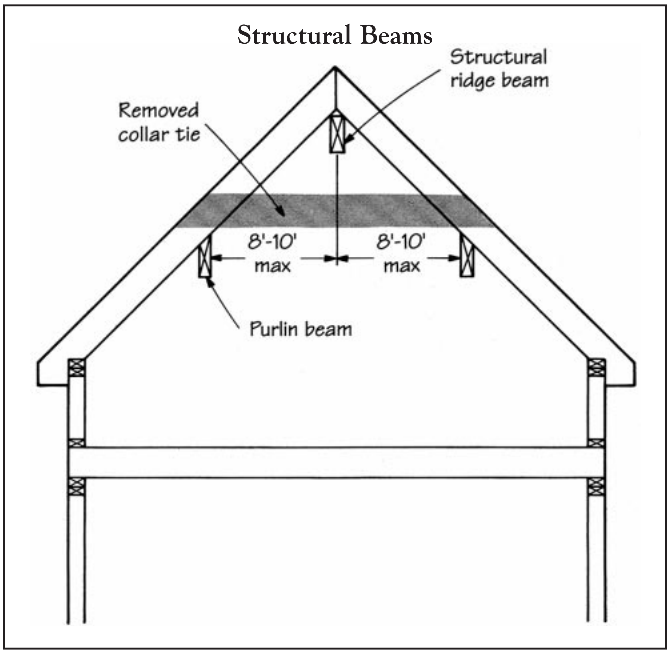


Figure 6. *Structural ridge beams and purlins can carry the roof's load to the gable ends, which must be framed adequately to carry the loads to the foundation.*

40%, to 900 pounds. That's ten nails, brother! Even if that looks okay, then we find another problem: bending stress in the rafter. Code loading demands either a double 2x10 or an engineered material (glulam, LVL, Parallam, etc.) for the rafters. Of course, the rafters are already in place, otherwise there wouldn't be a renovation job.

But, you might say, the house has been there for 80 years and the ties have only three nails in the ends and there's been no trouble. This is because real roof loads and code roof loads are not often the same (see "Code Vs. Reality, or Why Most Things Don't Fall Down," previous page). Without suggesting a violation of code, I'd say raise the ties as little as possible.

Removing alternate ties. And what about taking out every other tie? Doing this *doubles* the tension loads in the remaining ties, since you have half the supports. "But my cousin Jack did it on the Farthing job and it worked good!" Ayuh, code vs. physics again. My advice is to be prudent and not to remove any ties unless you understand the loading in the particular structure. With platform-framed half-walls, chances are the structure is already marginal and should not be made worse.

Solutions

So how do you get some space in the attic? Although you can't fight the collar tie problem directly and still conform to code, there are two general ways to circumvent it. The outward thrust can be removed, or it can be contained. The more effective method is to remove the thrust by holding up the rafters.

When the rafters are supported by other structure, they do not lean on each other and there is no outward push at the bottom ends. Containment of the thrust is achieved by holding the lower ends in by some method other than collar ties. (To get a feel for this, rest your elbows on the desk, clasp your hands, and push down on your clasped hands with your chin. You can contain the thrust with your triceps, but it's easier to support your chin with a structure — a stack of books.)

Partition walls. One solution for providing structure is to install partition walls that support the rafters (Figure 5). This takes practically no engineering and does a very effective job. Structurally speaking, the absolute best place for a partition wall is under the ridge, but transverse walls (perpendicular to the ridge) also work, functioning as massive ties. The roof rests on the partition walls and the lower ends do not push outward.

The builder should be careful with partition walls, so that the loads in the walls are carried to the ground without overstressing the floor joists. This is relatively easy to accomplish in a house, where lower-story partitions provide support for the new attic partitions.

However, partition walls are not always good architectural solutions, since getting some nice space under the roof is why we got into this mess in the first place.

Structural beams. A more difficult solution for removing thrust uses ridgewise support beams or purlins (Figure 6). Since the rafters hang from the beams, the low ends do not push outward. To install

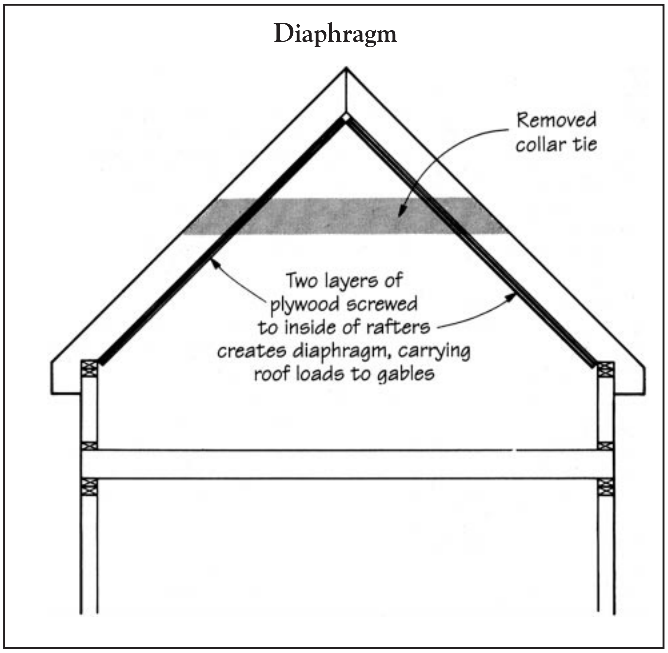


Figure 7. *An unusual solution for carrying roof loads is to skin the inside of the roof with two layers of plywood, creating a diaphragm. The entire assembly acts like a beam, carrying the roof loads to the gable ends.*

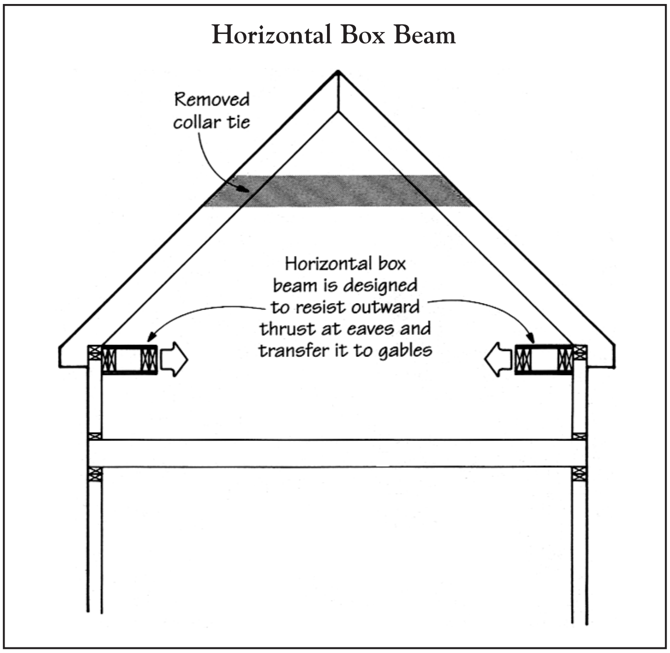


Figure 8. *A horizontal box beam can be designed to resist the outward thrust of a roof at the eaves. The loads are carried to the gables, which must be designed to carry the loads to the foundation.*

these beams, you often have to open up the gable ends. Beams also require posts in the gable end to carry the loads to the ground.

Structural beams can be installed anywhere between the ridge and the midpoint of the rafter span. They should usually not be more than 8 to 10 feet apart. They can be either engineered lumber or steel; ordinary wood is generally not strong enough to span from gable to gable. A 4x16 glulam or LVL ridge beam will hold up a roof measuring 24 feet eaves-to-eaves and 20 feet long with a 50 psf load. If two purlins and a ridge beam are used, 2x16s or 4x12s can be used.

If you choose to use steel for the ridge beam, a W12x14 beam or 12x4x5/16-inch tube will hold up the 24x20-foot roof described above. For purlins, 8x4x3/16-inch tubes will do. Rectangular tubes cost more and are heavier than W-sections (I-beams). But tubes work much better for ridge beams since it is easy to Ramset a facing board onto the side of the tube, and attach joist hangers to the facing board.

Diaphragms. And finally there are the exotic solutions, such as the folded plate or diaphragm (Figure 7). In an attic situation, this involves covering the underside of the rafters with an extremely strong integral plate. A workable plate consists of two layers of 1/2-inch BC plywood with the joints staggered. The plywood must be screwed to the bottom of the rafters with 1 3/8-inch and 1 3/4-inch drywall screws, about 4 inches on-center.

This system carries the roof load directly to the gables, with the plane of the roof acting as a beam. The flow of the load to the gables also stresses another component that must be watched carefully: the gables themselves. Often, the gables need to be strengthened with the same sort of careful double-sheathing as required on the pitches.

Using the inner skin of plywood demands some careful eaves venting to get rid of moisture, since both the inner skin and the exterior shingles act as vapor barriers. A diaphragm is neat and workable and can be installed directly inside the attic space.

Horizontal box beams. Another exotic is the horizontal box beam or steel beam at the eaves (Figure 8). This type of beam provides a transverse resistance to the outward thrust of the rafters. These beams must be carefully built and installed. Like diaphragms, they also transfer loads to the gables, which must be built accordingly. On our 24x20-foot roof, an engineered wood restraining beam should be 6x10 or 4x12, and a steel tube should be 6x4x1/4 inch or 4x4x3/8 inch.

Folded plates and eaves beams are rarely used, and there are no generally available guidelines for their design. Also, with these techniques, the load flow is not obvious and most builders do not have a feel for where to apply meticulous care and where to cut corners. Better call your neighborhood engineer on these. ■

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