# Inspecting ROOF TRUSSES

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This article discusses wood roof trusses, including problems with manufacturing, damage, installation, bracing, alterations and partition separation. Much of this information also applies to open-web floor trusses, although floor trusses have other unique issues not discussed here.

Wood roof trusses connected with metal plates have revolutionized the way we build houses. The earliest trusses in my area were built on-site in the 1950s on small, simple post-war houses (*see Figure 1*). The members were joined together with plywood gusset plates held in place with nails. Fabrication shifted into factories during the 1950s and 1960s with the development of metal connector plates.

With modern trusses, we're no longer confined to building a roof with simple rafter spans. Trusses allow us to build larger structures with more complicated shapes for lower cost, using less lumber and at the same time usually eliminating the need for interior bearing walls. They're fantastic products, as long as they're manufactured and installed properly. Unfortunately, manufacturing and installation problems do occur. Damaged or improperly installed trusses are weak and may not support extreme snow or wind loads.

Repairing a damaged truss is usually a straightforward carpentry job, but who should design it? Section 802.10.4 of the 2003 IRC says: "Truss members shall not be cut, notched, drilled, spliced or otherwise altered in any way without the approval of a registered design professional." In this case, they mean a registered engineer, and this includes repairing any damage.

## Manufacturing Problems

The factory setting allows for a high degree of quality control. Incorrectly manufactured trusses are quite rare, but not unheard of.

For simple joints, the plate should be centered, although this isn't always true for larger joints with multiple members coming together. Misaligned plates are not as strong as the designer intended (*see Figure 2*).

You should always see a metal connector plate on both sides of a joint. Missing plates are almost always due to improper handling during construction (*see Damage*), but if there are no marks in the wood, then the plate was never installed.

Since wood is a natural product, some knots are inevitable. But large knots weaken the member (*see Figure 3*), particularly if a metal connector plate is pressed into one. Acceptable knot size for metal connector plates should be listed in the manufacturer's evaluation report – which isn't likely to be available to you as a home inspector. If in doubt, refer the issue to a licensed structural engineer.

## Damage

Trusses are incredibly strong once they're installed as a system, but individual trusses are surprisingly fragile and construction crews often don't treat trusses with the respect they deserve. Plates can be torn off quite easily. Long trusses should be lifted with a spreader bar. If lifted improperly, trusses will bend sideways like a piece of spaghetti, resulting in plates that are torn out, plates that are buckled and broken web members. Perhaps the crews in my area have just gotten sloppy, but I find some truss damage in about one-forth of newly constructed houses, whereas damaged trusses are fairly rare in older houses (before about 1990). If you don't walk all the way through an attic, you might miss the damage.

Damaged trusses are often patched hastily by construction crews. If I see prior repairs, I suggest that my clients ask the seller or builder to provide documentation that the repairs were designed by a licensed structural engineer; if not, then the repair should be evaluated by an engineer to determine if it's appropriate. I also suggest that they keep a copy of the engineering documents for when they sell the house.

Damaged metal connector plates are one of the most common forms of damage. Obviously, a plate that's pulled completely out of the wood has no strength. But a plate that's pulled partway out no longer has full strength (*see Figure 4*). The Truss Plate Institute (TPI) publication QST-88, *Quality Standard For Metal Plate Connected Wood Trusses,* says that the gap under a plate should not exceed 10 percent of the tooth length or 1/16," whichever is greater. It also says that such a gap should not exceed 1/3 of the plate contact area on each member in the joint. Repair is not as simple as hammering the plate back in because the fingers on the plate are designed to be pressed one time into undisturbed wood. The normal repair is to install a plywood or OSB gusset plate, nailed in place. These are usually much larger than the metal plate being replaced. The size and nailing pattern will be specified by the engineer. Sometimes an engineer will specify a metal replacement plate with nails.

As a truss is bent sideways, the metal plates on the outside of the curve are stretched or pulled out (as described above), but the plates on the inside of the curve are compressed and can buckle. This damage is not as obvious (*see Figure 5*). If you find signs of damage in the accessible parts of the truss, you should also pull aside insulation to look for more damage to the lower chord.

Broken lumber in trusses can range from missing members to cracks that are almost invisible. Several times I have passed by cracked lumber without noticing it, only to find it on my way back out of the attic because it moved when I put my hand on it to steady myself. Take your time and look closely. Metal banding used to bundle trusses for shipping can also cut deeply into the ▶▶▶

*Figure 1: Site-built truss from 1950s*

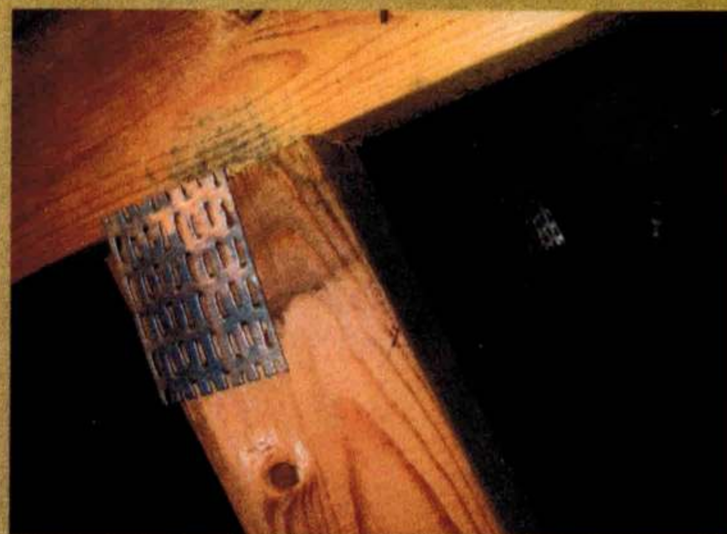

*Figure 2: This metal connector plate was misaligned at the factory.*

*Figure 3: Knotholes weaken web members.*

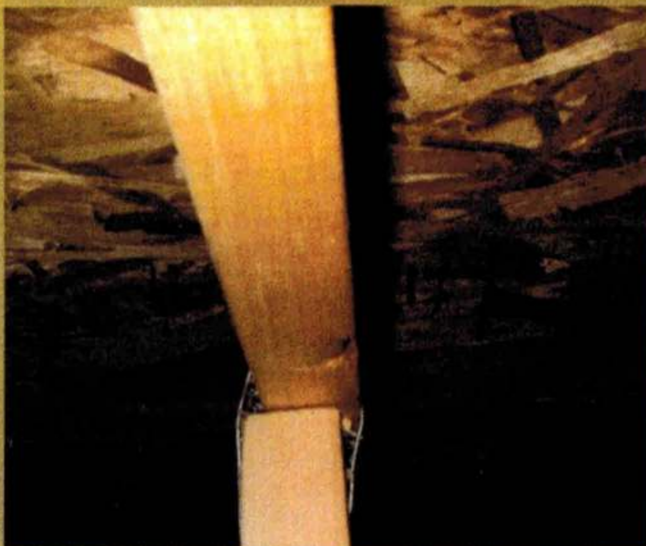

*Figure 4: Metal connector plates loose strength even when pulled only part way out.*

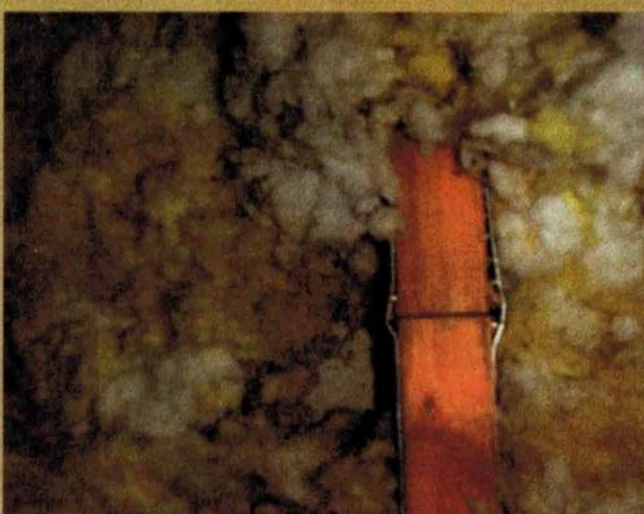

*Figure 5: Compression buckling of connector plate on truss that was bent during installation (left).*

*Figure 6: Ink stamp reads "BRACING REQUIRED".*



lumber. Damaged lumber is usually repaired by splicing new lumber along the side (sistering), but may also involve gusset plate repairs.

If you see a short piece of lumber added to one side of a top chord member with no visible damage on the other side, it's likely this 'scab' was added to support the end of a piece of sheathing that didn't quite reach the truss. Inspectors sometimes mistake this for truss damage.

## Bracing

Buckling is what happens when you push on the end of a yardstick and it bows sideways. Internal web members of trusses are just like big yardsticks, and long web members that are under compression can buckle. To prevent this, designers call for bracing on some web members. Sometimes the need for permanent bracing is indicated by a stamp or tag placed directly on the web member (*see Figure 6*). Other times, you have to look at the truss drawings to know if permanent bracing is needed (*see Figure 7*). In an older house, you won't necessarily know if bracing was intended as permanent bracing or simply as temporary bracing unless the truss has a tag.

Who should design the bracing? According to the IRC, truss design is governed by ASNI/TPI 1. Along with engineering guidance for designing a truss, that document also states that designing permanent truss bracing is the responsibility of the architect or engineer who designs the structure. The truss designer will indicate on the drawings which web members need to be braced. Sometimes the truss drawings will also specify how to install the bracing, but often they will not. I've never seen residential plans that provide details for permanent truss bracing. Instead, most building designers simply rely on footnotes on the truss drawings, which refer to industry standards for installation.

Truss installation used to be governed by HIB91, published by TPI. This document was superseded by *BSCI 1-03 Guide To Good Practice For Handling, Installation & Bracing Of Metal Plate Connected Wood Trusses* (effective 1/1/04) ▶▶▶

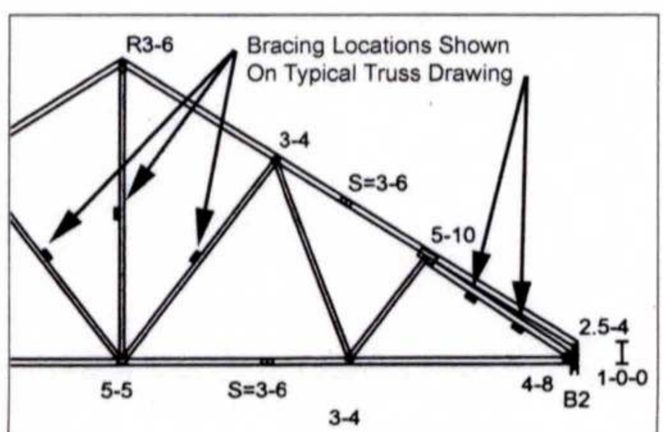


*Figure 7*

published jointly by TPI and the Wood Truss Council (www.sbcindustry.com/bcsi.php), which was further updated in 2006. They also publish a series of Summary Sheets — basically a 'Cliff Notes' version with excellent graphics. BCSI 1-03 discusses many things, including both temporary and permanent bracing. Temporary bracing is needed to keep the trusses from falling over like dominoes during construction. It's the permanent bracing that we're concerned about. Bracing can be either continuous lateral restraint (CLR) or individual web member reinforcement such as T-reinforcement. In older publications, CLR was called continuous lateral bracing (CLB).

Bracing that's required but not installed is an obvious problem. Less obvious issues are discussed below. Note that some of these criteria are more stringent in BCSI 1-03 than in the previous HIB91; the older the building, the less likely it will conform to modern standards.

- Bracing lumber should be 2"x4" stress-grade lumber unless otherwise specified by the designer.
- Each connection should have at least two nails.
- CLR must be connected to a fixed point in the building (such as a shear wall or roof plane) or it must be diagonally braced. This includes the top chords of the lower set of trusses in a piggyback configuration.
- CLR is not effective when the web pattern changes from one truss to the next (*see Figure 8*). T-reinforcement should be used instead.
- T-reinforcement should be 90 percent of the length of the web member and nailed at 6" on center unless specified otherwise by the designer.

Other issues related to bracing include:

- Bracing needs to be tight to the web member to be effective.
- CLR should be roughly centered in the span (*see Figure 9*). Note that some web members may require more than one CLR.
- CLR should be installed so that it does not block the access hatch.
- T-reinforcement must be continuous; it's not effective if it's spliced in the middle. (Yes, I've seen this several times.)
- Gable end trusses sometimes require special bracing – particularly in high wind areas.

Since the top chord of a roof truss is in compression, it's also subject to buckling. Normally, the sheathing restrains the top chord against buckling, but the sheathing can be missing where intersecting ridge lines are created by one set of trusses resting on top of a lower set at right angles (also called a 'valley set'). In this configuration, the lower set of trusses should still have sheathing, usually with a hole to provide access between the two parts of the attic.

## Installation Problems

Trusses must be properly integrated with the rest of the building. A common problem is nails missing in metal hanger brackets supporting trusses. It's worth noting that several manufacturers make brackets that are intended to be bent over the top of the supporting framing, but all nail holes still need to be filled (*see Figure 10*). Structural connectors to hold trusses down to the wall structure should conform to IRC section 802.10. ▸▸▸

*Figure 8: CLR is not effective when applied to trusses that do not have similar web patterns.*

*Figure 9: CLR should be roughly centered in span of web member.*

*Figure 10: All nail holes should be filled in metal hanger brackets.*

Heavy loads are carried by 'girder trusses.' A common example is a girder that supports the end of another set of trusses over the middle of the building without a supporting wall below. A girder truss could be a single truss, but more commonly it's a multi-ply girder made up of several trusses. In order to act together as a single structural component, the individual members of a multi-ply girder must be properly fastened together. This can be accomplished with nails and/or special structural screws or bolts, sometimes in combination with each other. Specific fastener type, size and spacing should be spelled out on the truss drawings.

As we've made houses larger, sometimes the trusses are too tall to be shipped on the highway as a single unit. In these cases, the trusses are shipped in two sets, a lower set with a flat top chord and a smaller triangular set that rests on top of the lower trusses (commonly called piggyback trusses). Pay close attention where the upper trusses rest on the lower ones. Just like other trusses, piggyback trusses are designed with a specific bearing point, which is almost always at the end (*see Figure 11*). In high wind zones, the top section of piggyback trusses may need to be strapped down to the lower set; toe-nailing may not be sufficient.

Conventional framing is often mixed with trusses, particularly to create intersecting gables (often called overframing). At the resulting valley, you'll want to pay close attention to how the conventional framing rests on the truss system below. The conventional rafters should rest on a bearing plate to distribute the load to the adjacent trusses. If this plate is missing, the rafters will be supported only by the roof sheathing, and will likely sag (*see Figure 12*). A similar situation can develop when a framed chimney chase rests on top of the roof. It should be fastened to the framing, not just to the sheathing.

Trusses are designed for a specific spacing, usually 24 inches on center. Increasing that spacing, even locally, can overload the trusses. BCSI 1-03 specifies that trusses should be spaced +/- 1/4 inch from plan position. It also specifies that trusses should be installed plumb within 1/50 of their height (with a 2" maximum) and should be bowed sideways no more than 1/200 of their length (with a 2" maximum).

## Alterations

A major advantage of lumber as a building product is that it can easily be cut and nailed in the field, but this also makes it easy to make improper modifications. As previously discussed, any alterations to a truss must be backed up by engineering designs. Truss members commonly get cut during installation of whole-house fans, drop-down stairs, fireplace chimneys and recessed light fixtures. Truss members also get cut during installation of rooftop vents (*see Figure 13*) or when installing mechanical and plumbing systems.

Trusses are designed with a specific bearing point. If the building configuration gets changed, then the truss must be altered to create a new bearing point. Again, this modification must be backed up by engineering designs. ▶▶▶

*Figure 11: These piggyback trusses are not supported at the bearing point.*

*Figure 12: These rafters bear only on-roof sheathing in between trusses.*

*Figure 13: Truss members should not be altered in the field.*

Section 802.10.4 of the 2003 IRC says: "Alterations resulting in the addition of load (e.g., HVAC equipment, water heater) that exceeds the design load for the truss shall not be permitted without verification that the truss is capable of supporting such additional loading." Another such change of loading is if clay or concrete tiles are substituted for asphalt shingles during re-roofing. The roofer should have an engineer verify that this increased loading is safe. Again, I suggest that my clients obtain a copy of the engineering documents and keep them on file for the time when they sell the house.

Attic storage is another way that design loads can be exceeded. The bottom chords of most trusses are designed to support only the dead weight of insulation and the finished ceiling. Storing heavy items in an attic can literally rip the bottom chord off the truss.

## Partition Separation

Because interior partition walls are typically not load bearing, a unique problem can develop where those walls meet the bottom of trusses, resulting in drywall cracks near the wall/ceiling joint. In areas where the relative humidity changes significantly from summer to winter, the truss lumber will expand and contract as its moisture content changes. As a result, the bottom chord of the truss will rise and fall seasonally as it bows up and flattens back out. This is called 'partition separation' or 'truss uplift' (*see Figure 14*). Other factors that can also cause partition separation include building settlement and deflection from snow or wind loads. You can read more about ways to avoid this problem in *Partition Separation Prevention and Solutions*, part of the Truss Technology in Building series published by The Wood Truss Council of America (www.sbcindustry.com). ■

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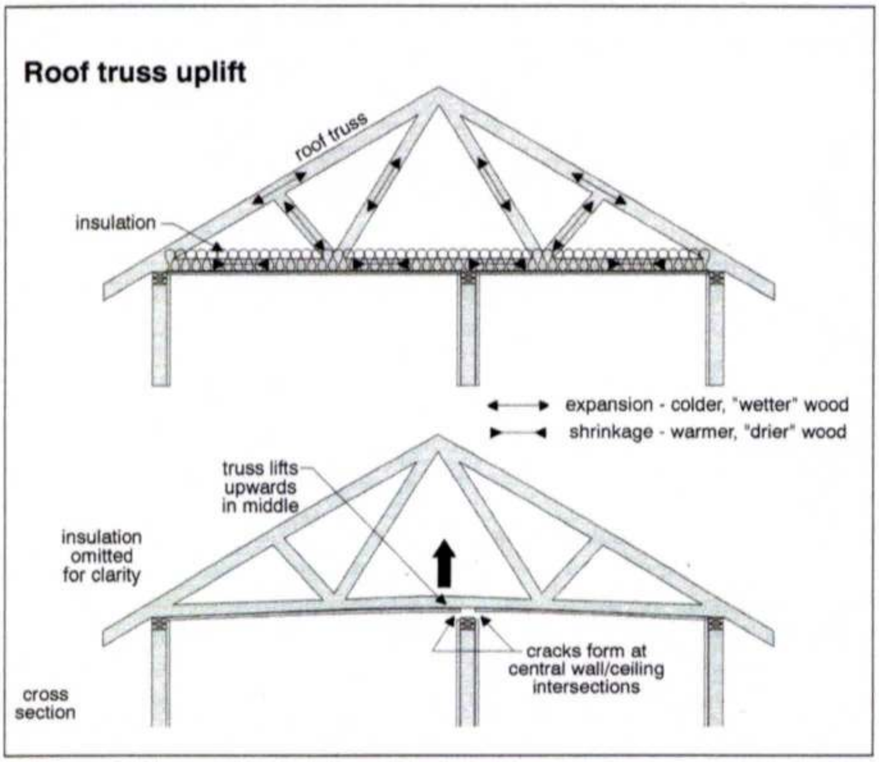


*Figure 14: Partition separation (from Carson Dunlop Illustrated Home, #0438 in 1st edition).*