Metal Plate Connected Wood Truss Inspection

By Odilo A. Grossthanner, David B. Brakeman S.E, P.E., Norman D. Wood P.E.

Part 1

INTRODUCTION

Trusses connected with metal connector plates are engineered, manufactured, and installed in compliance with specifications established by the Truss Plate Institute (TPI). A metal plate connected truss is a safe and durable structural component. Millions of these trusses have been installed in structures and have performed well over the last four decades. Full-scale testing and research facilities have shown that trusses produced in compliance with the TPI specifications have ultimate load-carrying capacities in the range of at least two to three times the design loads.

Inspection of metal plate connected trusses is most often conducted after installation to ensure that all material and erection specifications are met. Inspection also becomes necessary if performance problems occur in existing buildings.

In this two-part article, eight potential problem areas are identified. Part 1 addresses deviation from design, improper handling and installation, and field modifications and repair. In part 2 (to be printed in the next issue of *Peaks*), loading conditions, bracing, environmental conditions, and fire-retardant-treated lumber are discussed.

DEVIATION FROM DESIGN

Trusses are fabricated based on design drawings that specify plate sizes, plate placement, the configuration, and lumber grade and size. Manufacturing tolerances are specified by TPI in Quality Standards for Metal Plate Connected Trusses, 1988 (QST-88). When installed, the trusses must meet certain tolerances (TPI, 1991).

Plate Size and Placement. Correct thickness, placement and contact area of connector plates on each connected member is important.

Connector plates are fabricated in various thicknesses. Most joints are connected with 20-gage plates. However, splices, heel joints, and joints on long-span trusses with wide on-center spacing may require heavier gage material to develop the necessary load capacity. Verifying that these heavier gage plates were used is an extremely important part of the inspection. Plate manufacturers apply special identification symbols for their plates that allow proper identification of the thickness. The symbols are embossed on the outside face of every plate that is wider than 3 in. (76mm).

Connector-plate size specifications differ among manufacturers. Some specify the sizes in inches and others in manufacturing units. Thus, a 3x4 plate may be 3x4 inches, or it may be three units by four units, which actually could be larger or smaller than 3x4 inches.

Connector plates are required on both faces of every joint. QST-88 and some building codes provide tolerances for partial plate embedment and other manufacturing deviations. Acceptable tolerances also may be listed in the evaluation report, which is issued for every code-approved connector plate. Evaluation reports contain plate specifications and other important information. They should be obtained from the code authorities or from the plate manufacturers prior to any inspection.

Correctly sized plates may be inadequate due to plate misplacement *(Figure 1)* or changes in the size of the connected member. For example, in a three-member web joint, if wider lumber was substituted for the center member, but the specified plate size was not increased, the two outside members may not have an adequate contact area. Knots and wane in the contact area of the connector plate may be acceptable as long as the provisions of QST-88 are met.

Configuration. Inspectors must verify the correct number of panels in the top and bottom chords, the location of panel points as shown on the drawing, and the direction of the web members. These characteristics are sometimes changed during manufacturing to optimize the available lumber and may affect the structural integrity of the truss.

Lumber Grade and Size. Lumber characteristics such as knots, wane, slope of grain, and splits are controlled by the lumber grading rules that are available from the grading agencies. The lumber grade is indicated on each piece of lumber by a grade stamp. Some of the grading stamps are cut off during fabrication, but at least some of the truss members should show the grading stamps. Lumber grade verification is important especially if the top and bottom chord and the diagonal web members are intended to be of different grades, but are otherwise identical in cross section. The potential for erroneously mixing members and lumber grades during fabrication is greater for a product such as a flat truss. Lumber is not re-graded by the truss manufacturer and, occasionally, pieces with defects that are in excess of the allowable tolerances are mistakenly used in critical members.

IMPROPER HANDLING AND INSTALLATION

Improper handling and installation can be one source of service problems. Information on handling and installing metal-plate connected trusses can be obtained from the TPI's Handling, Installing and Bracing Metal Plate Connected Wood Trusses, HIB-91.

Handling. Damage can result from improper handling enroute to the job site. Trusses are banded into stacks by the manufacturer for delivery. The banding, if

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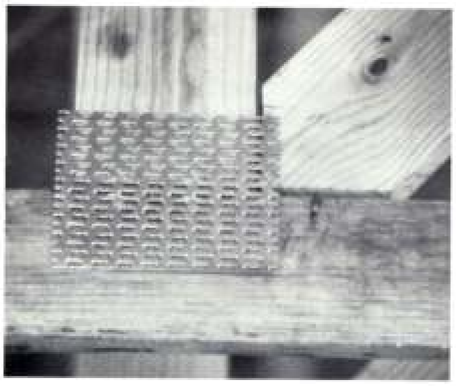

Figure 1

Figure 2

applied too tightly, can damage the unprotected edges of the outside trusses. Deep banding cuts on the edges are difficult to detect after installation, but they can be especially detrimental to tensile members.

Lifting without spreader bars will cause extreme bowing, especially in long-span trusses, *(Figure 2)* which are very limber perpendicular to the intended loading direction. Connector plates on the convex side of the bow, particularly the splices toward the center of the truss, can pop out or may be stretched close to failure, whereas connectors on the concave of the bow may buckle. A small crease or bubble along the splice indicates that this condition has occured.

Also, truss members can be cracked by rough and improper handling. These cracks are not always found during installation, but they open up when the truss is loaded. Although broken members may appear to be repaired, a repair might only be a patch that is inadequate *(Figure 3)* to restore the full structural integrity of the damaged members. Therefore, repairs on trusses should always be backed up by engineering design, and proper execution of the repairs must be verified.

Erection. During installation, trusses might be erected backwards or upside down. The problem can be difficult to identify. If the trusses were designed for higher loads at one end than the other, then reversed erection could be critical. Often, the only visual clue that the geometrically symmetric truss is not functionally symmetric is the presence of larger connector plates on the joints on one end.

Backward installation of a truss that was intended to cantilever on only one end may severely overstress the bottom chord, causing failure between panel points, while the cantilever strut, now on the wrong end, serves no purpose.

Flat trusses with square ends can be mistakenly erected upside down. The direction of the diagonal web members and excessive deflection may indicate this condition. When the truss is installed upside down, the splice plates that were actually designed for the compressive forces, which usually require much smaller plate sizes, are now on the tensile member. In addition, the diagonal web members that were designed for compressive forces now carry tensile forces that would normally need joints with much larger connector plates.

In this condition, what appears to be excessive deflection is most likely the camber that was built intentionally into the truss to provide for drainage. The condition would be further aggravated by the effect of additional loads from ponding due to the inverted camber. This has been identified as a predominant cause of flat roof failures.

Multiple truss members, such as girders, require connectors to tie the truss units together. The type of connector and spacing is specified on the engineering drawing, and the connectors are usually installed in the field where less precision and control exists. The connectors must be placed so that they can distribute the applied loads to all members. This is especially important if all the supported loads are connected to one face of the girder. The specified number of nails must be visible from both faces, especially if three or more members make up the girder truss. Bolts must be placed with sufficient edge distance, and the nuts must be tight. Also, the number of truss units should be counted to ensure that the specified number are actually in the girder.

Trusses framing into girder trusses must be connected with adequate framing hardware. Most framing hardware is marked with a visible identification by the manufacturer, who also will provide load ratings and specifications for connectors.

Most trusses are spaced 24 inches (610mm) on center. However, designs will sometimes specify a spacing less than 24 in. on center. This variation from the customary spacing can be missed during the erection process. Excessive localized deflection of a few adjoining trusses within a continuous run of otherwise identical trusses may be a sign of overloading by construction material that was stored temporarily on the trusses *(Figure 4)*. These trusses must be checked carefully for potential damage.

Gable end trusses, usually recognizable by the closely spaced vertical members and the absence of diagonal web members, are normally supported over their entire length by walls. At times, these trusses are errantly positioned as clear-span members and are then substantially over-stressed in that location. Large cantilevered corners of roofs often require additional structural framing in the form of sub-fascias and beams. The

(Continued On Next Page)

Figure 3

Figure 4

(Continued From Page 5)
members are specified on the engineering layout, but can be overlooked during erection or, if present, may be inadequately connected. The areas are not easily accessible for inspection since they are usually in the low heel areas of the trusses, but the additional framing is extremely critical for performance of the cantilevered corners and must be verified.

FIELD MODIFICATIONS AND REPAIRS

Lumber is easy to cut, drill and nail. This is a great advantage of wood, but it also presents a special problem since field modifications can be expediently, but improperly performed on trusses to fit them to structural situations for which they were not designed.

Standard carpentry practices that are used for conventional framing are routinely applied to trusses as well, but may be inappropriate for a truss that is an engineered product. For example, truss length is often field modified to account for mislocated walls. If the trusses are stubbed back for walls that are closer than expected, an important connection at the end of the truss is often replaced with an inadequately connected plywood gusset. Scabs and blocks to extend trusses to longer spans are often inadequately connected. Modifications to length must always be backed up by engineering designs. If the inspector has no engineering documentation, the modifications must be evaluated for structural adequacy based on the condition found during the inspection.

Figure 5

Height inaccuracies are sometimes corrected by trimming off a section of the chord members. This can be found at changes in the roof line or where a truss has been mislocated during erection. Uneven or rough edges of a chord member may indicate this condition.

The most frequent field modifications to trusses are made by notching and removing members to allow for duct work, plumbing, recessed lighting, and other mechanical items that pass through the attic space. Therefore, it is advisable to inspect trusses in the vicinity of these features.

The correct number of connectors, the size of the scabs, and the size of the plates for field splices should be verified by the truss inspector. Very long or very high trusses are usually delivered in sections to allow for convenient transportation. The sections are connected on the job site by a field splice, which consists either of nail-on plates or scabbed members. The engineering design always specifies the number of bolts or nails for this type of splice.

Frequently, field modifications are found around chimneys. Trusses in the way of the chimney may have been cut, transferring the load by headers to adjacent trusses. Sometimes the cut trusses are left supported on the chimney, which may be a code violation. Proper framing around fireplaces requires engineering design and always deserves special attention during truss inspection. Similar problems occur where skylights, attic fans, and attic access openings are added after construction has begun or during remodelling *(Figure 5)*.

SUMMARY

Metal plate connected wood trusses are safe and durable structural components. However, their performance may be adversely affected by deviations from design, improper handling or installation, or field amendments. The basic approach is visual inspection when examining trusses for these potential problems. Other points of inspection should address loading conditions, bracing, environmental conditions, and fire-retardant treated lumber. ▲

Part 2 of this article will appear in the Summer 1992 issue of Peaks.

Metal Plate Connected Wood Truss Inspection:



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Part 2

ABSTRACT

Inspection of metal plate connected wood trusses is discussed. To maximize effectiveness, inspection efforts should concentrate on critical and high-stress members and joints. This article, the second in a two-part series, emphasizes loading, bearing conditions, bracing, environmental conditions, and use of fire-retardant-treated lumber.

INTRODUCTION

Part 1 of this article *(Peaks Spring 1992)* discussed inspection for deviation from design *(TPI, 1980; 1988; 1991b)*, improper handling and installation, and field modifications and repairs. These represent some of the most common points of structural distress found by inspectors. However, several other aspects of structural condition should be considered during the inspection. The topics in this article, the second in a two-part series on inspection of metal plate connected wood trusses, focus on loading conditions, bearing conditions, bracing, environmental conditions, and fire-retardant-treated lumber.

LOADING CONDITIONS

All expected loads on the trusses are considered at the design stage. Concentrated loads are identified on the architectural plans for special consideration by the truss design engineer. However, additional loads are often imposed by features not shown on the architectural plans. These items must be identified by the inspector. One feature that is often not accounted for at the design stage is mechanical equipment, such as air conditioners, heaters, and water tanks. Other unanticipated concentrated loads are generated by fixtures such as folding partitions and chandeliers. These are often added after design and construction of the structure are complete. Large-diameter sprinkler pipes, especially in commercial buildings, represent substantial loads and must be shown on the truss design. Attic storage may have been added, but not considered in the original design in trusses with large open areas between the webs. Trusses in any roof area that has convenient access and sheathing on any portion of the bottom chords frequently become unanticipated storage sites.

Special shapes and roof lines such as valleys and hips are often formed by applying conventional framing over the trusses. The conventional framing members support the roof load and transfer it as concentrated loads to the supporting trusses *(Figure 1)*. This can cause critical loading conditions if the framing member is applied between panel points, unless the supporting truss was designed for these concentrated loads.

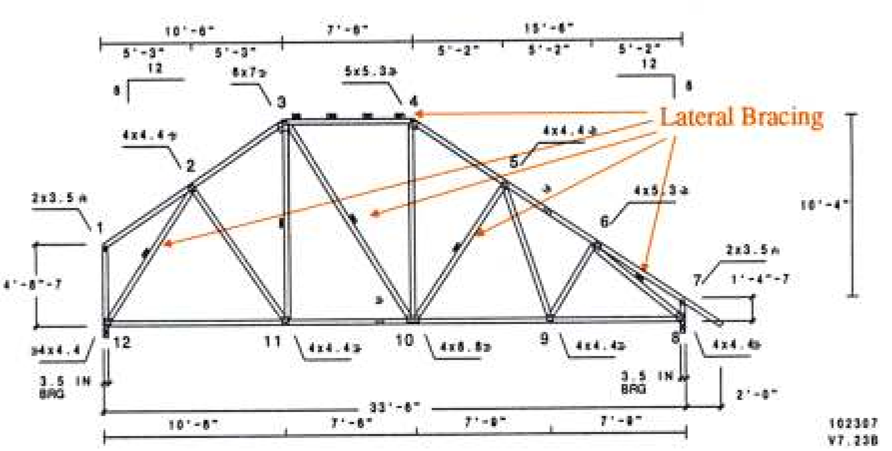
Design loads must always be verified against the existing loads. Trusses may be designed for light roof loads, such as asphalt shingles, but the roof may ultimately be covered with concrete tile. Similar discrepancies can exist on floor trusses, which sometimes support concrete overlays for which the trusses were not designed. Ceilings can be heavier than assumed if multiple layers of drywall are used to achieve a fire-rated system. Specified design loads on a truss design might not reflect the actual material that ends up on the truss.

Roof system problems have occurred in areas with potentially large snow accumulations. Critical locations can include large offsets in roof levels, attachments to higher adjoining buildings, and the addition of parapets or advertising signs around the perimeter of flat roofs. These features are often added to existing buildings; thus, proper design consideration must be verified during truss inspections.

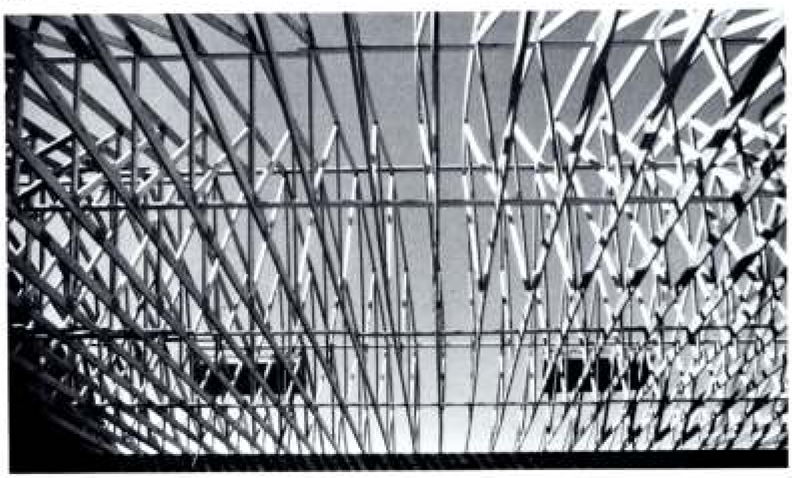
BEARING CONDITIONS

Trusses require adequate bearing to transfer the roof or floor load into the supporting structure. The required bearing widths are always specified on the truss design drawings. Girder design and long-span trusses may require a bearing width of up to 8 in. (203 mm) or more. In buildings with stud framing, the wide bearing width cannot always be accommodated easily; thus, it is frequently ignored in the field. Interior bearings specified on the drawings must be verified. These bearings must be continuous to a properly designed supporting element such as a foundation, a girder, or a header below. Interior partitions should not become casual bearings unless the truss

(Figure 1)



(Figure 2)



(Figure 3)

and the structure are designed to accommodate these conditions. This could become especially critical if the interior partition is supported on a clear-span floor member below. The inspection of any bearing condition should always include verification and evaluation of proper load-transfer capabilities to a foundation or a properly designed member below.

Trusses are sometimes supported at the walls by ledgers, which may be uneven and may deviate from a straight line. Consequently, some trusses may not have adequate support on the ledger. Adequate support should be verified on all trusses over the entire length of the building. Top-chord bearings on parallel- chord flat trusses should not have more than a 1/2-in. (13mm) gap between the support and the end vertical, or the point where the end diagonal meets the top chord. These gaps can sometimes be substantially greater due to inaccurate location of the wall or misplacement of the trusses. This often results in substantial bending and deflection in the top chord between the edge of the bearing and the end web of the truss.

Trusses always require some type of connection to the bearing. The connection may be specified on the engineering design drawing or must comply with the building codes.

Variability of construction practices and lack of control during the erection of the trusses often creates deviations from acceptable standards. Therefore, it is advisable to inspect and verify the existence of proper bearing conditions on every truss.

BRACING

The most critical element for lateral stability of trusses is the lateral bracing system. The Truss Plate Institute provides guidance for permanent bracing *(TPI, 1991a)* and temporary bracing *(TPI, 1989)*.

Lateral bracing may be provided by properly connected sheathing on the top and bottom chords of trusses, or by rows of lateral braces, cross brace members, T-braces and scabbed-on braces. The locations and the number of lateral braces are specified on the truss design drawings *(Figure 2)*. Each end of a row of continuous lateral bracing must be connected to a fixed point to prevent the bracing from acting only as a tie that would force all braced members to buckle simultaneously. The fixed points can be provided by extending and connecting the bracing to the walls, the roof sheathing, or by connecting to cross bracing in the plane of the diagonal or vertical webs. The truss design drawing does not show where these fixed points are located or what type of connection must be provided; therefore, they often are not provided in the field. In some instances in which continuous lateral bracing cannot be installed, scab bracing or T-bracing is specified. These applications are typical when the web configuration changes from truss to truss. Since this bracing typically is field applied, and only a few odd members require this type of bracing, it can easily be missed in the field; thus, requiring special attention during the inspection.

Trusses with purlins only on the top chord, such as the flat top chord of the carrier truss on piggy-backed trusses, require cross bracing to prevent simultaneous buckling of all top chords *(Figure 3)*. This cross bracing should be installed at each end of the building and at regular intervals throughout the length of the building. It must be connected to shear walls or other suitable fixed points of the structure. Many buildings that were not erected under the supervision of a competent professional may lack these bracing systems.

When special roof shapes are framed by conventional framing over a system of roof trusses, it is common practice not to apply sheathing to the over-framed top chord of the supporting trusses. These top chords must be braced by lateral bracing that should be specified by the truss designer. This requires special attention during a truss inspection since the truss designer is often not aware that this condition will exist and does not specify the bracing on the truss design drawing. The erection contractor in turn does not provide the bracing since it is not specified.

Floor trusses require strongbacks, which are typically continuous 2- x 6-in. (38- x 140-mm) members attached with three 16-penny nails to vertical webs *(Figure 4)* of the trusses *(TPI, 1991a)*. The number of rows and the location should be specified on the truss design drawing. Some builders prefer to use rows of cross braces, which are acceptable alternatives to strongbacks. Whatever method the builder chooses, it is necessary to verify that these braces have been provided and that they are properly connected to the trusses.

Trusses without ceilings or with suspended ceiling systems require bracing on the bottom chord to prevent buckling due to stress reversals. The spacing is specified on the engineering design drawings, but in no case should it be more than 10 ft (3 m) on center. All chord braces should be at least 2- x 4-in. (38- x 89-mm) members attached with two 16-penny nails to each chord, unless the engineering design drawing specifically permits something different.

The responsibility for bracing and its connection design is not always clearly defined. As a result, buildings are sometimes erected without permanent braces or with inadequate bracing. The truss inspector should be especially aware of this condition and use engineering judgment.


(Figure 4)

ENVIRONMENTAL CONDITIONS

All building codes require ventilation of attic areas and specify the minimum acceptable criteria. Ventilation, which controls humidity and temperature in the attic, becomes especially important when chemically treated lumber is used, particularly fire-retardant-treated lumber. An inspection of trusses should always include verification that at least the code-required ventilation is provided. Vent openings must be checked to ensure that they are not covered with insulation. Mechanical ventilation equipment must be checked for proper operation.

Sometimes, exhaust vents from inside the building terminate into the attic area. Some of the air vented from inside the building may be hot or carry very high humidity. This could cause performance problems, such as ceiling/partition separation due to upward movement of the trusses *(Percival, 1991)*. In the worst case, moisture vented into the attic space could even contribute to the lumber deterioration or connector corrosion. A truss inspector should verify that no vents from inside the building terminate into the attic space.

Trusses that have been in service for a long time should be inspected for lumber degradation. Areas of changing roof lines are potential sources for leaks. Flat roofs, breaks from a flat roof to a mansard, and areas around penetrations by mechanical equipment and ducts require special inspection for leaks *(Pneuman, 1991; Wetherholt, 1991)*. Water that penetrates into the roof area can collect between the sheathing and the truss chord member. The temperatures, which typically exist underneath the roof sheathing, and the moisture from the leak can create an ideal condition for decay fungi. Truss lumber in contact with masonry and concrete, and in areas where floor trusses penetrate exterior walls to form balconies, has a high potential for decay if air circulation and proper barrier materials between the wood and the masonry are not provided. These areas are not easily accessible, but they are critical for proper truss performance and should always be checked during a truss inspection.

FIRE-RETARDANT-TREATED LUMBER

Fire-retardant-treated lumber has been used for trusses for almost two decades. The chemical compositions for the treatment have been modified and differ depending on the supplier. The effects of the treatment process have also varied. The first- generation chemicals often caused corrosion of the connectors and other galvanized metal hardware, especially if used in high humidity environments. Second-generation chemicals did not cause corrosion problems. However, occasional lumber failure has occurred in a large number of trusses in a single structure. Cracks formed across the entire cross section of truss members. Failure has sometimes occurred even on members with very low axial forces. This occurrence seems to be more severe in roof areas with poor ventilation. The cause for this has not yet been fully defined, but the truss inspector must be aware of these additional potential problem sources.

SUMMARY

Deviations from design specifications and accepted standards are the sources of problems most frequently observed by design engineers during truss inspections, especially when they were called in after performance problems occur. The eight points discussed in this two-part series should serve as a guideline and do not represent a complete summary of potential truss problems. An inspector must always be alert for special conditions and unusual problems that may exist. It is also advisable that the inspecting engineer be knowledgeable of the truss design, the truss system, the layout, and the framing scheme. The engineer should become familiar with critical and highly stressed members and joints in the truss where the identified problem could be especially detrimental. A majority of the inspection efforts should be allocated to those areas. Further knowledge of the truss design and the design specifications, industry standards, and familiarity with the identified potential problem areas will allow inspectors to maximize their inspection efficiency. ▲

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