TRUSS, BUT VERIFY

(CONFIRM THE QUALITY OF MPC WOOD TRUSSES IN A POST-FRAME BUILDING)

Metal Plate Connected (MPC) Wood Trusses are quite common in Post-Frame Buildings. They hold up the roof of your building, and must withstand loads from snow, wind, and the occasional roof maintenance. On Post-Frame Buildings the trusses are most commonly spaced between 4' and 10' on center. The trusses are usually clear-span with no internal support. This construction is very efficient and is one of the advantages of Post-Frame Buildings.

Figure 1. Copyright MilMar Pole Buildings

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Taking MPC Wood Trusses to New Heights, Spans, and Spacings

The wide truss spacing and large clear-spans of Post-Frame Buildings are in contrast with the use of MPC Wood Trusses on most residential and other building types. This means the quality of the trusses in Post-Frame Buildings are more important to the building integrity than in other building types. The other building types often have more redundancy and multiple loads paths that can support the roof loads, even when one or more of the trusses are weak.

To assure the integrity of your Post-Frame Building you need to be confident that each truss is well-built and in good condition. A good builder, installer, owner, or consumer of a Post-Frame Building will "trust, but verify". This article will help you "verify" the quality of the MPC Wood Trusses in your building. The five major items to verify are:

- Specialized Engineering
- Truss Lumber
- Connections Using Metal Connector Plates
- Lateral Restraint of Truss Members and Bracing of the Lateral Restraints
- Building Maintenance

Specialized Engineering – the Truss Design Drawing (TDD)

A truss is a complex structural product that is specially designed and engineered to safely perform at a certain load level under specified conditions. All of this starts with a Truss Design Drawing (TDD). The Truss Design Drawing is usually sealed by a Professional Engineer that is registered by the State where the building is located. The Truss Design Drawing may be difficult to read, because it contains a lot of special information about the truss and the conditions of usage.

The Professional Engineer seal on the Truss Design Drawing is NOT a substitute for the services of a

qualified engineer in the design of the building. The Professional Engineer seal on the Truss Design Drawing confirms that the truss design meets the specialized requirements for the Lumber and Metal Truss Plates, for the loads and conditions stated on the Truss Design Drawing. Unless verified, the loads and conditions stated on the Truss Design Drawing may NOT be appropriate for your specific building and the building site. The Engineer, Architect, or whoever is responsible for the building design needs to verify that the Truss Design Drawing is appropriate for the specific building and site. The building designer (Engineer, Architect, or other designer) is responsible for confirming that the loads and other conditions stated on the Truss Design Drawing are appropriate for the building and site.

If an Engineer or Architect is NOT hired, this responsibility will usually fall upon the builder and/or the owner, depending on terms of contract and/or local laws. If the responsible party is not experienced in the review of Truss Design Drawings, they should seek assistance from a Professional Engineer.

The Truss Design Drawings should be obtained, reviewed, and verified before the trusses are manufactured. Otherwise, you may need to pay for trusses that are inadequate and should not be used on your building. This requires planning and coordination between the builder, truss manufacturer, and the reviewing engineer. Don't wait until it is too late to choose a quality truss supplier.

Once the Truss Design Drawings are accepted and approved, distribute copies to the installer, the building owner, building department, and inspectors. The installer will need to plan for installing all truss restraints and bracing at locations specified on the Truss Design Drawings in addition to bracing specified on the building plans. The owner should keep the Truss Design Drawings on file for future maintenance and use copies to allow verification that the installer/builder did their job well. The owner may wish to hire an inspector to help verify that the trusses are properly built and installed, including all the restraints, braces, and uplift/bearing connections.

Truss Lumber

Most of us know that lumber varies from piece to piece. Structural Lumber is graded at the lumber mill and stamped to indicate the lumber grade. Lumber has natural characteristics that can reduce the strength of the lumber, for example: knots, holes, splits. Lumber grading places limitations on the size of these characteristics. A higher grade of lumber will have smaller and/or fewer knots than a lower grade.

Most wood trusses use a higher grade of lumber in the top and bottom chord (the outer lumber) than for the web members (inner portion of the truss). The specific grades are specified on the Truss Design Drawing. You can verify a few pieces by reading the Grade Stamps.

When the trusses are delivered to the site and the installation process begins, the installer should look over each truss and verify that there is no damage to the lumber and that most of the lumber pieces have a grade stamp on each piece. Each lumber piece has a grade stamp from the lumber mill, but the lumber is cut and trimmed to length by the truss manufacturer. Thus, some grade stamps will be lost after piece cutting.

If any truss piece has significant damage, it should be noted and photographed (a repair may be needed). The installer and builder should work with the truss supplier to obtain specialized engineering for all truss repairs. Do not apply any permanent repair until a truss repair drawing is provided by the truss supplier. In some cases, the truss may need to be replaced, instead of being repaired.

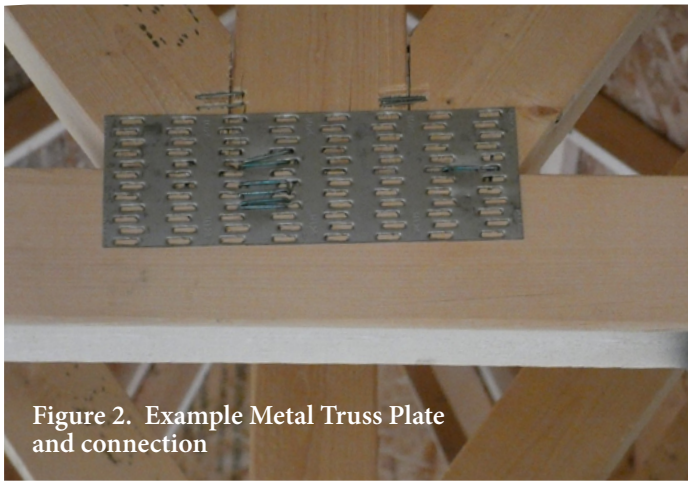

Figure 2. Example Metal Truss Plate and connection

Connections using Metal Connector Plates

The Metal Connector Plates are specialized connectors that are critical to the strength of the truss. A single weak joint can result in the collapse of a building under heavy loads. There are six items to verify:

1. The plate must be the type and size (length and width) specified on the Truss Design Drawing (or larger).
2. The plate must be located on the joint as specified on the Truss Design Drawing
3. The plate must be properly pressed into sound wood. There should be only a limited area of knots, wane, holes, etcetera in the area where the Metal Connector Plate grips into the lumber.
4. The plates must be installed onto both faces of each truss connection.
5. The plates must be completely embedded into the truss lumber (with little tolerance).
6. The cut lumber pieces must fit closely together at each joint as shown on the Truss Design Drawing.

Due to the large number of connections that should be verified, it is difficult and time-consuming to check all of them. One option is to hire an inspector for this task. Another is to closely verify only a smaller number of trusses. We call this smaller number of trusses a representative "Sample" of the larger group. If no significant problems are identified in the "Sample", then we "trust" that the group will likely be good. If problems are identified in the "Sample", then we can choose another "Sample" to verify or decide to verify all the trusses. When using a "Sample" method. the other trusses should still get a "quick look" to discover any missing Metal Connector Plates or other "glaring issues".

When verifying the plate connections, we are not looking for perfection. The plate locations will not be perfect, and some teeth of the Metal Connector Plate may be into unsound wood. There are complex manufacturing tolerances used for inspections in the truss plant. We need to keep verification simple. Any condition that looks off by more than 10% should be photographed and noted. Any issues identified should be sent back to the truss supplier. The truss supplier can decide which issues need a repair, and they can get a "repair drawing" for those cases.

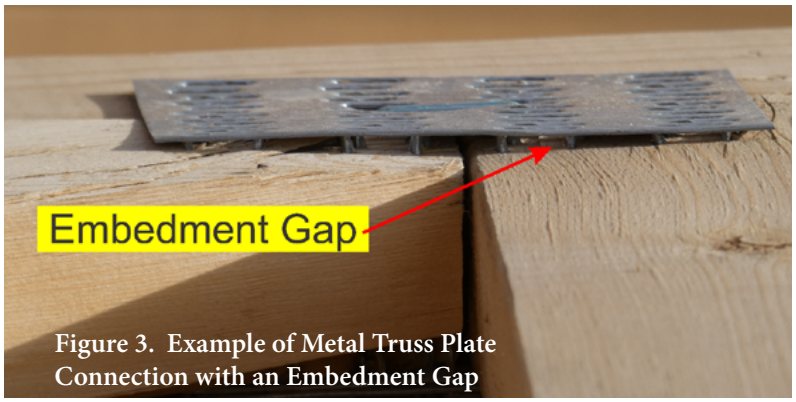

Figure 3. Example of Metal Truss Plate Connection with an Embedment Gap

One issue from the previous list that requires special attention is:

5. The plates must be completely embedded into the truss lumber (with little tolerance).

The teeth of the Metal Connector Plates are only about 3/8 inch (0.38") long (usually). Even a small gap between the truss plate and the wood will significantly weaken the connection. For

example: an embedment gap of 1/16 Inch (0.06") will result in a 40% reduction (60% Effectiveness) in the strength of the connection. The manufacturing tolerance (per ANSI/TPI 1) for embedment gap is 1/32 inch (0.03"). See table herein from ANSI/TPI 1.

Tooth Embedment Gap, G	Tooth Effectiveness
G = 0"	119%
0" < G ≤ 1/32" (0.03")	100%
1/32" < G ≤ 1/16" (0.06")	60%
1/16" < G ≤ 3/32" (0.09")	40%
G > 3/32" (0.09")	0%

Figure 4. Table reproduced from ANSI/TPI 1

Embedment gap issues can be:

- systemic, affecting a large number of connections.
- or specific, affecting only a few joints in a non-predictable way.

If an embedment gap issue is systemic, the shipment of trusses should be rejected at (or shortly after) the time of delivery. The outer trusses in the shipment should be quickly examined for this issue. Missing this opportunity could cause costly repairs and may shift the blame (expense) from the truss supplier to others.

The trusses should be kept dry at the job site and in the final building. When lumber is exposed to high moisture for extended periods, the lumber expands (mostly in the direction perpendicular to the wood grain). This expansion pushes out the Metal Connector Plates. Then when the lumber dries, the lumber will shrink, but the wood surface will not pull the Metal Connector Plates back into the wood. This process can cause, or increase, the embedment gap. That is why connections using Metal Connector Plates should be kept dry. The degree of the problem is dependent on the wetness conditions and the time period that MPC Wood trusses are exposed to the weather or other sources of moisture. A short period of high moisture may not cause significant problems, but longer periods (or periods that cycle from wet to dry) will increase embedment gaps. Once the trusses are received at the job site, the responsibility for protection from high moisture shifts to the new owner of the trusses.

When embedment gaps are identified long after the delivery of the trusses to the site, it is difficult to identify the cause of the problem.

Non-systemic embedment gaps can be caused by a variety of issues. Since they are usually few, the focus should be to identify them and get the connection repaired.

Owners of existing buildings may notice embedment gaps. One possible cause may be high moisture conditions (especially if the truss lumber cycles from high to low moisture over time). This can occur in some special buildings. The owner of a building with a high moisture environment may need to periodically inspect (or hire an inspector) to look for embedment gap issues.

Regardless of the cause, any Metal Plate Connections with significant embedment gaps should be repaired.

Lateral Restraint of Truss Members and Bracing of the Lateral Restraints

Although the track record for MPC Wood Trusses is good, some building failures have occurred. Failures usually occur when the roof is heavily loaded by snow or in high-wind events. Upon investigation of failures, the lack of proper installation of the lateral restraint and/or bracing is a common cause. The lateral restraint locations required for the top and bottom chords and for the webs (if any) are identified on the Truss Design Drawing.

Diagonal Bracing of the lateral restraints (if used) is also required and should be verified, but this bracing is NOT within the scope of the Truss Design Drawing nor is it the responsibility of the Truss Design Engineer. Diagonal Bracing locations

and connections should be provided in accordance with the intents reflected in the Building Component Safety Information (BCSI) guide, published jointly by the Truss Plate Institute (TPI) and the Structural Building Components Association (SBCA). The BCSI includes section B10 which is specific to trusses used in Post-Frame Construction. Your truss supplier should be able to provide this guideline (B10) to you.

Other means of restraint of web members may be used such as such as scabs, "T-bracing", or "L-bracing". See BCSI-B3 and BCSI-B10 for details.

There is often additional bracing that is specified on the building plan.

If you are a building owner of an existing or new Post-Frame Building, you should confirm that your trusses have lateral restraints at the locations specified (if any) on the Truss Design Drawing and that all lateral restraints are diagonally braced as shown on the building design drawings or at least to the diagonal braces shown in the BCSI guides B3 and/or B10.

Building Maintenance

The building owner should periodically inspect the building to identify and repair any issues that can weaken the MPC Wood Trusses. It may be worthwhile to hire an inspector or a Professional Engineer to do this task.

The most common problems are:

- broken/damaged truss members or connections
- poorly installed or missing truss bracing
- connections using Metal Connector Plates with excessive embedment gap

PERMANENT INDIVIDUAL TRUSS MEMBER RESTRAINT

Permanent Individual Truss Member Restraint (PITMR) shall be undertaken in accordance with **BCSI-B3** or the Building Designer's Permanent Building Stability Bracing (PBSB) plan, which must include all Bracing that is considered part of the lateral force resisting system for the entire Building. The PBSB is Bracing that transfers forces due to gravity, seismic, wind, and/or other external lateral forces, as well as collected forces caused by the restraint of members subject to buckling, into the shear walls, foundation or other lateral force resisting systems that are provided for the Building.

Some standard industry restraint and Bracing details are included in **BCSI-B3** and on the SBCA website at sbcindustry.com where several DXF/DWG details are provided to aid in tending to the wide variety of field situations that arise and to provide greater uniformity of detailing.

The locations for attaching Continuous Lateral Restraint (a type of PITMR) to individual compression members of a Truss are provided on the TDD. Bracing such as Diagonal Bracing is required for the Continuous Lateral Restraint (CLR) to prevent the simultaneous buckling of the series of Truss members to which the CLR is attached. Permanent Lateral Restraint and Diagonal Bracing are required for proper performance of individual Trusses within the roof or floor system. Permanent Lateral Restraint and Diagonal Bracing shall provide sufficient support at right angles to the plane of the Truss to hold every Truss member in the position assumed for it to properly carry the applied design loads. **If properly planned, the Temporary Installation Restraint/Bracing applied during Truss installation can be used as permanent Lateral Restraint and Diagonal Bracing, making the completion of the permanent Lateral Restraint and Diagonal Bracing more efficient.**

Finally as indicated in Section 2303.4.4 of the *2015 IBC*, the Registered Design Professional (RDP) (or where there is no RDP, the Building Designer [see Chapter 2 of *ANSI/TPI 1*]) is responsible for the proper transfer of design Loads and the Anchorage design of each Truss to the supporting structure. When the flow of Loads has been accounted for and all the Load resisting systems for the Building have been adequately designed, constructed and installed, the structural framing for the Building is complete.

FROM BCSI-B3, BCSI-06:

NOTICE **Proper installation of Trusses is extremely critical to the lifetime performance of the Building. Depending on the experience of the Contractor[1] it is strongly recommended that a meeting be held with the Building Designer[1] to ensure that all Permanent Building Stability Bracing (PBSB) is identified and will be properly installed and to review the provisions of:**

- the Construction Documents (i.e., architectural/structural plans and specifications)
- the Truss Submittal Package, which includes:
  - the Truss Design Drawings (TDD)
  - the Truss Placement Diagram(s) (if/when required by the Contract)
- this BCSI document and/or B-Series Summary Sheets (when provided)
- site-specific conditions
- any specific Truss member Permanent Bracing plans that are provided for the roof or floor structural system,
  - all special Permanent Bracing conditions such as unsheathed Top Chords, Long Span Scissors Trusses, Piggyback Truss Systems, and all 60' or greater clear span systems

⚠ **WARNING** **Disregarding Permanent Individual Truss Member Restraint and Permanent Building Stability Bracing recommendations is a major cause of Truss field performance problems and has been known to lead to collapsed roof and/or floor systems. Failure to install the proper restraint and Bracing will greatly increase the probability of Truss performance problems or an accident resulting in property damage, personal injury or death.**

Trusses, as with other types of structural framing components such as joists, beams, studs, etc. require lateral support in order to perform in the manner for which they are intended. Trusses are designed to carry Loads applied within their plane. Trusses are not designed to resist lateral (i.e., out-of-plane) Loads and rely on PBSB to transfer the lateral loads out of the Truss System into the supporting structure. Certain individual Truss members also require Lateral Restraint and Bracing to prevent buckling under the applied design Loads. Permanent Bracing provides sufficient support at right angles to the plane of the Truss to hold every Truss member in the position assumed for it in the design. Permanent Lateral Restraint and Bracing is needed for the proper performance of individual Trusses within the roof or floor system.

All the issues in this article can apply to an existing building, even if the cause was an error/defect in the original construction. Your building insurance may not cover a building collapse that is caused by a defect in construction or lack of building maintenance. Typical policies are for weather hazards, i.e.: extreme snow or remarkably high winds. You may need to check your insurance policy.

A good inspection of MPC Trusses should start with the Truss Design Drawing. In some locations you can obtain the Truss Design Drawing from the Building Department, if the drawings were submitted with the building plans. If you do not have a copy of the Truss Design Drawing, you may want to hire a Professional Engineer to "reverse engineer" the existing truss to identify any missing truss bracing and other issues.

Conclusion

The integrity of your Post-Frame Building requires that the MPC Wood Trusses are as strong as intended. This is important to support the heavy snow loads or high winds that can occasionally occur. MPC Wood Trusses perform very well, when properly engineered, built, installed, braced, and maintained. By verifying each step, you can maximize the useful life of your Post-Frame Building..

Bill Bolduc, the principal, is a registered Professional Engineer in 31 states and 5 provinces of Canada. He is a registered Structural Engineer in several states that recognize that specialty.

Bill has held senior engineering positions in several major companies including: Simpson Strong-Tie, Trus Joist MacMillan, and AC Houston Lumber.

Building Component Safety Information (BCSI) is produced by SBCA. BCSI is the truss industry's guide for jobsite safety and truss performance and includes the most current information regarding the handling, installation, restraining and bracing of metal plate connected wood trusses.

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