# STRUCTURAL BUILDING COMPONENTS MAGAZINE

August 2004


## Plating Truss Joints for Bending Force Transfer by Dave Brakeman, P.E., S. E. & Ryan J. Dexter

*Thanks to computer technology, more complex analysis of load transfer at joints—and more efficient truss designs—are possible.*

Do truss connector plates transfer bending forces from one member to another when a member at the joint has bending forces in it? The stiffness of the connection will determine how the joint performs. The terms "rigid" (i.e., fully rigid or fixed), "semi-rigid" (i.e., partially rigid) and "pinned" (i.e., hinged) are all used to indicate relative levels of rigidity, or bending stiffness, based upon the nature of the restraint.

If a joint is modeled as a pinned connection, no bending forces are transferred through the joint to another web member that is connected to that joint and all force transfers are axial; that is, they are in line with the direction of the member (Figure 1).

CLICK ON IMAGE FOR LARGER VIEW

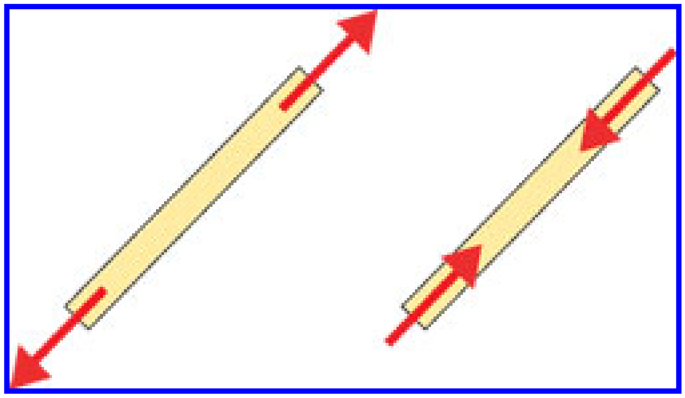

FIGURE 1. AXIAL FORCES ARE IN LINE WITH THE MEMBER

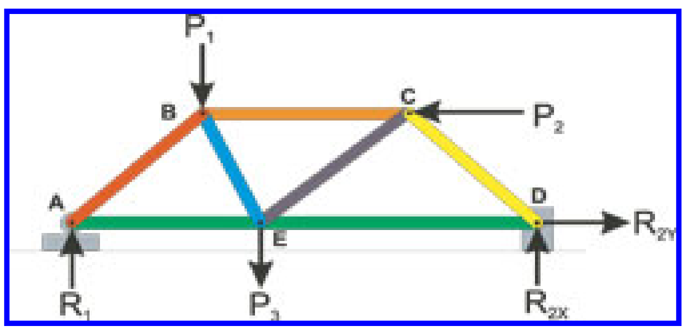


FIGURE 2. EXAMPLE TRUSSED STRUCTURE

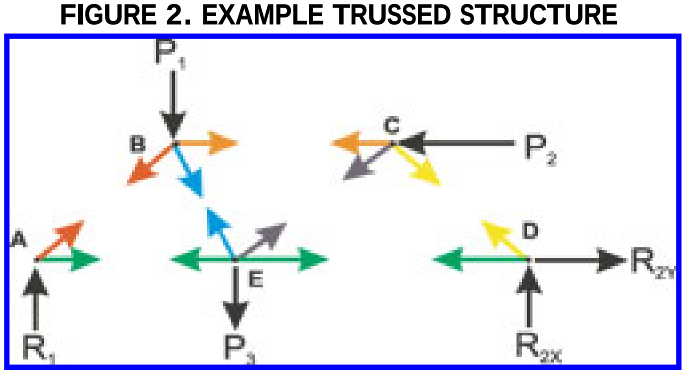


FIGURE 3. FORCE DIAGRAMS

The statement "physics in a vacuum" is used to describe a simplified theoretical situation that has very little practical application. In the case of trusses, beginning engineering students are taught that truss members are pin connected and all the forces are purely axial. The only forces assumed to be applied to a truss member are axial forces at each end of the member. Under these ideal conditions, members are not intended to see bending forces or torsion. This oversimplification makes the structural analysis of the truss simple enough to compute by hand.

In the early days of structural engineering, truss design was done using force diagrams and hand computation methods to determine the forces in each member. These methods assume that there are only axial forces in all truss members. For example, the trussed structure shown in Figure 2 contains five joints (A, B, C, D and E).

All of the joints would then be broken up into force diagrams as shown in Figure 3. Each connection would be designed for these idealized forces.

In reality (outside the vacuum), members do not exhibit purely pinned behavior and they do flex under load so there is a bending force in the member itself (Figure 4).

How to accurately model the true behavior of the joints in a metal plate connected wood truss is one issue that industry engineers and researchers have long debated. Is the joint hinged (pinned) or fixed (rigid)? A joint could be modeled as a pinned connection with no member bending force transferred at its ends. With this approach, the forces in the model members will not be identical to the forces actually seen in the real truss members (webs and chords). Some of the forces will be more and others less. The same holds true if the joints were all modeled as rigidly connected. In a real metal plate connected wood truss, the rigidity of the joints is somewhere in between the fully fixed and fully pinned joint modeling concepts (Figure 5).

Most joints, especially heels, do not act like pinned or rigid joints. In a semi-rigid connection, the joint is modeled as a spring that transfers some bending force due to this partial restraint. For example, a heel joint has some fixity and should not be modeled as pinned. It is necessary to create a transfer element member (i.e., spring) at the heel to model fixity of this joint (Figure 6).

Changing the way joints are modeled will affect the bending forces in the members adjacent to those joints and may result in higher or lower lumber stresses, which will determine both the size and the grade of lumber needed. As joint rigidity is increased, the bending force in the adjacent members will generally increase at the joint but decrease in the middle of the adjacent

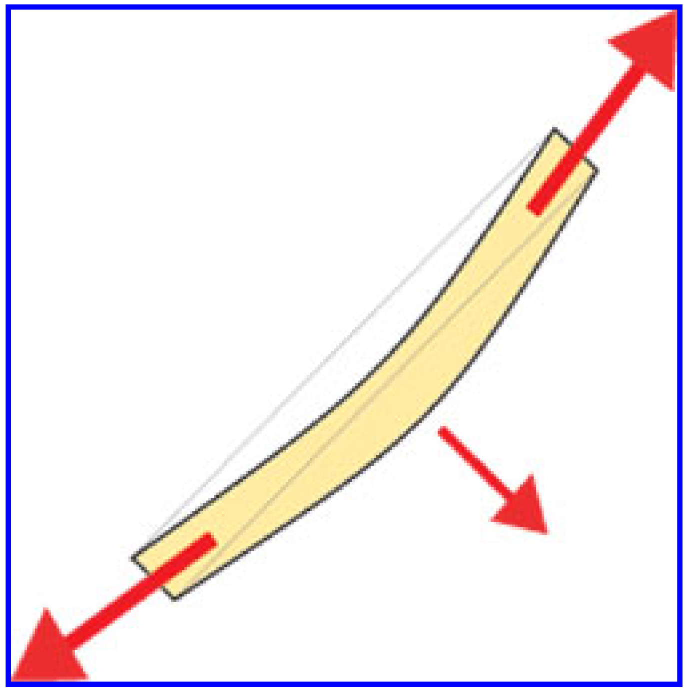

FIGURE 4. ROTATION OF A MEMBER DUE TO A BENDING FORCE

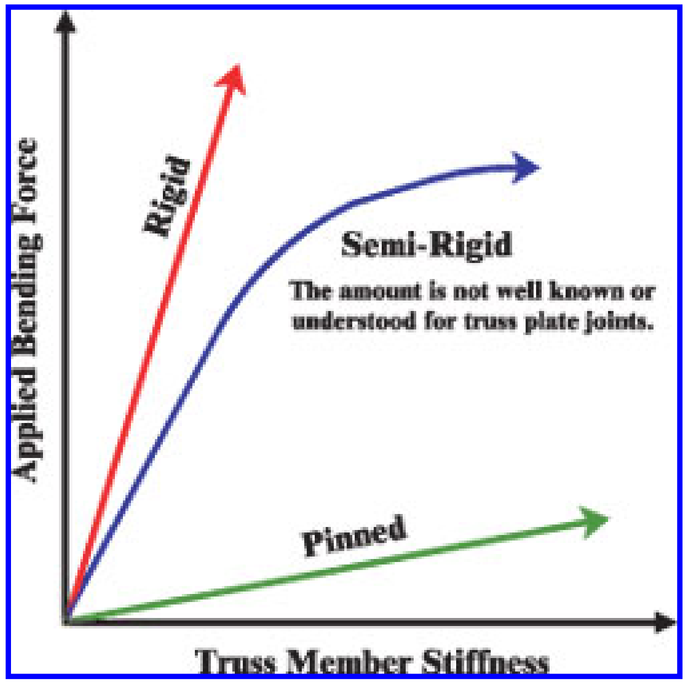


FIGURE 5. BEHAVIOR OF TRUSS MEMBERS WITH DIFFERENT JOINT FIXITY

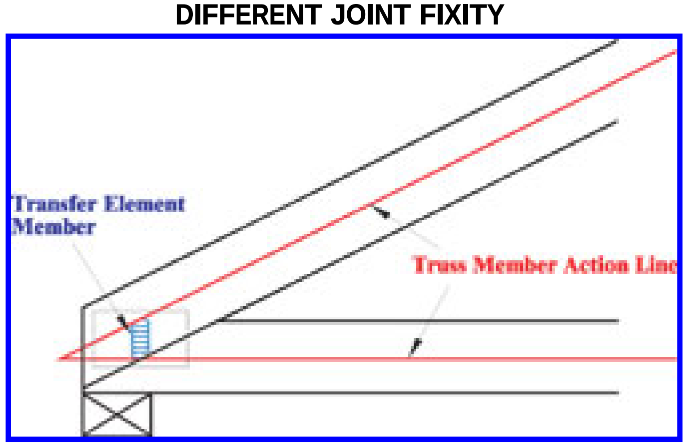


FIGURE 6. HEEL JOINT MODEL

panel. This affects both member design and plate design. For instance, if a splice joint is modeled as pinned, its location along the length of the chord does not affect the splice plate design. The same cannot be said if it is modeled as semi-rigid or rigid.

If the joint's rigidity depends upon the plate size, the member's lumber grade may change when the plate size changes. This is something that does not occur when joints are modeled as pinned. As joint rigidity increases, larger plates will generally be required because they will be designed for more bending moment. The opposite effects will occur as joint rigidity is decreased.

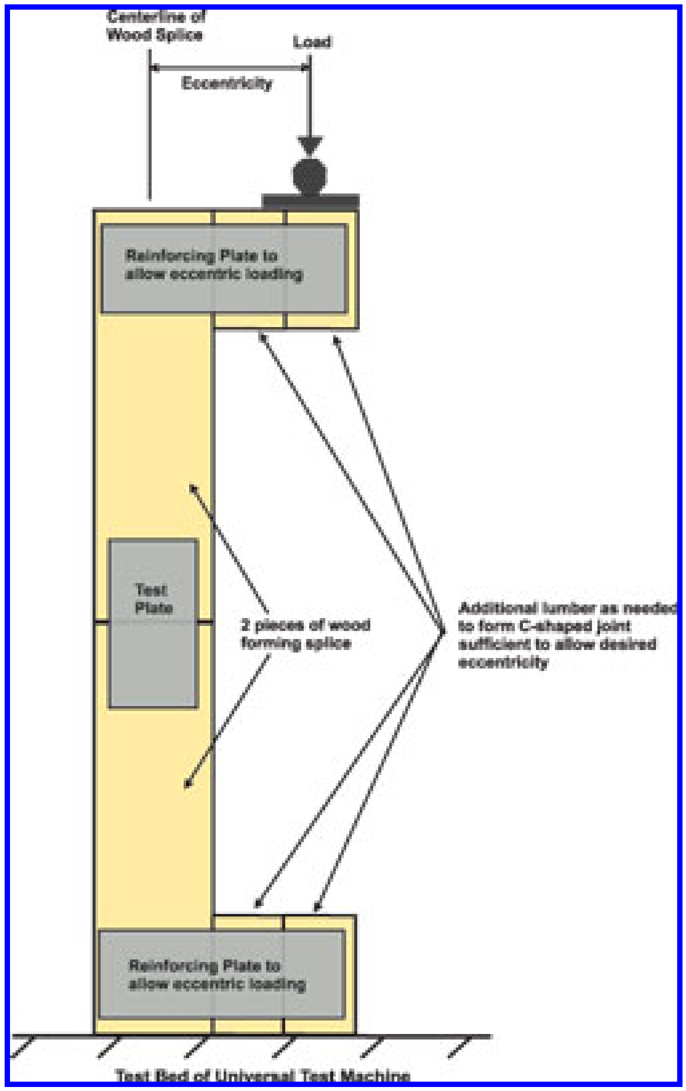


**FIGURE 7. TEST METHOD TO DETERMING BENDING STRENGTH AND STIFFNESS OF A PLATE JOINT**

Although we have known that most truss joint connections are not fully rigid or fully pinned, it was not until advancements in computer hardware that we have been able to even consider a different structural analysis approach, given the computing power needed to quickly perform a more accurate analysis. Actual joint behavior is semi-rigid, but the issue is complicated because it is also nonlinear (Figure 5). In other words, the amount of joint stiffness (the degree of semi-rigidity) changes with the load. The amount of nonlinearity is small at low loads (including loads up to design load levels) but at higher loads, the plates and/or lumber at joints can yield (flex or soften). This yielding can reduce the joint rigidity to nearly zero (i.e., pinned).

Prior to ANSI/TPI 1-2002, the standard did not include a design method to account for bending forces in connector plates. Previous standards have recommended modeling certain joints as pinned (web-to-chord joints and chord-to-chord joints at pitch changes) or using another modeling technique if considered more accurate. TPI 1-2002 removed the language that recommended modeling certain joints as pinned and simply retained the language specifying that the modeling that is used should be accurate.

As a side note, TPI 1-2002 also includes some increases to lumber design values. The 2002 edition includes a lumber specific gravity adjustment that should increase tooth holding strength in some designs (5.2.9.3). The 2002 edition has expanded the repetitive member provisions to include three possible increases for repetitive member assemblies (6.4.2). Stipulations on the use of the buckling stiffness factor have also been removed, which allows an increased modulus of elasticity (E value) to be used in some 4x2 trusses with longer panels (6.4.4). Finally, the 2002 edition permits the use of dry lumber design stresses for green lumber under special conditions (6.4.12). The increased cost from the larger plate sizes required to transfer bending forces should be offset by savings in the lumber from these adjustments. The amount of offset depends on what grades a manufacturer has in stock. In theory, truss spans should increase for a given grade of lumber.

The TPI 1 project committee included bending force calculations into both member and plate design because it was trying to promote more accurate modeling of the structural performance of joints. With each subsequent revision to TPI 1, refinements to the design methodology will bring the models closer to the true structural performance of the truss.

While it is now possible to model semi-rigid joints, most commercially available software still cannot model nonlinearity, so completely accurate joint models are not yet possible. Therefore, the goal is to most accurately model truss behavior at failure load levels without performing a very complex nonlinear analysis.

This has led to the creation of a TPI task group whose purpose is to study the bending force transfer issue of the plated joint, undertake testing and define with more accuracy how metal plate connected joints transfer combined axial and bending forces. An example of the testing is shown in Figure 7. Early test results indicate an increased moment capacity when the axial force on the joint is in compression as opposed to tension.

Our goal is to provide our industry with a better understanding of load transfer in metal plate connected joints. With this understanding, we will provide more accurate and efficient truss designs. Testing is scheduled to be complete near the end of the second quarter of 2004. TPI's Technical Advisory Committee (TPI TAC) will convene a meeting to review the results and recommendations. From there appropriate changes to ANSI/TPI 1 will be made. Once completed, we'll provide the results of this work and how it will provide the basis for creating more accurate and efficient truss designs.

---

SBC HOME PAGE