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MOMENT resistance

Why Bigger Plates Are a Good Thing

by Dave Brakeman, P.E., S.E. & Sean D. Shields

Consider for a moment the basics of manufacturing a truss. Based on SBCA's 2012 Financial Performance Survey, lumber accounts for roughly 40 percent of the total cost. Plates account for about eight percent of the total cost. Design and production labor account for 30 percent, and delivery, sales and overhead account for the remaining 22 percent (these are rough industry averages). All other things being equal, if you could decrease your lumber costs by a few percentage points while raising your plate costs a small amount, would you take the trade-off?

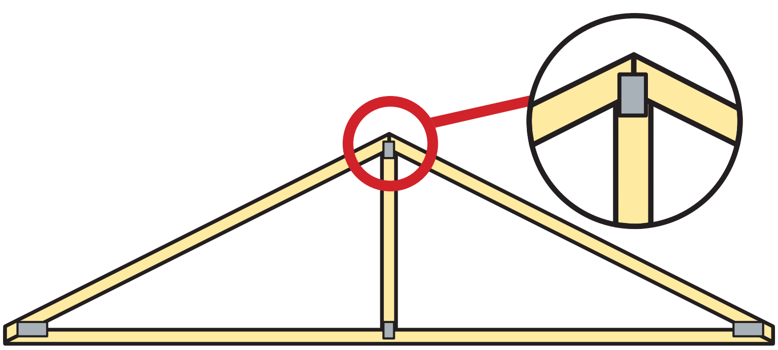

Figure 1. The peak joint of a kingpost truss.

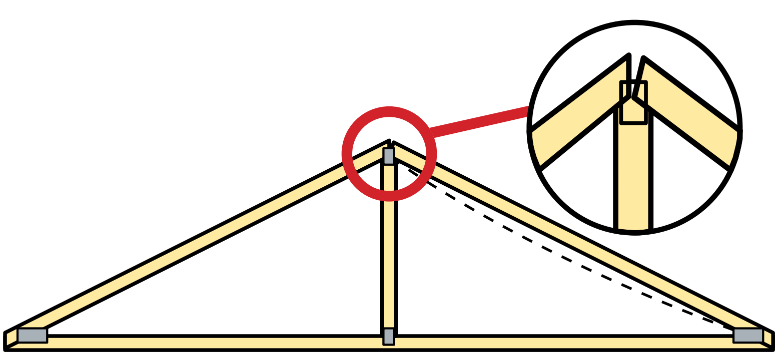

Figure 2. Bending moment forces as load is applied to the top chord of a kingpost truss.

This is exactly the question component manufacturers (CMs) and plate suppliers asked themselves in the late 1990s. The solution they found, to account for the bending moment resistance of metal connector plates (MCP), may or may not be well understood. Figuring in the MCP moment resistance allows for more even distribution of that stress throughout the wood member, typically resulting in a lower maximum CSI for that lumber member. The impact of this redistribution is significant to truss design in that it means that, in certain cases, a slightly larger MCP will allow a lower lumber grade to be used. This article will attempt, through simple terms and a few examples, to explain how and why.

Understanding Moment

What are bending moment forces? One of the easiest examples may be to look at a peak joint of a kingpost truss (see Figure 1).

As load is applied to the top chords of this truss, those chord members deflect and bend downward/inward. When the top chords deflect, the ends of the top of the chord members at the peak of the truss experience rotation, causing the lumber ends to move away from each other at the top of the peak joint, creating gaps in the joint (see Figure 2).

The top chords of that truss must be designed to resist this applied bending and rotational load. In this

Consider how factoring joint stiffness could save you money.

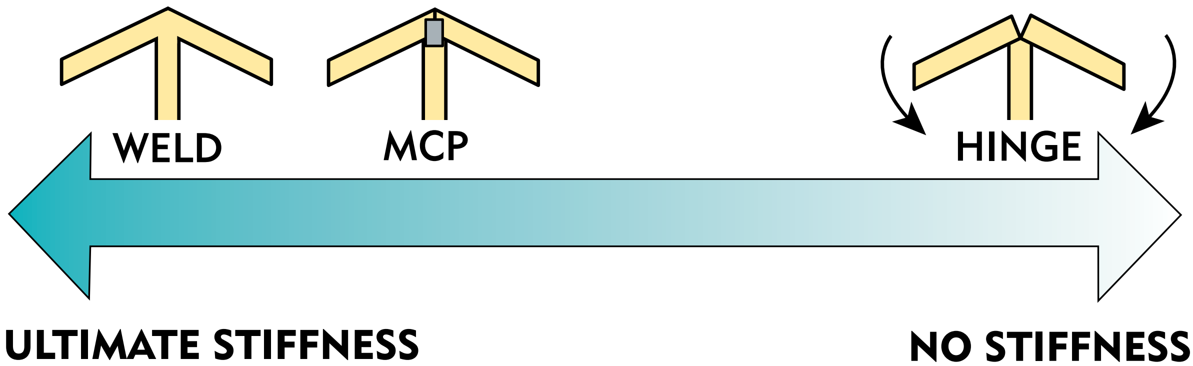

Figure 3. If stiffness were plotted on a spectrum, at one end there would be ultimate stiffness, and on the other, zero stiffness.

simple example of a kingpost truss, the span is a significant factor, as well as the strength of the lumber used in the top chords and the ability of the metal plate at the peak joint to resist these bending and rotational (bending moment) loads.

Let's take a small step back and look at the joint. Another way of thinking about the MCP's ability to resist the rotation of the end of the wood member is to talk about it in terms of stiffness. If stiffness were plotted on a spectrum, at one end there would be ultimate stiffness, and on the other, zero stiffness (see Figure 3). Ultimate stiffness could be achieved if there was some way to weld the ends of the top chord and kingpost members together, as if they grew that way.

At the other end of the spectrum would be something akin to the absence of stiffness, like a hinge. If all the ends of the chord and kingpost members were allowed to rotate freely, there would be little to no stiffness.

Obviously, a MCP provides stiffness or resistance to the bending moment rotation. It's also clear that the MCP is closer to the "weld" end of the spectrum versus the "hinge" end, but where exactly in this spectrum does it fall?

This is an important question because, instead of having to design a truss by relying entirely on the strength or stiffness of the wood used in the top chord, the MCP's stiffness can, and should, be accounted for in helping the lumber resist the rotational loads in the truss design.

Accounting for Moment

Prior to the publication of *ANSI/TPI 1-2002,* a MCP's ability to resist bending moment (rotation) forces was not typically factored into the design of a truss. While plate suppliers and CMs who conducted their own proprietary testing could factor in this resistance under *TPI 1* Section 1.3.2 (see sidebar below), which enables anyone to use their own test data to establish alternate designs as equivalent to the standard, this was not widespread.

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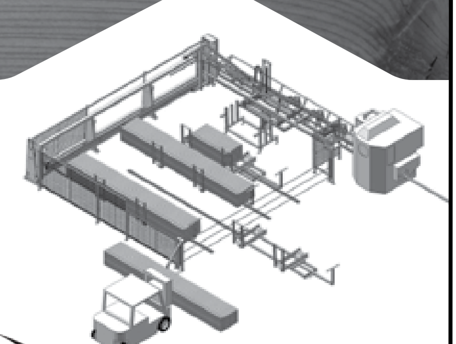
1.3.2 Alternate Provisions.

1.3.2.1 Materials, Assemblies, Structures, and Designs.

This Standard does not intend to preclude the use of materials, assemblies, structures, or designs not meeting the criteria herein, when they demonstrate equivalent performance for the intended use to those specified in this Standard. The use of such alternate provisions shall be indicated on the Truss Design Drawing.



Moment Resistance

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Recognizing that MCPs provide joint stiffness and resistance to rotation, testing of plates was undertaken in the late 1990s to determine their ability to resist moment forces. According to the *ANSI/TPI 1-2014 Commentary:*

> The results of the tested specimens were compared against three theoretical models used to predict the ultimate moment capacity of the steel-net sections.

Through that comparison, a formula was developed to account for a MCP's ability to resist moment forces. That formula was included for the first time in Section 8.7 of the *ANSI/TPI 1-2002* edition. Soon after this, plate manufacturers incorporated the formula into their truss design software. While this occurred over a decade ago, the practical application of the formula wasn't fully realized until years later.

In general, CMs didn't begin utilizing this equation until their local building codes referenced *ANSI/TPI 1-2002,* which began with the *2006 International Residential Code (IRC).* Further, the formula has gone through some revisions. Again, according to the *ANSI/TPI 1-2014 Commentary:*

> The equations in Section 8.7.1, originally included in the 2002 specification in a slightly different form, are developed from the most accurate model from this research as validated by testing. Subsequent use and further research showed the need for modification of this method to recognize the interaction between axial compression and moment stresses and to recognize the effect of plates located off center.

Application of the Formula

So what does this formula mean for CMs from a practical standpoint? Looking at the peak joint again, the stiffer that joint is, the more it is able to resist the rotation from the bending moment force. From a design perspective, the maximum critical force of the top chord member is then reduced because it is redistributed between the chord and the MCP. Figure 4 shows a graphical depiction of the force that the lumber has to resist when a MCP provides no stiffness.

Figure 5 shows a graphical depiction of the much smaller forces that the lumber has to resist when a MCP provides rotational stiffness.

In summary, because the moment force formula is now incorporated into the design software, from a design perspective, the lumber chord member no longer has to resist the applied load all by itself. By factoring in the MCP joint stiffness, the CSI of the top chord is reduced and a lower grade of lumber may be sufficient to resist the applied load. Let's look at two case studies to see the impact this has.

Case #1 Kingpost

Let's continue to look at a kingpost truss. If the moment force formula is ignored and the joint is treated as it theoretically and historically was, the truss joints would be designed using a hinge model (providing little to no rotational stiffness) and results in the truss design seen in Figure 6 on page 22.

Using a 4x4 plate at the peak, 2.5x6 plates at the heels, and a 2x4 plate at the D joint, the top chords would need to be constructed of 2x4 2700f – 2.2E MSR SP, the bottom chord would be 2x4 SPF #1, and the kingpost would be 2x4 SPF stud grade.

If the moment force formula was used, and MCP stiffness was factored into the design, the truss would be designed using partial fixity and would result in the truss design seen in Figure 7 on page 22.

If the plate sizes of the peak and heels were increased slightly, the top chord material needed to resist the applied loads could be reduced to 2x4 SPF 1650f – 1.5E, while the bottom chord and kingpost material would remain the same. This reduction in the grade of top chord material represents a significant cost savings to a CM. Let's look at another example.

Case #2 Modified Queen

Here's a fully triangulated queen truss. Again, if the moment force formula is ignored and the joint is treated as a hinge, the truss design would result in the truss design seen in Figure 8 on page 22.

Using a 5x5 plate at the peak, the T2 and T3 segments of the top chord would be constructed of 2x4 SPF 2100f – 1.8E, while the remaining top chord and bottom chord material would use 2x4 SPF 1650f – 1.5E, and the webs would be 2x4 SPF stud.

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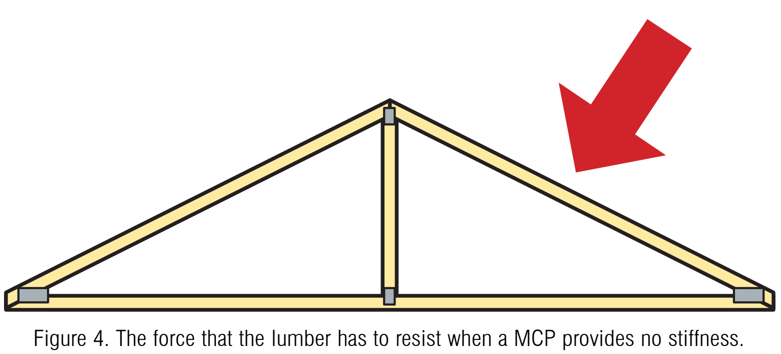

Figure 4. The force that the lumber has to resist when a MCP provides no stiffness.

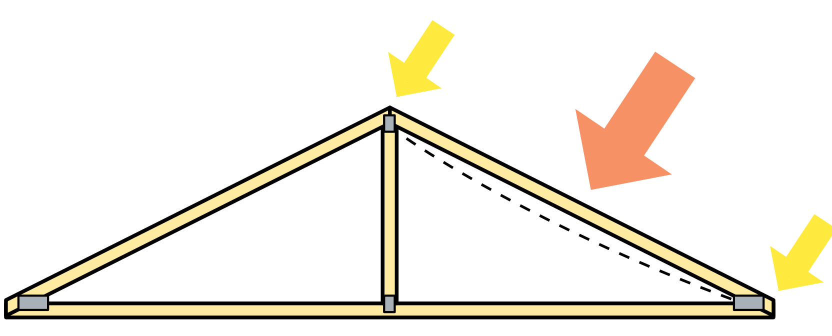

Figure 5. The much smaller forces that the lumber has to resist when a MCP provides rotational stiffness.

Moment Resistance

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If the moment force formula was used, and MCP stiffness was factored into the design, the truss could be designed as seen in Figure 9.

If the plate size of the peak was increased to 5x6, the T2 and T3 segments of the top chord could be constructed of 2x4 SPF #1/#2, while the remaining top chord and bottom chord material would still use 2x4 SPF 1650f – 1.5E, and the webs would be 2x4 SPF stud. Again, this reduction in the grade of T2 and T3 top chord material represents a real cost savings to a CM.

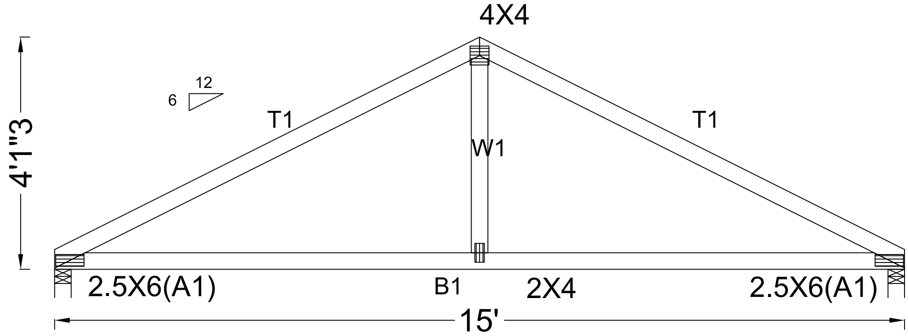

Figure 6. King post truss with joints designed using a hinge model.

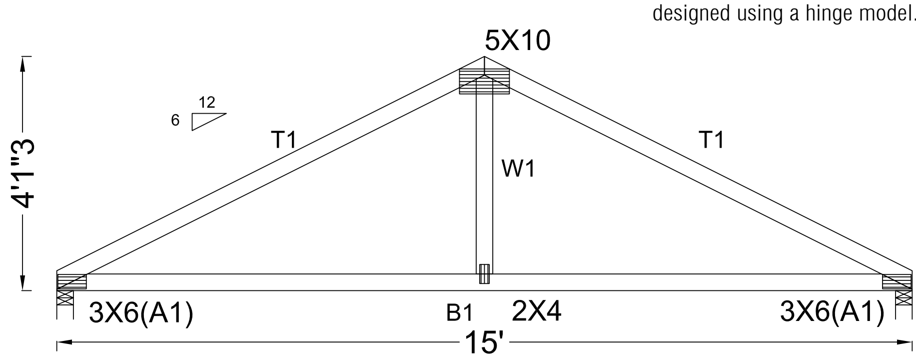

Figure 7. King post truss with joints designed using a partial fixity model.

Overall Material Savings

It's important to note the moment resistance formula is active and running behind the scenes in the design software (assuming your local code references *ANSI/TPI 1-2002* or later). The software automatically takes advantage of the stiffness the MCP provides. The result is that, in some cases, the software will specify larger plate sizes than it would have traditionally. This is a good thing, not because the plate sizes are bigger, but because the MCP now, in most cases, helps to lower the lumber and overall truss CSI by redistributing the maximum stress throughout the lumber members.

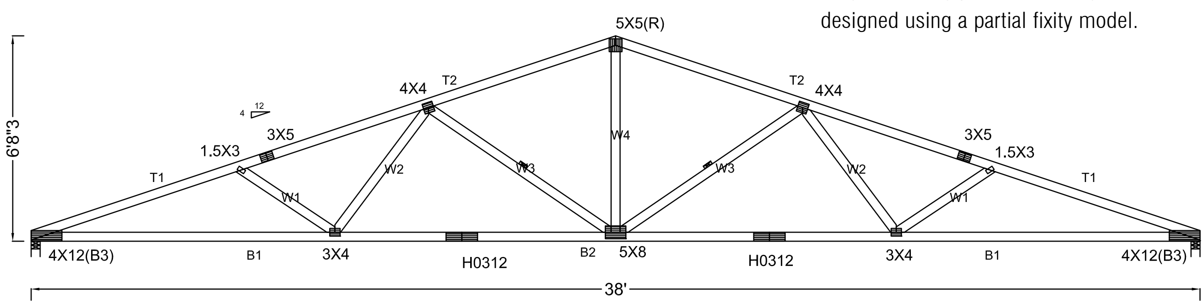

Figure 8. Modified queen truss with joints designed using a hinge model.

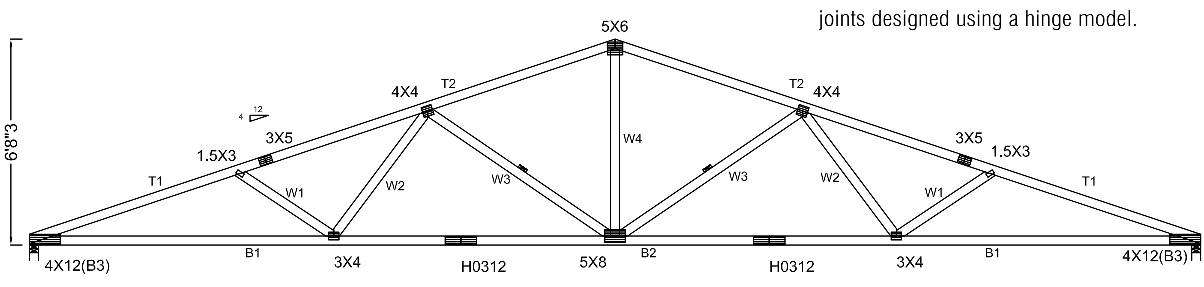

Figure 9. Modified queen truss with joints designed using a partial fixity model.

Again, this redistribution should allow for a lower grade of lumber to be used in a given application. As mentioned at the beginning of this article, with lumber representing roughly 40 percent of the cost of a truss, saving money on lumber will have the biggest impact on the total cost of producing that truss. In some cases, factoring in the stiffness of the MCP can also allow designers to eliminate some low force webs. Alternately, increasing plate sizes does increase the price, but at only eight percent of the total cost, that cost impact is not as significant.

Will it provide a benefit in every case? No. In some cases, like valley sets or other short span trusses, the increased plate size now specified by the software will reduce the necessary lumber grade of wood members to a grade lower than the lowest grade of lumber carried by a CM. As a result, even though there is a design benefit, the CM may not be able to take advantage of a lower grade because they don't keep it in stock. Taken as a whole, CMs benefit from taking advantage of the moment resistance formula through overall material cost savings. **SBC**

Dave Brakeman is the Engineering Director for Alpine, an ITW Company. He has served as chairman of the TPI 1 project committee for the last three editions of this standard.