The ESG Report
SUMMER 2010

TRUSS PART II

***Editors Note**: If you're like me, you might have forgotten the topic of our previous ESG Reports and could therefore find yourselves lost reading this one! I thought a brief recap would be helpful…Our fall 2009 issue on Design Factor Stress had a bonus article on the last page entitled* A Different Sort of Wrap-Up? *That article introduced the discussion about supporting aluminum truss spans using polyester roundslings. Then in the spring 2010 article* What Is A Truss? *we explained some basic concepts of truss behavior. In this issue we're going a step further to compare a frame and truss – and bring back the discussion of using roundslings. Will this article answer the mystery of truss vs. frame? No. Will it encourage you to think when designing using one or the other? We hope so.*

In our spring 2010 ESG Report we introduced you to some basic truss concepts. We made a distinction between how the panel shape or node location is important to defining the assembly as either a truss or a frame. We showed you some examples of truss component members, along with a brief description of how forces behave in a pure truss configuration.

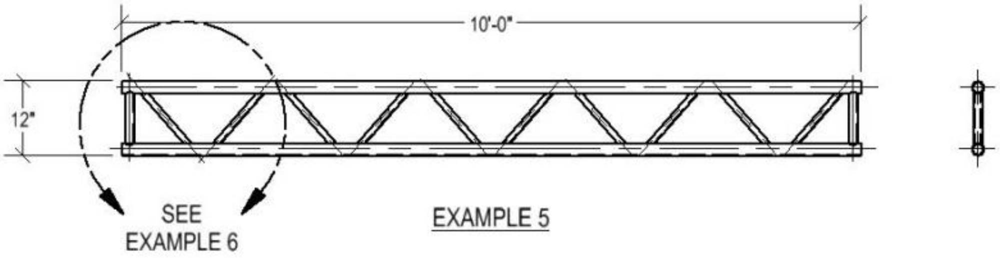
In this edition we are continuing the discussion about why frames behave differently than trusses. For clarity we'll assume that comparisons between the two consider these parameters: member size and wall thickness, material, and the span-to-depth ratio of each assembly to be essentially equal. All of those things being equal, frames are not equivalent to trusses and there is always a tradeoff in capacity, maximum span, or in the design factor used to determine either. This design factor (factor of safety) is built in to help provide reserve strength in the assembly for the allowable stresses mandated by design code requirements.

FRAMES & NODES

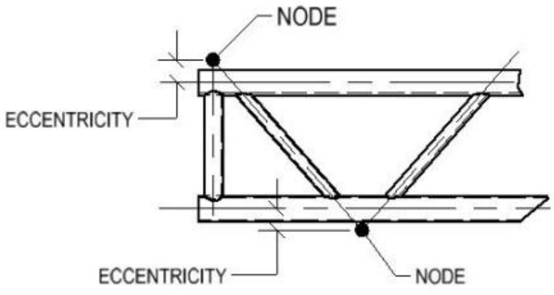
Previously, we said that a frame was basically a truss in which the panels weren't triangular or where the panel shapes did *not* connect at shared node points. Example 5 shows a frame: non-triangular panels and theoretical node points offset from the chord centerline.

Shown more clearly in Example 6, this offset is called a node eccentricity – sometimes referred to as misnoding. Misnoding causes a less efficient load path from member to member because the panel shape consists of more or longer load paths. More important, instead of being able to transfer forces directly through a single node point of intersection, the load path now includes additional short members where the forces are no longer pure compression or tension. These short segments represent small moment arms in the load path, causing bending moments in the truss, which result in a more complex combination of increased stresses through the members. Because these combined stresses must be analyzed on a more localized level, one might equate them to theoretical weak points, which don't occur in a pure truss assembly.

Example 7 shows a schematic illustration of this occurring at a single load point applied to the top chord of a frame panel. It shows an exaggerated deflection only where the load is applied, but in reality the deformation (or its effects) occurs in all of the node's participant members. Frames have a few practical advantages: Inherently, they are not as stiff as a truss and will flex more under load. Less stiffness is not necessarily bad – for a variety of reasons some frames need to flex more.



EXAMPLE 5



EXAMPLE 6

A vehicle frame is an example of how some amount of built-in flex is beneficial: Imagine the ride if the frame was too stiff! Because the diagonal members are spaced farther apart in a frame, the panel openings are larger and provide more clearance for things like mechanical system routing, etc.

However, in order to maintain comparable capacities, frame members must generally be heavier than those of their truss counterparts, but the heavier members also make for a heavier assembly. From this aspect, trusses are generally lighter and therefore more efficient in terms of strength-to-weight ratio. As a result, trusses also tend to have a lower raw material cost, but the reduced material cost may be offset if the truss isn't efficient to fabricate.

Look at Example 2 in our previous ESG Report and see how the diagonal meets the end vertical member to form a true, triangular truss panel. Notice that the diagonal requires a double miter on one end to achieve this connection. That's easy, but it's also an extra step in the fabrication process. Furthermore, the resulting joint connection probably requires a two-pass weld process instead of a single pass, which may be impractical for consistent quality assurance of the welded connection. To remedy this, the diagonal can be shifted away from the vertical member, but that impacts all of the other diagonal locations and their associated nodes. Logically, a possible solution is to reduce the number of diagonals and space them out a little farther apart. In fact, this is a way to reduce weight, material cost and labor – but you should also see that the truss then becomes a frame, with the associated caveats.

PRACTICAL DIFFERENCES

So far we've demonstrated how trusses can be lighter, generally less expensive to fabricate, and stiffer than an equivalent frame, but let's look at some truss caveats. When members fail in trusses, it's usually catastrophic because the load path changes to compensate, sharing the load through other members. Unless there is redundancy built into the design, the other members quickly become overstressed, and a domino effect occurs. By contrast, frames tend to be more forgiving, largely because of the increased member size, so the adjacent members often sufficiently compensate for the redirected load path (in effect, it is a form of built-in redundancy).

This comparison is helpful to illustrate why some trusses technically aren't "trusses" and why sometimes it doesn't matter if it's a truss or a frame. What does matter? Understanding the basic concepts of why they behave as they do. So far we've only really examined very basic behavior of 2D or planar assemblies under theoretically simple vertical loads. However, in the real world trusses are subjected to many different forces, some of which occur as a matter of intended design, others as a result of normal truss behavior in reaction to the applied forces. The effects of combined stresses in a frame exemplify this concept.

SPACE FRAMES

3-Dimensional box trusses used in the entertainment industry work in much the same way as their 2-Dimensional counterparts. Structurally, this is a space frame – a combination of trusses and frames – that solves a couple of problems. First, it significantly increases capacity by more than doubling the material used; the assembly is really two planar truss (or frame) assemblies connected together with horizontal lateral brace tube members at regular intervals along

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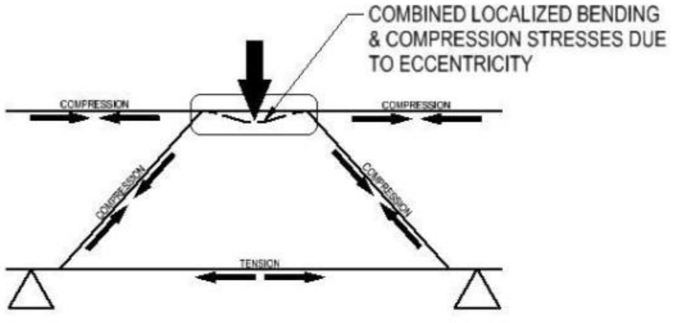

EXAMPLE 7

the truss chord length. The two opposing horizontal plane assemblies are frames, which provide resistance to lateral forces, which also counteracts the planar truss tendency to rollover under load. However, the horizontal tubes also connect at their own nodes, which might be at the same nodes as the vertical truss nodes, but may also create additional nodes – adding complexity to the load path.

The capacity of any given truss span is directly related to its depth. In essence, a 20.5" tall truss is stronger than a 12" tall truss and can span a larger distance. Longer spans mean higher span-to-depth ratio, which translates into greater deflection in the span. Look back at our article (Example 4) in the spring 2010 issue and remember the concepts of tension and compression in the truss chords. As the top chord compression increases, so does the natural tendency for the compression member to buckle and roll over or twist as a natural reaction to the top chord compression. This compressive buckling tendency is a critical consideration in maximizing all of the related factors that make a truss lightweight, strong, efficient and cost-effective to build.

We want to convey that truss behavior (2D or 3D) is almost always the combined result of interacting forces: tension, compression, bending, torsion and deflection. Each of these forces must be considered to determine which one governs the most likely failure mode. A truss is practicably limited by its span-to-depth ratio relative to its chord and diagonal member sizes. Trusses will eventually fail as the span-to-depth ratio increases, because the allowable chord forces are exceeded either in pure compression or because the combined lateral-torsional forces causes buckling as the truss tends to rollover under load.

In a space frame, if the load is shifted more towards one chord or the other you can see how this causes a tendency for rollover. This should illustrate how the vertical load component shifts towards the horizontal component, which means that the load – once theoretically only supported by the diagonally laced vertical truss – is now being directed into less efficient, non-triangular panels. We want to prevent this as much as possible, so not only is the load attachment location important, but so is the location of the supports. This is why the best place to attach a load is at a panel point.

SUSPENSION

The most common method of truss suspension in the entertainment industry is the flexible polyester roundsling (discussed in our fall 2009 issue). The pros and cons of using a roundsling for load suspension are so numerous that we won't even bother to address them all. The lingering question is "How should I hang my truss from them?" The answer is as much related to load stability as it is to force distribution, but these factors are also impacted by the practicality of overhead clearances to the existing structure as well as aesthetics.

Engineering principles do apply, but there are no engineering secrets. Wrap the truss chord at a panel point so the forces are more efficiently transferred through the truss members. Choke the bottom chord and wrap the top chord so the load will be more efficiently shared between the chords. Yes, depending upon whether the panel point is at the top chord or the bottom chord, one of those wraps causes a slight change in force distribution into the chord between panel points. Pay attention to bridle angles and make sure your slings are long enough to accommodate. Yes, you can only choke the top or bottom pair of chords, but using only the bottom chords contributes to rollover unless your loads are balanced between the two bottom chords. If overhead clearance is an issue, consider using a rigid truss lifting point.

The real intent behind this set of articles is to help you understand basic truss behavior a little better, because then you'll understand what's right or wrong about your roundsling connections. Roundslings are flexible in more ways than one, which is precisely why we use them so ubiquitously. There is no single right answer. Ask your truss manufacturer and follow their recommendations. Attend an ETCP-accredited training course. Better yet – get certified. Use common sense to apply what you learn. If you don't know, ask someone. Above all, be safe.

Disclaimer: This article is not intended to be a thorough treatment of the topic of structural evaluation. Local, state and national building codes should be consulted. The author cannot be responsible for any evaluation based solely upon this article.