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## Abstract

The design of timber joinery is as much art as science. This Technical Bulletin will cover the fundamentals of engineering timber joinery.


## Introduction

A timber frame structure can be defined as an assembly of joints separated by timber beams and posts. The design of timber joinery is certainly the most challenging part of engineering a timber frame.

There is a long tradition associated with the development of timber joinery by trial and error that spans centuries. However, timber joinery has only relatively recently been subject to engineering scrutiny and the design process is not prescribed in codes or standards. When time-proven traditional joinery details are utilized, their performance is somewhat predictable and reliable. However, it is not always practical to utilize traditional joinery details. Architectural design trends towards more exciting timber structures have put greater demands on the joinery.

While timber joints were once cut predominately with hand tools, the proliferation of robust power tools and automated CNC timber fabrication has made more complex "new age" joinery details possible and affordable. These "new age" joinery details have not had the benefit of centuries of trial and error and must be designed based solely on engineering principals with zero tolerance for failure.

It has become commonplace to engineer timber joints that rely on concealed steel hardware or proprietary fasteners to transfer structural forces. But that is not the subject of this Technical Bulletin. The topic at hand is the engineering of true timber joinery without the aid of hardware.

There are a few simple rules to keep in mind.


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## Rule #1

***The geometry of the joint should have mating surfaces that allow all structural loads to be transferred in bearing of one member against the other***. Pegs are best used to hold a joint together rather than to resist load. Let the geometry of the joint do the work, not the pegs.

Figure 1 - Truss Heel Joint

The truss heel joint shown in Figure 1 illustrates Rule #1. The compression force in the top chord is transferred to the bottom chord in bearing on the notch, counteracting the tension in the bottom chord. The pegs are not resisting load but have been draw bored to keep the joint tight as the timbers shrink. The net tension area of the bottom chord has only been reduced slightly (see Rule #2). The geometry of the notch will tend to cause the top chord to split when the timbers dry and shrink (see Rule #3).

## Rule #2

***The wood removed to create the joint should not unduly weaken either member***. The timber section of both members connected at a joint must be reduced in some fashion to create the joint. The challenge is to strategically remove wood only from the portion of each member that is not highly stressed. For instance, if a joint occurs at a point of maximum moment in a beam, remove wood near the neutral axis rather than from the extreme fibers.

Figure 2 - Failed Butt-Cog Joint

The failed butt-cog joint shown in Figure 2 violates Rule #2. The joists have been deeply notched at the point of maximum shear resulting in a shear failure and the supporting beam has been notched at the extreme fibers in bending.

A tusk tenon joint would have been a much better choice for this situation.

### Rule #3

***The geometry of the joint should not be altered by shrinkage of the wood and bearing surfaces should remain in tight contact.*** This is the rule that is most often forgotten.

Figure 3 - Knee Brace Joint

The knee brace joint shown in Figure 3 was tight prior to the timbers drying and shrinking. The joint is open and the bearing surfaces are no longer in contact. The mortise should have been cut deeper than the length of the tenon in anticipation of the mortised timber shrinking. The pegs could have been draw bored to prestress the joint and keep it tight.

### Rule #4

***Anticipate all potential modes of failure and provide sufficient strength to resist each potential failure mode***. This is a rule that naturally applies to any structure not just timber joinery.

For example, potential failure modes to consider for the heel joint shown in Figure 1 include:

1. horizontal shear of the relish on the bottom chord
2. crushing at the bearing surfaces
3. tension fracture of the bottom chord at the notch.

The challenge here is that you must think of everything. Failure to anticipate a potential failure mode can have dire consequences.

## Conclusion

The engineering of timber joinery is not a cookbook process of following overly prescriptive codes and standards. It requires considerably more ingenuity, creative energy and experience than the design of a typical steel connection. But if you faithfully follow the fundamental rules described in this technical bulletin, you too can master the art of joinery design.