Timber Design Guide 2020-20

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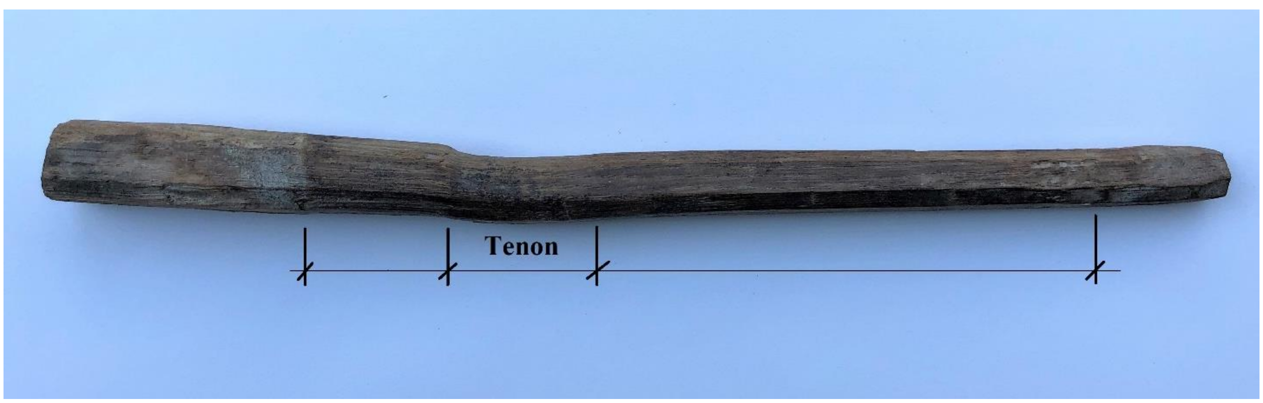
Title:	Draw Boring of Pegged Joints		

Background & History

Drawboring is a centuries old practice, essential to timber framing and traditional woodworking as well. Also referred to as "pull boring" or "draw pinning", it is the intentional off-set of the peg holes in mortise and tenon joints. By driving a tapered peg through the off-set holes, the joint can be brought tight together, and kept tight both during the raising and subsequent drying and shrinkage of the members. It was the standard technique for pinning joints at least as far back as the settling of this country. While English experts have noted evidence of its use by the 13th century, it is likely as old as the craft itself. During the 1970s revival of the craft here, draw boring was one of those aspects not universally resurrected along with other aspects of timber framing. There are many framers and engineers operating today not aware of the advantages of draw boring over simply boring a peg hole straight through an assembled joint. However, it will be seen that draw boring is not only better structurally and essential to a properly crafted frame, but it is a less time consuming and thereby less costly method of working.



This ¾" diameter oak peg from a 1426 barn in the UK, shows the evidence of draw boring to pull joints tightly together. Note the deformity at the tenon. The lighter section at left was protruding from the face.

How was drawboring accomplished traditionally? If you look closely at older, scribed frames here, the evidence points to the peg holes being pre-bored through the mortised member only. Their exact location was typically only “eyeballed”. When each joint was pre-assembled as part of the overall scribing process, it was brought as tight as practical “to a bearing”. The hole in the mortise was traced upon the tenon with a scratch awl, gouge, or an auger bit (a shell auger before about 1790) was inserted and rotated to mark the location. Then the joints would be withdrawn enough to see the mark on the tenon. The boring of the hole through the tenon would then be accomplished in one of two ways: Boring the hole straight through but a little closer to the shoulder, or starting the auger where marked but angling the boring towards the shoulder to get the drawbore. Angled boring provided an inclined plane for the pin to pull the joint together. If it wasn’t practical to get the joint completely together in order to mark it, the carpenter would simply add the amount of gap to the amount of drawbore.

Draw Boring Scribed Joints

In this 1801 Eastern white pine scribed Dutch barn frame, the peg holes location was pricked on the tenon. The huge offset was due to the joint not being brought to a bearing. The amount of gap was added to the drawbore.

In the square rule frames of post 1800, the drawboring was accomplished in a different way. As there is no trial fitting in square rule, the pin holes are laid out separately on both the mortise and tenon using a pattern all framers had in their tool box: the framing square. On the mortised member, the centers of the holes were usually either 1½” or 2” off the face of the mortise, corresponding to the tongue or blade of the square and typically the same distance from each end of the mortise. Or if there was a second row of holes, another 1½” or 2” increment. A line was scratched along the square for the centerline of each hole. For the location of the hole along the line, a Vee mark was applied using the graduations on the square. All layout and boring was done with the face side (upper face, fair face, best face, layout face) up! Since most mortises are closest to this face, the magnitude of any deviation from not quite perpendicular boring is minimized. The screw tip of the auger bit (Scotch pattern augers came in about 1790) was placed exactly on the Vee marks and the hole bored as perpendicular as practical, right through.

Square Rule Mortise Peg Layout

At left the layout for two peg holes on a mortise that was never cut (a mistake). If one looks closely, the line for the housing (near right edge) and the parallel line for the peg holes at the point of the Vee's can be seen.

On the tenon, the square was similarly applied creating a centerline parallel with the shoulder, and each peg's location marked with a Vee. The auger bit tip was not placed exactly on the Vee but a little closer to the shoulder, typically about one eighth of inch. On long through tenons or with three and four-inch thick tenons using 1¼ or 1½ diameter pins, the offset could be as much as 3/8"! On diagonal members like braces, the offset was along the axis of the brace to both draw it tight to the shoulder but also to the bearing end of the mortise. Likewise, where rafters are joined at the peak by a mortise and tenon, the offset is in two directions to bring the rafters together and down. On English tying joints with a gunstock or jowled post, the top tenon that secures the tie beam (teazle tenon) is also offset in two directions, down to the shoulder but also horizontally to anticipate the post's shrinkage and help prevent the post splitting. On exceptionally deep members such as Dutch barn anchor-beams where there is greater width shrinkage, holes are offset additionally towards the bottom, weight bearing side of the tenon. From the study of old work, it can clearly be seen that there is a science to the draw boring of pegged joints.

Square Rule Tenon Peg Layout

This early 19th century 10x12 tie beam end has a 2-1/2" thick tenon, 2" off the face with three 1-1/2" diameter peg holes. The 2" and 4" spacing of the holes off the shoulder is clearly seen. The offset here measures 5/32".

A tenon’s length is important to drawboring. A good rule of thumb is that in order to be pinned, a tenon’s length should be at least twice its thickness. So, a 2” thick tenon should be four inches long. These minimum tenons are pinned to hold the joint tight but are not designed for tensile loading. Those that will experience tensile loads are often much longer and typically through tenons. Though often pinned, most joints in an old frame are either in compression or under no load. In a typical dropped tie beam 30’ x 40’ English barn frame, there are only eight joints out of hundreds that could be loaded in tension. These tying joints are typically through tenons and may additionally be wedged dovetail versions for greater tensile capacity.

Square Rule Tenon Layout and Offset

On the left is a Red Spruce 3”x 4” brace tenon, about 1855, showing a one-inch peg hole 1-1/2” off the shoulder and 1-1/2” from the bearing nose on the 3” long tenon. The hole is offset diagonally along the axis of the brace about 1/8”.

On the right is the peak end of a Sugar Maple 3” x 4” rafter that joins to a continuous ridge beam. The 1-1/2” thick tenon is framed 1” off the face and is 3” long. The ¾” diameter peg hole is offset an incredible ¼” towards the shoulder. The hole is bored closer to the left edge to avoid holes in the ridge from opposing rafters intersecting. Note that despite the short tenons and huge offset on the one, neither one exhibits relish failure. Both joints are only loaded in compression.

Old Riven Pins

Note the variety of profiles. From the top:

1-1/2” diameter, 14” long Black Ash

1-1/8” dia. x 13” long White Oak

1” dia. x 9-1/2” long Red Oak

1” dia. x 8” long Chestnut

1” dia. x 7” long White Ash

7/8” dia. x 7” long Sugar Maple

The Pegs

A critical part of drawboring is the peg (Historically referred to as pins, tree nails, or trunnels). Traditionally pegs were riven (split) from green, straight grained, clear hardwood using a frow (also spelled froe). The riving process alone tends to favor using only structurally perfect material, free of knots, cross grain, wane, shake, decay, and all the other defects that tend to weaken wood. The preferred species for pegs are Northern Red Oak, White Ash, and Hickory. For unheated outbuildings and areas prone to damp, rot resistant species like White Oak, Black Locust, and Black Cherry are preferred. The billets are cut from clear, lower trunk sections above the butt flair. Non-leaning trees are preferred as they will be free of tension wood that makes the cleaving difficult.

Riving White Ash billets with a Frow

Billets should be cut squarely, about 4 inches longer than the largest timber they will go through. So, a frame with predominantly 8x8s, you will need 12" pegs. They are riven to a square section, slightly less that the diameter of the peg holes bored. For a one-inch diameter peg hole, the square riven blank should measure about 15/16" square. The end that was up during the riving will become the head of the finished peg. This square blank will then have the four edges shaved off with a drawknife or chisel to create an octagon. If properly sized, only the points of the octagon will engage the sides of the peg hole. Allowing a little daylight between the flats of the octagon and the hole eliminates binding. All eight faces of the peg will then be tapered for the last 1/3-1/2 the length to a blunt point about ¼" or 3/8". This taper ideally is a convex curved one like an elongated bullet or rocket nose cone. Judging by the lack of mushrooming found on the heads of old pegs, it seems they were allowed to season a bit before use. Too dry is also problematic. Store them in an unheated outbuilding at about 15% moisture content for the best results.

New Hand-Riven Octagonal Pegs of Ash, Cherry, and Sugar Maple

These riven pegs have absolute parallel grain and are drawn out to a long tapered point.

Hand-riven pegs will vary a bit in thickness, taper, and pointedness. It is the duty of the assembler during the raising to first look through the peg hole of the assembled joint and ascertain the amount of drawbore. If the drawbore is slightly more than desired, a thinner, more pointed peg is chosen. If it is less offset, a peg that is slightly thicker with less point is called for. The peg is carefully inserted and made sure that the point is slipped through the tenon and started in the far side of the mortise before driving. A misaligned peg will make its own hole through softer woods with unsightly results. As the peg is driven and the joint is pulled tight together, the resistance will increase. Driving a tapered peg creates incredible leverage so it isn't necessary to swing hard with the mallet. Stop driving when there is resistance, do not overdrive the pegs just to be flush. They can be cut off flush if necessary. A three-pound, rawhide faced, cast iron headed mallet (Garland Co.) is great for driving pegs.   Properly done, drawboring not only draws the joints tight on raising day, but keeps them tight during the racking from erection, and the effects of shrinkage from seasoning that follows. The slight bend they take on acts as sort of a spring to keep the joint tight.

Deformation of pins in old structures relates more to subsidence and distortion of the frame than to the drawbore. Because they are riven from absolutely straight, clear material, they can bend without breaking. In fact, it is rare to find broken pegs in old buildings unless decay or powder post beetles have gotten into them. Joints overloaded in tension are more likely to blow out the face of the mortise than break a riven peg.

Old Lathe Turned Pegs

Turned pegs are often found in the latter half of the 19th century onwards especially when there is a water powered (turbine) sawmill with an associated woodworking business.

On the left is a 1" dia. x 8" long Sugar Maple peg with a gradual point (blackened from soot). On the right, a 1" dia. x 7" long blunt pointed White Ash peg. Neither has any measurable taper along its length.

While riven pegs, crafted in the traditional fashion, are still commonly used in traditional frames and in the restoration of antique frames, it is more common to use turned hardwood pegs in modern timber frames. The use of manufactured pegs does not preclude the practice of drawboring. Manufactured pegs are turned from seasoned hardwood, usually Red or White Oak, and should comply with ***ASTM D8023-17 Standard Specification for Round Wood Dowels (Pegs) for Use in Wood Construction***. When drawboring, it is crucial that the turned pegs have a gradual tapered end and be long enough that the tapered portion extends beyond the face of the timber in the finished joint.

Manufactured Pegs

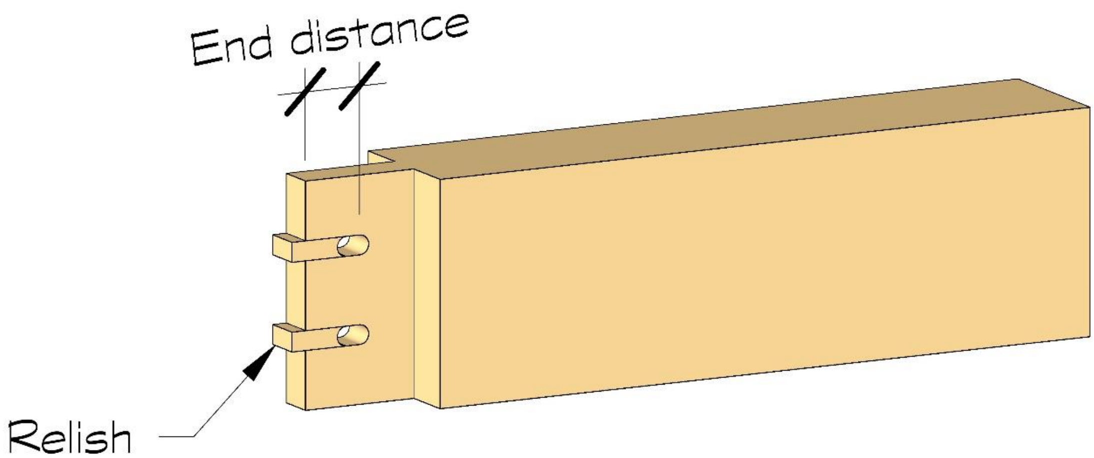
One inch and ¾” dia. turned pegs and at right, an octagonal one. All have a long-tapered point, essential for draw boring. Some cross-grain runout is visible on each of the turned pegs.

Detailing of Draw Bored Joints

When drawboring using lathe turned pins, the amount of drawbore should be reduced. Unlike octagonal pegs, there is little clearance between the peg and the sides of the hole. While riving pegs virtually guarantees clear, straight grain, turned pegs could easily have cross grain. Pegs should be visually inspected before insertion. Those with obvious cross grain should be relegated to joints of low importance.

So, what is the right amount of peg hole offset when drawboring? For a one-inch diameter peg, an offset of 1/8” in softwood frames and 3/32” in hardwood frames seems to perform best. These amounts should be roughly proportional for pegs of larger or smaller diameter.

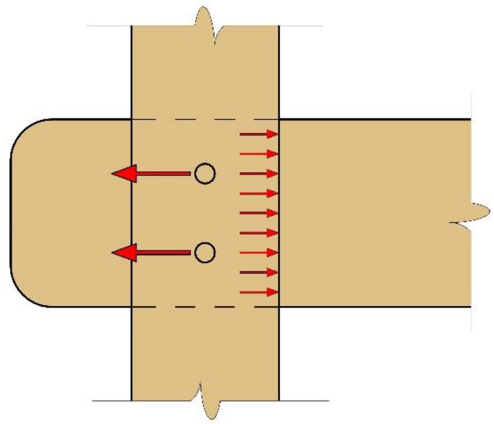
Adequate end distance for the peg holes in the tenon is crucial. If the peg is too close to the end of the tenon, there is a risk that the relish could shear off. Relish failures are non-ductile and, in most cases, they are concealed from view within a mortise. For joints under no loading, or compression loading only, a relish failure is of no consequence. However, if a joint is to be loaded in tension, under no circumstances should the end distance be less than 4 peg diameters.



Tenon Relish Failure

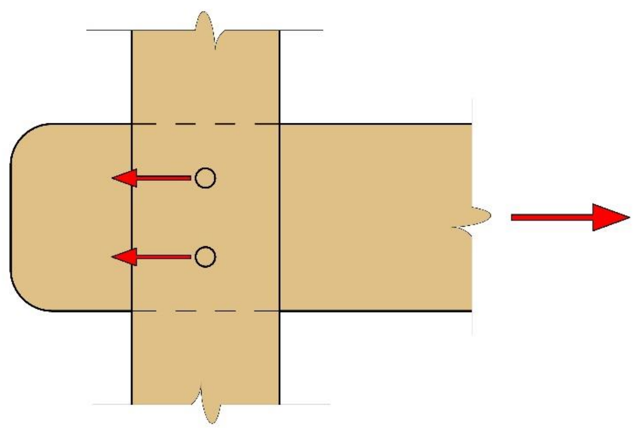
Joints Loading in Tension

In a well-engineered timber frame, the timber joints are loaded predominately in bearing and the pegs are not relied upon to resist structural loads. In certain instances, relying on the pegs to resist structural loads is unavoidable such as tie beam and truss joints.



Prestress in Joint

Drawbored joints have an initial prestress force. The shear force induced in the pegs is balanced by compression bearing against the mortise cheeks. As the timber seasons and shrinks, and as the pegs experience creep effects, the magnitude of the initial prestress force will relax.



Loaded Joint

When a drawbored joint is loaded in tension, the pegs will not experience any increase in load until the applied force exceeds the prestress. At that point, the compression bearing against the mortise cheeks diminishes to zero and the pegs feel only the applied force. Consequently, in a tension joint, the load that the pegs must resist is no different in a drawbored joint than if the joint had not been drawbored.

Conclusion and Recommendations

Drawboring is not some quaint, old-fashioned, custom for pegging timber joints, it is an efficient and effective technique that is as valid today as it was centuries ago. The main advantage of drawboring is that it allows a timber frame to be erected and assembled without the need for multiple cable pullers to bring the joints tightly together. As the timbers season, drawbored joints tend to stay tighter than those not drawbored.

When properly executed, the structural capacity of a drawbored joint is not diminished in any way.