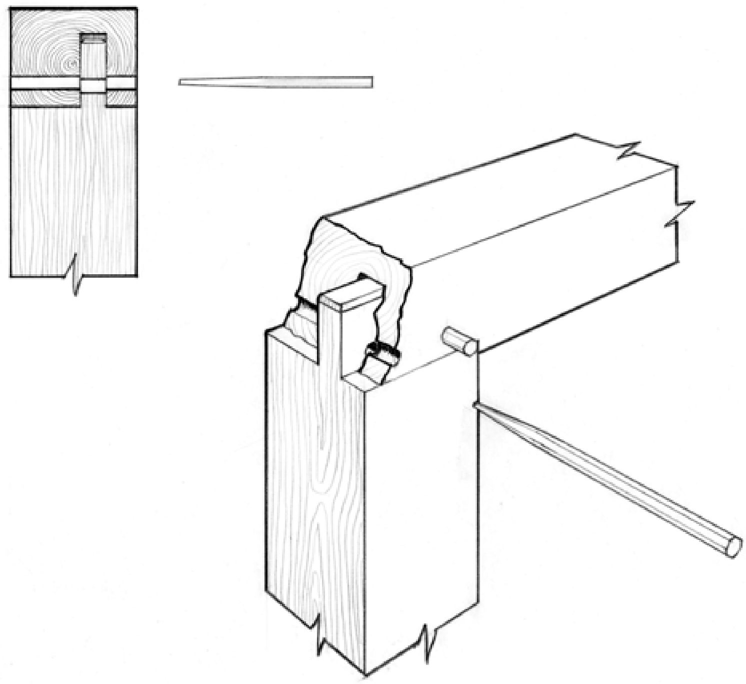
Drawboring of Pegged Joints

DRAWBORING is a centuries-old practice, essential to timber framing and other traditional woodworking trades. Also referred to as "pull boring" or "draw pinning," it is an intentional offsetting of the peg holes in mortise and tenon joints (Fig. 1). Driving a tapered peg through the offset holes draws the joint's bearing surfaces together, keeping them tight both during the raising and through the subsequent drying and shrinkage of the members. Drawboring was the standard technique for pinning joints at least as far back as the colonial European settling of America. English experts have noted evidence of its use by the 13th century, and it is likely as old as the craft itself (Fig. 2). (For more on historical references to drawboring, see "A Boring Essay," TF 67.) During the 1970s American timber framing revival, drawboring was one of those aspects of the craft not universally resurrected. As a result, there are many framers and engineers operating today not aware of the advantages of drawboring over simply boring a peg hole straight through an assembled joint. However, drawboring is essential to a properly crafted frame, not only performing better structurally, but also less time-consuming, and thereby less costly, as a method of working.



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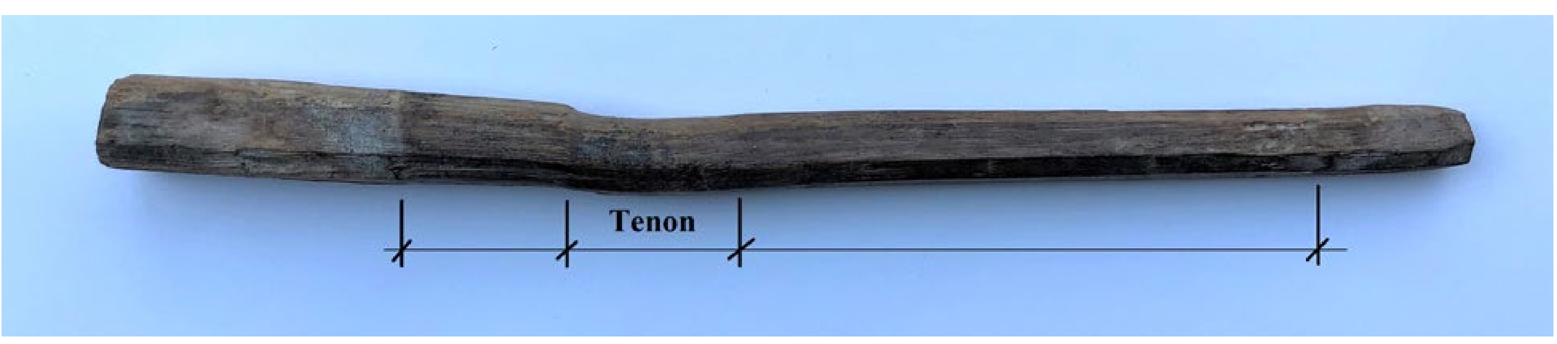
1 In drawboring, the peg hole in the tenon is intentionally offset from that of the mortise. Driving the tapered peg draws the joint's bearing surfaces together.

Technique How was drawboring accomplished traditionally? If you look closely at older American scribed frames, 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 preassembled as part of the overall scribing process, it was brought "to a bearing," as tight as practical. The hole in the mortise was traced upon the tenon with a scratch awl, gouge, or auger bit (a shell auger before about 1790, when the Scotch pattern auger, equipped with a lead screw, began coming into use) that was inserted and rotated to mark the location. Then the tenoned member would be withdrawn enough to see the mark. 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 toward 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 between bearing surfaces to the desired amount of drawbore (see back cover).

In square rule frames (generally 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 toolbox: the framing square. On the mortised member, the centers of the holes were usually either 1½ in. or 2 in. 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. If there was a second row of holes, another 1½-in. or 2-in. increment was used. A line was scratched along the square for the centerline of each hole. For the location of the hole along the line, a V-shaped caret (crow's foot) mark was applied using the graduations on the square (Fig. 3). All layout and boring was done with the layout face up. Since most mortises are closest to this face, this minimizes the magnitude of any deviation due to not-quite-perpendicular boring. The lead screw tip of the auger bit was placed exactly on the caret mark and the hole bored right through, as perpendicularly as practical.

On the tenon, the square was similarly applied, creating a centerline parallel with the shoulder, and each peg's location was



2 The deformity at the tenon location in this ¾-in. oak peg, from a 1426 UK barn, is evidence of drawboring to pull joints tightly together. The lighter section at left protruded from the face of the timber.

3 This old timber shows the square-ruled layout for two peg holes on a mortise that was never cut (a layout mistake). Looking closely, the line for the housing (near right edge) and the parallel line for the peg holes at the point of the carets can be seen.

marked with a caret. The auger bit tip was not placed exactly on the caret but a little closer to the shoulder, typically about ⅛ in. (Fig. 4). On long through-tenons, or with 3- and 4-in.-thick tenons using 1¼-in. or 1½-in.-diameter pins, the offset could be as much as ⅜ in.! On diagonal members like braces, the offset was along the axis of the timber to draw it tight to both the shoulder and 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 peg hole in the top tenon that secures the tie beam (teazle tenon) is also offset in two directions, down to the shoulder but also horizontally—anticipating the post's shrinkage to help prevent it from splitting. On exceptionally deep members, such as Dutch barn anchor beams, where there is substantial shrinkage in height, holes are offset additionally toward the bottom, weight-bearing side of the tenon. The study of old work shows a clear logic in the drawboring of pegged joints.

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-in.-thick tenon should be 4 in. long. These minimum-length tenons are pinned to hold the joint tight but are not designed for tensile loading (Fig. 5). Those that will experience tensile loads are usually much longer—often through-tenons. In a typical New England dropped tie beam, 30x40 English barn frame, only eight joints out of hundreds are loaded in tension. These tying joints are typically through-tenoned and may additionally be wedged-dovetail versions for greater tensile capacity. Though commonly pinned, most joints in an old frame are either in compression or under minimal load, the pinning as much to assist with raising as with the integrity of the standing frame.

The pegs A critical part of drawboring is the peg (historically referred to as "pins," "treenails," or "trunnels"—see sidebar, next page). Traditionally, pegs were riven (split) from clear, straight-grained, green hardwood billets using a froe (also spelled frow). The riving process favors using only structurally perfect material, free of knots, crossgrain, wane, shake, decay, and all the other defects that tend to weaken wood (see TFEC-1). The preferred species for pegs in the

4 This early-19th-century 10x12 tie beam end has a 2½-in.-thick tenon, 2 in. off the face, with three 1½-in.-diameter peg holes. The 2- and 4-in. spacing off the shoulder is clearly seen. The drawbore offset here measures 5/32 in.

5 On the left is a 3x4 red spruce (*Picea rubens*) brace end, cut about 1855, its 3-in.-long tenon showing a 1-in. peg hole, 1½ in. off the shoulder and 1½ in. from the bearing nose. The hole is offset diagonally along the axis of the brace about ⅛ in.

On the right is the peak of a 3x4 sugar maple (*Acer saccharum*) rafter that joins to a continuous ridge beam. The 1½-in.-thick tenon is framed 1 in. off the face and is 3 in. long. The ¾-in.-diameter peg hole is offset an incredible ¼ in. toward the shoulder. The hole is bored closer to the left edge to avoid intersecting the peg hole in the ridge from the opposite rafter. Note that despite the short tenons and huge offset on the latter, neither one exhibits relish failure—both joints were loaded only in compression.

Pinning Down a Name

It seems that "pin" was the dominant historical term used (see "A Boring Essay," TF 67), along with "treenail" and "trunnel." While "peg" is a term typically used to describe the fasteners for the leather soles of shoes, this term has also been used in the same manner as "pin" in some published sources. Henry Mercer discussed all of these terms in *Ancient Carpenters' Tools,* 1929. Mercer notes some distinctions between the uses of these terms but generally regards them as functionally equivalent. Following Mercer, Eric Sloane's 1954 *American Barns and Covered Bridges* uses "pegs" in descriptions of timber joinery, where he also refers to them as "treenails" and "trunnels." The first of the revival books, *The Timber Framing Book*, by Elliott and Wallas, 1977, uses "pegs" and says "pins" are small pegs. The use of "pegs" continues in Elliot's subsequent publications: *The Timber Frame Planning Book*, 1978, and *The Timber Frame Raising*, 1979. Tedd Benson's 1980 book follows Elliot, also using "pegs." While not historically consistent, it is so ingrained among today's timber framers that "peg" is likely to continue in use. The terms "trunnel," "treenail," "pin," and "peg" are thus generally interchangeable.

6 Riving white ash billets with a froe.

7 A selection of old riven pins. Note the variety of profiles. From the top:
1½x14-in. black ash (*Fraxinus nigra*)
1⅛x13-in. white oak (*Quercus alba*)
1x9½-in. northern red oak (*Quercus rubra*)
1x8-in. chestnut (*Castanea dentata*)
1x7-in. white ash (*Fraxinus americana*)
⅞x7-in. sugar maple (*Acer saccharum*)

8 New riven octagonal pegs of ash, cherry, and sugar maple. These riven pegs have absolutely straight grain and are drawn out to a long, tapered point.

eastern US are northern red oak (*Quercus rubra*), white ash (*Fraxinus americana*), and hickory (*Carya* spp.). For unheated outbuildings and areas prone to damp, the heartwood of rot-resistant species like white oak (*Quercus alba*), black locust (*Robinia pseudoacacia*), and black cherry (*Prunus serotina*) is preferred. The billets are cut from clear, lower trunk sections above the butt flare (Fig. 6). Non-leaning trees are preferred as they will be free of reaction wood that makes riving difficult.

Billets should be cut squarely, about 4 in. longer than the largest timber they will go through. So, for a frame predominantly of 8x8s, you will want 12-in. pegs (note that stock shorter than this is difficult to work on the shaving horse). Peg blanks are riven to a square section, slightly less than the diameter of the peg holes. For a 1-in.-diameter peg hole, the riven blank should measure about 15⁄16 in. square. The end that was up during 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 over between ⅓ and ½ their length to a blunt point of about ¼ in. or ⅜ in. This taper ideally is a convex curved one like an elongated rocket nose cone (Fig. 7). Judging by the lack of mushrooming found on the heads of old pegs, it seems they were allowed to season a bit before use, but too-dry pegs are less flexible when engaging the offset holes. Store them in an unheated outbuilding at about 15 percent moisture content for the best results. (For more information, see "Making Riven Pins," TF 107.)

Riven pegs will vary a bit in thickness, taper, and pointedness (see Fig. 8). During the raising, it is the duty of the assembler to 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 the offset is less, a peg that is slightly thicker and less pointed is called for. The peg is carefully inserted, making sure that the tip 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 tightly together, the resistance will increase. Driving a tapered peg generates tremendous leverage, so it is not necessary to swing the mallet hard. Stop driving when there is significant 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 is great for driving pegs. Properly done, drawboring not only draws the joints tight on assembly, but keeps them tight during the racking of raising and through the effects of seasoning shrinkage in the years that follow. The slight bend they take on acts as a sort of spring to keep the joint tight.

Fractured pins in old structures relate 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 powderpost 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.

While riven pegs, crafted in the traditional fashion, are still often used in traditional frames and in the restoration of historic frames, turned pegs were often used from the latter half of the 19th century onwards, especially near water-powered (turbine) sawmills with associated millwork businesses (Fig. 9), and turned hardwood pegs are quite common in contemporary 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*. For inserting into the offset holes, it is crucial that the turned pegs have a gradually tapered end and be long enough that the tapered portion extends beyond the face of the timber in the finished joint (Fig. 10). The gradual taper is necessary to ensure that the joint is pulled together slowly as the peg is driven, reducing the potential for a relish failure. If the tapered portion of the peg is not driven beyond the face of the timber, the shear strength of the peg will be reduced.

9 Old turned pegs. On the left is a 1x8-in. sugar maple peg with a gradual point (blackened from soot). On the right, a 1x7-in. blunt-pointed white ash peg. Neither has any measurable taper along its length.

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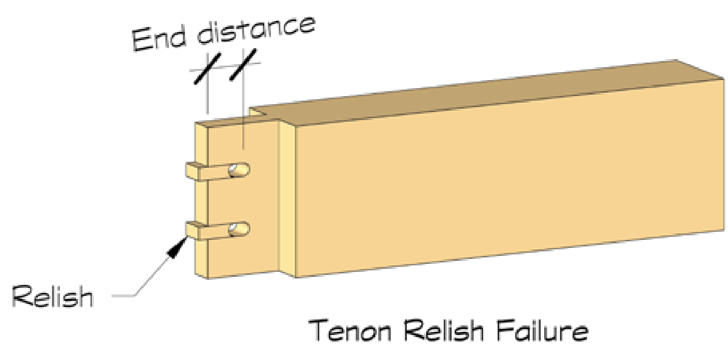
10 Manufactured pegs. On the left, 1-in. and ¾-in. turned pegs. On the right, a sawn octagonal one. All have a long, gradually tapered point, essential for drawboring. Some cross-grain runout is visible on each of the turned pegs.



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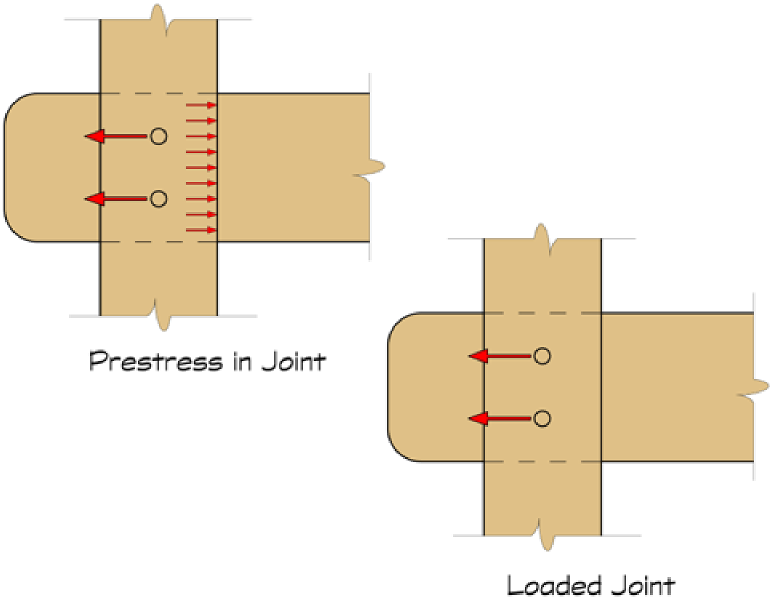
11 Tenon relish failure resulting from inadequate end distance in a joint loaded in tension.

Detailing of Drawbored Joints When drawboring using lathe-turned pegs, the amount of drawbore should be reduced. Unlike with octagonal pegs, there is little clearance between the turned peg and the sides of the hole. While riving pegs virtually guarantees clear, straight grain, turned pegs could easily be weakened by crossgrain. Pegs should be visually inspected before insertion. Those with obvious crossgrain should be relegated to secondary joints of minimal importance.

So, what is the right amount of peg hole offset when drawboring? For a 1-in.-diameter peg, an offset of ⅛ in. in softwood frames and $\frac{3}{32}$ in. in hardwood frames seems to perform best. These amounts should be increased or decreased proportionally for pegs of larger or smaller diameter.

Adequate distance between the peg hole and the end of the tenon is crucial, providing relish to resist tension. If the peg is too close to the end of the tenon, there is a risk that the relish could shear out (Fig. 11). Relish failures are non-ductile, so there is no warning of their imminent failure, 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 four peg diameters (see TFEC 1-2019, Table 3C).



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12 The effect of drawboring on shear force in pegs. At left, prestressed force in pegs is balanced by bearing of tenon shoulders against mortise cheeks. At right, when tension load exceeds prestressing, tenon shoulders no longer bear against mortise cheeks and shear force in pegs equals the applied load.

Joints Loaded in Tension In a well-engineered timber frame, the joints are loaded predominately in bearing (compression) 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 in tying joints and some truss joints.

Drawbored joints have an initial prestress force. The shear force induced in the pegs is balanced by compression bearing against the mortise cheeks (Fig. 12, left). As the timber seasons and shrinks, and as the pegs experience creep effects, the magnitude of the initial prestress force will relax.

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 (Fig. 12, right). Consequently, in a drawbored tension joint, the load that the pegs must resist is no different than if the joint had not been drawbored. In general, drawboring improves the structural performance of a joint because the joint remains tight after the timbers have seasoned.

Conclusion and Recommendations Drawboring is a highly developed traditional methodology for pegging timber joints, not some quaint, old-fashioned custom. It is an efficient and effective technique that is as useful today as it was centuries ago. The principal benefits of drawboring include allowing timber frames to be assembled and erected without the need for mechanical contrivances, such as comealongs, to bring the joints tightly together; as the timbers season, drawbored joints tend to stay tighter than those not drawbored; and, when properly executed, the structural capacity of a drawbored joint is not diminished in any way.

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