

Historically, timber framers have used scarf joints to fabricate long timbers for silk, plates and posts where the local forests no longer could provide them or, in the case of timbers for very long bridges, where they did not exist. Over the centuries, various scarf joints were developed for reasons of function and economy (see TF 60 for some American examples). Resisting loads in bending is one of the more challenging demands made of scarf joints.

Inspired by scarf joint testing at a UK Carpenters Fellowship conference, and renewing a Guild conference joint-bending tradition from the late 1980s, we sacrificed member-donated scarf joints for fun, theatrics and education at 2009 Saratoga (New York), 2010 Coeur d’Alene (Idaho) and, just recently, 2010 Montebello (Québec).

We built a portable bending rig of paired, cambered Douglas fir timber reaction beams, high-strength steel rods and a hand-pumped hydraulic ram. We used a 12-ton ram first but have since upgraded to a 30-ton model to obtain better results. The tested scarf joints were limited to 24 in. long and cut in nominal 8xtimbers to produce an assembled length of 96 in. Actual sections varied from 5½x7½ in. to 8½x in. square.

We applied a single-point load via a bearing plate at the center of the scarfed beam using the hydraulic ram (Fig. 1). Gradually increasing the load in bending, we brought the sample to failure unless the setup became unsafe or we ran out the 3-in. stroke of our ram. Except for the length and section of the scarfed beam and the length of the scarfed portion, we restricted the use of steel and steel connectors was encouraged.

In physics, a moment is defined as a tendency to cause rotation about a point or an axis. A point load acting in the middle of a beam, such as applied by our hydraulic ram, creates a moment that resists the load.

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We defined lap joints as the simple lapping of two timbers at a joint. Laps can be aligned vertically, horizontally or at some intermediate angle. Undersquinted abutments have been used historically in timber framing, but they are generally less effective than straightforward ones in rafters and purlin plates, where vertical and horizontal thrust loads sometimes occur, and they will suffer less indigestion under drying stresses. Joint efficiency seems to be improved by increasing the number of active shear planes of the connectors (See the last conclusion in the review and conclusions section below). Unfortunately, elaboration of the joint design also increases difficulty of fabrication.

The Scarf Joints Tested

1 Test rig to bend beams under controlled, monitored force.
2 Top right, simple theoretical ‘cogged’ scarf.
3 Middle right, split and mirrored theoretical edge-halved scarf.
4 Bottom right, split and mirrored theoretical face-halved scarf.

The greater a beam deflects under a given load, the lesser its stiffness. Stiffness or deflection is proportional to the width of the timber and the cube of its height. A vertically oriented half lap (a simple face-halved scarf) is the height of the beam and one-half as wide, so the maximum theoretical stiffness of the lap is one-half. A horizontally oriented half lap (an edge-halved scarf) is the width of the beam but only one-half as high, so the lap’s maximum stiffness is one-eighths (one-half to the third power) as much. Actual performance varies from these limits according to the joint configuration.

WODDEN scarf joint design is limited only by the nature of the material and the imagination and skill of the framers. Many of the joints we tested adapted historical precedent, stimulating us to devise a better building system (as measured by the table of results on page 13) that allowed us to classify the connections as engineers and draw broad conclusions useful to timber framers. The use of steel and steel connectors has been increased historically in timber framing, but they are generally less effective than straightforward ones in rafters and purlin plates, where vertical and horizontal thrust loads sometimes occur, and they will suffer less indigestion under drying stresses. Joint efficiency seems to be improved by increasing the number of active shear planes of the connectors (See the last conclusion in the review and conclusions section below). Unfortunately, elaboration of the joint design also increases difficulty of fabrication.
SOB (Saratoga or Bust) Scarf, Loyalist Timberframes. Code 2-VCS. Face-halved with sallied and bridled butts. Moment transfer through bearing. Tension perpendicular to the grain failure as load pried joint apart.

Double Deuce Scarf, Timberpeg. Code 3-VLD. Face-halved and tabled with two edge pegs. Moment transfer through bearing and dowel shear. Failure via almost pure block shear. Maker Jesse Kendall, at right, gives pep talk to scarf before testing.


Double Deuce Scarf. Timberpeg. Code 3-VLD. Face-halved and tabled with two edge pegs. Moment transfer through bearing and dowel shear. Failure via almost pure block shear. Maker Jesse Kendall, at right, gives pep talk to scarf before testing.


Pop-Side Scarf, Timberpeg. Code 5-VLW. Face-halved and keyed with radiused butts. Moment transfer primarily through bearing. Failures via tension perpendicular to grain and key shear. Insert in photo at right shows failure of folding-wedged key.


Below, Ringo Scarf, Cornerstone Timberframes. Code 7-VLSP. Face-halved and scissored with steel ring shear plates. Moment transfer through shear and bearing. Failure via tension perpendicular to the grain (split) and plug shear failure.
Bates Scarf, Virginia Military Institute (VMI). Code 8-VCSD. Face-halved with sallied butts and four edge pegs. Moment transfer in bearing and dowel shear. Failure in tension perpendicular to grain and dowel shear.

Jarrett Scarf, VMI. Code 9-VCSD. Variant on Bates. Face-halved with asymmetrical sallied butts and three edge pegs. Moment transfer through bearing and dowel shear. Failure in tension perpendicular to the grain (minimum dowel distress).

Peck Scarf, VMI. Code 10-VLSD. Face-halved scissor with four edge pegs. Moment transfer through bearing and dowel shear. Failure first through dowels followed by failure in tension perpendicular to grain.

Tunnell Scarf, VMI. Code 11-HLWD. Edge-halved and keyed, stop-splayed and double-tabled with undersquinted abutments and four face pegs. Moment transfer through bearing and dowel shear. Failure in tension perpendicular to the grain.

Heco Scarf, Herrmann’s Timber Frame Homes. Code 12-HLMC. Edge-halved and stop-splayed with numerous face screws. Moment transfer through axial loading of screws. Failure by withdrawal of screws and breaking of glulam fingerjoint. Toothed connector inside was ineffectual.

Hamlet Hemlock Solid-Sawn Beam, Hamlet Heavy Timberworks. Code 13-MN. Mother Nature’s entry. Classic modulus of rupture failure, at 33,840 lbs. Test beam was parted from longer one with drill and auger bit, under desperate conditions.

Hamlet Beaver Tail, Hamlet Heavy Timberworks. Code 14-HLMC. Edge-halved with briddled and pegged square abutments and eight face screws. Moment transfer through mechanical connectors and bearing. Failure by withdrawal of mechanical connectors and shearing of dowels. Small square brass plate is ornamental. Insert in photo at right shows shear failure of peg fastening briddled abutment.
Review and Conclusions
When viewing the results in the table and charts (Figs. 5–8), care should be taken when comparing any two scarf joints. Besides the type of scarf joint, the actual size of the timbers, strength of the wood and other factors have a substantial effect on the assembled member’s strength and stiffness.

For the best designs, the theoretical maximum limit for moment capacity of a simple face-halved scarf joint is 50 percent of a like-sized, solid sawn timber. For a simple edge-halved scarf joint, the theoretical maximum is one-quarter. The rule of thumb that a well-designed and well-crafted scarf joint’s moment carrying capacity is one-third of a solid-sawn timber’s is consistent with our results, assuming the joint orientation is designed for the load orientation.

Stiffness (resistance to deflection) is likewise limited by the reduced section at the scarf joint and the inability to perfectly transfer the forces from one part of the joint to the other through the joinery and the wood and mechanical connectors (threaded and compression fastenings). The theoretical maximum limit is also 50 percent for a vertical half lap and one-eighth for a horizontal half lap. Because there is no stress without strain, there must be some initial give before the wood joinery and the connectors take any load. This initial give also reduces stiffness. Another contributing factor to decreased stiffness in scarf joints is that wood cell structure’s efficiency in load transfer cannot be easily matched by dowel type connectors.

Tension perpendicular to the grain was the predominant failure mechanism in the scarf joints we tested. Improvement in scarf joinery can be achieved by augmenting the wood’s strength in this critical mode. In that connection, mechanical connectors appear by demonstration to be a very effective way to augment the moment capacity of scarf joints in bending. (Mechanical connectors would appear to be an effective way to augment scarf joints in tension as well.)

The use of bearing, compression force applied across an interface, to transfer moments seems to be more effective than the use of dowels, metal or wooden. Stiffness seems to be greater as well for scarf joints that rely on bearing.

Face-halved mirrored joints appear to have higher tenacity as well as higher ultimate capacity than joints that rely on dowels and other bearing transfer mechanisms.

Finally, with the use of suitable screws, quite simple scarf joints such as Hamlet Heavy Timberworks’ Beaver Tail, which might be cut straightforwardly, can prove as strong as far more complex and more-difficult-to-fabricate oak scarf joints such as the group cut at Virginia Military Institute.

—Mack Magee

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