

TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

Number 98, December 2010



Scarf Busting

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CONTENTS

GUILD NOTES & COMMENT Ken Rower	2
SCARF JOINT ADDENDUM Jack A. Sobon	4
TESTING SCARF JOINTS IN BENDING Mack Magee	6
TOU-KUNG AND CHINA'S WOODEN MONUMENTS Mike Laine	14
VANCOUVER ISLAND GREEN RETREAT Richard Lutz	20
VISIT WITH A COLLECTOR-CRAFTSMAN Sarah K. Highland	22

On the front cover, Joe Miller, foreground, measures deflection of test scarf as Ben Brungraber applies increasing pressure to the hydraulic ram. Applied force was recorded at 1/4-in. deflection and deflection recorded at 1000 lbs. pressure. Scarf joints were tested to destruction. Photo by Mack Magee. Story page 6. On the back cover, Chinese craftsman masks off polychrome woodwork in Forbidden City, Beijing. Photo by Mike Laine. Story page 14.

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1985



THE Château Montebello, roughly halfway between Montréal and Ottawa on the Outaouais River in Québec, provided the Guild its notable pleasures Halloween weekend, as a venue for our 26th annual Eastern Conference (*numéro vingt-six*, in local parlance), but Guild members, restrained by a shortage of funds that only politicians and bankers seem to have avoided, arrived in much fewer numbers, and some familiar things one has come to expect at a Guild conference were simply missing. To begin with, the conference packet contained no conference booklet, instead quite a bit about the Business Council and the trade fair. The only Guild papers were a photocopied auction promotion sheet and a single-page schedule with all the important words in just-legible type. You could get a conference booklet if you asked for one, but this year the office deemed it better to send out the document electronically before the conference. Susan Norlander, who ran the registration desk with only occasional help, reported that many people expressed delight to be free of the printed booklet.

There was no children's workshop, in the past a focal point of Guild conferences. Instead, the oak and fir pieces of a somewhat puzzling model of a 19th-century Midwestern-style barn frame, about one-quarter scale in ground plan but about half-scale in its major timbers, appeared in the Montebello lobby, ready to raise by interested kids. Intended as a teaching device for primary school students, the traveling model was built at Trillium Dell in Illinois to the specifications of its designers, the National Barn Alliance. Right next to it, a crisp white pine one-fifth scale model of an 18th-century New England-style English barn, the work of Jim Derby of Waldoboro, Maine, arose out of its pine storage case as if called forth to testify by its larger neighbor (photo above right). The kids had fun with assembling that, too, even if they had to be more careful with the slender scaled pieces of pine.

One consequence of no children's workshop (and of no other building project at the conference) was no large object to sell at the

Erratum

In John Stevens's article in TF 97, "Dutch Buildings in North America," a picture purporting to show the Wemple barn, Rotterdam, N.Y., in fact showed the Nielsen barn, ca. 1800, at nearby Mabie Farm. Right, the real Wemple barn, mid-18th century, properly proportioned. The editor regrets the error.



Ken Rower



Ken Rower



Lisa Sasser

Saturday night auction. Such an object generally fattens the auction take by a substantial amount between \$5,000 and \$10,000, and its absence was noticed. A matching-fund offer near the end of the auction by a well-meaning if indelicate donor temporarily diminished the good cheer of the group.

I WENT to three European presentations. The first, on European wooden building technologies, opened with a pitch for the speaker's company's products, nicely finished cast aluminum bed-rail hardware scaled up for use as a substitute for loadbearing mortise and tenon connections in timber. Hubert Burböck then skipped lightly over the admirable and extraordinary work Europeans do in glulam timber to concentrate on a recent continental engineered wood product called cross laminated timber (CLT)—plywood on a truly giant scale, in thicknesses to 16 in. and panel sizes to 7 ft. by 52 ft.—made of alternating-grain layers of boards laid side by side and glued or screwed together. This massive material competes with concrete construction, not with the crafts of timber framing or even log building, so it was appropriate to speak of the hundreds of millions of cubic meters of annual increase in the contents of European forests these days as a good reason to use the stuff. Fastened together into boxes with solid floors, CLT makes structures so sturdy that a full-scale multistory example, tested on a gargantuan shaking apparatus in Japan whose three-axis motions closely simulated the Great Hanshin (Kobe) earthquake of 1995, produced no structural damage, indeed no visible effect. After its prolonged violent shaking and the ruination of all domestic furnishings inside, the box just settled back exactly to its status quo ante.

The second European show I watched, on passive houses and airtightness, was performed by Patrick Haacke, whose company's name was neatly displayed in red at the edge of every slide he showed and whose pitch for the products his company makes (membranes, sealants, gaskets, tapes) was folded in invisibly with the instructive information he conveyed on the movement of air and vapor through a building wall. You do want to block inbound and outbound air movement, entirely on the warm side, but you don't want to prevent outbound moisture movement—you control it with a permeable, "semi-open" membrane, such as OSB. Patrick described a research wall fitted with sensors that detects moisture content over time and pinpoints where condensation occurs and where drying is more likely than wetting, leading to the considered placement of the warm-cold divider. Of the three ways to lose heat energy from a building, radiation can account for about 5 percent (generally ignored); conduction about 60 percent (fairly easy to control, by lots and lots and lots of trapped air); and convection about 35 percent (not so easy to control, only by perfect air sealing, which is where membranes, sealants, gaskets and tapes come in).

Though he might deny being European, Bill Keir, the reigning chair of the UK Carpenters Fellowship and a very old friend of the Guild, also addressed the problems of air and moisture movement

through building walls, in particular the walls of traditional half-timbered buildings still regularly produced by British craftsmen (some using Hundegger joinery machines) but now up against the energy-efficiency demands of modern UK building regulations. To meet these demands, Bill's company has devised studded infill panels of fiberboard with hemp insulation, with rainscreen membrane to the outside and vapor control membrane to the inside, and which fit their timber frames via gasketed grooves and lead flashing, the latter features notably time-consuming to achieve. These panels can still be rendered in the usual way to the outside and plastered inside. The considerable thermal bridging problem of many posts simultaneously exposed to inside and outside, especially in certain close-studded English designs, is mitigated by reducing the number of studs in fact exposed to the inside. For North American builders working in moderate climates (not New Hampshire or Minnesota, for instance), and who long to show the beautiful timber frame more or less the amazing way it looked just after the raising, these panels may be helpful.

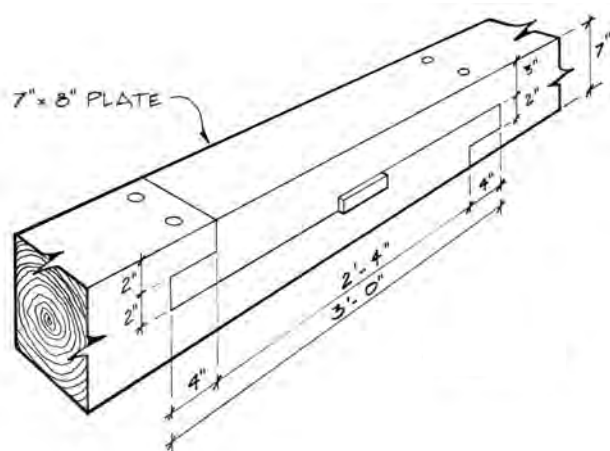
There was no members' meeting at this conference, apart from a few encouraging shouts from a lectern in a huge, noisy room by the Guild's executive director Joel McCarty between the animated end of a buffet dinner for 225 people and the beginning of the excellent slide show of members' new work—but that note marks the end of my list of things that did not happen. Here is what *did* happen, taught at this typically rich conference: conservation techniques, plumb line scribing, developed drawing, timber codes, historic and contemporary trusses, decay agents and resistance, timber grading, screw connections, architectural timber design, keyed beam research, working with engineers, Guild apprentice and French exchange programs, scarf joint busting (see page 6), solid and keyed-beam testing (photo left above), treehouses, shop drawings, straw-bale use with timber frames, fall protection, rigging hardware, managing timber frames and panels, finishing the house.

I HAD a talk with Josh Englander, a marketing consultant who came from Oregon to conduct a panel on the principles of adapting a business to diminished market conditions (now). Asked to manage advertising for the Guild, which as an educational organization is not naturally adept at the task, Josh and his business partner had a good look at the Guild and how it presents itself to the world. Their observation is that we appear pretty confused. Our publications look as if produced by different people (they are) and our website, to put it politely, runneth over. Accepting the criticism, which comes as no surprise in connection with the website, we will begin reform efforts there. The print publications, primarily this journal and the newsletter, seem to please the majority of their readers, who clap their hands at conferences when the editors are mentioned, so we will move more lightly when changing them. Still, anything can be improved, and it's probably true that the Guild should display a more unified public identity. —KEN ROWER

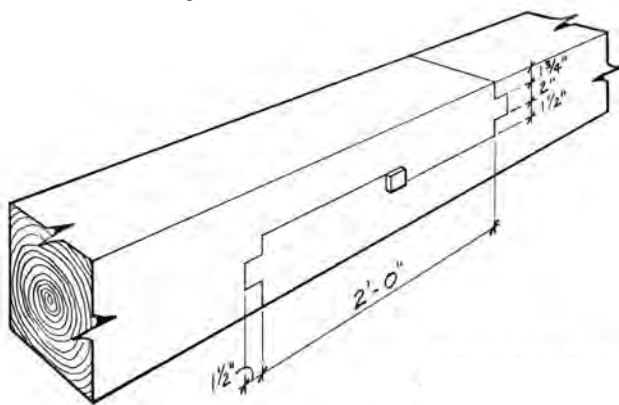
Scarf Joint Addendum

SINCE the Guild's 2002 publication of *Historic American Timber Joinery, A Graphic Guide*, additional timber joinery examples continue to surface. Herewith a selection of scarf joints.

—JACK A. SOBON

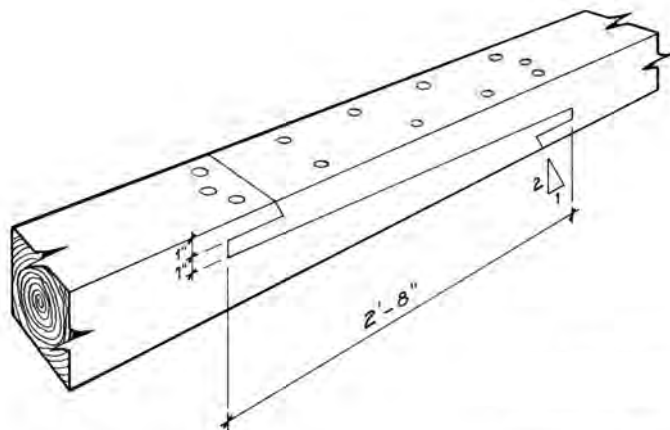


Drawings Jack A. Sobon

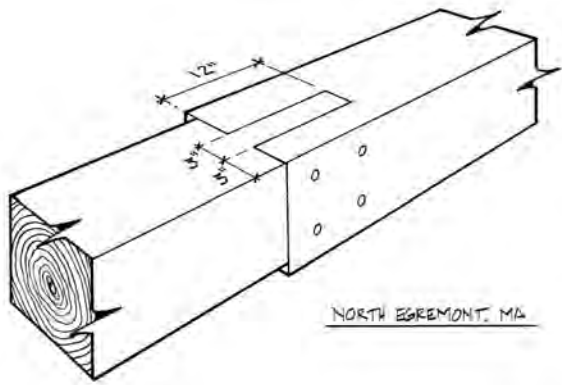


1 Plate scarf at Stowe Community Church, Stowe, Vermont, 1867. Each of the 85-ft. 7x8 wall plates is scarfed together from three spruce timbers. The carpenter chose an edge-halved, bladed, tabled and keyed scarf to repeat four times.

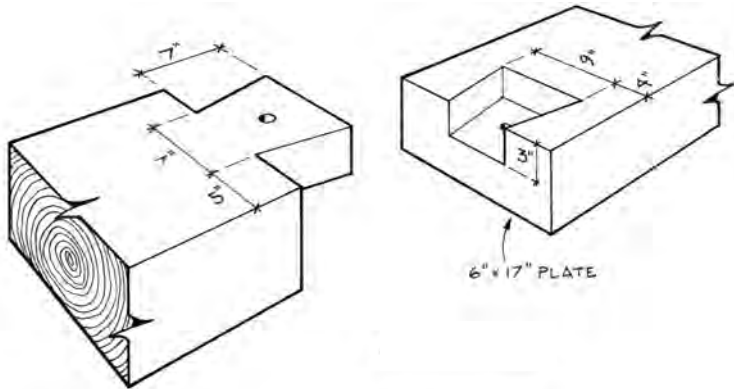
2 Edge-halved, bladed, tabled and wedged scarf in 9x9 spruce sills, 44x60-ft. barn, East Calais, Vermont, ca.1840. The carpenter apparently was trying to make a subtle design improvement over the normal arrangement seen in Fig. 1, moving the tenons out of the shear planes created by the key. A similar scarf, 6 in. longer, is used in the barn's wall plates. (From information provided by Seth Kelley.)



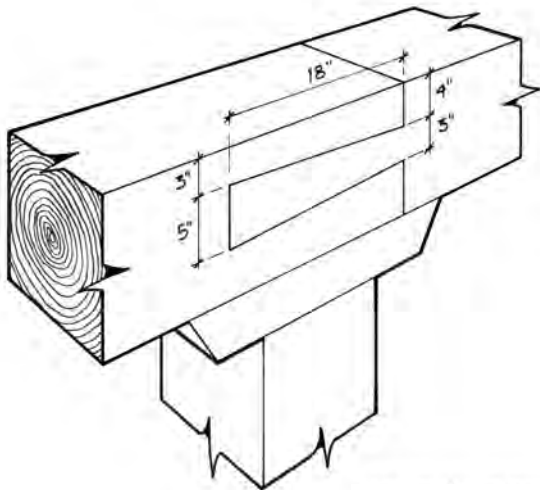
3 Splayed and bladed scarf with undersquinted butts in 5x7 red oak plates of a Dutch house in Millerton, New York. For its diminutive size and light loading, it has a remarkable number of $\frac{15}{16}$ -in. pins securing it. Perhaps the carpenter had seen one of his earlier scarfs fail from insufficient pinning.



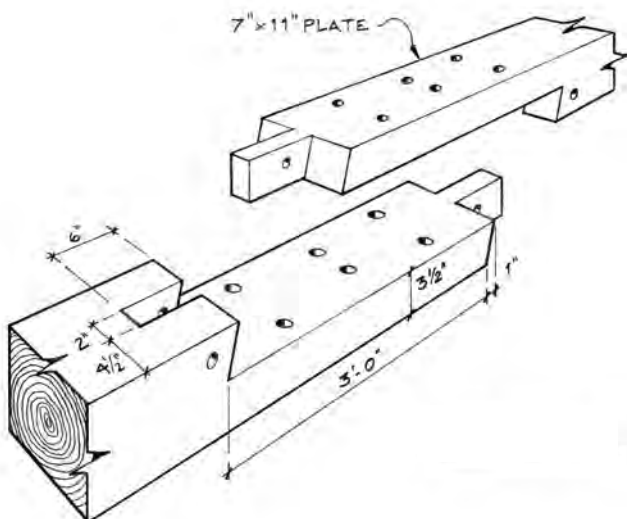
4 Bridled scarf, North Egremont, Massachusetts, ca. 1850. Two early English barns were moved and joined, and then added to, to create a long bank barn. The barns were fitted with new sills, floor framing and basement posts. The sills were hewn and tapered from about 10 in. to 12 in. square and joined with a simple bridle. One scarf, supported by the foundation, was framed with a 2-in. shoulder, 2-in. tenon and five pins. The other, in the unsupported span over the walkout portion of the basement and shown at left, was framed with 3-in. shoulder, 3-in. tenon and four pins.



5 Lapped plate scarf at Central Moravian Church, Bethlehem, Pennsylvania, 1803. The fully supported 17x6 wall plates that carry principal trusses and bear on the 27-in.-thick rubble masonry walls are end joined with a simple dovetailed tenon and pin.



6 Dovetailed bridle scarf supported by post and bolster ties 12x12 floor timbers in a mid-19th-century barn in Carson Valley, Nevada. Though its top surface cannot be seen to verify, likely the joint was pinned to prevent sideways movement. (From information provided by Paul Oatman.)



7 Halved, undersquinted and bridled scarf in pine plates, Christ Episcopal Church, Shrewsbury, New Jersey, 1769. The scarf falls over a brace and between rather closely spaced trusses, 6 to 7 ft. on center. Pins $\frac{7}{8}$ -in. dia. secure the bridle joint while $1\frac{1}{4}$ -in. pins secure the halved portion.

Testing Scarf Joints in Bending

HISTORICALLY, timber framers have used scarf joints to fabricate long timbers for sills, 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-busting 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 at 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 8x8 timbers to produce an assembled length of 96 in. Actual sections varied from 5¾x7½ in. to 8¼ 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 scarf, the donated test samples were not 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 bends the beam. To resist the applied load, a beam must develop an internal balancing moment. The internal moment consists of compression in the fibers closest to the loaded face and tension in the fibers opposite the loaded face. The tensile and compressive forces acting within the beam create the internal balancing moment that resists the load.

If the scarf joint is to resist a bending load, this internal moment, consisting of balanced tension and compression zones, must be transferred between the two halves of the scarf. There are two means of this force transfer: by bending both “halves” of the scarf joint equally through shear and bearing forces; or by transferring the compression and tension forces directly in their respective zones between the pieces. The more effectively these forces are transferred, the more effectively a scarfed beam resists a bending moment.

Of course, the scarf joint by its nature interrupts the wood fibers in both the compression and tension zones of the assembled beam. Interruption of fibers in the compression zone is not difficult to address. Compression force easily transfers between the two parts of the scarf through compressed bearing surfaces. Transferring tensile forces is more challenging. Scarf joints do so in numerous ways, most of which we investigated in the variety of joints we tested.

For joints like the simple half lap that transfer the moment across the split between the halves by bending both pieces more or less equally, we can easily define the maximum moment the joint can carry. The moment that a beam can carry is proportional to the width of the beam and to the square of the height of the beam. If the half lap is horizontal (or in traditional terms the scarf is *edge-halved*), the maximum moment it can carry is one-quarter the moment of a solid beam, because the half lap is the width of the

beam but one-half the height. For our vertical half lap (in traditional terms, the scarf is *face-halved*), the width is one-half the solid beam but the height of the half lap is equal, so the maximum moment the half lap can carry or transfer is one-half of what a solid beam will transfer.

These assertions assume perfect transfer of forces, an event not likely to occur; the effectiveness of an actual scarf joint will necessarily be less. A reasonable rule of thumb, confirmed by our observations during testing, is that a well-designed and well-executed scarf joint can sustain about one-third the moment sustainable by a solid timber (or glulam) of the same section.

The effect of the reduced section at the scarf joint is even more dramatic in stiffness. Deflection, or curvature, is a measure of stiffness. 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-eighth (one-half to the third power) as much. Actual performance varies from these limits according to the joint configuration.

WOODEN scarf joint design is limited only by the nature of the material and the imagination and skill of the framer. Many of the joints we tested adapted historical precedent, stimulating us to devise a coding system (preserved in the scarf descriptions and in the table of results on page 13) that allowed us to classify the connections as engineers and draw broad conclusions useful to timber framers.

We found it helpful to characterize scarf joints by their topology and their moment-transfer mechanism. We tested eight layouts in three broad topological categories: butts, laps and what we called *cogs*, giving the term a special meaning as explained below.

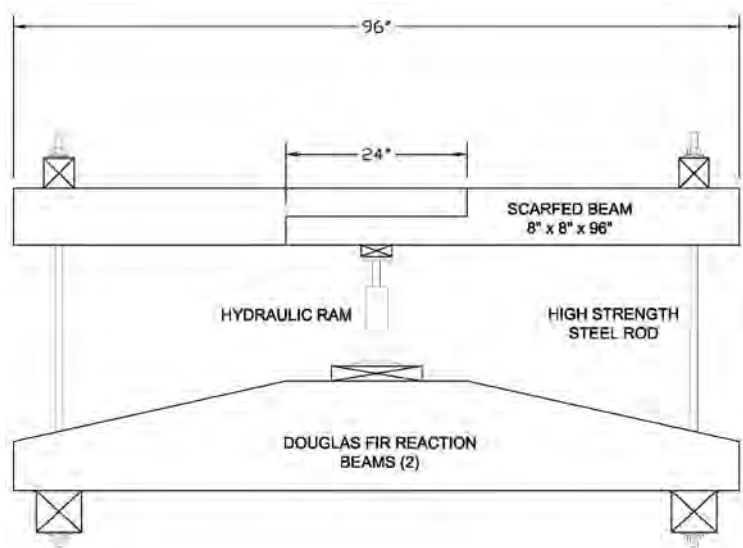
Butt joints can be simply fabricated with tension and compression connectors. While for some observers such connections might not constitute scarf joints, for our purposes a scarf joint is any end-to-end timber joint; thus fastened butt joints qualify.

We defined lap joints as the simple lapping of two timbers at a joint. Laps can be aligned vertically, horizontally or at some intermediate slope (splayed). “Cogged” joints lap as well, but they are differentiated by having their lapping parts interleaved across the grain like the teeth of meshing gears. Bridled scarf joints are examples of what in our internal classification we called cogged joints.

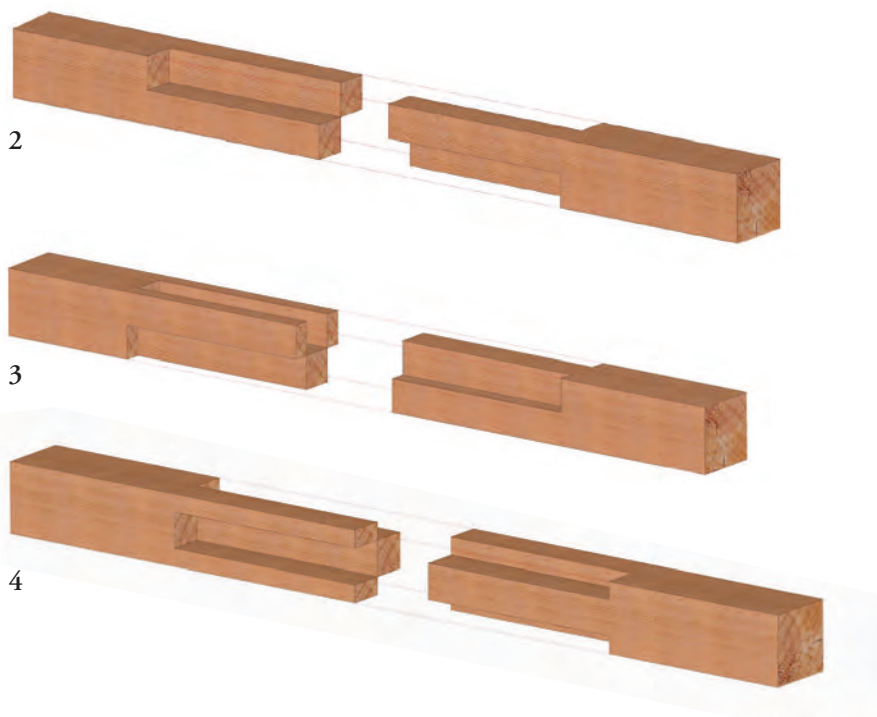
Finally, laps or cogs can be modified by “splitting” the lapped sections and mirroring them about the splitting axis, such as shown theoretically in Figs. 2–4. The increasing complexity of a scarf joint correlates well with an increase in bearing faces (if not necessarily *effective* bearing areas) and moment resistance.

The moment-transfer mechanism was equally helpful in categorizing the scarf joints we tested. Many joints relied upon more than one method of moment transfer, though the testing demonstrated that one method predominated in most cases.

The simple face-halved scarf, when pegged, screwed or bolted together, uses shear to transfer the moment from one part of the joint to the other. The simple edge-halved scarf, pegged, screwed or bolted together, uses shear and, to a lesser extent, bearing to transfer the moment. In both instances, connectors work against the separation of the joint through shear. And, in the latter instance, the pressure of the load also induces bearing forces in the lapped portions. (*Bearing* is compressive force transmitted across a



- 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.



discontinuity, such as the interface between the ends of the laps.) An important attribute of these joints is that the connectors crossing the joint are in single shear.

Joints such as bridles in various forms (which we classified internally as “cogged”) develop more complicated transfer mechanisms. Joint connectors here typically are in double shear, generally increasing the effectiveness of moment transfer and thus of the joint. Under high loads and significant deflections, face-halved bridled scarfs may develop additional bearing surfaces as trailing edges of lapping extremities, such as bridled abutment corners, interfere with their housings.

In edge-halved bridles, interleaved abutments (cogs in our terms) create more bearing surfaces and contribute to scarf joint effectiveness. Undersquinted abutments have been used historically in the belief that they increase effectiveness, and this was confirmed

by our testing. The bearing surface at the undersquint seemed to increase the load capacity of the joint and reduce the deflection, particularly in oak timbers. Anticipated splitting along the grain at the squint did not occur early in the loading despite wood’s relatively low strength in tension perpendicular to the grain, thus contributing to the performance of the joint.

“Splitting” and mirroring lapped and bridled scarf joints increase their resistance to twisting. Such joints will likely perform better than straightforward ones in rafter and purlin plates, where vertical and horizontal thrust loads sometimes occur, and they will suffer less indignity under drying stresses. Joint efficiency seems to be improved by increasing the number of active shear planes of the connectors. (But 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



Mack Magee

Big Dog Bone Scarf, Bensonwood Homes. Code 1-BJMC. Butted scarf with steel connector and pegged spline for joint alignment. Moment transfer through tension (steel) and compression (bearing surface). Testing stopped upon yielding of steel and incipient lateral buckling and block shear failure in the wood.



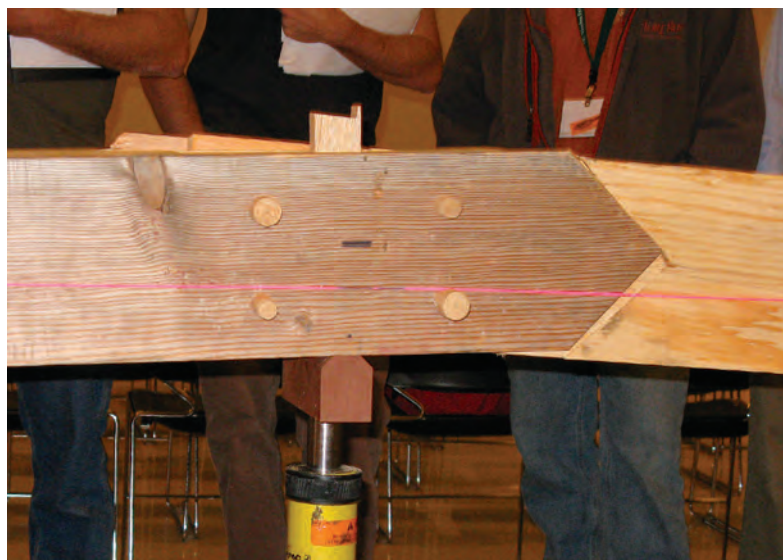
Photos this page Mack Magee

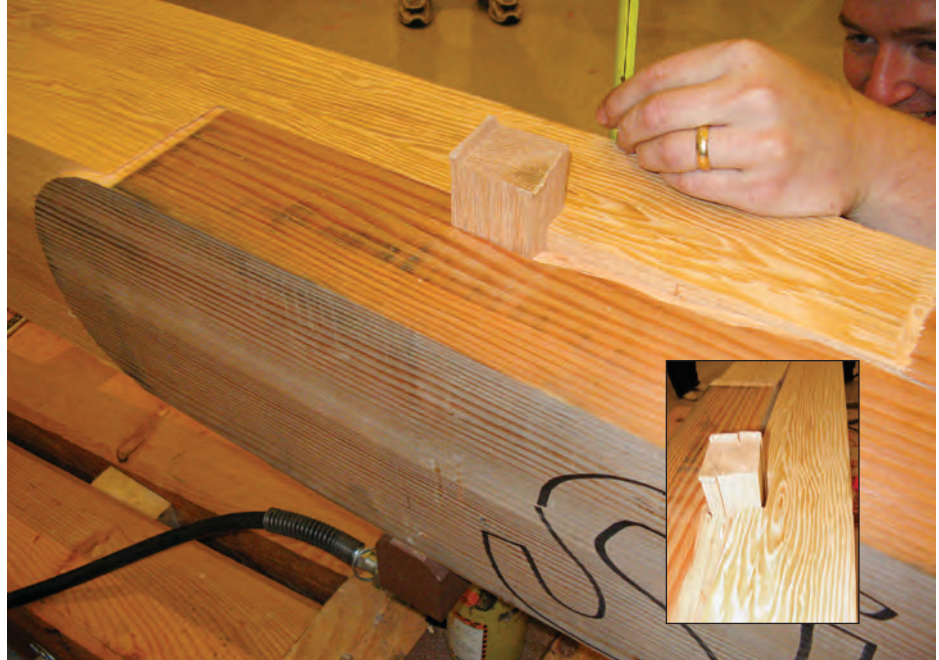
SOF (Saratoga or Bust) Scarf, Loyalist Timberframes. Code 2-VCS. Face-halved with sallyed and bridled butts. Moment transfer through bearing. Tension perpendicular to the grain failure as load pried joint apart.



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.

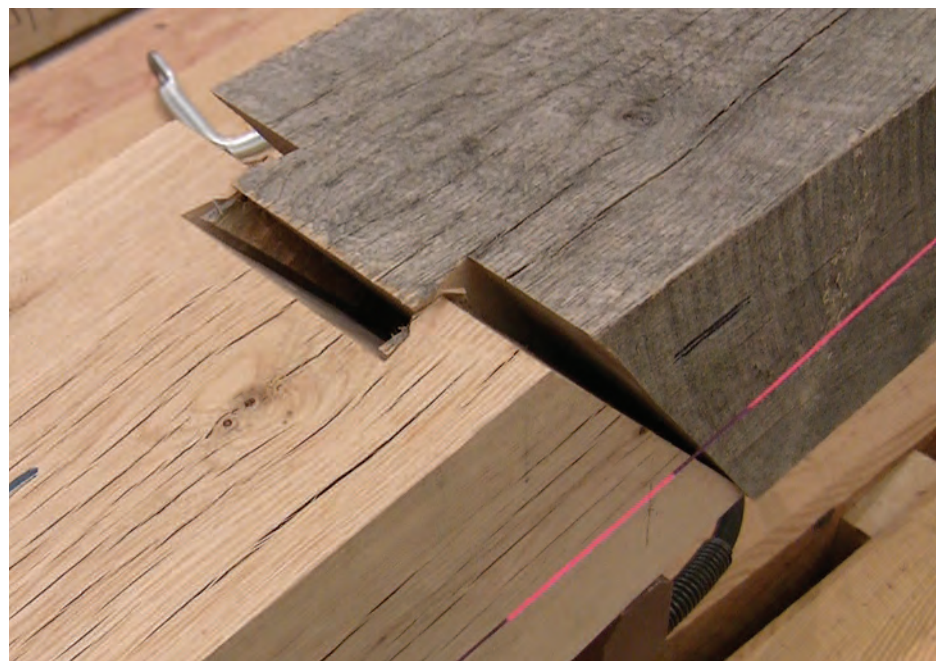
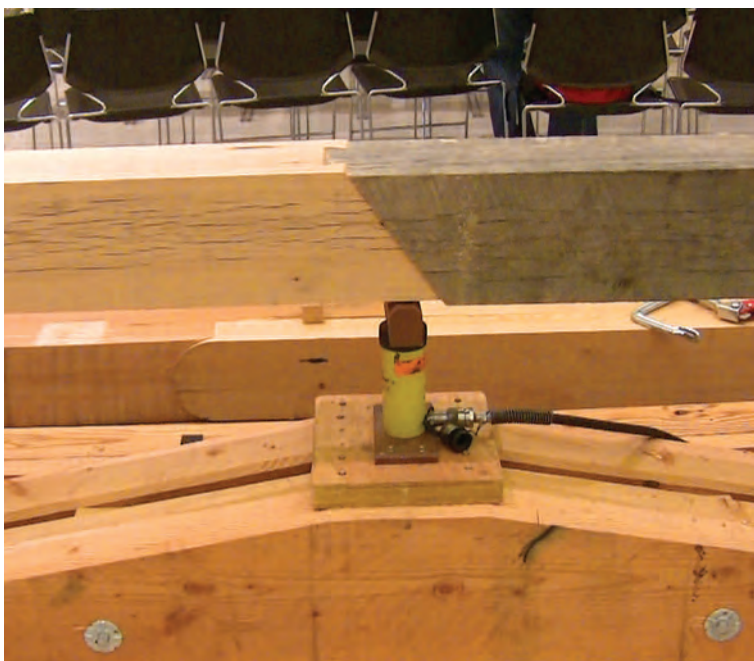
Below, Diamond Dove Scarf, Timberpeg. Code 4-CVLD. Face-halved and keyed with lapped sallyed butts and four edge pegs. Moment transfer through squinted bearing surfaces and dowels. Block shear failure.





Mack Magee

Pop-Sicle 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.



Mack Magee

Lignatools Scarf, Stefan Richter. Code 6-BJ. Squint-butted with dovetailed bridle. Moment transfer through dovetail tenon. Failure via shear at dovetail. Joint cut impromptu at Saratoga 2009 using machine at hand.

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.

Greg Stine



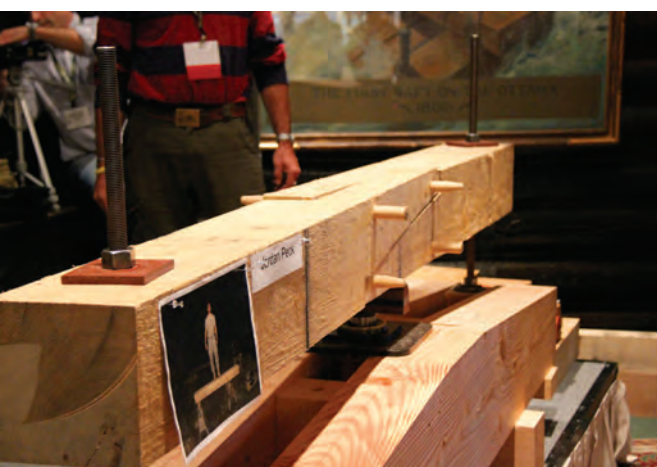


Photos these pages Joe Miller

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.

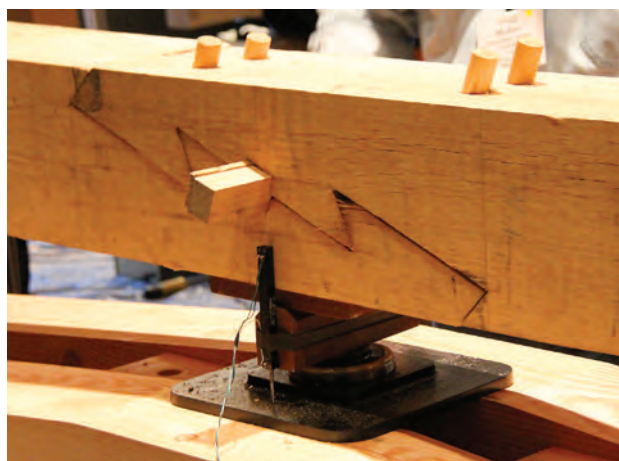


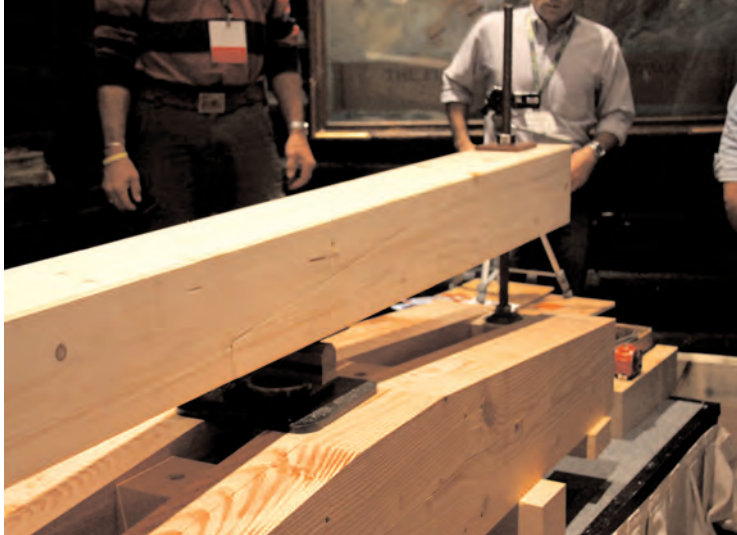
Jarrett Scarf, VMI. Code 9-VCSD. Variant on Bates. Face-halved with asymmetrical sallied butts and three edge pegs. Moment transfer through bearing and dowel shear. Failure in tension perpendicular to the grain (minimum dowel distress).



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.



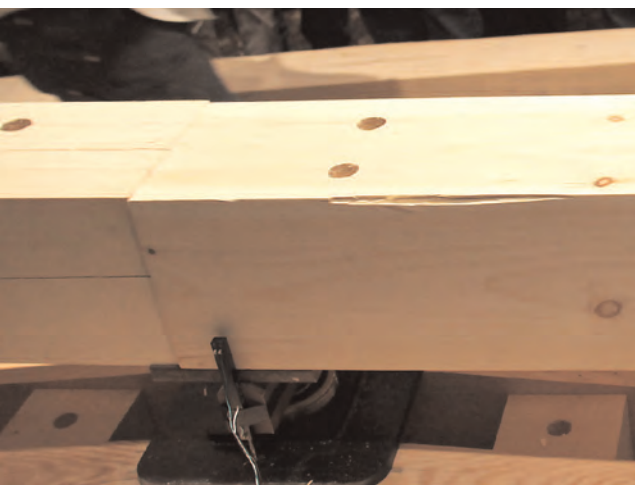
Hamlet Hemlock Solid-Sawn Beam, Hamlet Heavy Timberworks. Code 13-MN. Mother Nature's entry. Classic modulus of rupture failure, at 33,840 lbs. Test beam was parted from longer one with drill and auger bit, under desperate conditions.



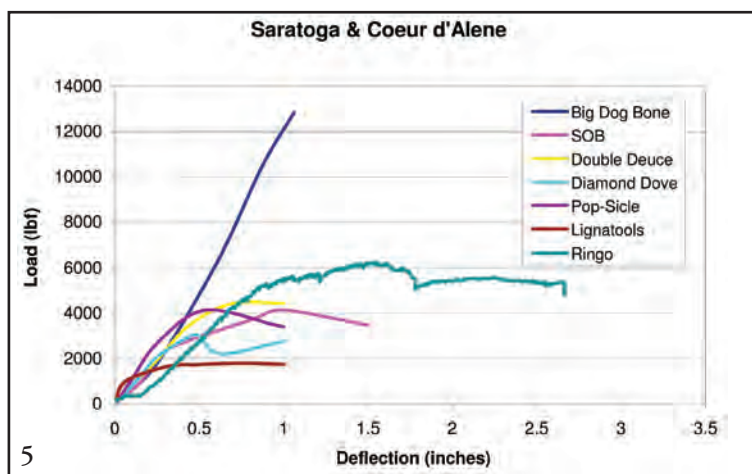
Hamlet Beaver Tail, Hamlet Heavy Timberworks. Code 14-HLMC. Edge-halved with bridled and pegged square abutments and eight face screws. Moment transfer through mechanical connectors and bearing. Failure by withdrawal of mechanical connectors and shearing of dowels. Small square brass plate is ornamental. Insert in photo at right shows shear failure of peg fastening bridled abutment.



Okake Daisen, Adam Zgola. Code 15-VL. Face-halved, stop-splayed, tabled and bladed. Moment transfer through bearing alone. Block shear failure predominated with minor failure in tension perpendicular to grain. Inset shows detail of top view.



Photos and charts this page Joe Miller



Timberlinx 1, Timberlinx. Code 16-BJMC. Square-butt with patent metal connectors. Moment transfer through tension and compression connectors in their respective zones. Failure via dowel bearing. View at right shows bending of (steel) dowels crossing tension connectors.

5 Graph of scarf test results at Saratoga 2009 and Coeur d'Alene 2010 conferences. Big Dog Bone test stopped for safety reasons.

6 Graph of scarf test results at Montebello 2010 conference.

7 Comparison of solid sawn beam with well-cut conventional edge-halved scarf with bridled abutments and mechanical connectors.

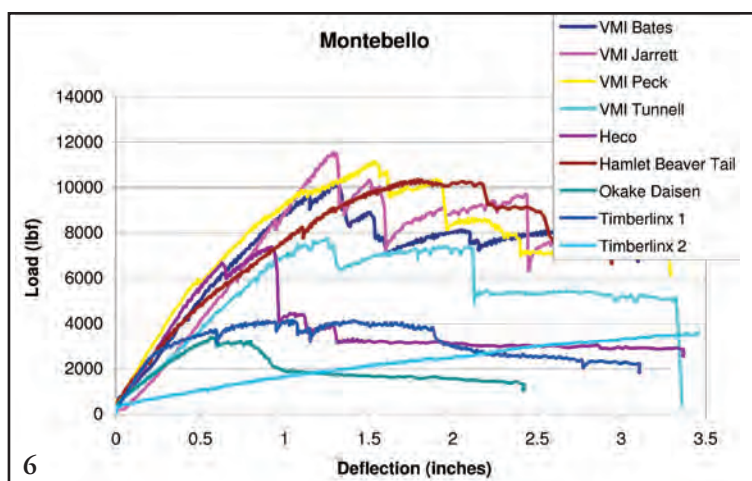


Table of Results

NAME	TEST	LOCATION	MAKER	SIZE	SPECIES	SCARF TYPE	DEFLECTION at 1000 lb (in.)	LOAD at 1/4 in. (lb)	MAX. LOAD
Big Dog Bone	01:BJMC-BVH	Saratoga	Chris Carbone Bensonwood	8 x 8	Red Oak	Square Butted with Steel Barbell Connector, Spline and 4 Edge Pegs	0.156	1795	12,835
SOB	02:VCS-LTF	Saratoga	Ray Gibbs Loyalist Timberframes	8 x 8	Recl. Doug. fir	Face-Halved with Sallied Butts	0.156	2040	4140
Double Deuce	03:VLD-TP	Saratoga	Jesse Kendall Timberpeg	7½ x 7½	Doug. fir	Face-Halved and Tabled with 2 Edge Pegs	0.125	1930	4445
Diamond Dove	04:CVLD-TP	Saratoga	Jesse Kendall Timberpeg	7½ x 7½	Doug. fir	Face-Halved and Keyed Lapped Sallied Butts with 2 Edge Pegs	0.125	2070	3010
Pop-Side	05:VLW-TP	Saratoga	Jesse Kendall Timberpeg	7½ x 7½	Doug. fir	Face-Halved and Keyed with Radiused Butts	0.094	2675	4140
Lignatools	06:BJ-LT	Saratoga	Stefan Richter Timber Tools	8¼ x 8¼	White Oak	Squint-Butted with Dovetail Bridle	0.063	1625	1795
Ringo	07:VLSP-CTF	Coeur d'Alene	Pete Peters Cornerstone Timberframes	8 x 8	Doug. fir	Face-Halved and Scissored with Steel Shear Plates	0.255	955	6275
VMI Bates	08:VCS-VMIB	Montebello	Nick Bates Virginia Military Institute	8¼ x 8¼	White Oak	Face-Halved V-Bridge with 4 Edge Pegs	0.064	2540	10,225
VMI Jarrett	09:VCS-VMIJ	Montebello	Marshall Jarrett Virginia Military Institute	8¼ x 8¼	White Oak	Face-Halved V-Bridge with 3 Edge Pegs	0.154	1725	11,535
VMI Peck	10:VLS-VMIP	Montebello	Jordan Peck Virginia Military Institute	8¼ x 8¼	White Oak	Face-Halved and Scissored with 4 Edge Pegs	0.050	3405	11,140
VMI Tunnell	11:HLWD-VMIT	Montebello	Andrew Tunnell Virginia Military Institute	8¼ x 8¼	White Oak	Edge-Halved and Keyed, Stop-Splayed and Tabled, Undersquinted Abutments and 4 Face Pegs	0.087	2005	7760
Heco	12:HLMC-HTFH	Montebello	Andreas Herrmann Herrmann's Timber Frame Homes	7½ x 7½	Spruce Glulam	Edge-Halved and Stop-Splayed with Face Screws	0.065	3950	7380
Hamlet Solid	13:MN-HHTW	Montebello	Daniel Addey-Jibb Hamlet Heavy Timberworks	7¼ x 8½	E. Hemlock	Mother Nature's Joint (Solid-Sawn Timber)	0.040	6320	33,840
Hamlet Beaver Tail	14:HLMC-HHTW	Montebello	Daniel Addey-Jibb Hamlet Heavy Timberworks	7¼ x 8½	E. Hemlock	Edge-halved with Bridled Abutments, 2 Edge Pegs and 8 Face Screws	0.051	2885	10,365
Okake Daisen	15:VL-AZ	Montebello	Adam Zgola	5¼ x 7¼	E. White Pine	Face-Halved, Stop-Splayed Tabled and Bladed	0.084	1910	3405
Timberlinx 1	16:BJMC-TL1	Montebello	Neil Maclean Timberlinx	7½ x 7½	E. White Pine	Butted with Patent Steel Connectors	0.070	2715	4140
Timberlinx 2	17:BJMC-TL2	Montebello	Neil Maclean Timberlinx	7½ x 7½	E. White Pine	Butted with Patent Steel Connectors	0.470	730	3625

8 Table of results. All told, scarf-jointed timbers perform in bending in a range of 20–30 percent of the strength of a solid timber.

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 suitably oriented 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
Mack Magee (mack@fjet.biz) is a principal at Fire Tower Engineered Timber in Providence, Rhode Island. Colleagues Joe Miller, Ben Brungraber and Duncan McElroy assisted materially with the preparation of this report, and Miller and Brungraber with the testing at the conferences. Bensonwood Homes and FraserWood Industries kindly supplied the reaction beams for the test rig.



All photos Mike Laine except where noted

- 1 Elementary brackets on utility building at Nan-ch'an Ssu (782), Wu-t'ai Shan, Shansi Province.
- 2 Gateway with ceramic brackets, Forbidden City, Beijing.
- 3 Elaborate brackets of a newly rebuilt temple building in the Forbidden City.

Tou-kung Brackets and China's Wooden Monuments

Earlier this year, Richard and Jean Wiborg, aficionados of Chinese architecture, escorted a 25-strong group of architectural adventurers around northern China, visiting ancient timber frame buildings. We were in good hands. Richard is fluent in Chinese and has been studying and surveying Chinese timber frames off and on for over 10 years, often with the help of Ma Bing-Jian, an architect, timber frame builder and China's reigning expert on historic timber-framed buildings, who frequently accompanied us.

While it's largely true that all timber-framed buildings are more alike than different, every culture develops a unique style, and so it is with the Chinese. A central element of the tour was to identify and learn the singular characteristics of northern Chinese timber frames. Mr. Ma (as everyone calls him) and the Wiborgs planned a tour that would survey the development of the Chinese timber frame, from buildings a few hundred years old to structures still standing after 1000 years or more. We saw and learned so much that only a very much longer account than what follows could describe the breadth of our experiences. Richard and Jean Wiborg must be thanked for their wonderful work in preparing this tour. If ever it is offered again, do not miss it.

THREE characteristics stand out in Chinese palace and temple timber frames built in the last 2000 years. They are always built on raised platforms, they are always built with at least two rings of posts (the peripteral or outer ring and the hypostyle or inner ring), and the roof eaves always rest on a bracket system assembled above and between the posts. Of the three characteristics, it's the bracket system, or *tou-kung*, that gets your attention and holds it. One iteration or another is an essential architectural and structural element in a great many historical timber frames built in China, whether utilitarian (Fig. 1) or ceremonial (Fig. 3).

Symbolically, the brackets are an identifying marker of Chinese architecture, so much so that the bracket motif is carved even into ancient stone buildings, and the brackets are fabricated in tile when an important gateway is made of masonry (Fig. 2).

Structurally, the brackets serve important functions. They support a purlin that runs outside the wall plane to support the rafters of superextended eaves, and through a multitude of connections they act as shock absorbers and points of flex to resist the shake, rattle and roll of earthquakes (Fig. 4).

Today's academic understanding of the bracket system (and generally of the history of Chinese timber framing) originates in field studies begun by Liang Ssu-ch'eng (1901–1972) and Lin Whei-yin, a married couple, in the early 1930s for the Institute for Research in Chinese Architecture in Peking. Both had studied architecture at the University of Pennsylvania in the 1920s and traveled widely before returning to China. The seminal work Liang eventually wrote in English, *A Pictorial History of Chinese Architecture*, edited by Wilma Fairbank and published posthumously in 1984, is beautifully composed and illustrated, and includes the compelling history of the brackets.

In the last 400 years, cantilevered eaves have been much reduced in projection, and the supporting function of the bracket similarly reduced. But perhaps because of their role in mitigating the destructive forces of earthquakes, they remain an essential feature of Chinese palace and temple frames. To get a quick lesson on the bracket system, there is a wealth of information in Liang's annotated drawings of the Chinese "Order," Sung dynasty building rules of 1103 and Ch'ing dynasty rules of 1733 (Figs. 5–7).

The illustrations of the early bracket systems show how the sloped cantilever arm, the *ang*, functions structurally. In the oldest buildings, the tail of the *ang* terminates under the first purlin inside the wall plane, and the beak of the *ang* (17 in Fig. 5) sup-



Ali Lam



Illustrations from Liang Su-ch'eng, *A Pictorial History of Chinese Architecture*, MIT Press, 1984, used by permission

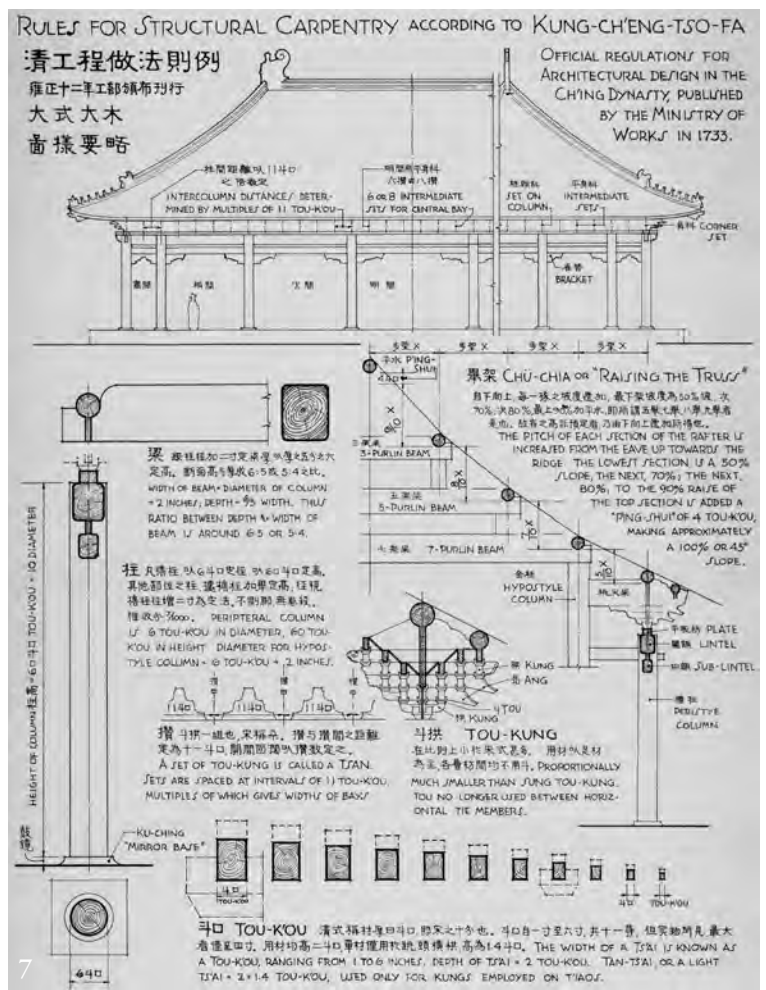
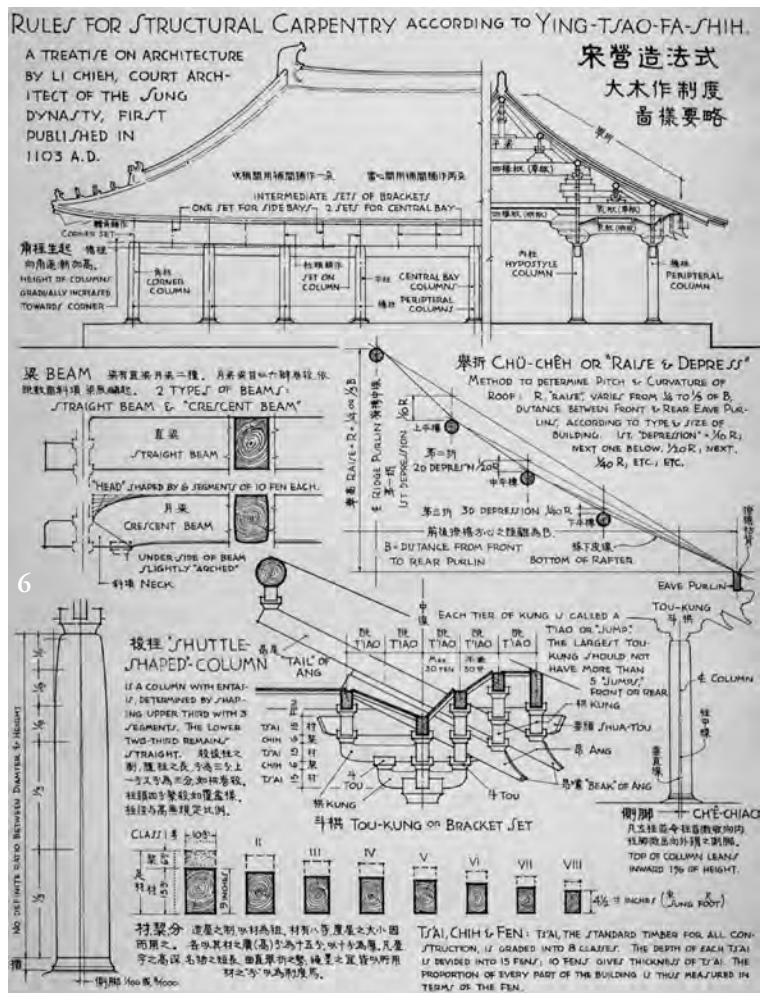
4 *Tou-kung* at the architecture school, Tsing Hua University, Beijing.

5 Liang's annotated perspective drawing of the Chinese "Order."

6 Liang's representation of Sung dynasty (960–1279) rules, 1103, with proportional rules in lower right corner.

7 Liang's representation of Ch'ing dynasty (1644–1912) rules, 1733.

ports a purlin outside the wall plane, using the weight of the roof inside the wall plane to balance the weight of the roof over the eaves. As the centuries rolled by and the superextended eaves were reduced, the *ang* morphed into a simple horizontal cantilever arm. Notice that in the Ch'ing building code manual of 1733, the *ang* is no longer a diagonal member but only a horizontal component with a fancy beak (Fig. 7).





8 Massive hip brackets at Kuan-yin Ke, or Hall of Avalokiteshvara, Hopei Province, built in 984, with added post under super-extended eaves. Building has survived 32 major earthquakes.



9 Maze of brackets supporting roof of T'ai Miao, Imperial Ancestral Temple, Imperial Palace, Forbidden City, Beijing. Rebuilt in 1545.

It is true that in the buildings that remain from earlier periods, the super-extended eaves often show obvious signs of serious stress and even imminent failure. For instance, the four hip rafters at Kuan-yin Ke, a large hall built around a 52-ft.-high Buddhist statue, are now supported by long posts, with extensions (Fig. 8). Perhaps the difficulty of maintaining the structural integrity of the long eaves, given the weight of the huge roof, drove Chinese timber framers to scale back their engineering by the time of the Ming dynasty (1368–1644).

Liang's illustrations (Figs. 6 and 7) also show the derivation of the proportions and dimensions of the bracket members (and thus of every other part of a building). The bracket arm, or *ts'ai*, is one of the short horizontals in a bracket set. During the Sung dynasty, there were eight standard sizes, all with the 3:2 proportion of depth to width. The depth of the *ts'ai*, divided into 15 parts called *fen*, then drives everything. First, the width of the *ts'ai* is 10 *fen*. Then, writes Liang on page 15 of *A Pictorial History*, "The height and breadth of every building, the dimensions of every member in the structure, the rise and curve of the roofline, in short, every measurement in the building, is to be measured in terms of *fen* of the grade of *ts'ai* used." The larger the *ts'ai*, then, the larger the *fen*. The highest grade of *ts'ai* was reserved for the emperor. In Chinese architecture, size matters, and no building could be taller or wider, or use timbers larger than the emperor's. The status of a building was determined by how close in dimension it came to the emperor's. But regardless of status, all monumental timber-framed buildings are scaled the same way, beginning with the *ts'ai*.

WITH some or none of this information in mind, 25 of us showed up in Beijing early in April. Our professional guide, Mr. Chen, met us at the airport and managed to get our travel-stunned group to the four-star Sunworld Hotel. We started the next morning with an assault on the Forbidden City, joined by a million or so other tourists in Tiananmen Square. We were herded through the crowd with our Mr. Chen in the lead, holding up a flag emblazoned with the TFG logo so we could keep him in sight. Most of the other million tourists were in similar groups, also with flag-bearers in the lead, so there was a parade feel to it all. As we made our way through this most amazing imperial compound, Mr. Chen supplied us with a steady stream of information, rattling off dates and explaining use patterns, the symbolism of the elaborate painting

motifs on the buildings and much more. Many of us were seeing Chinese buildings for the first time, and it was very impressive, even overwhelming. The Chinese think big (Fig. 9).

For a couple of hours, we inched our way through the public section of the Forbidden City, standing in awe of Chinese timber framing in its most elaborate form—learning about gemstones by starting with diamonds. After the morning tour, we boarded our bus and headed off toward T'ien-t'an, the Temple of Heaven, a complex of buildings southeast of the Forbidden City, with a stop first for lunch. Since tour groups are so common in China, numerous restaurants specialize in group feeding. Mr. Chen knows them all. We settled into one not far from the Temple of Heaven and had a meal that would become familiar over the next two weeks. We sat at round tables for ten, with a giant turntable in the middle piled with a dozen or more plates of stir-fried, deep-fried and steamed food, mostly vegetables, pork and rice. Mr. Chen assured us that he had checked with the chef to make sure that there was nothing too spicy or weird for our Western tastes—that it would be just like the Chinese food back home! There was definitely something for everybody, and always more than we could eat. Beer was the beverage of choice, or tea of course.

The most remarkable structure in the Temple of Heaven, the world's largest religious architectural complex, is Ch'i-nien Tien (Qi Nian Dian), the Hall of Prayer for Good Harvest, measuring some 104 ft. in diameter and 125 ft. tall, an astonishing building and a display of the Chinese thinking big in the 15th century (Fig. 10). The model on display behind glass gives a notion of how massive are the full-length coopered posts that go from foundation to roof (compare the riser height, probably 7 or 8 in., in the short stairway). The model also shows the countless brackets at the perimeters of the triple roof structure (Fig. 11).

Unlike the model, the interior of the building is painted, and, although the doors are open, there is no admission to these major tourist destinations, which makes sense given the thousands who come every day. But the interiors are dark and it is hard to see inside, so the model was very helpful in illustrating what exactly was going on structurally inside the Hall of Prayer. In spite of its overwhelming size, the Temple of Heaven and its surroundings are very peaceful places. I could have camped there for days.

For the next four days, with or without Mr. Ma and his assistant, Simone Wang, we toured temples and imperial buildings



10, 11 Ch'i-nien Tien, Hall of Prayer for Good Harvest, in the Temple of Heaven, Beijing, ca. 1420, burned and rebuilt 1895, 104 ft. in diameter and 125 ft. tall. Cutaway model shows full-length coopered posts.

12, 13 Below under the gaze of privileged tourists, workmen cart pavers in a courtyard under reconstruction in the Forbidden City. Below right, rough and ready mason's tools, including steel-soled planes used to trim and edge-bevel cast pavers for grouting.



around Beijing and the surrounding area, each one an astounding piece of work and worth every minute we had to examine them.

We spent a particularly interesting day at Tsing Hua University with Professor Wang and other faculty, where we had a two-hour discussion and question-and-answer session on Chinese timber framing, with a focus on brackets. We asked lots of questions about the brackets and earthquakes. To Western minds, it's counterintuitive that a building with an extraordinarily heavy roof (80 lbs. sq. ft. or more) sitting on a flexible bracket loosely connected to a post loosely connected to the foundation will withstand earthquakes successfully. But it does. The flexibility of the buildings is the primary reason for their survival. The absence of diagonal braces and the vast numbers of connections, many of them long through-tenons without pegs, not only allow for a great deal of flex, but the

latter also provide enough force to muscle the building back to its original shape when the shaking stops.

On our second visit to the Forbidden City, we examined a no-public-access section in the northwest quarter, in the vicinity of the Rain Flower Pavilion, a Tibetan temple, accompanied by Mr. Ma and Mr. Li, the director of restoration for the Forbidden City. He took us into the heart of the construction zone (Fig. 12). Much of the area has been quarantined since the 1920s. All around us we saw traditional Chinese hand-crafted carpentry, plastering and painting on restored or reconstructed buildings. Conspicuously absent were compressors and hoses, pneumatic tools or scatter boxes with cords running everywhere to power tools and appliances. We saw no Gradalls or forklifts, no electric lights. It all looked medieval, and so did some of the tools in use (Fig. 13).



14



15

DATONG (Ta-t'ung), a city of 3 million known for coal-mining, locomotives, rubber and heavy trucks, is a two-hour plane ride west of Beijing. Some of our ignorance of 21st-century China was dispelled during the bus ride into Datong from the airport. Our new guide, the very intelligent and informative Anna Liang, pointed out that Datong the city is moving—that is, a new Datong is being built next to the old one. Our very modern bus took us down a very new highway traversing a maze of new streets and boulevards, wide and straight, through a forest of cranes erecting high-rises in every direction. It's possible you have never seen anything like this. I certainly had no idea that so many cranes existed in the world, much less all apparently gathered here in this corner of China. And the concept of moving a city, all at once, was definitely new. Once again, I was reminded of the Chinese ability to think big, and of the power of the Chinese government.

The primary purpose of our stay here on the rim of China's coal region, with its countless power plants spewing horizon-killing smoke, was to visit the oldest timber-framed buildings in China. We spent five days in the countryside between Datong and Pingyao, the latter a UNESCO World Historical Site with city walls dating from 1370 and thousands of ancient houses, venturing forth in our comfortable bus to remote sites where these ancient timber frames have persisted for so many centuries. The buildings we visited, Shan-hua Ssu, Fo-kuang Ssu, Nanchan-Si, Fo-kung Ssu, Chin-t'su and several others, are the wooden treasures of China, and they evoke in a visitor the reverence and awe of magnificent structures in all ancient cultures.

The Hanging Monastery, or Hsuan-k'ung Ssu, about 40 miles southeast of Datong in Shansi Province, which we visited on a cold, snowy day, certainly got our attention for its audacious location about 150 ft. in the air above a riverbed (Figs. 14 and 15). A monk called Liao Jan is credited with founding the institution, which is devoted equally to Taoism, Buddhism and Confucianism. When we examined the deep mortises in the stone cliff for the timbers that hold up this narrow swallow's nest built piecemeal beginning about 1400 years ago, there was in our minds more than a bit of the question, "What were they thinking?" The unsightly long posts under the cantilevered buildings are a modern addition, perhaps a precaution to support the stream of tourists who wind their way through the temple every day, but their slenderness ratio does give one pause.

Standing at the entrance of the Fo-kuang Ssu Temple, built in 857 during the Tang dynasty (618–1907) and tucked into a deep valley of the Wut'ai mountains, I was overwhelmed by the commitment required to erect this structure, especially 1153 years ago. These were daring and energetic carpenters! The intricate cantilevered bracket system that supports the superextended eaves is bold engineering that can only be the result of centuries of practice on buildings that have vanished (Fig. 16).

This survivor, China's second-oldest known wooden temple (brought to light by Liang Ssu-ch'eng in 1937) is a testament to human devotion and to humanity's persistent need to erect awe-inspiring structures. We also saw China's oldest known wooden building, the main hall at nearby Nan-ch'an Ssu, dated to 782.

WHEN I first heard of this trip, the lure for me was to be in the presence of Mu-t'a, the Wooden Pagoda at Fo-kung Ssu in Ying Hsien, Shansi Province, built in 1056 (Fig. 17).

Mu-t'a is octagonal and appears to be a five-story building. But "since each upper story is underpinned by a mezzanine story," as Liang points out on page 68 of *A Pictorial History*, "it actually consists of nine tiers of superposed orders." Structurally, then, Mu-t'a is a nine-story tower, topped out by a finial 183 ft. above the deck—by modern standards the equivalent of at least a 15-story building. Fifty-six types of brackets hold up various porches, roofs and walls, making the pagoda a textbook example for any student of Chinese architecture. The building is a wizened giant displaying everything awesome in an ancient wooden building: grace, elegance, overwhelming grandeur, the courage, tenacity and skill needed to build it, and great age. Mu-t'a, burned and rebuilt 1191–1195, repaired 1320, 1508, 1722, 1866 and 1928, but not rebuilt since 1195, is such an emotionally moving structure that for anybody of any faith it could be a place of worship. At 815 years old, however, it could use a bit of help. The crushing weight of the upper stories is taking a toll on certain lower timbers (Fig. 18), and the tower shares a tilt with the better known one at Pisa.

—MIKE LAINE
Mike Laine (mike@woodenheart.us), an experienced builder and furniture maker lately specializing in entryways and gates, operates Wooden Heart in Menlo Park, California. For tour leader Richard Wiborg's perspective, visit www.richardwiborg.com. An earlier article about Beijing appeared in TF 94, and a series of analytic articles on traditional Chinese framing appeared in TF 16, 17 and 20.



16

Beth Bonora



17

14, 15 The Hanging Monastery near Datong was founded ca. 600 by the monk Liao Jan and has been repeatedly augmented and rebuilt. The slender props are recent additions.

16 Author standing under hip rafter bracket overhang of main hall, Fo-kuang Ssu (857), Wu-t'ai Shan, Shansi Province. Corner post's left-hand spiral grain, dreaded by Europeans, seems to have caused no harm.

17 Mu-t'a, the Wooden Pagoda at Fo-kung Ssu, Ying Hsien, Shansi Province, 1056, 183 ft. high.

18 Crushed timbers in the first level brackets, Mu-t'a. Paper tag appears to be part of a building-monitoring system.



18

Vancouver Island Green Retreat



Photos Jon Dewald

TOFINO, British Columbia, lies at the end of the Pacific Rim Highway on a western peninsula of Vancouver Island extending into Clayoquot Sound, just beyond Canada's Pacific Rim National Park. In this exceptionally endowed location we were asked to build a 1945-sq.-ft. timber-framed house intended as a second residence and for eventual retirement living. The house's main living area including master bedroom is thus on the ground floor, with only guest accommodation upstairs.

The Eco Rainforest Retreat, as we call it, aspires to balance sustainability with luxury, compact design with functional living and energy efficiency with architectural integrity. Tofino's 127-in. annual rainfall is captured from 75 percent of the roof area by an architectural rainwater catchment system, harvesting water used for laundry, toilet flushing, outdoor shower and exterior hose bibs. A 1600-gal. tank fills via a 2-in.-dia. inlet pipe every time it rains (which is a lot); excess water simply flows out of one of many overflows, including if necessary a 3-in.-dia. outlet from the tank, deliberately more than twice as large in section as the inlet. Municipal water supplies the potable lines and the pipes are color coded for identification.

The owners wanted the house constructed to a very high standard, and of durable materials suitable for the wet environment. It was to incorporate as many sustainable features as possible, to be energy efficient, large enough to accommodate guests yet small enough to manage later in life, all while making a small ecological footprint. Jamie Martin of Squamish, British Columbia, followed the program and produced the design. The house ultimately was certified Platinum by Built Green Canada and also certified the first LEED Canada for Homes Platinum Timberframe Home. It won the 2010 Highest Rated Built Green BC Home award.

Construction The timber frame was cut on a Hundegger K2 CNC machine from select structural Douglas fir timber, free of heart center, from local forests. Posts were 10x10 and beams mostly 10x12 with the odd 10x14 for higher loads; rafters were 4x8. With

a small footprint, the house had no especially large or long timbers, but the whole was erected with a mobile crane. The structure sits atop an insulated concrete form foundation wall with an insulation value of R24, enclosing a crawl space.

The timber joinery and other assembly connections were detailed to mitigate air infiltration, a common problem for infill-style timber frames (along with thermal bridging, but a lesser problem in our moderate climate), and finished with Broda, a water-based, low-VOC product. Air infiltration at the joinery was addressed with adhesive-backed foam tape placed between mating surfaces at tenon shoulders before erection, quite effective in the short term (based on our blower-door tests) though untested in the long term, and unable to account for eventual checking of timbers penetrating the building envelope. Air leakage after assembly will have to be addressed by applying a sealant.

The infill walls comprise 2x6 framing with formaldehyde-free R22 fiberglass insulation, sheathed outside with ½-in. plywood, a Typar air barrier with vented rainscreen behind it and cedar siding. This wall system, which exposes all of the 10-in. posts and beams to the interior and many to the exterior, looks beautiful, but we will be trying to avoid it in the future for energy reasons. The infill framing material was sealed to the timberwork with a nondrying caulk; the air barrier was also sealed to the timberwork with the same caulk and taped. (It's difficult and messy to achieve an airtight seal, and it allows for only a certain amount of movement. We look forward to the early arrival from Europe of very high elasticity tapes that will stick to various materials including concrete.)

The roof is a site-constructed foam insulation sandwich above the 4x8 fir rafters. The insulation extends to the exterior building envelope without any wood thermal bridging or any air leakage.

As southwest British Columbia is not a high-heating-demand region, the insulation levels required are quite a bit lower than for other parts of the country. Additional roof and wall insulation levels required elsewhere would likely eliminate the possibility of infill framing without resorting to giant timbers to have them exposed on both sides. A wrapped frame would then be a better choice.

Heating and Cooling A small ground-source heat pump incorporates horizontal loops placed below the water table to heat domestic hot water and to heat or cool interior air distributed via an air-handling system. A wood stove provides backup heat for the winter power outages frequent in Tofino, during which the heat pump is disabled. The house is also wired with a transfer switch for temporary use of a generator (if desired) during power failures as well as for the future addition of photovoltaic power generation on the south-facing roof slope.

Passive solar design (East-West axis) and overhangs allow glazing to be shaded during summer and unshaded during winter months. The drywall construction is airtight. The appliances, lights and windows are all Energy Star rated. The house has a Natural Resources Canada EnerGuide rating of 86 out of 100.

Indoor Air Quality Essential fresh air ventilation is handled by a heat recovery ventilator (HRV) that captures heat from extracted stale air to prewarm injected fresh air, with about 75 percent efficiency. Blower-door tests show air changes per hour at 1.33. (The North American norm is somewhere between 3.5 to 5.5.) The balanced HRV system provides forced fresh air in amounts equal to the amount of exhausted air, set as required by the British Columbia building code (quantity of bathrooms, kitchens, etc.) but programmable for additional fresh air when the occupant load is high, say during a party. In addition to the HRV installed for fresh air ventilation, the air-handler for heat and cooling uses very high efficiency (MERV 14) air filters.

The floor coverings are hardwood or tile to reduce dust; paints, finishes and construction adhesives (including in cabinet work) were all low-VOC rated to reduce interior air contamination. The airtight building envelope reduces the potential of contaminated outside air entering without being filtered by the HRV. Ducting for the air-handling system was sealed off during construction. Before occupancy the house was completely flushed with all systems on high for 48 hours, and new filters installed.

Sustainability From the beginning of construction, great emphasis was placed on preserving site soil and vegetation and on using local materials, salvaged or recycled when possible, as well as certified sustainably harvested wood and wood products. The building footprint was small, leaving 60 percent of the site untouched by invasive construction and landscaping practices such as grading and monoculture turf. The entire lot outside the building is permeable to rainwater. Only native species were planted, eliminating any need for irrigation. This allows the native ecosystem to flourish while awarding homeowners a natural view through the floor-to-ceiling windows. Designed specifically for the lot, the house is able to harvest passive solar energy through glazing unshaded in the winter, its broad overhangs meanwhile protecting the walls against the region's frequent rain.

—RICHARD LUTZ
Richard Lutz AIOC (richard@alpinetimberframe.ca) operates Alpine Timber Frame and Design in Garibaldi Highlands, B.C., Canada.

1 Wide exterior overhang to left in photo protects against wind-driven winter storms from that direction and provides a covered patio area in summer. Framing here is intentionally concealed from harsh environment, with siding flashed above every course.

2 Open plan of kitchen, living and dining spaces. Oversized landing has sitting area with pullout bed.

4 View of kitchen from dining area. Old telephone at far right is in working order and belonged to owner's grandfather. It was kept safe "until he had a timber-framed house to put it in."

3 Infill framing is apparent in this view looking out behind house.



Visit with a Collector-Craftsman



All photos Sarah K. Highland

HUSTON DODGE has been gathering and studying pieces of wood, mostly in Damariscotta, Maine, for 83 years (Fig. 1). At the age of ten he rescued a pair of fluted pilasters from a pile of old wood; years later they ended up flanking the door to the house he built himself from salvaged parts (Fig. 2). Now in his nineties, Huston still has wood-working projects he'd like to finish. Perhaps that's what gives such vitality and sparkle to his face and keeps him agile enough to climb ladders and thread his way through mazes of boards and trim.

Glad to meet a carpenter interested in history and old things, he received me with enthusiasm and a constant stream of stories. From the deluge of information emerged the portrait of a most remarkable man. Born Joel Huston Dodge in 1916 into a well-to-do family, his father was more than busy running several businesses in town. The son, however, was not interested in following his father's example. He spent his free time exploring the many abandoned houses in the neighborhood and learning about tools from retired shipwrights. As a teenager he rebuilt an outbuilding on his parents' property and used it to house his growing collection of scrounged woodwork and hardware. He was putting to use an expanding array of old hand tools, including molding and panel-raising planes, and he began his model-making career with a replica of Shakespeare's Globe Theatre. His father gave up on a plan to

send his son to Bowdoin College and Huston was instead able to attend Wentworth Institute in Boston in the 1930s, where he learned building construction, blacksmithing and welding.

After Wentworth, Huston spent eight months at Wallace Nutting's reproduction-furniture workshop in Framingham, Massachusetts, assembling chairs and mirror frames. After-hours he was allowed free range of the shop for his own projects. Over the years since, he built himself a number of pieces from Nutting's catalogue. During the Second World War, Huston spent four years overseas. His job, keeping the gas stoves running for Army kitchens, gave him a fair bit of time off to explore the buildings and flea markets of England, Belgium and Germany, and to widen his perspective considerably. He continued his projects in the Army, making small pieces of furniture and carved wooden boxes with hinges and locks he fashioned himself.

Returning home to Maine, he worked with carpenters and house-wreckers, including a season with a prominent builder who was unimpressed by his interest in old tools and methods, complaining, as Huston recalls, that "we carpenters have been trying to change things for a hundred years and now you want to go backwards!" At the time, abandoned houses and barns in the towns around Damariscotta were being dismantled by house-wreckers and the resulting timber sold off. Huston worked with a number



1 Huston Dodge at family house in Damariscotta with ship's billethead he carved from photo in book.

2 Discarded pilasters flank door of house in woods he built of salvaged materials, where he lived for many years.

3 Center-chimney Cape assembles house parts gathered up and down Maine coast.

4 View from loft. Roof framing, atypical of region, has square common rafters on about 3-ft. centers, while typical coastal framing comprises principal rafters, common purlins and English tying joint.

5 Periodic collar beams stiffen roof and support loft boards. Tie beams, unseen at base of rafter pairs, lap plates to form eaves overhang.



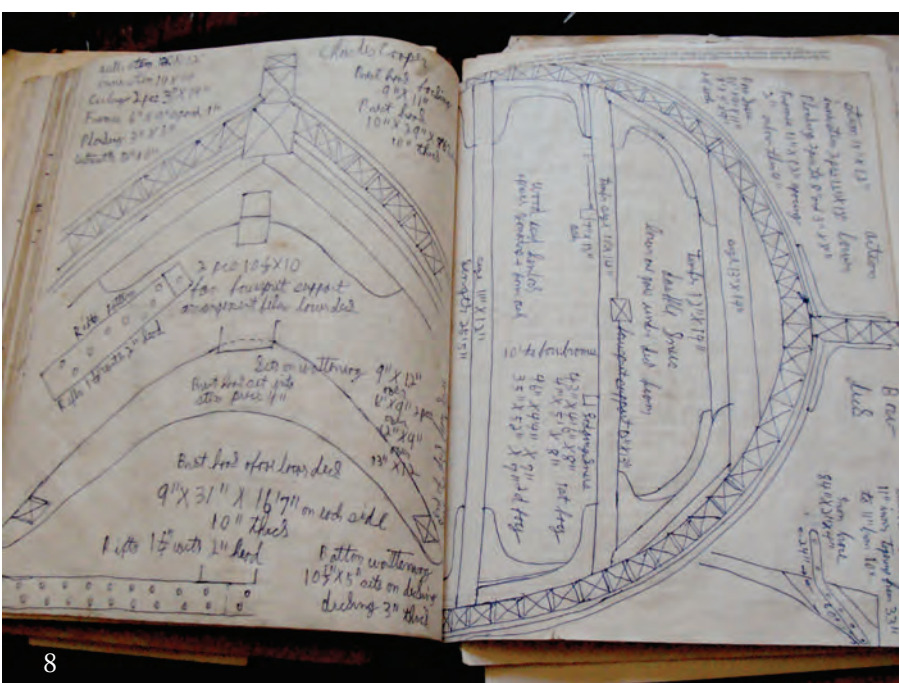
of these men and steadily collected building parts. Unlike many of his contemporaries, Huston was fascinated by the old frames and hand-wrought woodwork, and wanted to save as much as he could from destruction.

The house (Fig. 3) he built and lived in until he inherited the family home is a fascinating assemblage of salvaged pieces from up and down the coast. The frame is unusual for the area. Most houses of the region have what Huston calls rib-and-rafter roofs (principal rafters with common purlins), boarded up and down from ridge to eaves with full-length planks that shed much of the rainwater from the roof even before the shingles went on. The tie beams of these roofs are typically secured in English tying joints, with lap dovetails over the plates and mortises over the teazle tenons of the jowled posts (or "fantail" posts, as he calls them).

The roof frame (Figs. 4 and 5) Huston salvaged, however, has stout rafters and tie beams about 3 ft. on center, boarded parallel to the ridge. The ties lap the plates and extend beyond for a 6-in. overhang. The rafter peaks tenon into a full-length ridge beam, making for a difficult assembly job that required helpers and a good deal of scaffolding. There are two wind braces from rafter to ridge at each end, oddly located in separate rafter bays. Huston took boards from several houses to sheathe the building and sided it with clapboards that he scarfed in the old manner, beveling the

ends to lap. The inside is finished entirely in wood. The windows have 18th-century interior sliding pocket shutters. The walls are boarded with tongue-and-groove sheathing boards from another house in Damariscotta, some up to 2 ft. wide. The dentilled cornices came from Walpole (down the cove) and Portland and the ceiling boards were taken from the roof of an old schoolhouse. For one of the ceilings, Huston planed salvaged boards by hand with a halving (shiplap) plane and beader for one edge and a panel-raising plane for the other, making an elegant pattern overhead, one usually found only on walls.

For a while Huston owned a small water-powered sawmill, which he restored to working order. He did not run it commercially but it did produce the boards for some of his own projects. Intrigued by these old up-and-down mills, he built two scale models of mill buildings, one made of timber from the original dismantled frame, ripped to $\frac{3}{4}$ -in. by $\frac{3}{4}$ -in. posts and beams on the table saw. The other model contains a complete miniature sawmill with moving parts (Fig. 6 overleaf). The process of repairing and operating his own up-and-down mill gave Huston an understanding of historic machinery and methods that could not likely be gotten any other way, and his model-making experience dates from his youth in the 1930s, when he made an elaborate house model complete with interior finish and millwork (Fig. 7 overleaf).



The old barn at his family home having fallen down before he was born ("my father wasn't partial to barns"), Huston decided to replace it using the frames of two barns to build a new one on the old foundation. The frame, a five-bent rib-and-rafter assemblage with English tying joints, was raised with a few helpers, piece by piece with gin pole and comealong, over the course of two weeks. For barn doors, one set he simply rehung, estimating they were from the 1840s, though fitted with artful wrought hinges from a century before. The other set he built himself by the method he believed was traditional: setting three full-length battens across the opening in notches in the corners of the posts, nailing on vertical boards from the center out, mounting the hinges, and finally sawing the battens at the center to produce double doors. (See TF 84, "Finishing the Barn," for more on such construction.)

"It's an easy way to frame," Huston said of the big double doors. "They're heavy!"

In 1983, Huston was invited to join a small team to go to the Falkland Islands to document and salvage the *Snow Squall*, an 1851 Portland-built clipper ship, for the Spring Point Museum in South Portland, Maine. According to Huston, the Falkland Island Salvage Company had an arrangement with northern insurance companies such that when ships were disabled, they were sent down to the treeless archipelago. There they were beached in shallow water, dismantled and covered in tin roofing, and the dry upper decks used for warehouse space to store wool, while "the lower decks went to hell."

The team from Maine included historian and photographer Nicholas Dean (who initiated the project and published a book on the *Snow Squall*), a draftsman to make measured drawings of the hull, marine archaeologists, and carpenters to salvage sections of the ship to send back to the museum. Huston has a notebook filled with sketches from that trip. While other members of the group were attending cocktail parties, Huston said, he took advantage of the long sunlit evenings to prow and sketch as many vessels as he could get into. Though most of the hulls were rotting to pieces, they still afforded an extraordinary opportunity to examine a collection of century-old ships, and his drawings reflect a variety of carpentry in their construction (Fig. 8).

Huston's current home in Damariscotta (Fig. 9), built by a great-great-grandfather in 1795, is a big two-story structure with a hip roof framed with a pair of posts carrying the upper ends of the hips and connected to one another by a straining beam and a light ridge (Figs. 12 and 13). The posts sit on crossbeams in the attic floor, supported by plank bearing walls. Huston credits the massive and closely spaced attic floor beams for the excellent condition of the original plaster ceilings below.

Doorways in the interior plank partition walls are formed by rabbets in surrounding planks to provide integral stops for the doors, and cased to match the thickness of the lath and plaster (Fig. 10). On the exterior, the window jambs and casings are not separate slender elements boxed together as in today's construction, but rather stout single elements 3x4 in a tenoned assembly with the stools (or sills) below (Fig. 11). The sides and head are rabbeted on their outer front edges to receive the combined thickness of the wall sheathing and shingle siding, in a kind of self-flashing arrangement. Huston has reconstructed several windows that were enlarged during a remodeling phase in the last century.

HUSTON'S work is contradictory and hard to pigeonhole. His own timber framing work can tend toward the crude, with tie beams bolted down onto tenonless jowled posts and scarf joints simple splayed affairs reinforced by bolts. His models, doors and furniture, on the other hand, are meticulously joined. Some of his salvaged outbuildings appear to have been thrown up quickly to house his enormous collections.



9

6 Model sawmill built by Huston when he ran his own full-scale mill.

7 Model Cape house he built at the age of 20. Doors and windows function.

8 Sketch of the *Charles Cooper*, drawn on site in the Falkland Islands in 1983.

9 Huston's family house, Damariscotta, built 1795.

10 Plank wall is lathed and trimmed directly; backband covers plaster joint.

11 Exterior window frames are pegged together and self-trimming.

12 Roof hips, commons, ridge all arrive at post chamfered to octagon.

13 Hewn hips carry tenoned jacks; purlins span between commons or jacks.



10



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12



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14



15

Huston's jobs have included hand-planing moldings using original tools (Fig. 14), replacing sills, carving, house-wrecking and general carpentry. Over the years a number of dismantled ells and outbuildings found their way to Huston's property, including an ell reinforced by ship's knees taken out of an old fish-house, to support a formidable collection of tools and hardware upstairs (Fig. 15).

Until a few years ago, Huston could be seen out on the roads around Damariscotta in his ancient Jeep with a pile of long timber sticking out 10 or 20 ft. fore and aft, moving along cheerfully at 20 miles an hour with a line of summer traffic behind. Now he counts on friends to drive him places, and the Jeep has joined the acres of salvaged wood (Fig. 16) and buildings out back of the house.

The collection that I find most fascinating is Huston Dodge's memory. He can tell you where every bit of framing and molding came from in each of his buildings: "Oh yes, that oven door came from the Billy Hunter house over by Walpole meetinghouse—you know where that is?" Driving with him around Damariscotta, I got a running commentary on almost every building we passed. Huston can tell you the vintage of any house in town, which had its hip roof rebuilt as a gable a century ago, which church has ship's knees in the steeple. The cove where the hospital now sits was once home to the Day and Huston Shipyard, co-owned by his great grandfather.

With all his vast knowledge of things past, Huston is alive to the present as well. He enjoys company and continues to work on his house. He eats garlic with every meal. "You have to eat right, exercise, keep active or you'll fall to pieces," he says. Of his days so far, he observes, "I've had a life that hasn't been bad at all, accomplished a fair number of things." And that seems quite good enough for him.

—SARAH K. HIGHLAND

Sarah Highland (sarahkh@lightlink.com) is a builder and teacher in Ithaca, New York.

14 Jumble of tools belies working abilities.

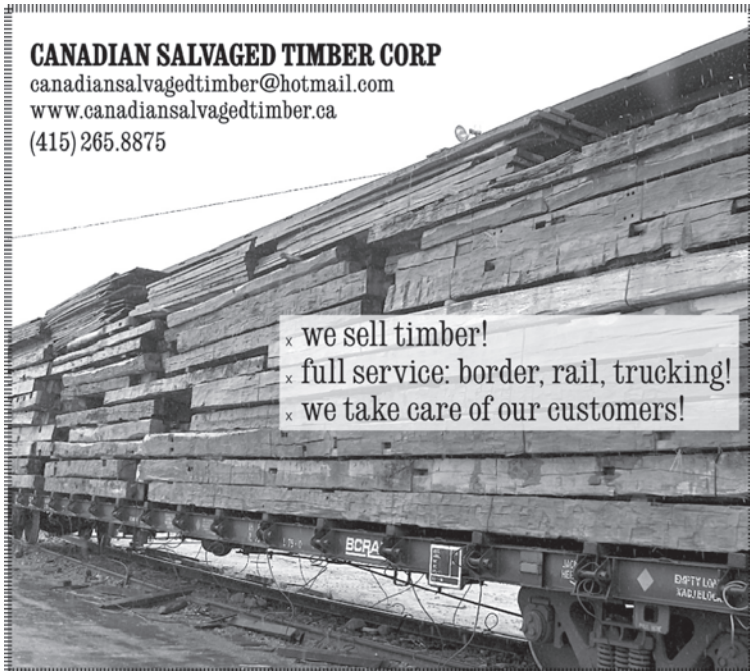
15 Rebuilt ell-frame from John Chase house, Damariscotta, protects collections of tools and hardware.

16 Salvaged lumber lives outside, stacked to drain.



16

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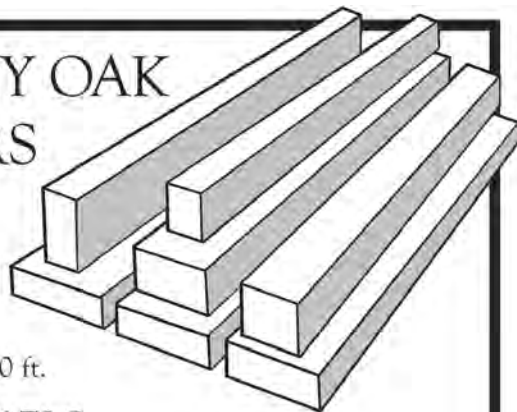
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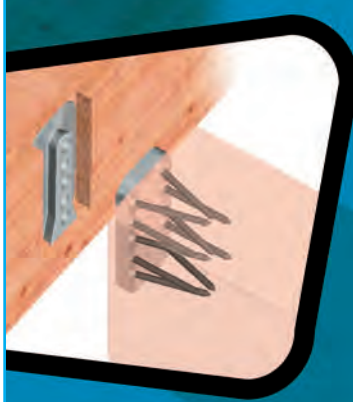
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