TIMBER FRAMING

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Timber Framing for the Homestead

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On the front cover, Kevin Kiwak adjusts choker strap on wall plate for English tying joint in cruck-framed outbuilding at his homestead in Sandisfield, Massachusetts. Cherry post and braces, white pine plate. Photo by Nikolas Geilen. On the back cover, shingle making at the Jüri Metsalu workshop, Karilatsi, Põlva county, Estonia. Complex action produces curved shingles of uniform thickness. Photo by Piret Uus.

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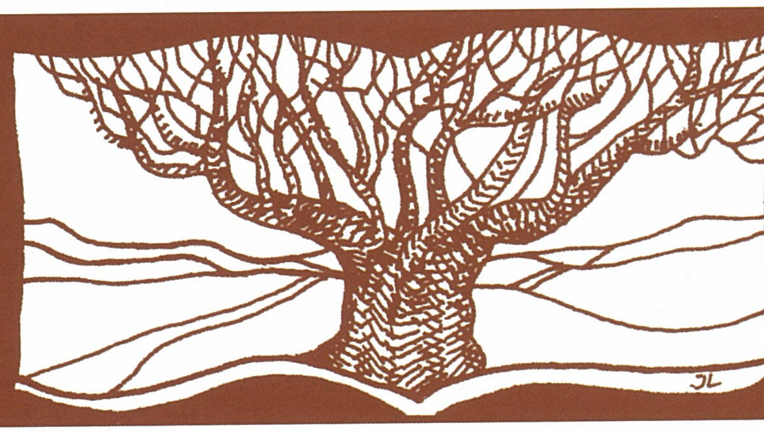
TIMBER FRAMING, Journal of the Timber Framers Guild, appears in March, June, September and December. The journal is written by its readers and pays for interesting articles by experienced and novice writers alike.

1985

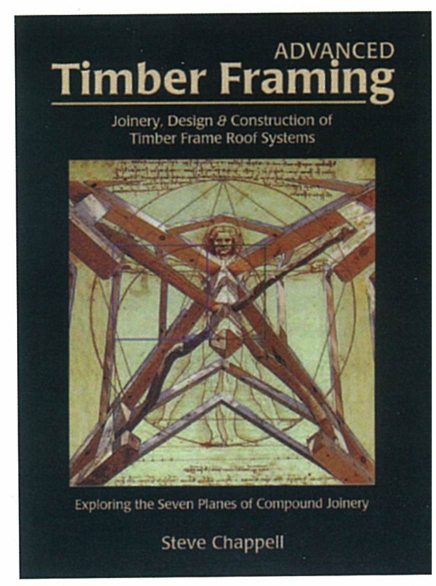
BOOKS



Complex Roof Framing

Advanced Timber Framing: Joinery, Design & Construction of Timber Frame Roof Systems, by Steve Chappell. Brownfield, Maine, Fox Maple Press, 2012. 8.5x11 in., 348 pp., profusely illustrated. Hardcover, $75.00.

STEVE CHAPPELL'S *Advanced Timber Framing*, 25 years in the making, is the magnum opus of one of the Guild's founders and the supplement to his 1998 work, *A Timber Framer's Workshop*. While *advanced* may seem a rather lofty adjective that promises a book of challenges veteran timber framers may have to face, this book is solely about roofs. It doesn't include steeples, bridges or trusses, but rather focuses on that milieu where timber framers worldwide usually "show their stuff": roof framing.



This volume is actually two books about timbered roofs, the first on design and history, the second on geometry and joinery. Each could stand on its own as a valuable addition to a timber framer's library. Together they provide the most comprehensive coverage of the subject that I know of. A few things are missing that we who do things differently would have liked to see, but not much.

The first section begins with the fundamentals of traditional design. This includes the Golden Mean and sacred geometry, how they are evident in the natural world and how they contribute tc good design in the built environment. Then the author moves tc the evolution of timber framing and vernacular architecture focusing on the development of roof systems. Engineering understanding evolved at the same time, presumably sometimes througł painful lessons, since empirical test methods were the only one: available.

Stunning photographs of roof structures, from Scandinaviar stave churches, Western European tithe barns and market halls tc Asian pagodas, illustrate the progression of building traditions anc craftsmanship up to the dawn of modern technology. The bool offers valuable examples of the development of scribe layout sys tems to achieve this soaring geometry with irregular timber.

But there is a bit of a disconnect here with the rest of the book Chappell's approach to solving the many complex roof problem posed later (covering nearly every imaginable combination of hips valleys, jack rafters and purlins, ridges and plates) relies on mathe matics, higher level geometry and trigonometry. An innumerat medieval carpenter would have used drawing and lofting to achiev the same results with irregular timber. It may be thought silly toda not to use math and calculators if one knows how, but there is mor

It Takes Three to Yield One

Susan Hammond

THE historic Bartonsville covered bridge across the Williams River in southeastern Vermont, built in 1870 and at 151 ft. one of the longest single-span covered bridges in the United States, was destroyed by flooding in August 2011 when the west abutment was scoured away from under the bridge in the aftermath of Hurricane Irene (Figs. 1, 2). The resulting 8-mile road detour made prompt replacement imperative, but the fact that the Bartonsville had been a covered bridge was an issue. Local residents wanted a similar timber bridge to replace it and recognized that added cost would be a factor.

The replacement effort had to commence immediately, starting with the construction of new abutments to accommodate whatever superstructure was ultimately approved. Eckman Engineering, LLC, of Portsmouth, New Hampshire, began a geotechnical exploration in short order as well as the design of new abutments based on estimated loads for several types of superstructure. A covered bridge built of timber would be the heaviest and require the longest supporting length of abutment.

The Town of Rockingham, Vermont, which owned the destroyed bridge, and with which I had worked before, invited our firm, CHA Consulting, to provide design services for the replacement superstructure. We were under contract within a month. The first task was to prepare construction cost estimates for a plain-vanilla bridge to compare with the cost of a covered bridge using traditional materials and details. The initial estimates demonstrated that a traditional covered bridge would cost about 10 percent more than a conventional bridge. A combination of insurance and Federal Emergency Management Agency disaster damage reimbursement funds would cover the cost of a conventional (least expensive) replacement. The community was prepared to pay the difference.

The replacement bridge utilizes the same Town lattice truss design (named after Ithiel Town, who patented the configuration in 1820) as the original bridge. Observing historic preservation principles, the single level of top-chord elements as well as the trim details of portals and windows closely simulate those of the earlier bridge. Further, the unusual double-intersection top lateral system configuration, rather than the typical X with a single intersection at midpanel, was retained. We intentionally specified glue-laminated floor beams instead of solid-sawn, to provide extra capacity and long service life, in keeping with provisions of the Secretary of the Interior's Standards for the Treatment of Historic Properties, when use of different materials (albeit still wood) is required. Unfortunately, the remains of the timber superstructure were sufficiently damaged that in our view they were of no practical use in the replacement structure.

The new bridge is 17 ft. longer than the original structure to allow an increase in its hydraulic opening. The new superstructure (168 ft. at deck level and 178 ft. overall) is the longest Town lattice single-span covered bridge in the United States (if not the world).

In keeping with common practice in Vermont for bridges with timber decks, the bridge had been posted with a 16,000-lb. vehicular weight limit. The town intends to maintain the same load posting on the replacement bridge. Nevertheless, we used a 30-ton, two-axle vehicle (H30 in national bridge design codes) for the bridge's design load. This size vehicle will provide reserve capacity for unauthorized overweight vehicles and extend the life of the structure, as normal stresses will be significantly lower than design allowables.

Sizing of the elements of the highly indeterminate Town lattice trusses and the verification of stresses in the solid sawn members and wood trunnels represented significant challenges. These were overcome by developing a first-order three-dimensional finite element model of the six planes of truss components. BSDI, Ltd., of Coopersburg, Pennsylvania, and Bates Engineering, Inc., of Lakewood, Colorado, worked together to prepare the model and provide forces to us for use in our evaluation of member stresses.

The extra length of the bridge and a desire for ample reserve capacity had led to a truss height increase of 2 ft., which naturally added considerable strength and stiffness to the trusses, approaching 25 percent (Fig. 3). But the community desired retaining the same bridge opening to deter use by oversize vehicles. Thus at the bridge entrances that extra height is hidden behind the portals and not noticeable to lay people traveling through the bridge.

The increase in truss height and element sizes led to a corresponding increase in the horizontal spacing of the lattice, from 4 ft. to 4 ft. 6 in., measured center-to-center of the crossings. Primary bottom chord and top chord elements sections increased from 3x12 to 4x14. The upper bottom chord (also called the secondary bottom chord), visible at deck level (Fig. 3), was made of two pairs of 4x12s (for a total of four) flanking the lattice. The top chord of 4x14s is configured similarly.

2 Facing page, the Williams iver in Bartonsville (Rock- gham), Vermont, still rising exceptional rains following urricane Irene in 2011, and rtial view of upper chord of estroyed Bartonsville covered idge (1870), dropped in river failed abutment.

Trusses 2 ft. higher and floor d tie-beam framing of new idge, 17 ft. longer, mostly mplete, on a work platform ght beside its eventual posi- on. Note double X-bracing at e beams.

Bridge builder Jim Hollar owns as bridge is moved to ermanent bearings.

At right, details of upper hord, butted diagonal roof racing and wedged ends of ansverse X-bracing.

Far right, details of lower- hord X-bracing, turnbuckled e rods and glulam floor beams underpinnings of new idge. Winter does not keep idge builders from their ppointed rounds.

Photos CHA

We increased the maximum length of chord laminae from 16 ft. 40 ft. 6 in. to provide better load distribution. All lattice ele- ents increased from 3x12 to 3x14 to accommodate the critical onnections with the primary bottom chords, using four 2-in.-dia. aditional oak trunnels. Three 2-in.-dia. trunnels fasten all other uss element connections.

The design originally called for select structural Southern yellow ine for primary truss elements, to take advantage of its slightly igher bending strength than Douglas fir. Concern over the imensional stability of such large pine elements during their rying, however, ultimately led us to accept Douglas fir.

Many original covered bridges supported by Town lattice trusses sed floor beams spaced to match the lattice spacing, with the eams threaded through the lattice openings to allow support by oth inner and outer pairs of lower bottom chord elements. In this ase, the 8½x16½ section of the floor beams prevented that option nd therefore they are only supported by the inner pair of chords Figs. 3, 4). Accordingly, bending stress is higher than usual in the hords, as is shear stress in the affected trunnels.

Since almost all floors have been replaced in historic covered ridges, we felt that it was tolerable to include some improvements the floor system. Reflecting the floor-design details of the nearby Hall covered bridge over the Saxtons River (built 1867, destroyed 980, current replacement built 1982 by the renowned Milton Graton and sons), also a Town lattice design, gaps for drainage and entilation are provided along the curbs, but with fills above the loor beams and bottom lateral system to prevent drainage from ripping directly on those critical elements.

Air spacing to avoid direct contact of siding and truss chords rovides extra ventilation around the truss elements. Additionally, hiplap siding protects better against rainfall penetration compared vith square-edged boarding.

The top lateral system comprises double intersecting elements connected to the tie beams with mortise and tenon connections held tight by opposing wedges. Knee braces are bolted through lattice intersections and connect to the tie beams in notches with bolts (Fig. 5).

At the abutments, bolster beams, glue-laminated from pretreated lumber to promote complete preservative penetration, support the trusses. (Floor beams were made in a similar fashion.) The bolster beams are supported by glulam bearing blocks atop raised concrete strip pedestals. At the bottom of the bridge, transverse tie rods hold tight the lateral system of single intersection timbers (Fig. 6).

Metal roofing sheds snow loads much faster than wood shingles (the original covering of most covered bridges), thereby lessening long-term loading on the bridge. At the time of its destruction, the original Bartonsville bridge likewise carried a metal roof.

Bensonwood, of Walpole, New Hampshire, provided rough-sawn, precut timber to the job for assembly and erection by the construction contractor, Cold River Bridges LLC, of Readsboro, Vermont. We specified wood preservative treatment for the 4-in. Douglas fir deck planking and the timber curbs. We did not specify it for the truss elements for a number of reasons.

First, Douglas fir elements must be incised to provide uniform retention of preservative treatment. US design codes specify a reduction in strength of 15 percent for incising—a critical loss of strength. Second, preservative treatment would have required an additional month to obtain materials, deemed too long given the urgency of the project. Finally, treatment would have added an extra $40,000 to the cost of the project. We were not convinced that it was a necessary or cost-effective investment. Many historic covered bridges have survived for more than 150 years without preservative treatment.

The bridge will weigh approximately 130 tons when its timber attains stable moisture content (Figs. 7, 8). The title of this article arises because Cold River Bridges, after building the abutments, installed a Mabey pony truss superstructure to carry traffic temporarily. Then they built the new covered bridge atop a work- platform bridge placed alongside the temporary bridge—three bridges, then, to yield one. Construction of the $1.2 million superstructure was completed and opened to traffic in January 2013. The work-platform bridge will be removed later in the year.

—Phil Pierce

Phil Pierce, P.E. (phil@philsbridges.com), is an Associate and Senior Principal Engineer at CHA Consulting, Inc., Albany, New York, and has worked and consulted on over 100 historic covered bridges. He was selected by the Federal Highway Administration as principal investigator and primary author to prepare the FHWA's Covered Bridge Manual *(2005). Phil has written several articles and a book chapter and made numerous presentations to national and international audiences about covered bridges.*

Photos CHA

7, 8 New Bartonsville bridge, dedicated in January 2013 (despite sign), is 168 ft. long at deck level and 178 ft. overall. Double transverse X-bracing, below, repeats unusual detail of original.