

It Takes Three to Yield One



Susan Hammond

THE historic Bartonville 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 Bartonville 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 suf-

ficiently 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.

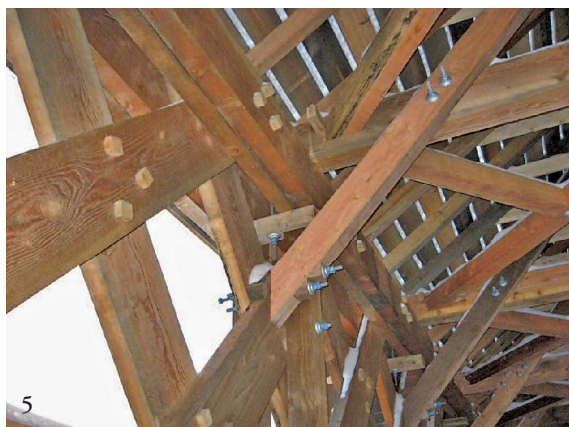
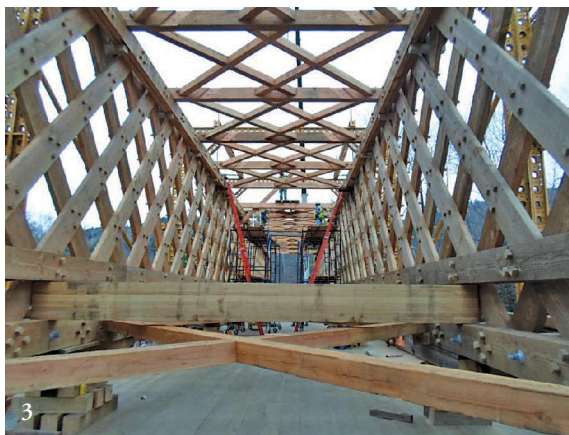
1, 2 Facing page, the Williams River in Bartonsville (Rockingham), Vermont, still rising in exceptional rains following Hurricane Irene in 2011, and partial view of upper chord of destroyed Bartonsville covered bridge (1870), dropped in river by failed abutment.

3 Trusses 2 ft. higher and floor and tie-beam framing of new bridge, 17 ft. longer, mostly complete, on a work platform right beside its eventual position. Note double X-bracing at tie beams.

4 Bridge builder Jim Hollar clowns as bridge is moved to permanent bearings.

5 At right, details of upper chord, butted diagonal roof bracing and wedged ends of transverse X-bracing.

6 Far right, details of lower-chord X-bracing, turnbuckled tie rods and glulam floor beams in underpinnings of new bridge. Winter does not keep bridge builders from their appointed rounds.



Photos CHA

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

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

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

Since almost all floors have been replaced in historic covered bridges, we felt that it was tolerable to include some improvements in the floor system. Reflecting the floor-design details of the nearby Hall covered bridge over the Saxtons River (built 1867, destroyed 1980, current replacement built 1982 by the renowned Milton Graton and sons), also a Town lattice design, gaps for drainage and ventilation are provided along the curbs, but with fills above the floor beams and bottom lateral system to prevent drainage from dripping directly on those critical elements.

Air spacing to avoid direct contact of siding and truss chords provides extra ventilation around the truss elements. Additionally, shiplap siding protects better against rainfall penetration compared with 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

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Photos CHA

7, 8 New Bartonville 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.

