

The Bartonville Covered Bridge Replacement

Phillip Pierce, P.E.
Associate, Sr. Prin. Engr.
CHA Consulting, Inc.
Albany, NY
ppierce@chacompanies.com



BSCE, ME, F ASCE;
40+ years experience;
Bridge engineering – all types –
movable, fixed, pedestrian; all
aspects;
Private and public sector
employment;
Focus on historical projects;
Nationally recognized covered
bridge expert.

Summary

The destruction of the 140 year old Bartonville Covered Bridge in the Town of Rockingham, Vermont by flood waters of Hurricane Irene not only forced a lengthy detour, it tore at the heartstrings of the local community and covered bridge lovers everywhere. A youtube video of its destruction instantly went viral and much attention by the press followed developments during its replacement. A replacement bridge was needed as quickly as possible, but it needed to honor and generally mimic the destroyed bridge. Abutment replacement commenced immediately with design support by a local consultant. CHA was invited, and quickly underway, to prepare bid documents for a new covered bridge, built for another century of service. At 51.2m (168 ft) between end joints, the new superstructure is the longest single-span covered bridge supported by Town lattice trusses in the world and was opened to acclaim on January 26, 2013. This presentation/paper discusses the design and construction of the replacement covered bridge using traditional materials and details and how it incorporated attention to the Secretary's Standards for Historic Preservation in the design and detailing.

Keywords: timber, covered, bridge.

The historic Bartonville Covered Bridge, built in 1870 and one of the longest single span covered bridges in the United States, was destroyed by the flooding caused by Hurricane Irene in August 2011, when the west abutment was scoured away from under the bridge – see Figures 1 and 2.



Figure 1 - The Bartonville Covered Bridge just prior to its destruction (photo provided by Susan Hammond)

A 12.9km (8-mile) one-way detour made prompt replacement of the bridge imperative. However, the fact that it was an historic timber covered bridge was an issue. The local residents wanted a similar bridge to replace it, but 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. A local consulting firm was authorized to start a geotechnical exploration in short order. That same firm also began designing the abutments based on initial estimated loads for several types of superstructures. A timber covered bridge would obviously be the heaviest and require the longest supporting length.



Figure 2 - Beyond salvage (photo provided by Susan Hammond)

Based on a past relationship involving an investigation and refined analysis of the destroyed covered bridge, the Town of Rockingham, VT, who owned the bridge, invited CHA to provide design services for the replacement superstructure. We were under contract within a month.

Because the weight of a timber covered bridge is substantially more than more modern bridges, and because the design of the abutments needed to proceed quickly, it was very important that a realistic estimate of weight of the timber bridge be prepared in advance of its design. CHA's strong background with covered bridge work enabled development of such an estimate, which turned out to be very close to the final.

Additionally, while developing the geometry and location of the abutments was the responsibility of the other consultant, a professional informal teaming effort between the two firms led CHA to offer key counsel on the abutment design. Limitations on positioning the abutments farther back from the stream (due to immediate proximity of an active railroad line), coupled with the unusually long bearing seat needed for a timber covered bridge, led to adoption of a rather unique concrete ledge designed to cantilever past the face of the abutment stem. This concrete ledge, acting in concert with traditional timber bolster beams, enabled the rear of the timber superstructure to be much closer to the front face of the abutment than would normally be possible, thereby providing the necessary hydraulic opening for flood waters.

The contract for construction of the abutments was let and contractor was on site by the first of December 2011 and the temporary bridge was open to traffic by March 12, 2012. The cost of abutments and temporary bridge installation was about \$850,000. The temporary bridge was rented directly by the Town at a cost of \$2000/week.

The first task for CHA was to prepare construction cost estimates for a "vanilla" bridge for comparison against a timber covered bridge using traditional materials and details. The initial estimates demonstrated that a traditional timber covered bridge would cost only slightly more (approximately 10%) than a more modern/traditional bridge and the community was prepared to pay the difference.

The replacement bridge utilizes the same Town lattice configuration of trusses - so named after Ithiel Town, whom patented the configuration in 1820. The single level of top chord elements, as well as trim details of portals and windows, closely simulates the earlier bridge; these were used to address historic preservation principles. Further, the unusual double intersection top lateral system configuration was retained. Glue-laminated floorbeams were intentionally used as substitutes for solid sawn floorbeams used in the original covered bridge 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) are required. Unfortunately, the remains of the destroyed timber superstructure were twisted and broken to such an extent that they were of no practical use in the replacement structure.



Figure 3 - Replacement timber bridge being built on a work platform bridge. The temporary vehicular bridge is at left in this photo. They were racing to beat bad weather, but looking good.

The new bridge was made 5.2m (17 feet) longer than the original structure to provide an increase in its hydraulic opening. The new superstructure (51.2m [168 ft] at deck level and 54.3m [178 ft] overall) will become the longest single-span covered bridge in the United States (if not the world) supported by Town lattice trusses. Figure 3 provides an image of the skeleton of the bridge showing construction of the Town lattice trusses with partial completion of overhead bracing and partial installation of floor beams. The timber structure is being erected on a work platform bridge alongside the temporary bridge, which sits atop the replacement permanent abutments.

In keeping with common practice in Vermont for bridges with timber decks, the bridge had been posted with a 7,260kg (16,000 pound) vehicular weight limit. The town intends to maintain the same load posting on the replacement bridge. As to the “design” weight vehicle, it was decided to use a 27.2t (30-ton) two axle vehicle (aka H30

per national bridge design codes), compared with 18.1t (20 ton) or even lighter vehicles often used for such structures. The heavier design vehicle will provide reserve capacity for unauthorized overweight vehicles and extend the life of the structure, as typical everyday stresses will be significantly lower than design allowables.

The sizing of the elements of the highly indeterminate trusses and 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 vertical planes of truss components.

The community desired retaining the original bridge opening to deter use by oversize vehicles. However, the extra length and desire for ample reserve capacity for potential overweight vehicles led to accepting a truss height increase of 0.6m (two feet). That extra vertical height remains hidden behind the portal entrance and is not noticeable to lay people traveling through the bridge.

The increase in truss height and element sizes led to a corresponding increase in the spacing of the lattice from 1220mm (4'-0") of the destroyed bridge to 1370mm (4'-6") for the replacement bridge. Primary bottom chord and top chord elements were increased from 75x305's to 100x355's (3x12's to 4x14's). The upper bottom chord (aka secondary bottom chord) was increased from 75x305's to 100x355's (3x12's to 4x12's). The maximum length of chord sticks was increased from 4.9m to 12.3m (16'-0" to 40'-6") to provide better load distribution among the chord elements. All lattice elements were made 75x355 (3x14) [original 75x305 (3x12)] to accommodate connections with the primary bottom chords using four 50mm (2") diameter traditional oak trunnels. Three 50mm (2") diameter trunnels were used in all other truss element connections.

The design originally called for Select Structural Southern Pine for primary truss elements to take advantage of its slightly higher bending strength than Douglas Fir. However, concern over the dimensional stability of such large pine elements during their drying led us to ultimately specify Douglas Fir.

Many original covered bridges supported by Town lattice trusses used floorbeams spaced to match the lattice spacing, and were “threaded” through the lattice openings to allow support by both the inner and outer pairs of lower bottom chord elements. In this case, the size of the truss elements prevented that option. The floorbeams therefore are only supported by the inner pair of chords.

Accordingly, the bending stresses were higher than usual in the chord, as were the shear stress in the 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. Based on the floor design details of the nearby Hall Covered Bridge, drainage/ventilation gaps were provided along the curbs, but with fills above the floorbeams and bottom lateral system to prevent drainage from falling directly atop those critical elements.

Extra ventilation was also provided around the truss elements by spacing timbers to avoid direct contact of the siding and the truss chords. Additionally, shiplap siding was used to protect against rainfall penetration.

The trusses are supported on glulam bolster beams made from pretreated lumber to promote complete preservative penetration. Floorbeams were made in a similar fashion. The bolster beams are supported by glulam bearing blocks atop raised concrete strip pedestals.

As noted above, the top lateral system is comprised of double intersecting elements which are connected to the tie beams with mortise and tenon connections held tight by opposing wedges. Kneebraces are bolted through lattice intersections and are connected to the tie beams in notches with bolts. The bottom lateral system is comprised of single intersection timbers and held tight with transverse tie rods.

Metal roofing was used on the destroyed bridge. It was also specified for the replacement bridge, as opposed to wood shingles (preferred by many purists inasmuch as wood shingles were typical on original covered bridges), in large part due to the designer's strong belief that metal sheds snow loads much faster, thereby lessening long term loading on the bridge.

Wood preservative treatment was specified for the 100mm (4") thick Douglas fir deck planks and the timber curbs. It was not specified for the truss elements for a number of reasons, including:

- Douglas fir elements must be incised to provide uniform retention of preservative treatment. US design codes specify a 15 percent reduction in strength due to the incising – a critical loss of strength.
- Preservative treatment would have required an additional month to obtain materials. This was deemed too long given the urgency of the project.
- Preservative treatment would have added an extra \$40,000 to the cost of the project. The designer was 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.



Figure 4 - Bridge being moved sideways into position atop the permanent abutments (with a bit of good-natured help from the owner of the construction company).



Figure 5 – A happy crowd turnout for the ribbon cutting.

Discussion and Conclusions

Design and construction of a timber bridge based on traditional materials and connections, with an anticipated service life of well beyond 100 years demonstrates that new timber covered bridges can handle modern loads and still resemble historic structures. And for bridges at sites such as this, where single lane service continues as it has for more than 140 years, this type of construction represents excellent cost/benefit value to the community.

Replacement of the destroyed bridge with one so similar to it, continues Vermont's long tradition of staunchly supporting its precious population of covered bridges. A more "modern" bridge of steel was possible and would have cost slightly less on a first-cost basis, but there was no hesitation of the community to commit to the slight increase in cost in order to obtain a timber replacement. This bridge received media attention across the world throughout the process of its replacement and the community continues to derive financial benefit via the thousands of tourists who roam Vermont's countryside each year visited these structures.

It is interesting to note that the contractor, who won separate bids, built the abutments and installed a temporary Mabey pony truss superstructure. Then the permanent replacement timber covered bridge was built atop a work platform bridge, placed alongside the temporary bridge – thus three bridges to yield one. Construction of the \$1.2M superstructure was completed with ribbon cutting on January 26, 2013.

Acknowledgements:

Owner - The Town of Rockingham, VT – what a wonderful client

Substructure Designer - Eckman Engineering, LLC – a cooperative effort between two engineering firms with no contractual relationship

Contractor - Cold River Bridges, LLC – a contractor who put their heart and soul into this bridge

The community of Lower Bartonsville – we would not have had a project without them

Pierce: The Bartonsville Covered Bridge Replacement