Historic Timber Bridges

Design and Rehabilitation of Three Structures in Massachusetts

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The Massachusetts Highway Department (MassHighway) is in the process of rehabilitating three historic timber covered bridges and has engaged the services of Fay, Spofford & Thorndike, LLC and Wood Advisory Services, Inc. to perform the evaluation and engineering. The three bridges are the Burkeville Covered Bridge in Conway; the Arthur A. Smith Covered Bridge in Colrain; and the Bissell Covered Bridge in Charlemont.

The bridges in Conway and in Colrain are to be upgraded to carry AASHTO H 15 truck loading, and the bridge in Charlemont is to be upgraded to carry AASHTO HS 20 truck loading.

Design Methodology

Elastic structural analyses for the three bridges were done with the computer program, GT STRUDL. The design criteria were based on the *Standard Specifications for Highway Bridges* by AASHTO and the *National Design Specification® (NDS®) for Wood Construction*. Since the AASHTO design specifications did not adequately address wind load and snow load for timber covered bridges, requirements from the Massachusetts State Building Code for these two design loading conditions were used. The structural integrity of each of the three bridges was assessed using basic wood science knowledge, as well as laboratory analyses and common tools (such as a hammer, a pick, and a resistance drill) to assess conditions of the timber components. Results of the wood science assessments were used by the structural engineer to develop the necessary timber member physical properties for computer model analyses and evaluation.

Case Study #1:

Burkeville Covered Bridge, Conway, Massachusetts

The historic Burkeville Covered Bridge carries Main Poland Road over the South River in the Town of Conway. The existing bridge superstructure, built circa 1871, is approximately 106 feet long by 17 feet wide with one 12-foot 10-inch wide lane, supported on stone masonry abutments. The structural system consists of a pair of Howe trusses, floor beams, and stringers with timber decking, protected by a roof assembly and timber siding. The Howe truss is made up of timber top and bottom chords, timber diagonals, and steel hanger rods for verticals. See *Figure 1* for condition of the existing structure.

The load carrying capacity of the existing timber structure was found to be lacking. The most difficult design issue for this bridge structure was providing the means to resist the lateral design wind load. Even at a wind pressure of 12 psf for the region, the existing structural system could not transmit this lateral load into the abutments. The increased live loads also overstressed many members of the Howe trusses. A secondary steel framing system was introduced to sister the top chords, cross beams on the top chords, diagonals, and verticals in order to resolve the capacity issues. A rigid moment connection was made between the sistering elements of the cross beams and verticals to effectively transmit the lateral wind load into the abutments. This secondary framing system was placed on the outside face of the Howe trusses and covered by the replacement timber siding, pretty much obscuring it from casual observers.

The construction for rehabilitation started in September 2004 with completion expected by the fall of 2005.

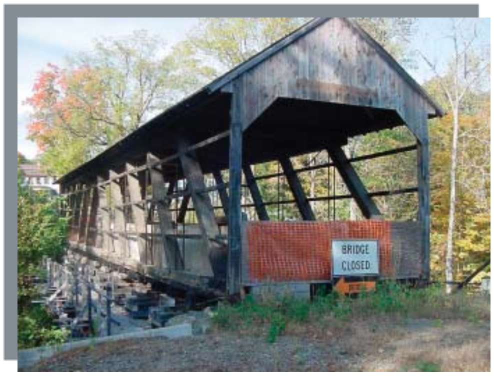

Figure 1: Burkeville Covered Bridge

Case Study #2:

Arthur A. Smith Covered Bridge, Colrain, Massachusetts

The historic Arthur A. Smith Covered Bridge carries Lyonsville Road over the East Branch of the North River in the Town of Colrain. The existing bridge structure, built circa 1870, is approximately 99 feet long by 17 feet wide with one 10-foot 11-inch wide lane, supported on stone masonry abutments. The structural system consists of a pair of Howe trusses with Burr arches, forming what is known as Burr trusses, and a pair of add-on nail-laminated timber arches located at the inside face of the Burr trusses. The nail-laminated arches were added around 1920 to strengthen the bridge for heavier design loads. Approximately fifteen years ago, due to extensive deterioration of the structural framing, the timber bridge structure was removed from its abutments and placed on top of timber cribbing supported on the east approach roadway. See *Figure 2* for a portal view of the existing bridge.

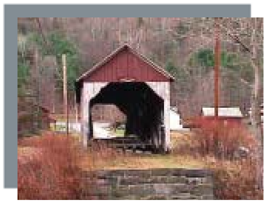

Figure 2: Arthur A. Smith Covered Bridge

Results of model analyses indicated that many members of the existing Burr trusses needed to be replaced due to lack of capacity, as well as due to deterioration. The axial capacity of the pair of nail-laminated timber arches is adequate for the new design loads. However, a relatively thin top and bottom steel cover plate has to be added to address localized bending due to steel hanger rods that are supporting the floor beams. For this particular rehabilitation, only replacement of members with stronger species and/or with slightly larger cross sectional areas is needed. An additional secondary structural system for strengthening is not required for the higher load demands on the bridge.

The construction project for rehabilitation is expected to start in July 2005 and to be completed by the fall of 2006.

Case Study #3:

Bissell Covered Bridge, Charlemont, Massachusetts

The historic Bissell Covered Bridge carries Route 8A over the Mill Brook in the Town of Charlemont. The existing bridge structure, built in 1950, has a span length of 92 feet. The curb-to-curb width is 24 feet with a total width of approximately 32 feet. The bridge is designed for two-way traffic on two travel lanes. See *Figure 3* for a portal view of the existing bridge.

The structural system consists of a pair of parallel chord main trusses with 6 panels each. Due to the two-lane width, the wide timber deck is supported by floor trusses and the roof subassembly is supported by roof trusses at each panel point of the main trusses.

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The structural timber members in this bridge are all Douglas Fir and are in excellent condition. The chemical preservative has been successfully protecting all of the timber members from a very moisture laden environment for the past 50 plus years. The bridge is located adjacent to a waterfall over a small dam. Two major structural problems contributed to closing of the bridge to all traffic. The first one is the severe deterioration of the unprotected steel bolts in all of the connections in the floor trusses. Some connections have completely missing bolt heads or nuts. Some floor truss diagonals have splits that run through multiple bolt holes. The second most critical condition is with the pair of main trusses. The problem at these main trusses is also the steel bolted connections. The unprotected steel bolts are all rusted to varying degrees of severity. The condition of these steel bolts is better than the steel bolts in the floor trusses.

A 3-dimensional computer model evaluation indicated that many existing timber members can carry the proposed upgraded live loads, but the steel bolted connections could not. All of the structural bolted connections are made with unprotected steel bolts with split rings. Even if the entire truss is taken apart and replaced with galvanized split rings and slightly larger diameter bolts, the size and configuration of the connection is simply not adequate to satisfy the new load demands. To overcome this deficiency in the panel point connections of the main trusses, a secondary structural system of steel tension rods is designed to share and relieve a significant portion of the design loads from the connections at each of the truss panel points. Due to the specific details of this pair of parallel chord main trusses, we are able to place the system of steel tension rods at the centroid of each truss by way of steel saddles to apply and transfer a pretensioned force into the tension vertical and tension diagonal members of the main trusses. A pair of steel tension rods is also pretensioned to relieve axial tension loads in the two bottom chords of the main trusses.

Figure 3: Bissell Covered Bridge

Final design for rehabilitation is on-going. The construction project is expected to begin in the spring of 2006 and be completed by the summer of 2007.

Conclusion

Rehabilitation of historic timber covered bridges is always a challenging engineering endeavor. Identifying structural deficiencies takes a combination of meticulous inspection and rigorous analysis and evaluation. A design team, comprised of a wood scientist and structural engineer, is necessary to effectively rehabilitate a timber bridge for modern day loads and at the same time save the maximum number of original timber members that are relevant to the historic fabric of the bridge. Otherwise, it will be very difficult to justify replacement of sound historic elements with new ones to satisfy demands from the required design loads—especially when one of the goals of the rehabilitation is to preserve as many of the original timber components and features of the historic bridge as possible.

The need for preservation versus the need for upgrading the load carrying capacity of the historic timber bridges will always be two opposing ideals that must be reconciled during design. Otherwise, an impasse will only delay rehabilitation and allow further deterioration to the timber elements of the bridge structure.▪

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