Preservation of Historic Gilbertville Covered Bridge

By S. D. Daniel Lee, P.E. and Matthew Anderson, M.S.

The Massachusetts Highway Department (MassHighway) engaged Fay, Spofford & Thorndike, LLC (FST), the engineer for MassHighway, and Wood Advisory Services, Inc. (WAS) to perform the evaluation and engineering for rehabilitation of the Historic Gilbertville Covered Bridge – the fourth of four historic timber bridges in the Commonwealth. WAS performed field inspections to determine timber species and performed visual grading of the components in the existing timber structure, which were necessary for evaluation and design.

Existing Conditions

The Gilbertville Covered Bridge, built in 1887, carries Bridge Street over the Ware River between the Towns of Hardwick and Ware. The bridge structure is comprised of a pair of Town Lattice Trusses with timber decking on floor beams and floor joists. It is covered with barn boards for siding and has a pitched shingle roof overhead. The bridge's span length is approximately 136 feet 10 inches. Minimum roadway width is 19 feet 10½ inches with an overall width of approximately 24 feet. (*Figure 1*)

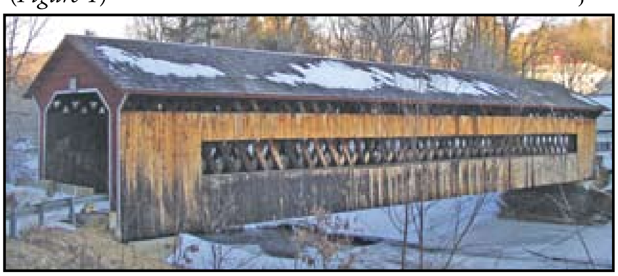

Figure 1: Winter setting of the covered bridge.

The longitudinal trusses that form the bridge structure are a unique design where the crisscrossing diagonal members are placed very close to each other, approximately 3 feet on center, forming a continuous lattice panel. Longitudinal members are placed at the top and bottom of the lattice panel, with member components placed to each side of the panel to form top and bottom chords of the two trusses. These diagonal members are either 3x10's or 3x12's, with occasional heavy gouging at their corners caused by vandals. Timbers for the original lattice truss members are spruce. Replacement timber members within the original trusses are Douglas-fir.

Structurally, the lattice panel essentially functions as the web of a deep beam, and the top and bottom chord members function as top and bottom flanges. The lattice members are interconnected with two trunnels (tree nails) at each intersection point. The top and bottom chord members are attached to the lattice members at intersection points with three trunnels. There is a steel bolt at the center of these groups of three trunnels at most of the connection points. These steel bolts were most likely added under a restoration project that occurred in 1987.

The timber decking is made up of 3-inch thick timber planks of southern pine, placed parallel to the direction of traffic, supported directly on floor beams and floor joists. This decking was placed during the 1987 restoration project. The floor beams are 5x12 southern pine and spruce. These members are original construction and are spaced at approximately 36 inches on center. The floor joists were installed during the 1987 restoration to improve capacity for carrying live loads. The floor joists are 3x12 Douglas-fir, alternatively spaced between the floor beams at approximately 36 inches on center, yielding a beam support spacing of approximately 18 inches on center.

Floor beams are supported by both interior and exterior components of the bottom chords (supported on bottom flange components at both sides of the lattice panel). Floor joists are supported only by the interior components of the bottom chords. Span length of the floor beams and floor joists is approximately 22 feet 2 inches. These beam members were found to have light surface decay. Even though the capacity of the floor framing has been increased with the addition of floor joists, it still does not have the necessary structural capacity to carry the proposed upgrade to AASHTO H15 truck loading.

Top and bottom braces are provided for lateral stability. The top lateral brace is comprised of roof cross-tie beams that are spaced at approximately 5-foot on center, connected to the top chords. Top cross bracing members are notched and connected to each roof cross-tie beam at their connection points to the top chords. The bottom lateral bracing members are similar to the top bracing member, but have transverse steel tie rods instead of cross-tie beams at the cross brace panel points. To complete the lateral stability system, diagonal knee braces are provided near each end of the roof cross-tie beams.

The pitched roof is comprised of purlins on roof rafters that are supported by a pair of eave beams on top of each end of the roof cross-tie beams. The purlins are spaced at approximately 16 inches on center. Wood shingles are attached to these purlins. The barn board siding for the covered bridge is supported by girts that are attached to the lattice members. A pair of rubble stone masonry abutments supports the bridge superstructure.

The bridge is presently closed to vehicular traffic; two conditions contributing to its closure. The condition is a broken floor beam, which has to be replaced, along with the fact that the original design in the 1880s is based on horse buggies and wagons, not the much heavier trucks of modern day. The second condition is the overall weakening of the structure due to infestation of anobiid beetles in the bottom third to the bottom half of many of the lattice members, as well as member components of the bottom chords.

An article discussing rehabilitation of three of the four covered bridges was presented in a STRUCTURE® magazine article *Historic Timber Bridges, Design and Rehabilitation of Three Structures in Massachusetts*, October 2005. As of the date of this article, the construction project for rehabilitation is basically completed for the Burkeville Bridge and the Arthur A. Smith Bridge. The Bissell Bridge is presently undergoing rehabilitation by MassHighway. The fourth of the group and subject of this article, the Gilbertville Bridge, is scheduled to begin rehabilitation in 2008 with a proposed upgrade to AASHTO H15 truck loading (15-ton, 2 axle vehicles).

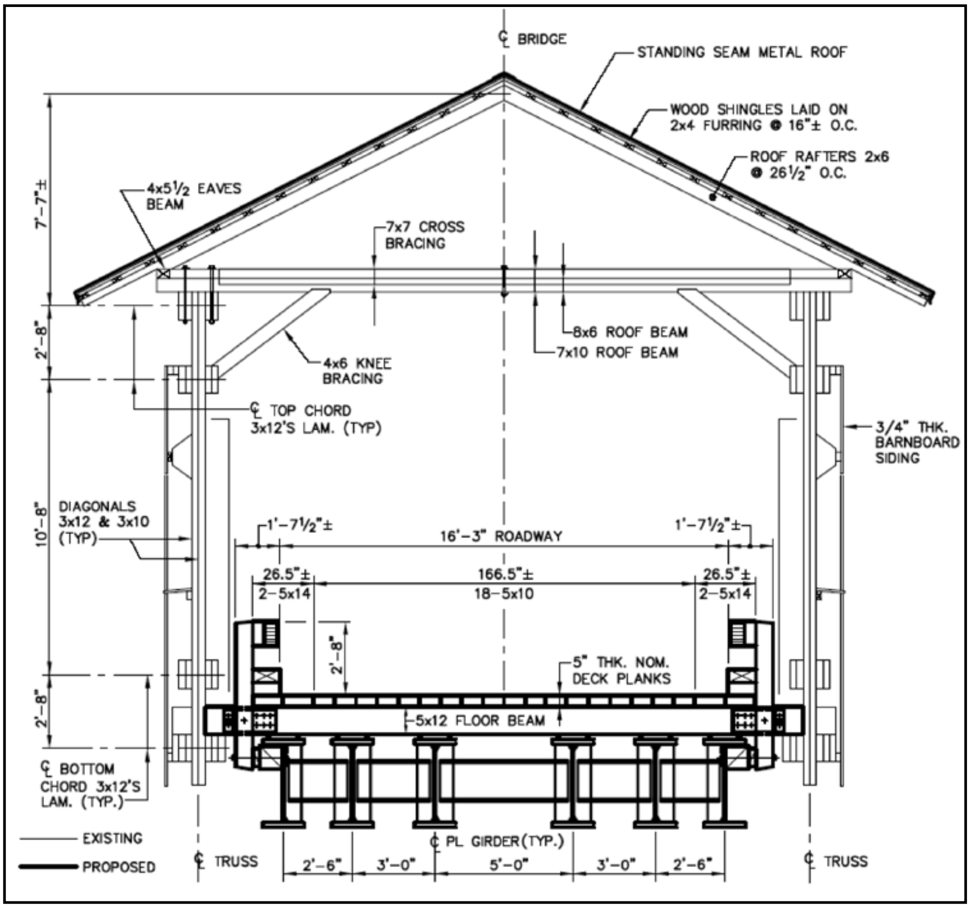

Figure 2: Proposed rehabilitation. Typical Cross Section.

Infestation of Anobiid Beetles

The structural integrity of the bridge was assessed using basic wood science knowledge, as well as laboratory analyses. Common tools such as a hammer and pick were used to locate areas of wood decay, and a resistance drill was used to document relative density profiles. The condition of each timber component on the bridge was documented during two different inspections.

During the first inspection, visual grades were either determined, or estimated for the lattice truss components, floor beams, floor joists, and decking. Species of the timber components were also determined. Reduced cross sections were estimated for the various structural components of the bridge based on the presence of wood decay as verified by laboratory analyses. These reduced member sections were used to evaluate structural adequacy based on 3-dimensional model analyses with the GT STRUDL computer program.

Selected lattice members, top and bottom chords, and connections at intersection points were examined using a resistance drill. Some of the connections exhibited evidence of insect attack. Based on the characteristics of the attack and the random pattern of bore holes (or bug holes) on the surfaces, it was determined to be the result of anobiid beetles. The bore holes were 1/16-to ⅛ inch in diameter, with the majority at 1/16-inch. Resistance drill profiles indicated low relative density levels within selected connections and lattice members, where bug holes are present.

A second inspection of the bridge was performed at a later date to more accurately document the anobiid beetle attack. At the time of the second inspection, 70% of the lower timber connections (adjacent to the deck) exhibited anobiid beetle attack, and 56% of those connections were active. No activity was observed in the upper timber connections just below the roof.

Proposed Improvements

Given the need for upgrading the bridge structure for heavier vehicular loading and the desire to preserve as much of the historic members of the structure as possible, a compromise was achieved with the addition of a secondary sub-framing system to carry the entire superstructure load. Six steel girders will be installed directly underneath the floor beams and floor joists. Four interior steel girders are designed to carry AASHTO H15 truck or uniform pedestrian live loads, and the two exterior steel girders are designed to primarily carry the weight of the timber superstructure, the entire snow load, and the effects of wind load plus a tributary amount of the live load. These girders will mostly be hidden by the siding of the covered bridge, as viewed from the roadway level. (*Figure 2*)

This design preserves most of the existing timber components of the historic bridge structure. The bottom lateral bracing system of transverse steel tie rods and timber cross bracing members will be removed, but stored and preserved for future restoration, in the event that the functional requirement of the bridge is to be changed.

No significant repair of the superstructure will be needed at this time. Minor repairs of floor beams will be done by using sistering elements. The 3x12 floor joists will be replaced with new 5x12 floor beams, maintaining the spacing of 18 inches on center for the support beams. The 3-inch thick deck planks will be removed and replaced with 5-inch thick deck planks. Crash-tested timber bridge rails will be installed. The present structure does not have any protective railing.

The beetle infestation will be treated with a surface application of insecticide, whose active ingredient is disodium, octaborate tetrahydrate.

At the request of the community, the existing roof shingles will be preserved to maintain the interior weathered appearance, a unique aesthetic feature of the interior of the structure. The existing shingle roof will be modified and covered with standing seam metal roofing.

Abutment seats will be modified to receive the new steel sub-framing members. The pair of massive stone masonry abutments has been determined to be adequate for the specified seismic load.

Before the bridge was closed to vehicular traffic, it had two-way traffic on two travel lanes. However, the present design requirement for crash-tested timber railing for protection of the trusses reduces the rehabilitated structure to a single lane. The community has requested that signage be used, instead of signalization, to control two-way traffic. The specific characteristics of the alignment of the two approaches to the bridge allow control with signage, instead of signalization.▪

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