Proof Loading Closed Timber Bridges

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Abstract
Using proof loads and safety factors developed according to recently accepted AASHTO procedures, it is demonstrated that a closed timber structure can safely carry 3 tons and thus be reopened. A literature survey was conducted to provide information that was synthesized into a strategy for proof loading closed timber bridges. The resulting strategy applies the concept of structural shakedown to the rating of timber bridges. Load tests and material tests were conducted.

Key Words: Proof loading, load rating, shakedown, off-system bridges, closed bridges, residual deformation, timber bridges

Introduction

The Louisiana Department of Transportation and Development (DOTD) is responsible for the inspection and load rating of thousands of on-system bridges (owned by the state) and, as a special service, several thousand off-system (locally owned) timber bridges. There are approximately 150 off-system timber bridges in Louisiana that are currently closed.

The load-carrying capacity of bridges is usually very conservatively based upon an inspector's qualitative rating as well as quantitative results from a computer analysis of the structure. When a bridge is judged unable to safely carry 3 ton truck loads, it must be closed. Closed off-system bridges are likely to remain a hardship for local travelers for a long time, since local governments which own the bridges often lack the money needed to repair or replace such structures. The intent of proof loading is to augment the bridge authority's information concerning the closure of a structure; proof loading is not intended to replace the existing procedures for bridge inspection and rating.

The Louisiana Transportation Research Center of the DOTD conducted this proof loading research as State Project 736-99-0311. The primary objective of this research effort is to develop a strategy for proof loading closed off-system timber bridges typical to Louisiana. A static load test, laboratory material tests, and a proof load test were all conducted as part of the research effort.

Synthesis of Relevant Literature

A review of the available literature related to proof loading and rating timber bridges was conducted, including documents which outline federal and state policies concerning the load rating of bridges. While there is a considerable body of literature dealing with proof loading large steel and concrete bridges, the literature that deals with load rating and/or proof loading deteriorated timber highway structures is limited.

Recent bridge research has focused on the reasonability of using proof loading as a means of rating bridges, and the latest version of the AASHTO bridge rating specifications (1) encourages the use of proof loading. The goal of this study was to develop a rational strategy to proof load a closed off-system timber bridge to determine if it could safely be reopened until repair or replacement could take place. Therefore, it was decided that since the structure was closed, it should not be fully reopened to the community. Instead, the proof loading will be directed at determining if the bridge is adequate to carry a single lane of traffic.

The specifications contained in the AASHTO and DOTD bridge rating manuals (1,2) state that an AASHTO H3 vehicle with a front axle of 0.6 tons and a rear axle of 2.4 tons should not create load effects that exceed operating stress levels in the bridge members. Every attempt is made to ensure that the general policies for inspecting and rating bridges outlined in these documents are followed when conducting proof loading.

When proof loading a structure, stresses are not necessarily measured; instead, it is generally quicker and easier to measure the load-induced deflections of the structure. In this case, the drafted proof loading manual developed by Lichtenstein (3) specifies that a safety factor of 1.6 for one lane of traffic applies for operating level rating. Thus for an AASHTO H3 proof load with its 4.8 kip rear axle, the target test load for short spans can be modeled by a 7.5 kip single axle trailer.

TxDOT conducted a thorough proof loading pilot study (4) wherein a car, a pickup, and then a water tank truck were used to load the structure while deflections were measured with the loads on and off the spans. Pre-established limits were placed both on the recoverable (elastic) deflections and the non-recoverable (residual) deflections However, no particular justification was found in the literature for the limits set by the TxDOT researchers. The target deflections were found to be too constrictive and difficult to measure.

The researchers of NCHRP Project 12-28(12) recommended (5) that structural shakedown should be adopted as the appropriate bridge rating limit state for steel bridges. Structural shakedown occurs when residual deflections from each successive passage of the factored target rating load are observed to diminish until no residual deflections are set up with the load’s passage. After shakedown occurs and some accumulated residual deflection is created, the rating load will be resisted elastically with an assured level of safety provided by the load factor.

For the proposed proof loading strategy of this project, the recommendations of NCHRP 12-28 (12) will be accepted and extended to the proof loading of timber structures.

Static Load Test

In order to establish orders of magnitude for the proof load effects on typical off-system timber structures, a timber bridge in the process of being replaced was subjected to a static load test. The state-owned structure was a fifteen span timber bridge carrying LA 424 over the Pushapatapa Creek near Franklinton, Louisiana.

The 35 year old bridge was structurally deficient with a load posting of 20 ton single and 35 ton combination vehicles. The structure was also functionally deficient: it was straight with a narrow 19 foot roadway width occurring on a curved highway section. The bridge was being replaced with a 32 foot wide concrete structure.

The structure was constructed from No. 1 Southern Pine. Each of its 19 foot simple spans consisted of eleven 6 inch by 14 inch stringers spaced 2 feet apart. As a result of a statewide timber bridge rehabilitation project that was carried out 15 years ago, seven 6 inch by 12 inch stringers were inserted between the original stringers. The bents consisted of 12 inch square cap beams supported by four 12 inch diameter short piles spaced 6.5 feet apart. To better model typical off-system bridges, the existing 12 inches of overlay ballast and asphalt were removed from the 3 inches by 10 inches plank deck. The test load was 200 kips loaded onto two spans using four stacks of five 4 foot by 20 foot precast concrete panels weighing 10 kips each

Pairs of stacks simulated midspan point loads in each lane. A pair of panel stacks was first created to simulate one lane loaded, then the second pair of stacks was created. The timber pads supporting the panels were sized to simulate the footprint of a single axle load on one span and a tandem axle load to the other.

The elevation shots at the midspan locations of both spans were very similar. The maximum deflection was 1 inch under the 100 kip midspan loads. This deformation was almost completely recovered upon removal of the load. Residual deflections were no more than 1/8 inch.

Prior to testing, a structural analysis of the simple span structure was carried out. It was assumed that the modulus of elasticity was 1,500,000 psi and that 50% of the deck was effectively acting as a composite flange with the stringers. On this basis, a center point load of 100 kips was calculated to create an elastic deflection of 1 inch.

Even though the test results matched the predicted behavior based on the structure modeled by assuming 50% effective composite deck action, this assumption had to be further proven correct -- it was necessary to ascertain that the modulus of elasticity was actually 1,500,000 psi as assumed.

Material samples were tested at the DOTD materials Laboratory. The lab personnel performed flexure tests on 11 clearwood beam samples. The average modulus of elasticity with the 1/0.94 span-depth ratio adjustment was determined to be 1,500,000 psi, as predicted for No. 1 Southern Pine.

The question of the order of magnitude of elastic and inelastic deformation was the primary interest of this test. For this structure, the midspan elastic deformation associated with 10 kips of load (a pair of panels) was about 1/8 inch. Under the full test load of 100 tons for this bridge which was posted for 20 tons, the residual deflections were less than 1/8 inch.

Proposed DOTD Proof Loading Procedure

The proposed DOTD proof load strategy requires a minimum of labor and equipment. The essentials include a minimum of two men, a surveying rod and level, and a light pickup truck towing a loaded single axle trailer with an axle weight of 7.5 kips. For the greatest safety to the pickup driver, the trailer should be long enough so that there is about 20 feet between the single axle and the rear axle of the pickup truck. For added safety, the tongue weight of the trailer should be kept low and the hitch loosened during the test.

The proposed DOTD proof load testing proceeds as follows:

1) Locate the midpoint of each span of the structure. At each of these midspan locations, mark three elevation points -- one at each of the two roadway edges and at one at the centerline of the bridge roadway. Note that for a bridge with N spans, there will be 3 X N marked elevation shot points.

2) Set up the level instrument somewhere off of the bridge structure and take the initial elevation shots to each of the marked points.

3) Drive the load across the structure along the roadway centerline. Stop the trailer axle over each midspan location for about two minutes. If any unusual visual or audible distressing is evident, the test should be terminated: it is unlikely that a bridge with visible deflections or audible stressing is in a condition suitable for opening. In any case, the pickup driver should be prepared to take quick action in the unlikely event that the loaded span behind the truck should completely collapse.

4) After the load has crossed and exited the bridge, take new elevation shots of each of the marked points. For each load crossing, compute the residual deflection values. Residual deflections for each load crossing are computed as the difference between each of the before and after elevation shots. If any of the residual deflections is 1/4 inch or more, the test should be terminated.

5) Repeat steps 3 and 4 several times. A load crossing may be accomplished by reversing the load back across the bridge.

Pass: If all of the computed residual deflections for a load crossing are zero, the structure is responding elastically, and it has reached a shakedown limit. This should be confirmed with another load crossing and another set of zero residual deflections.

Fail: If any of the computed residual deflections is greater than its previous value, the structure is exceeding the shakedown limit state. Additionally, based on field test data, if the total residual deflection should be 1/4 inch or more, the test should be terminated.

Proof Load Test

The proposed DOTD proof loading strategy was demonstrated on an off-system timber bridge near Springfield, Louisiana. The five span timber structure represents a standard Louisiana timber highway bridge and is similar in description to the structure of the static load test. The bridge is still open to traffic, though it is posted for the minimum 3 ton limit with an overall condition rating of 3.

A pickup was used to tow a fifth wheel trailer with a tandem axle weight of 11 kips. Since the tandem axle trailer creates a slightly higher moment than the recommended 7.5 kip single axle trailer, the substitution is acceptable. For each of several load crossings, the computed residual deflections were zero. Though it was not required, midspan elevation shots were taken with the load on the spans; the maximum observed elastic deflection was only 1/8 inch.

The procedure proved to be quick and easy to follow. The rod and level deflection readings are accurate to 1/8 inch.

Conclusion

The impetus for this research was that there may be instances where a closed bridge can safely be reopened -- if only to one lane of traffic -- and thereby reduce inconvenience to local automobile traffic until such time as the deficiencies of the structure can be remedied. While not intended as a solution to the problems posed by lack of bridge replacement funding, proof loading closed bridges offers the potential for local residents to temporarily continue to use a bridge.

Proof loading is likewise not intended to replace long established AASHTO procedures for inspecting and rating bridges. Proof loading is merely intended to supply additional information when making decisions about appropriate posting levels.

Several conclusions can be drawn:

- Load capacity ratings for timber highway bridge structures appear to be very conservative.
- It is reasonable to assume that 50% of the timber deck acts compositely with the stringers.
- Proof loads in the 10 kip range create elastic deformations of no more than 1/8 inch and generally little or no residual deformation.
- If residual deformations of 1/4 inch are observed, the bridge should not be reopened.
- A simple procedure to proof load off-system closed timber bridges based on a shakedown limit state has been developed and successfully demonstrated.

References

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Acknowledgments

The field work of this project was carried out by personnel from the DOTD Bridge Maintenance Section. Thanks to Mr. Joe Smith and Mr. Jay Carnell for their assistance in organizing the work. Special recognition goes to Mr. Frank Castjohn who directed the field work and provided countless helpful suggestions. Laboratory tests were conducted by Mr. Khit Ngo and Mr. Terry Cormier of the DOTD Materials Testing Laboratory. Thanks to these gentlemen and their staff for jobs well done.

In: Ritter, M.A.; Duwadi, S.R.; Lee, P.D.H., ed(s). National conference on wood transportation structures; 1996 October 23-25; Madison, WI. Gen. Tech. Rep. FPL- GTR-94. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.