Overview of the National Timber Bridge Inspection Study

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Abstract

As many engineers begin to implement life cycle cost analyses within the preliminary bridge design phase, there is a significant need for more reliable data on the expected service life of highway bridges. Many claims are being made about the expected longevity of concrete and steel bridges, but few are based on actual performance data. Because engineers are least familiar with timber bridges, their expected longevity is often unfairly estimated at only 25-30 years. A national scale project has been developed for the United States, led by the USDA Forest Products Laboratory and the U.S. Federal Highway Administration. In this project, a group of 6 bridge inspection teams, representing the major climate zone types in the U.S., each inspected at least 20 timber bridges. Nondestructive inspection techniques included visual, probing, sounding, stress wave, and resistance micro-drilling. The study results will help to provide a better understanding of the design, performance, and durability characteristics of timber bridge structures. This paper will highlight the overall inspection findings, which were instrumental in reliably estimating the expected service life for timber bridge superstructures and help support future designs that employ life cycle and sustainable features.

Keywords: bridge, inspection, nondestructive evaluation, service life, durability, condition

Introduction

As many engineers begin to implement life cycle cost analyses within the preliminary bridge design phase, there is a significant need for more reliable data on the expected service life of highway bridges. Many claims are being made about the expected longevity of concrete and steel bridges being 75 years or more, but few are based on actual performance data. Because engineers are least familiar with timber bridges; their expected longevity is typically unfairly estimated at 20 years. Additional research is needed on a national scale that provides more reliable data about the true longevity of timber bridges in the U.S. and allows for more accurate life-cycle assessments.

In order to generate more quantitative and unbiased bridge performance data, the Federal Highway Administration (FHWA) recently launched a new initiative called the Long-Term Bridge Performance Program (LTBP). The LTBP is national program and it includes detailed inspection, periodic evaluation and monitoring of approximate 200 bridges over a 20-year period. The LTBP program concentrates on “work-horse” highway bridges. This includes steel, reinforced and pre-stressed concrete bridges of

stringer/multi-beam or girder, multiple box beam or girders and slab design types constituting 75% to 80% of the National Bridge Inventory (NBI). Under the LTBP program, a representative sample of bridges will be evaluated in a cluster/reference bridge sampling method. Each reference bridge will anchor a cluster of 5 or more bridges that are within a small geographical location (along linear highway corridor or scattered about a geographic region approximately 30 miles wide) and subject to similar climate and traffic conditions. The reference bridges will involve 1) detailed and arm-length visual inspection (VI); 2) advance nondestructive evaluation (NDE); 3) global testing (load testing, modal testing, and continuous monitoring); and, 4) destructive material sampling. The cluster bridges will involve arm-length VI. The LTBP has developed an open, scalable, and extensive data management system called the "Bridge Portal". This database is capable of integrating LTBP data with other sources, such as NBI, PONTIS, weather, and traffic. Unfortunately, the LTBP currently does not include timber bridges in their current scope. This research study was developed to generate more reliable bridge performance data and establish a framework for long-term timber bridge performance monitoring. This background information will be needed if timber bridges are to be incorporated into the LTBP in the future.

National Bridge Statistics

Timber bridges are an indispensable component of the U.S. highway system especially on secondary rural roadways. The current December 2010 National Bridge Inventory (NBI) database includes 604,426 bridge structures (including culverts) with a span length greater than 20 ft (6 m), with approximately nearly 8 percent utilizing timber as a primary structural component for the superstructure (Table 1). Many of these structures have been in-service for decades and have performed well structurally, but have been deemed structurally deficient or functionality obsolete. In addition, many bridge inspectors are not as familiar with timber as a bridge material and tend to downgrade their condition rating in the NBI. The net result is that many timber bridges have been assigned poor load ratings, or posted for restricted loads, when their actual condition is satisfactory. The long-range impact is that many engineers hold the misconception that timber is a low durability bridge material having an estimated service life of less than 25 years.

Table 1—National bridge statistics as of December 2010.

Concrete	Steel	Timber	Masonry	Aluminum	Other	Total
391,161	185,148	24,267	1,743	1,459	648	604,426

All timber superstructure	Timber deck on steel stringers	Total – timber as primary component
24,267	24,492	48,759 (8% of total bridges)

Source: www.fhwa.dot.gov/bridge/britab.cfm

There are promising examples of length-of-service that support the long-term durability of timber bridges. The Forest Service (FS) maintains nearly 3,000 timber road bridges in their transportation network. Many of them are sawn timber superstructures that were installed in the post-WWII era and are still in-service after several decades. The FS also has a fairly large population of early glulam bridges built in the 1950s that are still providing vital transportation links in the Pacific Northwest. The railroads have used timber components for bridges for over 100 years and have several sawn timber structures that have been in-service for more than 75 years. Recently, long-term performance of stress laminated timber bridges was also reported (Wacker et al 2003). However, what is lacking in the literature is a scientific study on the long-term performance of timber highway bridges in the U.S.

The geographical distribution of the NBI inventory data shows that 19 States have greater than 500 bridges (Figure 1). States with more than 1,500 timber bridges include Louisiana, Iowa, and Minnesota; States having 1,000–1,500 timber bridges include Texas, Oklahoma, Mississippi, Kansas, Missouri, and Nebraska. States having 500–1,000 bridges include North Dakota, California, Oregon, Washington,

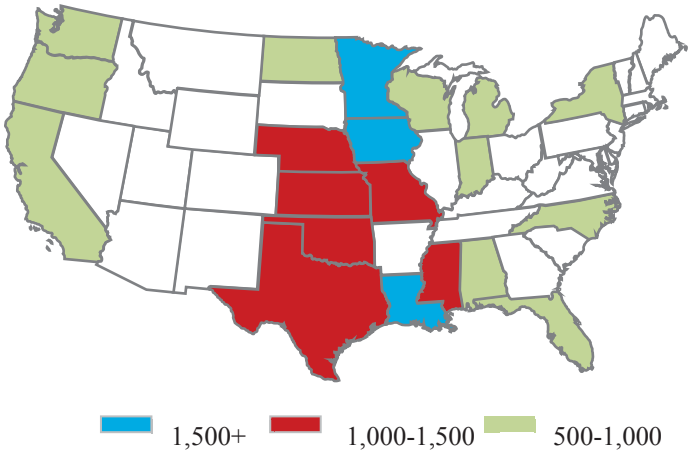

Figure 1—States with significant timber bridge inventories.

Wisconsin, Michigan, Indiana, Alabama, New York, North Carolina, and Florida. The remaining 31 states have less than 500 timber bridges in their bridge inventory.

There are a variety of timber bridge superstructure types (Figure 2). The main categories are longitudinal decks, stringer systems, and others. Longitudinal decks include nail-laminated, spike-laminated, stress-laminated (using either sawn lumber or glulam laminations), and longitudinal glulam bridges. The spike-laminated and longitudinal glulam deck superstructures consist of partial-width panels that are interconnected with transverse stiffener beams attached at intervals along the bridge length. The total bridge span ranges typically between 6 and 31m (20 and 100 ft.).

Figure 2—Examples of various timber bridge superstructures.

Objective and Scope

The primary objective of this study is to assess the condition and performance of more than 100 existing timber highway bridges representing the main climate regions in the continental United States. A secondary objective of this study was to establish the baseline framework for evaluating future performance of timber bridges nationwide. The study results will help to provide a better understanding of the design, performance, and durability characteristics of timber bridge structures, which can improve future bridge design and preservation practices and ultimately extend service life. Lastly, the findings should assist with timber bridge service life expectancy when compared with alternative bridge materials.

Research Methods

Project Team Overview

A team approach was used to inspect timber bridges in all USA regions. USDA Forest Products Laboratory and the U.S. Federal Highway Administration partnered with several other organizations to complete the field bridge inspection work. Each organization represented a US region and would be responsible for inspecting bridges in their respective regions. Figure 3 also shows the general geographic region assigned to each partner organization.

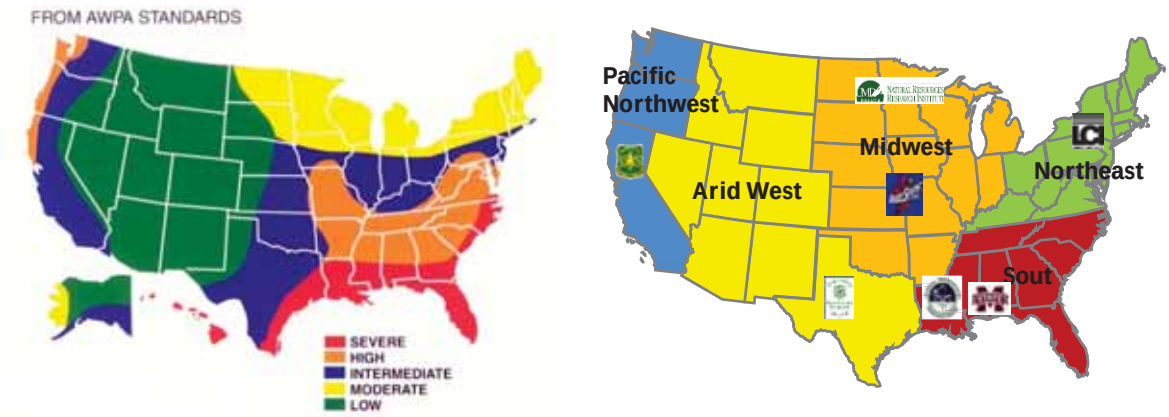

Figure 3—Project team designations for the various wood decay hazard climate zones in the continental US.

Selection of Bridge Candidates

Team members were asked to assess the inventory of timber bridges in their region and select candidate bridges for field evaluations. Teams were required to select timber bridge clusters within a multi-county region that had the same superstructure design type and preferably of similar age. Each project team selected approximately 20 bridges for inspection. This list was reviewed and approved by the project coordinators and used to assemble a national perspective for the candidate bridge selections and determine age and bridge type overview.

Bridge Inspection Work

The bridge inspection methods utilized involved a combination between visual, hammer sounding, moisture content surveys, stress wave timing, and various probing/drilling techniques. These techniques were reviewed among all teams prior to field inspection to emphasize uniformity among the various

inspection teams. More detailed description of these bridge inspection methods are currently available (Ritter 1990).

Inspection Results

At this time, field inspections have been completed and all data is being compiled for drafting a comprehensive final report. Table 2 provides a summary of the number and type of timber bridges inspected by each team. Typical inspection work being conducted at a field bridge is shown in Figure 4. A resistance micro-drill was utilized at locations where either high moisture contents were detected or other anomalies that were identified through visual inspection, hammer sounding, and/or stress wave timing investigations.

Table 2—Summary of bridges inspected in this national bridge inspection study.

US Region	State	County	No.	Bridge Types
Pacific West (*28 total*)	California	Del Norte	3	Glulam girder/nail-, glulam, & concrete
		Siskiyou	3	Glulam girder/nail-lam deck
	Oregon	Klamath	3	Sawn girder/plank deck
		Washington	7	Sawn girder/plank deck
	Washington	Yakima	7	Sawn girder/plank deck
		Grays Harbor	5	3 Sawn girder/plank (plus concrete deck) 1 glulam girder/glulam deck
Midwest (*36 total*)	Minnesota	Saint Louis	5	Spike-laminated deck
			5	Timber deck/steel girder
		Freeborn/Jackson	4	Sawn girder/plank deck
	Wisconsin	Sawyer/Price	5	Sawn girder/plank deck
	Iowa	Blackhawk	7	Sawn girder/plank deck
		Bremer	5	Sawn girder/plank deck
		Clarke	5	Spike-laminated deck
Northeast (*15 total*)	New York	Steuben-Chemung-Tioga	5	Glulam Stringer/transverse glulam deck
		Alleghany	6	Longitudinal glulam deck
	Maryland	Queen Anne/Dorchester	4	Spike-laminated deck
South (*60 total*)	Mississippi	Lafayette	8	Sawn girder/plank deck
	Alabama	Pickens	4	Sawn girder/concrete deck
	Tennessee	Crocket/Madison	7	Sawn girder/plank deck
	Louisiana	District 2	4	Sawn girder/plank deck
		District 8	5	Sawn girder/plank deck
		District 62	5	Sawn girder/plank deck
	Alabama	Shelby	5	Sawn girder/plank deck
	Georgia	Colquitt	5	Sawn girder/plank deck
		Stephens	5	Sawn girder/plank deck
	North Carolina	Johnston	4	Sawn girder/concrete deck
		Durham	3	Timber deck/steel girder
		Wake	5	Sawn girder/plank deck
		GRAND TOTAL =	**130**	

Summary and Conclusions

Over 130 timber bridges were inspected as part of a national study jointly administered by the USDA Forest Products Laboratory and the U.S. Federal Highway Administration. A team of project partners conducted the in-depth field inspections using a variety of methods. Many bridges have shown to be in remarkably good condition after more than 5 decades of service. The use of advanced NDE inspection tools when inspecting timber highway bridges provides a more reliable indication of its structural

condition. These findings have provided for a better understanding of the design, performance, and durability characteristics of timber bridge structures. Lastly, this study provides foundation for future long-term monitoring efforts and improved service life predictions for timber bridges in the US.

Figure 4—Inspection of a timber bridge superstructure located in Washington using a resistance micro-drilling unit.

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General Technical Report

FPL–GTR–226

Proceedings

18th International Nondestructive Testing and Evaluation of Wood Symposium

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Abstract

The 18th International Nondestructive Testing and Evaluation of Wood Symposium was hosted by the USDA Forest Service's Forest Products Laboratory (FPL) in Madison, Wisconsin, on September 24–27, 2013. This Symposium was a forum for those involved in nondestructive testing and evaluation (NDT/NDE) of wood and brought together many NDT/NDE users, suppliers, international researchers, representatives from various government agencies, and other groups to share research results, products, and technology for evaluating a wide range of wood products, including standing trees, logs, lumber, and wood structures. Networking among participants encouraged international collaborative efforts and fostered the implementation of NDT/NDE technologies around the world. The technical content of the 18th Symposium is captured in this proceedings.

Keywords: International Nondestructive Testing and Evaluation of Wood Symposium, nondestructive testing, nondestructive evaluation, wood, wood products

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