# AN OVERVIEW OF THE WOOD IN TRANSPORTATION PROGRAM IN THE UNITED STATES

**Sheila Rimal Duwadi, USDOT, Federal Highway Administration, USA**
**Michael A. Ritter, USDA, Forest Service, Forest Products Laboratory, USA**
**Edward Cesa USDA, Forest Service, National Wood in Transportation information Center, USA**

*Research end demonstration bridge projects to further develop the use of wood for transportation structures increased substantially in the United States (U.S.) in 1988 under a legislative action by the U.S. Congress known as the Timber bridge Initiative. This program, renamed the Wood in Transportation Program, continues today and is administered by the U.S. Department of Agriculture. Forest Service (FS). The U. S. Department of Transportation. Federal Highway Administration (FHWA) has been involved in timber bridge research since 1990. The FHWA program increased substantially under the transportation bill known as the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. ISTEA authorized significant funding from 1992 to 1997 for timber bridge research, technology transfer, and demonstration bridges. A large number of research projects have been initiated, and a number of demonstration bridges have been built under both programs. This paper will provide an overview of the research program as well as summarize the demonstration timber bridge programs.*

## I. INTROOUCTION

The FHWA, working with the States and local transportation authorities, assists in maintaining the U.S. highway system. The Forest Service has Its own vast network of roads and bridges it maintains in the U.S. National Forest System, plus it provides technical assistance to others. By continually striving to improve our roadway system, both agencies have been effective in enhancing the country's economic vitality, the quality of life, and the environment. The National Bridge inventory (NBI), a database of all vehicular bridges on U.S. public roads, contains 582,750 bridges, of which approximately 38,298 are timber bridges and 39,503 are steel bridges with timber decks. The total number of bridges, along with the number of timber bridges classified under the three roadway systems used in the U.S., is shown in Table 1. The National Forest System contains approximately 7,650 bridges, and approximately 3,500 of these are timber bridges. Although wood is not the predominant material for building U.S. highway bridges, there are a vast number of timber bridges on the U.S. roadway system, especially on the U.S. secondary, local, and rural highways, which predominantly serve low volumes of traffic.

Although timber bridges have been around for a long time, the national timber bridge programs have increased public awareness of using wood as one of the alternative material for carrying modern day highway loadings. Between 1988 to 1998 there have been approximately 2,762 timber bridges built, and approximately 419 of these bridges have been demonstration bridges.

| ROADWAY SYSTEM | ALL BRIDGES | TIMBER BRIDGES |
|---|---|---|
| National Highway System | 128,508 | 401 |
| Other Federal-Aid | 171,390 | 4,625 |
| Off-system | 282,852 | 33,272 |
| Total | 582,750 | 38,298 |

Table 1. Bridges in the National Bridges Inventory (Feb., 1998).

## 2. CONGRESSIONAL LEGISLATION

The main incentive behind the national timber bridge legislation has been the need to revitalize local economies by finding means and methods for developing the use of wood, especially, the abundant supply of the under-utilized wood species, for highway applications. Wood has proven to be a material suitable for transportation structures, as there are dose to 40,000 timber bridges in the U.S. However, it is necessary, as with any technology, to develop and advance the systems for changing needs. A large number of research projects have been initiated, and a number of demonstration bridges have been built under the timber bridge programs.

Funding for demonstration bridge construction and technology transfer activities at FS have ranged from $3.3 million in FY 1989 to $1.85 million in FY 1998. The funding level at FHWA for timber bridge research and technology transfer has been $1,000,000 per year, and for demonstration bridges, $7,500,000 per year ($7,000,000 in FY 92) from 1992 to 1997. Although there are specific requirements set by each agency for determining eligibility of demonstration bridge projects, the common factors for selection have been structural adequacy, longevity, serviceability, environmental sensitivity, economics, and design based on approved standards. Timber bridge research and technology transfer have been conducted under a joint national program, which is based on a comprehensive summary of timber bridge research needs reported in *Development of a Six-Year Research Needs Assessment for Timber Transportation Structures* [1].

## 3. DEMONSTRATION PROGRAMS

The majority of the demonstration timber bridges have been built on secondary and local U.S. road systems. These new timber bridges are designed for the same American Association of State Highway and Transportation Officials (AASHTO) specified bridge loadings as those of other materials such as steel and concrete. The majority of timber bridges are short span structures (usually 6 to 12 m spans); however, longer span (over 30 m long) timber bridges and/or multiple simple span timber bridges have also been built. Although the older designs such as covered bridges and nail-laminated bridges have been built as demonstration bridges, the majority have been newer designs such as glued-laminated timber bridges, stress-laminated bridges, dowel-laminated bridges, glued-laminated timber arches, and other state-of-the-art engineered wood bridges such as timber bridges reinforced with fiber-reinforced polymer (FRP) composites, and structural composite lumber. A number of stressed-T's and stressed-boxes have been built, although the majority of the stressed timber bridges have been deck types, which are built using either solid sawn or glued-laminated timber members. The T's and boxes were developed to extend the stress-laminating concept to include longer span timber structures. Longer spans have also been achievable using stress-laminated glulam deck bridge designs.

## 4. RESEARCH AND TECHNOLOGY TRANSFER PROGRAM

The national timber bridge research and technology transfer program Is being conducted in the following areas, which are identified In the ISTEA Legislation: Area I—system development and design; Area II—lumber design properties; Area Ill—preservatives; Area IV—alternative transportation system timber structures; Area V—inspection/rehabilitation; and Area VI—technology and information transfer. The objective is to advance the state of the practice for the use of wood in transportation structures. Currently, more than 44 studies have been Initiated within these six areas at over 24 different research institutions across the country. Although there is basic research being conducted, the thrust of this program is to produce implementable products for use by the transportation agencies. These products range from standard plans, to inspection manuals, to crash tested bridge rails. Summaries of current research studies underway have been presented in a number of publications including *Bridge and Structures Related Research-Summary* [2], *Proceedings of the International Wood Engineering Conference* [3], and *Proceedings of the Pacific Timber Engineering Conference* [4]. Below is an update of this ongoing research.

### 4.1 System Development and Design

Research studies conducted in this area will be used to refine and improve design, fabrication, and construction procedures, and formulate recommendations for changes in the design codes. With the start of the timber bridge programs, the States and counties were wanting to build new, innovative timber bridges. However, many of these newer design types had neither long-term performance data, nor approved specifications. Therefore, a significant effort has been spent investigating the field performance of timber bridges under a "national timber bridge monitoring program.' These structures are located across the U.S. and include emerging Umber bridge design technologies such as the stress-laminated bridges, glued-laminated timber bridges, structural composite lumber beam bridges, and glulam/FRP bridges. Reports on individual bridges are published as each monitoring project comes to an end. The publications are available on the internet at the FPL site (http://www.fpl.fs.fed.us/wit/), and/or through the National Wood In Transportation Information Center.

Other studies underway in this area include investigating the dynamic behavior of timber bridges due to vehicular loadings, assessing structural performance of timber bridges under seismic loadings, and developing alternative prestressing systems for the next generation of stressed timber bridges.

Below are all the research studies started in this area:

- National Timber Bridge Monitoring and Evaluation including Full-scale Load Testing,
- Field Evaluation of a Timber Bridge Constructed With Metal Plate Connected Trusses,
- Development of Long-Span Timber Bridge Systems Using Glued-Laminated Timber,
- Development of Stress-laminated Truss Bridges Using Light-frame Metal Plate Connected Trusses,
- Evaluation of Cold Temperature Effects on Stress-laminated Timber Decks,
- Dynamic Evaluation of Timber Bridges,
- Design Optimization of T, Bulb-T, and Box Stressed Timber Bridges,
- Stress-Laminated Wood T & Box Beam Bridge Superstructures,
- Evaluation of Alternative Prestressing Elements,
- Field Performance of a Stress-Laminated Timber Bridge With E-Glass FRP Tendons,
- Effects of Seismic Loadings on Timber Bridges, and
- Utilization of Structural Composite Lumber for Bridge Applications.

### 4.2 Lumber Design Properties

These research studies are aimed at developing engineering design criteria for structural wood products for use in highway bridges and at improving methods for characterizing lumber design properties. Studies underway have been aimed at improving the shear design criteria as it applies to nonchecked and checked solid sawn lumber, and to glued-laminated timber by determining whether there is a correlation between shear strength and beam size. Historically, shear strength properties of lumber have been determined from small, straight-grained, dear shear block specimens. However, controversies have existed on whether the results from the shear block specimens are representative of shear strength of structural beams or whether these small blocks account for local defects such as checks, splits, and knots present in full size beams. The findings of the shear study on solid sawn Douglas-fir beams are reported in research paper FPL-RP-553 [5]. The final report on the glued-laminated Umber beams is being prepared.

A second study In this area deals with determining the longitudinal modulus of elasticity (MOE) of in-place timber members within existing stress-laminated timber bridges using stress-wave nondestructive evaluation technology. Because of the variability of MOE within a lumber species and grade, field measurements of MOE in actual laminations is considered desirable to develop accurate models to determine the bridge behavior and load distribution under various field conditions, and to determine any changes that may occur over time, and/or due to effects of preservative treatments. This study is nearing completion.

The third study In this area is aimed at refining the Load and Resistance Factor Design (LRFD) calibration factors for timber bridges currently given in AASHTO's *LRFD Bridge Design Specifications* [6]. This is being accomplished through the development of toad models, resistance models, reliability analysis, reliability indices, and calculation of resistance factors. The LRFD approach is intended to provide a rational basis for the design of bridge structures by providing the same level of safety for all members of a bridge.

### 4.3. Preservatives

The goal of this area of research is to develop and/or refine the preservative systems for use in highway timber bridges. Environmental issues and environmental concerns are a top priority in all these studies. The end products will be identifying emerging preservatives, establishing appropriate preservative retention, and identifying species/chemical combinations to protect timber transportation structures against deterioration caused by fungi and insects. Some studies, especially the laboratory studies and/or studies where small size samples are included, will be studied further through applications in actual structures to determine the effectiveness. In addition to preservatives, which are applied at the beginning, effective remedial treatments such as fumigants are also being studied for use during the life of a structure at the onset of deterioration, checking, splitting, etc. Information on leachability of preservatives and any environmental hazards it proposes will be available for use by the States. Lastly, a manual on wood preservatives Is being prepared.

Specifically the following studies are underway in this area:

- Accelerated Laboratory Testing of New Wood Preservatives—Ecosystem Studies,
- Accelerated Laboratory Testing of New Wood Preservatives—Pure Culture Studies,
- Accelerated Testing of New Preservatives.
- Preservative Effects on Stress-Laminated Southern Pine Bridge Decks,
- Field Treatment Systems for Protecting Bridge Members,
- Development of Treatments and Methods for Field Treating Bridge Members,
- Manual on Wood Preservatives for Transportation Structures,
- Treatability of Heartwood.
- Copper Naphthanate Preservative for Bridge Applications, and
- Assessing Environmental Effects of Wood Preservatives Used in Timber Transportation Structures.

### 4.4 Alternative Transportation System Timber Structures

The research studies that have been conducted in this area have been directed toward the development of bridge rails and of sound barriers. The development of crash tested bridge rails for timber bridges was considered a high priority because many recognized that the static procedures for designing bridge rails were not adequately providing the performance characteristics when impacted by a vehicle, and regulations were set requiring only approved crash tested bridge rails be used on those bridges built using Federal highway funds.

Currently, the following bridge rail systems have been developed and successfully crash tested to meet AASHTO Performance Level-One (PL-1) [7] criteria for use on a transversely laminated timber deck bridge:

- Glued-laminated timber rail without curb,
- Glued-laminated timber rail with curb,
- W-beam rail without curb, and
- Glued-laminated timber transition rail.

The PL-1 requires two crash tests be conducted, one with a 2,449 kg vehicle impacting the rail at 20°, 72 km/h, and the other with a 816 kg vehicle impacting the rail at 20°, 80 km/h.

In addition, the following bridge rail systems have been developed and successfully crash tested to meet AASHTO PL-1 and Performance Level Two (PL-2), and NCHRP Report 350 Test Level Four (TL-4) [8] criteria for longitudinally laminated timber deck bridges:

- AASHTO PL-1, bridge rails:
  - Glued-laminated timber rail with curb,
  - Glued-laminated timber rail without curb,
  - Steel rail without curb, and
  - Approach rail transition for a glued-laminated Umber rail to a steel approach rail.
- AASHTO PL-2, or NCHRP 350 TL-4 bridge rails:
  - Glued-laminated Umber rail with curb (TL-4)
  - Steel rail without curb, and
  - Steel approach rail transition for use on the glued-laminated timber rail.

The PL-2 requires three tests consisting of impacting the rail with a 6.165 kg vehicle at 15°, 80 km/h; a 2,449 kg vehicle at 20°, 97 km/h; and a 816 kg vehicle at 20°, 97 km/h. The TL-4 requires three tests consisting of impacting the rail with a 820 kg vehicle at 20°, 100 km/h; 2000 kg vehicle at 25°, 100 km/h; and 8000 kg vehicle at 15°, 80 km/h.

Currently, a study is ongoing to develop bridge rails to meet TL-4. and TL-2 requirements for transversely laminated timber deck bridges. Test Level Two (TL-2) requires two tests consisting of impacting the rail with a 820 kg vehicle at 20°, 70 km/h; and 2000 kg vehicle at 25°, 70 km/h.

Highway noise is a constant problem, especially in urban areas. The wood sound barrier developed will help alleviate this problem and provide communities with an alternative noise wall system from those that are currently available. Recommended design criteria and designs for wood sound walls. along with a set of standard plans, will be available as a result of this ongoing study.

### 4.5 Inspection/Rehabilitation

The goal of this area of research is to develop effective, safe, and reliable methods for rehabilitating existing highway timber structures. Existing preservative systems end those being studied under this research program are intended to alleviate the problem of wood deterioration due to biotic agents. Often times the problem lies not in the effectiveness of preservative systems, but in not having the tools necessary to locate deterioration, and thereby apply remedial treatments to prevent further degradation. The current state-of-the-practice for evaluation of timber bridges is through destructive and/or semi-destructive means. Probing, coring, and drilling are all destructive and/or semi-destructive methods that are used to verify detertoration and/or rot in timber members. The most common nondestructive means is "sounding.' when the wood is impacted by a hammer and the sound that is produced is used to quantify the extent of deterioration. This process, however, requires someone with trained ears and is subject to individual interpretation depending on the experience of the inspector. Seeing a need to advance the current inspection techniques, emphasis has been given on identifying, developing, and evaluating promising nondestructive evaluation (NDE) techniques to accurately inspect and assess the structural integrity and remaining service life of timber bridge members.

The one NDE technique that has been used more than others for inspecting wood members is stress wave technology. However the use of this technology is still limited due to a need for qualified personnel for equipment operation and data interpretation. Therefore, guidelines for equipment use and better Interpretive procedure for evaluation of bridge components using NDE stress waves is being prepared. More advanced inspection systems are also being explored lo provide 2-D or 3-D. real-time images of the area inspected, which are easier to interpret.

Other studies in this area include finding effective products for protecting timber members from moisture fluctuations, thereby reducing or preventing checking and splitting; finding effective wearing surfaces for timber decks; and developing an inspection manual for timber bridges.

### 4.6 Technology and information Transfer

A study is nearing completion on developing standard plans and specifications for several types of timber bridge superstructures. All designs are being developed in accordance with the current *Standard Specifications for Highway Bridges* using AASHTO HS20 and HS25 loadings [9]. The intent is to provide complete design, fabrication, and construction information. Design details and specifications will be available as half-size drawings and on computer disks for use in computer aided drafting systems.

In addition to these standard plans, the following design aids and/or manuals have been developed or are under development as tools for technology transfer:

- Standard *Plans for Southern Pine Bridges* [10],
- *Interactive Computer Programs for Wood Bridge Superstructures* (under beta testing),
- *Standard Plans for Crash Tested Bridge Rails for Use on Longitudinally Laminated* Decks [11],
- *Standard Plans for Crash Tested Bridge Rails for Use on Transversely Laminated Timber Bridges,*
- *Standard Plans for Crash Tested Wood Bridge Rails for Concrete Decks* (under review),
- *Manual for Timber Bridge lnspection* (under review), and
- *Preservatives Manual.*

A national conference and an international workshop have been held to further disseminate information related to wood utilization in transportation applications. The National Conference on Wood Transportation Structures, held in Madison, WI, on October 23-25,1996, provided a forum for the exchange of state-of-the-art information on timber transportation structures. The proceedings of the National Conference on Wood Transportation Structures was prepared [14]. An international workshop on timber and temporary bridges was held in conjunction with the PIARC (World Road Congress) sponsored International Seminar on Bridge Engineering and Management in Asian Countries in Jakarta, Indonesia, September 10-13,1996.

The publications resulting from all these research studies will also be provided on compact discs and on the Internet. The last year of funding under ISTEA for new research and demonstration projects ended fiscal year (FY) 1997; however, most of the research studies are ongoing and will be completed within the next several years. Funding for the Wood in Transportation Program is ongoing, with the funding level determined each year. The research and demonstration projects resulting from these programs are a major step towards advancing the state of the practice for the use of wood in transportation applications.

## 5. BIBLIOGRAPHICAL REFERENCES

[1] Wipf, T.J.; Ritter, M.A.; Duwadi, S.R.; Moody, R.C. *Development of Six-year Research Needs Assessment for Timber Transportation Structures*, Gen. Tech. Rep. FPL-GTR-74. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, 1993.

[2] *Summary of Bridge and Structures Related Research*, Federal Highway Administration, http://www.tfhrc.gov/structur/summary/summary.htm, 1997.

[3] Ritter, M.A.; Moody, R.C.; Duwadi, S.R. "Summary of U.S. Research on Wood Transportation Structures", Gopu, V.K.A., ed(s). *Proceedings of the International Wood Engineering Conference*; New Orleans, LA, Vol. 1: 81-88, 1996.

[4] Ritter, M.A.; Moody, R.; Duwadi, S. "U.S. Timber Bridge Research", PTEC 94 *Timber Shaping the Future: Proceedings of Pacific Timber Engineering Conference*; Gold Coast, Australia, Vol. 2: 148- 155. 1994.

[5] Rammer, D.R.; Soltis, L.A.; Lebow, P.K. *Experimental Shear Strength of Solid-sawn Douglas-fir Beams*, Res. Pap. FPL-RP-553, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, 1996.

[6] *Load Resistance Factor Design Bridge Design Specifications*, American Association of State Highway and Transportation Officials, Washington, DC.

[7] *Guide Specifications for Bridge Railings*, American Association of State Highway and Transportation Officials, Washington, DC, 1989.

[8] Ross, H.E.; Jr., Sicking, D.L.; Zimmer, R.A.; Michie, J.D. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, DC, 1993.

[9] *Standard Specifications for Highway Bridges*, American Association of State Highway and Transportation Officials, Washington, DC.

[10] Lee, P.D.H.; Ritter, M.A.; Triche, M. *Standard Plans for Southern Pine Bridges*. Gen. Tech. Rep. FPL-GTR-84, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, 1995.

[11] Ritter, M.A.; Faller, R.K.; Lee, P.D.H.; Rosson, B.T.; Duwadi, S.R. *Plans for Crash-Tested Bridge Railings for Longitudinal Wood Decks*. Gen. Tech. Rep. FPL-GTR-87, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI,1995.

[12] Ritter, M.A.; Duwadi, S.R.; Lee, P.D.H.; eds., *National Conference on Wood Transportation Structures*, Gen. Tech. Rep. FPL-GTR-94, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, 1996.

Cet ouvrage est une publication des Presses Polytechniques et universitaires romandes, le catalogue des publications peut être obtenu par courrier à I'adresse suivante, EPFL - Centre Midi, CH- 1015 Lausanne, par E-Mail à ppur@cpfl.ch, par téléphone au (0)21 693 40 27.

Vous pouvez consulter notre catalogue général sur notre serveur:
*Please consult our general calalog on the Web:* http://ppur.epfl.ch

ISBN 2-88074-380-X

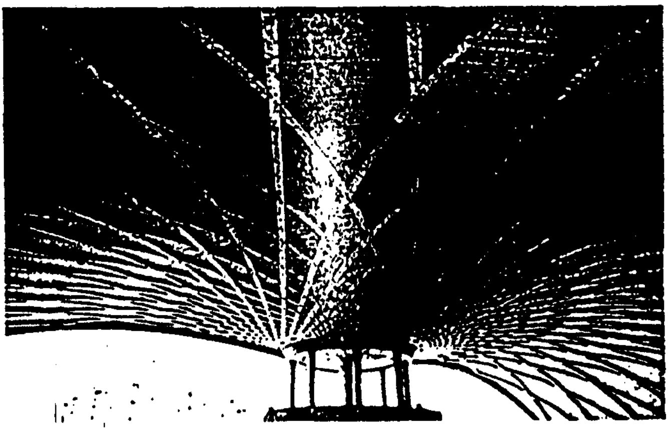
Presses polytechniques et universitaires romandes,
CH - 1015 Lausanne

W C T E '98

SWISS FEDERAL
INSTITUTE OF TECHNOLOGY
LAUSANNE - SWITZERLAND

# 5th World Conference on Timber Engineering,

August 17-20, 1998
Montreux, Switzerland



# PROCEEDINGS

Volume 1

**Edited by J. Natterer and J.-L. Sandoz**

Presses polytechniques et universitaires romandes