CURRENT TIMBER BRIDGE RESEARCH AND DEVELOPMENT IN THE UNITED STATES

Until the mid 1800's, the majority of the bridges constructed in the United States were made of timber. By the early 1900's, preference for new bridge construction shifted to steel and concrete as the technology for these materials rapidly advanced. In the first half of the 20th century, many timber bridges continued to be built, but their use was mostly restricted to secondary rural road systems and little advancement occurred in timber bridge technology. By the late 1960's, new timber bridge systems employing structural glued laminated (glulam) timber were introduced and the development and use of timber bridges began to slowly advance; however, the percentage of timber bridges for new construction continued to be a small fraction of those constructed of steel and concrete. Based on the current National Bridge Inventory, approximately 10% of the highway bridges in the United States are constructed of timber. One of the primary reasons for the decline of timber bridges has been a lack of research and development to advance timber bridge technology to meet modern needs.

As a result of national legislation, and other programs sponsored by state and local organizations and the timber industry, timber bridge research and development have increased dramatically.

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FISCAL YEAR 1993 TIMBER BRIDGE CONSTRUCTION GRANTS AWARDED

The Timber Bridge Initiative proposal Evaluation Panel met January 27-29, 1993, at Morgantown, West Virginia to review and recommend for funding the Fiscal Year 1993 timber bridge construction grant recipients. Panel members were:

Edward Cesa, Timber Bridge Initiative Coordinator, NA Representative
Kenneth Kilborn, Timber Bridge Initiative Coordinator, NA Representative
Robert Westbrook, Timber Bridge Initiative Coordinator, Southern Representative
William vonSegen, Timber Bridge Initiative Coordinator, Western Representative, Region 6
Clare Mitchell, Timber Bridge Initiative Coordinator, Western Region, Region 3
Vernon Meyers, Timber Bridge Initiative Coordinator, Western Region, Region 1
Stephen Bunnell, National Forest System, Engineering, Washington Office
Russell Moody, Forest Products Laboratory, Engineered Wood Products
John Sebelius, State and Private Forestry, Washington Office Representative
Dade Foote, Bridge Engineer, National Forest System, Region 8
Thomas Williamson, Executive General Manager, American Plywood Association
Marc Liszewski, Southern Forest Products Association
H.M. “Mac” Luphold, Manager, Manufacturing Wood Products
Lou Triandafilow, Federal Highway Administration, Office of Structures, Baltimore, MD
John Pasquantino, NA Representative
Stephen C. Quintana, Timber Bridge Initiative Program Director

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Current Research ... continued from page 1

in the U.S. over the past five years. This paper presents an overview of selected current research and related activities.

USDA FOREST SERVICE, FOREST PRODUCTS LABORATORY (FPL)

Timber bridge research at the FPL has been divided into six major categories: Engineering Design Criteria, Improved Timber Bridge Systems, Design Criteria for Stress-Laminated Timber Bridges, Preservatives, Economics of Timber Bridges, and In-Place Evaluations Procedures. Selected highlights of current research within each of these categories follow.

Engineering Design Criteria

Yield and properties of red oak and red maple structural lumber. A study to develop structural grade yield and property information for red oak and red maple as a function of log quality is being completed.

Properties of red oak structural lumber. A study is continuing at West Virginia University to determine the mechanical properties of red oak lumber. A paper on the results of this study has been prepared and is currently being reviewed.

Acoustic grading for red oak lumber. A study is continuing with West Virginia University to investigate the suitability of acoustic emission technology for use in sorting red oak lumber. After detailed analysis of the data, a report will be prepared on acoustic emission attributes that can be used to predict strength and potentially serve as a basis for assigning structural grades.

Red Maple glulam timber. Pennsylvania State University, in cooperation with the Pennsylvania Department of Transportation and FPL, is developing design information for red maple glulam timber for use in bridges. The FPL staff provided recommendations on methods for obtaining standards approval for more efficient and cost-effective combinations. A draft report has been prepared and presented to a task committee of the American Institute of Timber Construction. This industry organization is proceeding to develop a design specification based on the research.

Construction and evaluation of a cottonwood stress-laminated bridge deck. A project is continuing to design, construct, and monitor a stress-laminated bridge deck constructed of eastern cottonwood lumber. This project will provide information on the feasibility of using cottonwood lumber and similar secondary commercial species for bridge construction.

Crashworthy bridge rail systems. A study with the University of Nebraska has been completed to develop crashworthy bridge rail systems for timber decks. The rails are for use on longitudinal wood deck systems at American Association of State Highway and Transportation Officials (AASHTO) PL-1, and consist of (1) a wood rail system with curbs; (2) a wood rail system without curbs; (3) a steel rail system; and (4) an approach rail transition from a wood bridge rail to a steel approach rail. A final report is currently being prepared.

Yellow poplar glulam timber. The FPL is cooperating with West Virginia University in developing efficient combinations of yellow poplar for glulam timber. Proposed combinations were developed based on available lumber data, material was purchased, and 45 beams have been manufactured and evaluated. Results are encouraging and an industry organization is proceeding to develop a design specification based on the research.

Shear design procedures for structural lumber. A study is continuing to determine if a bending/shear strength correlation exists for glulam timber. A publication that proposes a new approach to shear design is planned.

Wood-nonwood composites for bridges. This project is investigating wood-nonwood composites for bridge applications. Fiber-reinforced pultruded composites are to be bonded to wood beams to increase their stiffness. Initial work has focused on determining the ability of various adhesives to form acceptable bonds between wood and the fiber-reinforced composites. The adhesives included phenol-resorcinon-formaldehyde (PRF),
Current Research ... continued from page 2

epoxy, and emulsion polymer isocyanate. Only the PRF-bonded joints performed well in wet tests. Tests of cyclic delamination resistance of bonded joints are underway. Work has recently started on a second phase, which will include construction of several glulam timber beams with fiber-reinforced composites for outer laminations.

Improved Timber Bridge Systems

Feasibility of stress-laminated truss bridges. Research is continuing at the University of Maine to evaluate the feasibility of stress-laminated truss bridges.

Design Criteria for Stress-Laminated Timber Bridges

Effect of butt joints on stress-laminated decks. A study is in progress to experimentally determine the effect of butt joints on the performance of stress-laminated decks. The information obtained from the study will be used to refine design procedures to more accurately reflect butt joint effects.

Stress-laminated sections using glulam timber. A study has been completed with the University of Wisconsin to investigate the load distribution characteristics of flanges and box sections for stress-laminated systems constructed of glulam timber components. At this time, a final report is being prepared.

National bridge monitoring program. Field performance is being monitored on numerous stress-laminated bridges located across the United States. These structures include bridges constructed as demonstration bridges under the Timber Bridge Initiative as well as those built by the Forest Service and local governments. Also, cooperative bridge monitoring is in progress to assess the field performance of 12 stress-laminated bridges in West Virginia, which include stress-laminated decks, T-sections and box sections.

Pennsylvania bridge monitoring. The FPL is currently cooperating to assist the Pennsylvania Department of Transportation in evaluating the field performance of timber bridges constructed under a demonstration program.

Fastener systems and fatigue data for stress-laminated decks. A study is continuing with West Virginia University to develop fastener systems and fatigue data for modular stress laminated deck systems used on high-volume roads. Promising connection systems have been evaluated in 3 full-size cyclic load tests under simulated service conditions and a report is being prepared.

Effectiveness of disk springs for maintaining rod stress in stress-laminated bridges. The FPL is continuing to evaluate the effectiveness of disk-type springs for maintaining the rod force level in stress-laminated bridges. Results will be used to evaluate spring effectiveness and formulate recommendations on spring type, configuration, and placement.

Preservatives

Effectiveness of preservatives and water repellents on hardwood. Evaluations of the efficacy of CCA alone, and of CCA plus water repellents or stabilizers in hardwoods are being conducted using small wood beams exposed in soil beds (fungus cellars) at Mississippi State University. Small samples of Yellow Poplar, Red Oak, Red Maple and Southern Pine (control) have been treated with CCA and various water repellents and stabilizers. Data generated in these studies will be used in the development of future long-term field studies with larger test samples.

Performance of a stress-laminated bridge deck constructed of CCA-treated Southern Pine lumber. A project is continuing to construct and monitor a stress-laminated deck constructed of Southern Pine lumber treated with CCA. Results of this project will be used to formulate recommendations on the use of waterborne preservatives in stress-laminated bridge applications.

Economics of Timber Bridges

Economics of demonstration bridges. The FPL is participating in a project to collect and analyze economic information on demonstration bridges. These bridges include those constructed as part of...
FEDERAL HIGHWAY ADMINISTRATION AND FPL: CURRENT RESEARCH

Under the Intermodal Surface Transportation Efficiency Act of 1991, the Federal Highway Administration (FHWA) was mandated to initiate a six-year timber bridge research program. To execute this program, the FHWA and the FPL have combined funding and are working together to cooperatively develop and complete projects through staff studies and cooperative studies with universities, government agencies, private individuals, or organizations. Studies for the first year of the program will begin in early 1993 and will be in five research areas, as summarized below.

System Development and Design

Timber bridge monitoring and load testing. A timber bridge monitoring program modeled after existing FPL bridge monitoring program will serve to evaluate the field performance of timber bridges constructed primarily through the FHWA timber bridge demonstration program. Information obtained from monitoring and load testing will be used to assess structural condition and will serve as a basis for revising/confirming design procedures.

Long-span timber bridge systems using glulam timber. Phase 2. The second phase of a Forest Products Laboratory cooperative research project at the University of Wisconsin will be started to develop stress-laminated box beam bridges using glulam timber. This second phase will develop analytical methods for analyzing multi-cell box beam bridges and will formulate recommended design guidelines.

Stress-laminated truss bridges using light-frame metal plate connected trusses. The second phase of a Forest Products Laboratory cooperative research program with the University of Maine will be continued. The second phase will address added concerns about connection durability under design environmental conditions. Specific topics include possible connection corrosion, reduction in static load capacity due to cyclic loads and moisture conditions, and effects of cyclic moisture on joint fatigue capacity. A report on these topics will also include preliminary information on how fatigue and moisture affect finite element design analogs to be used in the truss bridge design phase.

Cold temperature effects on stress-laminated timber bridges

This project is an extension of work currently in progress at both the University of Minnesota and FPL to investigate the effects of cold temperatures on the performance of stress-laminated timber decks.

Economics of timber bridges

A study will be initiated to develop initial cost, life-cycle cost, and design life comparisons of timber bridge superstructures compared to steel and concrete superstructures. Comparisons will be on a regional basis and national in scope.

Additional Preservative Research

Accelerated laboratory testing of new wood preservatives. A study to evaluate potential new wood preservatives will involve testing of 4-5 new wood preservatives that currently show promise for bridge applications but have not been fully evaluated.

Treatments and methods for field-treating bridge members. The project will develop equipment, preservative formulae, and procedures for effectively treating field cuts, bore holes, and other breaks in preservative treatment encountered during bridge construction and maintenance operations.

Performance characteristics of various wood preservatives for stress-laminated bridge applications. A study to evaluate the effects of various wood preservatives and anchorage configurations on the dimensional stability of stress-laminated decks has been initiated with Florida State University/Florida A&M University.

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Current Research ... continued from page 4

Inspection/Rehabilitation

Guidelines for the design and application of waterproof asphalt wearing surfaces for timber bridge decks. This project will examine the behavioral characteristics of various types of timber deck systems and develop recommendations for the design and application of waterproof asphalt wearing surfaces using membranes and/or geotextile fabrics.

Methods for the in-place evaluation of timber bridges using stress wave technology. A project to develop guidelines for applying existing stress wave technology for the in-place evaluation of timber bridges will be initiated.

Equipment and methods for determining the in-place stiffness of stress-laminated timber decks constructed of sawn lumber. A study has been started at FPL to adapt existing nondestructive evaluation (NDE) technology to develop a simple procedure for determining the in-place stiffness of individual laminations within existing stress-laminated lumber bridges. This information will be used to evaluate field performance and assess structural integrity.

Technology and Information Transfer

Standard plans and specifications for timber bridge superstructures. This project will develop standard design plans and construction specifications for several or all of the following timber bridge superstructures: (1) glulam beams with transverse glulam deck; (2) longitudinal glulam deck; (3) longitudinal stress-laminated deck; (4) longitudinal spike-laminated deck; and (5) timber decks on steel beams.

Development of AASHTO specifications for timber bridge design. Work will be conducted towards revision of applicable sections of the AASHTO Standard Specifications for Highway Bridges related to timber bridges.

Pennsylvania Department of Transportation: Current Research

The Pennsylvania Department of Transportation has maintained a significant timber bridge research and development program for the past 3 years. In addition to a demonstration bridge program, which involves the construction and evaluation of 17 timber bridges, research has focused on developing bridge systems using glulam hardwood timber at Pennsylvania State University. Research completed to date has resulted in new material standards and a series of standard plans for hardwood glulam bridges, which will be finalized in the near future. Additionally, the project was recently expanded to include (1) evaluation of fastening and diaphragm systems; (2) optimization of laminating and gluing schemes; (3) efficient combinations of Red Oak glulam; (4) glulam bridge quality assurance and inspection; (5) identification of additional hardwood species for bridge construction; (6) field evaluation of a Red Maple demonstration bridge; and (7) treatment options for wood bridge railings.

National Cooperative Highway Research Program: Current Research

A project sponsored through the National Cooperative Highway Research Program (NCHRP) is currently in progress to develop a comprehensive bridge design specification and commentary for AASHTO. This project involves the development of a completely new specification in a Load and Resistance Factor Design (LRFD) format. After these reviews are completed, the final version of the project specification will be completed and presented to the AASHTO for adoption.

NOTE: This article is summarized for publication by the Editor. For copies of this complete publication, contact USDA Forest Service, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398; Phone: 608-231-9268.
Bridge Construction Grants Awarded... 

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Over 150 proposals were evaluated and 36 proposals were selected for funding for Fiscal Year 1993. Of the proposals funded, 27 bridges are vehicular and 9 bridges are pedestrian. The total dollar amount awarded was $995,075. Following is a list of the approved bridges. An asterisk (*) indicates the pedestrian bridges.

—Tinathan A. Coger
Editor
Morgantown, West Virginia

Funded Bridges

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* Pedestrian Bridges

Structural Behaviour of Timber

This book provides a descriptive presentation of the structural behavior of timber. A sharp distinction is made between wood in the sense of clear defect-free wood and timber in the British sense of a versatile building material. "Timber is as different from wood as concrete is from cement." We have long believed that the strength of timber could be predicted from strength tests with small clear wood specimen and that has caused timber to be placed in an unfavorable position relative to other building materials. This book describes the need for the development of the In-Grade testing philosophy and illustrates how the design community and the timber industry have been misinformed by the small clear wood specimen approach to deriving strength properties for timber. The structural behavior of timber when subjected to different forces (tension, bending, shear, etc.) is examined and the effects of duration of load, moisture content, and size are studied. This book then presents specific suggestions as to how the new knowledge and understanding can be incorporated into the design procedure of timber members. This book is directed to anyone associated with the structural use of timber, be it producer, designer, regulator, or user. It is recommended reading for serious students of timber engineering. It is presented in an easy to read form with an abundance of illustrations and pictures.

For more information contact: Dr. Borg Madsen, P.E.; Timber Engineering Ltd.; 575 Alpine Court, North Vancouver B.C., Canada, V7R 2L5
Phone and Fax: (604) 987-3430

EDITOR'S NOTE: The enclosed brochure has been provided for information on and convenience in ordering a copy of Structural Behaviour of Timber.