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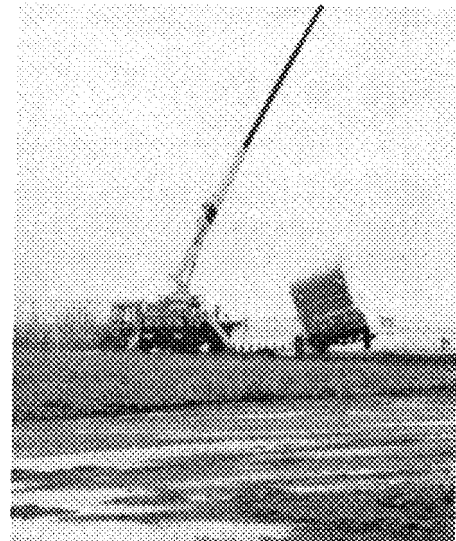
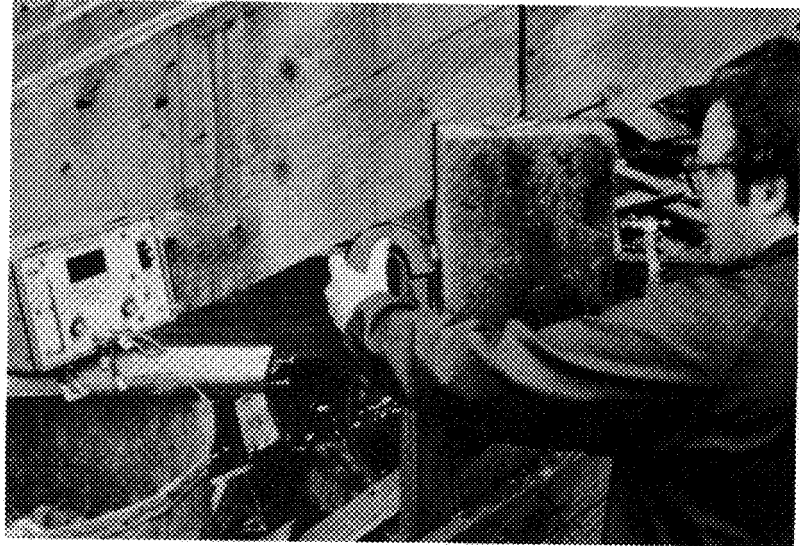
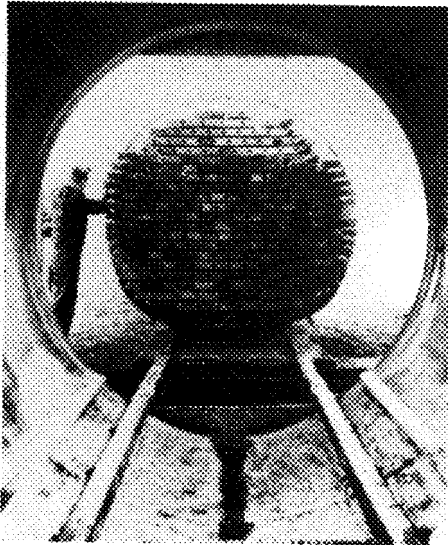
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Development of a Six-Year Research Needs Assessment for Timber Transportation Structures

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Abstract

A timber bridge, once a thing of the past, is now becoming a thing of the present. Interest in timber bridges and other transportation structures has been rapidly increasing. Much of this is due to new technologies in design and construction as well as advances in material manufacturing and preservative treatments. Although timber bridges and other transportation structures are gaining in popularity, there is much to be accomplished to fully develop wood as a material for transportation structures. This report summarizes research needs determined and prioritized by public and private individuals, and groups and organizations that have a potential interest in bridges and transportation structures. These research needs are categorized into research areas that correspond to the categories identified in the Intermodal Surface Transportation Act of 1991, Section 1039(a). Analysis of the research needs shows that there is a great deal of interest in wood preservation, development of standardized procedures, guidelines and specifications, and technology transfer. The projects and priorities identified in this study will be used by the Federal Highway Administration and the USDA Forest Service, Forest Products Laboratory as a basis for developing a national 6-year research program for timber transportation structures.

Keywords: Timber, wood, research, bridges, transportation structures

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Introduction

Interest in the area of timber bridges has significantly increased in the past several years. Much of this interest has resulted from the programs and activities of the USDA Forest Service Timber Bridge Initiative, which was passed by the Congress in 1989. An important part of the initiative is aimed at stimulating local economies and enhancing rural transportation systems through the use of locally available wood species for timber bridge and highway structural applications. For this to occur, additional research is needed to further develop timber as a material for transportation structures. New technology must be developed, adapted, and expanded to improve existing designs and develop new systems that allow for the efficient use of primary commercial wood species and previously underutilized species such as hardwoods.

Over the next several years, it is anticipated that funding will be available for research on timber transportation structures both at the USDA Forest Service, Forest Products Laboratory (FPL) and the Federal Highway Administration (FHWA). Presently, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 authorizes expenditures by the FHWA of up to \$1,000,000 per year for 1992-1997 for research and information transfer related to timber transportation structures. It is anticipated that future research will encompass a wide range of topics, including material properties, preservatives, system development and design, maintenance, inspection, and economics. To effectively develop and execute such a research program, a comprehensive summary of potential projects and priorities must be developed based on nationwide needs. This report describes the identification of potential research projects and priorities related to timber transportation structures.

Objective and Scope

The objective of this study was to develop a comprehensive summary of research needs and their relative priorities for timber transportation structures. The scope included all aspects of timber utilization in applications for transportation structures, from tree harvesting to bridge maintenance, rehabilitation, and replacement.

Methodology

To accomplish the objectives of this study, a four-step methodology was developed to complete a survey of targeted participants. This methodology consisted of (1) identifying participants, (2) completing an initial assessment of research needs, (3) assessing research needs in order of priority, and (4) analyzing data.

Participant Identification

To solicit input from a broad range of expertise and interests, study participants were drawn from the following groups and organizations:

- American Society of Civil Engineers, Timber Bridge Committee
- American Society of Civil Engineers, Committee on Wood
- National Society of Professional Engineers
- Army Corps of Engineers
- Bureau of Indian Affairs
- Soil Conservation Service
- Parks Service
- Bureau of Land Management
- USDA Forest Service
- Federal Highway Administration
- State foresters (all states)

State bridge engineers (all states)
Selected resource conservation and development (RC&D) coordinators
University researchers involved in wood research
National Association of County Engineers
National Forest Products Association, Timber Bridge Task Group
FHWA Research Specialty Committee on Timber
Regional Technical Assistance Program (RTAP) centers
1890 Colleges (Land Grant)
Ministry of Transportation, Ontario, Canada

Initial Needs Assessment

Initial research needs were assessed by soliciting potential research projects from study participants. This was accomplished through an initial mailing that included a cover letter and a brief summary of research needs previously prepared by the FHWA (limited survey completed in 1989) (Appendix A). The cover letter summarized the purpose of the project and the information requested, and was prepared in two versions: one directed at individuals and the other directed at groups and organizations. The summary of research needs listed 42 potential research projects in eight categories:

- Materials
- Preservatives
- System Development and Design
- Construction
- Inspection
- Maintenance and Rehabilitation
- Economics
- Other

The initial mailing was sent to all study participants. Each was asked to add additional projects and/or modify those presented in the summary. Additionally, groups and organizations were encouraged to solicit input within their membership. Of the 328 letters sent in the initial mailing, 193 responses were received. After combining duplicate responses, a total of 118 potential research projects were identified.

Prioritized Needs Assessment

After the potential research projects obtained from the initial mailing were compiled, a second mailing was prepared to obtain the relative project priorities. This mailing consisted of a cover letter and a list of the research projects, by category, obtained from the initial mailing (Appendix B). Participants were asked to rate each project as high, medium, or low priority on an electronic coding form (Appendix B).

The second mailing was sent to all study participants, regardless of whether they had responded to the initial mailing. Again, groups and organizations were encouraged to solicit input within their membership. Of the 328 letters sent in the second mailing, 182 responses were received.

Data Analysis

Priorities received from study participants were assigned a numerical value of 1, 2, or 3 for low, medium, or high priority, respectively. Using these numerical values, the mean ranking for each potential project was determined and an overall ranking of projects was developed. Additionally, projects were ranked within each of the eight categories.

To develop a more usable format for outyear research planning, the data were subjected to further analysis and presentation. This involved a redefinition of the eight categories into the seven general

research areas defined in the ISTE A. These research areas, including an area for other studies that did not fit those identified in ISTE A, were as follows:

- I. System development and design
- II. Lumber design properties
- III. Preservatives
- IV. Alternative transportation system structures
- V. Inspection and rehabilitation
- VI. Technology and information transfer
- VII. Other

Within each area, potential studies were grouped under a descriptive heading and a general needs statement. In the process, similar potential studies were combined and wording was edited as necessary to further define the scope of potential studies. When similar studies were combined, the highest priority of the combined studies was assigned.

Results

The results obtained from this study are presented in two formats based on priorities assigned by participants. The first format is the overall priority ranking of all research needs. The second format is the relative ranking of each research need within the original eight research categories.

Ranking of Research Needs by Overall Priority

Research needs were ranked, from highest to lowest priority, as follows:

1. Develop crash-tested bridge rails for longitudinal and transverse timber decks, including approach rail transitions, at American Association of State Highway and Transportation Officials (AASHTO) PL-1 and PL-2.
2. Prepare guidelines and standard design details for designing timber bridges for minimum maintenance and long life.
3. Develop economical, easy-to-use equipment and methods to conduct nondestructive testing of in-place timber bridge components, including piles.
4. Develop guidelines on effectiveness, use, and application of wood preservatives for field treating during fabrication and construction, especially for holes and other limited access areas.
5. Develop standard designs, details, and specifications for timber bridge superstructures.
6. Develop and test new wood preservative chemicals that do not pose environmental hazards.
7. Develop crashworthy bridge rails for low-volume roads.
8. Prepare a comprehensive manual for inspection and evaluation of timber bridges.
9. Develop guide specifications for timber bridge construction.
10. Develop standardized procedures and specifications for nondestructive evaluation of timber bridge components.
11. Prepare a comprehensive manual on maintenance practices for timber bridges.

12. Develop designs and standards for long-lasting, waterproof, skid-resistant wearing surfaces for timber bridges.
13. Develop standard designs, details, and specifications for timber bridge substructures.
14. Develop initial cost, lifecycle cost and design-life comparisons of timber as opposed to steel bridges and culverts.
15. Conduct field evaluations of existing structures to determine load distribution characteristics of AASHTO-approved timber bridge systems to refine procedures and criteria for design and load rating.
16. Develop standardized methods for load testing and load rating of existing timber bridges.
17. Investigate and define acceptable live-load deflection criteria for various timber superstructure and deck types based on structural behavior.
18. Evaluate leachability and potential environmental hazards posed by wood preservatives in exposed bridge applications.
19. Develop and evaluate economical, long-lasting methods for sealing and protecting exposed end-grain.
20. Develop prefabricated, modular timber bridge systems that are easily transported.
21. Develop methods for fastening wood decks to steel and concrete stringers for both new construction and replacement decks.
22. Develop an informational summary on restrictions, use recommendations, and application of wood preservatives.
23. Develop materials for sealing wood against moisture in areas subject to prolonged moisture.
24. Refine inspection methods to more accurately detect incipient decay in timber bridge components.
25. Develop guidelines for comparing relative cost and design-life of various types of timber bridges, including composite construction.
26. Develop guidelines for disposal and/or reuse of treated timber in accordance with Environmental Protection Agency, (EPA) guidelines.
27. Refine horizontal shear design values and requirements for sawn lumber and glued laminated (glulam) timber.
28. Collect, analyze, and report bridge cost data obtained through Forest Service, FHWA, and State timber bridge demonstration projects.
29. Evaluate effect of aging, moisture cycling, and repetitive loading on lumber stiffness.
30. Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.

31. Develop specifications and standards for use of structural composite lumber, including laminated veneer lumber (LVL) and parallel strand lumber in highway structural applications.
32. Evaluate suitability and performance characteristics of structural composite lumber in exposed bridge applications.
33. implement mechanism for transferring timber bridge technology to users in a timely manner.
34. Evaluate effects of chromated copper arsenate (CCA), and other waterborne preservatives on physical and mechanical properties of wood.
35. Study means for obtaining composite action between timber beams and timber decks.
36. Summarize methods of construction for various timber superstructures and substructures, including case histories.
37. Evaluate suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.
38. Develop guidelines for effectiveness and use of wood preservatives for in-place treating of deteriorated timber components.
39. Adapt existing computerized bridge design programs (BRADD, MERLIN-DASH, etc.) to include timber bridges and timber bridge components.
40. Evaluate effect of preservative treatment (chemicals and treating processes) on sawn lumber and glulam timber produced from hardwood species and structural composite lumber products produced from either hardwoods or softwoods.
41. Develop interactive computer programs for design of timber bridge systems and timber components used with other bridge materials.
42. Develop and evaluate alternative methods of wood preservation, other than chemical preservatives to protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).
43. Evaluate compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives, both before and after gluing.
44. Develop methods and comprehensive guidelines for restoring, increasing capacity of, or replacing deteriorated bridge timber components and piles with an emphasis on accuracy and minimal traffic disruption.
45. Investigate methods for determining post-decay strength of timber components.
46. Evaluate effects of salt and de-icing chemicals on physical and mechanical properties of wood.
47. Compile material resistance values for use in LRFD design for lumber, glulam, and timber piles.
48. Evaluate suitability of timber connections subjected to dynamic loading (fatigue).
49. Develop guidelines for use of treated timber.
50. Develop serviceability requirements for timber bridges based on use requirements.

51. Evaluate suitability of waterborne preservatives for sawn lumber and glulam timber relative to dimensional stability in exposed bridge applications.
52. Compile and distribute information on use of hardwoods and secondary softwoods in bridge applications.
53. Develop methods for determining embedment length of timber piles.
54. Conduct field evaluations of stress-laminated decks, constructed of various species and exposed to differing environmental conditions, to determine load distribution and performance characteristics.
55. Investigate use of glulam T-beam and box-beam sections for long spans.
56. Investigate and determine methods for evaluating residual bending strength of beams that split or have failed in horizontal shear.
57. Develop guidelines on treatability and applicability of various preservatives and treatment processes on heartwood and sapwood of all commercially viable softwood and hardwood species.
58. Develop technology for economical glulam timber manufactured from hardwood or secondary softwood species.
59. Evaluate effectiveness and develop guidelines and standards for water-repellant additives used in conjunction with waterborne preservatives for hardwood and softwood species.
60. Evaluate suitability of galvanizing and epoxy coatings to protect stress-laminated bridge stressing bars from corrosion.
61. Evaluate effects of wood preservatives on metal hardware and corrosion protection systems for metal hardware.
62. Compile summary of ongoing timber bridge research and distribute quarterly to interested parties.
63. Develop methods for reducing live-load deflection of AASHTO-approved timber bridge systems.
64. Develop methods and design criteria for post-tensioning timber beams and bridge systems.
65. Develop guidelines for economically optimizing material requirements for specific bridge types.
66. Investigate feasibility of gluing wood treated with creosote or other oilborne preservatives to improve treatment of large glulam members.
67. Develop cost-estimating guide for determining transportation, labor, and equipment requirements for timber bridge construction, based on time-in-motion studies of bridge construction projects.
68. Develop educational materials for use in colleges and trade schools.
69. Investigate potential for preservative treatment leaching and distribute information on subject.
70. Develop innovative methods of using steel, reinforced plastics, or other materials to improve strength and stiffness of timber components.

71. Evaluate effect of cold temperature on physical and mechanical properties of wood under static and dynamic loading conditions.
72. Investigate potential for composite construction using timber with nonwood materials.
73. Develop methods to restore capacity of beams with horizontal shear failures.
74. Develop modular timber superstructure and substructure designs for temporary applications and portability.
75. Determine lateral support provided for steel beams by different timber deck systems.
76. Determine effect of moisture content on properties of hardwood lumber.
77. Develop design criteria for stress-laminated T-section bridges through laboratory and field evaluations.
78. Establish applicable penetration and retention requirements for use of copper naphthenate in bridge components of softwood and hardwood sawn lumber and glulam timber.
79. Investigate suitability of borate treatments for softwoods and hardwoods in exposed bridge applications.
80. Develop methods and design criteria for longitudinal stress-lamination of timber bridges.
81. Develop fatigue level (S-N) curves for softwood and hardwood lumber species.
82. Develop and field-evaluate new methods for shear transfer between glulam deck panels
83. Determine potential creep characteristics for lumber and glulam timber manufactured from softwood and hardwood.
84. Develop guidelines for effectiveness and use of fumigants for in-place treating of deteriorated timber components.
85. Investigate methods for developing bolt-laminated beams and decks.
86. Develop new methods of protecting for stress-laminated deck stressing bars against corrosion, including coatings and mechanical and cathodic protection.
87. Develop design criteria for timber arches and trusses for submission to AASHTO.
88. Evaluate longitudinal creep characteristics of stress-laminated deck bridges.
89. Refine National Design Specification (NDS) properties for visually graded hardwood lumber through in-grade testing.
90. Develop data base of timber bridges, by type and material, constructed **in United States and Canada** over past 30 years.
91. Investigate and define acceptable live-load deflection criteria for performance of wearing surfaces and human response.
92. Develop technology for glulam timber manufactured from mixed species.

93. Investigate and document performance of timber bridges subjected to seismic loading.
94. Develop designs and field tests of timber piers, abutments, and culverts.
95. Refine applications of stress lamination to include rehabilitation of existing components.
96. Develop designs for retaining walls and evaluate field performance.
97. Refine methods for assigning property values to hardwood lumber.
98. Revise existing treating standards to limit quantity of untreatable heartwood and restate moisture content requirements to reflect maximum rather than average values.
99. Develop base-line treating cycles for hardwoods and other underutilized species.
100. Develop design criteria for stress-laminated box-beam bridges through laboratory and field evaluations.
101. Evaluate suitability of using toothed metal plate connectors (truss plates) in bridge components subjected to fatigue loading and cyclic moisture changes.
102. Develop economical, portable, reliable, and simple-to-use methods and equipment for machine grading hardwood and softwood lumber.
103. Refine duration of load adjustments for bridge applications.
104. Document experiences and lessons learned from using previously underutilized hardwood and secondary softwood species for bridge construction.
105. Investigate suitability and efficacy of existing preservative chemicals and treatment processes for applications involving hardwoods and secondary softwood species.
106. Develop methods for stress-laminating timber with nontimber materials.
107. Investigate suitability of diffusible borate for bridges.
108. Develop methods for determining residual strength of fire damaged timber components.
109. Develop quality control procedures appropriate for mechanical grading of lumber from mixed species that are applicable to small mills.
110. Develop and field-test bridges constructed of stress-laminated trusses manufactured with toothed metal plate connectors.
111. Evaluate volume effect on strength and stiffness properties of hardwood structural lumber.
112. Develop designs and evaluate field performance of noise barriers constructed of timber and of timber with other materials.
113. Document economic multiplier effect of using local materials and labor for transportation structures.

114. Evaluate feasibility of developing small, mobile pressure-treating units for applying wood preservatives.
115. Conduct grade and yield studies for hardwood logs, considering commercially viable species.
116. Complete analysis of U.S. bridge needs in next 30 years based on span and functional classification.
117. Develop economical, portable equipment to scan and evaluate suitability of log for structural lumber before cutting the log.
118. Evaluate comparative energy requirements for production and construction of timber, steel, and concrete bridges and culverts.

Ranking of Research Needs by Category

In this section, each research need is ranked by research category: materials, preservatives, system development and design, construction, inspection, maintenance and rehabilitation, economics, and other. The number in the far left column indicates the ranking within the category; the number in parentheses indicates the overall ranking relative to all stated research needs.

Materials

1. (27) Refine horizontal shear design values and requirements for sawn lumber and glulam timber.
2. (29) Evaluate effect of aging, moisture cycling, and repetitive loading on lumber stiffness.
3. (31) Develop specifications and standards for use of structural composite lumber, including LVL and parallel strand lumber in highway structural applications.
4. (32) Evaluate suitability and performance characteristics of structural composite lumber in exposed bridge applications.
5. (40) Evaluate effect of preservative treatment (chemicals and treating processes) on sawn lumber and glulam timber produced from hardwood species and structural composite lumber products produced from either hardwoods or softwoods.
6. (46) Evaluate effects of salt and de-icing chemicals on physical and mechanical properties of wood.
7. (47) Compile material resistance values for use in LRFD design for lumber, glulam, and timber piles.
8. (52) Compile and distribute information on use of hardwoods and secondary softwoods in bridge applications.
9. (58) Develop technology for economical glulam timber manufactured from hardwood or secondary softwood species.
10. (60) Evaluate suitability of galvanizing and epoxy coatings to protect stress-laminated bridge stressing bars from corrosion.

11. (66) Investigate feasibility of gluing wood treated with creosote or other oilborne preservatives to improve treatment of large glulam members.
12. (70) Develop innovative methods of using steel, reinforced plastics, or other materials to improve strength and stiffness of timber components.
13. (71) Evaluate effect of cold temperature on physical and mechanical properties of wood under static and dynamic loading conditions.
14. (76) Determine effect of moisture content on properties of hardwood lumber.
15. (81) Develop fatigue level (S-N) curves for softwood and hardwood lumber species.
16. (83) Determine potential creep characteristics for lumber and glulam timber manufactured from softwood and hardwood.
17. (86) Develop new methods of protecting stress-laminated deck stressing bars against corrosion, including coatings and cathodic and mechanical protection.
18. (89) Refine NDS properties for visually graded and mechanical hardwood lumber through in-grade testing.
19. (2) Develop technology for glulam timber manufactured from mixed species.
20. (7) Refine methods for assigning property values to hardwood lumber.
21. (1 02) Develop economical, portable, reliable, and simple-to-use methods and equipment for machine grading hardwood and softwood lumber.
22. (108) Develop methods for determining residual strength of fire damaged timber components.
23. (1 09) Develop quality control procedures appropriate for mechanical grading of lumber from mixed species that are applicable to small mills.
24. (111) Evaluate volume effect on strength and stiffness properties of hardwood structural lumber.
25. (1 15) Conduct grade and yield studies for hardwood logs, considering commercially viable species.
26. (1 17) Develop economical, portable equipment to scan and evaluate suitability of log for structural lumber before cutting the log.

Preservatives

1. (4) Develop guidelines on effectiveness, use, and application of wood preservatives for field treating during fabrication and construction, especially for holes and other limited access areas.
2. (6) Develop and test new wood preservative chemicals that do not pose environmental hazards.
- 3 (18) Evaluate leachability and potential environmental hazards posed by wood preservatives in exposed bridge applications.

4. (22) Develop an informational summary on restrictions, use recommendations, and use of wood preservatives.
5. (26) Develop guidelines for disposal and/or reuse of treated timber in accordance with EPA guidelines.
6. (34) Evaluate effects of CCA and other waterborne preservatives on physical and mechanical properties of wood.
7. (38) Develop guidelines for effectiveness and use of wood preservatives for in-place treating of deteriorated timber components.
8. (42) Develop and evaluate alternative methods of wood preservation, other than chemical preservatives, to protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).
9. (43) Evaluate compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives, both before and after gluing.
10. (49) Develop guidelines for use of treated timber.
11. (51) Evaluate suitability of waterborne preservatives for sawn lumber and glulam timber relative to dimensional stability in exposed bridge applications.
12. (57) Develop guidelines on treatability and applicability of various preservatives and treatment processes on heartwood and sapwood of all commercially viable softwood and hardwood species.
13. (59) Evaluate effectiveness and develop guidelines and standards for water-repellant additives used in conjunction with waterborne preservatives for hardwood and softwood species.
14. (61) Evaluate effects of wood preservatives on metal hardware and corrosion protection systems for metal hardware.
15. (69) Investigate potential for preservative treatment leaching and distribute information on subject.
16. (78) Establish applicable penetration and retention requirements for use of copper naphthenate in bridge components of softwood and hardwood sawn lumber and glulam timber.
17. (79) Investigate suitability of borate treatments for softwoods and hardwoods used in exposed bridge applications.
18. (84) Develop guidelines for effectiveness and use of fumigants for in-place treating of deteriorated timber components.
19. (98) Revise existing treating standards to limit quantity of untreatable heartwood and restate moisture content requirements to reflect maximum rather than average values.
20. (99) Develop base-line treating cycles for hardwoods and other underutilized species.
21. (105) Investigate suitability and efficacy of existing preservative chemicals and treatment processes for applications involving hardwoods and secondary softwood species.

22. (107) Investigate suitability of diffusible borate for bridges.
23. (1 14) Evaluate feasibility of developing small, mobile pressure-treating units for applying wood preservatives.

System Development and Design

1. (1) Develop crash-tested bridge rails for longitudinal and transverse timber decks, including approach rail transitions, at AASHTO PL-1 and PL-2.
2. (2) Prepare guidelines and standard design details for designing timber bridges for minimum maintenance and long life.
3. (5) Develop standard designs, details, and specifications for timber bridge superstructures.
4. (7) Develop crashworthy bridge rails for low-volume roads.
5. (12) Develop designs and standards for long-lasting, waterproof, skid-resistant wearing surfaces for timber bridges.
6. (13) Develop standard designs, details, and specifications for timber bridge substructures.
7. (15) Conduct field evaluations of existing structures to determine load distribution characteristics of AASHTO-approved timber bridge systems to refine procedures and criteria for design and load rating.
8. (17) Investigate and define acceptable live-load deflection criteria for various timber superstructure and deck types based on structural behavior.
9. (20) Develop prefabricated, modular timber bridge systems that are easily transported.
10. (21) Develop methods for fastening wood decks to steel and concrete stringers for both new construction and replacement decks.
11. (35) Study means for obtaining composite action between timber beams and timber decks.
12. (39) Adapt existing computerized bridge design programs (BRADD, MERLIN-DASH, etc.) to include timber bridges and timber bridge components.
13. (41) Develop interactive computer programs for design of timber bridge systems and timber components used with other bridge materials.
14. (48) Evaluate suitability of timber connections subjected to dynamic loading (fatigue).
15. (50) Develop serviceability requirements for timber bridges based on use requirements.
16. (54) Conduct field evaluations of stress-laminated decks, constructed of various species and exposed to differing environmental conditions, to determine load distribution and performance characteristics.
17. (55) Investigate use of glulam T-beam and box-beam sections for long spans.

18. (63) Develop methods for reducing live-load deflection of AASHTO-approved timber bridge systems.
19. (64) Develop methods and design criteria for post-tensioning timber beams and bridge systems.
20. (72) Investigate potential for composite construction using timber with nonwood materials.
21. (74) Develop modular timber superstructure and substructure designs for temporary applications and portability.
22. (75) Determine lateral support provided for steel beams by different timber deck systems.
23. (77) Develop design criteria for stress-laminated T-section bridges through laboratory and field evaluations.
24. (80) Develop methods and design criteria for longitudinal stress lamination of timber bridges.
25. (82) Develop and field-evaluate new methods for shear transfer between glulam deck panels.
26. (85) Investigate methods for developing bolt-laminated beams and decks.
27. (87) Develop design criteria for timber arches and trusses for submission to AASHTO.
28. (88) Evaluate longitudinal creep characteristics of stress-laminated deck bridges.
29. (91) Investigate and define acceptable live load deflection criteria for performance of wearing surfaces and human response.
30. (93) Investigate and document performance of timber bridges subjected to seismic loading.
31. (100) Develop design criteria for stress-laminated box-beam bridges through laboratory and field evaluations.
32. (101) Evaluate suitability of using toothed metal plate connectors (truss plates) in bridge components subjected to fatigue loading and cyclic moisture changes.
33. (103) Refine duration of load adjustments for bridge applications.
34. (106) Develop methods for stress-laminating timber with nontimber materials.
35. (110) Develop and field test bridges constructed of stress-laminated trusses manufactured with toothed metal plate connectors.

construction

1. (9) Develop guide specifications for timber bridge construction.
2. (30) Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.
3. (36) Summarize methods of construction for various timber superstructures and substructures, including case histories.

Inspection

1. (3) Develop economical, easy-to-use equipment and methods to conduct nondestructive testing of in-place timber bridge components, including piles.
2. (8) Prepare comprehensive manual for inspection and evaluation of timber bridges.
3. (10) Develop standardized procedures and specifications for nondestructive evaluation of timber bridge components.
4. (16) Develop standardized methods for load testing and load rating existing timber bridges.
5. (24) Refine inspection methods to more accurately detect incipient decay in timber bridge components.
6. (45) Investigate methods for determining postdecay strength of timber components.
7. (53) Develop methods for determining embedment length of timber piles.
8. (56) Investigate and determine methods for evaluating residual bending strength of beams that have split or have failed in horizontal shear.

Maintenance and Rehabilitation

1. (11) Prepare comprehensive manual on maintenance practices for timber bridges.
2. (19) Develop and evaluate economical, long-lasting methods for sealing and protecting exposed end-grain.
3. (23) Develop materials for sealing wood against moisture in areas where prolonged moisture exposure is likely to occur.
4. (37) Evaluate suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.
5. (44) Develop methods and comprehensive guidelines for restoring, increasing capacity of, or replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.
6. (73) Develop methods to restore capacity of beams with horizontal shear failures.
7. (95) Refine applications of stress-laminating to include rehabilitation of existing components.

Economics

1. (14) Develop initial cost, life-cycle cost, and design life comparisons of timber bridges and culverts as opposed to steel and concrete bridges and culverts.
2. (25) Develop guidelines for relative cost and design life comparison of various types of timber bridges including composite construction.
3. (28) Collect, analyze, and report bridge cost data obtained through Forest Service, FHWA, and State timber bridge demonstration projects.

4. (65) Develop guidelines for economically optimizing material requirements for specific bridge types.
5. (67) Develop cost-estimating guide for determining transportation, labor, and equipment requirements for timber bridge construction, based on time-in-motion studies of bridge construction projects.

Other

1. (33) implement mechanism for transferring timber bridge technology to users in a timely manner.
2. (62) Compile summary of ongoing timber bridge research and distribute quarterly to interested parties.
3. (68) Develop educational materials for use in colleges and trade schools.
4. (90) Develop data base of timber bridges, by type and material, constructed in United States and Canada over past 30 years.
5. (94) Develop designs and field tests of timber piers, abutments, and culverts.
6. (96) Develop designs for retaining walls and evaluate their field performance.
7. (104) Document experiences and lessons learned from using previously underutilized hardwood and secondary softwood species for bridge construction.
8. (1 12) Develop designs and evaluate field performance of noise barriers constructed of timber, and of timber with other materials.
9. (113) Document economic multiplier effect realized when local materials and labor are used for transportation structures.
10. (116) Complete analysis of bridge needs in United States for next 30 years based on span and functional classification.
11. (118) Evaluate comparative energy requirements for production and construction of timber, steel, and concrete bridges and culverts.

Analysis of Results

Analysis of the response results showed high priority objectives within all the research categories. From an overall ranking, work in the categories of System Development and Design, Preservatives, Construction, Inspection, Maintenance and Rehabilitation, and Economics included many high priority areas. The highest priorities were in the System Development and Design category, where needs in the development of crashworthy rail systems were given high ranking. In this category, as well as Construction and several others, there is also a strong interest in the development of standardized plans, specifications, and guidelines, indicating voids in these areas. There is also interest in the Inspection and Maintenance/Rehabilitation categories, where high priority areas include the development of nondestructive inspection techniques and effective maintenance practices. Within the category of Preservatives, high priorities primarily centered around guidelines on the proper use of preservatives and the development of new, more environmentally acceptable techniques for wood preservation. Issues related to preservative leaching and the disposal of hazardous waste were also considered of high

national importance. Economics also was an area of interest, where the development of initial cost, life-cycle cost, and design life information was identified as a high priority need.

To develop the basis for outyear research planning, the data were analyzed further and projects were regrouped into the seven general research areas defined in the ISTEA legislation. These research areas, with projects listed under a descriptive heading and a general statement of research need, are listed here. The number in parentheses indicates the relative overall ranking of the potential study.

Area 1. System Development and **Design**

Fastener Design Criteria and Corrosion Protection

Research need: To determine the potential for corrosion of metal fasteners used in treated wood.

Potential studies:

- (21) Develop methods for fastening wood decks to steel and concrete stringers for both new construction and replacement decks.
- (48) Evaluate suitability of timber connections subjected to dynamic loading (fatigue).
- (60) Evaluate suitability of galvanizing and epoxy coatings for providing corrosion protection for steel hardware used in timber bridge applications.
- (61) Evaluate effects of wood preservatives on metal hardware and corrosion protection systems for metal hardware.
- (86) Develop new methods of providing corrosion protection for stress-laminated bridge stressing bars, including mechanical protection, epoxy coatings, galvanizing, and cathodic protection.
- (101) Evaluate suitability of using toothed metal plate connectors (truss plates) in bridge components subjected to fatigue loading and cyclic moisture changes.

Structural Glulam Timber

Research need: To extend and improve structural glulam timber technology for transportation structure applications.

Potential studies:

- (43) Evaluate compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives, both before and after gluing.
- (58) Develop technology for economical glulam timber manufactured from hardwood or secondary softwood species.
- (66) Investigate feasibility of gluing wood treated with creosote or other oilborne preservatives to improve treatment of large glulam members.
- (92) Develop technology for glulam timber manufactured from mixed species.

Structural Composite Lumber

Research need: To evaluate suitability of structural composite lumber and to develop specifications and standards for use in transportation structure applications.

Potential studies:

- (31) Develop specifications and standards for use of structural composite lumber, including laminated veneer lumber and parallel strand lumber in transportation structure applications.
- (32) Evaluate suitability and performance characteristics of structural composite lumber in exposed bridge applications.

Design Aids

Research need: To develop design aids related specifically to design of timber transportation structures.

Potential studies:

- (2) Prepare standard designs, details, and specifications for designing timber bridge superstructures for minimum maintenance and long life.
- (13) Develop standard designs, details, and specifications for timber bridge substructures and culverts.
- (39) Adapt existing computerized bridge design programs (BRADD, MERLIN-DASH, etc.) to include timber bridges and timber bridge components.
- (41) Develop interactive computer programs for design of timber bridge systems and timber components used with other bridge materials.
- (65) Develop guidelines for economically optimizing material requirements for specific timber bridge types.

Timber Bridge Design Criteria

Research need: To refine and expand structural design criteria for timber bridge systems currently included in AASHTO Standard Specifications for Highway Bridges.

Potential studies:

- (15) Conduct field evaluations of existing structures to determine load distribution characteristics of AASHTO-approved timber bridge systems to refine procedures and criteria for design and load rating.
- (35) Study means for obtaining composite action between timber beams and timber decks.
- (54) Conduct field evaluations of stress-laminated decks, constructed of various species and exposed to differing environmental conditions, to determine load distribution and performance characteristics.

- (75) Determine level of lateral support provided for steel beams by different timber deck systems.
- (82) Develop and field evaluate new methods for shear transfer between glulam deck panels.
- (87) Develop design criteria for timber arches and trusses for submission to AASHTO.
- (93) Investigate and document performance of timber bridges subjected to seismic loading.

Timber Bridge Serviceability

Research need: To develop serviceability design criteria for timber bridge systems, especially for live-load deflection.

Potential studies:

- (12) Develop designs and standards for long-lasting, waterproof, skid-resistant wearing surfaces for timber bridges.
- (17) Investigate and define acceptable live-load deflection criteria for various timber superstructure and deck types based on structural behavior, wearing surface performance, and human response.
- (50) Develop serviceability requirements for timber bridges based on use requirements.
- (63) Develop methods for reducing live-load deflection of AASHTO-approved timber bridge systems.
- (88) Evaluate longitudinal creep characteristics of stress-laminated deck bridges.

Design Criteria for New Bridge Systems and Components

Research need: To develop new timber bridge systems that are structurally efficient and allow for use of underutilized wood species.

Potential studies:

- (20) Develop prefabricated, modular timber bridge systems that are easily transported for temporary applications.
- (55) Investigate use of stress-laminated glulam T-beam and box-beam sections for long spans.
- (64) Develop methods and design criteria for post-tensioning timber beams and bridge systems.
- (77) Develop design criteria for stress-laminated T-section bridges through laboratory and field evaluations.

- (80) Develop methods and design criteria for longitudinally stress-laminating transverse timber bridges and decks.
- (85) Investigate methods for developing bolt-laminated beams and decks.
- (100) Develop design criteria for stress-laminated box-beam bridges through laboratory and field evaluations.
- (110) Develop and field test bridges constructed of stress-laminated trusses manufactured with toothed metal plate connectors.

Area II. Lumber Design Properties

External Influences on Wood Properties

Research need: To clearly quantify the effect of various external influences on wood properties in reference to transportation structures.

Potential studies:

- (29) Evaluate effect of aging, moisture cycling, and repetitive loading on lumber stiffness.
- (46) Evaluate effects of salt and de-icing chemicals on physical and mechanical properties of wood.
- (71) Evaluate effect of cold temperature on physical and mechanical properties of wood under static and dynamic loading conditions.
- (76) Determine effect of moisture content on properties of hardwood structural lumber.

Wood Design Values and Properties

Research need: To fully develop the potential for efficient wood use in transportation structures by improving methods for assigning design values and providing better definitions of material properties.

Potential studies:

- (27) Refine horizontal shear design values and requirements for sawn lumber and glulam timber.
- (47) Compile material resistance values for use in LRFD design for lumber, glulam, and timber piles.
- (81) Develop fatigue level (S-N) curves for softwood and hardwood lumber species.
- (83) Determine potential creep characteristics for lumber and glulam timber manufactured from softwood and hardwood.
- (89) Refine NDS properties for visually graded hardwood lumber through in-grade testing.

- (97) Refine methods of assigning property values to hardwood lumber based on small, clear procedure.
- (103) Refine duration of load adjustments for bridge applications.
- (111) Evaluate volume effect on strength and stiffness of hardwood structural lumber.

Lumber Grading and Yield

Research need: To develop more accurate procedures and equipment for grading various species and determining potential log yield.

Potential studies:

- (102) Develop economical, portable, reliable, and simple-to-use methods and equipment for machine-grading hardwood and softwood lumber.
- (109) Develop quality control procedures appropriate for mechanical grading of lumber from mixed species that are applicable to small mills.
- (115) Conduct grade and yield studies for hardwood logs, considering commercially viable species.
- (117) Develop economical portable equipment to scan and evaluate suitability of a log for structural lumber, before it is cut.

Composite Materials

Research need: To determine the feasibility of developing composite materials using wood and other materials, such as steel and reinforced plastics.

Potential studies:

- (70) Develop innovative methods of using steel, reinforced plastics, or other materials to improve strength and stiffness of timber components.
- (72) Investigate potential for composite construction using timber with other nonwood materials.
- (106) Develop methods for stress-laminating timber with nontimber materials.

Area III. Preservatives

Field Treatment

Research need: To improve methods for field-treating timber cut, drilled, or damaged during field construction or in service.

Potential studies:

- (4) Develop guidelines on effectiveness, use, and application of wood preservatives for field-treating during fabrication and construction, especially for holes and other limited access areas.

- (38) Develop guidelines for effectiveness and use of wood preservatives and fumigants for in-place treating of deteriorated timber components.
- (114) Evaluate feasibility of developing small, mobile pressure-treating units for applying wood preservatives.

Preservative Effects on Material Properties

Research need: To determine the effect of preservatives on the physical and mechanical properties of wood and metal hardware for transportation structure applications.

Potential studies:

- (34) Evaluate effects of CCA and other waterborne preservatives on physical and mechanical properties of wood.
- (40) Evaluate effect of preservative treatment (chemicals and treating processes) on sawn lumber and glulam timber produced from hardwood species, and structural composite lumber products produced from either hardwoods or softwoods.
- (51) Evaluate suitability of waterborne preservatives for sawn lumber and glulam timber relative to dimensional stability in exposed bridge applications.

Environmental Considerations for Wood Preservatives

Research need: To provide data on environmental concerns related to use and disposal of preservative-treated timber.

Potential studies:

- (18) Evaluate leachability and potential environmental hazards posed by wood preservatives used in exposed bridge applications.
- (26) Develop guidelines for disposal and/or reuse of treated timber in accordance with EPA guidelines.
- (69) Investigate potential for preservative treatment leaching and distribute information on subject.

Preservation Methods and Chemicals

Research need: To improve wood preservation methods and chemicals based on new and existing technology.

Potential studies:

- (6) Develop and test new wood preservative chemicals that do not pose environmental hazards.
- (42) Develop and evaluate methods of wood preservation other than chemical preservatives to protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).

- (59) Evaluate effectiveness and develop guidelines and standards for water-repellant additives used in conjunction with waterborne preservatives for hardwood and softwood species.
- (78) Establish applicable penetration and retention requirements for using copper naphthenate in bridge components of softwood and hardwood sawn lumber and glulam timber.
- (79) Investigate suitability of borate treatments for softwoods and hardwoods used in exposed bridge applications.
- (105) Investigate suitability and efficacy of existing preservative chemicals and treatment processes for applications involving hardwoods and secondary softwood species.

Preservative Application and Use

Research need: To provide more information on application and use of wood preservatives.

Potential studies:

- (57) Develop guidelines on treatability and applicability of various preservatives and treatment processes on heartwood and sapwood of all commercially viable softwood and hardwood species.
- (98) Investigate and revise existing treatment standards to limit quantity of untreatable heartwood and restate moisture content requirements to reflect maximum rather than average values.
- (22) Develop informational summary on restrictions, use recommendations, and use of wood preservatives.
- (99) Develop base-line treating cycles for hardwoods and other underutilized species.

Area IV. Alternative Transportation System Structures

Bridge Rails

Research need: To develop and crash-test timber bridge rail systems that meet AASHTO specifications.

Potential studies:

- (1) Develop crash-tested bridge rails for longitudinal and transverse timber decks, including approach rail transitions, at AASHTO PL-1 and PL-2.
- (7) Develop crashworthy bridge rails for low-volume roads.

Retaining Structures

Research need: To provide information on design and performance of timber retaining structures.

Potential studies:

- (96) Develop standard designs for timber retaining walls and evaluate their field performance.

Noise Barriers

Research need: To provide information on design and performance of timber noise barriers.

Potential studies:

- (1 12) Develop standard designs and evaluate field performance of noise barriers constructed of timber, and of timber with other materials.

Area V. Inspection and Rehabilitation

Construction

Research need: To provide information for bridge engineers on fabrication, transportation, and construction of timber bridge systems.

Potential studies:

- (9) Develop guide specifications for timber bridge construction.
- (30) Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.
- (36) Summarize methods of construction for various timber superstructures and substructures, including case histories.
- (67) Develop cost-estimating guide for determining transportation, labor, and equipment requirements for timber bridge construction, based on time-in-motion studies of bridge construction projects.

Inspection and In-Place Evaluation

Research need: To develop technology to accurately assess in-place condition of wood transportation structures.

Potential studies:

- (3) Develop economical, easy-to-use equipment and methods to conduct in-place nondestructive evaluation of timber bridge components and develop standardized procedures and specifications for the evaluation.
- (8) Prepare comprehensive manual for inspection and evaluation of timber bridges.
- (16) Develop standardized methods for load-testing and load-rating existing timber bridges.
- (24) Refine inspection methods to more accurately detect incipient decay in timber bridge components.

- (53) Develop methods for determining embedment length of timber piles.

Structure Strength and Property Assessment

Research need: To develop methods to determine residual strength and properties of deteriorated or damaged members in wood transportation structures.

Potential studies:

- (45) Investigate methods for determining post-decay strength of timber components.
- (56) Investigate and determine methods for evaluating residual bending strength of beams that have split or failed in horizontal shear.
- (108) Develop methods for determining residual strength of fire-damaged timber components.

Maintenance and Rehabilitation

Needs Statement: To provide information to engineers on methods for maintaining and rehabilitating timber bridges.

Potential studies:

- (11) Prepare comprehensive manual on maintenance practices for timber bridges.
- (19) Develop and evaluate economical, long-lasting methods for sealing and protecting wood against moisture (especially end-grain) when exposure to moisture is prolonged.
- (37) Evaluate suitability of wearing-surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.
- (44) Develop methods and comprehensive guidelines for restoring, increasing capacity of, or replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.
- (73) Develop methods to restore capacity of beams with horizontal shear failures.
- (84) Develop guidelines for effectiveness and use of fumigants for in-place treating of deteriorated timber components.
- (95) Refine applications of stress-laminating to include rehabilitation of existing components.

Area Vi. Technology and Information Transfer

Research need: To improve the means for distributing information on timber transportation structures.

Potential studies:

- (33) Implement mechanism for transferring timber bridge technology to users in a timely manner.

- (62) Compile summary of ongoing timber bridge research and distribute quarterly to interested parties.
- (68) Develop educational materials for use in colleges and trade schools.
- (90) Develop data base of timber bridges, by type and material, that have been constructed in United States and Canada over past 30 years.

Area VII: Other

Economics

Research need: To provide accurate information on timber bridge economics in such areas as initial cost, life-cycle cost, and design life.

Potential studies:

- (14) Compare initial cost, life-cycle cost, and design life of timber bridges and culverts as opposed to steel and concrete bridges and culverts.
- (25) Develop guidelines for comparing relative cost and design life of various types of timber bridges, including composite construction.
- (28) Collect, analyze, and report bridge cost data obtained through Forest Service, FHWA and State timber bridge demonstration projects.

Resource Utilization

Research need: To document potential need for wood as a transportation material and effects of using local wood resources for construction of transportation structures.

Potential studies:

- (52) Compile and distribute information on use of hardwoods and secondary softwoods in bridge applications.
- (104) Document experiences and lessons learned from using underutilized hardwood and secondary softwood species for bridge construction.
- (113) Document economic multiplier effect realized when local materials and labor are used for transportation structures.
- (116) Complete analysis of U.S. bridge needs for next 30 years based on span and functional classification.
- (118) Evaluate comparative energy requirements for production and construction of timber, steel, and concrete bridges and culverts.

Concluding Remarks

Research related to the development of timber in transportation structures has significantly lagged behind that for other materials. Recently, the need for research in this area has been recognized nationally, and research programs related to timber transportation structures have been implemented by both the USDA

Forest Service and the U.S. Department of Transportation, Federal Highway Administration. To identify and prioritize potential national timber research needs, we solicited input from a broad spectrum of individuals and groups involving all aspects of timber utilization. The results of this input demonstrate an urgent need for further research on the utilization of wood in transportation structures. To provide a usable base for developing future research programs, the potential research studies and priorities identified by study participants were formulated into research areas that correspond to the general research categories identified in the Intermodal Surface Transportation Act of 1991.

The information compiled in this study will be used by the Forest Service and the Federal Highway Administration as a basis for developing future research programs dealing with timber transportation structures. In so doing, we recognize that additional high priority projects may surface as research is completed and the use of timber as a transportation material develops further. The process of project identification and prioritization is considered to be dynamic, and additional input related to research needs will be solicited from interested parties in the future. By allowing for a free exchange of information and *ideas*, we hope that both the effectiveness and efficiency of completed research will be maximized to provide the greatest national benefit.

Appendix A. Initial Mailing

Cover Letter to Individuals

Cover Letter to Groups and Organizations

List of Previously Recommended Research Needs

Cover Letter to Individuals

Dear Study Participant:

The purpose of this letter is to solicit your help in identifying research needs for timber bridges and other transportation structures. This request is to provide assistance in completing a task that is part of a cooperative agreement between Iowa State University (ISU), and the Forest Products Laboratory (FPL) in cooperation with the Federal Highway Administration (FHWA). The primary objective of the project is to identify, describe and prioritize a list of research needs that will serve as a basis for developing and funding Forest Service and FHWA research which will include cooperative research with universities and other organizations. Thus the results of this project will significantly influence timber bridge research over the next six years.

Enclosed is a list of some recommendations for current research needs developed recently by the FHWA. These statements have been organized based upon the following categories:

- 1) Materials
- 2) Preservatives
- 3) System Development and Design
- 4) Construction
- 5) Inspection
- 6) Maintenance and Rehabilitation
- 7) Economics
- 8) Other

Please add any research needs you feel are important and place them in the appropriate categories. We would also like a brief description (2 or 3 sentences) for each statement so we can interpret the objectives and scope of your recommendations. The research needs categories shown encompass a broad range to encourage you to be unrestricted in your input. A separate form is enclosed for your response, and a self-addressed, postage paid envelope is enclosed for your convenience. We would appreciate your response by September 20, 1991.

All of the information we receive will be compiled and prioritized for making decisions with regard to the performance of the research over a six-yr. time frame. Subsequently, a second mailing will be sent to you for your input on the prioritization. We anticipate that you will be receiving this during September. We are asking in advance for your cooperation in responding in a timely manner to this request.

Respectfully,

Terry J. Wipf, P.E.
Associate Professor of Civil Engineering
Iowa State University

Michael A. Ritter, P.E.
Research Engineer
Forest Products Laboratory

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As the representative for your organization, please distribute this information to appropriate personnel to solicit their input as well. To expedite this process, please request that they send their response to the address listed at the top of the enclosed response form.

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Respectfully,

Terry J. Wipf, P.E.
Associate Professor of Civil Engineering
Iowa State University

Michael A. Ritter, P.E.,
Research Engineer
Forest Products Laboratory

List of Previously Recommended Research Needs

Research Needs for Timber Bridges and Timber Transportation Structures

The following recommended research projects were obtained from a survey conducted by the Federal Highway Administration (FHWA) through members of the FHWA Research Specialty Committee on Timber.

1) Materials:

- a) Develop specifications and standards for the use of laminated veneer lumber (LVL) in highway structures applications. Although LVL is currently used in building construction, and is recognized as an acceptable material by building codes, it is not recognized by AASHTO. A national standard for LVL with tabulated design values should be developed for bridges and presented to AASHTO.
- b) Develop technology for economical hardwood glued laminated timber. Current hardwood glulam standards are inefficient and are not applicable to many abundant hardwood species.
- c) Develop technology for glued laminated timber manufactured of multiple species. Mixing hardwoods and other abundant secondary species for glulam may result in more economical, efficient members.
- d) Develop innovative methods of using steel, reinforced plastics or other materials in glulam members to improve strength and stiffness.
- e) Investigate the feasibility of gluing wood treated with creosote or other oilborne preservatives to improve treatment of large glued laminated members.

9 Refine National Design Specification (NDS) stress values for hardwoods. Present NDS values are based on ASTM standards. The values appear conservative because adjustment factors specific to softwood species were used. This conservatism promotes inefficiency in design through oversized members, etc.

- g) Develop methods and equipment to grade wood members and determine their ultimate strength. This would remove the human judgement factor and help designers and contractors provide a higher quality product within given standards and specifications.

2) Preservatives:

- a) Develop EPA approved guidelines for the disposal of treated timber, CALTRANS has quit using timber guardrail posts. Are the chemicals such a problem? Are there others that would be acceptable?
- b) Develop guidelines for the use of treated timber. Recent EPA regulations may severely limit the use of treated timber by establishing that such material is a hazardous waste which cannot be readily disposed of at the end of its life. The engineering profession needs clear guidance on types and levels of treatment that will serve highway needs and not violate EPA regulations.
- c) Investigate the potential for preservative treatment leaching and distribute information on the subject. In New York state creosote seems to be a significant problem if it comes in contact with the stream. Is this typical?
- d) Determine the effect of wood preservatives on metal hardware.

e) Investigate the suitability of diffusible borate for bridges. Borate is a water-based salt which tends to leach out after a number of years. Either a setting agent or a suitable sealing process would have to be developed.

f) Develop base line treating cycles for hardwoods and other underutilized species.

3) System Development and Design

a) Develop crash tested bridge rails for longitudinal and transverse timber decks at AASHTO PL-1 and PL-2.

b) Adapt the BRADD computer design system to include glulam bridges. Penn State University is working on a project to develop hardwood glulam standards for bridge design. It would be extremely beneficial to be able to use the Bridge Automated Design and Drafting System developed by PennDot and now licensed through AASHTO.

c) Develop methods for fastening wood decks to steel stringers for both new construction and for replacement decks.

d) Study the means of obtaining composite action between timber beams and timber decks. A composite system could reduce overall superstructure depths and provide savings in materials.

e) Improve design criteria for existing sawn and glulam timber bridge systems through field evaluation of existing structures.

f) Investigate methods for developing bolt-laminated beams and decks. Glue laminating could possibly be eliminated if rough sawn lumber was treated, laid up, compressed and bolted or doweled together without glue or surfacing. The individual members would be treated before fabrication to increase the protection requirements.

g) Develop methods of longitudinally post-tensioning timber bridges. Longitudinally **prestressed** timber to control live load deflection and reduce superstructure depth may have usefulness. The use of post-tension strands running longitudinally on either plank structure or glulam stringer bridges would induce camber and prevent severe live load deflection.

h) Develop serviceability requirements for timber bridges based on use requirements.

i) Conduct full-scale testing of innovative timber bridge designs. Recent hardwood design proposals include stress-lam bridges, stressed steel/hardwood composite bridges and glulam bridges. To utilize these and other innovative design concepts, a comprehensive test program is required. Prototype bridges should be constructed according to selected design concepts and tested under controlled conditions. Parameters of interest include: long term deformations under traffic loading, vibrations, connection performance and ultimate load capacity.

j) Develop methods for pre-tensioning wood with non-steel materials. Research in glulam has investigated strengthening timber with composite materials. This may be extended to pretensioning the girders. Properties of composites are closer to wood than are steel rods, thus loss and relaxation problems associated with steel may be more manageable with synthetic materials.

k) Optimize sorting/grading/treating/manufacturing criteria for wood products to meet performance criteria in bridges.

l) Develop methods to reduce timber bridge live load deflection. For stringer type timber bridges, the strength of the wood does not control the design. The controlling factor is the live load deflection.

Research is needed to identify possible approaches to reduce live load deflection. A method needs to be developed to increase the stiffness of timber stringers by increasing the modulus of elasticity and the moment of inertia.

m) Develop field-proved design criteria for stress-laminated T and box sections.

n) Investigate the potential for composite construction of wood bridges using concrete. Some 30 to 40 years ago, composite concrete and timber bridges were built with relatively satisfactory results. Does this type of construction lend itself to today's stressed timber bridge technology?

4) Construction

a) Develop appropriate guidelines for wood fabrication, transportation and storage.

b) Assemble a summary of different construction methods that can be used for different types of timber bridges. This will include illustrated case histories for different bridges.

5) Inspection

a) Develop economical, easy to use equipment and methods to conduct non-destructive testing of in-place timber bridge components.

b) Develop standardized methods for load testing and load rating existing timber bridges.

c) Investigate methods for determining the post-decay strength of timber components.

d) Refine inspection methods in order to more accurately detect incipient decay in timber bridge components.

e) Develop methods for determining the residual strength of timber components that have undergone fire damage.

6) Maintenance and Rehabilitation

a) Develop designs and standards for long-lasting skid-resistant wearing surfaces for timber bridges. An area of concern is the need to provide a skid resistant wearing surface that will remain in place for a long time. In particular, what can be done to improve the performance of an asphalt wearing surface subjected to stop-and-go traffic?

b) Develop methods for the rehabilitation of deteriorated timber components used in bridges.

7) Economics

a) Develop guidelines for comparison of the lifespan and relative costs of various types of timber bridges.

b) Develop life cycle costs of comparisons of timber vs. other materials in bridge construction.

c) Collect, analyze, and report bridge cost data obtained through the Forest Service and state timber bridge demonstration projects.

8) Other:

a) Facilitate technology transfer through development of national standards and design aids. A series of standard designs for short span bridges that meet AASHTO standards would be helpful to small jurisdictions.

b) Develop designs for hardwood retaining walls and evaluate their field performance. These walls may be a very cost effective alternative for some of the more expensive and extensive retaining structures that are commercially available.

c) There has been a tremendous amount of research conducted in the past few years on all aspects of timber bridge construction. This information should be collected and made available to practicing engineers. The engineering community should be made aware of the utilization of timber for bridge construction.

APPENDIX B. SECOND MAILING

Cover Letter to Individuals
Cover Letter to Groups and Organizations
Coding Form for Assigning Project Priorities

Cover Letter to Individuals

Dear Study Participant:

The information contained in this mailing is a follow-up to the solicitation for Research Needs statements for timber bridge and timber transportation structures sent to you last August. Following that initial solicitation, a significant number of research needs statements were received and they have been compiled into an updated list which is enclosed.

Please prioritize the enclosed list in each of the eight categories regarding their order of importance in terms of meeting the objectives of the six year research plan: *To prioritize a list of research needs that will serve as a basis for developing and funding Forest Service and FHWA research which will include cooperative research with universities and other organizations.* You are asked to use the rating system of **high** (highest priority), medium (medium priority) and low (lowest priority). The list has been incorporated into a code form for your convenience in responding. A self-addressed, postage paid envelope is also enclosed for your convenience. We would appreciate your response by December 20, 1991.

As mentioned in the initial mailing, a final report will be furnished to you at the conclusion of the project. We are asking in advance for your cooperation in responding in a timely manner.

Respectfully,

Terry J. Wipf, P.E.
Associate Professor of Civil Engineering
Iowa State University

Michael A. Ritter, P.E.
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Cover Letter to Groups and Organizations

Dear Study Participant:

The information contained in this mailing is a follow-up to the solicitation for Research Needs statements for timber bridge and timber transportation structures sent to you last August. Following that initial solicitation, a significant number of research needs statements were received and they have been compiled into an updated list which is enclosed.

Please prioritize the enclosed list in each of the eight categories regarding their order of importance in terms of meeting the objectives of the six year research plan: *To prioritize a list of research needs that will serve as a basis for developing and funding Forest Service and FHWA research which will include cooperative research with universities and other organizations.* You are asked to use the rating system of high (highest priority), medium (medium priority) and low (lowest priority). The list has been incorporated into a code form for your convenience in responding. A self-addressed, postage paid envelope is also enclosed for your convenience. We would appreciate your response by December 20, 1991.

As before, as the representative for your organization, you may wish to distribute this information to appropriate personnel to solicit their input as well. To expedite this process, please request that they send their response to the address at the bottom of the enclosed response form.

As mentioned in the initial mailing, a final report will be furnished to you at the conclusion of the project. We are asking in advance for your cooperation in responding in a timely manner.

Respectfully,

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Coding Forms for Assigning Project Priorities

CATEGORY 1: MATERIALS

1. Compile and distribute information on the use of hardwoods and secondary softwoods in bridge applications.
2. Develop specifications and standards for the use of structural composite lumber, including laminated veneer lumber (LVL) and parallel strand lumber in highway structure applications.
3. Evaluate the suitability and performance characteristics of structural composite lumber in exposed bridge applications.
4. Develop economical portable, reliable and simple to use methods and equipment for machine grading hardwood and softwood lumber.
5. Evaluate the suitability of galvanizing and epoxy coatings to protect stress-laminated bridge stressing bars from corrosion.
6. Develop new methods of providing corrosion protection for stress-laminated deck stressing bars including mechanical protection, coatings and cathodic protection.
7. Develop innovative methods of using steel, reinforced plastics or other materials to improve strength and stiffness in timber components.
8. Develop technology for economical glued laminated timber manufactured from hardwood or secondary softwood species.
9. Develop technology for glued laminated timber manufactured of mixed species.
10. Investigate the feasibility of gluing wood treated with creosote or other oilborne preservative to improve treatment of large glued laminated members.
11. Refine National Design Specification (NDS) properties for visually-graded hardwood lumber through in-grade testing.
12. Refine the methods for assigning property values to hardwood lumber.
13. Determine potential creep characteristics for lumber and glued laminated timber manufactured from softwood and hardwood.
14. Refine horizontal shear design values and requirements for sawn lumber and glued laminated timber.
15. Develop fatigue level (S-N) curves for softwood and hardwood lumber species.
16. Evaluate the effect of preservative treatment (chemicals and treating processes) on sawn lumber and glued laminated timber produced from hardwood species, and composite lumber products produced from either hardwoods or softwoods.
17. Evaluate the effect of aging, moisture cycling and repetitive loading on lumber stiffness.
18. Evaluate the effect of cold temperature on the physical and mechanical properties of wood under static and dynamic loading conditions.
19. Evaluate the effects of salt and deicing chemicals on the physical and mechanical properties of wood.
20. Develop methods for determining the residual strength of timber components that have undergone fire damage.

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- 41. Develop an informational summary on the restrictions, use recommendations and use of wood preservatives.
- 42. Develop guidelines for the use of treated timber.
- 43. Investigate the potential for preservative treatment leaching and distribute information on the subject.
- 44. Evaluate the effects of wood preservatives on metal hardware and corrosion protection systems for metal hardware.
- 45. Investigate the suitability of diffusible *borate* for bridges.
- 46. Investigate the suitability and efficacy of existing preservative chemicals and treatment processes for applications involving hardwoods and secondary softwood species.
- 47. Develop base line treating cycles for hardwoods and other underutilized species.

- 48. Evaluate the compatibility and relative bond strength of various adhesives used for glued laminated timber treated with different wood preservatives, both before and after gluing.
- 49. Evaluate the feasibility of developing small, mobile pressure treating units for applying wood preservatives.

CATEGORY 3: **SYSTEM DEVELOPMENT AND DESIGN**

- 50. Develop crash tested bridge rails for longitudinal and transverse timber decks, including approach rail transitions, at AASHTO PL-1 and PL-2.
- 51. Adapt existing computerized bridge design programs (BRADD, MERLIN-DASH, etc) to include timber bridges and timber bridge components.
- 52. Develop interactive computer programs for the design of timber bridge systems and timber components used with other bridge materials.
- 53. Develop standard designs, details and specifications for timber bridge superstructures,
- 54. Develop standard designs, details and specifications for timber bridge substructures.
- 55. Prepare guidelines and standard **design** details for designing timber bridges for minimum maintenance and long life.
- 56. Develop methods for fastening wood decks to steel and concrete stringers for both new instruction and for replacement decks.
- 57. Study the means of obtaining composite action between timber beams and timber decks.
- 58. Investigate the potential for composite construction using timber with other non-wood materials.
- 9. Conduct field evaluations of existing structures to determine the load distribution characteristics of AASHTO approved timber bridge systems to refine procedures and criteria for design and load rating.
- O. Investigate and define acceptable live load deflection criteria for various timber superstructure and deck types based on structural behavior.

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- 61. Investigate and define acceptable live load deflection criteria for the performance of wearing surfaces and human response.
- 62. Conduct field evaluations of stress-laminated decks, constructed of various species and exposed to differing environmental conditions, to determine load distribution and performance characteristics.
- 63. Develop designs and standards for long-lasting, waterproof, skid-resistant wearing surfaces for timber bridges.
- 64. Determine the level of lateral support provided for steel beams by different timber deck systems.
- 65. Refine duration of load adjustments for bridge applications.
- 66. Develop and field evaluate new methods for shear transfer between glulam deck panels.

67. Develop modular timber superstructure and substructure designs for temporary applications and portability

68. Evaluate the suitability of timber connections subjected to dynamic loading (fatigue).

69. Evaluate the longitudinal creep characteristic of stress-laminated deck bridges.

70. Develop design criteria for timber arches and trusses for submission to AASHTO,

71. Investigate and document the performance of timber bridges subjected to seismic loading.

72. Develop crashworthy bridge rails for low-volume roads.

73. Investigate methods for developing bolt-laminated beams and decks.

74. Develop methods and design criteria for longitudinally stress-laminated timber bridges.

75. Develop methods and design criteria for post-tensioning timber beams and bridge systems.

76. Develop serviceability requirements for timber bridges based on use requirements,

77. Develop methods for stress-laminating timber with other non-timber materials.

78. Develop methods for reducing the live load deflection of AASHTO approved timber bridge systems.

79. Develop design criteria for stress-laminated T section bridges through laboratory and field evaluations.

80. Develop design criteria for stress-laminated box beam bridges through laboratory and field evaluations.

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81. Evaluate the suitability of using toothed metal plate connectors (truss plates) in bridge components subjected to fatigue loading and cyclic moisture changes.

82. Develop and field test bridges constructed of stress-laminated trusses manufactured with toothed metal plate connectors.

83. Develop prefabricated, modular timber bridge systems that are easily transported.

84. Investigate the use of glulam T-beam and box beam sections for longer spans.

CATEGORY 4: CONSTRUCTION

85. Develop appropriate guidelines for fabrication, transportation and storage of timber components and bridge systems.

86. Develop guide specifications for timber bridge construction.

87. Summarize methods of construction for various timber superstructures and substructures, including case histories.

CATEGORY 5: INSPECTION

88. Develop economical, easy to use equipment and methods to conduct nondestructive testing of in-place timber bridge components, including piles.

89. Develop standardized procedures and specifications for the nondestructive evaluation of timber bridge components.

90. Develop methods for determining the embedment length of timber piles.

91. Develop standardized methods for load testing and load rating existing timber bridges.

92. Investigate methods for determining the post-decay strength of timber components.

93. Refine inspection methods in order to more accurately detect incipient decay in timber bridge components.

94. Prepare a comprehensive manual for the inspection and evaluation of timber bridges.

95. Investigate and determine methods for evaluating the residual bending strength of beams that split or have failed in horizontal shear.

CATEGORY 6: MAINTENANCE AND REHABILITATION

96. Develop and evaluate economical, long lasting methods for sealing and protecting exposed end grain.

97. Prepare a comprehensive manual on maintenance practices for timber bridges.

98. Develop methods and comprehensive guidelines for the restoring, increasing the capacity of or replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.

99. Develop methods to restore the capacity of beams that have horizontal shear failures.

100. Refine applications of stress-laminating to include the rehabilitation of existing components.

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101. Evaluate the suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.

102. Develop materials for sealing wood against moisture in areas where prolonged moisture exposure is likely to occur.

CATEGORY 7: ECONOMICS

103. Develop guidelines for the relative cost and design life comparison of various types of timber bridges including composite construction.

104. Develop initial cost, life cycle cost and design life comparisons of timber bridges and culverts vs. steel and concrete bridges and culverts.

105. Collect, analyze, and report bridge cost data obtained through the Forest service, Federal Highway Administration and state timber bridge demonstration projects.

106. Develop a cost estimating guide for determining transportation, labor and equipment requirements for timber bridge construction, based on time-in-motion studies of bridge construction projects.

107. Develop guidelines for economically optimizing material requirements for specific bridge types.

CATEGORY 8: OTHER

108. Implement a mechanism for transferring timber bridge technology to users in a timely manner.

109. Develop designs for retaining walls and evaluate their field performance.

110. Develop designs and evaluate the field performance of noise barriers constructed of timber, and/or other materials.

111. Document the economic multiplier effect realized when local materials and labor are used for transportation structures.

112. Develop a data base of timber bridges, by type and material, that have been constructed in the US and Canada over the past 30 years.

113. Develop educational materials for use in colleges and trade schools

114. Complete an analysis of bridge needs in the US for the next 30 years based on span and functional classification.

115. Evaluate the comparative energy requirements for the production and construction timber, steel and concrete bridges and culverts.

116. Document experiences and lessons learned from using underutilized hardwood and secondary softwood species for bridge construction.

117. Compile a summary of ongoing timber bridge research and distribute quarterly to interested parties.

118. Develop designs and field test timber piers, abutments, and culverts.

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