FINAL REPORT

INDUSTRIALIZED TIMBER STRUCTURES

by

Harry E. Brown
Highway Research Engineer

Virginia Highway Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia
Department of Highways and the University of Virginia)

Charlottesville, Virginia

June 1974
VHRC 73-R63

SUMMARY

It was recently learned that a number of innovations in structural timber components are available to the construction industry, but that they were largely unknown to bridge designers. The purpose of this study was to develop for the Department a feasibility document that presented the latest technology in industrialized structural timber components. In addition, cost information on the most feasible timber system was to be presented. This work was carried out by the American Institute of Timber Construction (AITC), and the system selected by the AITC was one featuring glue-laminated timber deck panels on either glue laminated timber girders or on steel girders where deck replacement would bring an in-service bridge up to acceptable standards.

The glulam process embodies a number of industrialized construction precepts, including the following:

1. All components can be prefabricated in a form ready for rapid on-site assembly, which is particularly advantageous for emergency repairs;

2. rapid on-site assembly minimizes on-site labor costs and construction time, and

3. assembly of modular glulam units can be accomplished at the construction site by semiskilled labor and with unusually light construction equipment.

The Department's Bridge Division is currently considering several sites for field trial of the glulam concepts.

FINAL REPORT

INDUSTRIALIZED TIMBER STRUCTURES

by

Harry E. Brown
Highway Research Engineer

INTRODUCTION

During the period May 17-19, 1971, the Transportation Research Board, the University of Virginia, and the Virginia Highway Research Council cosponsored a workshop directed to the study of industrialized construction of bridges. In the workshop, which was held at the Airlie House in Warrenton, Virginia, representatives of industry, government and educational and research institutions pursued the overall objective of developing means for reducing bridge construction time through the use of an industrialized construction approach. It was brought out at this meeting that a number of fairly recent innovations in structural timber components are available, but that they are largely unknown to bridge designers.

A study of these innovations and the possible application of them to the Department's need would normally be undertaken by a staff researcher or joint appointee, however it was decided that this study should be conducted under a contract with the American Institute of Timber Construction (AITC) because of the absence of any local expertise. Between members of the AITC staff and associate members of the AITC, the necessary expertise to conduct the study was readily available. The working plan outlining this study was issued in September 1972 (Brown 1972) and the final report by the AITC was submitted to the Council on July 1, 1974 (AITC 1973).

PURPOSE

The principal purpose of this project was to develop a feasibility-type document on the use of timber bridge systems so as to aid in informing the Department of the latest technology in industrialized structural timber components. More specifically, the project was to:

1. Review alternate systems available in industrialized timber bridge construction,

2. develop preliminary structural design calculations for the selected bridge system,

3. compile cost estimates for the selected system, and

4. assess timber decking on steel stringers.

BENEFITS

The benefits anticipated from the use of timber bridge systems on low traffic volume roads are listed below:

1. Timber bridge systems should be competitive in first costs and in maintenance costs to the concrete and steel systems that are frequently used in bridges of this type.

2. The remoteness of some bridge sites sometimes make them practically inaccessible to ready-mix concrete trucks. The timber bridge would help alleviate this problem.

3. The time for erection should be reduced relative to that required for concrete and steel bridges now being constructed. Thus, labor costs should be less. This is particularly important in cases where labor is paid for travel time. Also, expensive detour roads may possibly be eliminated because erection of industrialized bridge systems can be carried out more briskly.

4. The assembly of an industrialized timber bridge should be relatively simple, and therefore low skilled and economical labor can be employed.

5. The durability of timber decks on these lightly traveled structures may be better than that of concrete because of timber's immunity to deicing chemicals.

6. The aesthetics of a timber bridge in a rural setting should be pleasing.

The remaining part of this report deals with a summary of the AITC report, a discussion of a design seminar presented by the AITC, and the status of efforts for field implementation.

A SUMMARY OF AITC REPORT

The most common type of timber decking on timber bridges is an assembly constructed on-site by nailing pieces of dimension lumber together and toenailing each lamination to the stringers. But this system, used in the Department's standard SS4 and SS5 bridges, has a drawback in that the boards tend to work loose because of shrinking and swelling stresses resulting from changes in moisture conditions and from load vibrations. The result is a noisy bridge that allows water to penetrate into the deck elements and onto the stringers below.

Recent research, principally by the Forest Products Laboratory (FPL) Division of the USDA Forest Service, located at Madison, Wisconsin, has revealed the concept of glue-laminating dimension lumber (glulam) into girder and deck panels (see Figure 1). Glulam refers to an engineered and stress rated product of a timber laminating plant. There are a number of laminating plants throughout the country and thus there is a competitive market for their products.

Figure 1. Glulam deck panels being placed into position on glulam girders.

The glulam process was selected by the AITC as the timber product most nearly meeting the needs of industrialized construction for rural secondary bridges. Of the number of characteristics of glulam that make it a desirable material for the design and construction of highway bridges, the first is that almost any shape or size structural member can be constructed with it. Secondly, since the individual pieces making up a member are dried prior to laminating, susceptibility to checking is greatly reduced and dimensional stability is vastly improved over large sawn members. And thirdly, there is an efficient placement of varying lamination grades in the structural member with respect to the stress requirements placed upon the timber.

A factor that has promoted the use of glulam elements is the advent of modern pressure impregnated preservative treatments. It is reported that with modern preservative treatment measures and a good design in which the superstructure is well protected from the elements, the service life of timber bridges can be extended to fifty years or more.

Although the glulam process for girders has been around for a number of years, it is only recently that the concept of glulam deck panels has been explored. In order to fabricate the glulam deck panels, the same two-inch dimension material now used in the nailed deck is glued with a weather-resistant glue into a flat slab. The resulting panel is very stiff and sufficiently impervious when treated with a preservative and covered with a wearing surface to resist penetration of surface water. The research, design, and construction criteria for these deck panels have been established by the FPL, so that these criteria are now being effectively used.

When the glulam girders and deck panels are combined into a bridge system, a number of industrialized construction precepts become evident. Some of these are summarized as follows:

1) Glulam lends itself to a systems approach because all components can be prefabricated in a form ready for rapid on-site assembly. Therefore, on-site labor costs and construction time can be minimized.

2) Timber is a very lightweight construction material and thus allows for the transportation of large, complete structural units such as girders with glulam panel decking that have been preassembled at the manufacturing site. This again minimizes on-site labor construction time, and reduces shipping costs based on a weight basis.

3) The lightweight feature previously mentioned also permits use of lighter on-site construction equipment. This, plus the relatively low cost of glulam, leads to a lower total cost for the initial structure.

4) Assembly of modular glulam units can be accomplished at the construction site by semiskilled labor and field modification is unlikely.

5) Aesthetically, timber best fits into many existing environments, particularly in rural and suburban areas where a natural appearance is desired.

6) Glulam timber components are not affected by chemicals or corrosive materials and thus possible corrosion of the decks is unlikely. Such is not always the case with concrete decks.

7) Timber exhibits excellent reserve strength in dynamic loading situations that occur in highway bridge use.

8) When considering construction materials, it is important to realize that timber is the only natural resource that can be replenished.

9) Through the use of modern pressure impregnated preservative treatments, timber becomes a durable material with expected life spans of 50 years or more.

10) The use of a timber bridge system will greatly minimize maintenance costs as it will not be affected by chemicals, the elements, or other factors normally influencing the longevity and maintenance characteristics of a bridge structure.

One of the aforementioned objectives was that preliminary structural calculations would be made of the selected timber system. Actually, preliminary structural design calculations were made on two systems: (1) glulam deck panels on glulam girders, and (2) glulam deck panels on steel girders. Calculations of the latter were undertaken in order to generate design parameters for redecking operations in cases where present toenailed decks need replacing but the steel girders are in satisfactory condition.

Design considerations were based upon the following conditions:

1. Loading

AASHTO, HS 15-44 or HS 20-44. Dead loads include a uniform three-inch asphalt wearing surface.

2. Spans

20' (6.1 m) to 80' (24.4 m) in four-foot (1.2 m) increments.

3. Widths

   26' (7.9 m) to 34' (10.4 m) in two-foot (0.6 m) increments.

4. Decks

   Glued laminated deck panels, 5 - 1/8" (13.0 cm) or 6 - 3/4" (17.1 cm) in thickness, 48" (121.9 cm) in width, full length sections to span across bridge.

5. Materials

   Deck

   L2 Douglas fir or Number 2 MG, Southern pine, wet use stresses.

   Glued Laminated Stringers

   24F Combination, Douglas fir or Southern pine, dry use stresses.

   Sawn Timbers

   No. 1 grade, Douglas fir.

6. Structural Steel

   ASTM A-36

The design information is listed in tabular form in the preliminary plans. For a particular loading (HS 15-44 or HS 20-44), span length (20' - 80') (6.1 - 24.4 m), and roadway width (26' - 34') (7.9 - 10.4 m) the following design parameters are given: girder size, girder spacing, deck thickness (5 1/8" or 6 3/4") (13.0 or 17.1 cm) size and total number of dowels, total board feet of girder (glulam), and total board feet of deck. Because material costs are variable, total board feet are given in the tables as opposed to dollars. With the board footage for a particular layout known, current cost quotations can be readily obtained from a fabricator.

As was shown under design considerations, an asphalt wearing surface is called for on the glulam deck panels. The wearing surface is needed to provide adequate traction for vehicles and to provide a crown for drainage in cases where bridges are not sloped.

It is well to note again in these times when conservation efforts are popular that timber is the only material used in construction that is a replenishable resource.

AITC SEMINAR

A part of the contract package with the AITC was a one-day design seminar for interested designers which was held at the Research Council on November 30, 1973. The seminar speakers were Thomas Williamson and Paul Beattie of the AITC, Billy Bohannan of the Forest Products Laboratory, and Ben Hurlbut, the consulting engineer responsible for the design aspects of the report. Approximately 45 persons attended the seminar, including members of the Research Advisory Committee for Industrialized Construction, District Bridge Engineers, Bridge Engineers of the Central Office, representatives of the FHWA and manufacturers, and other interested parties.

The outline of the seminar consisted of the following topics:

A. Glulam as a Basic Structural Material

B. Research Leading to Design Criteria for Glulam Panel Decks

C. Timber Bridge Design Criteria

D. Preservative Treatments for Glulam

E. Field Erection Techniques and Cost Savings Using the Glulam Bridge System

The meeting was highly informative, and it was well received by those in attendance.

CURRENT STATUS

The Research Advisory Committee for Industrialized Construction, in late February 1974, made the formal recommendation that glulam timber deck panels be tried on the Secondary Road System in the redecking of a present bridge and/or in new construction. The administration concurred with this recommendation and subsequently preliminary sites were offered by all eight construction districts to the Secondary Roads Division, and these in turn were offered to the Central Office's Bridge Division. These sites are presently under study by the bridge engineers of the Central Office. If field implementation of the glulam concepts result, the work will be covered under a new study and file number.

REFERENCES

1. Brown, H. E., "Industrialized Timber Structures — Working Plan", Virginia Highway Research Council, September 1972.

2. "Modern Timber Highway Bridges — A State of the Art Report", American Institute of Timber Construction, July 1973.