New Ideas for Timber Bridges

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ABSTRACT

Because nearly one-half of the bridges in the United States are listed as either functionally or structurally deficient lends impetus to search for new ideas for building and maintaining bridges. Most of these bridges are on secondary and rural roads where spans are short, which makes timber a prime candidate for construction. The Forest Service, U.S. Department of Agriculture, with a vast number of bridges under its care, is cooperating with the University of Wisconsin to investigate new techniques for timber bridge design and construction. Described in this paper are promising new ideas, which are being examined for bridge construction, rehabilitation, and production of efficient performance and low cost in timber bridge systems. The scope of the research covers reviewing recent advancements in bridge design, applying new techniques to enhance the performance of common bridge types, and evaluating totally new structural configurations for use in bridges. The performance enhancement may be achieved by increasing the transverse spread of load through distributor beams, prestressing techniques, and dowels. New structural configurations include plane trusses, multileaf trusses, and composite beams assembled together to produce parallel chord longitudinal deck systems. The research involves theoretical evaluations to estimate span capabilities. The more promising concepts, which are based on structural potential, estimated cost, and simplicity, are being experimentally tested to verify models, theory, and design procedures.

The bridge problem and its impact on the nation's transportation infrastructure is widely recognized. Nearly one-half of our bridges have been listed as either functionally or structurally deficient, and about 75 percent of them are on secondary and rural roads. The replacement cost of off-system deficient bridges has been estimated at $18.8 billion (1).

Wood has already proved to be a competitive material for short-span bridges. However, wood can become even more attractive if current limitations on available timber, connection methods, configurations, and code-recognized behavior can be improved. Current practice dictates the need for large sizes in preferred species, notably Douglas fir. New concepts may permit the use of smaller sizes, lower grades, or alternative species that will encourage the use of local and low-cost timber for bridge construction.

The development of new ideas for timber bridges requires the screening of a wide array of different concepts in the hope of finding a viable system or systems that will supplement or replace current practices. Recently developed bridge-building methods can be adopted, existing techniques can be upgraded using new technology, new materials can be used in previously unseen forms, and new design techniques may be implemented using modern analytical tools.

Some recent concepts have been introduced by others in an effort to solve particular bridge problems. The Canadians have been leaders in new bridge technology and some interesting work has recently been completed in the United Kingdom on segmental bridges. Other ideas might be reclaimed from the past. Some older systems have disappeared because of an intrinsic weakness (e.g., fasteners) and new techniques and technologies may overcome these problems.

New materials and technologies developed for other purposes may find applications in bridge construction. Foundation Grade Plywood, developed for building construction, has proven durability and might serve as the structural diaphragm for bridge components. Metal plate truss connectors might provide a better way to join structural elements. New design configurations or better methods of structural analysis might lead to more efficient bridges. Modern analytical tools (most notably high speed computers), allow the investigation of complex systems previously not amenable to slide rule solutions.

The Forest Service, U.S. Department of Agriculture, has a vast number of bridges under its care that represent a sizable investment for both new construction and maintenance. The Washington Office, Division of Engineering, requested the USDA Forest Products Laboratory (FPL) to investigate new and better ways to build and maintain bridges. The FPL, in turn, is cooperating with the University of Wisconsin (UW) to help investigate new construction concepts.

This paper will outline current ideas and research aimed at developing new timber bridge construction and design methodologies. Many of the new ideas cited herein may prove unworkable for one reason or another, but hopefully some will emerge as feasible. These concepts all work in theory, although some depend on techniques or assumed behaviors that are not recognized in the current national design codes. The logical sequence will be to screen those ideas that appear promising, verify theoretical designs experimentally, and, finally, build prototype systems to monitor in-situ performance. Actual acceptance and use of workable concepts by bridge designers will be contingent on the definition of design criteria and recognition by AASHTO.

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CURRENT BRIDGE SYSTEMS

Timber bridges have been used throughout the national bridge system, but the majority are used on secondary and rural roads. Timber was the primary construction material for only about 13 percent of U.S. bridges over 20 ft in span, but more than 85 percent of these were located on secondary and rural roads. Substantial federal funding has been made available for bridge replacement. Timber bridges are being used, as seen recently in Wisconsin, to replace deficient bridges on local and county rural roads.

Timber bridges are quite versatile and well suited for a wide range of applications. Glued-laminated construction tremendously extended the capabilities of timber span. The Keystone Wye bridge near Mount Rushmore is a 155-ft arch that supports a 290-ft 3-level interchange. A parallel chord bridge near Randall, Washington, has a main span of 120 ft. The Canadian Forest Service has designed and built king post and queen post bridges for clear spans ranging from 125 to 180 ft. The British Columbia Forest Service has built simple beam bridges using glued-laminated I-beams, which span 150 ft (2).

However, timber bridges are most commonly used in short-span situations. Of nearly 11,000 Forest Service bridges, 40 percent fall in the 20- to 40-ft range, and almost 80 percent are 60 ft or less in span. If these figures are similar to rural and county bridge inventories, it is obvious that the biggest market, in terms of numbers, is for bridges under 60 ft. The concepts discussed in this paper focus on these short-span bridges.

TIMBER BRIDGE TYPES

Timber bridges might be described as falling within four categories--girder, longitudinal deck, parallel chord, and special. Figure 1 shows the basic components and layout that might be found in each of the first three categories. The last category (not shown) would include "special" types that are not widely used.

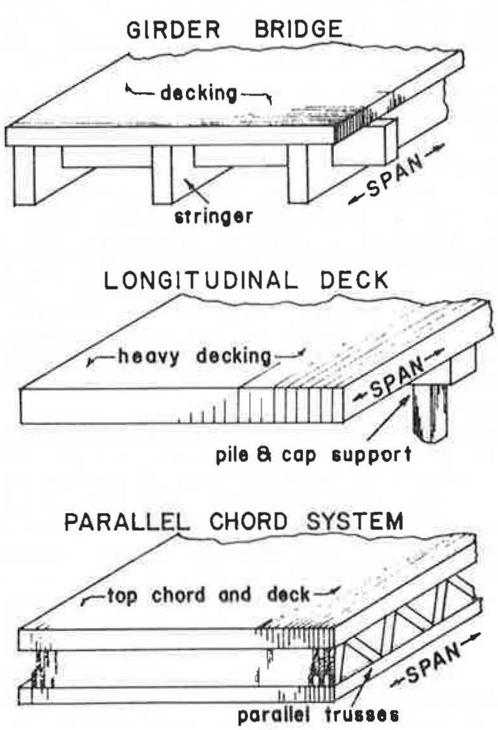

FIGURE 1 Timber bridge types.

Girder Bridges

The most widely used of all timber bridge superstructures is the longitudinal stringer or straight girder bridge. The stringers reach across the entire length of the span and support a transverse deck. Transverse diaphragms may be used to brace the main stringers. Glued-laminated construction took over much of this market years ago when high-quality timber in the required sizes became scarce and more expensive.

One unique girder bridge was built in the George Washington National Forest in 1977 using Press-Lam, a thick form of laminated veneer lumber (LVL). It is produced by parallel-laminating thick sheets of veneer to produce structural-sized members. The process was developed to improve resource recovery and to provide a means of producing large members from small trees.

LVL members contain butt joints and lathe checks, which must be considered in design. However, because wood defects are randomly dispersed in the laminating process, bending stress can be increased and stiffness is more uniform. Also, the lathe checks provide paths for improving penetration and retention of oil-based preservatives. The Virginia Department of Highways and Transportation has monitored the performance of this demonstration bridge and has prepared progress reports (3).

The traditional deck system used with girder bridges was a nail-laminated assembly of nominal 2-in. dimension lumber placed transverse to the stringers with the wide face in the vertical direction. Installation consisted of through-nailing the laminations and toe-nailing to the stringers. Alternate wetting and drying plus impact loading tends to loosen the fasteners and degrades performance. Also, glued-laminated stringers are further apart, thus placing added distress on the deck system. This led to the development of the glued-laminated deck system, which provided a stiff and durable deck and also protected the girders from the elements. Weyerhaeuser Company in Tacoma, Washington, designed a method of attaching the glued-laminated deck panels to the stringers. The system uses angular clips fastened in place in the field.

The FPL developed a process for designing transverse decks based on orthotropic plate theory (4,5). Continuity between individual panels was provided by steel dowel connectors that could effectively transfer both moment and shear across the joint between adjacent panels. Although the system performs extremely well, its use is not nearly as widespread as it could be. Experimental bridges and those erected by experienced crews went together very well in the field. However, construction problems were often encountered in the field with production bridges. These problems appear to be related to the experience of the erection crew and preciseness of drilling dowel holes by the fabricator. The lesson to be learned here is that requiring tight tolerances and high precision tends to deter wide acceptability of a particular system.

Longitudinal Deck Bridges

The longitudinal deck is probably the simplest form of bridge in existence, being a simple slab spanning between supports. This single component system is easy to fabricate and install. The low profile is an added advantage in that it provides maximum clearance during times of high water. There are currently three forms of longitudinal deck bridges: nail-laminated, glued-laminated and panelized (spiked).

The secret to achieving optimum performance of any longitudinal deck bridge is to distribute the load transversely to increase the effective width of deck elements resisting the applied forces. Ideally, the deck should approach full plate action. AASHTO currently recognizes transverse distribution afforded by mechanical fasteners (spikes) between laminations or glued joints, and the effective width is taken as the wheel width plus two times the deck thickness. Additional methods of achieving transverse distribution of loads are distributor beams, transverse prestressing, and dowelled connections between members.

From a practical standpoint, the distributor beam may be the simplest means of achieving transverse load distribution and would be the easiest to fabricate and install on site. A distributor beam is a transverse structural member secured to the bottom of a deck to increase the transverse stiffness. Iowa State University recently concluded a research study for the American Institute of Timber Construction (AITC) on distributor beams for glued-laminated panels (6), which defined distribution factors to be used in design. A new design procedure has been proposed to AASHTO based on this study and should appear in the next edition of the code.

A system of compressing wood perpendicular to the laminations to induce high interlaminar friction was developed in 1976 by the Ontario Ministry of Transportation (7,8). The concept was originally intended as a method for rehabilitating existing nail-laminated decks, but has been extended to new bridge decks as well. To date, some 15 bridges have been built or rehabilitated with the Ontario system. High-strength steel rods are positioned perpendicular to the span direction and tensioned against steel bearing surfaces along the two outside edges of the bridge. The system depends on a minimum stress level in the wood to produce plate action, and displays good load distribution characteristics. Design procedures are contained in the latest Ontario Highway Bridge Design Code (9).

One longitudinal deck bridge was built in the Hiawatha National Forest using glued-laminated panels and short dowels similar to the transverse glued-laminated deck system. Dowels were positioned at 1-ft intervals for the full 38-ft length of the panels and each had to be aligned before the panels could be pulled together. Although the system went together well and is performing satisfactorily, construction is too complicated to be attractive.

Special Bridges

Numerous special bridge systems such as arches, king post and queen post trusses, and long-span parallel chord systems are in use. They are designed for a particular location and require special materials and construction procedures. One new, special bridge that should be mentioned is the prefabricated modular type of a specific design intended for multi-use situations. The United Nations Industrial Development Organization (UNIDO) developed a prefabricated wooden bridge system for use in developing countries (10, 11). The concept was first introduced in Kenya and proved highly successful. The Timber Research and Development Association (TRADA) was awarded a contract by UNIDO in 1981 to extend this technology for use in Latin America, with bridges recently completed in Honduras.

The system uses standard triangular panels that are approximately 10-ft long and 5-ft deep (see Figure 2). The panel is the basis of the prefabricated module and several are joined in line to make trusses. Bridges are designed this way for spans approaching 100 ft with 40-ton loads, but an 80-ft length would be more practical for AASHTO H20 loading. The segments are joined with matching steel end plates at the top chords and steel tension bars or wood members for the lower chords. This modular bridge can be erected without lifting cranes or highly skilled labor. Although costs have not been firmly established, TRADA claims that material and transport costs are lower than for prefabricated steel or concrete. A particular advantage of this system is that all the modules are alike and can therefore be disassembled and reused for relocatable bridges.

NEW IDEAS IN BRIDGE CONSTRUCTION

The bridges mentioned previously are already in widespread use and are competitive with concrete and steel bridges in short-span applications. The new ideas presented in this section are intended to enhance performance, reduce cost, and simplify construction. Many of the innovations will also make use of small size and short-length materials in various species, taking advantage of regional timber supplies and cost reductions.

The concepts discussed in this paper focus on short span bridges. Some goals must be set for these "new ideas" on timber bridges. To be practical, the concepts should meet the following criteria:

- A bridge must be cost effective. Both initial construction and life-cycle costs must be competitive with current designs and other alternative materials. The added cost to gain greater durability and life service must be included when selecting the initial design.

In other words, the anticipated life of the bridge must be considered. Some bridges, particularly in the Forest Service, are temporary and will be taken out of service following a particular operation. One option in such an instance would be to build the minimum-cost structure that will safely perform for a short time. For example, native log stringer bridges are often used for temporary structures on logging roads. A second option would be to design a more expensive relocatable bridge in anticipation of using it in the future at another location.

- It must be simple to fabricate, transport, and erect. The market for short-span bridges is scattered geographically and could best be served by local firms. Thus, to be attractive, the bridge system should be simple to fabricate and one that does not require large capital investments or special equipment. The base material for bridge elements and ancillary components should be easily procurable from nearby sources.

Transportation and erection considerations should recognize several factors. The bridge site is often in a remote area with difficult access. The contract value of a job may not support the cost of heavy lifting equipment, or other special apparatus required for some sophisticated systems. Temporary shoring and falsework should be avoided wherever possible. Finally, because bridges are so widely dispersed geographically, the work force may have had little or no experience in timber bridge construction. These smaller jobs simply do not justify sending a trained crew around the country. The erection process should be at a level consistent with average journeyman skills employing common tools of construction.

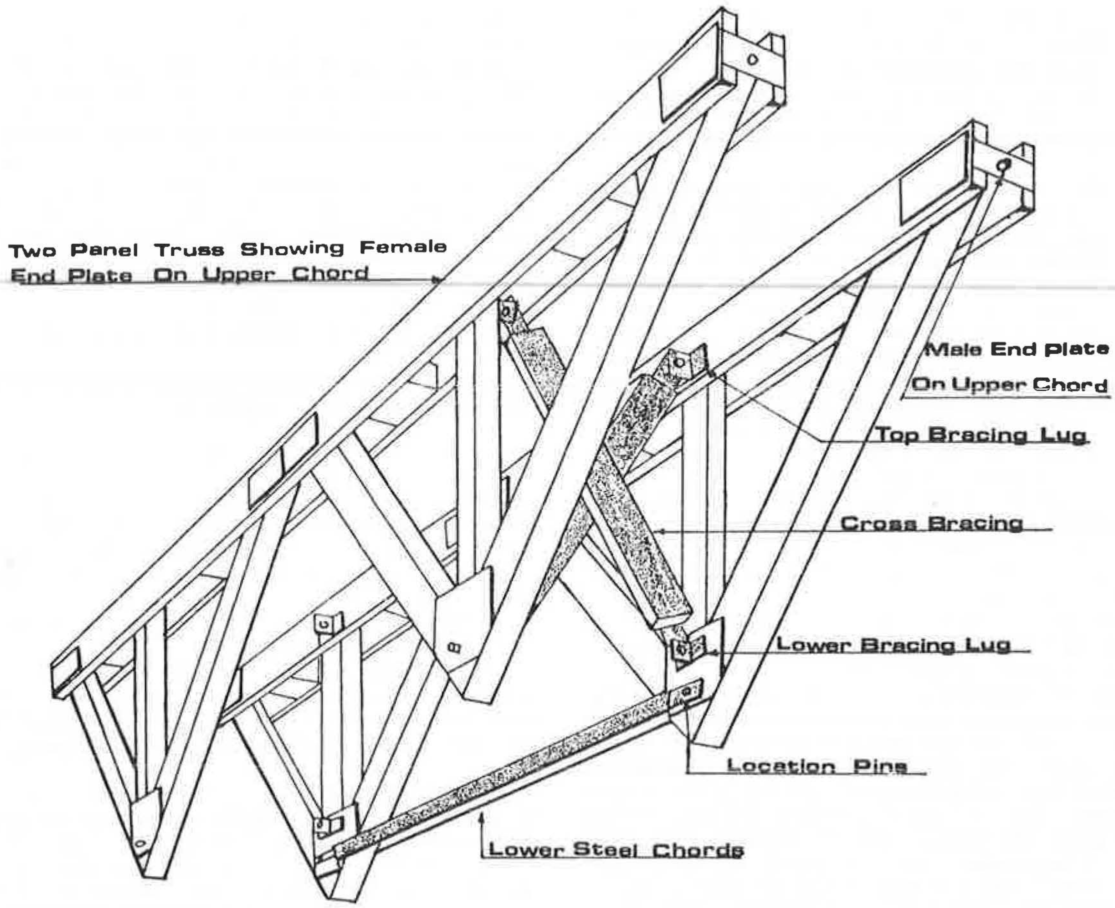

FIGURE 2 UNIDO bridge system: four triangular panels shown with connecting elements.

Girder Bridges

The glued-laminated industry, under the lead of the AITC, has had an active and effective research program for many years. The AITC is continually seeking new ways to improve the performance of glued-laminated systems and this type of bridge construction is in good hands.

Glued-laminated decks with steel dowel connectors on girder bridges might be more attractive if erection could be simplified. Fabrication tolerances could be relaxed if some type of a plastic filler material could be developed, which would be used to fill one of each pair of matching dowel holes. The filler would allow oversized holes to be drilled so that field alignment problems would be reduced.

Longitudinal Deck Bridges

The simplest form of bridge is the longitudinal deck bridge. True "deck" behavior can only be attained when plate behavior exists, and requires continuity between the individual elements comprising the deck. Improved deck performance can be obtained by developing new connection techniques that will spread resistance to an applied load transversely across the deck. Three possible ways to spread the load include distributor beams, transverse stressing of the deck, and dowels. The relative effectiveness of the three options is not yet known, but the upper limit in performance would be total plate action.

Distributor Beams

The use of distributor beams, as noted, has been investigated when used with glued-laminated panels. Wheeler Bridge Company has been using distributor beams with their spiked, panelized, longitudinal deck system for years because they know it improves performance. Yet, they have been unable to take advantage of this factor in their designs because effects of the distributor beams are not yet recognized by the design codes.

With glued-laminated systems, the distributor beam transfers loads across the joints between relatively stiff panels that may be 4 ft or more apart. Thus, the forces are highly concentrated at the joints as the beam attempts to enforce a continuous deformation profile across joints between panels. For a longitudinal deck bridge constructed of dimension lumber or individual timbers, the transverse deflection profile is more continuous and uniform than in glued-laminated panels. Distributor beams could more effectively spread uniform transverse deflection across these bridges and might prove to be more efficient than with glued-laminated panels. Part of the current UW/FPL research program is to test the effectiveness of distributor beams with nail-laminated decks and to devise an analytical model.

Stressed Wood Decks

Transverse stressing of longitudinal decks to create friction connections between laminae was developed by the Ontario Ministry of Transportation and Communication and is included in the Ontario Highway Bridge Design Code (9) but is not yet recognized by AASHTO. Most of the 15 existing bridges using this system are multispan longitudinal decks supported by pile caps or floor beams. The stressing technique requires special proprietary equipment and material that might discourage its use for small jobs in remote areas.

Research is currently underway at the UW Structures Laboratory to examine use of the stressed wood system over longer spans (48 ft) with the deck assembled of random short timbers that could be of local wood species. Techniques of hand-stressing the rods are being examined in an attempt to simplify the stressing process and limit the need for extensive equipment. Orthotropic finite element analytic procedures are being used to achieve correlation with the test results.

Dowelled Systems

Dowel rods extending across the full with of the bridge through prebored holes can distribute forces by "beam-on-elastic-foundation" action. The same plate theory developed for deck panels can be extended to a different range of aspect ratios (e.g., span-to-width ratios) to predict the structural response of longitudinal deck with dowels. For longitudinal decks, the normal deflections would be many folds greater than the short-span deck panels. Hence, the tolerance needed to achieve full dowel action could be relaxed considerably compared to that in short transverse deck panels. Also, the individual lamination, being but 2-in. nominal lumber, could be flexed a little in the field to accommodate a small amount of vertical misalignment.

A perceived advantage of the dowelled system over the Ontario system is that it would not require any special equipment or materials to construct. Also, the concerns over loss of stress due to relaxation or changes in moisture content would be alleviated. This new idea is being investigated under the current UW/FPL research study.

Parallel Chord Bridges

A new idea for short span bridges is borrowed from recent technology developed for light-frame construction. The parallel chord bridges would be made up of trusses fabricated primarily from dimension lumber rather than glued-laminated or timber. The adjacent trusses would be in contact much like the elements in a longitudinal deck. The resulting system forms a wooden box girder extending the length of the span and acting similarly to concrete box-girder bridges.

The parallel chord bridges may relieve the primary limitation of simple longitudinal decks--the need for deep solid material to achieve sufficient stiffness in moderate spans. At first glance, the parallel chord concept using adjacent trusses might appear to be material-intensive, but it may not be. In a typical 20-ft girder-deck bridge, over 70 percent of the wood is in the deck. The amount of wood in the deck exceeds that in the stringers up to spans of about 50 ft. Also, the quantity of material alone does not control the total cost. The cost per unit of material, and ease of transportation and erection must also be considered. With trusses, shorter pieces can be utilized and lower quality lumber can be selectively used for some members. Individual trusses can be fabricated full length and are self supporting for erection. Also, individual trusses are relatively light for easy handling on site.

Three types of parallel chord bridges are being studied by UW/FPL: plane trusses, multileaf trusses, and composite beams (see Figure 3). The first phase is to evaluate the span capabilities of different

PARALLEL CHORD TRUSSES

TYPE	POTENTIAL MAX. SPAN	
Multi-Leaf Truss		
24" depth (61cm)	25ft	(7.6m)
30" (76cm)	32ft	(9.8m)
36" (91cm)	36ft	(11.0m)
Metal Plate Connections		
24" (61cm) deep	27ft	(8.2m)
30" (76cm)	35ft	(10.7m)
36" (91cm)	40ft	(12.2m)
Composite Beam		
24" (61cm) deep	23ft	(7.0m)
30" (76cm)	30ft	(9.1m)
36" (91cm)	35ft	(10.7m)

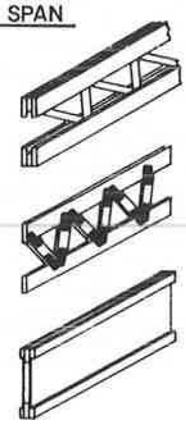

FIGURE 3 Parallel chord bridges: types and potential spans.

configurations based on direct loads, and the second will look for ways to enhance performance through various means of transverse load distributions.

Plane Trusses

Plane trusses are most commonly fabricated using metal truss plates. This type of truss is shown under the "metal plate connection" type in Figure 3. The truss plate industry comprises some 2,000 fabrication plants strategically located throughout the United States, so bridge contracts using this type of truss anywhere in the country could probably be served by local fabricators.

Structurally, plane trusses can readily span 40 ft under H-20 loads without the benefit of transverse load distribution. The major compromise is in reducing the truss depth to achieve a low profile versus using a depth that provides optimum performance. With shallow trusses, the number of web elements becomes excessive, which adds greatly to the fabrication costs.

Alpine Engineered Products has patented a new truss configuration, the J-24 series, which may be particularly well suited for bridges (see Figure 4).

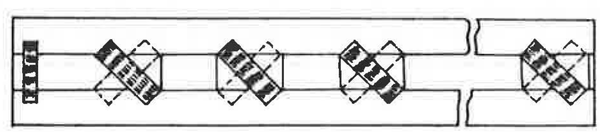

FIGURE 4 Patented J-24 series of Alpine Engineered Products (plates drawn with dashed lines are on the back side of the truss).

The J-24 truss is a kind of hybrid, a combination of a metal plate truss and a Vierendeel truss. It has no diagonal wood web members--only spacer blocks, which are positioned between the flanges. Two metal truss plates, one on each side, are pressed in diagonally opposite each other. This concept looks extremely simple to fabricate, and might provide an economic way to produce bridge trusses.

However, some unanswered questions remain on the use of metal plates for exposed structures. First, it is not known how they will perform under cyclic changes in moisture content. Although the plates will be tightly nested between adjacent trusses, some joint slip might occur. Second, treatment would most likely be with an oil-based preservative and there does not appear to be any information on how metal plates perform in oil preservative-treated wood. The current UW/FPL study will investigate plate performance.

The Ontario Ministry of Transportation and Communications built a prototype bridge in 1981 using metal truss plates. It is a slant-leg rigid frame (12) rather than a simple truss, and future performance studies could provide good data on transverse load distribution and suitability of using metal truss plates in treated wood under cyclic loading and exposed conditions. It is critical that questions on the performance of metal plates under adverse conditions be fully resolved before this idea can be extended to operational bridges.

Multileaf Trusses

Multileaf trusses provide an alternative for parallel chord bridges that can be easily fabricated in a small shop without special equipment. This concept uses three pieces of dimension lumber in both top and bottom flanges. The two outside pieces would be 2 in. deeper than the center one in both flanges, as shown in Figure 3. The ends of the diagonal web members would butt against the center flange piece, and the two side pieces would straddle it providing a clamping action. Webs would be secured by nail-gluing each end. Theoretically, this type of truss could span to about 40 ft without the benefit of transverse load distribution. The critical design consideration appears to be the end restraint on tension web members. The performance of this joint will need to be confirmed experimentally.

Composite Beams

The advent of Foundation Grade Plywood provides a new opportunity for the design of composite beams. Foundation Grade Plywood has a proven record of durability, and should perform well for bridges. Standard I-beams, with single webs of plywood or oriented strand board, are rapidly gaining in popularity for residential and light commercial building. These composite I-beams are cost effective, lightweight, and can be fabricated in any desired length. However, preliminary analysis of composite beams indicates that the web is critical in shear under truck wheel loads. A single web using standard plywood thicknesses does not appear to provide the required shear area, but a multileaf configuration with two webs might.

As before, it is envisioned that the two flanges would be built up of three pieces of dimension lumber, but, in this case, the center piece would be 2-in. deeper than the other (see Figure 3). The ledge provided by the center piece would provide the bonding surfaces for attaching plywood webs on both sides. The total width of each composite beam would be controlled by the thickness of lumber as the plywood would be recessed below the flanges. Thus, it would be possible to reduce the thickness of plywood away from the high shear areas.

Engineering calculations show that the three preceding concepts could carry highway trucks over reasonable spans without the benefit of transverse load distribution. Only the members within the wheel width were considered in resisting load. However, the open space in the webs provides easy access to install load distribution devices. If the distributor beam and stressing system are effective for longitudinal deck bridges, they should also work with parallel chord bridges. This would be a logical extension for research to parallel chord systems.

The current UW/PFL research is analytically studying the three parallel chord systems using truss analysis programs to evaluate their span capabilities and connection requirements. Experimental investigation of metal splice plate joints in preservative-treated wood is planned.

SUMMARY

Several new ideas have been presented for building more efficient and low-cost timber bridges to satisfy current needs in replacement of deficient bridges and future needs for new bridges. Some of these ideas may prove to be viable and competitive. Many of these innovations are being examined cooperatively by the University of Wisconsin and the Forest Products Laboratory of the Forest Service, U.S. Department of Agriculture.

The present UW/FPL research is experimentally investigating the effectiveness of distributor beams, transverse stressing, and metal dowels in improving the transverse load distribution of longitudinal decks. Test results are being used to verify computer-aided analytical methods for predicting behavior. Preliminary analytical studies are underway to evaluate the efficiency of various parallel chord systems. Each of the proposed new ideas will eventually be studied.

The concepts will first be analyzed to estimate their behavior and theoretical capacities. Then, the more promising ideas will be tested experimentally to confirm the analytic theory and to prepare design models. Finally, prototype bridges need to be built using the most practical concepts to obtain field data on actual performance under service loads with environmental effects.

REFERENCES

1. Highway Bridge Replacement and Rehabilitation Program. 3rd Annual Report of the Secretary of Transportation to the Congress of the United States in Compliance With Section 144 (I), Chapter 1 of Title 23, U.S. Code, Washington D.C., 1982.
2. R.G. Scarisbrick. Laminated Timber Logging Bridges in British Columbia. Journal of the Structural Division, Vol. 102, No. ST1, ASCE, Jan. 1975.
3. D.S. Gromala, R.C. Moody, and M.M. Sprinkel. Performance of a Press Lam Bridge: A 5-Year Load-Testing and Monitoring Program. Research Note FPL-0251. Forest Products Laboratory, U.S. Department of Agriculture, Madison, Wis., May 1985.
4. W.J. McCutcheon and R.L. Tuomi. Procedure for Design of Glued-Laminated Orthotropic Bridge Decks. Research Paper FPL 210. Forest Products Laboratory, U.S. Department of Agriculture, Madison, Wis., 1973.
5. W.J. McCutcheon and R.L. Tuomi. Simplified Design Procedure for Glued Laminated Bridge Decks. Research Paper FPL 233. Forest Products Laboratory, U.S. Department of Agriculture, Madison, Wis., 1974.
6. W.W. Sanders, F.W. Klaiber, and T.J. Wipf. Load Distribution in Glued Laminated Longitudinal Timber Deck Highway Bridges. Report ERI-AMES-85441. Iowa State University, Ames, April 1985.
7. R.J. Taylor, B. deV Batchelor, and K. Van Delan. Prestressed Wood Bridges. Report SRR-83-01.

Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1983.
8. R.J. Taylor. Design of Prestressed Wood Bridges Using the Ontario Highway Bridge Design Code. Report SRR-83-03. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1983.
9. Ontario Highway Bridge Design Code. Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, April 1984.
10. J.D. Parry. The Kenyan Low Cost Modular Timber Bridge. Laboratory Report 970. Transportation and Road Research Laboratory, Crowthorne, Berkshire, England, 1981.
11. Wooden Bridges--UNIDO's Prefabricated Modular System. Information Booklet Reference V.83-59018. United Nation's Industrial Development Organization, Vienna, Austria, Sept. 1983.
12. R.J. Taylor and H. Walsh. Prototype Prestressed Wood Bridge. In Transportation Research Record 950, TRB, National Research Council, Washington, D.C., 1984, pp. 110-122.

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Performance and Rehabilitation of Timber Bridges

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ABSTRACT

Eighteen timber bridges were inspected to assess their long-term performance. In general, they were in excellent structural condition with glued-laminated decks performing better than nail-laminated decks. Extensive moisture content readings indicated that wet-use stresses should be used when designing bridge decks, regardless of deck type or treatment. Dry-use stresses are appropriate for the stringers. A comprehensive program, including new technologies and demonstration projects, must be developed to address the repair and rehabilitation of older nailed-laminated decks.

Many recent developments have increased the interest in timber bridges, such as new materials and manufacturing methods, improvements in preservative treatment, a systems approach to bridge engineering, alarm over needed bridge replacement and rehabilitation, and improved technology (1,2). A number of these developments reflect the advancement in knowledge of the general behavior of wood as a structural material (3). The importance of these developments has been underscored in comprehensive state-of-the-art reports and technical presentations and publications (4-7). A recent workshop helped identify research needs that are pertinent to timber bridge engineering (8).

The Forest Service (U.S. Department of Agriculture) is keenly interested in this engineering area because it maintains over 10,000 road bridges and adds 100-250 bridges to the system annually. Wood is the major construction material in over one-half the existing and new bridges. In the late 1960s and early 1970s, the Forest Service sponsored the construction of timber bridges containing novel features that would be expected to improve performance. These bridges were built in various national forests in seven states across the northern United States. They were primarily constructed with transverse glued-laminated (glulam) panel decks and a variety of interpanel connections. Some bridges had nail-laminated (nail-lam) decks for comparative purposes. Also, different types of members, construction, and materials were used in the remainder of the superstructure and substructure. Some of the new features were, at the time, considered to be experimental.

Although these bridges had received routine inspections over the years, little had been done to specifically monitor the structural performance and condition of the experimental features. The relative performance of glulam decking and traditional nail-lam decks is of particular interest. Although nail-lam construction is still used at some sites and numerous nail-lam decks are still in service in Forest Service timber bridges, the glulam panel deck is now the preferred material.

There are thousands of older, poorly maintained, timber bridges in the United States with nail-lam decks that have deteriorated badly. At some time, a decision must be made in each case to abandon the

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