Innovative Design and Construction of Modern Timber Bridges

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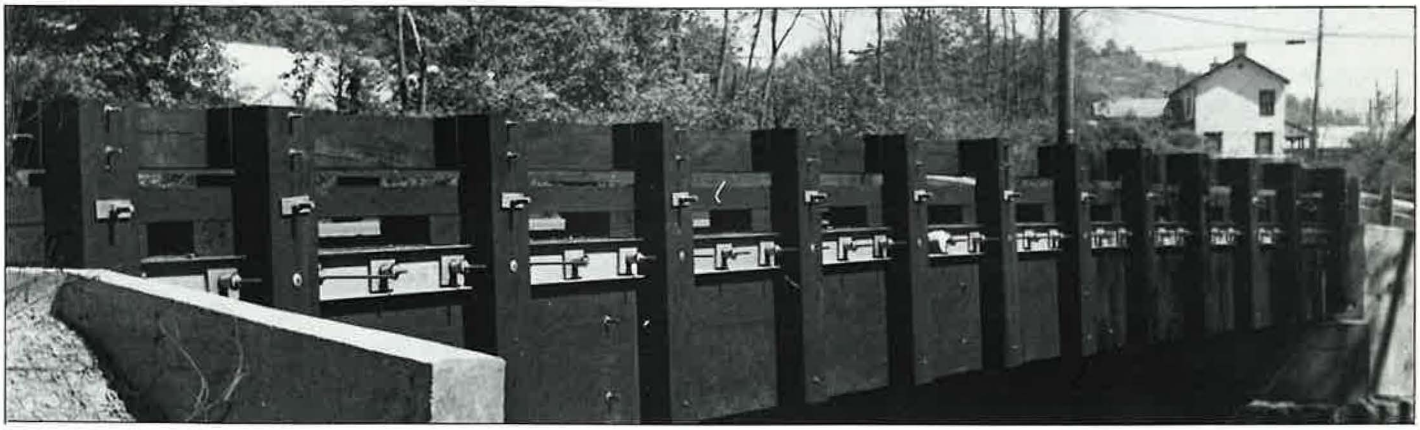

T-beam bridge at Charleston, West Virginia.

Because of rapid advancement in timber bridge technology, the timber used in today's bridges is different from the material with which many engineers are familiar. New assembly methods, timber products made with glues or timber composites, and preservative treatments have made timber a feasible alternative to steel or concrete. Timber is particularly well suited for structures that are subject to harsh environments. The Timber Bridge Initiative (TBI) program, sponsored by the U.S. Department of Agriculture Forest Service, promotes the use of timber as a bridge material because of its high strength-to-weight ratio, abundance, familiarity to contractors, and cost savings potential. The TBI program includes research and development, implementation, monitoring, and technology transfer throughout the United States. The progress being made in these areas is summarized here.

Research and Development

The research team of the Constructed Facilities Center (CFC), West Virginia University, is working closely with the USDA Forest Service to develop innovative post-tensioned timber systems for single span bridges that range from 20 to 150 feet and are subject to American Association of State Highway and Transportation Officials HS-20 truck loads. Special emphasis will be placed on modular construction and improvements in system stiffness. This work extends the Ontario Ministry of Transportation's concept of posttensioning timber laminae in the transverse direction to develop plate action.

Research is also under way on machine stress-rating techniques, acoustic emission methods, and optical scanning techniques to grade hardwoods and the use in the United States of a stress-class grading system similar to systems used in other countries. In addition, efforts are being made to: (a) economically rehabilitate deteriorating Interstate bridge decks by creating new joints for modular stressed decks so that they might better withstand fatigue stresses caused by highway loads; (b) arrive at realistic elastic constants (moduli of elasticity and rigidity) for stressed timber bridge systems; and (c) extend these concepts to railroad bridges.

Eventually research may even make possible the development of efficient hybrid cable-stayed bridge systems composed of timber decking and steel stringer and diaphragm stiffening systems for 300- to 600-foot bridge spans.

Design specifications for hardwoods were not available to engineers until recently. With increasing use of hardwoods, design values have been developed by Al DeBonis of Wood Advisory Services for the Northeastern Lumber Manufacturers Association for several species and published in *National Design Specification for Wood Construction*. In addition, research on preservative treatments on hardwoods has been initiated by the USDA Forest Service in cooperation with the Mississippi State University. To make timber bridge systems economical, rail system ("safety barriers") performance through full-scale crash testing has to be established. The USDA Forest Service and the University of Nebraska-Lincoln are cooperating to develop rail systems and then conduct the crash testing.

Implementation

The CFC is cooperating with the USDA Forest Service and the West Virginia Department of Transportation (WVDOT) Highways Division to prepare standard

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design and construction specifications, computations, and drawings. Standardization has become a necessity for economic competitiveness. Standards are developed by CFC researchers on the basis of the capabilities of available timber, composite timber products, and the skills of local labor forces. To meet some of these requirements, the following three types of timber structures have been designed and standard drawings made for each:

- Type A: stressed solid timber decks,
- Type B: stressed timber box sections, and
- Type C: stressed timber "Tee" sections.

Stressed solid decks consist of a group of laminae squeezed together (posttensioned) by high-strength galvanized steel rods. The maximum span of this bridge type is about 35 feet. Types B and C (box and Tee) structures were developed to combine the low cost of stressed decks with the higher stiffness and load-carrying ability of glue-laminated (glulam) beams or laminated veneer lumber. Tee sections can be built up to about 100 feet, although 75 feet is probably a more practical limit. Similarly, box sections—a modification of the stressed Tee with bottom flange—can be built up to about 150 feet.

An alternative to the above systems, particularly for longer spans, is the parallel-chord truss system. This system has been developed by the USDA Forest Service in cooperation with the University of Wisconsin. An experimental parallel-chord truss bridge was designed in 1987. Additional research is planned by the University of Wisconsin to develop more efficient truss systems.

Yet another alternative is under consideration by the Pennsylvania Department of Transportation (PennDOT). PennDOT is building 17 posttensioned timber slab decks, of which at least 5 are designed with thin steel plates embedded between timber planks. This novel approach was suggested by Ralph Mozingo, of the Pennsylvania State University, to improve the overall stiffness of slab timber decks. In addition, PennDOT is researching the feasibility of using hardwood glulam planks for timber bridge construction.

Monitoring

Because stressed timber systems are new in the United States, the CFC, in cooperation with the USDA Forest Service, WVDOT, and PennDOT, is monitoring several prototype bridge systems to understand short- and long-term performance, fabrication and erection problems, and cost-effectiveness. Preliminary field information on properly designed stressed timber bridges reveals that these bridges are performing well. At least two to three years of performance and maintenance cost studies have to be conducted before definite conclusions can be drawn. WVDOT and PennDOT are committed to the development of a systematic field monitoring program during the next three to five years to establish design criteria and improve the life-cycle costs of timber bridges.

On the basis of a partial cost analysis, construction costs, including guardrail and installation, are about $50 to $60 per square foot of deck for stressed solid decks and $70 to $80 per square foot for box sections. These initial costs are somewhat higher than comparable concrete or steel sections. However, CFC researchers are examining such cost-cutting measures as (a) using lower-grade lumber for decking, (b) revising guardrail designs, (c) familiarizing contractors with this new technology, and (d) modifying treatment processes. Construction costs of solid decks in West Virginia, using March 1990 bidding costs, have dropped to about $38 per square foot (including erection costs). CFC researchers believe that this cost will decline further to about $30 in 1991, which compares favorably with prestressed concrete sections, whose costs are about $35 per square foot.

Technology Transfer

This work is being carried out in close cooperation with the USDA Forest Service through their Timber Bridge Information Resource Center at Morgantown, West Virginia. In 1989 several seminars were conducted by the staff of the CFC to inform contractors and designers about stressed timber.

The 33 bridges built in West Virginia during 1989–1990 include stressed solid decks and box sections, as well as bridge deck rehabilitation projects. Standard designs and drawings for these stressed timber systems are being used by WVDOT Division of Highways and other state highway agencies. Nationally, the CFC is participating in the drafting of new AASHTO specifications for timber structures.

Research and development is also being carried out by the Ministry of Transportation, Ontario, Canada (the originator of the stressed timber deck concepts), the University of Wisconsin, the Pennsylvania State University, the USDA Forest Service, the University of Nebraska, and many other private firms and professional agencies.

CFC researchers believe that economical timber bridge systems with competitive life-cycle costs will be developed in the next two to three years because of the intensive nationwide research and development through TBI. Competitive life-cycle costs will be achieved by gaining additional insights into design, materials, fabrication, erection, and maintenance. On the basis of the past performance of well-designed and constructed timber structures, modern timber bridges can be built to last at least 75 years. Furthermore, CFC researchers are convinced that a partnership among industry, contractors, university researchers, and government agencies is evolving through this effort.

A VHS videotape, "Timber Bridges Built Better and Save with Modern Timber Bridges," is available on loan from the Federal Highway Administration. Contact Report Center, FHWA, 6300 Georgetown Pike, McLean, Virginia 22101-2296 (telephone 703-285-2145).

The work summarized here would not have been possible without the cooperation, support, and guidance of the WVDOT Highway Division, especially Commissioner Fred VanKirk. Special thanks are due also to Senator Robert Byrd (D.-W.Va.) for supporting the modern timber bridge research and construction effort across the country.