National Wood In Transportation Information Center

CROSSINGS

NEWSLETTER OF THE WOOD IN TRANSPORTATION PROGRAM

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World's First FRP-Glulam Ocean Pier; Bar Harbor, Maine

In June 1995, the world's first fiber-reinforced polymer (FRP) composite-glulam hybrid pier was placed in service at the Bay Harbor Yacht Club. This pier, which replaces a failed 40-year-old steel pier is 124 feet 5 inches (37.6 m) in length, approximately 8 feet in width, and comprises one span of 26 feet 6 inches and two spans of 48 feet 8 inches. The FRP-glulam beams are 27-7/8 inches in depth. The pier was designed for a live load of 85 psf and a dead load of 40 psf. The lateral bracing for the system was designed for a 90 mph wind load.

Bar Harbor Pier.

The technology for this FRP-glulam pier was developed through a cooperative research project which included the University of Maine Structural Engineering and Wood Sciences programs at Orono, Maine, the Winona State University's Composite Materials Engineering program, and industry participants, including Applied Fiber

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The Modern Timber Bridge Program in the State of Maine: A Five-Year Report

Abstract

According to the most recent USDA Forest Service survey, Maine is the most heavily forested state in the United States. However, less than 3% of Maine's bridges are made out of timber. In 1989, the University of Maine led a state effort to develop a plan that would increase the use of Maine timber in bridge construction. The plan, called the Maine Timber Bridge and Infrastructure Initiative (MTBI), called for research at the University of Maine, construction of sixteen demonstration bridges over 10 years, and technology transfer. This paper describes the goals of the MTBI, the accomplishments of the program in the first five years, and outlines some obstacles and opportunities.

Introduction

According to the most recent USDA Forest Service survey conducted in 1982, and now being repeated in 1996, Maine is the most heavily forested state in the United States with nearly 89% of its land covered by forests. In recent years, Maine has also ranked fourth in the nation behind Oregon, Idaho, and Washington in the percentage contribution of the lumber/solid wood products industry to the total gross state product.

While the Forest Products Industry is a cornerstone of Maine's economy, less than 3% of Maine's bridges are made from wood. Maine is very typical of the New England states where wood is rarely used as a structural material in bridges. In comparison, other states have a significantly larger percentage of their bridge inventory made of wood. Arkansas for example has nearly one-third of its bridges made of wood, and Minnesota has nearly 15% of its inventory made of wood. Therefore, there appears to be some opportunities to utilize more wood on Maine's bridges.

The lack of use of timber in New England's bridges is also true for other aspects of heavy construction in the region. As

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opposed to the pacific Northwest, the New England region seldom uses heavy timber (including engineered wood products such as glued-laminated timber) framing in applications such as commercial and institutional buildings, large condominiums, hotels, manufacturing facilities, warehouses, shopping centers, and the like.

In 1989, the University of Maine led a state effort to develop a plan that would increase the use of Maine timber in bridge construction. In the same year, a coalition was organized which included the Maine Department of Transportation, the Maine Resource Conservation and Development Areas (RC&Ds), the Maine Forest Service, representatives of Maine's structural wood products industries, and representatives of Maine's congressional delegation. In 1990, the coalition issued a report entitled the Maine Timber Bridge and Infrastructure Initiative (MTBI). The report outlined a 10-year plan to increase the use of modern timber bridges in the state of Maine.

The 10-Year Maine Timber Bridge and Infrastructure Initiative Plan

Increasing the use of Maine timber in bridge applications was the ultimate goal of the MTBI. Timber bridges were seen to add value to the State's largest natural resource, possibly creating a new export potential for the state. The 1990 MTBI plan called for:

1. Research at the University of Maine to develop economical timber bridge designs using Maine wood species.
2. The construction of sixteen demonstration bridges in the state over the 10-year period to demonstrate the new technology.
3. A technology-transfer effort to disseminate the new information through publications, seminars, conferences, and videotapes.

Now that a plan was developed, it was necessary to secure resources so that it could be carried out. To help move the timber bridge technology forward both at the state and national levels, the MTBI coalition worked with Maine Senator George Mitchell. Maine Senator Mitchell then spearheaded the creation of a timber bridge program through the Federal Highway Administration (FHwA). This FHwA timber bridge program, made possible though the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, provided federal funding on a competitive basis for states to encourage the construction of innovative timber bridges using regional wood species. The five-year program also provided federal funding on a competitive basis for research in timber bridge technology.

The ISTEA legislation enabled the MTBI and the Maine DOT to build and monitor new types of modern timber bridges that would have been financially difficult to construct or monitor without the support of the program. To conduct the research, the University of Maine worked with the USDA Forest Products Laboratory Timber Bridge Team in Madison, Wisconsin, on a number of cooperative programs. These cooperative research programs allowed the state of Maine to benefit from on-going research at the national level and to obtain better data on its own wood species. The University of Maine also obtained funding to carry out the research and technology transfer activities called for in the MTBI plan from various sources including the National Science Foundation, the Maine DOT, the Maine Science and Technology Foundation, and the USDA Timber Bridge Initiative.

Activities of the Maine Timber Bridge Initiative in the First 5 Years

Since the MTBI plan was developed in 1990, considerable progress has been achieved on accomplishing the three objectives outlined in the MTBI plan: (1) research, (2) demonstration bridges, and (3) technology transfer.

In the research area, a number of projects have been conducted and some are still on-going. In general, the technical challenges result from the fact that many Maine wood species have relatively low mechanical properties and are only available in smaller dimension-size lumber. Also, many of Maine's wood species are refractory and difficult to properly treat with preservative chemicals. The situation is compounded by the fact that Maine has no glue-laminating facility, the closest being in Unadilla, New York. The state has no facility for treating wood with either creosote or pentachlorophenol. Up until very recently, the only local preservative treatment available has been Chromated Copper Arsenate (CCA).

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Examples of Research Projects Conducted as Part of the MTBI

The following are examples of the research projects that have been conducted in association with the MTBI.

1. *Survey of Maine timber resources for bridge construction.* One of the first projects that was completed was a critical survey of Maine wood resources to select species that would be most suitable for bridge construction. In evaluating each species' suitability, the following criteria were used: Adequate stiffness and strength, good treatability with wood preservatives, availability in Maine forests, availability in lumber mills in the appropriate sizes and grades, and under-utilized species. Using these criteria, eastern hemlock, red maple, and red pine appeared to be promising candidates for bridge construction in Maine.

Crowley Island, Maine. 194 ft. long roadway bridge. Piers are wood and abutments are wood –eastern hemlock.

2. *Use of CCA-treatment in stress-laminated decks*. CCA has been the only wood treatment available in the state. Not using CCA would have meant shipping Maine lumber out of state for treatment then back to the state, a situation which significantly reduces the economic viability of timber bridges. As a result, the Maine DOT has constructed three CCA treated decks; the oldest was constructed in 1991. The University of Maine has been monitoring these projects which have performed well so far.

3. *Use of metal plate connected (MPC) wood trusses in bridge applications.* In Maine, as in many parts of the United States, the highest-capacity wood structural member fabricated locally is the metal plate connected (MPC) truss. MPC trusses are lightweight wood trusses assembled using dimension lumber and metal connector plates. They are commonly used for framing roofs and floors in both commercial and residential buildings. MPC trusses are cost-effective because they are constructed using widely available dimension lumber, are simple to fabricate, structurally efficient, and easy to handle. MPC trusses also offer high stiffness, which is particularly important in bridge construction. Until recently, however, these trusses have not been used for constructing timber bridges.

In 1991, the University of Maine and the USDA Forest Products Laboratory initiated a cooperative study to investigate the use of MPC trusses in low-volume rural bridge applications. The study showed that MPC trusses can be used in bridge applications provided that proper consideration for fatigue of MPC joints, corrosion protection, and details to prevent connector plate 'back-out' are incorporated into the design. Using fatigue test results of 172 individual MPC joints and 33 full-scale trusses, recommendations for fatigue design were developed. Two MPC truss bridges, 46 ft. and 39 ft. long, were built in Maine in 1993 and 1994.

4. *Use of eastern hemlock and red maple in glulam bridges.* Eastern hemlock and red maple are abundant wood species in Maine, but are not used in commercial glulam construction. Glulam members in building and bridge construction in the state of Maine are currently imported from other states. This project, conducted cooperatively with the USDA Forest Products Laboratory and the Maine DOT, carried out modulus of elasticity (MOE) and knot-size testing of eastern hemlock and red maple needed for developing glulam combinations for these species. Thirty-one thousand lf of red maple and 1,000 lf of eastern hemlock were surveyed. Lay-ups for $24F_b$-1.8E red maple glulams were developed and a 52 ft. span red maple girder bridge was constructed in Maine in 1995.

5. *FRP reinforced eastern hemlock glulams.* The benefits of reinforcing glulam beams made with eastern hemlock, a relatively weak and under-utilized wood species in the state of Maine, are being studied. As part of one study, nine beams reinforced with fiber-reinforced plastics (FRP) on the tension side and

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three unreinforced controls were instrumented and tested to failure in four-point bending. Low, medium, and high quality wood were used in the experimental study. FRP reinforcement ratios ranged from 0.3% to 3.1 %. A nonlinear numerical model that predicts the performance of the FRP-glulam beams through the entire load range was developed, and its predictions were compared with the test results. The reinforced beams showed substantial gains in strength (up to 56%) and stiffness (up to 37%) by the addition of less than 2.1 % FRP reinforcement. The reinforced beams also showed a significant increase in ductility as the failure mode was shifted to a compression of the top wood fibers.

Despite the encouraging results, further research is necessary before FRP-reinforced wood beams are widely used in bridge applications. One major concern is the long-term durability of the FRP-wood interface in a bridge environment. The hygro-thermal-mechanical stresses that will develop at the wood-FRP interface in service need to be evaluated carefully. In addition, the interaction between moisture, temperature, and fatigue and their effect on bond strength and creep behavior of the system are not entirely understood. Fundamental research at the University of Maine is on-going to address these and other related issues. To start collecting field data on durability, a 124 ft. long FRP-reinforced glulam pedestrian pier was constructed on the Maine coast in 1995. The pier is being monitored with particular attention to creep and the FRP-wood interface. Two more FRP-reinforced glulam vehicular bridges are planned for construction in Maine in 1997.

Creep test of FRP-Glulam girders — University of Maine.

Demonstration Bridges Constructed in Maine

The 1990 MTBI plan called for the construction of 16 demonstration timber bridges in the state of Maine over 10 years. In 1996, the demonstration bridge effort is on target in terms of the number of bridges built. Table 1 gives a list of the projects completed and those planned.

Table 1 - Maine Demonstration Bridges

Bridge Location	Length (ft)	Structure type	Wood species	Treatment	Funding	Year built
Gray	22	Stresslam deck	eastern hemlock	CCA	USDA	1991
Byron	46	Stresslam truss	southern pine	CCA	MDOT[a]	1993
N. Yarmouth	39	Stresslam truss	southern pine	CCA	MDOT	1993
Bangor	70	Covered bridge	eastern hemlock	CCA	USDA	1994
Sangerville	54	glulam	red maple	penta	MDOT	1995
Bar Harbor	124	FRP-glulam	red maple	penta	USDA	1995
Crowley Island	192	glulam	SP & e. hemlock	penta	Private	1995
Garland	30	stresslam/glulam	red maple	penta	MDOT	1996
Milbridge	16	FRP-stresslam	eastern hemlock	CCA	Town	1996
Milbridge Pier	185	FRP-stresslam	southern pine	CCA	Town	1997
Sebois	36	FRP-glulam	red pine	penta	USDA	1997
Otisfield	25	glulam	red maple	penta	MDOT	1997
Biddeford	28	glulam	red maple	penta	MDOT	1997
Malone	190	glulam	southern pine	penta	Private	1997
Medway	52	FRP-glulam	red maple	penta	MDOT	1997

[a] Most MDOT timber bridges were constructed under the ISTEA timber bridge demonstration program

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The technology transfer activities over the past five years have included over thirty presentations and conferences to various groups within the state and the preparation of videotapes on timber bridge technology. The MTBI activities have been featured in over forty news articles and television segments in and outside the state of Maine.

Concluding Remarks: Obstacles and Opportunities

Following more than five years of research and the construction of numerous demonstration bridges, much has been learned by the MTBI participants. The following summarizes some of the important obstacles and opportunities:

1. *Cost of timber bridges.* This is probably the most significant barrier to the increased use of timber bridges, at least in the state of Maine.

Unfortunately, often times the ISTEA demonstration bridges are demonstrating to DOTs how expensive timber bridges can be. As one would expect, the cost of a one-of-a-kind demonstration bridge is high. In Maine, the most cost-effective demonstration projects were generally constructed outside the ISTEA program, often when town personnel or small local contractors were responsible for the construction. An opportunity might be for future demonstration programs to increase focus on non-DOT bridges.

2. *Durability of timber bridges.* This, along with the cost issue, are possibly the two most important barriers to the increased use of timber bridges in the state of Maine. The durability issue is always on the top of the list of concerns expressed by DOT engineers in MTBI meetings. On one occasion, an experienced DOT bridge maintenance engineer stated in a meeting "I have spent a career removing deteriorated timber bridges. Why do we want to build more of them?" However, many of the bridges that the engineer was referring to were not properly designed, and some were not even treated with preservative chemicals. In any case, the DOT perception that timber does not last in a bridge environment has been expressed at the national level by recent surveys of DOT engineers where wood was ranked last for durability when compared with steel or concrete. Maine DOT experience is that treated wood piles have a useful life of only 20 to 30 years, whereas steel and concrete bridges are often assumed to last between 70 and 90 years.

To answer legitimate concerns of DOT engineers, it is critical to collect proper information on timber bridge durability. There is a lack of data on the durability of properly designed, properly treated timber in a bridge environment. This is mainly because "modern timber bridges" have only been constructed in recent years. The required data may be best obtained by conducting on-site condition surveys of timber bridges in the US. The surveys should cover different environments, wood species, preservative types, and structural systems and should attempt to identify design or construction related causes of wood deterioration.

3. *Cost and availability of "under-utilized" local wood species*. On many demonstration projects, it has been difficult to secure wood at reasonable prices in the grades or quantities or sizes required, particularly when "under-utilized" native species were called for. For example, red maple is the second most abundant species in the state of Maine. It is considered a 'weed' by many, and it has very few uses. Only hardwood mills carry it, and it is not graded to softwood standards.

As a result, demonstration projects in Maine have had to pay up to $1,200/thousand bf to obtain #2 or better, 2x6 red maple. On the other hand, imported southern pine is available in Maine at almost half the cost of native red maple. Contractors preparing bids for ISTEA projects quickly learn that there might only be one supplier for the required native species, that there might be significant delays in wood delivery, and that the native species must be transported out of state to be fabricated and treated. These barriers have caused bid prices to increase.

4. *Expanding the scope of the timber bridge initiative.* In recent years, the state of Maine DOT has been constructing at most thirty vehicular bridges/year. If 20% of these were made out of wood, at most six timber bridges would be built every year in Maine. This is hardly a number to sustain an industry or to create opportunities for a sustained supply of under-utilized wood species. Therefore, a good approach may be to expand the two national timber bridge programs to a general wood-in-construction utilization program. This is the direction that the MTBI has taken. A glulam plant that supplies girders for an industrial facility can also supply girders for bridges.

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World's First FRP-Glulam Ocean Pier . . . *continued from page 1*

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Composites (a division of MMFG) and Georgia-Pacific Resins. The project was funded by the National Science Foundation and the United States Department of Agriculture.

In 1994, the Bar Harbor Yacht Club approached University of Maine researchers for assistance in designing a replacement pier. University of Maine developed plans for the first FRP-glulam pier. The Bar Harbor Yacht Club selected the FRP-glulam proposal for the following reasons:

1. Lowest cost (25 percent less expensive than steel).
2. Minimal maintenance in harsh ocean environment.
3. Most pleasing aesthetics for the waterfront site.
4. 70-year design life vs. 25-40 years for traditional materials.

Design and Construction

The beam portion of the FRP-glulam design consists of NELMA graded No. 2 and better Red Maple timber. Sections of nominal 2 by 6 inch by approximately 7 to 16 feet in length were kiln-dried and then surfaced on four sides to a thickness of 1-5/8 inches and a width of 5-1/2 inches. All of the lumber for the beams was E-tested by a team of University of Maine students.

The FRP portion of the structure was only 3/8 inch thick and was produced by Aligned Fiber Composites (AFC) of South Chatfield, Minnesota, in cooperation with a team from Winona State University of Winona, Minnesota, lead by Professor Beckry Abdel-Magid. The FRP layer was placed in the tensile zone, approximately two inches above the lower face of the beam, and provided less than one percent of the overall depth of the structural beam. Following fabrication, the beams were treated with 0.6 pcf Penta (pentachlorophenol) preservative which is expected to provide a 70-year service life for the wood components. Tests on the laminated FRP-glulam beam showed a tensile strength and modulus of approximately 156 ksi and 6.6 Msi, respectively.

Beams were fabricated by Unadilla Laminated Products of Sidney, New York, during May 1995. The pier was constructed during the summer of 1995, by Harbor Place, a Division of Frenchman's Bay Boating Co., Bar Harbor, Maine. Under a monitoring contract with the USDA Forest Service, Wood In Transportation Program, load test, acoustic emissions monitoring, and visual inspection will be carried out periodically through 1999.

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Sangerville, ME: Red Maple Glulam Timber Bridge over the Carlton Stream

The Emery Bridge over the Carlton Stream, located on Route 23 about a half mile from downtown Sangerville, needed to be replaced for two major reasons:

1. The water from Carlton Stream would occasionally overflow the bridge during peak flows.
2. The bridge was very narrow, only 22 feet wide, and consequently hazardous to traffic.

The original bridge was a superstructure of 18" to 20" concrete slab which spanned 25 feet, and it was about 25 feet from curb to curb. The new Emery Bridge superstructure consists of red maple glulam timber girders supporting a red maple glulam timber deck. Twenty 54-foot-long glulam timber girders, spaced at 2 feet center-to-center, span the distance between the new abutments.

The new width of the bridge allows a 40-foot-wide roadway. The doubling of the bridge length allowed the new abutments to be located behind the old ones, an important consideration since it improved the hydraulic flow in the river. The new bridge is also higher than the old, which prevents river peak flows from damaging the bridge. The new Sangerville

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By creating more demand for engineered wood products in heavy construction in general, rather than just bridges, there will be better opportunities to develop sustained value-added markets for under-utilized local species.

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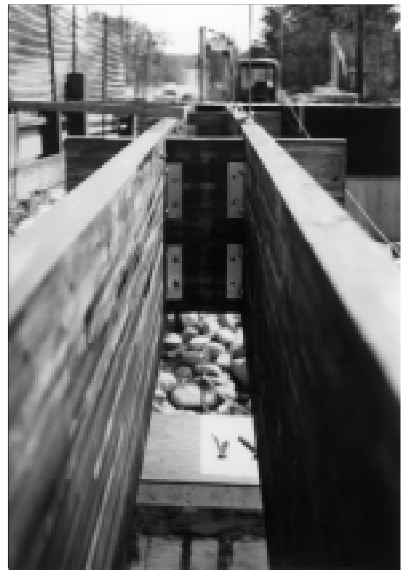
For additional information about the Maine Timber Bridge Initiative and other projects, please visit their web site at:
www.aewc.um.maine.edu

Sangerville, ME: Red Maple Glulam Timber Bridge . . . *continued from page 6*

bridge was designed by the Maine Department of Transportation for an HS25 live load. The red maple glulam timber beams and deck used in its construction were treated with an oil-borne pentachlorophenol (penta) preservative.



Construction of the Sangerville bridge utilizing all Maine red maple.

The major research leading to the building of the new Sangerville bridge focused on evaluating the suitability of using Maine timber species in glulam timber bridges. This is an economic priority to the state since glulam timbers used in Maine are imported and usually made with southern pine because Maine has no glulam fabrication facility.

To explore Maine timber species suitable for glulam timber bridges, five criteria were used:

- Adequate stiffness and strength for the intended design applications
- Good treatability with wood preservatives
- Availability in Maine forests
- Availability in the lumber mills in appropriate sizes and grades
- Underutilized species

Using these five criteria, several Maine timber species suitable for glulam timber bridge construction were identified. They included sugar maple, red maple, yellow birch, American beech, eastern hemlock, and red pine. Red pine and eastern hemlock were deemed most promising and were selected for further study. The red maple was chosen for the Sangerville bridge.

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Sangerville, ME: Red Maple Glulam Timber Bridge . . . ***continued from page 7***

A literature search provided that a number of studies on red maple found that the modulus of elasticity (MOE) values in the National Design Specifications were conservative, but that additional studies were needed to warrant changing the allowable design values. The review also found no information on the prior commercial use of red maple grown in Maine in glulam timber construction.

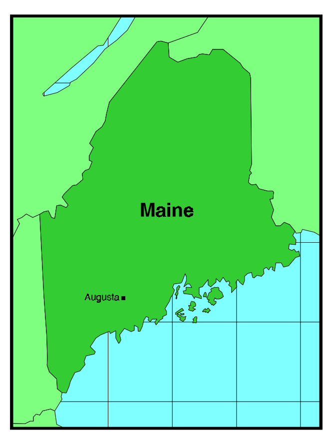
To use new timber species in glulam timber, MOE and knot size must be collected for these species. Data for red maple were collected for more than 31,000 lineal feet of No. 2 and better, mostly 2x6 material. The developed data were used to design glulam timber girders. The 54-foot-long Sangerville bridge used red maple glulam timber girders which support a red maple glulam timber deck. The bridge project provided the opportunity to study the yields of red maple 2x6 lumber from mostly Grade 1 logs based on USDA Forest Service log grading rules.

More than 30,800 lineal feet of No 2 and better red maple 2x6 lumber were MOE tested for the 54 foot glulam timber bridge constructed in Sangerville. This was equivalent to 5.84 miles of 2x6s placed end-to-end. Results indicated that the 1991 NDS MOEs were conservative for the No. 1 and No. 2 red maple grades. In addition to MOE data, knot sizes were measured and the mean and 99.5 percentile knot sizes for each grade of lumber were determined.

The overall bridge study determined several relevant points regarding maple:

- Locally, red maple was more commonly known as soft or white maple.
- Most Maine mills graded red maple according to National Hardwood Lumber Association hardwood grading rules. However, the Northeastern Lumber Manufacturer's Association was certified to grade red maple.
- Some Maine hardwood mills were accustomed to sawing red maple into 4/4 stock (nominal thickness of 1") instead of into structural sizes such as 2x4s and 2x6s.
- Red maple was often called a weed because of its growth characteristics. It was a very abundant species in Maine forests and the No.2 and better red maple tested in this study proved to have excellent MOE properties for use in glulam timber bridges
- Because of the size of red maple trees, it was recommended that the maximum size of lumber for future projects be 2x6. The larger 2x8 material can be procured, but the increased lumber cost would be a problem. As an alternative to using wider lumber for wider glulam timber beams, a system could be designed to anchor or bolt two beams together or use edge-glued glulam.
- The lengths of the red maple lumber should be specified to meet the requirements necessary for E-rating and the laminating facility.
- Red maple should be treated with one of the following three oil-borne preservative treatments for glulam timber bridges: penta, creosote, or copper naphthenate. The last of the three must be considered experimental because only laboratory data exist which indicate acceptable preservative performance. The use of the other two has been extensive and was considered a reliable treatment for red maple.

***For more information on this project, please refer to Karie-An Lanphner, *"Investigation and use of Maine Red Maple and Eastern Hemlock in Glulam Bridges,"* thesis presented in partial fulfillment of the requirements for the Masters of Science in Civil Engineering, University of Maine; www.aewc.um.maine.edu**



Byron, ME: Stress-laminated Truss Timber Bridge

The Byron Bridge was constructed in 1993 in Oxford County, Maine. It is a timber stress-laminated truss bridge, 46' long, 32' 1.5" wide, with a skew of 18 degrees. The design is unique because it is the second known stress laminated timber bridge in the United States constructed of lightweight metal plate connector (MPC) truss laminations rather than the more commonly used solid sawn lumber laminations.

Construction of the Byron bridge. Galvanized MPC (G90) joints are painted with an epoxy paint to add corrosion resistance.

The Byron Bridge was load tested immediately before it was opened for traffic; the test included data on the moisture content, the force in the stressing bars, the mid-span deflection profile, and the stresses in the truss members under static truck loading. Tests have continued, and the bridge is performing well with no structural or serviceability deficiencies.

The Byron Bridge serves to help investigate the use of stress-laminated metal plate connected wood trusses in bridges. Specifically, it shows how to design, construct. and evaluate full-scale stress-laminated bridges.

The Byron Bridge was constructed using three foot deep structural trusses and spacer trusses, with 50% structural trusses. The testing of the bridge consisted of measuring member strains and mid-span deflections under the load of one pre-weighed (65 kip) dump truck. The truck was positioned at six critical locations on the bridge; eight strain gauges were mounted on each of the four instrumented trusses; 11 DCDTs were used to measure deflections.

Construction of the Byron bridge. Packets of 10 to 20 trusses lifted in single units.

In addition to the DCDTs and strain gauges, three moisture sensors and two temperature sensors were installed in the bridge. Load cells were placed on six of the prestressing bars. The prestress level in the bridge was 125 psi, and the average moisture content of the bridge was 22 percent on the day of the load test. It is important to note that test results vary from bridge to bridge depending on many parameters including length, depth, width, truss stiffness, material properties, and prestress. These test results are specific to the Byron Bridge.

The model used to design the truss bridge was based on the AASHTO 1991 Guide Specifications for the design of solid stress laminated wood decks. In section 3.25.5.2 of the AASHTO specifications for solid decks, the wheel load is assumed to be distributed transverse to traffic at a 45-degree angle through the deck thickness. In the model used to design the truss bridge, it was conservatively assumed that the wheel load is distributed at a 45-degree angle through the top chord only, rather than through the entire truss depth.

The maximum measured stresses and deflections in the bridge at a prestress of 125 psi were observed in load case (1+2). Load case (1+2) consists of two 65 kip trucks with their center of gravity at the transverse centerline of the bridge.

These experimental results are compared with the results of the AASHTO 45-degree model (loaded with the wheel line from the 65 kip truck.) The AASHTO 45-degree model assumes a minimum prestress of 50 psi in the bridge, whereas the bridge was tested at 125 psi.

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Stress-laminated Truss Timber Bridge . . .
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Our tests indicate that under two trucks at a prestress of 40 psi, the AASHTO 45-degree model over-predicts the maximum live load deflection by 29%. Under two trucks at a prestress of 40 psi, the AASHTO 45-degree model over-predicts the maximum live load top chord stress by 13%. Under two trucks at a prestress of 40 psi, the AASHTO 45-degree model over-predicts the maximum live load bottom chord stress by 36%. We can conclude that there is a need to modify the distribution width of the AASHTO Guide Specifications for Solid Stress Laminated Decks before it can be applied effectively to stress laminated trusses.

The AASHTO solid deck model results in different levels of conservatism for top chord stresses, bottom chord stresses, and deflections. It might be necessary to develop a basic distribution width for the top chord stresses which is increased for bottom chord stresses and deflections. To modify the AASHTO solid deck distribution width will require more experimental data and a parametric 3-D element analysis.

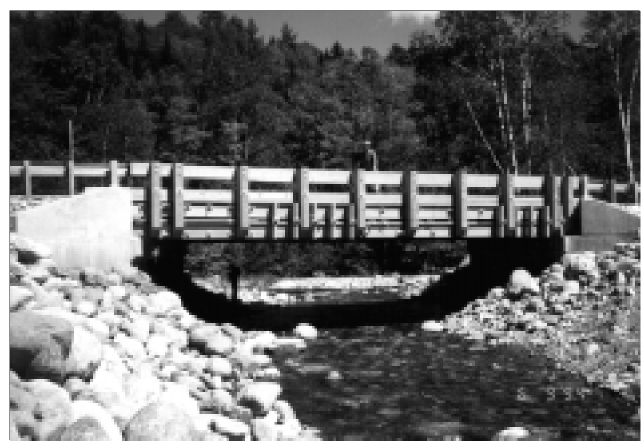
Test results of the as-built Byron Bridge show that it is conservative at a prestress of 40 psi under dead load plus the live load from two 90 kip trucks.

Detail in the construction of the Byron Bridge reduced the possibility of future problems. Reducing the rate of corrosion of the metal components of the bridge was critical to insuring a long-lasting structure. All metal components of the bridge were provided with corrosion protection.

The MPCs were galvanized with a 0.6 mil zinc coating prior to plate punching. In addition, the exposed face of the plate was brush painted at the site with an epoxy paint. The stressing bars and anchorage hardware were epoxy coated by the manufacturer. Steel channels and structural tubes were Grade 50 All Weather Steel. In addition, two layers of asphalt impregnated self-sealing Protectowrap were run continuously along the deck, over the concrete back walls, and up along the curbs to keep moisture out of the middle and ends of the bridge.

Preventing plate back out due to load and moisture cycles and avoiding plate-on-plate contact between adjacent trusses were design concerns considered when detailing the truss connections. Preventing plate back out was achieved by using spacer trusses with deeper chords than the structural trusses and by the prestress. Avoiding plate-on-plate contact between adjacent trusses is important to prevent distortion of the bridge during stressing. This was achieved by using a minimum number of plates on the spacer truss and positioning these plates to prevent metal-on-metal contact.

Construction of the bridge also confirmed that passing the prestressing rods through web openings is preferable to passing the rods through holes drilled in the webs. This is because not having to drill precisely located holes in the chords will simplify truss fabrication and reduce costs. Also, construction of the bridge is simplified by not having to pass a 1 in. bar through a 1.5 in. hole across the entire width of the bridge. (Having a few bars pass through holes in the chords is desirable to help keep the bridge in alignment during construction and to provide some dowel action resistance to lamination slip.)



Completed Byron bridge.

One of the most important factors to insure acceptable performance is providing an adequate level of prestress for the entire life of the bridge. Even low levels of prestress (15 psi) dramatically improve the load-sharing ability of the structure. It is recommended to monitor the prestress level in these bridges and re-stress the bridge when the prestress level approaches 50 psi.

For additional information on completed projects in Maine, visit their web site at: **www.aewc.um.maine.edu**

Maine's Advanced Engineered Wood Composites Center (AEWC)

The Scenario:

- Millions of acres of lower-grade wood species grow in Maine and other timber-producing states.
- Major portions of the United States civil infrastructure are in need of repair and replacements.
- Economic imperatives require new employment sources and meticulous attention to methods of providing value-added products.

Researchers at the Advanced Engineered Wood Composites Center, University of Maine, are developing methods to reinforce lower-grade wood species and turn them into stronger, stiffer, lighter, and less expensive construction materials. Maine's researchers have combined the problems of lower-grade wood species and the aging US infrastructure to produce a win-win situation.

How are they doing this?

This research is being conducted by the Advanced Engineered Wood Composites Center (AEWC) staff. The AEWC Center is funded through multi-million dollar grants from the National Science Foundation, the US Department of Commerce, and the US composites and wood industries. To speed the development of these new hybrid composites, the University of Maine is constructing a 23,000 square foot laboratory. This new facility, scheduled for completion in December 1998, is entirely dedicated to the development of Advanced Engineered Wood Composites.

Advanced Engineered Wood Composites (AEWC) are a new class of materials which combine wood and Fiber-Reinforced Plastics (FRP). The resulting hybrid materials have properties derived from, yet different from, each separate material. Researchers are using a variety of synthetic fibers including glass, carbon and kevlar and a variety of resin systems to give greater strength, stiffness, and ductility to timber.

An example of an end result: a 3% reinforcement of fiber-reinforced plastic can increase wood bending strength by over 70%. Properly reinforced wood is a viable alternative to traditional materials and functions well in commercial and industrial projects.

There are new attractive business opportunities for lower grades of timber. AEWC hybrids provide new value-added end markets for these raw materials; they help stabilize the markets for timber species, and they help increase the diversity of species on timber-producing land.

The project is state of the art technology blended with respect and caution for the environment. With this new technology, less wood yields more strength: our wood resources can be used in a careful, environmentally cautious way.

In the mid-19th Century, reinforcing concrete with steel produced one of the dominant materials in engineering construction. As we enter the 21st Century, by reinforcing wood with composite materials, AEWC researchers seek to revolutionize engineered wood construction.

The University of Maine's Advanced Engineered Wood Composite Center continues to expand and improve reinforced wood composites. Researchers continue to investigate control mechanisms and interactions between the materials needed to develop optimal durable AEWC hybrids. They are focusing on three major research goals:

- To develop and optimize a new class of fiber-reinforced plastic materials which are compatible with properties of wood.
- To develop and maintain the bond (interface) between the materials needed to ensure full composite action over the lifetime of the products.
- To develop a basic understanding of the short- and long-term behavior of composite-reinforced wood structural elements.

Product development, manufacturing process development, prototype fabrication, materials testing, large-scale structural testing, and code and standards development and approval are all being conducted on a world-class level. AEWC Center researchers are pushing the envelope with state of the art research and development.

For more information on the AEWC Center, visit their web site at: **www.aewc.um.maine.edu**

ACKNOWLEDGMENT

Partners of the Maine Timber Bridge Initiative

The Maine timber Bridge Initiative and the University of Maine Advanced Engineered Wood Composites (AEWC) Center wish to acknowledge the many organizations and individuals who have contributed to their programs. Mr. Michael Ritter at the USDA Forest Products Laboratory (USDA-FPL) has been instrumental in the development and technical support of both programs. Mr. Russ Moody and Mr. Ron Wolfe of the USDA-FPL have provided significant technical support in the reinforced glulam and truss bridge projects. The National Science Foundation and the Maine Science and Technology Foundation have provided significate financial support to the AEWC Center. The Maine Resource Conservation and Development areas have collectively provided personnel, facilities, and support for the Maine Timber Bridge Initiative. The Maine Department of Transportation has been very accommodating to the development and support of the Maine Timber Bridge Initiative.

NEW PUBLICATION

Skidder Bridge Fact Sheet

The University of Massachusetts Extension has developed a fact sheet titled, *"Skidder Bridge Fact Sheet,"* and it addresses the use of temporary skidder bridges.

Twenty-one western Massachusetts loggers who use portable skidder bridges contributed their best ideas and experiences to describe the state-of-the-art design in successful portable skidder bridges.

The design shown in the fact sheet is simple, inexpensive, and low-tech. It is suitable for construction and use by the many thousands of United States loggers who work small jobs, move their equipment often, and who cannot afford to invest in highly engineered structures.

To obtain a copy of the fact sheet, contact:

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National Wood In Transportation Information Center at
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Article contributions, questions or comments may be sent to Ed Cesa, Program Manager, Wood In Transportation National Information Center or Ms. Tinathan A. Coger, Information Assistant; USDA Forest Service; 180 Canfield Street; Morgantown, WV 26505; Phone: 304-285-1591 or 304-285-1596; or FAX: 304-285-1505; or E-mail to tcoger@mserv.fsl.wvnet.edu.

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