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

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Abstract
According to the most recent US Forest Service survey, Maine is the most heavily forested state in the US. 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.

Keywords: Timber, bridges, research, design, cost, durability

Introduction
According to the most recent US Forest Service survey conducted in 1982, and now being repeated in 1996, Maine is the most heavily forested state in the US 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 appear 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 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.

This paper describes the goals of the MTBI, the accomplishments of the program in the first five years, and outlines some obstacles and opportunities.

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 the plan 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).

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.

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 MOE and knot-size testing of eastern hemlock and red maple that are needed for developing glulam combinations for these species. 31,000 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 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, 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 124ft long FRP-reinforced glulam pedestrian pier was constructed on the Maine coast in 1995. The pier is being monitored with particular attention to the FRP-wood interface and to creep. Two more FRP-reinforced glulam vehicular bridges are planned for construction in Maine in 1997.

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.

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 over 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 is 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

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

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, 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. 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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