Timber Highway Bridge Construction Practices in The United States

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Abstract

Wood has been successfully used as a highway bridge material in the United States for hundreds of years. Some of the earliest examples of wood bridge construction, dating back to the mid to late 1800's, are the covered bridges, many of which are still in service today in the Eastern U.S. From the early 1900's to the mid 1960's, thousands of highway bridges were built in the U.S. using a longitudinal wood stringer and transverse nail-laminated sawn lumber deck system. In the late 1960's, extensive research was undertaken to develop more efficient wood bridge systems which would result in lower material and labor costs and which would minimize the maintenance requirements often associated with the older wood bridges.

This research has continued for the past 25 years and has led to the development of many innovative wood bridge systems which are now leading to a rediscovery of wood as a highway bridge construction material in the U.S. These systems include a variety of glued laminated timber framing systems, stress-laminated sawn lumber deck bridges and stressed T and box sections utilizing different combinations of lumber, glulam and laminated veneer lumber (LVL) components. New technology is moving towards the use of a broader spectrum of species, the use of prefabricated metal plate truss systems, new stressing rod technologies, the use of high strength plastic composites for reinforcement of wood members and the application of Load and Resistance Factor Design to bridges.

Introduction

As with many European countries, covered bridges using structural wood framing systems represent an important era in timber bridge construction in the U.S. Many of these bridges constructed in the mid to late 1800's are still in service today although most have undergone renovation to bring them up to current design standards. An example of this is the Cornish Windsor covered bridge which connects the towns of Cornish, New Hampshire and Windsor, Vermont. This bridge consists of two 75m spans which are claimed to be the longest individual spans of any covered bridge in the U.S.

This bridge underwent extensive restoration in 1990 to replace damaged members, re-introduce camber into the structure and increase it's load capacity to current American Association of State Highway and Transportation Officials (AASHTO) specifications. In order to achieve these structural enhancements, the design engineers used glulam components to replace original sawn timber members such as floor beams and truss members as shown in Figure 1. Similar structural improvements have been used to renovate numerous covered bridges in the U.S. thus extending their useful lives for another 50 years or more.

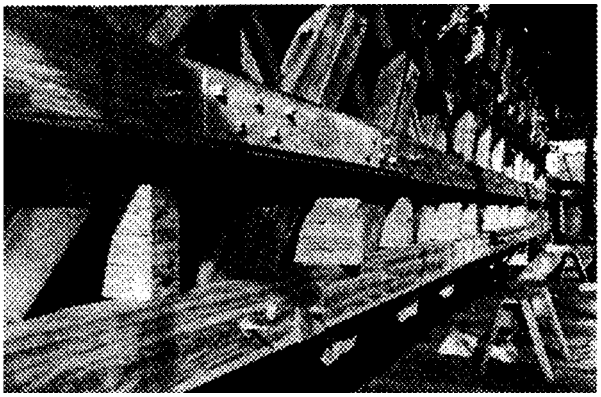

Figure 1 — Rehabilitation of Windsor Cornish Covered Bridge Using Glulam Components

From the early to mid 1900's, the use of longitudinal sawn timber beams and transverse sawn lumber decking was the prevalent timber bridge construction system used in the U.S. The decking consisted of dimension lumber positioned on edge with individual pieces being attached to adjacent pieces by through nailing. Toe-nailing was used to attach these decking pieces to the timber beams. While this system provided a structurally sound and tight deck system when initially installed, the effects of annual moisture cycling combined with the dynamic impact of moving vehicles often resulted in a loosening of the mechanical fasteners.

This in turn permitted moisture to migrate into untreated areas of the wood members with decay often resulting in these areas. This combination of loosening of the mechanical fasteners combined with subsequent decay development led to extensive maintenance requirements for these bridges and often county and state bridge engineers discontinued the use of timber in highway bridge construction in favor of pre-stressed concrete or steel systems.

Use Of Glued Laminated Timber

One of the first significant breakthroughs in timber bridge construction in the U.S. was the expanded use of glued laminated timber (glulam) components. Glulam has been succsssfully used as a structural building material in Europe since the late 1890s. In the United States, it has been used in buildings since approximately 1935. The introduction of wet use adhesives in the mid 1940's allowed the uses of glulam to be expanded to include exposed applications such as highway and railway bridges, transmission facilities and other exterior structures. While glulam was accepted as suitable alternative to sawn timbers for bridge construction, its use was limited by the lack of knowledge of this relatively new construction product new at least to the US. Glulam is a versatile engineered wood material that provides several distinct advantages for bridge construction. Because it is a manufactured product, glulam can be produced in a wide range of shapes and sizes to fit virtually any end use requirements. Most glulam used in bridges in the U.S. has involved straight members, but curved members have also been used successfully in a number of applications. For example, the Keystone Wye bridge, shown in Figure 2, built in 1968 in South Dakota is a unique tri-level interchange using both a straight girder glulam bridge and a long span glulam arch structure. This high visibility bridge structure has performed well for over 25 years with only minimal maintenance being required for the timber components. Numerous other glulam arch bridges have been built during the past 25 years using both suspended and supported deck systems and are a popular type of construction where aesthetics are a key design consideration.

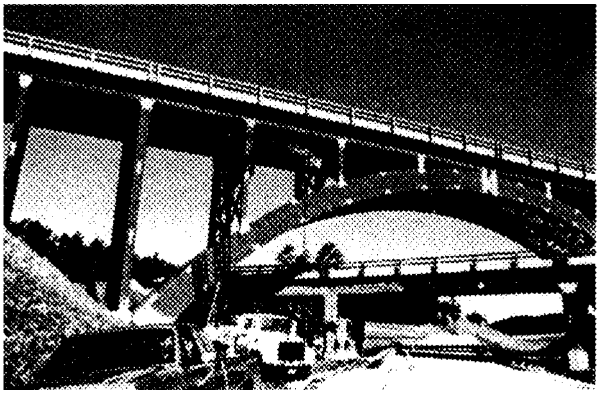

Figure 2 — Keystone Wye Glulam Bridge

Another advantage of glulam as compared to sawn lumber is related to the laminating process which randomly disperses the strength-reducing characteristics (src's) of the lumber laminations throughout the member. This random dispersal of src's, results in reduced material properties variability and increased strength characteristics. Glulam also provides better dimensional stability because it is manufactured from dry lumber. Glulam bending members are manufactured using selective lamination placement with higher quality lumber positioned in the highly stressed zones of the member and lower quality material placed in the inner layers of the beam, where bending stress is lower. This practice, which also permits the mixing of species within a single glulam member, helps to extend the available lumber resource and improves the economy of glulam as a construction material.

The majority of the glulam bridges built in the United States during the past 25 years have used either longitudinal girders with transverse deck or longitudinal deck superstructures. Due to the relatively long span and wide spacing capabilities that can be achieved with the use of longitudinal glulam girders, the incompatibility of the traditional transverse nail-laminated decks as previously described became a limiting factor in expanding the use of glulam.

Glulam Deck Panel Technology

During the late 1960's, research engineers at the USDA Forest Products Laboratory, in cooperation with USDA Forest Service regional bridge engineers and the glulam industry undertook a research program to develop a glulam deck panel to replace the traditional nail-laminated deck system. The concept was to use a vertically laminated glulam member spanning transversely across the longitudinal bridge girders. The length of the deck panel was equal to the overall width of the bridge with the thickness of the panel being dependent on the grade and species of laminating lumber and the spacing of the deck panels. In order to facilitate handling of these deck panels at the manufacturing facility, during transportation and on the jobsite, an industry decision was made to fabricate these deck panels in widths of approximately 122 cm.

In order to achieve plate action for this deck system along the longitudinal direction of the bridge and to minimize the differential deflection at the joints beyond the individual panels, several alternative load transfer mechanisms between panel interfaces were evaluated. The most efficient was the use of a steel dowel inserted in holes prebored at the mid-depth of each panel face as shown in Figure 3. While hundreds of bridges were successfully constructed using this dowel system, alignment problems were occasionally encountered in the field when attempting to pull the individual panels together.

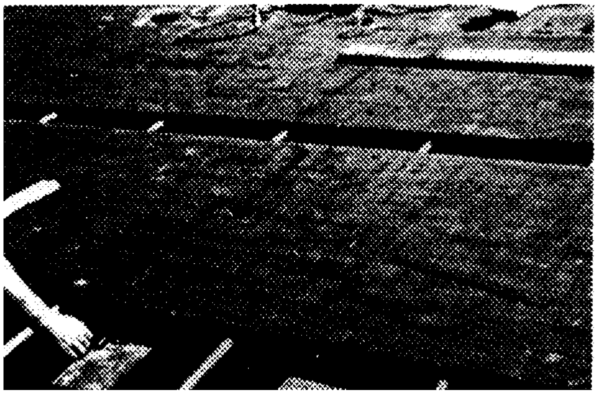

Figure 3 — **Use of Steel Dowels as Load Transfer Mechanism**

To provide the required load transfer between panel edges but not require the close construction tolerances associated with the steel dowel system and it's associated pre -bored deck panel holes, the Weyerhaeuser Company developed a cast aluminum bracket. This bracket, as shown in Figure 4, is positioned in grooves pre-routed in the side of the glulam girders prior to pressure treating and is then attached to the deck panels with a single through bolt. Since the bracket was manufactured from aluminum, this eliminated concerns of corrosion. The use of this deck bracket essentially replaced the steel dowel and has become the standard connector device for the longitudinal girder and transverse glulam deck panel system.

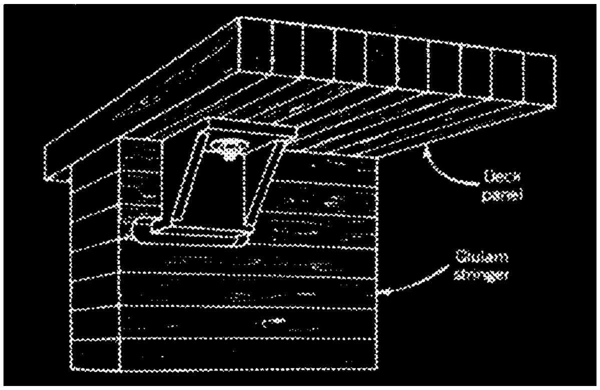

Figure 4 -- Cast Aluminum Deck Bracket

A natural evolution of the transverse glulam deck panel was to use these members as vertically laminated beams spanning longitudinally between supports where spans were relatively short. However, the load distribution provisions in the American Association of State Highway and Transportation Officials (AASHTO) Specifications for Highway Bridges were not favorable to the use of these longitudinal deck panels. The glulam industry sponsored an extensive test program of this system which was conducted at Iowa State University. The results of this study led to more favorable and realistic distribution factors for this type of deck system which were adopted in the AASHTO Highway Bridge Specifications.

As with the transverse deck panels, the longitudinal deck panels are also manufactured in widths of 122 cm. This created a necessity to develop a mechanism for transferring loads transversely between these longitudinal panels. Thus, in addition to developing new load distribution factors for the longitudinal glulam deck panel system, the Iowa State research led to design provisions for spreader beams (typically small glulam sections) which are positioned transversely beneath the longitudinal deck panels at approximately 2.45 meters on center. These spreader beams can be attached to the deck panels with a variety of mechanical fastening devices, several of which are shown in Figure 5. One of the most successful has been the use of the same cast aluminum deck bracket used to attach transverse deck panels to longitudinal stringers.

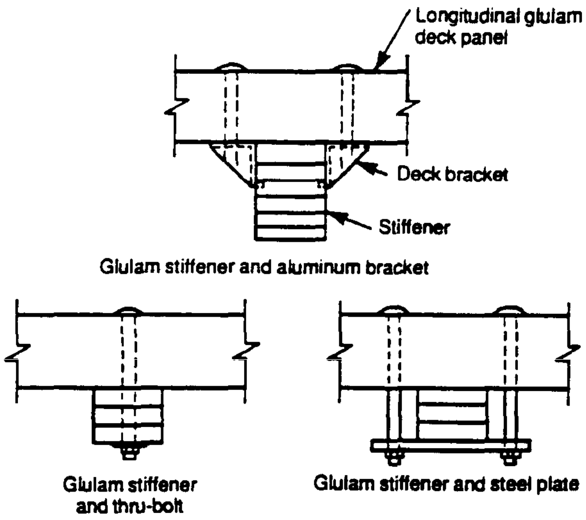

Figure 5 — Attachment Techniques for Spreader Beams to Longitudinal Decks

Stress-Laminating Concepts

Stress-laminating has been an evolving technology in both Canada and the U.S. for almost 20 years and has achieved considerable success in highway bridge construction during this time. The idea of using stress-laminating techniques for the rehabilitation of existing timber bridges and for the construction of new timber bridges was frost introduced in Ontario, Canada in 1976. The first use of this emerging technology in the U.S. was in the mid 1980's. Since that time, several hundred stress-laminated vehicular bridges have been constructed in the U.S. using sawn lumber laminations, and a guide specification for the design of this type of timber bridge was published by AASHTO in 1991.

Longitudinal stress-laminated decks are typically constructed by placing sawn lumber laminations (either 2x, 3x or 4x material) on edge and stressing the laminations together transversely with high-strength steel bars installed through the mid-depth of the laminations (Ritter, 1990). Figure 6 schematically illustrates this concept.

The compression stress existing between the laminations due to the pressure induced by the transverse stressing rods serves to transfer load between the laminations by friction, causing the deck to act as a large orthotropic wood plate. The typical force induced in these stressing rods ranges when used in conjunction with sawn lumber laminations varies from 355-445 kN.

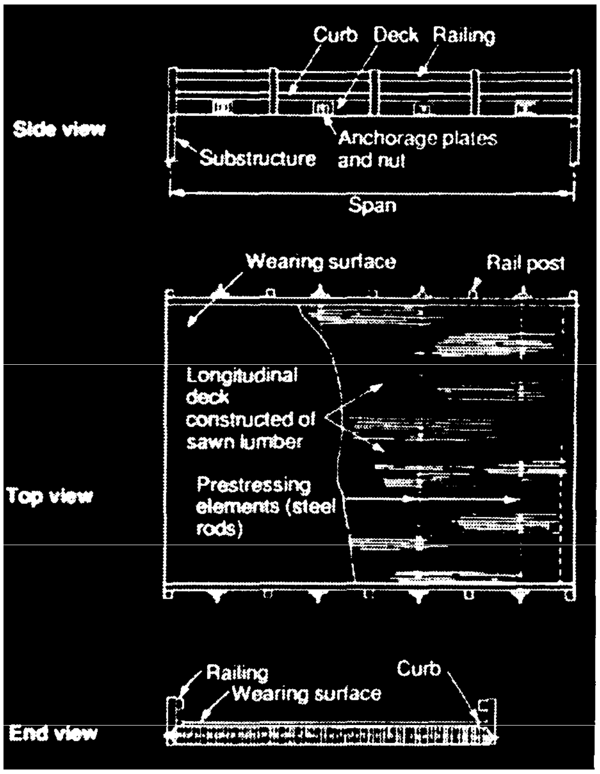

Figure 6 — Schematic of a Longitudinal Stress-Laminated Timber Bridge

In order to verify the work done in Ontario, Canada and to develop the necessary design criteria for using this stress-laminating technology in the U. S., extensive testing was undertaken at the University of Wisconsin in cooperation with the USDA Forest Products Laboratory. This testing involved the evaluation of two lumber lamination systems. One system utilized nominal 2x12 laminations and was tested over spans up to 8 m. The second system incorporated nominal 4x16 laminations with test spans ranging up to 16 m. Figure 7 shows an example of this laboratory testing program.

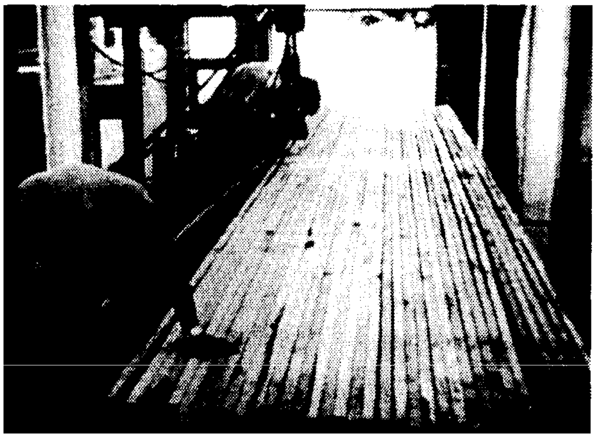

Figure 7 — Laboratory Evaluation of a Stress-laminated Lumber Bridge

This research led to a basic understanding of the behavior of these stress-deck systems including (a) the effect of lamination butt joints on wheel-load distribution and deck stiffness, (b) the mechanism of stress transfer into the deck and related edge effects on wheel-load distribution, (c) the effects of transverse bending on the required level of compressive stress and (d) requirements for the anchorage of the pre-stressing rods. Other research efforts have evaluated time related stress losses due to such environmental variables as moisture cycling and investigated various anchorage systems to transfer the pre-stressing force into the wood laminations without over-stressing the outer pieces.

One of the natural characteristics of wood is that it will creep over time under a continually applied load. As the wood laminations creep under the pre-stress force, the level of pre-stress decreases correspondingly. Thus, typically three stressing operations are required to account for these pre-stress losses. After initial pre-stressing the deck. to a level of approximately 0.70 MPa, a second pre-stressing is applied after approximately one week to bring the stress back to the initial level. Final stressing is applied 4-6 weeks after the second stressing. Studies indicate that a pre-stress loss as high as 50% can occur with no significant loss in system capacity.

As part of the ongoing USDA Forest Service timber bridge program, stress-laminated bridges are routinely monitored to verify pre-stress level, load carrying capacity and deflection characteristics. This involves periodic full scale load testing of many of these structures. While most of this load testing has been conducted using static loads to evaluate bridge performance, a recent innovation in load testing has been to evaluate the dynamic performance of the bridges under moving vehicular loads. This is an exciting new technology which offers considerable promise for the future.

Stress-Laminated Glulam Decks

Due to increasing lack of availability of dimension lumber in the U.S. in wide width sizes greater than 2x12 or 2x14 the use of the vertically laminated longitudinal deck systems was limited to spans of approximately 10 meters. Thus, an alternative systsm was sought which would permit the construction of longitudinal deck systems for spans greater than 10 meters. It was conceived that one such solution would be to apply the concept of stress-laminating, as previously described for sawn lumber members, to a series of longitudinal glulam beams placed side by side.

This concept of stress-laminating glulam beams together to form a longitudinal deck system was first used in the U.S. in 1989 for the construction of the Teal River bridge constructed in Wisconsin (Wacker and Ritter, 1992), Figure 8 shows this bridge during the construction sequence. Since the construction of this prototype bridge. a number of other similar structures have been built.

Figure 8 — Teal River Bridge During Construction

Bridges using glulam in stress-laminated deck applications have demonstrated excellent in-service performance. Because horizontally laminated glulam beams allow for deeper sections, longer bridge spans are possible. Additionally, the glulam beams can be manufactured to be continuous over the bridge length and butt joints, which can reduce the bridge strength and serviceability of sawn lumber stress-laminated decks, are not required. These continuous long length beams can also be used to span across intermediate supports resulting in very high stiffness multiple span bridges, further reducing bridge deck deflections.

One of the most noteworthy advantages of using glulam components has been the force retention in the pre-stressing bars. Because the glulam members are dry when installed (moisture content of 16% or less), the beams typically absorb moisture slowly and the deck swells slightly as it moves toward an equilibrium in-service moisture content. As a result, this minimal swelling offsets force loss in the pre-stressing rods due to stress relaxation in the wood and the net loss in bar force is minimal. Extensive monitoring of these bridges by the U.S. Forest Service has verified this performance characteristic.

Stress Laminated T-Beam and Box-Beam Sections

In the mid 1970's, an extensive test program was conducted at Colorado State University to determine the degree of T-beam action which could be expected in a longitudinal girder and transverse glulam deck system. Full size double T-sections spanning 12 meters were tested under simulated AASHTO truck loading. These test sections used conventional 122 cm wide transverse deck panels with steel dowels used to provide load transfer between adjacent panels. The deck panels were attached to the stringers using steel lag screws. While there was approximately a 10-15% decrease in stringer deflection, the degree of T-beam action was limited by the effectiveness of the mechanical connections and the associated slip which occurred during loading.

However, the advent of stress-laminating offered new opportunities to achieve composite T-beam action between the deck and stringers without being dependent on the mechanical fasteners between the deck and stringers. The clear span of glulam bridges is typically controlled by design considerations related to the depth of the superstructure and by economical limitations on the bridge depth. Creating T and other composite configurations allowed designers to overcome these limitations, thus permitting much greater span capabilities for glulam bridges.

Two types of composite bridges that have been successfully used in the U.S. are the T-section and box-beam bridges, shown schematically by Figure 9. T-beam bridges can be constructed using vertical glulam or laminated veneer lumber (LVL) web members with flanges constructed of sawn lumber or glulam deck panels. The composite action between the flange and the web is developed through friction by stress-laminating the section with stressing bars through the flanges and webs. The box section is similar to the T-section, but with flanges and stressing bars added to the bottom of the section to create a higher overall section modulus and moment of inertia.

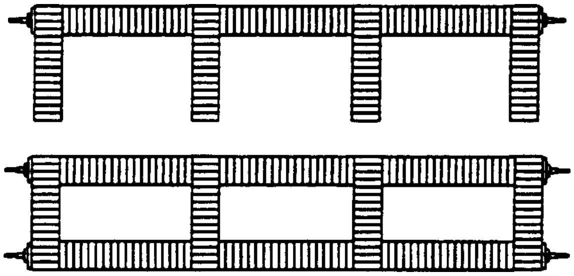

Figure 9 — End View Cross-Sections of a Stress-Laminated T-Beam Bridge (top) and a Stress-Laminated Box-Beam Bridge (bottom)

The concept of stress-laminated T-section and box-beam bridges has been well received and more than 30 bridges have been built over the past 3 years in the U.S. The longest span structure to date is a 27 meter span stress-laminated T-beam bridge, which was built in Arkansas in 1993. Recent research work regarding these glulam superstructure configurations was completed at West Virginia University, in cooperation with the Federal Highway Administration (FHWA) and the U.S. Forest Products Laboratory, and used a modular construction approach (Barger, et al., 1993; Davalos, et al., 1993).

In addition to continued research on stress-laminated T-section and box-beam bridges using glulam or LVL webs and sawn lumber flanges, research is underway at the University of Wisconsin, in cooperation with the U.S. Forest Products Laboratory and the U.S. Federal Highway Administration, to develop systems constructed completely from glulam components (Oliva and Rammer, 1993). It is estimated that glulam bridges built using this technology will be able to clear span over 30 meters with structural sections less than 106 cm in depth.

Research and field evaluation are continuing on the structural performance of these systems. Draft specifications for the design and construction of stress-laminated T-section and box-beam bridges are currently being developed for adoption by AASHTO.

Alternative Species For Glulam

Glulam can be manufactured from virtually any softwood or hardwood species provided the end product meets necessary strength and stiffness requirements. In actuality, most of the glulam manufactured in the U.S. during the past 60 years has utilized either Douglas Fir-Larch or Southern Pine lumber. However, with continuing changes in the availability of worldwide wood resources, and with increased emphasis on using underutilized local wood species, there has been a growing interest in the U.S. towards developing new glulam layups utilizing both hardwood and softwood species. Over the past 5 years, most of the work on alternative species for glulam has centered on the utilization of hardwood lumber, but several secondary softwood species have also been evaluated.

Recent glulam research completed at the Pennsylvania State University, West Virginia University, and the U.S. Forest Products Laboratory has been directed at developing glulam layups using Red Maple, Red Oak and Yellow Poplar (Manbeck, et al., 1993; Shaffer, et al., 1991; Moody, et al., 1993). Recent full scale tests of glulam beams manufactured using mechanically graded Red Maple and Yellow Poplar support the use of bending and modulus of elasticity design values comparable to those achieved with the traditional Douglas Fir-Larch and Southern Pine softwoods.

In addition to developing specifications for glulam produced from hardwood species, efforts to develop high strength and cost efficient glulam layup combinations utilizing secondary softwood species have also been successful. A project in Wisconsin using a combination of red pine and Southern pine to manufacture glulam beams resulted in the construction of the Teal River stress-laminated deck bridge previously described (Wacker and Ritter, 1992), These beams used Southern pine for the outer tension and compression zones with the red pine being used for the core of the beams. The resultant beams had similar bending strength and stiffness characteristics as beams manufactured from all Southern pine laminations. This further led to the design and construction of a stress-laminated bridge using glulam manufactured exclusively from red pine lumber. Other projects using secondary softwoods, such as Eastern hemlock, Ponderosa pine and cottonwood are underway.

Laminated Veneer Lumber Bridges

Other glued engineered wood products are also being used for bridge construction in the U.S. Laminated veneer lumber, LVL, has long been used in both residential and commercial building construction. LVL is produced by bonding together veneers of wood (with the thickness of the individual veneers not to exceed 6mm) with the grain of all veneer layers approximately parallel to the long direction of the member. This product has very high bending strength and stiffness characteristics as compared to other wood products and is thus ideally suited as a bridge construction material where these properties typically control design. LVL also has a high propensity for absorbing preservative treatment chemicals due to the lathe checks inherent in the individual veneers. This further enhances its characteristics as a bridge construction material.

LVL has been used in numerous bridges in the U.S. One system involves the use of LVL components to create a longitudinal “slab” type deck system. The individual LVL pieces are stressed together using the stress-laminating technique previously described for sawn lumber bridges As with glulam, the use of LVL permits longer spans due to the higher strength characteristics assigned to this product as well as due to the wider range of sizes available.

Another use of LVL in bridge construction has been as the web members of composite stress-laminated T-systems using sawn lumber deck pieces. In this type of application, the LVL is used as an alternative material to glulam. As an extension of this technology, one manufacturer produces a prefabricated all-LVL T-section. These individual T-sections are produced in variable depths depending on design span and loading. After the individual T-sections are positioned side by side, they are stressed together using high strength steel rods. Figure 10 shows a bridge being erected using these LVL T-sections.

Figure 10 — Installation of an LVL T-section

Crash Tested Rail Systems

One ongoing concern expressed by bridge designers in the U.S. has been related to the need for cost efficient crash-worthy timber bridge guardrail systems. AASHTO and the Federal Highway Administration have a program underway which will require all highway bridges guardrail systems to be fully crash tested. Several levels of guardrail performance are being considered in this program ranging from resisting the impact of passenger vehic1es to that of large over over commercial trucks. Both the US. Forest Products Laboratory and the Federal Highway Administration have completed full scale crash test programs to evaluate the performance of various timber bridge guardrail systems on both longitudinal glulam deck and longitudinal glulam stringer and transverse deck bridge configurations.

These crash tests have been conducted using a variety of test vehicles ranging from passenger cars to pick-up trucks to larger commercial trucks. Rail system tested have included (a) single glulam rail with wood posts, (b) single steel rail with wood posts, (c) glulam rail, wood wheelguard and wood posts and (d) other combinations of guardrail system components. To date, all of the guadrail systems tested in these two research studies have met the crash test requirements established by AASHTO and the Federal Highway Administration. The availability of fully crash tested guardrail systems will provide a major impetus to the further use of glulam highway bridge systems in the U.S.

Emerging Technologies

Many other innovative technologies for timber bridge construction are being evaluated by U.S. researchers. One of these concepts uses metal gusset plate wood trusses as the main longitudinal superstructure elements. While metal gusset plate wood trusses are used extensively for floor and roof framing in both residential and commercial building construction, their use in bridge construction is on an experimental basis with only a few prototype bridges having been constructed.

Two possible technologies using these trusses are being evaluated. In one system, a series of identical trusses are placed in direct contact with each other (in the same manner that sawn lumber laminations would be used) and these are then stressed together using the stress-laminating concept. Once stressed together, these multiple truss bridges create a bridge with a very high degree of stiffness.

A second approach using pre-engineered metal gusset plate trusses is to prefabricate girder trusses using several of these trusses mechanically tied together. These girder trusses are then used as the vertical web elements in combination with stress-laminated sawn lumber deck pieces to create a T-beam configuration.

Work is also underway to evaluate alternative stressing rod materials using high strength steel strands in lieu of the traditional steel rods which have typically been used in the stress-laminated systems. Other researchers are evaluating the potential for using high strength structural composites such as reinforced plastics for these stressing elements.

Another evolving technology involves combining high strength structural plastic composites with wood such as by reinforcing the tension zone of glulam beams with fiber reinforced plastic (FRP). In virtually all instances, the bending strength of glulam is controlled by the tensile strength of the lumber or the end joints on the tension side of the beam. The potential for increasing the bending strength of glulam by reinforcing the outer tension zone has been evaluated by many investigators during the past 30 years using a variety of materials. Recent developments in the use of FRP suggest that this high-performance material offers the possibility of being bonded to the wood laminations under factory conditions thus providing this tension reinforcement.

Forming a composite beam by using a relatively small amount of FRP to reinforce the outer tensile zone offers the potential for significantly increasing the bending strength of glulam beams. However, the use of this reinforcement material may have limited effect on increasing overall stiffness when used in the relatively small percentages required to achieve the increased tensile performance yet be cost competitive with alternative materials.

Recent work has been completed using various types of fibers in pultruded plastic products, often referred to as FRP, to reinforce glulam (Tingley, 1990). Tingley and other researchers from Oregon State University report highly favorable results by reinforcing the tension zone of glulam using fiber reinforced plastics and have obtained U.S. building code acceptance of their proprietary technology. This has led to the use of these reinforced glulam in a number of building and highway bridge applications. Cooperative research has also been undertaken between West Virginia University and the U.S. Forest Products Laboratory to investigate similar uses of FRP bonded to either the tension side only or to both the tension and compression sides of beams. Other research evaluations related to reinforcing glulam beams using FRP products has also been undertaken by the University of Maine and by APA-The Engineered Wood Association.

These research efforts could soon lead to the construction of additional bridges using composite glulam and fiber reinforced plastic beams. Reinforced beams appear to have the greatest opportunity for showing economic advantages in applications where either (a) bending strength controls the design, (b) it is critical to minimize beam depth, or (c) the beams are part of a composite structure where the added strength provides substantial benefits.

Another related technology being pursued is to use high strength reinforcing fibers, such as Kevlar, to pre-stress the tension zone of glulam beams in a manner similar to pre-stressed concrete design. In this application, fiber mats are positioned between outer laminations of the glulam beam and then prestressed prior to face bonding the glulam beams. The pre-stressing force is then relaxed after the bonding operation is completed. While this research appears promising, it is only in its infancy and considerable work remains to be completed before it can become a marketable technology.

Summary

Beginning in the late 1960's, extensive research has been ongoing in the U.S. to advance the technology for using timber in highway bridge construction. This research has resulted in many innovative technologies that have been successfully incorporated in numerous timber highway bridge applications throughout the U.S. Continuing research will undoubtedly expand on existing technologies and create new technologies which will enhance the competitiveness of timber as a highway bridge construction material. In addition, these technologies also have applications in other types of bridges such as pedestrian bridges and railroad bridges thus leading to an expanded use of wood in those types of structures.

It is further hoped that much of the timber bridge technology developed in the U.S. over the past 25 years may have application in other countries where the use of timber in bridge construction is a design option. For example, although not located in the U.S., one of the most striking examples of the innovative use of glulam in highway bridge construction is the cable-stayed glulam bridge constructed in Hiroshima, Japan as shown in Figure 11.

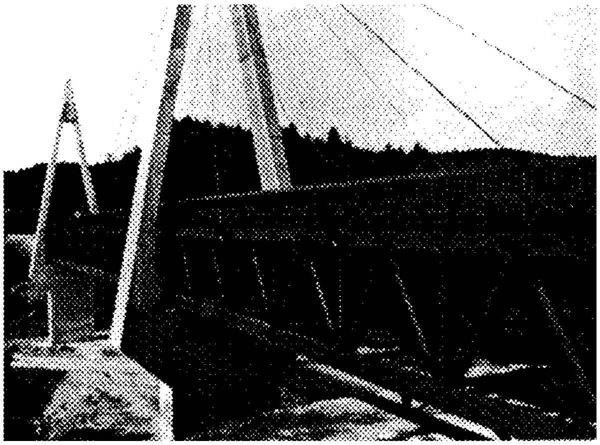

Figure 11 — Cable Stayed Glulam Highway Bridge.

This two lane wide bridge has a total length of 145 meters with a center clear span between support towers of 84 meters. This bridge uses a glulam truss configuration for the suspended superstructure. Although constructed in Japan, the glulam components for this unusual timber bridge were all rnanufactured, pre-fabricated for all connections and pressure preservatively treated at manufacturing facilities in the U.S. Perhaps this and other innovative timber bridge systems as described in this paper will once again lead designers to timber as a modern highway bridge construction material.

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