Development and Evaluation of the Teal River Stress-Laminated Glulam Bridge

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The Teal River bridge was constructed in late 1989 in Sawyer County, Wisconsin, as part of the demonstration timber bridge program of the U.S. Department of Agriculture Forest Service. The bridge is a stress-laminated deck structure with a 9.91-m length and a 7.23-m width. The design is unique in that it is the first known stress-laminated timber bridge in the United States to be constructed of full-span glued-laminated timber beams rather than the traditionally used sawn lumber laminations. The performance of the bridge was continuously monitored for 2 years, beginning at the time of installation. The performance monitoring involved gathering data relative to the moisture content of the wood deck, the force level of stressing bars, the deck dead load deflection, and the behavior of the bridge under static-load conditions. In addition, comprehensive visual inspections were conducted to assess the overall condition of the structure. On the basis of 2 years of field evaluations, the bridge is performing well with no structural or serviceability deficiencies.

In 1988 the U.S. Congress passed the Timber Bridge Initiative legislation. The objective was to establish and annually fund a national timber bridge program to provide effective utilization of wood as a structural material for highway bridges. Responsibility for the development, implementation, and administration of the timber bridge program was assigned to the USDA Forest Service. A key element of this program is a demonstration bridge program, which provides matching funds to local governments to demonstrate timber bridge technology through the construction of demonstration bridges (*1*).

As a national wood utilization research laboratory within the USDA Forest Service, the Forest Products Laboratory (FPL) has taken a lead role in assisting local governments in evaluating the field performance of demonstration bridges, many of which use design innovations. This has involved the development and implementation of a comprehensive national bridge monitoring program, which collects, analyzes, and distributes information on the field performance of timber bridges. This information provides a basis for validating or revising design criteria to improve efficiency and economy in bridge design, fabrication, and construction.

This paper describes the development, design, construction, and field performance of the Teal River bridge located in Sawyer County in northwestern Wisconsin. The bridge, built in 1989, is a two-lane, single-span, stress-laminated deck with a length of 9.91 m. The bridge design is the first known U.S. application that uses full-span structural glued-laminated (glulam) timber beams in a stress-laminated deck. In 1991 this bridge design was awarded first place in a National Timber Bridge Design Competition in the "Under 12-m Individual Span Vehicular Bridge" category.

BACKGROUND

The Teal River bridge site is located approximately 32 km east of Hayward, in Sawyer County, Wisconsin. It is on County Highway S, a two-lane paved road that crosses the Teal River. This road is located within the boundary of the Chequamegon National Forest and provides access to several popular recreation areas. In addition, the road is on the Chequamegon National Forest transportation network and is a primary route for logging traffic. The estimated average traffic over this section of the road is 100 vehicles per day.

The Teal River bridge was originally constructed in 1925 and consisted of steel stringers with a concrete deck supported by concrete abutments. The bridge was 10.37 m long and 4.88 m wide and included a rail system constructed of steel angles. In 1988, inspections of the bridge indicated that the concrete deck was in poor condition and the steel girders were badly corroded, although not to a point where restricted load limits were required. In addition, the railing system was substandard, and the narrow bridge width on a two-lane road raised safety concerns. It was apparent to the Sawyer County Highway Department that major rehabilitation or replacement of the structure would be required in the near future.

Subsequent to the bridge inspection, Sawyer County officials determined that the Teal River bridge would be replaced. Through a cooperative effort involving Sawyer County, the North Twenty Resource Conservation and Development Council, and the Chequamegon National Forest, a project proposal was submitted to the USDA Forest Service for partial funding of the Teal River bridge replacement as a demonstration bridge under the Timber Bridge Initiative. The proposal included a stress-laminated deck constructed of red oak sawn lumber harvested from Wisconsin forests. In 1989 the project was approved as proposed, and matching funds were provided through the USDA Forest Service Timber Bridge Information Resource Center in Morgantown, West Virginia. In finalizing project plans, it was found that neither red oak nor red pine lumber was readily available in the required size. Consequently, FPL was contacted for assistance in developing material options for the bridge, where the use of wood products native to Wisconsin was a primary consideration. Preliminary investigations indicated that glulam timber beams presented the best alternative for design. Hence, red pine lumber

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could be laminated with structural waterproof adhesives to form beams of the size required for the bridge laminations.

DESIGN, CONSTRUCTION, AND COST

The design and construction of the Teal River bridge was completed by the Chequamegon National Forest engineering staff in cooperation with the Sawyer County Highway Department officials. Assistance was provided by the bridge design office of the Forest Service Eastern Regional Office and FPL. An overview of the design, construction, and cost of the bridge superstructure is presented.

Design

Design of the Teal River bridge was a two-part process involving the development of the glulam timber beams followed by the design of the bridge superstructure. As with most stress-laminated timber bridge decks, it was anticipated that stiffness rather than strength would be the primary design concern. To serve as a basis for designing the glulam timber beams, a preliminary analysis of the Teal River bridge indicated that an acceptable deck depth could be obtained if a minimum design modulus of elasticity (MOE) of 11 204 MPa could be achieved. Analysis conducted at FPL indicated that a glulam timber beam manufactured entirely of red pine was feasible. However, little information was available on the properties of red pine lumber, and no information was available on red pine glulam timber. Therefore, the FPL engineers proposed that southern pine lumber be combined with red pine lumber to provide additional beam stiffness. No design information on southern pine–red pine glulam timber beams was available in current American Institute of Timber Construction (AITC) standards (*2*). However, the concept of developing beams using lower stiffness species for the inner lumber laminations and higher stiffness species for the outer lumber laminations had been used for other species in this standard. The same concept was used to develop a proposed beam design with southern pine outer laminations and red pine inner laminations. The proposed beam design was subsequently approved by AITC and was used in the Teal River bridge (Figure 1).

After the glulam timber design values were developed, design of the Teal River bridge was completed by the engineering staff of the Chequamegon National Forest using criteria developed at the University of Wisconsin—Madison and FPL (*3*). The design geometry of the deck provided for a 9.91-m length, a 7.32-m width, and a 350-mm thickness (Figure 2). This required the use of 91 southern pine–red pine glulam timber beams, each measuring approximately 79 mm wide. The outside beam along each deck edge was designed to be red oak glulam timber. The red oak would provide additional strength in distributing the force in the stressing bars into the deck without damaging the southern pine–red pine beams. All glulam beams were used as bridge laminations to form a continuous deck and hereafter are referred to as beam laminations.

All beam laminations were designed to be continuous between supports, without butt joints. The deck was also provided with a curb and bridge rail system to meet AASHTO static-load design requirements (*4*). Following fabrication, all wood components were specified to be pressure treated with pentachlorophenol in accordance with American Wood Preservers' Association Standard C14 (*5*).

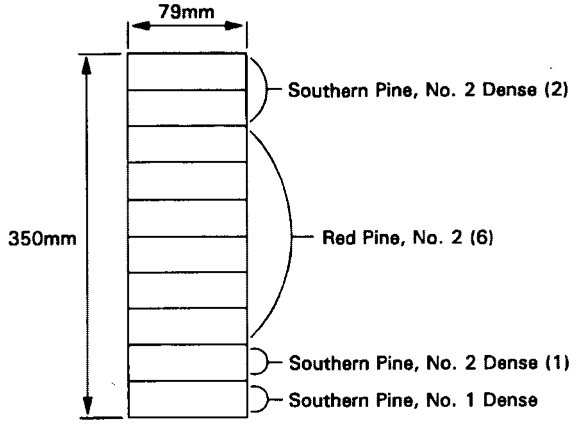

FIGURE 1 Southern pine–red pine beam laminations used for Teal River bridge.

The stressing system for the Teal River bridge was designed to provide a uniform compressive stress of 0.69 MPa between the beam laminations. It was assumed that approximately 60 percent of this compression will be lost during the lifetime of the bridge as a result of transverse stress relaxation of the wood laminations. The remaining 40 percent, or 0.28 MPa of compression between the laminations, provides a safety factor greater than 2.0 against relative lamination movement caused by transverse shear or bending. To provide this interlaminar compression, 25-mm-diameter high-strength stressing bars were spaced 1.12 m on center. The bars were specified to comply with the requirements of ASTM A722 and to provide a minimum ultimate tensile strength of 1034 MPa. The bar anchorage system was the discrete plate anchorage system, consisting of 305- by 305-mm steel-bearing plates with 102- by 165-mm steel anchorage plates. To provide protection from deterioration, all steel components were galvanized, including hardware, stressing bars, and anchorage plates.

Construction

Construction of the Teal River bridge was completed by Sawyer County and Chequamegon National Forest personnel in fall 1989. Following work on the approach roadway and widening of the existing concrete abutments, construction of the bridge superstructure began November 14 and was completed November 15. However, several additional days were required for construction of the bridge railing and approach railing. During this period, the construction site was subjected to inclement weather conditions, including snow and cold temperatures. Although the weather tended to slow the construction, it was completed on schedule with little difficulty.

Construction of the bridge began with the arrival of the beam laminations at the bridge site. The 91 southern pine–red pine beam laminations were transported to the site on a flatbed trailer in banded panels consisting of 15 to 16 beam laminations per panel. Each beam lamination measured 79

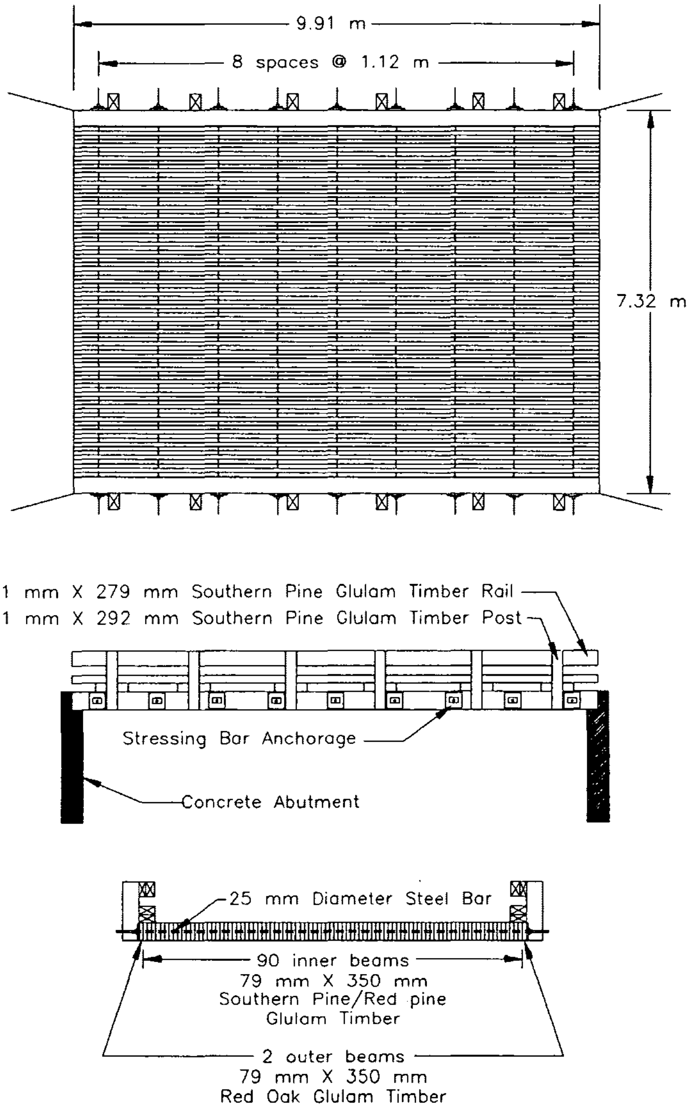

FIGURE 2 Design configuration of Teal River bridge: *top*, plan view; *middle*, profile view; *bottom*, cross section.

mm wide by 350 mm deep by 9.91 m long. Panels were placed on the abutments by a crane, bands were removed, and the beam laminations were positioned by the work crew. After placement of the southern pine–red pine beam laminations, a red oak beam lamination was placed along each deck edge. During placement, it was discovered that the abutment configuration restricted the bridge width and would not allow placement of all the beam laminations. Consequently, one southern pine–red pine beam lamination was removed, resulting in a finished bridge width of approximately 7.23 m (design width was 7.32 m).

After all beam laminations were in place, steel stressing bars were manually inserted through the predrilled holes in the beam laminations; bearing plates and anchor plates were installed, and nuts were hand tightened. Several stressing bars were then partially tensioned to bring all beam laminations in contact, and the initial deck stressing began. This was accomplished with a hydraulic jacking system consisting of a hydraulic pump, a single hollow core jack, and a stressing chair (*3*). Using this system, force applied by the jack is transferred through the stressing chair to the bar bearing plate. The bar is pulled away from the deck until the design force (269 kN) is reached. Then, the anchorage nut is tightened with a wrench to lock off the tension force in the bar. Starting at one bridge end, each stressing bar of the Teal River bridge was tensioned in this manner. After all bars were tensioned, each was retensioned to ensure that the stress level in the deck was uniform and at the required design level.

Following the initial stressing, the timber curb and rail system was installed, and a glulam timber approach rail was constructed. Approximately 1 week after the initial stressing, the bridge was restressed to compensate for anticipated losses in the bar force. Approximately 7 weeks after the second deck stressing, the third and final deck stressings were completed. An asphalt wearing surface was subsequently applied in June 1990. The completed bridge is shown in Figure 3.

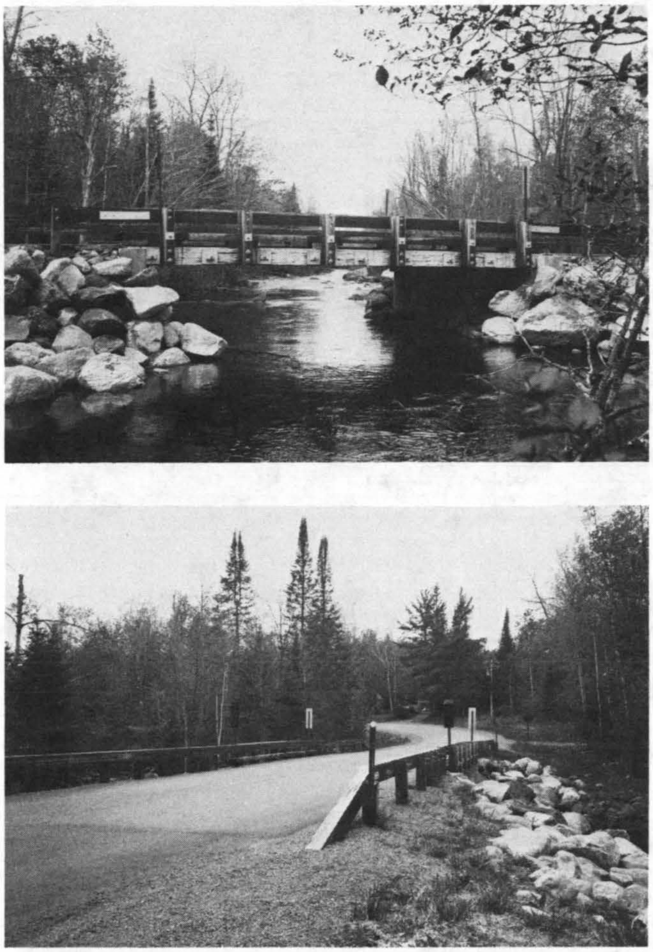

FIGURE 3 Completed Teal River bridge.

Cost

Costs for the design, fabrication, and construction of the Teal River bridge superstructure and rail system were $4,000 for survey and design, $26,485 for materials, and $5,400 for labor and equipment, for a total cost of $35,885. On the basis of a total deck area of 72.5 m^2, the cost per square meter was approximately $495.

EVALUATION METHODOLOGY

To evaluate the structural performance of the Teal River bridge, Sawyer County representatives contacted FPL for assistance. By agreement, a bridge monitoring plan was developed by FPL and implemented as a cooperative research effort with Sawyer County and the Chequamegon National Forest. The plan called for stiffness testing of the beam laminations before bridge construction and for performance monitoring of the deck moisture content, bar force in stressing bars, bridge creep, and load test behavior and for condition assessments of the structure for the first 2 years in service. The evaluation methodology used procedures and equipment previously developed (*6*) and is discussed in the following sections.

Lamination Stiffness

The glulam timber beam developed for the beam laminations of the Teal River bridge was a new combination. Thus, stiffness tests were completed to verify design assumptions. At the manufacturing plant, MOE tests were performed on the lumber before gluing and on the completed glulam timber beams before preservative treatment. Three methods were used to determine MOE values (*7*). The first, known as the static-load method, involved placing a known load at the lumber or beam midspan and measuring the deflection with a dial gauge. The second, known as the transverse vibration technique, involved striking the lumber or beam to induce a transverse vibration and measuring the natural frequency with a computer (*8*). The third used stress-wave technology and involved inducing a longitudinal stress wave in the lumber or beam and measuring the time of flight of the wave along the lamination length.

Moisture Content

Changes in the moisture content level of stress-laminated timber decks can significantly affect the performance of the structure. If moisture decreases, the deck can shrink, resulting in a decrease in stressing bar force. If moisture increases, swelling of the timber can occur and cause an increase in stressing bar force. Changes in moisture content level can also affect the deck stiffness, creep, and transverse stress relaxation.

To measure the moisture content of the Teal River bridge deck, an electrical resistance moisture meter with 76-mm pins was used. Measurements were obtained on a monthly basis by driving probe pins into the deck underside at depths of 51 to 76 mm, recording the moisture content value from the unit, then adjusting the values for temperature and wood species. At the 76-mm maximum pin penetration depth, measurements were taken in the lower southern pine portion of the beam laminations.

Bar Force

For stress-laminated bridges to perform properly, an adequate level of interlaminar compression must be maintained between the bridge laminations. This compression is placed in the bridge by tensioning the stressing bars to high levels and maintaining a portion of this force during the life of the structure. Thus, the force level in the bars provides a direct indication of the interlaminar compression in the bridge. For the Teal River bridge, the initial interlaminar compression of 0.69 MPa required a force in each stressing bar of 269 kN. If the force level decreases more than approximately 80 percent (i.e., less than 20 percent remaining), structural and serviceability problems can occur.

To monitor bar force, load cells developed by FPL were installed on two of the nine stressing bars when the bridge was assembled. The cells consisted of a steel cylinder that was placed between the stressing bar bearing plate and anchorage plate (*6*). Each cell was provided with two 90-degree strain gauge rosettes that measured the strain in the load cell. Strain measurements were then converted to force levels to determine the force remaining in the bar.

Load cell measurements were obtained by connecting a portable strain indicator to a plug on the load cell body. Measurements were taken on a biweekly basis for the first year and monthly thereafter. Approximately midway through the monitoring period, 1 year after bridge construction, the load cells were unloaded and checked for zero balance shift.

Creep

As a structural material, wood can deform permanently as a result of long-term sustained loads. For stress-laminated bridges, creep caused by structure dead load is an important consideration, because excessive creep can result in a sag in the superstructure (*8*). Creep of the Teal River bridge was measured on a monthly basis with a displacement rule attached to the deck underside at midspan. Vertical movement over time was recorded relative to a stringline attached near the abutments. In addition, a surveying level and rod were used periodically to confirm stringline data.

Load Test Behavior

Static-load testing of stress-laminated bridges is an important part of a comprehensive bridge monitoring program. The information obtained from these tests is used to refine and improve design procedures and evaluate the effects of various design variables on bridge performance. To determine the load test behavior of the Teal River bridge, load tests were conducted 7 and 17 months after installation. Each test consisted of positioning fully loaded trucks on the bridge deck and measuring the resulting deflections at a series of locations along the bridge centerspan, quarter points, and abutments. Measurements of bridge deflections were taken before testing (unloaded), for each load position, and at the conclusion of testing (unloaded).

Load Test 1

For the first load test on June 19, 1990, the vehicle used was a three-axle loaded dump truck with a gross vehicle weight of 355.2 kN. The vehicle was positioned longitudinally on the bridge so that the centroid of the vehicle aligned with the bridge centerspan for each of three transverse load positions (Figure 4). Measurements of bridge deflections from an unloaded to loaded condition were obtained by placing a surveying rod on the deck underside and reading values with a surveyor's level to the nearest 1.5 mm.

Load Test 2

The second load test, on April 26, 1991, involved two test vehicles: Truck 11 with a gross vehicle weight of 265.1 kN and Truck 13 with a gross vehicle weight of 266.4 kN. For this test, the vehicles were positioned longitudinally with the two rear axles centered over the bridge centerspan (front axles were off the bridge), and three transverse load positions were used (Figure 4). Measurements of bridge deflections were obtained by suspending calibrated rules from the deck underside and reading values to the nearest 1.5 mm with a surveyor's level.

Predicted Behavior Under HS 20-44 Loading

Previous research showed that stress-laminated decks can be accurately modeled as orthotropic plates (*9*). To further analyze the behavior of the Teal River bridge, an orthotropic model currently being developed and verified at FPL was used to predict the deflection of AASHTO HS 20-44 loading and evaluate changes in bridge stiffness.

Condition Assessment

The general condition of the bridge was assessed initially at the time of installation, twice during the load testing, and finally during a site visit near the end of the monitoring period. These assessments involved visual inspections, measurements, and photographic documentation of the bridge condition, specifically the condition of the timber deck and rail system, asphalt wearing surface, stressing bars, and anchorage systems.

RESULTS AND DISCUSSION

The performance monitoring of the Teal River bridge extended from November 1989 through October 1991.

Lamination Stiffness

Results of MOE tests using the transverse vibration technique on southern pine lumber before gluing indicated an average MOE of 14 262 MPa for No. 1 dense material and 13 298 MPa for No. 2 dense material. In both cases, average values were slightly greater than assumed design values. For red pine, lumber MOE tests using the same method provided an average MOE of 10 266 MPa, which was approximately 35 percent greater than assumed design values.

Tests of 30 laminated beams using the transverse vibration technique resulted in an average MOE of 12 265 MPa. Additional testing at the plant using the static-load method resulted in an average MOE of 12 195 MPa for 24 laminated beams. MOE tests using the stress-wave technique did not provide reliable data and were not used for evaluation.

The average MOE of the laminated beams exceeded the target value of 11 204 MPa by approximately 10 percent. This was because lumber properties for both southern pine and red pine exceeded those assumed in the original design.

Moisture Content

The beam laminations were initially installed at an average moisture content of less than 10 percent. Since installation,

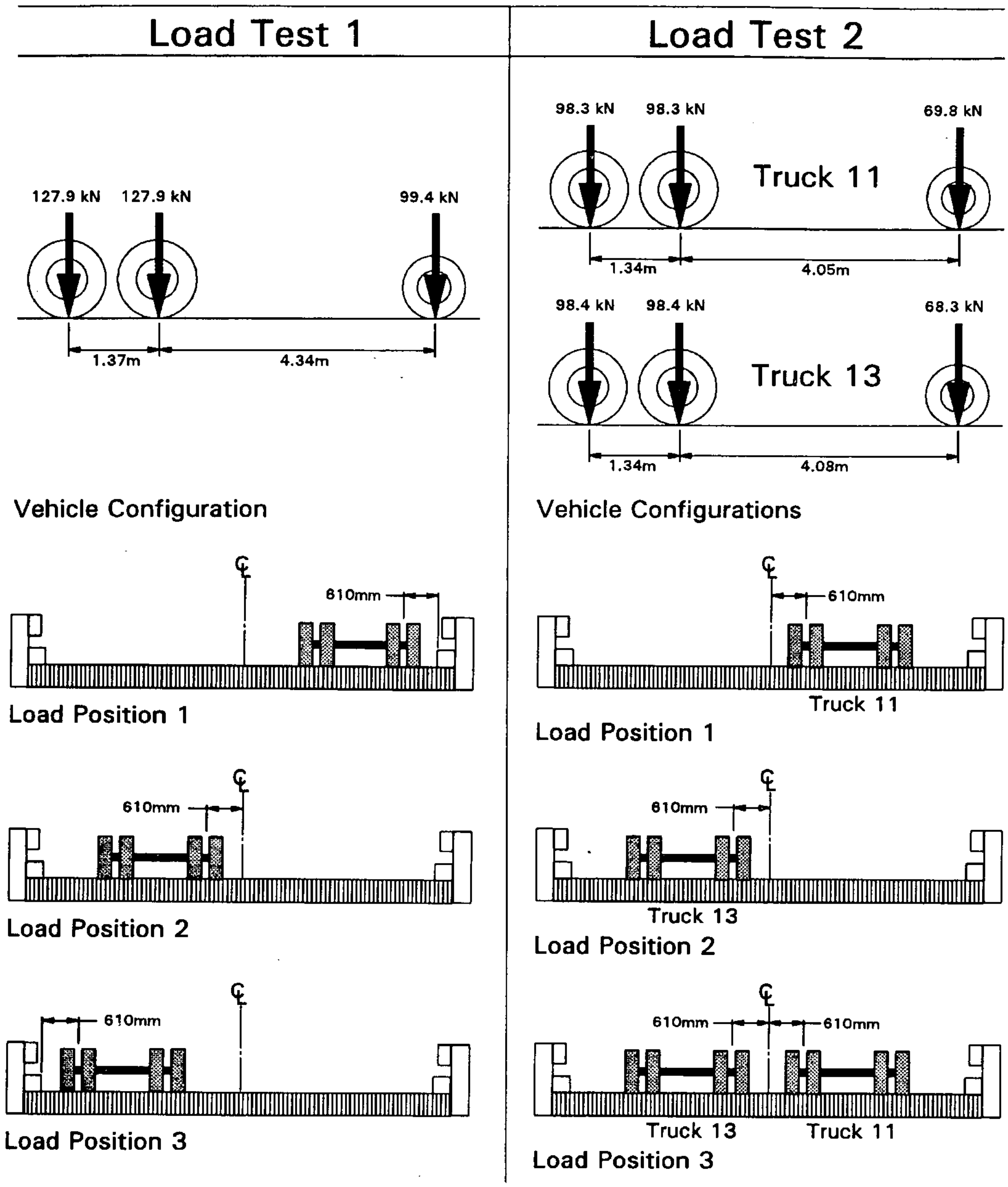

FIGURE 4 **Load test vehicle configurations and positions. Vehicles in the right lane face north, into the page; those in the left lane face south, out of the page. For Load Test 1, the longitudinal centroid of the vehicle was placed over the bridge centerspan. For Load Test 2, the rear axles were centered over centerspan and front axles were off the bridge. The transverse track width for all vehicles was 1.83 m, measured center-to-center of the rear tires.**

moisture content gradually increased to an average level of approximately 13 percent at the conclusion of the monitoring period. Moisture content fluctuated following seasonal climate changes, with a maximum average moisture content of approximately 15 percent occurring in fall 1990. These changes will continue over the life of the structure and were generally most apparent in the outer 25 to 76 mm of the deck, where moisture measurements were taken. Moisture changes in the interior portion of the deck, where the moisture content will continue to increase until an equilibrium level is reached, were gradual. It is anticipated that the average moisture content of the deck will eventually stabilize at an equilibrium value of 18 to 20 percent (*10*), although short-term seasonal changes will continue, primarily in the outer 51 to 76 mm of the deck.

Bar Force

Bar tension force was measured with load cells on two stressing bars and averaged. The first two stressings were at the design force of 269 kN. The final stressing, which occurred about 8 weeks after installation, was approximately 10 percent greater than the design force level. As is typical of stress-laminated decks, the rate of bar force loss as a result of transverse stress relaxation decreased substantially with each restressing.

The observed minor fluctuations in bar force were a result of moisture changes and stress relaxation in the deck. However, force losses were minimal, and the average bar force was within 10 percent of the design force at the end of the monitoring period. This can be attributed to several factors, the most significant of which was the initial low moisture content level of the beam laminations. As the deck slowly gained moisture in reaching an equilibrium moisture content, the wood swelled slightly, which tended to offset force losses as a result of transverse stress relaxation. Other stress-laminated decks installed at relatively high moisture content levels had bar force losses of as much as 80 percent during 2 years (*11*). The Teal River bridge vividly illustrates the advantage of low wood moisture content levels at the time of construction in reducing the rate of bar force loss.

Creep

The beam laminations for the Teal River bridge were manufactured with a positive camber of approximately 51 mm. After the dead load deflection of about 10 mm, measurements indicated that approximately 3 mm of vertical creep occurred at centerspan during 2 years. At the conclusion of the monitoring period, approximately 38 mm of positive camber remained in the deck at centerspan.

Load Test Behavior

Results for both load tests and the predicted response of the bridge under AASHTO HS20-44 loading are presented. In each case, transverse deflection measurements are given at the bridge centerspan as viewed from the south end (looking north). To aid visual interpretation, deflection values are presented as fourth-order polynomial curve fits to the measured data points. For each load test, no permanent residual deformation was measured at the conclusion of the testing. In addition, movement at either of the abutments was not detected.

Load Test 1

Transverse deflection values for Load Test 1 are shown in Figure 5. For Load Position 1, the maximum deflection of 21 mm occurred under the outside wheel line, 915 mm from the downstream deck edge. For Load Position 2, the maximum deflection of 22 mm was measured 254 mm from the outside wheel line, toward the upstream deck edge. For Load Position 3, the maximum deflection of 22 mm occurred under the outside wheel line, 915 mm from the upstream deck edge.

Load Test 2

Transverse deflection values for Load Test 2 are shown in Figure 5. With a single truck on the bridge, both Load Positions 1 and 2 produced a maximum deflection of 15 mm approximately midway between the truck wheel lines. With both vehicles on the bridge, the maximum deflection for Load Position 3 was 24 mm under the inside wheel line of Truck 11.

Predicted Behavior Under HS20-44 Loading

On the basis of an analysis of both load tests using an FPL computer model, the maximum deflection of the Teal River bridge subjected to two lanes of HS20-44 loading was estimated at 25 mm. Further analysis of Load Test 2 compared with Load Test 1 indicated that for equivalent HS20-44 loading, no significant decrease occurred in bridge stiffness during the monitoring period. This was expected because neither a significant decrease in bar force nor an increase in deck moisture content occurred during the monitoring period.

Condition Assessment

Condition assessments of the Teal River bridge indicated that structural and serviceability performance were good. Inspection results for specific items follow.

Wood Components

Wood components of the bridge showed no signs of deterioration, although minor checking was evident on rail members exposed to wet-dry cycles. Checking was most pronounced in the end grain of the southern pine glulam timber rail posts. This would likely have been prevented if a bituminous end-grain sealer or a metal cap had been placed at the time of construction. In addition, the top of the bridge rail showed minor checking, but the checks did not appear to penetrate the preservative treatment envelope of the member. Inspection showed no evidence of wood preservative loss and no preservative or solvent accumulations on the wood surface. The red oak edge beams showed a lightening in color from a medium tan to a very light tan as a result of exposure to sunlight.

Wearing Surface

Inspection of the asphalt wearing surface indicated minor transverse cracking in a random pattern. This was attributed to a deficiency in the asphalt mix or application procedures, because the same cracking was observed on both approach roadways, which were paved at the same time as the bridge deck. Aside from the minor cracking, the asphalt was in good condition and showed no other signs of distress.

Anchorage System

The stressing bar anchorage system performed as designed with no significant signs of distress. Inspection indicated no crushing of the discrete plate anchorage into the outside red oak beams and no measurable distortion in the bearing plate. A very gradual compression deformation was noted along the

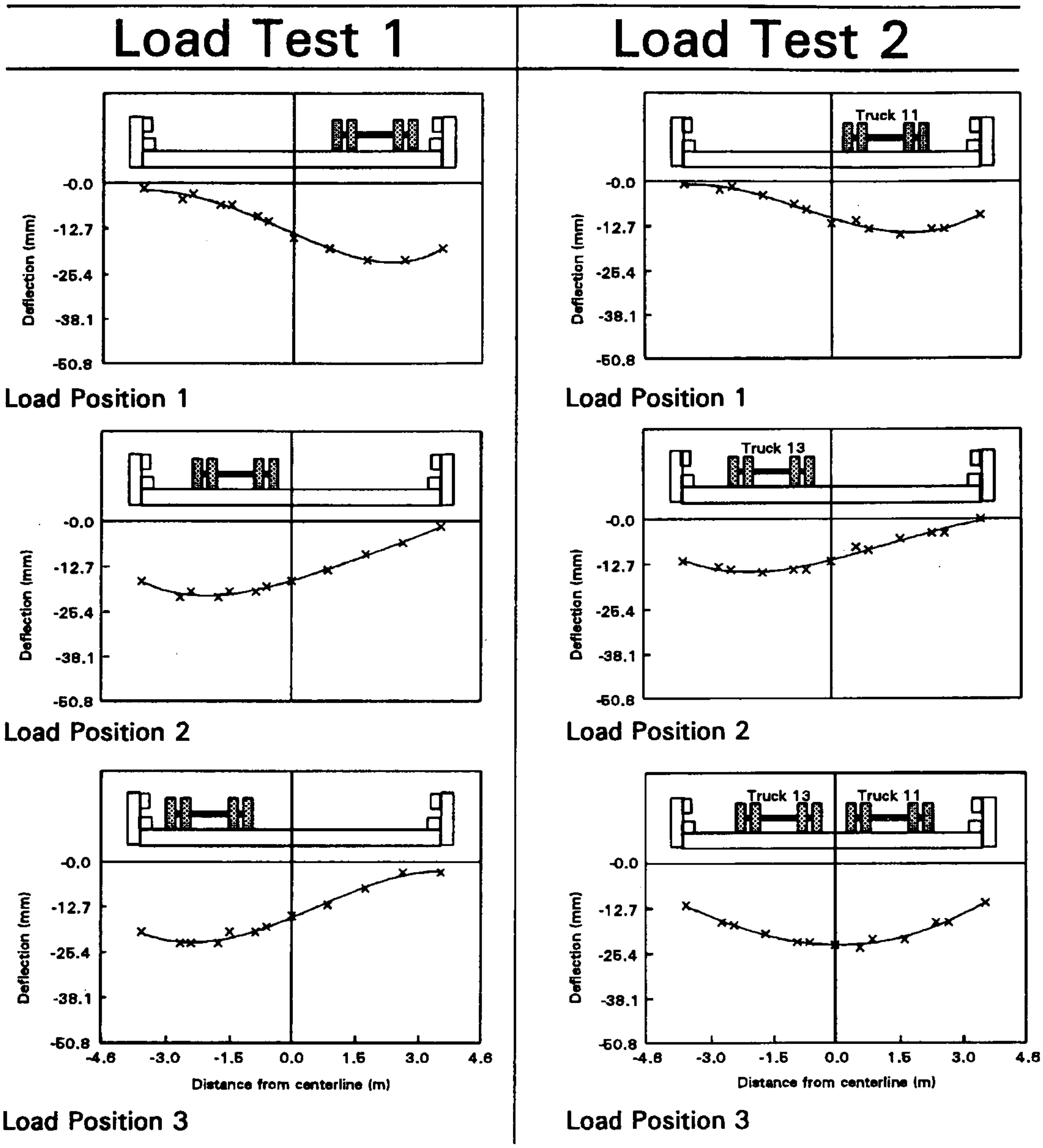

FIGURE 5 Load test transverse deflections, measured at the bridge centerspan. Bridge cross sections and vehicle positions are shown to aid interpretation and are not to scale.

deck edge for a distance of several feet on either side of several anchorages. This deformation was difficult to detect visually and was likely the result of transverse stress relaxation in the beam laminations.

Stressing Bars and Hardware

The exposed steel stressing bars and hardware showed no visible signs of corrosion except at the ends of stressing bars. At bar ends, minor corrosion appeared where the galvanized coating had been stripped from the bar, exposing uncoated steel. This occurred because the nuts were not adequately oversized to compensate for galvanizing and were forced on the bars during construction. This problem would not have occurred if nuts had been properly oversized to compensate for galvanizing or a cold galvanizing compound had been applied to the bar to replace the removed coating.

CONCLUSIONS

After 2 years in service, the Teal River bridge is exhibiting excellent performance and should provide many more years of acceptable service. On the basis of the extensive monitoring conducted since bridge fabrication, the following conclusions are given:

1. It is both feasible and economically practical to manufacture structural glulam timber beams for bridge applications using a combination of red pine and southern pine lumber. The evaluation of this project indicates that beams could prob-

ably be manufactured entirely from red pine, provided that appropriate quality control measures are implemented to ensure stiffness requirements for the specific design.

2. Stress-laminated decks can be constructed using glulam timber beams for the deck laminations. The ability to manufacture the glulam timber beam laminations as continuous members greatly facilitates transportation and construction because butt joints are not required.

3. The use of red oak outside edge laminations facilitates good performance of discrete plate stressing bar anchorages. Red oak provides sufficient strength to adequately distribute the bar force into the deck without wood crushing or anchor plate deformation.

4. The average trend in deck moisture content indicates that global moisture content changes are occurring very slowly, with an average increase of approximately 3 percent during the 2 years. Cyclic seasonal variations in moisture content are occurring more rapidly and at greater magnitudes in the outer 51 to 76 mm of the exposed deck.

5. Stressing bar force remained at a relatively high level during the 2-year monitoring, with less than a 10 percent average decrease in bar force below the initial level. This is attributable primarily to low average moisture content levels of the bridge laminations at installation, which were less than the anticipated equilibrium moisture content for the site. Loss in bar force caused by transverse stress relaxation in the wood is minimized by dimensional increases in the deck as moisture content increases toward an equilibrium level. The lower moisture content level also reduces the rate of stress relaxation within the deck and in the vicinity of bar anchorage plates.

6. Creep of the bridge deck is minimal with approximately 3 mm of vertical displacement during the 2 years. A positive camber of approximately 38 mm remains at centerspan.

7. Load testing and analysis indicate that the Teal River bridge is performing as a linear elastic orthotropic plate when subjected to highway loading. The maximum deflection caused by two lanes of AASHTO HS20-44 loading is estimated to be 25 mm.

8. The deck stiffness is not appreciably changed. This is attributable to the high level of prestress maintained in the deck during the monitoring period.

9. Wood checking is evident in the exposed end grain of bridge rail posts and other components. It is likely that this would not have occurred if a bituminous sealer or metal cap had been applied to the end grain at the time of construction.

10. The ends of some stressing bars show signs of minor corrosion at locations where the galvanizing was removed during construction. This would not have occurred if the stressing nuts had been oversized to compensate for the thickness of the galvanized coating.

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