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Field Performance of Timber Bridges

5. Little Salmon Creek Stress-Laminated Deck Bridge

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Abstract

The Little Salmon Creek bridge was constructed in November 1988 on the Allegheny National Forest in Pennsylvania. The bridge is a simple span, single-lane, stress-laminated deck superstructure that is approximately 26-ft long and 16-ft wide. The bridge is unique in that it is the first known stress-laminated timber bridge to be constructed of hardwood lumber. The performance of the bridge was monitored continuously for approximately 4 years, beginning at the time of installation. Performance monitoring involved gathering and evaluating data relative to the moisture content of the wood deck, the force level of stressing bars, the deck vertical creep, 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. Based on field evaluations, the bridge is performing well with no structural deficiencies, although the bridge has developed a slight sag as a result of vertical creep.

Keywords: Timber, bridge, wood, stress laminated

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Contents

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Introduction

In 1988, Congress passed the Timber Bridge Initiative (TBI) to further develop and extend the use of timber as a bridge material. Responsibility for administration of the TBI was delegated to the USDA Forest Service and included a demonstration timber bridge program managed by the Timber Bridge Information Resource Center (TBIRC) in Morgantown, West Virginia, and a research program at the Forest Products Laboratory (FPL) in Madison, Wisconsin (USDA 1994). In addition, the Forest Service National Forest System, which administers the National Forests of the country, made a commitment to demonstrate new technology in timber bridge design and construction. A large percentage of the National Forests is located in rural communities where local economies depend on natural resource management and utilization. Traditionally, the National Forest System maintains jurisdiction over thousands of bridges, a significant percentage of which are timber bridges.

This report is the fifth in a series that documents the results from the FPL bridge monitoring program. This paper describes the development, design, construction, and field performance of the Little Salmon Creek bridge on the Allegheny National Forest in Pennsylvania. The bridge was constructed in November 1988 as part of a commitment by the Forest Service National Forest System to demonstrate new and emerging timber bridge technology. The bridge is a single-lane, single-span, stress-laminated deck that is approximately 26-ft long and 16-ft wide. (See Table 1 for metric conversion factors.) The bridge is unique in that it is the first known stress-laminated deck superstructure constructed of hardwood lumber. An information sheet on the Little Salmon Creek bridge is provided in the Appendix.

Background

The Little Salmon Creek bridge is located within the Allegheny National Forest, approximately 40 miles south of Warren, Pennsylvania (Fig. 1). The bridge is on Forest Road 145 (Salmon Creek Road), a single-lane, gravel roadway that provides access to popular recreation areas in the Allegheny National Forest. Traffic is mostly light passenger vehicles and occasionally logging trucks. The average traffic is estimated between 15 to 20 vehicles per day.

Table 1—Factors for converting English units of measurement to SI units

English unit	Conversion factor	SI unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	0.09	square meter (m^2)
mile	1,609	meter (m)
pound (lb)	0.14	Newton (N)
lb/in^2 (stress)	6,894	Pascal (Pa)

The original Little Salmon Creek bridge was constructed in the early 1930s and consisted of a reinforced concrete slab. Inspection of the bridge in the mid-1980s indicated that the concrete deck was in poor condition and insufficient to carry required traffic loads. The bridge was also only 9 ft wide, and increased width was required to meet acceptable geometric standards established by the forest. Based on these deficiencies, a decision was made by the Allegheny National Forest to replace the bridge.

Several options for replacement of the Little Salmon Creek bridge were considered by the Allegheny National Forest engineering staff. A timber bridge was determined the best option because it would provide an opportunity to demonstrate and evaluate new and emerging timber bridge technology. In addition, a timber bridge could be built using lumber from the Allegheny National Forest and a Forest Service construction crew. Thus, the decision was made to construct a stress-laminated deck using local Northern Red Oak lumber. It was further determined that the field performance of the bridge should be monitored after bridge installation to provide assurance that the performance of the newly developed stress-laminated timber bridge system was satisfactory. Subsequently, FPL and the Allegheny National Forest entered into an agreement to complete structural monitoring of the bridge as part of a developing national timber bridge monitoring program at FPL.

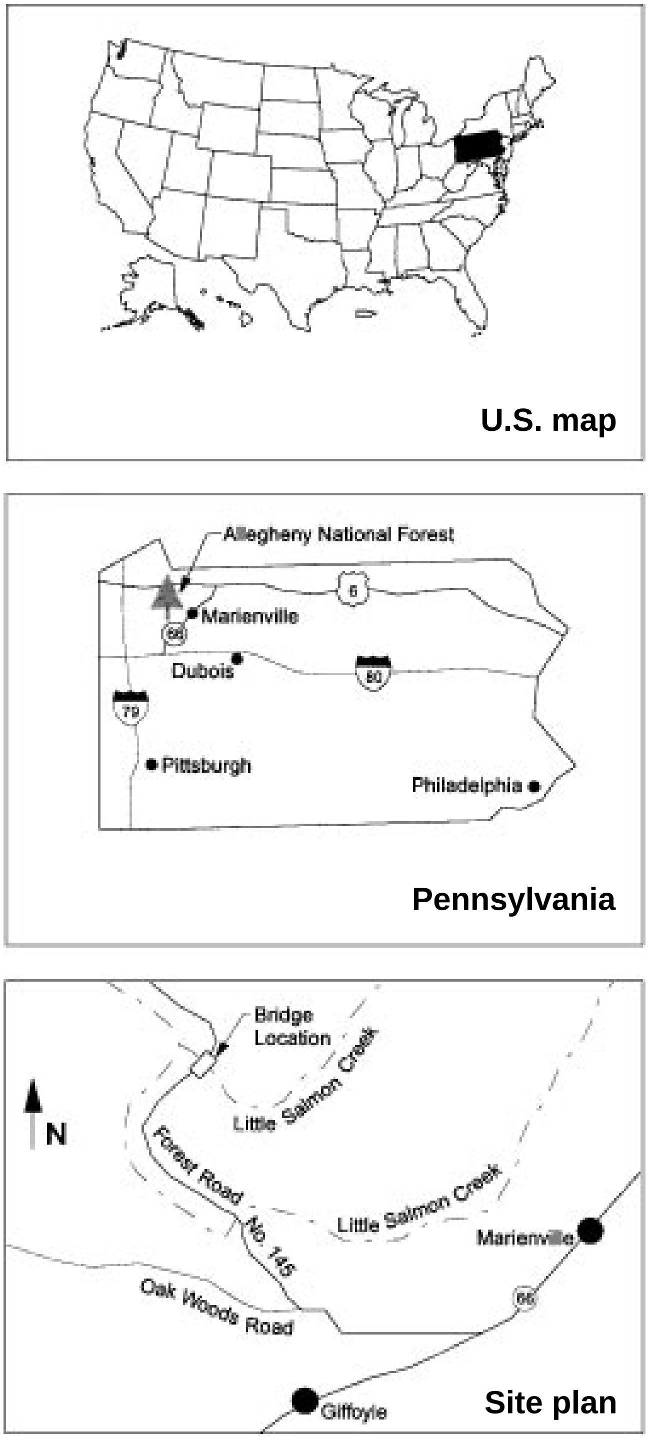

Figure 1—Location maps of the Little Salmon Creek bridge.

Objective and Scope

The objective of this project was to determine the field performance characteristics of the Little Salmon Creek stress-laminated bridge by monitoring the bridge for approximately 4 years, beginning at bridge installation. The project scope included data collection and analysis related to the wood moisture content, stressing bar force, vertical bridge creep, behavior under static truck loading, and general structure condition. The results of this project will be considered with similar monitoring projects in an effort to improve design and construction methods for future stress-laminated timber bridges.

Design, Construction, and Cost

The design and construction of the Little Salmon Creek bridge were completed by the engineering staff of the Allegheny National Forest. An overview of the design, construction, and cost of the bridge superstructure is presented.

Design

The Little Salmon Creek bridge was designed before a nationally recognized design procedure for stress-laminated timber bridges was available in the United States. The design criteria for those aspects relating directly to stress laminating were based on a draft version of *Timber Bridges: Design, Construction, Inspection, and Maintenance* (Ritter 1990). The remainder of the design was based on *Standard Specifications for Highway Bridges*, published by the American Association of State Highway and Transportation Officials (AASHTO 1983).

The Little Salmon Creek bridge was designed for AASHTO HS 20-44 loading with a span length of 25 ft center-to-center of bearings, a width of 16 ft, and a nominal deck thickness of 12 in. (Fig. 2). Visually graded No. 2 Northern Red Oak was selected as the bridge material. At the time of design, tabulated design values for Northern Red Oak were not included in the AASHTO specifications or in the *National Design Specification for Wood Construction* (NDS) (NFPA 1988). Based on proposed design values for the species and lumber grade prepared by Northeastern Lumber Manufacturers Association (NELMA), tabulated design values of 1,375 lb/in^2 for bending and 1,350,000 lb/in^2 for modulus of elasticity (MOE) were used. These values were adjusted for wet-use conditions using NDS wet-use factors of 0.86 for bending and 0.97 for MOE. Final bridge design was controlled by a live-load deflection limit for AASHTO HS 20-44 loading, defined as 1/360 of the bridge span measured center-to-center of bearings. The design live-load deflection was 0.85 in. or 1/353 of the bridge span.

Design of the Little Salmon Creek deck was based on nominal 2- by 12-in. Northern Red Oak laminations, pressure treated with creosote after fabrication. The length of the laminations varied from 3 to 16 ft, and butt joints in the deck laminations were placed transversely in every fourth

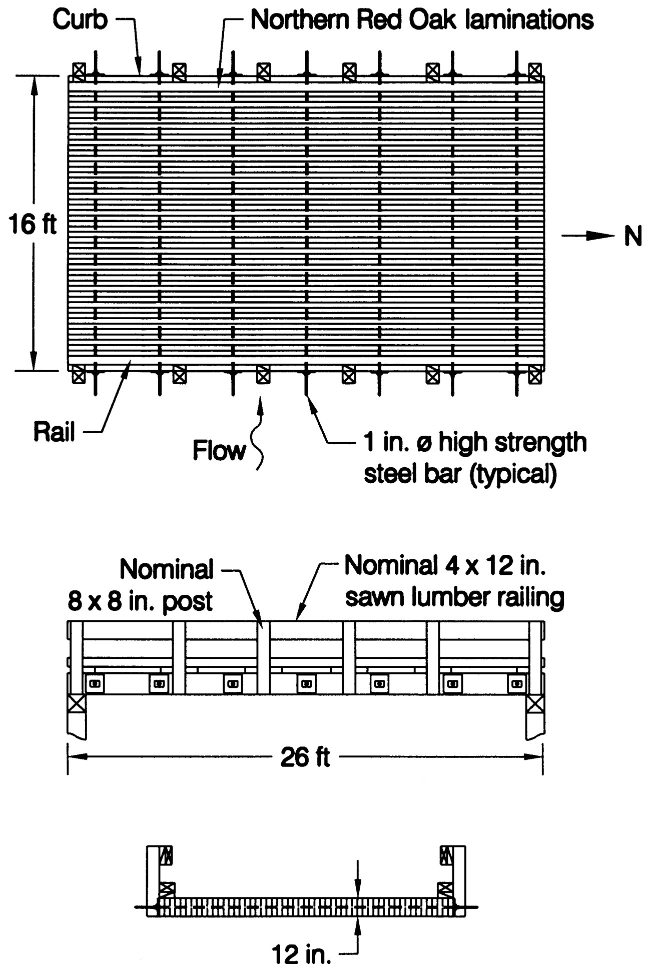

Figure 2—Design configuration of the Little Salmon Creek bridge.

lamination, with a 4-ft longitudinal spacing between butt joints in adjacent laminations (Fig. 3). The stressing system was designed for seven 1-in.-diameter, high strength, threaded-steel bars conforming to the requirements of ASTM A722 (ASTM 1988). Average bar spacing was 46 in. on-center, beginning 18 in. from the bridge ends. The design bar tension force was 60,000 lb, which resulted in 109 lb/in^2 of interlaminar compression. The bar anchorage system was the discrete plate anchorage, consisting of two steel plates (Fig. 4). The bridge railing consisted of a Northern Red Oak sawn lumber curb, post, and rail. The railing was designed for 50 percent of the AASHTO static-load design criteria, which is typical for Forest Service bridges on single-lane roads, and was extended beyond the bridge ends to serve as the approach railing. Because of the low level of traffic, no wearing surface was specified.

Construction

Lumber for the Little Salmon Creek bridge was obtained from trees on the Allegheny National Forest that had been killed by insect attack. The trees were felled, transported to a local saw mill, and sawn into lumber for the deck laminations, railing, and substructure. After processing, the material was visually graded by a NELMA certified grader and fabrication was completed. From the saw mill, the lumber was transported to a local treating plant for pressure treatment with creosote.

Construction of the Little Salmon Creek bridge began with building a temporary bypass, consisting of three metal culverts. After completion of the bypass, the existing structure was removed, and excavation and construction of the two post and sill abutments were completed (Fig. 5). Superstructure assembly began at the treating plant where treated deck laminations were nailed together to form two deck sections, each half the width of the bridge. Temporary steel bars were then inserted through the laminations at several locations so that the deck sections could be transported to the bridge site.

After completion of the substructure, the deck sections were loaded on a flatbed truck at the treating plant and were transported to the bridge site (Fig. 6). At the site, the sections were unloaded from the truck and placed side-by-side on temporary supports on the approach roadway. The temporary steel bars were removed, and stressing bars were inserted through both sections (Fig. 7). The stressing bars were tensioned to the required 60,000-lb force using a single hydraulic jack. After bar tensioning, the entire superstructure was lifted as a unit by a small crane onto the abutments (Fig. 8). Attachment of the superstructure was completed by bolting the deck to a steel angle that was then bolted to the side of the substructure cap (Fig. 9).

The installation of the bridge superstructure was completed in 1 day under winter weather conditions, which included snow and freezing temperatures. After the initial bar tensioning, the bars were again retensioned to 60,000 lb approximately 1 and 6 weeks after installation. The curb, bridge railing, and approach railing were installed shortly after the bars were tensioned for the second time. The completed bridge is shown in Figure 10.

The as-built configuration of the Little Salmon Creek bridge varied slightly from the design configurations shown in Figure 2. After the final stressing, the bridge width measured 16.2 ft at the abutments and 15.9 ft at midspan.

Cost

Final costs for materials, fabrication, and construction of the Little Salmon Creek bridge superstructure, including curb and railing, are given in Table 2. Based on a deck area of 416 ft^2, the cost total was approximately \$37/ft^2.

Evaluation Methodology

As a result of the experimental nature of the Little Salmon Creek bridge, Allegheny National Forest representatives contacted FPL for assistance in evaluating the structural performance of the bridge. Through mutual agreement, a bridge monitoring plan was developed by FPL and implemented as a cooperative effort with the Allegheny National Forest.

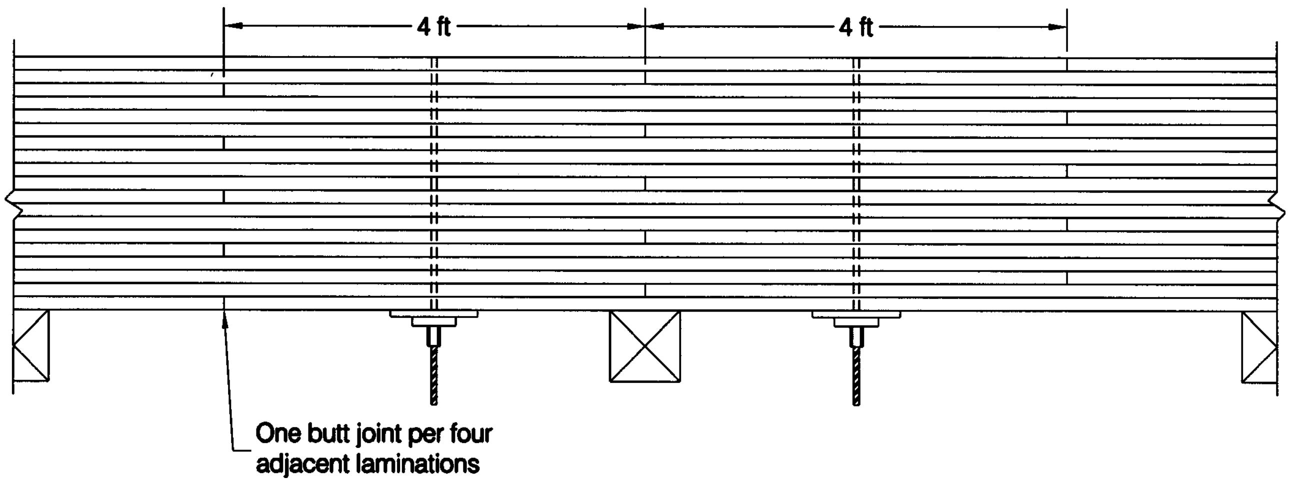

Figure 3—Butt joint configuration used for the Little Salmon Creek bridge. A butt joint was placed transversely to the bridge span in every fourth lamination. Longitudinally, butt joints in adjacent laminations were separated by 4 ft.

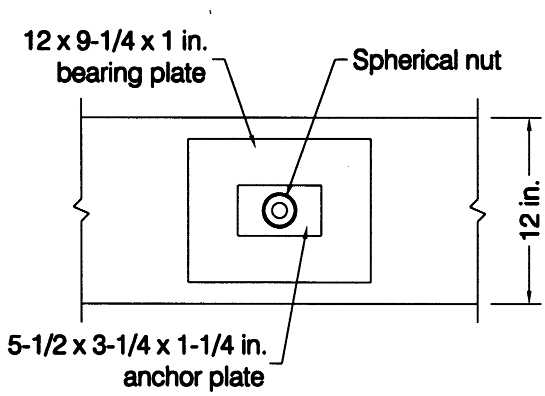

Figure 4—Discrete plate bar anchorage configuration.

Figure 5—Construction of the post and sill abutments for the Little Salmon Creek bridge.

Figure 6—The two deck sections for the Little Salmon Creek bridge were transported from the treating plant to the bridge site on a flatbed truck.

Figure 7—At the bridge site, the temporary steel bars in the two deck sections were removed and stressing bars were inserted through both deck sections.

The plan called for the performance monitoring of the deck moisture content, bar force in the stressing bars, vertical bridge creep, load test behavior, and condition assessments of the structure. The evaluation methodology utilized procedures and equipment previously developed at FPL (Ritter and others 1991).

Moisture Content

The moisture content of the Little Salmon Creek bridge was measured on the underside of the deck, using an electrical-resistance moisture meter with 3-in. probe pins in accordance with ASTM D4444-84 procedures (ASTM 1990). Measurements were obtained by driving the pins into the deck at depths of 1 to 2 in., recording the moisture content value from the unit, and adjusting the values for temperature and wood species. Moisture content measurements were taken at the time of bridge installation, periodically during the monitoring period, and at the conclusion of the monitoring.

Figure 8—After the stressing bars were tensioned, the entire superstructure was lifted on the abutments by a small crane.

Figure 9—Attachment of the superstructure was by bolting the deck to steel angles that were then bolted to the side of the substructure cap.

Bar Force

Bar force for the Little Salmon Creek bridge was measured using load cells that were developed at FPL. The load cells were installed between the bearing plate and anchor plate on the second and fourth stressing bars from the north abutment. Load cell measurements were obtained by Allegheny National Forest personnel using a portable strain indicator. Strain measurements from the indicator were converted to units of bar tensile force by applying a laboratory calibration factor to the strain indicator reading. Bar force measurements were taken on a biweekly basis for several months following construction and approximately bimonthly thereafter. Approximately 2 years into the monitoring period, the load cells were replaced with new load cells of a similar design. At the conclusion of the monitoring period, the load cells were removed, checked for zero balance shift, and recalibrated to determine time-related changes in the initial load cell calibration. The bar tensile force was also checked with a hydraulic jack several times during the monitoring period to verify load cell readings.

Figure 10—Completed Little Salmon Creek bridge.

Table 2—Estimated costs for the Little Salmon Creek bridge

Item	Cost ($)
Wood Stumpage, cutting, skidding, sawing, and delivery to the preservative treatment plant	3,000
Stress grading	400
Fabrication and pressure treating Cutting, drilling, preservative treatment, and delivery to project site	3,200
Steel Stressing bars, plates, nuts, bolts, lag screws, and nails	3,900
Miscellaneous Gravel, seeding, and erosion control	200
Crane rental for 1 day	1,000
Construction equipment and labor construction crew, backhoe, dump truck	3,700
Total	15,400

Creep

Vertical creep of the Little Salmon Creek bridge was measured periodically during the monitoring period. Measurements were obtained at midspan on both the upstream and downstream deck edges, using a stringline between bearings and a calibrated rule. The stringline served as a horizontal benchmark, and the relative deck elevation at midspan was measured with the rule.

Load Test Behavior

Static-load testing of the Little Salmon Creek bridge was conducted twice during the monitoring period to determine the response of the bridge to full truck loading. Each test consisted of positioning a fully loaded truck on the bridge deck and measuring the resulting deflections at a series of transverse locations at midspan. Measurements of bridge deflections were taken prior to testing (unloaded), for each load position (loaded), and at the conclusion of testing (unloaded). In addition, analytical assessments were conducted to determine the theoretical bridge response.

Load Test 1

The first load test was completed September 10, 1990, approximately 11 months into the monitoring period. The bridge interlaminar compression at the time of the test was 63 lb/in^2, or approximately 58 percent of the 109 lb/in^2 design level. The test vehicle consisted of a fully loaded, three-axle dump truck with a gross vehicle weight of 53,700 lb (Fig. 11). The vehicle was positioned longitudinally on the bridge so that the two rear axles were centered at midspan and the front axle was off the bridge span. Transversely, the vehicle was placed for two load positions (Fig. 12). For load position 1, the vehicle was centered on the bridge width. For

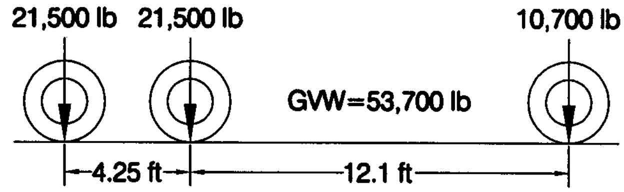

Figure 11—Load test 1 truck configuration and axle loads. The transverse vehicle track width, measured center-to-center of the rear tires, was 6 ft.

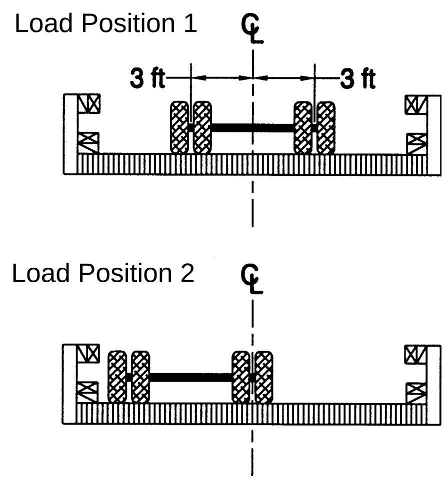

Figure 12—Load test 1 transverse load positions (looking north). For all load positions, the two rear axles were centered over the bridge midspan with the front axle off the span.

load position 2, the vehicle was positioned on the downstream side, with the center of the inside wheel line over the bridge centerline. Measurements of the bridge deflection from an unloaded to loaded condition were obtained by placing a calibrated rule on the deck underside and reading values with a surveyor's level to the nearest 0.005 ft (Fig. 13). The accuracy of this method for repetitive readings is estimated to be ±0.06 in.

Load Test 2

The second load test was completed July 18, 1993, 44 months into the monitoring period. At the time of the test, the interlaminar compression was at the full design level of 109 lb/in^2. The vehicle used for load test 1 was also used for load test 2, but the vehicle gross weight was reduced to 46,450 lb (Fig. 14). As with load test 1, the vehicle was positioned longitudinally so that the two rear axles were centered at midspan and the front axle was off the bridge span. Transversely, three load positions were used (Fig. 15). Load positions 1 and 2 placed the vehicle at the center of the bridge width and on the downstream side, respectively, as in load test 1. For load position 3, the vehicle was placed along the upstream bridge edge, with the center of the inside wheel line over the bridge centerline. Measurements of the bridge deflection from an unloaded to loaded condition were

Figure 13—Load test 1 bridge deflections were measured by suspending a calibrated rule from the deck underside and reading displacement values with a surveyor's level.

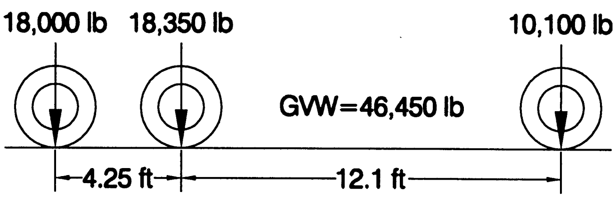

Figure 14—Load test 2 truck configuration and axle loads. The transverse vehicle track width, measured center-to-center of the rear tires, was 6 ft.

measured using string potentiometers and an electronic data acquisition system (Fig. 16). The accuracy of this method for repetitive readings is estimated to be ±0.0005 in.

Analytical Evaluation

Previous research has shown that stress-laminated decks can be accurately modeled as orthotropic plates (Oliva and others 1990). To further analyze the theoretical behavior of the Little Salmon Creek bridge, an orthotropic plate computer model developed at FPL was used to analyze the load test results and predict the bridge deflection for AASHTO HS 20-44 truck loading.

Condition Assessment

The general condition of the Little Salmon Creek bridge was assessed on four separate occasions during the monitoring period. The first assessment occurred shortly after installation. The second and third assessments took place during the first load test and during an intermediate site visit, respectively. The final assessment occurred at the time of the final load test, which concluded the monitoring activities. The assessments involved visual inspections, measurements, and photographic documentation of the bridge's condition. Items of specific interest included the bridge geometry, the

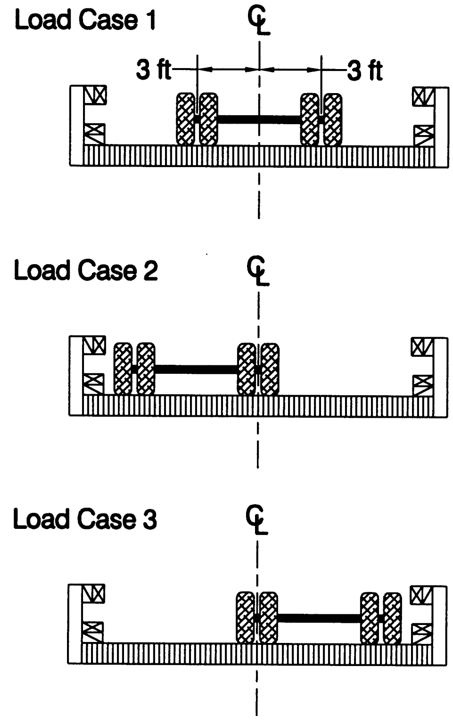

Figure 15—Load test 2 transverse load positions (looking north). For all load positions, the two rear axles were centered over the bridge midspan with the front axle off the span.

Figure 16—Load test 2 bridge deflections were measured with string potentiometers attached to the underside of the bridge. The transducers were supported by a wood beam and tripods.

condition of the timber deck and rail system, and the condition of the stressing bars and anchorage systems.

Results and Discussion

The performance monitoring of the Little Salmon Creek bridge extended from November 1988 through July 1993.

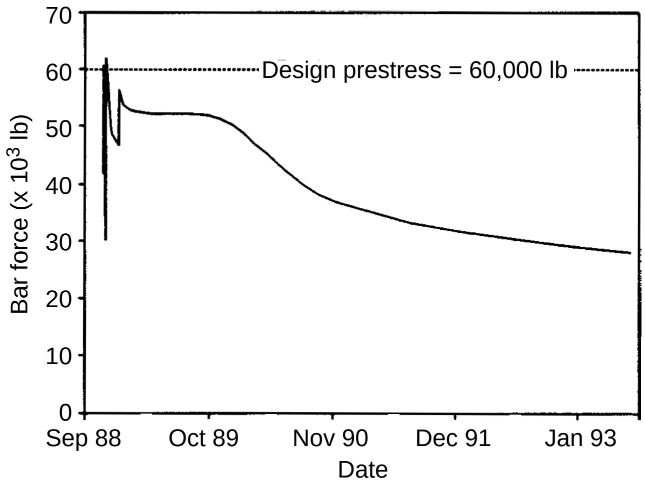

Figure 17—Average trend in bar tension force obtained from load cells installed on two stressing bars.

Figure 18—The 2.5 in. of superstructure sag on the downstream bridge side is visually evident in the bridge deck and the railing.

Moisture Content

The Little Salmon Creek bridge was installed at an average lamination moisture content of approximately 39 percent. Since installation, the bridge experienced a gradual decrease in moisture content, to approximately 31 percent at the conclusion of the monitoring program. The 8 percent decrease in moisture content occurred at a relatively constant rate during the 44 months, although moisture content fluctuated 2 to 3 percent in the measurement zone as a result of seasonal climatic changes. It is expected that the moisture content at the interior of the laminations is greater than the values obtained in the measurement zone because of slower moisture migration through the lamination depth.

Because of the high initial moisture content at installation, the deck moisture content remains above the fiber saturation moisture content of 25 to 30 percent. Above this level, changes in the moisture content have little effect on dimensional stability. In time, the moisture content will gradually decrease below the fiber saturation point and the moisture content will stabilize. When the moisture content falls below fiber saturation, subsequent moisture loss will result in shrinkage of the laminations and could significantly affect bar force retention.

Bar Force

The general trend in average bar force for the Little Salmon Creek bridge is shown in Figure 17. The first two bar tensionings, separated by 1 week, were approximately to the design force of 60,000 lb (approximately 109 lb/in^2 interlaminar compression). The final bar tensioning, which occurred in December 1988, 6 weeks after installation, was approximately 56,000 lb, or 93 percent of the design force. After the final bar tensioning, the bar force remained relatively stable until October 1989 when it began to decline. The decline continued throughout the monitoring period, although the rate of loss decreased with time. At the conclusion of the monitoring period, the average bar force was approximately 28,000 lb, or 47 percent of the design force, which corresponds to an average interlaminar compression of approximately 51 lb/in^2. Because the moisture content of the deck laminations remained above the fiber saturation point, there was no lamination shrinkage. Thus, the decline in bar force is primarily attributable to stress relaxation in the lumber laminations as a result of the high moisture content. Although the average bar force remained above the minimum recommended interlaminar compression of 40 lb/in^2 (Ritter 1990) at the end of the monitoring period, the bars were retensioned at that time because bar tensioning equipment was readily available.

Creep

The Little Salmon Creek bridge was constructed without camber and was approximately level with the abutments when installed. In September 1990, approximately 1 year into the monitoring period, the bridge had sagged below the level position, and 1.7 in. of negative camber was measured along the downstream bridge edge. In July 1993, at the conclusion of the monitoring period, negative camber measured 2.5 in. on the downstream bridge edge and 2 in. on the upstream bridge edge (Fig. 18). The visible sag in the bridge is due to creep and is not typical of most stress-laminated timber bridges. It is likely that the high moisture content of the laminations and cyclic moisture changes in the exposed deck surface contributed significantly to this high creep level.

Load Test Behavior

Results for both load tests are presented in this section. In each case, transverse deflection plots are shown at the bridge midspan as viewed from the south end (looking north). For each load test, no permanent residual deformation was measurable at the conclusion of the testing. In addition, there was no detectable movement at either of the abutments.

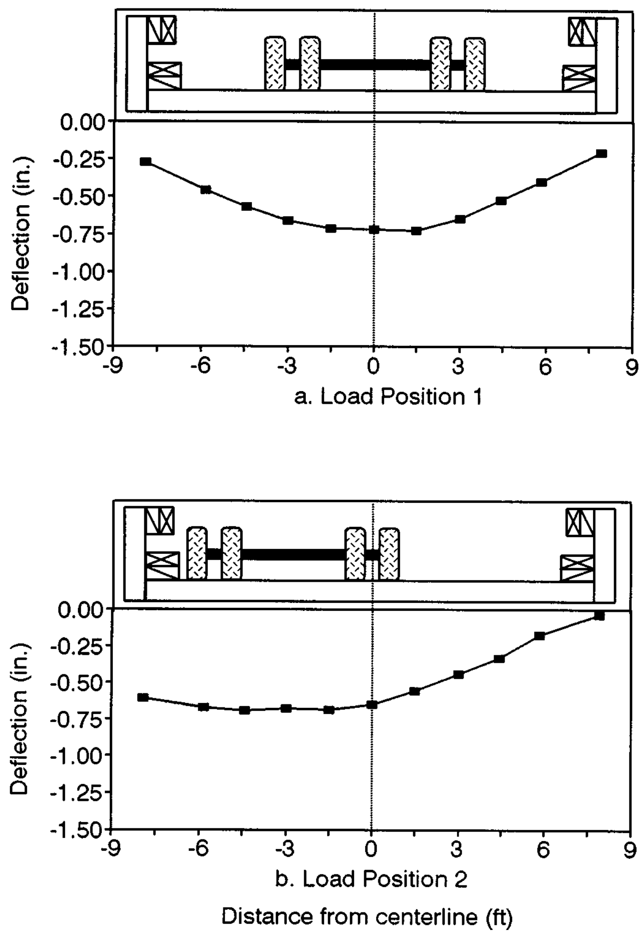

Figure 19—Transverse deflection for load test 1, measured at the bridge midspan (looking north). Bridge cross-sections and vehicle positions are shown to aid interpretation and are not to scale.

Load Test 1

Transverse deflection for load test 1 is shown in Figure 19. For each of the two load positions, deflection is typical of the orthotropic plate behavior of stress-laminated bridges (Ritter and others 1990). For load position 1 (Fig. 19a), the maximum measured deflection of 0.73 in. occurred between the wheel lines, 1.5 ft from the bridge centerline on the upstream (right) side. For load position 2 (Fig. 19b), the maximum measured deflection of 0.69 in. was also between the wheel lines, 1.5 ft from the bridge centerline on the downstream (left) side. For both load positions, the deflection of the three data points between the wheel lines (ranging from 0.71 to 0.73 in. for load position 1 and 0.68 to 0.69 in. for load position 2) was approximately the same. Thus, it is not possible to determine the exact maximum deflection location given the accuracy of the readings.

Load Test 2

Transverse deflection for load test 2 is shown in Figure 20. As with load test 1, deflection is typical for orthotropic plate behavior. For load position 1 (Fig. 20a), the maximum measured deflection of 0.56 in. occurred between the wheel lines, 1.5 ft from the bridge centerline on the upstream (right) side. For load position 2 (Fig. 20b), the maximum measured deflection of 0.59 in. was also between the wheel lines, 1.5 ft from the bridge centerline on the downstream (left) side. For load position 3 (Fig. 20c), the maximum measured deflection of 0.62 in. was under the upstream (right) wheel line. Given the improved accuracy of the measurement method compared with that used for load test 1, it is likely that the measured deflection accurately represents the actual bridge behavior.

Assuming uniform material properties and loading, the bridge deflections for load positions 2 and 3 should be a mirror image. Figure 21 shows the actual load position 2 deflection and the mirror image of load position 3 deflection. As shown, minor differences are indicated between the deflections, ranging from 0.03 to 0.05 in. at the bridge centerline and at the edges. The differences in deflection for the two load positions are most likely the result of a slight difference between the wheel-line loading caused by eccentric loading of the test vehicle.

Load Test Comparison

A comparison of load positions 1 and 2 deflection measurements for load tests 1 and 2 is shown in Figure 22. For both load positions, the measurements are similar, although load test 1 deflections exceed those of load test 2. Maximum measured deflections for both load tests occurred at the same location for the respective load positions and differed by 0.17 in. for load position 1 and 0.10 in. for load position 2. The difference in the deflections is attributable to the 6,650 lb additional rear-axle load for load test 1 and the change in longitudinal bridge stiffness caused by the difference in prestress levels at the time of load testing.

Analytical Evaluation

Comparisons of the measured load test results to the theoretical bridge response are shown in Figure 23. As shown, the theoretical bridge deflection is very close to that measured. Using the same load test analytical parameters, the theoretical deflection for AASHTO HS 20-44 truck loading is shown in Figure 24. Based on this analysis, the predicted maximum AASHTO HS 20-44 static deflection is 0.70 in. (or approximately 1/429 of the bridge span) for load test 1 and 0.63 in. (or approximately 1/476 of the bridge span) for load test 2. Assuming constant bridge properties, the same bridge deflection would be expected for the same loading. However, it is known that an increase in interlaminar compression in stress-laminated bridges with butt joints results in an increase in longitudinal bridge stiffness (Oliva and others 1990). The differences in the maximum deflection for the two load tests are attributable to a 13-percent increase in bridge stiffness at load test 2, as a result of the increased level of interlaminar compression of 109 lb/in^2 for load test 2 compared with 63 lb/in^2 for load test 1.

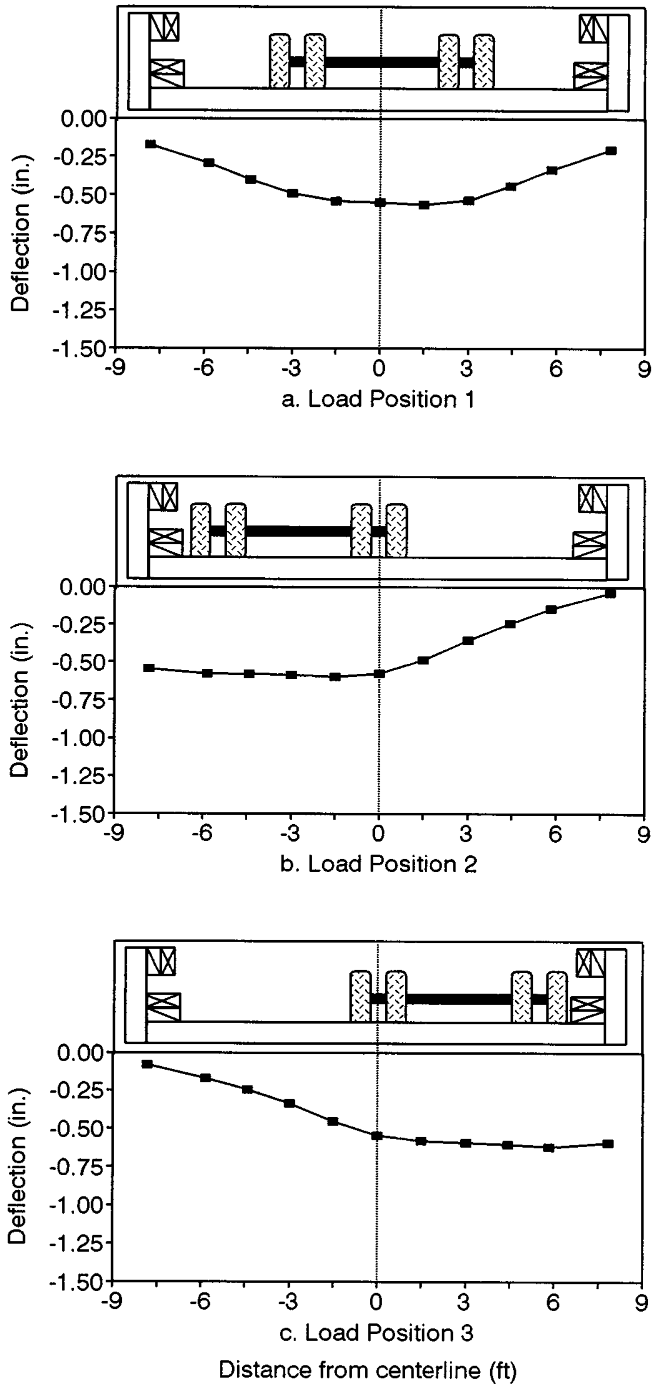

Figure 20—Transverse deflection for load test 2, measured at the bridge midspan (looking north). Bridge cross-sections and vehicle positions are shown to aid interpretation and are not to scale.

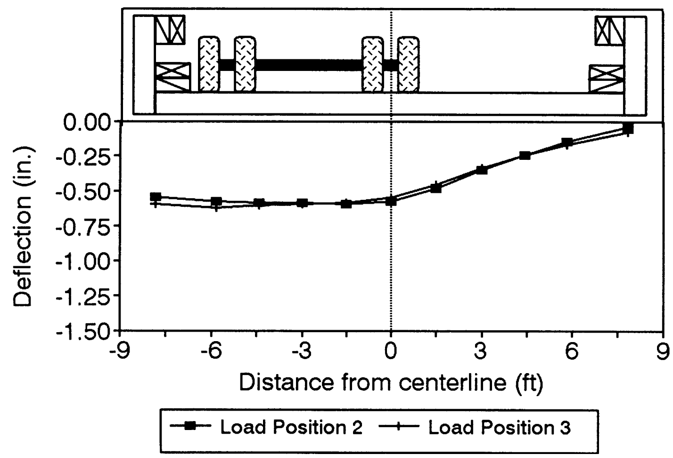

Figure 21—Comparison of load test 2 measured deflections, showing the actual deflection for load position 2 and the mirror image of load position 3 (looking north).

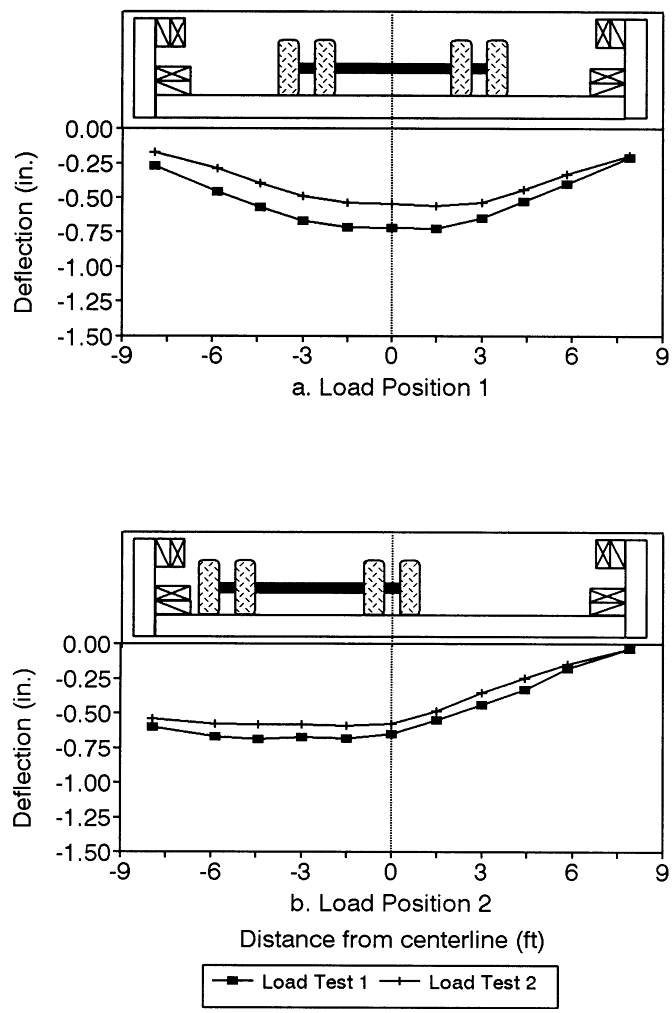

Figure 22—Comparison of the measured deflections for load tests 1 and 2 (looking north), for load positions 1 (a) and 2 (b).

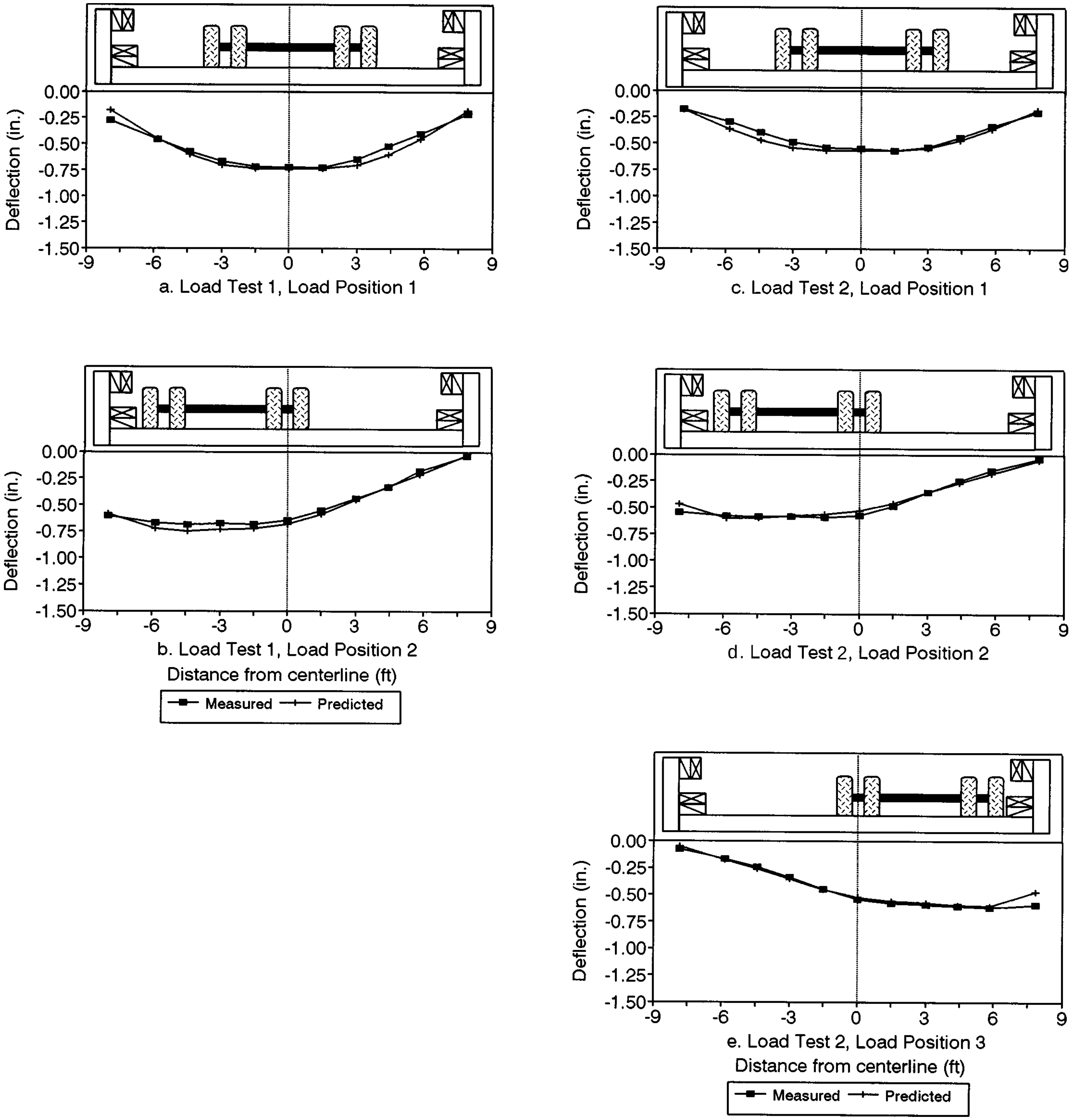

Figure 23—Comparison of the measured deflections for load tests 1 and 2, compared with the theoretical deflection using orthotropic plate analysis (looking north).

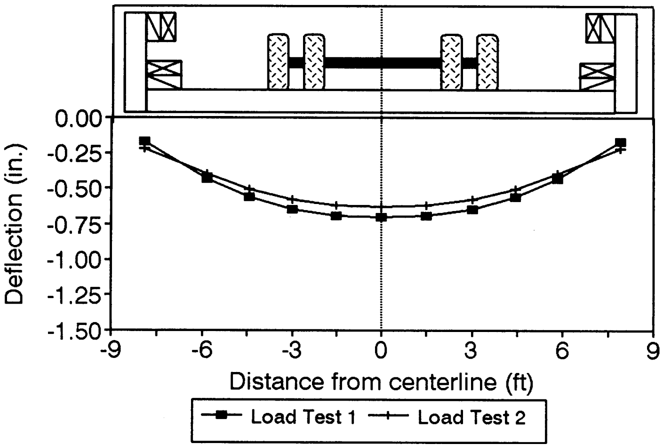

Figure 24—Maximum predicted deflection profile at the bridge midspan for AASHTO HS 20-44 truck loading.

Condition Assessment

Condition assessments of the Little Salmon Creek bridge indicated that structural and serviceability performance was acceptable. Inspection results for specific items follow.

Bridge Geometry

Bridge width measurements during the monitoring period indicated that the bridge width narrowed approximately 0.4 ft (Table 3). The change in bridge width is most likely the result of stress-relaxation in the oak laminations. Additional reductions in bridge width may be expected as stress relaxation continues and the lamination moisture content falls below the fiber saturation point.

Table 3—Bridge width measurements during the monitoring period

	Bridge Width (ft)	
Date	Abutments	Midspan
March 21, 1989	16.2	15.9
September 10, 1990	15.9	15.7
July 18, 1993 (after bar retensioning)	15.8	15.5

Wood Condition

Inspection of the 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 timber rail posts. This may have been prevented if an end grain sealer had been applied at the time of construction. In addition, the top of the bridge rail showed minor checking, but the depth of the checks did not appear to penetrate the preservative treatment envelope. Evidence did not indicate a loss in wood preservative, and preservative or solvent accumulations were not present on the wood surface.

Wearing Surface

The Little Salmon Creek bridge was designed and constructed without a wearing surface; hence, vehicles ride directly on the treated-wood deck. During each site visit, gravel and other debris from the unpaved approach roadway were present on the deck surface (Fig. 25). Deck wear from vehicle tracking and debris abrasion was noted in several locations, although the level of wear was minor and did not significantly reduce the deck section or extend below the preservative treatment. Over time, it is anticipated that deck wear will continue and could result in reduced deck section and accelerated deterioration as the preservative treatment envelope wears away.

Figure 25—Debris accumulations on the bridge's deck noted during condition assessment.

Stressing Bars and Hardware

The exposed steel stressing bars and hardware showed no visible signs of corrosion or other distress.

Bar Anchorage System

The stressing bar anchorage system has performed as designed with no significant signs of distress. There is no indication of the discrete plate anchorage crushing into the outside oak laminations and no measurable distortion in the bearing plate. A gradual deck compression deformation of 0.13 to 0.25 in. was noted in the outside laminations in the vicinity of the bearing plates. The deformation is most likely due to stress relaxation in the wood, which was more pronounced due to the high moisture content of the laminations.

Conclusions

After approximately 4 years inservice, the Little Salmon Creek bridge is exhibiting acceptable performance, although several serviceability deficiencies were noted. These deficiencies are primarily attributed to the high moisture content of the lumber laminations at the time of construction and throughout the monitoring period. Based on monitoring conducted since bridge construction, we make the following conclusions and observations:

- It is feasible to construct stress-laminated decks using Northern Red Oak lumber laminations.
- Prefabricating panels for stress-laminated decks and joining them at the construction site is a viable method of bridge construction. Assembling the panels at the construction site and lifting the entire superstructure into place with a small crane minimizes field work and traffic disruption and may be an economical alternative to field construction.
- The cost of materials, fabrication, and construction of the Little Salmon Creek bridge superstructure, including curbs and railings, was approximately $37/ft^2. Because this was the first bridge of its type built in the United States, the cost should decrease as more bridges are built and people become familiar with the bridge system and materials.
- The average moisture content in the outer 1 to 2 in. of the laminations of the Little Salmon Creek bridge decreased from 39 percent at the time of construction to 31 percent at the end of the monitoring period, but remains above the fiber saturation moisture content of 25 to 30 percent. It is anticipated that the moisture content will continue to decrease below the fiber saturation point, resulting in lamination shrinkage and bar force loss. For future bridges of this type, we recommend that the average moisture content of the lumber laminations not exceed 19 percent at the time of construction.
- During the monitoring period, the average bar force for the Little Salmon Creek bridge decreased from 60,000 lb (109 lb/in^2 interlaminar compression) to 28,000 lb (51 lb/in^2 interlaminar compression). The decline in bar force is greater than expected and is primarily attributed to stress relaxation in the lumber laminations caused by the high lamination moisture content.
- Vertical creep over the monitoring period resulted in a sag at the superstructure midspan of 2.5 in. along the downstream bridge edge and 2 in. along the upstream bridge edge. This is much greater than expected and is again attributed to the high lamination moisture content.
- Load testing and analyses indicate that the Little Salmon Creek bridge is performing as a linear elastic orthotropic plate when subjected to static truck loading. Based on an analytical comparison of load test results at different levels of interlaminar compression, the longitudinal bridge stiffness increased approximately 13 percent when the interlaminar compression increased from 63 to 109 lb/in^2. The maximum predicted bridge deflection as a result of AASHTO HS 20-44 static truck loading is estimated to be 0.70 in. (L/429) at 63 lb/in^2 interlaminar compression and 0.63 in. (L/476) at 109 lb/in^2 interlaminar compression.
- Visual inspections of the bridge indicate that the performance of wood and steel components is satisfactory. The exposed steel stressing bars and hardware showed no visible signs of corrosion or other distress, and the discrete plate bar anchorage is not distorted or crushing into the lumber laminations. The lack of a wearing surface has resulted in deck wear from vehicle tracking and debris abrasion, although the level of wear is minor and does not significantly reduce the deck section or extend below the preservative treatment. It is expected that wear will continue, and the placement of a watertight asphalt wearing surface is recommended to protect the deck.

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Appendix—Information Sheet

General

Name: Little Salmon Creek bridge

Location: Forest Road No. 145, Allegheny National Forest, Pennsylvania

Date of Construction: November 1988

Owner: Allegheny National Forest

Design Configuration

Structure Type: Stress-laminated deck with butt joints

Butt Joint Frequency: 1 in 4 laminations transverse with joints in adjacent laminations separated 4 ft longitudinally

Total Length (out-out): 26 ft

Skew: None

Number of Spans: 1

Span Lengths (center-to-center bearings): 25 ft

Width (out-out): 16 ft

Width (curb-curb): 14.5 ft

Number of Traffic Lanes: 1

Design Loading: AASHTO HS20–44

Wearing Surface Type: None

Material and Configuration

Timber:

Species: Northern Red Oak

Size (actual): 1-1/2 to 1-5/8 in. wide; 12 in. deep

Grade: Visually graded No. 2 and better

Moisture Condition: 39 percent average at installation at 1 to 2 in. depth

Preservative Treatment: Creosote

Stressing Bars:

Diameter: 1 in.

Number: 7

Design Force: 60,000 lb

Spacing: 46 in. average center-to-center beginning 18 in. from bridge ends

Type: High strength, steel thread bar with coarse right-hand thread, conforming to ASTM A722

Anchorage Type and Configuration:

Steel Plates: 12 by 9.25 by 1 in. bearing
5.5 by 3.25 by 1.25 in. anchor