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**Design and Field Performance of a  
Metal-Plate-Connected Wood Truss Bridge**

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Abstract

This paper describes an on-going study on the design and performance attributes of an experimental wood-truss bridge. This is believed to be the first roadway bridge application of metal-plate-connected wood trusses. Constructed in the Fall of 1992 on a rural Alabama road, the bridge comprises two spans: Span 1 is a bolt-laminated transverse deck supported by multi-truss girders and Span 2 is a stress-laminated truss system. A comprehensive monitoring program, initiated shortly after construction, is providing information on seasonal variations in lumber moisture content, stressing bar forces and overall bridge condition. This includes periodic static load testing. After one year, the monitoring program shows the bridge to be performing as expected.

Introduction

In many areas, the local timber supply is limited to relatively small diameter trees that can produce structural lumber of limited widths, often not beyond 8 inches (nominal). The wide lumber required for solid-sawn longitudinal decks is often available only at a premium price.

This paper describes the design and field performance of a metal-plate-connected (MPC) wood truss bridge in Tuscaloosa County, Alabama. The bridge is an innovative use of MPC wood trusses and is believed to be the first application of such components in roadway bridges. The bridge is 40 ft (12.2m) in length with a 28 ft (8.53m) curb-to-curb width, Figure 1. Two 20 ft (6.1m) spans are used and the structural elements are MPC wood trusses fabricated from chromated copper arsenate (CCA) treated Southern Pine 2x4 and 2x6 lumber. Span 1 utilizes a bolt-laminated transverse timber deck over

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multi-truss girders, and Span 2 consists of stress-laminated trusses which form the deck and transfer the load to the bridge substructure. This innovative use of dimension lumber in bridges is believed to result in several benefits over other types of bridges, one of which is the ability to use local timber resources.

The design is experimental but the information gained by an extensive monitoring program will be needed by the American Association of State Highway Transportation Officials in considering possible standards. This research is directly related to the development of a strategy for state transportation system infrastructure improvement and natural resource-based (forestry) economic development.

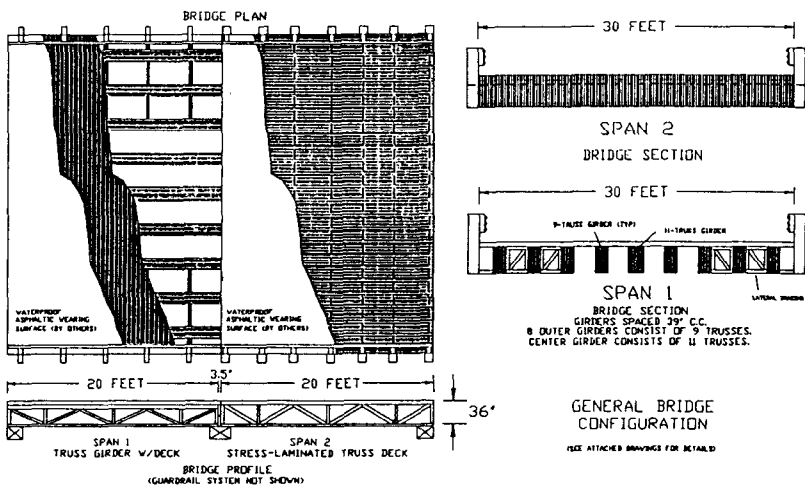


Figure 1. Plan view and cross section of bridge.

### Bridge Design

As with any innovative application of materials, there are several areas of concern that were considered in the design. For the girder span (span 1), these concerns include: 1) corrosion of the metal connector plates in exterior exposure conditions, 2) the effect of preservative treatments on tooth holding strength of the connector plates, 3) the potential for excessive shrinkage and swelling of the lumber due to the wide moisture content variation, possibly resulting in reduced tooth holding strength of the connector plates, and 4) the effect of cyclic loading on the plate strength, in both tooth holding and steel fracture failure modes. For the stress-laminated span (span 2), the suitability of prestressing for MPC trusses is an additional

concern to those mentioned for the girder span. Because previous studies involving stress-laminating have been limited to the use of sawn lumber (Ritter, 1990), there was concern for the potential of slippage between trusses due to plate-to-plate contact, rather than wood-to-wood contact.

Corrosion of the metal connector plates was addressed by utilizing a G90 galvanized coating and providing an impermeable membrane above the trusses. By inhibiting moisture infiltration and preventing frequent direct wetting of the plates, it is anticipated that corrosion will not be a concern.

It is not expected that preservative treatment will have any significant effect on tooth holding strength. Experience with plate tooth holding in wood treated with recent formulations of CCA preservative indicates no significant reduction occurs if the lumber is dry prior to plate embedment.

The potential for plate back-out due to lumber shrinkage and swelling is reduced by the use of an impermeable membrane above the trusses. This should prevent moisture infiltration into the trusses and keep moisture content levels in the 12-20 percent range. In addition, multiple-trusses are bolted together to form the girders and the stress-laminated trusses will also be in perpetual compression thus preventing the possibility of plate back-out.

Regarding suitability of metal-plate-connected trusses for prestressing, initial tests were conducted to verify assumptions and assure that adequate load-carrying capacity exists in the stress-laminated span. These tests indicated that adequate load transfer was easily achievable.

The bridge was designed for the HS20-44 standard truck loading, using the load provisions of the American Association of State Highway and Transportation Officials "Standard Specifications for Highway Bridges" (AASHTO, 1993). According to AASHTO, wood design must use the wheel loads with a load duration factor of 1.0, while steel design uses wheel loads increased by 30% for impact. Because these components are not specifically addressed by AASHTO, conservative assumptions were made regarding the distribution of the wheel loads. For the girder span (span 1), wheel loads were assumed to be distributed according to the provisions for nail-laminated decks on timber stringers, while the stress-laminated trusses (span 2) were designed assuming that the wheel load was not distributed beyond the tire width.

Tooth holding of plates is governed by wood failure, and thus should be subject to the same load duration adjustments as other wood stresses. However, for this design, a 30% reduction in tooth holding values was used to account for cyclic loading and the use of regalvanized plates. All tests to date indicate that cyclic loading and adequate regalvanizing do not reduce tooth holding design stresses below their normal levels, but the reduction was used for this bridge as testing is continuing for other factors, i.e. additional fatigue tests and exterior moisture cycling.

The trusses were designed using provisions of the Truss Plate Institute. Design

Specification (TPI, 1985). A series of designs were examined with the appropriate fraction of the wheel loads located at different locations along the bridge in order to find the maximum wood stresses and joint forces. The final truss design used the largest plates and lumber sizes obtained for wheel loads located at any location on the bridge.

### Field Performance

A three year monitoring plan has been established to track the field performance of the bridge. In December of 1992, approximately two months after the bridge was completed, the bridge was load-tested and load cells were installed on three of the seven stressing bars. Since that time, visits to the bridge are made twice a month to monitor the forces in the stressing bars, take moisture content readings, and perform visual inspections.

### Load Testing

Load tests involved the measurement of bridge deflections from an unloaded to loaded condition using several load positions. Two fully-loaded three-axle dump trucks were used as the test vehicles for this double lane bridge. Figure 2 shows the axle spacings and weights of the two trucks. Truck 405 had a gross vehicle weight of 90.54k (402.7kN) and truck 407 weighed 91.76k (408.2kN).

Maximum deflection was obtained with the center of the two rear axles placed at centerspan (front axles were off the bridge). In the transverse direction, 6 vehicle positions were used, 3 for centered loading and 3 for outside loading. For centered loading the truck wheel line nearest the bridge centerline was placed 2 ft (0.61m) from the bridge centerline. Positions 1 and 2 involved individual vehicle loads in each lane, while position 3 included both vehicles. For outside loading, the center of the outside wheel line was placed 2 ft (0.61m) from the bridge edge. Load positions 4 and 5 involved one vehicle in each lane while position 6 included both vehicles. The same procedure was used for both spans.

Deflection readings during load tests were taken at several points located across the bridge centerspan and across each quarter point. The method used to measure deflection utilized calibrated steel rules which were attached at each data point on the bridge underside and remained in place for the entire test procedure. Deflections were read with a surveyors level as the relative movement of the rule from the unloaded to loaded position.

Figure 3 shows the results for the span 1 and 2 under the centered loading with both trucks on the bridge (position 3). This is the most severe of the centered loading conditions. The transverse deflection across the centerline of the span is plotted. For span 1 the maximum deflection was 0.28 in (7.11mm) and occurred under the first girder truss to left of the centerline. For span 2, the stress-laminated span, the maximum deflection was 0.19 in (4.82 mm) and occurred 2 ft (.61m) to the right of centerline, under the heaviest vehicle wheel line.

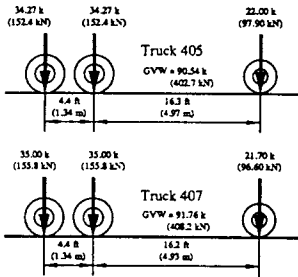


Figure 2. Load test vehicle configurations.

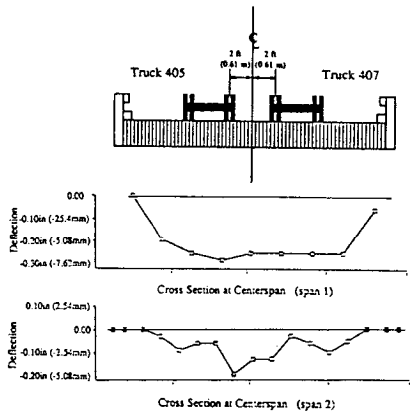


Figure 3. Load test results for centered positioning with both vehicles on the bridge.

### Bar Forces

For the stress-laminated span, calibrated load cells were installed between the anchorage and bearing plate of three of the seven stressing bars. The stressing bars are 5/8 in (15.88 mm) diameter high strength steel bars with an allowable load of 29,000 lbs (129.0kN). The bars had been restressed four times over a two month period prior to the installation of the load cells. Once installed, load cell readings were taken twice a month with a portable strain indicator. After approximately four months from the time the cells were installed, the stress was removed from the bars, a new zero balance for the load cells obtained, and the bars restressed. Figure 5 shows the bar forces versus time. As indicated in the figure, bar forces have dropped significantly. This is believed to be the result of two factors: gaps in the trusses caused by nails used to fasten the individual trusses into bundles for handling purposes; and small gaps under individual metal connector plates which have been gradually reduced under the transverse stress.

### Moisture Content Measurements

Moisture content readings have been taken using an electrical resistance meter at 10 locations in the bridge with raw readings in the 16%-22% percent range. These convert to an approximate range of 13%-19% when adjustments for temperature and CCA treatment effects are considered. Moisture content readings were calibrated to oven-dry samples and according to this data, meter readings average about 3% higher than those determined by the oven-dry method.

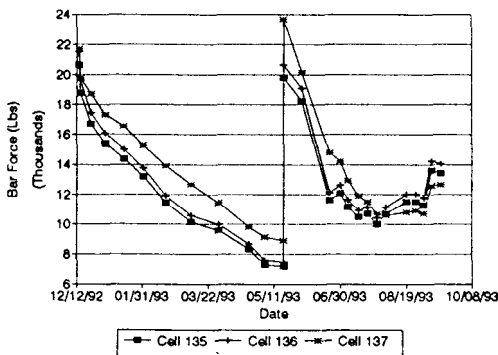


Figure 4. Bar force versus time.

### Condition Assessment

The general condition of the bridge was assessed at the time of installation, during the load testing, and approximately every three months thereafter. These assessments involved visual inspections, measurements, and photographic documentation of the bridge condition, specifically the condition of the asphalt wearing surface, stressing bars and anchorage systems, and the metal connector plates. Visual inspections have revealed no major problems although there are some minor problems associated with the stress-laminated span. The bulk of these problems are due to the use of a crowned pile cap which caused out-of-plane bending of the edge trusses resulting in uplift at the substructure supports. Modified design details, including the use of a flat pile cap and modified stressing bar positioning, should eliminate these problems in future bridges.

### Summary

This innovative MPC wood truss bridge has been in service for just over a year. Bar force loss has been substantial over time, but appears to be leveling off. The bridge, which will continue to be monitored over the next two years with load testing repeated at the conclusion of the monitoring program, has performed as expected in its first year of service.

### Appendix: References

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