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Timber Bridges in Southern Iowa

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Abstract

The state of Iowa is composed of 99 counties. These counties have limited funds for bridge rehabilitation on many rural and agricultural roadways. In recent years, several counties have looked to timber construction as a bridge replacement alternative. In southern Iowa, two counties are constructing stress-laminated timber bridges using eastern cottonwood, a locally abundant, underutilized species. The performance of three such bridges is presented.

Introduction

Approximately 35% of 575,000 highway bridges in the United States are currently in need of repair or replacement (USDA 1996). Many of these bridges are short-span crossings on rural roadways, ideally suited for wood construction. To encourage effective and efficient use of wood as a structural material for highway bridges, the U. S. Congress passed legislation known as the Timber Bridge Initiative (TBI) in 1988 to establish a national program. The research portion of the program was assigned to the USDA Forest Service, Forest Products Laboratory (FPL).

As a result of the TBI, numerous timber bridges have been constructed from species not previously used in structural applications. One such species is eastern cottonwood, overlooked because its strength and stiffness are less than typical structural species. Traditionally, cottonwood is used for lightweight containers, plywood core stock, and pulp. Because cottonwood is abundant, readily available, and the fastest growing tree in North America, it is potentially an economic alternative to traditional structural species, assuming the reduced strength and stiffness are addressed through design (Kennedy 1985).

The state of Iowa, where cottonwood is plentiful, is composed of 99 counties that have limited funds for bridge rehabilitation and replacement on primary rural and agricultural roadways. In recent years, several counties in Iowa have looked to timber construction as a bridge replacement option. Based on the success of the Cooper Creek bridge, the first cottonwood stress-laminated deck (Ritter et al. 1995), three more such bridges were constructed in Iowa during 1994. Since the

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use of cottonwood in stress-laminated decks is still relatively new, FPL was contacted to implement performance evaluation programs for each of the bridges.

The objective of the monitoring program is to evaluate bridge performance for a minimum of 2 years, beginning shortly after installation. Evaluation includes data collection and analysis relating to bridge behavior under static truck loading and structural performance. Results will be evaluated with those of other stress-laminated bridges to develop recommendations for improved design criteria.

Bridge Design

In 1994, three cottonwood stress-laminated bridges were constructed in southern Iowa: the Hibbsville and Dean bridges in Appanoose County and the Decatur bridge in Decatur County, Each is a simple span, approximately 7.3 m (24 ft) long, constructed with creosote-treated lumber (Fig. 1). Because available material did not extend the full length of the bridge, butt joints were employed (Fig. 2). Each bridge is unpaved and located on a low volume county road.

The stressing system for each bridge consists of six 25.4-mm- (l-in.-) diameter high strength steel bars, spaced 1.2 m (48 in.) on-center. The design bar force provides a uniform compressive stress of 689.5 kPa (100 lb/in^2) between the laminations.

The discrete plate bar anchorage systems are similar in design, although actual plate dimensions vary (Fig. 3). A unique anchorage system feature of the Dean and

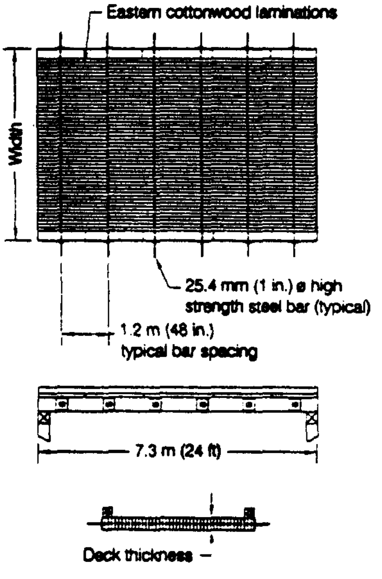

FIG. 1. Typical configuration for the eastern cottonwood stress-laminated bridges.

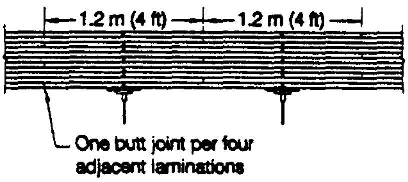

FIG. 2. Typical butt joint configuration.

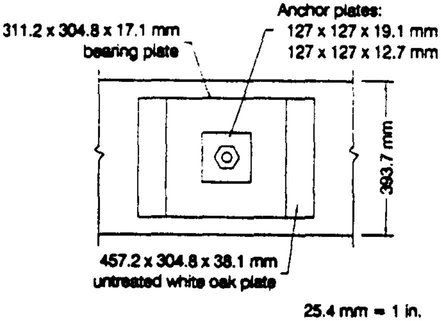

FIG. 3. Typical discrete plate anchorage system (Dean bridge). Plate sizes vary for each bridge.

TABLE 1. Distinct bridge features

Features	Hibbsville	Dean	Decatur
Width (m)	5.2 (17 ft)	7.0 (23 ft)	6.4 (21 ft)
Deck thickness (mm)	355.6 (14 in.)	393.7 (15.5 in.)	355.6 (14 in.)
Design bar force (kN)	298.9 (67,200 lb)	330.9 (74,400 lb)	298.9 (67,200 lb)
Wearing surface	none	Gravel	Gravel

Decatur bridges is an untreated white oak plate, employed to simulate the performance of full-length hardwood exterior laminations. Although many similarities exist between the bridges, each has several distinct features, which are summarized in Table 1.

Research Methods and Results

The evaluation program for the bridges required monitoring the moisture content, bar force, static load behavior, and general structural condition. The research methods utilized procedures and equipment previously developed (Ritter et al. 1991; Wacker and Ritter 1992). Results from 2 years of monitoring are summarized. Examples from the Decatur bridge are presented and are typical of the performance of the other bridges.

Moisture Content (MC). Changes in MC can cause dimensional changes in the deck, affecting the overall structural performance. The MC level cart also influence deck stiffness, creep, transverse stress relaxation, and anchorage system performance. The installation average lamination MC for the Decatur bridge was approximately 23% and exceeded the equilibrium MC, which is expected to average 18% to 20% (McCutcheon et al. 1986). Throughout the monitoring, the MC remained relatively stable, with 3% to 5% fluctuations resulting from seasonal climatic changes. One contributing factor to the continued high MC level was the absence of a watertight membrane over the surface of the deck. Water is allowed to contact the surface of the bridge, and the grovel wearing surface inhibits drying of the deck.

Bar Force. Interlaminar compression is critical to structural performance and was evaluated by monitoring the stressing bar force. The average bar force trend for the Decatur bridge is shown in Figure 4. At the start of monitoring, the bars were

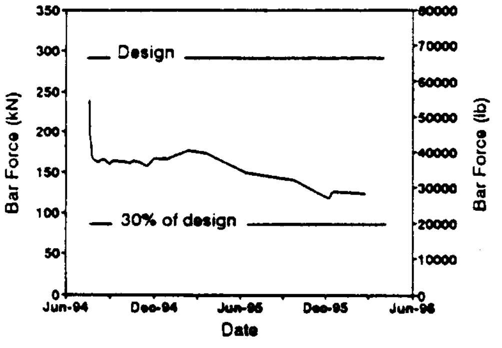

FIG. 4. Average trend in bar force of the Decatur bridge.

tensioned to approximately 239.8 kN (53,900 lb), or 80% of the design force. The force decreased to approximately 166.4 kN (37,400 lb), or 56% of the design force, within the first month of monitoring, at which time the rate of loss greatly decreased. The large initial bar force loss and subsequent slower force reduction are indicative of stress relaxation in the laminations, enhanced by high moisture levels. Because the global MC has not declined, force loss cannot be attributed to deck dimensional changes nor cart it be attributed to anchorage performance because crushing has not occurred.

Load Test Behavior. Static load test results are used to assess bridge performance. A load test was performed on each bridge at the beginning and end of the monitoring, In each case, fully loaded vehicles were positioned longitudinally with the two rear axles centered about the bridge midspan, and transversely, various load positions were used. Resulting deflections were measured along the midspan. Load test results indicate that the behavior of each bridge is typical of other stress-laminated bridges and within the linear elastic range under the applied loads.

Condition Assessment. The general condition of each bridge was assessed at the beginning and end of the monitoring and involved visual inspections, measurements, and photographic documentation. Items of specific interest include the bridge geometry and the condition of the timber deck, stressing bars, and anchorage system.

The wood components and anchorage systems are performing well. No exterior lamination crushing or measurable distortion of the steel bearing plates was detected, although slight bending of some of the white oak plates was noted. Ungalvanized steel components exhibited slight corrosion.

Inspection of the Dean bridge geometry revealed that the width was distorted. The north edge of the deck was approximately 215.9 mm (8.5 in.) narrower in width at midspan than at abutments. Most likely this is the result of the layout of laminations that varied in width as much as 12.7 mm (0.5 in.) at the butt joints. Using even-width laminations would prevent such behavior.

Along the west abutment of the Decatur bridge, it was noted that both comers curled upward approximately 38.1 mm (1.5 in.) away from the abutment (Fig. 5). At both edges, the displacement of the deck away from the abutment gradually reduced until at 457.2 mm (18 in.) from each deck edge, the deck made contact with the abutment. This condition has not altered throughout the monitoring and is thought to be a result of deck construction that occurred adjacent to the bridge site.

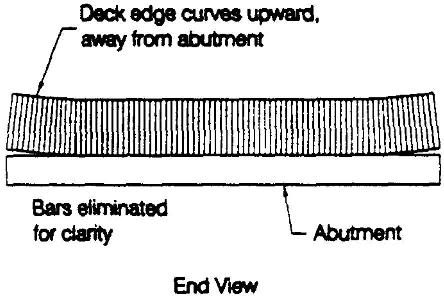

FIG. 5. Deck distortion at west abutment.

Conclusions

The Hibbsville, Dean, and Decatur bridges are performing well and are expected to provide many years of acceptable service. Their success demonstrates the feasibility and practicality of constructing stress-laminated decks using eastern cottonwood, a species not typically used in structural applications. Such bridges have the potential to be an economic bridge replacement alternative in Iowa because a native natural resource is utilized and the system is easily implemented by local labor forces.

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