The Use of Eastern Cottonwood for Stress-Laminated Sawn Lumber Bridges in Iowa

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Historical Reference

1988 - Timber Bridge Initiative

*Legislation passed by Congress.*

Objective: To establish a national timber bridge program to encourage the effective and efficient use 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. The Forest Products Laboratory was responsible for the research portion of the TBI.
Historical Reference cont.

As part of this research program, FPL assumed a lead role in assisting local governments in evaluating the field performance of demonstration bridges, many of which used design innovations or materials that had not been previously evaluated.
Historical Reference cont.

Through such assistance, FPL collected, analyzed and distributed information on the field performance of timber bridges, thereby providing a basis for validating or revising design criteria and subsequently improving efficiency and economy in bridge design, fabrication, and construction.
Case Study

This case study presents information pertaining to 3 stress-laminated sawn lumber timber bridges constructed from Eastern Cottonwood in Iowa.
Iowa

- 99 counties
- extensive rural road network
- many short span crossings
- limited funds
- ideal situation for wood construction by local work crews
Eastern Cottonwood

- plentiful in Iowa
- lightweight containers
- plywood core stock
- pulp
Iowa Bridges

Due to the success of the Cooper Creek Bridge, 3 additional bridges were constructed.

*The Chariton Valley Resource Conservation and Development Council provided the lamination material.*

- 2 in Appanoose County
- 1 in Decatur County
Bridge Locations
# Design Configuration

<table>
<thead>
<tr>
<th>Location</th>
<th>Width</th>
<th>Length</th>
<th>Deck Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean</td>
<td>23 ft. (7m)</td>
<td>24 ft. (7.3m)</td>
<td>15 in. (381mm)</td>
</tr>
<tr>
<td>Hibbsville</td>
<td>17 ft. (5.2m)</td>
<td>24 ft. (7.3m)</td>
<td>14 in. (356mm)</td>
</tr>
<tr>
<td>Decatur</td>
<td>21 ft (6.4m)</td>
<td>24 ft. (7.3m)</td>
<td>14 in. (356mm)</td>
</tr>
</tbody>
</table>

Design Loading: AASHTO HS20-44  
Butt joint configuration: 1 in 4 at 4 ft. o.c.
Typical Bridge Plan

1.2 m (4 ft) bar spacing

Eastern cottonwood laminations

25.4 mm (1 in.) Ø high strength steel bar (typical)
Typical Bridge Elevation/Section
Typical Bridge Butt Joint Configuration

One butt joint per four adjacent laminations
Design Configuration

<table>
<thead>
<tr>
<th>City</th>
<th>Wearing Surface</th>
<th>Design Bar Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean</td>
<td>gravel</td>
<td>72k (320 kN)</td>
</tr>
<tr>
<td>Hibbsville</td>
<td>none</td>
<td>67.2 k (299 kN)</td>
</tr>
<tr>
<td>Decatur</td>
<td>gravel</td>
<td>67.2 k (299 kN)</td>
</tr>
</tbody>
</table>

Design Interlaminar Compressive Stress: 100 psi
Preservative Treatment: Creosote
Design Configuration

Anchorage System

- Six 1-in. (25.4mm) dia. high strength steel bars at 4 ft. (1.2m) o.c.
- Galvanized bars and anchor nuts
- Steel bearing and anchor plates
- White oak anchor plates *(Dean and Decatur)*
Dean Anchorage Configuration

- 311 x 305 x 19 mm (12.25 x 12 x 0.75 in.) bearing plate
- 2 anchor plates:
  - 127 x 127 x 19 mm
  - 127 x 127 x 13 mm (5 x 5 x 0.75 in.
  - 5 x 5 x 0.5 in.)
- 457 x 305 x 38 mm (18 x 12 x 1.5 in.) untreated white oak plate
- 381 mm (15 in.)
Hibbsville Anchorage Configuration

- Bearing plate: 254 x 254 x 19 mm (10 x 10 x 0.75 in.)
- Anchor plate: 152 x 152 x 19 mm (6 x 6 x 0.75 in.)
- Bearing plate: 610 x 305 x 19 mm (24 x 12 x 0.75 in.)
- Height: 356 mm (14 in.)
Decatur Anchorage Configuration

- **Bearing Plate**: 254 x 254 x 19 mm (10 x 10 x 0.75 in.)
- **Anchor Plate**: 127 x 127 x 19 mm (5 x 5 x 0.75 in.)
- **Untreated White Oak Plate**: 457 x 311 x 44 mm (18 x 12.25 x 1.75 in.)

Dimensions:
- 356 mm (14 in.)
## Construction

<table>
<thead>
<tr>
<th>Substructure</th>
<th>Date Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean</td>
<td>October 1993</td>
</tr>
<tr>
<td>Concrete abutments and wingwalls</td>
<td></td>
</tr>
<tr>
<td>Hibbsville</td>
<td>January 1994</td>
</tr>
<tr>
<td>Timber piling with backwall planks and timber pile caps</td>
<td></td>
</tr>
<tr>
<td>Decatur</td>
<td>June 1994</td>
</tr>
<tr>
<td>Timber piling with backwall planks and steel I-beam pile caps</td>
<td></td>
</tr>
</tbody>
</table>

All bridges were built adjacent to sight and lifted or skidded into place.
Hibbsville
Decatur
Evaluation

To evaluate the structural performance of these bridges, the Chariton Valley RC&D officials contacted FPL for assistance. As a result the bridges were included in the FPL/FHWA timber bridge monitoring program. Through mutual agreement, a bridge monitoring plan was developed and implemented.
Evaluation Methodology

2 year time period
- Moisture Content
- Bar Force
- Vertical Creep
- Load Test Behavior
- Condition Assessment
Moisture Content

Measured at beginning and end of monitoring period and on a bi-monthly basis for Hibbsville.

<table>
<thead>
<tr>
<th>Location</th>
<th>Beginning</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Hibbsville</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Decatur</td>
<td>21%</td>
<td>26%</td>
</tr>
</tbody>
</table>

2 to 3% fluctuations throughout monitoring
Moisture Content

The primary contributing factor to the continued high moisture content was the absence of a watertight membrane over the surface of the deck. The gravel wearing surfaces inhibit drying of the deck surface.
Hibbsville
Bar Force – Dean
Bar Force – Hibbsville

![Graph showing force over time from March 1994 to August 1996 with a peak of 276 kPa (40 lb/in²) and a design line at a higher force level.](image)
Bar Force – Decatur

The diagram shows the force (kN) over time from March 1994 to August 1996. The force drops sharply in October 1994 and remains below the design level of 276 kPa (40 lb/in²) until January 1996. A significant increase is observed in August 1996.
The majority of the bar force loss is attributed to stress relaxation of the lumber laminations, augmented by the high moisture content of the laminations.
Vertical Creep

<table>
<thead>
<tr>
<th>Location</th>
<th>Beginning</th>
<th>End</th>
<th>Vertical Creep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean</td>
<td>unknown</td>
<td>-22 mm (-0.875 in.)</td>
<td>unknown</td>
</tr>
<tr>
<td>Hibbsville - average</td>
<td>+41mm (+1.625 in.)</td>
<td>-38mm (-1.5 in.)</td>
<td>79mm (3.125 in.)</td>
</tr>
<tr>
<td>Decatur - s. edge</td>
<td>+38mm (+1.5 in.)</td>
<td>+38mm (+1.5 in.)</td>
<td>none</td>
</tr>
</tbody>
</table>

Vertical creep was influenced by high moisture content of laminations.
Load Test Setup
Load Test Behavior

- Two static load tests were conducted at each bridge.
- Deflections were measured at midspan of bridge.
- Deflections were typical of orthotropic plate behavior.
Dean
Load Test 1

Hibbsville

Distance from centerline (m)

Max. deflection = 8.5 mm

Max. deflection = 9.6 mm

Max. deflection = 6.7 mm

Measured

Theoretical
Decatur
Dean Comparison

Shows actual deflection of load position 1 and mirror image of load position 2.
Hibbsville Comparison

Shows actual deflection of load position 2 and mirror image of load position 3.
Decatur Comparison

Shows actual deflection of load position 1 and mirror image of load position 2.
Decatur Comparison

Shows sum of load positions 1 and 2 and load position 3.
Analytical Conclusions

- Bridge decks act as orthotropic plates
- Increase in interlaminar compression results in an increase in stiffness of the deck
- Theoretical deflections are generally similar to those measured
Analytical Conclusions

Assuming uniform material properties, proper vehicle placement and linear elastic bridge behavior:
Analytical Conclusions

- Deflections resulting from a single test vehicle placed in symmetrical load positions should be a mirror image.
- Summation of deflections resulting from 2 separately applied truck loads should equal the deflection of both trucks applied simultaneously.
Condition Assessment

Dean Bridge Geometry

at LT1 8.5 inches narrower at midspan of north edge

Attributed to layout of laminations that varied in width as much as 0.5 inches
Condition Assessment

Dean and Decatur Bearing Condition
Unchanged throughout monitoring period.
Likely result of constructing deck on uneven temp. supports
Condition Assessment

- Anchorage system performing as designed.
- Crushing of plates into outer lamination negligible.
- No distortion visible.
- Corrosion of plates minimal because roads are unsalted.
Condition Assessment

- White oak plates will eventually deteriorate, negatively affecting the bar force.
Conclusions

- Bars for each bridge have been re-tensioned at least once since the time of the 2nd load test.
- County officials report bridges are performing well with no problems.