Use of Red Pine for Stress-Laminated Glulam Bridges in Wisconsin

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National Wood In Transportation

• Established 1988 by Congress and administered by the U.S. Forest Service

• Program Components:
  – Demonstration Timber Bridges
  – Research
  – Technology Transfer & Information Management
  – Rural Revitalization

• Main Emphasis Areas
  – Underutilized, locally-available wood species
  – Innovative material and bridge designs
What is a Stress-Laminated Bridge?

- Slab-type bridge deck
- Sawn lumber, glulam, or structural composite lumber (SCL)
- No mechanical fasteners or glue between adjacent lams
- High-strength steel bars
- Butt joints permitted
- Improved wheel load distribution
- Innovative superstructure design
Wisconsin Lumber Species

- *Pinus resinosa*
- Strength properties
- CCC plantations
- Good treatability
Red Pine as a Bridge Material

• Technical Obstacles
  – Design values for WI red pine lumber
  – Lumber sizes limited availability
  – Not recognized by AITC for glulam manufacturing
  – Not recognized by AWPA for pressure-treatment

• Development of glulam beam layups
Advantages of Glulam for Bridges

• Utilization of small-diameter materials
• Longer span capabilities
• Deeper member sections
• Low quality material in low stress zones
• Conserve high quality material
• Dry moisture content at installation
Teal River Bridge - Description

- Double-lane bridge
  - Simple span
  - 32.5 ft long
  - 24 ft wide
  - HS20 loading
  - Penta treatment
  - 1” dia. steel bars @ 44in.
  - No butt joints
  - Red Oak glulam at edge lams
Teal River Bridge – Beam Layup

13-3/4 in.

3-1/8 in.

No.2 Dense
No.2 Dense
No.2
No.2
No.2
No.2
No.2
No.2 Dense
No.1 Dense

Southern Pine
Southern Pine

Combination of Pine Species
Visual Grading Techniques

Beam Design
$F_b = 2,000 \text{ lb/in.}^2$
$E = 1,600,000 \text{ lb/in.}^2$
Development of Red Pine Glulam

- E-rating of individual lams (by grade) at plant
  - dynaMOE and E-computer
- Stiffness testing of fabricated beams
  - dynaMOE and static beam deflection
Development of Red Pine Glulam

- Verifying beam design at the Teal River site
Teal River Bridge – Construction
Teal River Bridge – Construction
Teal River Bridge – Field Monitoring

• 2-year period after construction
  – Moisture content
  – Stressing bar force
  – Static load testing
  – General condition
Teal River - Moisture Content Trend
Teal River – Bar Force Trend

![Graph showing Teal River Bar Force Trend]

- 100% Design Level
- 40% Design Level
Teal River – Current Condition

- After 20 yrs of service
Pine River Bridge

• Double-lane bridge
  – 3-span continuous
  – 90 ft long
  – 38 ft wide
  – HS20 loading
  – Penta treatment
  – 1” dia. steel bars @ 40 in.
  – No butt joints
  – Red Oak glulam at edge lams
Pine River Bridge – Beam Layup

Beam Design
\[ E = 1,600,000 \text{ lb/in.}^2 \]

Visual & Mechanical Grading Techniques

All Red Pine

Mechanically Graded

Visually Graded

13-1/2 in.

3 – 9 in. width

1.8 E

1.6 E

1.4 E

1.4 E

1.4 E

1.4 E

1.4 E

1.6 E

1.8 E
## Lumber Stiffness – Flatwise Vibration

### 2 x 8 in. Nominal Red Pine

<table>
<thead>
<tr>
<th>Lamination Grade</th>
<th>No. Tested</th>
<th>Average</th>
<th>Coefficient of Variation</th>
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<tbody>
<tr>
<td>1.8 MOE bottom</td>
<td>49</td>
<td>1.66</td>
<td>16.7%</td>
</tr>
<tr>
<td>1.8 MOE top^b</td>
<td>30</td>
<td>1.84</td>
<td>12.1%</td>
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<tr>
<td>1.6 MOE</td>
<td>24</td>
<td>1.35</td>
<td>13.9%</td>
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<tr>
<td>No. 2</td>
<td>7</td>
<td>1.10</td>
<td>----</td>
</tr>
</tbody>
</table>

Modulus of Elasticity, MOE (x 10^6 lb/in²)
# Beam Stiffness – Static Deflection

## 13-1/2 in. deep Glulam Beams

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>MOE (x10^6 lb/in²)</th>
<th>Beam No.</th>
<th>MOE (x10^6 lb/in²)</th>
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<tbody>
<tr>
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<tr>
<td>13</td>
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<td>30</td>
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<td>1.51</td>
<td>6</td>
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<tr>
<td>5</td>
<td>1.52</td>
<td>5</td>
<td>1.28</td>
</tr>
<tr>
<td>22</td>
<td>1.53</td>
<td>1</td>
<td>1.31</td>
</tr>
<tr>
<td>7</td>
<td>1.54</td>
<td>4</td>
<td>1.35</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>1.48</strong></td>
<td><strong>Average</strong></td>
<td><strong>1.23</strong></td>
</tr>
<tr>
<td><strong>C.O.V.</strong></td>
<td><strong>4.3%</strong></td>
<td><strong>C.O.V.</strong></td>
<td><strong>6.9%</strong></td>
</tr>
</tbody>
</table>
Pine River Bridge – Construction
Pine River Bridge – Construction
Pine River Bridge

- Field Monitoring Study
  - 5 year monitoring
  - Moisture content
  - Stressing bar force
  - Deck temperatures
  - Static load testing
  - Overall condition

- Datalogger utilized
Pine River – Moisture Trend
Pine River – Bar Force Trend
Pine River – Static Load Test
Pine River – Current Condition

- After 18 yrs of service
Red Pine Bridges (MI L. Peninsula)
Summary

• The former National Wood In Transportation Program facilitated the development of Red pine as a structural material.

• These two bridges were key in demonstrating the feasibility and potential for utilizing red pine for highway bridge applications.

• Additional glulam bridges have since utilized Red pine lumber and other small diameter species.

• Current condition of bridges is satisfactory after 20 years.
Acknowledgements

• Financial Support and Guidance
  – National Wood In Transportation Program
  – Federal Highway Administration
  – North Twenty RC&D

• Glulam Development → Russ Moody (FPL retired)

• Design Assistance → Westbrook Engineers, Chequamegon NF

• Field Data Acquisition → FPL Engineering Mechanics Laboratory

• Field Monitoring → Lola Hislop, Paula Hilbrich Lee, James Kainz

• Bridge Owners → Richland Center, Sawyer County

• Glulam Supplier → Sentinel Structures, Peshtigo, WI
Questions?