INSPECTION AND REHABILITATION DESIGN FOR PALOS BRIDGE

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America’s covered bridges are one of the nation’s most treasured architectural achievements.

Popular in the late 1800s, covered bridges served two purposes: their barn-like appearance made it easier to transport cattle across them; and builders discovered that protecting a bridge’s underpinnings with a roof meant the bridge could stand for seventy to eighty years, as opposed to an uncovered bridge’s lifespan of ten to fifteen years.

Palos Bridge is one of the five historical covered timber bridge in Ohio (by FHWA?)

Location: Township Rd. 347, spanning Sunday Creek in Athens County, Ohio

Directions from the City of Athens: Take Route 33 north toward Columbus, exiting at Routes 550/13. Take Route 13 north through Glouster. Turn right on Twp. Road 347/Red Rock Road.
PALOS BRIDGE
INSPECTION - Public Safety and Confidence

- To evaluate structural configuration and integrity; some of the vertical tension rods were found loose; large deflection of the bearing section of one end support was identified; No immediate danger of catastrophic failure.

- To establish a reasonable assumption for load rating analysis; as if the bridge was performing a wood truss structure?

- Two simple span steel stringer bridge would be appropriate to load rating analysis.

- Field measurement of member dimensions.
INSPECTION - Accurate Structure Records
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LOAD RATING - Assessing Structure Needs
The king post timber truss does not perform for the Palos Bridge at present (after rehabilitation repair through post-tensioning).

Load rating software Bars-PC not applied.

By hand calculations with AASHTO Load Factor Design method.

Steel yield strength = 36 ksi

Assumptions

- stringer beam simple span 1 L=29.6 ft
- stringer beam simple span 2 L=34.6 ft
- stringer beam cantilever span supporting one floor beam
- simple support steel cap beam
### LOAD RATING - Assessing Structure Needs

- **Member size**

  The measured structural member dimensions \( \rightarrow \) matched member size

<table>
<thead>
<tr>
<th>Stringers</th>
<th>bf (in.)</th>
<th>tf (in.)</th>
<th>d (in.)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span 1</td>
<td>8.25</td>
<td>0.5</td>
<td>20.75</td>
<td>W21x55</td>
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<tr>
<td>Span 2</td>
<td>7.125</td>
<td>0.688</td>
<td>16.375</td>
<td>W16x57</td>
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<tr>
<td>Cantilever</td>
<td>9.0</td>
<td>0.563</td>
<td>23.75</td>
<td>W24x68</td>
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<tr>
<td>Cap Beam</td>
<td>8.5</td>
<td>0.375</td>
<td>20.75</td>
<td>S20x96</td>
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<tr>
<td>End Beam</td>
<td>8.0</td>
<td>0.5</td>
<td>6.75</td>
<td>W6x25</td>
</tr>
</tbody>
</table>
LOAD RATING - Assessing Structure Needs

- Loading
  - Dead load: self weight, floor beams, wood stringers and riding board; wood truss, roof and siding not included.
  - Live load: AASHTO H15.
  - Loading conditions: for maximum moment and maximum shear, respectively; combination effects not analyzed.
Two scenarios

Scenario 1: un-braced for stringer compression flange buckling

Scenario 2: full braced for stringer compression flange buckling

AASHTO 10.21 Lateral Bracing: The need for lateral bracing shall be investigated; flanges attached to concrete decks or other decks of comparable rigidity will not require lateral bracing.

AASHTO 10.48 for symmetrical beams was followed for stringer capacity assessment.
LOAD RATING - Assessing Structure Needs

- Calculation for Span 1 Moment Capacity (AASHTO 10.48.1)
- The section was checked as un-braced compact
- $I_{yc} = 24.5 \text{ in}^4$, $I_y = 48.4 \text{ in}^3$, $I_{yc}/I_y = 0.506$, $L_b = 355.2 \text{ in}$, $J = 1.045$, $C_b = 1.0$, $M_r = 135.3 \text{ k-ft}$, $R_b = 1.0$, $M_u = M_r R_b = 135.3 \text{ k-ft}$
LOAD RATING - Assessing Structure Needs

- Calculation for Span 1 Moment Capacity under the assumption that the *section is braced*.

- \( S_x = 110 \text{ in}^3 \), \( F_y = 36 \text{ ksi} \), \( M_u = F_y S_x = 330 \text{ k-ft} \)
**LOAD RATING - Assessing Structure Needs**

- **Un-braced**

<table>
<thead>
<tr>
<th></th>
<th>Inv.</th>
<th>Load</th>
<th>Ope.</th>
<th>Load</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Ton)</td>
<td>(Ton)</td>
<td>(Ton)</td>
<td>(Ton)</td>
</tr>
<tr>
<td>Member</td>
<td>M</td>
<td>S</td>
<td>M</td>
<td>S</td>
</tr>
<tr>
<td>Span 1 Stringer</td>
<td>4.5</td>
<td>51</td>
<td>7.5</td>
<td>84</td>
</tr>
<tr>
<td>Span 2 Stringer</td>
<td>0.9</td>
<td>43.5</td>
<td>1.5</td>
<td>72</td>
</tr>
<tr>
<td>Cantilever</td>
<td>106.5</td>
<td>76.5</td>
<td>177.9</td>
<td>127.5</td>
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<tr>
<td>End Beam</td>
<td>15.45</td>
<td>10.7</td>
<td>25.7</td>
<td>17.9</td>
</tr>
<tr>
<td>Pier Cap</td>
<td>17.85</td>
<td>91.5</td>
<td>299</td>
<td>150</td>
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</table>
LOAD RATING - Assessing Structure Needs

- Braced

<table>
<thead>
<tr>
<th></th>
<th>Inventory Moment (Ton)</th>
<th>Load Shear (Ton)</th>
<th>Operating Moment (Ton)</th>
<th>Load Shear (Ton)</th>
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<tbody>
<tr>
<td>Member</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span 1 Stringer</td>
<td>15.3</td>
<td>51</td>
<td>25.5</td>
<td>84</td>
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<tr>
<td>Span 2 Stringer</td>
<td>9.5</td>
<td>43.5</td>
<td>15.9</td>
<td>72</td>
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<tr>
<td>Cantilever</td>
<td>138</td>
<td>76.5</td>
<td>229.5</td>
<td>127.5</td>
</tr>
<tr>
<td>End Beam</td>
<td>15.5</td>
<td>10.7</td>
<td>25.7</td>
<td>17.9</td>
</tr>
<tr>
<td>Pier Cap</td>
<td>40.5</td>
<td>91.5</td>
<td>67.5</td>
<td>150</td>
</tr>
</tbody>
</table>
To Ensure Safety and Public Confidence

- Tip deflection of the end beam bearing section: 0.09 in. under dead load and 0.22 under H15 live load.

- Possible cause of the observed deflection (slide No. 10): by construction handling

- Recommended operating live load capacity: H3 or 3 tons for posting.
REHABILITATION DESGN: Protecting Public Investment

- Design for Spacing of Lateral Bracing (AASHTO 10.48.2)
- \( L_b \leq 9.3 \text{ ft for Span 1} \)
Design for Spacing of Lateral Bracing (AASHTO 10.48.2)

- $L_b \leq 14.7$ ft for span 2
REHABILITATION DESGN: Protecting Public Investment

- Span 1: Floor Beam Locations for Bracing

<table>
<thead>
<tr>
<th>Beam Location</th>
<th>Designed $L_b$</th>
<th>Required $L_b$</th>
<th>$Mr/Mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{51} - FB_6$</td>
<td>$10.5' - 1.3' = 9.2'$</td>
<td>$9.3'$</td>
<td>1.0</td>
</tr>
<tr>
<td>$L_{FB_6 - FB_8}$</td>
<td>$7.0'$</td>
<td>$9.3'$</td>
<td>1.0</td>
</tr>
<tr>
<td>$L_{FB_8 - FB_{10}}$</td>
<td>$7.0'$</td>
<td>$9.3'$</td>
<td>1.0</td>
</tr>
<tr>
<td>$L_{FB_{10} - 5_2}$</td>
<td>$6.4'$</td>
<td>$9.3'$</td>
<td>1.0</td>
</tr>
</tbody>
</table>
REHABILITATION DESGN: Protecting Public Investment

- Span 2: Floor Beam Locations for Bracing
**REHABILITATION DESGN: Protecting Public Investment**

- **Design for Lateral Bracing**
  - (1) Direct bracing through proper floor system attachment
  - (2) Cost effective and construction simplification
  - (3) Lateral Bracing Force = 2% of Compressive Force in the Flange or 3 kips
REHABILITATION DESGN: Protecting Public Investment
The king post timber truss does not perform for the historical Palos Bridge after rehabilitation through post-tensioned rods.

The steel stringers (in place for rehabilitation construction) assumes some live load capacity,

A post of 3 tons live load was suggested to replace the on-site post of 10 tons.

The large tip deflection of the end beam was introduced, probably, during the previous rehabilitation construction but did present first sight integrity concern.

The steel stringers capacity was to be improved by lateral bracing through six floor beams.

The lateral braces were designed.