Efficacy of Laboratory pre-tensioned prism specimens in predicting transfer lengths of real concrete railroad ties

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Presentation Overview

- Background
- Transfer Length (TL) definition
- Parameters that influence TL
- Test set-up and TL measurements
  - Lab phase
  - Plant phase
- Transfer length results
- Conclusions
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Prestressed Concrete Railroad Ties

- Withstand high impact loads
- Provides more rigidity for the track which leads to safety
- More service life
- Environmentally friendly

Source: http://www.lightrail-hartbeat.com
Railroad Ties
Railroad Ties

Isometric View of a Tie

Bottom View of a Tie

Top View of a Tie

Side View of a Tie
(Total Length of the Tie is 102-Inches)
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Prestressing and Transfer Length

- Prior tensioning of steel reinforcement is called prestressing.
- Prestressing force is transferred to the concrete, once the concrete reaches strength.
Prestressing and Transfer Length

- Typically (20) 5.32 mm wires are used to produce railroad ties.
- Some tie manufacturers use 7-wire and 3-wire strands.
Prestressing and Transfer Length

• The distance required to transfer the entire prestressing force into the member is called Transfer Length (TL)

• Maximum performance of a tie can be utilized when TL is shorter than rail seat location

Source: Rob Murphy
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Parameters That Influence TL

- Indentation and type Reinforcement
- Release Strength the Concrete
- Consistency of the Concrete Mix (Slump)
Present Study involved 12 wires and three strands
WA (smooth)    WB (chevron)    WC (spiral)    WD (chevron)    WE (spiral)    WF (diamond)

WG (chevron)    WH (chevron)    WI (chevron)    WJ (chevron)    WL (2 DOT)
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Transfer-Length Prism Test Matrix-Lab phase

- A total 45 prisms are cast in this study

<table>
<thead>
<tr>
<th>Reinforcement samples</th>
<th>Slump (inches)</th>
<th>Release strength (psi)</th>
<th># of Prisms per group</th>
<th>Total # of Prisms</th>
<th>Total # of TL measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests on 15 groups</td>
<td>6</td>
<td>4500</td>
<td>3</td>
<td>45</td>
<td>90</td>
</tr>
</tbody>
</table>
Experimental Set-Up

• A smaller cross-sections were chosen with 69” length to replicate the original Tie.
Prestressing Frame
<table>
<thead>
<tr>
<th>Cell #1</th>
<th>6950</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell #2</td>
<td>6910</td>
</tr>
<tr>
<td>Cell #3</td>
<td>6900</td>
</tr>
<tr>
<td>Cell #4</td>
<td>6985</td>
</tr>
<tr>
<td><strong>Cell #5</strong></td>
<td><strong>27760</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27745</strong></td>
</tr>
</tbody>
</table>
3 Prisms are cast at a time
SURECURE Match Curing System
Transfer Length Measurements

- Brass inserts are embedded into concrete while casting
Transfer Length Measurements

- Surface strains due to prestressing force are calculated by measuring distances between points, before and after detensioning using whittemore gage

\[ \varepsilon = \frac{\Delta L}{L} \]
Surface Strain profile along the member
95% Average Maximum Strain

- All strain values in flat plateau are considered to draw the 95% Average Maximum strain (AMS) line
- Point of intersection between Surface strain profile and 95% AMS line is the Transfer length
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Transfer-Length Tie Test Matrix

- A total 750 Transfer lengths were attempted during plant phase

<table>
<thead>
<tr>
<th>Reinforcement samples</th>
<th># of concrete ties fabricated for each reinforcement type</th>
<th># of Transfer lengths for each reinforcement type (attempted)</th>
<th>Total # TL measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests on 15 groups</td>
<td>25</td>
<td>50</td>
<td>750</td>
</tr>
</tbody>
</table>
Reinforcement patterns

Typical cross-sections for prisms in Plant:

- Cross-section for (20) 5.32-mm-diameter indented wires
- Cross-section for (12) 5/16-inch-diameter strands
- Cross-section for (8) 3/8-inch-diameter indented strands
Devices to Measure Transfer Length

- Whittemore gage
- Laser Speckle
Devices to Measure Transfer Length

- Laser Speckle – optical device that correlates surface patterns (before and after detensioning)
Laser Speckle

- As the member undergoes deformation due to prestress release, the speckle pattern moves.
- Surface deformation can be converted to a change in strain.
- Surface needs to remain constant throughout the measurement process.
Grind Groove
Paint Groove
Finished surface
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TL measurements from laboratory phase
TL measurements from plant phase

- Smooth
- Chevron
- Diamond Spiral
- 2-Dot strand
- 7-wire strand
- 3-wire strand

Transfer Length (Inches)

WA, WG, WB, WD, WI, WJ, WH, WM, WF, WE, WC, WL, SA, SB, SC
Comparison of average transfer length from the plant and laboratory phases.
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Conclusions

• Results from both phases indicated that there is a large variation in the bond quality of reinforcements that are currently used in the fabrication of pre-tensioned concrete railroad ties worldwide.
Conclusions

• The average TL s for the 15 different reinforcements, during lab phase, ranged from 7.4 in. to 18.7 in.

• In the plant phase, which had a higher strength at de-tensioning, average transfer lengths of these same reinforcements was between 7.8 in. and 15.9 in.
Conclusions

• There was excellent correlation between the plant-phase data and the laboratory-phase data. This indicates that the laboratory prisms, cast with a similar concrete mixture, were able to accurately represent the behavior of the same reinforcement in a concrete railroad tie.
Opportunity

- Plant can send aggregates and 30-ft pieces of wires to lab
- Match-Cured prism tests can be conducted at lab and average transfer lengths at plant can be predicted with high degree of accuracy for a given release strength
- This data can be used to establish required release strength.
Acknowledgements

- Ryan Benteman, Research technician
- Grad Students and Undergraduate helpers
Thank You