Results of International Concrete Crosstie and Fastening System Survey

2012 Joint Rail Conference
Philadelphia, PA
17-19 April 2012
Brandon J. Van Dyk, Marcus S. Dersch, J. Riley Edwards, and Christopher P.L. Barkan
Outline

• Role of International Survey in UIUC FRA Concrete Tie and Fastener BAA
• Survey Objectives
• Audience
• Development and Content
• Results
• Preliminary Conclusions
FRA Tie and Fastening System BAA
Objectives and Deliverables

• Program Objectives
  – Provide mechanistic design recommendations for concrete crossties and fastening system design in the US
  – Conduct experimental laboratory and field testing, leading to improved recommended practices for design
  – Conduct comprehensive international literature review and state-of-the-art assessment for design and performance

• Program Deliverables
  – Improved mechanistic design recommendations for concrete crossties and fastening systems in the US
  – Improved safety due to increased strength of critical infrastructure components
  – Centralized knowledge and document depository for concrete crossties and fastening systems
Survey Objectives

- Conduct an international survey on the use and performance of concrete crossties and fastening systems
- Understand the current state-of-practice regarding the use of concrete crossties and fastening systems
- Develop an understanding of the most common types of crosstie and fastening system failures
- Continue establishing relationships and encouraging collaboration with railways, researchers, and manufacturers around the world
Role of International Survey

Analysis
- Determine typical loading for modeling systems
- Provide references for previous analyses

Lab
- Identify relevant international testing
- Compare US test criteria and practices with various international standards

Field
- Identify conditions where failure most commonly occurs
- Develop understanding of probabilistic loading conditions
Survey Audience

• Representation from the following continents:
  – North America
  – Europe
  – Asia
  – Africa
  – Australia

• Categories of experts surveyed:
  – Infrastructure owner, operator, or maintainer
  – Academic, industry, or institutional researcher
  – Concrete crosstie or fastening system manufacturer
Incentives for Organizations to Participate

• Acquisition of study results
• Inclusion in release of future publications in concrete tie and fastening system research at UIUC
• Access to reference list of journal and conference papers, design standards, and specifications
Development of Survey

- Created lists of questions for infrastructure owners, researchers, and concrete crosstie manufacturers
- Reviewed by industry partners and internal team
- Survey tool researched and selected – Zoomerang
- Created, revised, and deployed survey
Survey Content

- Usage
- Crosstie Characteristics and Manufacturing Techniques
  - Concrete
  - Prestress
- Fastening System Performance and Characteristics
  - Prevalence
  - Materials
- Effectiveness and Failure
  - Design Life
  - Maintenance
  - Failure Modes
- Industry Recommended Practices and Tests
- Research
Results of International Concrete Crosstie and Fastening System Survey

Survey Results – Responses

• 28 Total Responses
• Geography
  – 10 in North America
  – 18 internationally
• Role in Railway Industry
  – 9 Infrastructure Owners
  – 12 Researchers
  – 7 Concrete Crosstie Manufacturers
• Two Fastening System Manufacturers
## Survey Results – Loading Environment

<table>
<thead>
<tr>
<th></th>
<th>International Responses</th>
<th>North American Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average maximum freight axle load*</td>
<td>29.5 tons (26.8 tonnes)</td>
<td>39.1 tons (35.4 tonnes)</td>
</tr>
<tr>
<td>Average maximum passenger axle load*</td>
<td>21.6 tons (19.6 tonnes)</td>
<td>29.1 tons (26.4 tonnes)</td>
</tr>
<tr>
<td>Average concrete crosstie design axle load</td>
<td>27.6 tons (25.0 tonnes)</td>
<td>37.4 tons (33.9 tonnes)</td>
</tr>
<tr>
<td>Average tangent crosstie spacing</td>
<td>24.2 inches (61.4 centimeters)</td>
<td>24.0 inches (61.0 centimeters)</td>
</tr>
<tr>
<td>Average annual tonnage (per track)</td>
<td>38.7 million gross tons (35.1 million gross tonnes)</td>
<td>100.0 million gross tons (90.7 million gross tonnes)</td>
</tr>
</tbody>
</table>

*Interpreted from responses due to discrepancies in wheel or axle loads*
## Survey Results – Criticality of Problems

<table>
<thead>
<tr>
<th>Problem (higher ranking is more critical)</th>
<th>Average Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>International Responses</strong></td>
<td></td>
</tr>
<tr>
<td>Tamping damage</td>
<td>6.14</td>
</tr>
<tr>
<td>Shoulder/fastening system wear or fatigue</td>
<td>5.50</td>
</tr>
<tr>
<td>Cracking from center binding</td>
<td>5.36</td>
</tr>
<tr>
<td>Cracking from dynamic loads</td>
<td>5.21</td>
</tr>
<tr>
<td>Cracking from environmental or chemical degradation</td>
<td>4.67</td>
</tr>
<tr>
<td>Derailment damage</td>
<td>4.57</td>
</tr>
<tr>
<td>Other (e.g. manufactured defect)</td>
<td>4.09</td>
</tr>
<tr>
<td>Deterioration of concrete material beneath the rail</td>
<td>3.15</td>
</tr>
<tr>
<td><strong>North American Responses</strong></td>
<td></td>
</tr>
<tr>
<td>Deterioration of concrete material beneath the rail</td>
<td>6.43</td>
</tr>
<tr>
<td>Shoulder/fastening system wear or fatigue</td>
<td>6.38</td>
</tr>
<tr>
<td>Cracking from dynamic loads</td>
<td>4.83</td>
</tr>
<tr>
<td>Derailment damage</td>
<td>4.57</td>
</tr>
<tr>
<td>Cracking from center binding</td>
<td>4.50</td>
</tr>
<tr>
<td>Tamping damage</td>
<td>4.14</td>
</tr>
<tr>
<td>Other (e.g. manufactured defect)</td>
<td>3.57</td>
</tr>
<tr>
<td>Cracking from environmental or chemical degradation</td>
<td>3.50</td>
</tr>
</tbody>
</table>
## Survey Results – Importance of Research

<table>
<thead>
<tr>
<th>Research topic (higher ranking is more important)</th>
<th>Average Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>International Responses</strong></td>
<td></td>
</tr>
<tr>
<td>Track system design</td>
<td>4.08</td>
</tr>
<tr>
<td>Optimize crosstie design</td>
<td>3.93</td>
</tr>
<tr>
<td>Fastening system design</td>
<td>3.50</td>
</tr>
<tr>
<td>Materials design</td>
<td>2.23</td>
</tr>
<tr>
<td>Prevention or repair of rail seat deterioration</td>
<td>1.58</td>
</tr>
<tr>
<td><strong>North American Responses</strong></td>
<td></td>
</tr>
<tr>
<td>Prevention or repair of rail seat deterioration</td>
<td>3.60</td>
</tr>
<tr>
<td>Fastening system design</td>
<td>3.60</td>
</tr>
<tr>
<td>Materials design</td>
<td>3.00</td>
</tr>
<tr>
<td>Optimize crosstie design</td>
<td>2.80</td>
</tr>
<tr>
<td>Track system design</td>
<td>2.00</td>
</tr>
</tbody>
</table>
## Design and Performance Trends

<table>
<thead>
<tr>
<th></th>
<th>International Responses</th>
<th>North American Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average minimum allowable concrete strength at transfer</td>
<td>6,500 psi</td>
<td>4,700 psi</td>
</tr>
<tr>
<td>Average 28-day concrete compressive strength</td>
<td>8,700 psi</td>
<td>8,250 psi</td>
</tr>
<tr>
<td>Prominent concrete crosstie manufacturing process</td>
<td>Carousel</td>
<td>Long line</td>
</tr>
<tr>
<td>Abrasion plate or frame</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Commonly failed components</td>
<td>Screw, clip</td>
<td>Pad, rail seat</td>
</tr>
<tr>
<td>Rail seat deterioration</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Focus of research</td>
<td>Loading, testing, design</td>
<td>Life cycle cost reduction</td>
</tr>
</tbody>
</table>
Fastening System Design Considerations

- Tonnage
- Daily train volume and frequency
- Velocity of trains
- Static loads
- Dynamic impact loads
- Ability of pad to evenly distribute load to rail seat
- Abrasion of concrete rail seat by pad or abrasion plate
Conclusions

• North American loads are, on average, substantially higher than those throughout the rest of the world

• The most critical failure concerns in **North America** are related to wear or fatigue on the rail seat, rail pad, or shoulder

• The most critical failure concerns **internationally** are cracking from dynamic loads, shoulder wear, and tamping damage

• Greater emphasis placed on system design and optimization internationally
Future Survey Use

- Follow up with those who are willing to share unpublished test results
- Advance laboratory and field testing procedure in accordance with survey responses
- Pursue completion of research in areas determined to be most critical by industry responses
- Use responses to continue development of mechanistic design practices for concrete crossties and fastening systems
Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

• Funding for this research has been provided by the Federal Railroad Administration (FRA)

• Industry Partnership and support has been provided by
  – Union Pacific Railroad
  – BNSF Railway
  – National Railway Passenger Corporation (Amtrak)
  – Amsted RPS / Amsted Rail, Inc.
  – GIC Ingeniería y Construcción
  – Hanson Professional Services, Inc.
  – CXT Concrete Ties, Inc., LB Foster Company

• For assistance in survey development:
  – Eric Gehringer, Mauricio Gutierrez, Andrew Nicol, Seth Ogan
  – Adam Heinz, Ryan Kernes, David Lange, Chris Rapp, Amogh Shurpali
Questions

Brandon Van Dyk
Graduate Research Assistant
Rail Transportation and Engineering Center – RailTEC
University of Illinois at Urbana-Champaign
e-mail: vandyk2@illinois.edu