Top 10 Findings and Outcomes
FRA Crosstie and Fastening System BAA Research Program

FRA Tie and Fastener BAA Industry Partners Meeting
15 October 2014
Riley Edwards, Marcus Dersch, Brent Williams, and Yu Qian
FRA Crosstie and Fastening System Research Program – Select Impacts

1. Quantification of wheel loads
2. Development of technique for measuring lateral forces
3. Quantification of rail seat pressures
4. Development of revised crosstie bending analysis methodology
5. Development of full-scale laboratory setup (RAIL)
6. FE model developed and validated
7. Simplified Design Tool (I-TRACK)
8. Revisions to AREMA Chapter 30 (Ties)
10. Workforce Development (Education of Students)
1. Quantification of Peak Wheel Loads

![Graph showing the quantification of peak wheel loads for different types of rail vehicles. The graph plots the percentage of peak loads exceeded against peak vertical load in kips. The types of rail vehicles include Freight Locomotives, Intermodal Freight Cars, Passenger Coaches, Passenger Locomotives, and Other Freight Cars.]

- Freight Locomotives
- Intermodal Freight Cars
- Passenger Coaches
- Passenger Locomotives
- Other Freight Cars

10 kips $\approx 45$ kN
Comparison of Dynamic Wheel Load Factors

- Talbot
- Indian Railways
- Eisenmann
- ORE/Birmann
- German Railways
- South African Railways
- Clarke
- WMATA
- Sadeghi

Speed (mph)

Dynamic Factor, \( \phi \)

10 mph \( \approx \) 16 kph
Dynamic Wheel Load Factors (Real Loads)

- Dynamic Wheel Load Factors
- Real Loads

Graph showing dynamic factor ($\phi$) vs speed (mph) for different rail systems.

Talbot
Indian Railways
Eisenmann
ORE/Birmann
German Railways
South African Railways
Clarke
WMATA
Sadeghi

Legend:
- Freight Cars
- Locomotives
- Passenger Coaches

10 mph ≈ 16 kph
2. Successful Development of Lateral Force Measurement Technology

- Development and testing of Lateral Load Evaluation Device (LLED)
  - Original shoulder face is removed
  - Insert designed as a beam and optimized to replace removed section and maintains original geometry
  - Measures bending strain of beam under 4-point bending
Lateral Load Data – Sample Field Results

- Force (lbf) vs. Force (kN)
- Peak force: 40 kips, 20 kips, 10 kips, 5 kips
- Diagram showing forces and positions
3. Quantifying Rail Seat Pressure Magnitude and Distribution

- Pad/Abrasion Plate
  - BoPET: 0.007”
  - PTFE: 0.006”
- Sensor: 0.004”
- Gauge
- Cast-in Shoulders
- Concrete Crosstie

Matrix Based Tactile Surface Sensor
Rail Seat Pressure Distribution Data

40 kips

20 kips

% Initial Contact Area

3: 62%

11: 58%

Unloaded

Increasing Pressure
Loading: 32.5kip (145kN) vertical, 16.9kip (75kN) lateral (0.52 L/V Force Ratio)

Contact Area: \( \text{in}^2 (\text{cm}^2) \)
- 25.8 (166) \( \text{TPV} \)
- 19.0 (123) \( \text{MDPE} \)
- 23.9 (154) \( \text{Two-Part Pad Assembly} \)

Max Pressure: psi (kPa)
- 2,925 (20,000) \( \text{TPV} \)
- 3,721 (25,600) \( \text{MDPE} \)
- 2,990 (20,600) \( \text{Two-Part Pad Assembly} \)
4. Development of Revised Crosstie Bending Moment Analysis Method (Comparison of Methods)

<table>
<thead>
<tr>
<th></th>
<th>AREMA C30.4</th>
<th>UIC 713R</th>
<th>AS 1085.14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail Seat Load</td>
<td>62.1 (276.2)</td>
<td>66.4 (295.4)</td>
<td>53.3 (237.1)</td>
</tr>
<tr>
<td>kips (kN)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Seat Positive</td>
<td>300 (33.9)</td>
<td>224 (25.3)</td>
<td>280 (31.6)</td>
</tr>
<tr>
<td>kip-in (kN-m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Seat Negative</td>
<td>-159 (-18.0)</td>
<td>-112 (-12.7)</td>
<td>-187 (-21.1)</td>
</tr>
<tr>
<td>kip-in (kN-m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center Positive</td>
<td>141 (15.9)</td>
<td>209 (23.6)</td>
<td>112 (12.7)</td>
</tr>
<tr>
<td>kip-in (kN-m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center Negative</td>
<td>-201 (-22.7)</td>
<td>-299 (-33.8)</td>
<td>-240 (-27.1)</td>
</tr>
<tr>
<td>kip-in (kN-m)</td>
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</tbody>
</table>
Comparison Between Current and Proposed ($M_C$)
5. Development and Use of a Full-Scale Track Loading System
Full-Scale Track Loading System – Vertical and Lateral Loads Being Applied
6. Development and Validation of Crosstie and Fastener Finite Element (FE) Model

- Development of both multiple-tie and single-tie models
- Validated with laboratory and field data
- Ability to run parametric analyses
7. Development of Simplified Design Tool (I-TRACK)

- Software based on statistical analyses of the UIUC FE model
- A neural network model was developed to predict track components responses based on user defined inputs

**Development of I-TRACK**

- Definition of Input Parameters
- Design of Experiments
- FE Model Runs
- Output Data
- Radial Basis Function Neural Network
- I-TRACK
I-TRACK Preliminary Project Phases

- The development of I-TRACK follows a systematic process. The project was divided in 3 phases, which add additional complexity and analysis capabilities.

- Goal: expedite the development of I-TRACK, test the model accuracy and functionalities on a continuous basis, and provide interim utility to end users.

**Phase I: I-TRACK Version 1.0**

- Vertical Wheel Load
- Lateral Wheel Load
- Clip Young’s Modulus
- Insulator Young’s Modulus
- Rail Pad Young’s Modulus
- Track Vertical and Lateral Deflection
- Clamping Force
- Clip Max Stress
- Rail Base Lateral Translation
- Abrasion Frame Lateral Translation
- Rail Seat Load
- Max Rail Seat Pressure
8. Changes to AREMA Chapter 30 (Ties)

- Multiple proposed changes to AREMA Chapter 30 (5 Total)
- Driven by students funded on this project (and through IPs)
- Expected to continue for some time…

<table>
<thead>
<tr>
<th>Proposed Ballot Title</th>
<th>Description of Ballot</th>
<th>Lead Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition of Rail Seat Load Distribution</td>
<td>Introduce language characterizing the loading environment at the rail seat, which may affect crosstie failure mechanisms associated with Rail Seat Deterioration (RSD).</td>
<td>Matthew Greve</td>
</tr>
<tr>
<td>Amendments to Loading Environment</td>
<td>Update section 1.2 Load Environment, which covers wheel to rail loads of North American freight and passenger traffic. Revisions are intended to update the load table currently provided in AREMA using modern traffic data.</td>
<td>Andrew Scheppe</td>
</tr>
<tr>
<td>Addition of Lateral Load Distribution</td>
<td>Add language to the proposed sections stating that lateral load distribution may not mimic vertical load distribution as previously hypothesized. Also, that fastening system design (e.g. friction, stiffness) will have an effect on lateral load distribution.</td>
<td>Brent Williams</td>
</tr>
<tr>
<td>Crosstie Flexural Capacity Analysis Method</td>
<td>Update sections on flexural analysis of concrete crossties to address issues with current analysis process and introduce new and improved method of analysis.</td>
<td>Henry Wolf</td>
</tr>
</tbody>
</table>

- Co-organized by: **AREMA Committee 30 (Ties), Railway Tie Association (RTA)**
- **2014 Event: 140 total attendees**
- Focus → state of the art in timber, concrete, and composite crosstie and fastening system design, performance, research, modeling, and inspection
- Presentations available at: [http://railtec.illinois.edu/Crosstie/2014/presentation.php](http://railtec.illinois.edu/Crosstie/2014/presentation.php)
- **THANKS FOR SPONSORSHIP from INDUSTRY PARTNERS!**
10. Our role in Rail Workforce Development…

RailTEC Tie and Fastener Team in June 2014
Acknowledgements

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INTEGRICO COMPOSITES
Questions and Comments?

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