Field Instrumentation of Concrete Crosstie Rail Seats for Investigating Rail Seat Pressure Distribution

2013 Joint Rail Conference
Knoxville, TN
18 April 2013

Christopher T. Rapp, Marcus S. Dersch, J. Riley Edwards
Outline

• Current Objectives of Experimentation
• Testing Background
  – Laboratory Experimentation
• July 2012 Field Instrumentation
  – TLV Experimentation
• Conclusions
• Future Work
  – Field Instrumentation
  – Tool for Pressure Estimation
Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

• Measure magnitude and distribution of pressure at the concrete crosstie rail seat

• Investigate the feasibility of crushing as a mechanism leading to rail seat deterioration (RSD)

• Gain improved understanding load transfer from wheel/rail interface to the rail seat

• Compare pressure distribution on rail seats:
  – Under various loading scenarios
  – Under various fastening systems

• Identify regions of high pressure and quantify peak values
MBTSS Testing Background

- Proven feasibility for use on concrete crosstie rail seats
- Laboratory experimentation performed varied:
  - Rail pad materials, geometry, and type
  - Fastening clip type
- Lessons learned from experimentation at Transportation Technology Center (TTC) in 2011-12
  - Protection and sizing of sensors is critical
  - Need for an input load to correlate to raw sum data
- Data collection speed limitations
  - 100 Hz
Laboratory Experimentation: Rail Pad Assemblies

- Load Applied: 32.5 kip vertical, 16.9 kip lateral (0.52 L/V Force Ratio)

<table>
<thead>
<tr>
<th>Material</th>
<th>Contact Area (in²)</th>
<th>Max Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPV</td>
<td>25.8</td>
<td>2,925</td>
</tr>
<tr>
<td>MDPE</td>
<td>19.0</td>
<td>3,721</td>
</tr>
<tr>
<td>Two-Part Pad Assembly</td>
<td>23.9</td>
<td>2,990</td>
</tr>
</tbody>
</table>

Gauge

Pressures (psi)
Conclusions from Laboratory Testing

• Rail Pad Test
  – Lower modulus rail pads distribute rail seat loads over a larger contact area
    • Mitigates highly concentrated loads at this interface
    • Allows greater rail base rotation
  – Two-Part Pad Assembly
    • Maintains relatively consistent contact area under increasing L/V force ratios
    • Peak pressures similar to the lower modulus TPV pad

• Effect of Lateral/Vertical (L/V) Force Ratio
  – Higher L/V force ratios cause a concentration of pressure on the field side of the rail seat, resulting in higher peak pressures
TTC Field Testing Locations

High Tonnage Loop (HTL)
5° Curve: Balance Speed of 33 mph

Railroad Test Track (RTT)
Tangent: Speed up to 105 mph
TTC Field Testing Locations

- Instrumented section of track using various instrumentation technologies to capture loads and behavior of various aspects of the concrete crossties and fastening systems
Track Loading Vehicle (TLV) Testing

- L/V force ratio testing: continuous 40 kip vertical load applied
  - Lateral loads ranging from 0 to 20 kips
  - L/V force ratios ranging 0 to 0.5
- Assumption that 50% of load applied to rail is carried by crosstie immediately below loading (literature reviews and strain gauge data)
TLV Varying L/V Force Ratios at HTL

- 40 kip vertical load applied to rail, lateral load varying based on respective L/V ratio
- Maximum pressure at 0.0 L/V force ratio = 1,400 psi
- Maximum pressure at 0.5 L/V force ratio = 2,200 psi
TLV Varying L/V Force Ratios at HTL

Graph showing the maximum pressure (psi) varying from Field Side to Gauge Side as a function of distance from the Field Side Shoulder. The graph includes lines representing different L/V Force Ratios: 0.00, 0.10, 0.20, 0.30, 0.40, and 0.50.
TLV Varying L/V Force Ratios at HTL

- High Rail Seat:
  - Max. pressure at 0.0 L/V = 2,400 psi
  - Max. pressure at 0.5 L/V = 2,700 psi

- Low Rail Seat:
  - Max. pressure at 0.0 L/V = 2,700 psi
  - Max. pressure at 0.5 L/V = 3,640 psi
TLV Varying L/V Force Ratios at HTL

High Rail Seat

Low Rail Seat

Field Side  Distance from Field Side Shoulder (in)  Gauge Side

Maximum Pressure (psi)

L/V Force Ratio

0.00  0.10  0.20  0.30  0.40  0.50
Maximum Pressure vs. L/V Force Ratio

- **Low Rail**
- **High Rail**
- **Low Rail (Adjacent)**

- **X-axis:** L/V Force Ratio
- **Y-axis:** Maximum Pressure (psi)

The graph shows the relationship between the maximum pressure and the L/V force ratio for different rail seats. The pressure increases as the L/V force ratio increases.
Contact Area vs. L/V Force Ratio

Ratio of Initial Contact Area vs. L/V Force Ratio

- Low Rail
- High Rail
- Low Rail (Adjacent)
Conclusions

• Laboratory and field data both show same increase of load on field side under increasing L/V force ratios

• Maximum pressures did not exceed 3,640 psi, but more extreme conditions could cause higher values
  – Crushing as a mechanism of RSD does not appear feasible under these load magnitudes and L/V force ratios
  – Other factors like motion, moisture must also be considered

• Variability in rail seat support conditions can occur from tie to tie

• Allowable movement of the rail base can affect the distribution of pressure at the rail seat
  – Greater rotation decreased contact area and increased maximum pressures
Future Work: Field Instrumentation

- Collect data from 8 sensors simultaneously
- View distribution of a single load over multiple crossties
- Collect greater quantity of high vs. low rail seat data points
  - Determine linearity or non-linearity of transfer of load from low to high rail seats under increasing train operating speeds
- Investigate effect of crosstie support conditions on load distribution by correlating MBTSS data with crosstie deflections

![Diagram with partially instrumented, fully instrumented, and MTSS instrumented ties, and driven rod for vertical tie displacement]
Future Work: Tool for Pressure Estimation

- Analytical tool for calculating maximum rail seat pressure values at various L/V force ratios under different loads
  - In early stages of development, currently theoretical graphs based on available field experimentation data
  - Future field instrumentation plan focusing on collecting data needed to advance and refine this tool
- Benefits to Industry
  - Incorporate proven industry technologies (WILD, IWS, TPD)
  - Estimate pressure distribution
  - Estimate pressure magnitude at rail seat
- Effects design of crossties due to change in bending moment
Future Work: Tool for Pressure Estimation

*Theoretical graph based on available field experimentation data*
Future Work: Tool for Pressure Estimation

*Theoretical graph based on available field experimentation data
Acknowledgements

- Funding for this research has been provided by the Federal Railroad Administration (FRA)
- Research Assistantship funding for the lead author has been provided by Amsted Rail / Amsted RPS
- 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
- UIUC – Matthew Greve, Marc Killion, and Timothy Prunkard
- University of Kentucky - Professor Jerry Rose and students
- Association of American Railroads (AAR) and Transportation Technology Center, Inc. (TTCI)
Questions & Comments

Christopher T. Rapp
Graduate Research Assistant
crapp3@illinois.edu