Rail Seat Load Results from July 2012
Field Testing at TTC

AREMA Committee 30 Fall 2012 Meeting
Tampa, FL
25 October 2012

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

• Current Objectives of Experimentation
• Chapter 30: Rail Seat Pads
• Testing Background
• Laboratory Experimentation: Rail Seat Pads
• Field Test Setup and Locations
  – Rail Seat Load Calculation
  – Train Operation Data
  – Preliminary Conclusions
• Future Work
• Appendix
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 better understanding of how load from wheel/rail interface is transferred to 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
Rail Seat Load Results from July 2012 Field Testing at TTC

FRA Tie and Fastener Program Structure

**Inputs**
- Comprehensive Literature Review
- International Tie and Fastening System Survey
- Loading Regime (Input) Study
- Rail Seat Load Calculation Methodologies
- Involvement of Industry Experts

**Outputs/Deliverables**
- Data Collection
  - Document Depository
- Groundwork for Mechanistic Design
  - International Survey Report
- Load Path Map
  - Parametric Analysis
  - State of Practice Report
  - Validated Tie and Fastening System Model

**Laboratory Study**
- Modeling
- Field Study
Railseat Pads
AREMA Chapter 30 Section 1.7.3.4

• **Existing Content:**
  – Purpose, recommendations for varying loading environments
  – Recommended railseat pad property tests

• **Proposed Improvement:**
  – Improve description of purpose
  – Recognize effect of varying pad moduli and geometries

• **Methodology:**
  – Laboratory experiments with varying pad moduli and geometries
  – Field experimentation to better understand actual loading conditions

• **Timeline:**
  – Submit to full committee for ballot (Spring 2013)
MBTSS Testing Background

- Proven feasibility for use on concrete crosstie rail seats
- Laboratory experimentation performed to vary:
  - Rail pad materials and type
  - Fastening clip type
- Lessons learned from testing at Transportation Technology Center (TTC) in November 2011
  - 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: Railseat Pads

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

<table>
<thead>
<tr>
<th></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>
Conclusions from Laboratory Testing

- **Effect of L/V Ratio**
  - Lower L/V ratios distribute the pressure over a larger contact area
  - Higher L/V ratios cause a concentration of pressure on the field side of the rail seat, resulting in higher peak pressures

- **Rail Pad Test**
  - Lower modulus rail pads distribute rail seat loads over a larger contact area
    - Reduces peak pressure values
    - Mitigates highly concentrated loads at this interface
  - Higher modulus rail pads distribute rail seat loads in more highly concentrated areas
    - Possibly leads to localized crushing of the concrete surface
  - **Two-Part Pad Assembly**
    - Maintains relatively consistent contact area under increasing L/V ratios
    - Peak pressures similar to the lower modulus TPV pad
TTCI Field Testing Locations

- 5 degree curve
  Balance Speed = 33 mph

- Tangent Speed up to 105 mph
Test Setup and Locations

- Instrumented sections at both Heavy Tonnage Loop (HTL) and Railroad Test Track (RTT)
Field Rail Seat Load Calculation

1. Calibrate strain gauge bridges with track loading vehicle (TLV)
2. Determine wheel force
3. Determine wheel force minus rail seat force
4. Difference is rail seat load
RTT Passenger Consist

- Runs at 15, 30, 50, 60, 80, 90, 102 mph
- Locomotive Weight: 255,475 lbs (4 axles)
- Passenger Car Weights: 86,000 – 88,000 lbs (4 axles)
RTT Freight Consist

- Runs at 2, 15, 30, 38, 41, 60 mph
- Locomotive Weight: 393,000 lbs (6 axles)
- Freight Car Weights: 250,000 – 315,000 lbs (4 axles)
RTT Passenger Consist - 15 mph

**Lead Truck, Lead Axle of Locomotive**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel Load, lbs</td>
<td>30,600</td>
</tr>
<tr>
<td>Rail Seat Load, lbs</td>
<td>15,800</td>
</tr>
<tr>
<td>% of Wheel Load Carried by Rail Seat</td>
<td>52</td>
</tr>
<tr>
<td>Maximum Pressure, psi</td>
<td>1,584</td>
</tr>
<tr>
<td>Average Pressure, psi</td>
<td>538</td>
</tr>
<tr>
<td>Contact Area, in²</td>
<td>38.2</td>
</tr>
</tbody>
</table>

**Image Description:**
- **GAUGE**
- **FIELD**
- **Pressure (psi):**
  - 0
  - 1000
  - 2000

**Notes:**
- Rail Seat Load Results from July 2012 Field Testing at TTC
- Lead Truck, Lead Axle of Locomotive
- Wheel Load, lbs: 30,600 lbs
- Rail Seat Load, lbs: 15,800 lbs
- % of Wheel Load Carried by Rail Seat: 52%
- Maximum Pressure, psi: 1,584 psi
- Average Pressure, psi: 538 psi
- Contact Area, in²: 38.2 in²
RTT Freight Consist - 15 mph

**Lead Truck, Lead Axle of Locomotive**

<table>
<thead>
<tr>
<th>Description</th>
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<tbody>
<tr>
<td>Wheel Load, lbs</td>
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</tr>
<tr>
<td>Rail Seat Load, lbs</td>
<td>14,500</td>
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<tr>
<td>% of Wheel Load Carried by Rail Seat</td>
<td>48</td>
</tr>
<tr>
<td>Maximum Pressure, psi</td>
<td>1,710</td>
</tr>
<tr>
<td>Average Pressure, psi</td>
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## Rail Seat Load Results from July 2012 Field Testing at TTC

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<td>538</td>
</tr>
<tr>
<td>Locomotive: Lead Truck, Lead Axle</td>
<td>50</td>
<td>27,200</td>
<td>11,300</td>
<td>1,273</td>
<td>425</td>
</tr>
<tr>
<td>Passenger Car: Lead Truck, Lead Axle</td>
<td>15</td>
<td>11,790</td>
<td>6,410</td>
<td>1,244</td>
<td>320</td>
</tr>
<tr>
<td>Passenger Car: Lead Truck, Lead Axle</td>
<td>50</td>
<td>9,900</td>
<td>3,100</td>
<td>941</td>
<td>229</td>
</tr>
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## Passenger Consist

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<td>509</td>
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<tr>
<td>Locomotive: Lead Truck, Lead Axle</td>
<td>60</td>
<td>23,400</td>
<td>8,700</td>
<td>1,342</td>
<td>348</td>
</tr>
<tr>
<td>Freight Car: Lead Truck, Lead Axle</td>
<td>15</td>
<td>34,500</td>
<td>16,700</td>
<td>1,816</td>
<td>561</td>
</tr>
<tr>
<td>Freight Car: Lead Truck, Lead Axle</td>
<td>60</td>
<td>39,100</td>
<td>24,300</td>
<td>2,486</td>
<td>746</td>
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</tbody>
</table>
Preliminary Observations

- Pressure values are governed by a combination of factors:
  - wheel load, rail seat load, contact area, etc.
- Pressure values are not always speed dependent
- Locomotive is the governing weight for the passenger consist for well-maintained wheels
- Crushing mechanism does not appear feasible under well-maintained track and rolling stock
- However, we still believe a “perfect storm” for crushing would be:
  - Adjacent ties not supporting load
  - Flat spots on wheels
  - Imperfect rail seat surface and/or external particles intruding into rail seat
Future Work with MBTSS

- Continue laboratory testing with external particles on the rail seat and non-perfect rail seats
- Continue field testing at TTC in Pueblo, CO to understand pressure distribution varying track and loading conditions
  - Instrument high and low rail seats of a crosstie to compare varying track geometries
  - Instrument consecutive rail seats to see load transfers between crossties
- Continue testing common North American fastening systems
- Incorporate rail seat pressure results into other RSD mechanism studies
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.
    - Specifically for use of Pulsating Load Testing Machine
  - 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?

Christopher T. Rapp
Graduate Research Assistant
ctrapp3@illinois.edu
Appendix

- RTT Train Operation Data
- TLV Data from TTC HTL Testing
- Laboratory Rail Pad Test Results
- Laboratory and Field Comparison
### RTT Passenger Consist - 15 mph

#### Truck 1, Axle 1 of Passenger Car

<table>
<thead>
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</tr>
<tr>
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<td>54</td>
</tr>
<tr>
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</tr>
<tr>
<td>Average Pressure, psi</td>
<td>320</td>
</tr>
<tr>
<td>Contact Area, in²</td>
<td>34.9</td>
</tr>
</tbody>
</table>

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**Graph:**
- **X-axis:** Pressure (psi) from 0 to 2000
- **Y-axis:** Field Gauges

A heat map showing pressure distribution with a color scale ranging from dark black to bright red, indicating varying pressure levels. The graph illustrates pressure variation across the field gauges with a scale ranging from 0 to 2000 psi.
RTT Passenger Consist - 50 mph

**GAUGE**

**FIELD**

<table>
<thead>
<tr>
<th><strong>Truck 1, Axle 1 of Locomotive</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel Load, lbs</td>
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</tr>
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<td>Rail Seat Load, lbs</td>
<td>11,300</td>
</tr>
<tr>
<td>% of Wheel Load Carried by Rail Seat</td>
<td>42</td>
</tr>
<tr>
<td>Maximum Pressure, psi</td>
<td>1,273</td>
</tr>
<tr>
<td>Average Pressure, psi</td>
<td>425</td>
</tr>
<tr>
<td>Contact Area, in²</td>
<td>37.8</td>
</tr>
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</table>
RTT Passenger Consist - 50 mph

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
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<tr>
<td>Truck 1, Axle 1 of Passenger Car</td>
<td></td>
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<tr>
<td>Wheel Load, lbs</td>
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</tr>
<tr>
<td>Rail Seat Load, lbs</td>
<td>3,100</td>
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<td>Average Pressure, psi</td>
<td>229</td>
</tr>
<tr>
<td>Contact Area, in²</td>
<td>34.3</td>
</tr>
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</table>
RTT Freight Consist - 15 mph

### Truck 1, Axle 1 of Freight Car

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel Load, lbs</td>
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<td>Average Pressure, psi</td>
<td>561</td>
</tr>
<tr>
<td>Contact Area, in²</td>
<td>38.2</td>
</tr>
</tbody>
</table>
RTT Freight Consist - 60 mph

**GAUGE**

**FIELD**

**Truck 1, Axle 1 of Locomotive**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel Load, lbs</td>
<td>23,400</td>
</tr>
<tr>
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</tr>
<tr>
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<td>348</td>
</tr>
<tr>
<td>Contact Area, in²</td>
<td>38.6</td>
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</table>
RTT Freight Consist - 60 mph

<table>
<thead>
<tr>
<th>Field Gauge</th>
<th>Truck 1, Axle 1 of Freight Car</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Wheel Load, lbs</td>
</tr>
<tr>
<td></td>
<td>Rail Seat Load, lbs</td>
</tr>
<tr>
<td></td>
<td>% of Wheel Load Carried by Rail Seat</td>
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<td></td>
<td>Maximum Pressure, psi</td>
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<tr>
<td></td>
<td>Average Pressure, psi</td>
</tr>
<tr>
<td></td>
<td>Contact Area, in²</td>
</tr>
</tbody>
</table>
HTL TLV - Increasing L/V Ratios

Input Load
L/V Ratio

<table>
<thead>
<tr>
<th>GAUGE</th>
<th>40V</th>
<th>40V 2L</th>
<th>40V 4L</th>
<th>40V 6L</th>
<th>40V 8L</th>
<th>40V 10L</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>.05</td>
<td>.10</td>
<td>.15</td>
<td>.20</td>
<td>.25</td>
</tr>
<tr>
<td>FIELD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40V 12L</td>
<td>.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40V 14L</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40V 16L</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>40V 18L</td>
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<td></td>
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<tr>
<td>40V 20L</td>
<td>.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD
TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD
TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD
TLV 40 kip Vertical - HTL Low Rail
TLV 40 kip Vertical - HTL Low Rail
TLV 40 kip Vertical - HTL Low Rail

GAUGE

FIELD
Rail Seat Load Results from July 2012 Field Testing at TTC

TLV 40 kip Vertical – HTL Low Rail

<table>
<thead>
<tr>
<th>Location of Load</th>
<th>Tie S</th>
<th>Crib T</th>
<th>Tie U</th>
<th>Crib V</th>
<th>Tie W</th>
<th>Tie Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Sum</td>
<td>13,390</td>
<td>18,082</td>
<td>20,574</td>
<td>27,875</td>
<td>37,529</td>
<td>49,490</td>
</tr>
<tr>
<td>% of Centered Load</td>
<td>27</td>
<td>37</td>
<td>42</td>
<td>56</td>
<td>76</td>
<td>-</td>
</tr>
</tbody>
</table>
Rail Pad Test

- **Objective:** gain understanding of effect of pad modulus on rail seat pressure distribution
- Bound the experiment by using low and high modulus pads
- Two rail pad types with same dimensions and geometry
  - Thermoplastic Vulcanizate (TPV - lower modulus)
  - Medium-Density Polyethylene (MDPE – higher modulus)
- Concrete rail seat and fastening system held constant
- Identical loading conditions
  - 32.5 kip vertical load
  - Lateral load varies based on respective L/V ratio

<table>
<thead>
<tr>
<th></th>
<th>TPV</th>
<th>MDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shore Hardness</td>
<td>86 (A)</td>
<td>60 (D)</td>
</tr>
<tr>
<td>Flexural Modulus, psi</td>
<td>15,000*</td>
<td>120,000</td>
</tr>
</tbody>
</table>

*Approximate flexural modulus based on a TPV with a similar Shore Hardness of 87A
Rail Pad Test Results

<table>
<thead>
<tr>
<th>L/V Ratio</th>
<th>Contact Area (in²)</th>
<th>% of Rail Seat</th>
<th>Peak Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>28.8</td>
<td>85</td>
<td>2,139</td>
</tr>
<tr>
<td>0.44</td>
<td>27.9</td>
<td>82</td>
<td>2,573</td>
</tr>
<tr>
<td>0.48</td>
<td>27.3</td>
<td>80</td>
<td>2,800</td>
</tr>
<tr>
<td>0.52</td>
<td>25.8</td>
<td>76</td>
<td>2,925</td>
</tr>
<tr>
<td>0.56</td>
<td>24.0</td>
<td>71</td>
<td>3,162</td>
</tr>
<tr>
<td>0.60</td>
<td>21.3</td>
<td>63</td>
<td>3,400</td>
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</tr>
<tr>
<td>0.56</td>
<td>18.6</td>
<td>55</td>
<td>3,838</td>
</tr>
<tr>
<td>0.60</td>
<td>17.8</td>
<td>52</td>
<td>4,096</td>
</tr>
</tbody>
</table>
Average Pressure Distribution for TPV Rail Pad
Average Pressure Distribution for MDPE Rail Pad

Pressure (psi) vs. Distance from Gauge Edge of Sensor on Rail Seat (in.)

L/V Ratio
- 0.60
- 0.56
- 0.52
- 0.48
- 0.44
- 0.25
Rail Pad Test Results (cont.)

- Two-Part Pad Assembly
  - Poly Pad
  - Nylon 6-6 Abrasion Frame
- 32.5 kip vertical load
- Lateral load varies based on respective L/V ratio

**Contact Area (in²)**
- 24.9
- 24.0
- 23.9
- 23.9
- 23.4
- 23.4

**% of Rail Seat**
- 80
- 77
- 77
- 77
- 75
- 75

**Peak Pressure (psi)**
- 2,550
- 2,821
- 2,877
- 2,990
- 3,201
- 3,325

**Pressure (psi)**
- 0
- 1000
- 2000
- 3000
- 4000
Average Pressure Distribution for Two-Part Pad Assembly

Pressure (psi) vs. Distance from Gauge Edge of Sensor on Rail Seat (in.)

L/V Ratio:
- 0.2
- 0.24
- 0.28
- 0.32
- 0.36
- 0.4
- 0.44
- 0.48
- 0.52
- 0.56
- 0.6
# Rail Pad Comparison at 0.52 L/V

- **Load Applied:**
  - 32.5 kip vertical
  - 16.9 kip lateral

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

- **Effect of L/V Ratio**
  - Lower L/V ratios distribute the pressure over a larger contact area.
  - Higher L/V ratios cause a concentration of pressure on the field side of the rail seat.
    - Results in higher peak pressures.

- **Rail Pad Test**
  - Lower modulus rail pads distribute rail seat loads over a larger contact area.
    - Reduces peak pressure values.
    - Mitigates highly concentrated loads at this interface.
  - Higher modulus rail pads distribute rail seat loads in more highly concentrated areas.
    - Possibly leads to localized crushing of the concrete surface.
  - **Two-Part Pad Assembly**
    - Maintains relatively consistent contact area under increasing L/V ratios.
    - Peak pressures similar to the lower modulus TPV pad.
Lab vs. Field - L/V 0.40

PLTM Test
2-Part Pad Assembly
Contact Area: 24.44 in²

Field Test
2-Part Pad Assembly
Contact Area: 36.35 in²
Lab vs. Field - Increasing L/V Ratios

PLTM Testing in Laboratory

Field Testing at TTC HTL