Measuring Concrete Crosstie Rail Seat Pressure Distribution with Matrix Based Tactile Surface Sensors

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Outline

- Pulsating Load Testing Machine (PLTM)
- Current Objective and Roles of MBTSS
- Sensor Layout and Data Representation
- Experimentation at UIUC
  - Pad Modulus Test
  - Fastening Clip Test
- Conclusions from Testing
- Future Work with MBTSS
- Questions / Comments
Pulsating Load Testing Machine (PLTM)

- Housed at Advanced Transportation and Research Engineering Laboratory (ATREL)
- Owned by Amsted RPS
- Used for Full Scale Concrete Tie and Fastening System Testing
- Following AREMA Test 6 – Wear and Abrasion recommended practice
- Three 35,000 lb. actuators: two vertical and one horizontal
  - Ability to simulate various Lateral/Vertical (L/V) ratios by varying loads
Pulsating Load Testing Machine (PLTM)
Current Objectives of Experimentation with MBTSS

- Research co-sponsored by Amsted RPS and Federal Railway Administration as part of a larger research program on concrete crossties and fastening systems
- **Measure magnitude and distribution of pressure at the rail seat**
- Gain better understanding of how load from wheel/rail contact is transferred to rail seat
- Compare pressure distribution to rail seats in various loading scenarios
- Compare pressure distribution of various fastening systems
- Identify regions of high pressures and quantify peak values
Roles of MBTSS

**Analysis**
- Compare field data with lab data and theorized behaviors
- Refine modeling (analysis) with understanding of actual loading conditions

**Lab**
- Conduct experimentation with known input loads and controlled variables
- Simulate conditions found in field (L/V ratio, etc.)

**Field**
- Instrument various loading conditions
- Consider track geometry, speed, fastening system, etc.
Sensor Installation Layout

MBTSS Setup

- Cast-in Shoulders
- Concrete Crosstie

MBTSS

- Rail
- Rail Seat
- Field
- Gauge

Pad/Abrasion Plate
- Mylar (0.007”)
- Teflon (0.006”)
- Sensor (0.004”)
- Teflon (0.006”)
- Mylar (0.007”)

Concrete Crosstie
Visual Representation of Data

- Data visually displayed as color 2D or 3D images
- Calculate force and pressure at each sensing point
- Set standard color scale to apply to all data for better comparison
Measuring Rail Seat Pressure Distribution with MBTSS

**Pressure (PSI)**
- 0
- 500
- 1000
- 1500
- 2000
- 2500
- 3000

**Slide 9**

- **FIELD GAUGE**
  - 0.22”
  - **Area = 0.0484 in²**

- **GAUGE**
  - 0.22”
  - **162**
Experimentation at UIUC

- Lab experimentation to measure effect of L/V ratio on pressure distribution in the rail seat varying:
  1. Rail pad modulus
  2. Fastening clip
- Attempt to simulate field loading conditions in the lab
Rail Pad Test

- **Objective**: bound the experiment by using low and high modulus pads

- Two rail pad types with same dimensions and geometry
  - Santoprene™ (Low Modulus)
  - High-Density Polyethylene (HDPE – High 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
### Rail Pad Test Results

**Contact Area (in²)**
- Santoprene™: 28.8, 27.9, 27.3, 25.8, 24.0, 21.3
- HDPE: 20.1, 19.3, 19.1, 19.0, 18.6, 17.8

**% of Rail Seat**
- Santoprene™: 85, 82, 80, 76, 71, 63
- HDPE: 59, 57, 56, 56, 55, 52

**Peak Pressure (psi)**
- Santoprene™: 2,139, 2,573, 2,800, 2,925, 3,162, 3,400
- HDPE: 3,213, 3,469, 3,546, 3,721, 3,838, 4,096

**L/V Ratio**
- 0.25, 0.44, 0.48, 0.52, 0.56, 0.60
Average Pressure Distribution for Santoprene™ Rail Pad
Average Pressure Distribution for HDPE Rail Pad
Clip Test

- **Objective:** gain preliminary understanding of clip geometry on pressure distribution
- Two fastening clips tested
- Rail pad material held constant
- Identical loading conditions
  - 32.5 kip vertical load
  - Lateral load varies based on respective L/V ratio
Clip Test Results

<table>
<thead>
<tr>
<th>L/V Ratio</th>
<th>Clip A</th>
<th>Clip B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>28.4 in²</td>
<td>27.6 in²</td>
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<tr>
<td></td>
<td>84%</td>
<td>81%</td>
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<tr>
<td></td>
<td>2,188 psi</td>
<td>2,744 psi</td>
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<tr>
<td>0.44</td>
<td>26.6 in²</td>
<td>24.5 in²</td>
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<tr>
<td></td>
<td>78%</td>
<td>72%</td>
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<tr>
<td></td>
<td>2,327 psi</td>
<td>3,067 psi</td>
</tr>
<tr>
<td>0.52</td>
<td>23.6 in²</td>
<td>21.0 in²</td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td>2,872 psi</td>
<td>3,385 psi</td>
</tr>
<tr>
<td>0.60</td>
<td>16.6 in²</td>
<td>17.2 in²</td>
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<tr>
<td></td>
<td>49%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>3,809 psi</td>
<td>4,083 psi</td>
</tr>
</tbody>
</table>

% of Rail Seat

Peak Pressure (psi)

Pressure (psi)
Average Pressure Distribution for Clip A

Graph showing the average pressure distribution along the rail seat width for different L/V ratios (0.60, 0.52, 0.44, 0.25). The x-axis represents the rail seat width in inches, and the y-axis represents the pressure in psi. The graph displays four curves, each corresponding to a different L/V ratio, illustrating how the pressure distribution changes with varying L/V ratios.
Average Pressure Distribution for Clip B
Conclusions from Testing

• L/V Ratio
  – A lower L/V ratio of the resultant wheel load distributes the pressure over a larger contact area
  – A higher L/V ratio of the resultant wheel load causes a concentration of pressure on the field side of the rail seat, resulting in higher peak pressures

• Pad Modulus
  – Lower modulus rail pads distribute rail seat loads over a larger contact area, reducing peak pressure values and mitigating highly concentrated loads at this interface
  – Higher modulus rail pads distribute rail seat loads in more highly concentrated areas, possibly leading to localized crushing of the concrete surface
Conclusions from Testing (cont.)

• Fastening Clip
  – Design of the clip component of the fastening system affects the shape of the pressure distribution on the rail seat
  – Minimal differences in peak pressures and contact areas of pressure distribution between the two clips tested
Future Work with MBTSS

- Field testing at TTC in Pueblo, CO to understand pressure distribution varying:
  - Degree of curvature
  - Fastening system design
  - Train speeds
- Perform field testing at Monticello Railway Museum in Monticello, IL on section of concrete crosstie track
- Instrument high and low rail seats of a crosstie to compare varying track geometries
- Continue pad modulus testing within bounded experiments
- Continue testing various fastening systems
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Questions / Comments

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