The Effect of Particle Intrusion on Rail Seat Load Distributions

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Outline

• Motivation for Research
• Equipment Overview
• Crushing as a Failure Mechanism
• Experimental Matrix
• Preliminary Results
• Conclusions
• Future Work
Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

• Compare pressure distribution on rail seats:
  – Under various loading scenarios
  – Under various stages of rail seat wear
  – Under presence of fines and small particles

• Develop design metric for mechanistic evaluation of rail seat load distribution
Motivation for Research

- Rail Seat Deterioration (RSD) is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems.
- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked RSD as one of the most critical problems associated with concrete crosstie and fastening system performance.
- Potential RSD mechanisms as determined through research at UIUC:
  - Abrasion
  - Crushing
  - Freeze-thaw
  - Hydraulic pressure cracking
  - Hydro-abrasive erosion
Equipment Preparation and Protection

- Matrix Based Tactile Surface Sensors (MBTSS) trimmed to fit rail seat
- BoPET and PTFE layered on each side of sensor to protect from shear and puncture damage
- Plastic sleeves and plastic bags to protect sensor tabs and handles from puncture and debris

![Plan View of Sensor and Protective Layers](image)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pad/Abrasion Plate</td>
<td>0.007”</td>
</tr>
<tr>
<td>BoPET</td>
<td>0.007”</td>
</tr>
<tr>
<td>PTFE</td>
<td>0.006”</td>
</tr>
<tr>
<td>Sensor</td>
<td>0.004”</td>
</tr>
<tr>
<td>PTFE</td>
<td>0.006”</td>
</tr>
<tr>
<td>BoPET</td>
<td>0.007”</td>
</tr>
</tbody>
</table>

![Concrete Crosstie](image)
Laboratory Experiment Program

**Objective:** Explore behavior of rail seat load distribution under the presence of fines and small particles at high rail seat loads.

**Location:** Research and Innovation Laboratory (RAIL) at Schnabel, UIUC

- **Pulsating Load Testing Machine (PLTM):**
  Biaxial loading frame owned by Amsted RPS able to simulate various L/V force ratios by varying loads

**Instrumentation:**

- MBTSS deployed to capture rail seat load concentration
- Potentiometers deployed to capture vertical rail base displacement

**Loading:** hydraulic actuators used to apply lateral and vertical loads to single fastening system assembly
Crushing as a Failure Mechanism

- Crushing may occur in the presence of pressures exceeding design compressive strength of concrete (7,000 psi)

- Previous experimentation has not yielded pressures exceeding design strength
  - New fasteners: 1,700 psi
  - Worn fasteners: 2,400 psi
  - 3/4” RSD (20,000 lbf): 4,400 psi

- Particle intrusion at the rail seat may lead to extreme pressures
  - Presence of fines at rail seat noted in field visits on both worn and unworn rail seats
  - Sand is used to generate abrasive environment in AREMA Test 6: Wear and Abrasion
## Experimental Matrix

- Particle intrusion scenarios representing both typical and extreme field conditions

- Two-dimensional matrix:
  - Particle size
    - Locomotive sand
    - Class B crushed stone aggregate
      - Smaller than No. 4 sieve
  - Intrusion region
    - Entire rail seat
    - Critical region
      - 1” closest to field side shoulder

<table>
<thead>
<tr>
<th>Intrusion Region</th>
<th>Locomotive Sand</th>
<th>B-Stone Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field 1”</td>
<td>1” Sand</td>
<td>1” Aggregate</td>
</tr>
<tr>
<td>Full Seat</td>
<td>Full Sand</td>
<td>Full Aggregate</td>
</tr>
</tbody>
</table>
Loading Environment

• 40,000 lbf (178 kN) vertical wheel load assumed

• Rail seat load will be distributed in field conditions, but PLTM only tests one rail seat

• Three primary levels of load transfer selected for experimentation:
  – 25% (10,000 lbf (45 kN) rail seat load)
  – 50% (20,000 lbf (89 kN) rail seat load)
  – 75% (30,000 lbf (133 kN) rail seat load)

• Typical L/V force ratio experimentation range (0 – 0.6) tested at each level of load transfer
Qualitative Effect of Particle Intrusion

30,000 lb (128 kN) Vertical Rail Seat Load

L/V Force Ratio

<table>
<thead>
<tr>
<th>L/V Force Ratio</th>
<th>0.0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform Distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Field</td>
</tr>
<tr>
<td>No Fines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gauge Field</td>
</tr>
<tr>
<td>1” Sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gauge Field</td>
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<tr>
<td>Full Sand</td>
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<td></td>
<td></td>
<td>Gauge</td>
</tr>
</tbody>
</table>

Pressure

<table>
<thead>
<tr>
<th>Pressure Psi (MPa)</th>
<th>0</th>
<th>1,500 (10.3)</th>
<th>3,000 (20.7)</th>
<th>4,500 (31.0)</th>
<th>6,000 (41.4)</th>
</tr>
</thead>
</table>
Effect of Particle Intrusion on Contact Area

30,000 lbf (133 kN) Vertical Rail Seat Load

- 1" Sand
- Full Sand
- No Fines
- 1" Aggregate
- Full Aggregate

Contact Area (in²)

L/V Force Ratio

Contact Area (cm²)
Effect of Particle Intrusion

Effect of Contact Area Reduction

30,000 lbf (133 kN) Vertical Rail Seat Load

- 1" Sand
- 1" Aggregate
- No Fines

Average Pressure (MPa)

- Full Sand
- Full Aggregate
- Theoretical Uniform

L/V Force Ratio

Average Pressure (psi)

0.0 0.1 0.2 0.3 0.4 0.5 0.6

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 7 14 21 28 34 41 48

0 0.1 0.2 0.3 0.4 0.5 0.6

0 4 8 12 16 20 24 28 32 36 40 44 48

0 41 41 41 41 41 41 41 41 41 41 41
Effect of Contact Area Reduction

30,000 lbf (133 kN) Vertical Rail Seat Load

- 1" Sand
- Full Sand
- 1" Aggregate
- Full Aggregate
- No Fines
- Theoretical Uniform

Maximum Pressure (psi) vs. L/V Force Ratio

Maximum Pressure (MPa)
Conclusions

• Intrusion of sand particles has little effect on contact area
  – 3% average deviation
• Intrusion of aggregate on entire rail seat leads to load concentrations on aggregate peaks
  – 15% average reduction of contact area below 0.3 L/V
• Particle intrusion only in critical region (field side inch) significantly increases maximum pressure
  – 45% average increase over No Fines case
• Crushing due to a single load application is not expected on a healthy rail seat
  – 6,050 psi (41.7 MPa) maximum pressure from experimentation
• Crushing due to repeated loading is feasible on a healthy rail seat in the presence of fines
  – 3,500 psi (24.1 MPa) threshold exceeded in extreme loading scenarios
Future Work

- How repeatable are results on additional rail seats?
- How can these findings be applied to the development of RSLI?
- Can we correlate load nonuniformity to RSD?
  - How does rail seat pressure correlate to damage?
  - How does rail seat pressure correlate to crosstie life expectancy?
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Thank You

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