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

U.S. Department of Transportation
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RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Rail Transportation and Engineering Center (RailTEC)
University of Illinois at Urbana-Champaign (UIUC) – Christopher T. Rapp, Marcus S. Dersch, J. Riley Edwards, Christopher P.L. Barkan
Amsted RPS – Brent Wilson, Jose Mediavilla

Background and Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked rail seat deterioration (RSD) as one of the most critical problems associated with concrete sleeper and fastening system performance (2008, 2012)
  - RSD is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems
- **Research objective: measure magnitude and distribution of pressure at concrete sleeper rail seat and investigate crushing as a feasible failure mechanism leading to RSD**
- Experimentation is being performed to compare pressure distributions on rail seats under various loading scenarios and fastening systems, and identify regions of high pressure while quantifying peak values
- MBTSS experimentation is providing a better understanding of the load transfer from the wheel/rail interface to the rail seat

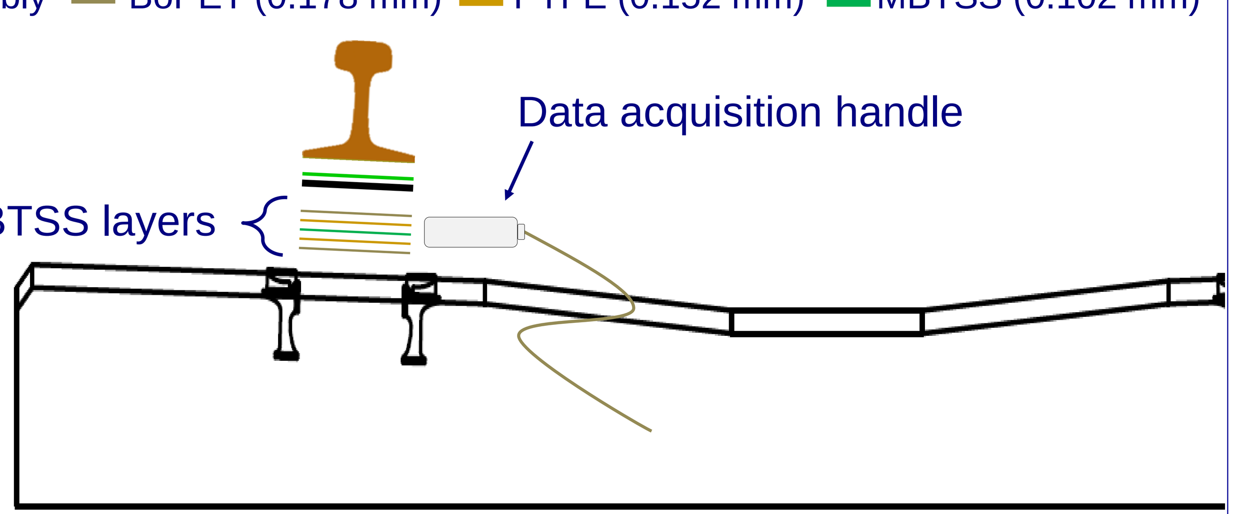
MBTSS Technology

- Sensors are comprised of two thin sheets of polyester with a total thickness of 0.102 millimeters
- On one sheet, a pressure sensitive semi-conductive material is printed in rows; on the other, in columns, which forms a grid when overlaid
- Conductive silver leads extend from each column and row to the “tab” from which data is collected by a data acquisition handle
- Known input loads are currently applied to MBTSS data to measure the pressure distributions
- Sensors can be trimmed to fit various concrete rail seat dimensions

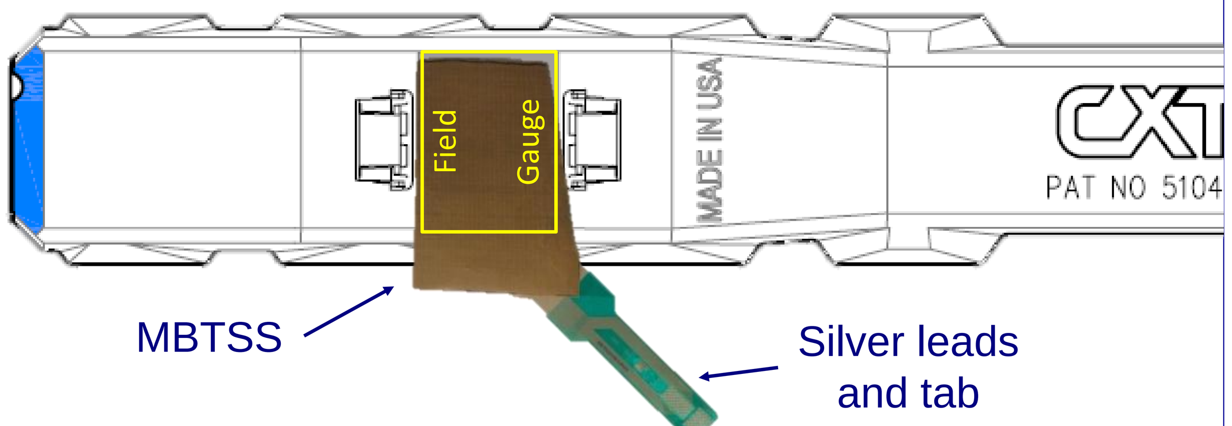
MBTSS Layout and Installation

- The sensor is placed at the interface between the concrete rail seat surface and the rail pad component of the fastening system assembly
- To protect from shear forces and puncture, the sensor is covered on both sides with thin layers of polytetrafluoroethylene (PTFE) and bi-axially oriented Polyethylene Terephthalate (BoPET)

Pad Assembly · BoPET (0.178 mm) · PTFE (0.152 mm) · MBTSS (0.102 mm)



Profile view of MBTSS layers



Plan view of MBTSS installed on a concrete sleeper with relative rail seat area

Pulsating Load Testing Machine (PLTM) Experimental Test Setup

- Owned by Amsted RPS
- Three 156 kN actuators: two vertical and one horizontal
- Allows for simulation of various Lateral/Vertical (L/V) force ratios
- Used for Full Scale Concrete Sleeper and Fastening System Testing
  - Following AREMA Test 6 – Wear and Abrasion
- Housed at Advanced Transportation and Research Engineering Laboratory (ATREL)

Amsted RPS
Amsted Rail

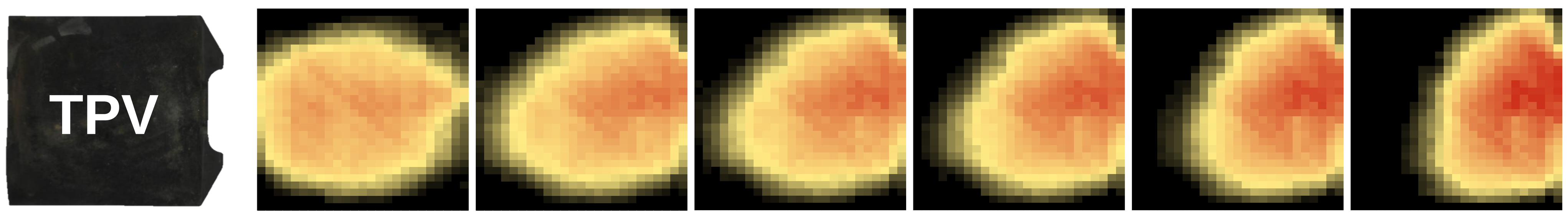
Laboratory Experimentation – Rail Pad Test

- Laboratory experiments were performed to investigate the effect of pad modulus on load distributions
- Low/high modulus pads were used to bound the problem, as well as a commonly used pad assembly
  - Thermoplastic Vulcanizate (TPV): Shore Hardness of 90 (A), Flexural Modulus of 103.42 mPa
  - Medium-Density Polyethylene (MDPE): Shore Hardness of 65 (D), Flexural Modulus of 827.37 mPa
  - Two-Part Pad Assembly: Poly pad – Shore Hardness of 94 (A), Nylon 6-6 abrasion frame – Shore Hardness of 76 (D)
- Loading regime of 144.56 kN constant vertical load, lateral load varied with respective L/V force ratio

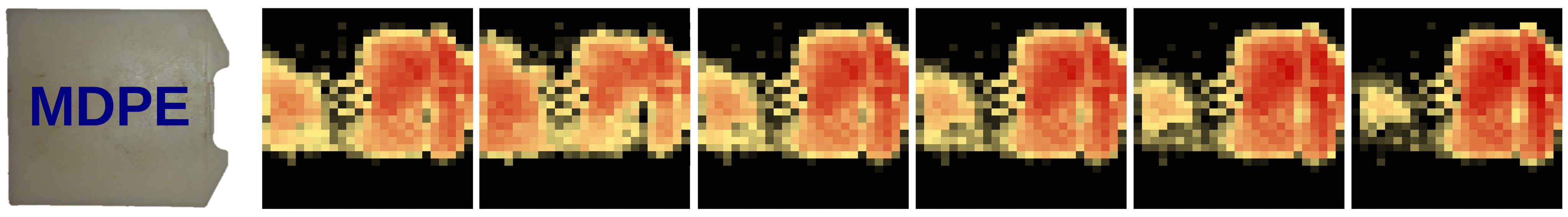
Laboratory Experimentation – Rail Pad Test Results

← GAUGE · PRESSURE (mPa) · FIELD →

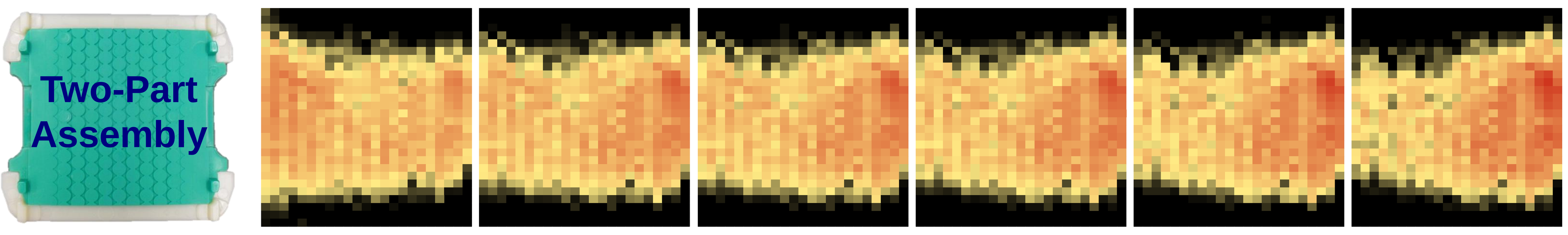
0 · 7 · 14 · 21 · 28



L/V Force Ratio	0.25	0.44	0.48	0.52	0.56	0.60
TPV Contact Area (cm^2)	185.5	180.2	175.8	166.1	154.6	137.4
TPV Peak Pressure (mPa)	14.75	17.74	19.31	20.17	21.80	23.44



L/V Force Ratio	0.25	0.44	0.48	0.52	0.56	0.60
MDPE Contact Area (cm^2)	129.6	124.6	123.4	122.7	120.2	144.6
MDPE Peak Pressure (mPa)	22.15	23.92	24.45	25.66	26.46	28.24



L/V Force Ratio	0.25	0.44	0.48	0.52	0.56	0.60
Two-Part Assembly Contact Area (cm^2)	160.6	154.8	154.2	154.2	151.0	151.0
Two-Part Assembly Peak Pressure (mPa)	17.58	19.45	19.84	20.62	22.07	22.93

Conclusions from Laboratory Experimentation

- Effect of L/V force ratio
  - Lower L/V force ratios distribute the pressure over a larger contact area
  - Higher L/V force ratios concentrate pressure on the field side of the rail seat, with higher pressures
- Rail Pad Test
  - Lower modulus pads distribute loads over a larger contact area, reducing peak pressure values and mitigating highly concentrated loads at this interface, though allowing greater rail base rotation
  - Higher modulus rail pads distribute rail seat loads over a smaller contact area, possibly leading to localized crushing of the concrete surface, while reducing rail base rotation
  - The two-part pad assembly maintains a relatively consistent contact area under increasing L/V force ratios while yielding peak pressures similar to the lower modulus TPV pad, and reducing rail base rotation similar to the higher modulus MDPE pad
- Crushing does not appear to be a feasible mechanism of RSD under these loading conditions
  - Peak values do not approach the ~48 mPa minimum design compressive strength of concrete as recommended by the American Railway Engineering and Maintenance-of-Way Association (AREMA)
  - It is still believed that a “perfect storm” of poor track support conditions and high impact loads in the field could result in peak values that cause crushing of the concrete surface

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Future Work

- Continue investigating common North American fastening systems
- Perform field experimentation to understand varying track and loads
- Incorporate rail seat pressures into other RSD mechanism studies