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

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Federal Railroad Administration

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Background and Current Objectives of Experimentation with MBTSS

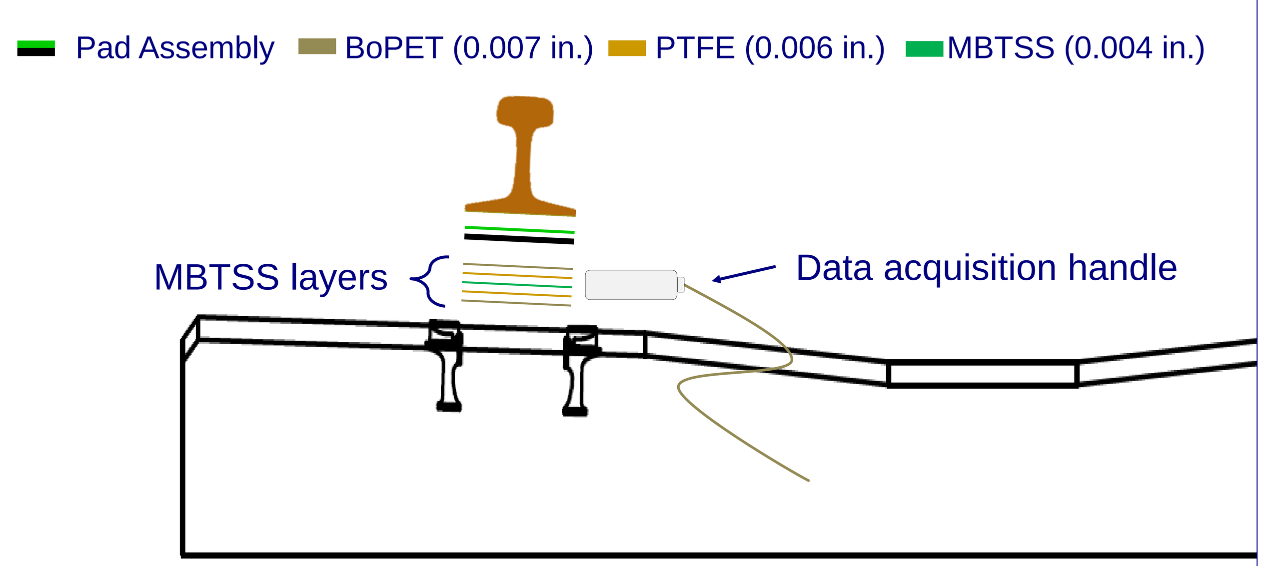
- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked rail seat deterioration (RSD) as one of the most critical problems associated with concrete crosstie and fastening system performance (2008, 2012)
  - RSD is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems
- **Research objective: measure the magnitude and distribution of pressure at the concrete crosstie 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
- Results from experimentation with MBTSS are providing a better understanding of the load transfer from the wheel/rail interface to the rail seat

MBTSS Technology

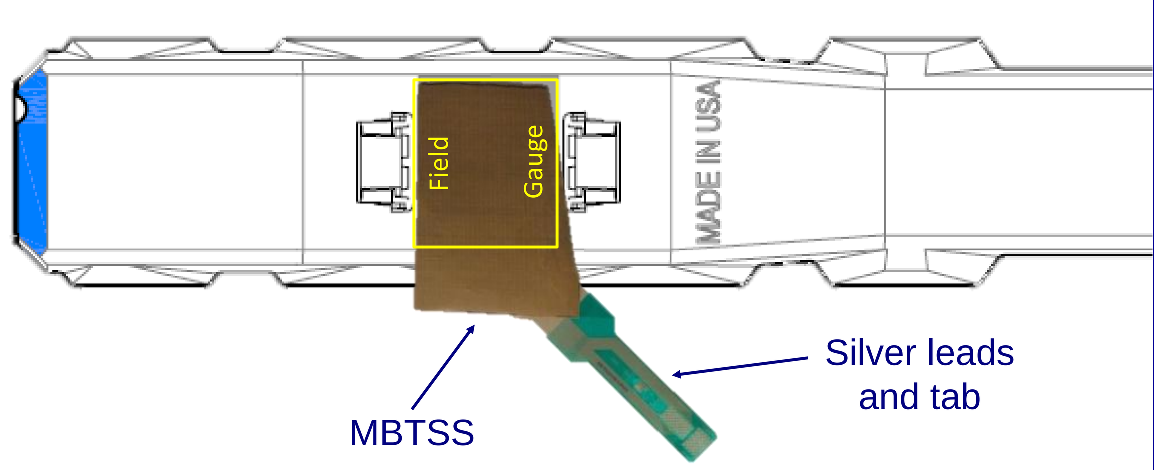
- Sensors are comprised of two thin sheets of polyester with a total thickness of 0.004 inches
- On one sheet, a pressure sensitive semi-conductive material is printed on rows; on the other, in columns, which forms a grid when overlaid
- Conductive silver leads extend from each column and row to the "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)



Profile view of MBTSS layers



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

Pulsating Load Testing Machine (PLTM) Experimental Test Setup

- Owned by Amsted RPS
- Three 35 kip actuators: two vertical and one horizontal
- Allows for ability to simulate various Lateral/Vertical (L/V) force ratios
- Used for Full Scale Concrete Tie and Fastening System Testing
  - Following AREMA Test 6 – Wear and Abrasion
- Housed at Advanced Transportation and Research Engineering Laboratory (ATREL)

Laboratory Experimentation – Rail Pad Test

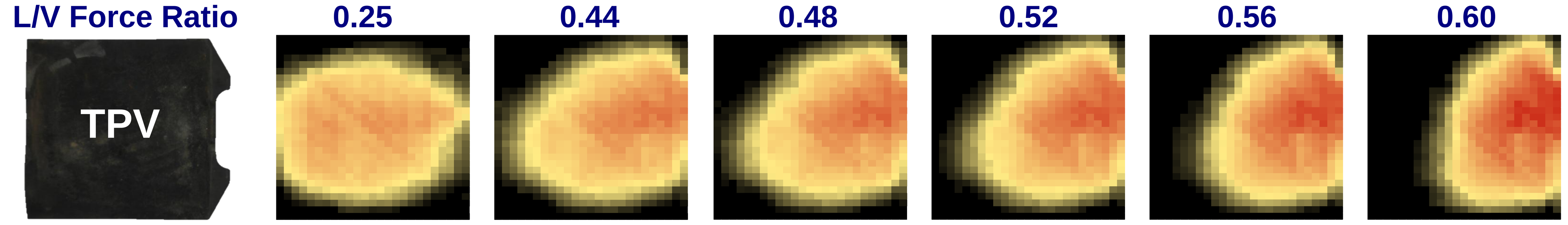
- Laboratory experiments were performed to investigate the effect of pad modulus on rail seat pressure distribution
- Three pad types were used for this experiment; low and high modulus pads to bound the problem, and a commonly used pad assembly
  - Thermoplastic Vulcanizate (TPV – lower modulus)
    - Shore Hardness of 90 (A), Flexural Modulus of 15,000 psi
  - Medium-Density Polyethylene (MDPE – higher modulus)
    - Shore Hardness of 65 (D), Flexural Modulus of 120,000 psi
  - Two-Part Pad Assembly
    - Poly pad – Shore Hardness of 94 (A)
    - Nylon 6-6 abrasion frame – Shore Hardness of 76 (D)
- Loading regime of 32.5 kip constant vertical load and lateral load varying based on respective L/V force ratio

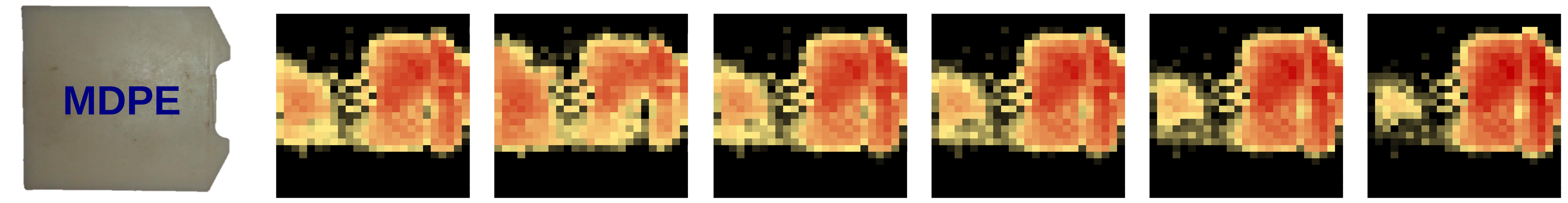
Future Work

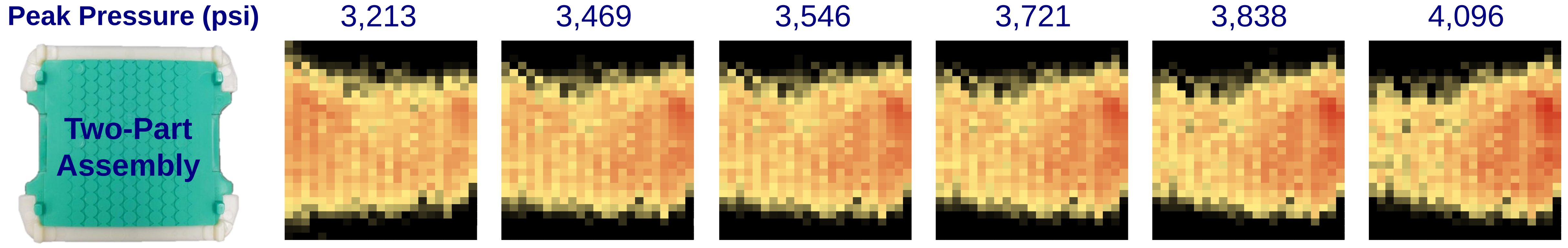
- Continue investigating common North American fastening systems
- Perform field experimentation at Transportation Technology Center in Pueblo, CO to understand pressure distribution varying track and loads
- Incorporate rail seat pressures into other RSD mechanism studies

Laboratory Experimentation – Rail Pad Test Results

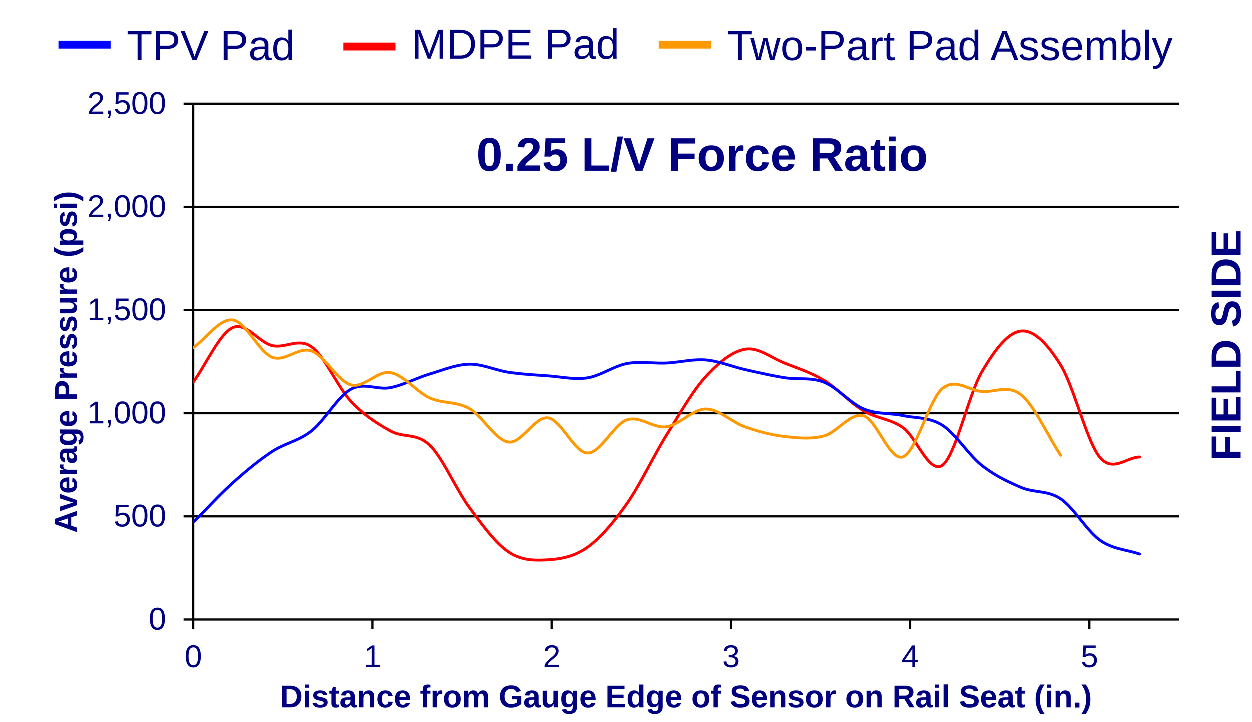
L/V Force Ratio	0.25	0.44	0.48	0.52	0.56	0.60
TPV						
Contact Area (in²)	28.8	27.9	27.3	25.8	24.0	21.3
Peak Pressure (psi)	2,139	2,573	2,800	2,925	3,162	3,400
MDPE						
Contact Area (in²)	20.1	19.3	19.1	19.0	18.6	17.8
Peak Pressure (psi)	3,213	3,469	3,546	3,721	3,838	4,096
Two-Part Assembly						
Contact Area (in²)	24.9	24.0	23.9	23.9	23.4	23.4
Peak Pressure (psi)	2,550	2,821	2,877	2,990	3,201	3,325

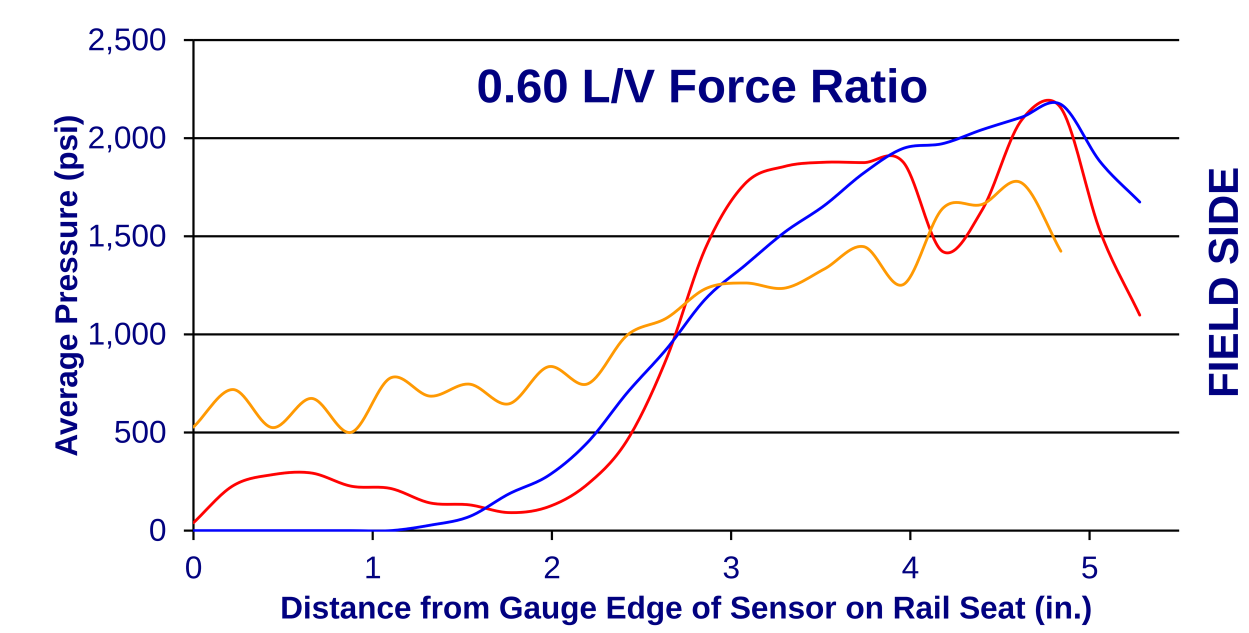






Average Pressure Distributions at Various L/V Force Ratios





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 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, 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 MDPE pad
- Crushing does not appear to be a feasible mechanism of RSD under these loading conditions
  - Peak values do not approach the 7,000 psi 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

Acknowledgements – FRA Tie and Fastener BAA Industry Partners

Amsted RPS, Amsted Rail, Union Pacific – Building America, BNSF Railway, Amtrak, GIC, Hanson, LBFoster CXT Concrete Ties