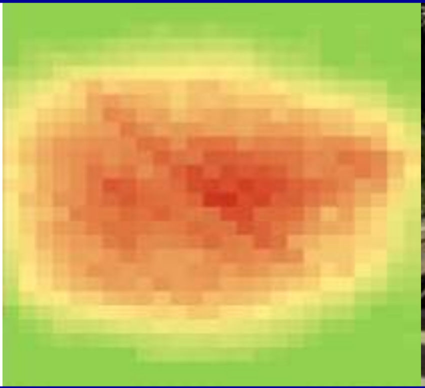
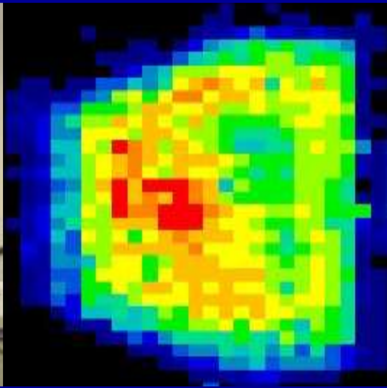
Measuring Concrete Crosstie Rail Seat Pressure Distribution with Matrix Based Tactile Surface Sensors



2012 Joint Rail Conference

Philadelphia, PA

17-19 April 2012

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U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Amsted RPS
Amsted Rail

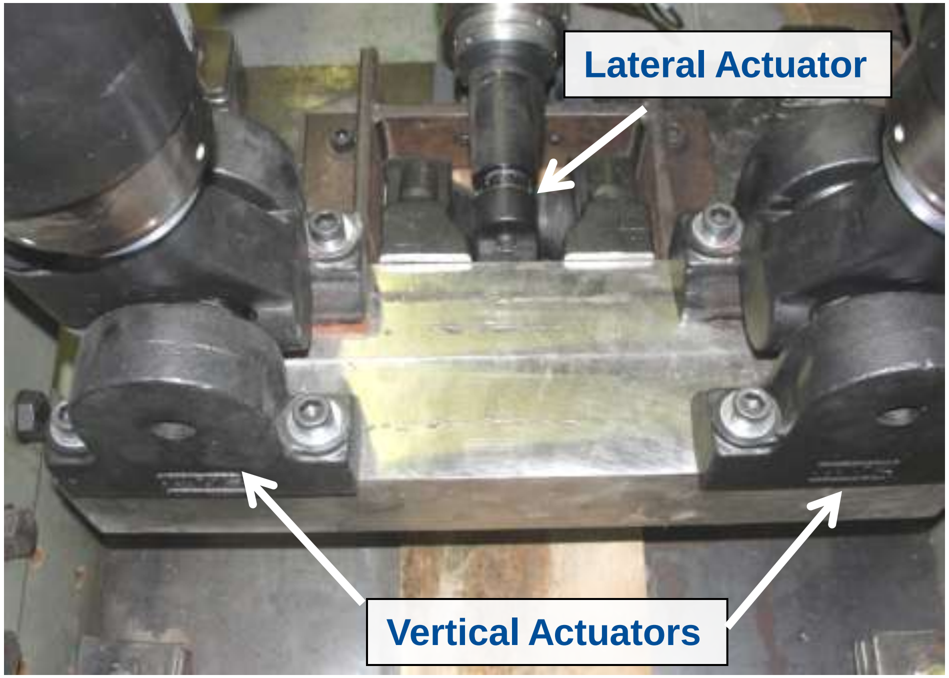
Outline

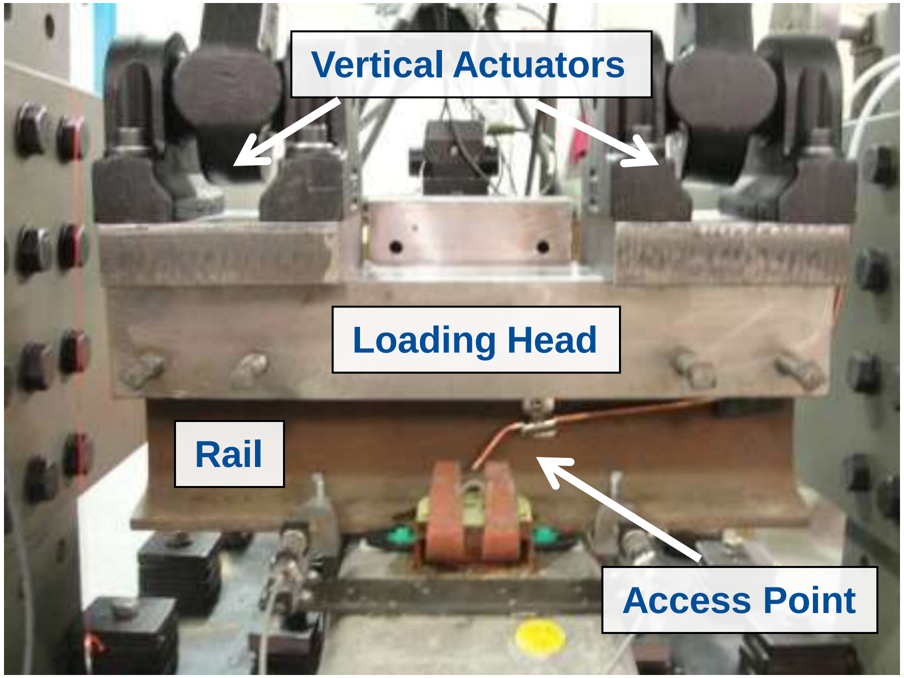
- Pulsating Load Testing Machine (PLTM)
- Current Objective and Roles of MBTSS
- Sensor Layout and Data Representation
- Experimentation at UIUC
  - Pad Modulus Test
  - Fastening Clip Test
- Conclusions from Testing
- Future Work with MBTSS
- Questions / Comments

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)





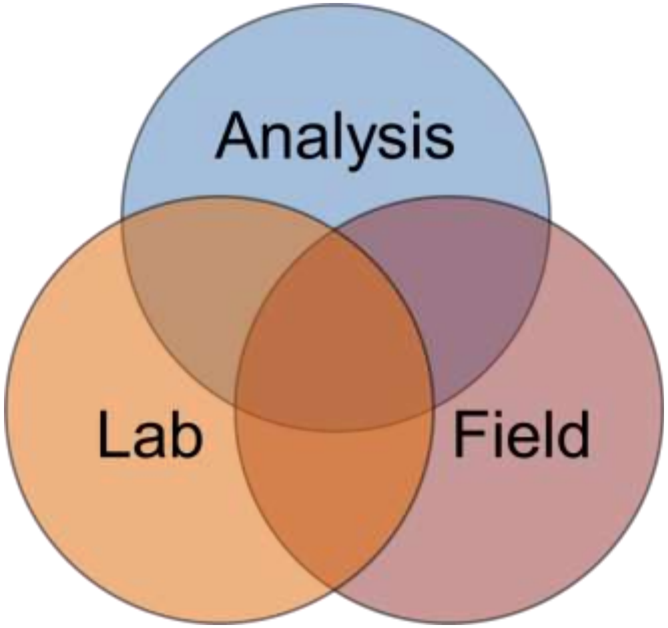
Current Objectives of Experimentation with MBTSS

- 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



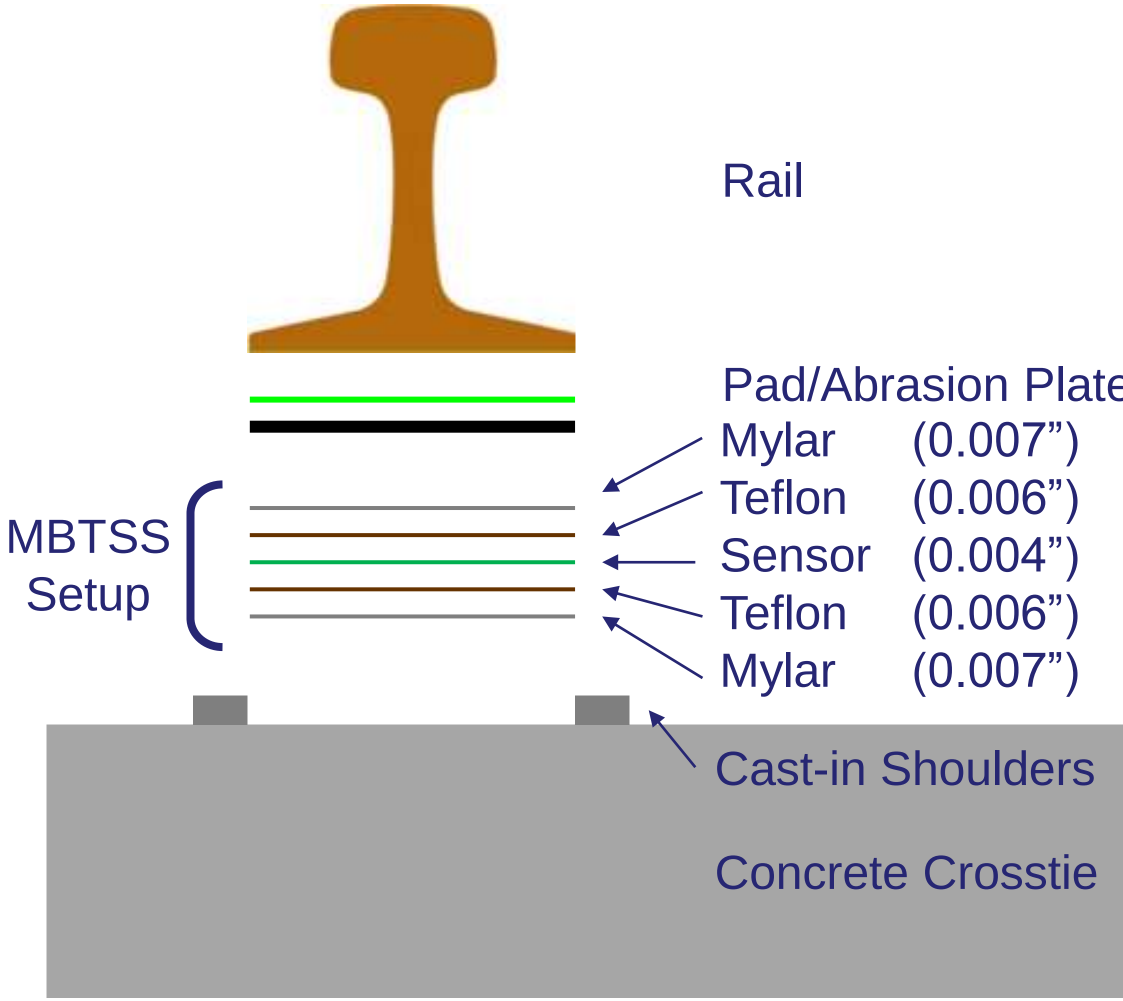
Lab

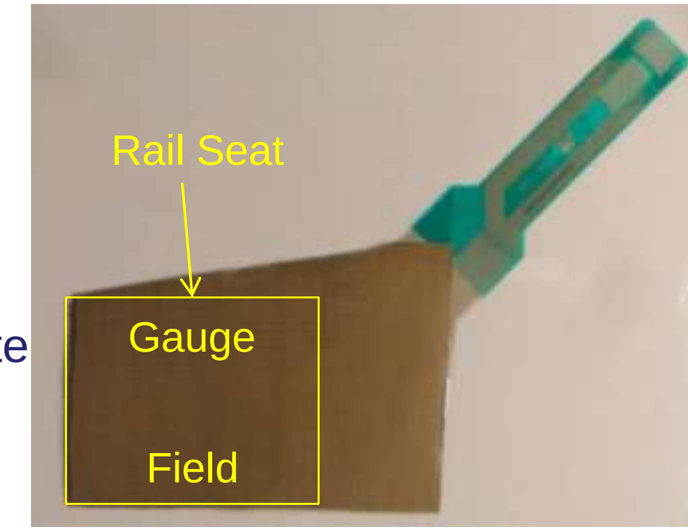
- Conduct experimentation with known input loads and controlled variables
- Simulate conditions found in field (L/V ratio, etc.)

Field

- Instrument various loading conditions
- Consider track geometry, speed, fastening system, etc.

Sensor Installation Layout

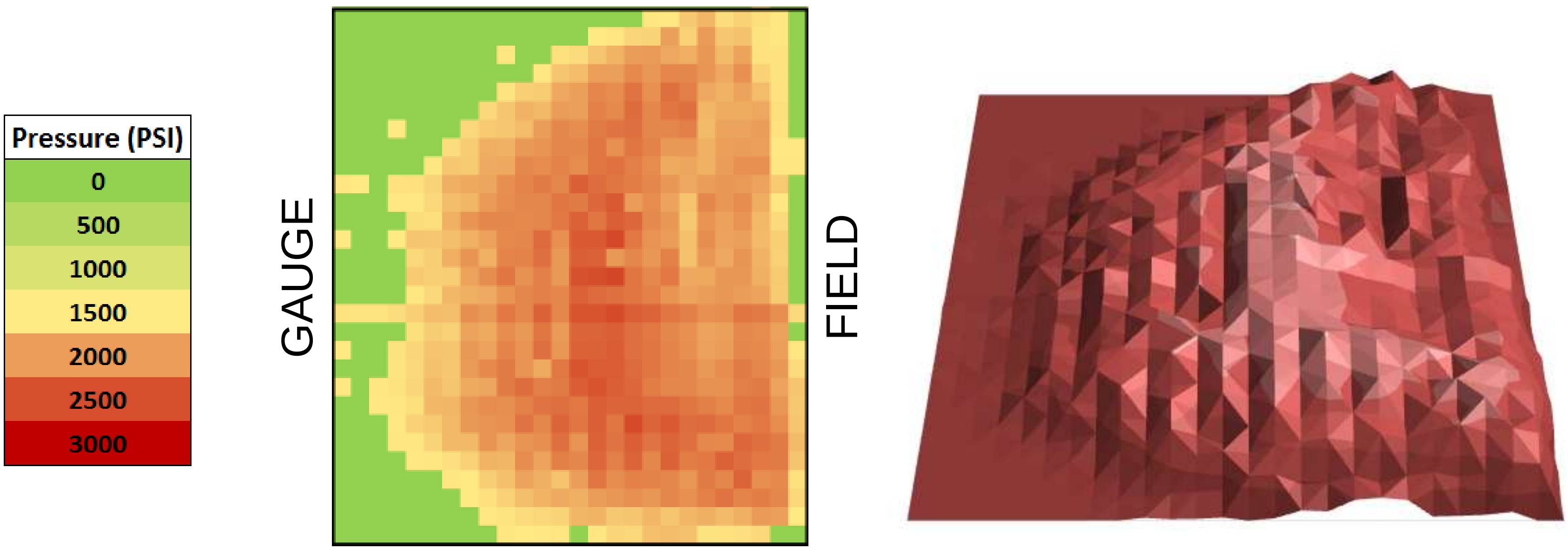




MBTSS

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



Sample MBTSS output

Pressure (PSI)
0
500
1000
1500
2000
2500
3000

GAUGE

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	45	451	667	180	324	162	54	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	81	270	297	964	342	1036	460	541	108	72	0
0	0	0	0	0	0	0	0	0	54	0	0	135	207	496	712	1000	1036	874	784	1072	622	928	126	126	0
0	0	0	0	0	0	0	0	0	0	0	45	496	604	982	964	1253	1072	1280	1289	1090	856	1162	324	108	0
0	0	0	0	0	0	0	0	0	99	369	387	856	964	1280	1208	1541	1162	1577	1397	874	739	928	604	126	0
0	0	0	0	0	0	0	0	234	478	739	640	1000	964	1361	1253	1631	1289	1505	1577	676	811	811	874	162	0
0	0	0	36	0	0	0	261	424	469	604	1000	1289	1199	1433	1541	1577	1289	1289	1397	622	928	928	1000	117	0
0	0	0	0	0	0	180	396	784	748	1054	1108	1289	1289	1505	1162	1505	1343	1054	1063	748	982	1000	964	45	45
0	0	0	0	0	63	460	415	838	856	1271	1217	1343	1217	1505	1559	1397	1217	820	892	748	1000	1162	1171	54	54
54	36	0	117	135	315	757	847	892	1180	1325	1433	1289	1793	1613	1505	1415	1289	1072	874	1000	1072	1036	928	424	0
0	0	0	45	45	252	586	676	1036	1217	1289	1289	1505	1433	1685	1865	1018	1217	928	514	1289	1072	1217	802	54	0
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36	0	0	36	487	460	568	748	955	1253	1289	1649	1162	1865	1865	2082	1469	1126	1018	559	1199	928	964	631	369	0
0	0	0	0	252	378	784	1108	748	1325	1343	1577	1054	1793	1757	1054	1289	1072	1361	541	1072	856	1108	739	342	0
0	0	0	0	424	369	378	928	1199	1505	1153	1397	1054	1973	2010	2118	1505	1271	1469	856	847	1072	1072	757	433	0
0	0	0	0	72	234	658	766	838	1108	1289	1397	1280	1757	1649	1577	1487	1361	1108	910	1000	1072	1000	910	415	0
108	90	99	180	369	604	568	1180	1054	1469	1289	1757	1289	1937	1937	2046	1793	1730	1505	1397	1162	1199	1505	1433	1180	225
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36	0	0	108	279	523	478	1054	928	1325	1135	1577	1072	1757	1757	1829	1577	1487	1325	1180	946	1000	1289	1253	982	63
0	0	0	99	261	541	469	1036	1253	1433	1126	820	1469	1937	1829	1829	1649	1505	1325	1289	1054	1217	1433	1289	1072	207
45	0	54	108	279	622	496	820	892	1433	1613	1397	1433	1829	1937	1793	1685	1415	1289	1289	1144	1144	1397	1433	928	496
0	0	45	54	162	658	685	1072	1217	1180	1361	1541	1577	1469	1793	1721	1739	1649	1649	1487	1397	1253	1505	1541	1072	442
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0	0	0	54	63	315	640	640	1108	883	1108	1180	1577	1126	1757	1541	1793	1541	1730	1577	1271	1253	1685	1577	1433	622
0	0	0	0	45	63	153	333	712	694	1217	928	1388	1289	1685	1397	1739	1289	1757	1415	1469	1757	1613	1469	1433	505
0	0	0	0	0	0	54	36	378	559	928	766	514	991	1505	1199	1361	1352	1289	1072	1433	1289	1739	1180	1253	135
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0	0	0	0	0	0	0	0	45	90	207	252	297	676	712	451	496	676	487	676	766	631	757	1036	982	36
0	0	0	0	0	0	0	0	0	72	36	45	81	0	63	270	243	550	604	541	108	126	153	234	0	0

FIELD

0.22”

0.22”

162

Area = 0.0484 in^2

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

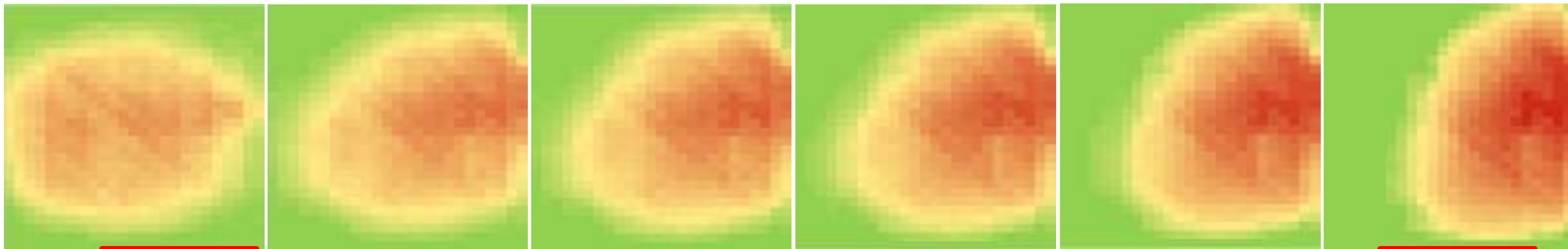
Santoprene

HDPE

Rail Pad Test Results

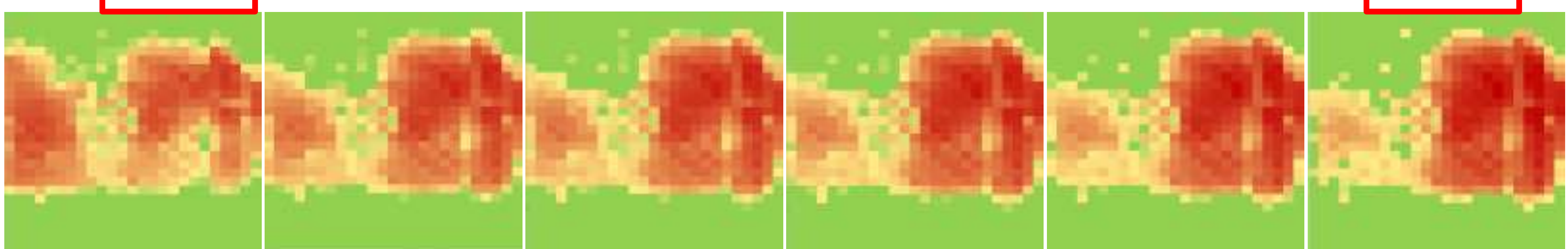
← GAUGE FIELD →

Santoprene™



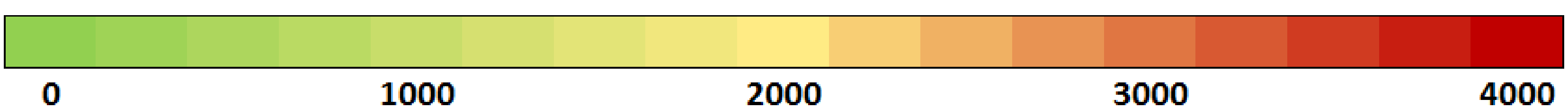
L/V Ratio	0.25	0.44	0.48	0.52	0.56	0.60
Contact Area (in²)	28.8	27.9	27.3	25.8	24.0	21.3
% of Rail Seat	85	82	80	76	71	63
Peak Pressure (psi)	2,139	2,573	2,800	2,925	3,162	3,400

HDPE

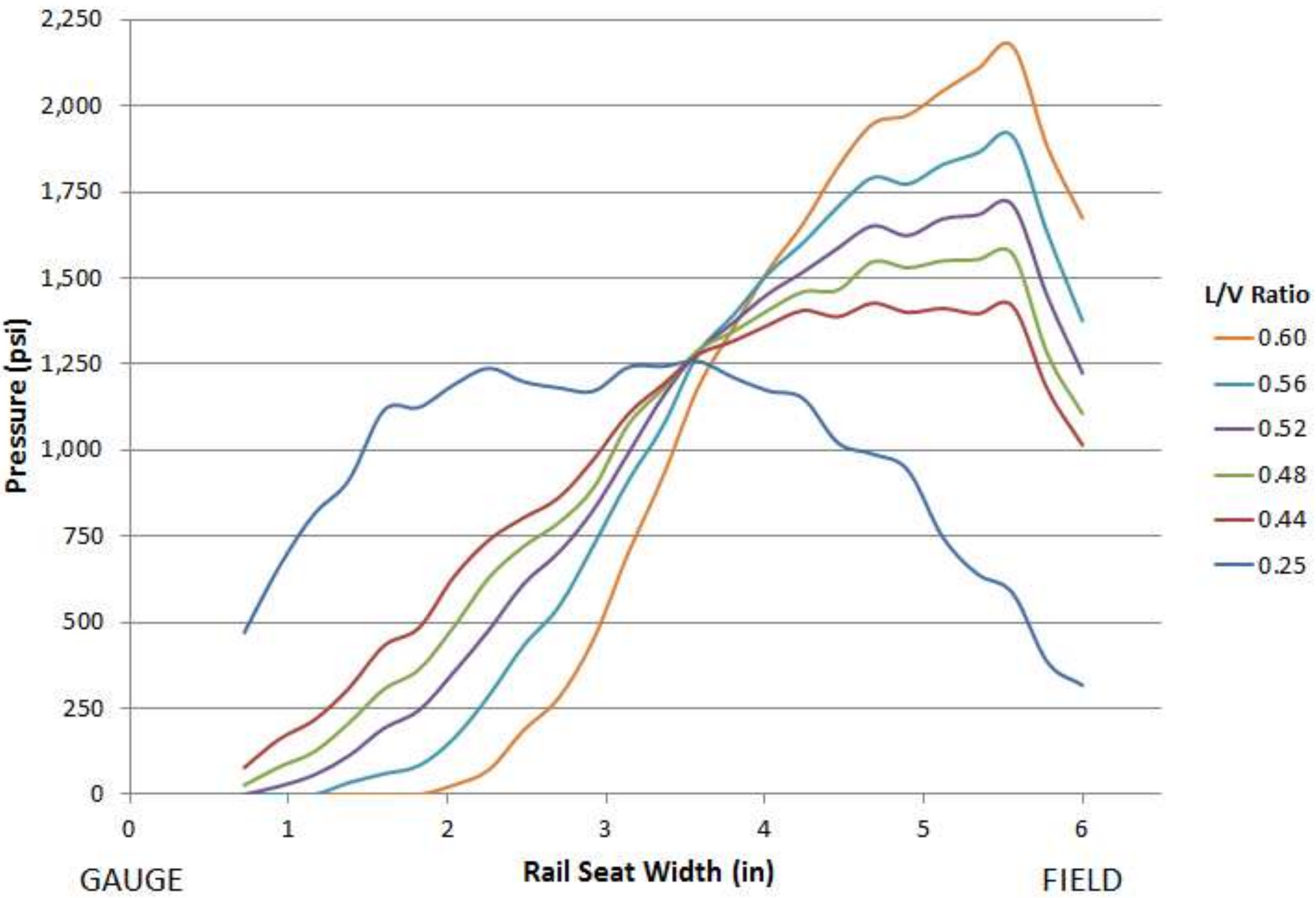


L/V Ratio	0.25	0.44	0.48	0.52	0.56	0.60
Contact Area (in²)	20.1	19.3	19.1	19.0	18.6	17.8
% of Rail Seat	59	57	56	56	55	52
Peak Pressure (psi)	3,213	3,469	3,546	3,721	3,838	4,096

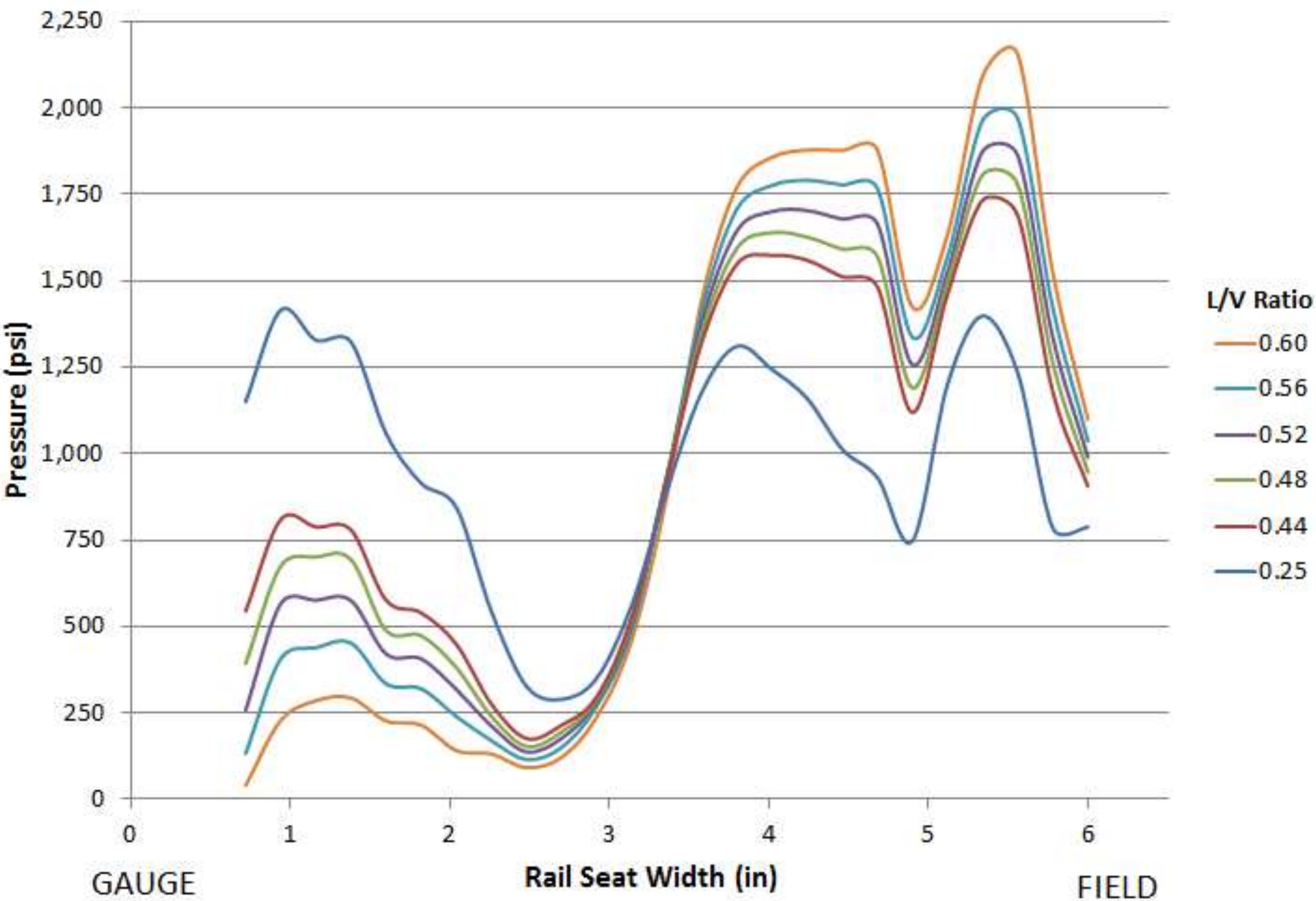
Pressure (psi)



Average Pressure Distribution for Santoprene™ Rail Pad



Average Pressure Distribution for HDPE Rail Pad



Clip Test

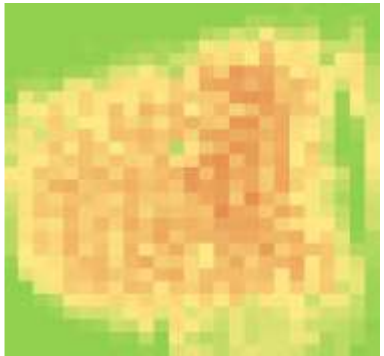
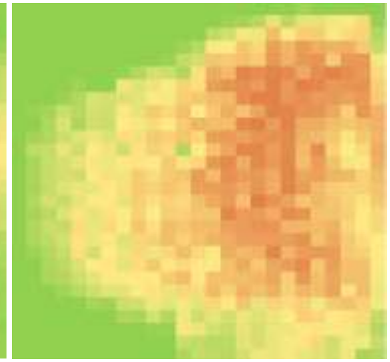
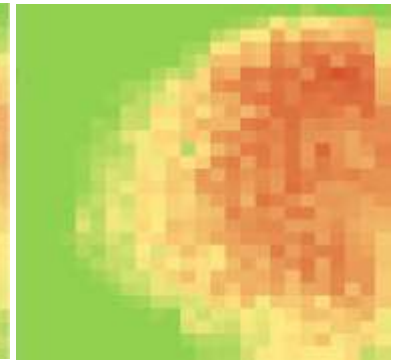
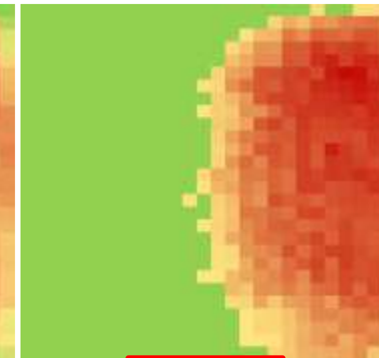
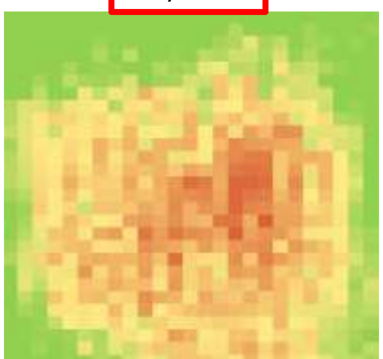
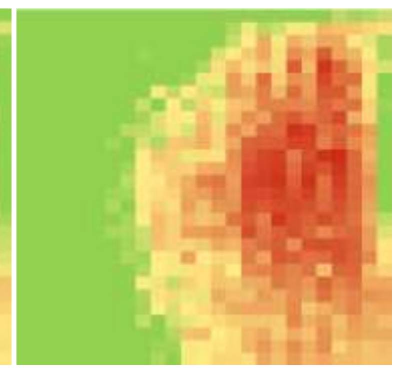
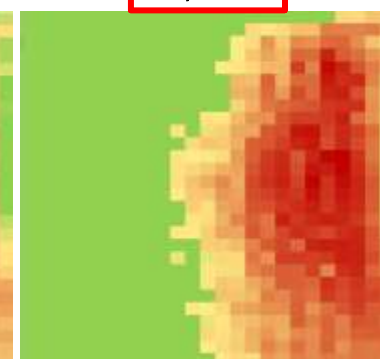
- **Objective:** gain preliminary understanding of clip geometry on pressure distribution
- Two fastening clips tested
- Rail pad material held constant
- Identical loading conditions
  - 32.5 kip vertical load
  - Lateral load varies based on respective L/V ratio

Clip A

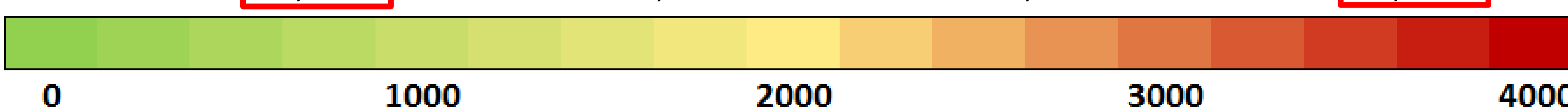
Clip B

Clip Test Results

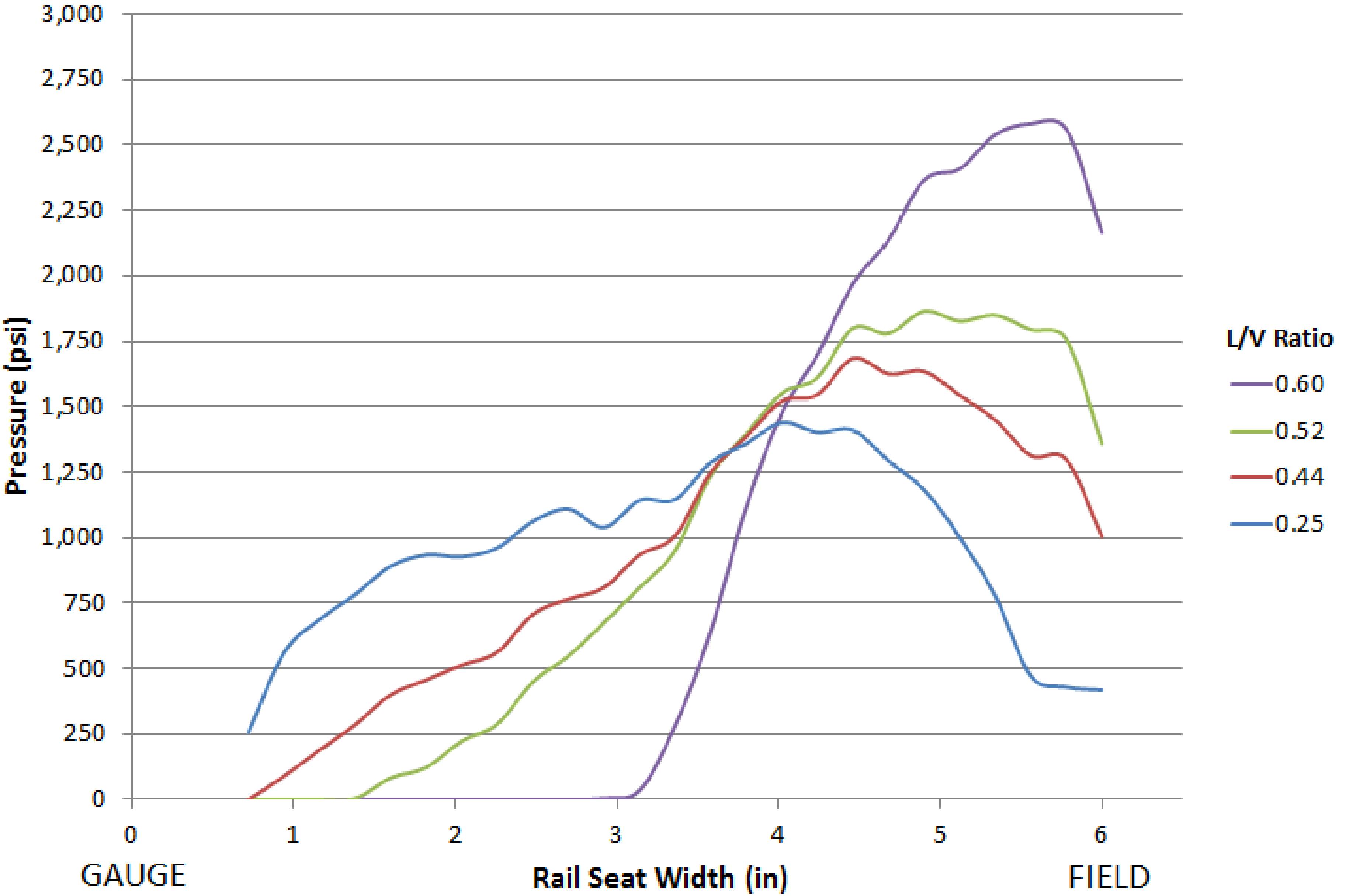
← GAUGE FIELD →

L/V Ratio	0.25	0.44	0.52	0.60
 Clip A				
Contact Area (in^2)	28.4	26.6	23.6	16.6
% of Rail Seat	84	78	70	49
Peak Pressure (psi)	2,188	2,327	2,872	3,809
 Clip B				
Contact Area (in^2)	27.6	24.5	21.0	17.2
% of Rail Seat	81	72	62	51
Peak Pressure (psi)	2,744	3,067	3,385	4,083

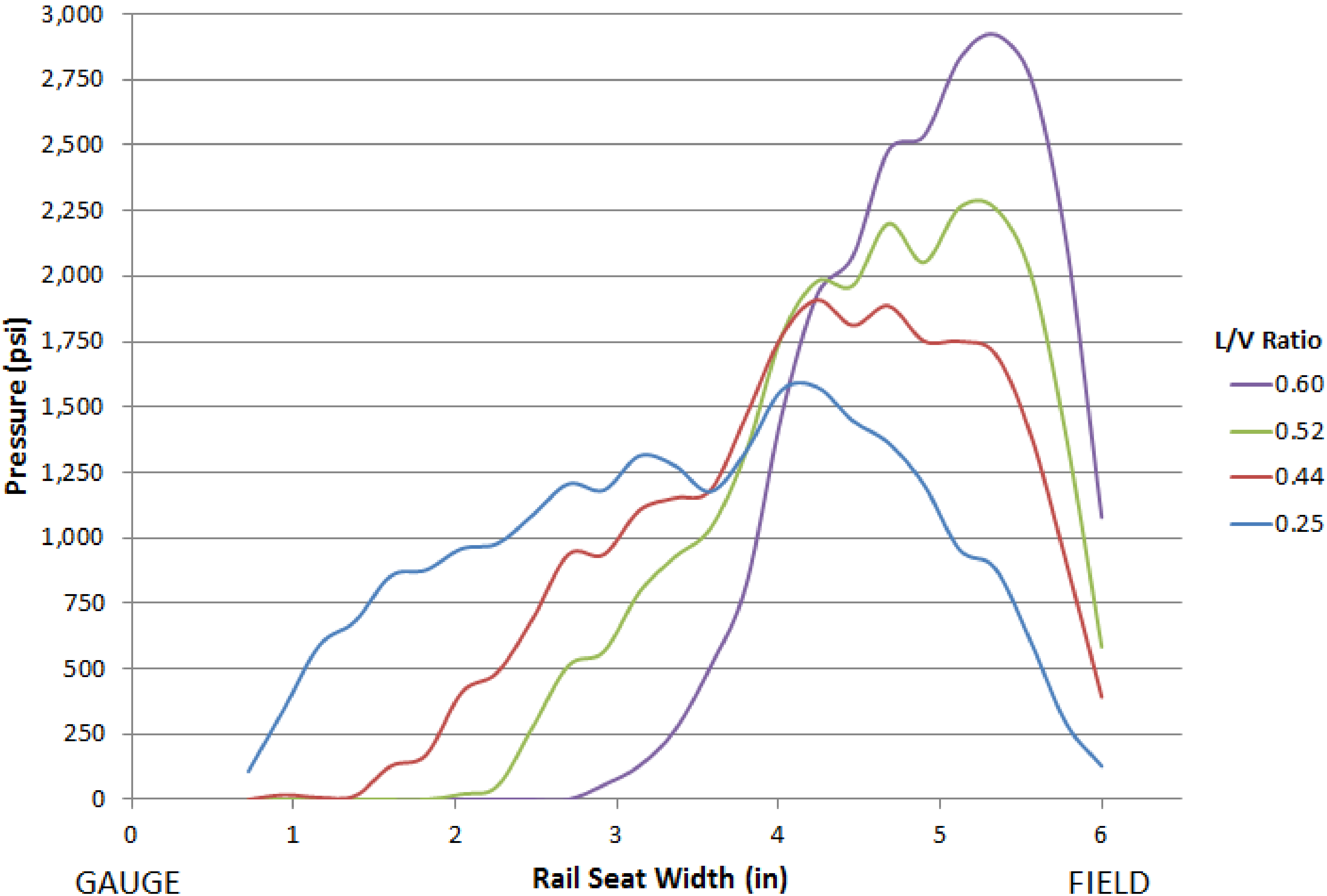
Pressure (psi)



Average Pressure Distribution for Clip A



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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TTCI Transportation Technology Center, Inc.

Acknowledgements

U.S. Department of Transportation

Federal Railroad Administration

FRA Tie and Fastener BAA Industry Partners:

- Funding for this research has been provided by the Federal Railway Administration (FRA)
- Industry Partnership and support has been provided by
  - Union Pacific (UP) Railroad
  - BNSF Railway
  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS / Amsted Rail, Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
- Marc Killion and Timothy Prunkard – UIUC
- Professor Jerry Rose and graduate students – University of Kentucky
- AAR/TTC – Dave Davis, for assisting in field tests

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HANSON

LBFoster CXT Concrete Ties

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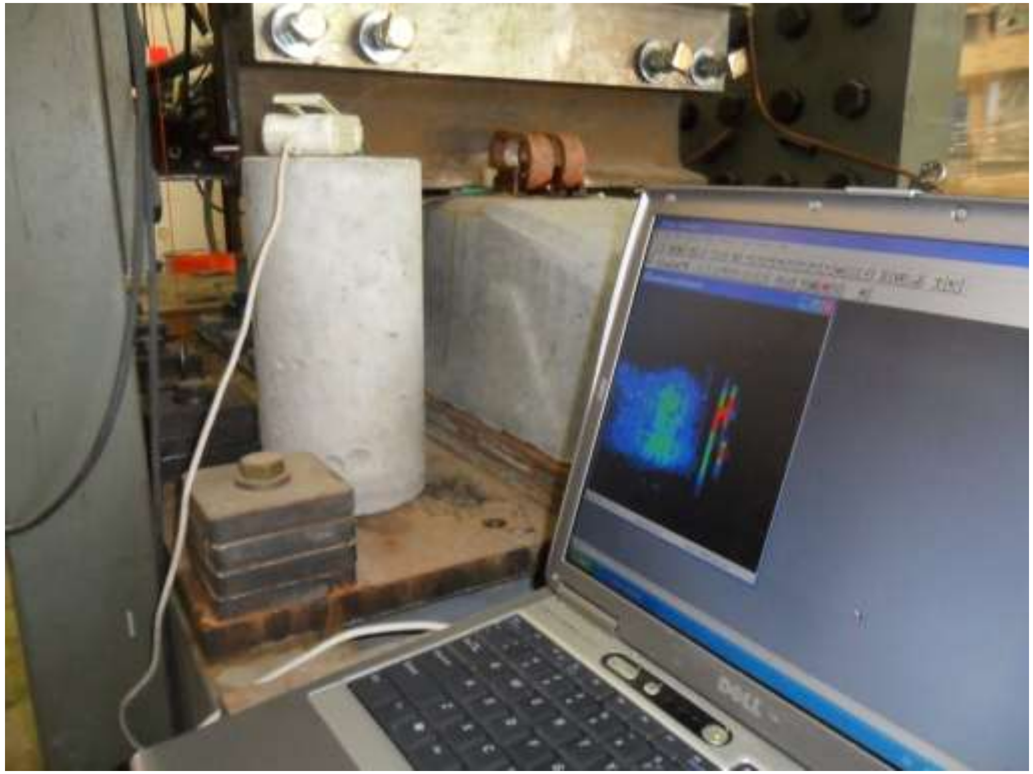
Questions / Comments



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