Laboratory Instrumentation of Concrete Crossties and Fastening Systems

AREMA Committee 30 Fall 2012 Meeting

Tampa, FL

25 October 2012

Sihang Wei, Daniel Kuchma, Justin Grassé,
Riley Edwards and Marcus Dersh

U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

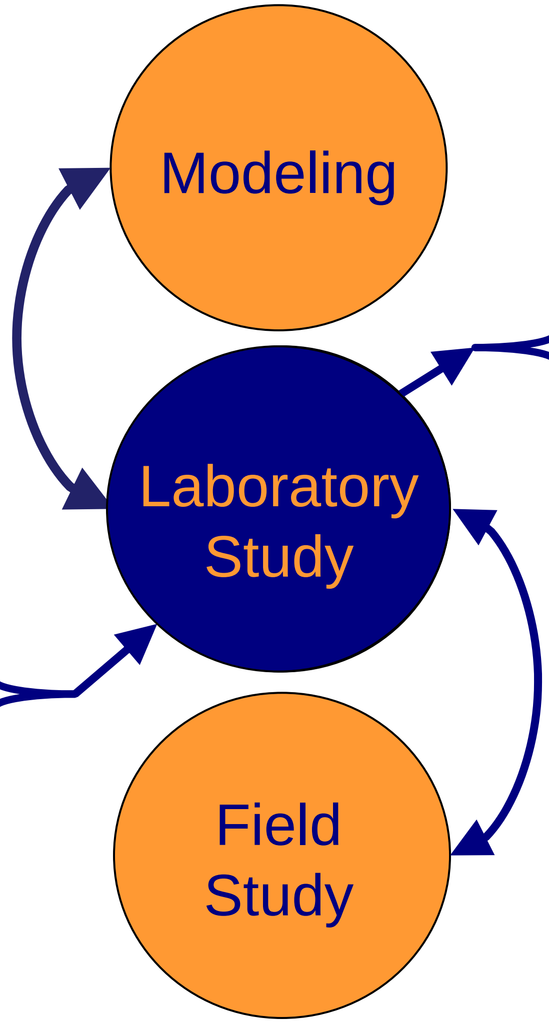
Outline

- Objectives of Laboratory Instrumentation
- Scope of Investigation
- Laboratory Experimentation at UIUC
  - Rail Deformation Test
  - Rail Seat Reaction Test
- Conclusions
- Future Work
- Acknowledgments

FRA Tie and Fastener Project Structure

Inputs

- **Comprehensive Literature Review**
- International Tie and Fastening System Survey
- **Loading Regime (Input) Study**
- Rail Seat Load Calculation Methodologies
- **Involvement of Industry Experts**



Outputs/Deliverables

- **Data Collection**
- Document Depository
- **Groundwork for Mechanistic Design**
- International Survey Report
- **Load Path Map**
- **Parametric Analysis**
- State of Practice Report
- Validated Tie and Fastening System Model

Improved Recommended Practices

FRA Tie and Fastener BAA Laboratory Testing

- **Objectives:**
  - Measure forces at critical interfaces (rail-pad, pad-tie, insulator-clip, rail-insulator-shoulder, etc.)
  - Guide and focus field instrumentation efforts
  - Provide a repeatable tool for FEA model validation
- **Experimental Approach:**
  - Component-level tests (e.g. concrete crosstie)
  - System-level tests (e.g. fastening system)
  - Close coordination and with FEA Modeling team

Built up Load Cell Feasibility Study

(Aug. 2011)

- **Objective**: Test feasibility of built up load cell concept
- **Strategy**: Used eight strategically located strain gauges mounted on the rail
- **Test**: 3-point bending test with loads ranging from 0 to 32,500 pounds
- **Results**:
  - Strains remained linear within elastic range

Test Set-up at Newmark Lab,
University of Illinois at Urbana-Champaign (UIUC)

Preliminary Partial Instrumentation Plan Feasibility Study

(Sep. 2011)

- **Objective**: Test feasibility of built up load cell & strain gauged clips
- **Strategy**: Utilize 20 strategically located strain gauges on rail & clips
- **Test**: Applied load to single rail seat on a fully supported tie at an L/V of 0.25 & 0.52 with vertical loads ranging from 0 to 32,500 pounds
- **Results**:
  - Strain shows non-linear character at clips
  - Strain behavior at rail is linear
  - Residual strains exist in system
  - Strain in gauge side clip is greater than field side clip

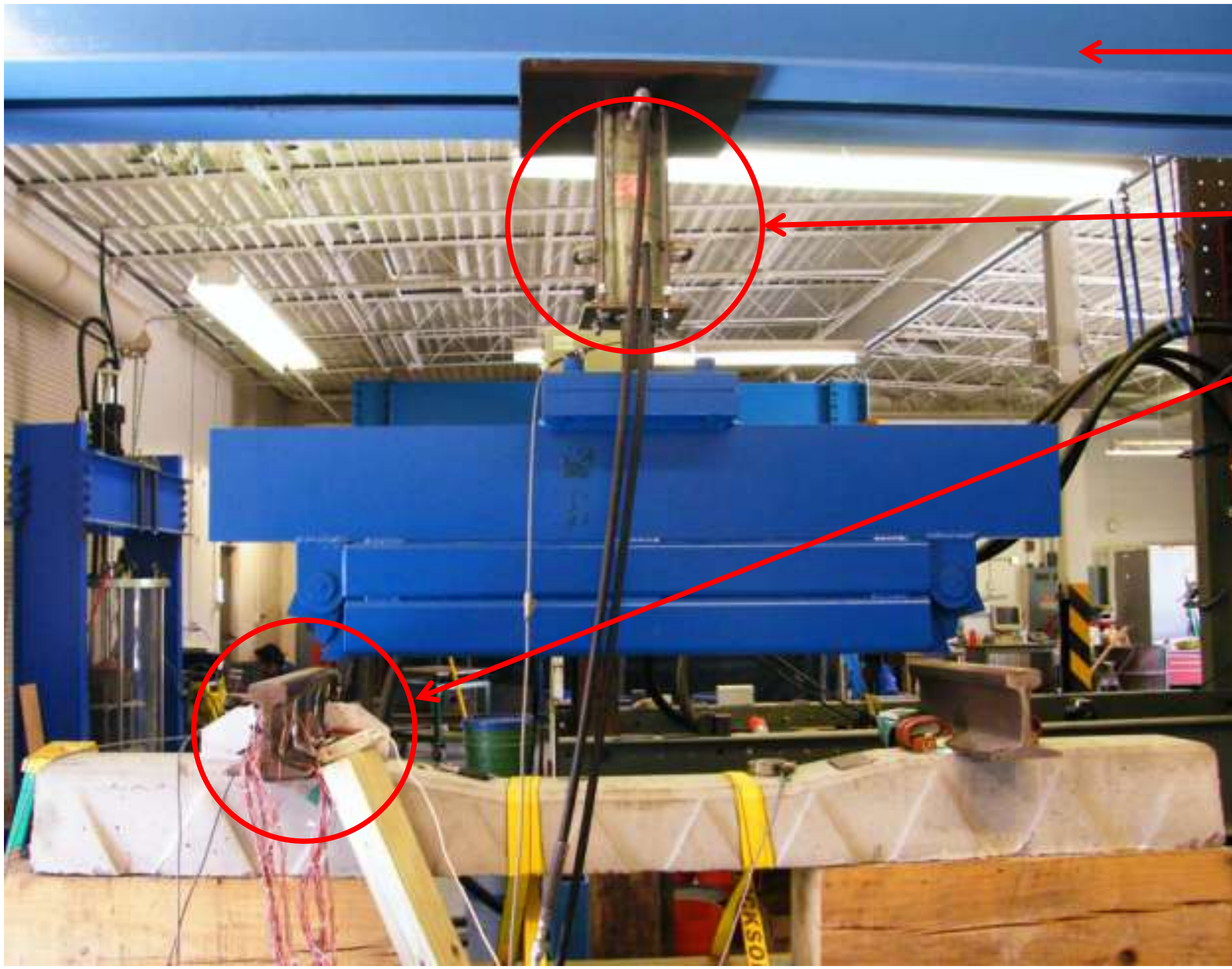
Pulsating Load Testing Machine (PLTM),

Advanced Transportation Research and Engineering Laboratory (ATREL)

Preliminary Test at Monticello Railroad Museum (MRM)

- Provide instrumentation experience prior to field testing at TTC
- Stain gauges and potentiometers were installed
- Lateral load was placed on rail head by using Portable Track Loading Fixture (PTLF) loader
- Future plan: apply multiple combinations of lateral & vertical load under controlled conditions

Rail Deformation Test



Loading Frame

Hydraulic Jack

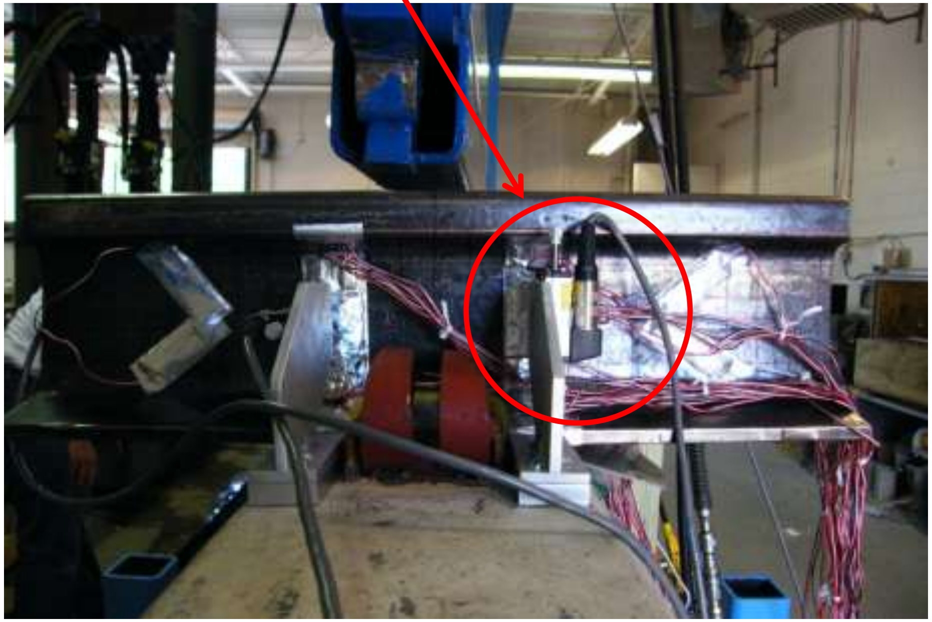
Instrumented
Rail & Rail Seat

ATREL, UIUC

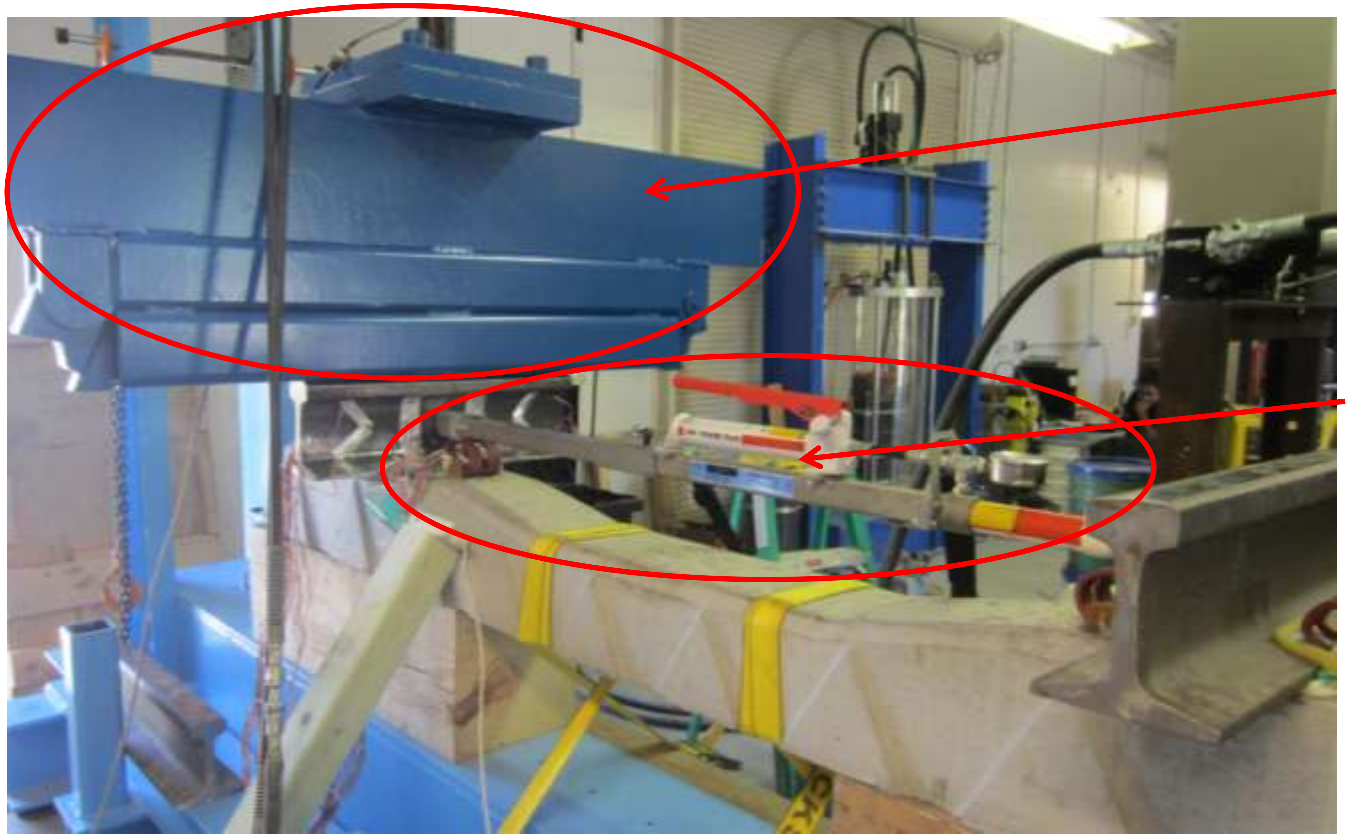
Rail Deformation Test Setup

Potentiometers to measure rail movement

ATREL, UIUC



Test Setup



Loading head for vertical load

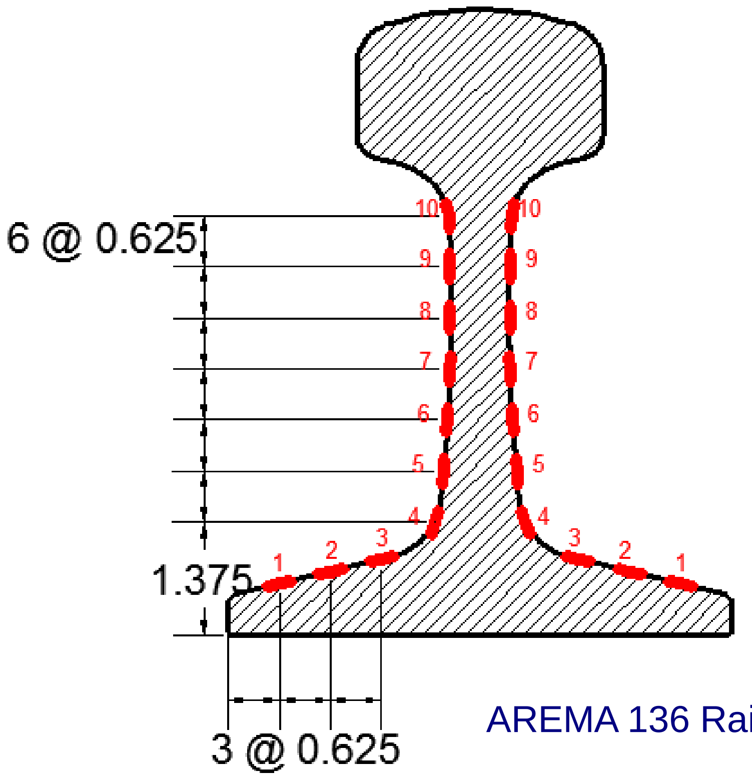
Portable Track Loading Frame (PTLF) for lateral load transfer

ATREL, UIUC

Rail Deformation Test

- **Objective:**
  - Understand the rail behavior as well as the load path under different combinations of static loading (lateral and vertical)
- **Instrumentation methodology:**
  - Measure the rail deformation using strain gauges
  - Measure the rigid body displacements of rail using potentiometers
  - Measure the change of clamping force and lateral load going through the insulator as a function of input load
  - Understand the limitations of the current lab test's boundary conditions
- **Analysis:**
  - Generate deformation map of rail to visualize the lab test results and rail behavior
  - Compare with FEM results and use to calibrate FEM

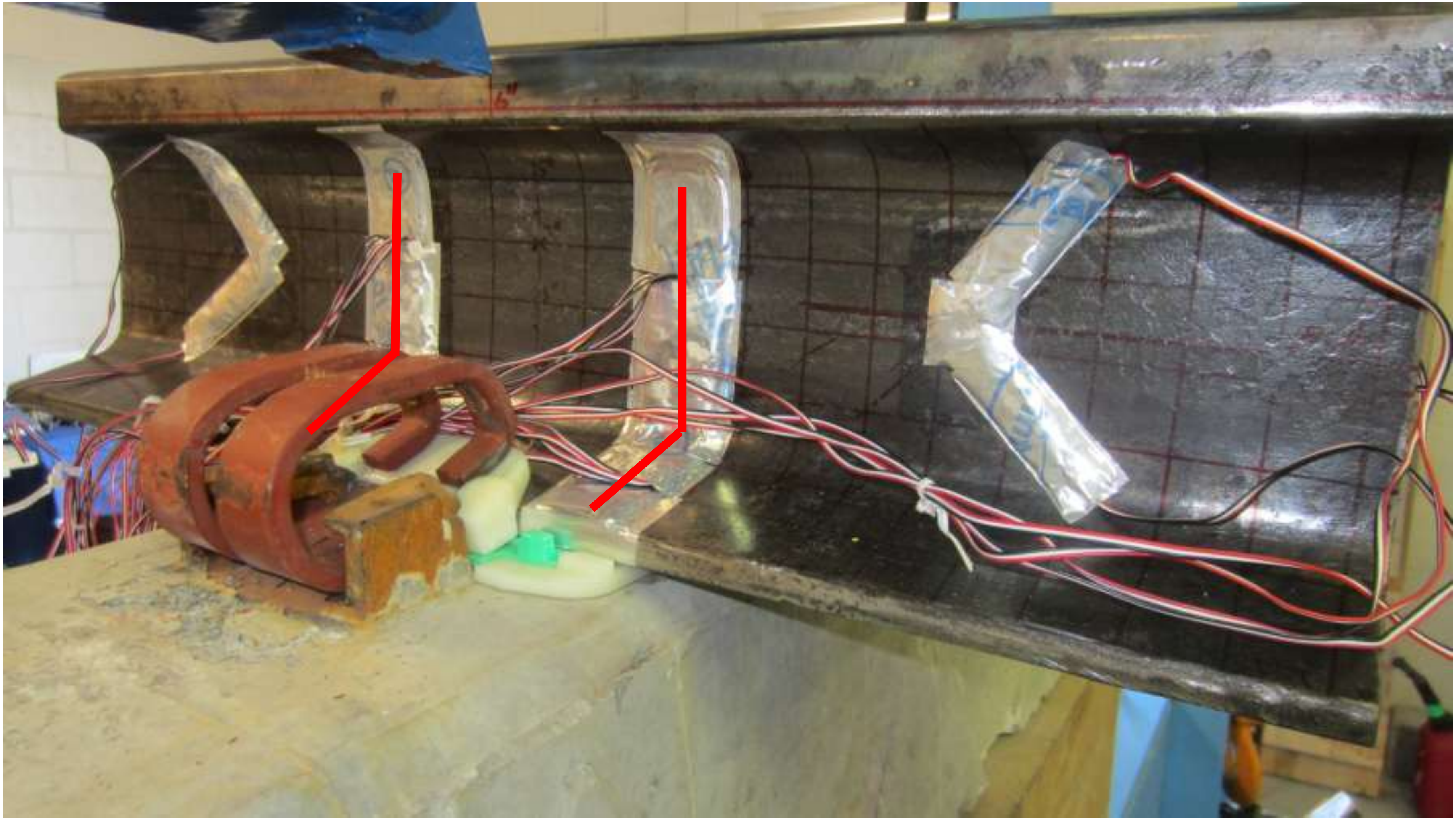
Strain Gauge Locations



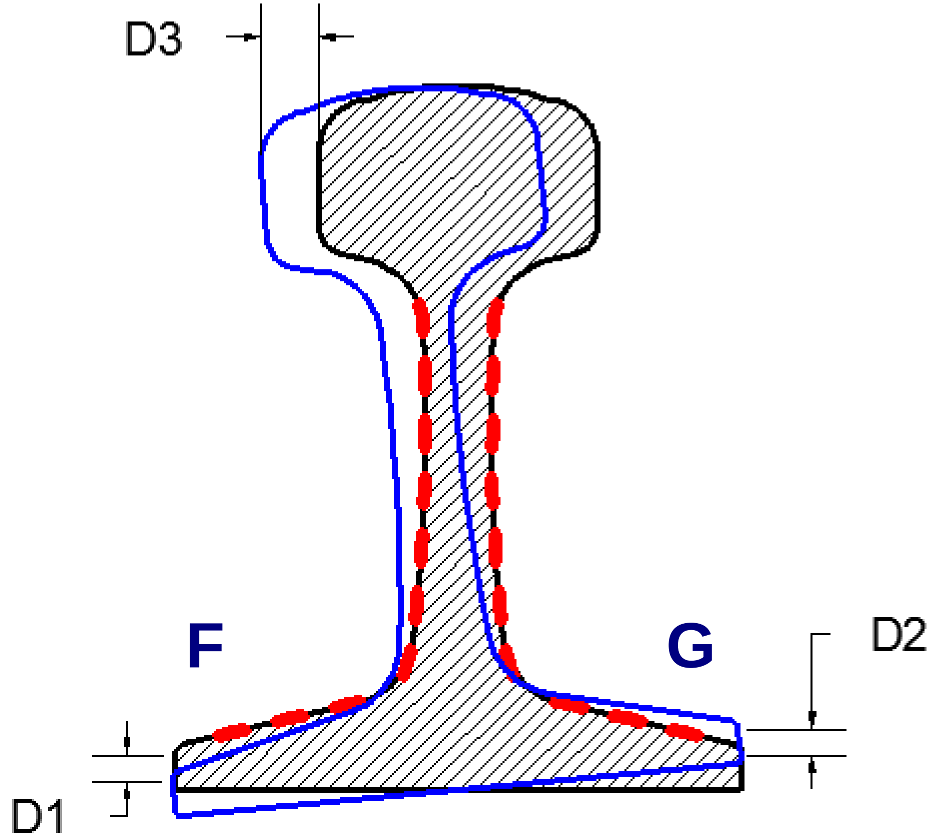
AREMA 136 Rail

Gauge #	Locations
Gauge 1	rail base, 0.625" from edge
Gauge 2	rail base, 1.250" from edge
Gauge 3	rail base, 1.875" from edge
Gauge 4	rail web, 1.375" from bottom
Gauge 5	rail web, 2.000" from bottom
Gauge 6	rail web, 2.625" from bottom
Gauge 7	rail web, 3.250" from bottom
Gauge 8	rail web, 3.875" from bottom
Gauge 9	rail web, 4.500" from bottom
Gauge 10	rail web, 5.125" from bottom

Strain Gauge Locations



Potentiometer Measurements

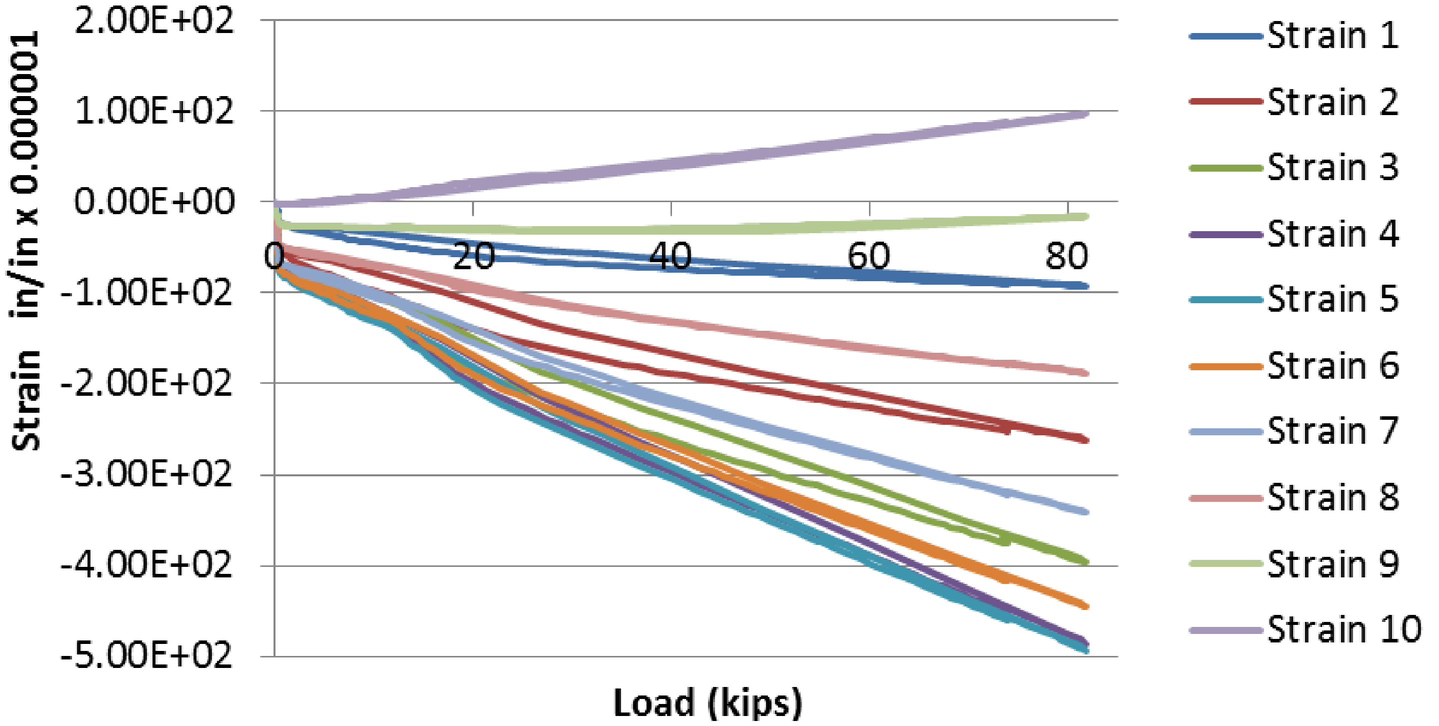


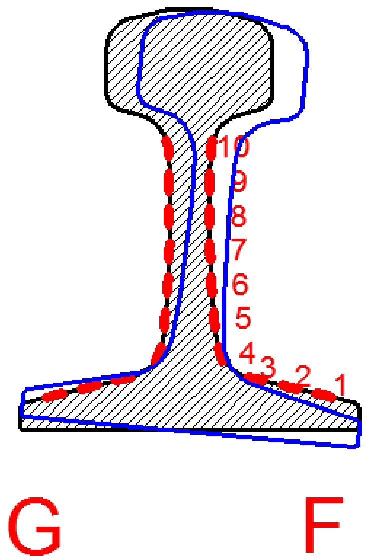
Pot #	Locations
D1	Vertical displacement - Field side at rail base
D2	Vertical displacement - Gauge side at rail base
D3	Lateral displacement - Field side at rail head

Loading Equipment and Testing Procedure

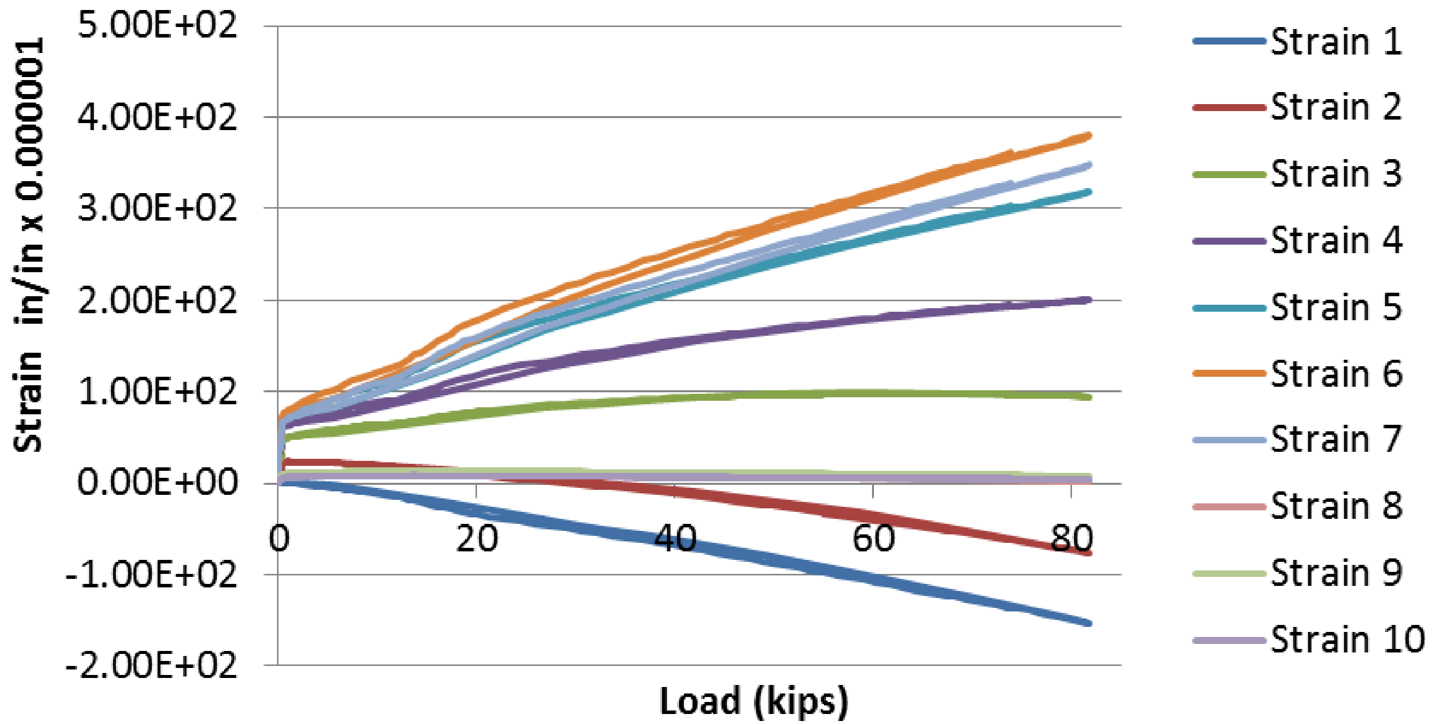
- **Static Load Testing Machine (SLTM)**
  - Vertical & lateral load were applied to the rail head
  - L/V = 0.5, θ = 26.5°
- **Testing Procedure**
  - **Pure Vertical Load**
  - **Pure Lateral Load**
    - BNSF Gauge Restraint Measurement System (GRMS)
  - **Combinations of vertical & lateral loads**

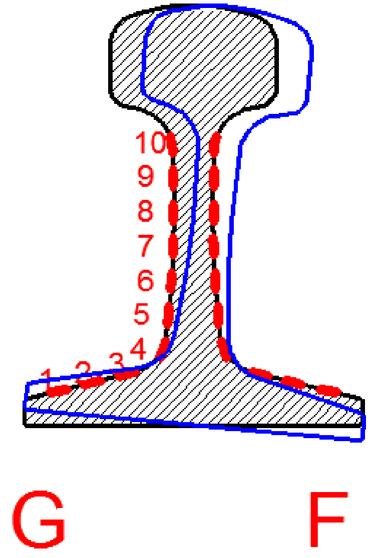
Strain Distribution (Field Side)



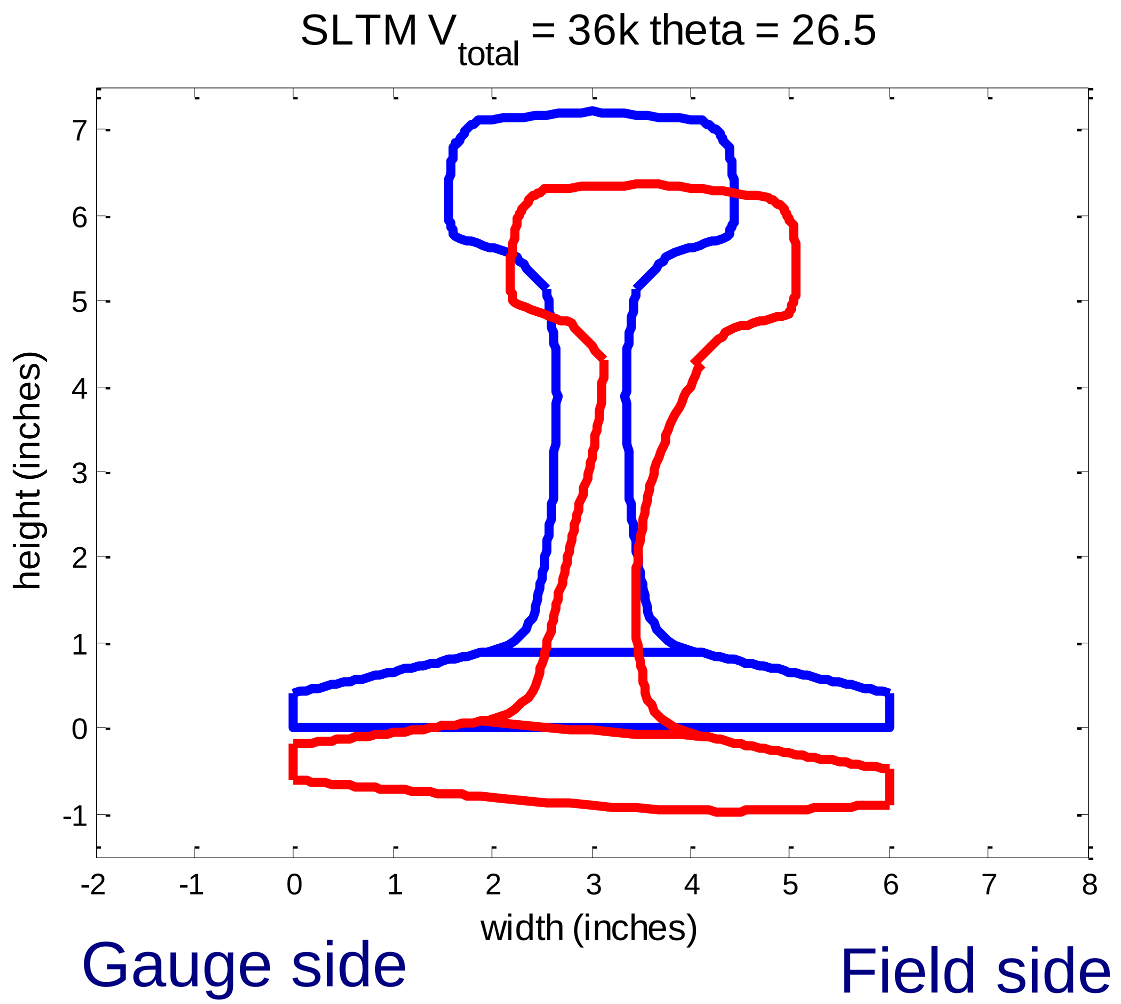


Strain Distribution (Gauge Side)



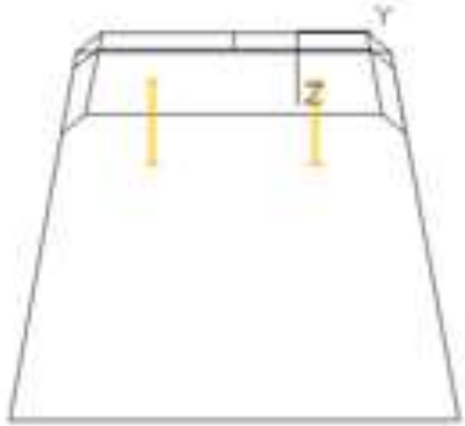


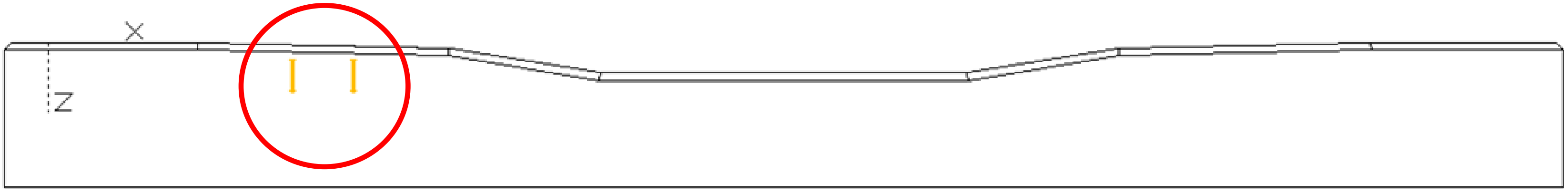
Rail Deformation Map

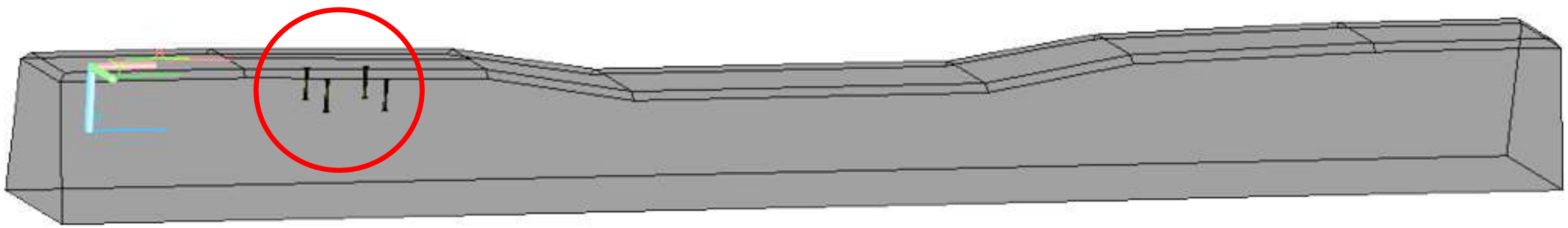


Blue - undeformed
Red - deformed

Embedment Strain Gauge Installation





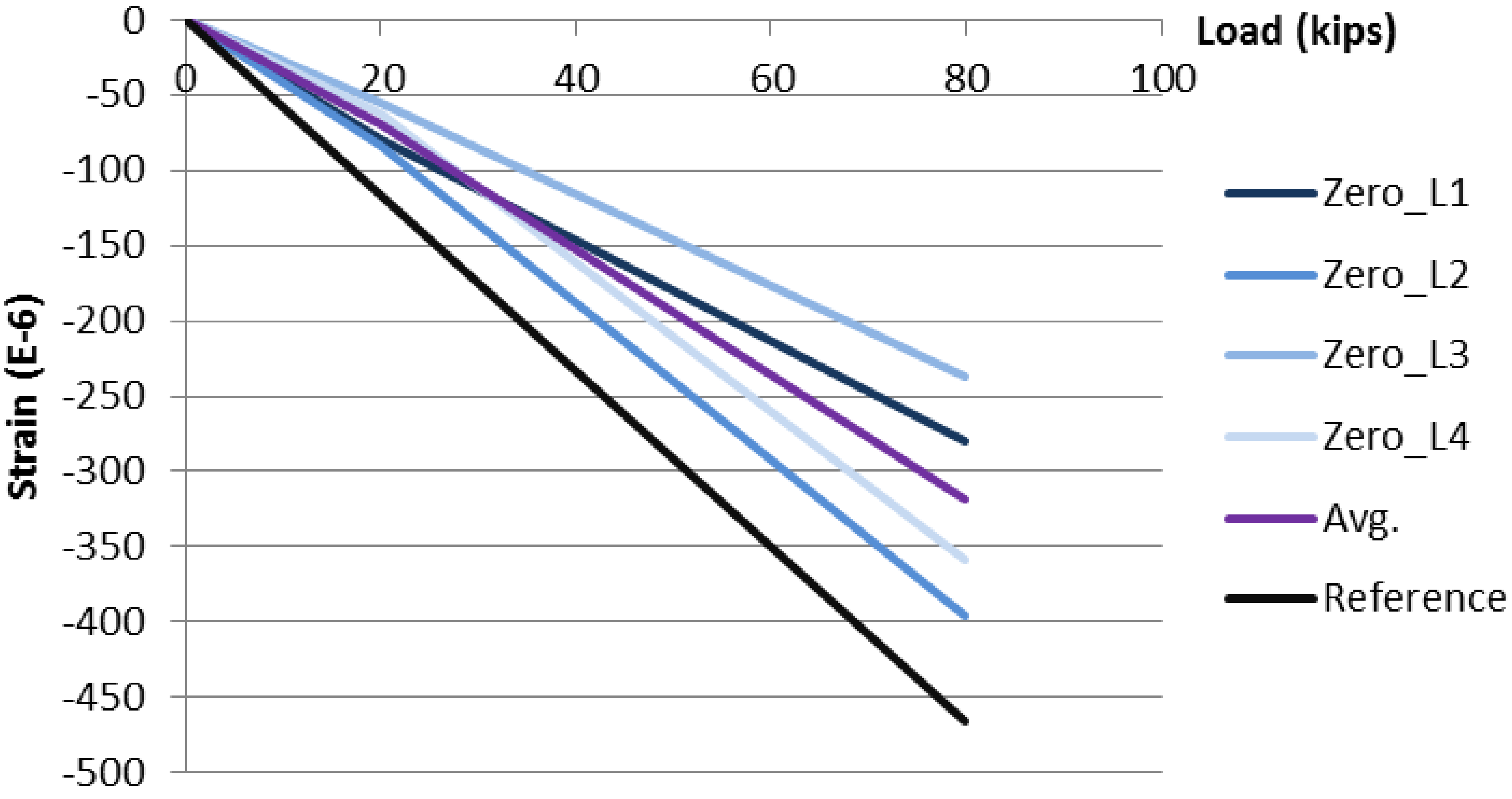


Embedment Strain Gauge Installation (CXT, Tucson)

Embedment Strain Gauges - Testing

Newmark Lab, UIUC

Embedment Strain Gauges - Calibration



$E_c = 57{,}000\sqrt{f'_c}$ $f'_c = 7000\ psi$

Conclusions

- The curvature of rail base is relatively small compared with the rigid body displacement of the rail
- The behavior of each embedment strain gauge in rail seat shows variability
- Lab calibration for embedment strain gauges shows agreement with the material's elastic modulus
- Challenges exist with current test setups – unrealistic boundary and support conditions
- Challenges remain in terms of mapping lab results and model output

Future Work

- Design and execution of tests on specific components (e.g. crossties, clips, insulators, etc.)
- Develop tests for accurate (i.e. representative of field) support and boundary conditions
- Design and utilize new experimental test setup to reduce variability in lab tests and provide valuable data for FEA model validation

Questions?

Sihang Wei
Graduate Research Assistant
Department of Civil and Environmental Engineering
University of Illinois, Urbana-Champaign
Email: wei22@illinois.edu

Acknowledgements

U.S. Department of Transportation

Federal Railroad Administration

- Funding for this research has been provided by the Federal Railroad Administration (FRA)
- Industry Partnership and support has been provided by
  - Union Pacific 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
- For assisting with lab testing:
  - Justin Grasse, Marcus Dersh, Marcus Killion

FRA Tie and Fastener BAA Industry Partners:

UNION PACIFIC BUILDING AMERICA®

BNSF RAILWAY

AMTRAK®

Amsted RPS

Amsted Rail

GIC INGENIERÍA Y CONSTRUCCIÓN S.A. DE C.V.

HANSON

LBFoster CXT Concrete Ties