

Field Instrumentation of Concrete Crossties and Fastening Systems



FRA Tie and Fastener BAA Industry Partners Meeting

Tampa, FL

25 October 2012

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RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Background on Field Research
- Field Instrumentation Strategy
- July Testing at TTC
- Experimental Results
- Preliminary Findings
- Future Work

FRA Tie and Fastener Project Structure

Inputs

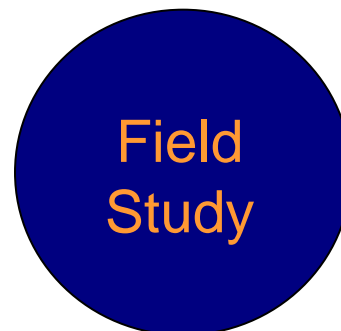
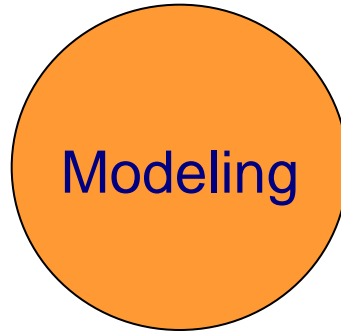
Comprehensive Literature Review

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

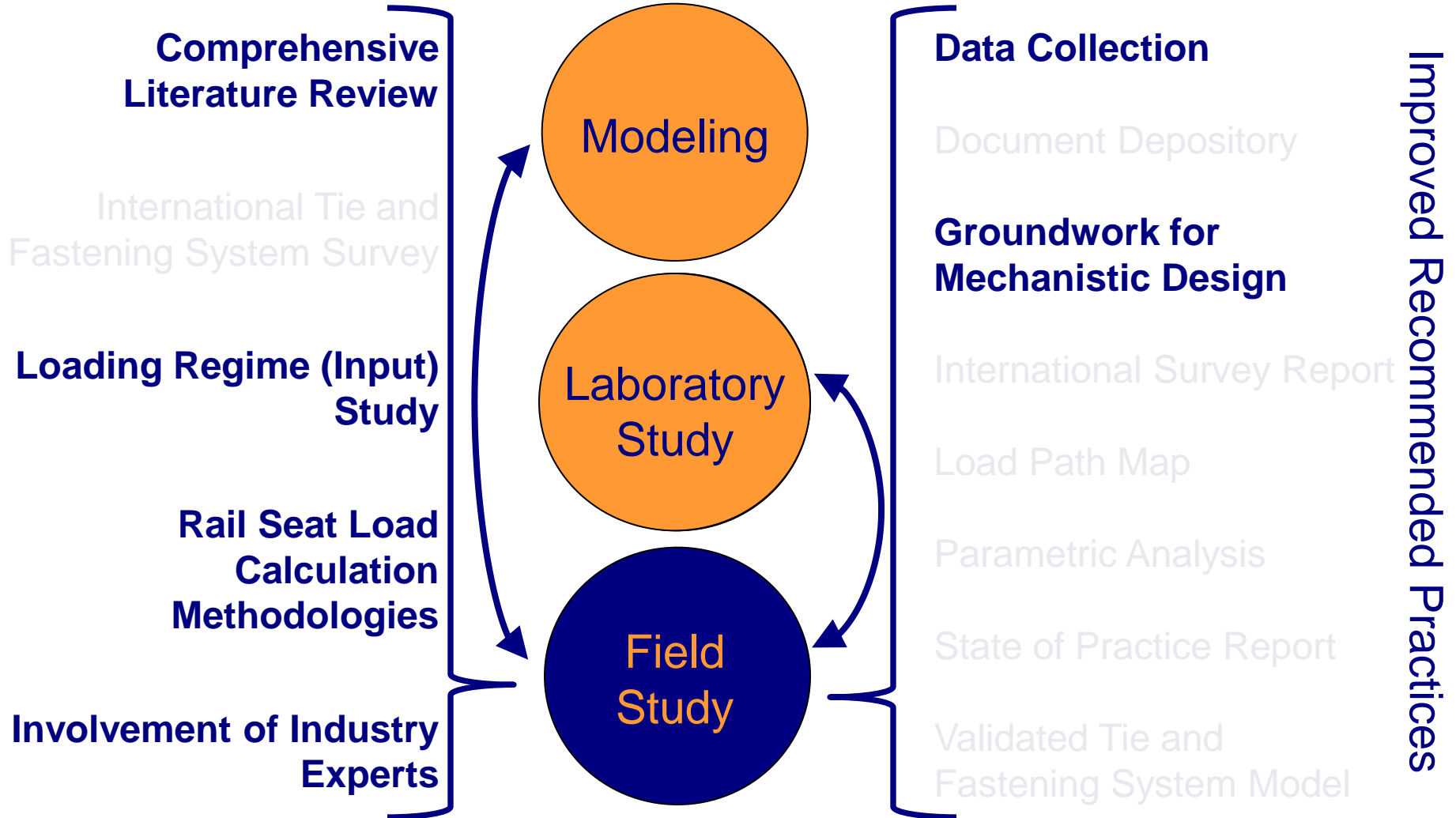
Load Path Map

Parametric Analysis

State of Practice Report

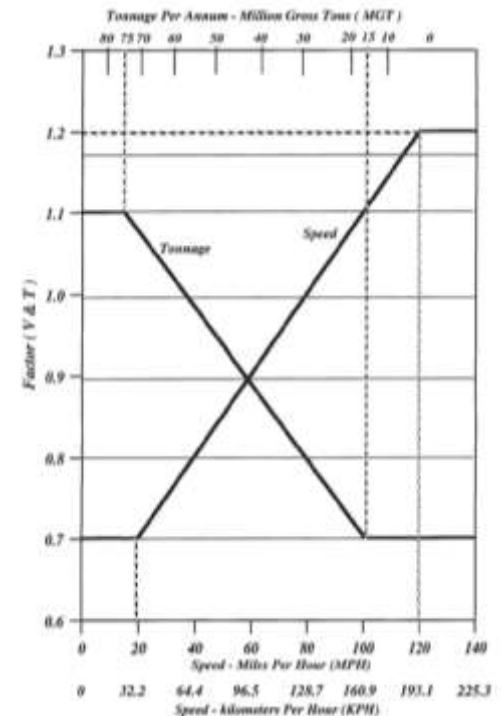
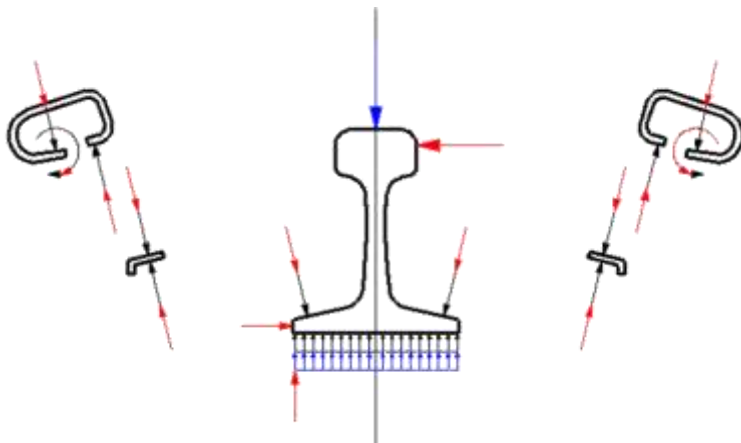
Validated Tie and Fastening System Model

Improved Recommended Practices



Goals of Field Instrumentation

- Lay groundwork for mechanistic design of concrete crossties and fasteners
- Map stresses through the fastening system
- Develop an understanding into probabilistic loading conditions
- Provide insight for future field testing



(AREMA 2010)

Loading Demands

AREMA Chapter 30 Section 4.1.2.3, 4.1.3, 4.4.1

- **Existing Content:**
 - Load factors for tie spacing (4.1.2.3)
 - Discussion of lateral stability (4.1.3)
 - Design flexural values from tie spacing, tonnage, and speed (4.4.1)
- **Proposed Improvements:**
 - Verify or modify load factors in representing field conditions
 - Quantify the demands for lateral stability and lateral resistance
- **Methodology:**
 - Conduct parametric analysis of loading conditions in the field
 - Test multiple behaviors of lateral stability: displacement, clamping force, insulator compression, etc.
 - Coordination with finite element model to provide agreement
- **Timeline**
 - Present updates to Subcommittee 4 (C-30 Spring 2013)
 - Submit ballot proposal to Subcommittee 4 (C-30 Fall 2013)

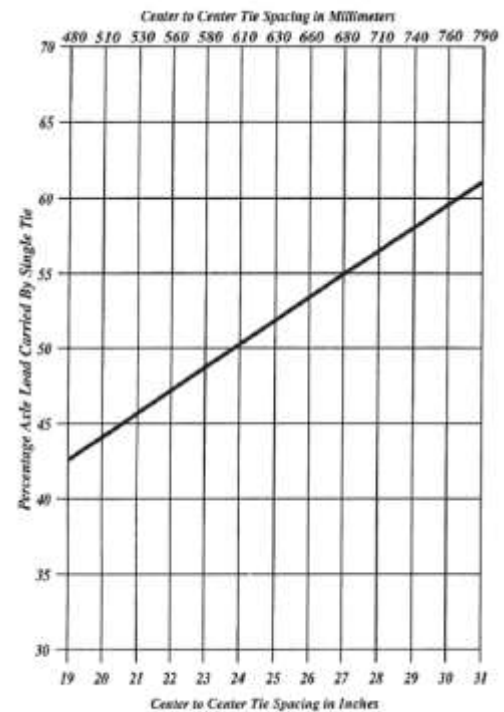
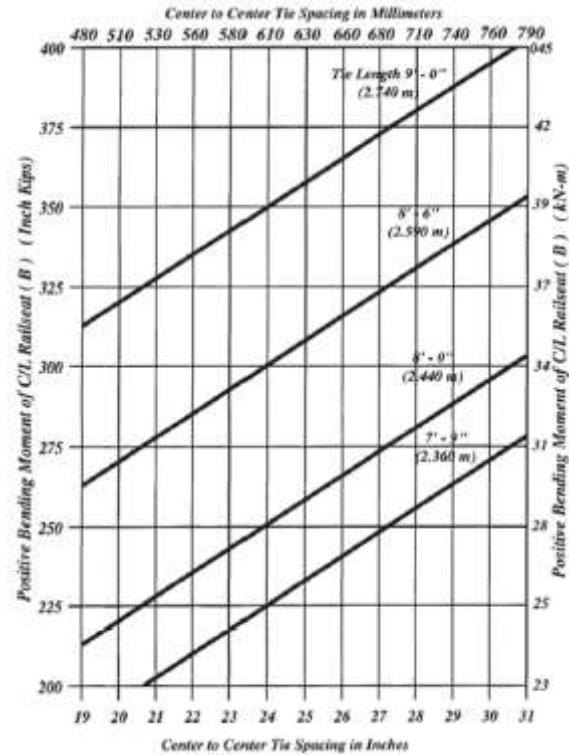
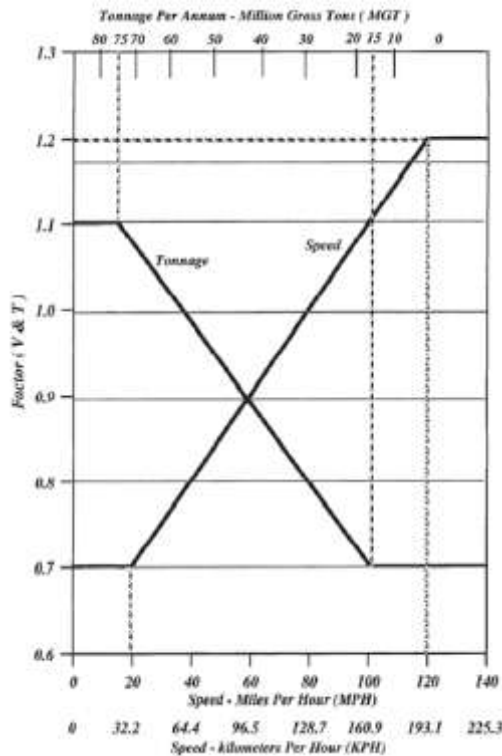


Figure 3D-4-1. Estimated Distribution of Loads

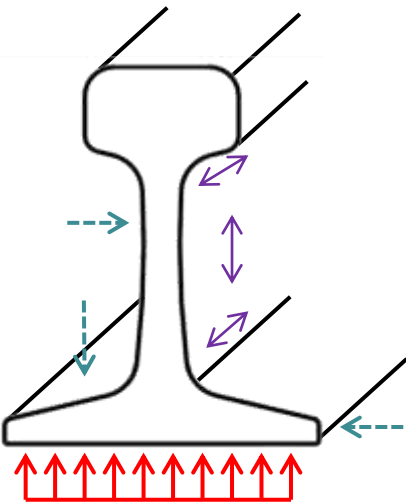
4.1.3 LATERAL LOADS (1992)

- The lateral loads generated by moving railway equipment are applied by wheel treads and flanges to the rails, which in turn must be held in place by fastenings, ties and ballast.
- Lateral stiffness of rail distributes lateral loads to fasteners and their ties. Structural strength of fastenings and ties hold the rail to gage. The mass of ties, friction between the ties and ballast, lateral bearing area of ties (end surface), and the mass of ballast all act to restrain lateral tie movement.
- Lateral track stability can, therefore, be increased by decreasing tie spacing of ties of similar dimensions, increasing tie mass, increasing end bearing area of ties per unit length of track, and by increasing frictional resistance between ties and ballast. Structural strength of fastenings must be commensurate with the lateral load individual ties restrain, which in turn is determined by lateral rail stiffness and tie spacing.
- The magnitude of lateral loads which must be restrained depends not only upon the dimensions, configuration, weight, speed and tracking characteristics of the equipment, but also upon the geometric characteristics of the track structure.

Areas of Investigation

Rail

- Stresses at rail seat
- Strains in the web
- Displacements of web/base



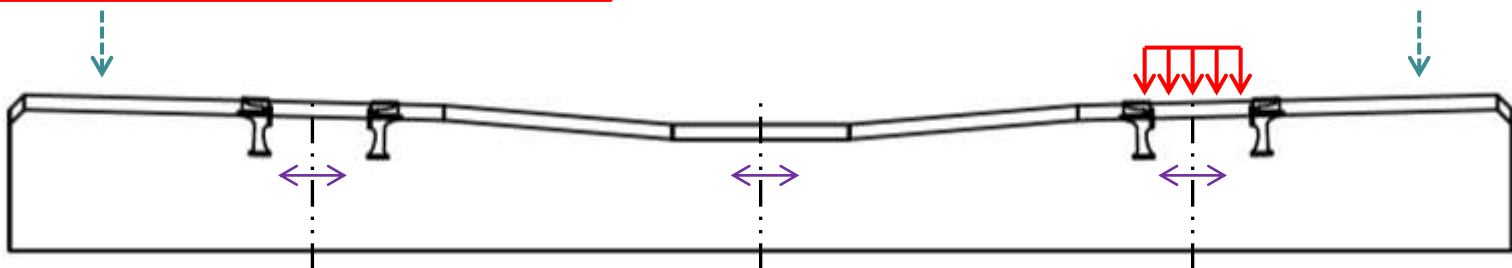
Fasteners/ Insulator

- Strain of fasteners
- Stresses on insulator



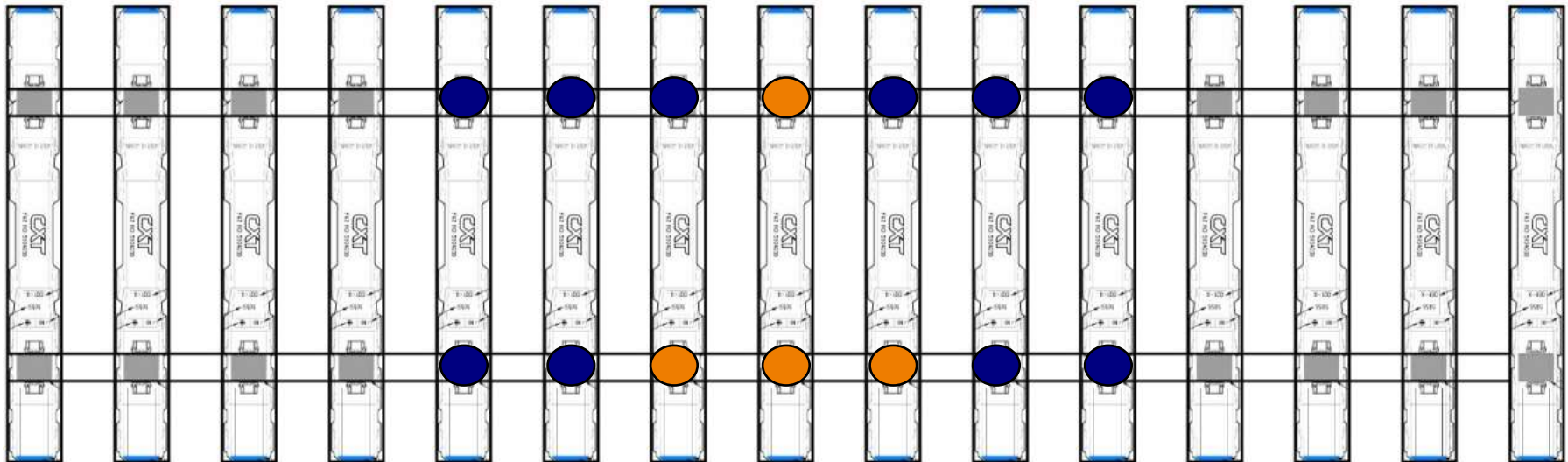
Concrete Crossties

- Moments along crosstie
 - Midspan
 - Rail Seat
- Stresses at rail seat
- Vertical displacements of crosstie

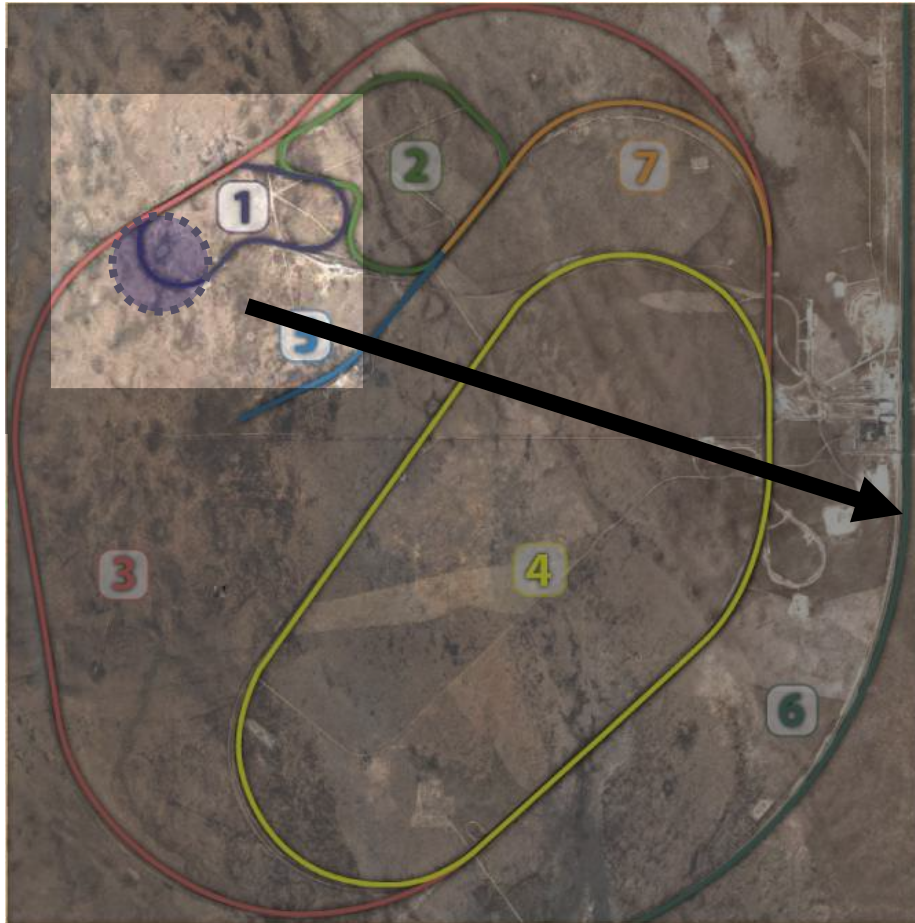


Field Instrumentation Strategy

- **Full Instrumentation** ●
 - Vertical & lateral loads
 - Embedment and external strains of tie
 - Clip, insulator, and rail base strains
 - Displacements on rail and crosstie
- **Partial Instrumentation** ●
 - Vertical strain gauges on rail



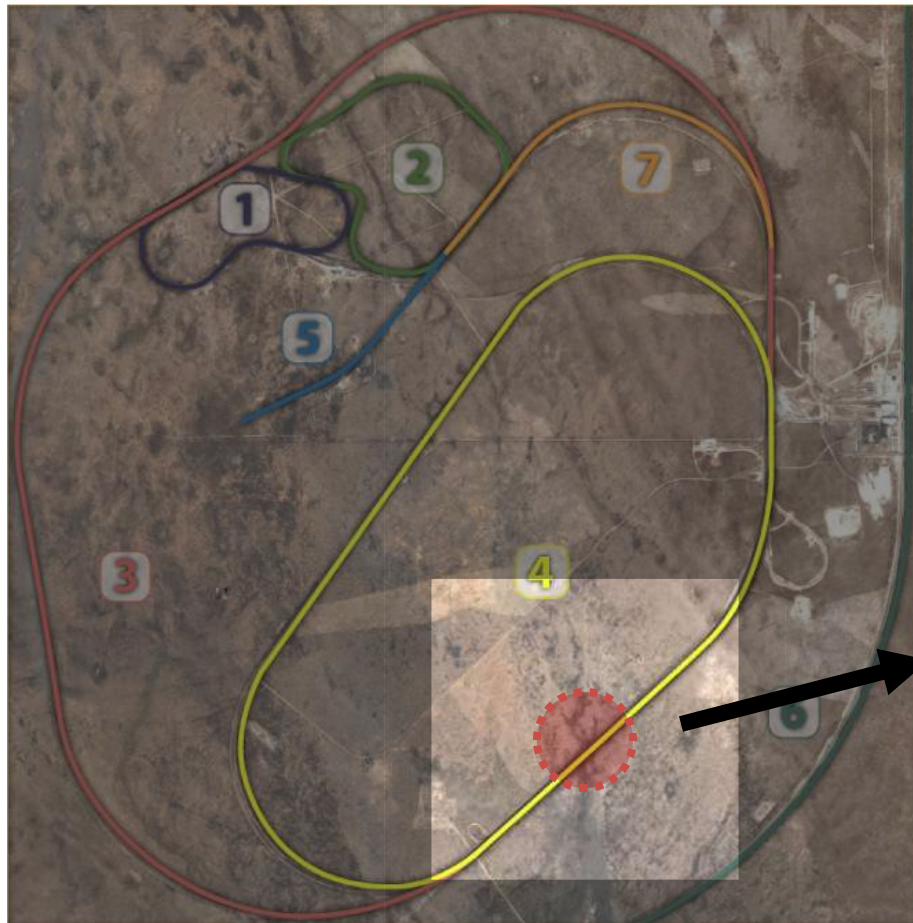
Field Instrumentation Locations



- TTCI (Pueblo, CO)
- High Tonnage Loop (HTL)
 - Curve ($\sim 5^\circ$)
 - Safelok I Fasteners



Field Instrumentation Locations



- TTCI (Pueblo, CO)
- Railroad Test Track (RTT)
 - Tangent
 - Safelok I Fasteners

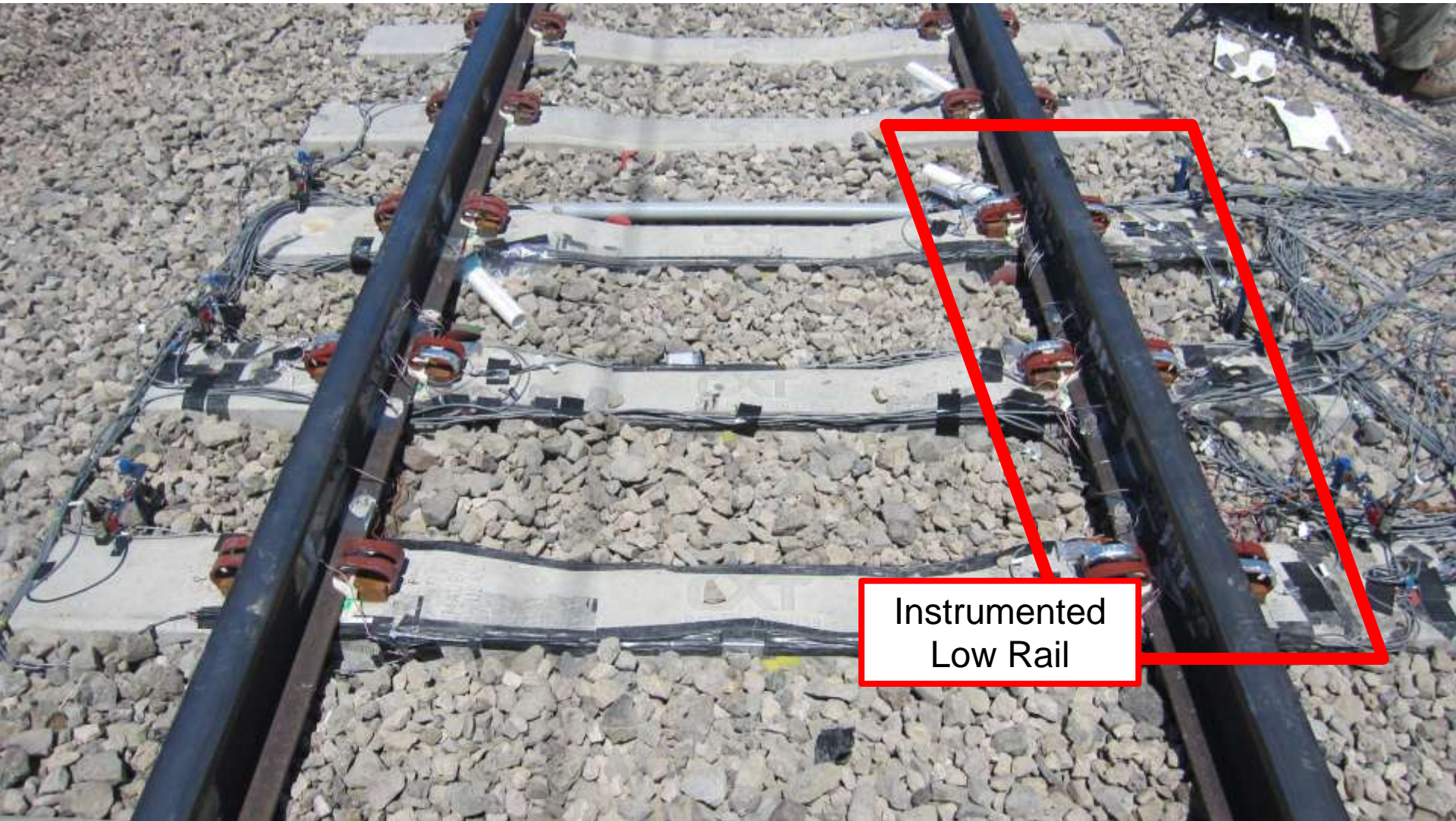


Loading Environment

- Track Loading Vehicle (TLV)
 - Static
 - Dynamic
 - Track modulus
- Freight Consist
 - 6-axle locomotive (393k)
 - Instrumented car
 - 263, 286, 315 GRL Cars
- Passenger Consist
 - 4-axle locomotive (255k)
 - Nine coaches
 - 87 GRL



Fully Instrumented Ties

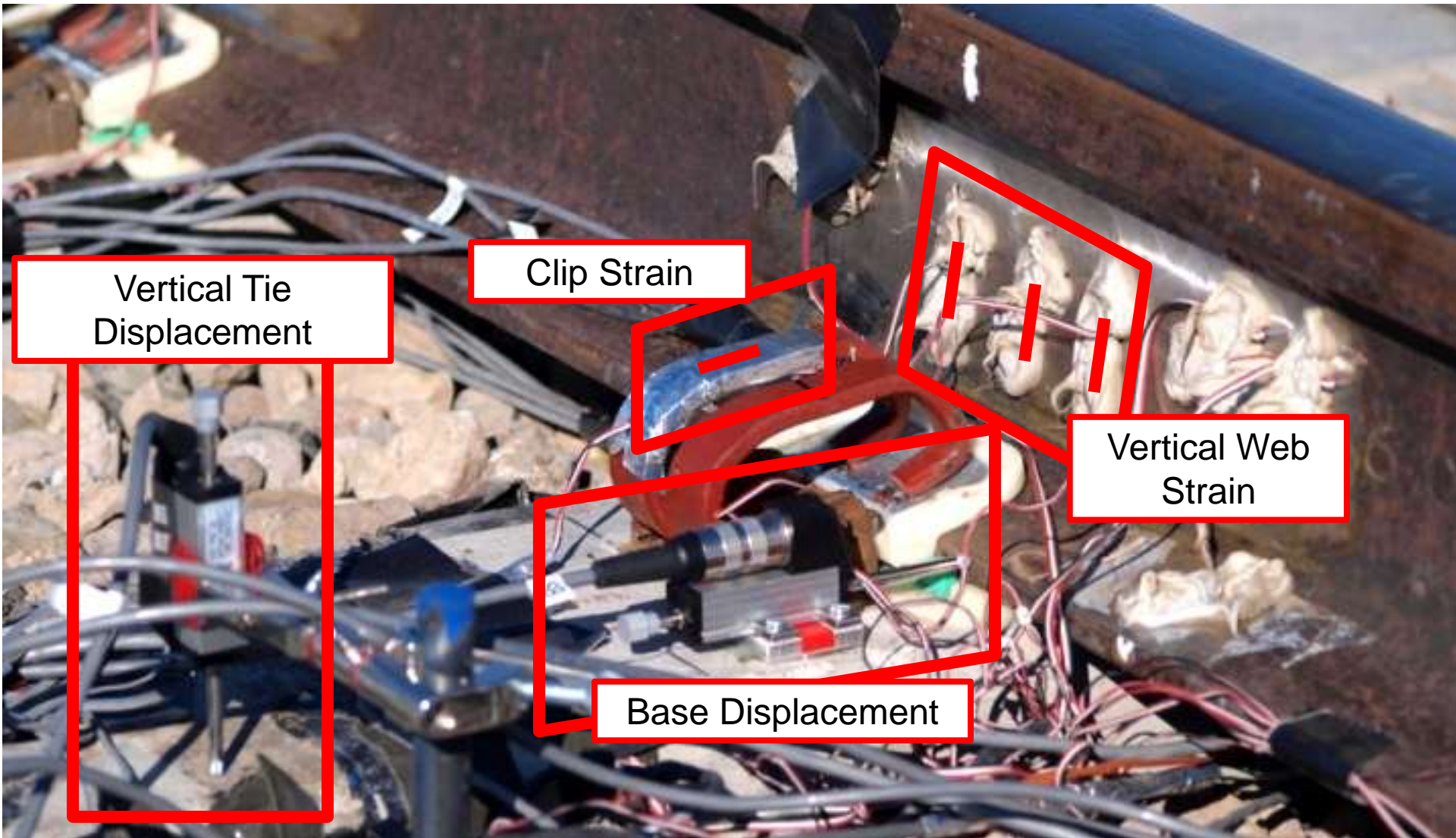


Instrumented
Low Rail

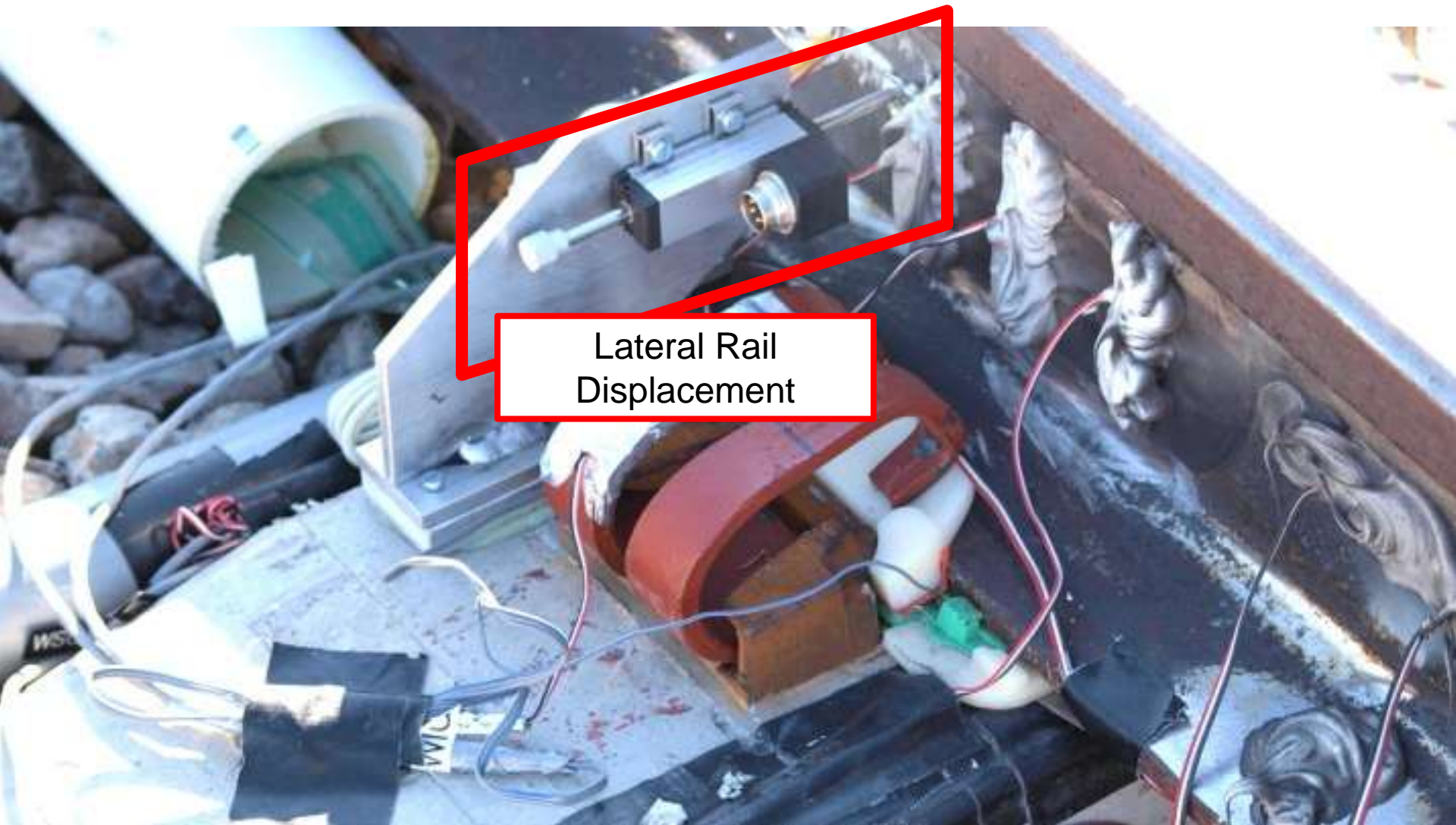
Instrumented Low Rail



Field-side Instrumentation

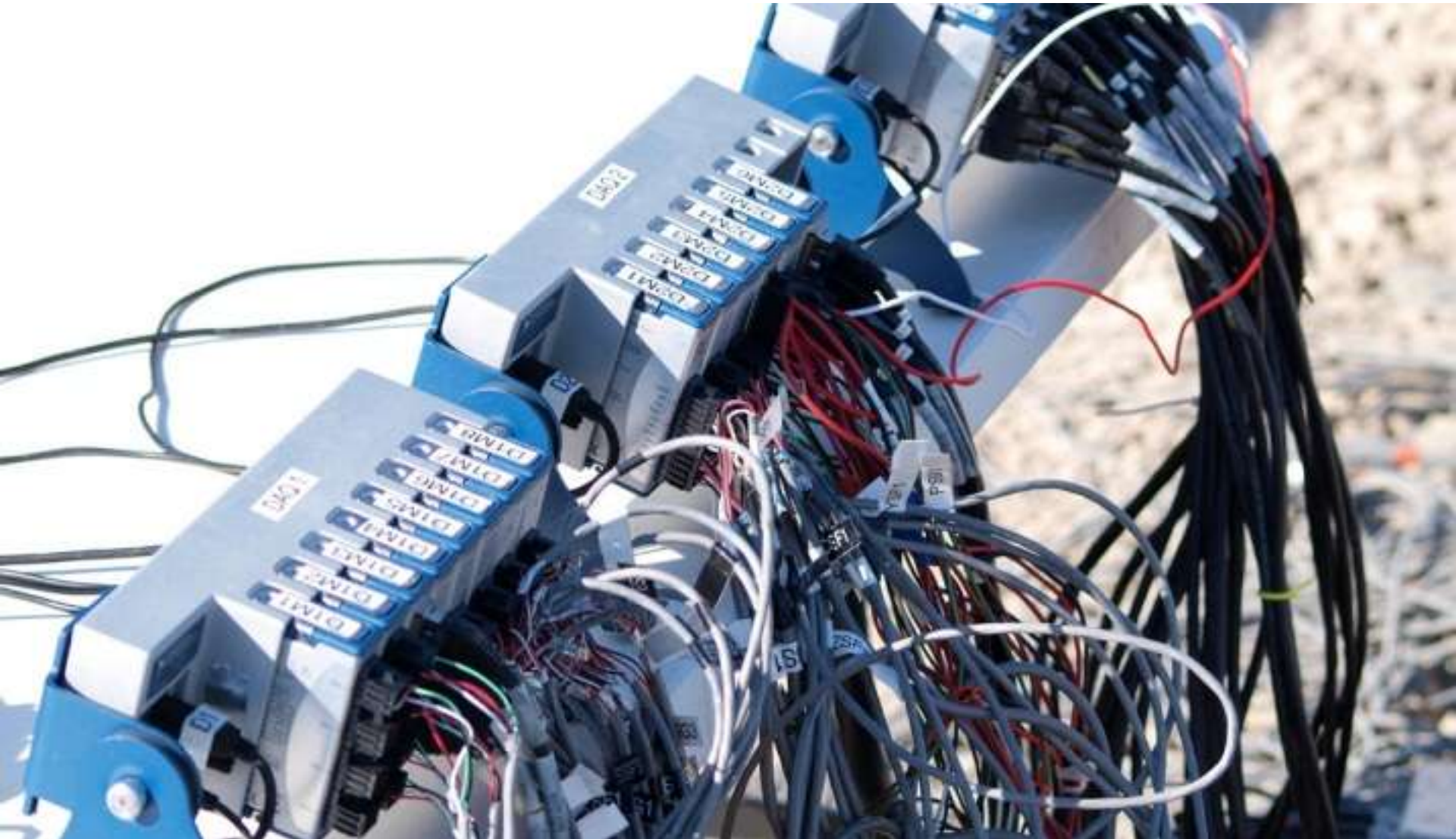


Gauge-side Instrumentation

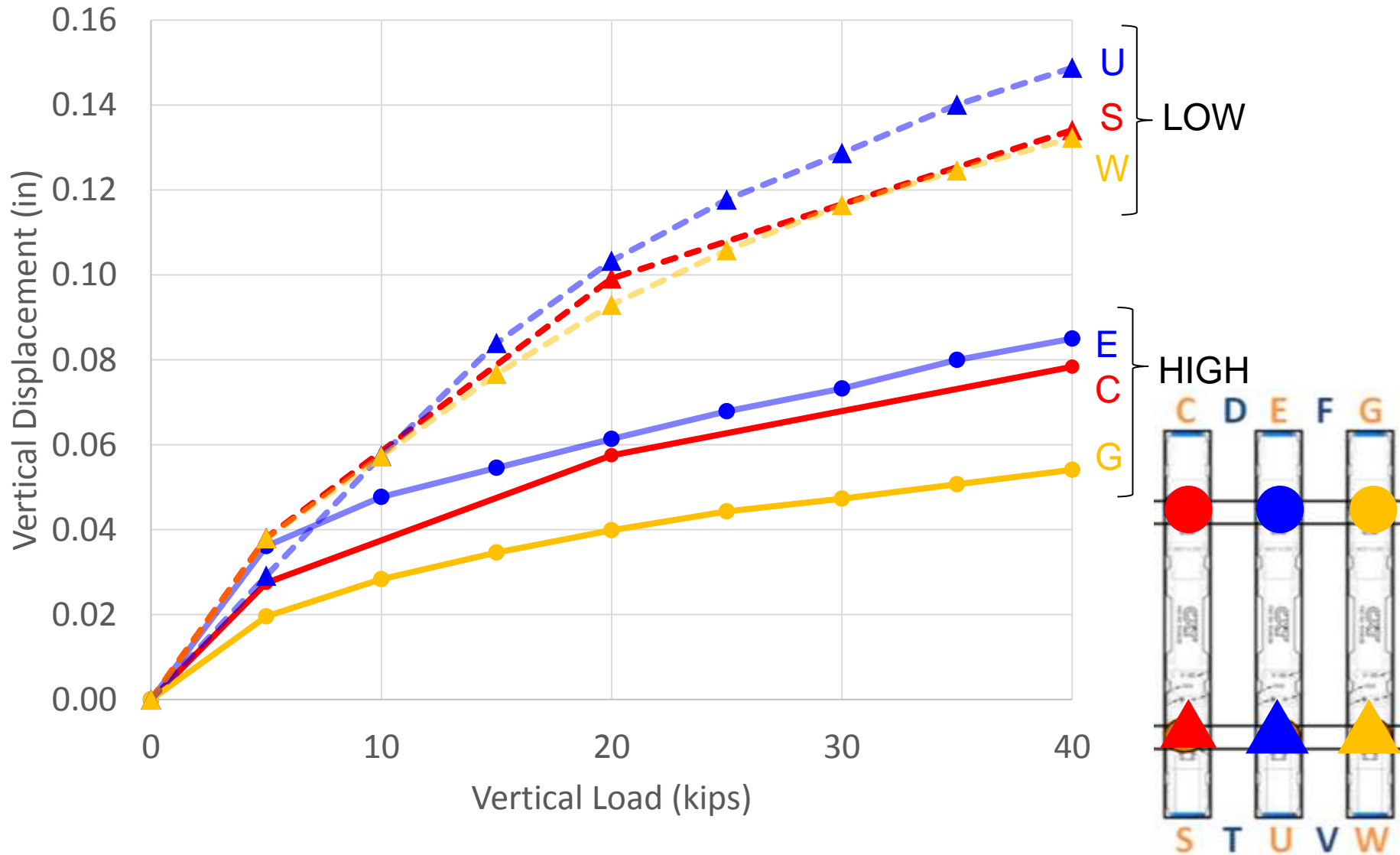


Lateral Rail
Displacement

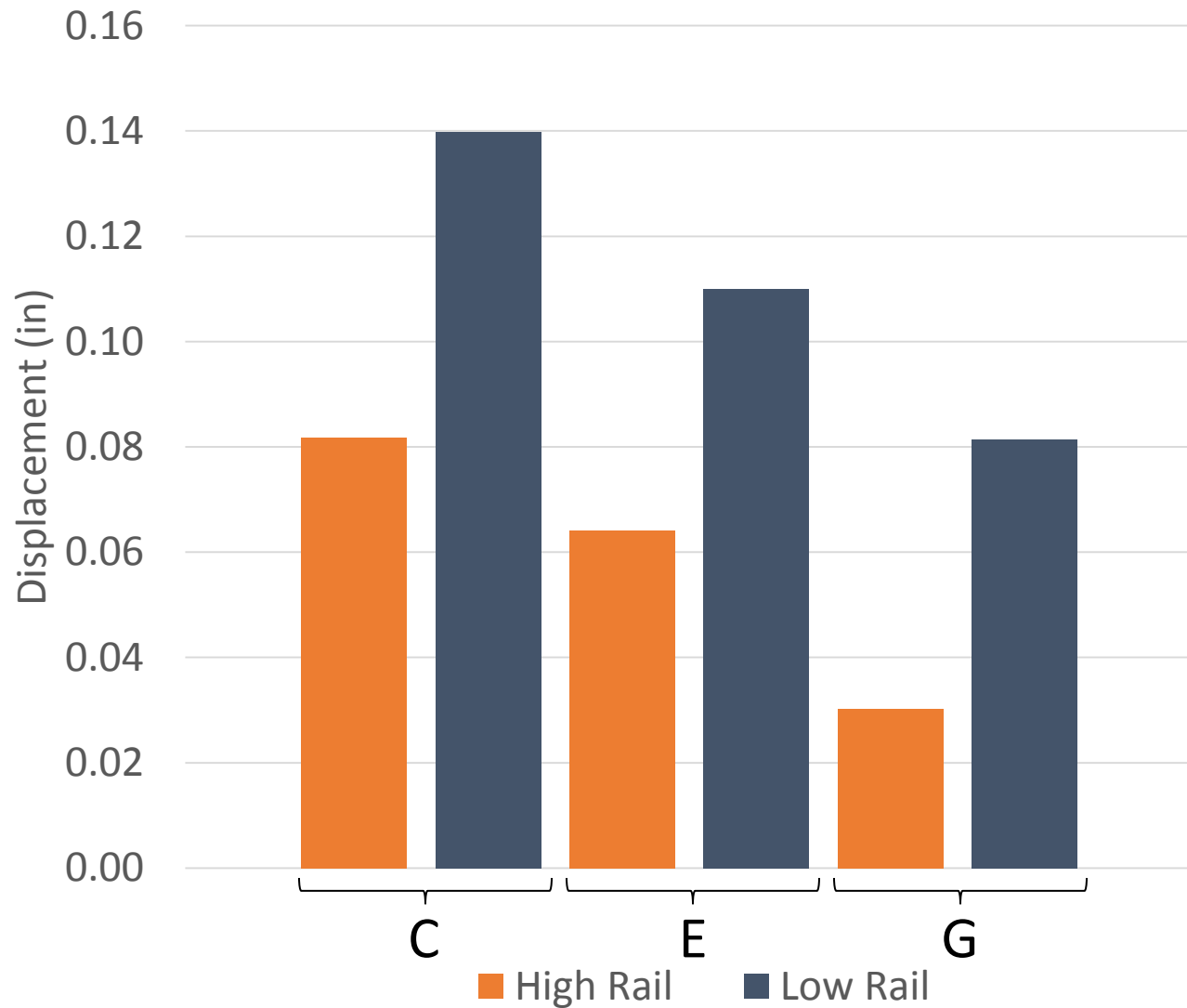
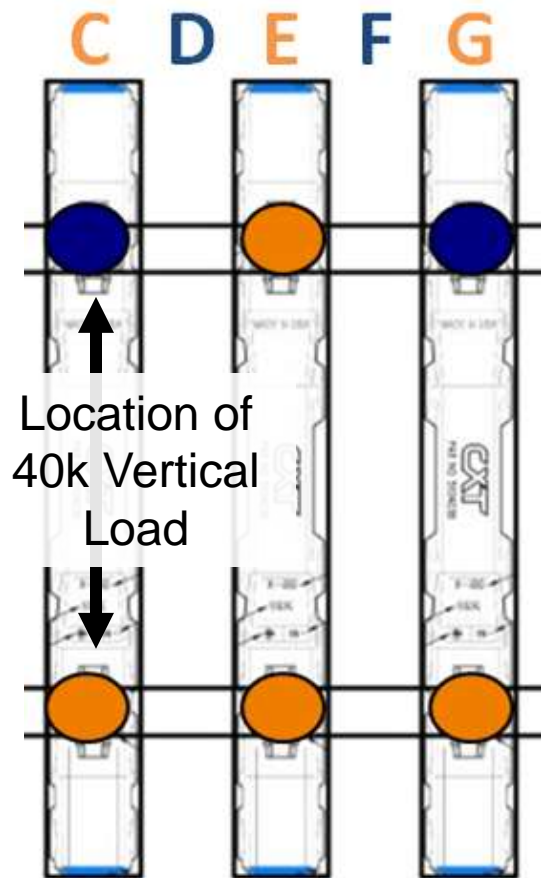
Data Acquisition System



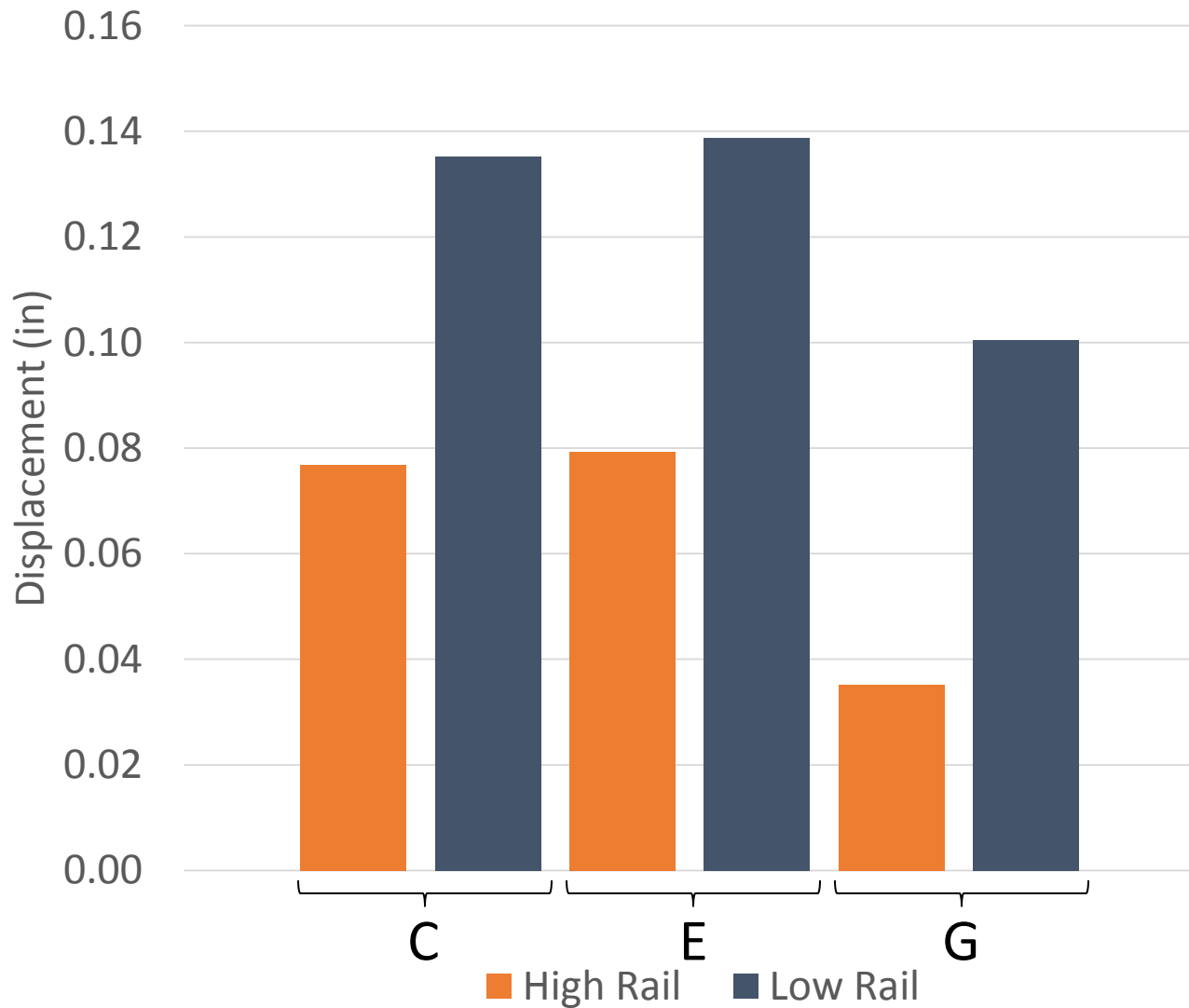
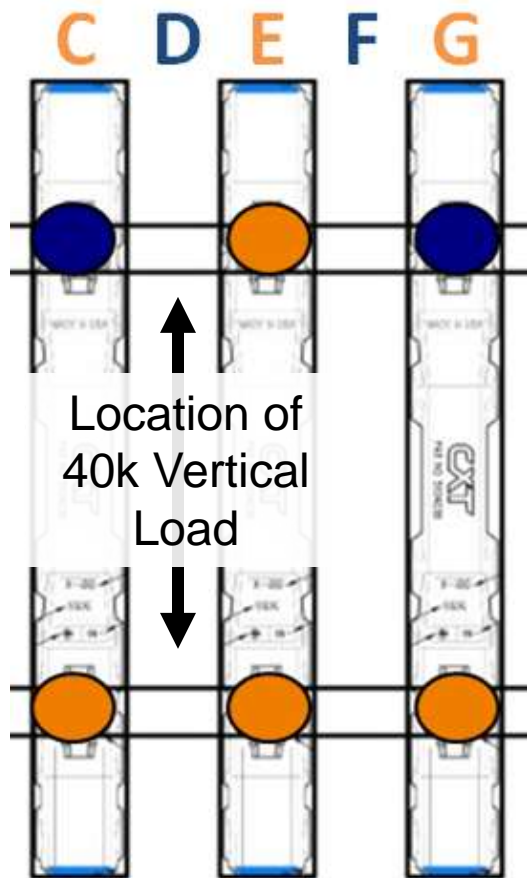
Vertical Displacements of the Ties (HTL)



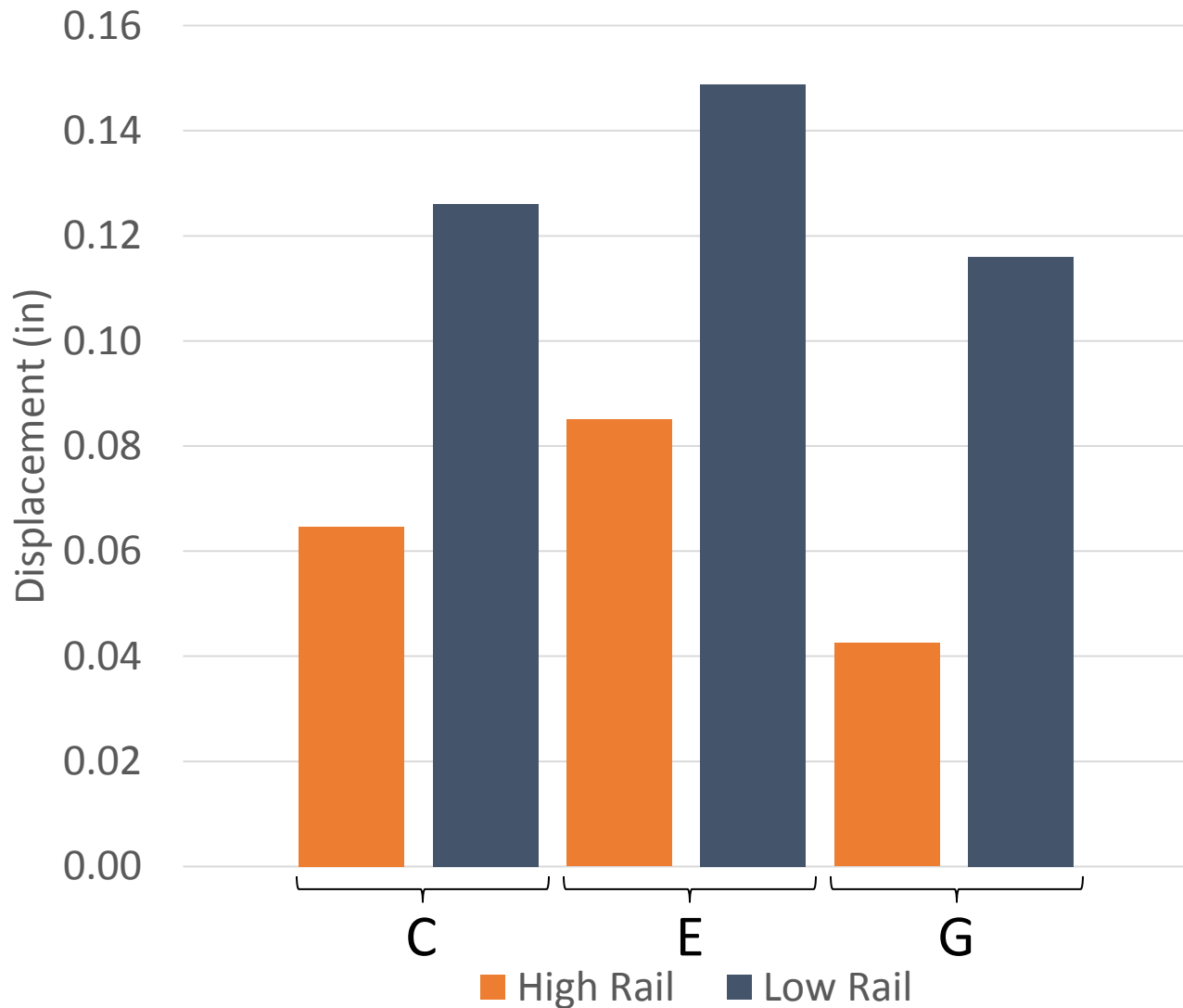
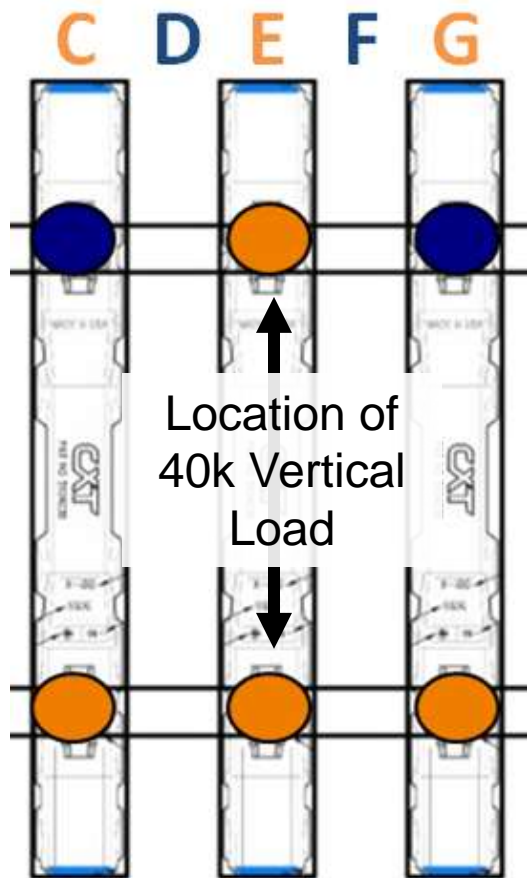
Vertical Tie Displacements (HTL)



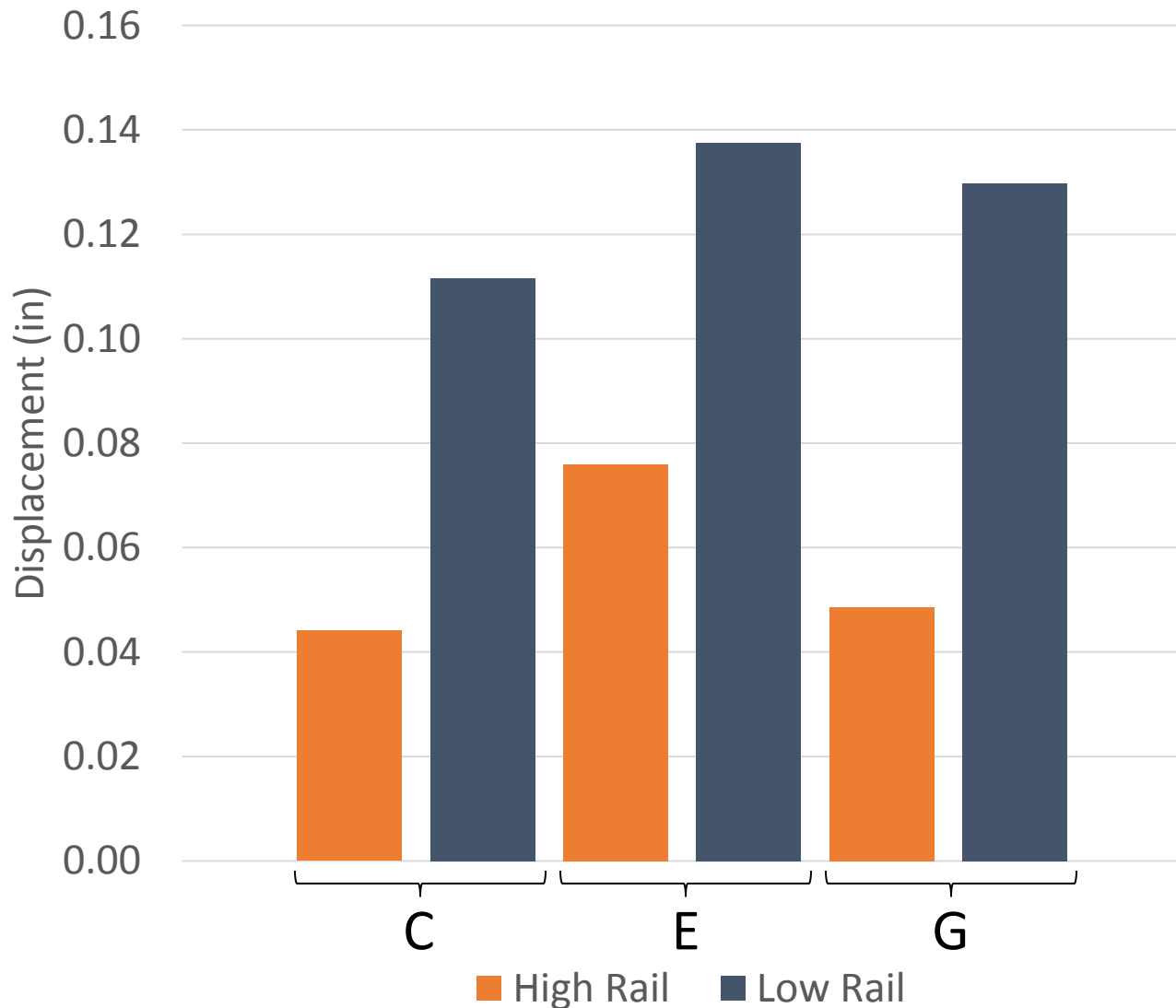
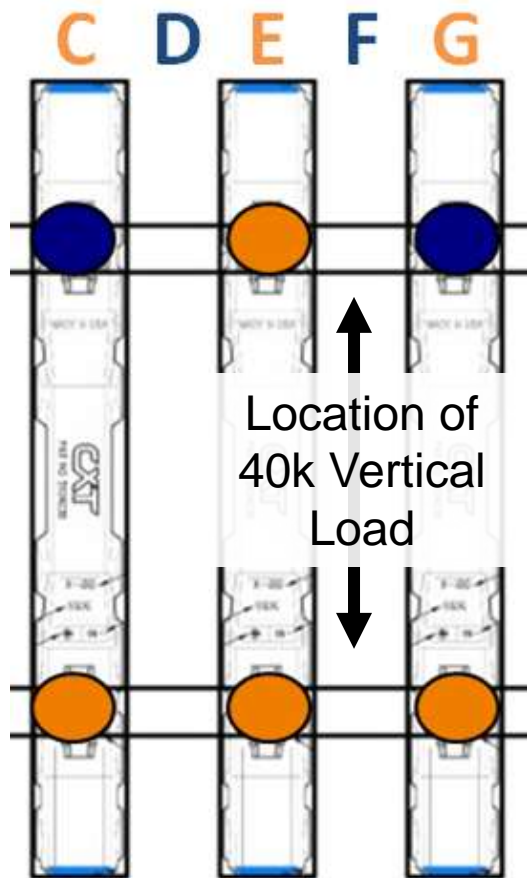
Vertical Tie Displacements (HTL)



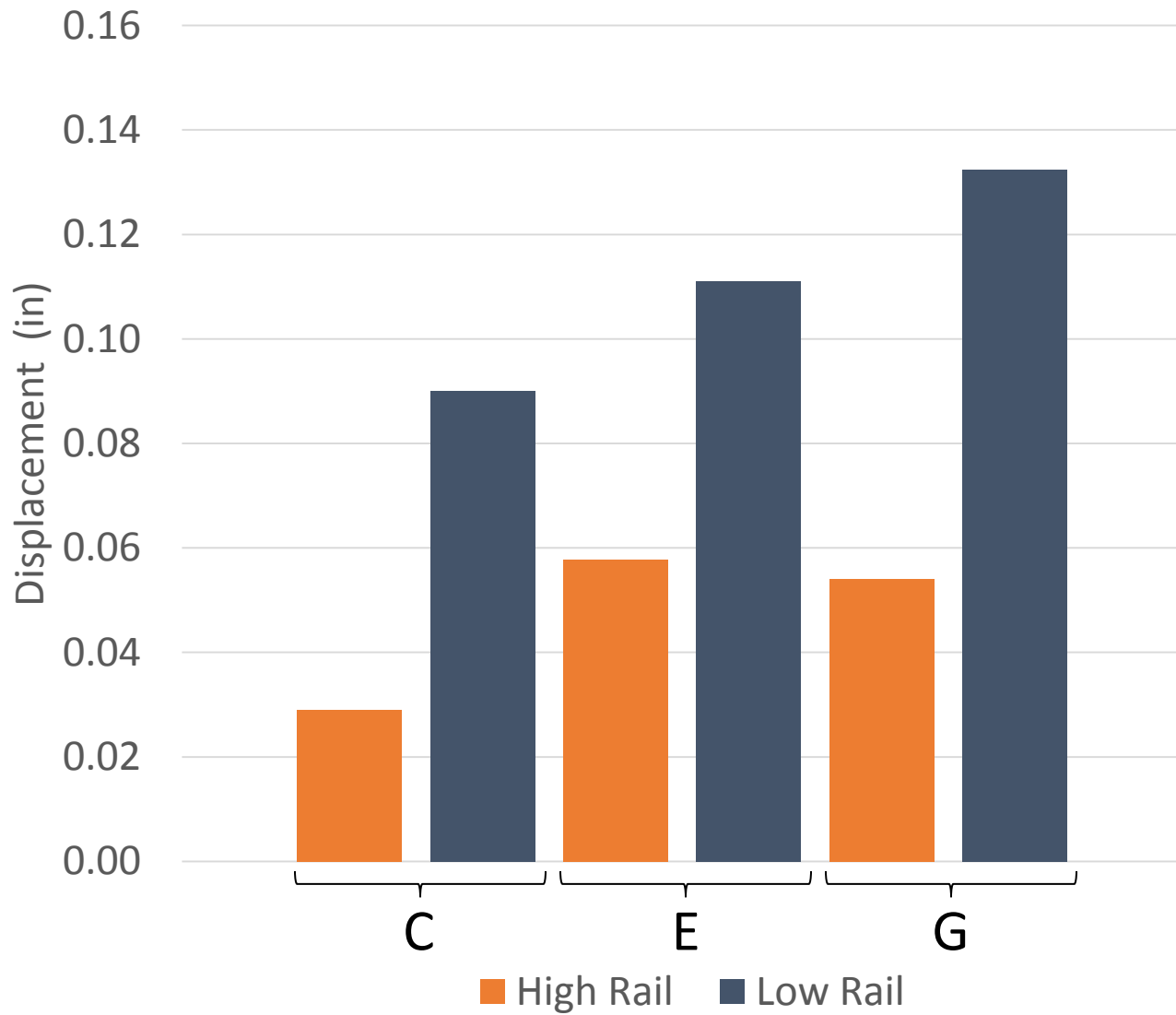
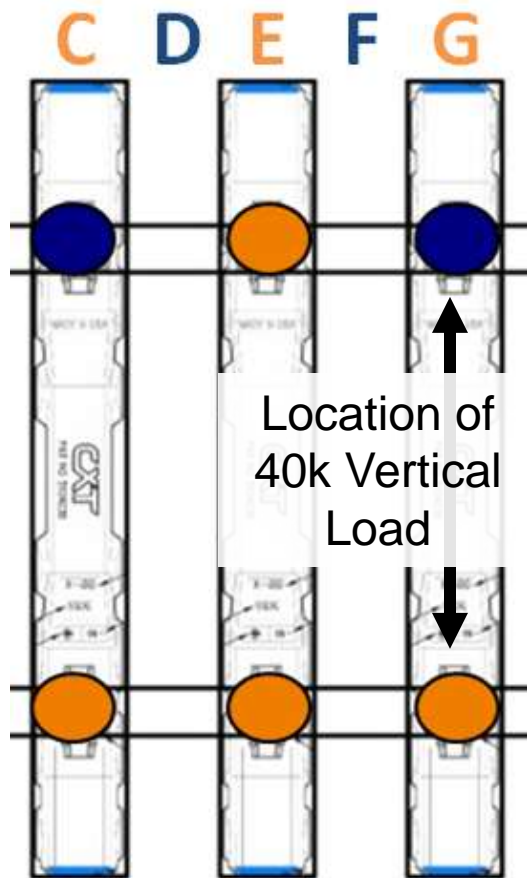
Vertical Tie Displacements (HTL)



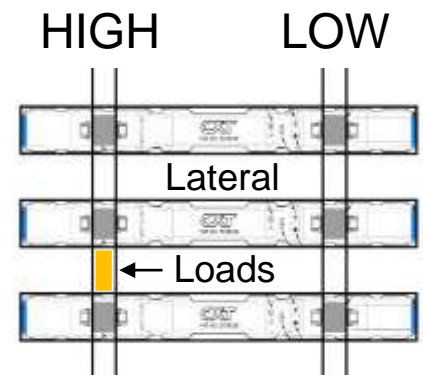
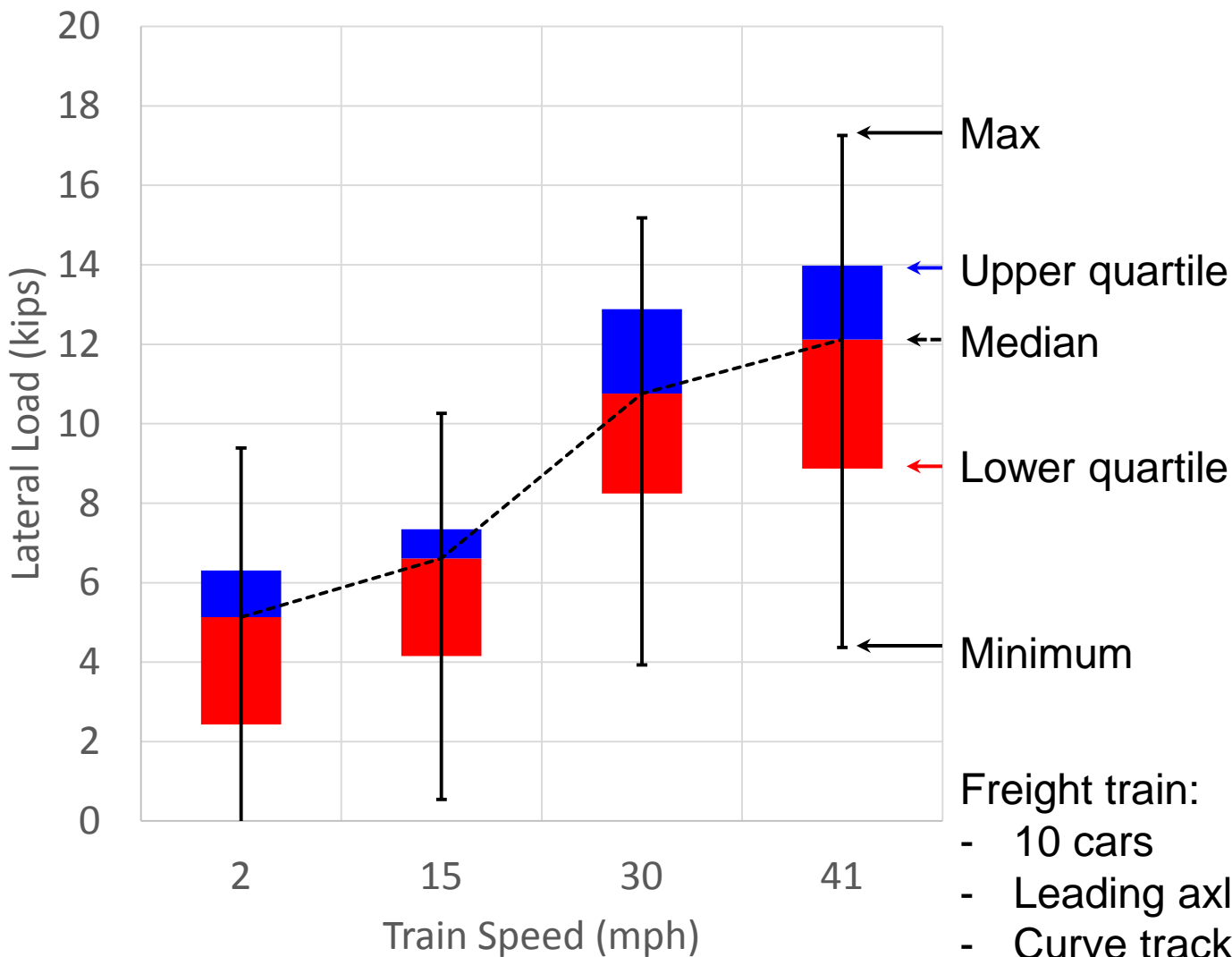
Vertical Tie Displacements (HTL)



Vertical Tie Displacements (HTL)

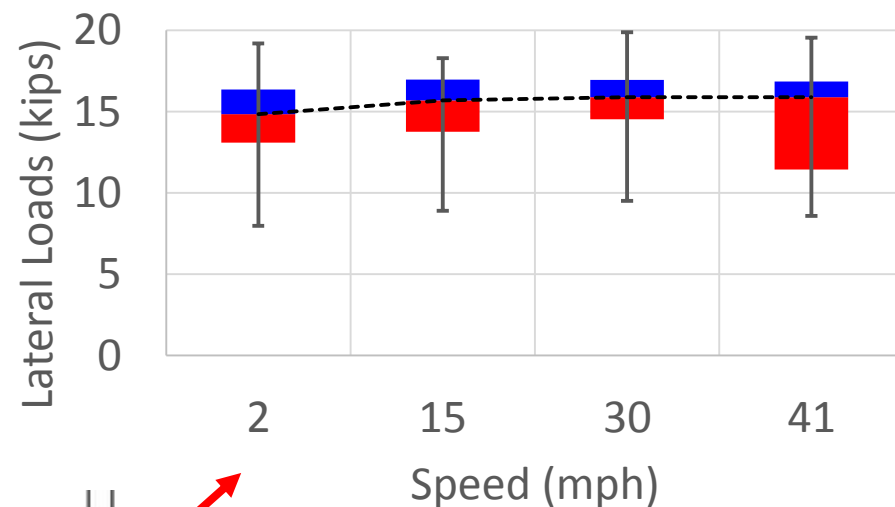
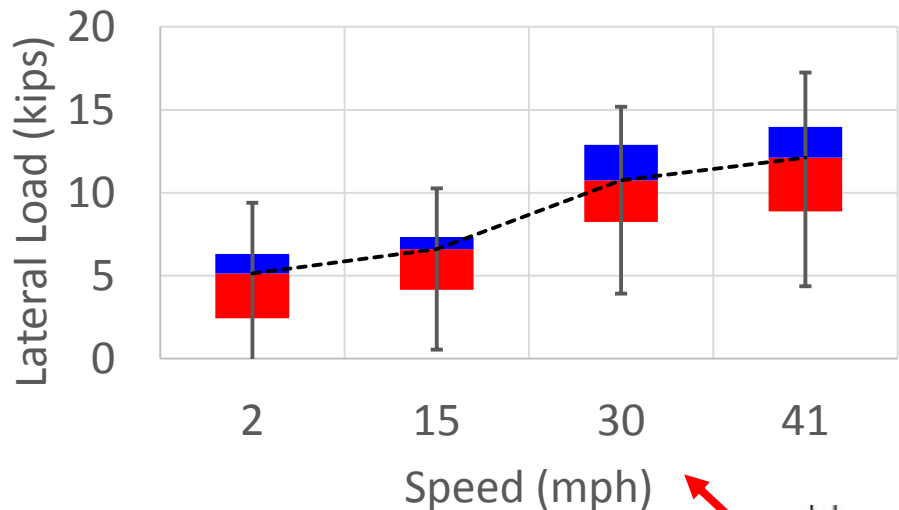


Lateral loads Acting on Crib F (HTL)



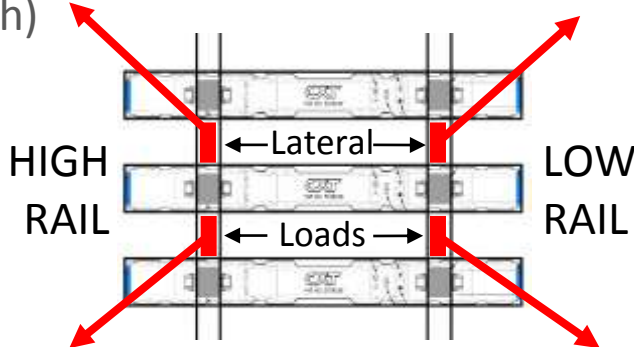
Freight train:

- 10 cars
- Leading axles
- Curve track (5°)
- Locomotive: 390k
- Freight cars: 260-315k

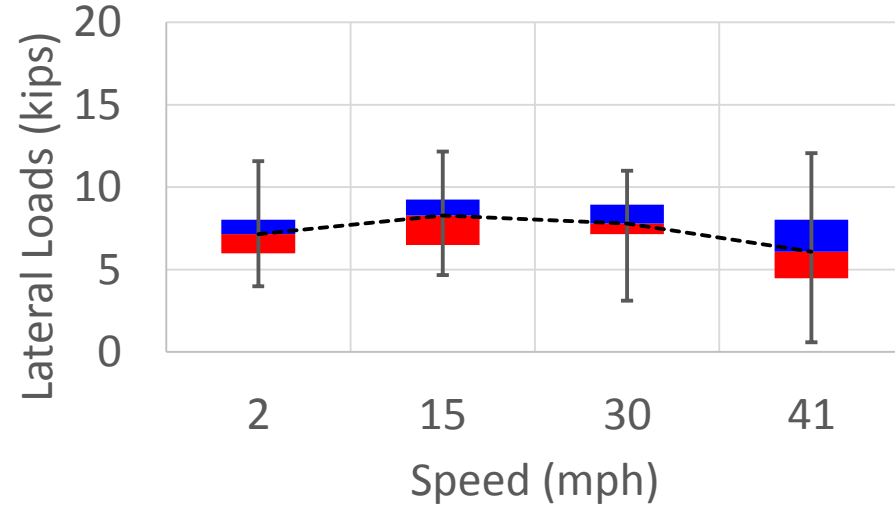
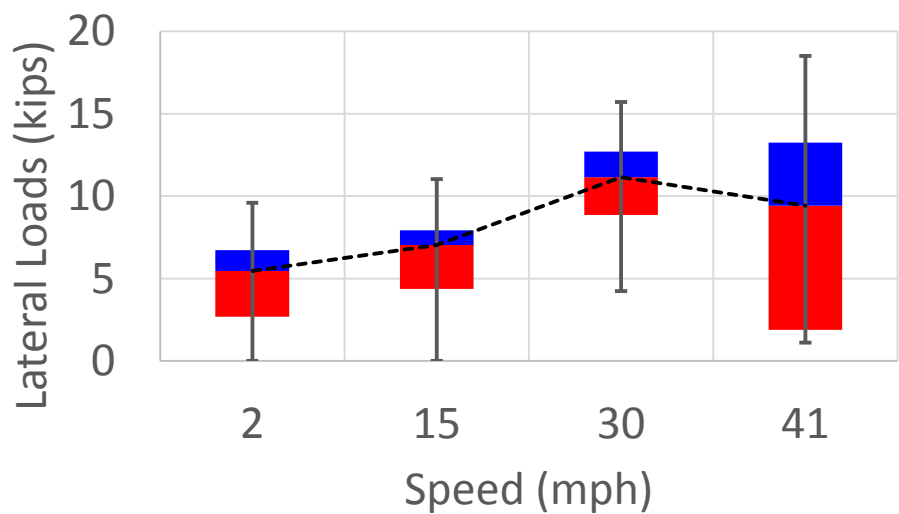


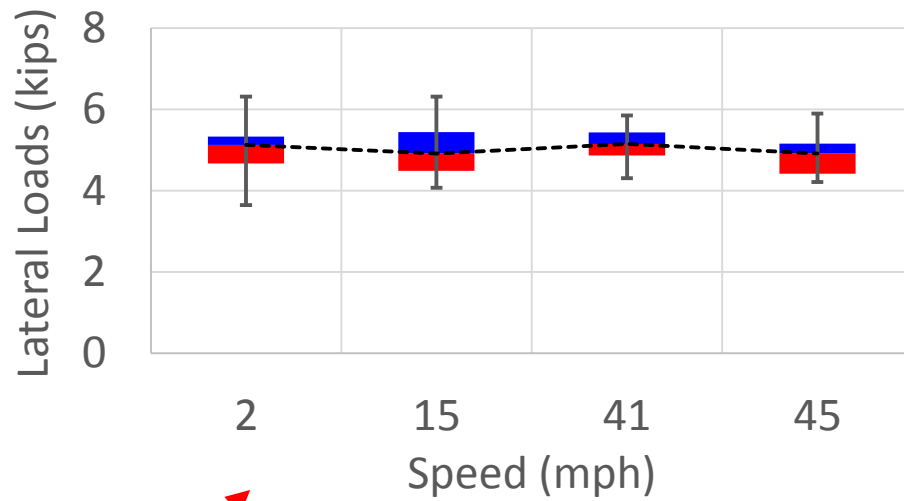
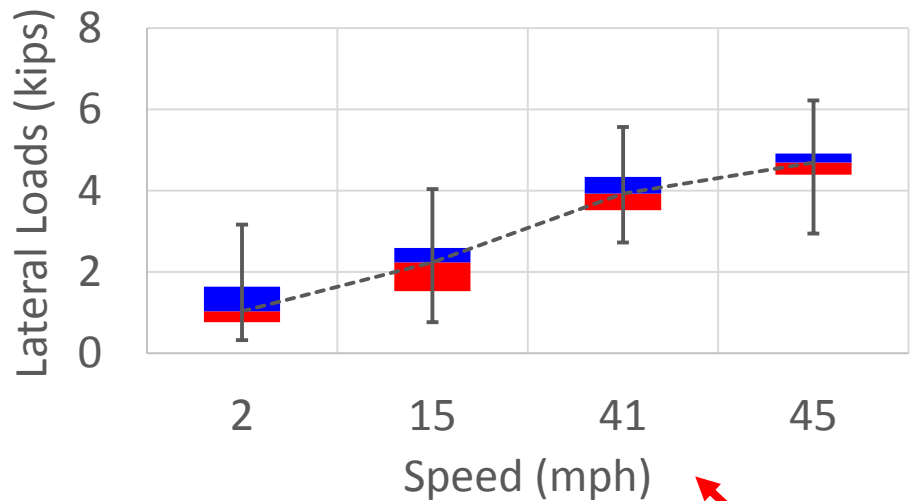
Freight train:

- 10 cars
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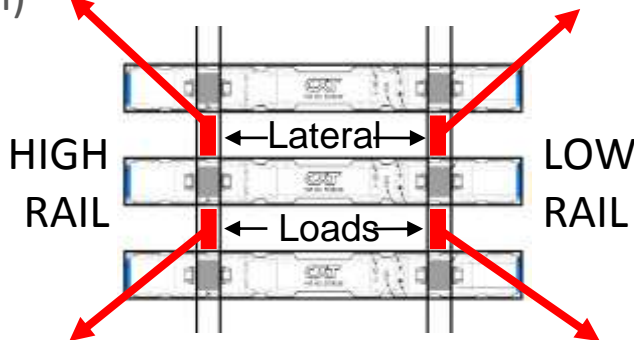
- Locomotive: 390k
- Freight cars: 260-315k



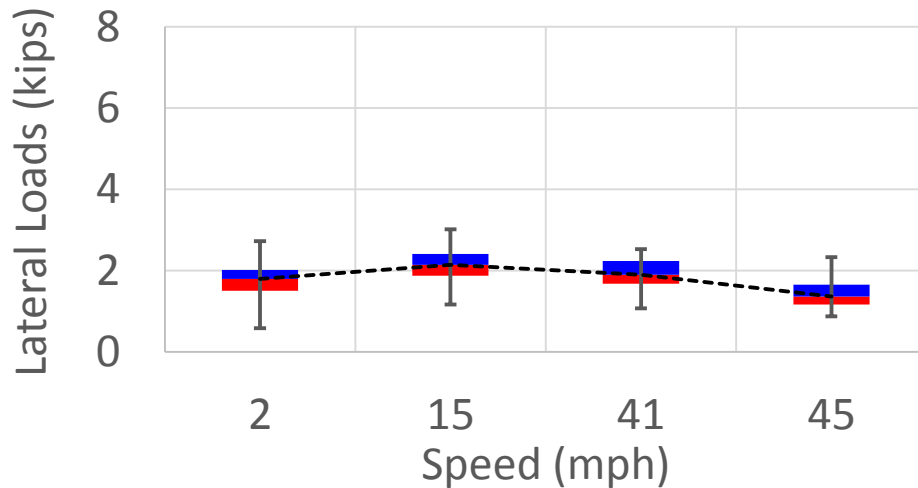
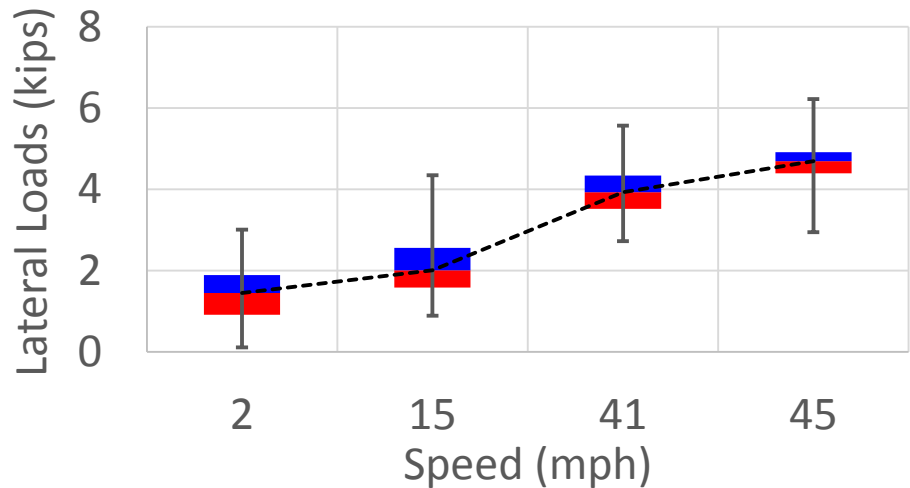


Passenger train:

- 10 cars
- Leading Axles
- Curve track (5°)



- Omitting locomotive
- Passenger coaches: 85k



Preliminary Findings

- Global tie displacements provide an understanding of load distribution and substructure stiffness, and should be expanded in future field testing
- Increasing train speeds generate higher lateral forces on the high rail
- Preliminary comparison of some axles with the finite element model shows correlation with rail strains
- Results for strains at all instrumentation locations appear relatively similar on the tangent track with more variability in the curve track
- Highest loads were imparted by the locomotives and leading axles on railcar trucks

Future Work

- Continued **data analysis** to understand the governing mechanics of the system
- Continued **comparison and validation** of the finite element model
- Improvements on an **instrumented insulator** to provide post compression and lateral load
- Preparation for **instrumentation trip** (Spring 2013)
 - Focus on displacement measurements
- Small-scale, evaluative tests on Class I Railroads



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Acknowledgements

U.S. Department of Transportation

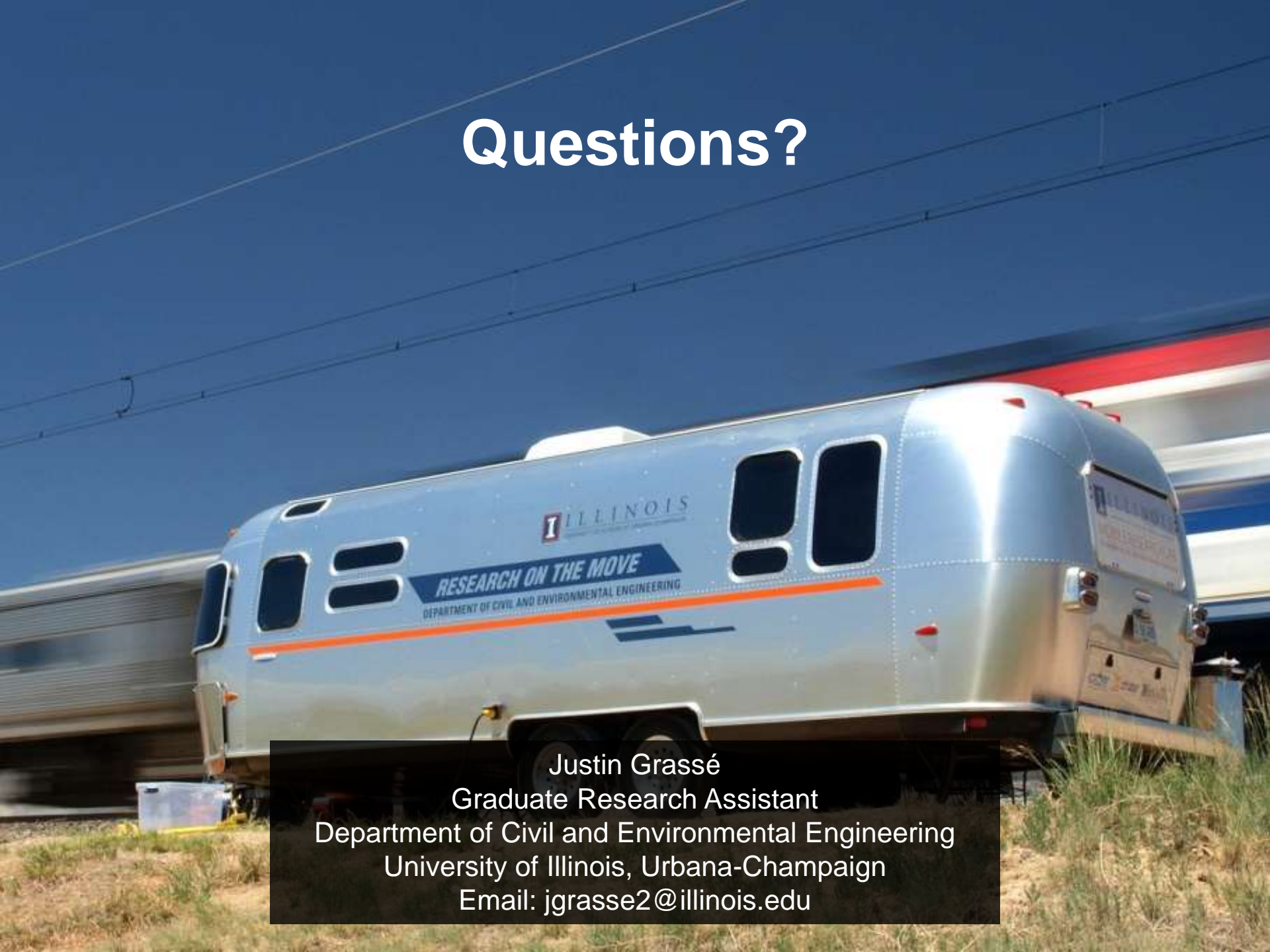
Federal Railroad Administration

- Funding for this research has been provided by the Federal Railroad Administration (FRA)
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 - Union Pacific Railroad
 - BNSF Railway
 - National Railway Passenger Corporation (Amtrak)
 - Amsted RPS / Amsted Rail, Inc.
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 - Hanson Professional Services, Inc.
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- Transportation Technology Center, Inc.
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FRA Tie and Fastener BAA Industry Partners:



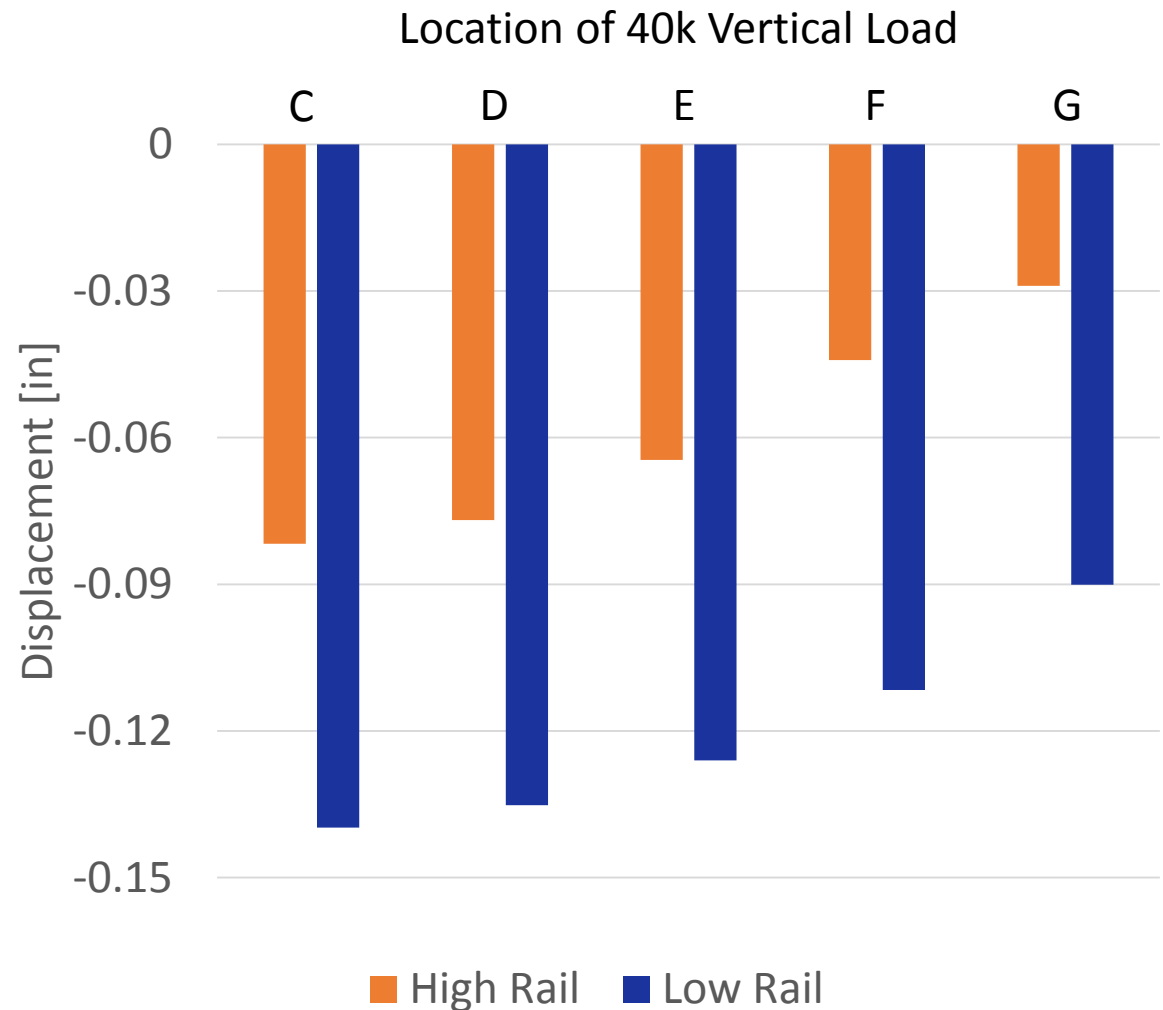
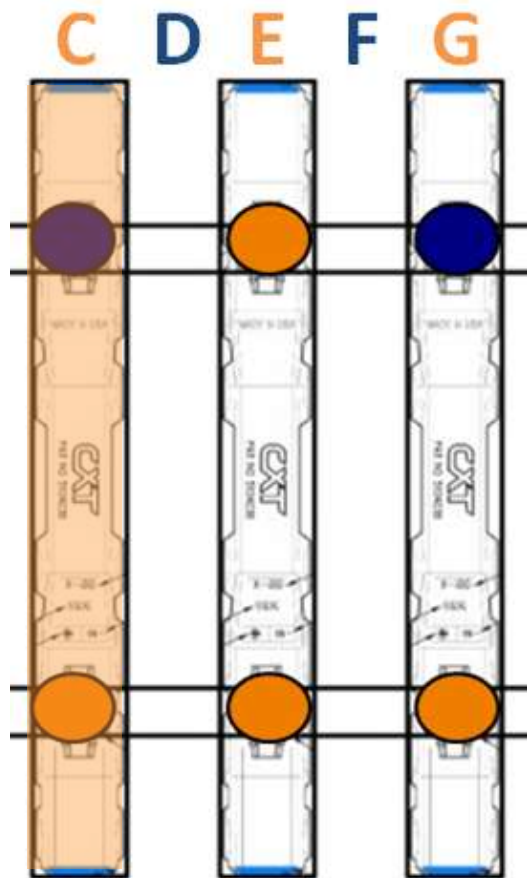
Questions?



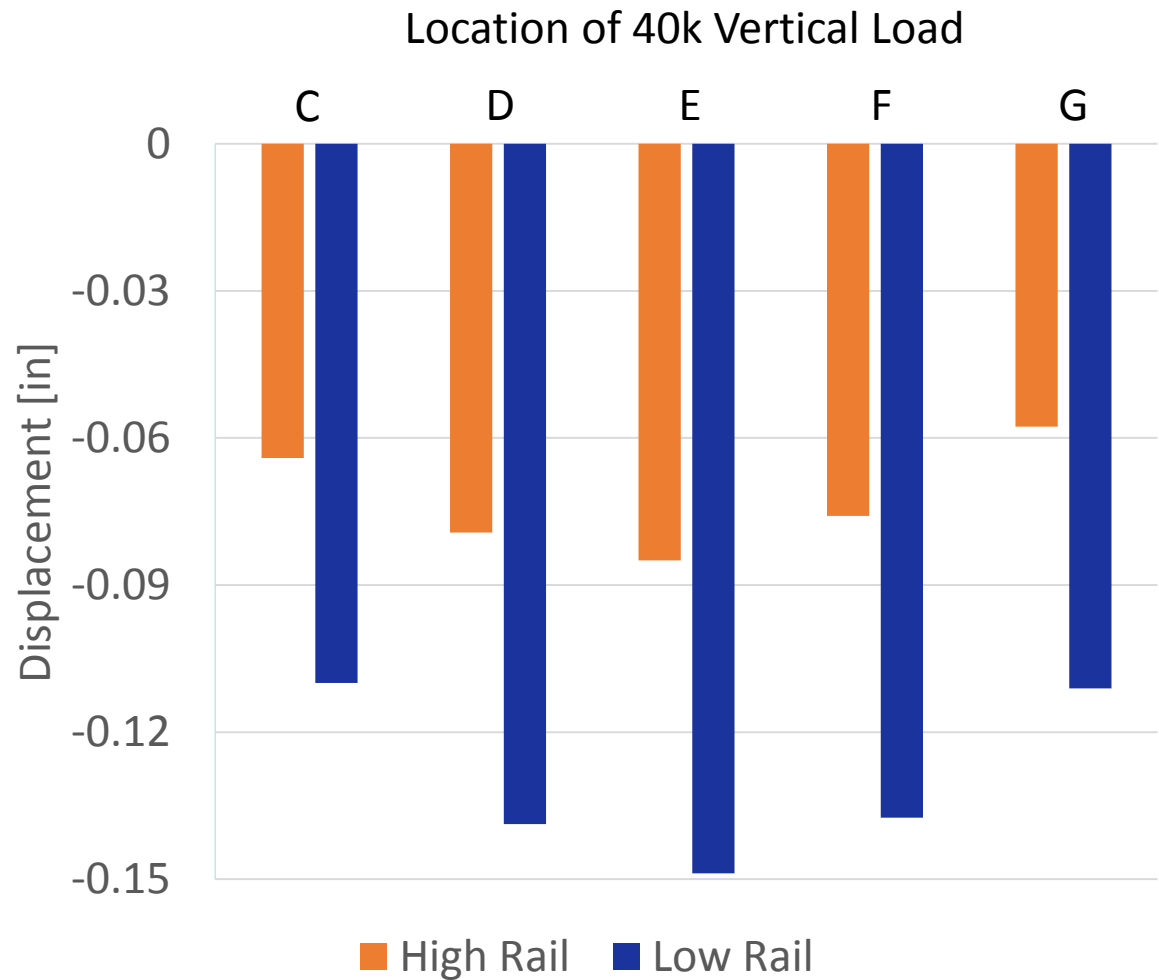
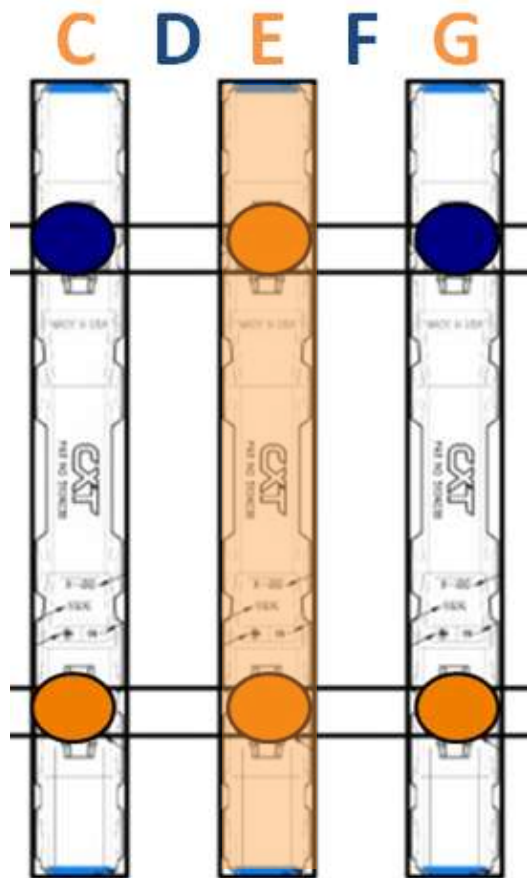
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Appendix

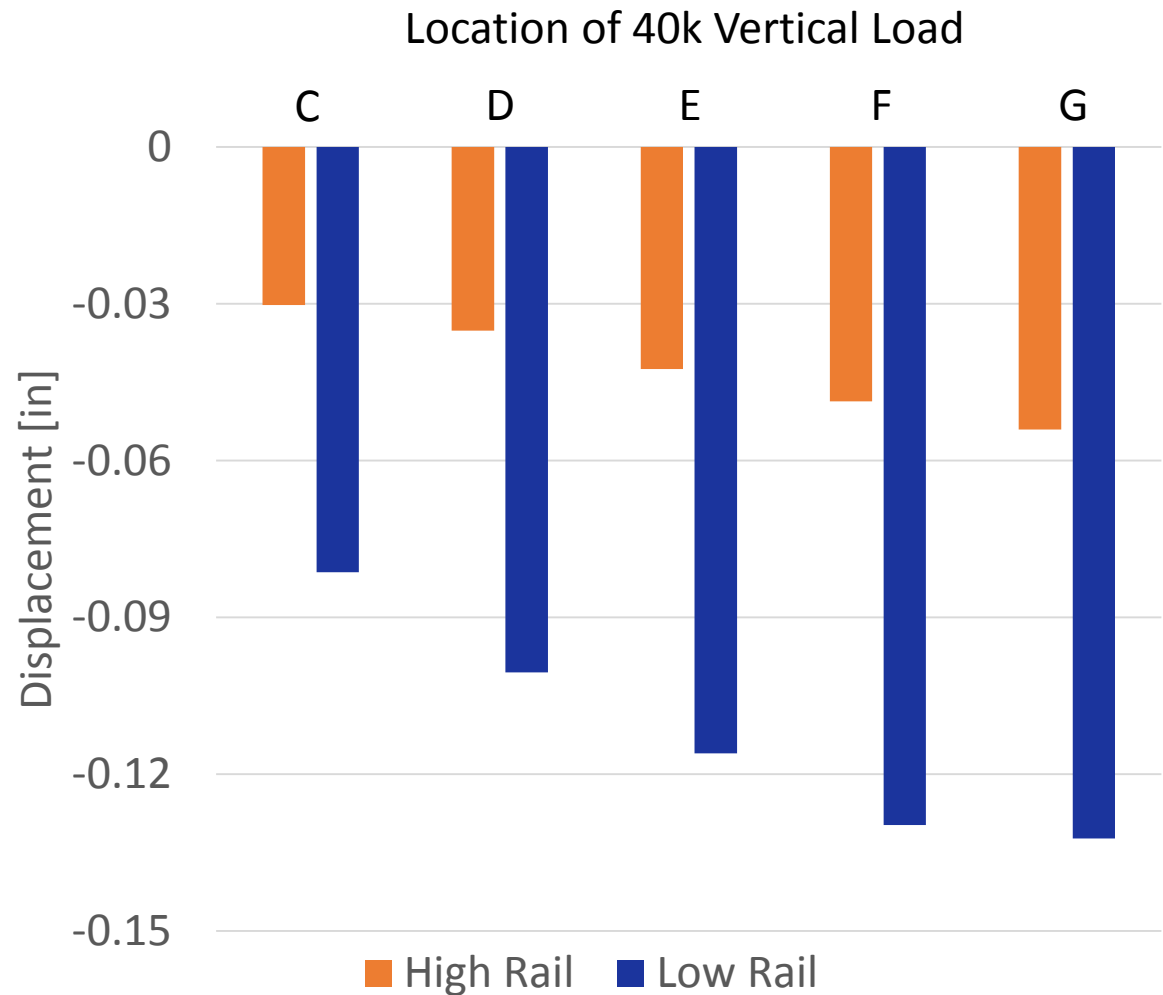
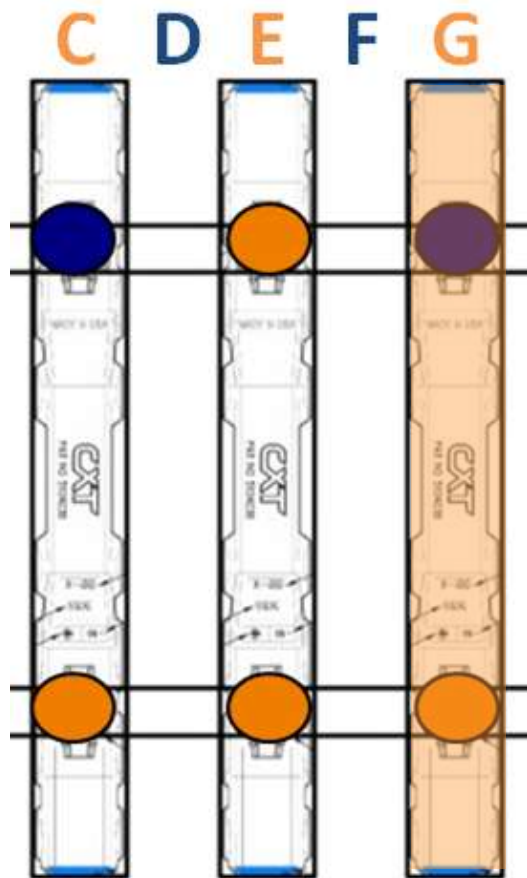
Vertical Displacements of Tie C (HTL)



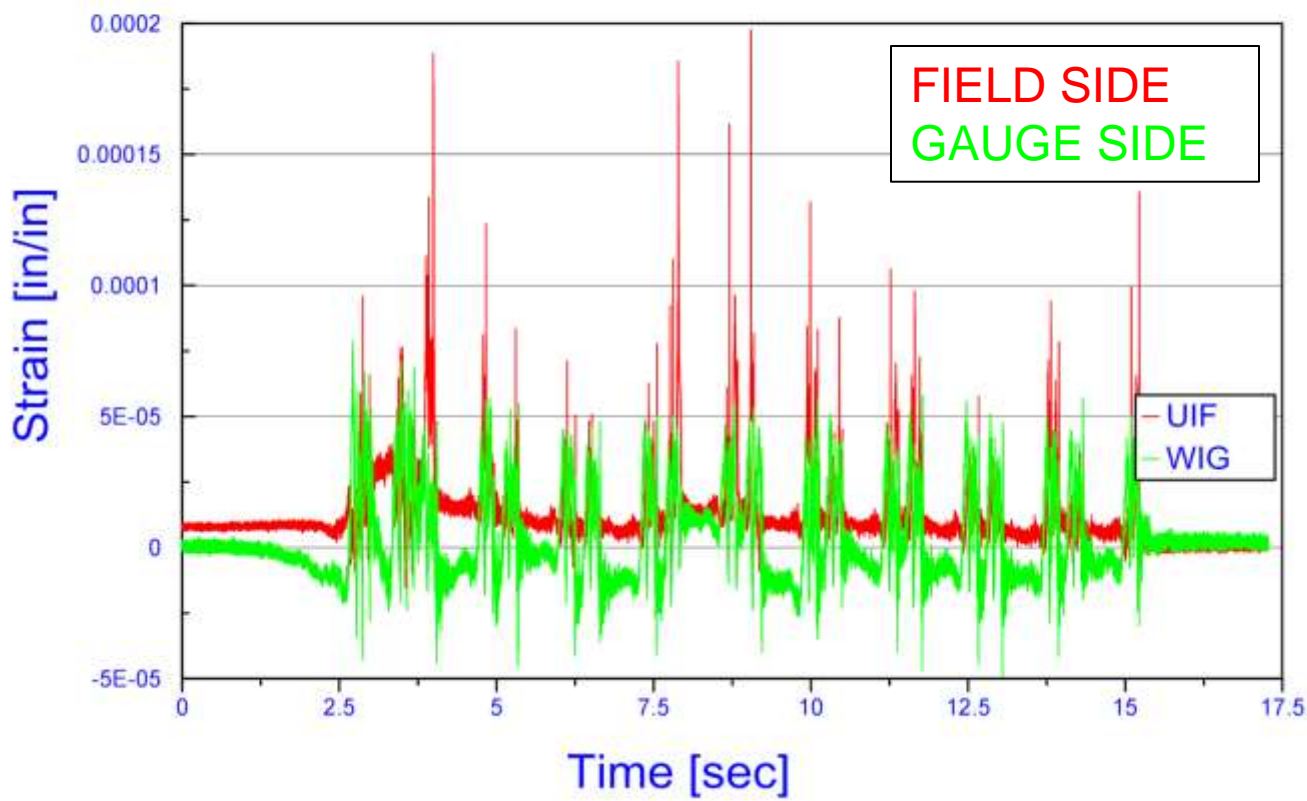
Vertical Displacements of Tie E (HTL)



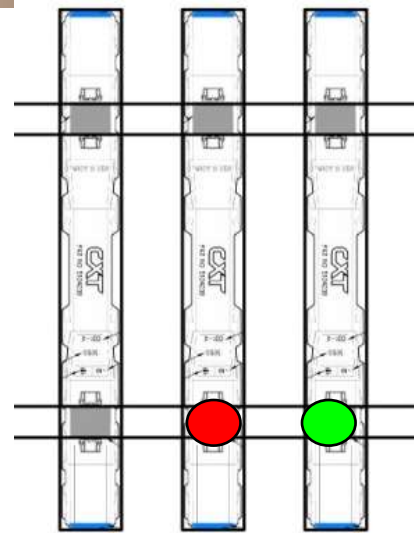
Vertical Displacements of Tie G (HTL)



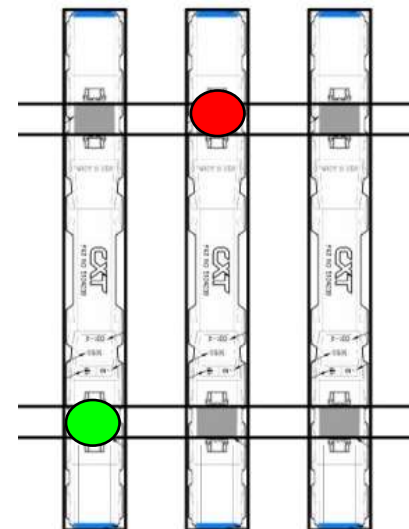
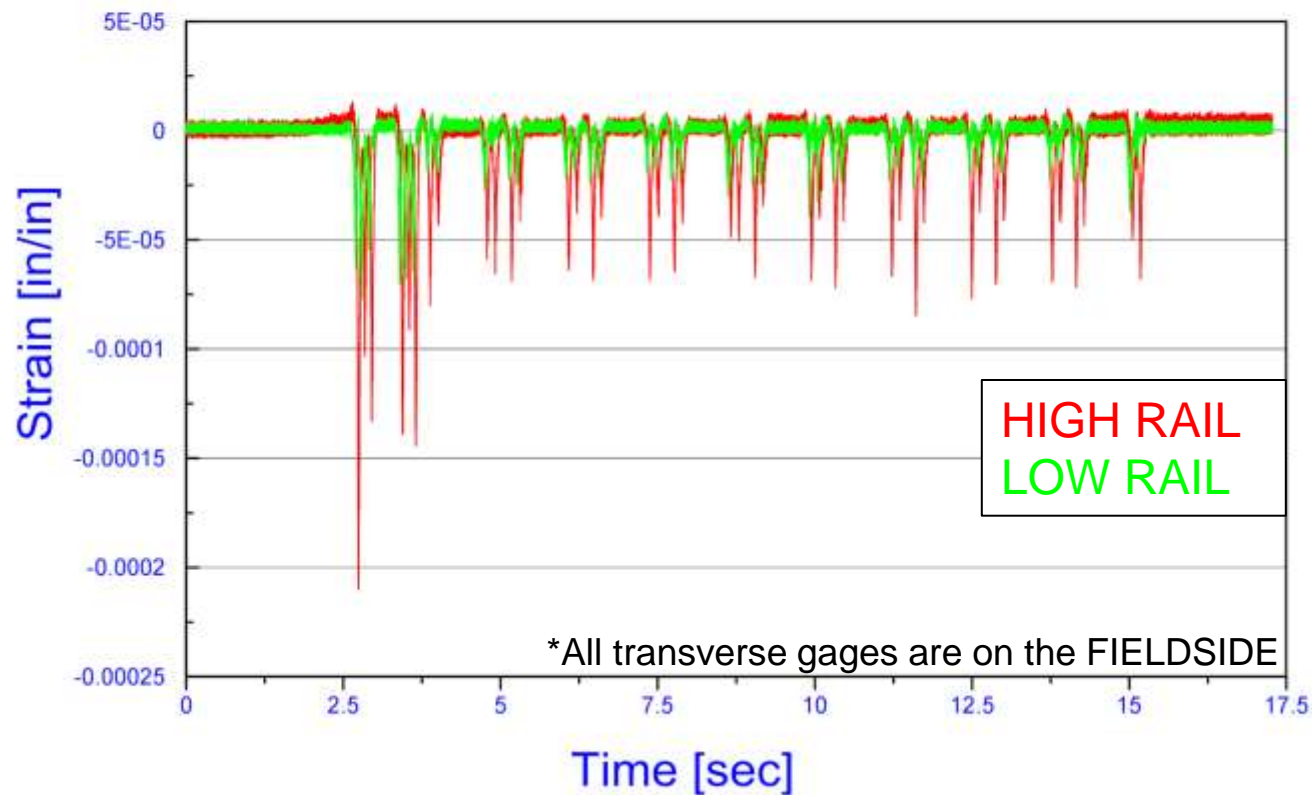
Insulator Post Compressive Strains Passenger Train over Curve (45mph)



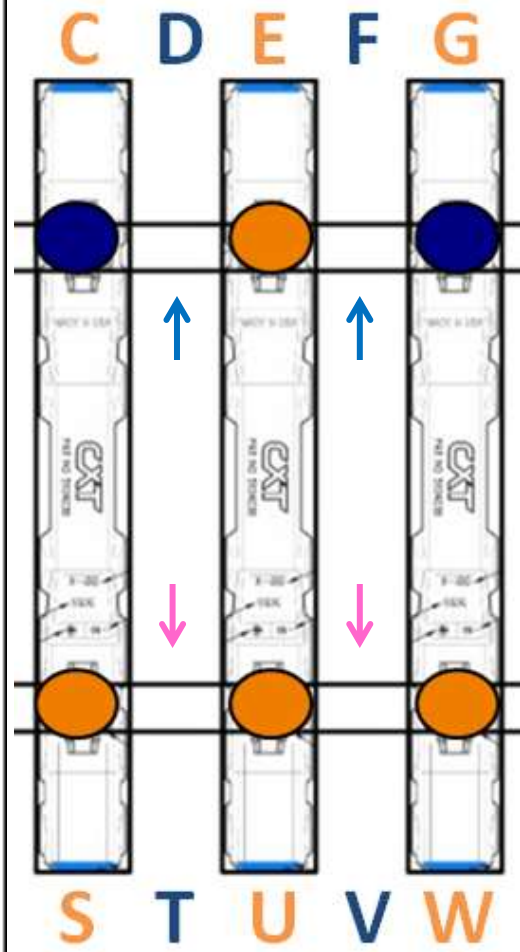
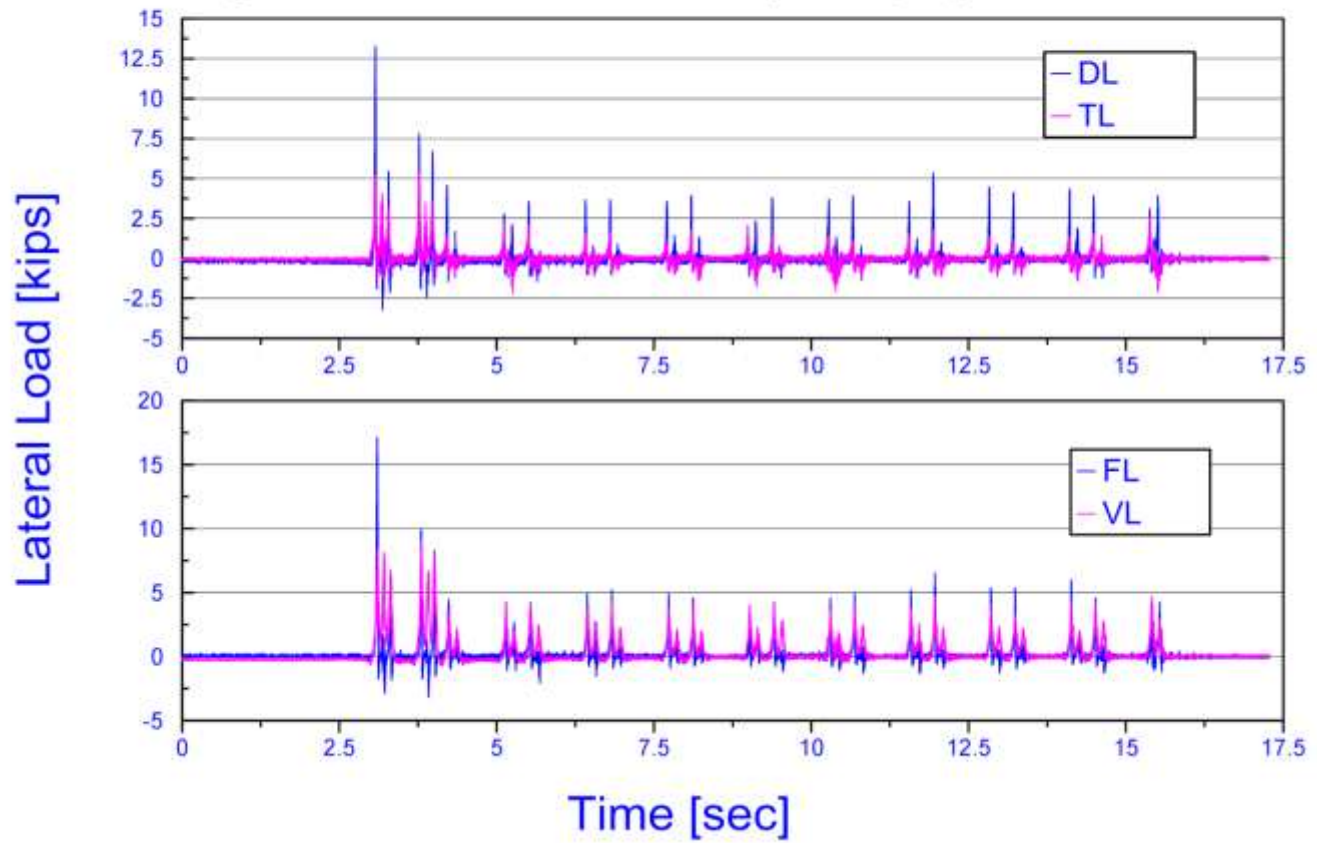
FIELD SIDE
GAUGE SIDE



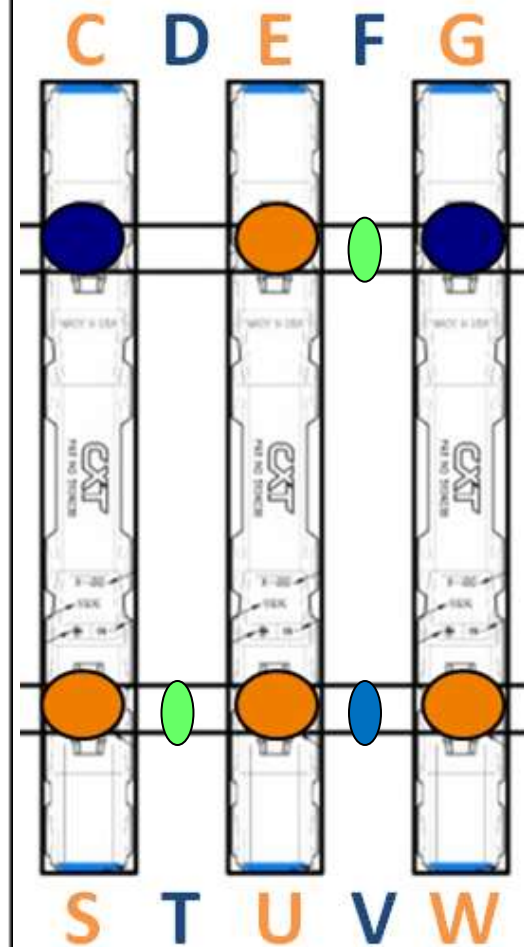
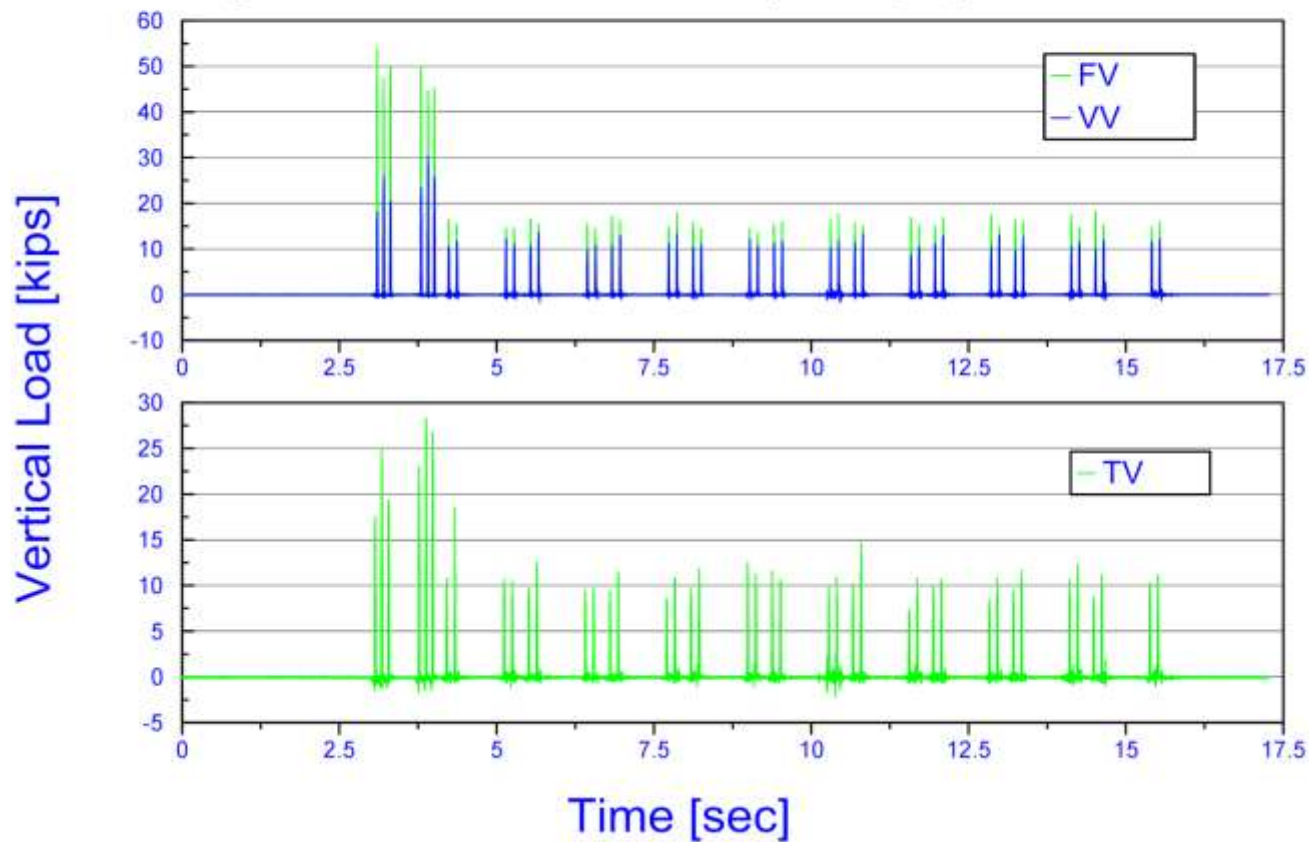
Transverse Strains at Rail Base Passenger Train over Curve (45mph)



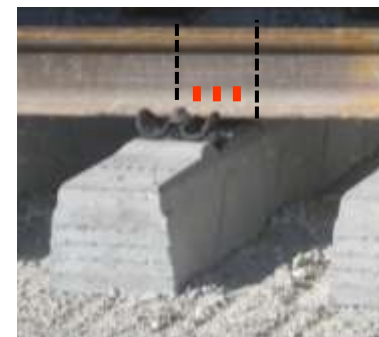
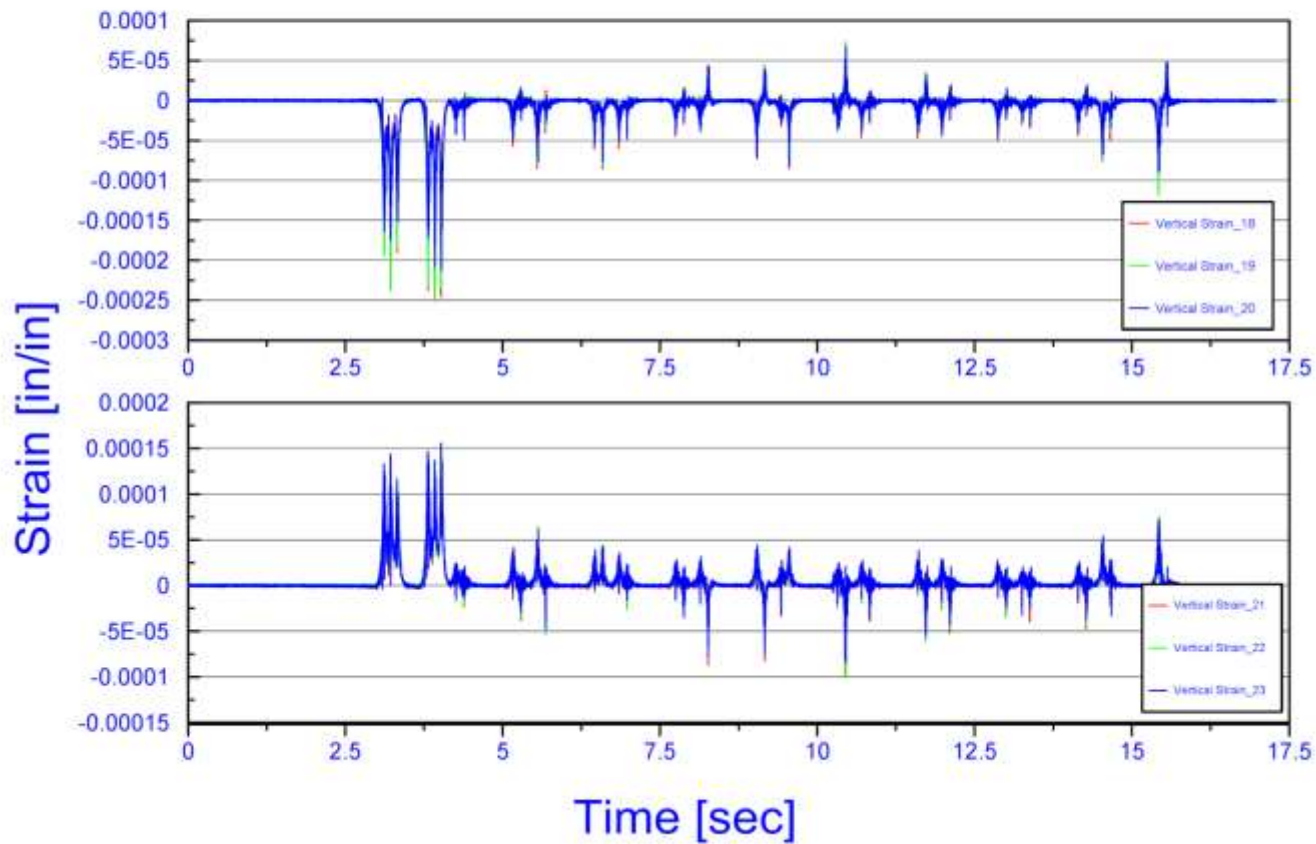
Lateral Load Measurements of Two Adjacent Crib Passenger Train over Curve (45mph)



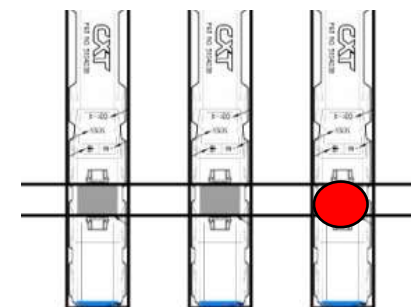
Vertical Load Measurements of Two Adjacent Cribs Passenger Train over Curve (45mph)



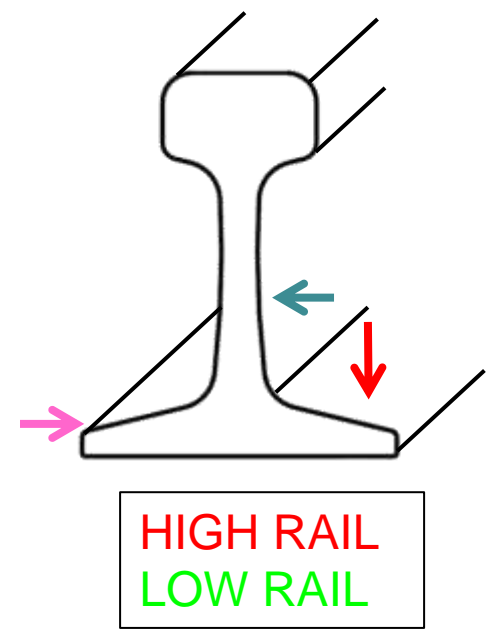
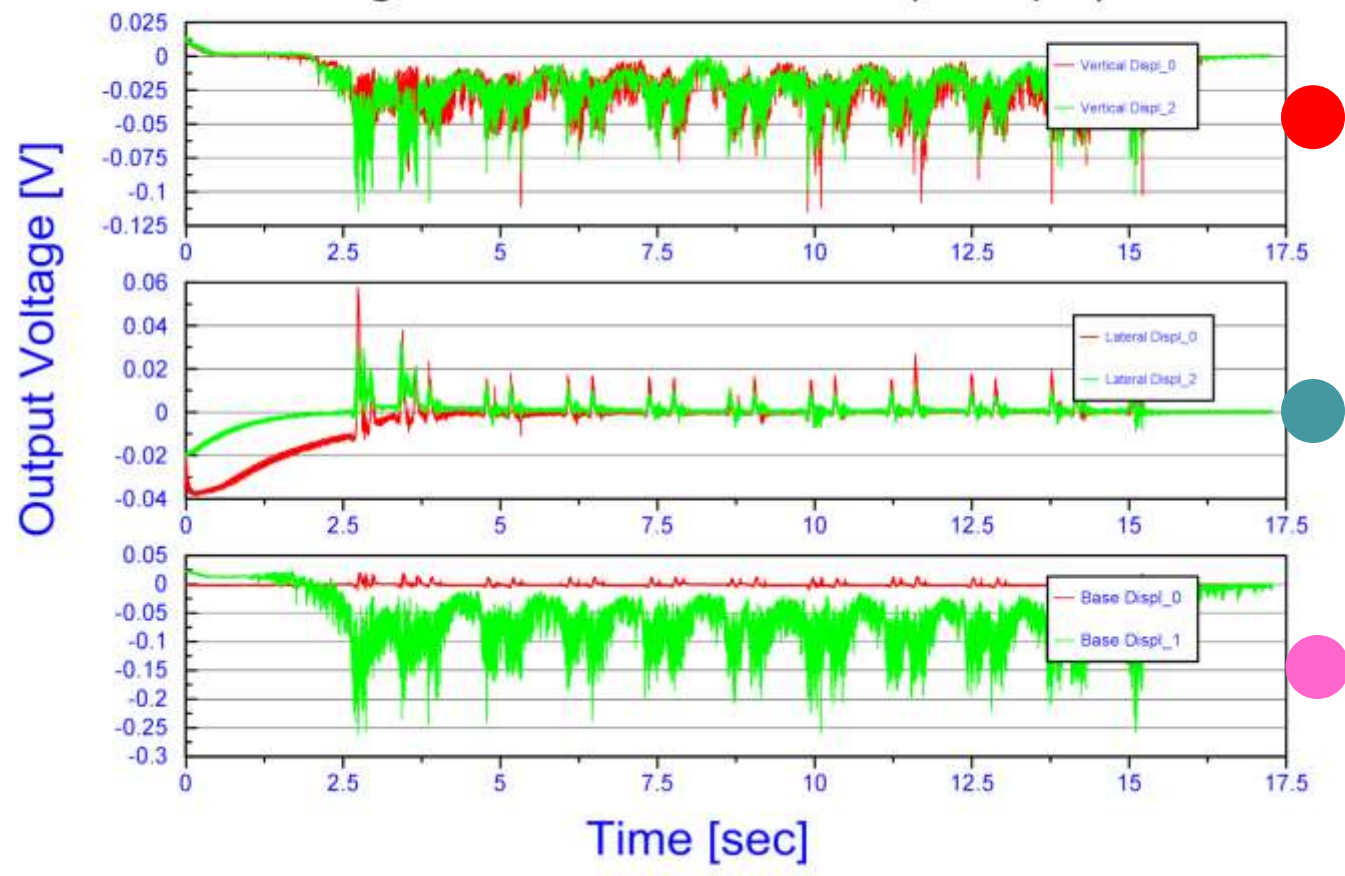
Vertical Strains near Rail Seat Passenger Train over Curve (45mph)



- Field-side strains on Top Graph
- Gauge-side strains on Bottom Graph
- ALL strains on ONE railseat on the LOW RAIL

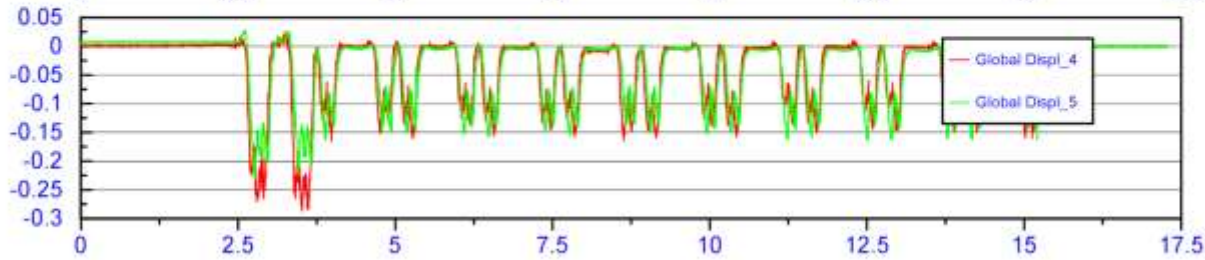
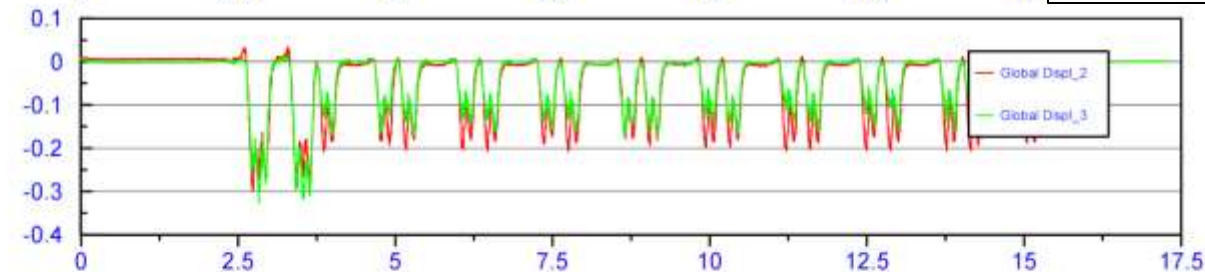
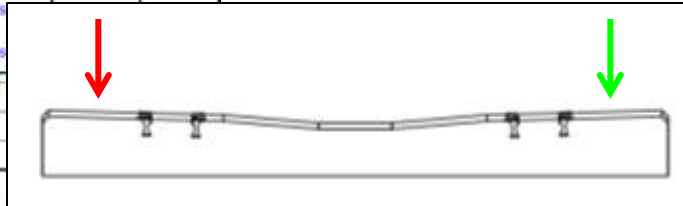
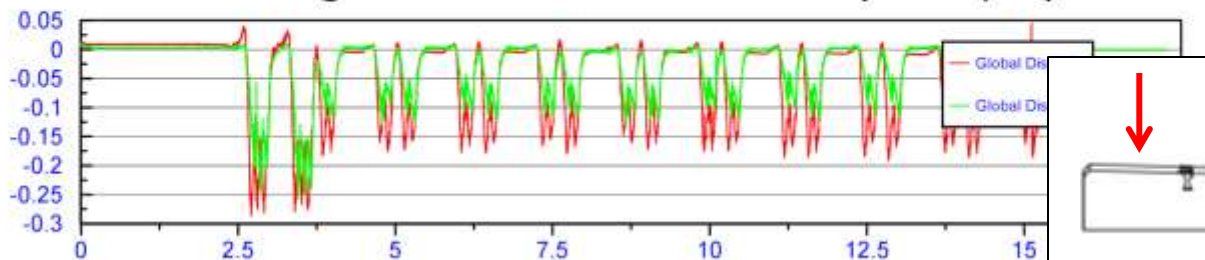


Displacement Data from Rail Seat Passenger Train over Curve (45mph)



Displacement Data from Tie Passenger Train over Curve (45mph)

Output Voltage [V]



Time [sec]

