Field Testing of the Crosstie-Fastener System for the Understanding of Mechanistic Behavior

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Justin Grassé, David Lange

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Federal Railroad Administration

RAILTEC

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Objectives of Field Research
- Field Instrumentation Strategy
- Testing at Transportation Technology Center (TTC)
- Experimental Results
- Findings
- Future Work

FRA Tie and Fastener Project Structure

Inputs

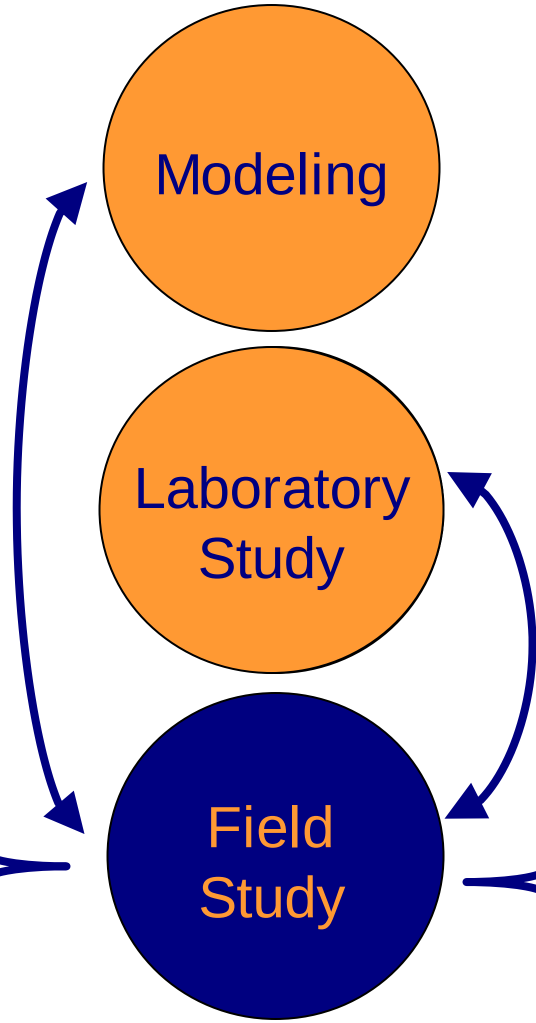
Comprehensive Literature Review

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

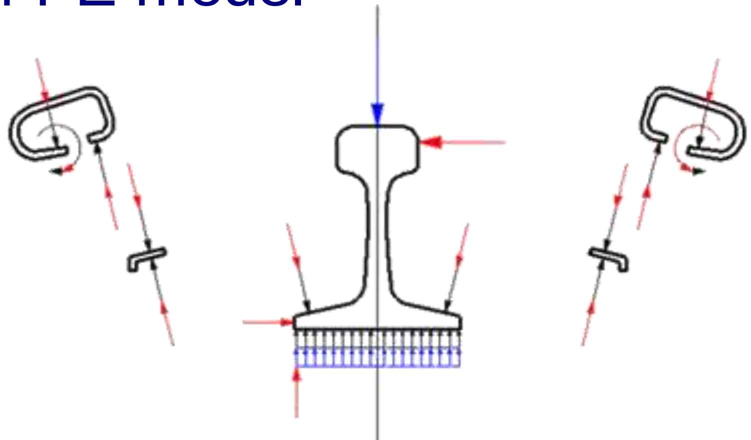
State of Practice Report

Validated Tie and Fastening System Model

Improved Recommended Practices

Goals of Field Instrumentation

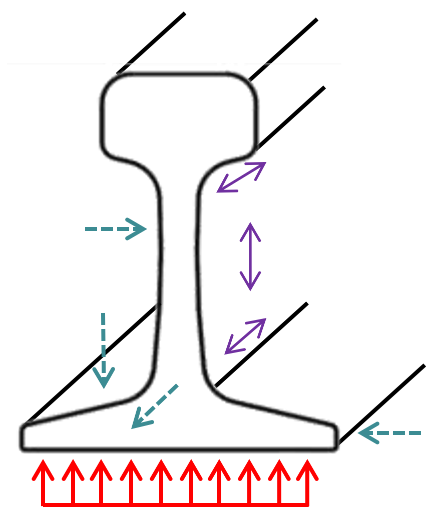
- Lay groundwork for mechanistic design of concrete crossties and elastic fasteners
- Quantify the demands placed on each component within the system
- Develop an understanding into field loading conditions
- Provide insight for future field testing
- Collect data to validate the UIUC concrete crosstie and fastening system FE model



Areas of Investigation

Rail

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

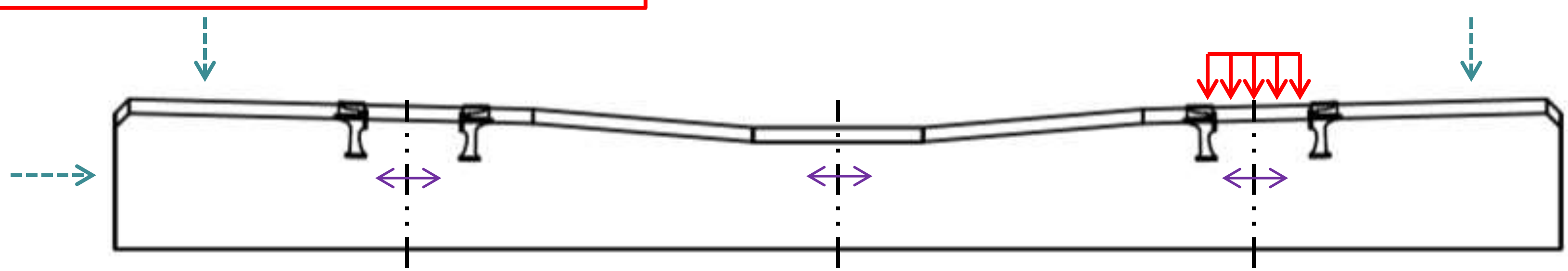


Fasteners/ Insulator

- Strain of fasteners
- Stresses on insulator

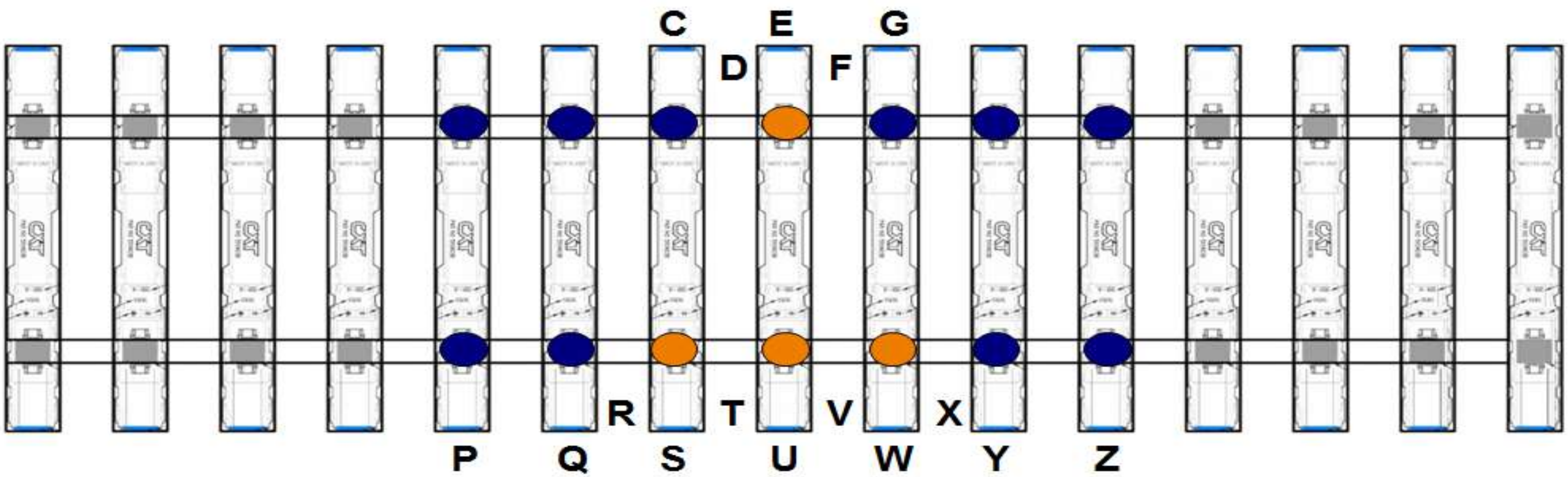
Concrete Crossties

- Moments at the rail seat/tie center
- Stresses at rail seat
- Vertical/Lateral displacements of crossties

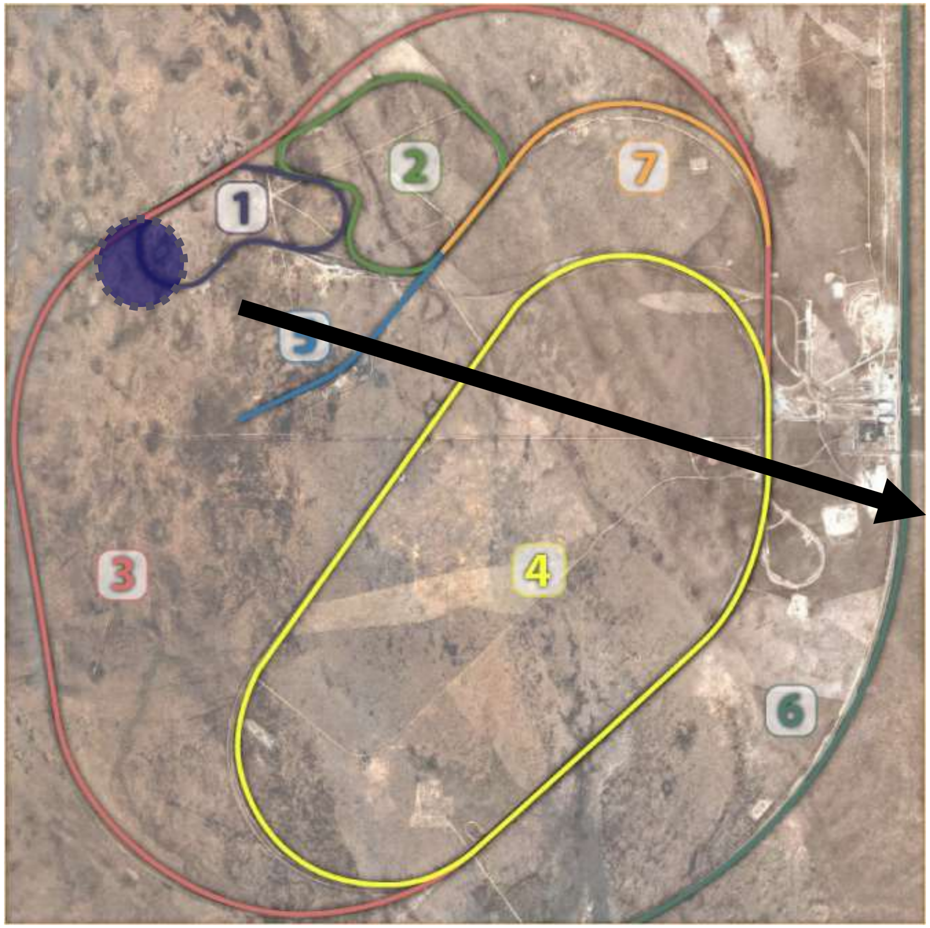


2012 Field Instrumentation Map

- **Full Instrumentation**
  - Lateral, vertical, and chevron strain gauges on rail
  - Embedment and external concrete strain gauges on crosstie
  - Matrix based tactile surface sensors at rail seat (at rail seat W)
  - Linear potentiometers on rail and crosstie
- Partial Instrumentation
  - Vertical strain gauges on rail
  - Matrix based tactile surface sensors (at rail seats G and Y)
  - Linear potentiometers on crosstie (at rail seats C and G)

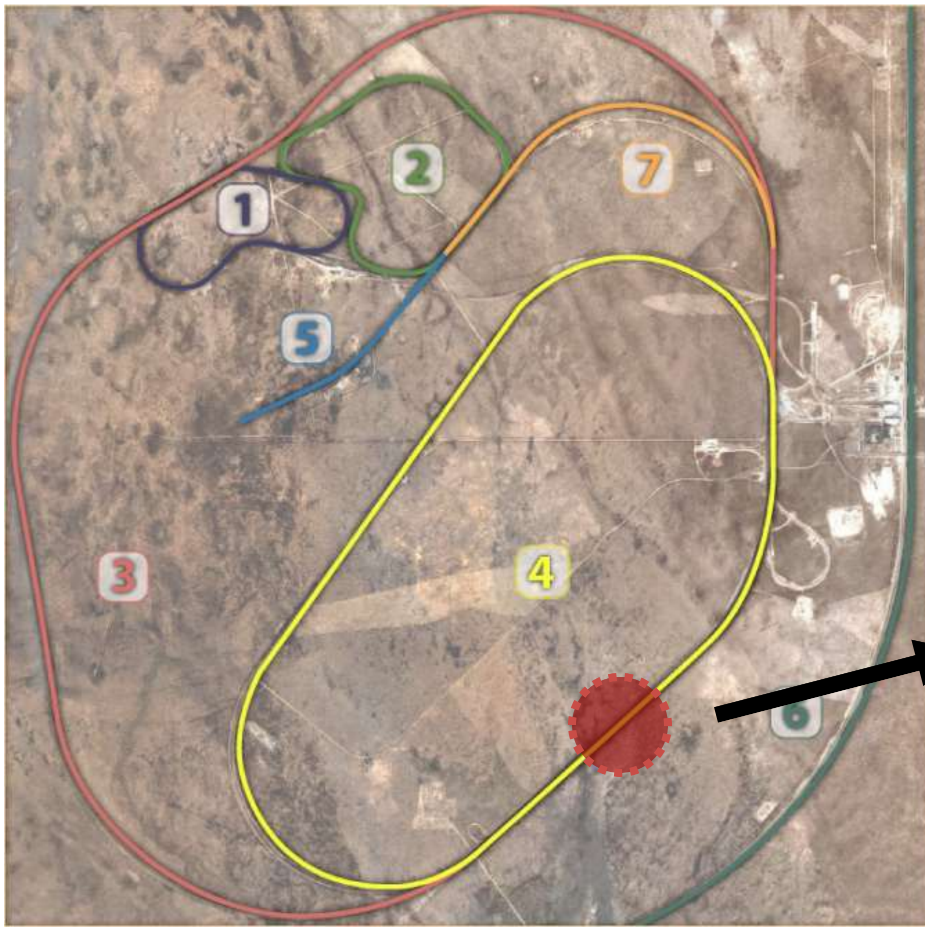


Field Instrumentation Locations

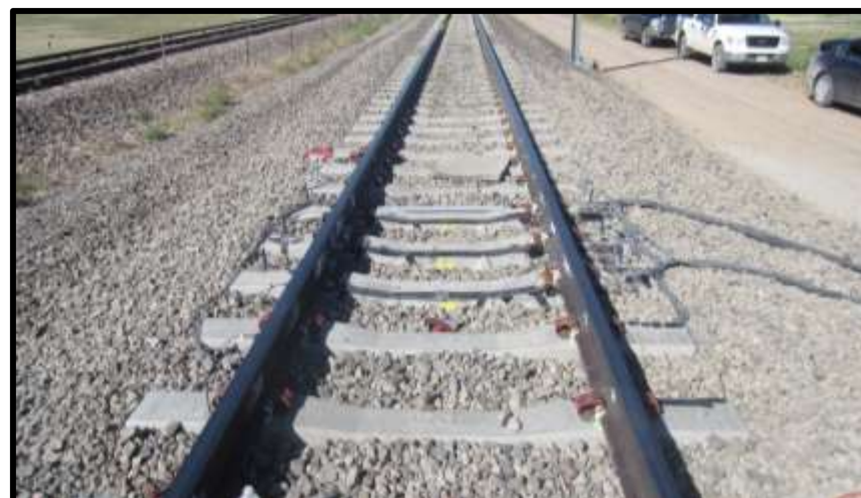


- TTC (Pueblo, CO, USA)
- High Tonnage Loop (HTL)
  - Curve (~5°)
  - Safelok I Fasteners

Field Instrumentation Locations



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

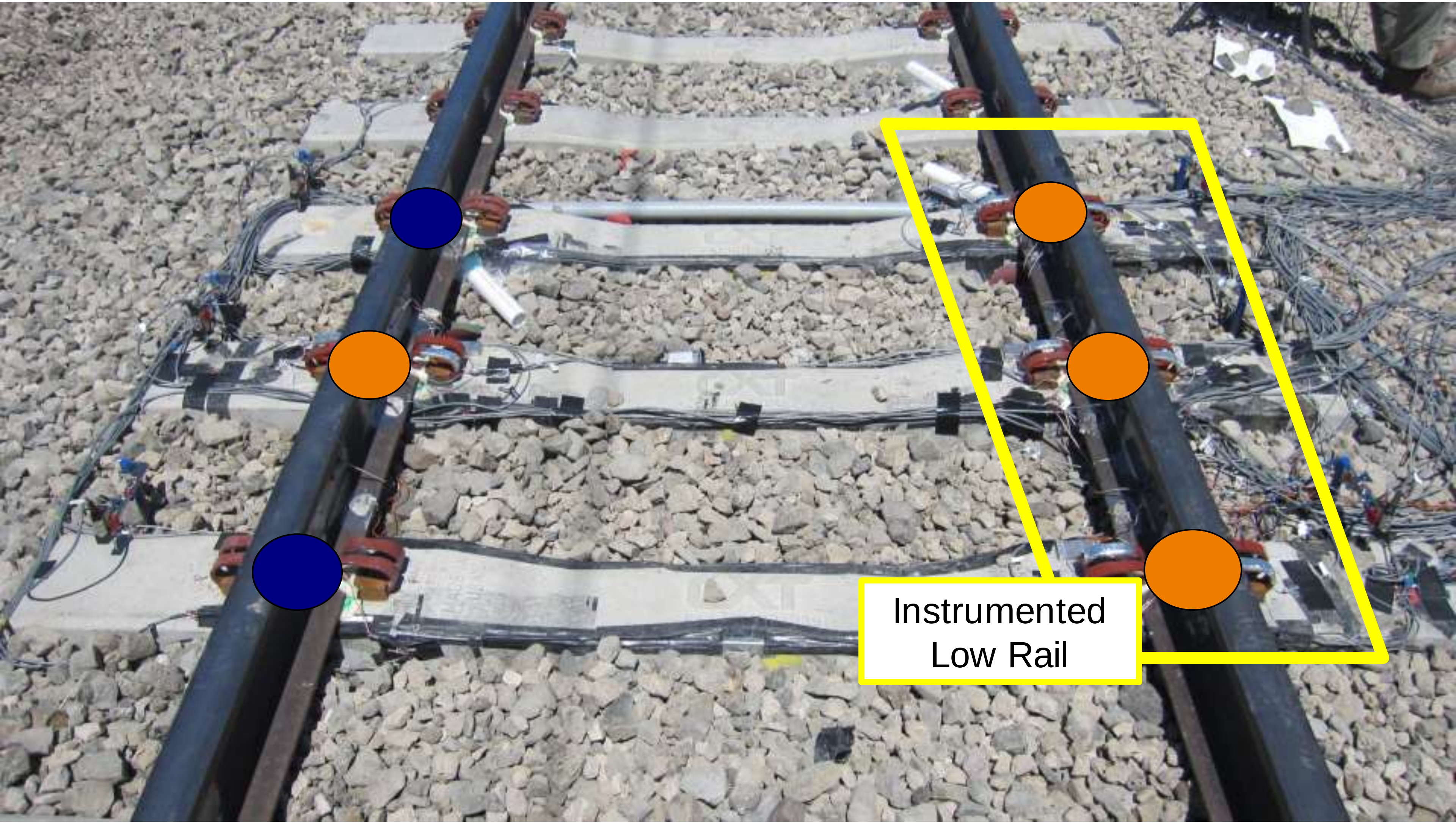


Loading Environment

- Track Loading Vehicle (TLV)
  - Static
  - Dynamic
    - Track modulus

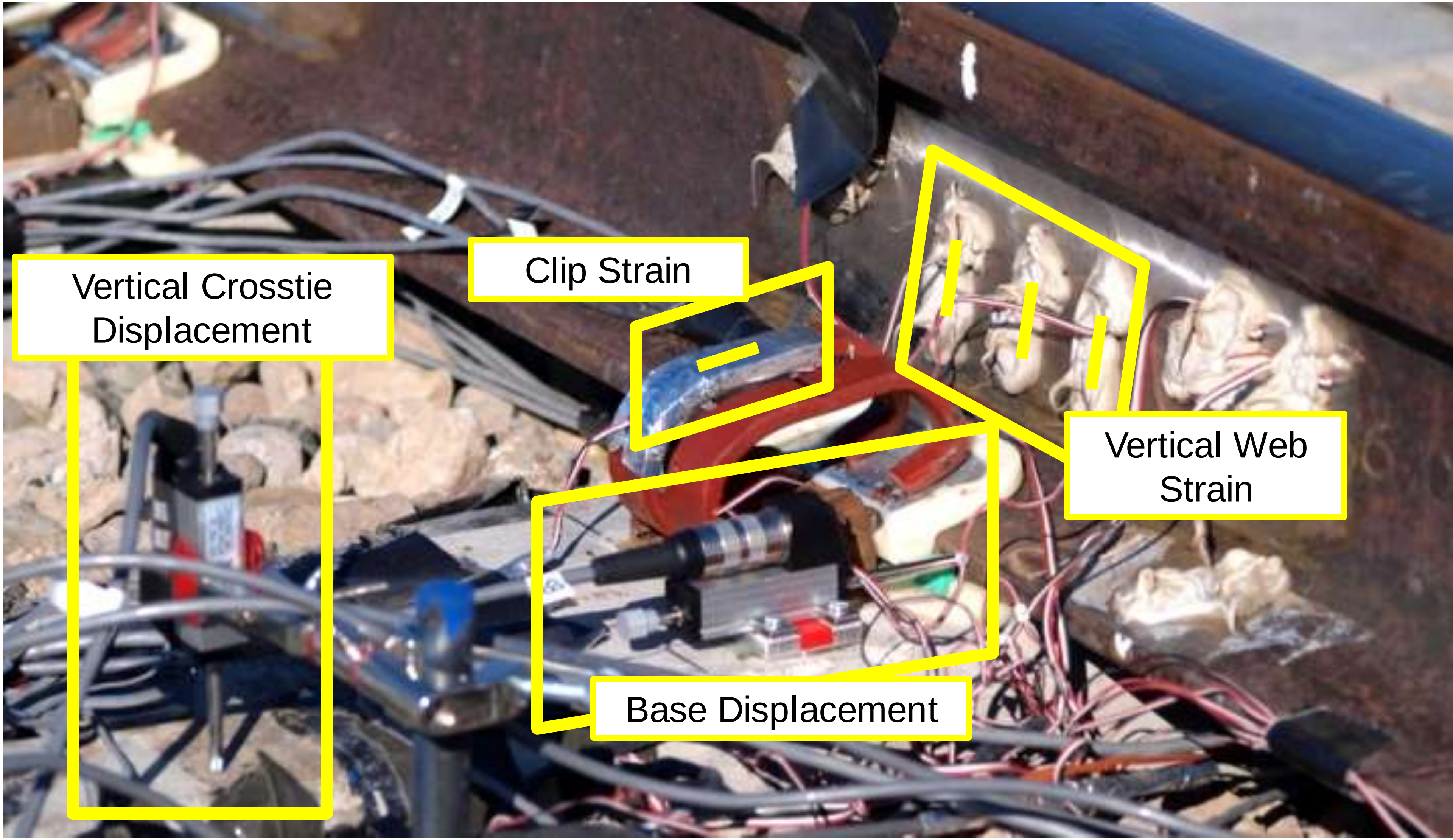
- Freight Consist
  - 6-axle locomotive (393k)
  - Instrumented car
  - Nine cars
    - 263, 286, 315 GRL Cars
- Passenger Consist
  - 4-axle locomotive (255k)
  - Nine coaches
    - 87 GRL

Fully Instrumented Rail Seats

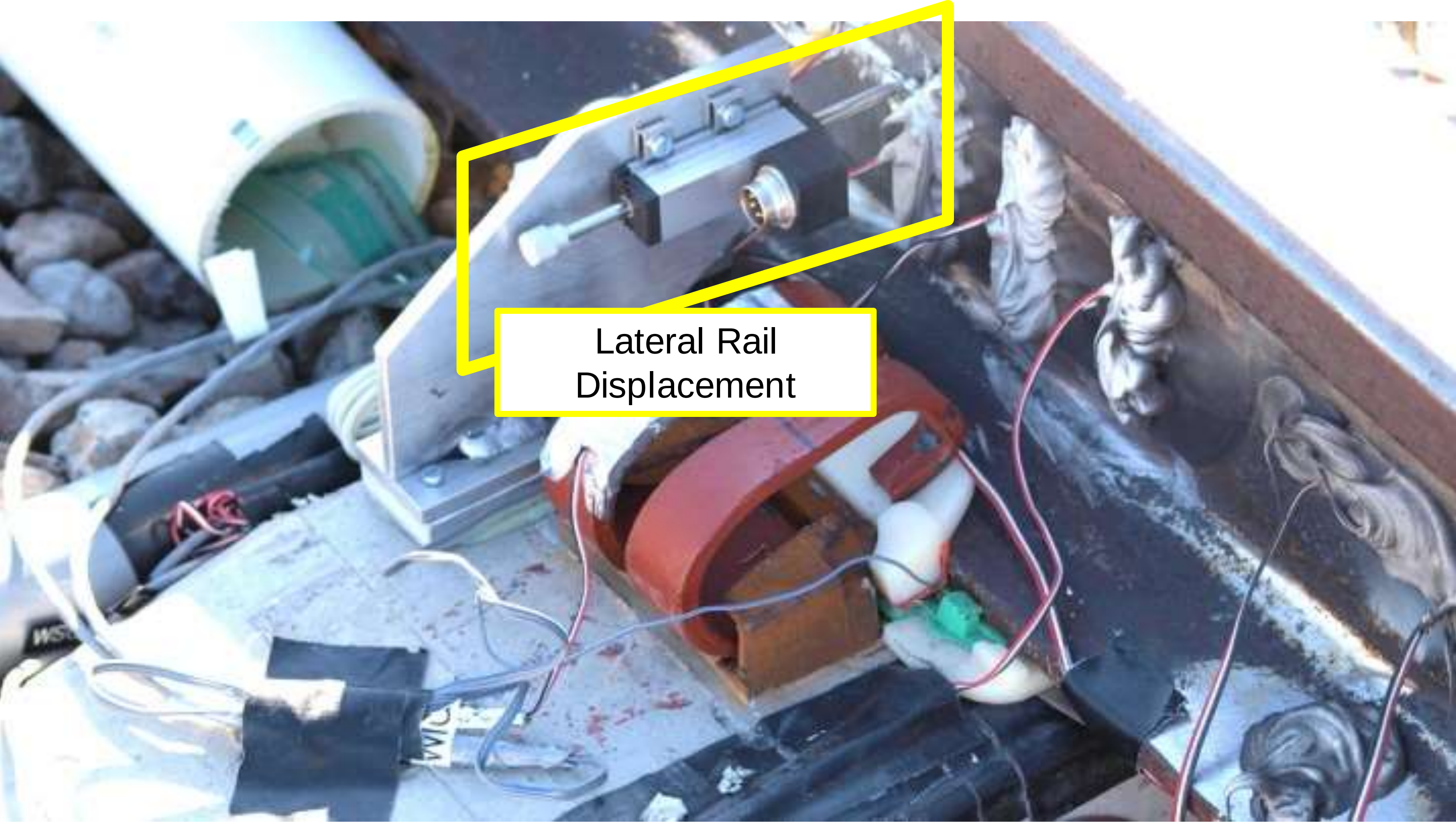


Instrumented Low Rail

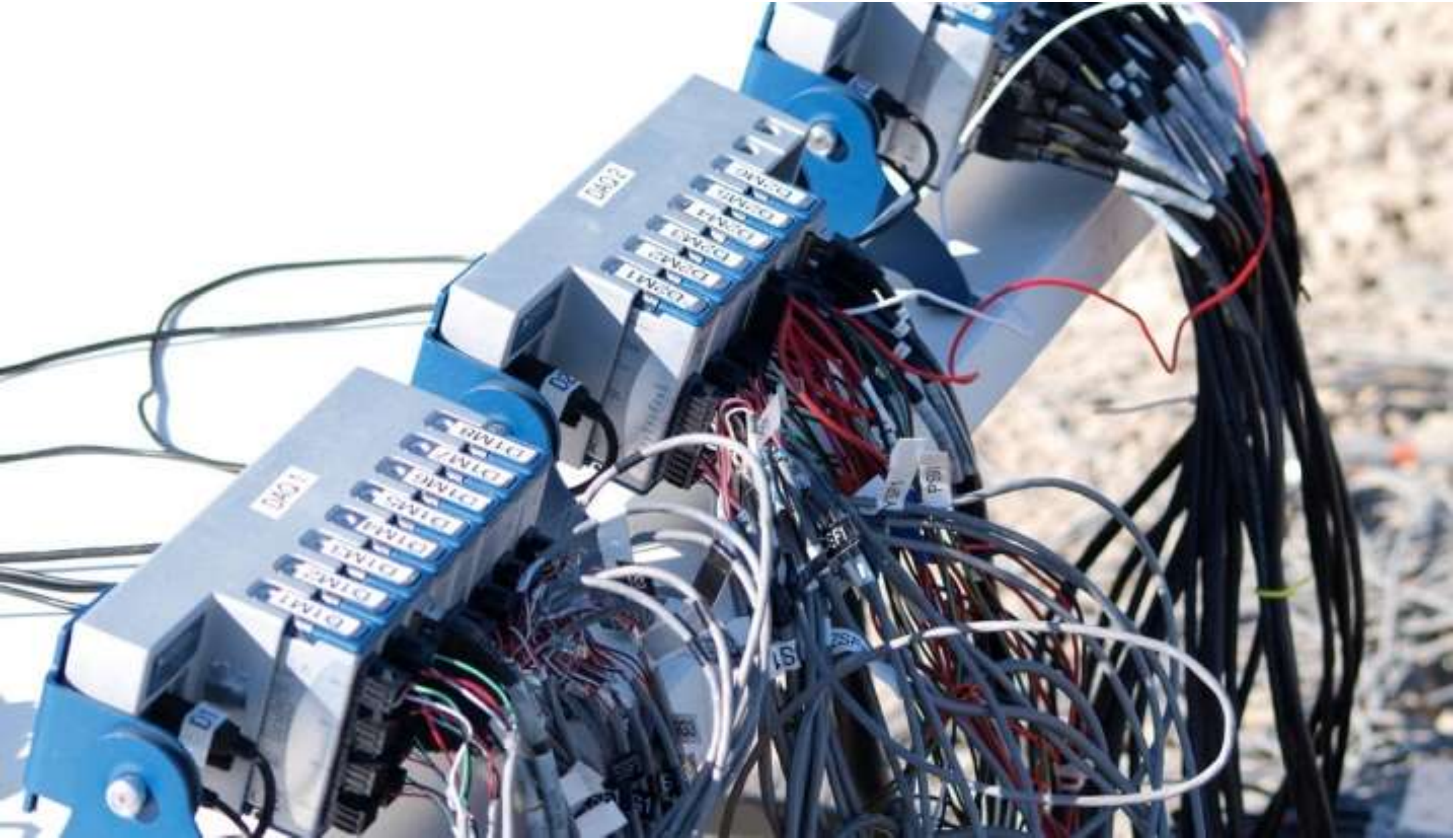
Field-side Instrumentation



Gauge-side Instrumentation

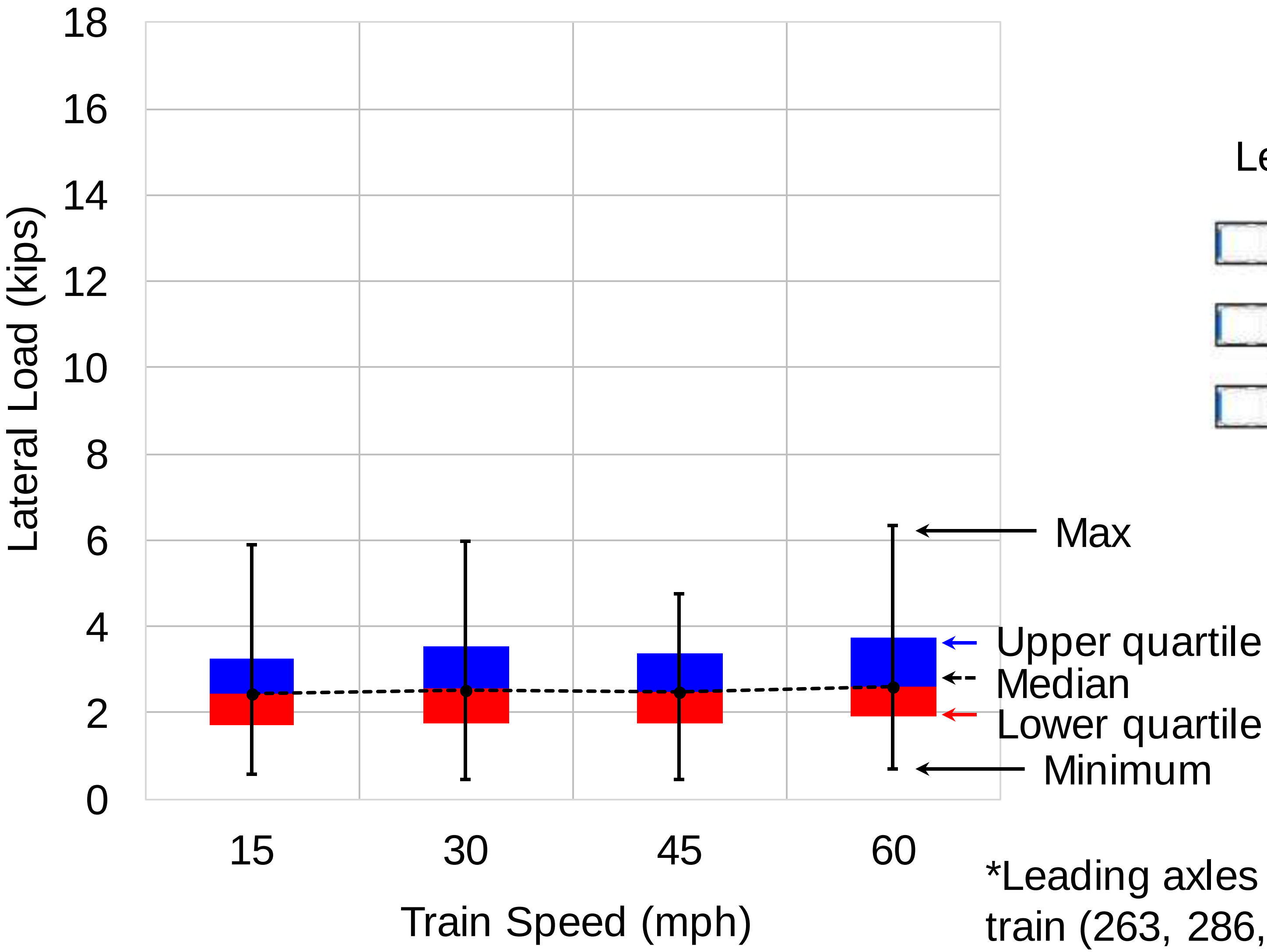


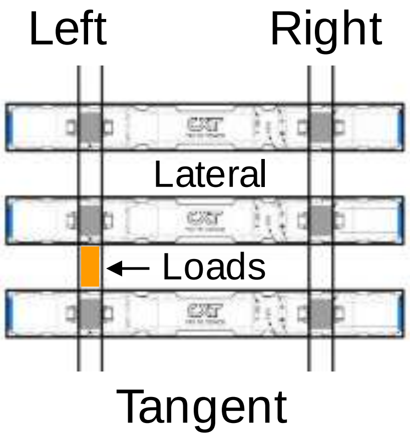
Data Acquisition System



Experimental Results

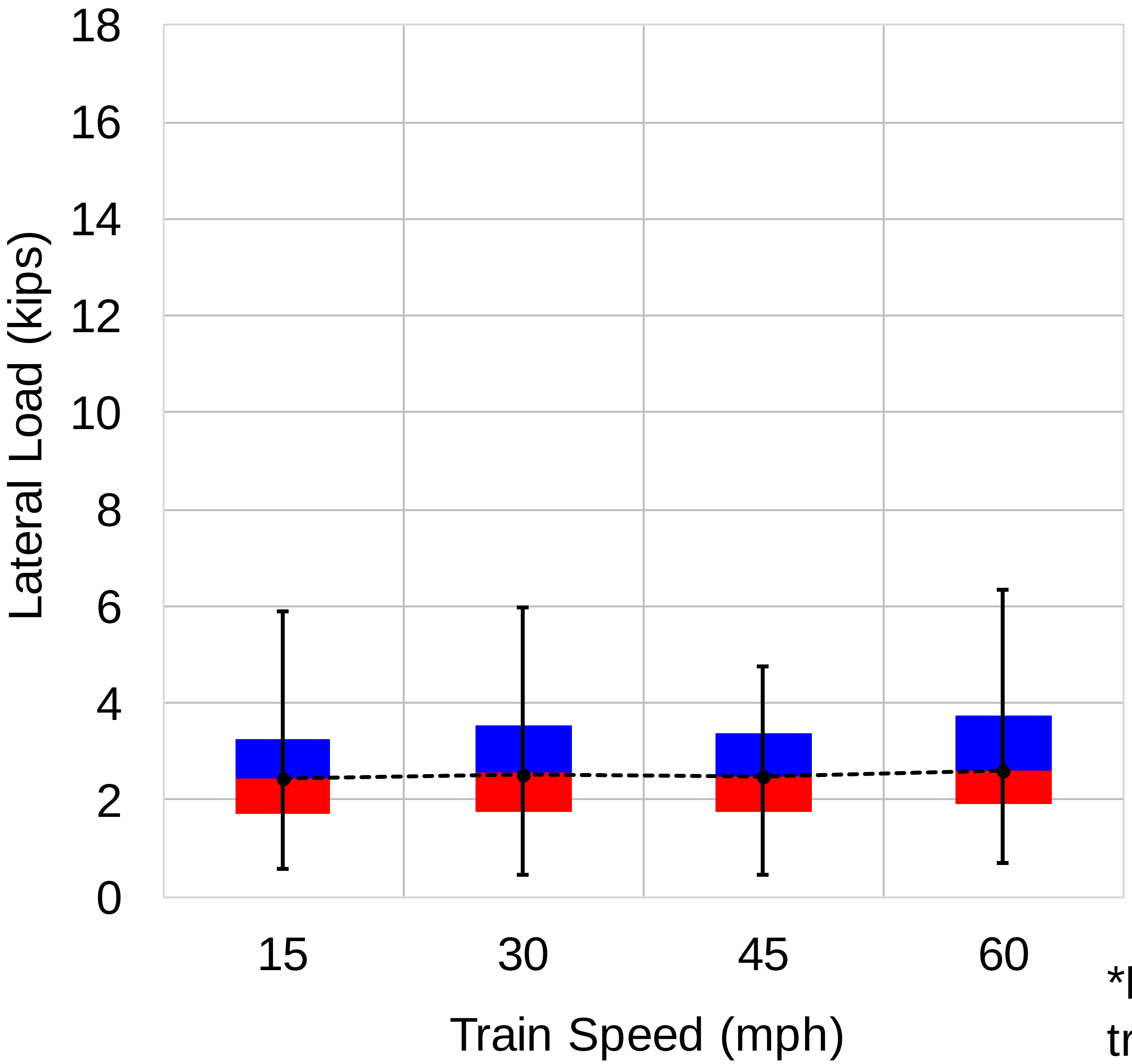
Lateral Loads Acting on Tangent Track

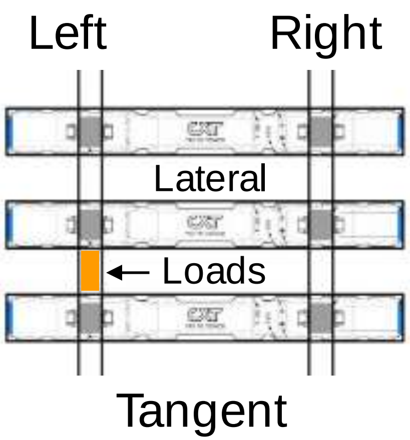




*Leading axles of a 9-car freight train (263, 286, 315 GRL Cars).

Lateral Loads Acting on Tangent Track

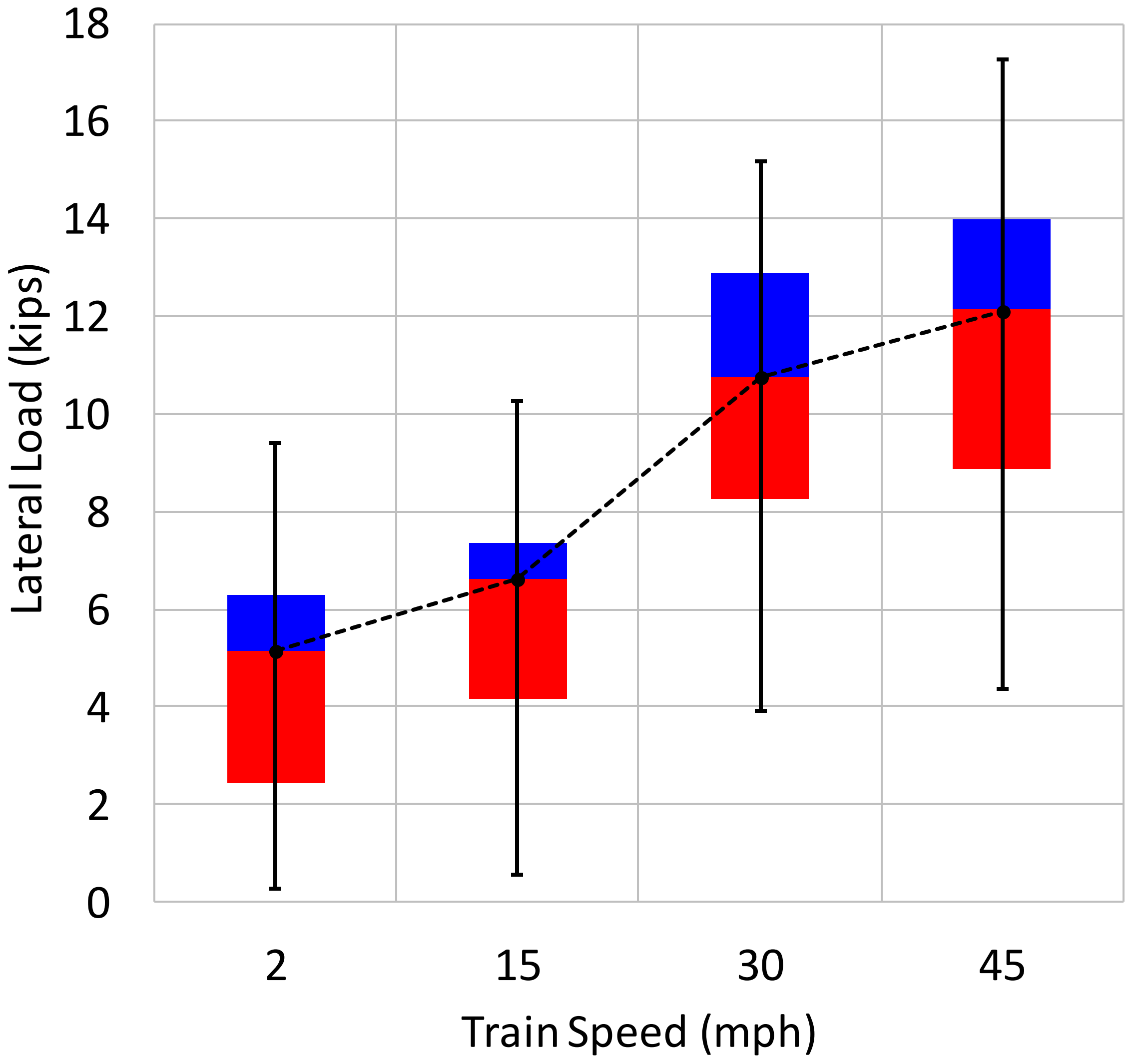


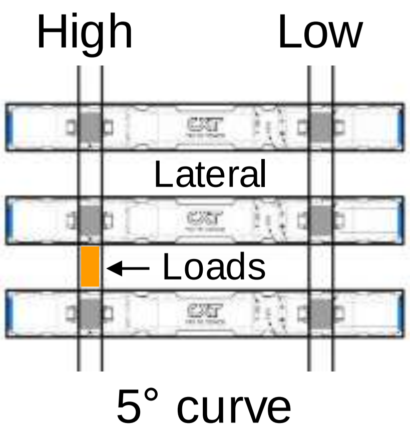


- No correlation between lateral loads and train speed on tangent track.

*Leading axles of a 9-car freight train (263, 286, 315 GRL Cars).

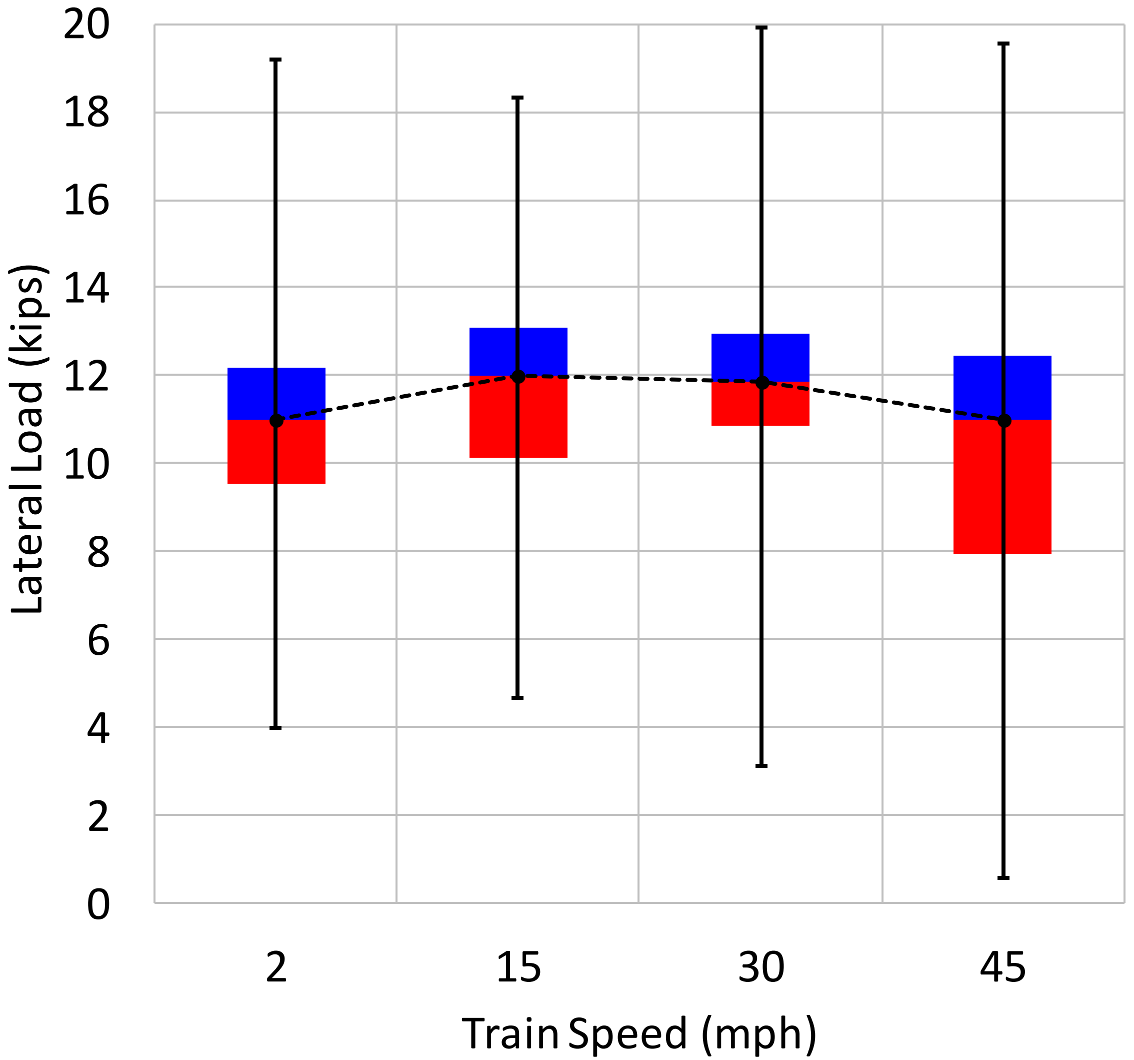
Lateral Loads Acting on Curved Track

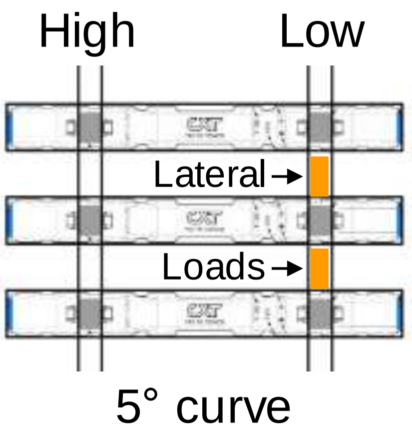




- Median loads can be 4 times larger than loads on tangent track.

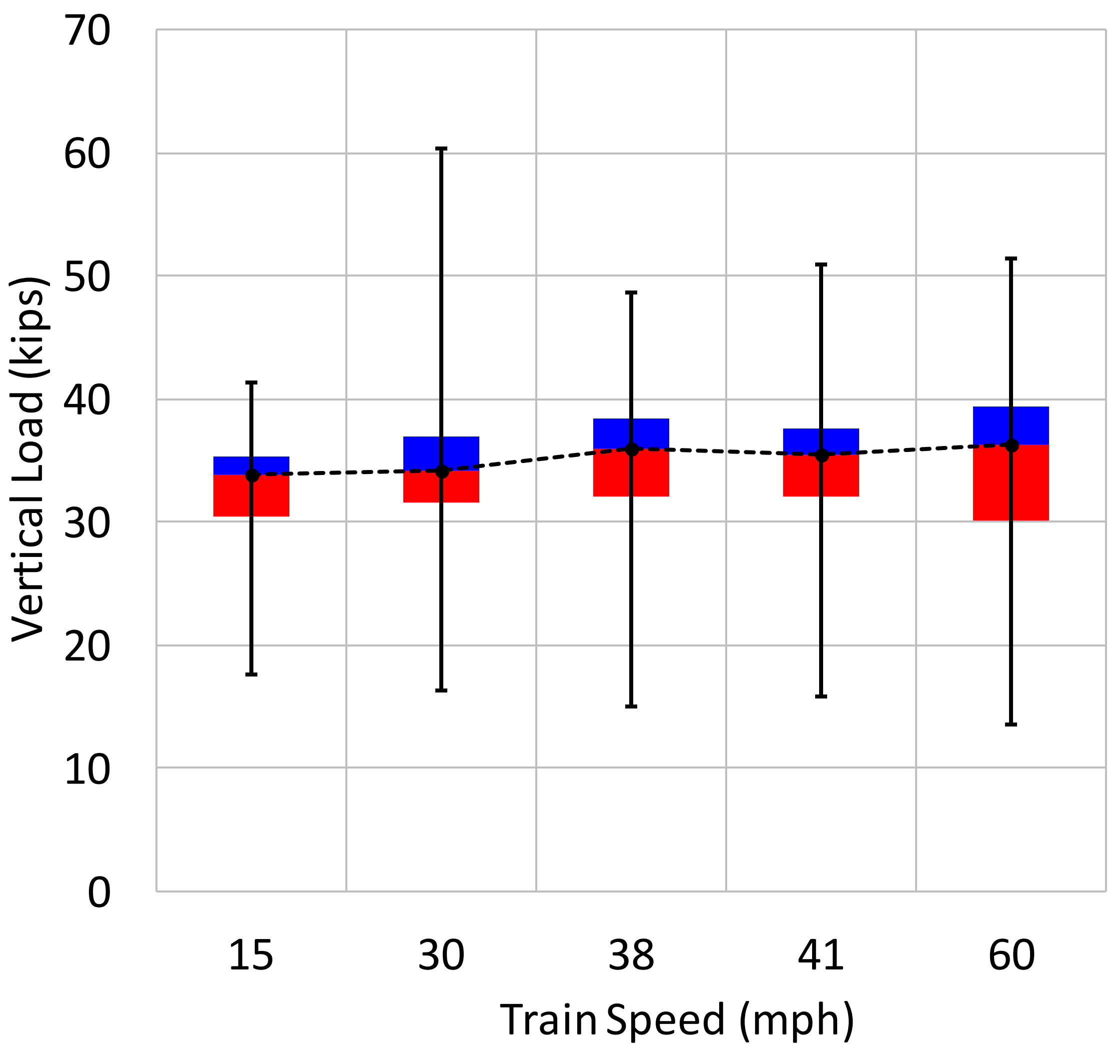
Lateral Loads Acting on Curved Track

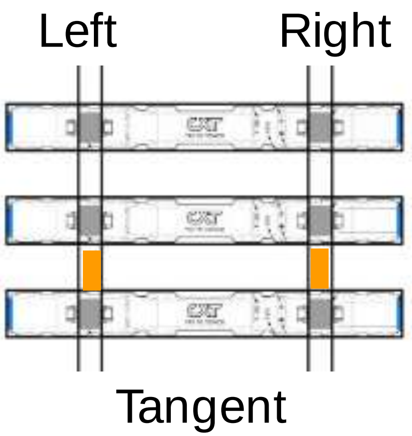




- Highest loading demands
- Twice as high as high rail at low speeds

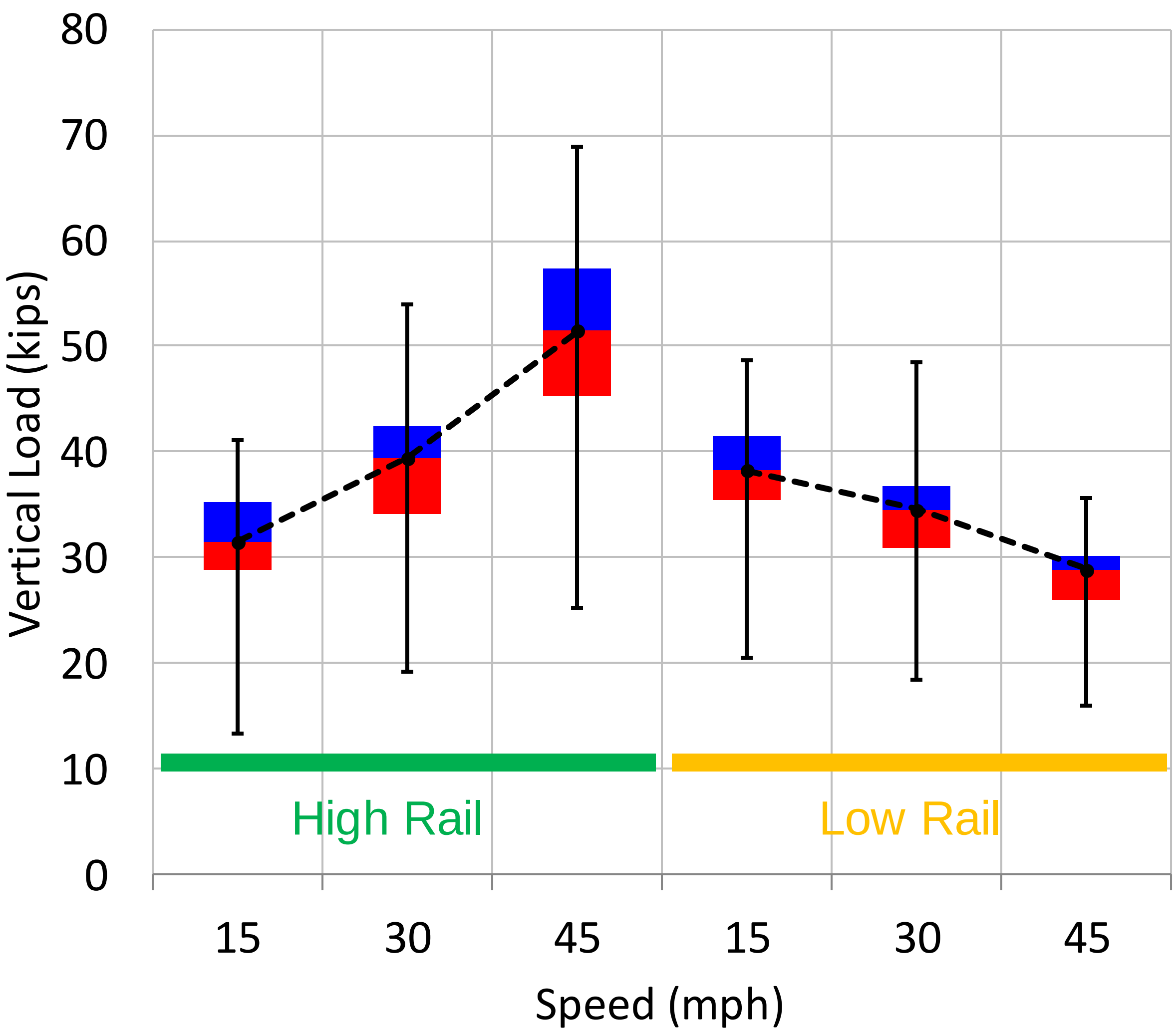
Vertical Loads Acting on Tangent Track

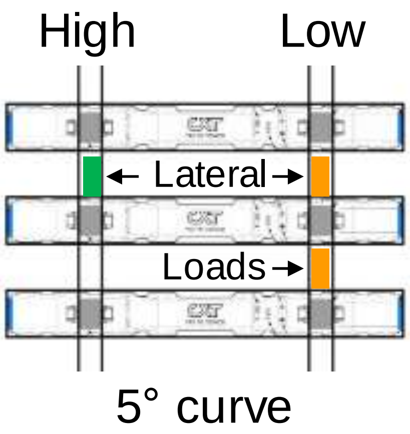




- Negligible correlation between vertical loads and speed on tangent

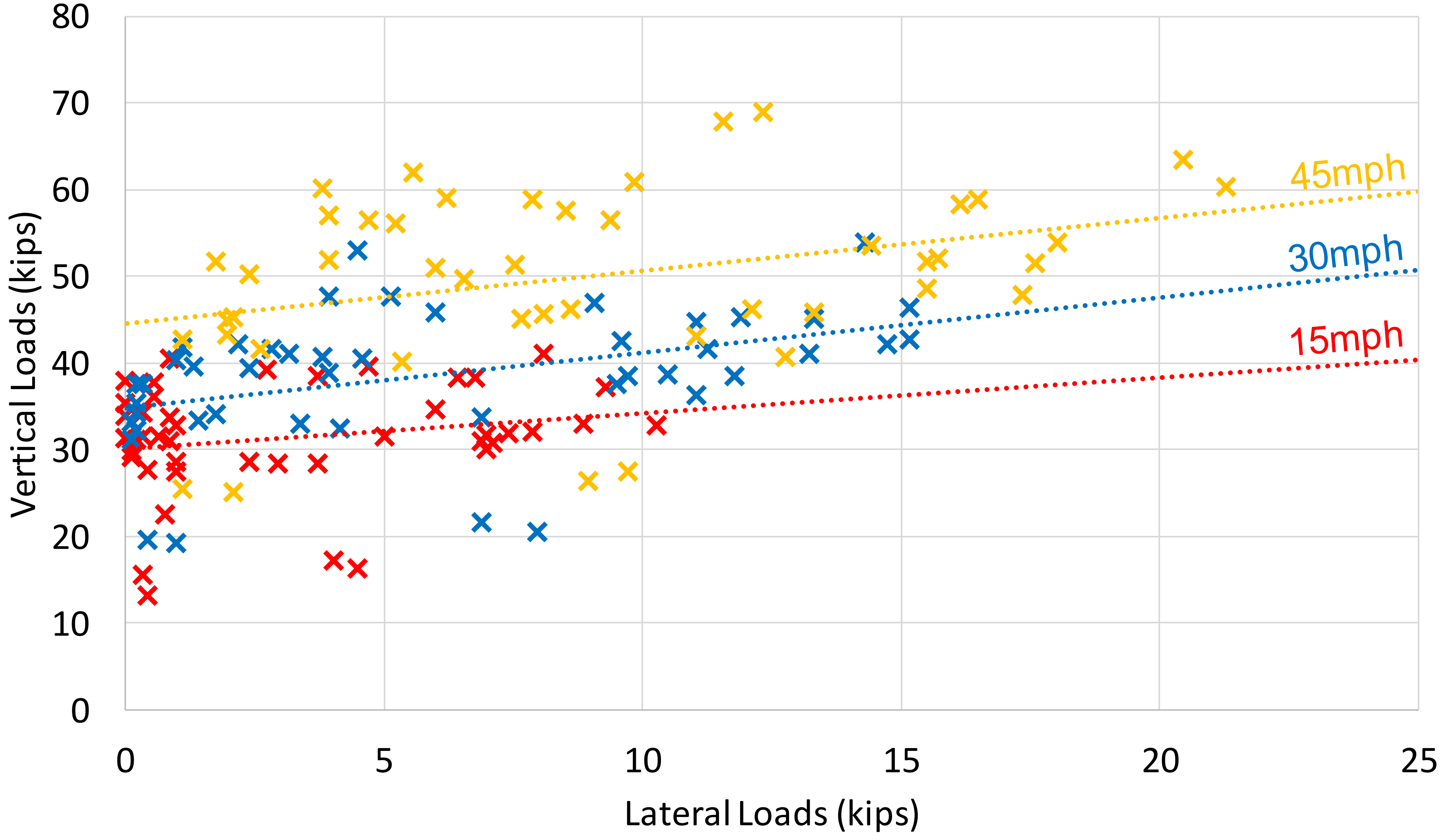
Vertical Loads Acting on Curved Track



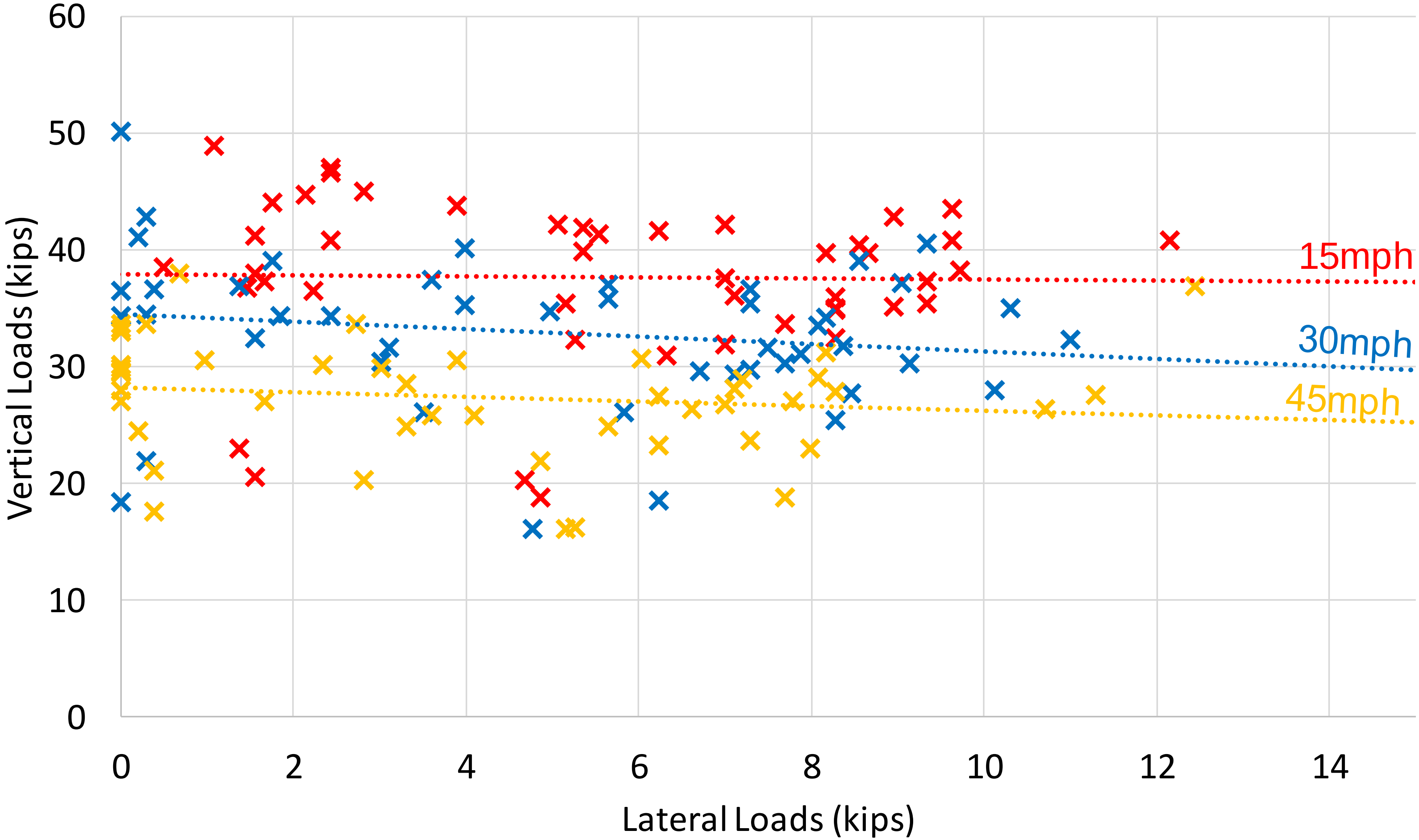


- Highest vertical loading demands on high rail at higher speeds

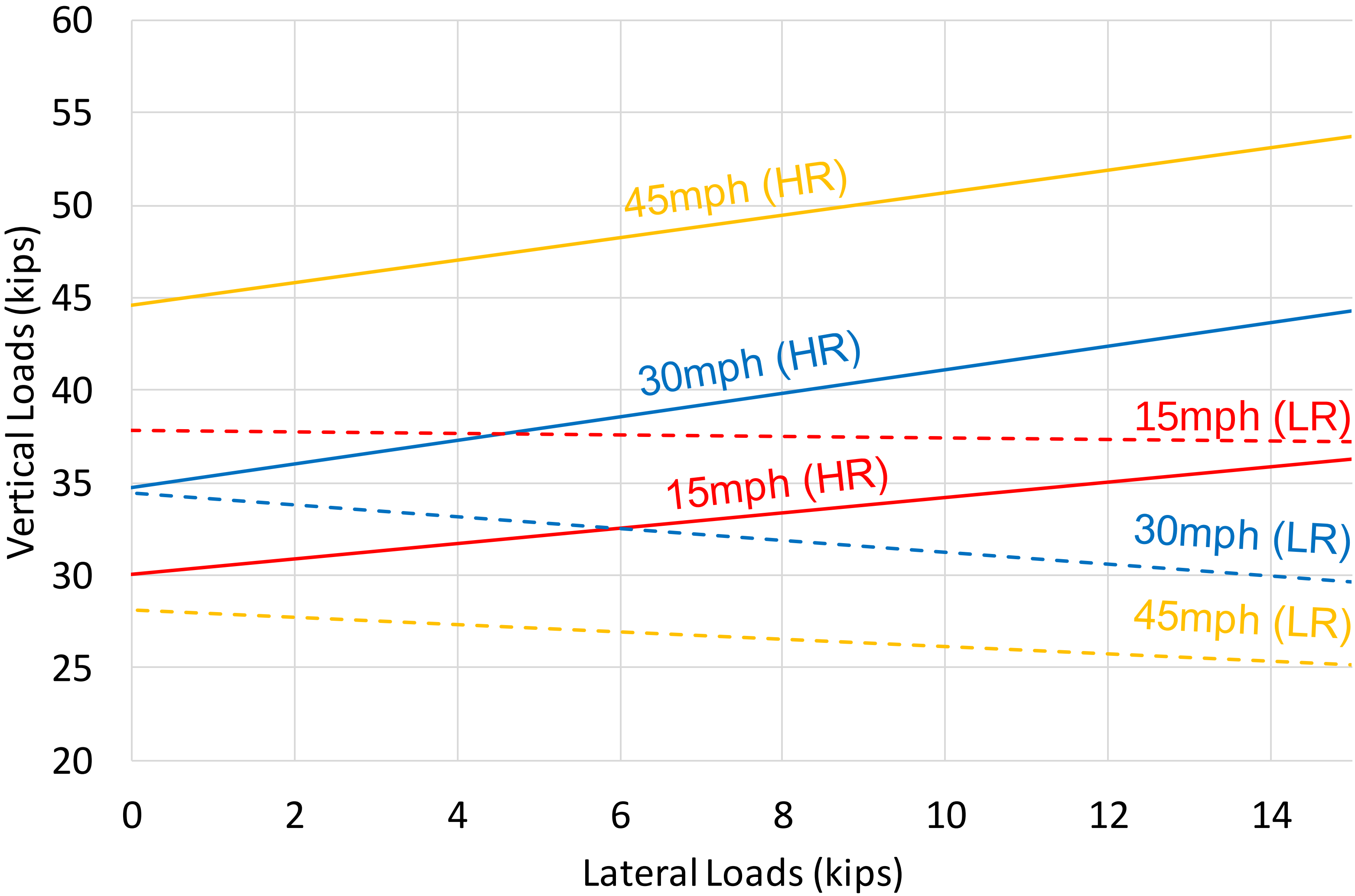
Variability in Loading Conditions (High Rail)



Variability in Loading Conditions (Low Rail)

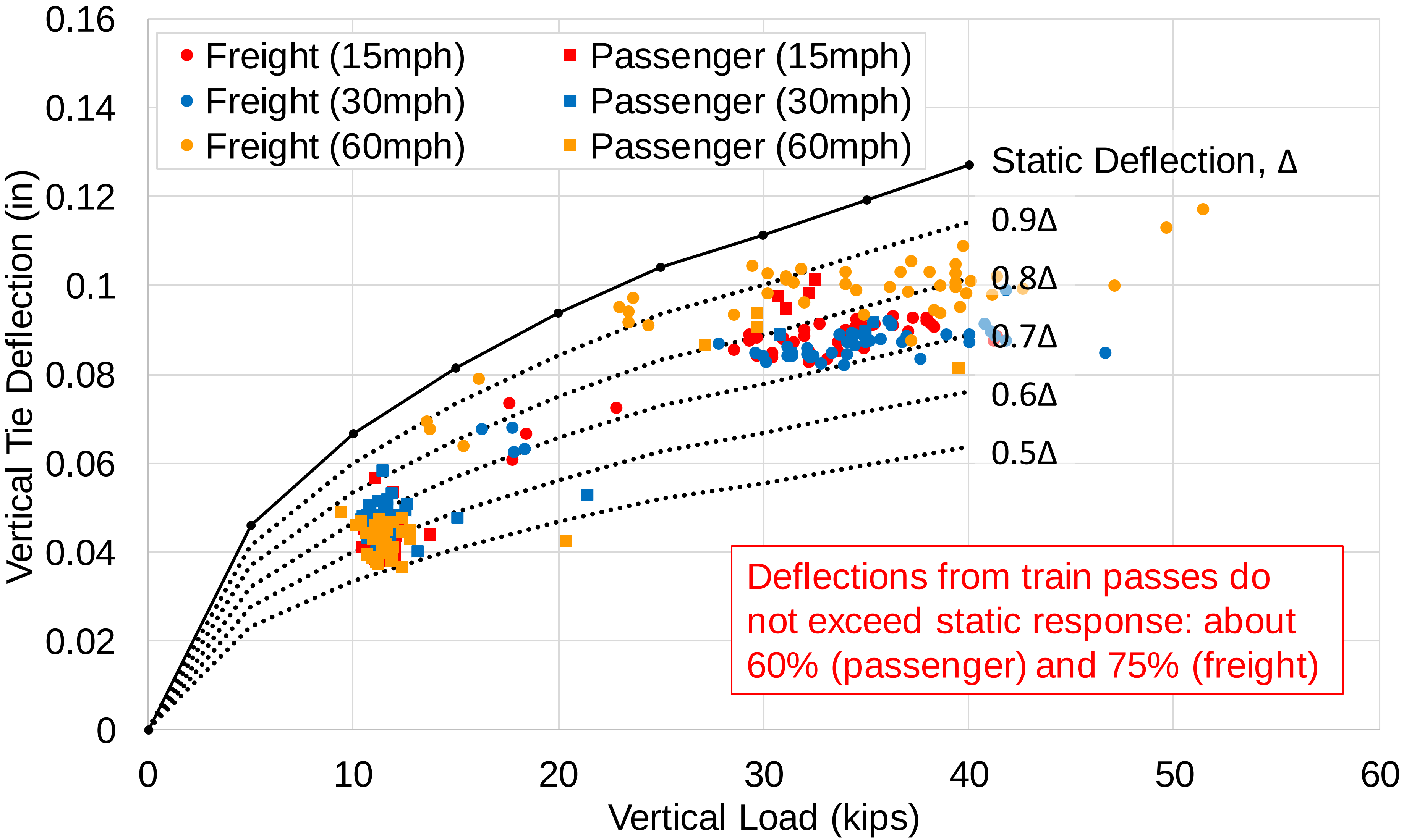


Variability in Loading Conditions

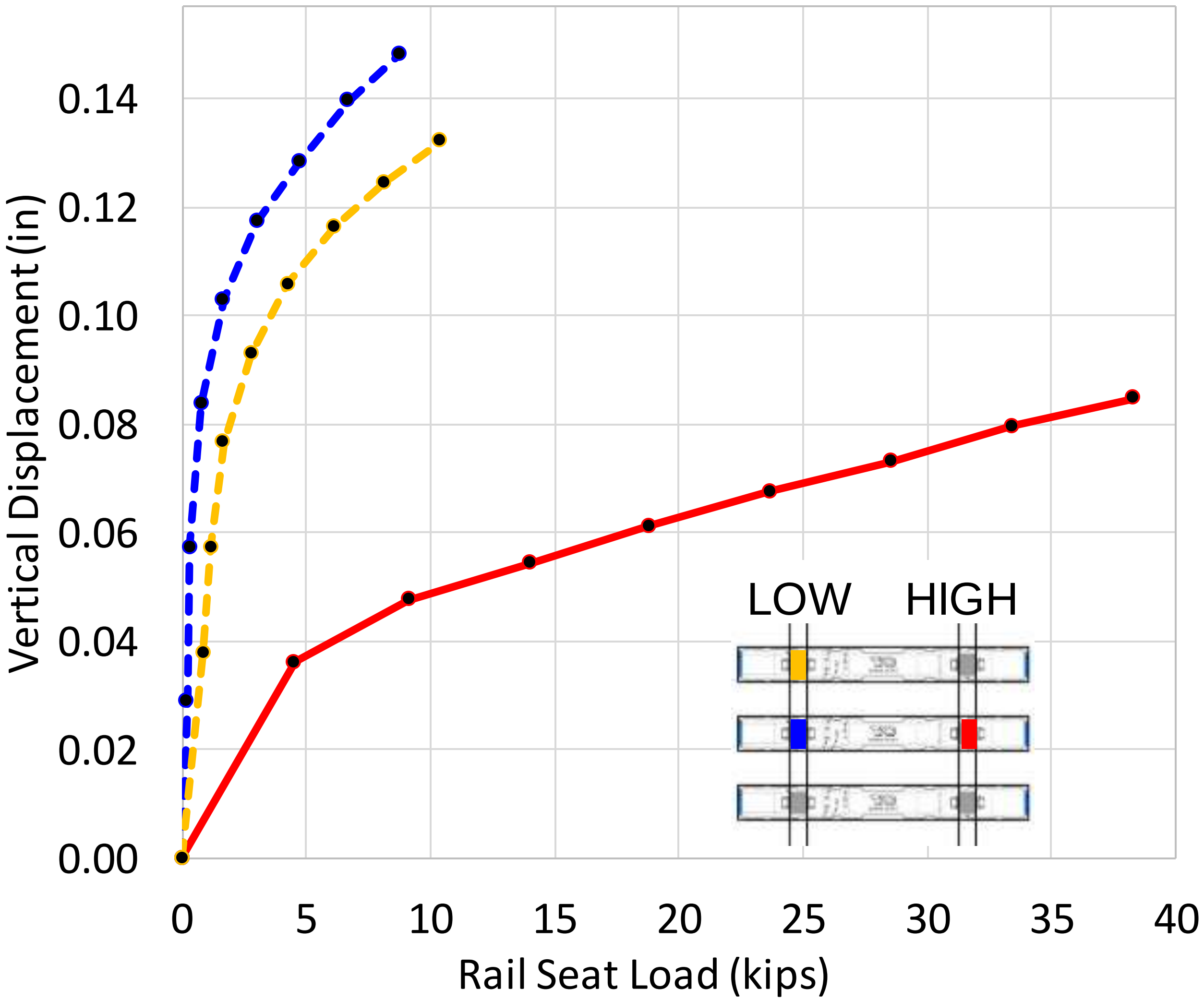


*HR = High Rail; LR = Low Rail

Effect of Train Speed on Crosstie Deflection

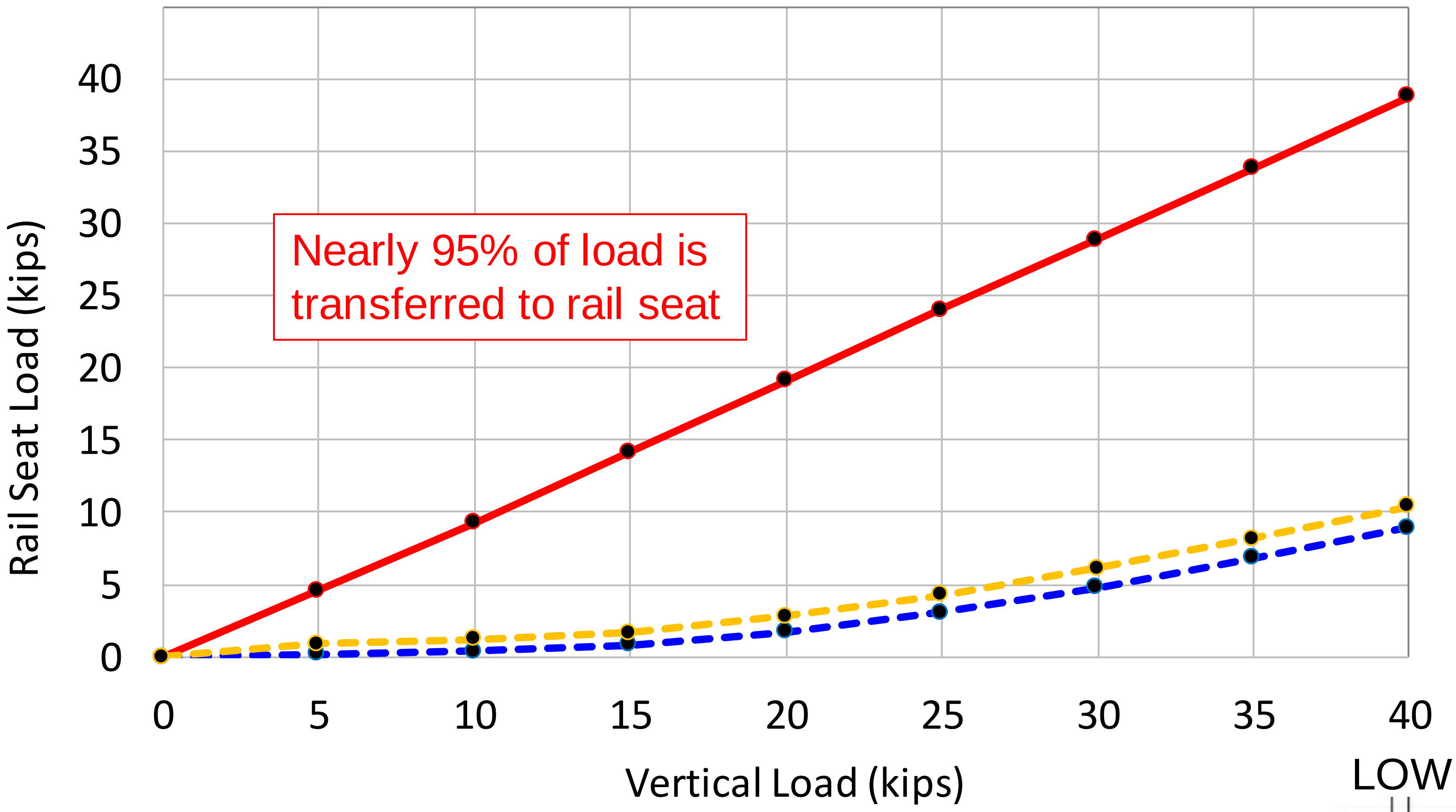


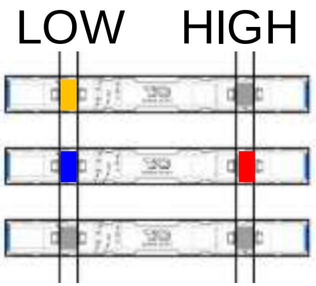
Variability in Support Conditions



- Curve/Static Loads
- Each point = +5kips vertical load
- Max load = 40kips
- Low rail: weak support (slack or gap in support system)
    - Low rail seat forces
- High rail: stiff boundary conditions (well-supported)
    - High rail seat forces

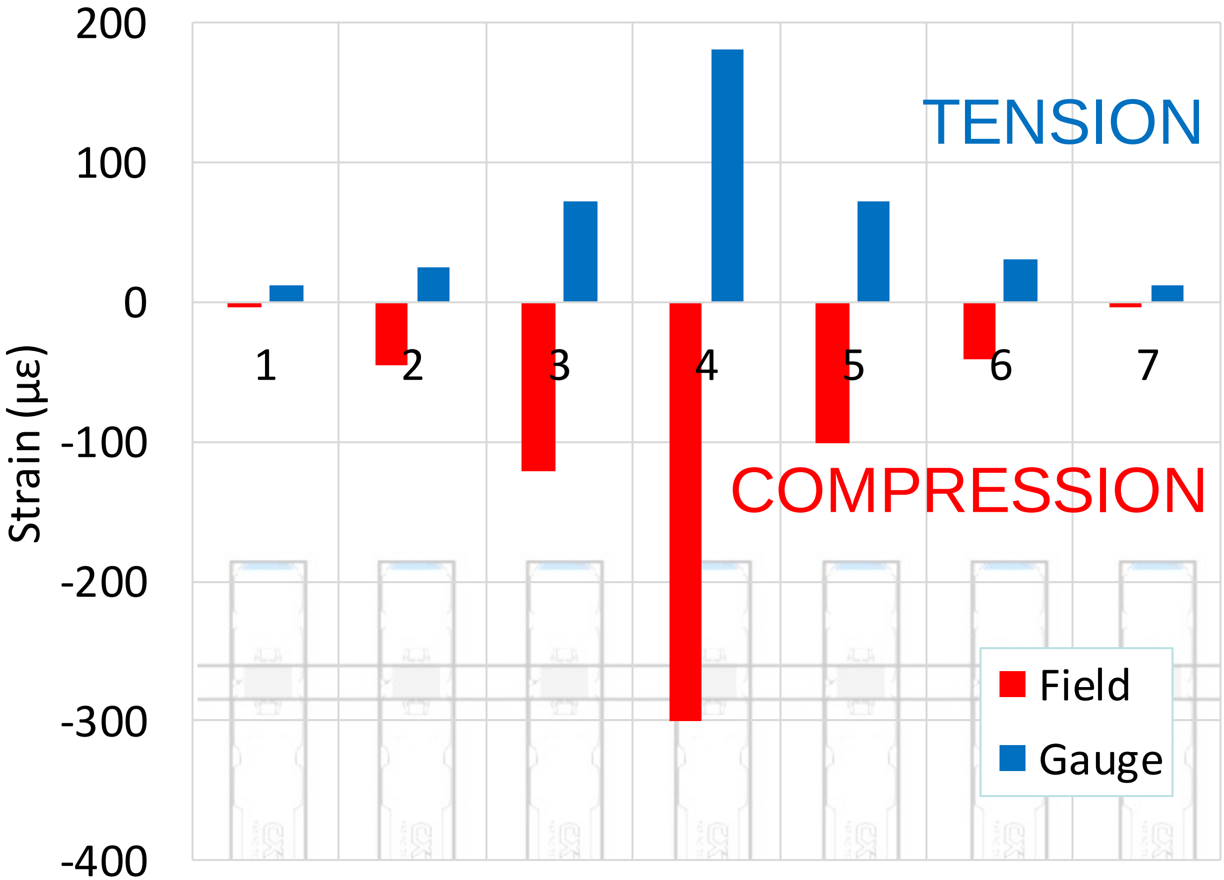
Variability in Support Conditions

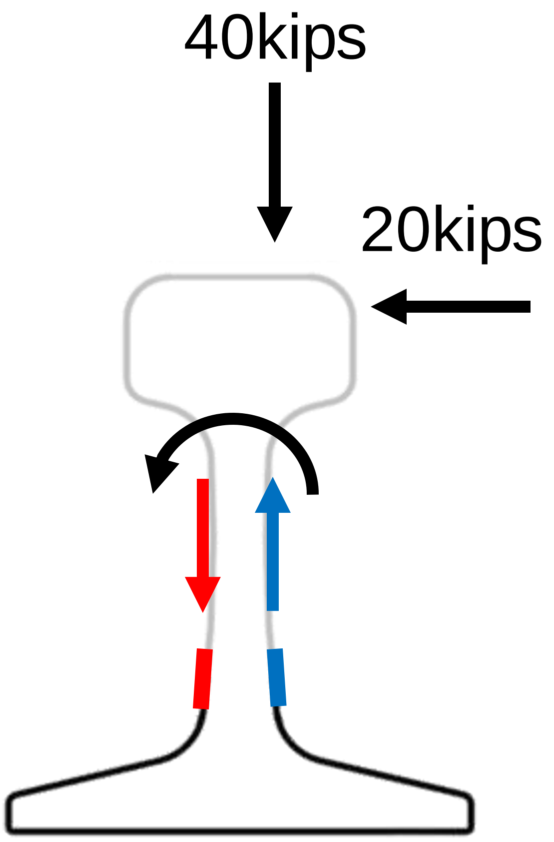




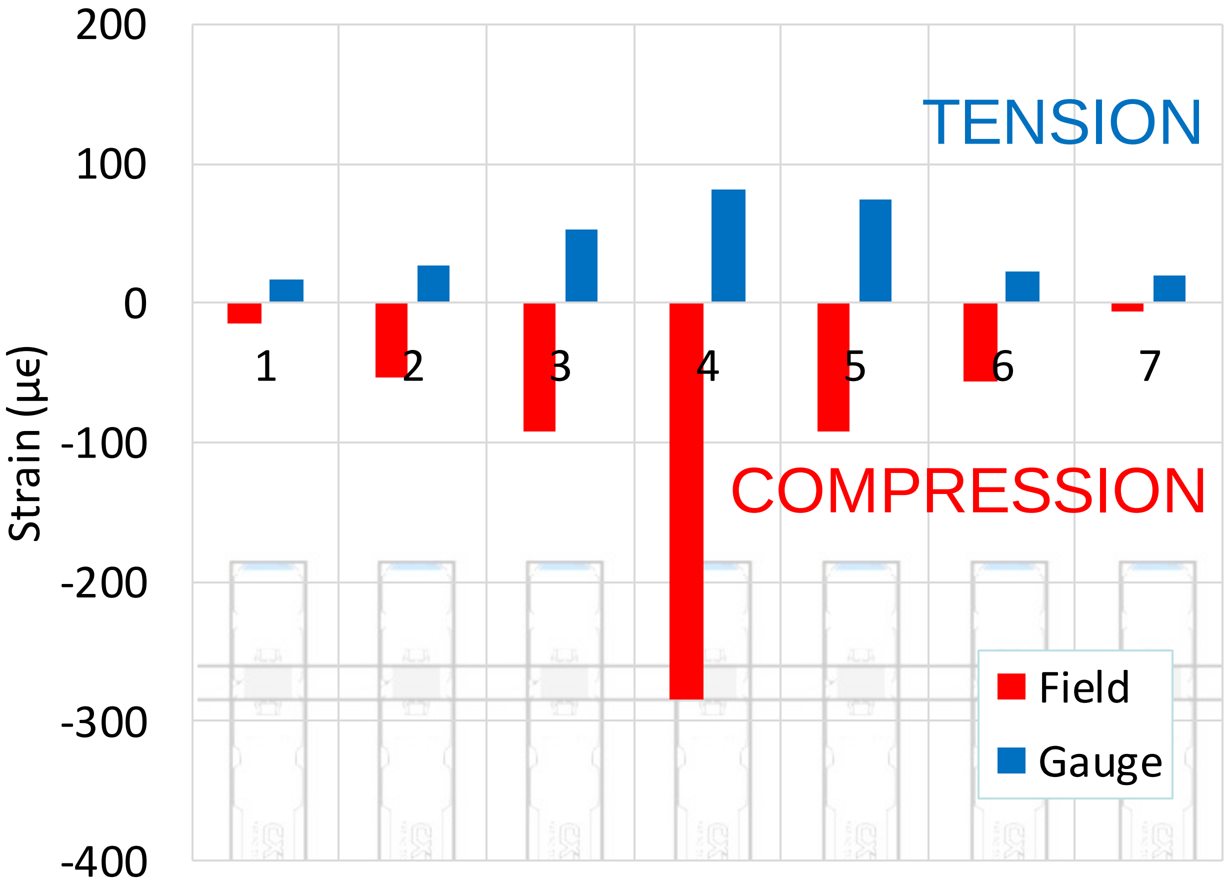
With a weak substructure much of the vertical load (over 75%) is transferred to adjacent crossties and resisted by the bending of the rail

Vertical Strain Distribution, High Rail



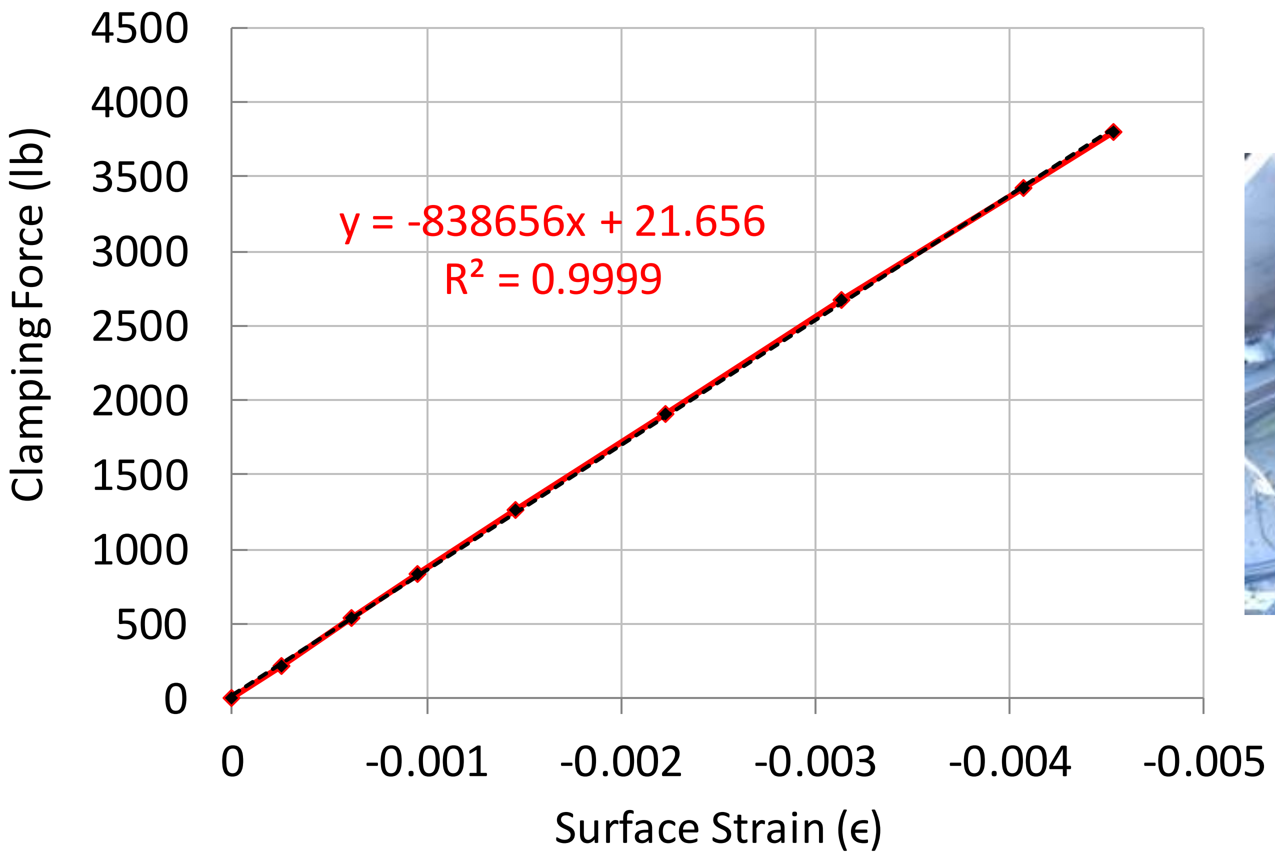


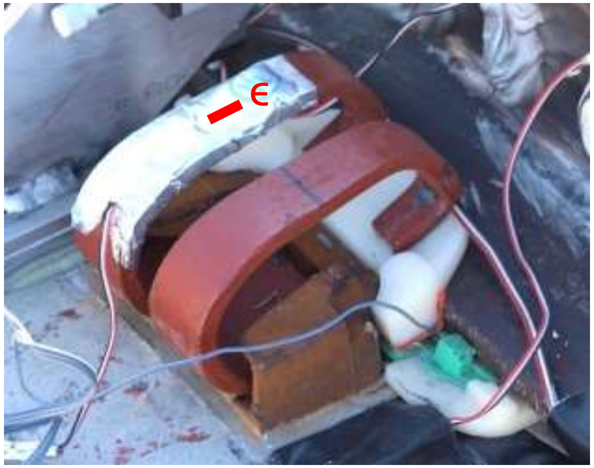
Vertical Strain Distribution, Low Rail



TLV (load on center tie)
- 40kips vertical
- 20kips lateral

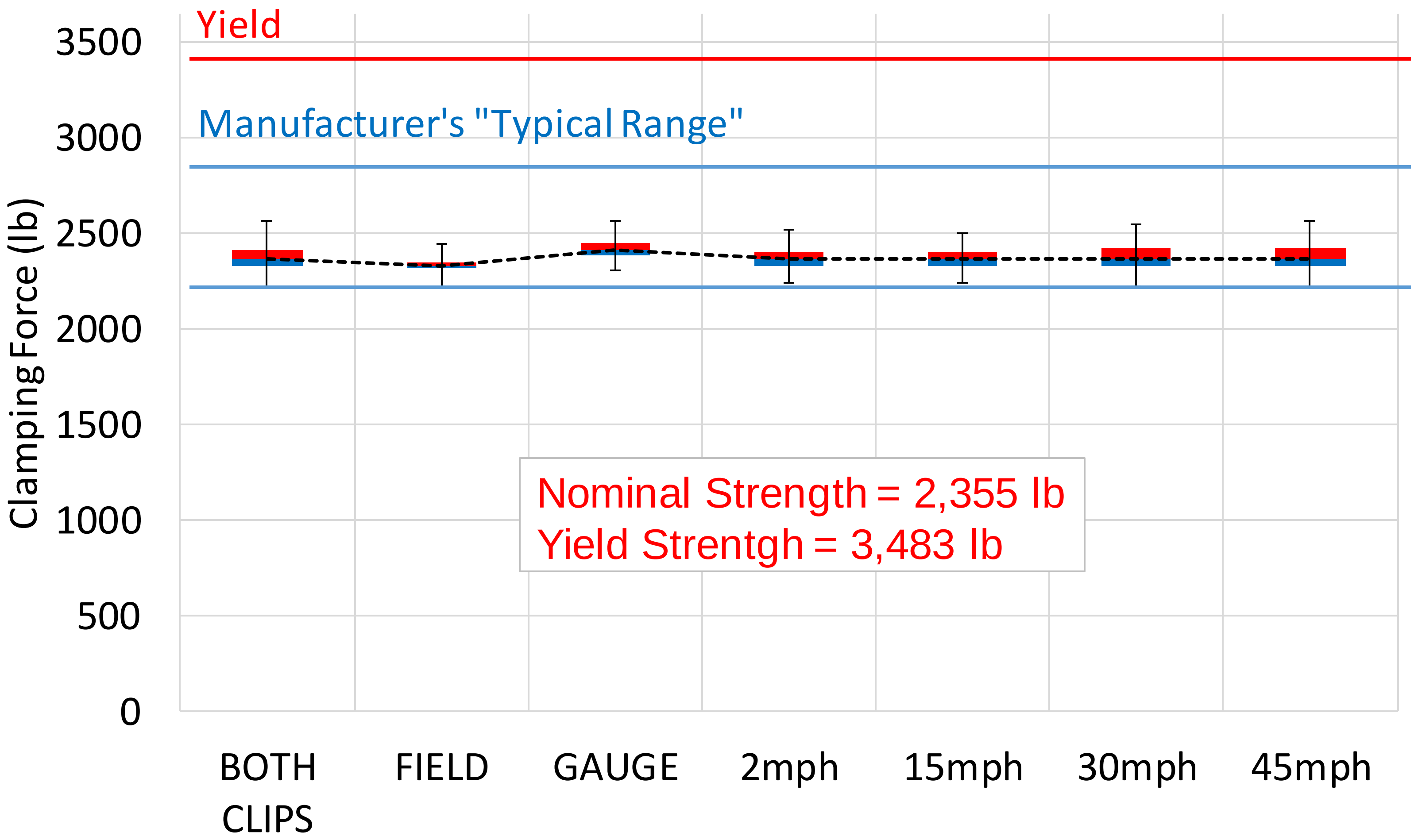
Single Clip Behavior



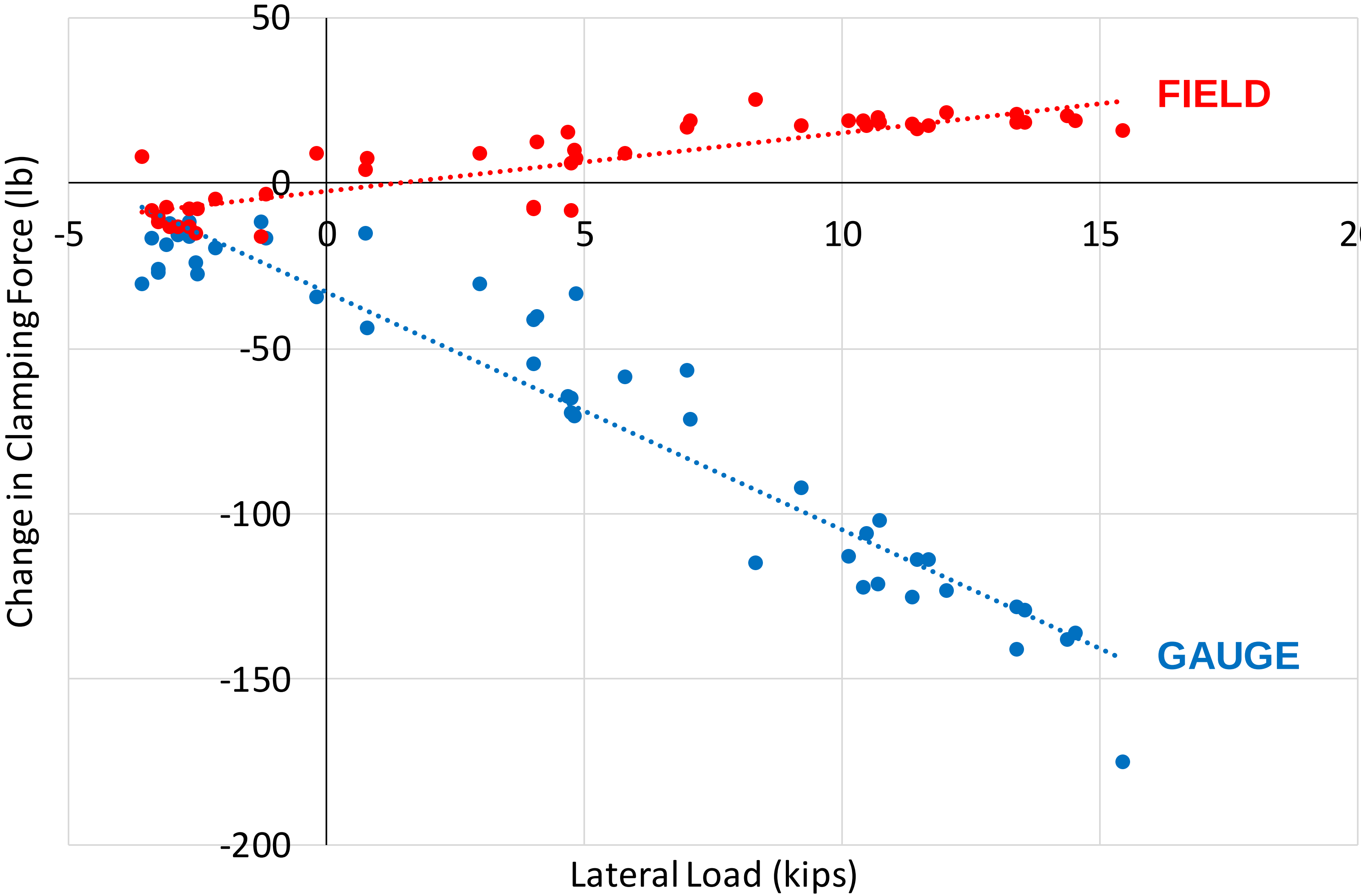


Courtesy of George Chen (UIUC)

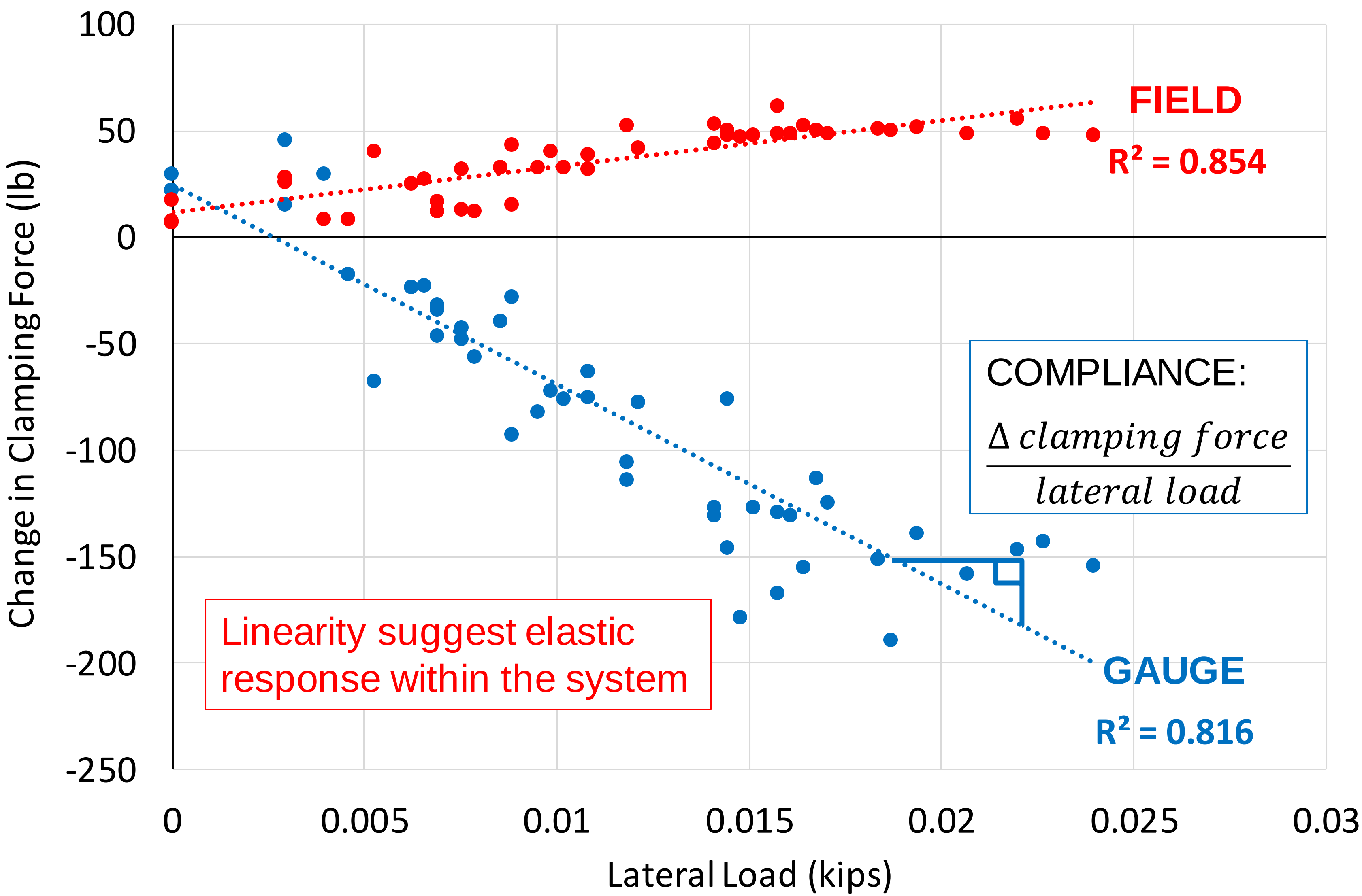
Clamping Force Distribution (Curve)



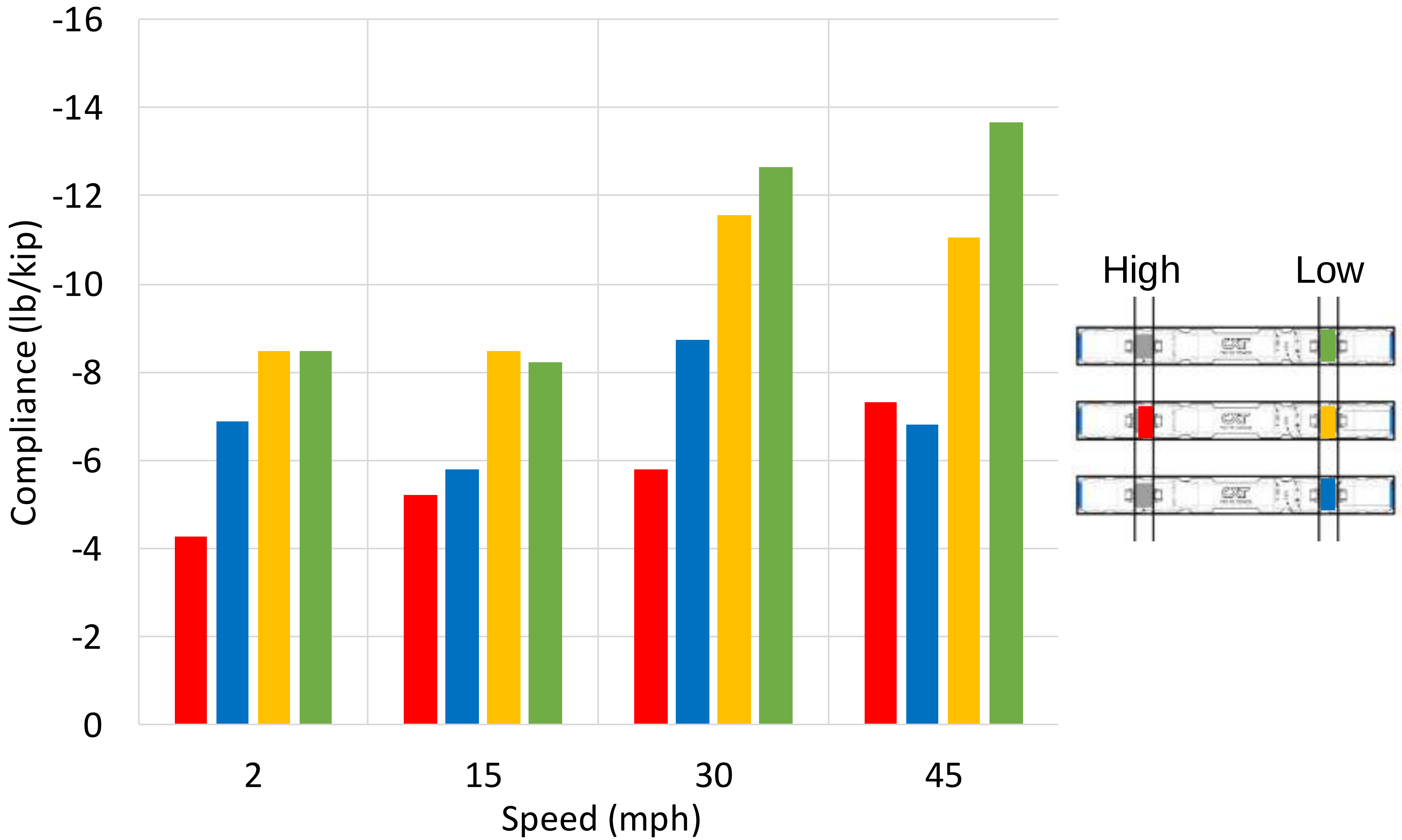
Change of Clamping Force on High Rail



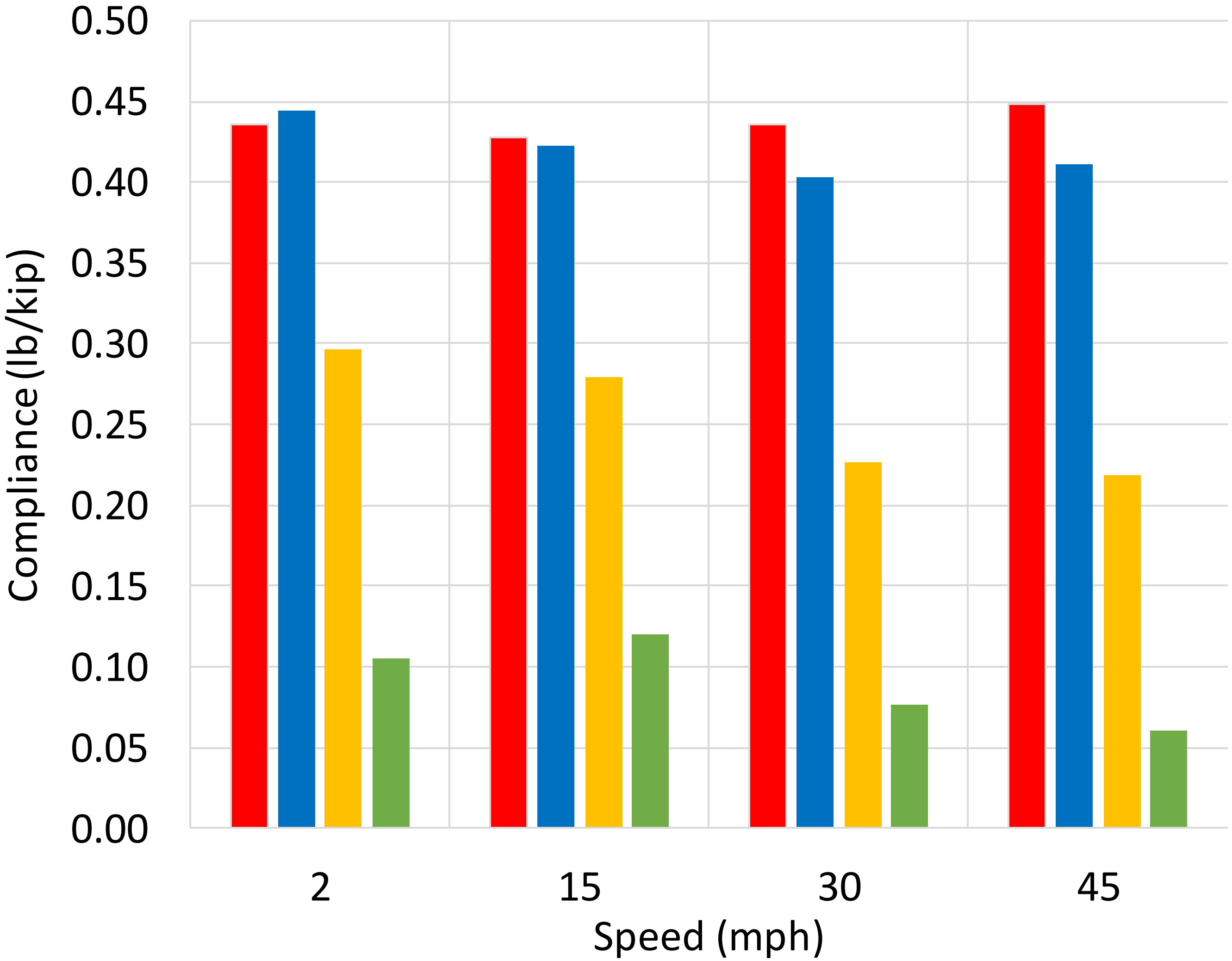
Change in Clamping Force on Low Rail



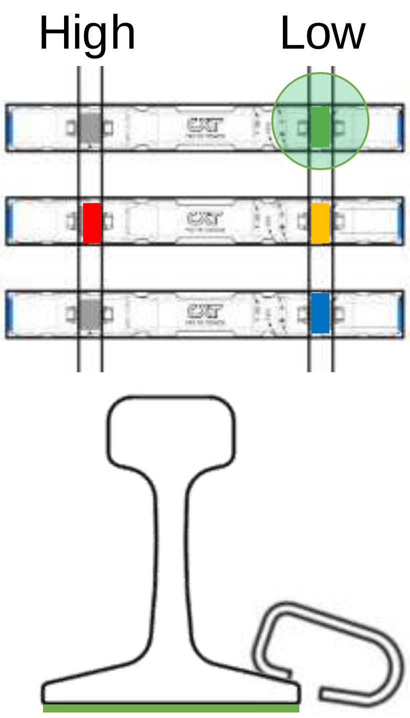
Compliance of Gauge-Side Clips



Compliance of Field-Side Clips



MBTSS =
Frictionless Layer



Findings with Potential Design Considerations

- Lateral loading demands were measured 3-6 times as high on curved track than on tangent track, on average
  - Design should consider specialized components in the curve
- Vertical and lateral loading demands show positive correlation on high rail, slight negative correlation on low rail, and no correlation on tangent track
- Vertical loading demands were highest at higher speeds on high rail
- Rail seat forces are highly dependent on the stiffness of the substructure and support conditions and range from 20% to 90% of the wheel-rail load
  - Design should incorporate probabilistic loading conditions
- Measured static loads had a distributed response over about 5-7 crossties
- The observed clip response within the system was relatively elastic and well below the point of yield
- Clip compliance is relatively consistent per rail seat over different speeds
  - Design could consider clip as linear elastic spring for simplification

Future Work

- Continued **data analysis** to understand the governing mechanics of the system by investigating the:
  - factors that determine load distribution
  - bending moments of the crossties
  - pressure magnitude and distribution at the rail seat
- Continued **comparison and validation** of the UIUC finite element model
- Preparation for **instrumentation trip** (Summer 2013)
  - Focus on lateral load path by gathering
    - relative lateral crosstie displacements
    - longitudinal stresses and displacements of the rail
    - load transferred to the clamp, insulator-post, and shoulder
- Small-scale, **evaluative tests** on Class I Railroads

Acknowledgements

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Federal Railroad Administration

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  - BNSF Railway
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  - Hanson Professional Services, Inc.
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FRA Tie and Fastener BAA Industry Partners:

Questions?

Justin Grassé
Department of Civil and Environmental Engineering
University of Illinois, Urbana-Champaign
Email: jgrasse2@illinois.edu