Testing of Concrete Sleepers and Fastener Systems for the Understanding of Mechanistic Behavior

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U.S. Department of Transportation

Federal Railroad Administration

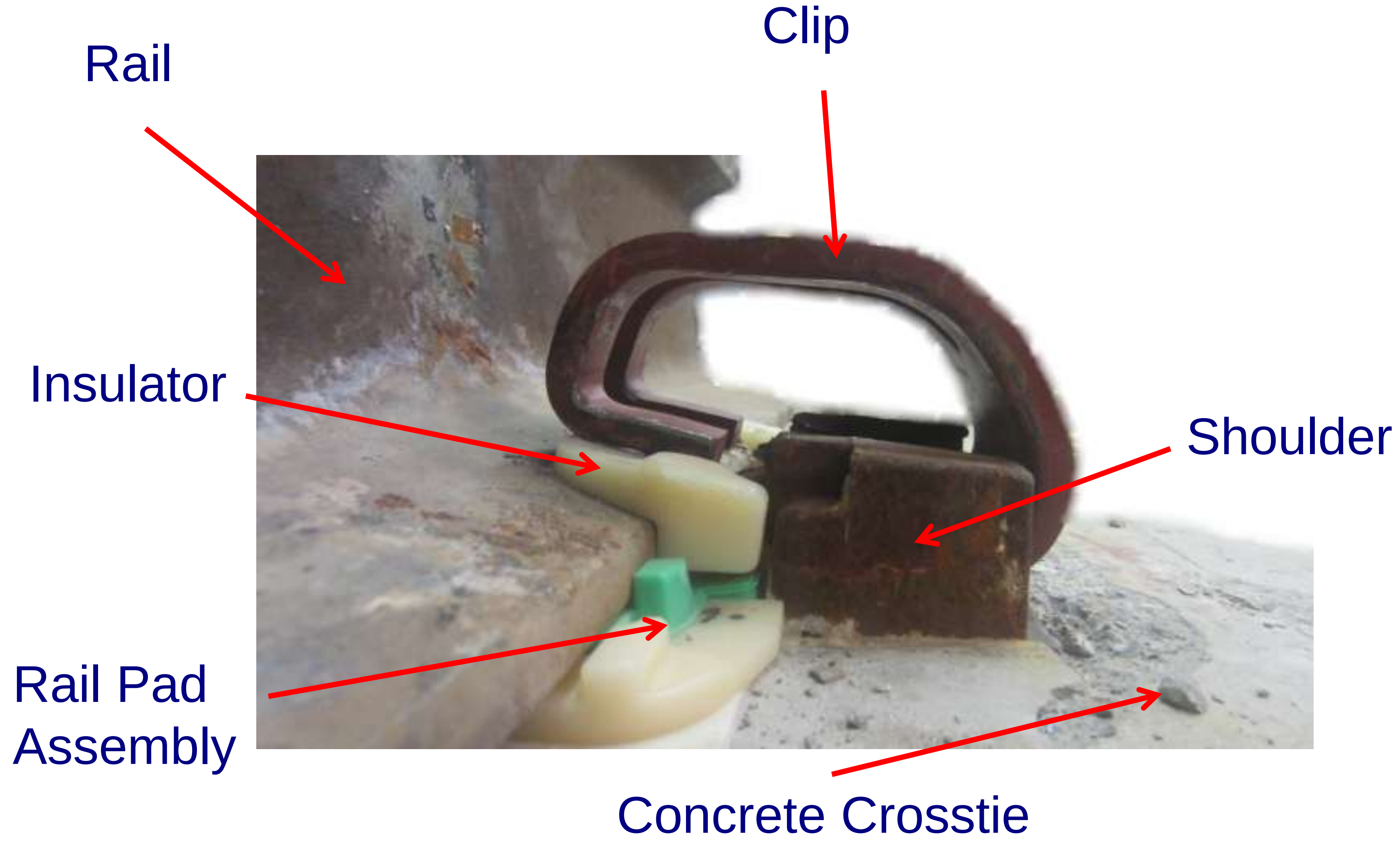
RAILTEC

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Background
- UIUC Concrete Sleeper Research Overview
- Objectives of Field Research
- Field Instrumentation Strategy
- Testing at Transportation Technology Center (TTC)
  - Pueblo, CO, USA
- Experimental Results
- Findings
- Future Work

Fastening System Components



2012 International Survey Results

Criticality of Problems – North American Responses

Failure Mode	Average Rank
Deterioration of concrete material beneath the rail	6.43
Shoulder/fastening system wear or fatigue	6.38
Cracking from dynamic loads	4.83
Derailment damage	4.57
Cracking from center binding	4.50
Tamping damage	4.14
Other (e.g. manufactured defect)	3.57
Cracking from environmental/chemical degradation	3.50

Research Topic	Average Rank
Prevention or repair of rail seat deterioration	3.60
Fastening system design	3.60
Materials design	3.00
Optimize crosstie design	2.80
Track system design	2.00

Research Levels (and Examples)

Materials

Concrete Mix Design

Rail Seat Surface Treatments

Pad / Insulator Materials

Components

Fastener Yield Stress

Insulator Post Compression

Concrete Prestress Design

System

Finite Element Modeling

Full-Scale Laboratory Experimentation

Field Experimentation

Research Sponsors and Projects

- CN Fellowship in Rail Engineering (RSD)
- Association of American Railroads (AAR) Technology Scanning Program (RSD and Fastening System Wear and Fatigue)
- Amsted RPS / Amsted Rail, Inc. (Fastening System Wear and Fatigue)
- NEXTRANS Region 5 Transportation Center (RSD)
- Federal Railroad Administration (FRA) (Fastening System Wear and Fatigue, Cracking, Environmental, etc.)
- National University Rail (NURail) (Fastening System Wear and Fatigue)

CN

ASSOCIATION OF AMERICAN RAILROADS

Amsted RPS

Amsted Rail

Nextrans

National University Rail Center

U.S. Department of Transportation

Federal Railroad Administration

FRA Tie and Fastener Project Structure

Inputs

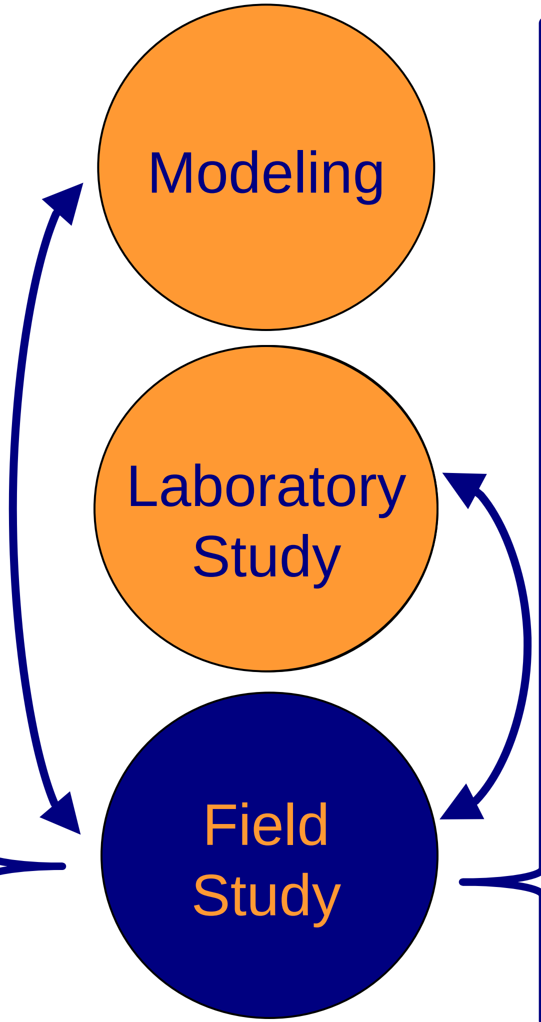
Comprehensive Literature Review

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

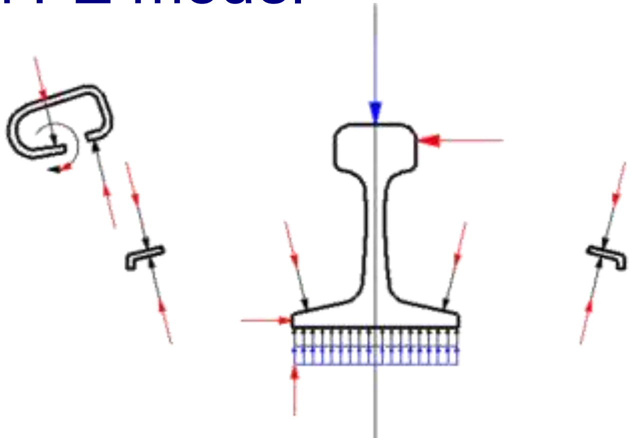
State of Practice Report

Validated Tie and Fastening System Model

Improved Recommended Practices

Goals of Field Instrumentation

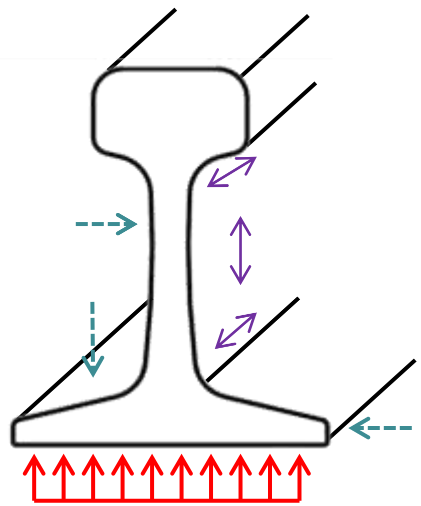
- Lay groundwork for mechanistic design of concrete sleepers and elastic fasteners
- Quantify the demands placed on each component within the system
- Develop an understanding into field loading conditions
- Provide insight for future field testing
- Collect data to validate the UIUC concrete sleeper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



Areas of Investigation

Rail

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

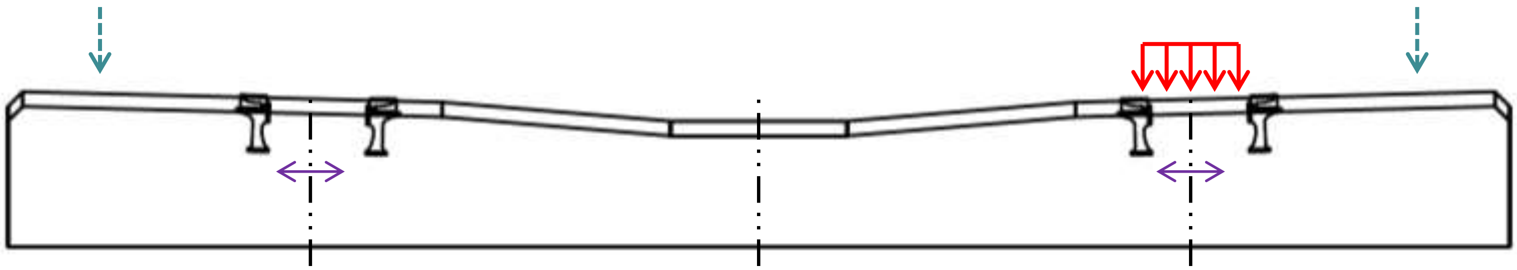


Fasteners/ Insulator

- Strain of fasteners
- Stresses on insulator

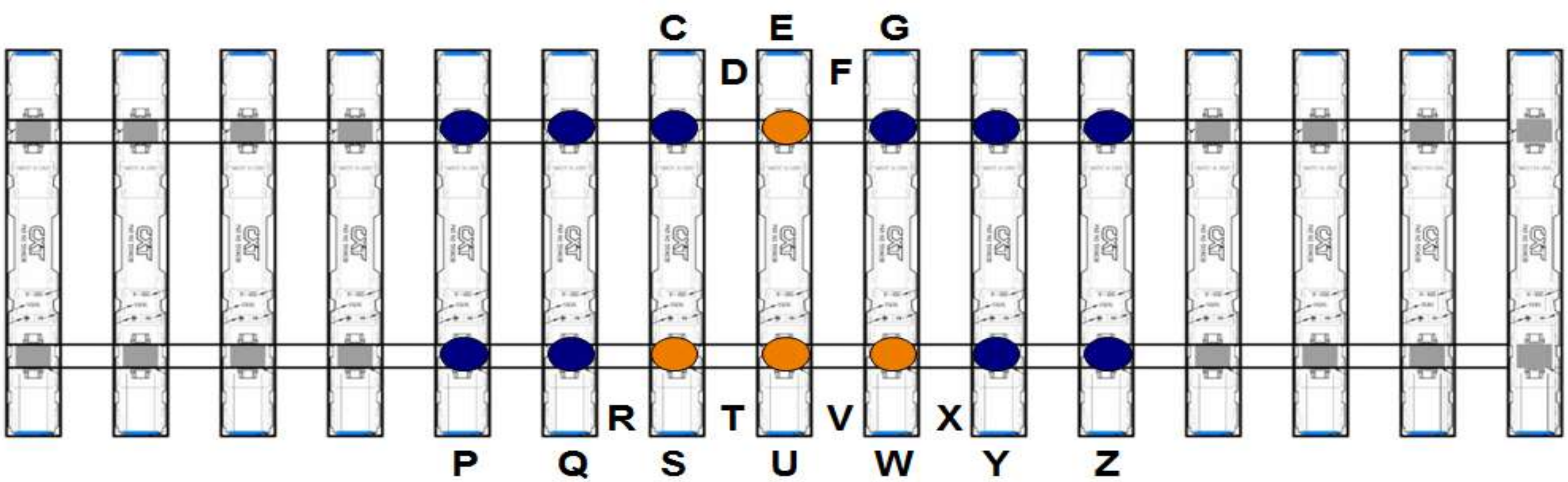
Concrete Sleepers

- Moments at the rail seat
- Stresses at rail seat
- Vertical displacements of sleepers

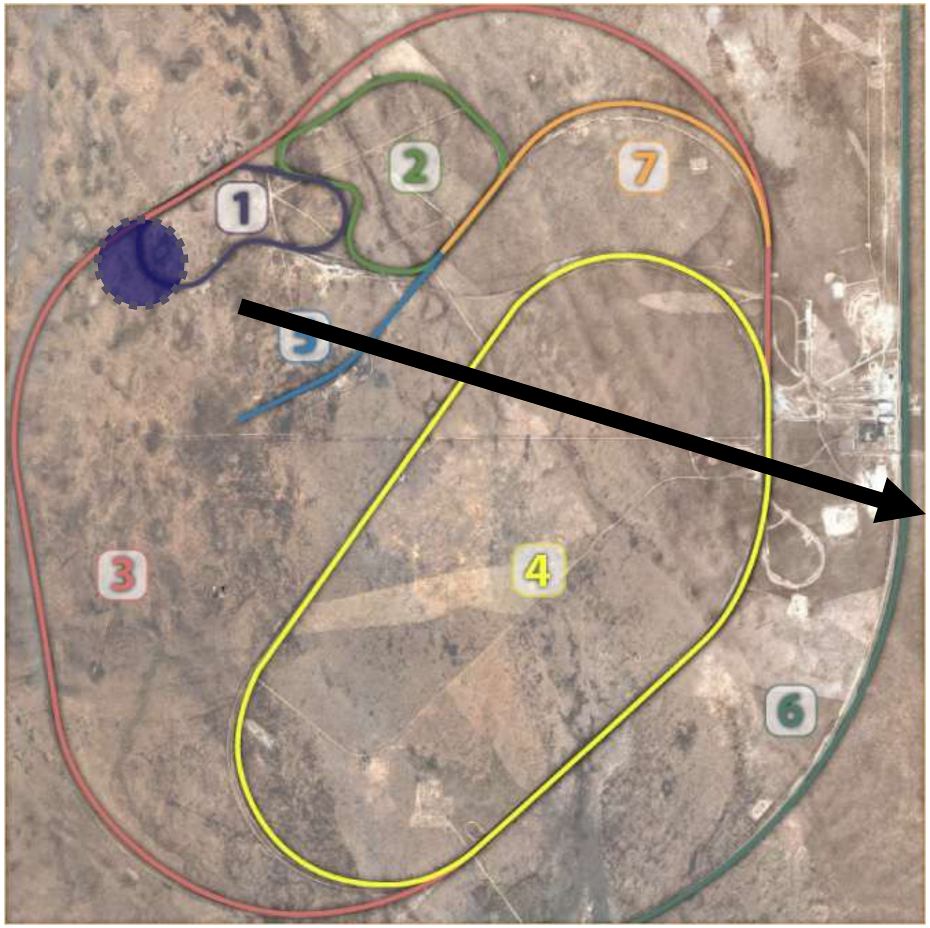


2012 Field Instrumentation Map

- **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)

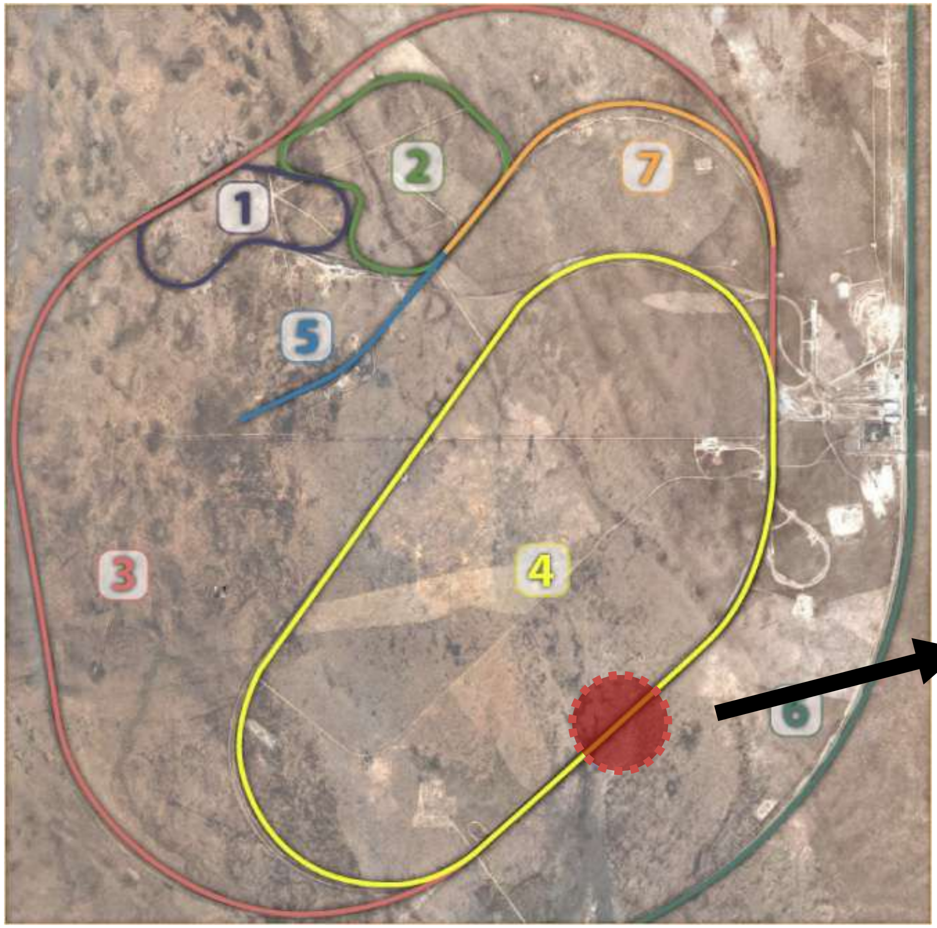


Field Instrumentation Locations



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

Field Instrumentation Locations



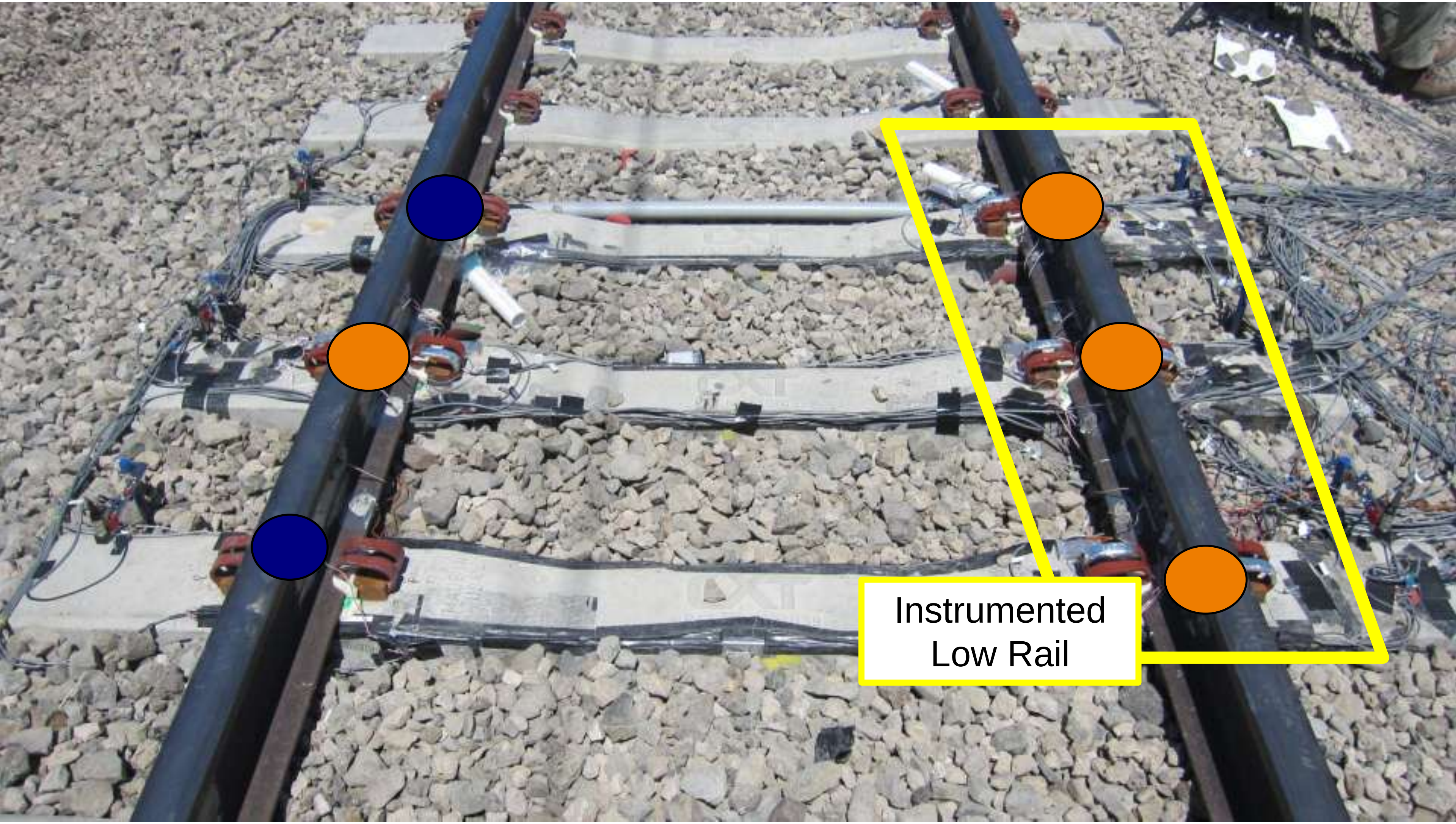
- TTC (Pueblo, CO, USA)
- Railroad Test Track (RTT)
  - Tangent
  - Safelok I Fasteners

Loading Environment

- Track Loading Vehicle (TLV)
  - Static
  - Dynamic

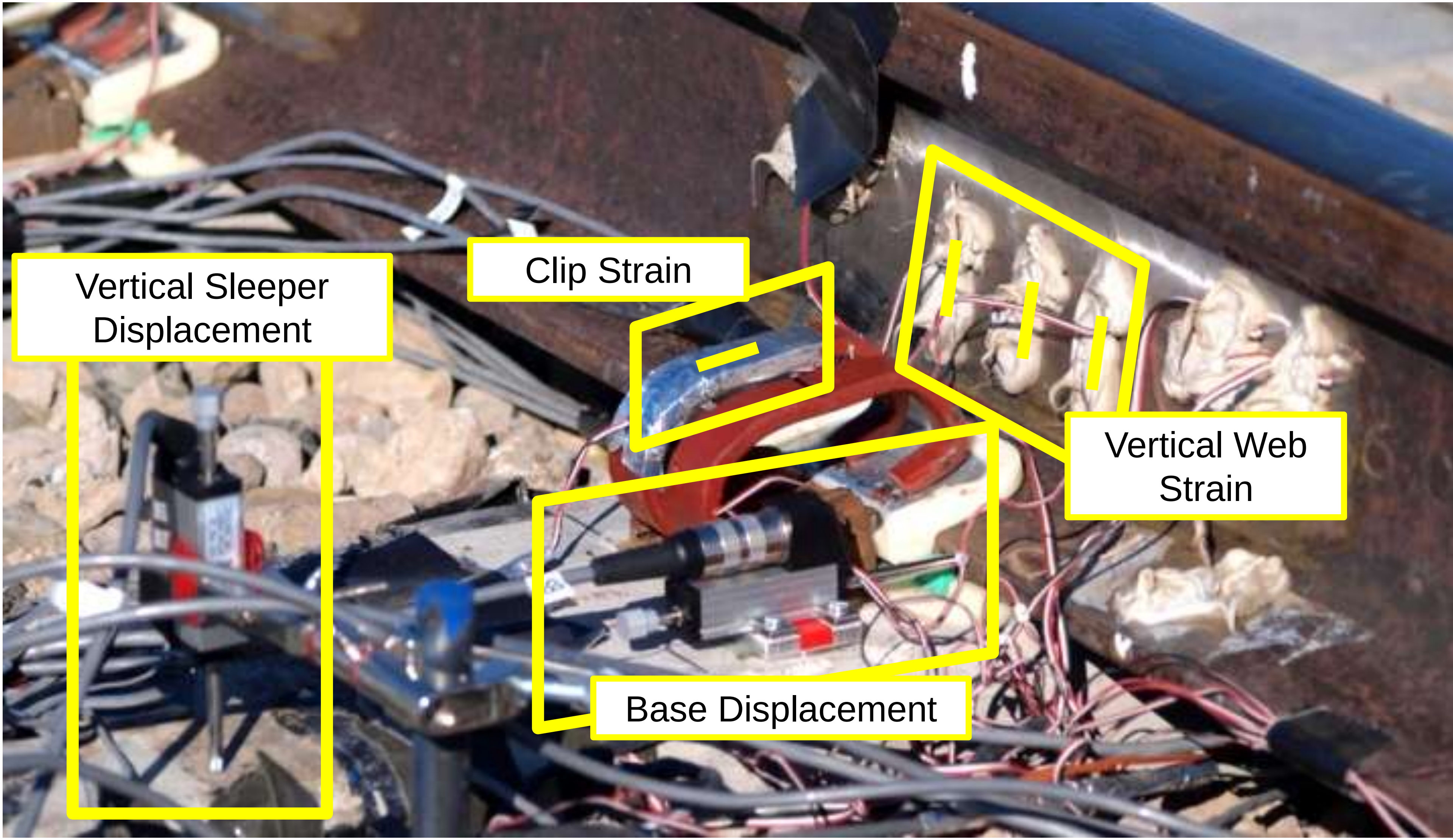
- Freight Consist
  - 6-axle locomotive
    - 30t axles (393 GRL)
  - Instrumented car
  - Nine cars
    - 30, 33, and 36t axles (263, 286, 315 GRL cars)
- Passenger Consist
  - 4-axle locomotive
    - 29t axles (255 GRL)
  - Nine coaches
    - 10t axles (87 GRL cars)

Fully Instrumented Rail Seats

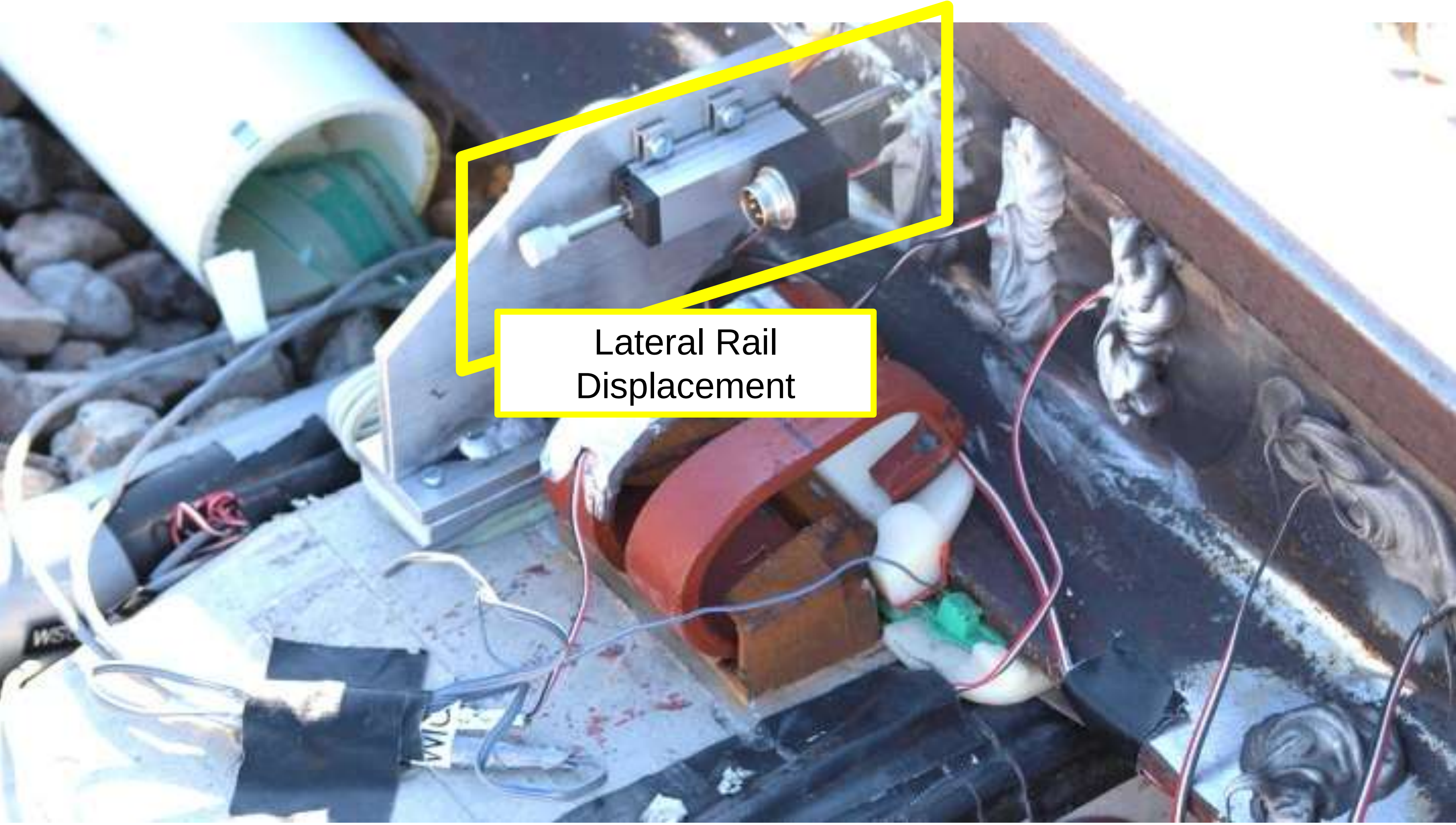


Instrumented Low Rail

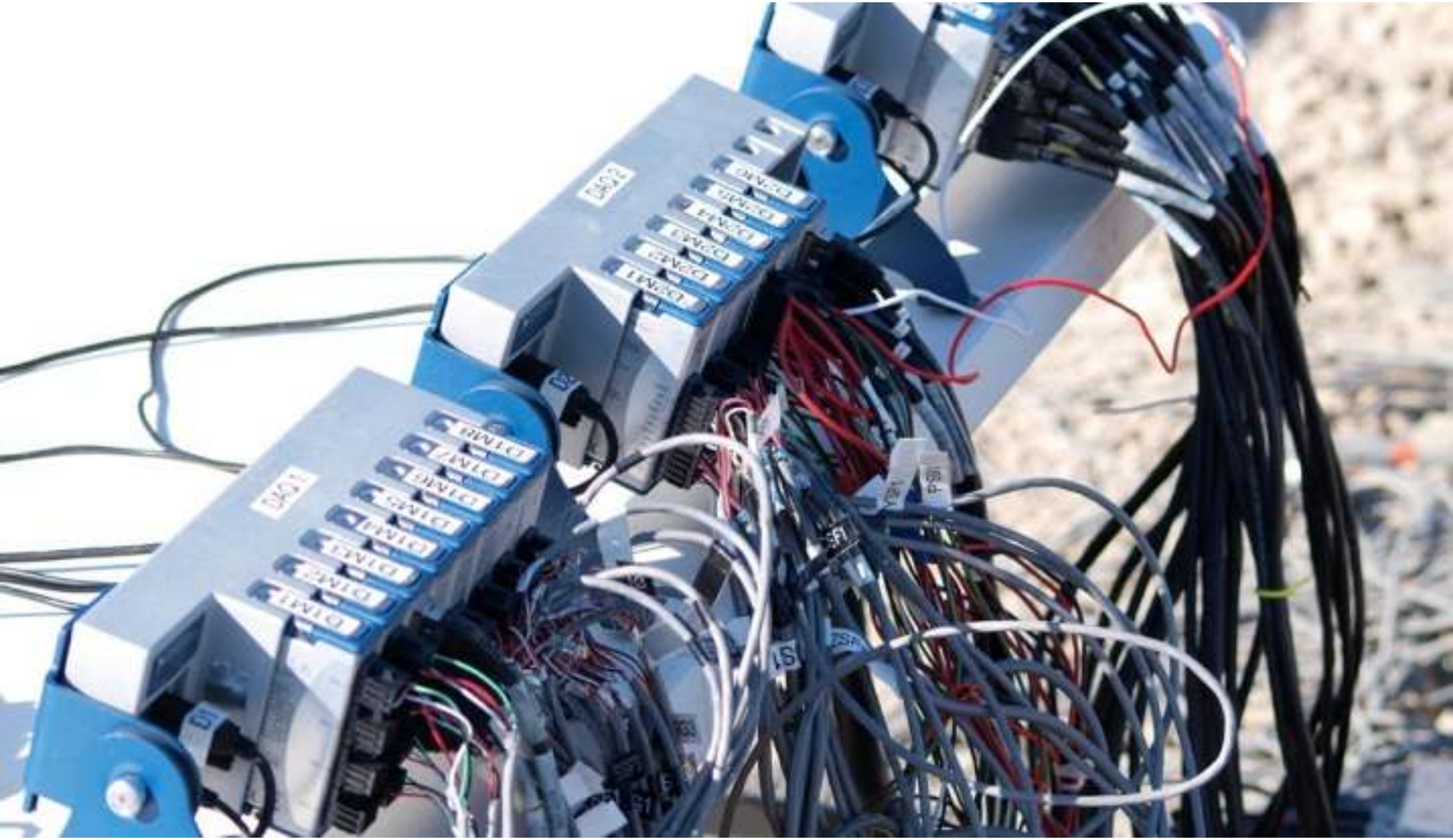
Field-side Instrumentation



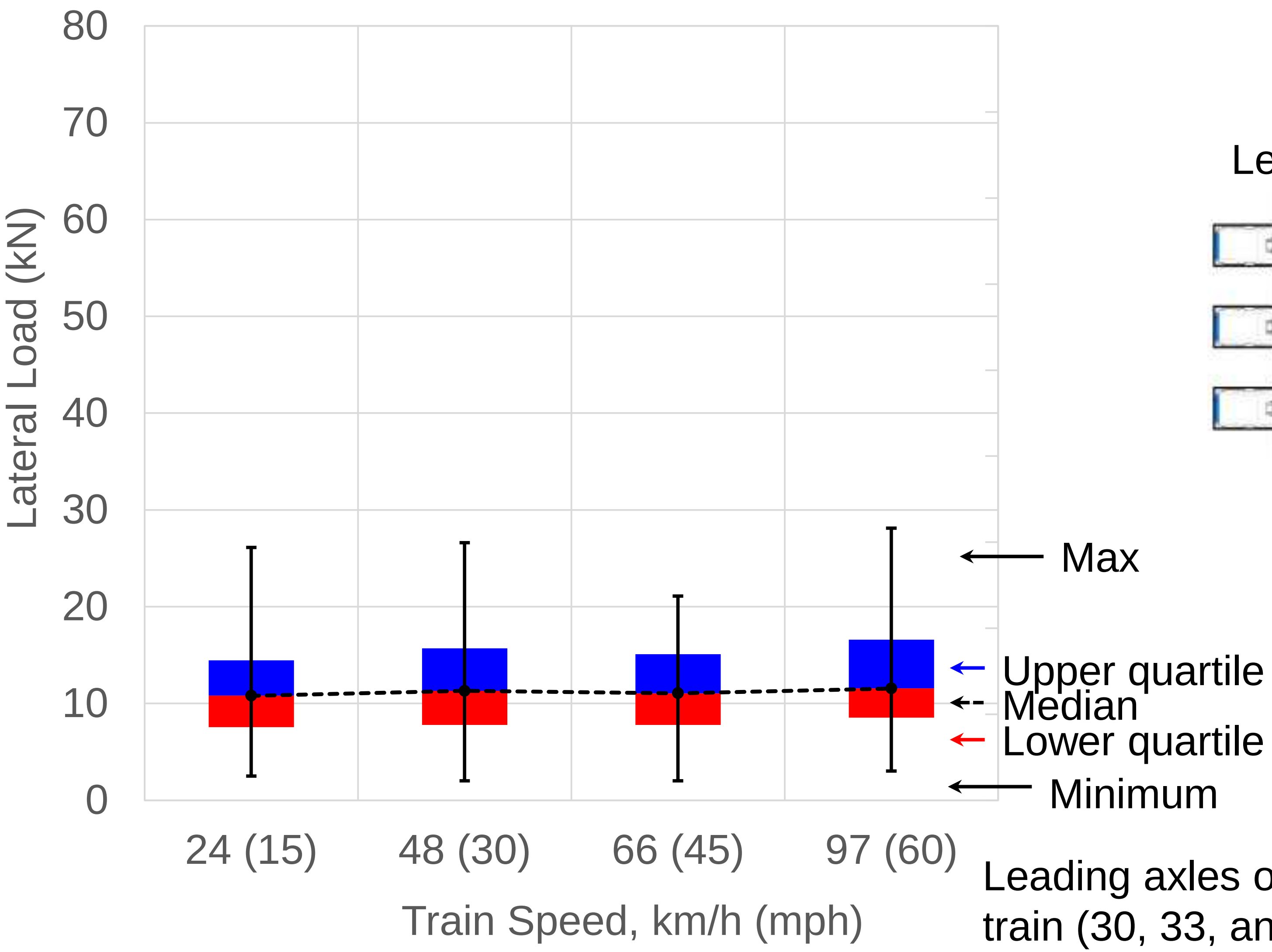
Gauge-side Instrumentation

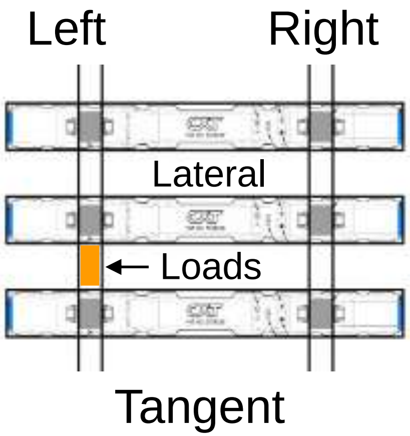


Data Acquisition System



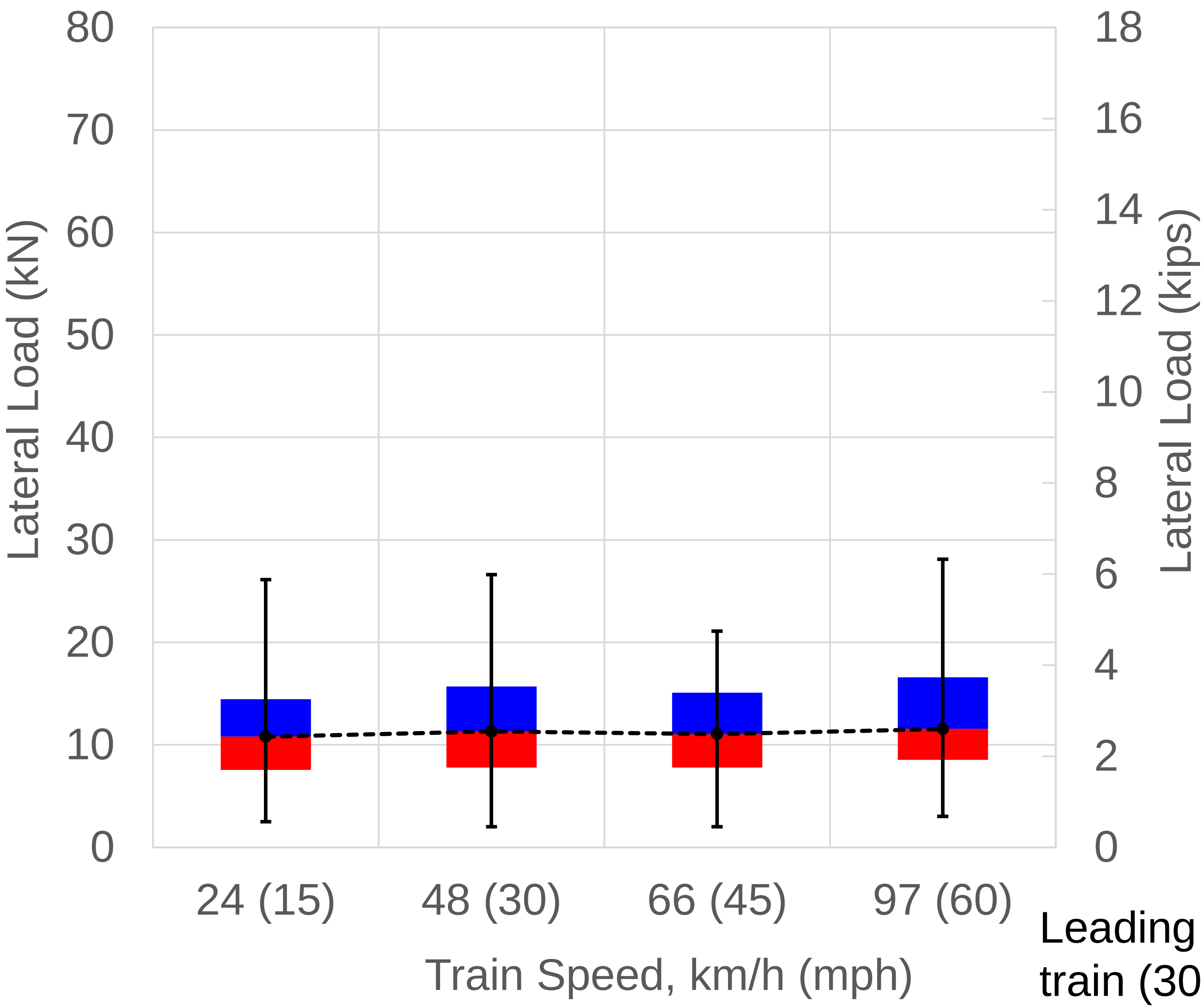
Lateral Loads Acting on a Tangent Track

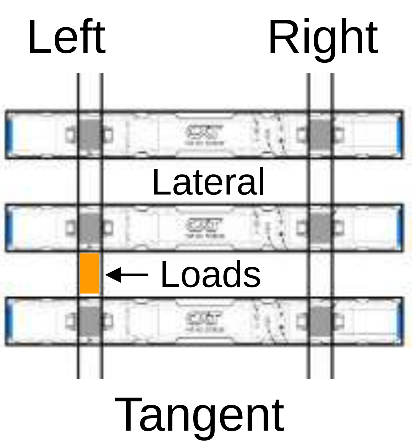




Leading axles of a 10-car freight train (30, 33, and 36t axle loads).

Lateral Loads Acting on a Tangent Track

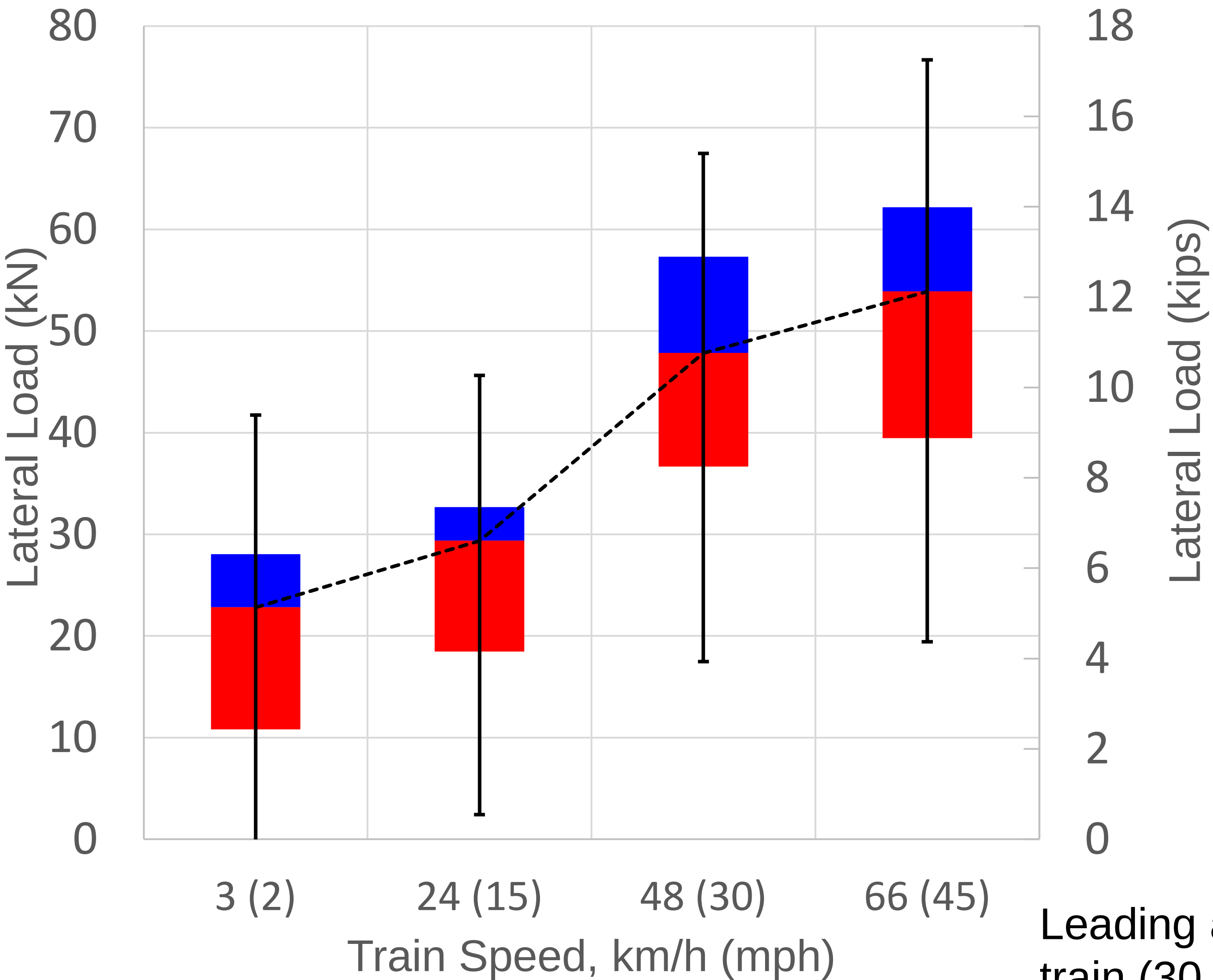


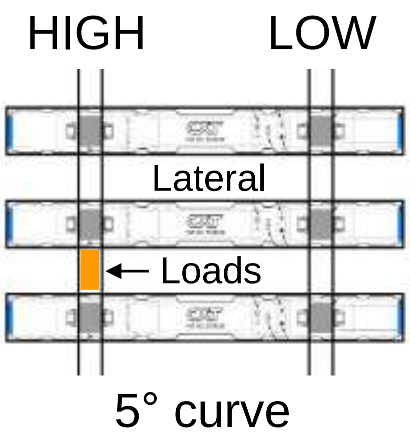


- No correlation between lateral loads and train speed on tangent track.

Leading axles of a 10-car freight train (30, 33, and 36t axle loads).

Lateral Loads Acting on a Curve Track

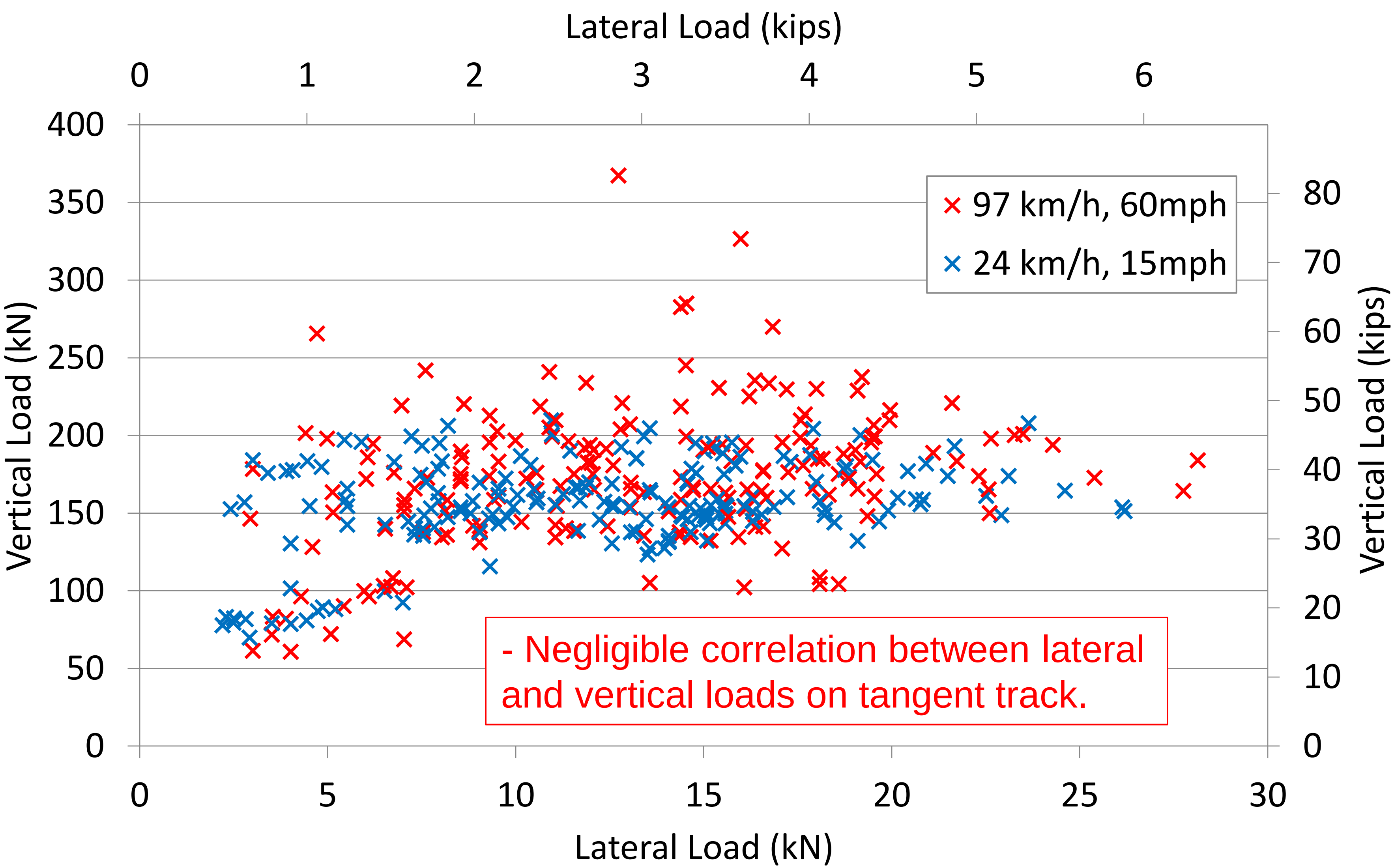




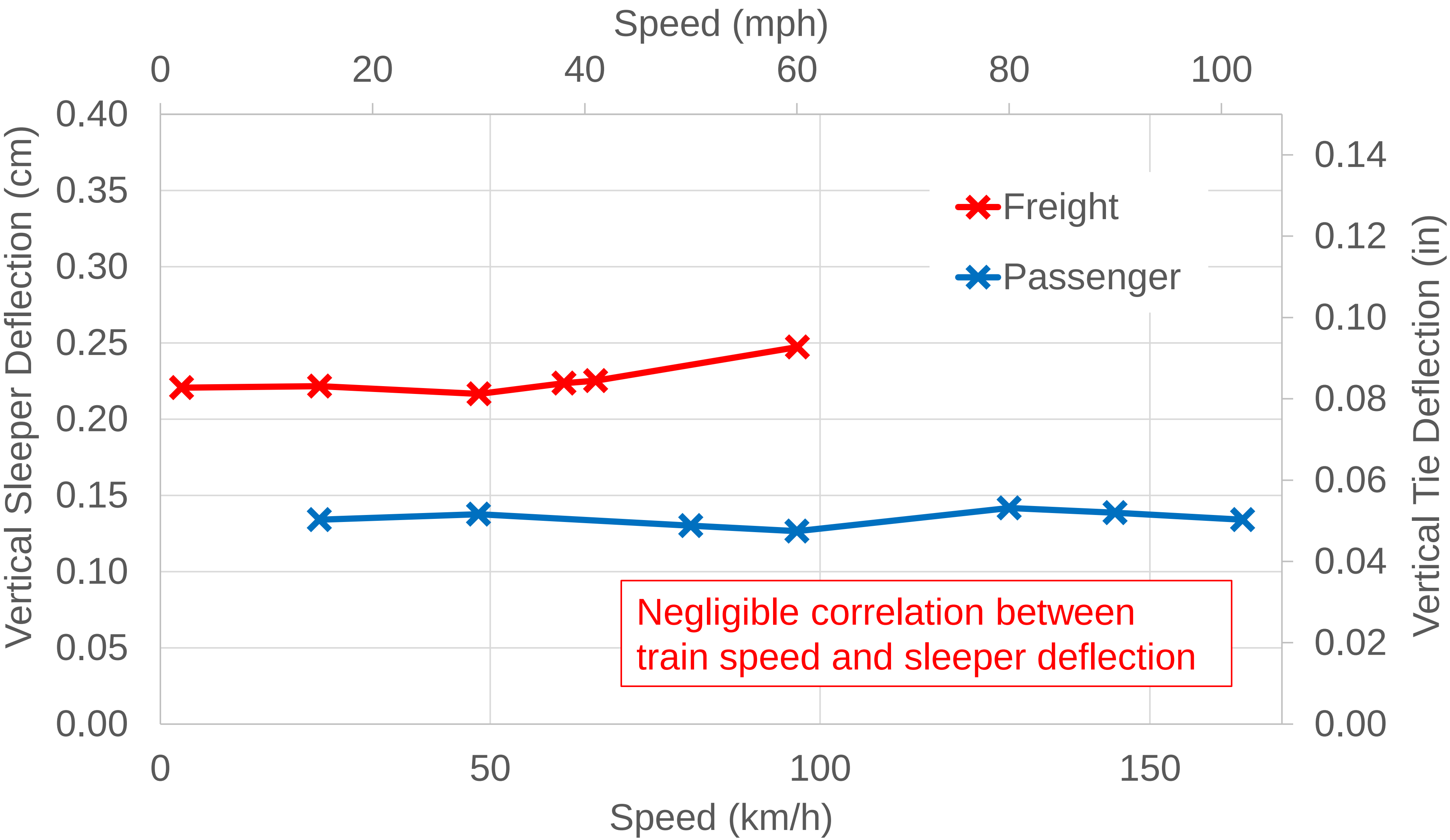
- Median load is ~5.5 times larger than what was recorded in tangent track.

Leading axles of a 10-car freight train (30, 33, and 36t axle loads).

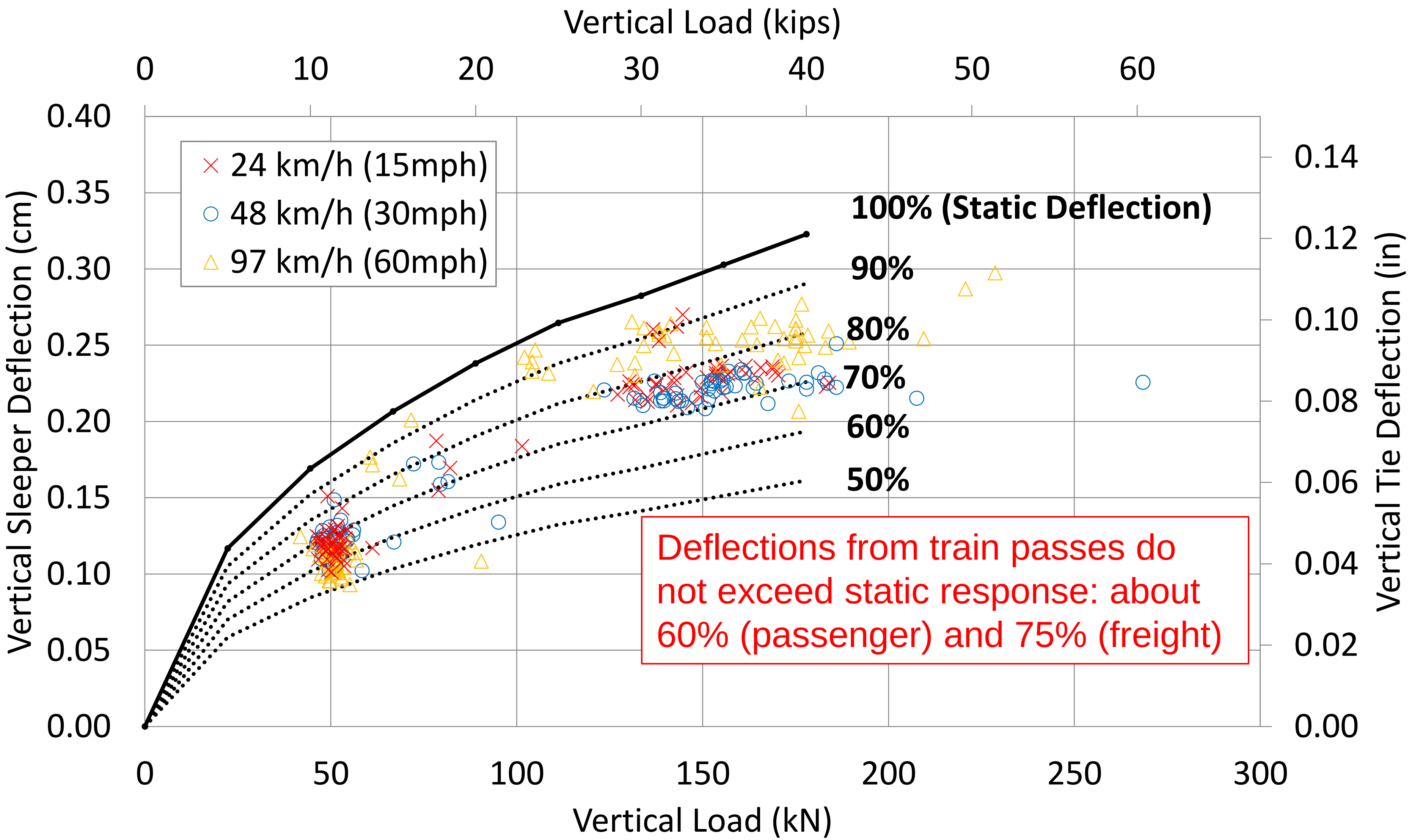
Variability in Loading Conditions



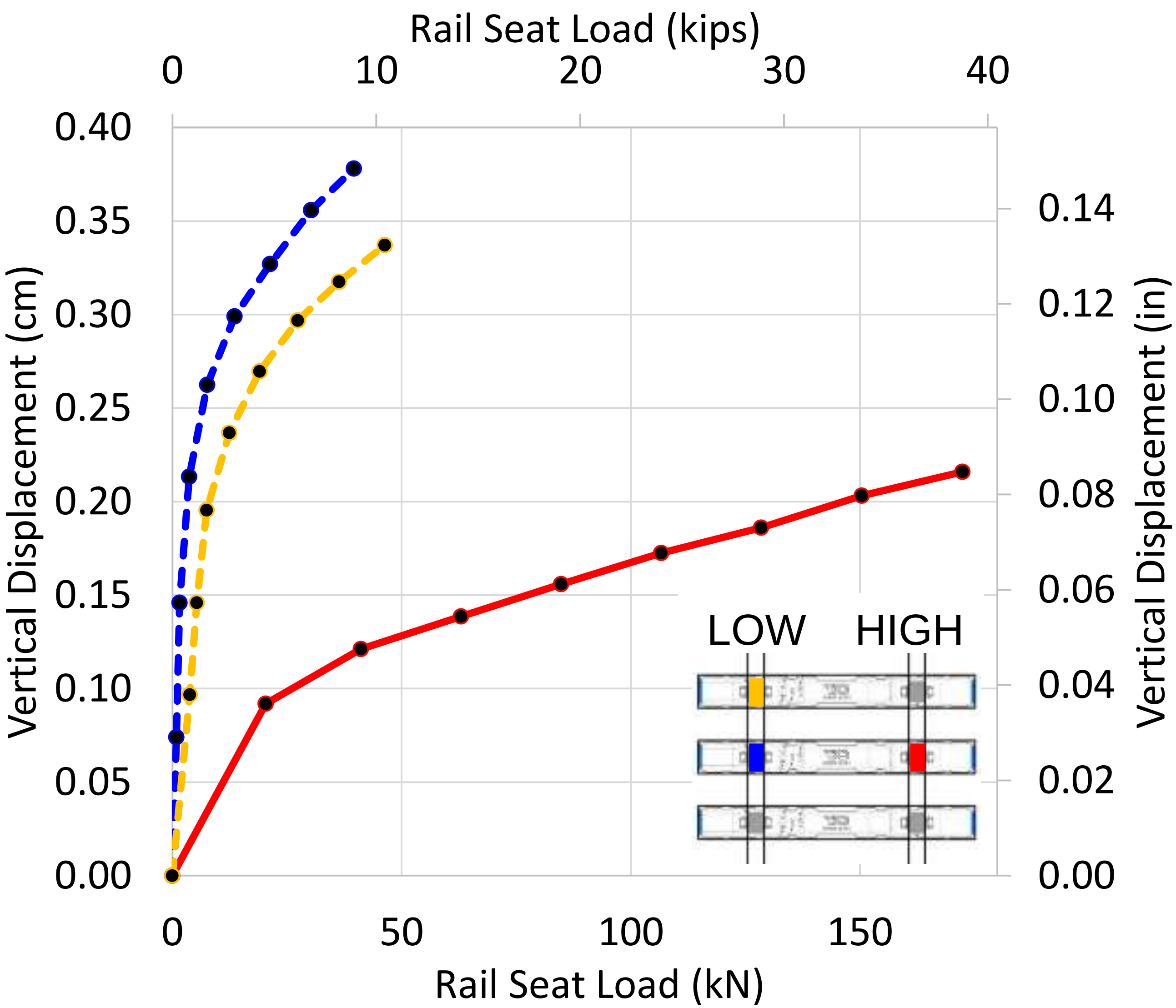
Effect of Train Speed on Sleeper Displacement



Effect of Train Speed on Sleeper Deflection (cont.)

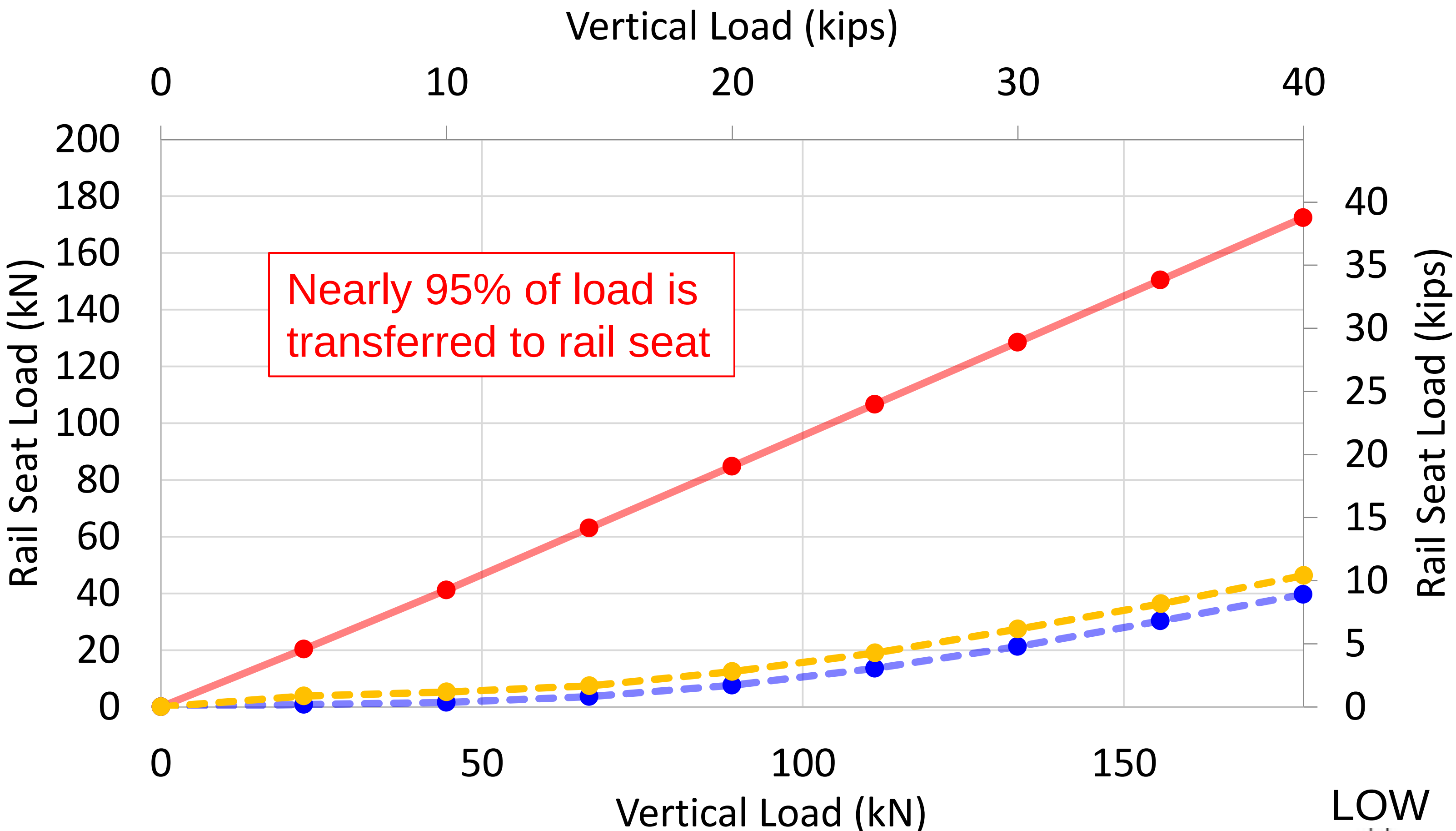


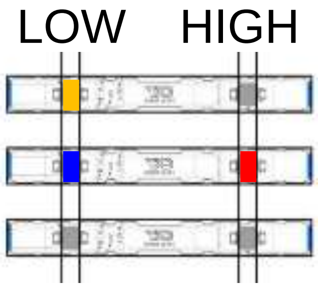
Variability in Support Conditions



- Curve/Static Loads
- Each point = +22kN (+5kips) vertical load
- 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 sleepers and resisted by the bending of the rail

Preliminary Findings with Potential Design Considerations

- The lateral loading demands were 5.5 times higher in the curve than on tangent track
  - Design should consider specialized components in the curve
- The vertical and lateral loading demands on tangent track are not dependent on train speed
  - Design should not weight speed highly on tangent track
- There is negligible correlation between concurrently acting lateral and vertical loads on tangent track
- Dynamic vertical sleeper displacement never exceeded the purely static response
- Rail seat forces are highly dependent on the stiffness of the substructure and support conditions and can range from below 20% to over 90% of the wheel-rail load
  - Design should incorporate probabilistic loading conditions

Future Work

- Continued **data analysis** to understand the governing mechanics of the system by investigating the:
  - elastic fastener (clamp) strain response
  - number of ties effected simultaneously
  - bending modes of the sleepers
  - pressure magnitude and distribution at the rail seat
- Continued **comparison and validation** of the UIUC finite element model (Chen, Shin)
- Preparation for **instrumentation trip** (Summer 2013)
  - Focus on lateral load path by gathering
    - relative lateral sleeper displacements
    - global lateral sleeper displacements
    - load transferred to the clamp, insulator-post, and shoulder
- Small-scale, **evaluative tests** on Class I Railroads

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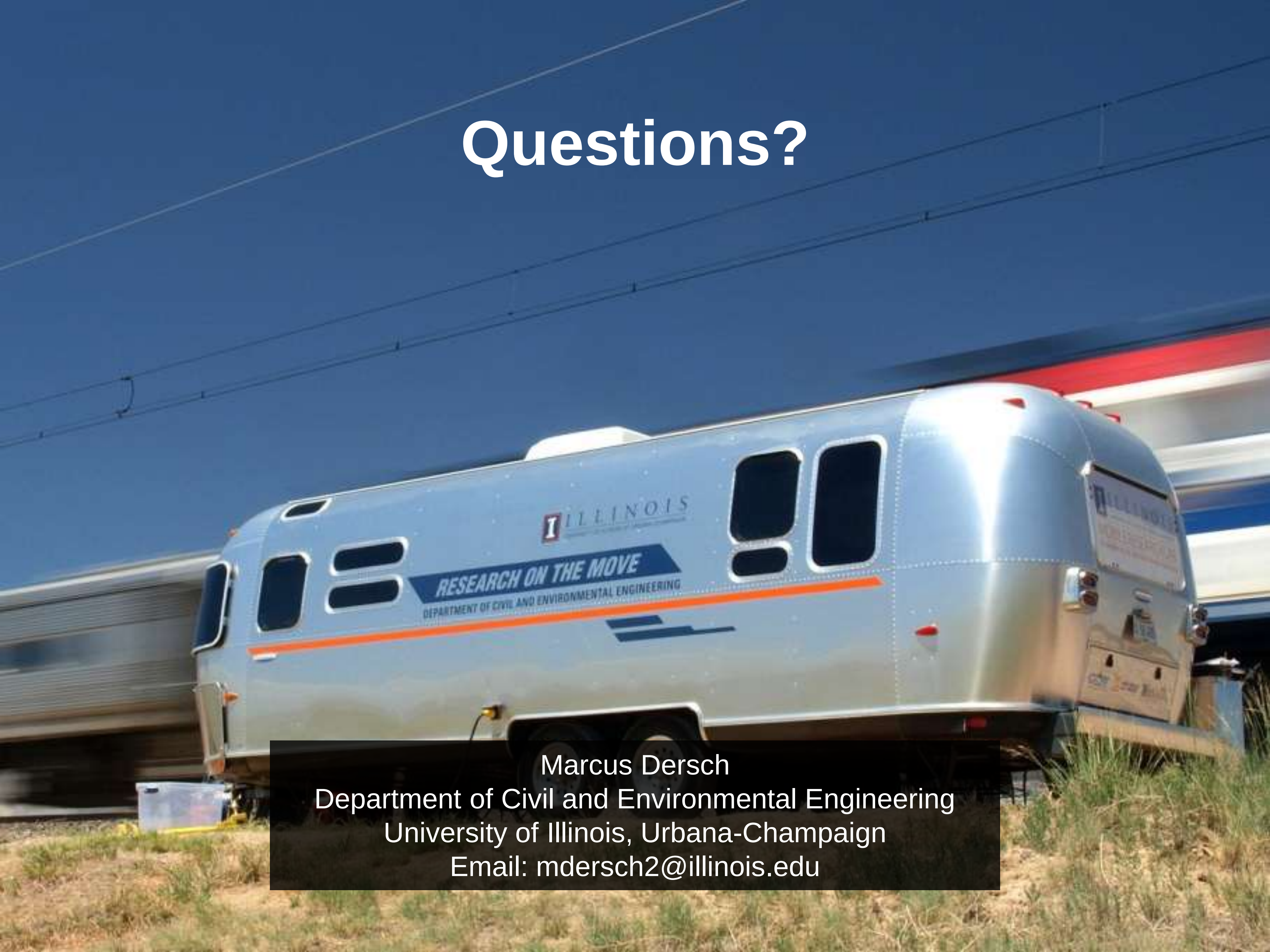
Questions?



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