Quantification of Lateral Forces in Concrete Crosstie Fastening Systems

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U.S. Department of Transportation
Federal Railroad Administration

Outline

- Research Motivation
- Defining Lateral Load Path and Fastening System
- Field Experimental Setup – TTC
  - Dynamic Transfer of Lateral Loads
- Laboratory Experimental Setup - TLS
  - Demand on Shoulder Varying Static Vertical Load
  - Quantifying Lateral Load Distribution Varying Friction
- Conclusions
- Future Work

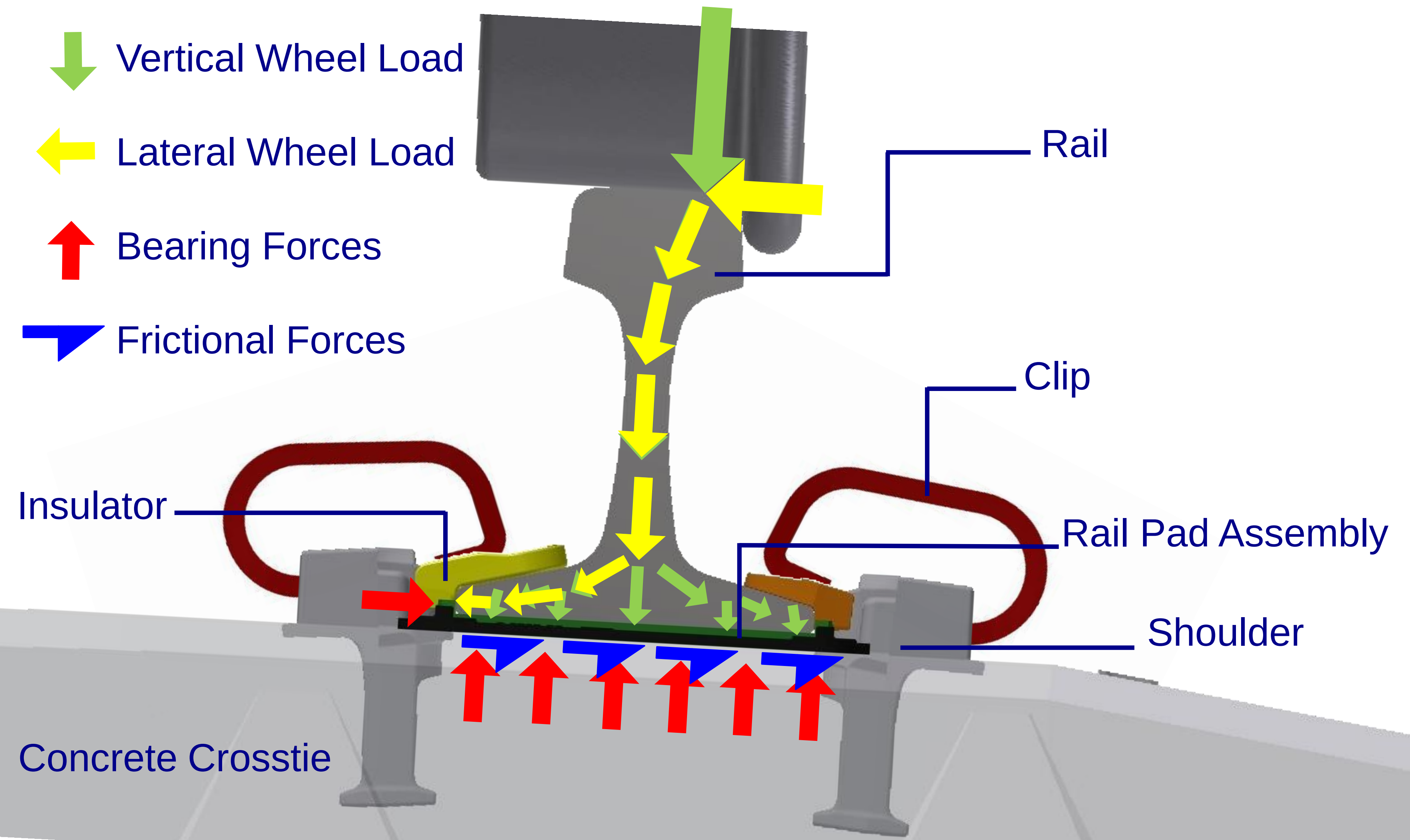
Current Performance Challenges Relating to Lateral Loads

- Lateral forces through fastening system is believed to be a contributor to shoulder and insulator deterioration

Purpose of Lateral Force Measurement

- **Quantify lateral loading conditions to aid in the mechanistic design of fastening systems**
- Understand demands on fastening system components under loading conditions known to generate failures
- Gain understanding of the lateral load path by:
  - Quantifying forces and stresses acting on the insulator and shoulder
  - Quantifying the distribution of lateral forces in fastening system
    - e.g. **Bearing** on shoulder, **frictional resistance** from rail pad assembly or clip, etc.
  - Understanding the causes of variation on lateral load distribution among adjacent crossties

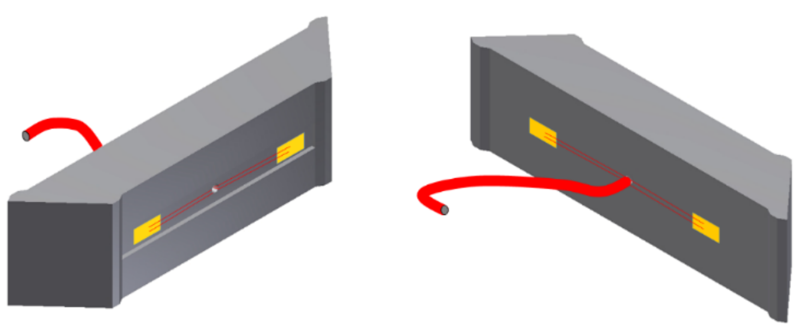
Defining the Lateral Load Path

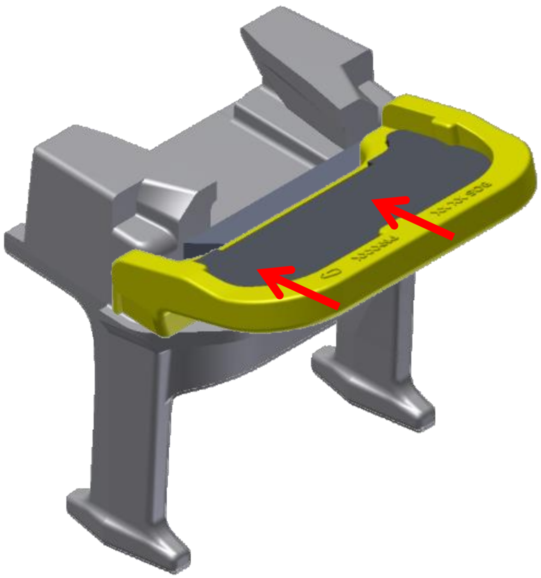


Measurement Technology

Lateral Load Evaluation Device (LLED)

- Replaces original face of cast shoulder
- Maintains original fastening system geometry
- Designed as a beam in four-point bending
- Bending strain is resolved into force through calibration curves generated in the lab



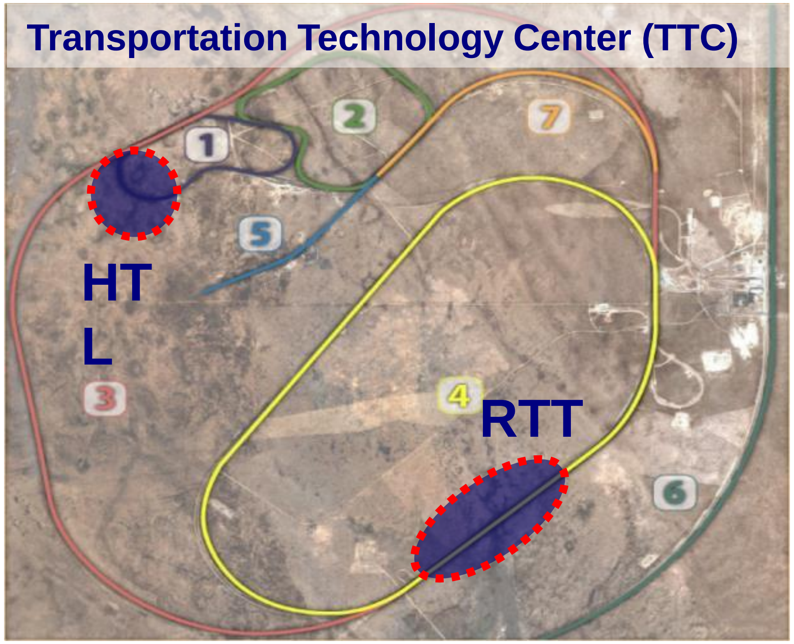


Field Experimental Setup - TTC

- **Objective:** Analyze the distribution of forces through the fastening system and impact on the relative displacement of components

- **Location:** Transportation Technology Center (TTC) in Pueblo, CO
  – **Railroad Test Track (RTT):** tangent section
  – **High Tonnage Loop (HTL):** curved section

- **Instrumentation:**
  - Strain gauges
  - LLED
  - Potentiometers



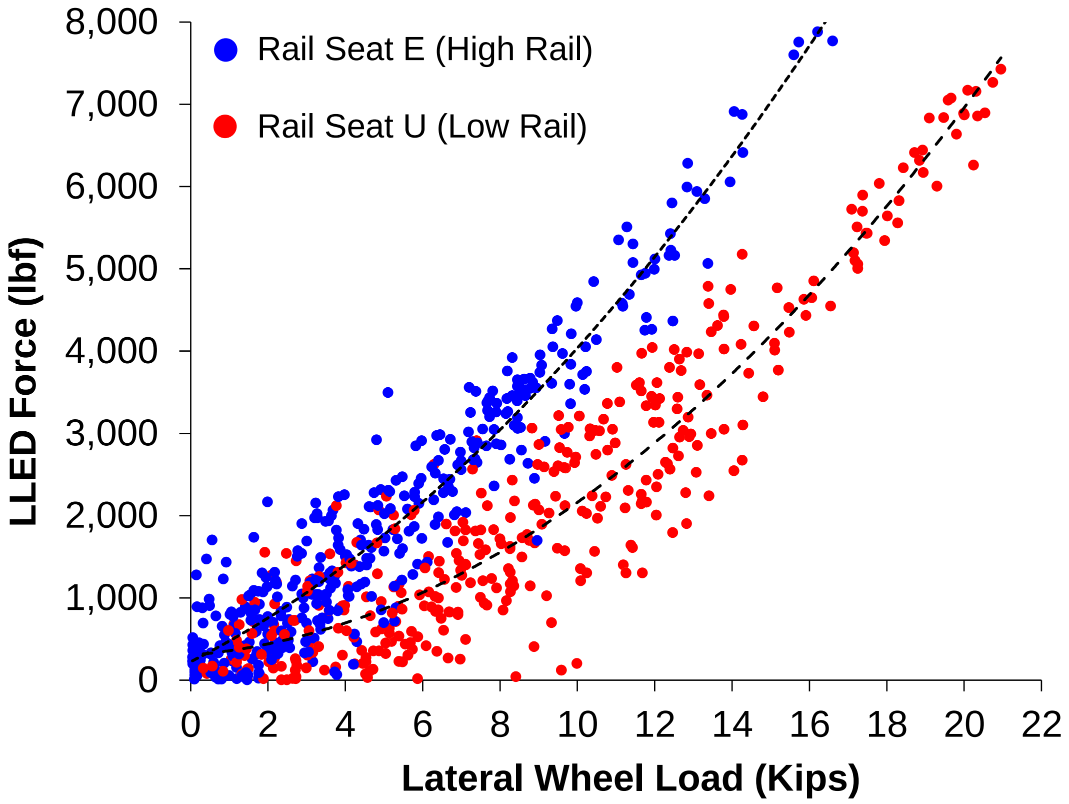
High Tonnage Loop (HTL)

Dynamic Loading Environment

- Customized freight train
  - Three six-axle locomotives
  - Ten freight cars with 263k, 286k, and 315k cars
  - Speeds of 2 mph,15 mph, 30 mph, 40 mph, and 45 mph
- FAST train
  - Speeds of 20 - 40 mph
- Tested on HTL (curved section)

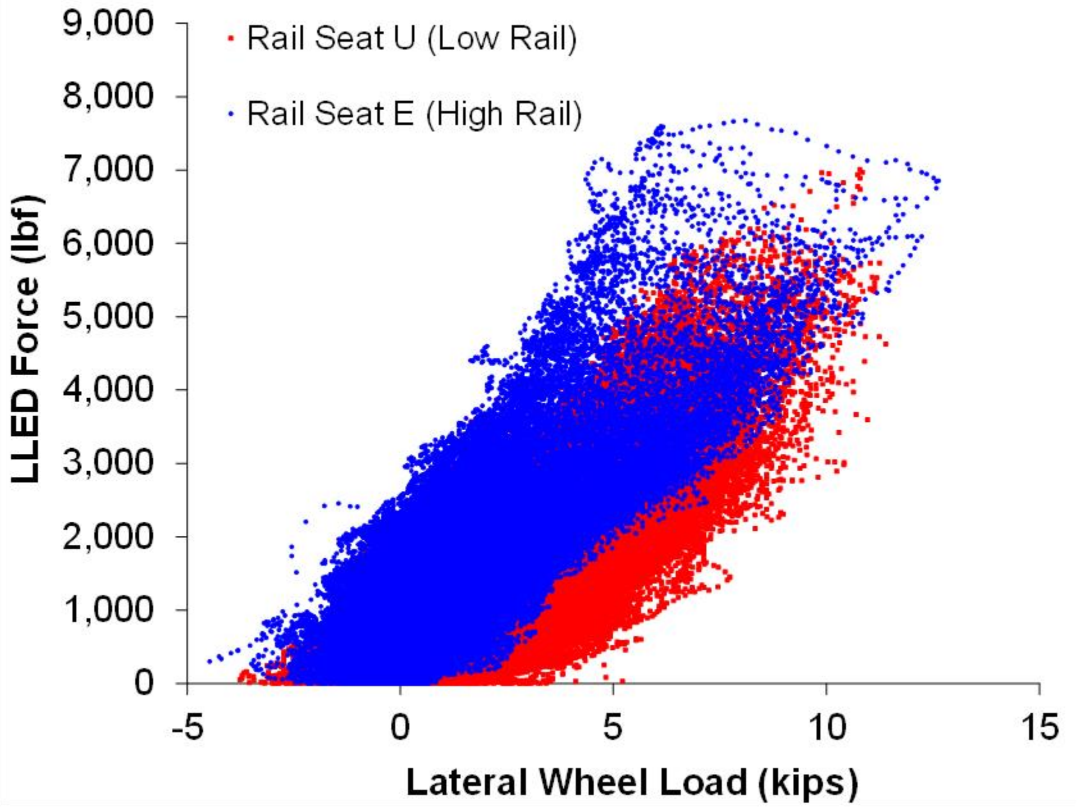
Dynamic Transfer of Lateral Loads:
Freight Train - Measured at Shoulder

- Peak LLED and lateral wheel loads from each passing freight wheel
- Dynamic loads are applied at much higher rates than static
- Higher bearing forces may be caused by lowered COFs



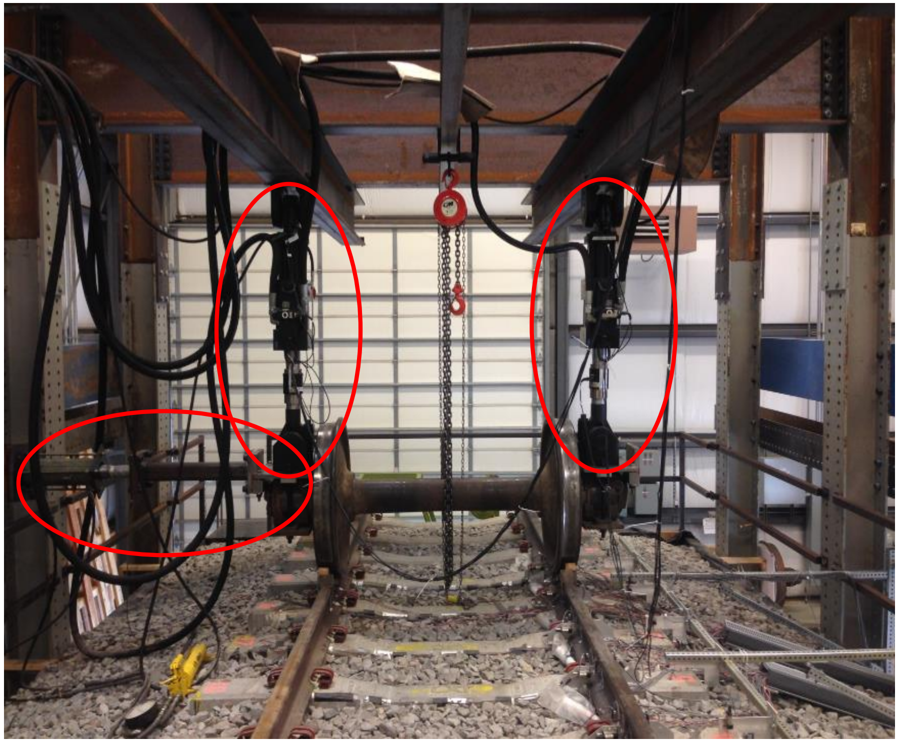
Dynamic Transfer of Lateral Loads:
Freight Train - Measured at Shoulder

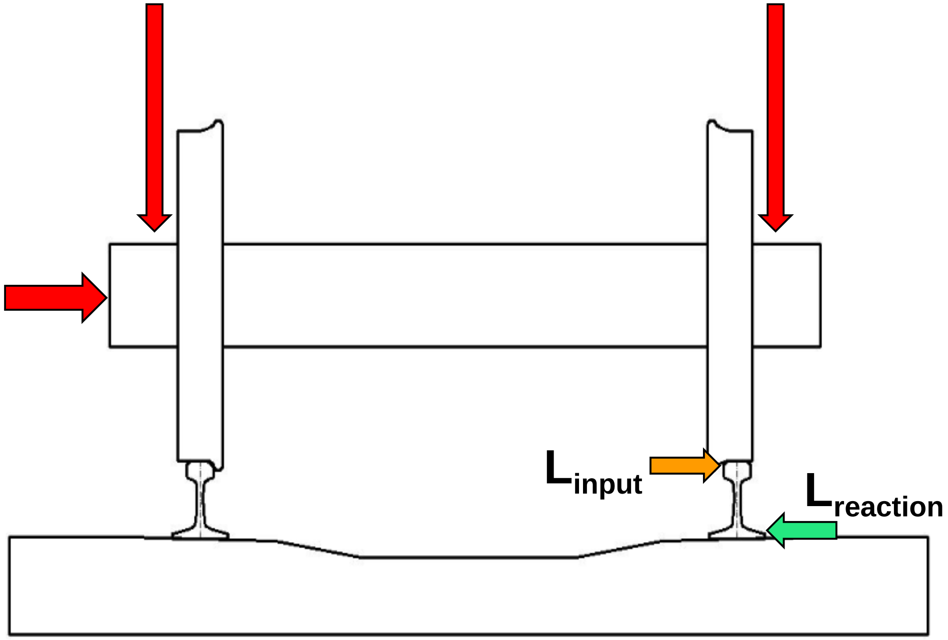
- Absolute LLED values recorded throughout each pass of the FAST train
- Data recorded during varying speeds:
  - 20 – 40 mph
- Large variability in forces on the shoulder at higher lateral wheel loads



40 MPH

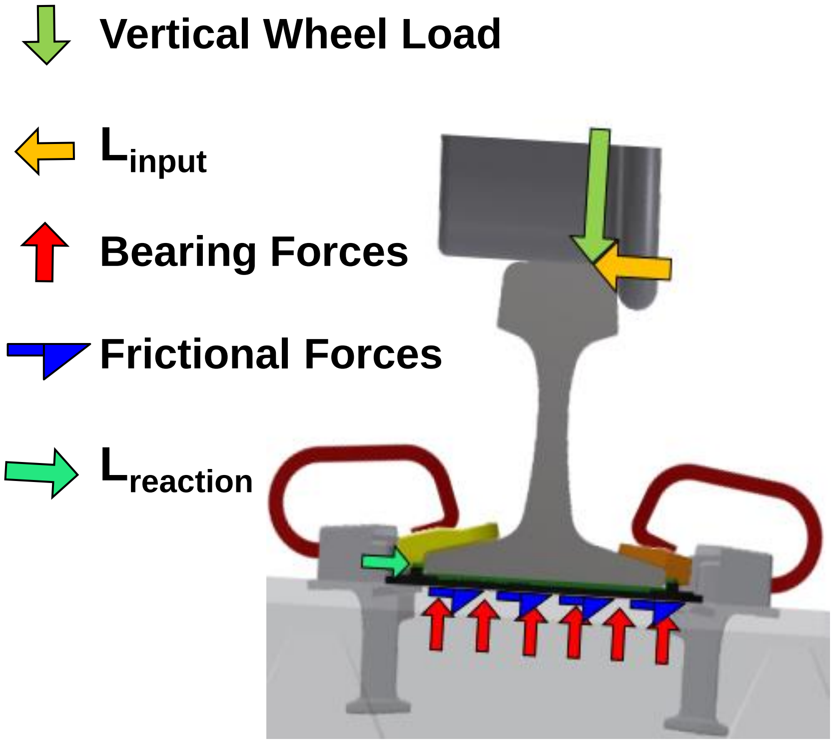
Lab Experimental Setup – Track Loading System (TLS)

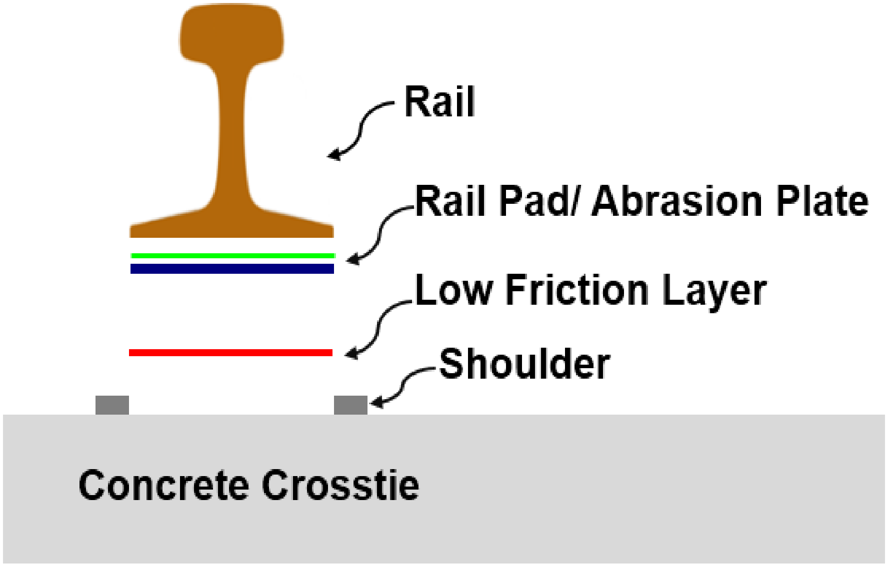




- Track Loading System (TLS) allows for testing of track infrastructure similar to field conditions.
- L_{input} is obtained from strain gauges attached to the rail
- $L_{reaction}$ is obtained from LLED devices installed in the shoulder of crossties being tested

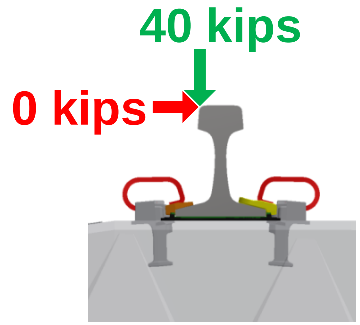
Lateral Load Path and Fastening System Setup

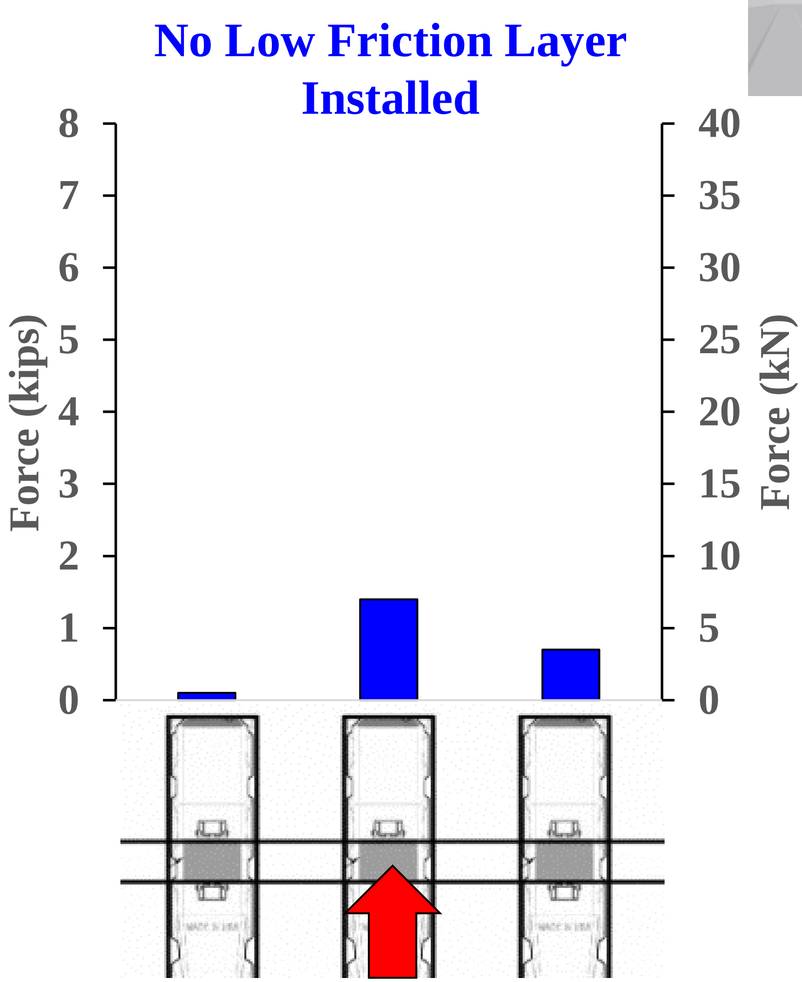


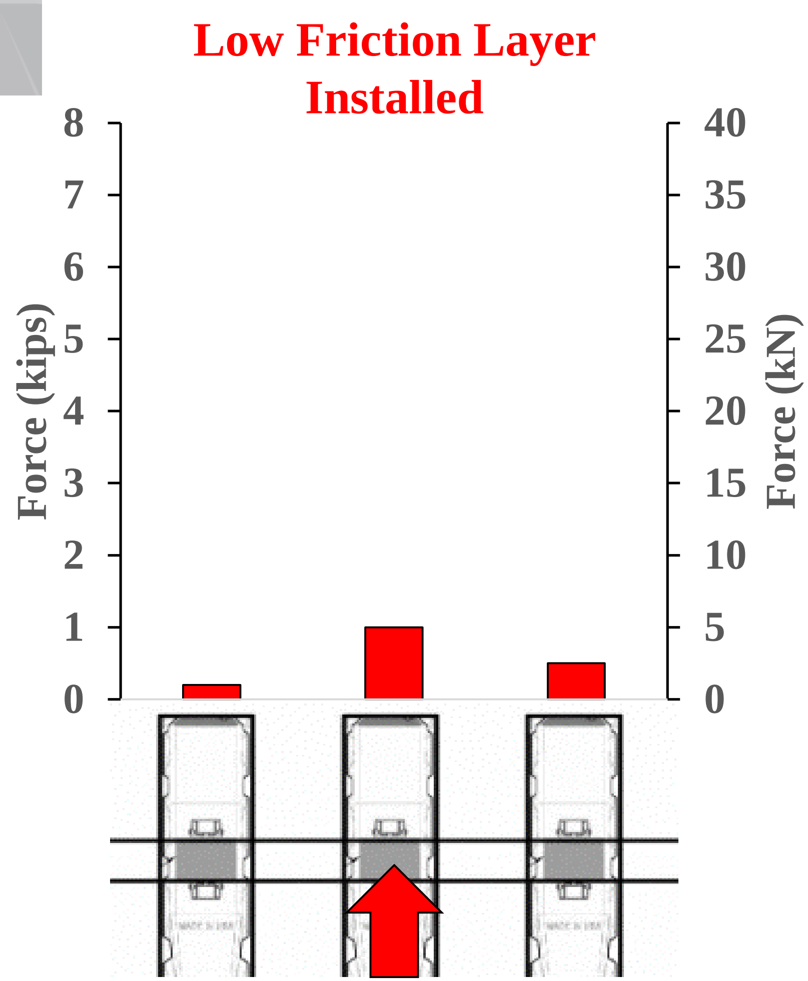


- Primary lab research objective is to study the frictional force between the rail pad and the rail seat.
- Low friction layer made of BoPET used to investigate the importance of friction in lateral force distribution through track infrastructure

Quantifying Lateral Load Distribution







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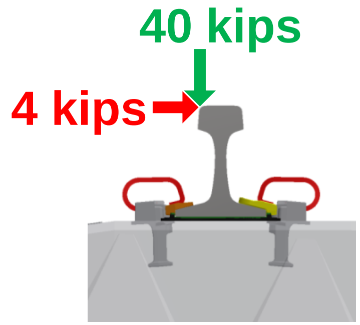

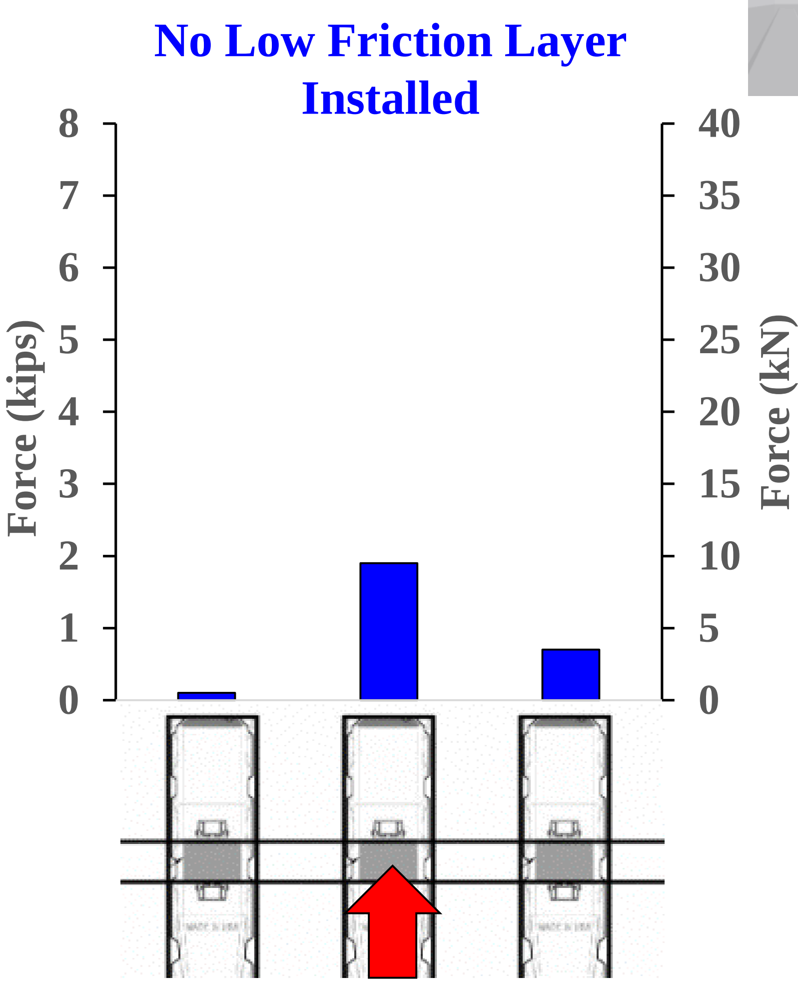

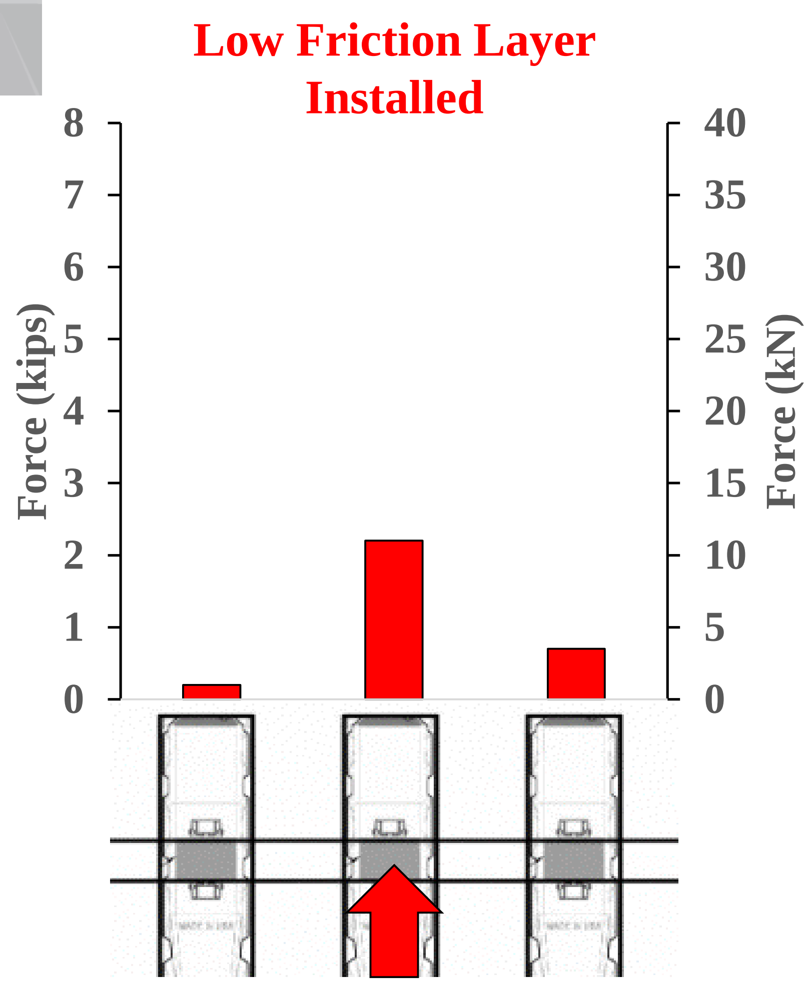

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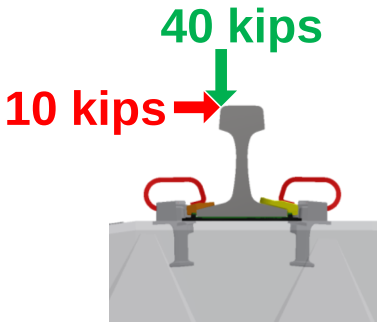
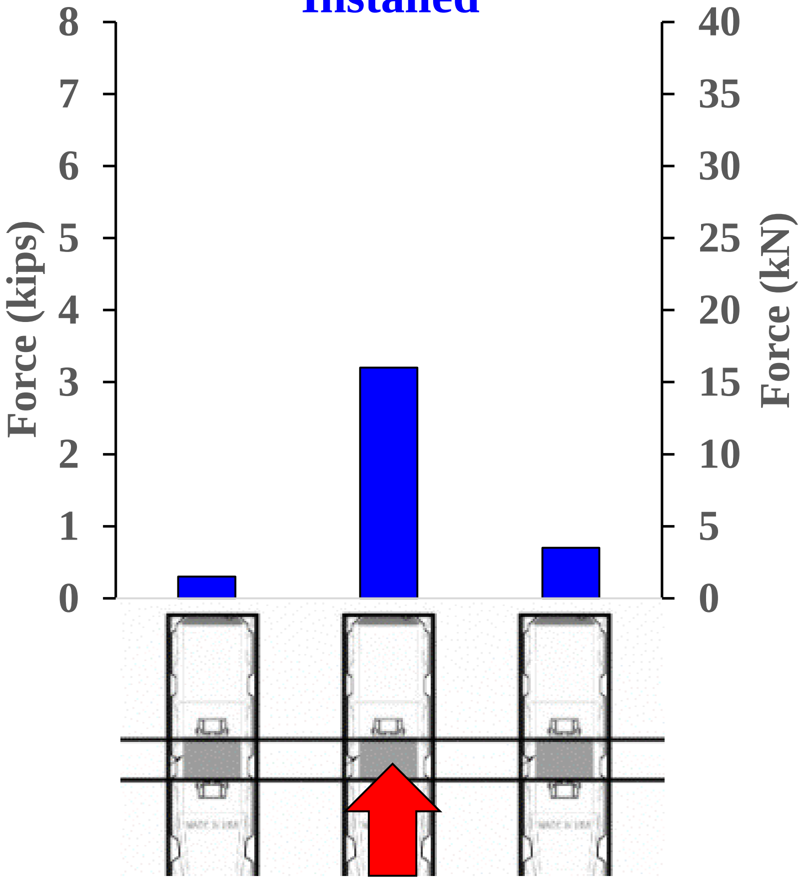


No Low Friction Layer Installed



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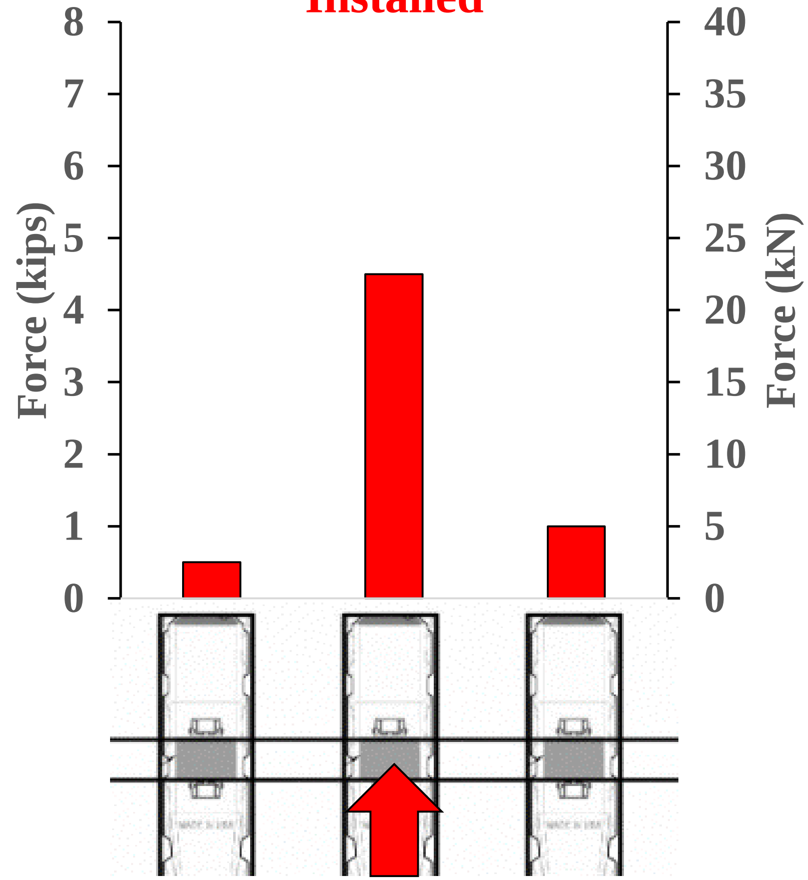

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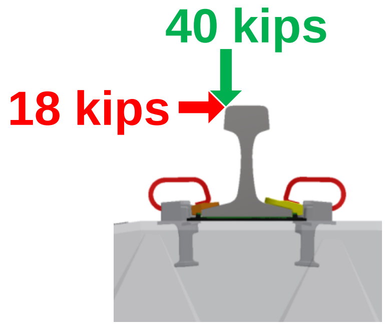

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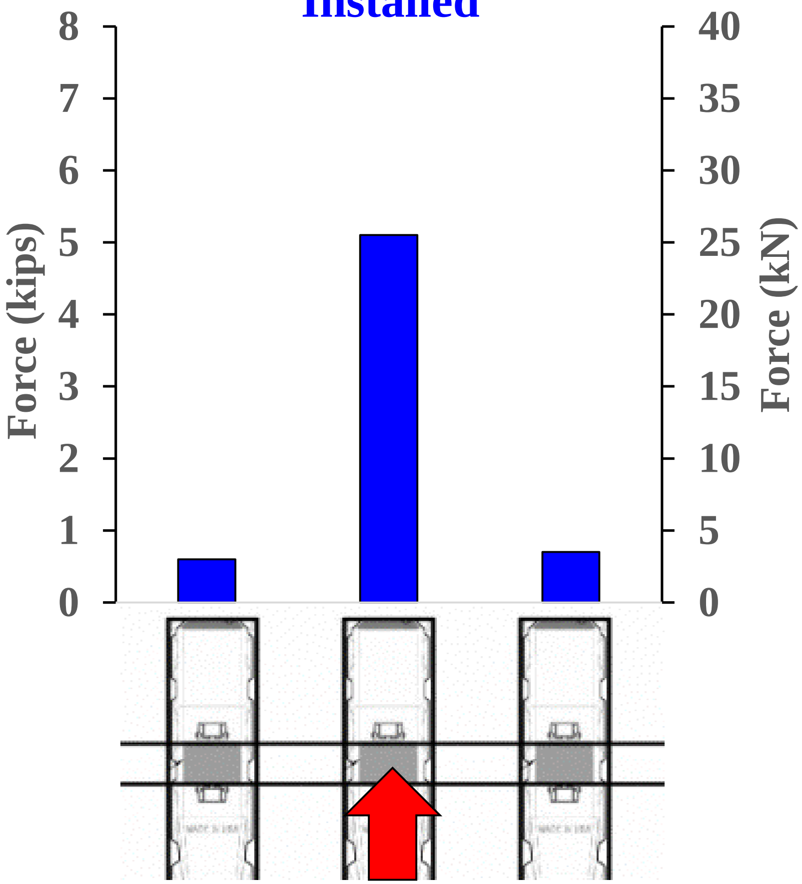

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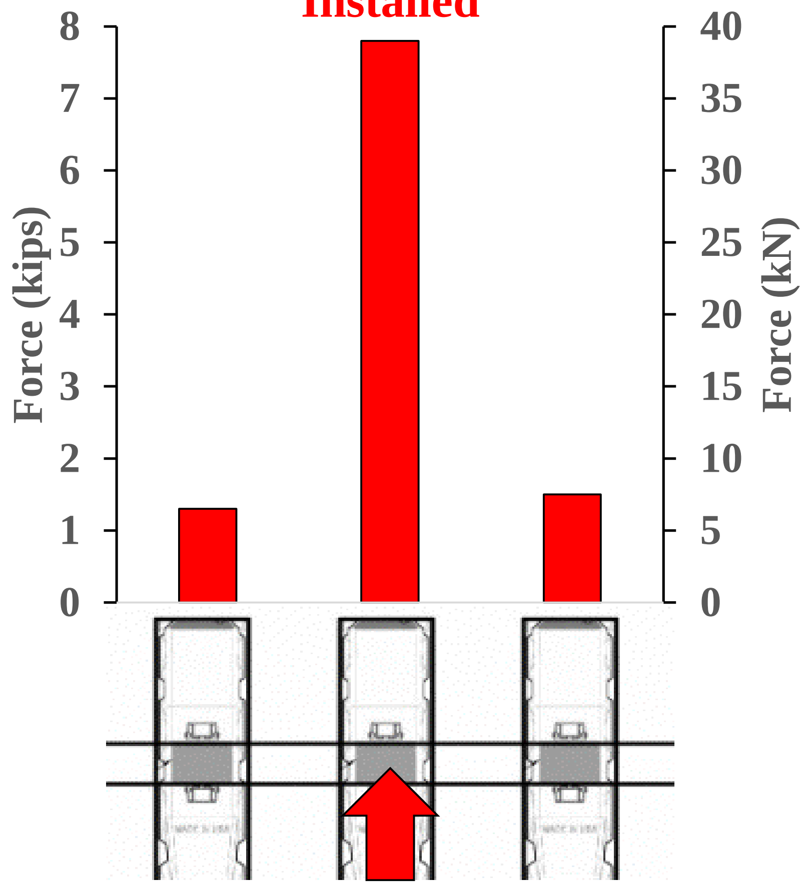

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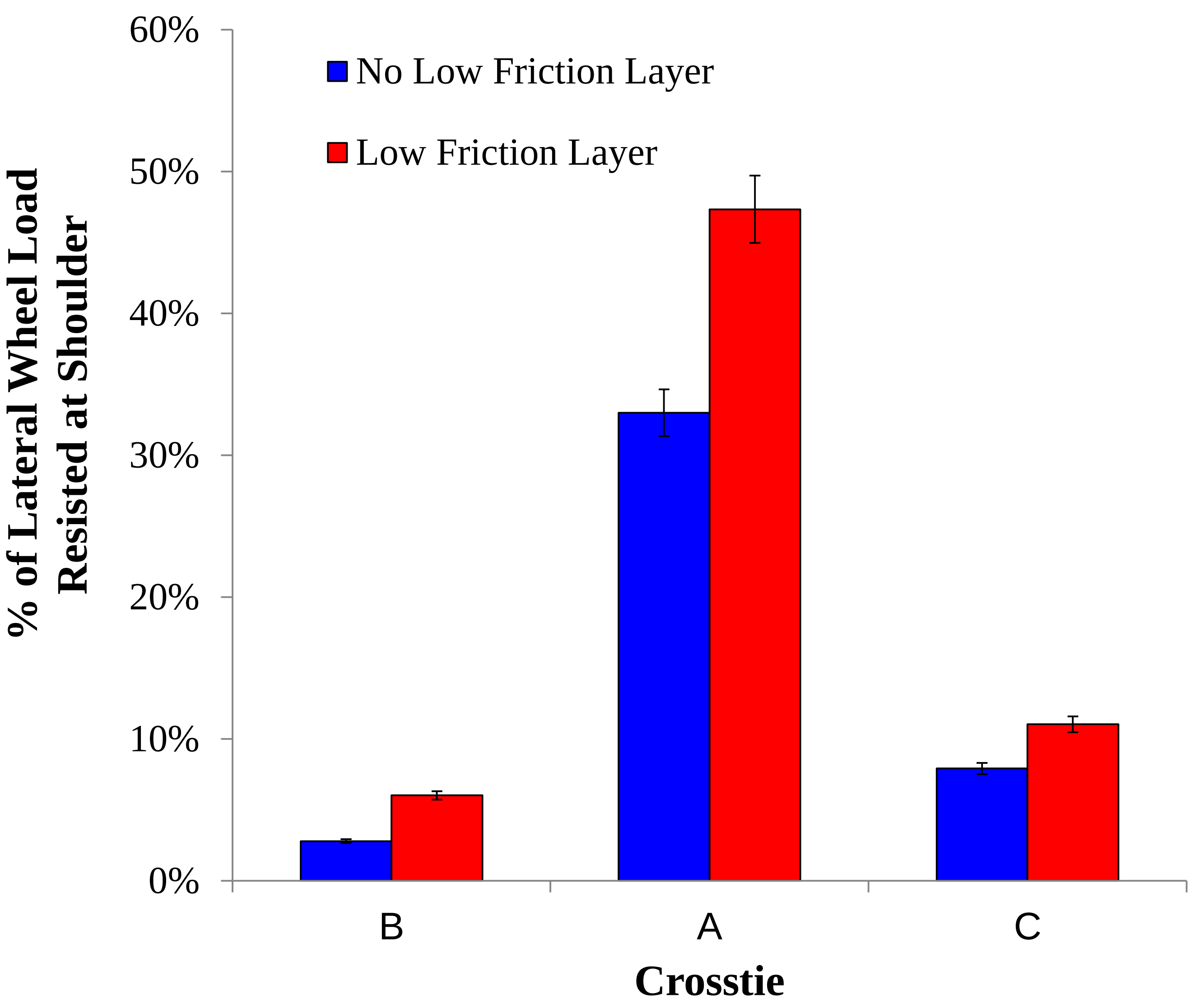
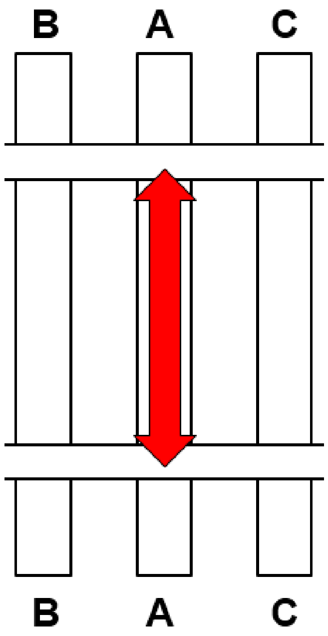
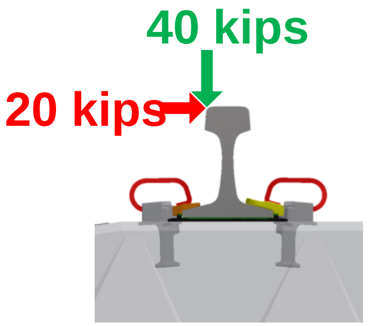
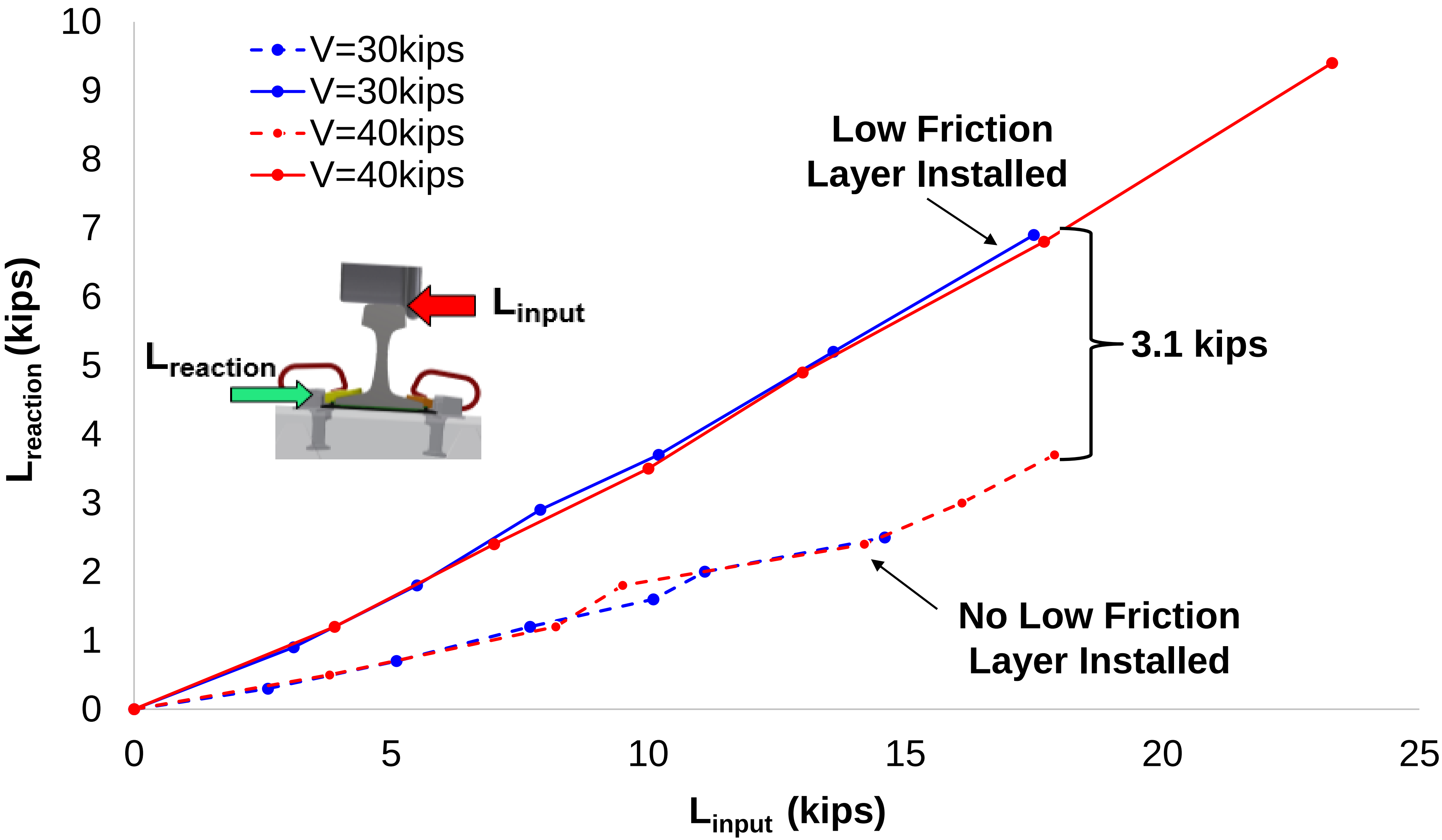


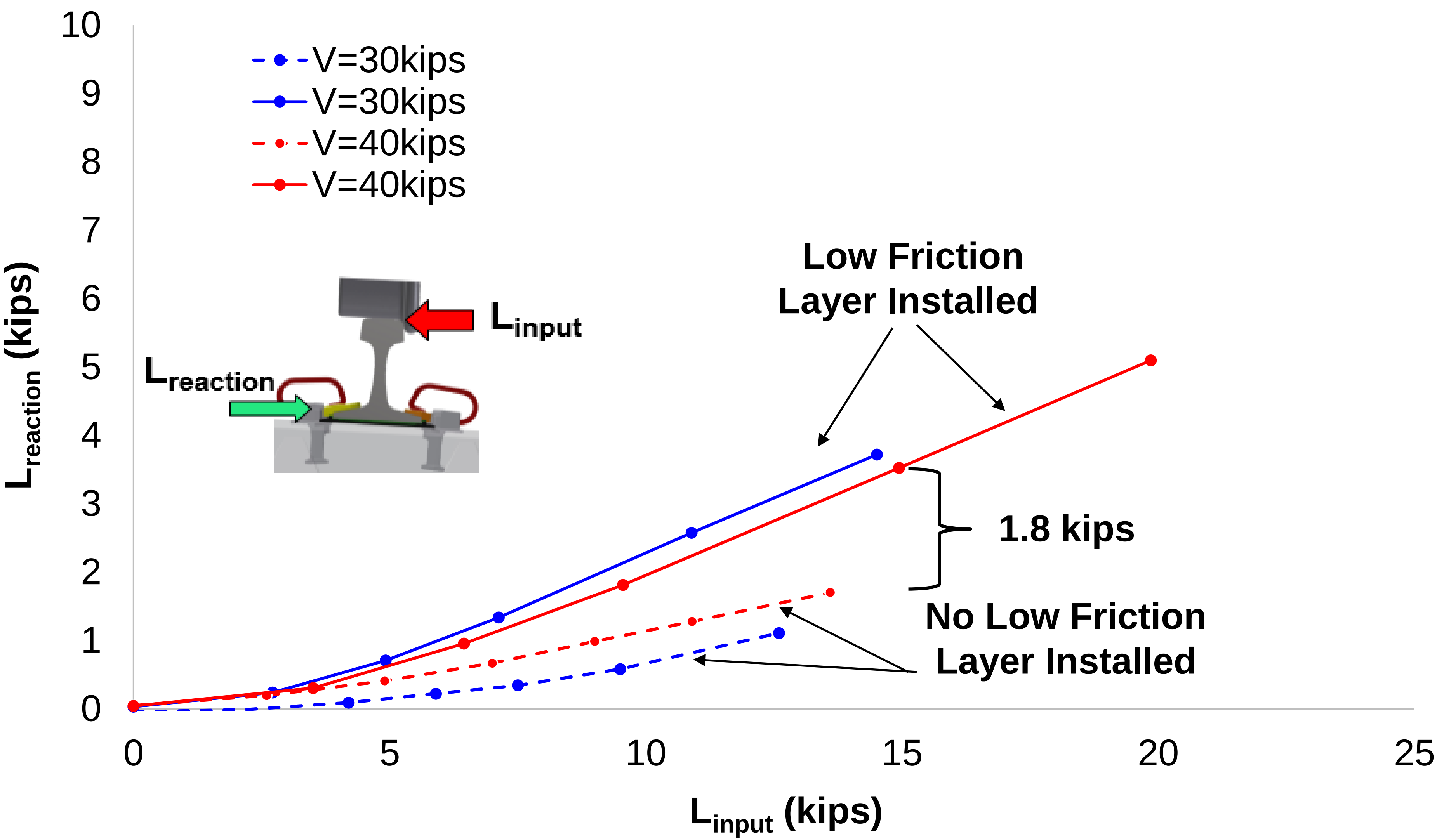




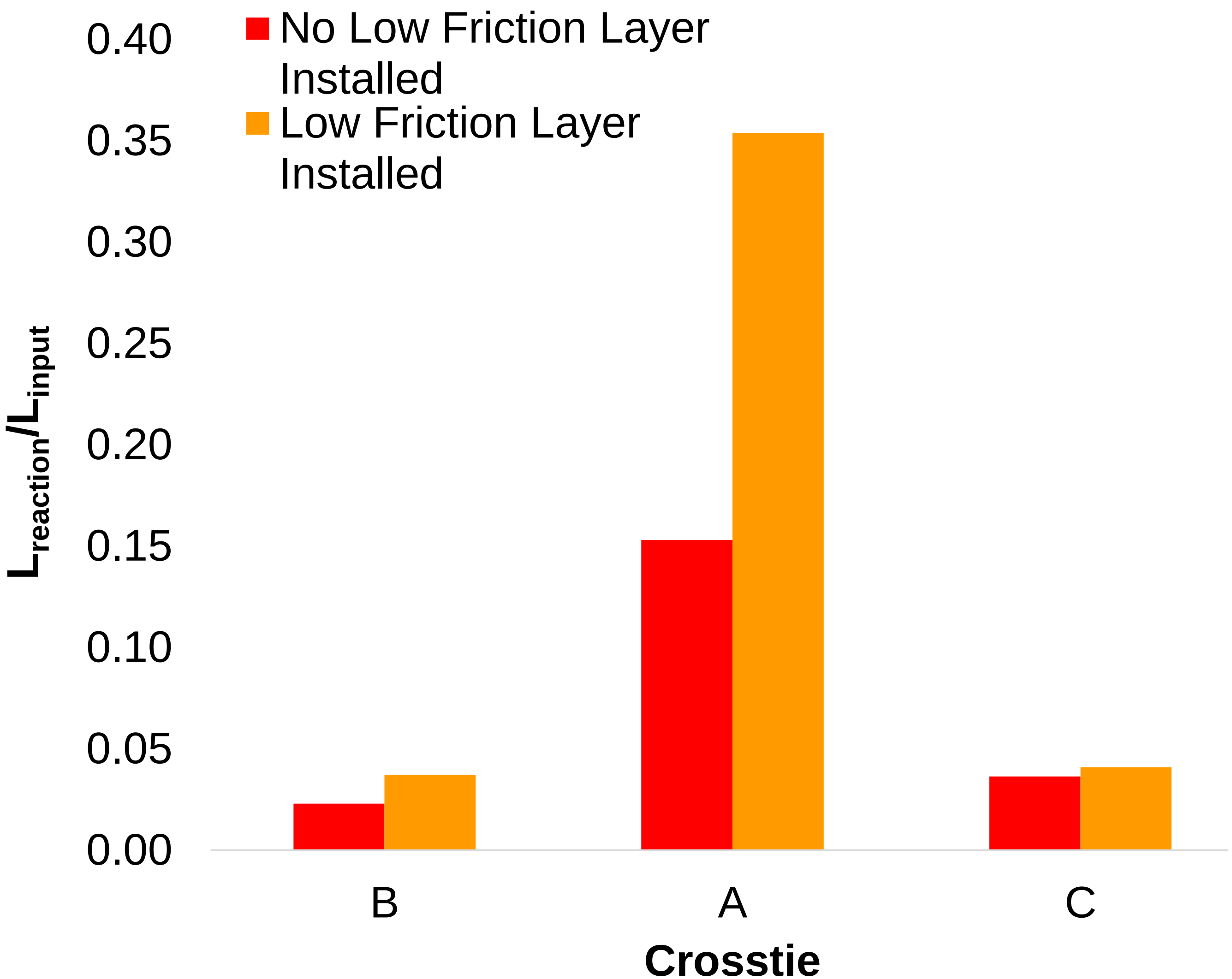
Contribution of Friction in Properly Supported Crosstie

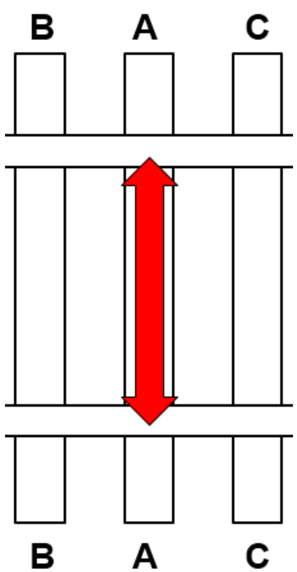


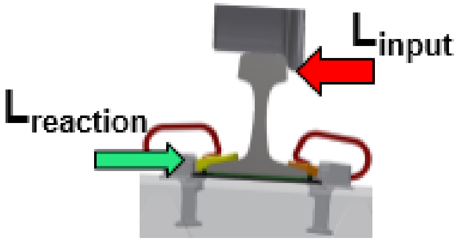
Contribution of Friction in Poorly Supported Crosstie



Global Distribution of Lateral Forces in Properly Supported Crosstie







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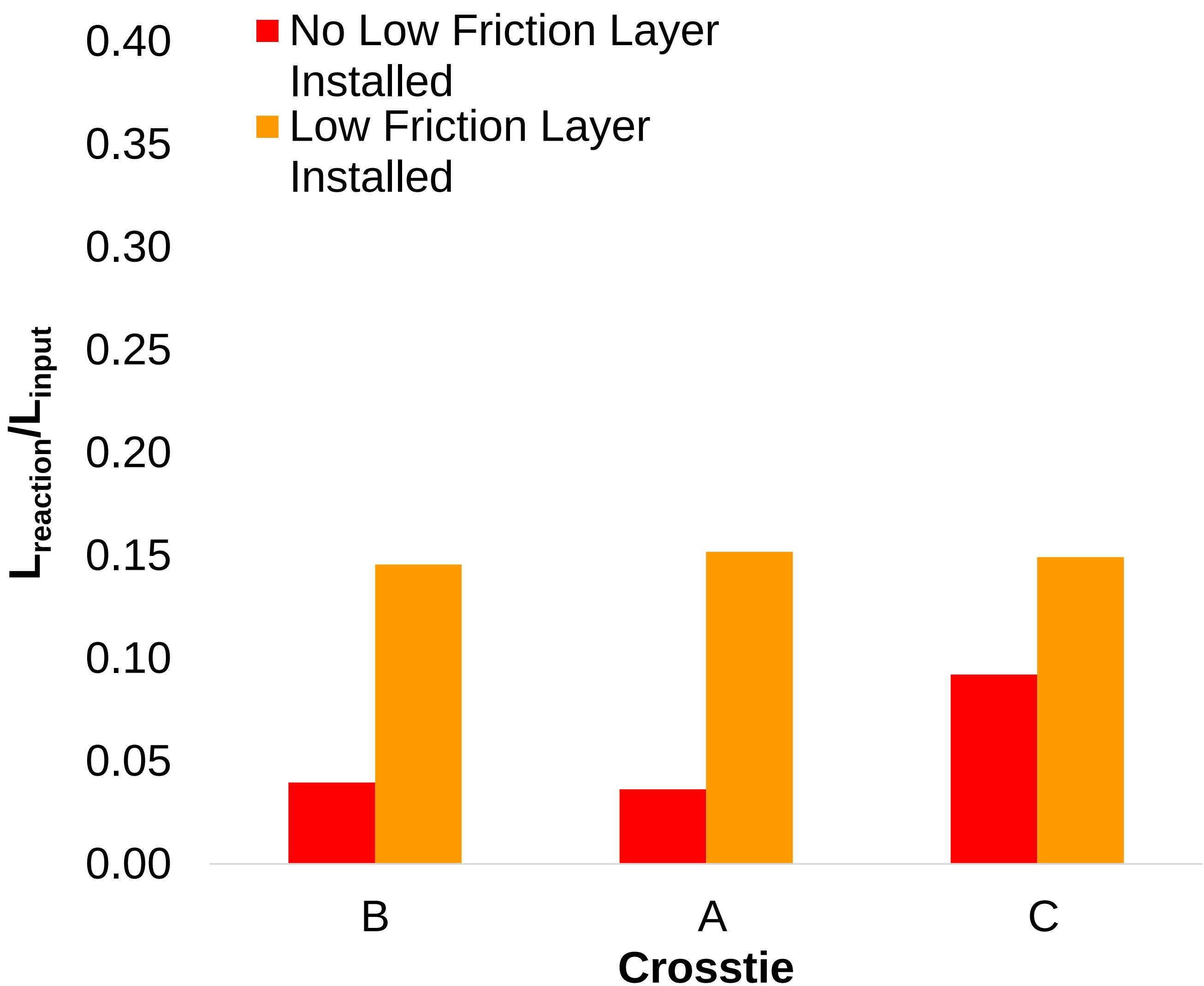

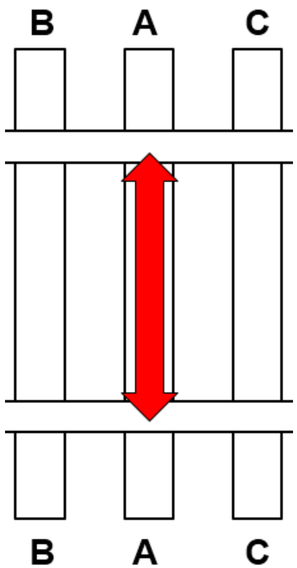

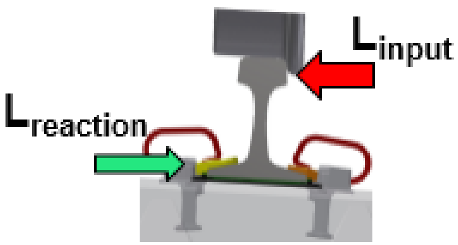

Conclusions

- A higher percentage of lateral wheel loads is transferred to the fastening system under dynamic loading than static loading
- Increasing vertical load increases the lateral bearing force against the shoulder
- Altering the lateral friction between rail pad and rail seat increases the magnitude of lateral bearing force at the shoulder
  - Implications on the design of fastening systems to better distribute lateral loads
- Support conditions influence the magnitude of lateral load transfer into the shoulder

Future Work

- Focused experimentation to better understand lateral forces through the fastening system under varying support conditions
- Investigating the lateral load distribution through the track structure with missing fastening system components
- Comparison of the lateral load performance between the spring clip (Safelok I) and the Skl style (tension clamp) fastening system

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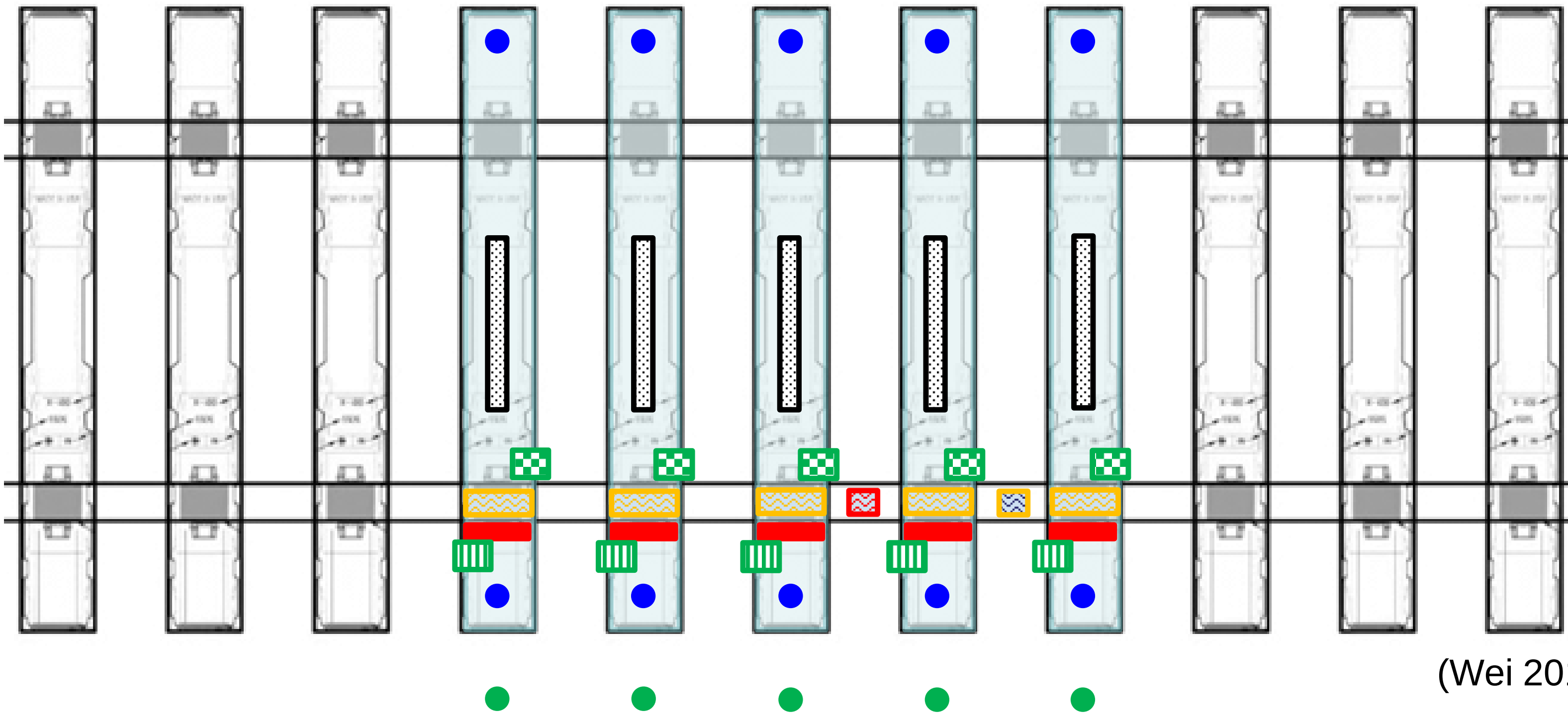
Appendix

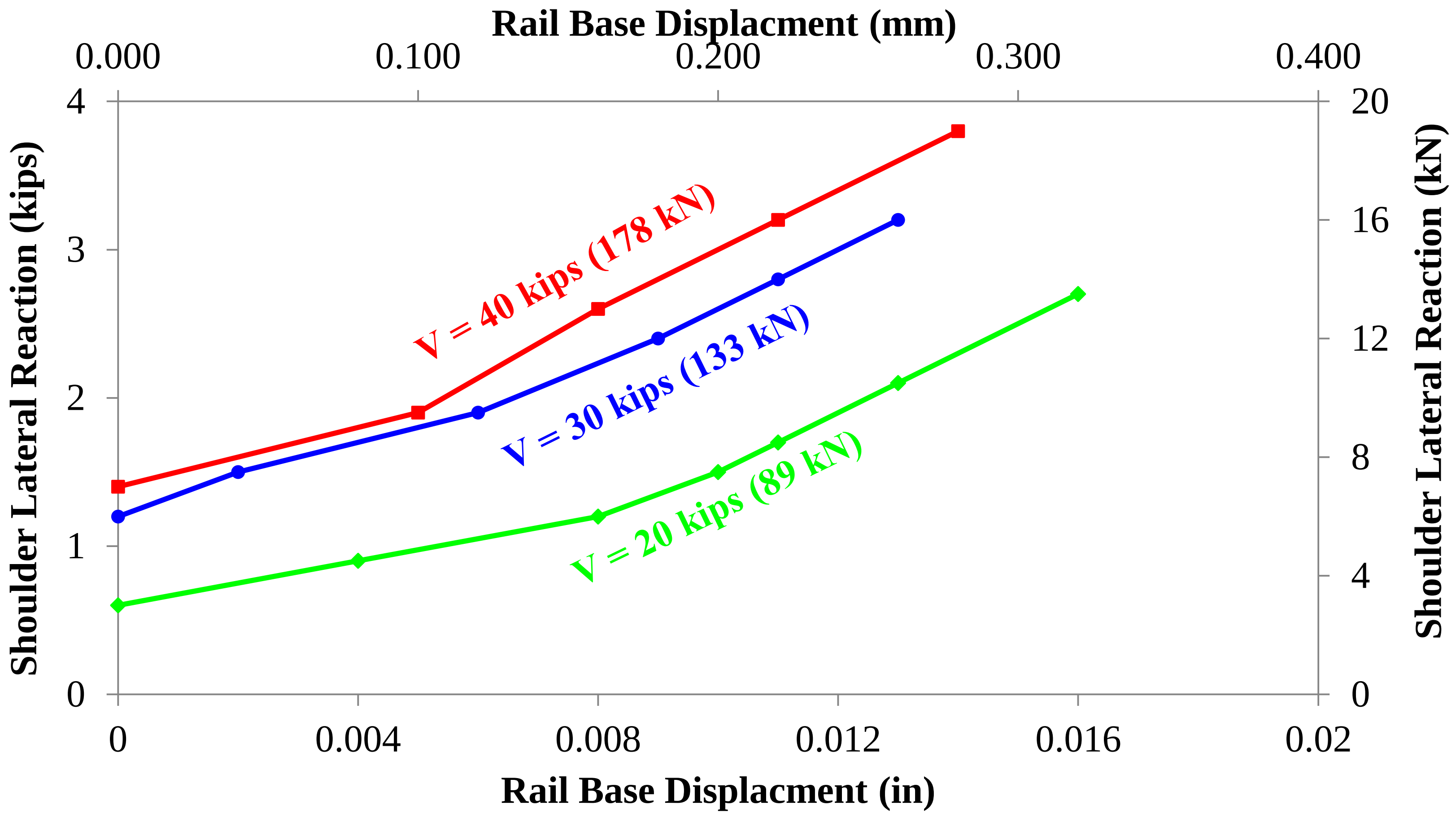
TLS Instrumentation Map



(Wei 2014)

- Lateral Load Evaluation Device (LLED)
- Lateral and Rail Seat Load Circuits
- Vertical Load Circuit
- Lateral Load Circuit
- Rail Displacement (Base Vert. Gauge, Base Lat., Web Lat.)
- Rail Displacement (Base Vert. Field)
- Embedment Gauges
- Crosstie Surface Strains
- Lateral Crosstie Displacement
- Vertical Crosstie Displacement

Lateral Stiffness



TLS Track Installation

After Clip Installation