WMATA'S DIRECT FIXATION TRACK FASTENING SYSTEM

INTERNATIONAL CROSSTIE AND FASTENING SYSTEM SYMPOSIUM

BY: RAVI AMIN, PE, WMATA

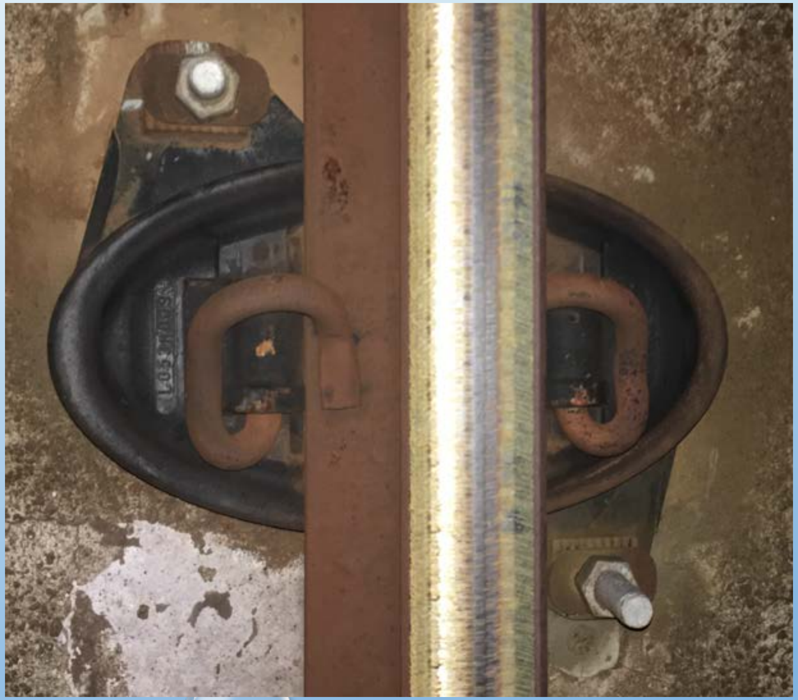
OVERVIEW OF WMATA'S RAIL SYSTEM

- 238 MAINLINE TRACK MILES, 6 ROUTE SYSTEM, ~40 MGT ON HEAVIEST LINE,
- 600K PASSENGERS ON AVERAGE DAY
- 136 MILES OF DIRECT FIXATED TRACK
- APPROXIMATELY 15 MILES OF FLOATING SLAB

PHOTOS OF TRACK FASTENERS

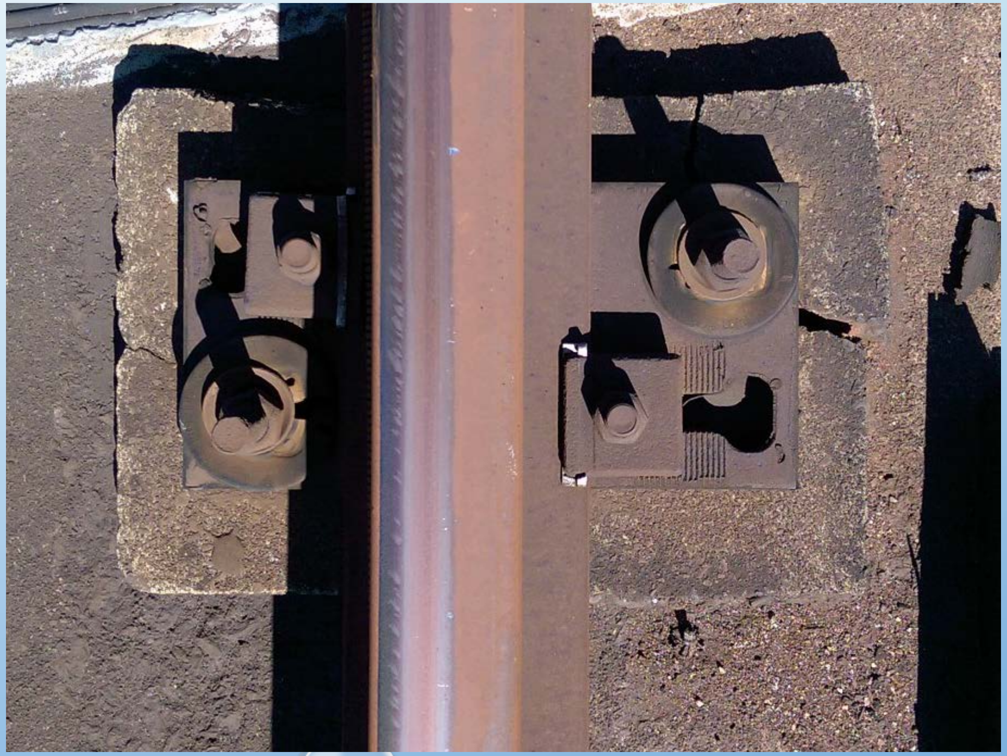
STANDARD DESIGN

RESILIENT DESIGN

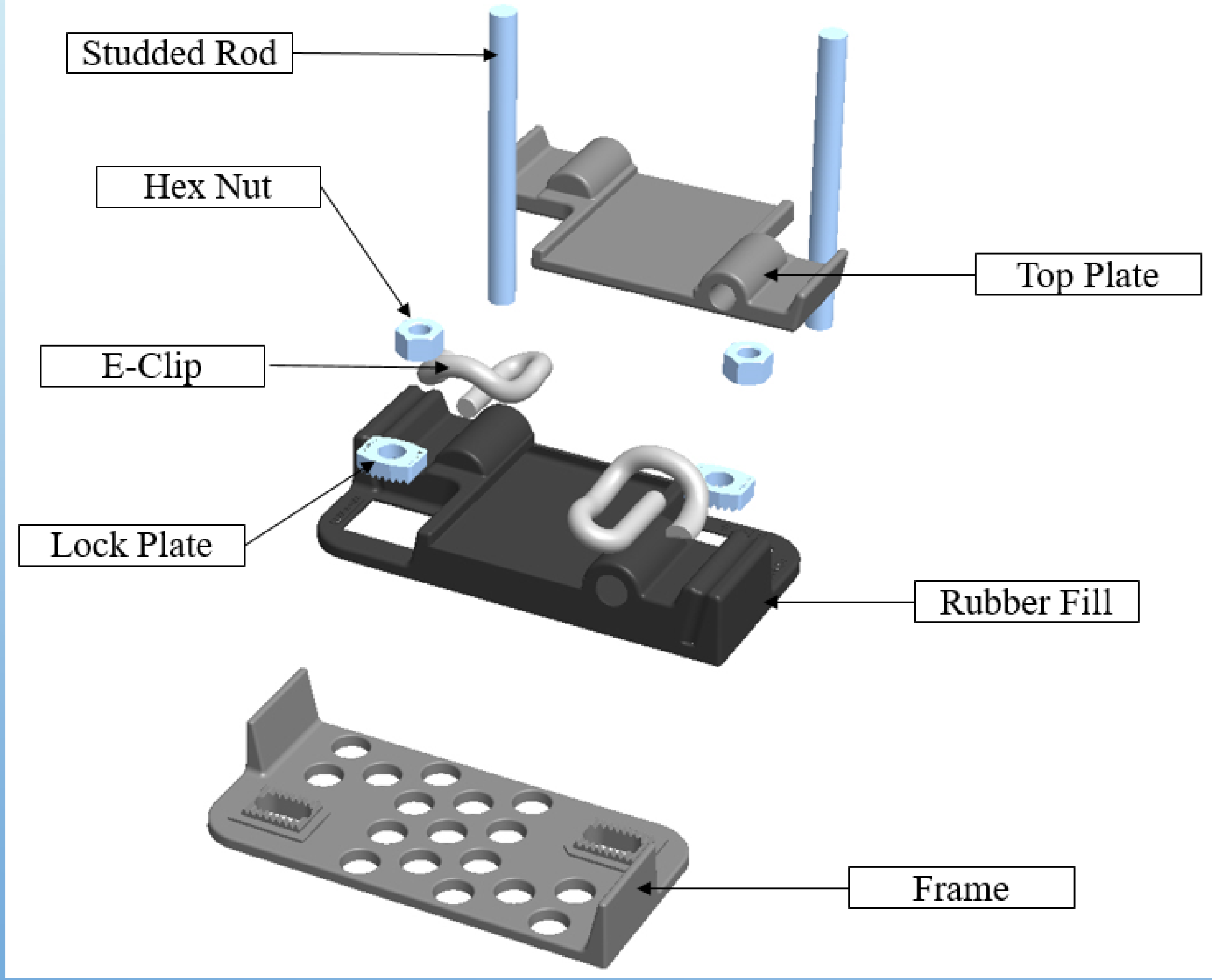


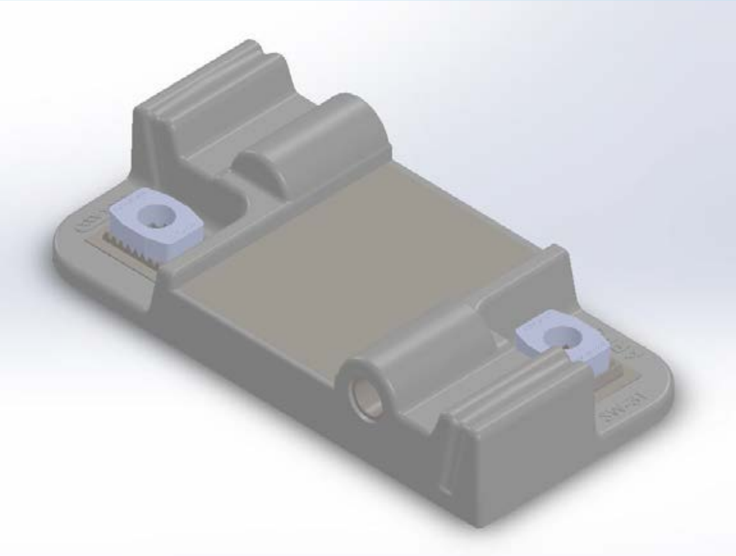
PHOTOS OF TRACK FASTENERS

LEGACY DESIGNS: HIXSON, LORD, LANDIS MODELS

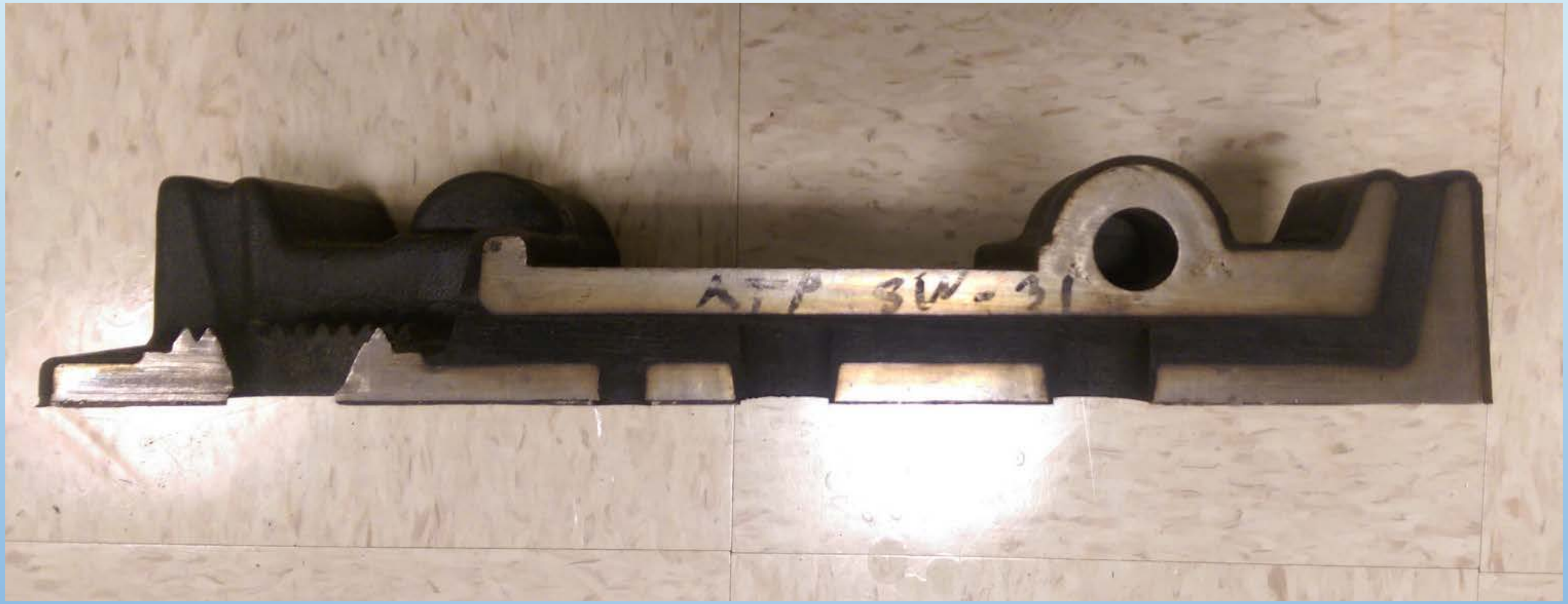


OVERVIEW OF TYPICAL FASTENER AND ANCHORAGE





CROSS SECTION OF A TYPICAL FASTENER



PERFORMANCE SPECIFICATIONS FOR DF TRACK

- ELECTRICAL ISOLATION: 10^{11} OHM-CM UNDER A WET CONDITION
- ELASTOMERIC STIFFNESS: 45-55 DUROMETER
- SPRING RATE

  STANDARD: 94K – 120K PSI

  RESILIENT: 50K -75K PSI

LATERAL AND VERTICAL LOAD CAP. IS BASED ON ALLOWED DEFLECTION VS. LOAD

- RESILIENT FASTENERS: 8 TO 12 DB OF VIBRATION
- FLOATING SLAB: 14 TO 18 DB OF VIBRATION

BENEFITS OF DF TRACK

- BALLASTED DESIGN PROVIDES LESS WEIGHT ON BRIDGE STRUCTURES, REDUCED CAPITOL COST
- TIGHTER CONTROL OF DYNAMIC ENVELOPE. REDUCED COST ON TUNNEL DESIGN AND CONSTRUCTION

DF SPECIAL TRACKWORK

FLOATING SLAB TRACK

- Applied in sensitive locations to mitigate noise and vibrations at or near the ground level.
- Resilient fasteners have been used as an alternative.

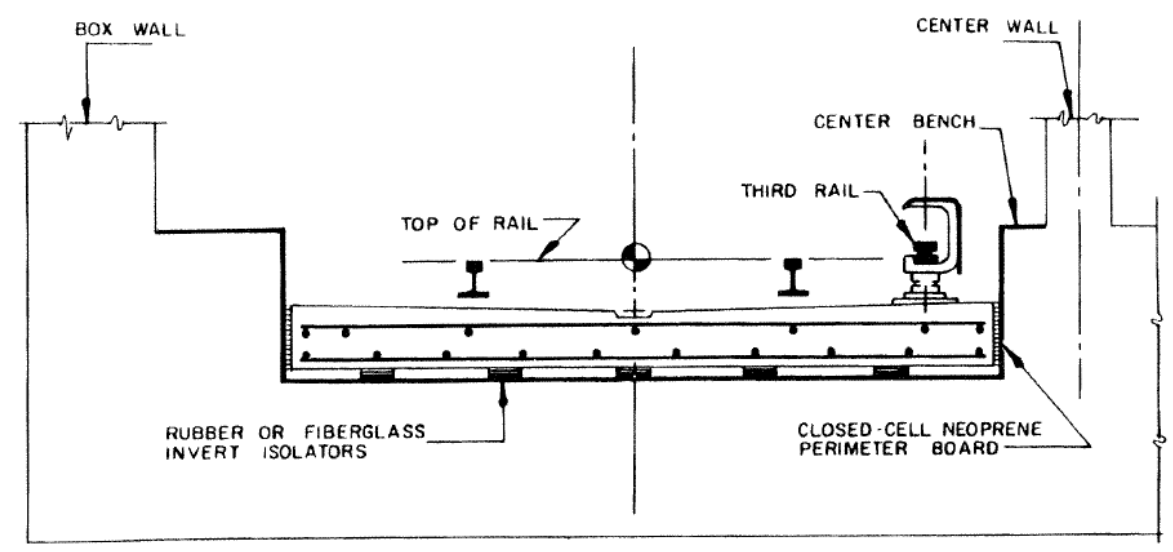


FIGURE 1 Typical floating slab section in subway box.

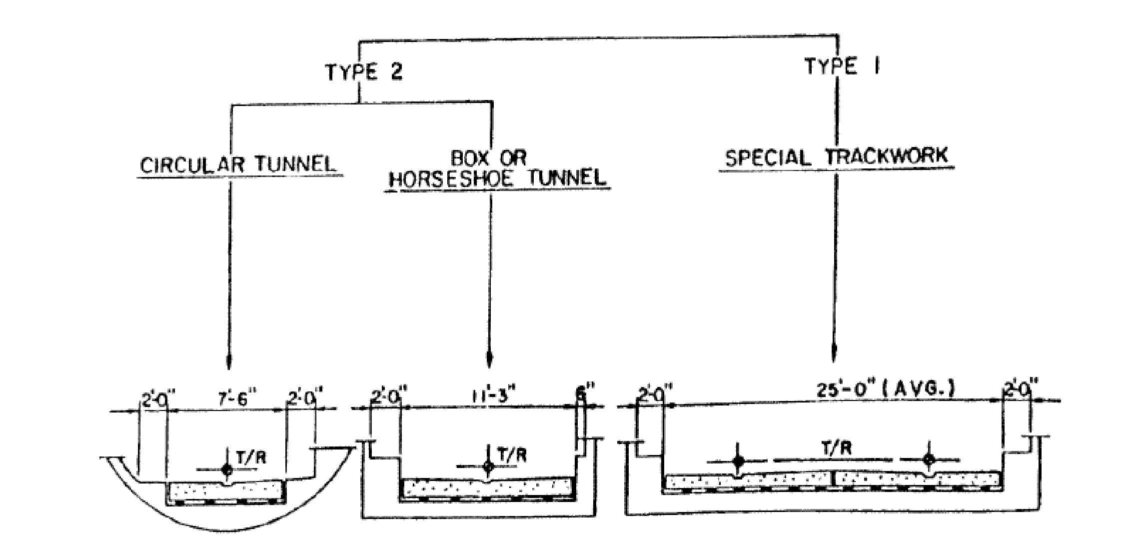


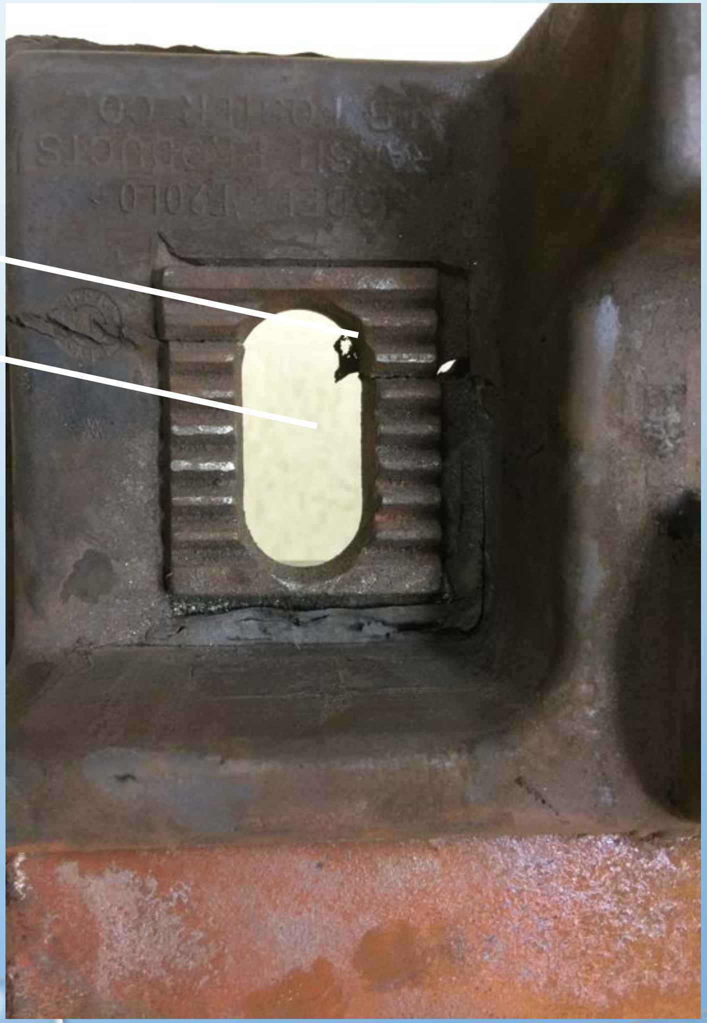
FIGURE 2 WMATA existing floating slab configurations.

PROBLEMS WITH DF TRACK

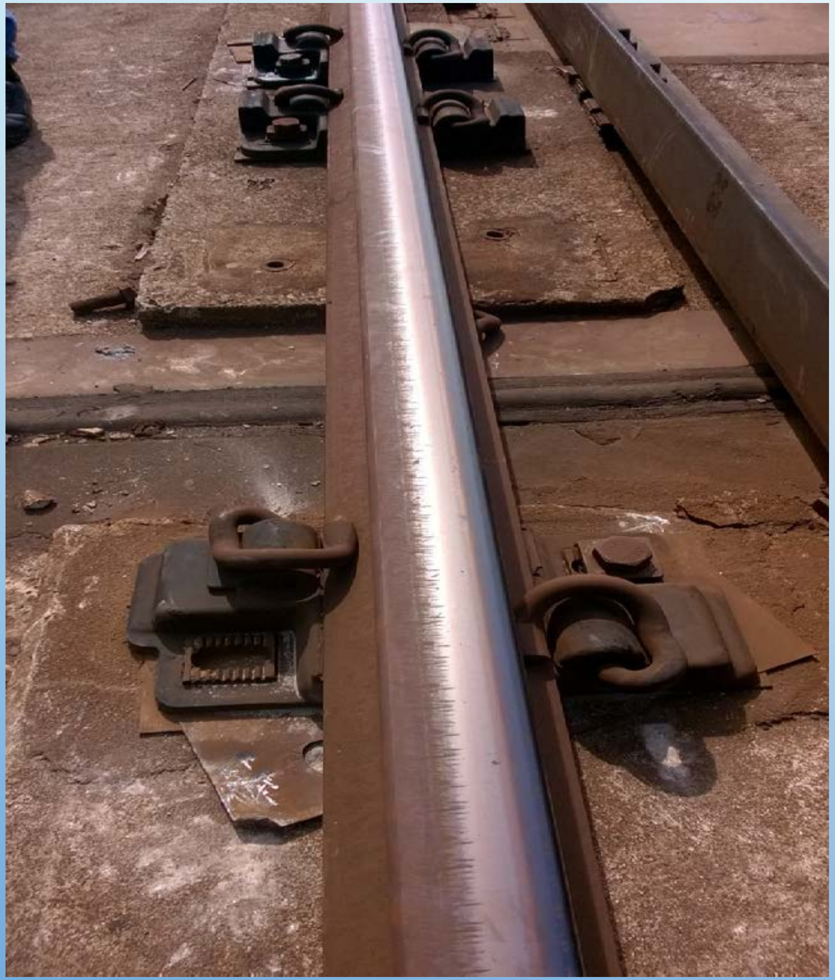
- LOOSENING OF NUTS DUE TO VIBRATIONS AND DYNAMIC TRACK LOADING
  - VERTICAL AND HORIZONTAL MOVEMENT OF THE PLATE
    - BROKEN STUDS
    - WORN WASHER SERRATIONS AND LOSS OF GAUGE RESTRAINT
    - BROKEN RAIL CLIPS
    - INCREASED RAIL FATIGUE

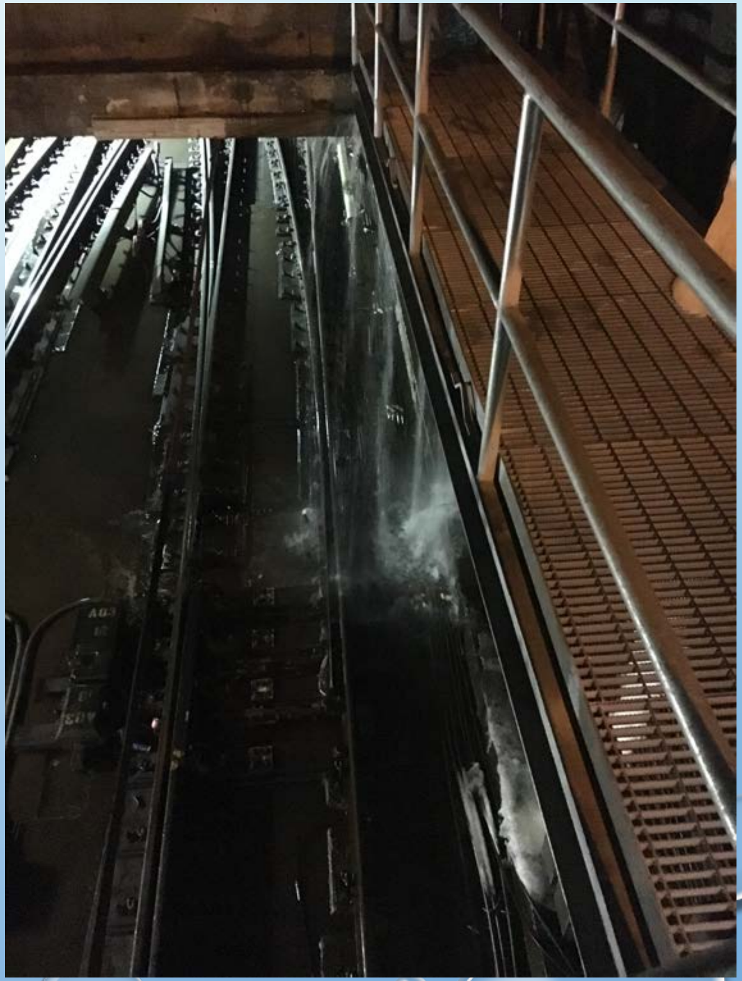
- IMPROPER SUPPORT OF THE FASTENER
    - **ALL THE ABOVE ISSUES**
    - IMPROPER CURING AND FINISHING OF MASONRY
    - BATTERED JOINTS
    - DERAILMENT DAMAGE
    - CORROSION (STRAY CURRENT)

PHOTOS OF DEFECTS



PHOTOS OF DEFECTS





FUTURE OF DF TRACK

- WMATA CONTINUES TO BUILD AND MAINTAIN DF TRACK
- MORE ATTENTION TO MATERIAL CONTROL AND FINISHING NEEDED
- SWITCHING TO FLAT GROUT PAD AND CANTED FASTENERS
- UIUC STUDY TO GUIDE UNDERSTANDING OF INTEGRITY OF CURRENT DESIGN
- PERSONALLY WOULD LIKE TO SEE REINFORCED PLINTHS ON FUTURE TRACK (LIKE DULLES EXTENSION) MORE DURABLE AND PERMANENT SUPPORT DESIGN

QUESTIONS ?

Dulles Phase II (Silver Line Extension) DF Construction

Field Investigation of the Performance of Direct Fixation Fastening Systems on Heavy Rail Transit Infrastructure

Luis W. Chavez Quiroz, Yu Qian, J. Riley Edwards, and Marcus S. Dersch

International Crosstie and Fastening System Symposium

15 May 2018

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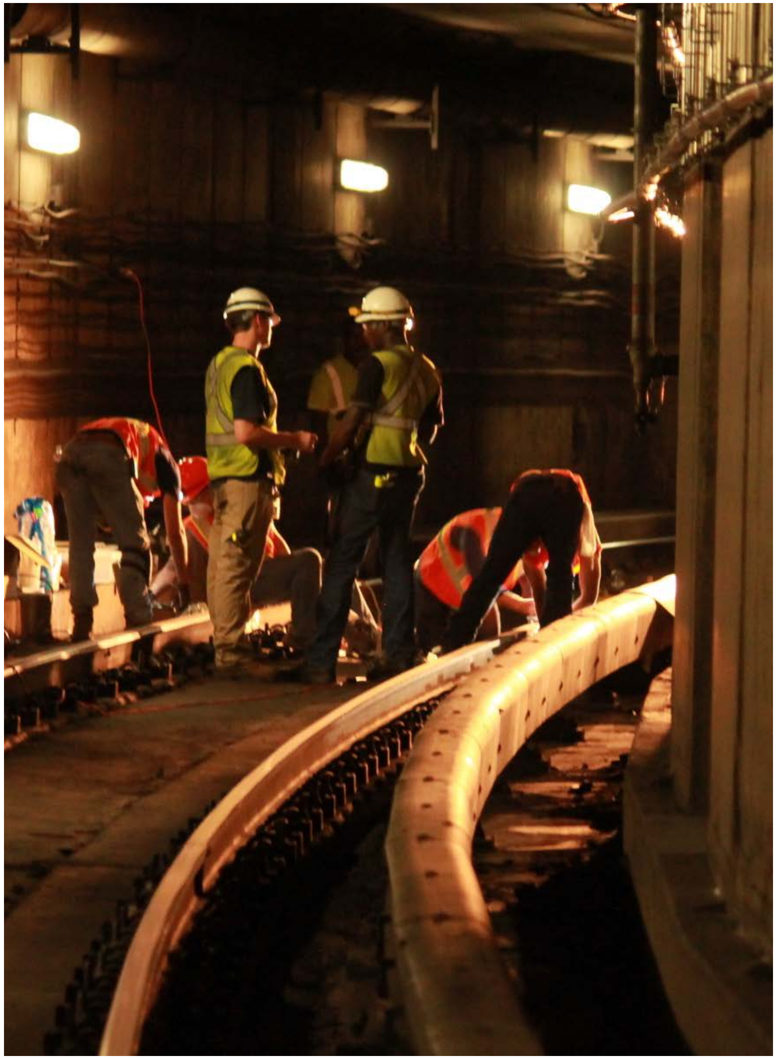
metro

Outline

- Objectives & Approach
- Field Experimentation
  - Sites
  - Results
- Finite Element (FE) Model
  - Fastener Failures
  - Stress Concentrations
  - Recommendations
- Results
- Conclusions



Research Motivation

Mission:

Perform a comprehensive study of WMATA’s (Washington Metropolitan Area Transit Authority) track fastening systems to quantify typical load environment and response of the existing fastening system design, then develop analytical models to investigate their performance and recommend alternative designs.

Key Objectives:

- Compare WMATA’s direct fixation track system to industry best practices
- Quantify field performance of fastening systems
- Use finite element (FE) modeling to perform parametric study on fastening system behavior
- Provide recommendations for improved fastening system design and maintenance

Project Approach


quantification of the wheel–rail
rface of rail vehicles for the
rastructure of light rail, heavy rail,
nd commuter rail transit

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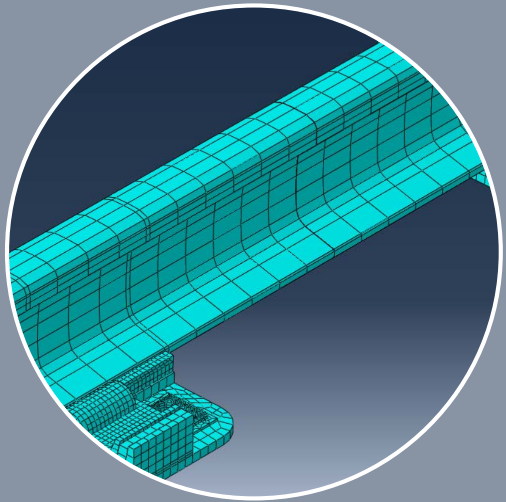
Xiao Lin, J Riley Edwards, Marcus S Dersch, Thomas A Roadcap and Conrad Ruppert Jr

Abstract
The type and magnitude of loads that pass through the track superstructure have a great impact on both the design and the performance of the concrete crossties and fastening systems. To date, the majority of North American research tha focus on quantifying the rail infrastructure loading conditions has been conducted on heavy-haul freight railroad However, the results and recommendations of these studies may not be applicable to the rail transit industry due variety of factors. Unlike the freight railroads, which have standardized maximum gross rail loads and superstruct sign practices for vehicles, the rail transit industry is home to a significant variety of vehicle and infrastructure des e of the current transit infrastructure design practices, which were established decades ago, need to be update t to the current loading environment, infrastructure types, and understanding of the component and syste . This study focuses on quantifying the current load environment for light rail, heavy rail, and com frastructure in the United States. As an initial phase of this study, researchers at the University mpaign (UIUC) have conducted a literature review of different metrics, which is used to eval t, and rail seat loads for the rail transit infrastructure. UIUC will compare these me to determine which provide the most accurate depictions of the expected loading structure characteristics. A proper load quantification of rail transit syst of the load path and rail seat load, will help to establish the basis n process for the rail transit infrastructure component increase the effectiveness of their capital sp and the life cycle of

Literature Review

Field Testing



Finite Element Modeling

Linked together - field results inform and assist in calibrating finite element model

Field Experimentation

Objectives:

- ► Quantify fastening system behavior when subjected to revenue service load environment
  - Loading magnitude on rail
  - Displacement levels of rail
- ► Compare these conditions to the failure modes that have been seen in the field
- ► Understand variability in loading and displacement associated with rolling stock operation
- ► Generate data set for model calibration and validation

Approach:

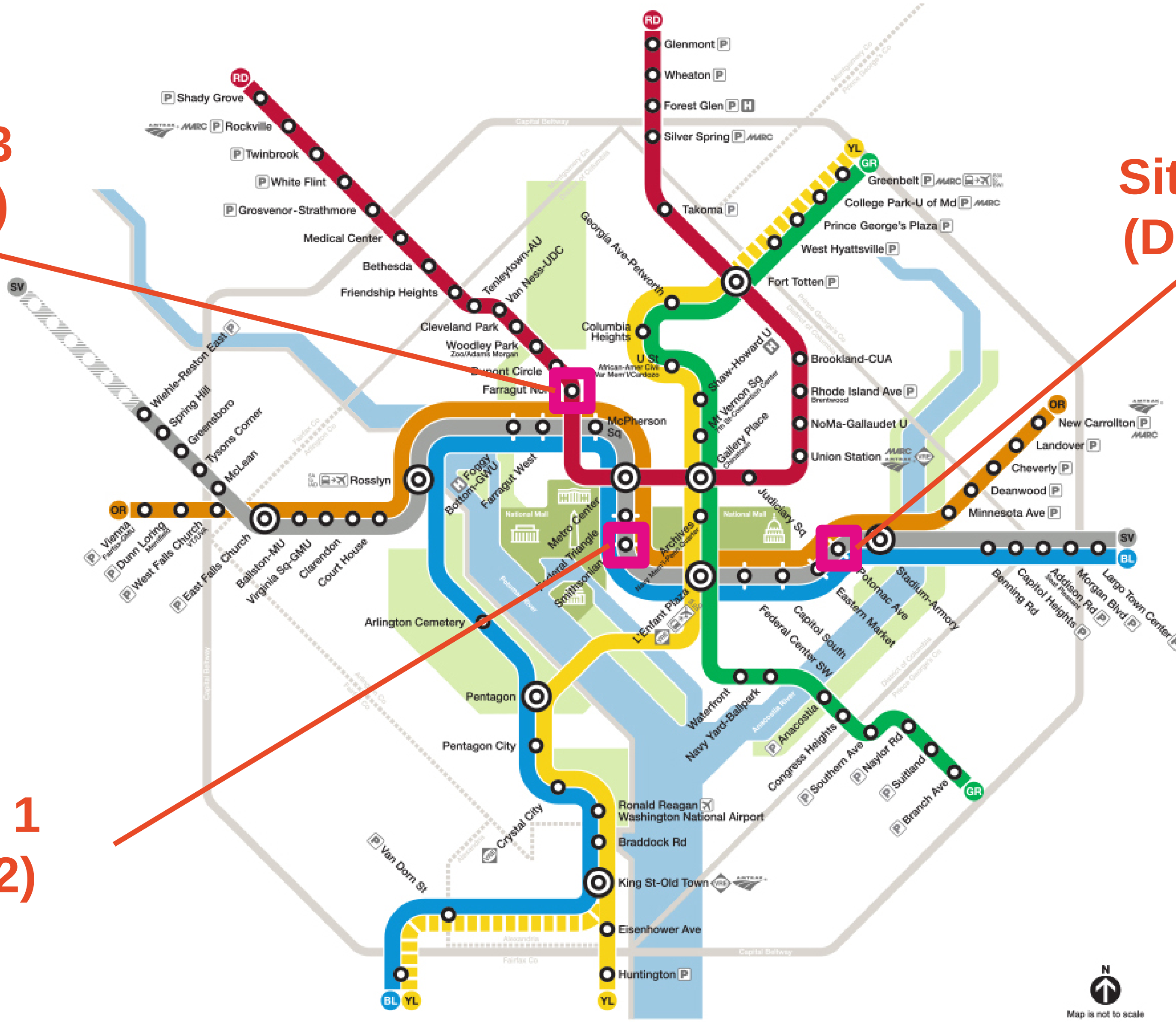
1. Instrument three locations on WMATA infrastructure
2. Monitor typical peak service loads and displacements

Locations of WMATA Field Sites

Site 3
(A02)

Site 2
(D07)

Site 1
(D02)



Site 1 | Smithsonian (D02)

Site 2 | Potomac Ave. (D07)

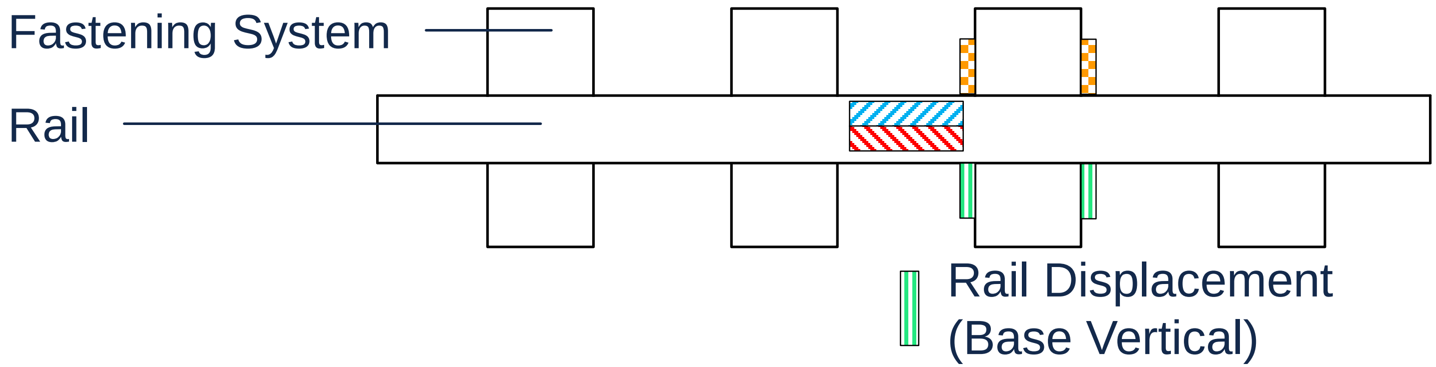
Site 3 | Farragut North (A02)

WMATA Site Summary

Descriptor Category	Site 1	Site 2	Site 3
WMATA Site ID	D02	D07	A02
Service Line(s)	Blue, Orange, Silver	Blue, Orange, Silver	Red
Curve Radius (ft)	769	755	1,200
Degree of Curve (°)	7.44°	7.59°	4.77°
Max Speed (mph)	35	40	50
Balance Speed (mph)	24	27	36
Actual Superelevation (E_a)	3.00”	4.00”	4.00”
Unbalanced Super. (E_u)	3.38”	4.50”	4.36”

WMATA Field Instrumentation Map

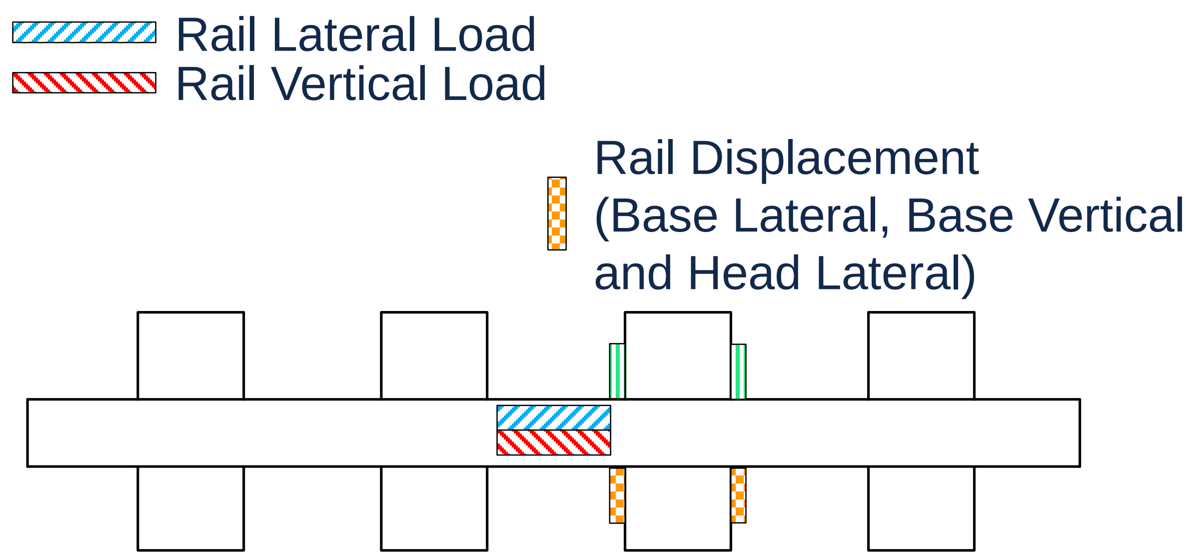
Deployed at All Three Sites



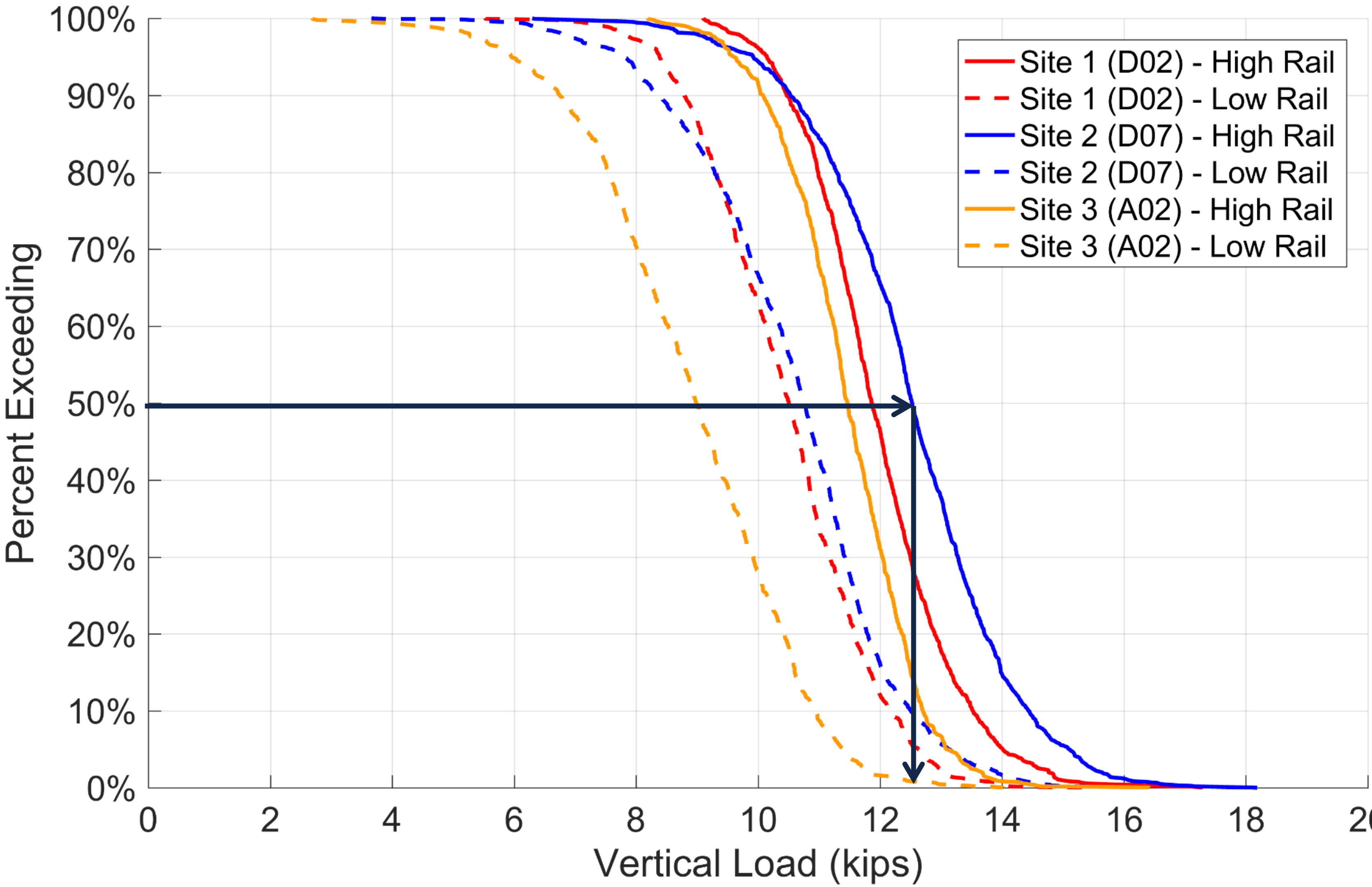
Metrics to quantify:

– **Vertical and lateral loads (wheel-rail interface)**

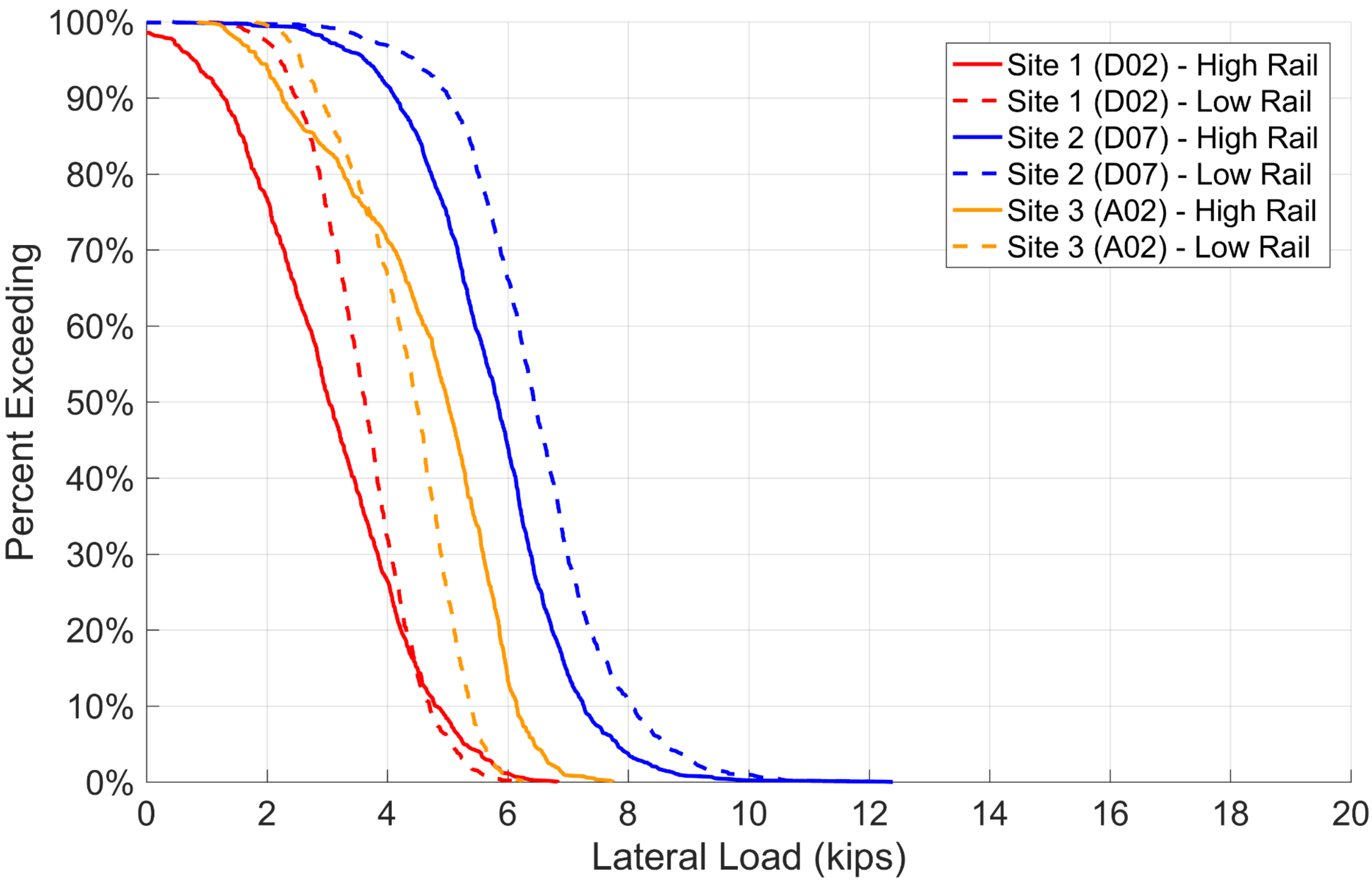
– **Rail displacements**



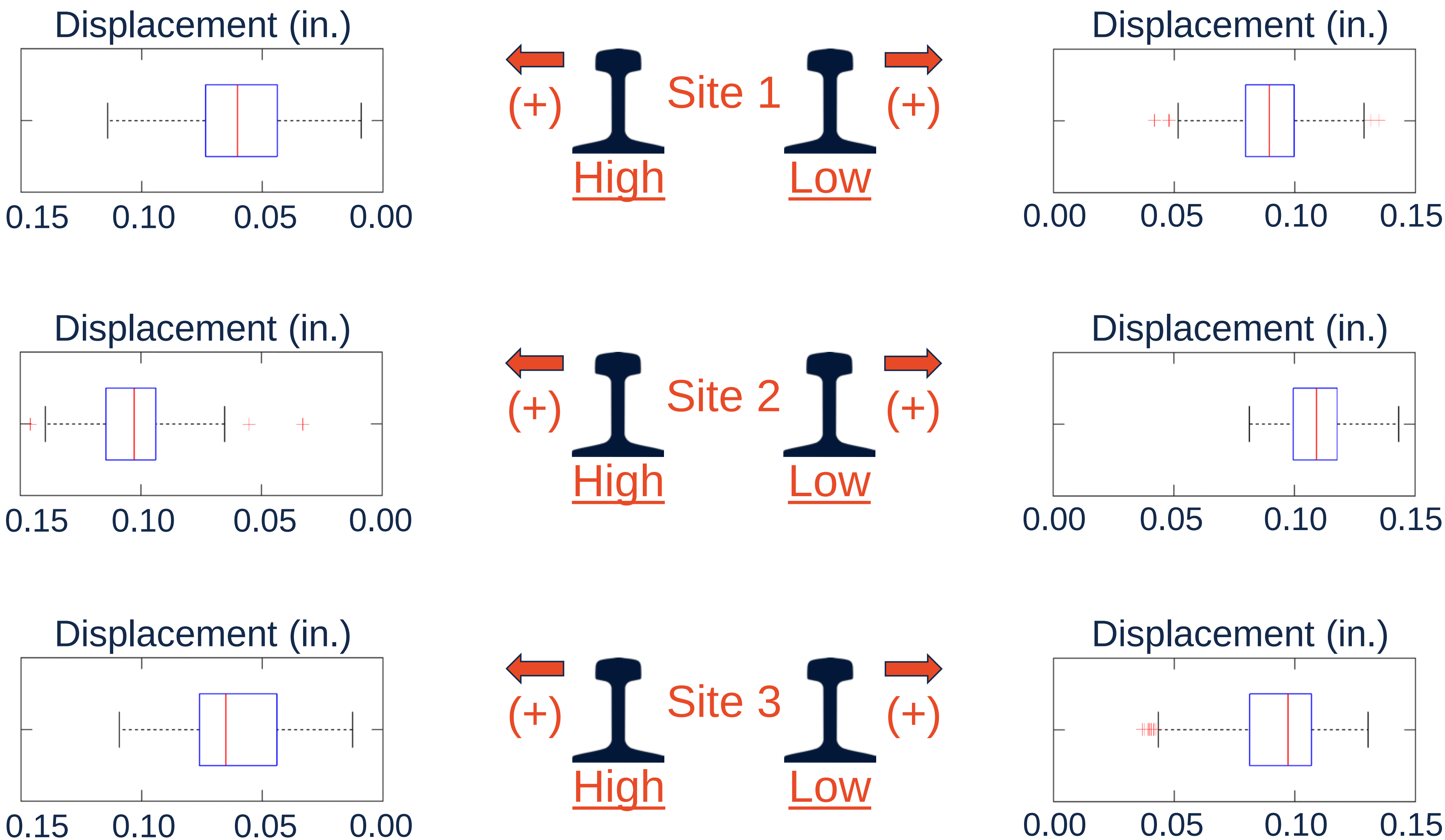
Vertical Wheel Loads



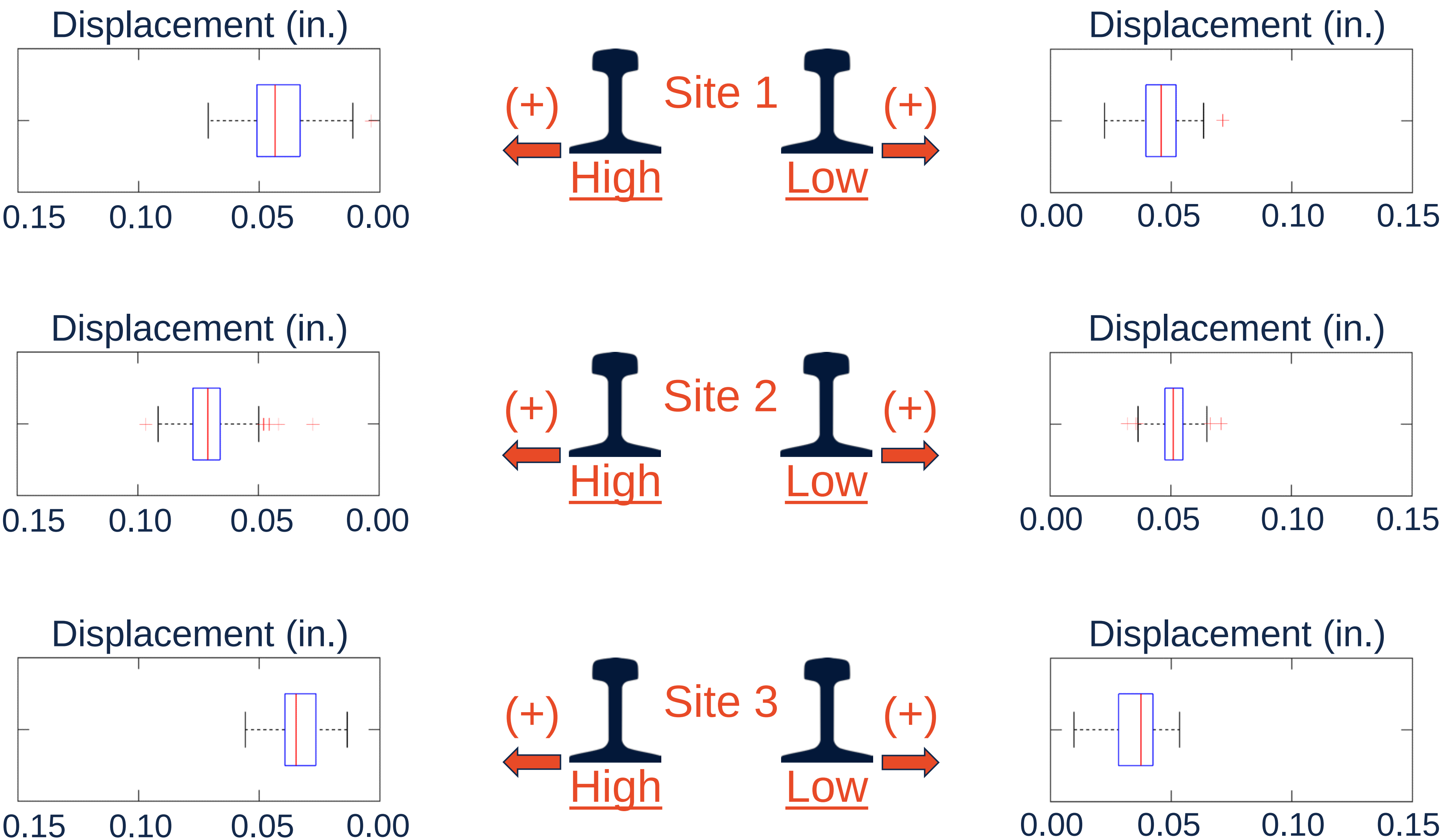
Lateral Wheel Loads



Rail Head Displacement – Lateral



Rail Base Displacement – Lateral



Conclusions

Field Experimentation

- Field study allowed us to quantify loading environment, 99th percentiles for three sites were as follows:
  - Vertical loads → 12.4 – 15.9 kips
  - Lateral loads → 5.6 – 9.8 kips
- Median lateral rail head displacement → 0.06 – 0.10 in.
- Maximum gauge widening → 0.27 in.
- Site 2 (D07) showed greater displacements and higher loads
- High rail consistently sees greater vertical loads at all speeds
- Site 1 (D02) had maintenance activities performed prior to data collection may have influenced results

Finite Element (FE) Model

Objectives:

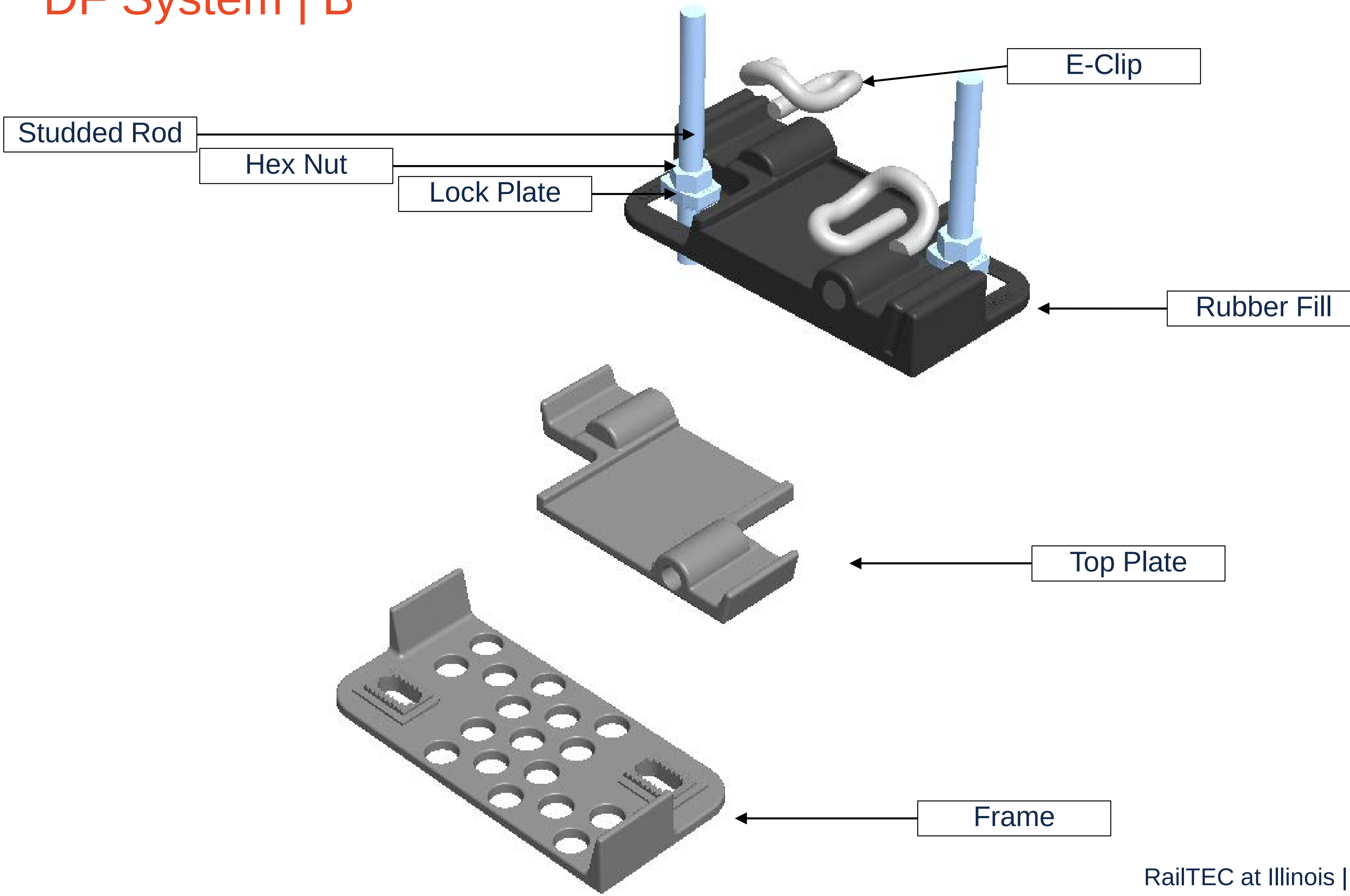
- Evaluate the effect of the following on WMATA's existing fastener
  - Fasteners mounted on uneven surfaces
  - Fasteners mounted on shim(s)
  - Shim material
- Determine if support condition can withstand load environment
  - Stress criteria
  - Displacement criteria
- Provide recommendations on fastener design and maintenance

Approach:

1. Develop half-track model for simulation
2. Address condition changes via project matrix

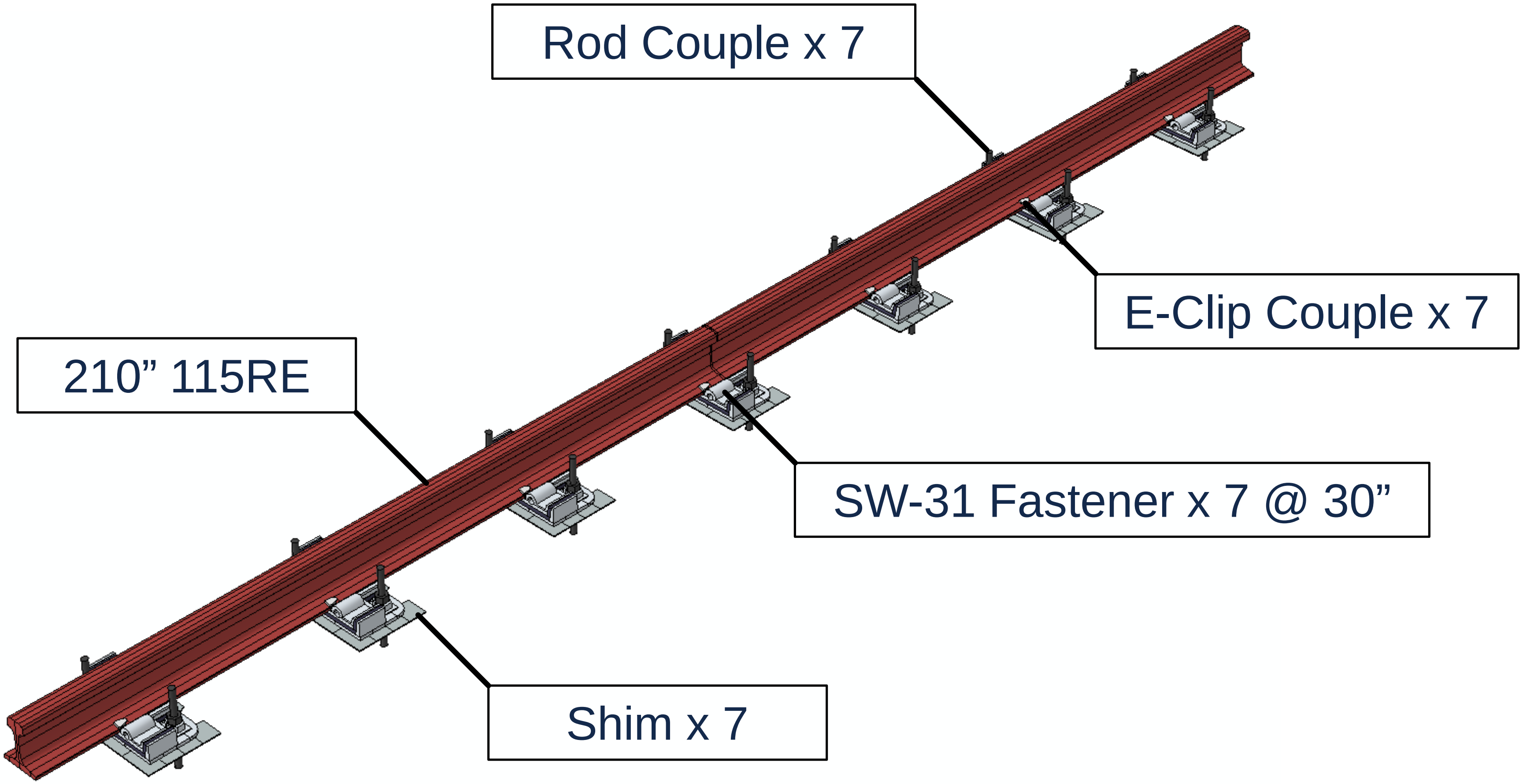
Direct Fixation System on WMATA

DF System | B



Model Environment

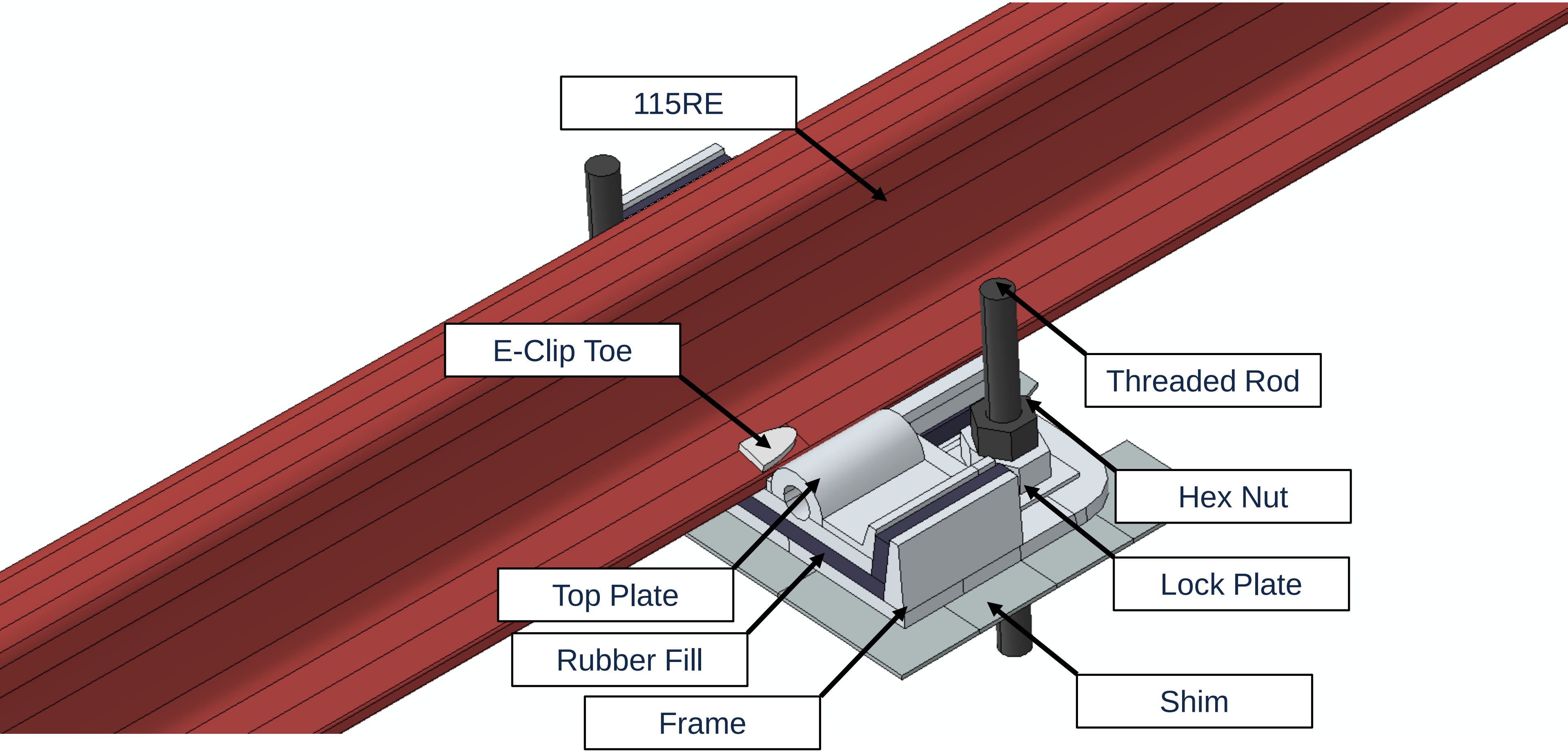
Full Size, Half-Track Model



17’6” 115RE on 7 x SW-31 Fasteners @ 30”

Model Environment

Full Size, Half-Track Model

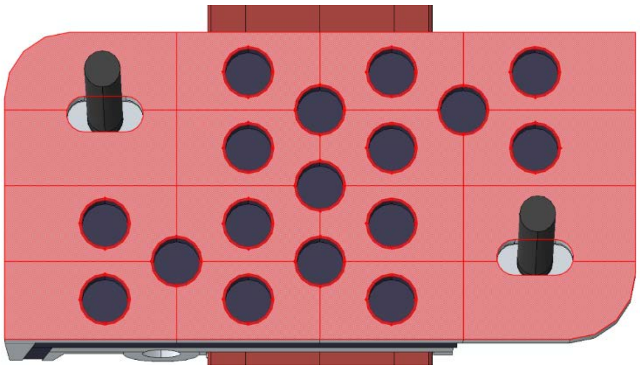


17’6” 115RE on 7 x SW-31 Fasteners @ 30”

Model Environment – Example Scenerio

Fastener Support | A

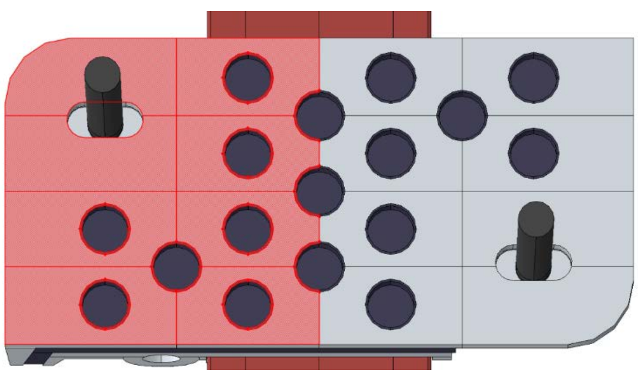
A



Fully Pinned
Model Environment

100% Cover

Fully Pinned
Lab Environment

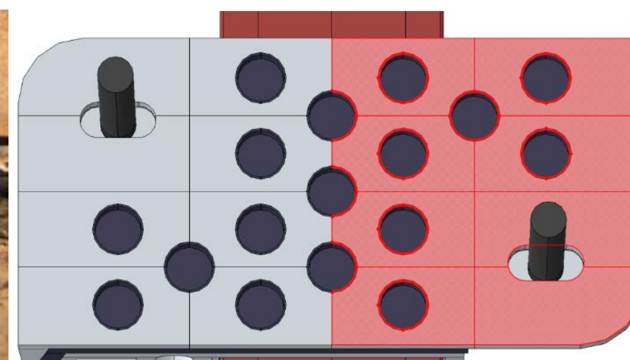


Half Pinned (Field Side)
Model Environment

B

Half Pinned (Field Side)
Field Environment
50% Cover

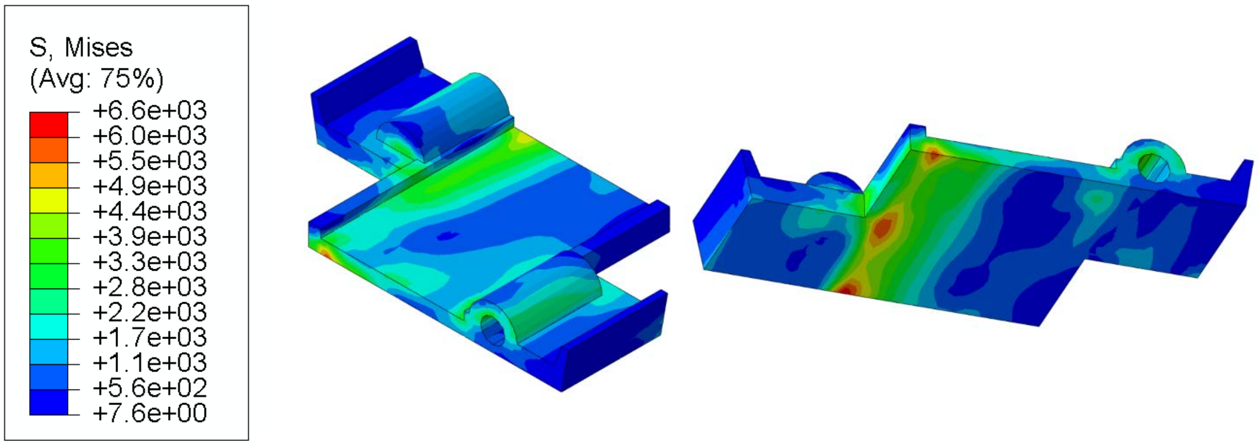
C

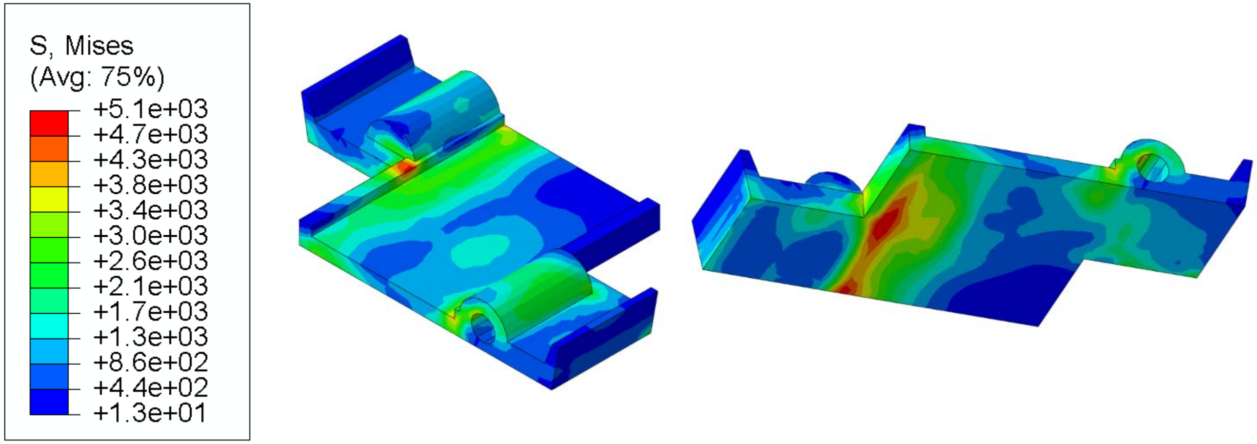


Half Pinned (Gauge Side)
Model Environment

Qualitative Model Results

Stress Concentrations | Top Plate





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  - **Washington Metropolitan Area Transit Authority (WMATA)**

- Special thanks to Progress Rail Services (PRS) for continued assistance with the understanding of the SW-31 fastener and for participation from LB Foster

- For assistance with field instrumentation preparation and manufacturing PDMDs
  - UIUC Machine Shop

Path to Completion


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...quantification of the wheel–rail
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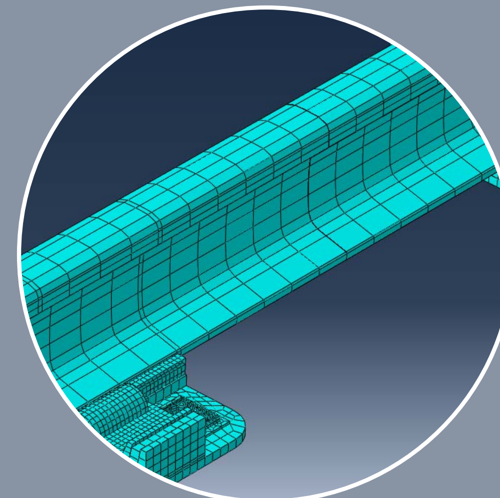

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Linked together - field results inform and assist in calibrating finite element model

Thank you for your attention!

J. Riley Edwards, P.E.
Research Scientist and Senior Lecturer
jedward2@illinois.edu

University of Illinois at Urbana-Champaign (UIUC)
Rail Transportation and Engineering Center (RailTEC)

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Rail Base Displacement – Vertical