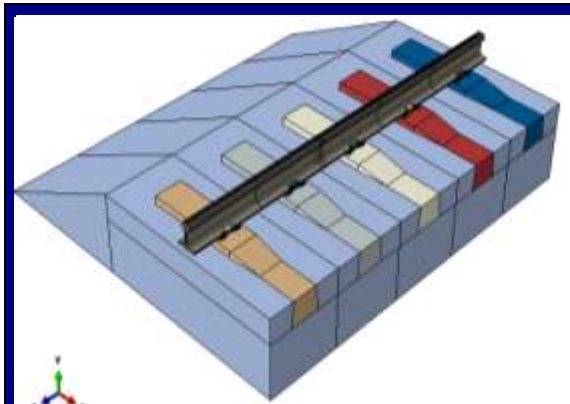
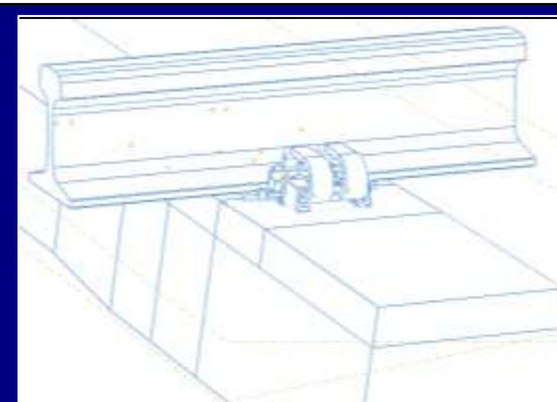
Finite Element Modeling Crosstie and Fastening System at UIUC





Joint Rail Conference 2013

Knoxville, TN

18 April 2013

Moochul Shin, George Zhe Chen and Professor Bassem O. Andrawes

U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Research Objective and the Role of Modeling
- State of the Art
- Component Modeling
- System Modeling
  - Fastening System (2D and 3D)
  - Single-Tie System Modeling
  - Multiple-Tie System Modeling
- Conclusions
- Future Work

FRA Tie and Fastener Project Structure

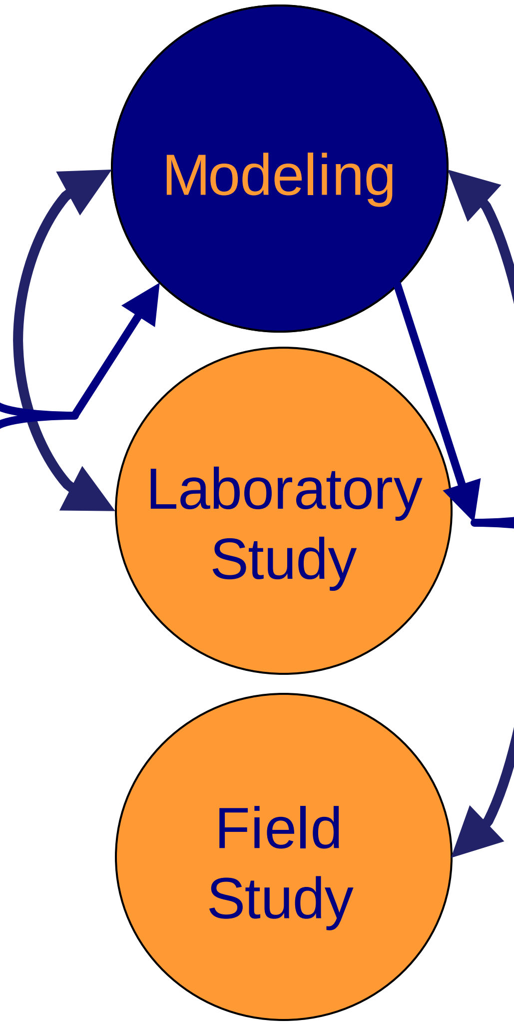
Inputs

Comprehensive Literature Review

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

Validated Tie and Fastening System Model

Load Path Map

Parametric Analysis

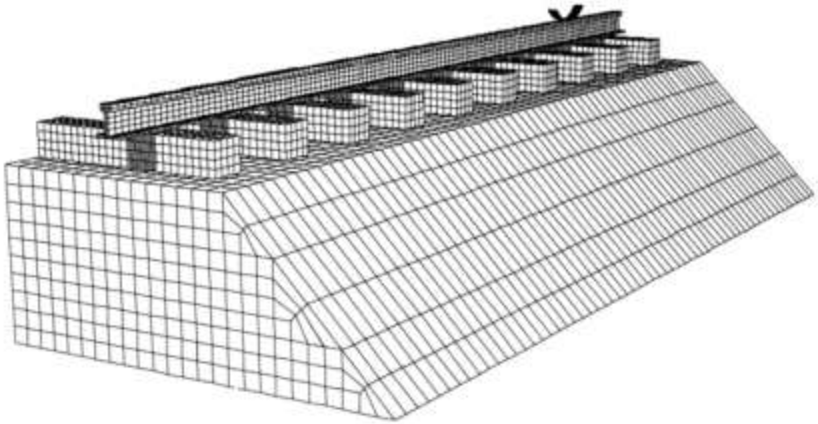
State of Practice Report

Improved Recommended Practices

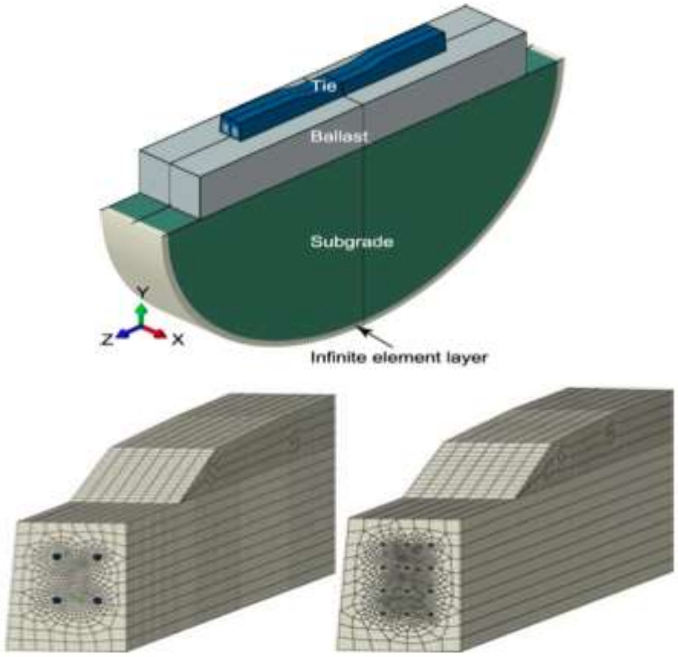
State of the Art

Track System Modeling

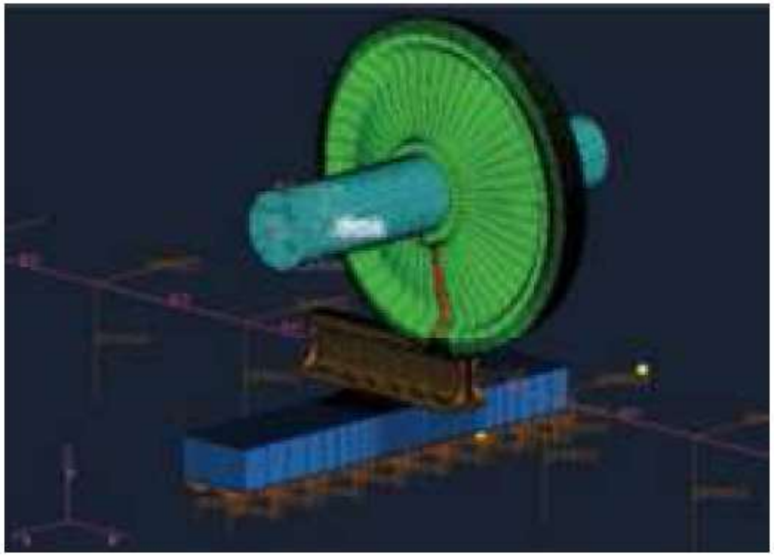
- Simplified fastening systems
- Focused on vertical loading
- Simplified support conditions



(Lundqvist and Dahlberg, 2005 - Sweden)

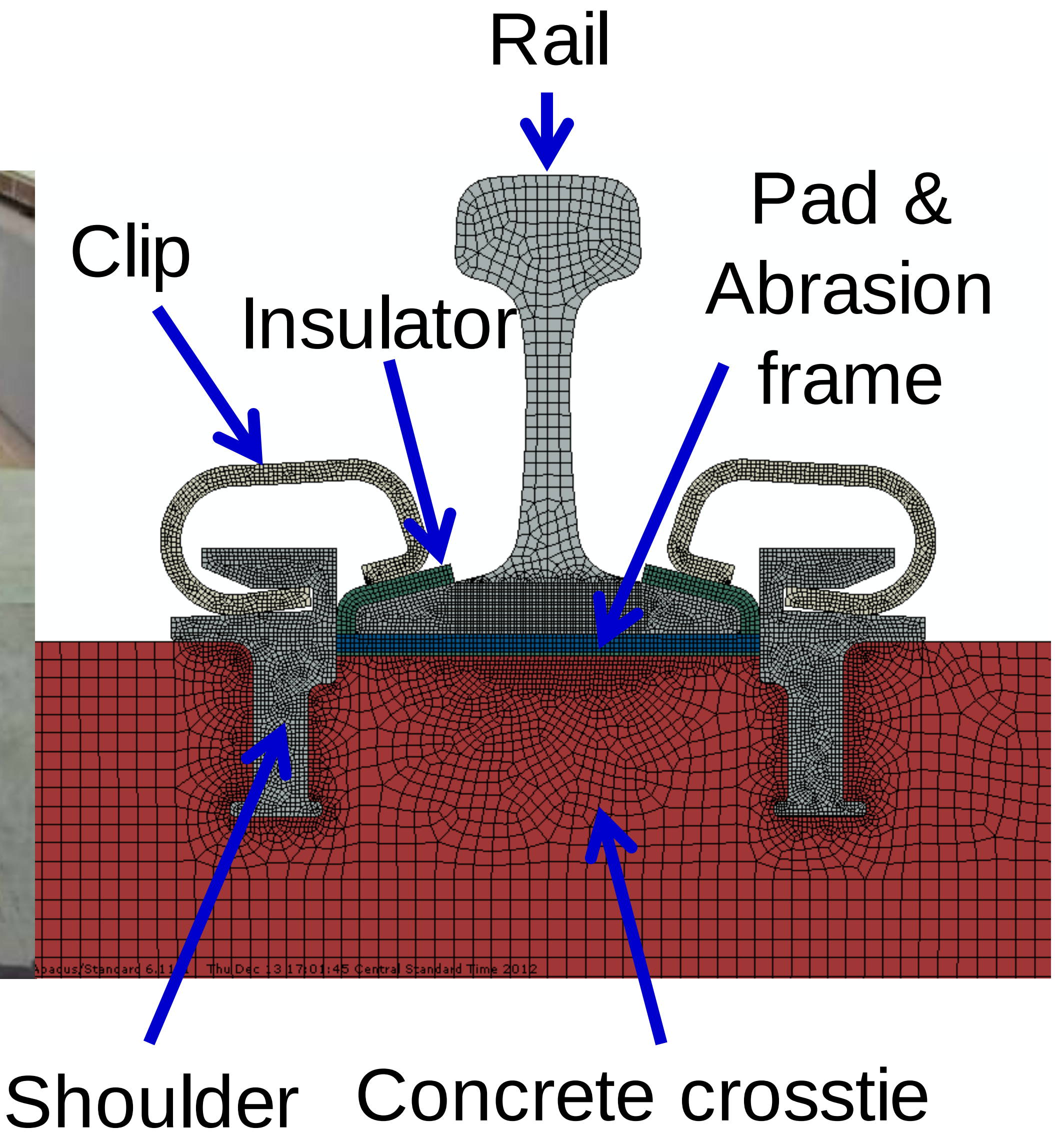


(Yu and Jeong, 2011)



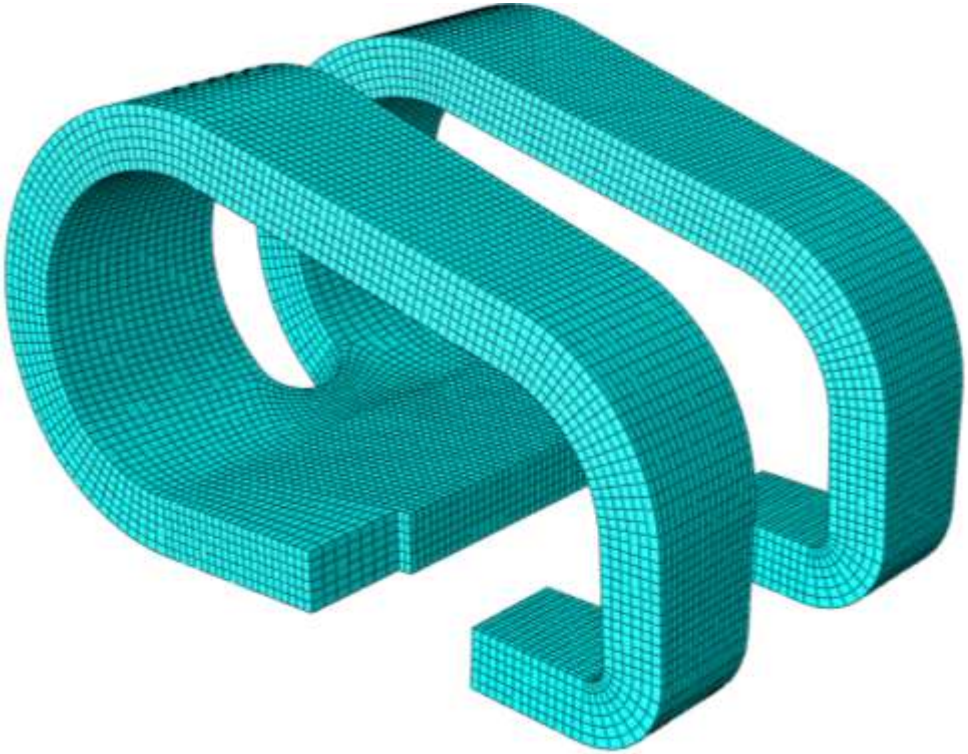
(Tangtragulwong 2009)

Concrete Crosstie and Fastening System



Component Modeling

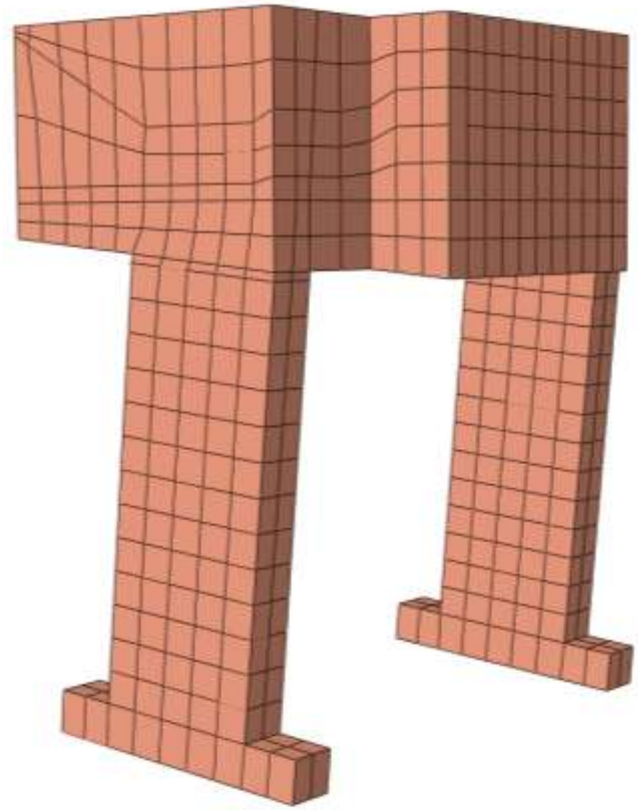
Rail Clip



Rail Clip model

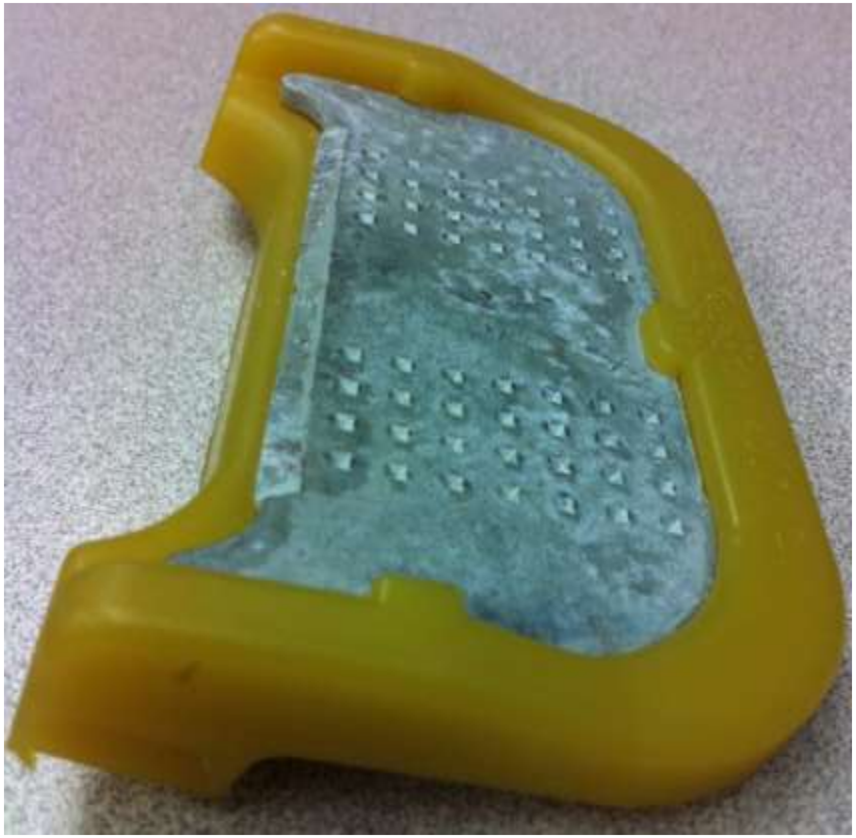
Component Modeling

Rail Shoulder

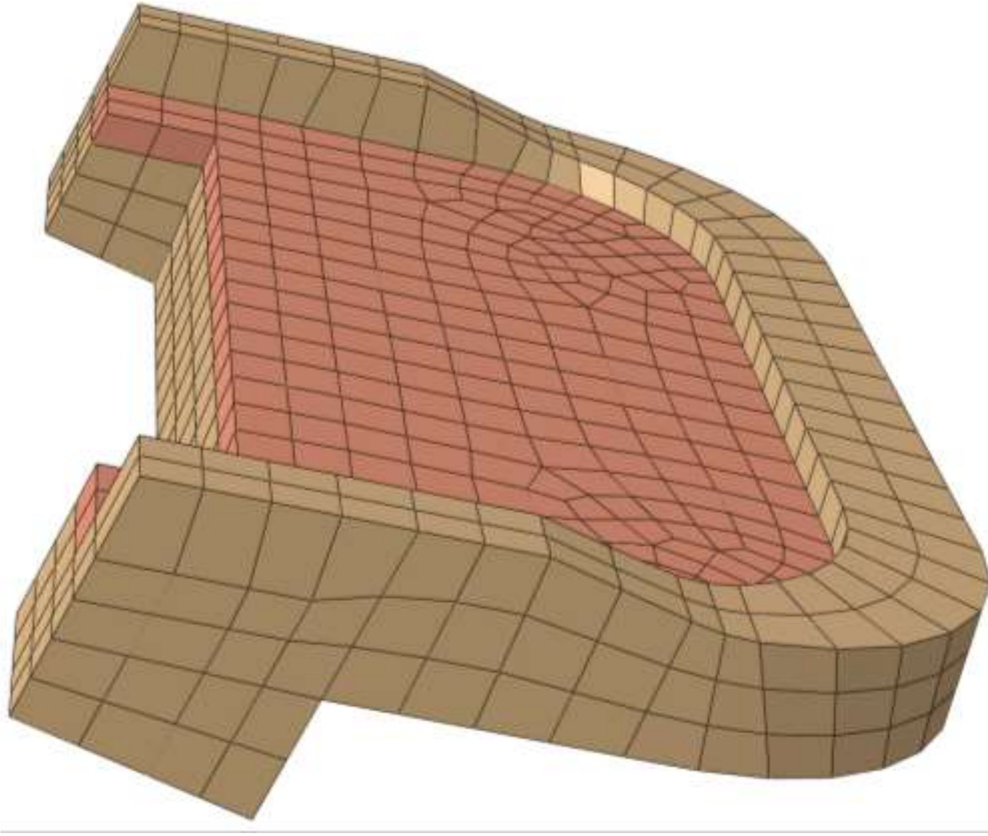


Rail Shoulder model

Component Modeling



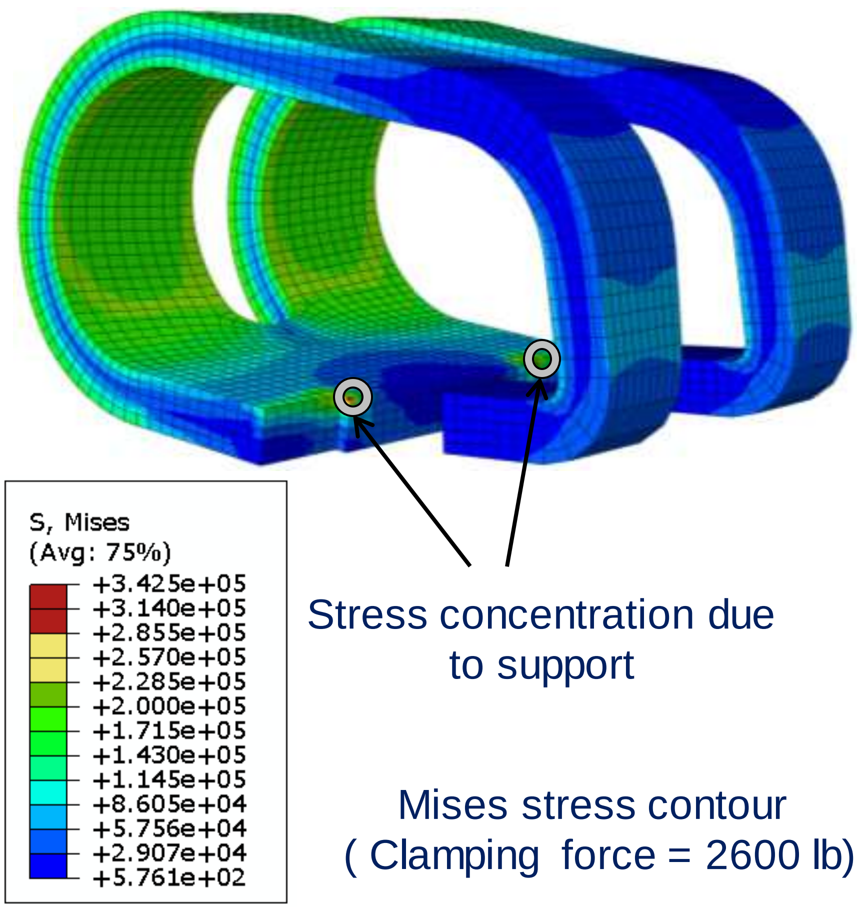
Rail Insulator



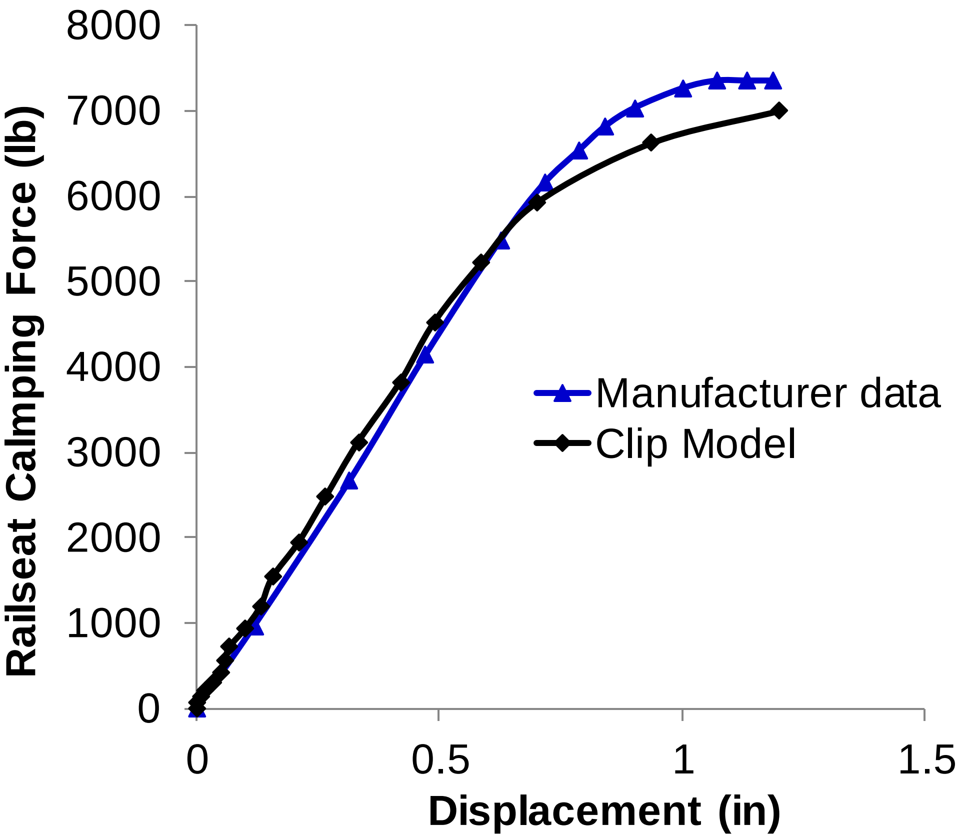
Rail Insulator model

Component Modeling: Validation

- Clip Model



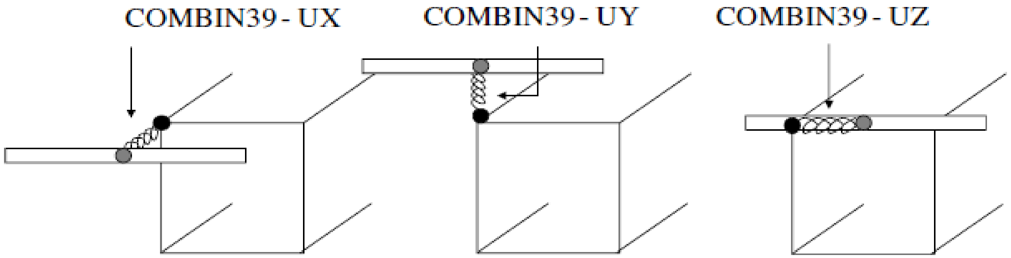
Mises stress contour
(Clamping force = 2600 lb)



Clamping force-displacement curves

Component Modeling: Concrete Tie

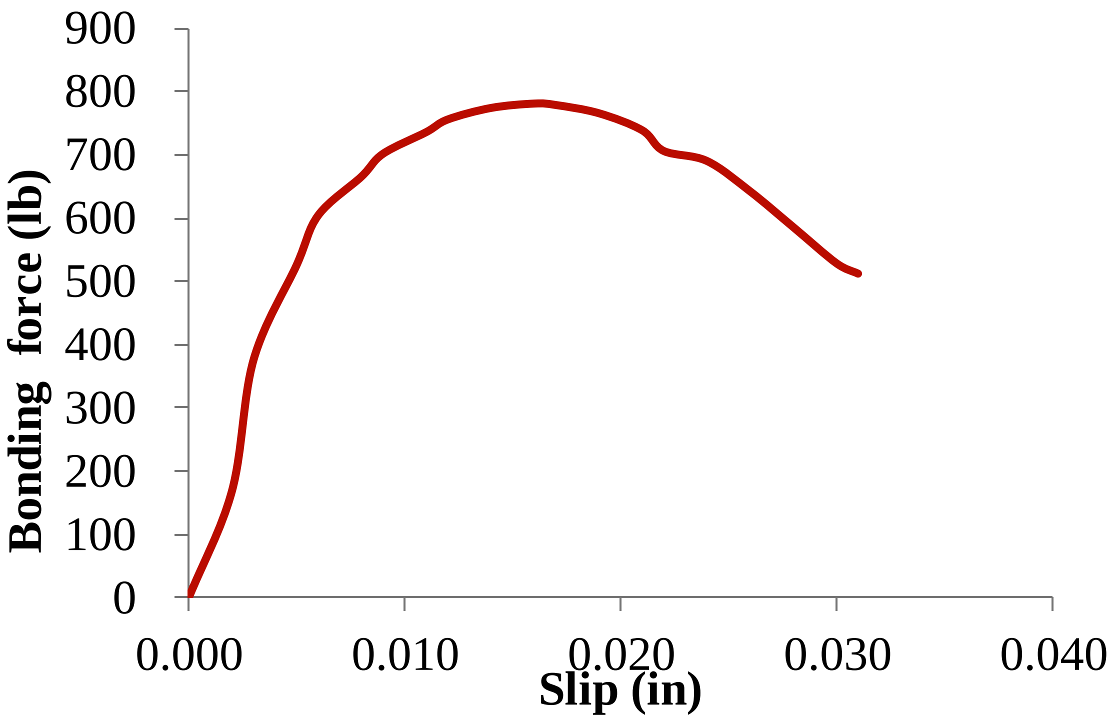
- Model Features:
  - Concrete material property: damage plasticity model
  - Connector element is used to simulate the bond relationship between concrete and strand
  - Prestress and vertical static loading is applied in the model
  - The effect of confining pressure on material property is considered in ballast modeling



3-D elastic spring connection between concrete and strand
(Pozolo and Andrawes 2011)

Component Modeling: Concrete Tie

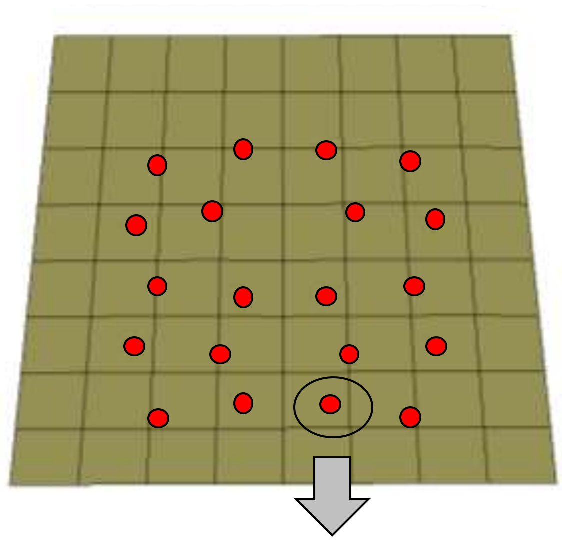
– A bonding force-slip relationship is defined in the model



Bonding force-slip Relationships

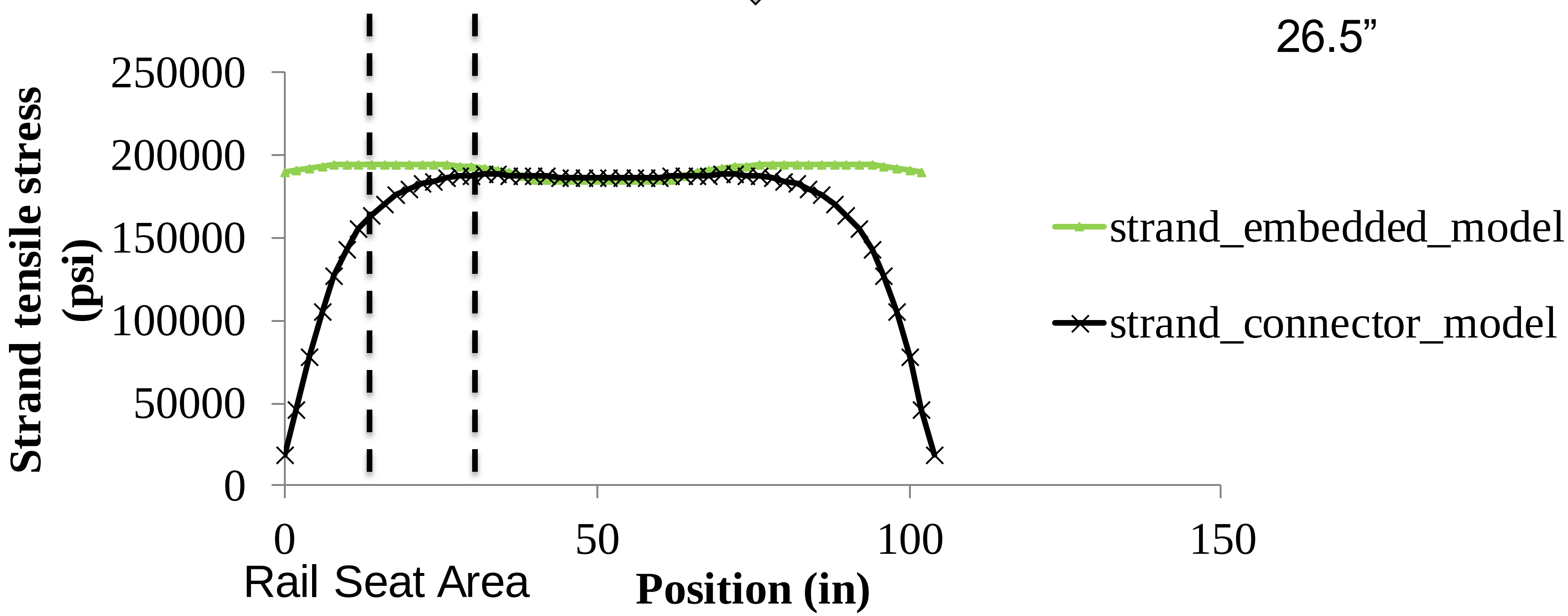
(Testing Data from the Kansas State University)

Component Modeling: Concrete Tie



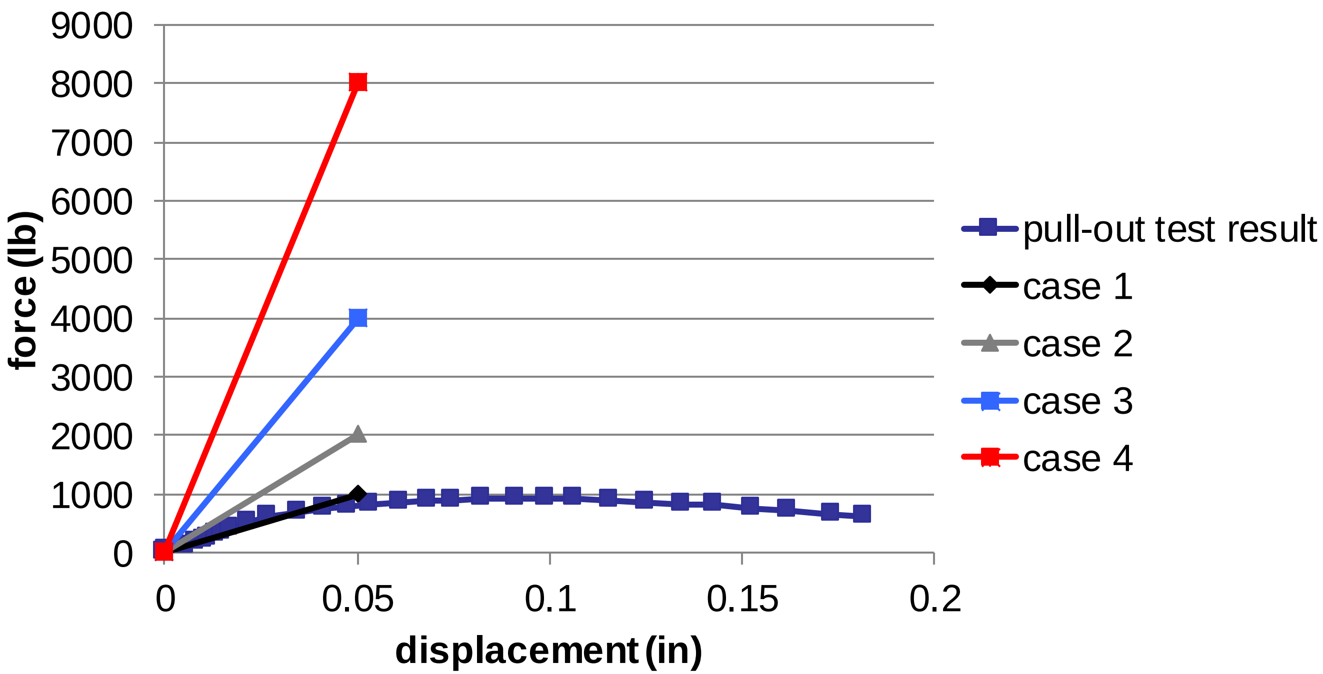
Positions of strands

Rail seat area is between 15.2” to 26.5”



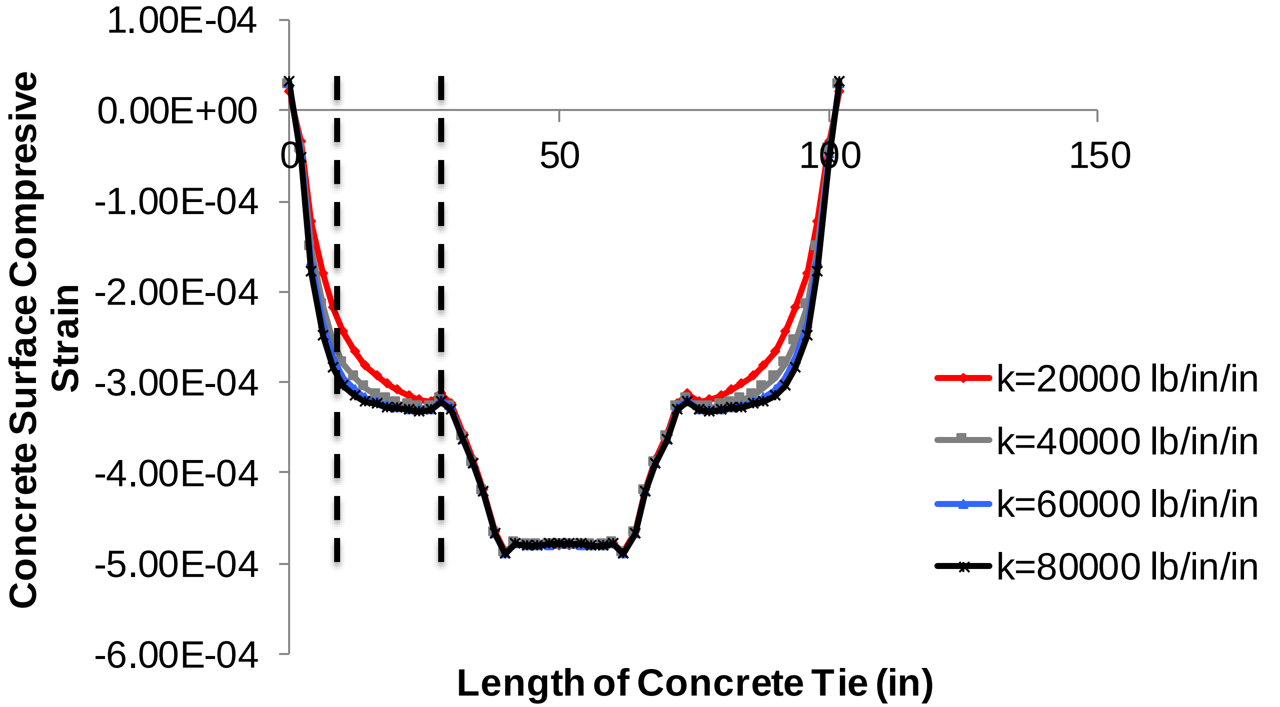
Component Modeling: Concrete Tie

- Different bond-slip behavior are defined for parametric study.
- The force-displacement relationship of connectors was simplified as elastic.
- Range of parameter is justified by pull-out tests of similar material in literature.



Component Modeling: Concrete Tie

- Transfer length gradually reduced with higher bond-slip stiffness.
- The rail-seat region is within transfer length with in case 1 and case 2.

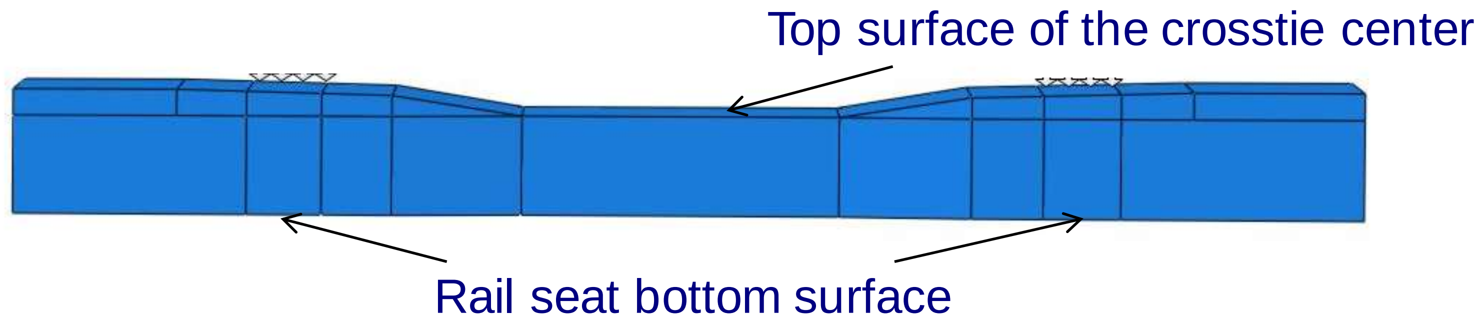


Rail seat area is between 15.2” to 26.5”

bond-slip stiffness	k= 20000 lb/in/in	k=40000 lb/in/in	k=60000 lb/in/in	k=80000 lb/in/in
transfer length (in)	22	16	14	12

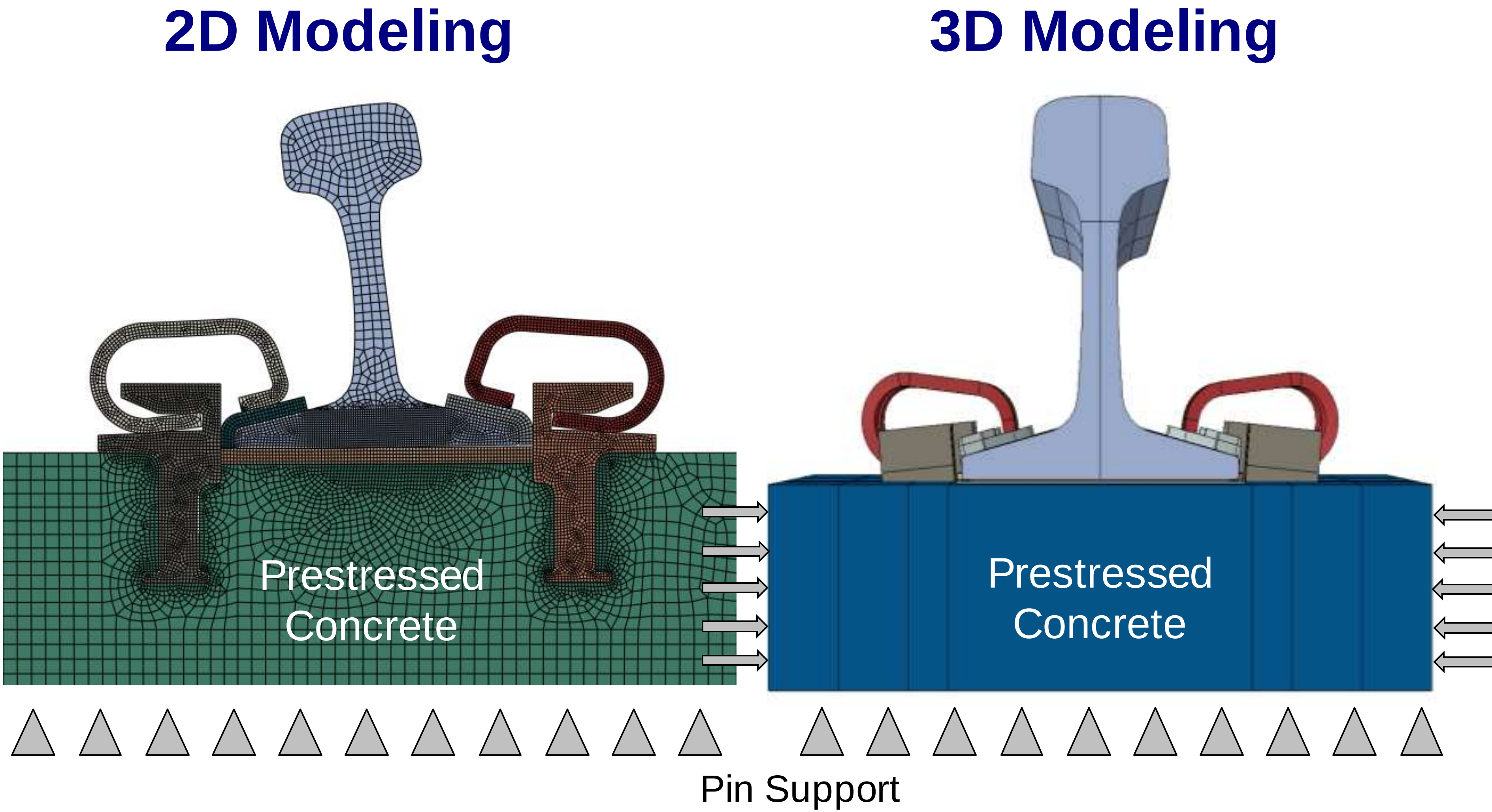
Component Modeling: Concrete Tie

- The bond slip stiffness had little effect on the concrete prestress at the top surface of tie center.
- The concrete prestress at the bottom surface of rail seat region gradually increased with higher bond-slip stiffness.



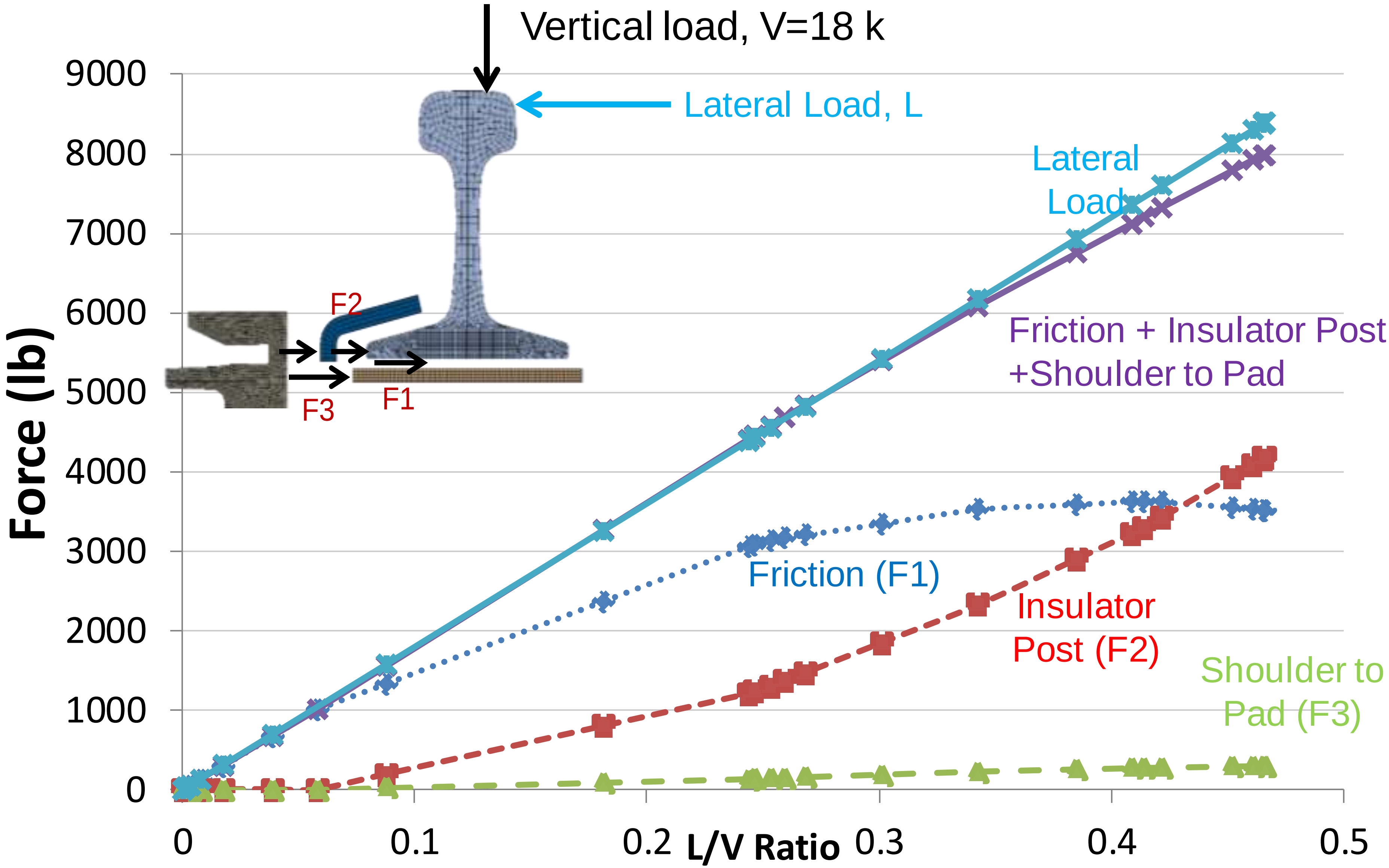
Bond slip stiffness	k= 20000 lb/in/in		k=40000 lb/in/in	
Surface position	Rail seat bottom surface	Tie center top surface	Rail seat bottom surface	Tie center top surface
Concrete surface stress after prestress release (psi)	-1793	-2416	-1863	-2414
Bond slip stiffness	k=60000 lb/in/in		k=80000 lb/in/in	
Surface position	Rail seat bottom surface	Tie center top surface	Rail seat bottom surface	Tie center top surface
Concrete surface stress after prestress release (psi)	-1880	-2412	-1886	-2411

System Modeling: 2D and 3D Modeling



System Modeling: Fastening Systems

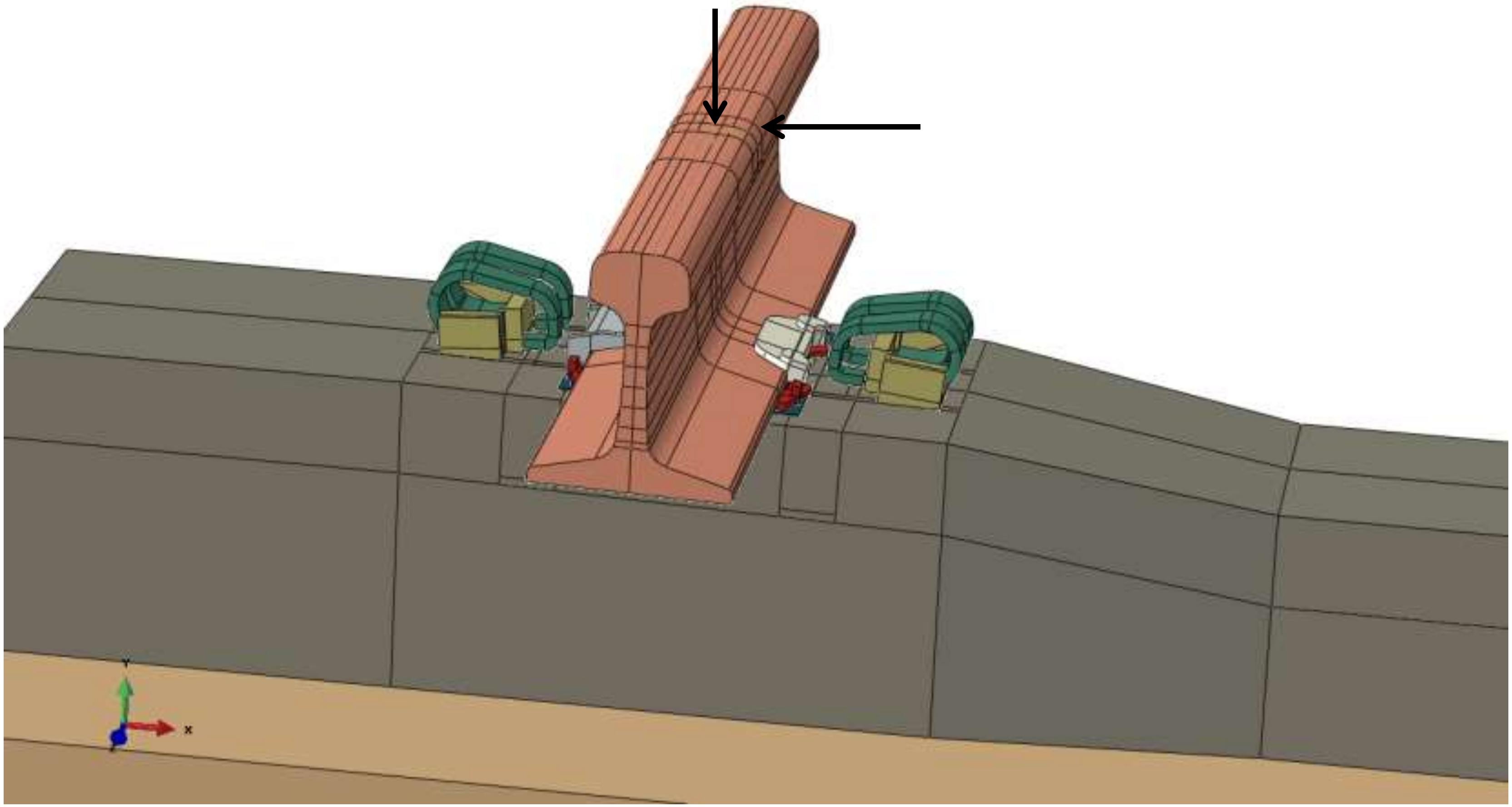
Lateral Loading Path



Lateral Force to a Shoulder

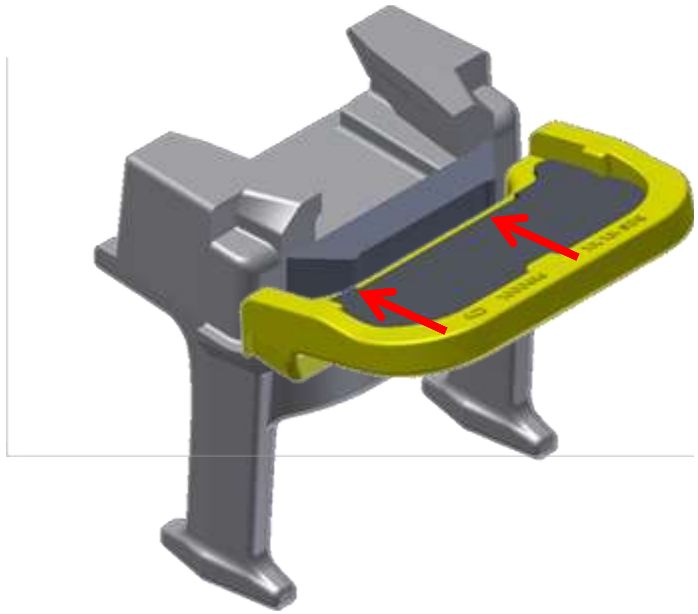
Vertical Force:

1. Magnitude: 32.5 kips

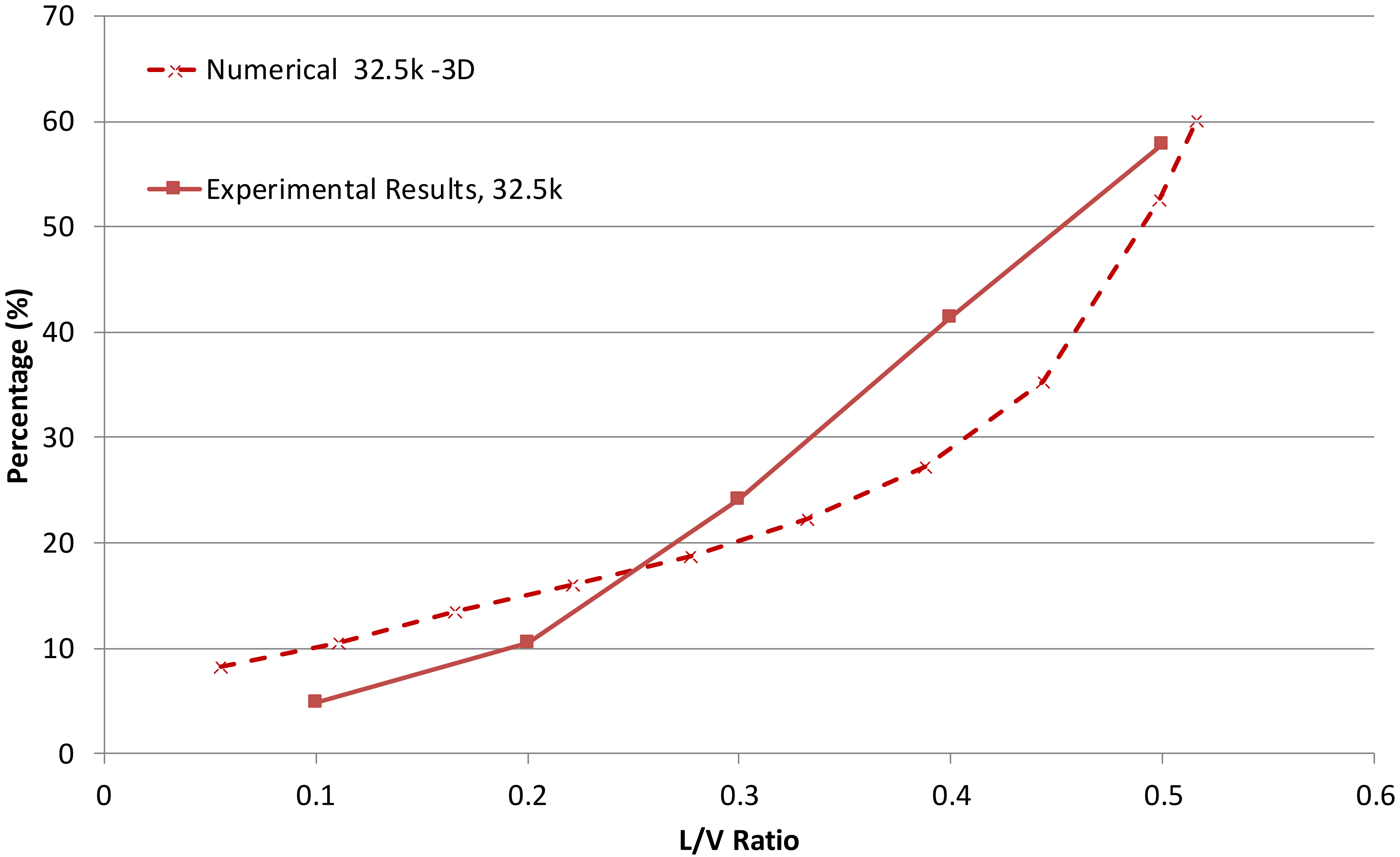


Quantifying lateral load on the insulator post (F2)

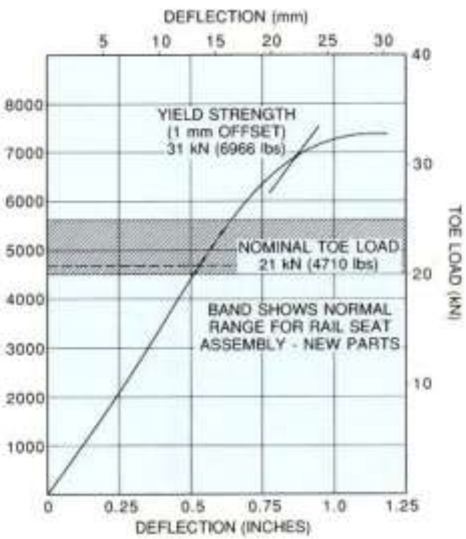
- Instrumented shoulder face insert



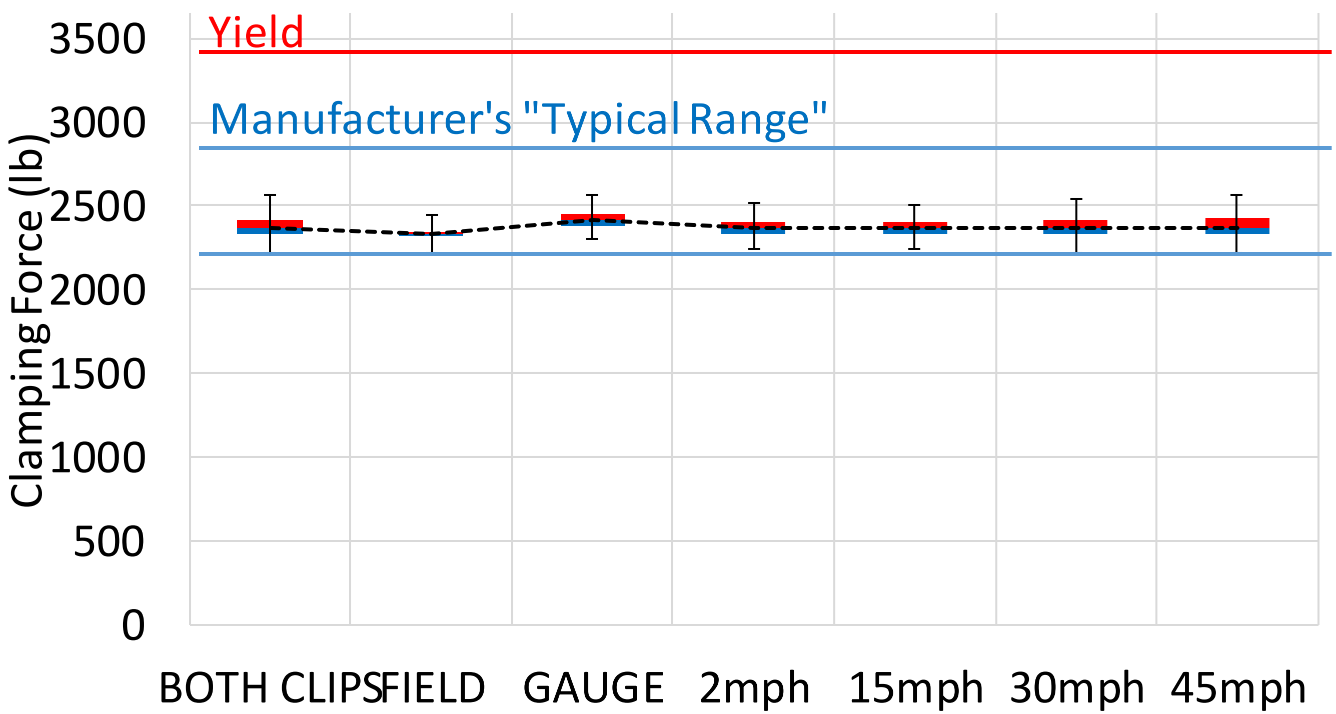
Lateral Force to a Shoulder



Changes of the Clamping Force



Range of the clamping force: ±300 lb

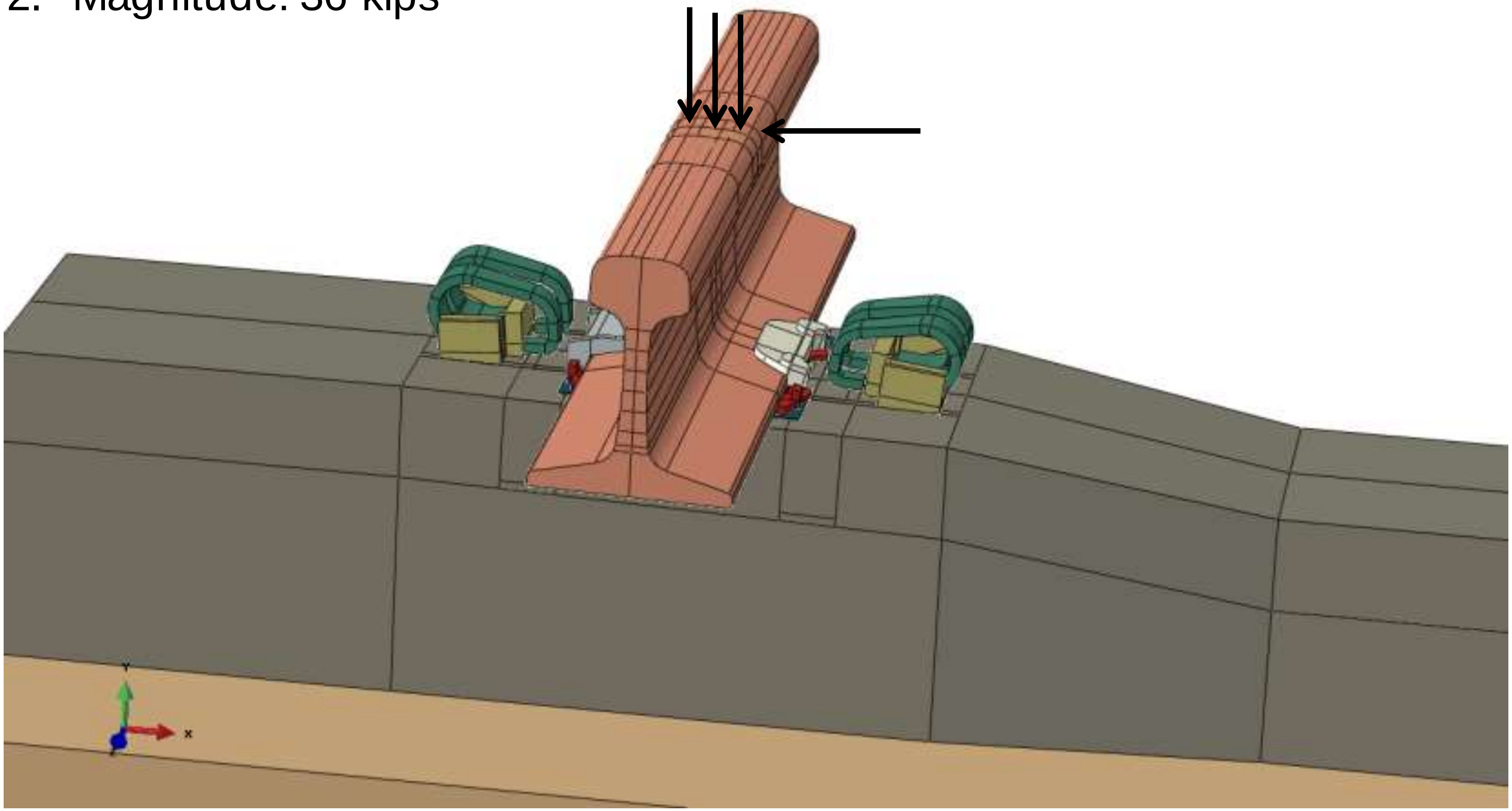


(Grasse JRC Presentation, 2013)

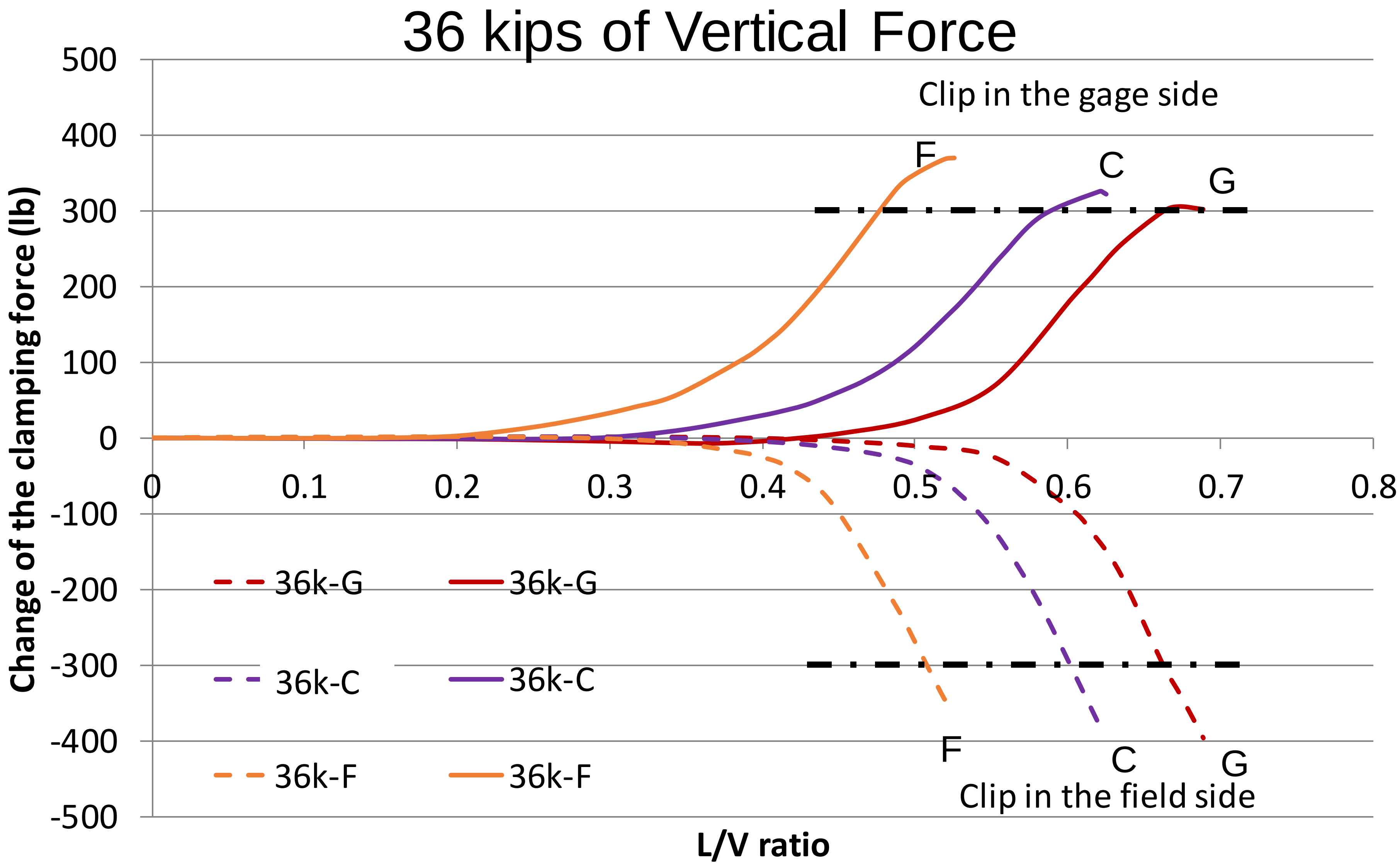
Changes of the Clamping Force

Vertical Force:

1. Location: Gage, Center, Field
2. Magnitude: 36 kips

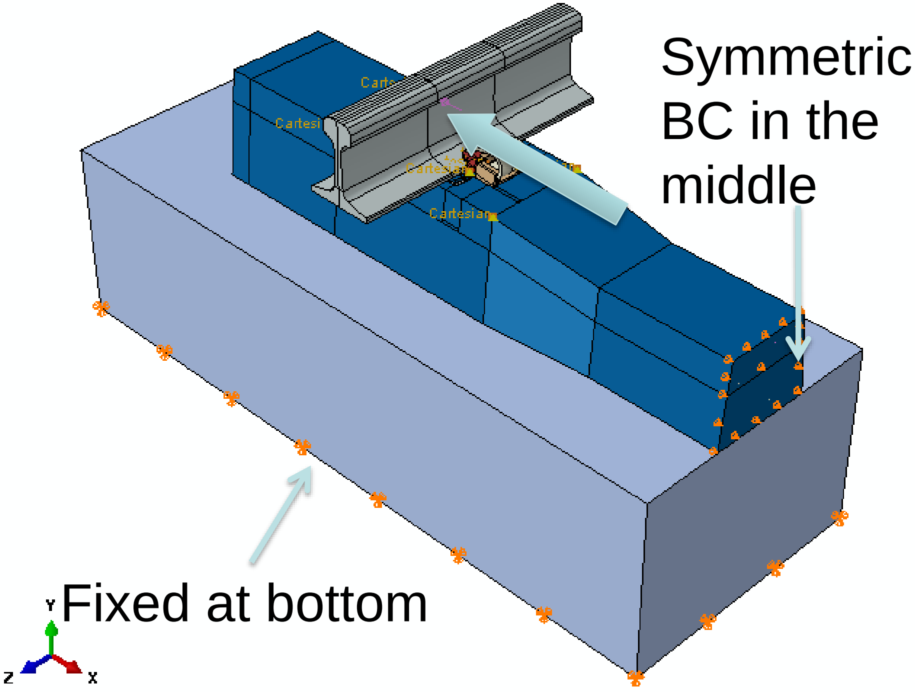


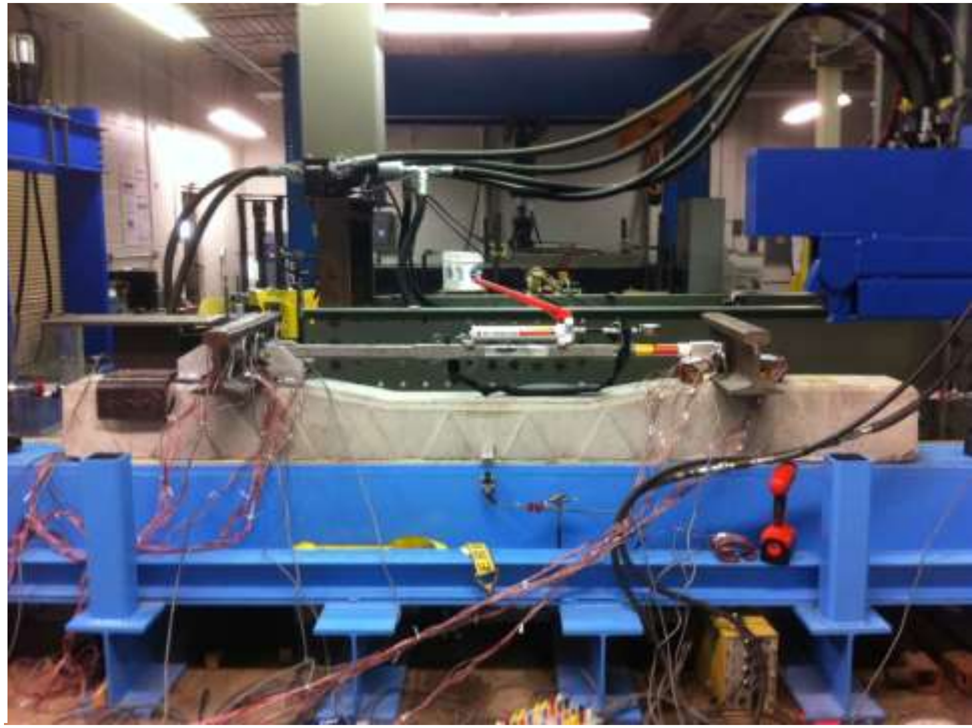
Change of the Clamping Force



System Modeling: Single-Tie Modeling

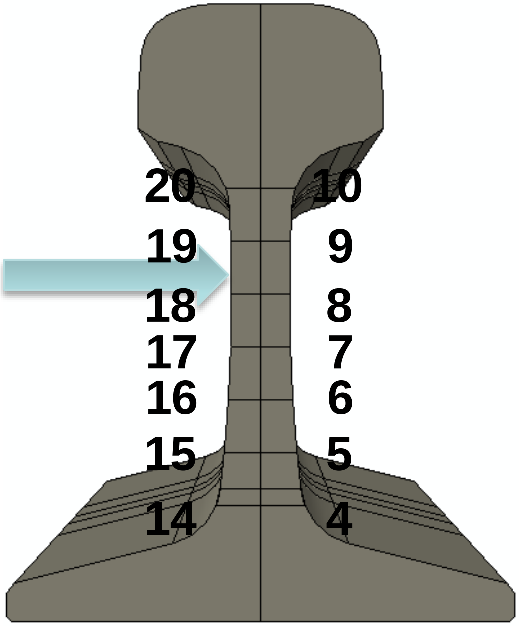
Laboratory Test Validation





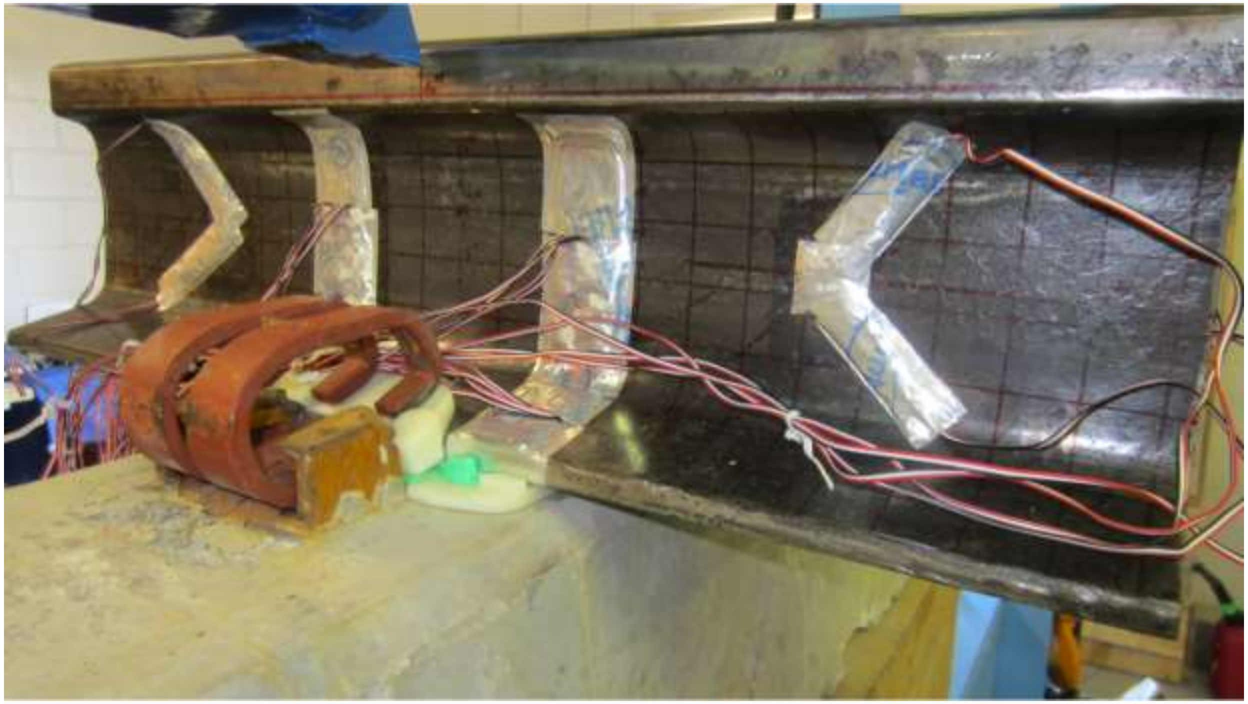
System Modeling: Single-Tie Modeling

- Strain gauges are attached to the rail to measure vertical web strain
- Lateral loading is applied on rail web.



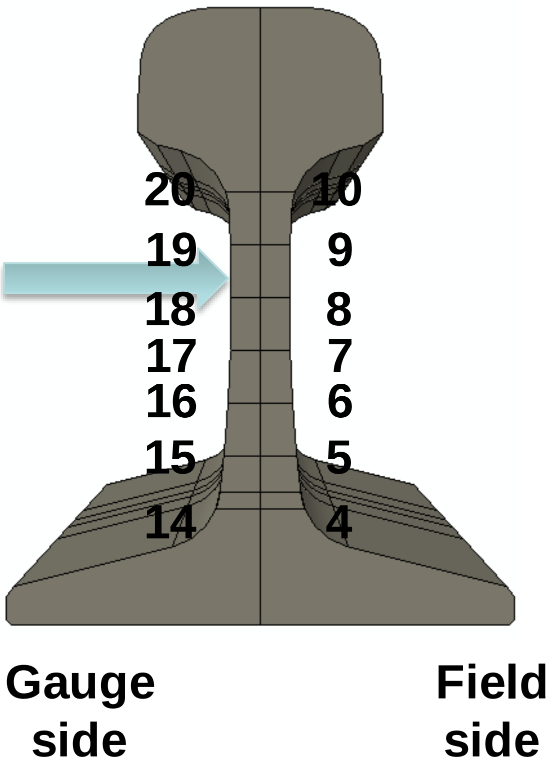
Gauge side

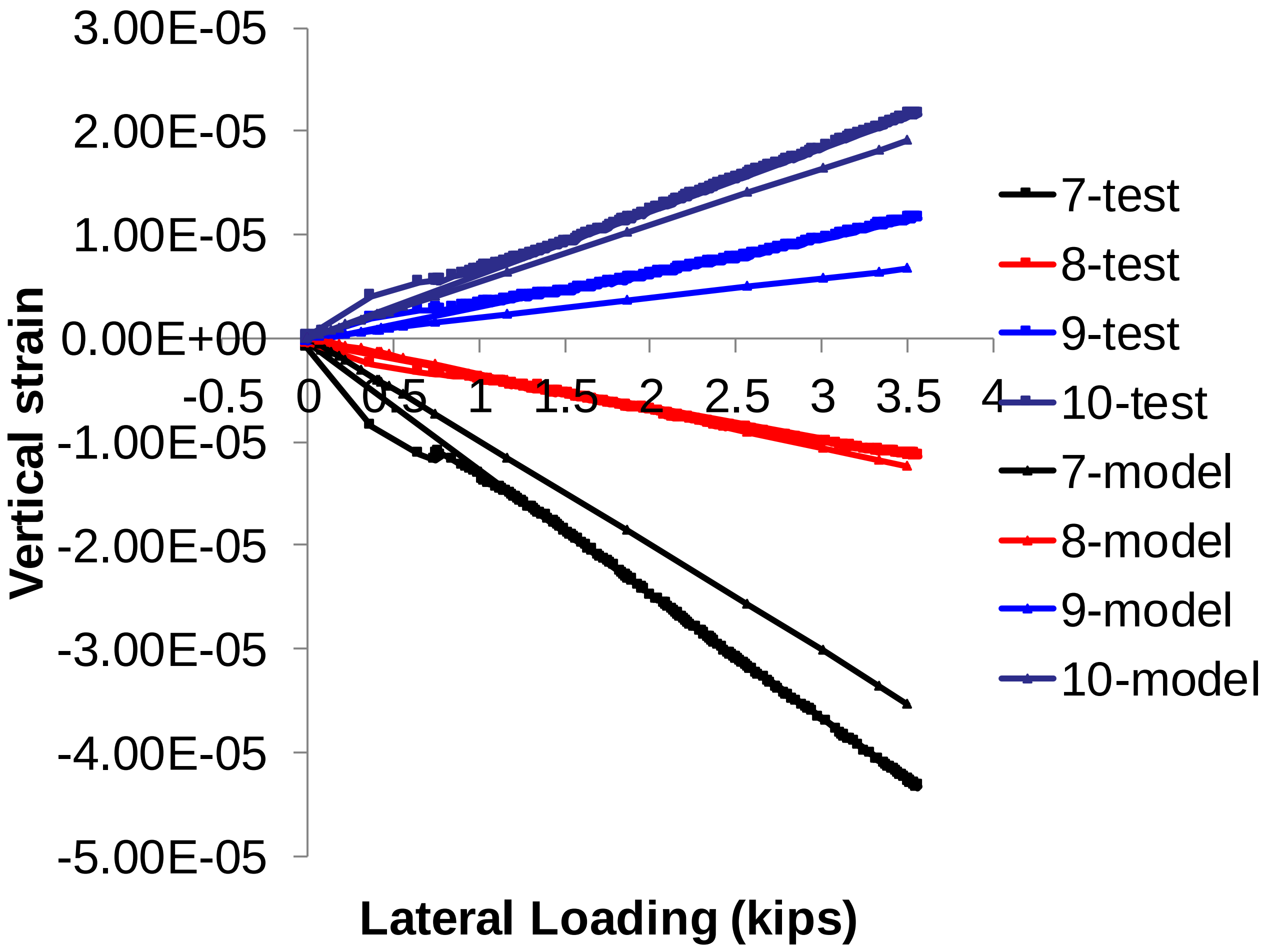
Field side



System Modeling: Single-Tie Modeling

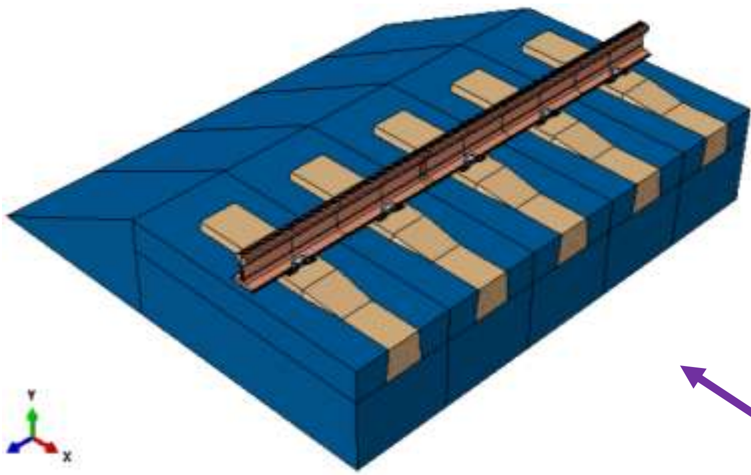
Comparisons of strains



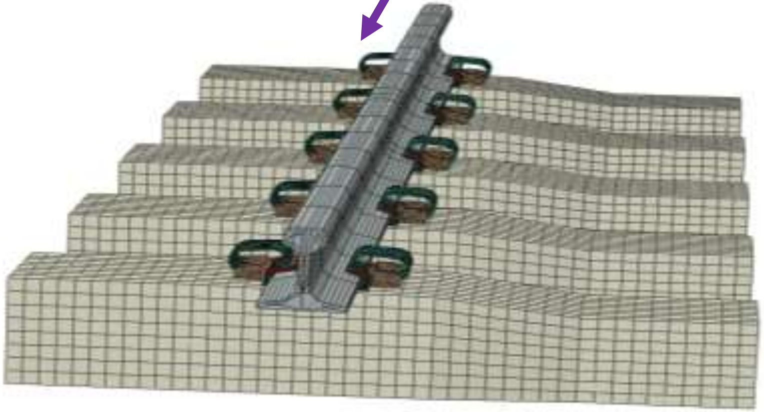


System Model: Multiple-Tie Modeling

- Track loading vehicle (TLV) applying vertical and lateral loads to the track structure in field
- The symmetric model including 5 ties



Simplified model:
Fastening system were replaced by bcs and pressure



Detailed model with the fastening system

Conclusions

- Some component models were validated with manufacturer data
- Single tie model was used to study bond-slip behavior of strands
- With the fastening system model, the loading path (vertical and lateral) can be identified
- Current laboratory tests were validated, and good agreement was observed
- Multiple tie models have been developed and ready to validate the track system models in field

Future Work

- **Further comparisons:** More measurements on the lab testing set-ups will be deployed and compared with the models
- **Validation of FE models in field:** Comparisons with data collected with the field instrumentations at Transportation Technology Center, Pueblo, CO
- **Realistic loading**: More load types (vertical, lateral, and longitudinal loads) and load forms (static and dynamic load) will be applied to the track system to better simulate the actual loading environment
- **Parametric studies**: Parametric studies about material properties and geometric dimensions will be conducted using the model
- **Simplified analytical tool**

Acknowledgements

U.S. Department of Transportation

Federal Railroad Administration

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  - National Railway Passenger Corporation (Amtrak)
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  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
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FRA Tie and Fastener BAA Industry Partners:

Questions?

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