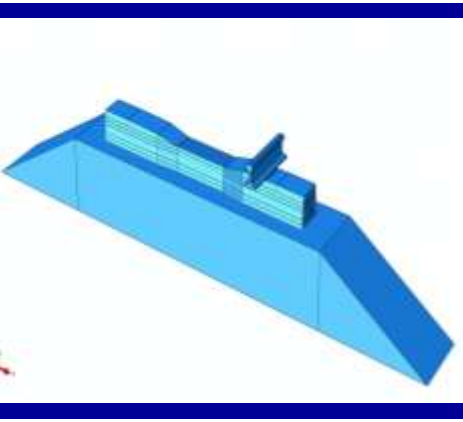
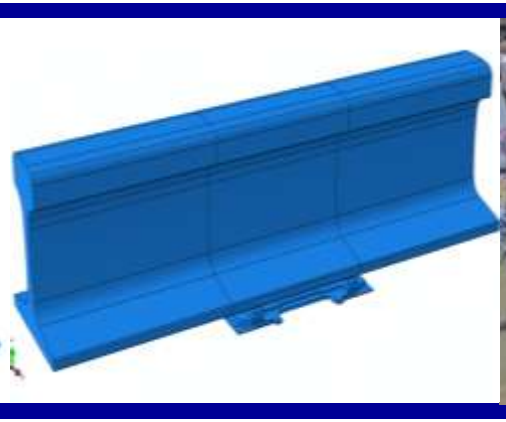
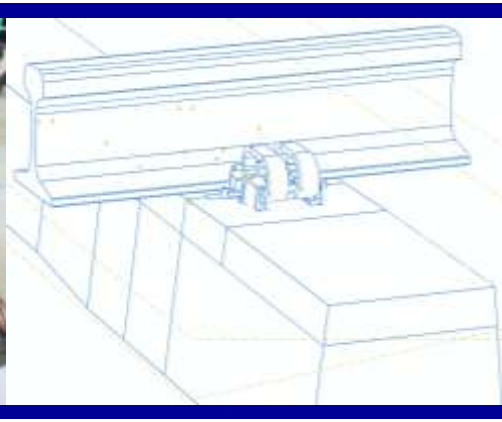
Concrete Crosstie and Fastening System Modeling at UIUC



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U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
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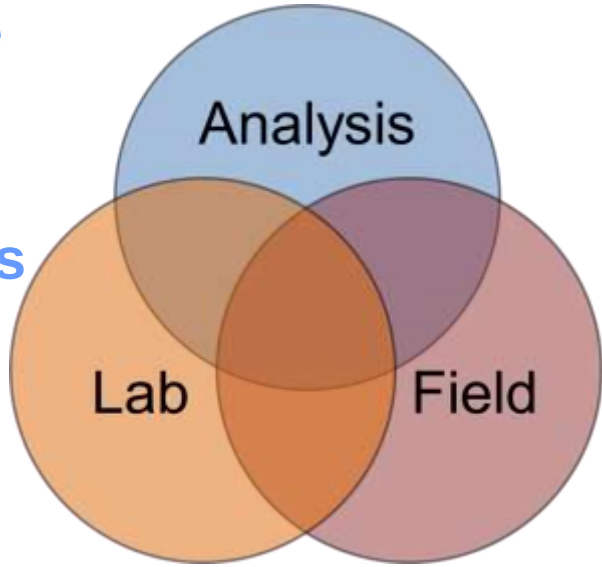
Outline

- Role of Modeling in UIUC FRA Concrete Tie & Fastener System
- Literature Review
- Component Modeling
- Assembly Modeling
- Comparison Between Component and Assembly Model
- Future Work

Role of Modeling

Analysis

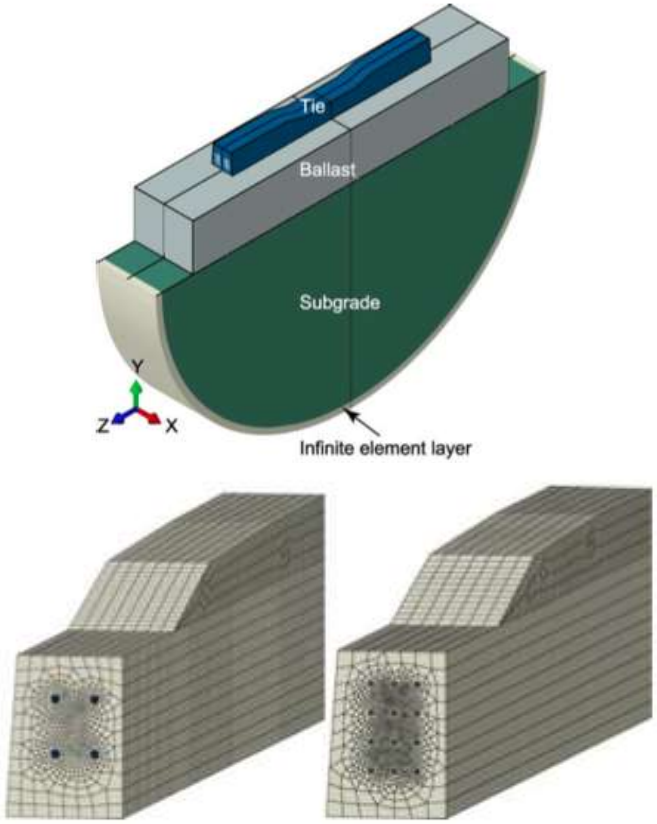
- Conduct parametric analysis based on the detailed structural model
- Develop a simplified physical representative model for the critical parties



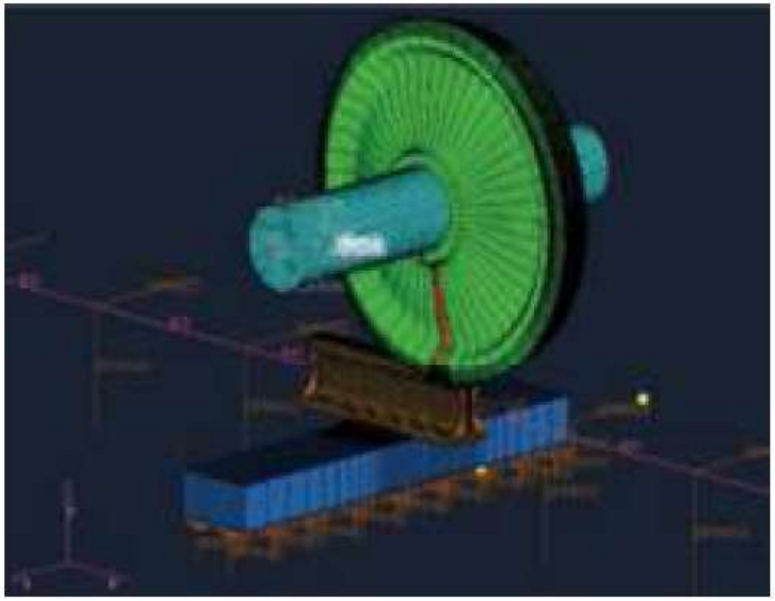
Analysis – Field & Lab

- Build parallel models to provide reference for experiment data (concrete tie, clip, rail pad, etc.)
- Develop a preliminary load path model to provide a measure of the loads at each interface

Literature Review: Relevant Research



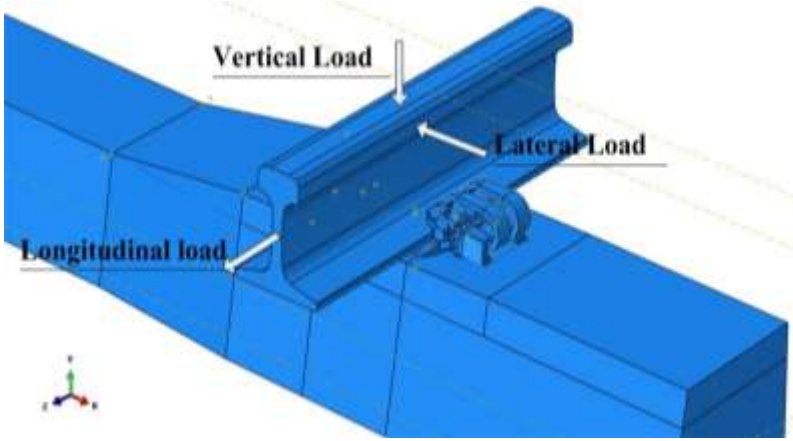
Finite Element Modeling of
Prestressed Concrete Crossties with Ballast and
Subgrade Support
(Yu and Jeong 2011)



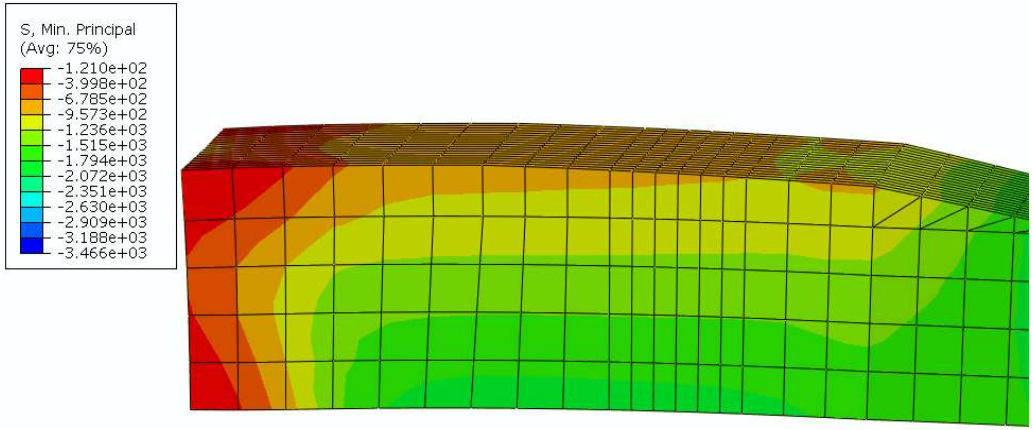
Analysis of Tie Plate Cracking
(Tangtragulwong 2009)

Potential for Improvement

- In most models the fastener system is simplified with boundary conditions in longitudinal and lateral direction
- Typically only a vertical load is applied to the model, and lateral and longitudinal loads are rarely applied
- The effect of dynamic load is not sufficiently considered (strain rate effect)
- For prestressed concrete tie: the transfer length and the bond between concrete and strand demand further research
- The load path including all the components is not fully understood



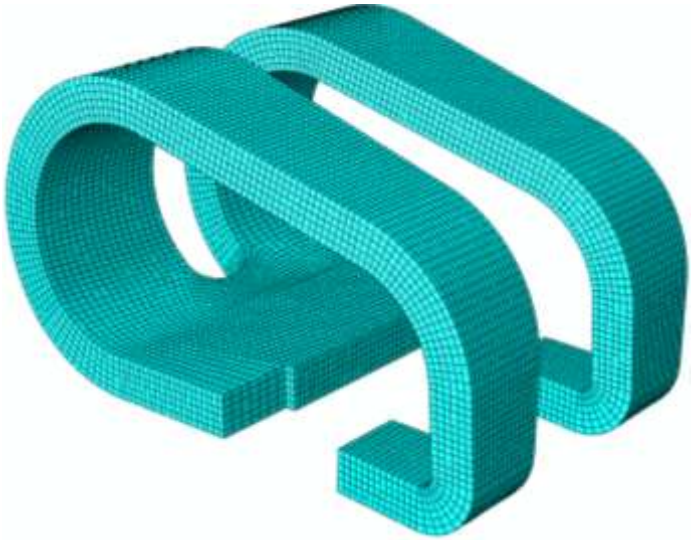
Rail loading dimensions
(UIUC Model)



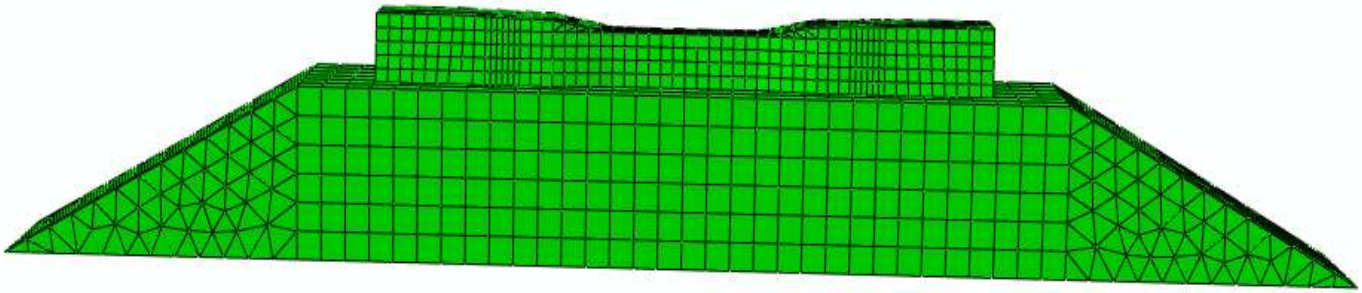
Minimum principal stress contour
of concrete after release (UIUC Model)

Current UIUC Model Focus

- Current work is primarily focused on component modeling and assembly modeling (e.g. concrete tie, clip, etc.).



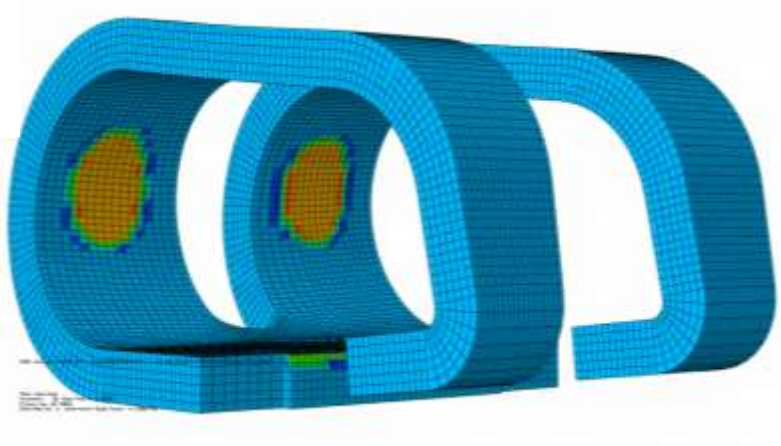
Example: clip model



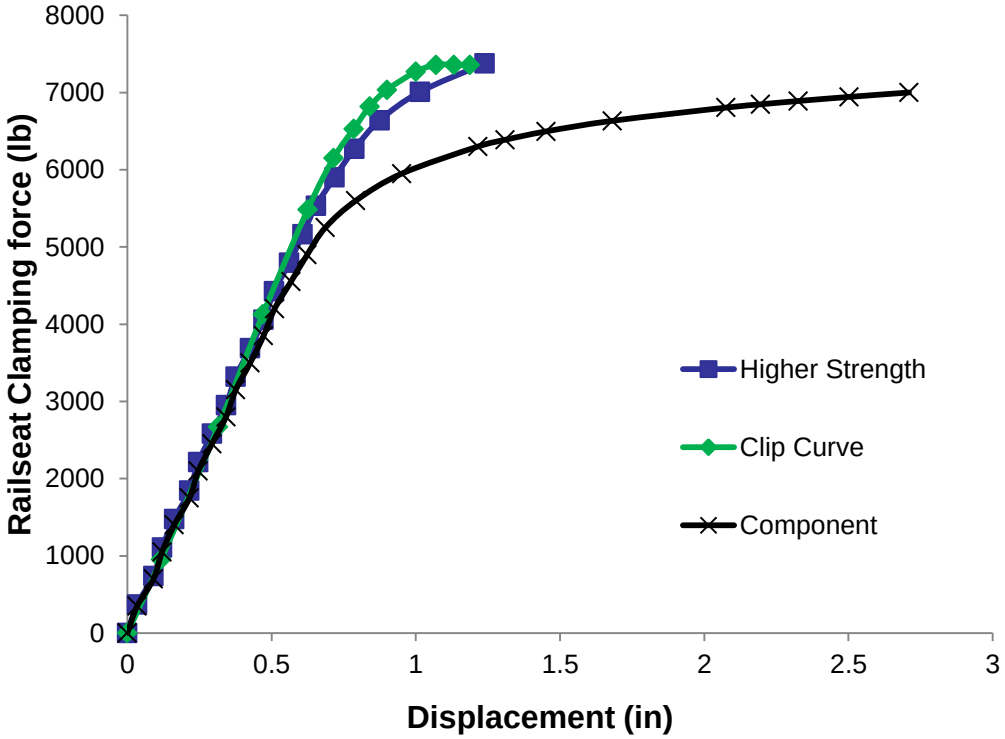
Preliminary model of concrete tie and ballast (UIUC Model)

Current Model: Component Modeling

- Clip Model



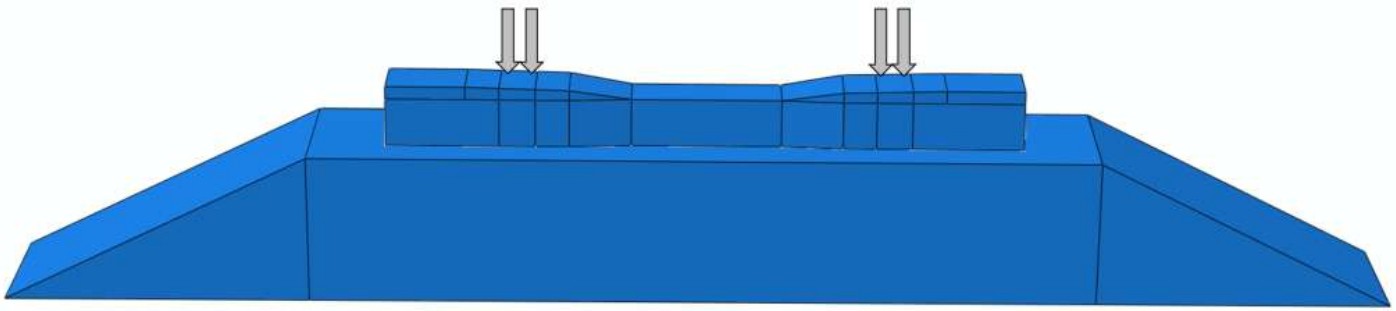
Active yielding contour
(Clamping force = 2143 lb)



Clamping force-displacement curves

Current Model: Assembly Modeling
Concrete Tie and Ballast

- 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

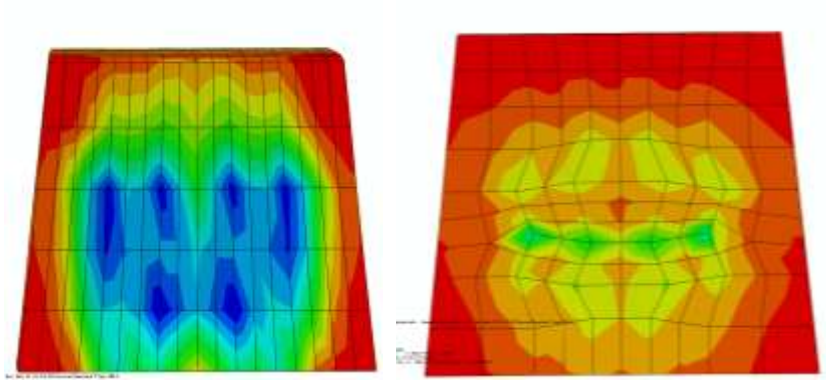


Static loading of the model (UIUC Model)

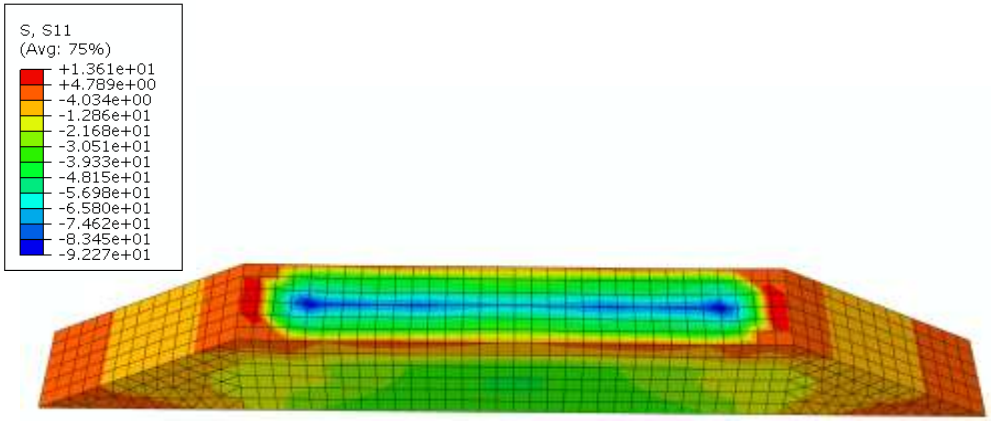
Current Model: Assembly Modeling

Concrete Tie and Ballast

- In comparison with full bond model, relative-slip bond model can prevent unreasonable stress concentration and provide more realistic simulation for concrete-strand interaction
- At a rail seat loading of 30 kips elasto-plastic model could provide sufficiently accurate estimation for the performance of ballast, but non-uniform material model is needed at higher loading

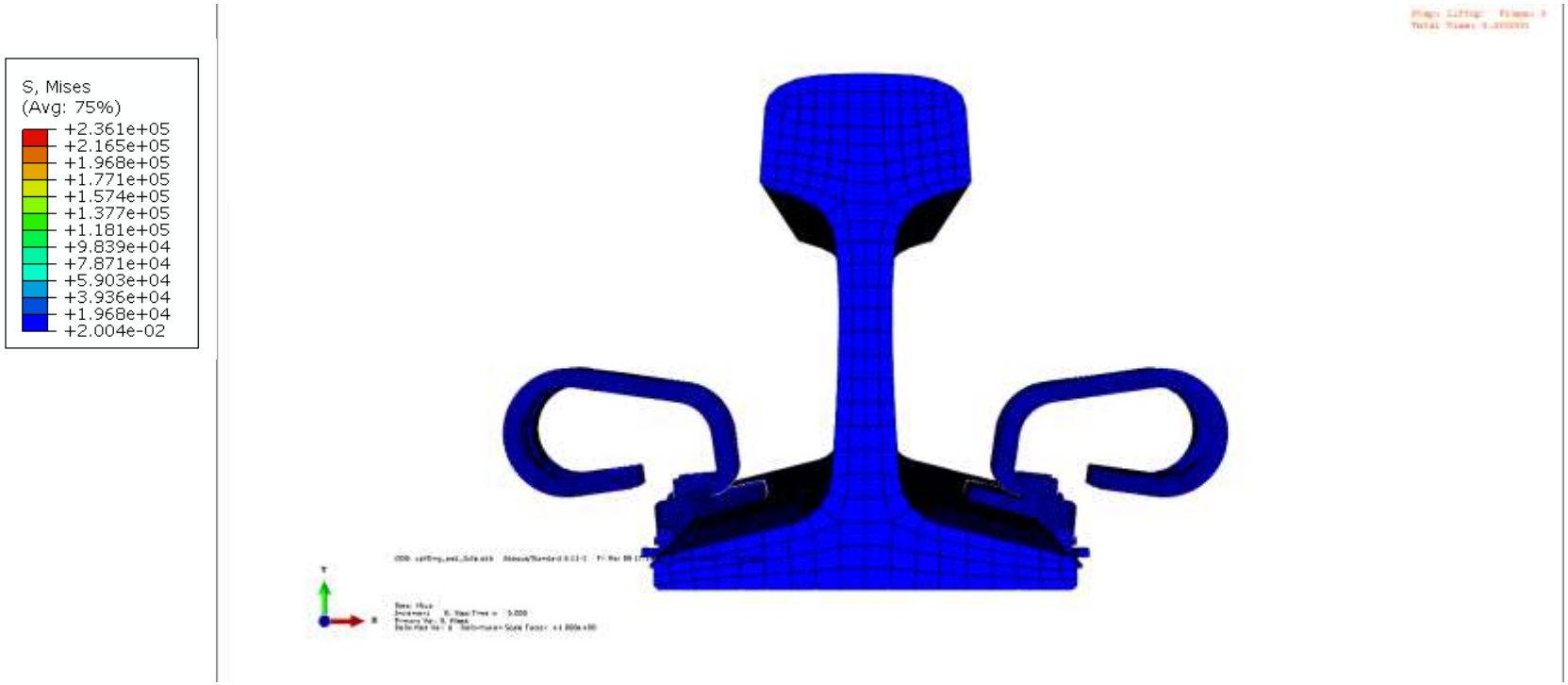


Lateral compressive stress contour
(full bond model & slip bond model)



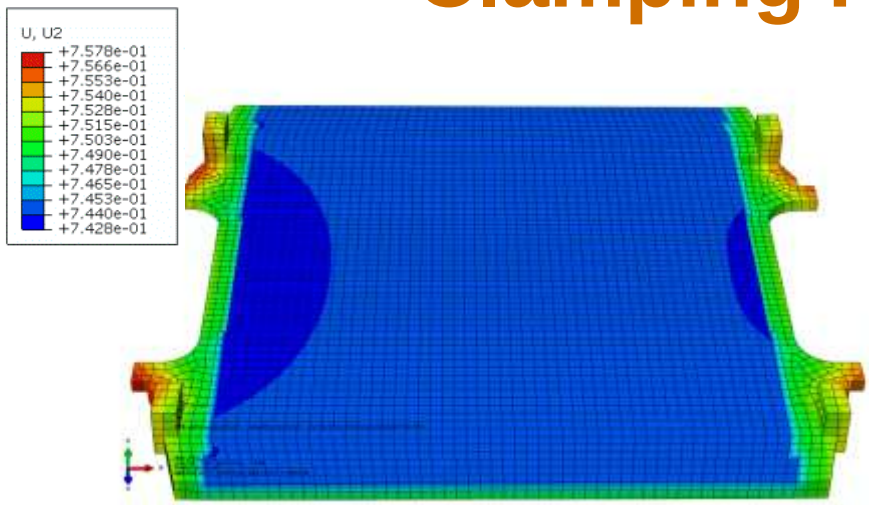
Ballast lateral stress contour after loading
(UIUC Model)

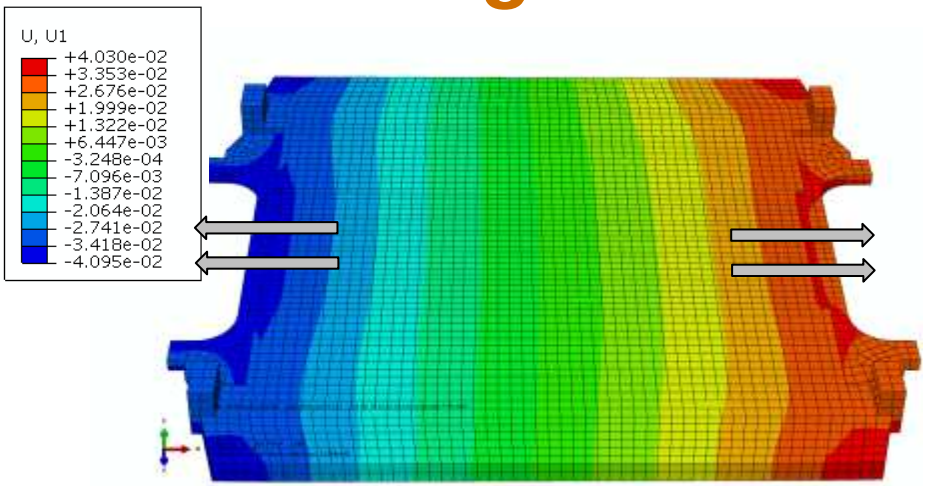
Current Model: Assembly Modeling
Clamping Force Modeling

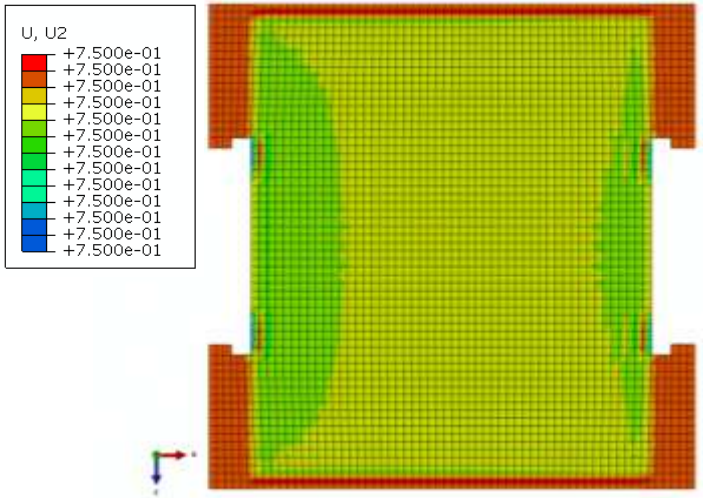


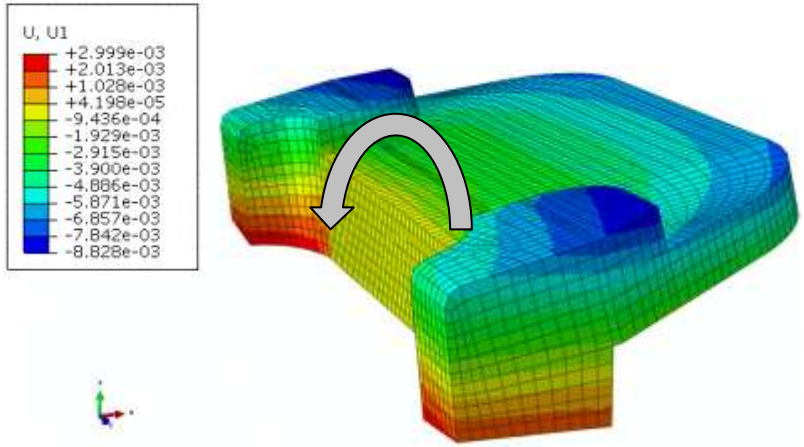
Simulation for driven-in process

Current Model: Assembly Modeling
Clamping Force Modeling



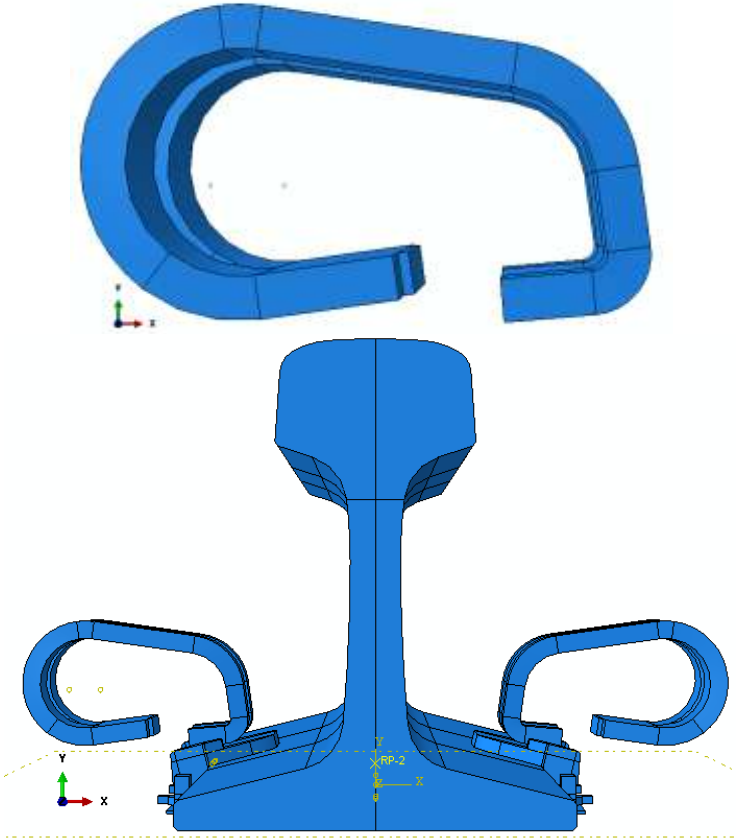






Current Model: Comparison between Component and Assembly Model

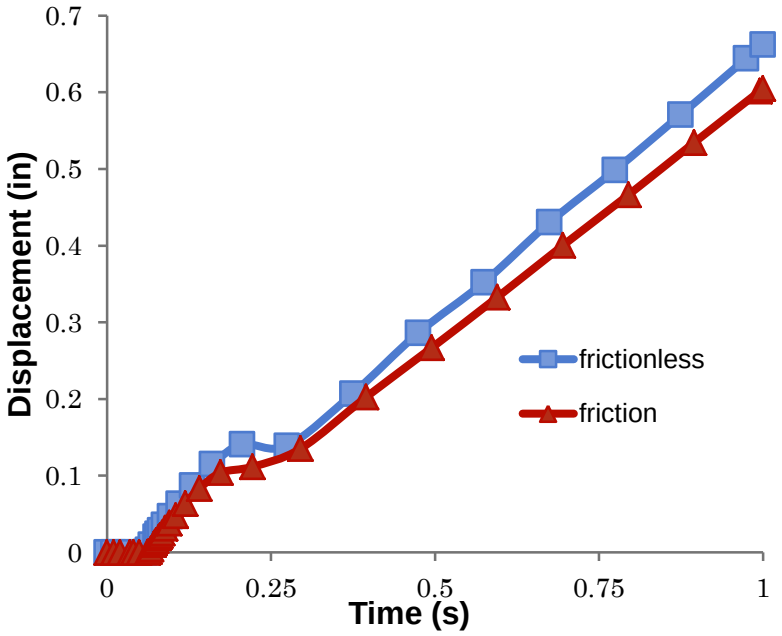
- Clip component response is compared with its response in the system with or without friction
- A coefficient of friction of 0.5 is assumed for clip-insulator interaction



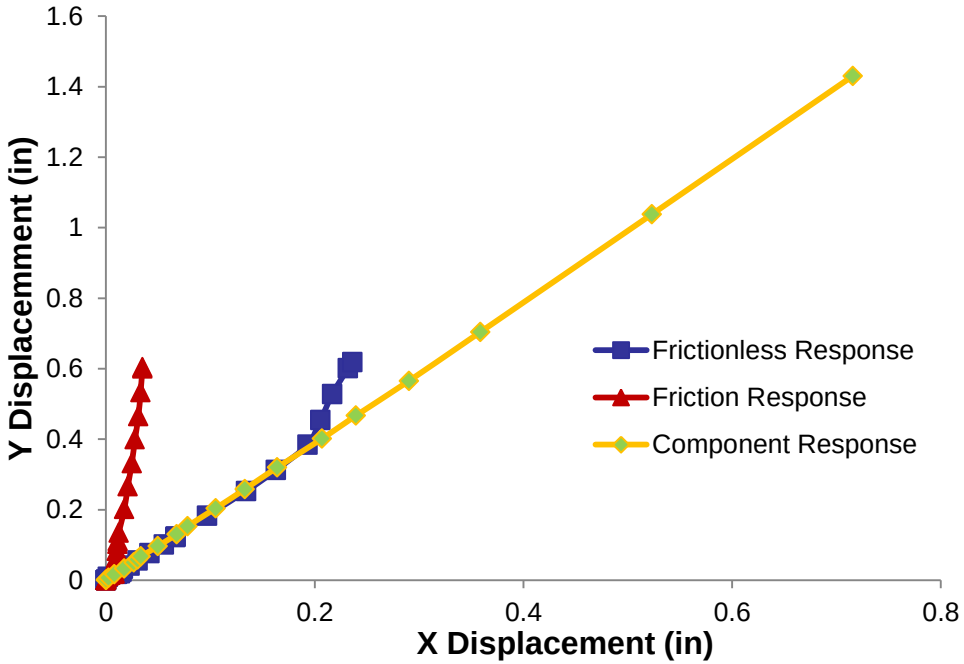
Clip component model (up) and system model (down)

Current Model: Comparison between Component and Assembly Model

- Based on the displacement trace of clip toe, the loading conditions in the two cases are quite different



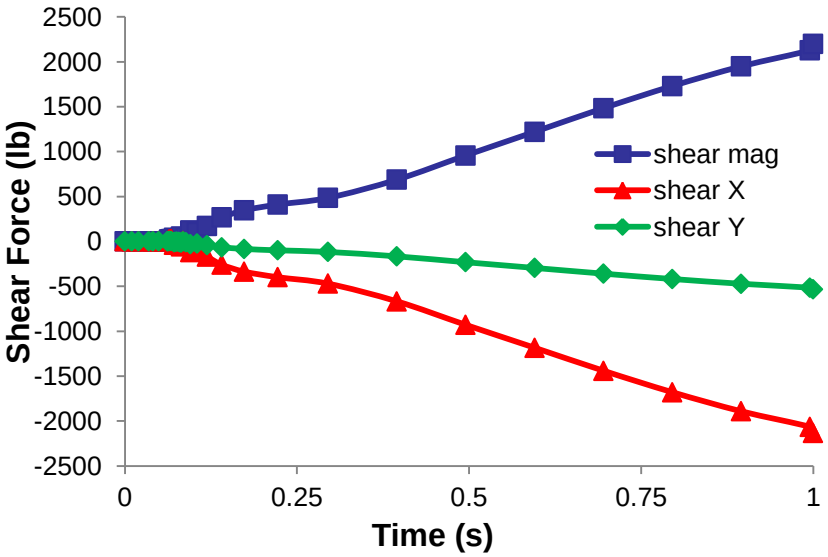
Displacement magnitude comparison



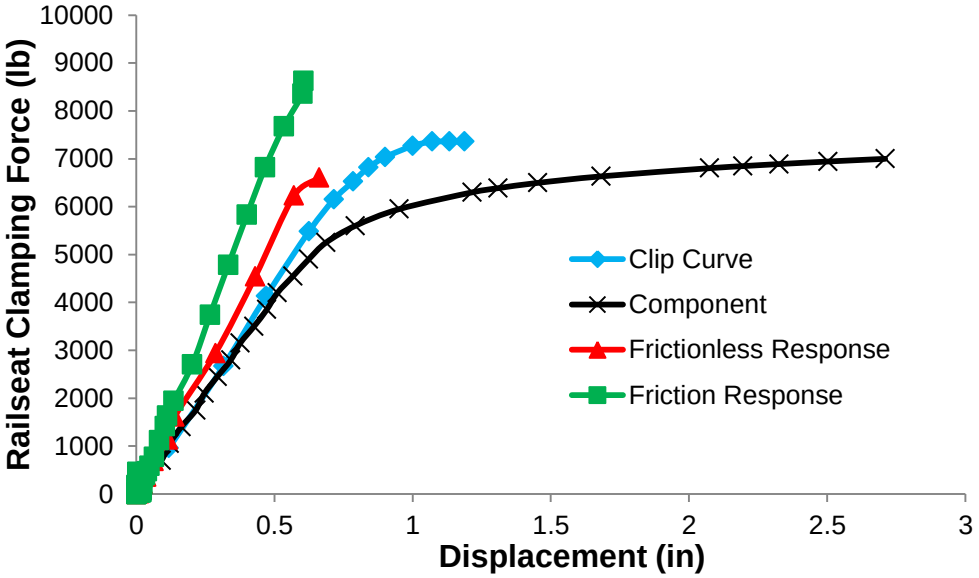
Displacement trace of different cases

Current Model: Comparison between Component and Assembly Model

- The two components of shear force remain a ratio of tangent 14 degree, which is in agreement with the slope of rail base
- With friction the clip appear to be even stiffer as the deformation shape is different and is more energy-consuming



Friction force between clip and insulator



Clamping force-toe displacement relationships

Future Work: Modeling Improvement

- **System modeling:** Future model will incorporate the interaction between concrete tie and fastening system to gain a realistic understanding of the load path and the interaction between different components
- **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 study**: Parametric study about material property and geometric dimension will be conducted using the model

Acknowledgements

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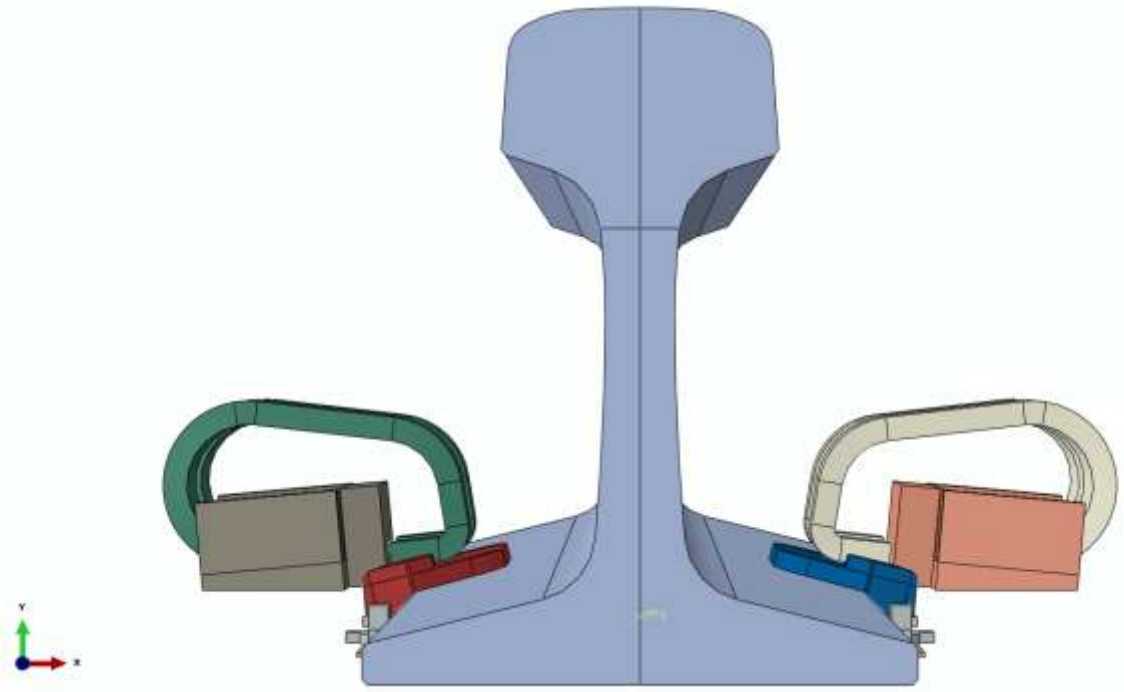
Questions?



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