Concrete Crosstie and Fastening System Modeling at UIUC

2012 Joint Rail Conference
Philadelphia, PA
17-19 April 2012
George Zhe Chen and Moochul Shin
Advisor: Prof. Bassem Andrawes
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.

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

Rail loading dimensions (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

Railseat Clamping force (lb)
Displacement (in)
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)
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.
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.
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

U.S. Department of Transportation

Federal Railroad Administration

- Funding for this research has been provided by the Federal Railroad Administration (FRA)
- Industry Partnership and support has been provided by
  - Union Pacific (UP) Railroad
  - BNSF Railway
  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS / Amsted Rail, Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
- Professor Erol Tutumluer for assisting with ballast modeling. (UIUC)
- Amsted RPS (Jose Mediavilla) and CXT Concrete Tie Inc. (Pelle Duong) for providing engineering drawings, models, and other advice.
Questions?

George Zhe Chen and Moochul Shin
Department of Civil and Environmental Engineering
University of Illinois, Urbana-Champaign
Email: zhechen3@illinois.edu, mshin7@illinois.edu