Vertical Load Path Analysis

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Outline

- Objectives
- Background
- Instrumentation Overview
- Defining the vertical load path
- Understanding rail seat loads
  - Fraction of vertical load
  - Vertical tie deflections
    - Effect on rail seat load
- Dynamic wheel loads
Overall Project Deliverables

Mechanistic Design Framework
- Literature Review
- Load Path Analysis
- International Standards
- Current Industry Practices
- AREMA Chapter 30

I-TRACK
- Statistical Analysis from FEM
- Free Body Diagram Analysis
- Probabilistic Loading

Finite Element Model
- Laboratory Experimentation
- Field Experimentation
- Parametric Analyses
Purpose of Vertical Load Path Analysis

• Identify the load path of vertical forces through the concrete crosstie and fastening system
• Quantify the demands on each component in the system
• Determine how crosstie support variability affects the demands on the components within the vertical load path
• Provide vital inputs to the development of a finite element (FE) model and method of performing mechanistic design of the concrete crossties and fastening systems
• Provide insight for future field testing in revenue service applications
Background Knowledge and Findings

- Field experimentation and modeling show that vertical load is distributed over multiple ties.

- Rail seat load is of more relevance than the wheel load with respect to the design of the concrete crosstie and fastening system.

- Stiffness of each component is critical to the system and contributes to overall behavior.
July 2012 Field Instrumentation

First stage of field instrumentation conducted to capture loads and understand the behavior of the system

Findings:
- Global tie displacements are important to understand load distribution
- Highest loads were imparted by the locomotives and leading axles of railcar trucks

Limitations:
- Comparison and validation through FEM analysis
- Lateral load path not effectively understood
Field Instrumentation Locations

- TTCI (Pueblo, CO)
- High Tonnage Loop (HTL)
  - Curve (2-3°)
  - Safelok I Fasteners
Field Instrumentation Locations

- TTCI (Pueblo, CO)
- Railroad Test Track (RTT)
  - Tangent
  - Safelok I Fasteners
Field Instrumentation Strategy (May 2013)

- Rail Displacement Fixture
- Rail Longitudinal Displacement/Strains
- Vertical Web Strains
- Vertical and Lateral Circuits
- Steel Rods
Vertical Load Path Analysis

**Field Side**
Vertical Load Path Instrumentation

**Gauge Side**

- Vertical Web Strain
- Vertical Wheel Loads
- Rail Seat Loads
- Vertical Rail Displacement
Track Modulus Estimation

- Classical method (most commonly used) – based on load deflection characteristics
  \[ EI \frac{d^4 w}{dx^4} + kw(x) = q(x) \]
  \[ k = \frac{1}{4} \sqrt[4]{E I w^m} \]

- TTCI proposed – Similar strategy with 10kip pre-load

- Other empirical and classical mechanics approaches do exist
  - Timoshenko and Langer (1932)
  - Hay (1982)
  - Eisenmann and Fastenrath (1981)
Vertical Load Path Analysis

Loading Environment

- Track Loading Vehicle (TLV)
  - Static
  - Dynamic

- Freight Consist
  - 3, 6-axle locomotives on HTL
  - 4-axle locomotives on RTT
  - 9 loaded and one empty freight cars

- Passenger Consist
  - 6-axle locomotive on HTL
  - 4-axle locomotive on RTT
  - 10 coaches

- FAST Train
Defining the Vertical Load Path
Rail Seat Loads
Tangent Track, RTT

![Graph showing rail seat loads vs. vertical load applied. The graph plots rail seat load (kips) against vertical load applied (kips), with three lines representing different load conditions: Load Applied, Rail Seat Load - E, and Rail Seat Load - U.](image-url)
Defining the Vertical Load Path
Crosstie Support Variability: Vertical Crosstie Displacement

- Curve track
- Static vertical loads
- Max applied load = 40 kips
- Low rail: soft support (slack or gap in support system)
- Modulus calculated as per classical method 2,500 – 4,500 lb/in² (except C = 8500)
Crosstie Support Variability:
Vertical Crosstie Displacement – with 10 kip zero

- Curve track
- Static vertical loads
- Max applied load = 40 kips
- Support modulus ranges from 6000 – 7,800 lb/in^2 (except C)
Vertical Load Path Analysis

Rail Seat Loads and Deflection

- Tie Deflection - E
- Tie Deflection - U
- Rail Seat Load - E
- Rail Seat Load - U
- Load Applied
Vertical Wheel Loads - RTT

Vertical Loads on far rail (RTT, Freight)

Vertical Loads on near rail (RTT, Freight)

Vertical Loads on far rail (RTT, Passenger)

Vertical Loads on near rail (RTT, Passenger)

- Static Load
- Dynamic Wheel Load
Conclusions

• **Observed Loads**
  • Dynamic wheel loads are not significantly higher than static wheel loads
  • Observed loads are similar to revenue service loads, minus the impact loads

• **Rail Seat Loads**
  • 30-80% of the vertical wheel load is resisted by each rail seat (high variability)
  • Ballast stiffness plays key role
  • Vertical rail seat load is independent of lateral loads

• **Tie Deflection**
  • Tie deflections are highly affected by track stiffness
  • Static deflection is considered an important system parameter for design
Future Work

- Continue analysis of data to understand the governing mechanisms of the tie and fastener system
- Continue to compare and validate the FE model
- Relate ballast stiffness to the tie deflections
- Create empirical models relating stiffness to loading demands on each component (rail pad, rail seat, etc.)
- Investigate the influence of lateral loads on the vertical load path
- Conduct small-scale, evaluative revenue service testing on Class I railroads
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Questions or Comments?

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Appendix
Defining the Vertical Load Path

Observe the change in Rail seat Load distribution
Vertical Wheel Loads - HTL

Vertical Loads on High rail (HTL, Freight)

Vertical Loads on Low rail (HTL, Freight)

Vertical Loads on High rail (HTL, Passenger)

Vertical Loads on Low rail (HTL, Passenger)
Rail Seat Load - RTT

Rail Seat Loads on far rail (RTT, Freight)

Rail Seat Loads on far rail (RTT, Passenger)

Rail Seat Loads on near rail (RTT, Freight)

Rail Seat Loads on near rail (RTT, Passenger)