OFFICE OF RESEARCH & DEVELOPMENT

2012 R&D REVIEW

Next Generation Foundation for Special Trackwork

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Federal Railroad Administration

Program Area & Risk Matrix

Next Generation Foundation for Special Trackwork

Program Areas \ Risk Factors	Trespass	Grade Crossing	Derailment	Train Collision	All Other Safety Hazards
Railroad Systems Issues					
Human Factors					
Track & Structures			X		
Track & Train Interaction					
Facilities & Equipment					
Rolling Stock & Components					
Hazardous Materials					
Train Occupant Protection					
Train Control & Communications					
Grade Crossings & Trespass					

Acknowledgements & Stakeholders

Acknowledgements

- Facility for Accelerated Service Testing (FAST) High Tonnage Loop
- American Association of Railroads (AAR) Project on Reduced Impact Track

Stakeholders & Project Partners

- BNSF (Frog donations)
- AAR member railways (TAG)
- Volpe National Transportation Center

Next Generation Foundation for Special Track Work (STW)

Objective

- Develop improved performance foundation designs for special trackwork frogs

Research approach

- Develop analytical tools to understand vehicle-frog interactions
- Investigate effects of frog structure and foundation characteristics on vehicle and frog dynamic performance through test and modeling
- Provide general guidance to designers for optimal frog foundation/ system designs

Next Generation Foundation for STW

Major Tasks

- Review of relevant frog failure modes
- Measurement of service load environment and load path
- Parametric study of foundation characteristics and their effects on frog and car performance
- Recommendations for additional work (go/no go on prototype development)

Motivation for project

- Special trackwork is the third leading cause category for track-related accidents
- There have been significant improvements in performance of frogs due to superstructure (rail and ties) changes
- Modeling suggests improvements can be made by optimizing foundation properties

Previous Methods

- Frogs designed for static loads
- Dynamic design methods not used
- Frog foundation is the same as the rest of the track
  - Dynamic load environment is more severe

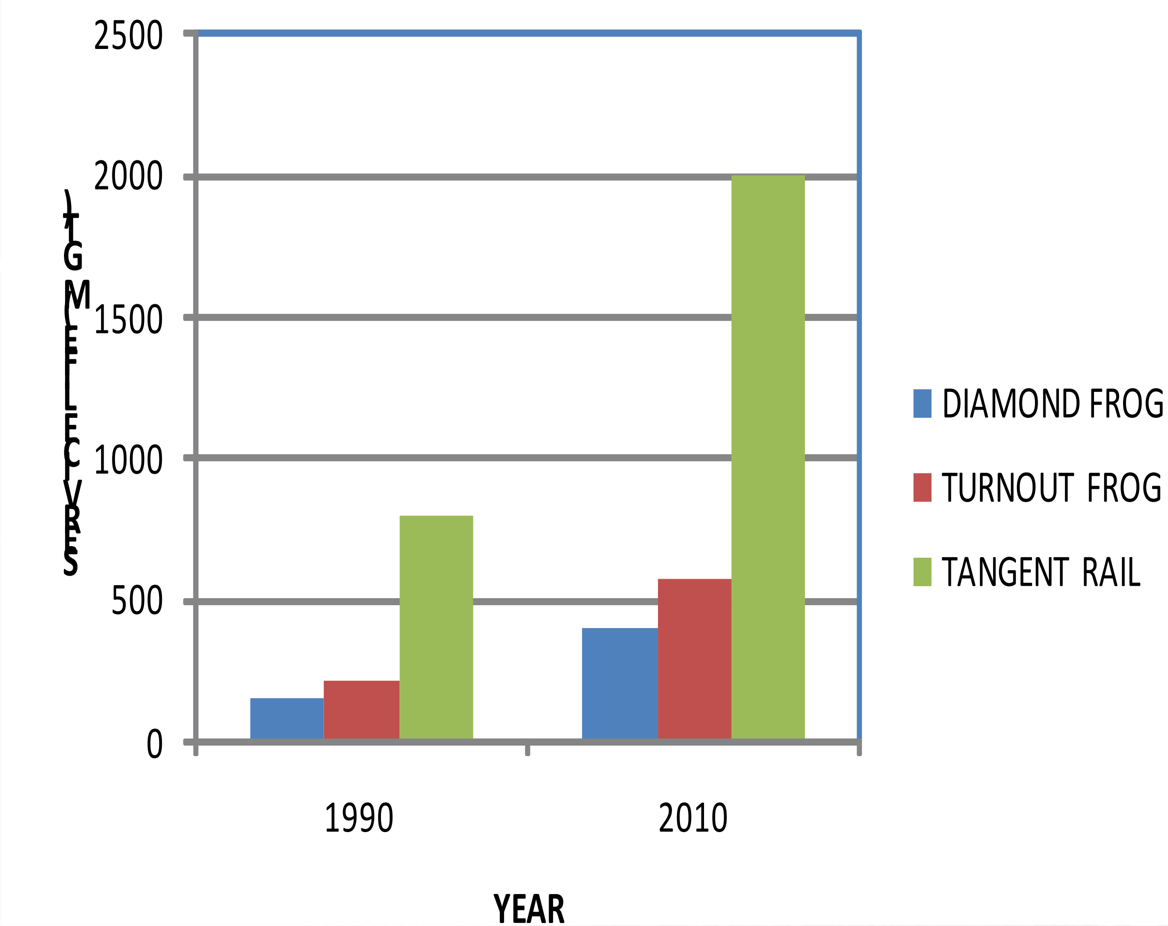
Next Generation Foundations for STW

Typical Frog Designs Used Today

Next Generation Foundations for STW: Literature Survey Results

<u>Frog Service Life</u>

- **Relatively short compared to other track components**
- **Significantly improved in past 20 years due to superstructure improvements**

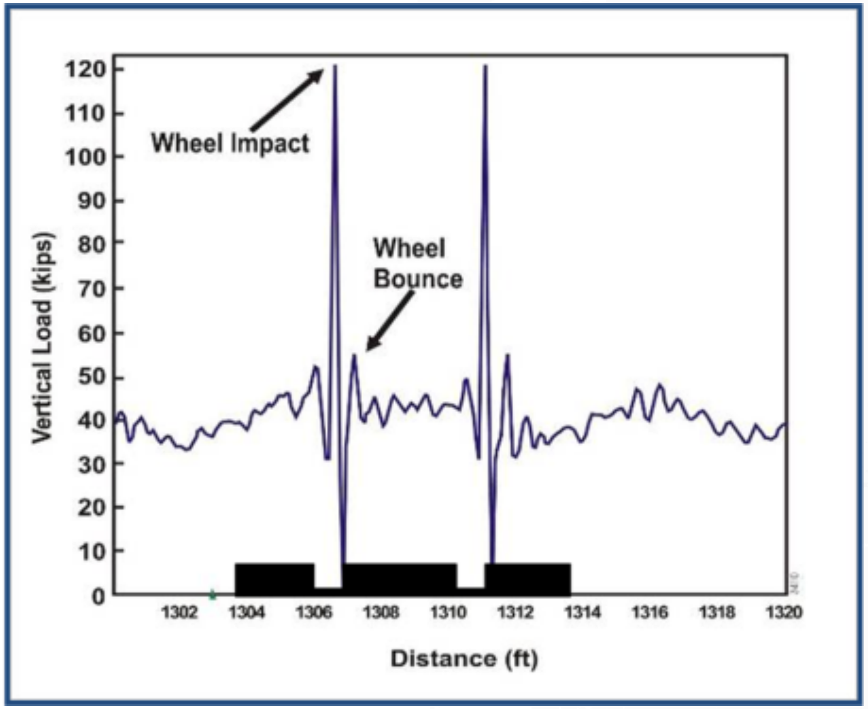


Root Causes of Special Trackwork Wear & Fatigue

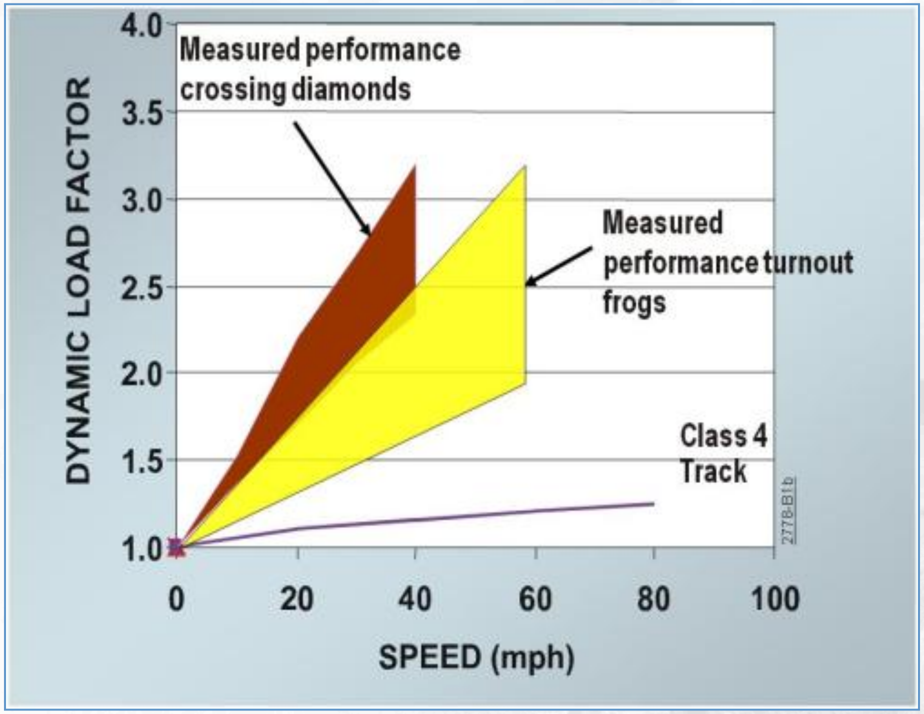
Track Structure Transitions

- Significant changes in rails, platework and crossties from open track to carry high dynamic loads
- Generates high dynamic loads
  - Broken bolts, fasteners and platework
  - Increased settlement, noise and foundation damage

Service Environment



High and Lower Frequency Impacts



Speed Effect on Frog Impacts

Failure Modes

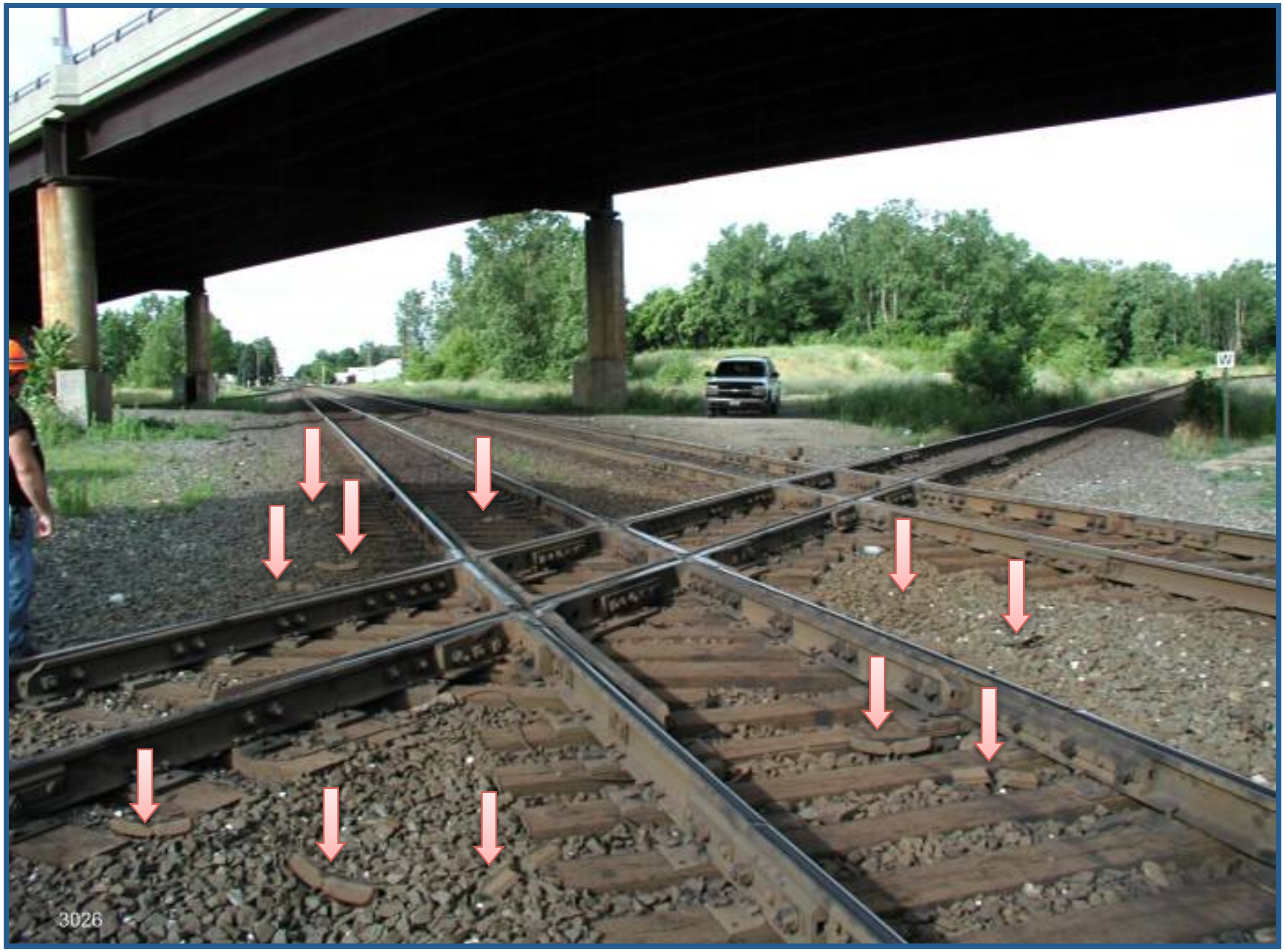
- Running surface height loss
- Differential settlement
- Casting cracking
- Frog point cracking
- Rail bolt hole cracks
- Joint bar cracking
- Track bolt failures
- Rail fastener/ shoulder weld fatigue
- Platework cracking
- Plate welded stop failure
- Crosstie splitting
- Crosstie/ ballast abrasion
- Loss of alignment

Next Generation Foundations for STW: Failure Modes by Frog Type

Failure Mode	Fixed point (RBM)	Spring	Moveable point	3 RAIL	SOLID	FBF
Running surface height loss (metal flow)	X	X			X	X
Running surface height loss (wear)			X	X		X
Casting cracking	X				X	
Frog point cracking (casting or rail point)	X	X	X	X	X	
Rail bolt hole cracks	X		X	X	X	
Joint bar cracking	X			X	X	
Track bolt failures	X			X	X	
Platework cracking	X	X		X	X	
Rail fastener/ shoulder weld fatigue	X	X	X	X	X	
Plate welded stop failure	X	X	X	X	X	
Crosstie splitting	X			X	X	
Crosstie/ ballast abrasion	X			X	X	
Loss of surface	X			X	X	
Loss of alignment	X					X

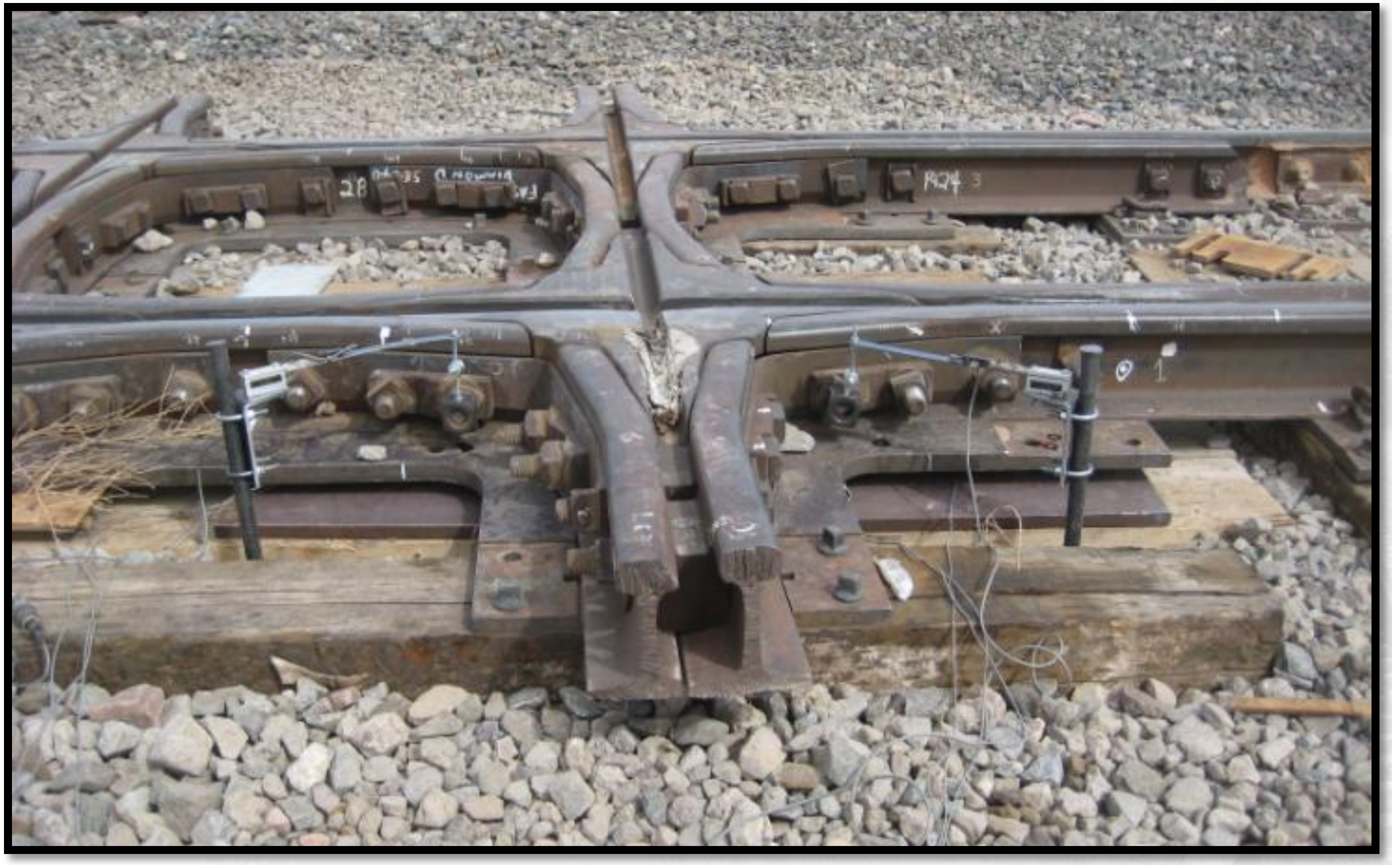
Effect on Car Damage

"Car Parts Graveyard" around diamond



Wayside Instrumentation

Measured deflections and forces in a typical diamond crossing design



Instrumented Wheel Set (IWS) Consist

- IWS measures wheel forces in 1 truck of loaded 315 kip car
- Instrumented Freight Car (IFC) measures forces & accelerations

Scaled Foundation Test Panels

Base Case – Control Panel
Represents Current Designs

Rubber Base – Test Panel
Higher Damping Design

Scaled Foundation Test Panels

Field tests of track stiffness, damping and running surface conducted

Base Case – Control Panel

Rubber Base – Test Panel

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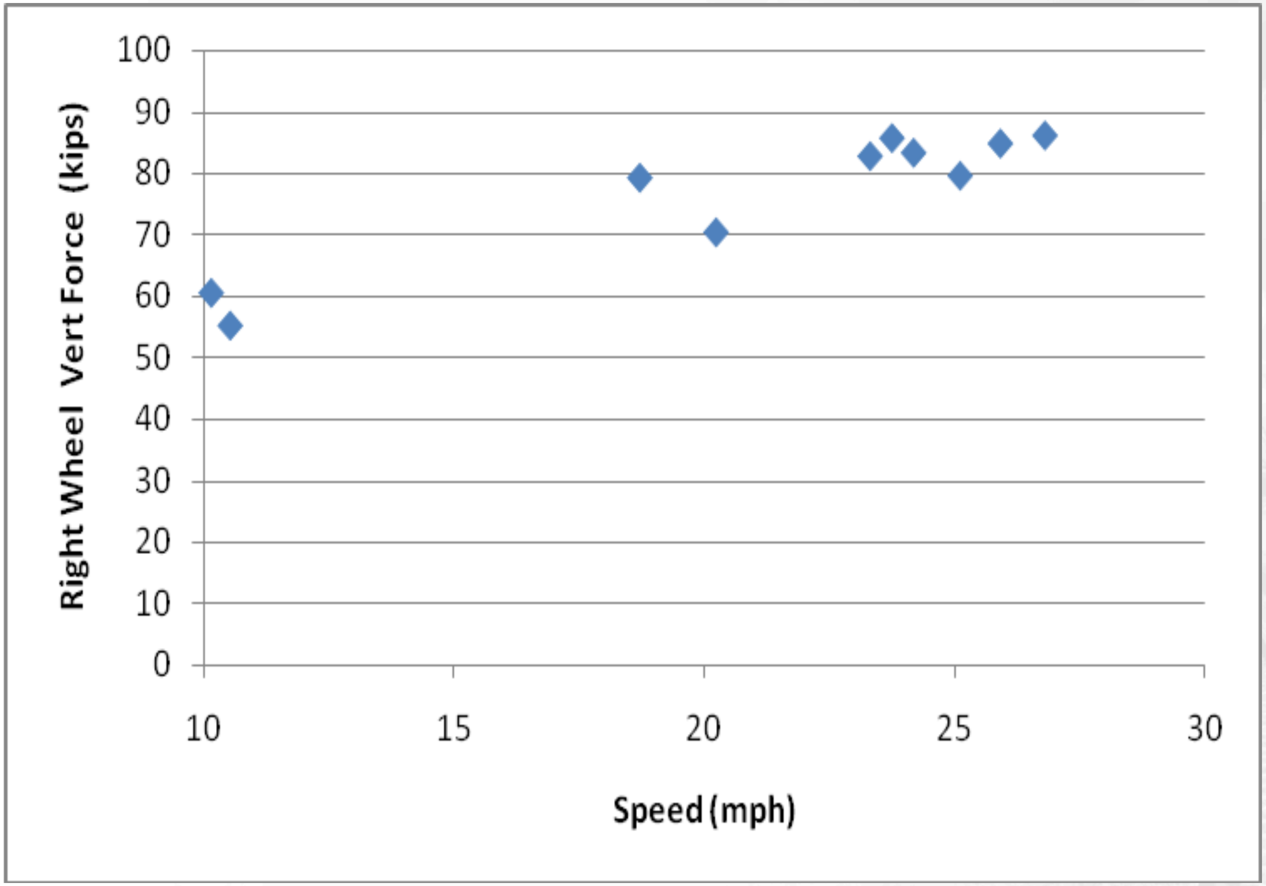
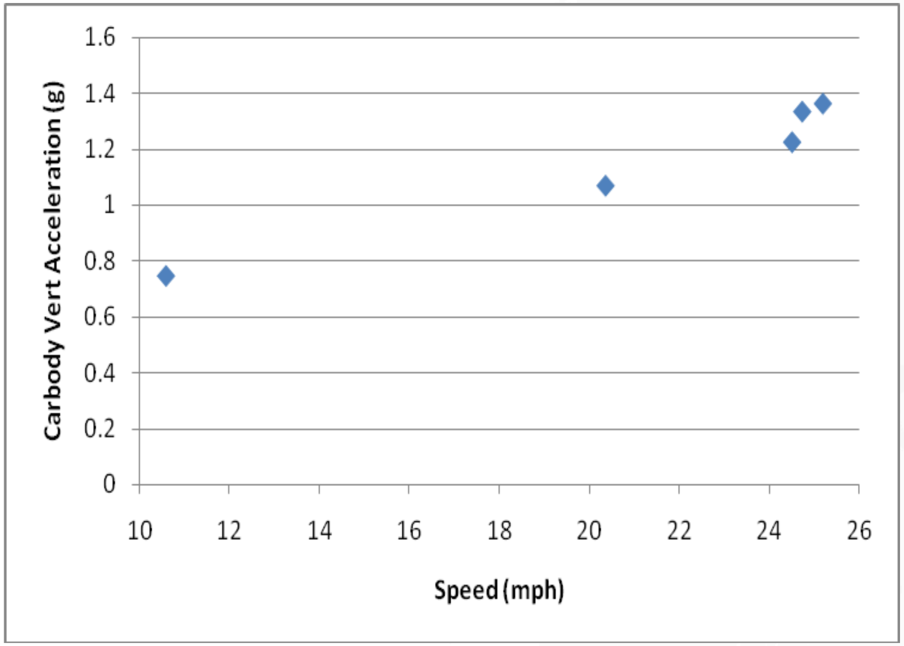
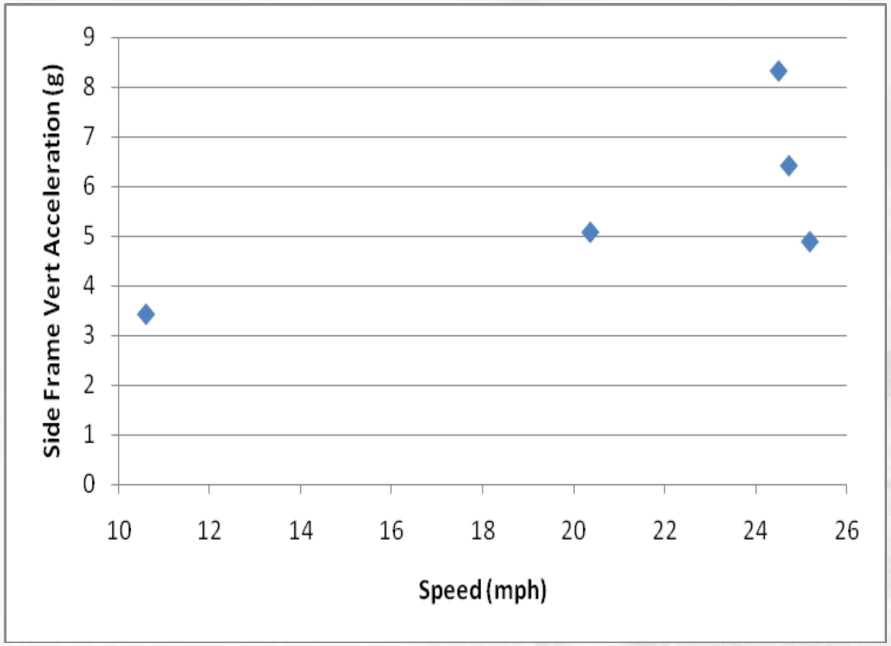
Instrumented Wheel Set (IWS) Test – Wheel Impact



Maximum forces measured at diamond frogs

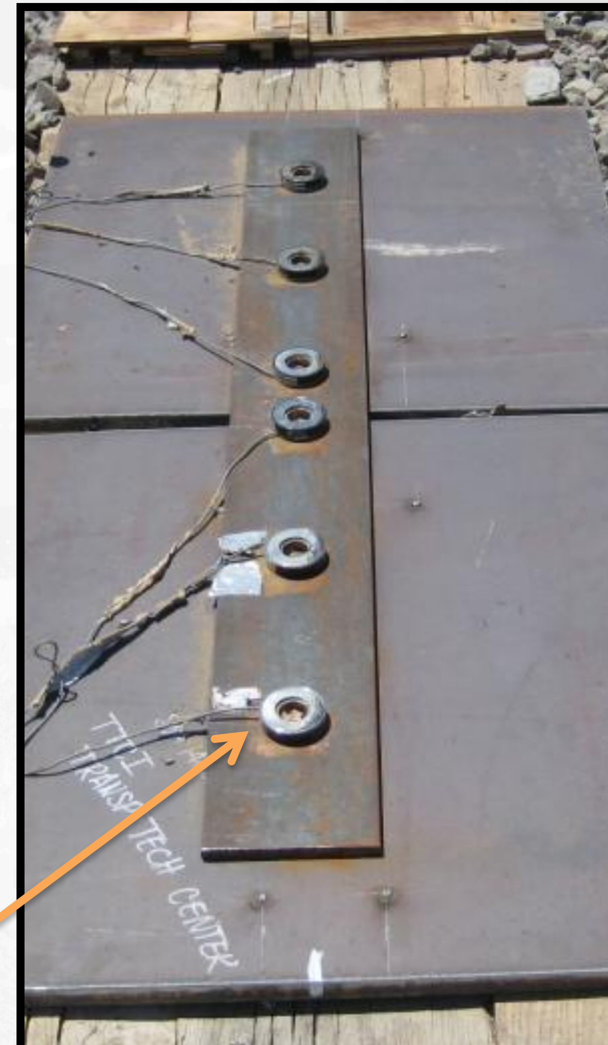
Instrumented Freight Car (IFC) Measurement





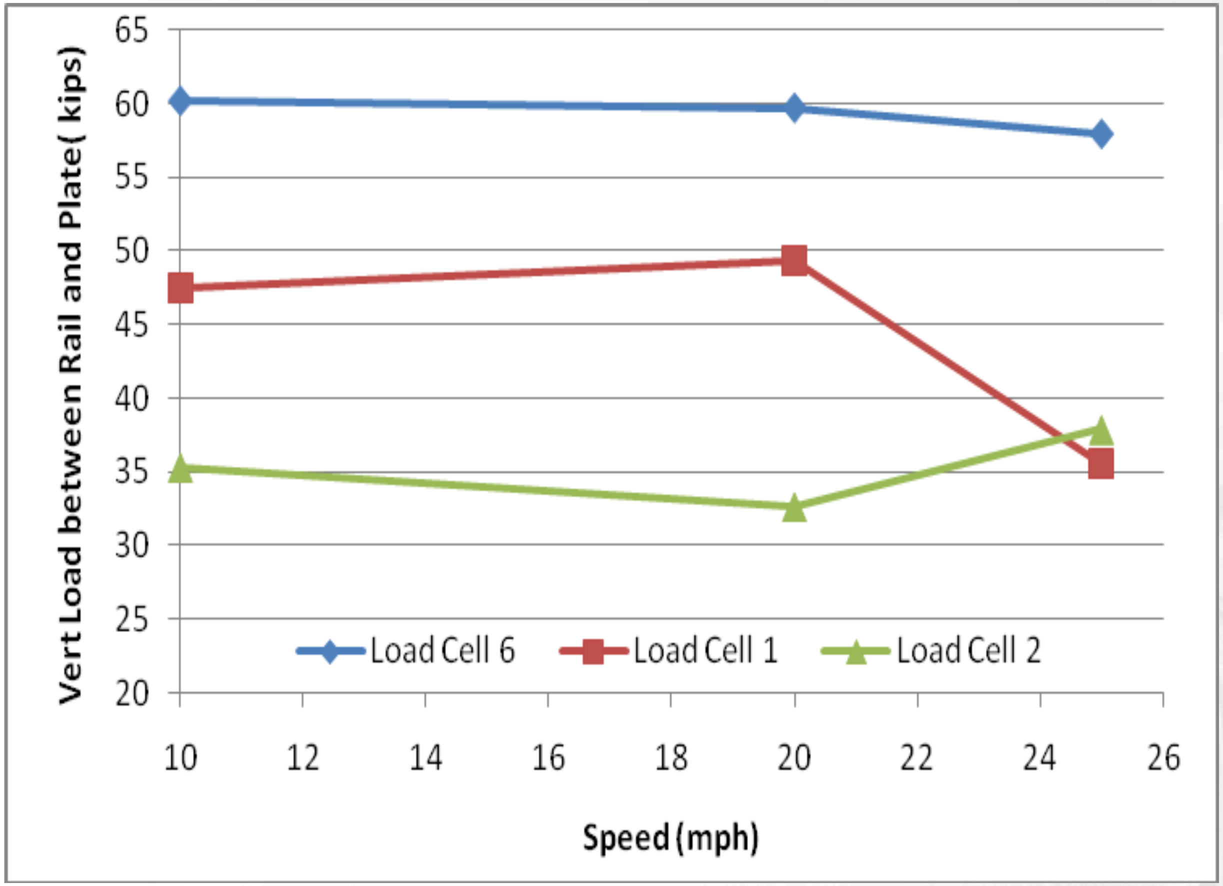
IFC has the same trend as IWS

Load Cell Uneven Contact



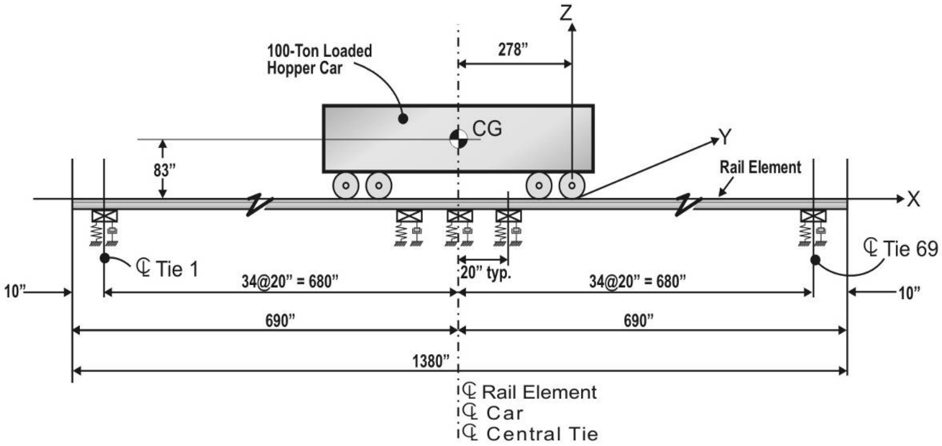
"Hot" Spot,
Uneven Contact

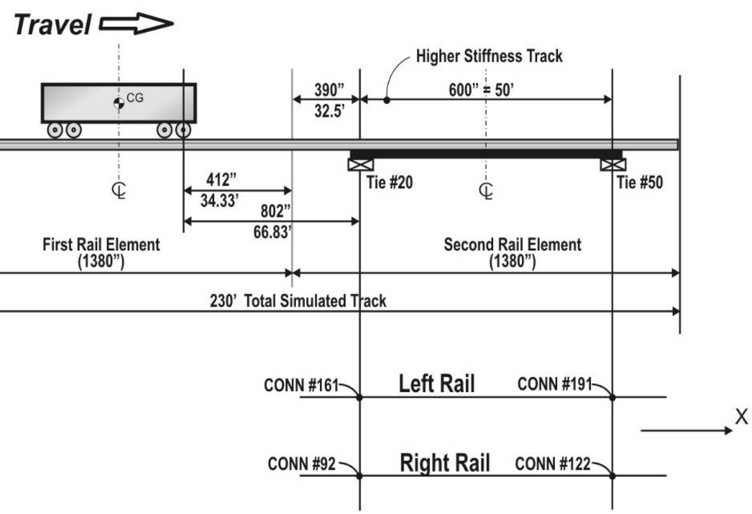
Tie-Plate Load Measurement



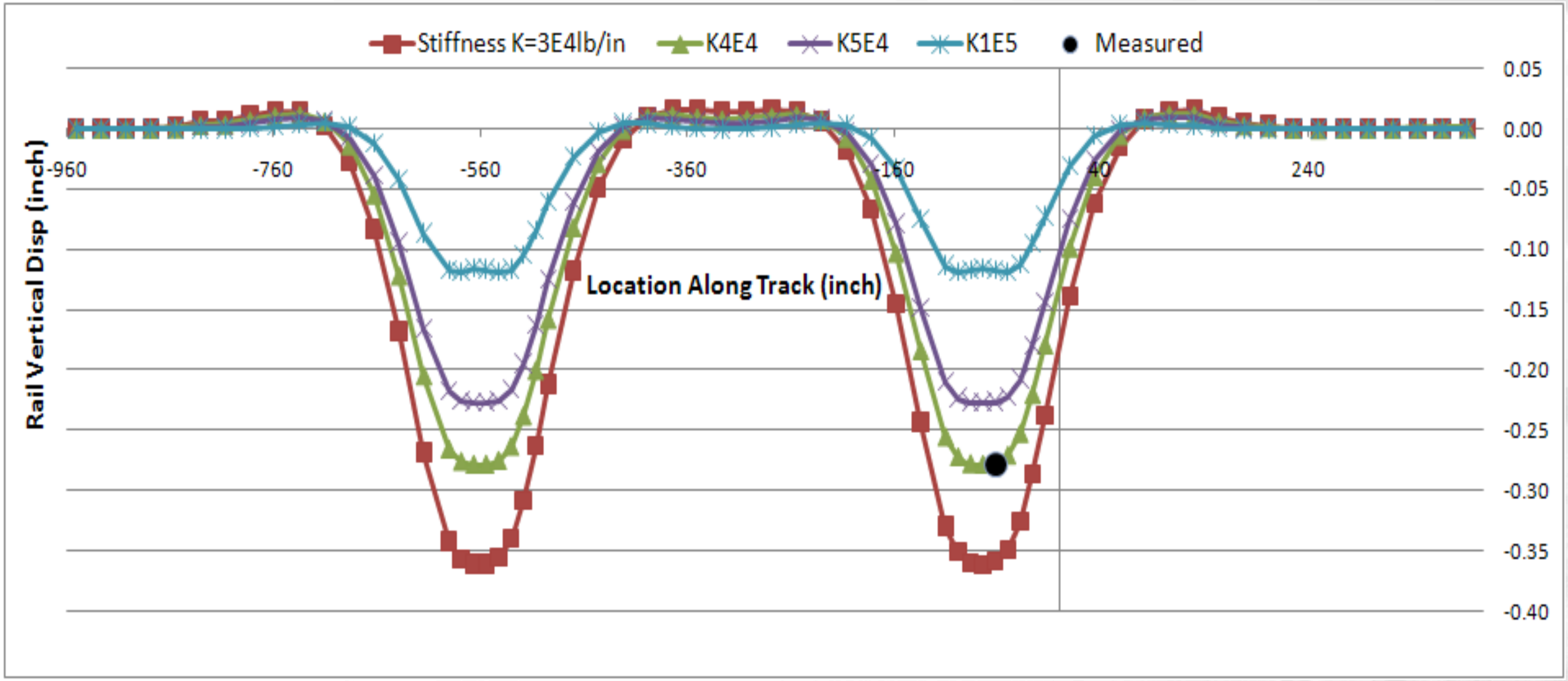
Loading is not uniform – Hot spots produce high loads

NUCARS® Vehicle-Track Dynamics Modeling



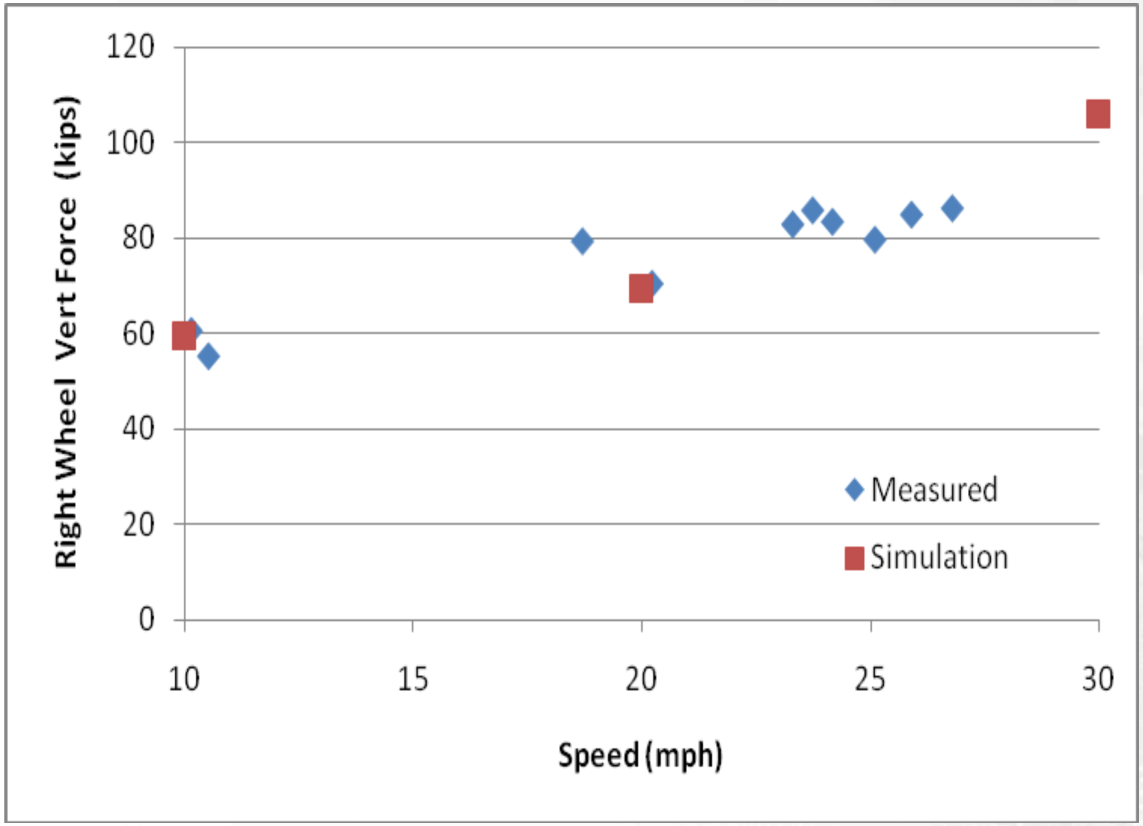


Track Model Validation – Static



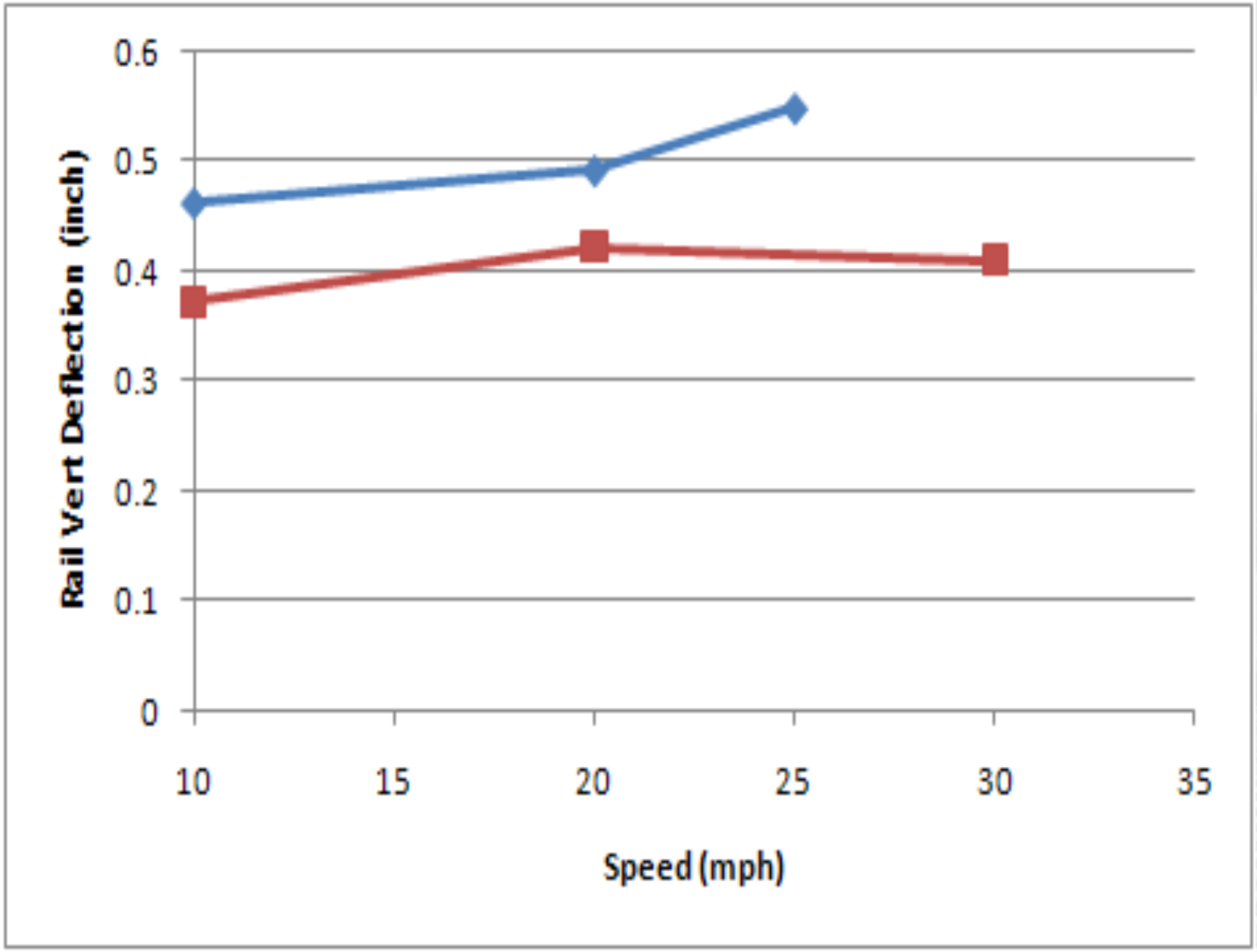
Static track deflections measured under 39 ton axle loads used to calibrate model

Model Validation – Dynamic Force

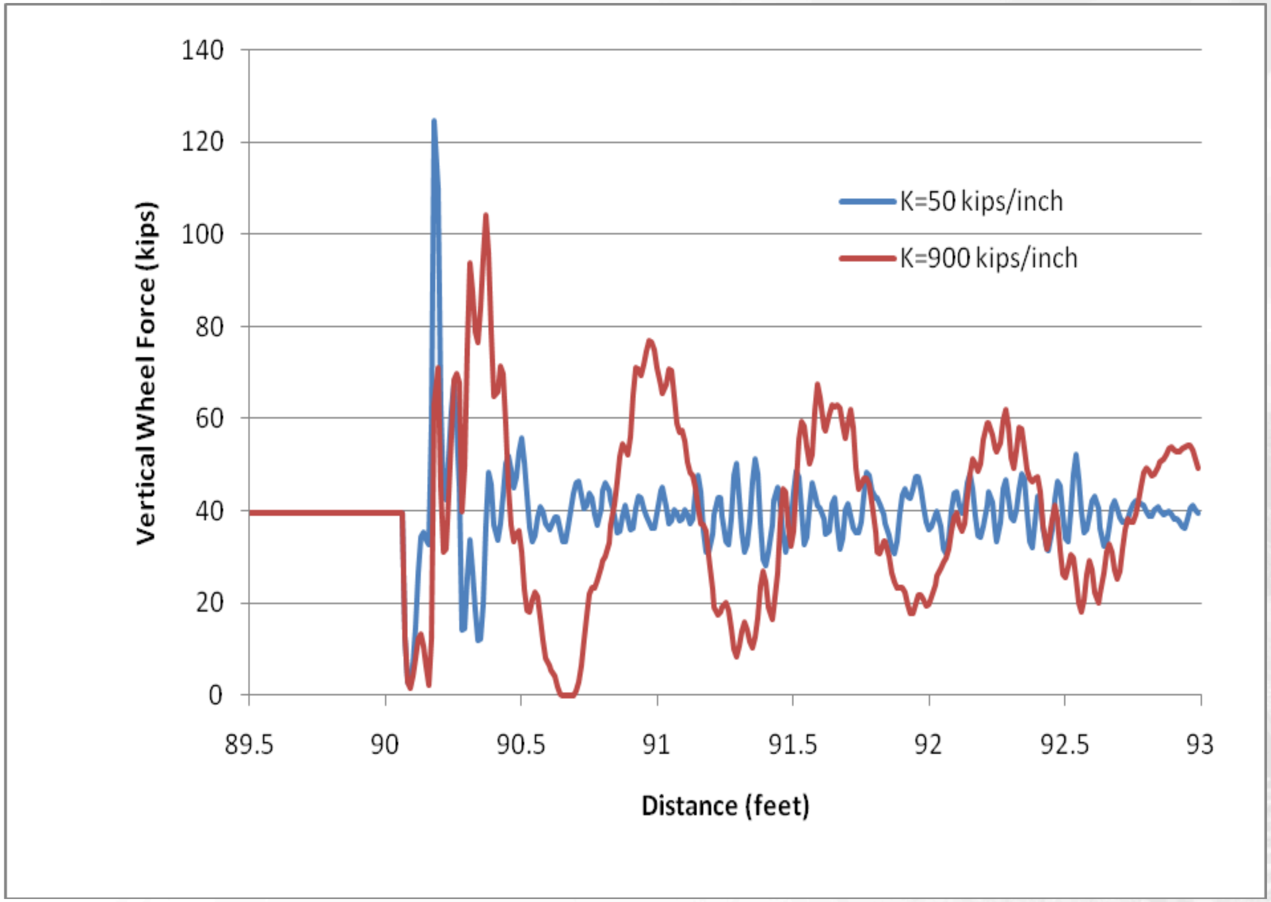


Calibrated model able to simulate measured wheel/rail forces

Model Validation – Dynamic Deflection



Modeling – Foundation Stiffness



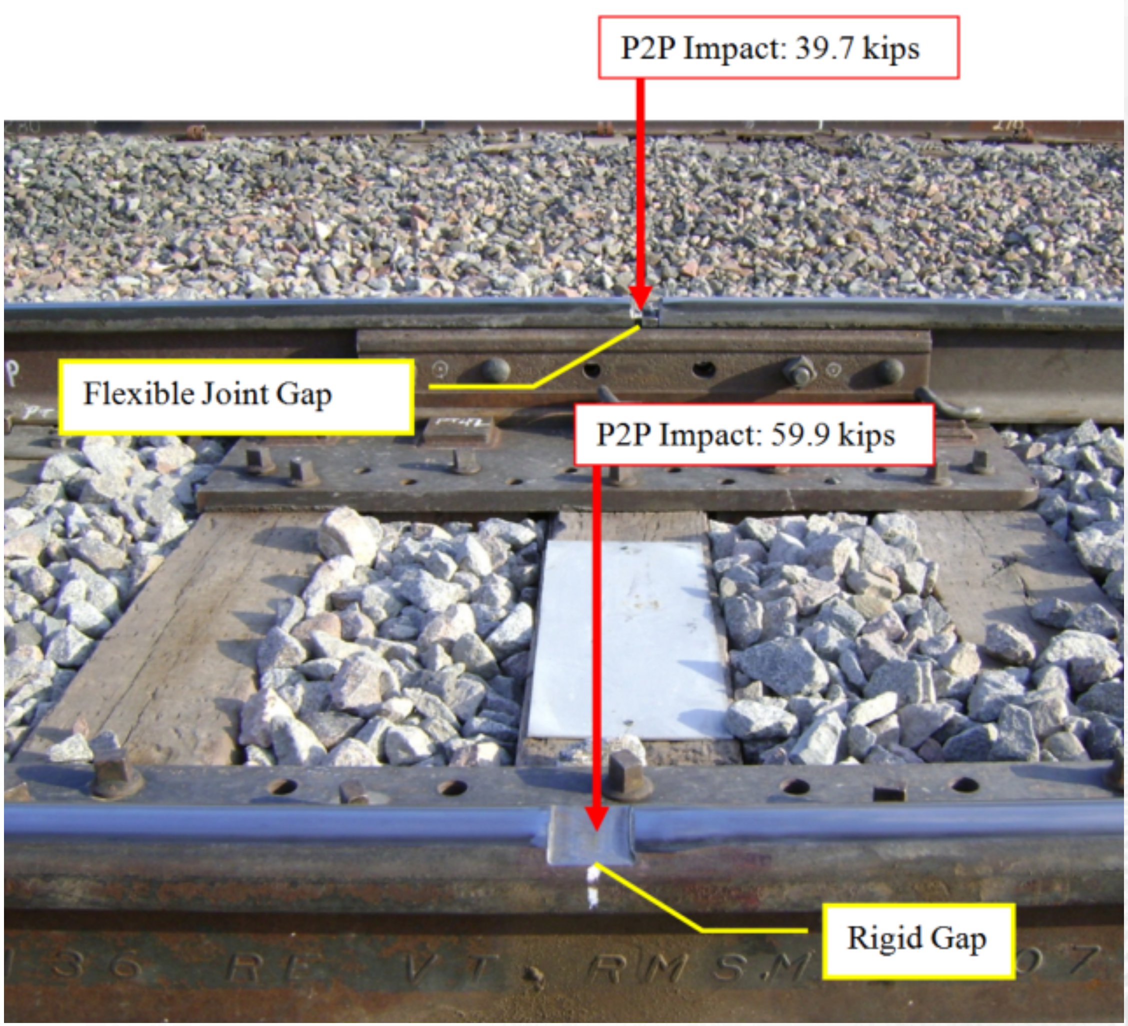
Flangeway caused impacts put more energy (damage) into stiff track

Wood Panel with Ballast Foundation- Case 1

Rubber Panel with Ballast Foundation- Case 2

- Rail stiffness
- Develop on mainline switches

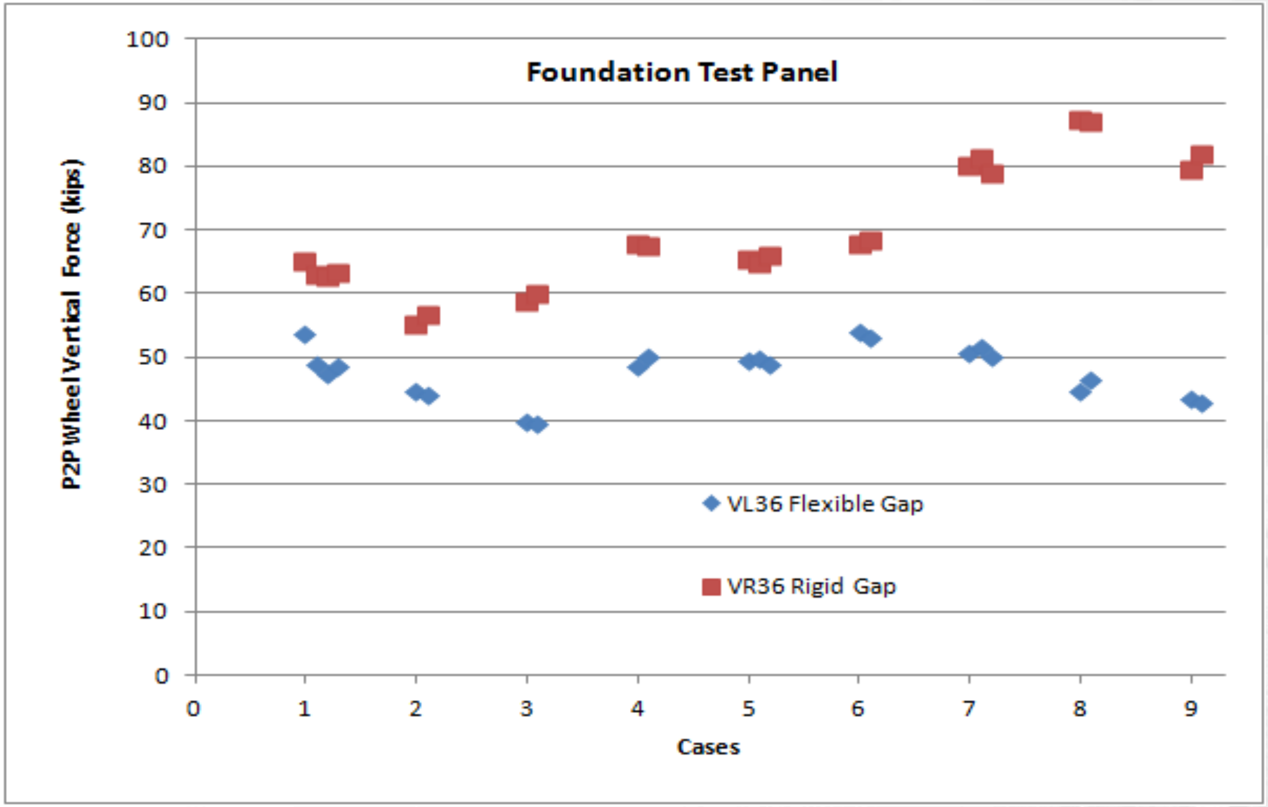
Effect of Rail Stiffness- Case 3



Joint generates flexibility

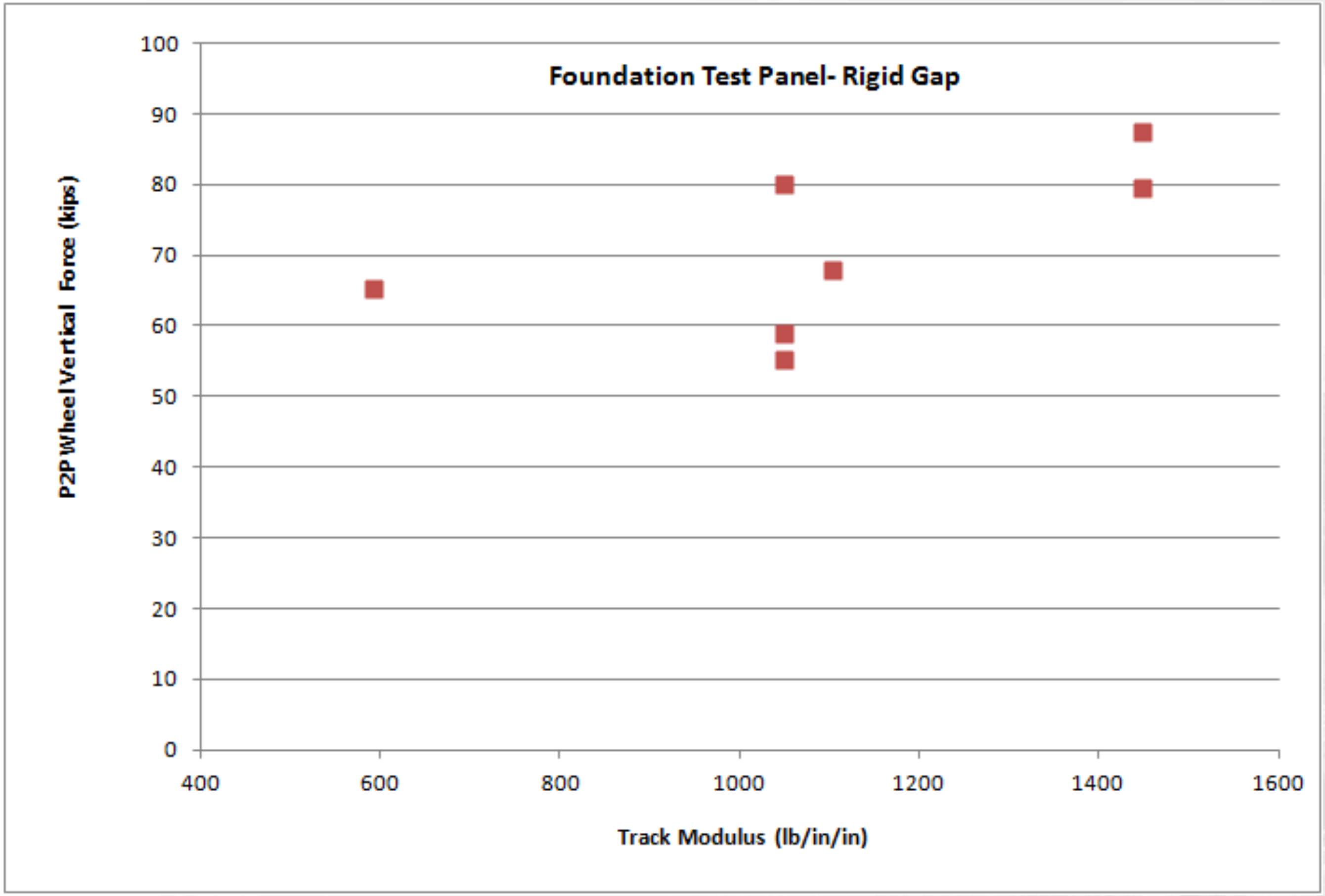
Rubber Panel Non-Ballast Foundation- Case 4

Measured Forces with Different Foundations



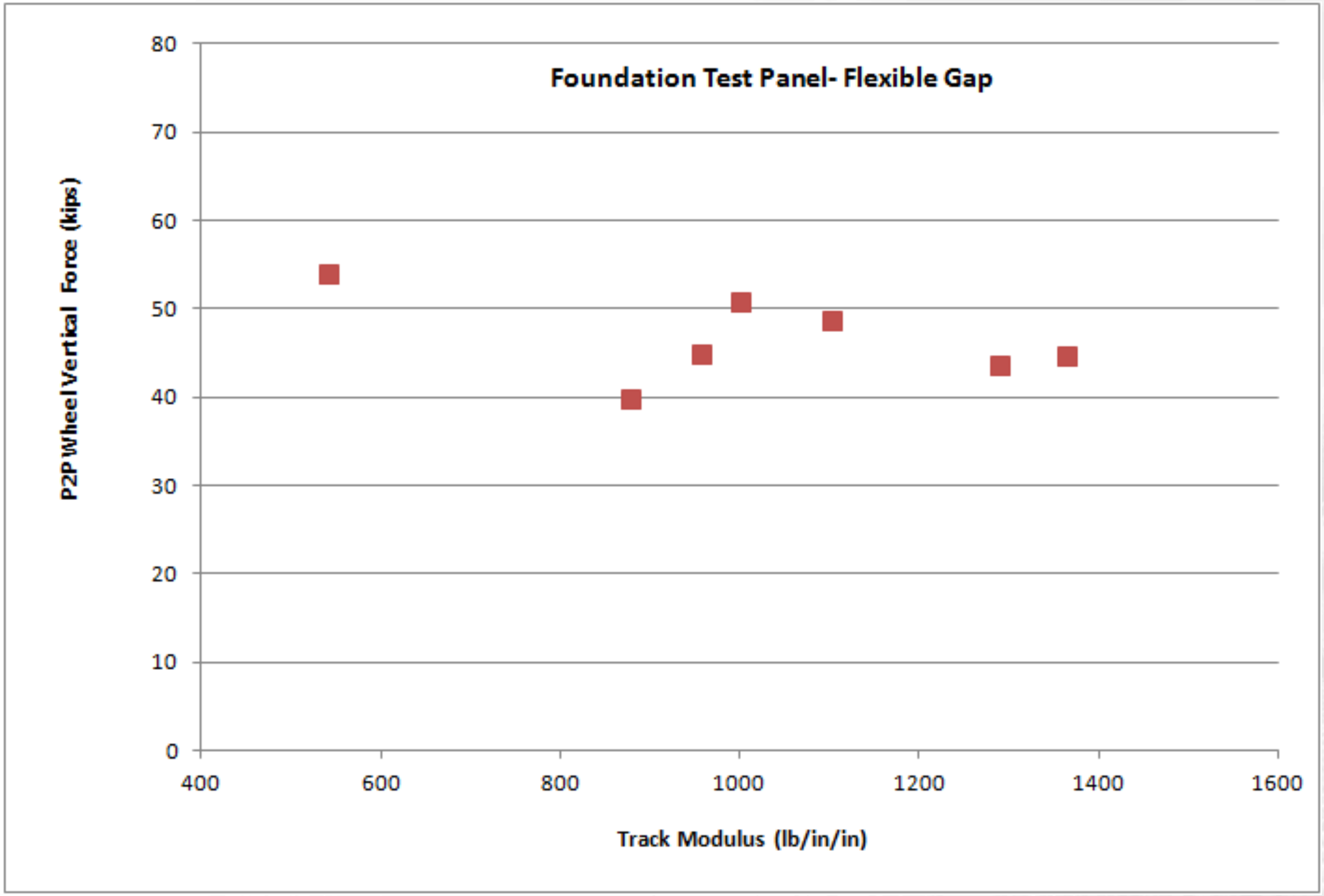
- Flexible versus rigid gap: 17% ~ 49% reduction
- Flexible gap: Max 26% reduction due to foundation changes
- Rigid gap: 37%

Effect of Foundation Stiffness and Damping



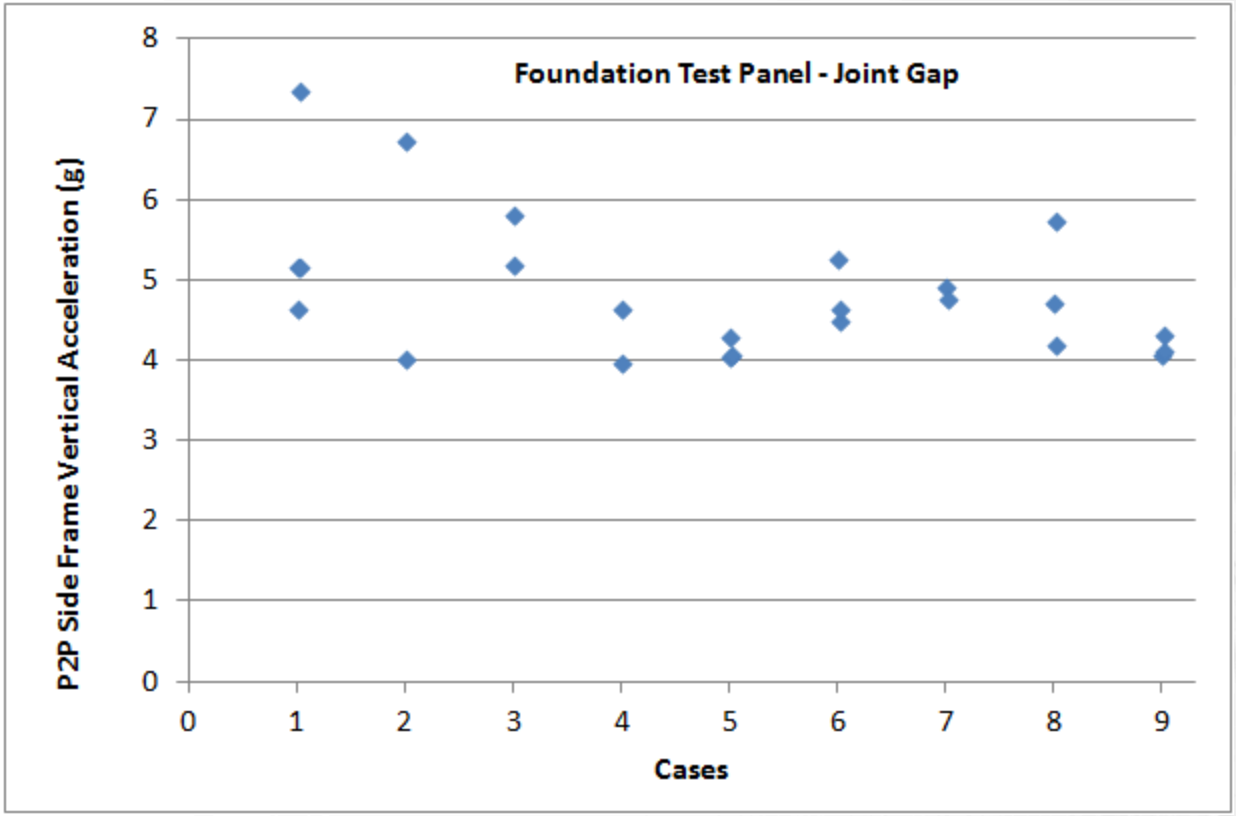
Rigid gap: in general, impact increases with stiffness

Effect of Foundation Stiffness and Damping



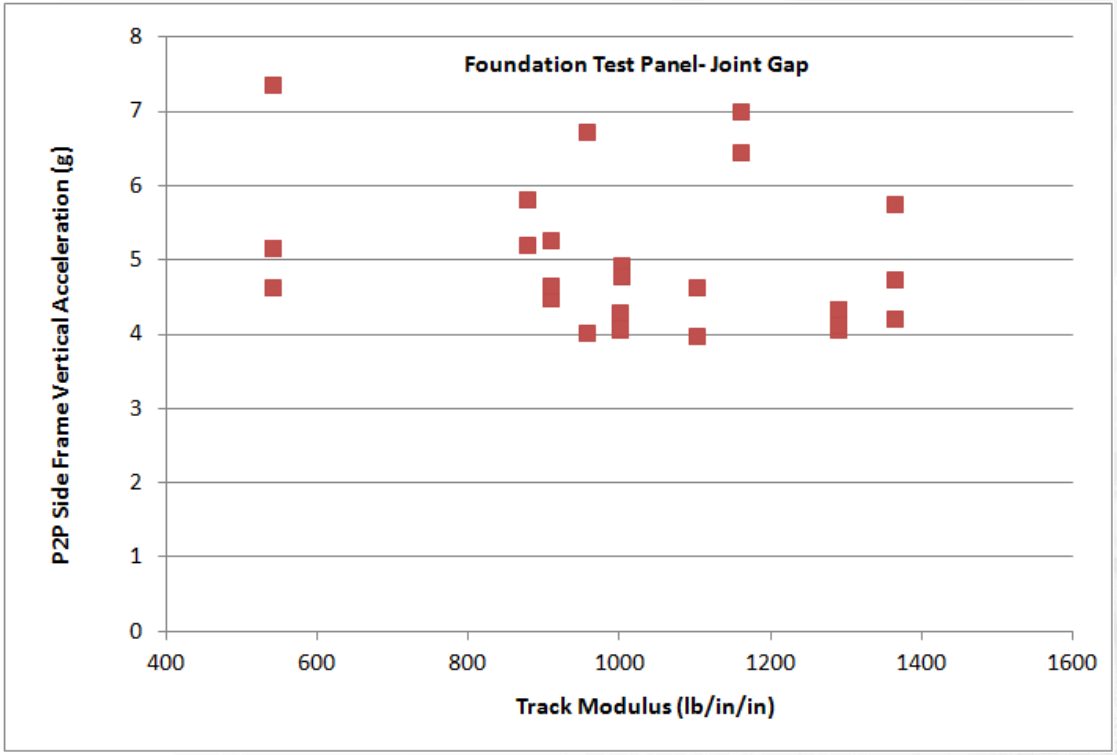
Flexible gap: nonlinear relationship between stiffness and impact

Effect on Truck Side Frame Acceleration



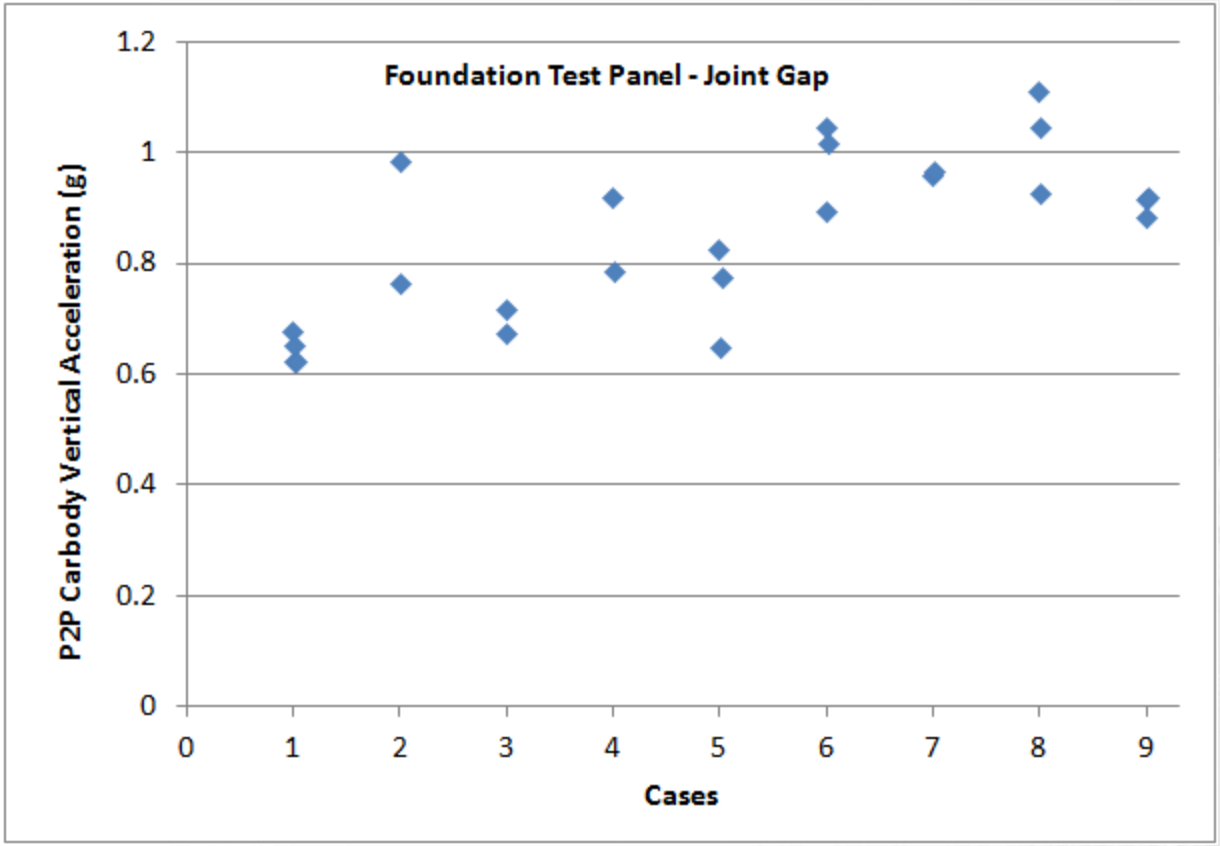
Flexible gap: Max 45% reduction due to foundation changes

Effect of Foundation Stiffness and Damping



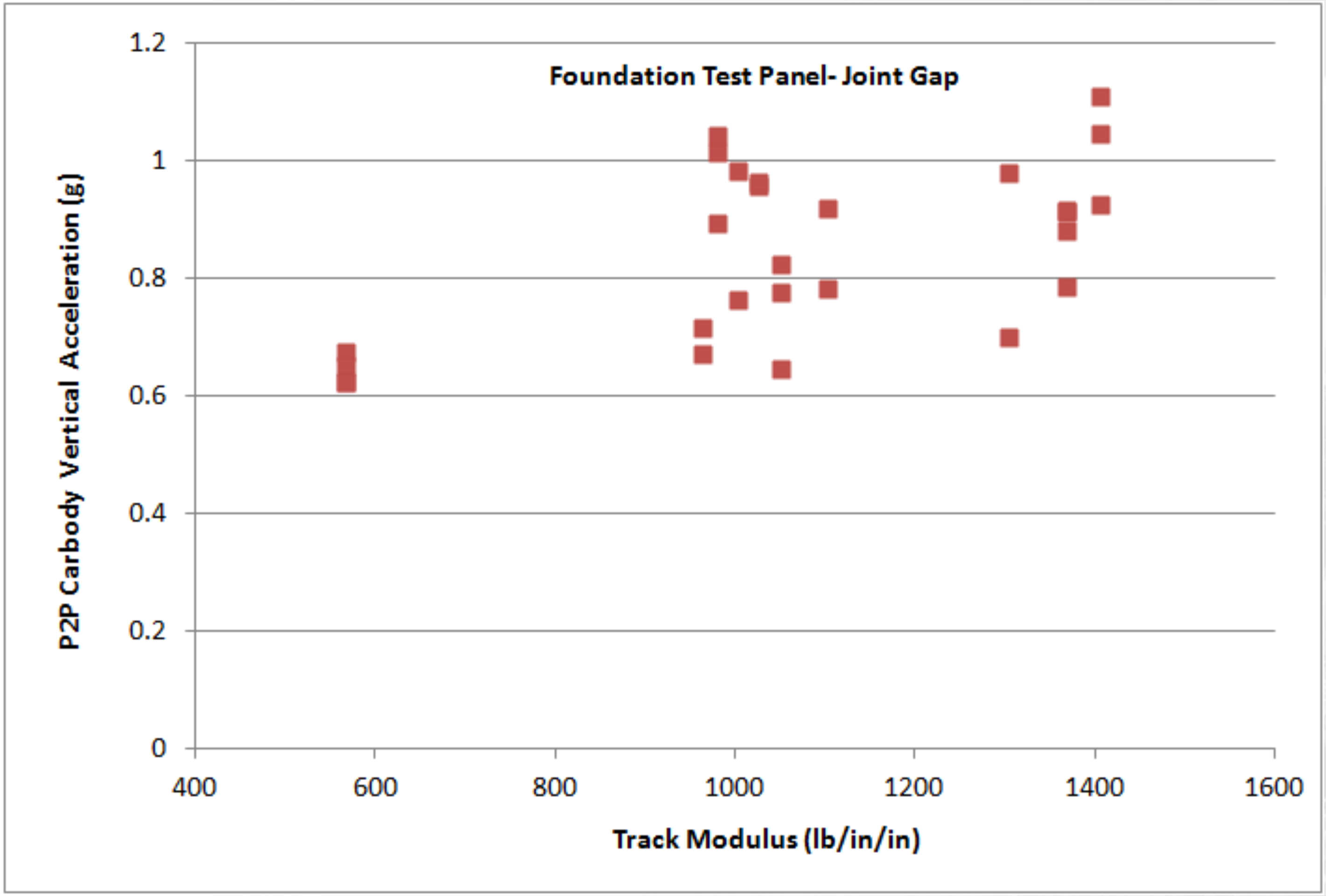
- Side frame acceleration over flexible joint gap: distributes widely, decrease trend as foundation stiffness increases
- Need increase IFC car sampling frequency for side frame acceleration

Effect on Carbody Acceleration



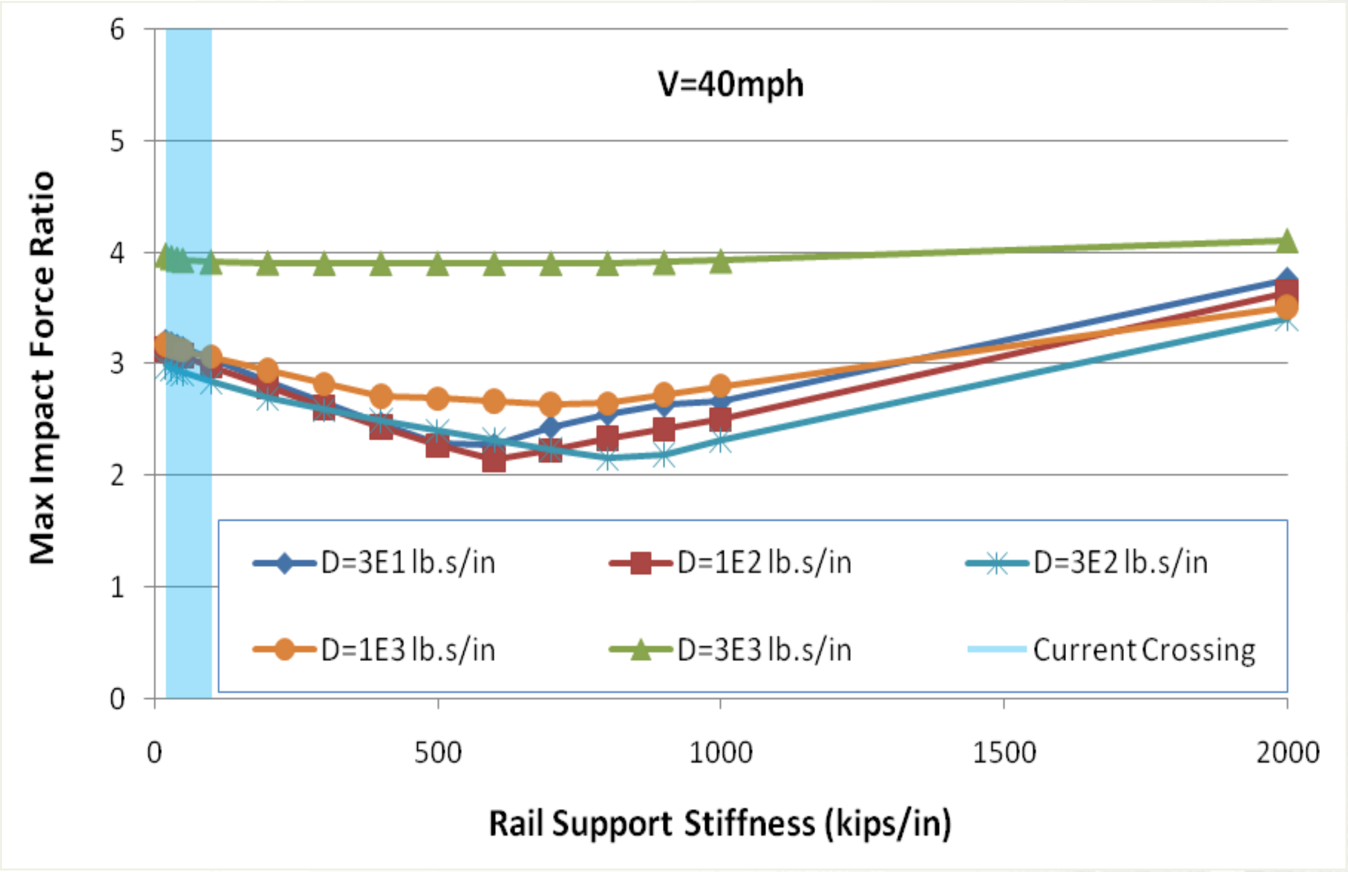
Flexible joint gap: Max 40% reduction due to foundation changes

Effect of Foundation Stiffness and Damping



Carbody acceleration increases with foundation stiffness

Optimization of Foundation Stiffness and Damping



Modeling shows optimization of stiffness and damping possible, but structure and material limit feasibility

Conclusions

- Foundation stiffness change without short wave length track geometry has small effect on dynamic load
- High frequency dynamic load in transition track can be mitigated by changing track structure
- Rail stiffness has significant effect on impact
- Three-rail high angle diamond crossing could generate less impact than casting crossing
- Carbody impact acceleration increases with frog foundation stiffness
- Foundation stiffness and damping optimization depends on track geometry and rail stiffness

Positive Project Support

- Railway track standards engineers contributed their design expertise and experience to the project.

- The practical aspects of design ideas were debated openly

Lessons Learned

- Running surface profile (longitudinal) is important in determining maximum vertical forces
  - It can overwhelm foundation changes we are studying

- Ballasted track surface is difficult to maintain at track transitions
  - This makes comparison testing of foundations difficult

Break/Posters | Nearby Food Options (all within 5-7 minutes walking distance)

- Au Bon Pain: 601 Indiana Ave NW # 1Washington, DC 20004
- Burger King: 501 G Street NW, Washington, DC 20001
- Chipotle: 601 F Street NW, Washington, DC 20005
- Cosi: 601 Pennsylvania Ave NW # 2 Washington, DC 20004
- Dunkin Donuts: 601 F Street NW, Washington, DC 20004
- Firehook Bakery & Coffee House: 441 4th Street NW, Washington, DC 20001
- Jack's Famous Deli: 501 3rd St NW # 2, Washington, DC 20001
- Quiznos Sandwiches: 772 5th St NW, Washington, DC 20001
- Starbucks: 443 7th St. NW, Washington, DC 20004
- Subway: 501 D Street NW, Washington, DC 20001