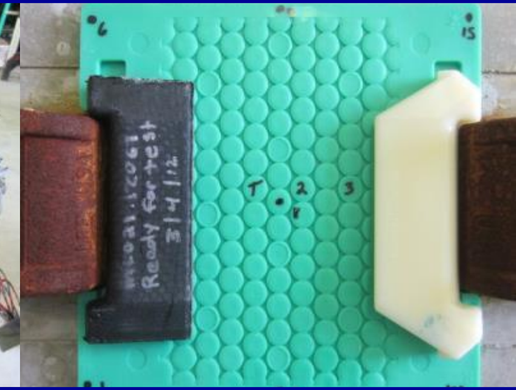
Top 10 Findings and Outcomes
FRA Crosstie and Fastening System BAA 2010-1 Research Program



2 April 2015

Riley Edwards, Marcus Dersch, and Yu Qian

RAILTEC
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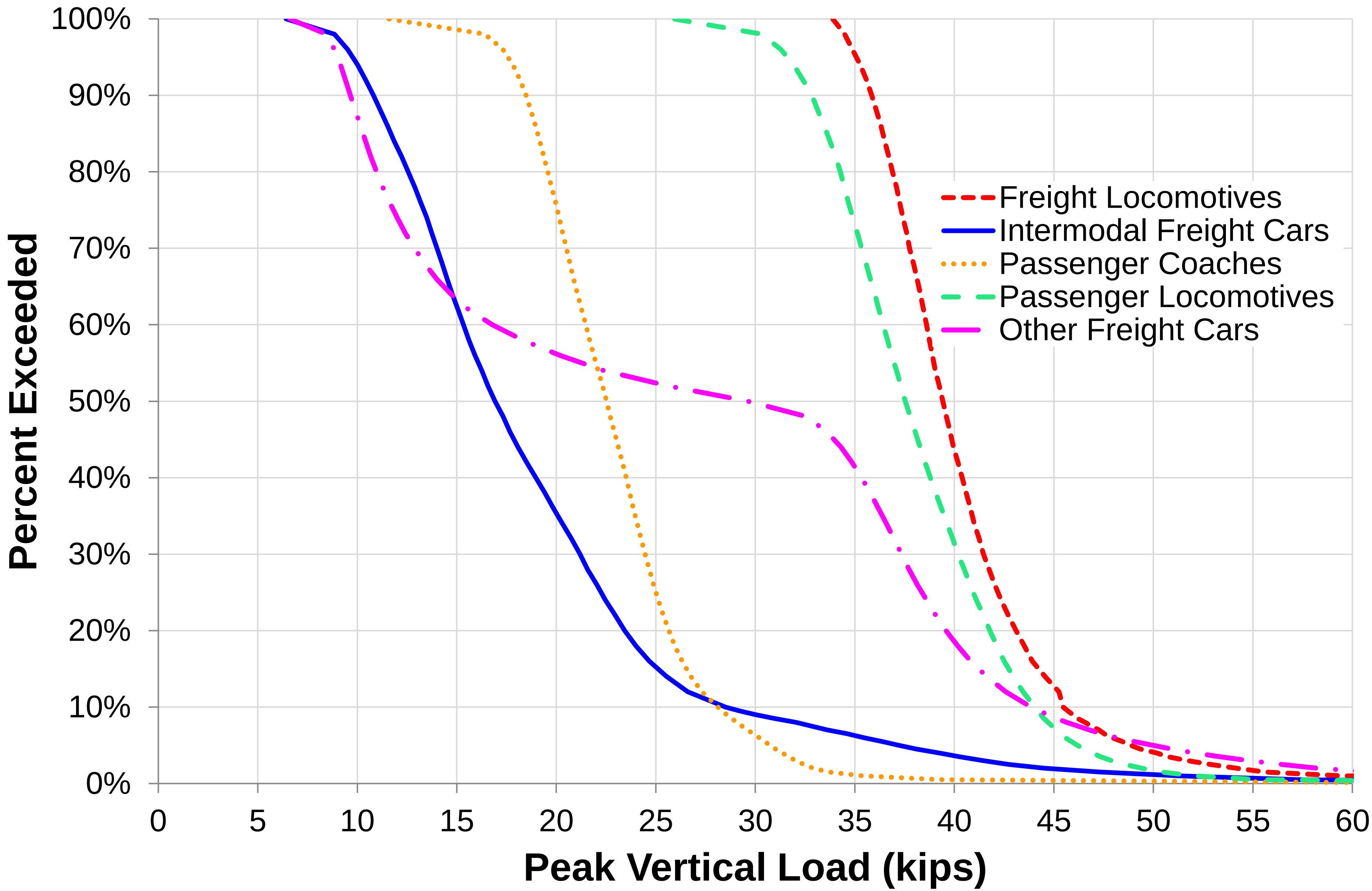
FRA Crosstie and Fastening System Research Program – Select Impacts

U.S. Department of Transportation
Federal Railroad Administration

FRA Tie and Fastener BAA Industry Partners:

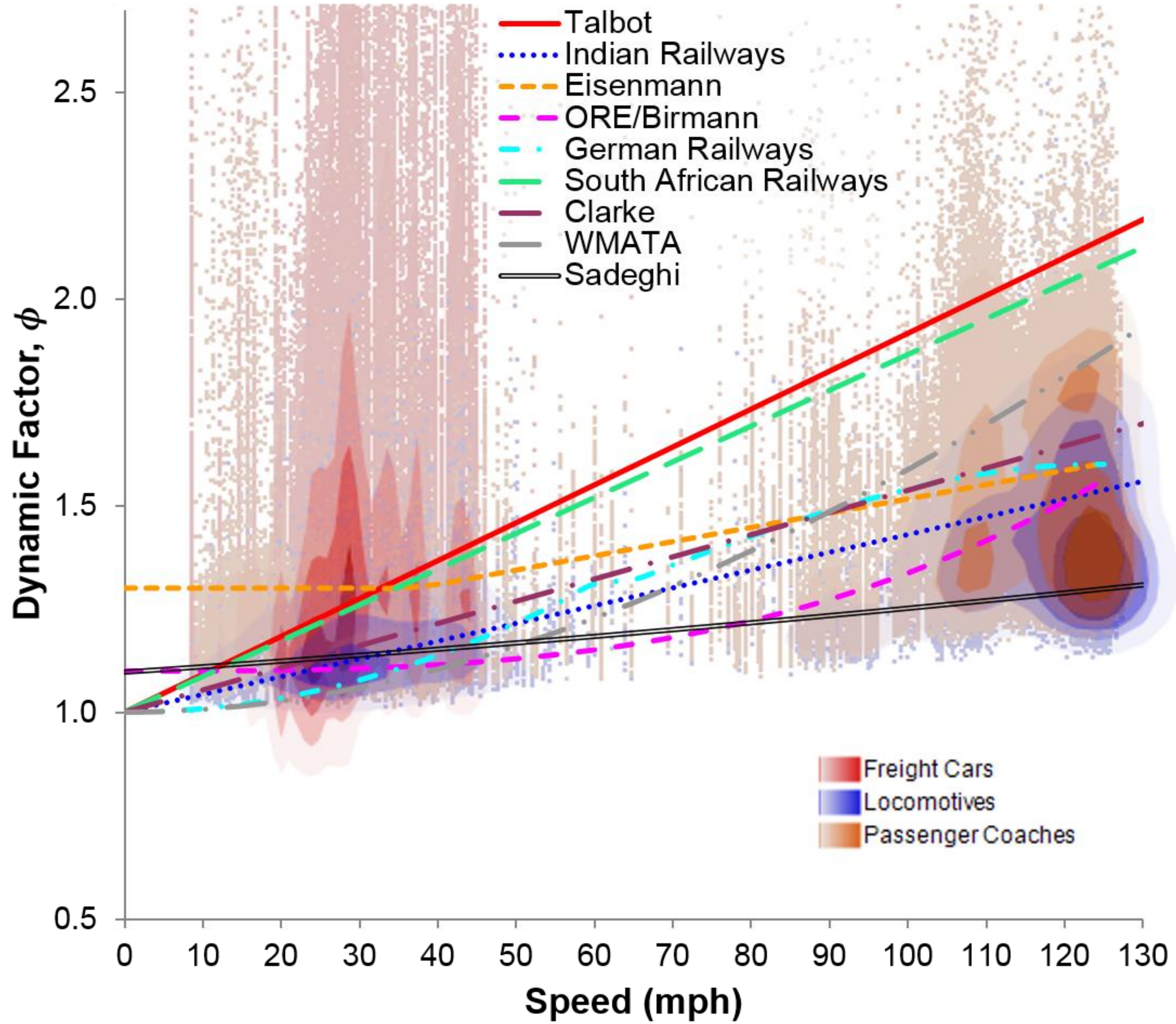
1. Quantification of wheel loads
2. Development of technique for measuring lateral forces
3. Quantification of rail seat pressures
4. Development of revised crosstie bending analysis methodology
5. Development of full-scale laboratory setup (RAIL)
6. Performance modeling tools
7. Mechanistic design framework for ties/fasteners
8. Additions and Revisions to AREMA Chapter 30 (Ties)
9. Industry outreach
10. Workforce development (student education and career placement)

1. Quantification of Peak Wheel Loads



10 kips ≈ 45 kN

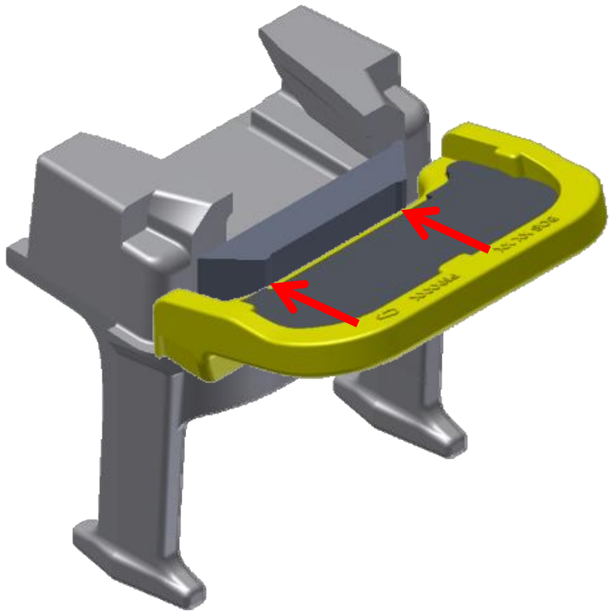
Comparison of Dynamic Wheel Load Factors



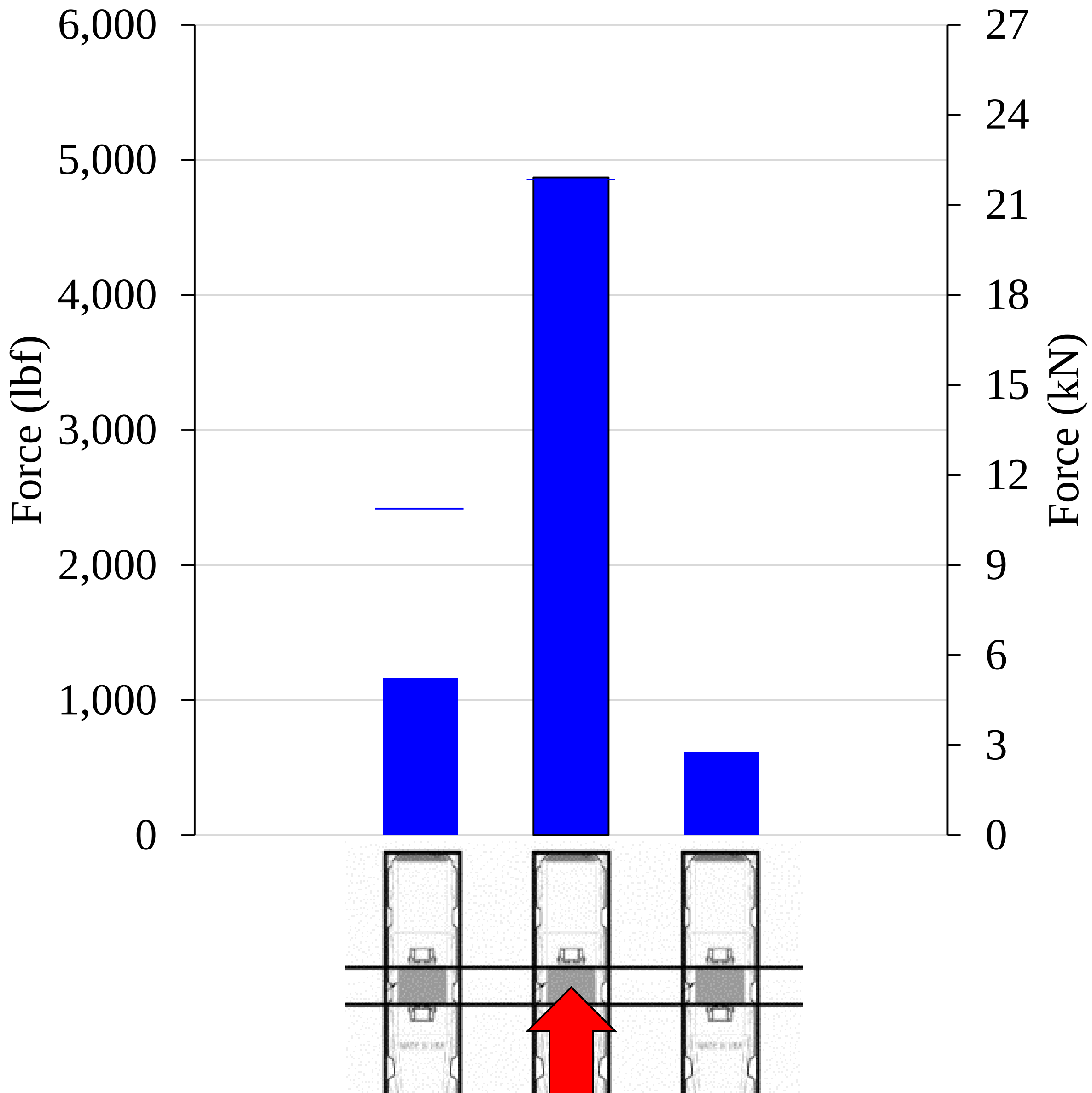
10 mph ≈ 16 kph

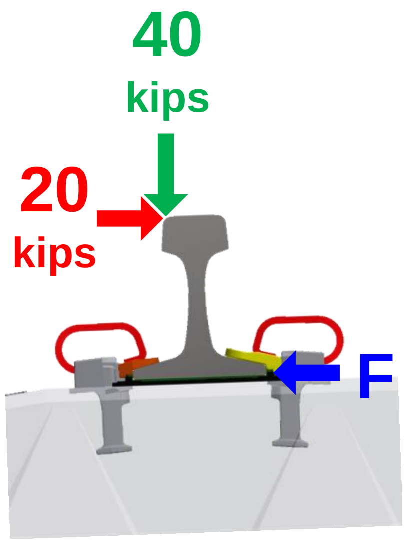
2. Successful Development of Lateral Force Measurement Technology

- Development and testing of Lateral Load Evaluation Device (LLED)
  - Original shoulder face is removed
  - Insert designed as a beam and optimized to replace removed section and maintains original geometry
  - Measures bending strain of beam under 4-point bending

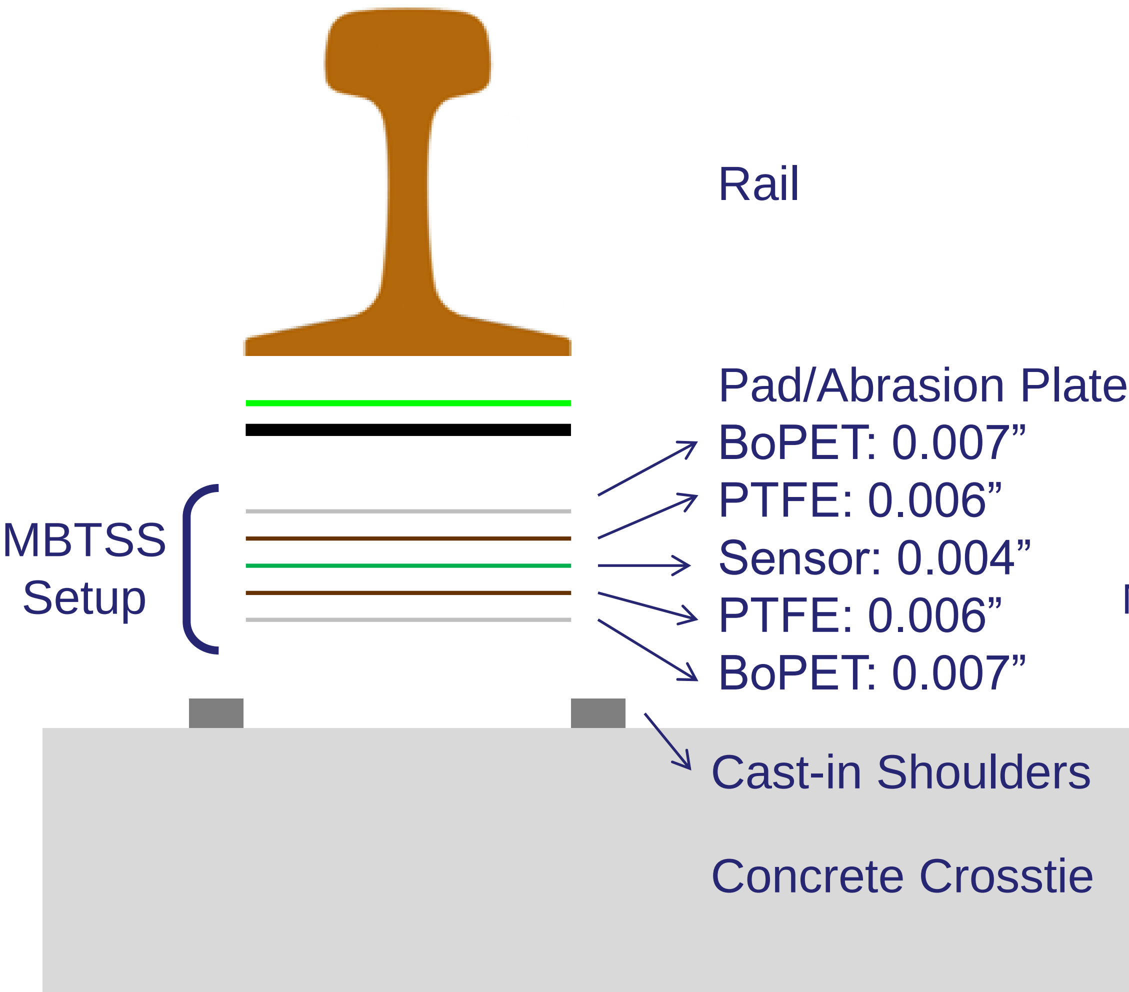


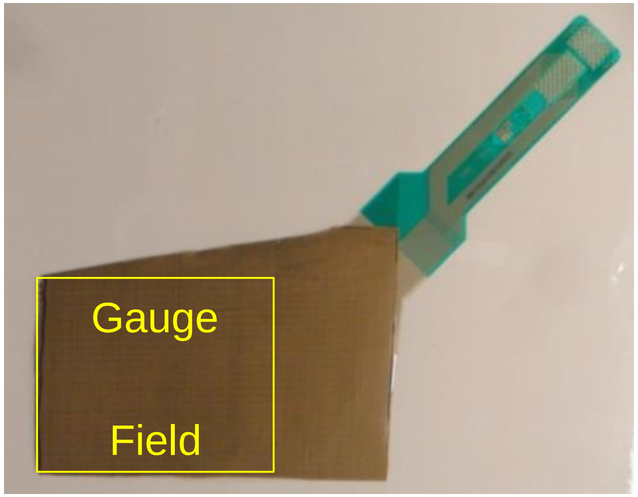
Lateral Load Data – Sample Field Results





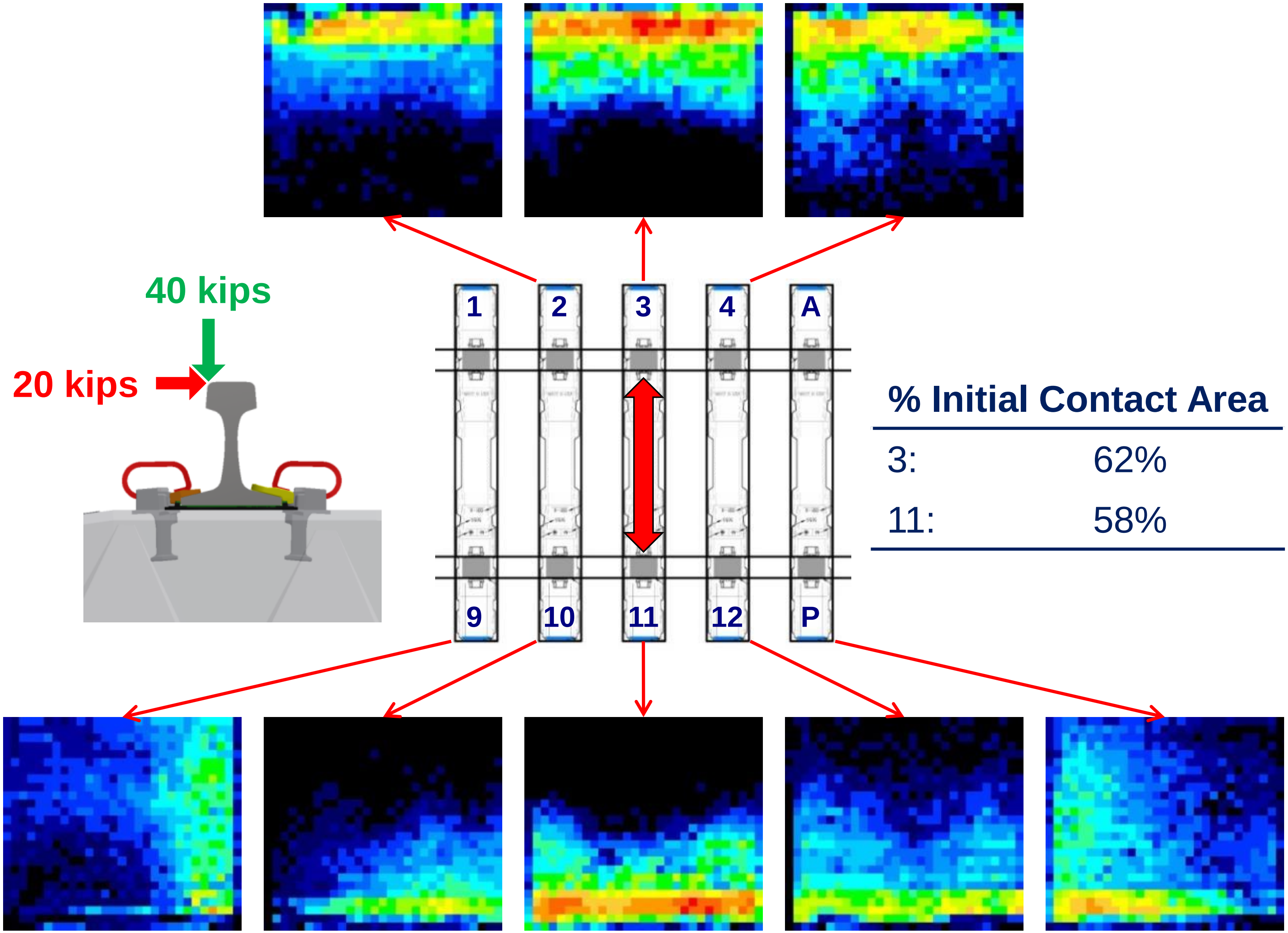
3. Quantifying Rail Seat Pressure Magnitude and Distribution



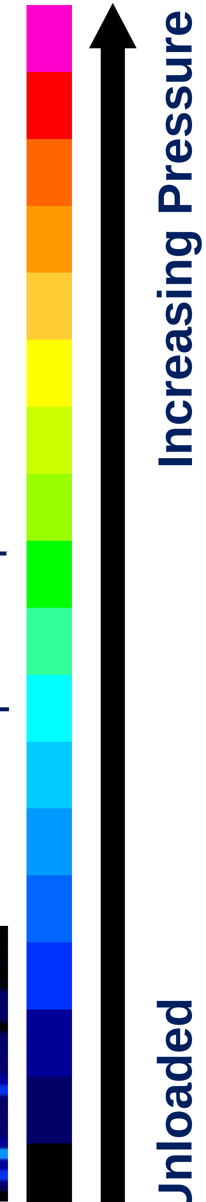


Matrix Based Tactile Surface Sensor

Rail Seat Pressure Distribution Data



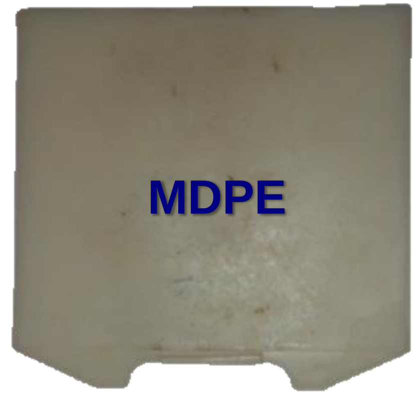
% Initial Contact Area	
3:	62%
11:	58%



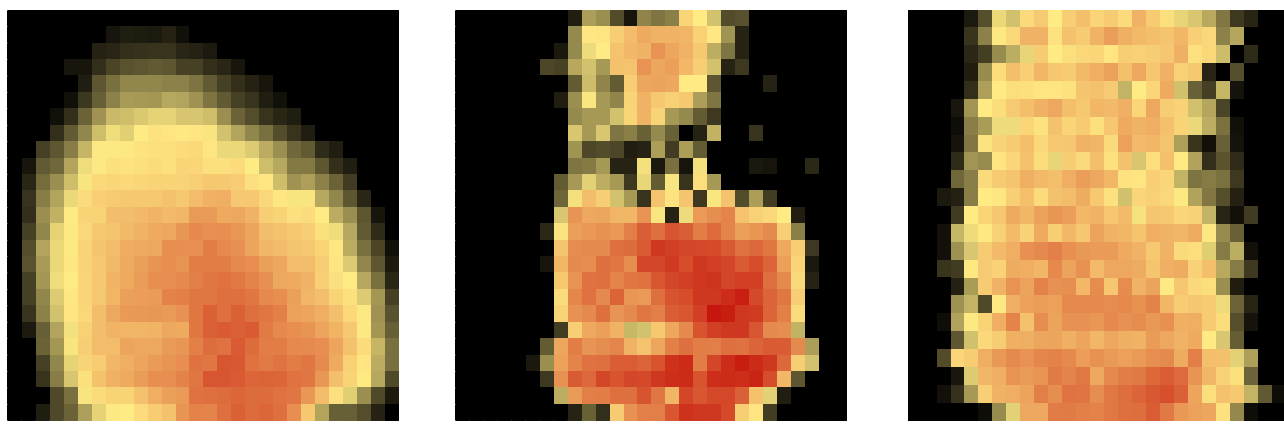
Rail Pad Assemblies - Pressure Distribution

Loading: 32.5kip (145kN) vertical, 16.9kip (75kN) lateral (0.52 L/V Force Ratio)

Pulsating Load Testing Machine (PLTM)



GAUGE

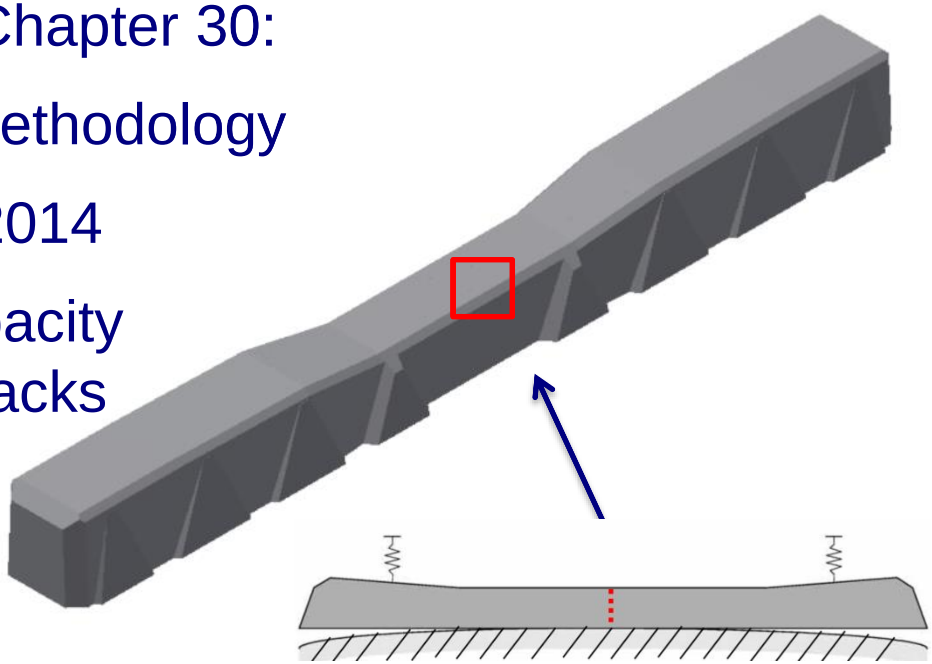


PRESSURE (psi)

	TPV	MDPE	Two-Part Pad Assembly
Contact Area: in^2 (cm^2)	25.8 (166)	19.0 (123)	23.9 (154)
Max Pressure: psi (kPa)	2,925 (20,000)	3,721 (25,600)	2,990 (20,600)

4. Development of Revised Crosstie Bending Moment Analysis Method

- Cracking from dynamic loads and center cracking considered critical problems in North America and Internationally
- Current AREMA analysis methodology reviewed and found to be insufficient
- Proposed changes to AREMA Chapter 30:
  - Improve clarity of analysis methodology
    - Accepted as of October 2014
  - Increase center moment capacity to reduce center negative cracks
    - To be discussed further during Spring 2015



Center Negative

Comparison of International Bending Moment Analysis Methods

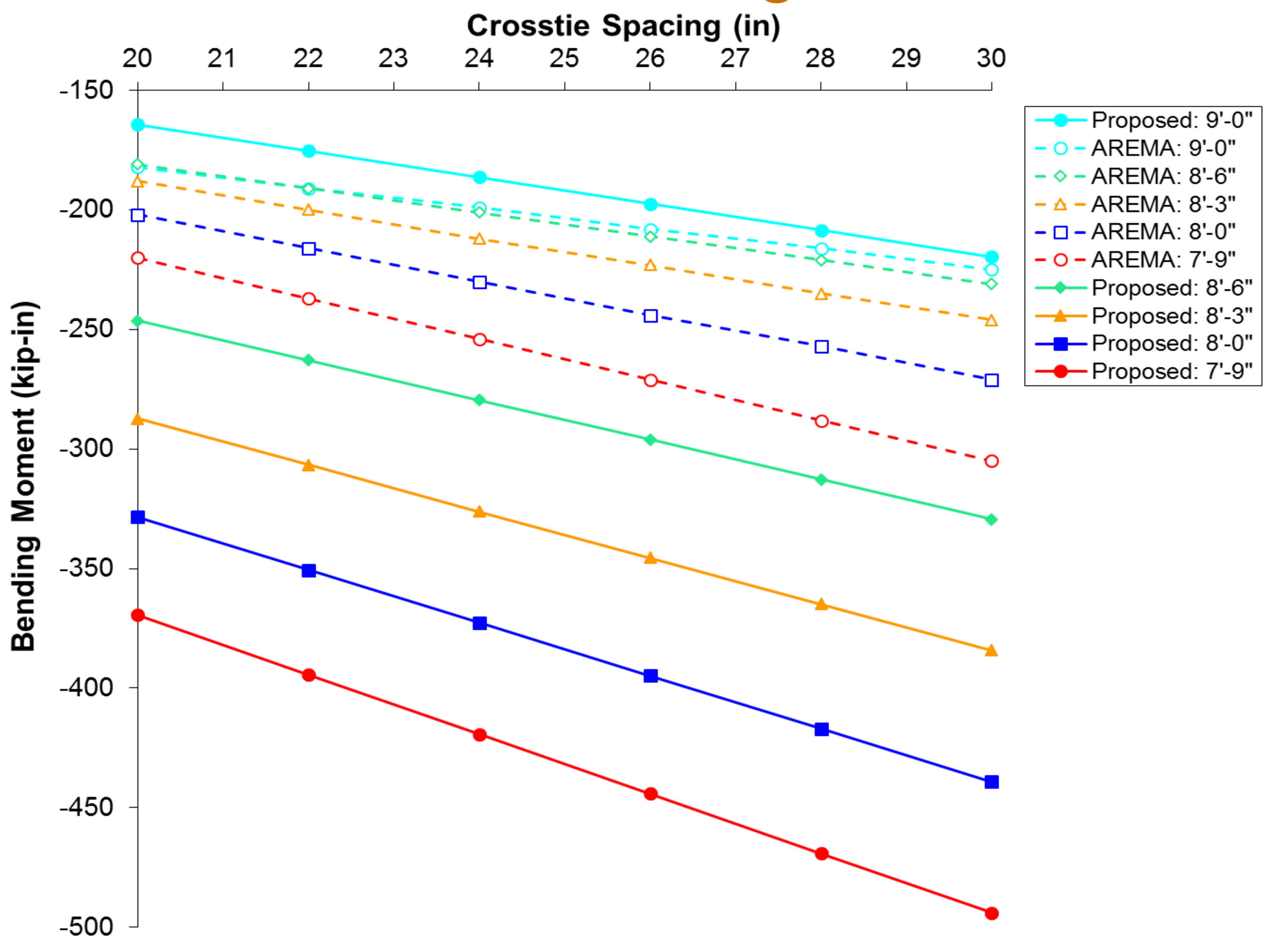
American Railway Engineering and Maintenance-of-Way Association

INTERNATIONAL UNION OF RAILWAYS

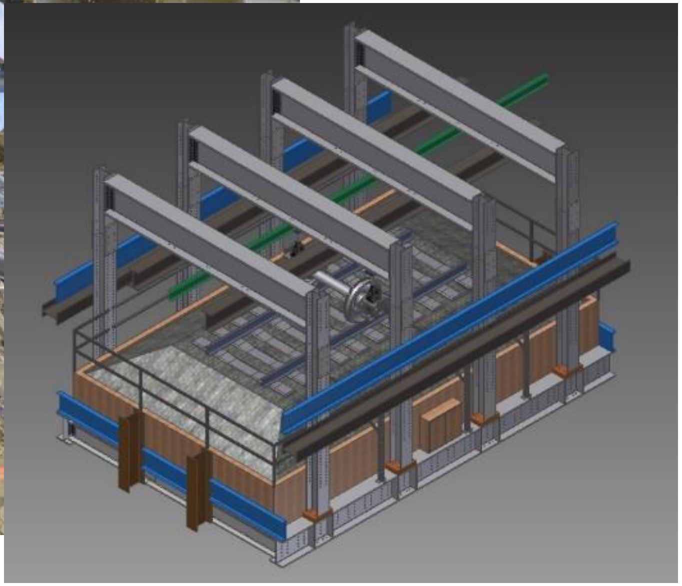
STANDARDS Australia

	AREMA C30.4	UIC 713R	AS 1085.14
Rail Seat Load kips (kN)	62.1 (276.2)	**66.4 (295.4)**	53.3 (237.1)
Rail Seat Positive kip-in (kN-m)	**300 (33.9)**	224 (25.3)	280 (31.6)
Rail Seat Negative kip-in (kN-m)	-159 (-18.0)	-112 (-12.7)	**-187 (-21.1)**
Center Positive kip-in (kN-m)	141 (15.9)	**209 (23.6)**	112 (12.7)
Center Negative kip-in (kN-m)	-201 (-22.7)	**-299 (-33.8)**	-240 (-27.1)

Comparison Between Current and Proposed (M_{C-})



5. Development and Use of a Full-Scale Track Loading System

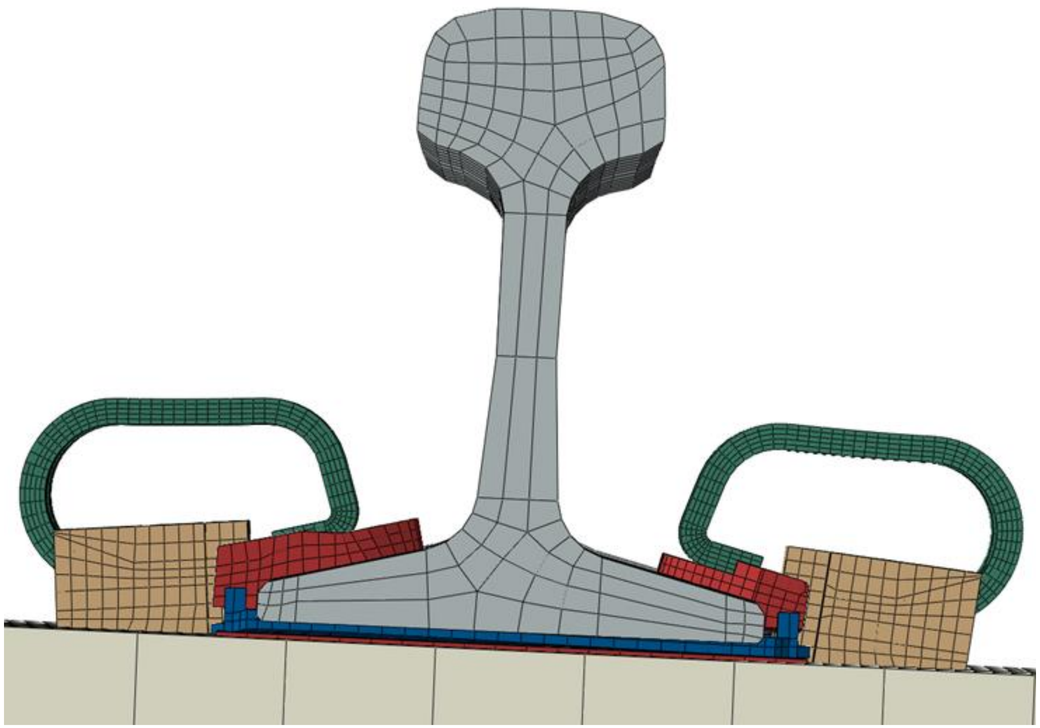


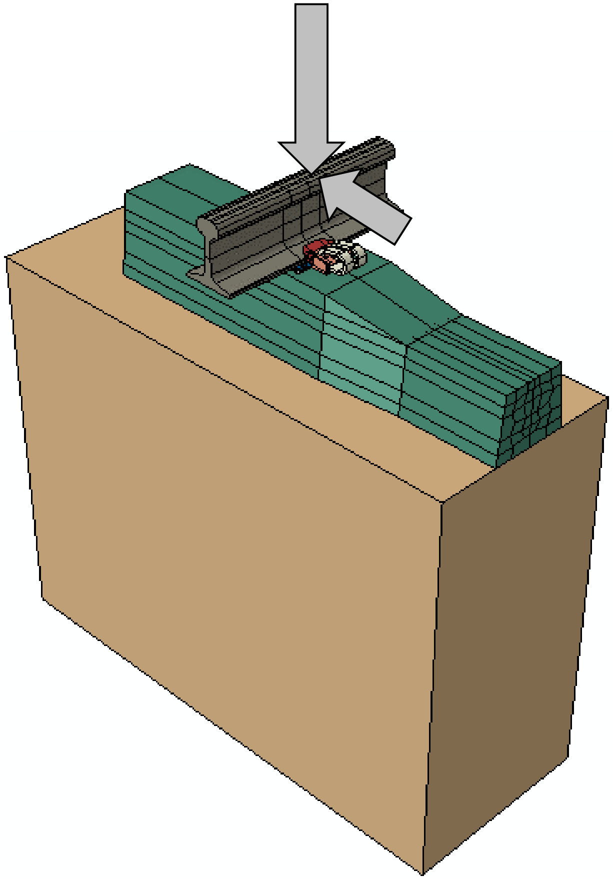
6. Performance Modeling Tools

- Crosstie and fastening system finite element model (FEM)
  - Quantify effect of design modifications to components
    - Geometry, material properties, tolerances, etc.
  - Quantify effect of system modifications:
    - Tie spacing, etc.
- I-TRACK design software
  - User friendly (compared to FEM)
  - Quickly quantify effect of:
    - Design change already studied by FEM
      - Component geometry, material, etc.
    - Load applied to rail (vertical and lateral)

Development and Validation of Crosstie and Fastener Finite Element (FE) Model

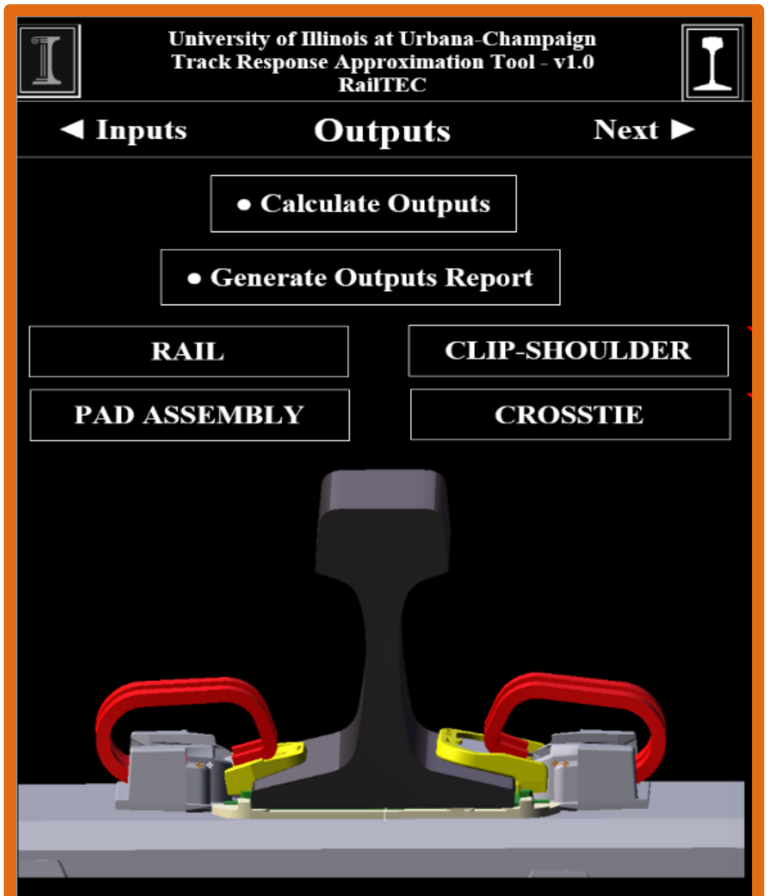
- Development of both multiple-tie and single-tie models
- Validated with laboratory and field data
- Ability to run parametric analyses





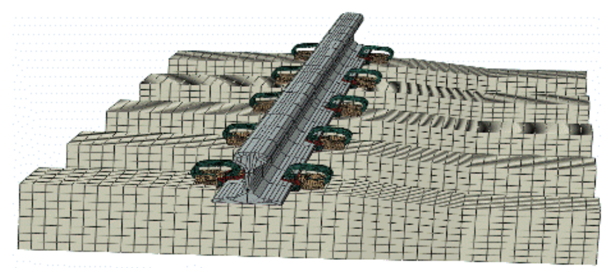
Development of Simplified Design Software (I-TRACK)

- Software based on statistical analyses of the UIUC FE model
- A neural network model was developed to predict track components responses based on user defined inputs



Development of I-TRACK

- Definition of Input Parameters
- Design of Experiments
- FE Model Runs

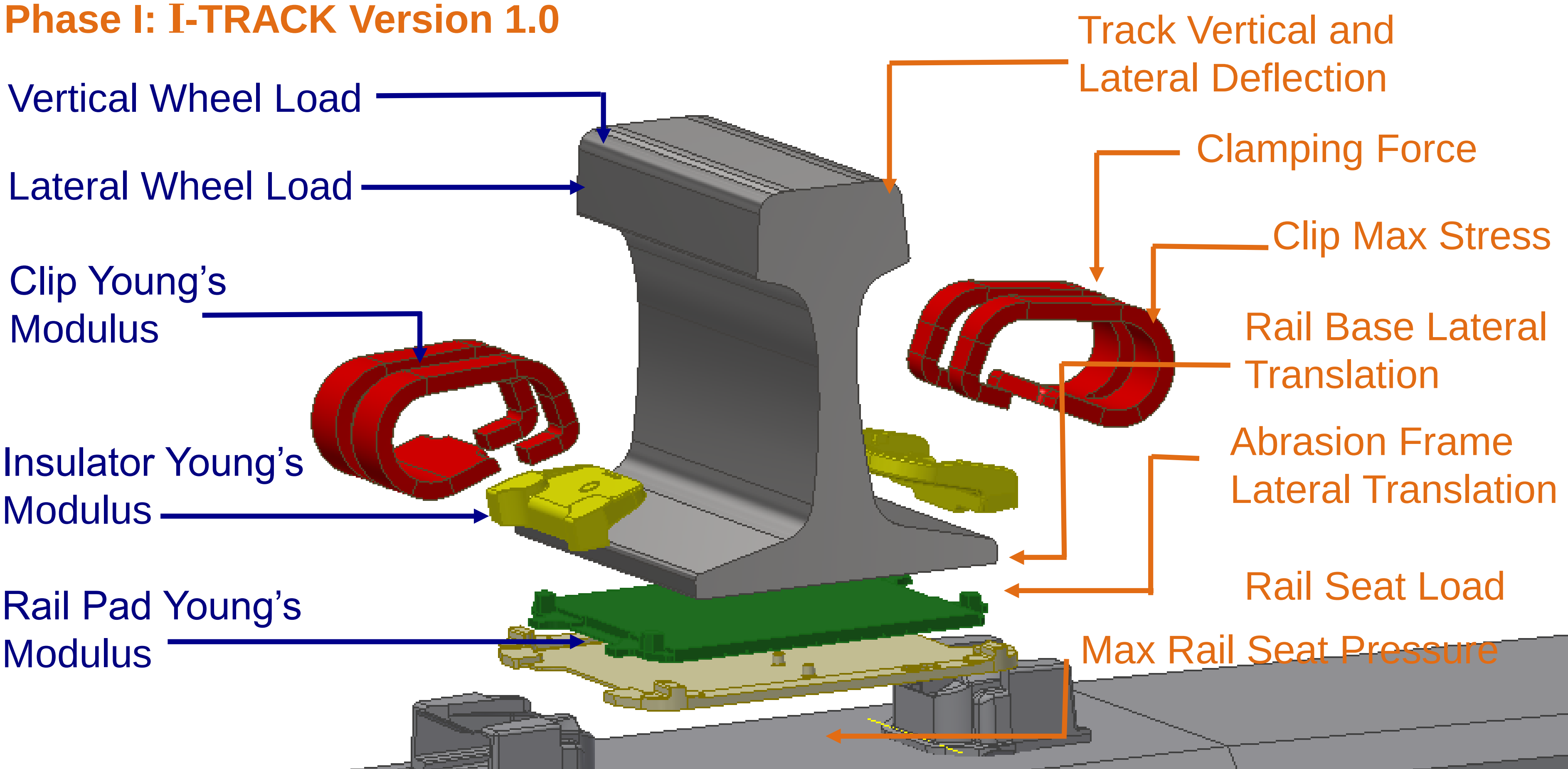


- Output Data
- Radial Basis Function Neural Network
- I-TRACK

I-TRACK Preliminary Project Phases

- The development of I-TRACK follows a systematic process. The project was divided in 3 phases, which add additional complexity and analysis capabilities
- Goal: expedite the development of I-TRACK, test the model accuracy and functionalities on a continuous basis, and provide interim utility to end users

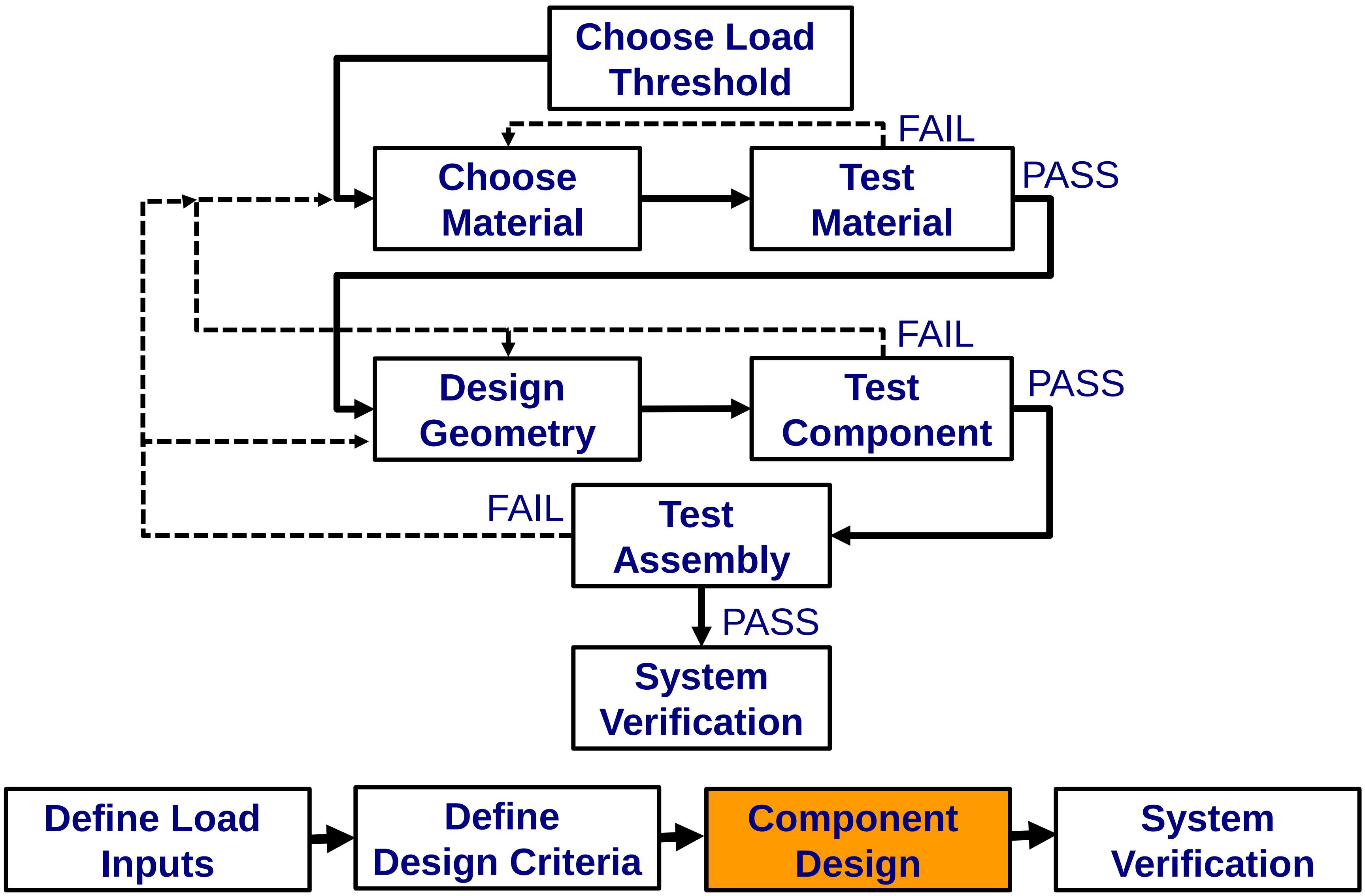
Phase I: I-TRACK Version 1.0



7. Mechanistic Design Framework

- Design approach utilizing forces measured in track structure and properties of materials that will withstand or transfer them
- Uses responses (e.g. contact pressure, relative displacement) to optimize component geometry and materials requirements
- Based on measured and predicted response to load inputs that can be supplemented with practical experience
- Requires thorough understanding of load path and distribution
- Allows load factors to be used to include variability due to location and traffic composition
- Used in other engineering industries (e.g. pavement design, structural steel design, geotechnical)

Mechanistic Component Design Example



8. Changes to AREMA Chapter 30 (Ties)

- Multiple proposed changes to AREMA Chapter 30 (5 Total)
- Driven by students funded on this project (and through IPs)

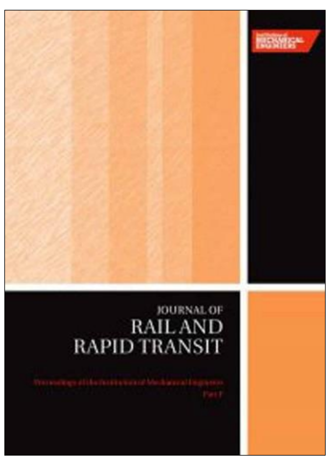
Proposed Ballot Title	Description of Ballot	Lead Student	Status
Addition of Rail Seat Load Distribution	Introduce language characterizing the loading environment at the rail seat, which may affect crosstie failure mechanisms associated with Rail Seat Deterioration (RSD).	Matthew Greve	PASSED
Amendments to Loading Environment	Update section 1.2 Load Environment, which covers wheel to rail loads of North American freight and passenger traffic. Revisions are intended to update the load table currently provided in AREMA using modern traffic data.	Andrew Scheppe	PASSED
Addition of Lateral Load Distribution	Add language to the proposed sections stating that lateral load distribution may not mimic vertical load distribution as previously hypothesized. Also, that fastening system design (e.g. friction, stiffness) will have an effect on lateral load distribution.	Brent Williams	PASSED
Crosstie Flexural Capacity Analysis Method	Update sections on flexural analysis of concrete crossties to address issues with current analysis process and introduce new and improved method of analysis.	Henry Wolf	PASSED

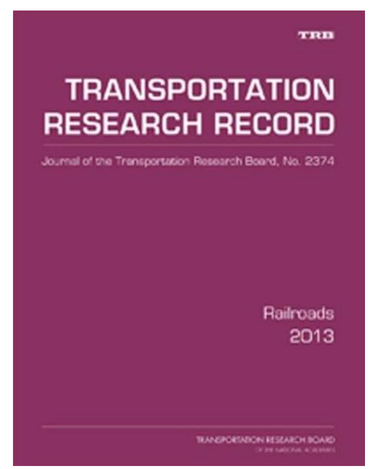
9. Industry Outreach:
Papers, Posters, and Presentations

Year	Conference / Meeting	Papers	Presentations	Posters
2009	AREMA	1	1	
	IHHA	1	1	0
2010	TRB	1	1	0
	AAR Research Review			1
	JRC	1	2	0
	AREMA	2	2	
2011	TRB	1	0	1
	IHHA	3	0	2
	AAR Research Review			1
	JRC	0	2	0
	WCRR	2	0	2
	AREMA	1	1	
2012	TRB	1	1	1
	AAR Research Review			1
	JRC	2	6	0
	WRI		1	
	PCI	1	1	0
	AREMA	1	1	
	ACerS Concrete Conference	0	0	1
2013	TRB	2	2	0
	IHHA	6	6	1
	AAR Research Review			4
	JRC	3	8	0
	WRI		1	
	AREMA	1	1	
	WCRR	4	1	3
2014	TRB	4	3	1
	JRC	4	8	
	AREMA	1	1	
2015	TRB	4	1	3
	JRC	2	6	
	IHHA	5	3	2
	Total	**54**	**61**	**24**

RailTEC Crosstie Journal Articles

Year	Journal	Topic	Lead Author	Status
2012	**American Concrete Institute (ACI) Materials**	**RSD Mechanisms**	**Zeman**	**In Press**
2013	**Tranportation Research Record (TRR)**	**Rail Seat Pressures**	**Rapp**	**In Press**
2013	**ASCE Journal of Transportation Engineering (JTE)**	**RSD Materials Research**	**Shurpali**	**In Press**
2013	*ASTM Advances in Civil Engineering Materials (ACEM)*	*SSART Abrasion*	*Shurpali*	*Final Internal Review*
2013	**Journal of Rail and Rapid Transit (JRRT)**	**Small and Large Scale Abrasion Research**	**Kernes**	**In Press**
2013	**Journal of Rail and Rapid Transit (JRRT)**	**Crosstie and Fastening System Modeling**	**Chen**	**In Press**
2014	**Tranportation Research Record (TRR)**	**Vertical Wheel Load Quantification**	**Van Dyk**	**In Press**
2014	**Engineering Failure Analysis**	**Modeling**	**Chen/Shin**	**In Press**
2014	***Journal of Rail and Rapid Transit (JRRT)***	***Vertical Loading Quantification***	***Van Dyk (Scheppe)***	***Accepted***
2015	***Tranportation Research Record (TRR)***	***RSD Field Testing***	***Greve***	***Accepted***
2015	*Journal of Rail and Rapid Transit (JRRT)*	*Lateral Load Quantification*	*Williams*	*Submitted*
2015	*Journal of Rail and Rapid Transit (JRRT)*	*Vertical and Lateral Loading Quantification*	*Scheppe*	*Under Development*
2015	*Structure and Infrastructure Engineering*	*Modeling - Field Validation*	*Chen*	*Under Development*
2015	*Journal of Rail and Rapid Transit (JRRT)*	*Comparison of Dynamic Factors*	*Van Dyk*	*Under Development*





International Crosstie and Fastening System Symposia (2012 and 2014)

- Co-organized by: **AREMA Committee 30 (Ties), Railway Tie Association (RTA)**
- ***2014 Event: 140 total attendees***
- **Focus → state of the art in timber, concrete, and composite crosstie and fastening system design, performance, research, modeling, and inspection**
- Presentations available at: http://railtec.illinois.edu/Crosstie/2014/presentation.php
- **THANKS FOR SPONSORSHIP from INDUSTRY PARTNERS!**

10. Our role in Rail Workforce Development…

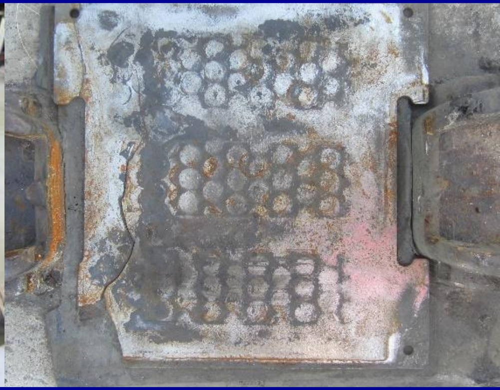
RailTEC Tie and Fastener Team in June 2014

Industry Placement

- Crosstie Manufacturer
  - Mauricio Gutierrez: GIC
  - Ryan Kernes: GIC
- Fastening System Manufacturer
  - Thiago Bizarria: Vossloh Fastening Systems
  - Brandon Van Dyk: Vossloh Fastening Systems
- Rail Engineering Design Firm
  - Chris Rapp: Hanson Professional Services
  - Andrew Scheppe: Hanson Professional Services
  - Amogh Shurpali: BARSYL
- Academia/Research
  - Moochul Shin: Western New England University

UIUC FRA Crosstie and Fastening System BAA 2014-2: Investigation of Deteriorated Crossties and Support Conditions



3 Year Research Program

2015 - 2017

Riley Edwards, Bassem Andrawes, Marcus Dersch,
Yu Qian, and Josué César Bastos

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

FRA BAA 2014-2
Objectives and Deliverables

U.S. Department of Transportation
Federal Railroad Administration

- **Program Objectives**
  - Determine common failure types and quantify the common track conditions in repeat failure locations
  - Quantify the effect worn/degraded track conditions have on critical track component' stress state via conducting:
    - Laboratory experimentation
    - Finite Element Modeling (FEM) parametric studies incorporating poor support conditions
- **Program Deliverables**
  - Improved mechanistic design recommendations for concrete crossties and fastening systems in the US
  - Proposed revisions to AREMA Recommended Practices
  - Improved safety due to increased strength of critical infrastructure components and revisions to FRA Track Safety Standards, CFR 213
  - Industry outreach and workforce development

FRA Tie and Fastener BAA Industry Partners:

UNION PACIFIC BUILDING AMERICA®

BNSF RAILWAY

AMTRAK®

Amsted RPS
An Amsted Rail Company

GIC

HANSON

LBFoster
CXT Concrete Ties

Resilient Concrete Crosstie and Fastening System Designs for Light Rail, Heavy Rail, and Commuter Rail Transit Infrastructure

Funded by:
Federal Transit Administration (FTA)

Rail Transportation and Engineering Center *(RailTEC)*

University of Illinois at Urbana-Champaign

2.5 Year Program
2015 - 2017

RAILTEC

U.S. Department of Transportation
Federal Transit Administration

FTA Research Project Objectives and Deliverables

- **Program Objectives**
  - Conduct extensive literature review regarding current design practices and needs
  - Quantify the loads entering rail transit infrastructure:
    - Laboratory and field experimentation
    - Finite Element Modeling (FEM)
  - Develop mechanistic design recommendations for crossties and fasteners
- **Program Deliverables**
  - Quantification of loading conditions for rail transit
  - Improved mechanistic design recommendations for concrete crossties and fastening systems for rail transit
  - Proposed revisions to AREMA Recommended Practices for rail transit

U.S. Department of Transportation
Federal Transit Administration

FTA Tie and Fastener Industry Partners:

MTA New York City Transit
TRIMET See where it takes you.
Metra® The way to really fly.
APTA
Amsted RPS An Amsted Rail Company
PANDROL TRACK SYSTEMS DELACHAUX GROUP
GIC
LBFoster CXT Concrete Ties
HANSON
AMTRAK®

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UNION PACIFIC BUILDING AMERICA®

GIC

Amsted RPS An Amsted Rail Company

BNSF RAILWAY

LBFoster CXT Concrete Ties

AMTRAK®

HANSON

TTX®

FTA Tie and Fastener Industry Partners:

APTA

Amsted RPS An Amsted Rail Company

MTA New York City Transit

GIC

TRI MET See where it takes you.

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Metra® The way to really fly.

AMTRAK®

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Acknowledgements

U.S. Department of Transportation
Federal Transit Administration

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  - **Federal Transit Administration (FTA)**
- Industry Partners:
  - New York City Transit (New York, NY)
  - TriMet (Portland, OR)
  - Metra (Chicago, IL)
  - MetroLink (St. Louis, MO)
  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS, Inc.
  - Pandrol USA
  - GIC
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
  - American Public Transportation Association (APTA)

FTA Tie and Fastener Industry Partners:

Other Supporting Organizations

BNSF RAILWAY

UNION PACIFIC BUILDING AMERICA

AMTRAK

NORFOLK SOUTHERN

CSX

CN

CANADIAN PACIFIC RAILWAY

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Federal Railroad Administration

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An Amsted Rail Company

GIC

LBFoster
CXT Concrete Ties

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NORTRAK

BASF
The Chemical Company

PANDROL
TRACK SYSTEMS
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vossloh

TTCI
Transportation Technology Center, Inc.

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