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

Experimental Matrix Development

FRA and FTA Crosstie and Fastening System Research Program
Industry Partners (IP) Meeting

Tucson, AZ

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RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

U.S. Department of Transportation
Federal Railroad Administration

Outline

- Project Introduction
- Motivation for Research
  - FRA Accident Database
  - Literature Review
  - Industry Survey
- Laboratory Experimentation
  - Equipment
  - Experimental Matrix
- Expected Industry Impact
- Preliminary Conclusions

Current FRA Concrete Crosstie Research at UIUC

- Prior FRA-funded concrete crosstie research at UIUC focused on new track components and optimal track geometry and support conditions
- Current project focuses on degraded components and sub-optimal track conditions
  - Component level
  - System level
- Laboratory experiments, field experiments, finite element modeling (FEM), expert opinion, and literature review are used to maximize impact on:
  - CFR 213 (Track Safety Standards)
  - AREMA Chapter 30 (Ties)
  - Crosstie manufacturers
  - Railroads
  - Researchers

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:

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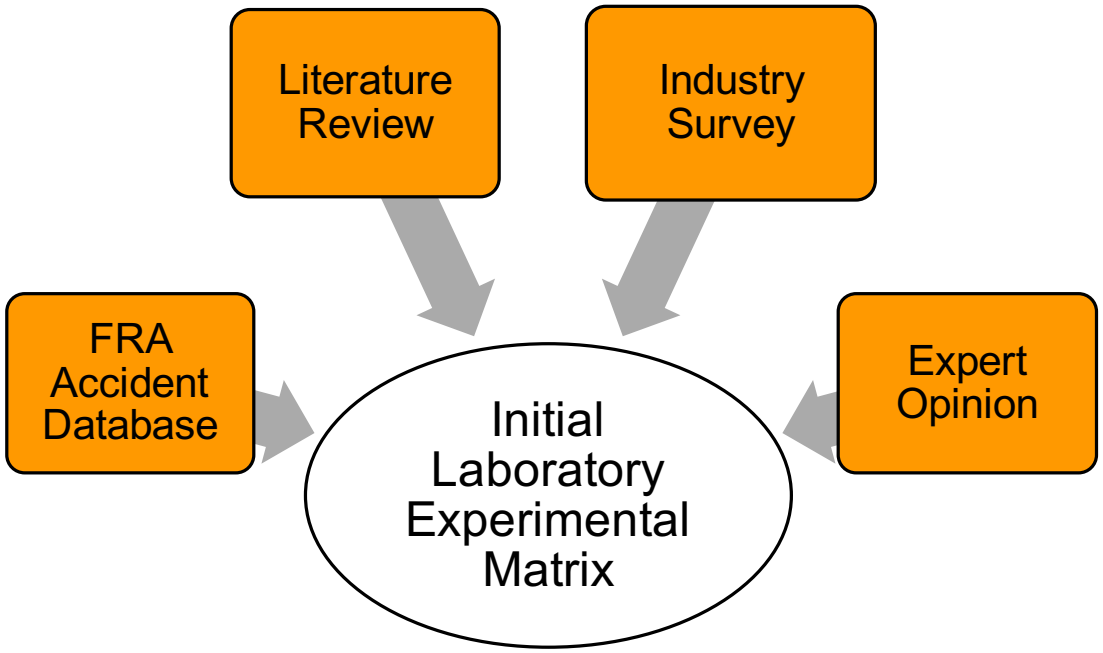
HANSON
LBFoster CXT Concrete Ties

Development of Initial Experimental Matrix



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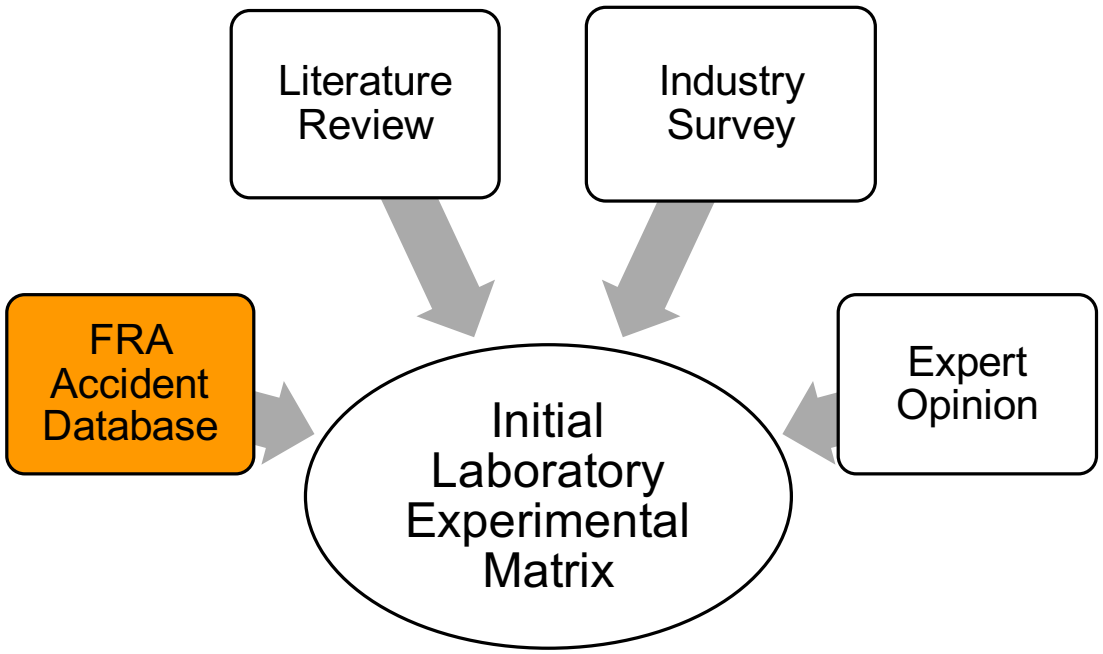
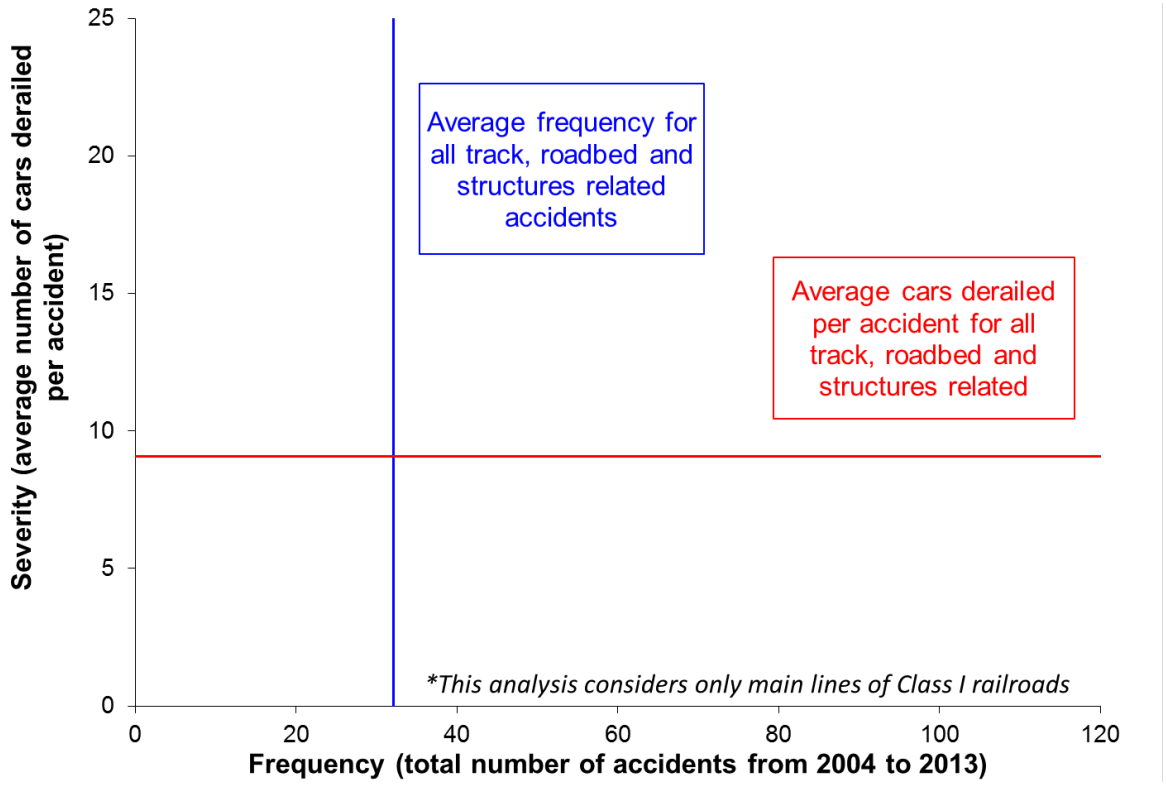


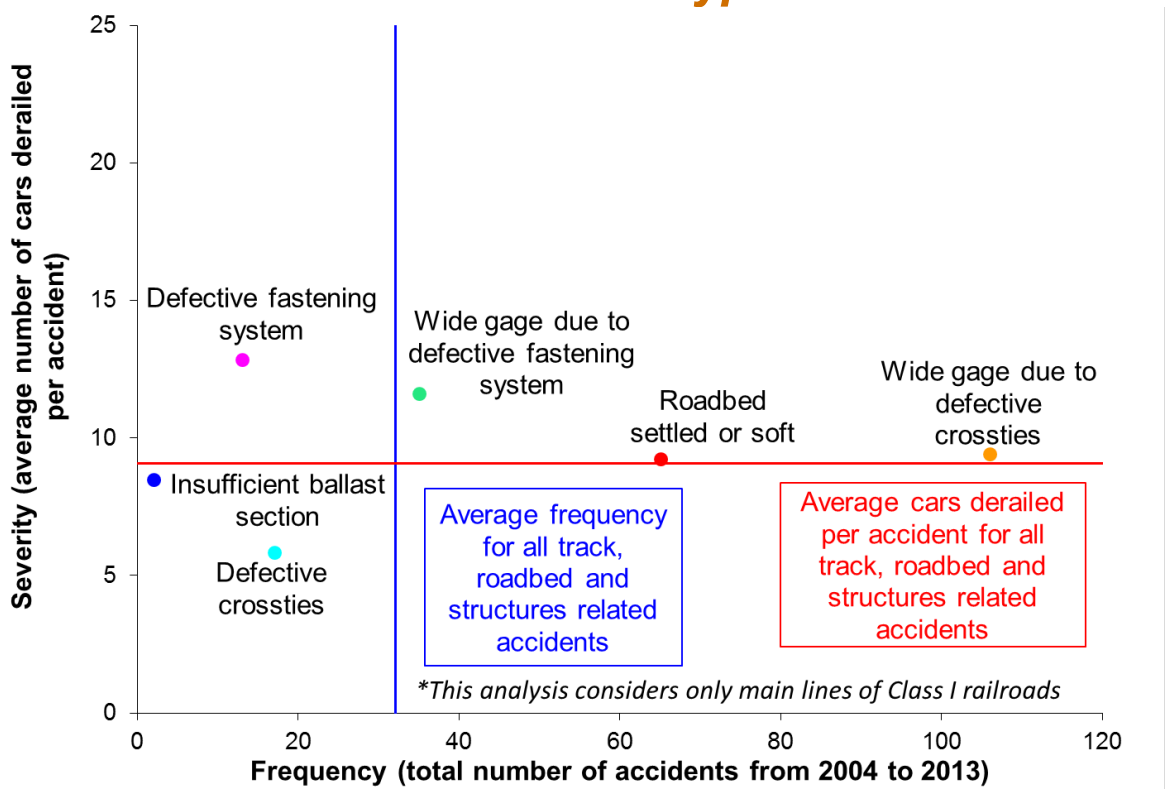
FRA Accident Database Analysis

- Performed analysis of 10 years of accident data from the FRA accident database, from 2004 to 2013, filtering for the following accident causes:
  - **T001** Roadbed settled or soft
  - **T105** Insufficient ballast section
  - **T110** Wide gage (due to defective or missing crossties)
  - **T111** Wide gage (due to defective or missing spikes or other rail fasteners)
  - **T205** Defective or missing crossties
  - **T206** Defective spikes or missing spikes or other rail fasteners (use code T111 if results in wide gage)

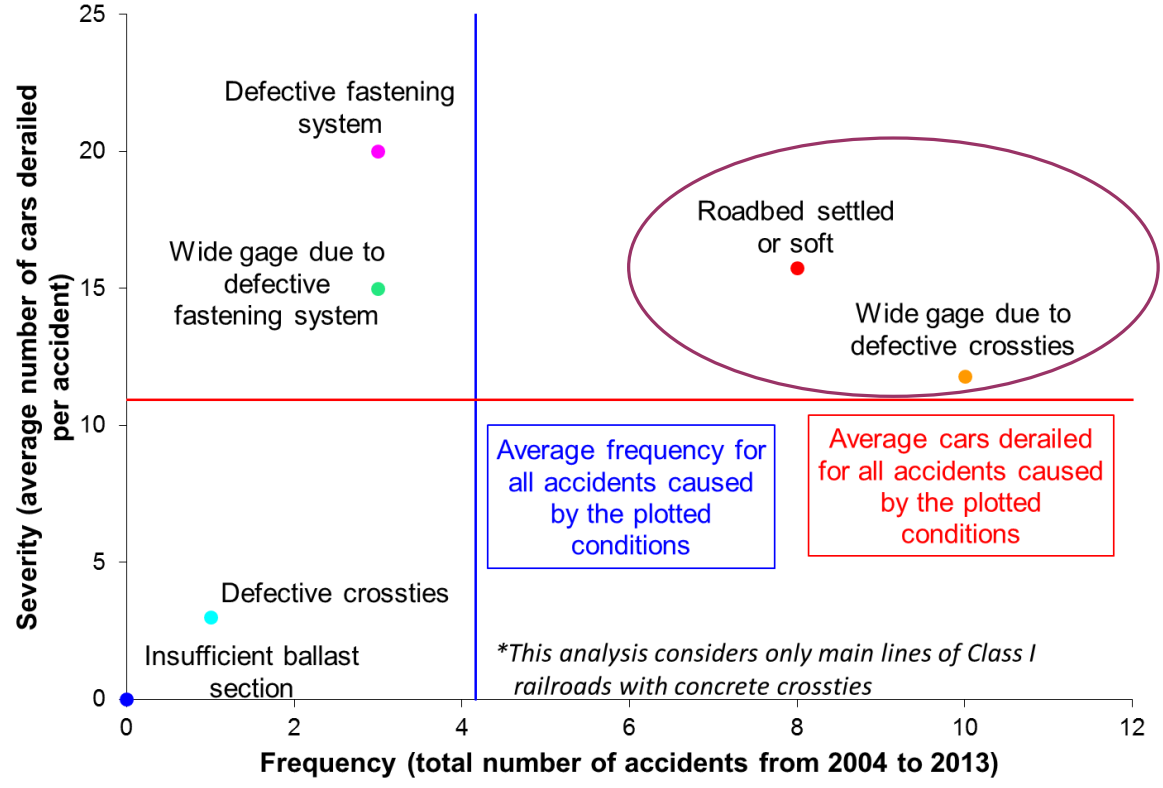
Overview of Track-caused Derailments



Track-caused Derailment Analysis
All Crosstie Types



Track-caused Derailment Analysis
Concrete Crossties



Understanding the Accident Causes

- **Roadbed settled or soft:**
  - Weak subgrade offering poor track support
  - Poor drainage areas affecting track stiffness and removal of excess water

- **Wide gage due to defective or missing crossties:**
  - Rail cant deficiency (e.g. rail seat deterioration)
  - Cracked crossties (e.g. center cracking, rail seat cracking, etc.)
  - Missing crossties

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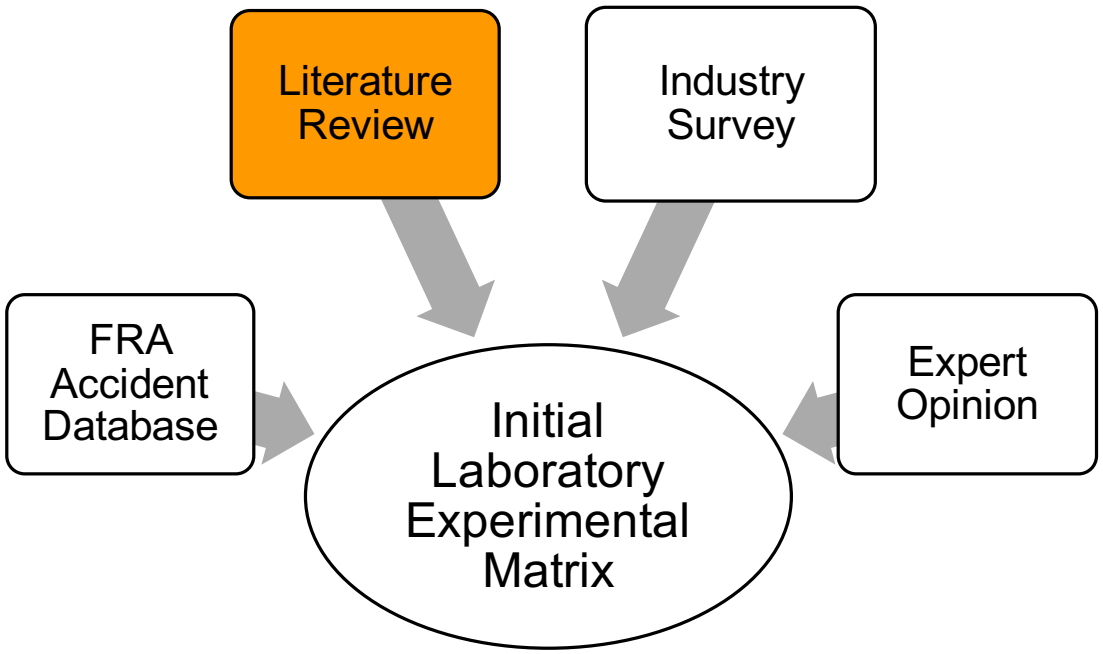

Literature Review

- Volpe report on 2013 derailment of CSX freight train on Metro-North tracks in Bronx, NY

- Caused by combination of degraded track conditions caused derailment as presented within report:
  - Poor drainage
  - High temperature induced rail to push under insulator
  - Center bound and worn crossties

- Accident cause reported to FRA as *T110 Wide Gage (due to defective or missing crossties)*

Marquis, B., J. LeBlanc, H. Yu and D. Jeong. 2014. *Volpe Report on CSX Train Derailment on MN Tracks*. United States: National Transportation Safety Board.

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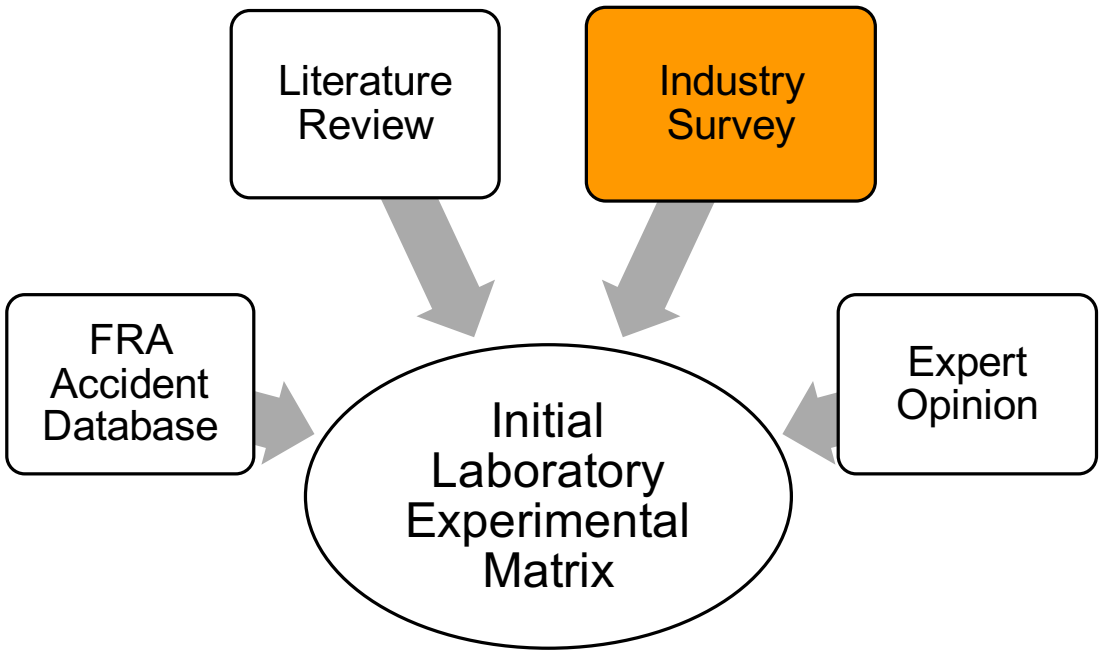


Industry Survey
Content and Audience

- **Mission:** quantify common failure types and understand research needs

- **Objectives:**
  - Develop criticality ranking of specific track superstructure problems and FRA accident codes
  - Pairing track problems that could lead to derailments when combined
  - Identify laboratory tests that are relevant to the industry

- **14 survey respondents**, all industry experts in one of the following categories:
  - Railway infrastructure owner, operator, or maintainer
  - Academic, industry, or institutional researcher
  - Concrete crosstie or fastening system manufacturer

Industry Survey Results
Criticality Ranking of Problems

Problem (higher rank is more critical)	Average Rank
Rail seat deterioration and other forms of rail cant deficiency	4.57
Worn or missing shoulder	4.14
Worn or missing insulator	3.79
Missing clip	3.71
Center negative crosstie bending	3.43
Missing rail pad	3.36
Fouled ballast	3.21
Insufficient depth of ballast	3.00
Weak subgrade	3.00
Concrete crosstie with deteriorated bottom	2.93
Rail seat positive crosstie bending	2.45

Survey Results
Criticality of FRA Accident Codes

FRA Accident Code (higher rank is more critical)	Average Rank
Wide gage due to defective or missing crossties (T110)	4.33
Wide gage due to defective or missing spikes or other rail fasteners (T111)	4.25
Defective or missing crossties (T205)	3.64
Defective spikes or missing rail fasteners (T206)	3.42
Roadbed settled or soft (T001)	3.25
Insufficient ballast section (T105)	3.00

Fouled ballast

Rail seat deterioration

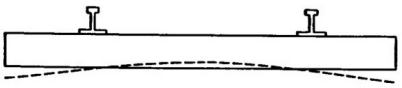
Survey Results
Ranking of Paired Problem

- Votes indicate the number of survey respondents that considered that the problem pair could lead to a derailment

Problem Pair (there were 14 survey takers)	Votes
Rail seat deterioration and other forms of rail cant deficiency Worn or missing shoulder	11
Worn or missing insulator Worn or missing shoulder	11
Center negative crosstie bending Concrete crosstie with deteriorated bottom	10
Missing clip Worn or missing shoulder	10
Rail seat deterioration and other forms of rail cant deficiency Missing clip	9

Survey Results
Essay Question on Laboratory Experiments

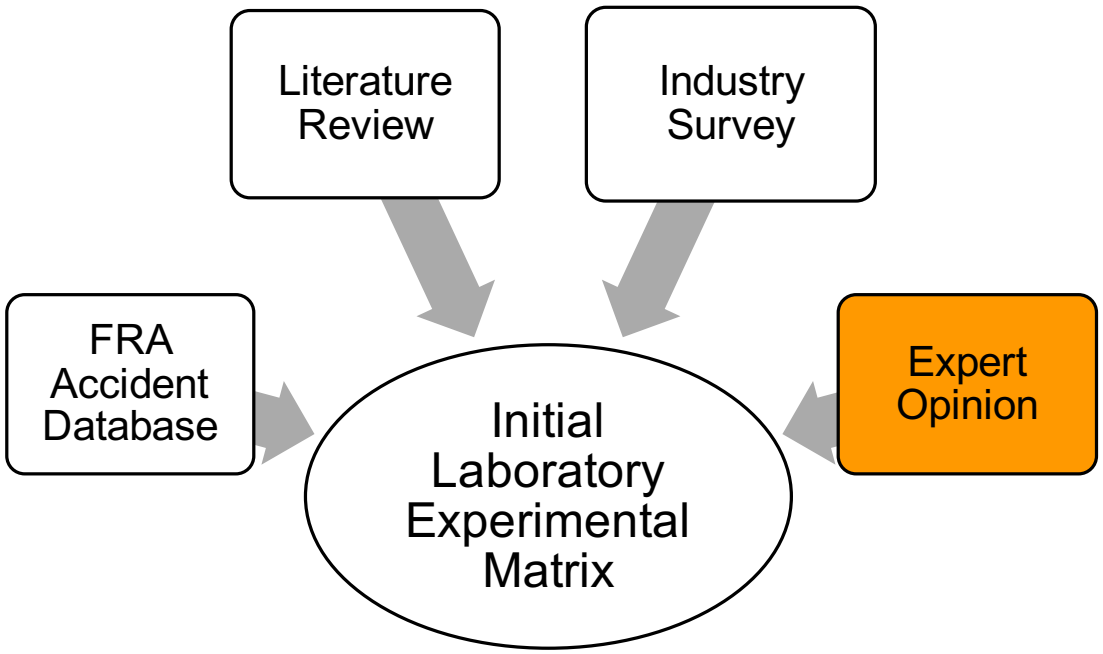
- Out of 14 survey respondents:
  - **6 would like to see different support conditions and center negative crosstie bending tested in a laboratory**
  - **4 would like to see cracked crossties tested in a laboratory**
  - 3 would like to see wet ballast tested in a laboratory



Center binding

Broken crosstie

Development of Initial Experimental Matrix



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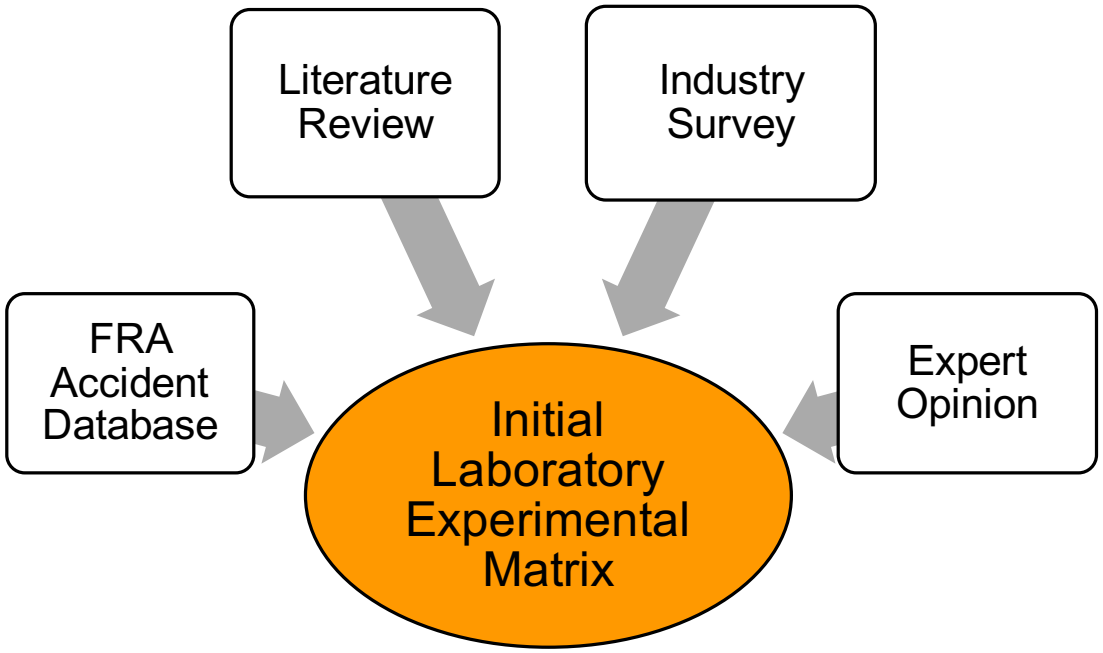
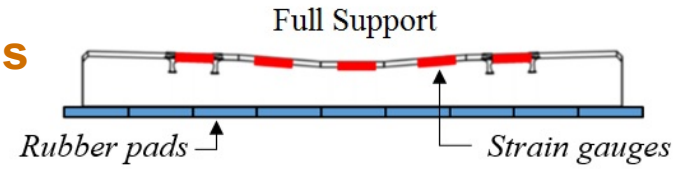
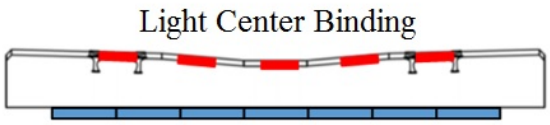
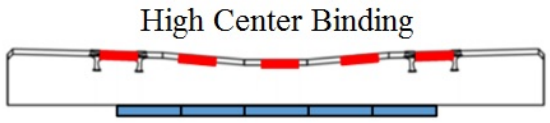


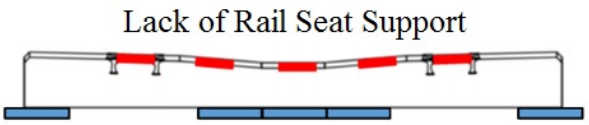
Experimental Variables
Support Conditions

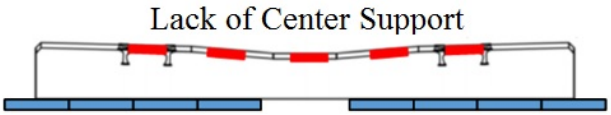
- **Support conditions**
  - Proper support
  - Center binding
  - Rail seat positive
- **Cases were based on:**
  - Field conditions
  - Expert opinion
  - Industry partners feedback on draft experimental matrix





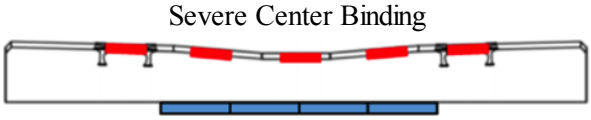




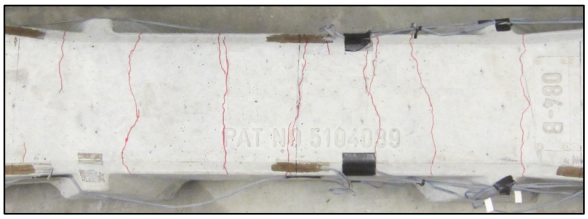


Experimental Variables
Crosstie Cracking

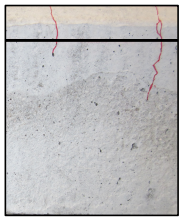
- All cracks were generated with a severe center binding condition, with rail seat load of 20 kips applied at both rail seats



- Cracks along the crosstie span were approximately symmetric about the center
- Cracks closed up after unloading (indication of presstressing members)
- Cracks were deeper than the first level of prestress (e.g. AREMA failure for center negative test)
- Cracked crossties are not classified as failed ties according to CFR 213



Plan view of cracked crosstie

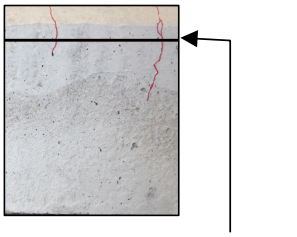


Profile view

Defining Failed Concrete Crossties

- FRA – CFR 213 (Track Safety Standards)
  - *Broken through or deteriorated to the extent that prestressing material is visible;*
  - *Deteriorated or abraded at any point under the rail seat to a depth of ½ inch or more;*
  - *Configured with less than two fasteners on the same rail;*
  - *[…]*

- AREMA Chapter 30 (Ties)
  - Various standardized laboratory tests
    - Crack beyond first level of presstress for center negative test



- Railroads (Specific Track Maintenance Standards)
  - Various thresholds for different railroads

Experimental Matrix

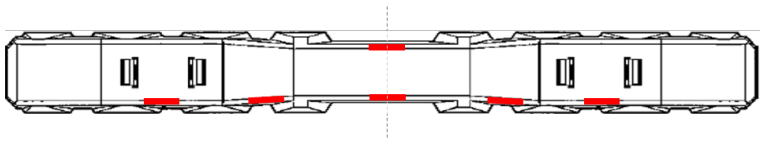
- Matrix was executed five times to account for variability
- 12 combinations of support conditions and crosstie health variation

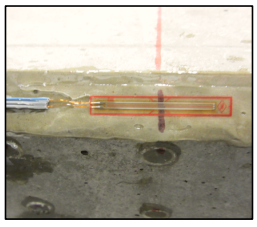
FRA BAA 2014-2 Test Matrix 1 DRAFT

Run Number	Support Condition	Crosstie Condition	Purpose	Vertical Load Applied to Each Rail Seat Simultaneously	
				kips	*kN*
1	1	Healthy Crosstie	Baseline - Healthy Crosstie, Full Support	0-20	0-89
2	2		Healthy Crosstie, Light Center Binding		
3	3		Healthy Crosstie, Moderate Center Binding		
4	4		Healthy Crosstie, Severe Center Binding		
5	5		Healthy Crosstie, High Impact Loads (Rail Seat Positive)		
6	6		Healthy Crosstie, Newly Tamped		
7	1	Center Cracked Crosstie (Beyond First Level of Presstress)	Deep Cracks, Full Support		
8	2		Deep Cracks, Light Center Binding		
9	3		Deep Cracks, Moderate Center Binding		
10	4		Deep Cracks, Severe Center Binding		
11	5		Deep Cracks, High Impact Loads (Rail Seat Positive)		
12	6		Deep Cracks, Newly Tamped		

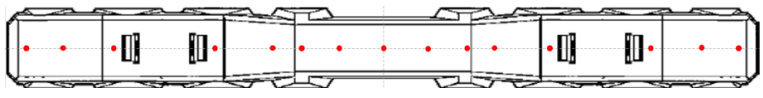
Measurement Devices

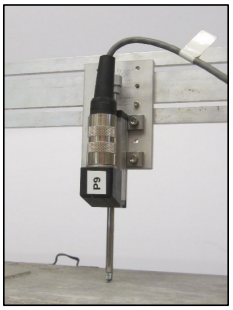
- **Surface Strain Gauges**
  - Calculation of bending moments





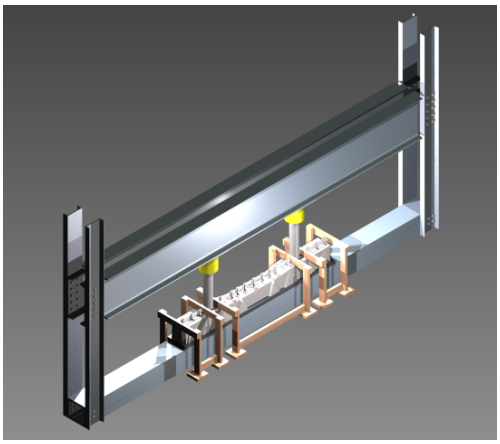
- **Linear Potentiometers**
  - Measurement of vertical displacements
  - Estimation of crosstie shape

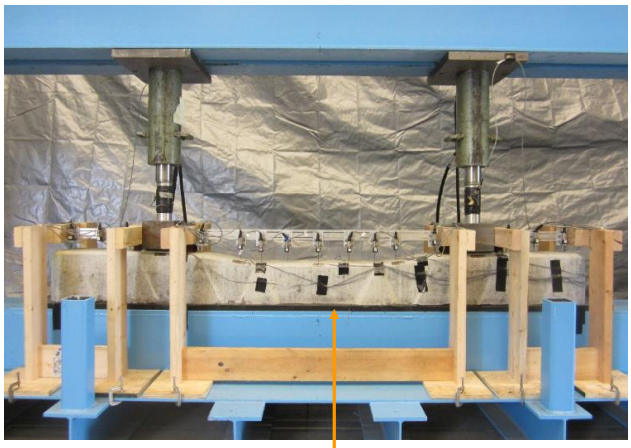




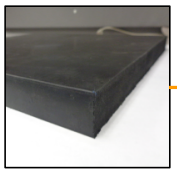
Laboratory Experimentation Equipment

- **Loading frame**





- **Supporting rubber pads**



Expected Industry Impact

Expected Impacts	Crosstie Manufacturers	Railroads	AREMA Chapter 30	FRA - CFR 213
Consensus on definition of failed concrete crossties	x	x	x	x
Input on expected crosstie bending moments		x	x	x
Input on expected concrete crosstie deflections and gage widening effect based on crosstie shape	x		x	
Estimation of crosstie support conditions based on bending moment measurements and cracking observation	x		x	

Impacted Groups

Preliminary Conclusions and Path Forward

- ***Wide gage due to defective or missing crossties*** and ***Roadbed settled or soft*** are two of the most common track related accident causes in the US for both timber and concrete crossties

- Industry Survey results indicated the need for research on
  - Crosstie support conditions
  - Crosstie cracking

- Results from this project will guide future experimentation using the **Track Loading System (TLS)** at UIUC

TLS at RailTEC's RAIL

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  - Rail Product Solutions (RPS), Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
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  - TTX Company
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- RailTEC Team

FRA Tie and Fastener BAA Industry Partners:

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