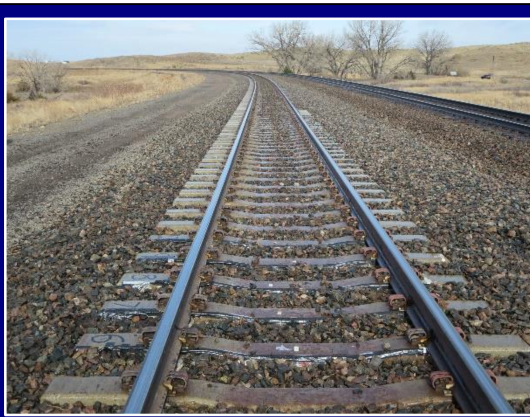
Field Measurements and Analysis of Concrete Crosstie Bending Moments



2016 International Crosstie & Fastening System Symposium

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Marcus Dersch, Zhengboyang Gao, Riley Edwards, David Lange,
Yu Qian, Matt Csenge

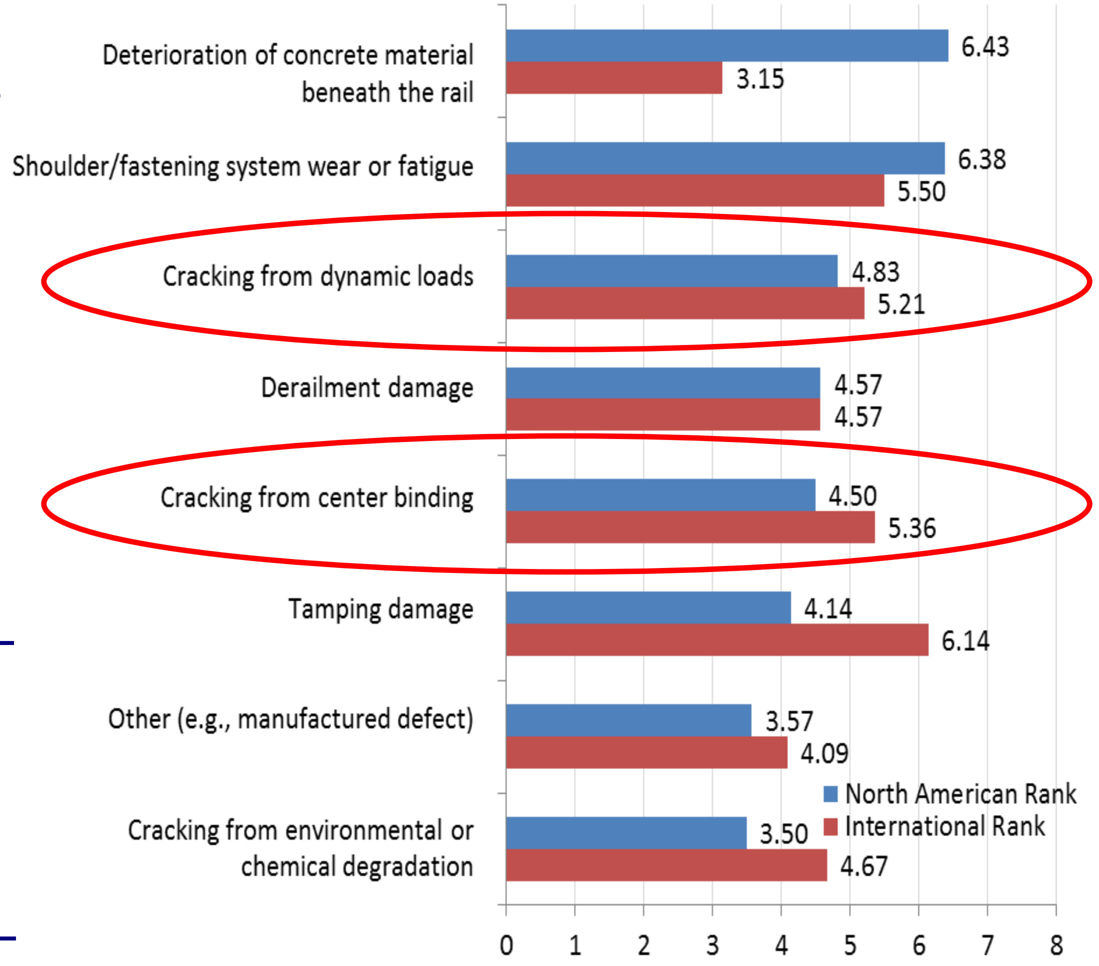
RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Background and motivation
- Site layout and instrumentation
- Project approach
- Preliminary results
- Preliminary conclusions
- Path forward

Project Background

- In 2013, UIUC conducted an international survey to determine most critical issues in concrete crosstie track
- Survey of railroads, concrete crosstie manufacturers, and researchers around the world
- Cracking from center binding (3rd most critical problem – International, 5th most critical – North America)
- Cracking from dynamic loads (4th most critical problem – International, 3rd most critical – North America)



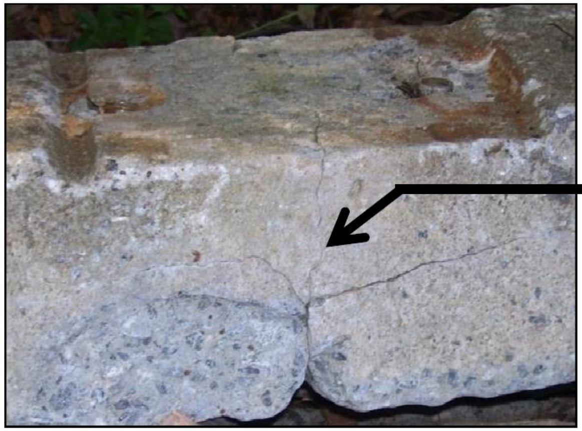
Motivation for Research

- Previous analysis of FRA accident database indicated that deteriorated concrete crossties and support conditions are among the major track related accident causes in the US

Broken crosstie

Fouled ballast

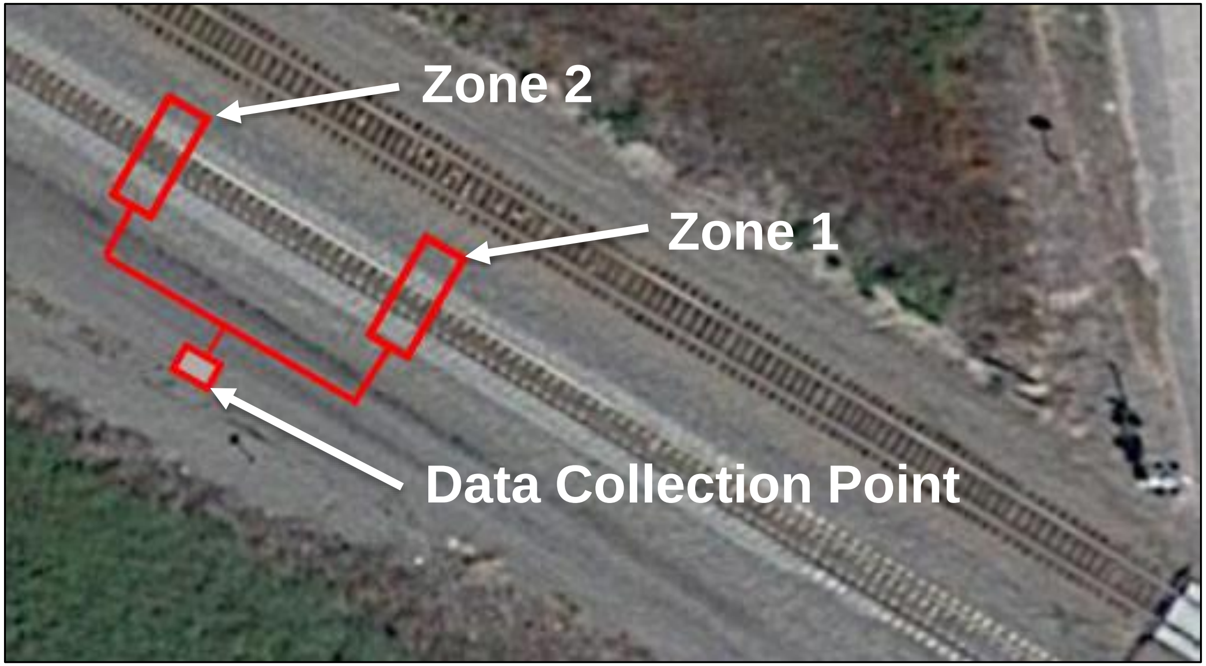
- Industry partners stated that rail seat positive cracks are rarely seen in the field



Rail seat positive crack

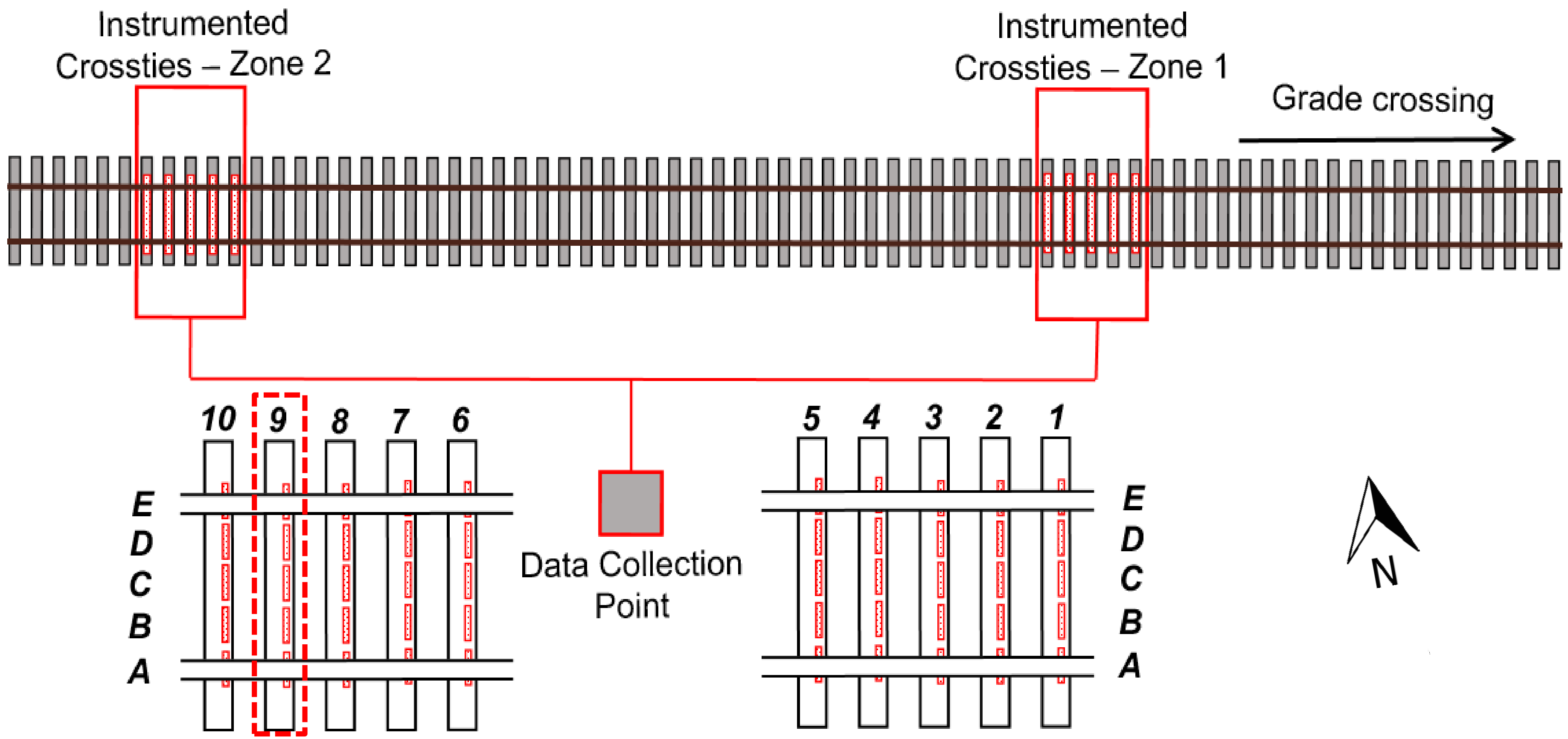
Experimentation Site Layout

- **Site broken up into two sections with different support conditions based on visual inspection:**
  - Zone 1: Poor support
    - Historic geometry deviations and larger visible deflection
  - Zone 2: Good support
    - No visible ballast issues, smaller visible deflection



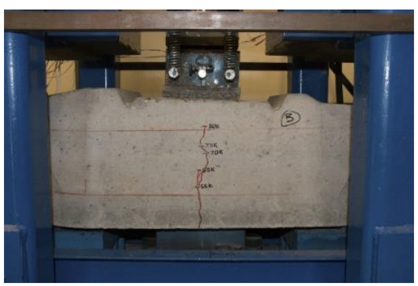
Experimentation Site Layout

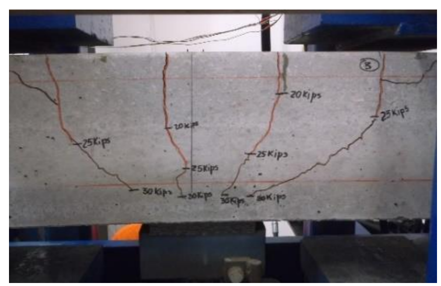
- 50 surface strain gauges installed on 10 crossties

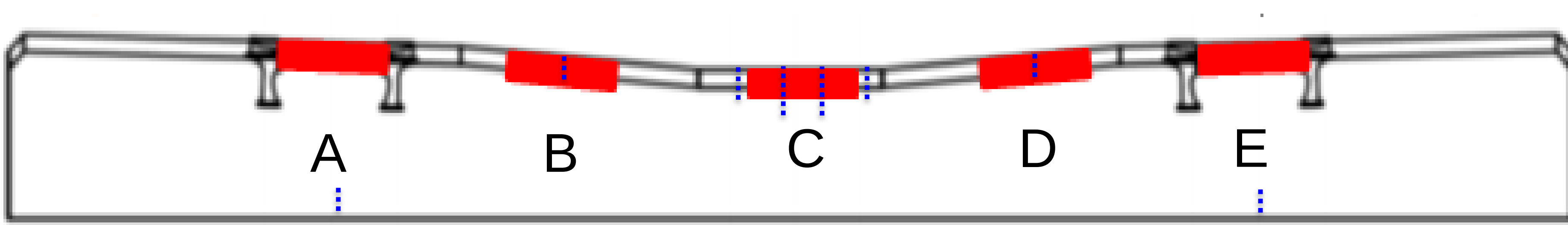


Crosstie Instrumentation

- 5 surface strain gauges installed on each crosstie:
  - Rail seat gauges (to measure rail seat positive bending)
  - Center gauge (to measure center negative bending)
  - Intermediate gauge (to measure asymmetric loading or support)

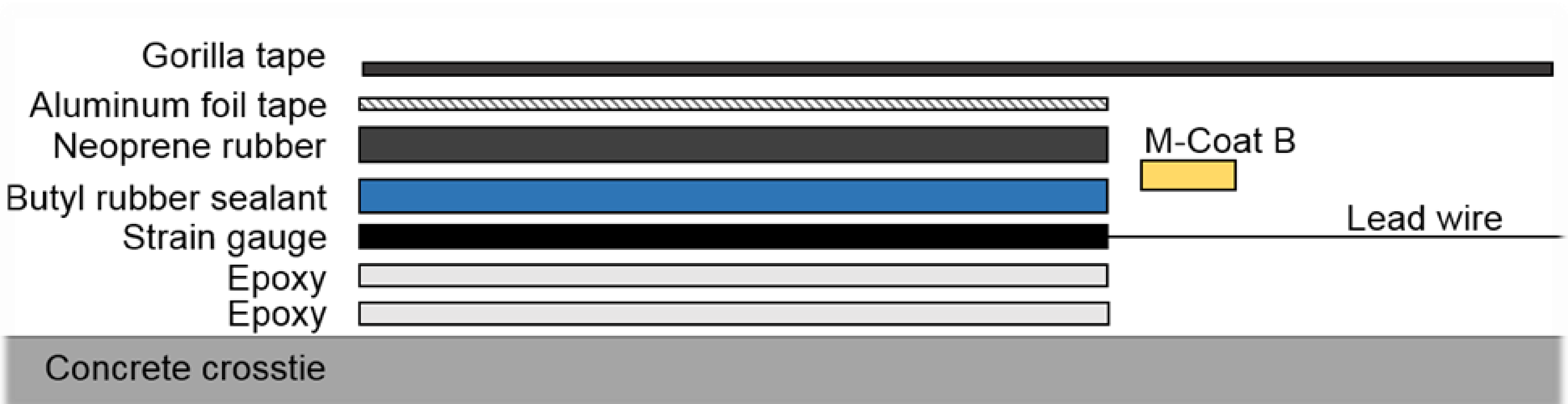






Instrumentation Protection Plan

- Surface strain gauges are delicate sensors and must be protected
- Potential types of damage:
  - Mechanical damage – impacts or pressures caused by train passes or maintenance activities
  - Moisture damage – ingress of water can cause wire shorts and failures



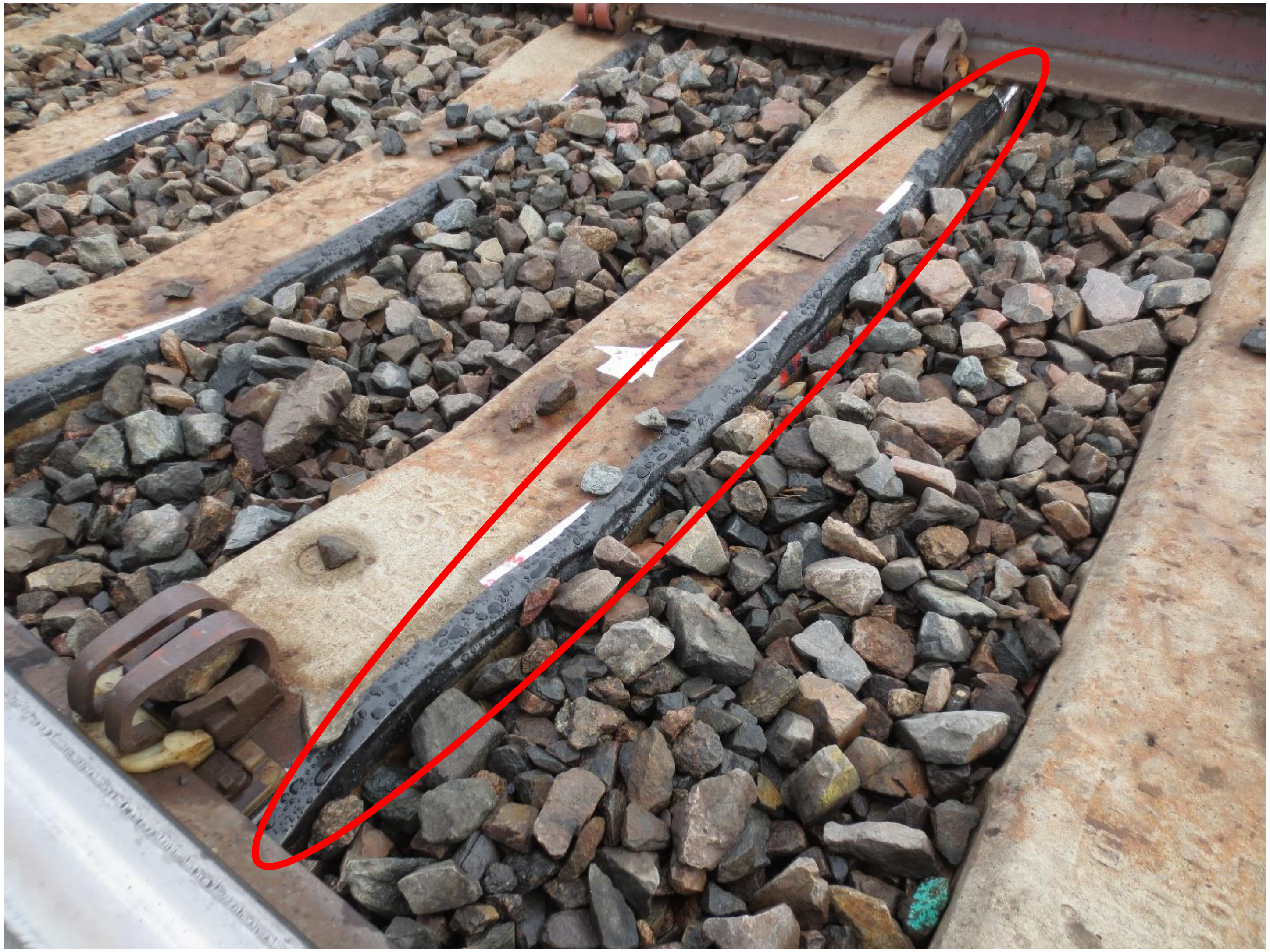
Installation Details

- **Dates:** 25 – 27 March 2015
- **Safety:** Work performed under watchman/lookout
- **Scope:**
  - Installed 54 surface strain gauges
    - 4 “dummy” gauges were placed on concrete cylinders to provide “baseline” comparison
  - Trenched 80 ft to cover strain gauge lead wires
  - Collected data from 4 trains

Close-up of Intermediate Strain Gauge

Installed and Protected Rail Seat Gauge

Completed Instrumented Crosstie

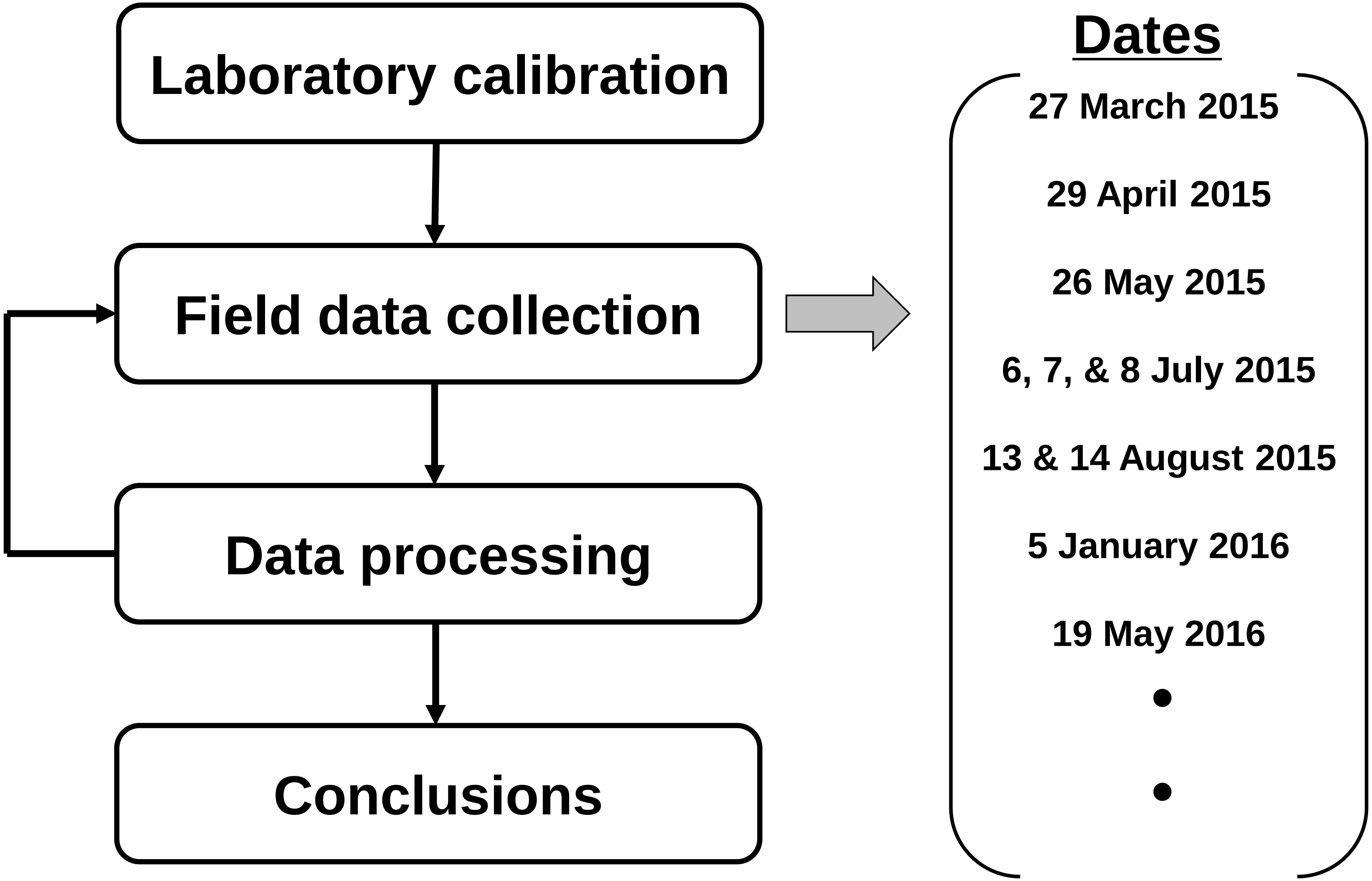


Completed Instrumentation Zone

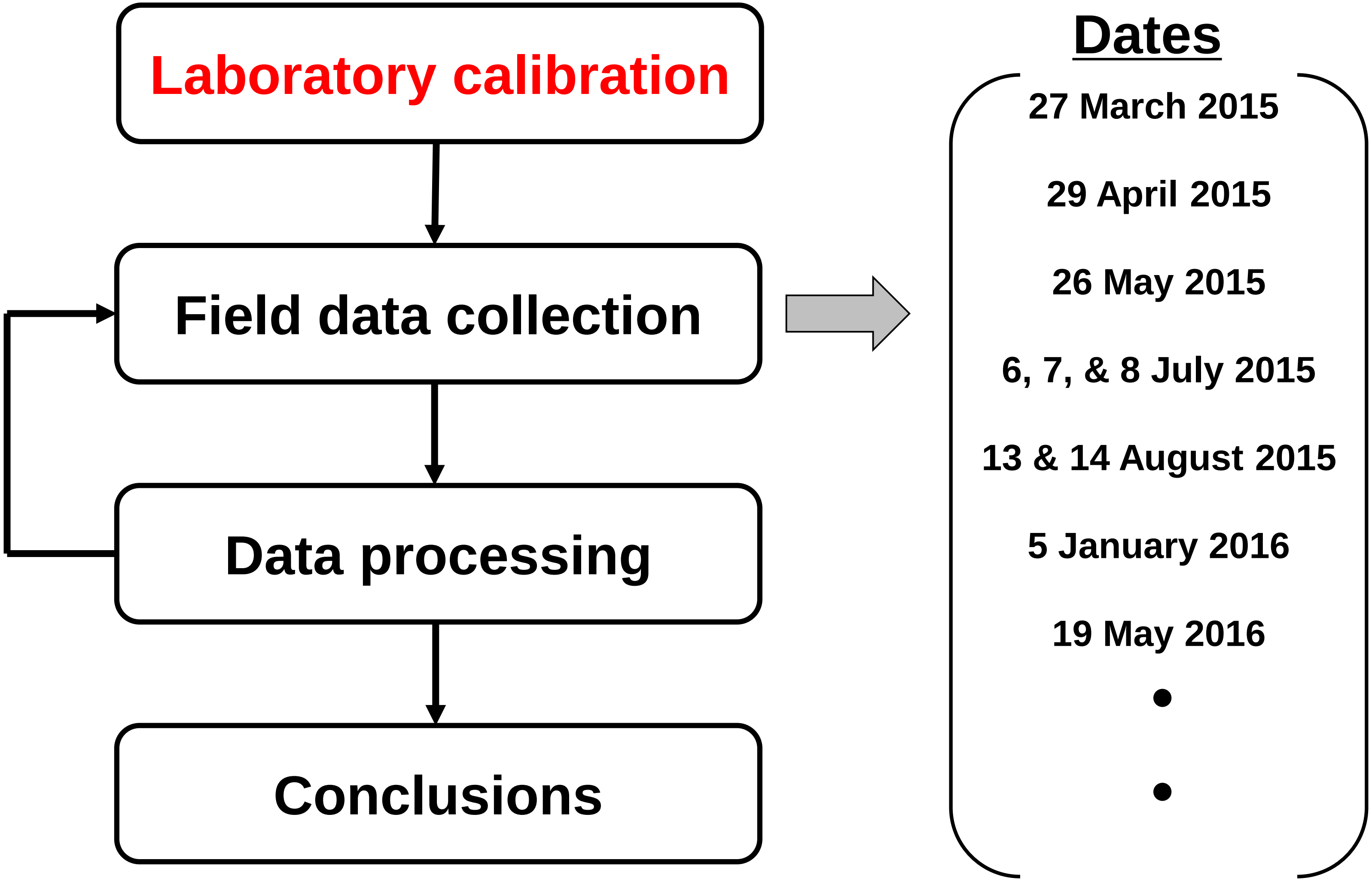
Completed Junction Box

Data Collection

Project Approach



Project Approach



Strain to Moment Laboratory Calibration: *Purpose*

- Measured bending strains can be converted to bending moments through sectional properties,

$$M = \frac{EI}{y}\varepsilon$$

where,

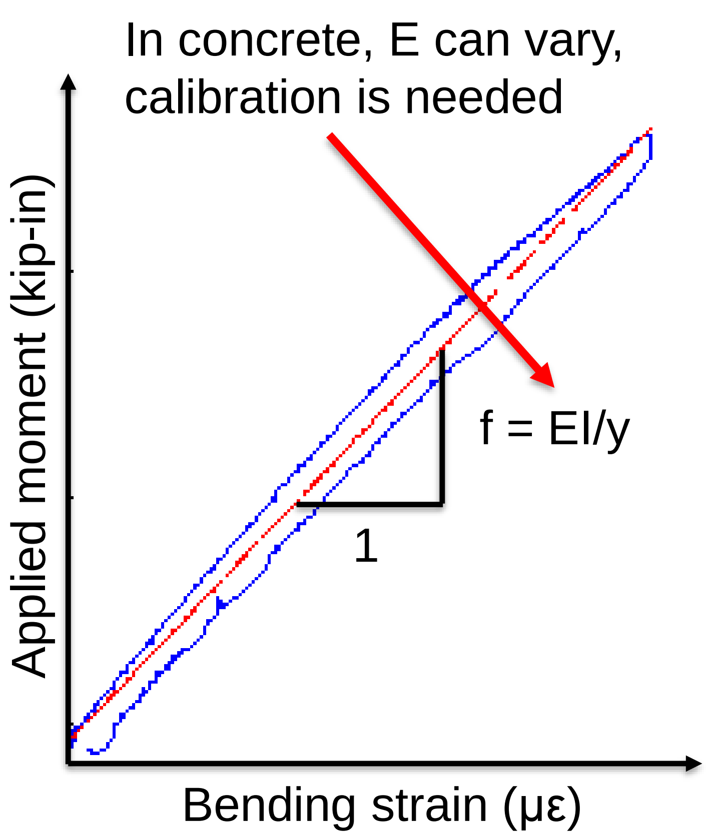
M = bending moment

E = elastic modulus

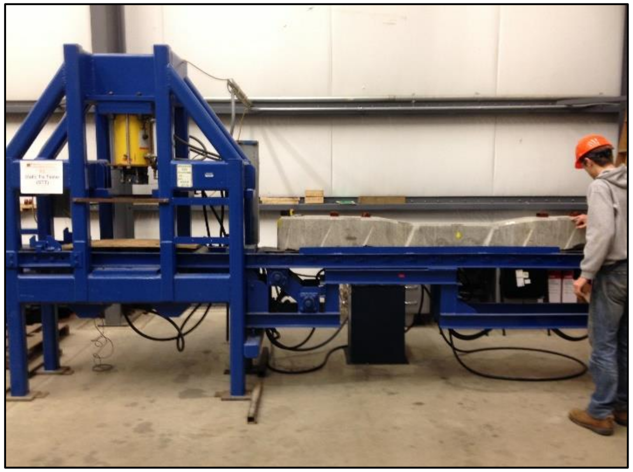
I = moment of inertia

y = distance from neutral axis

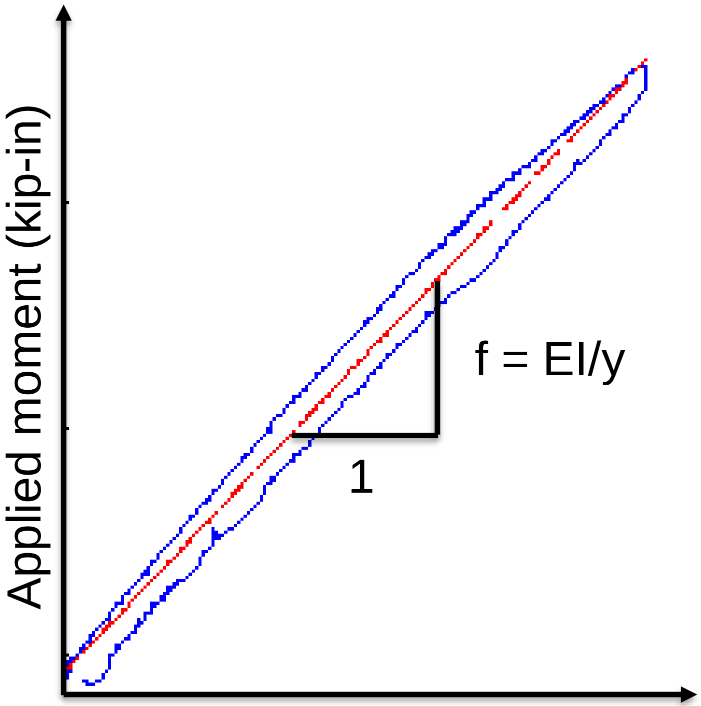
ε = bending strain

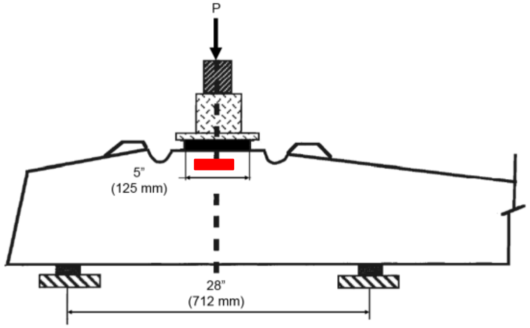


Strain to Moment Laboratory Calibration: *Procedure*

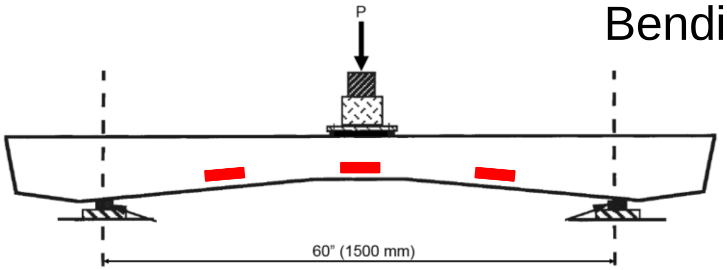


Known moment applied with Static Tie Tester (STT) to crosstie in controlled loading configurations, record bending strain and find slope of curve



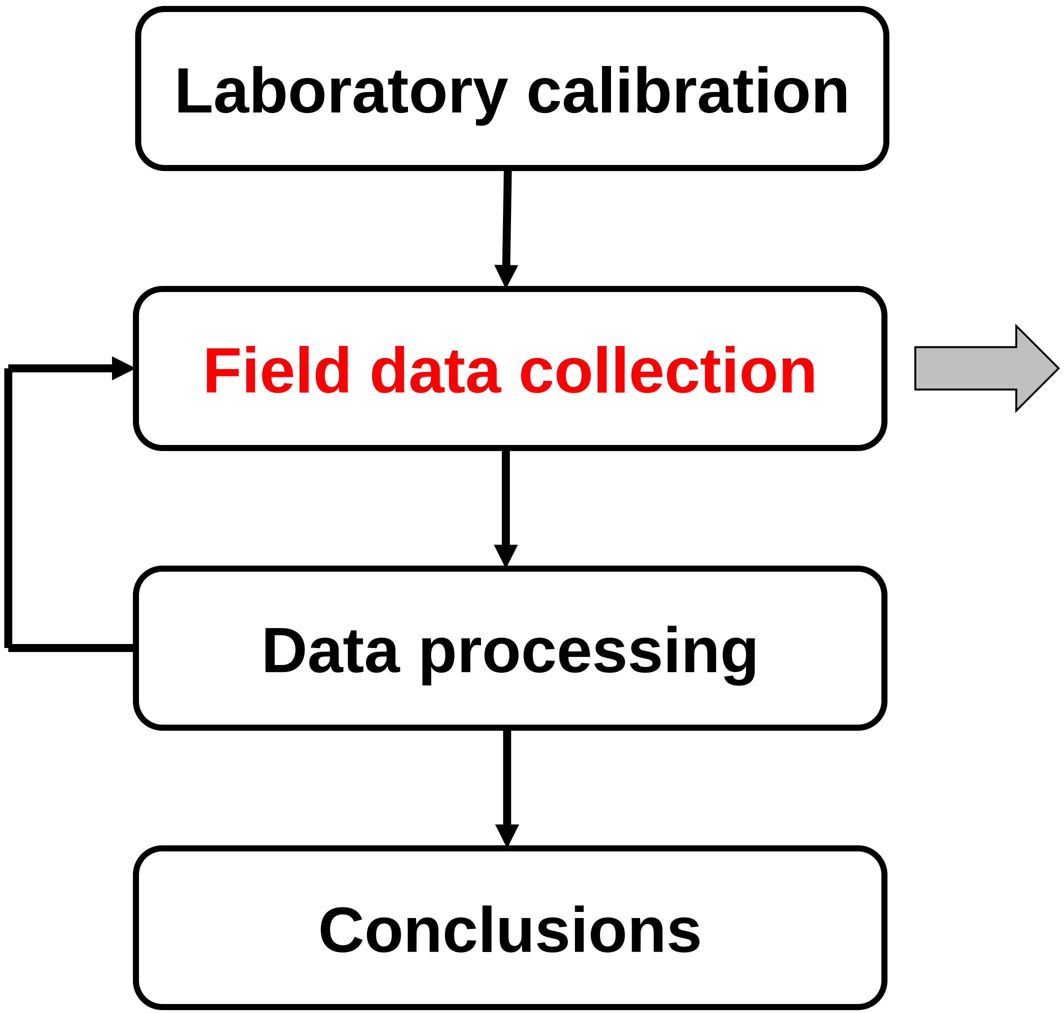


Rail Seat Positive



Center Negative

Project Approach



Dates

27 March 2015

29 April 2015

26 May 2015

6, 7, & 8 July 2015

13 & 14 August 2015

5 January 2016

19 May 2016

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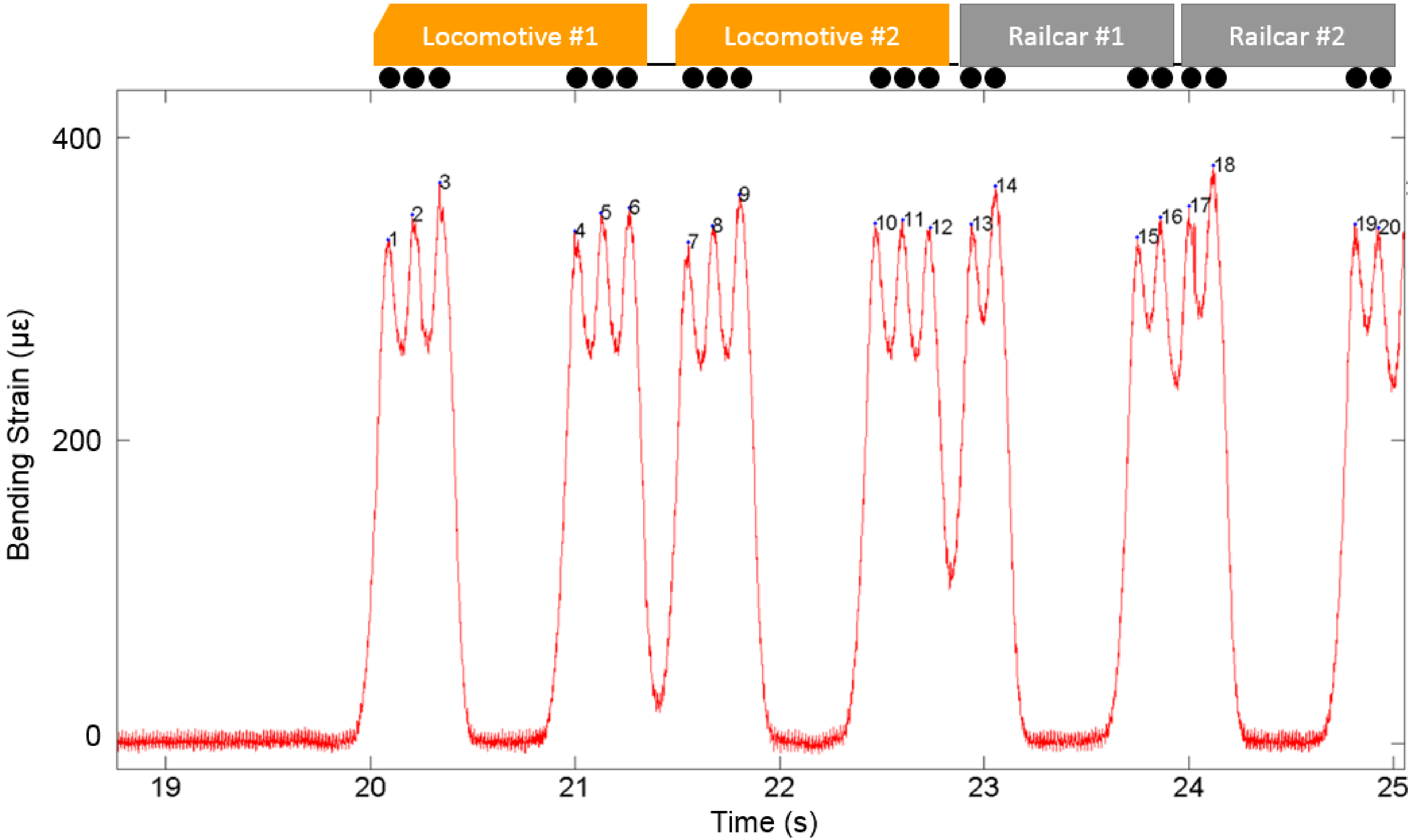
Data Collection Details

Date	27 Mar.	29 Apr.	26 May	6, 7, 8 Jul.	13, 14 Aug.	17 Sep.	12 Nov.	5 Jan.	19 May
No. Days	1	1	1	3	2	1	1	1	1
No. Trains	4	6	4	24	14	8	5	5	4
No. Axles	2,000	3,244	2,250	13,112	7,772	4,964	2,888	2724	2144
Time Range	8:52 AM–1:11 PM	9:40 AM–3:11 PM	8:52 AM–1:15 PM	12:02 AM–9:14 PM	8:34 AM–7:36 PM	7:47 AM–3:37 PM	4:02 PM–6:37 PM	8:30 AM–3:39 PM	7:43 AM–4:36 PM
Temp. Range (°F)	H: 63 L: 37	H: 73 L: 59	H: 65 L: 57	H: 76 L: 59	H: 95 L: 71	H: 97 L: 66	H: 53 L: 37	H: 49 L: 22	H: 53 L: 68
Conditions	Clear, Overcast	Clear	Overcast	Overcast, Light drizzle	Clear	Clear	Clear, Overcast	Clear	Clear

WILD data provided

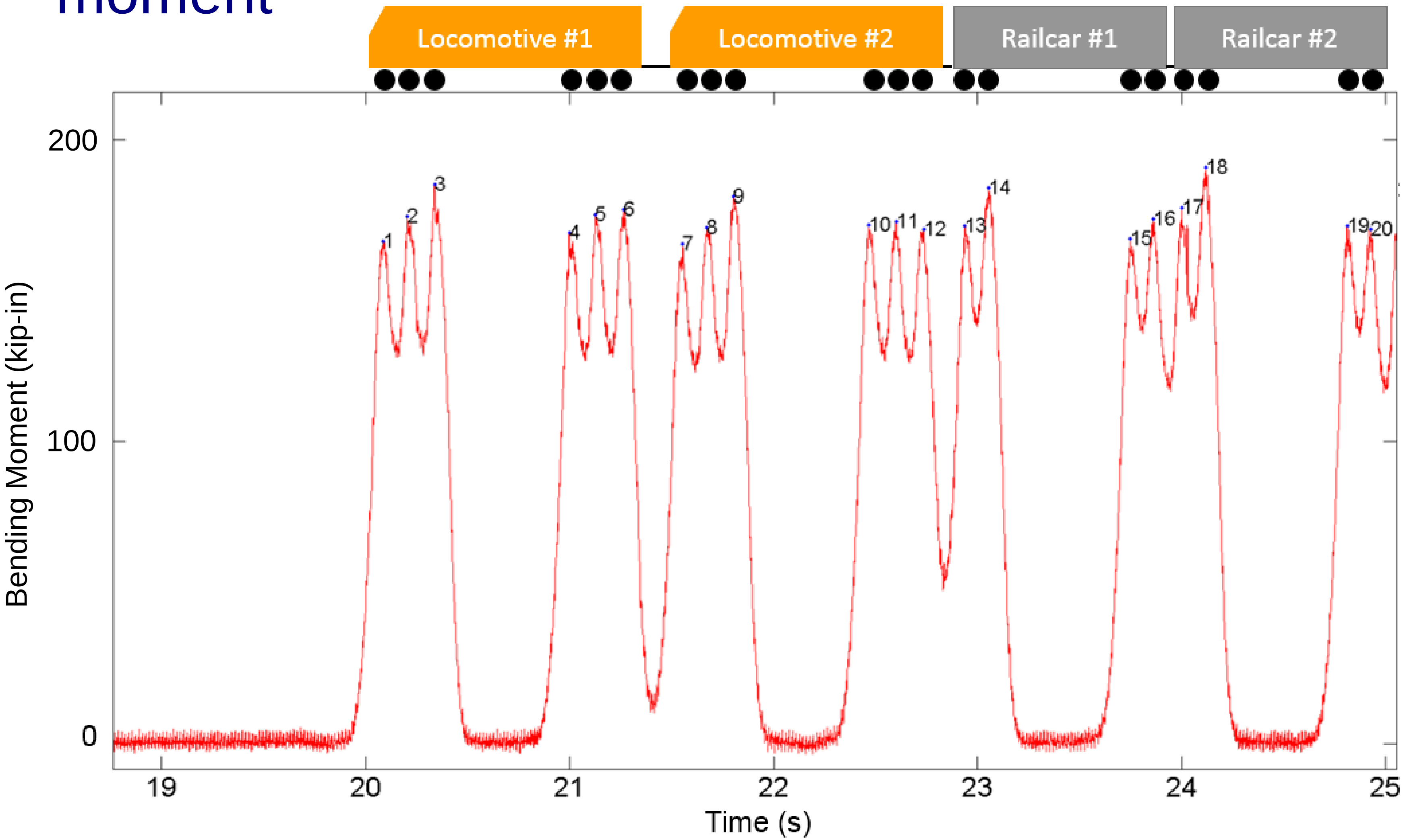
Example Strain Signal (Gauge C)

- Strain peaks correspond to loaded axles

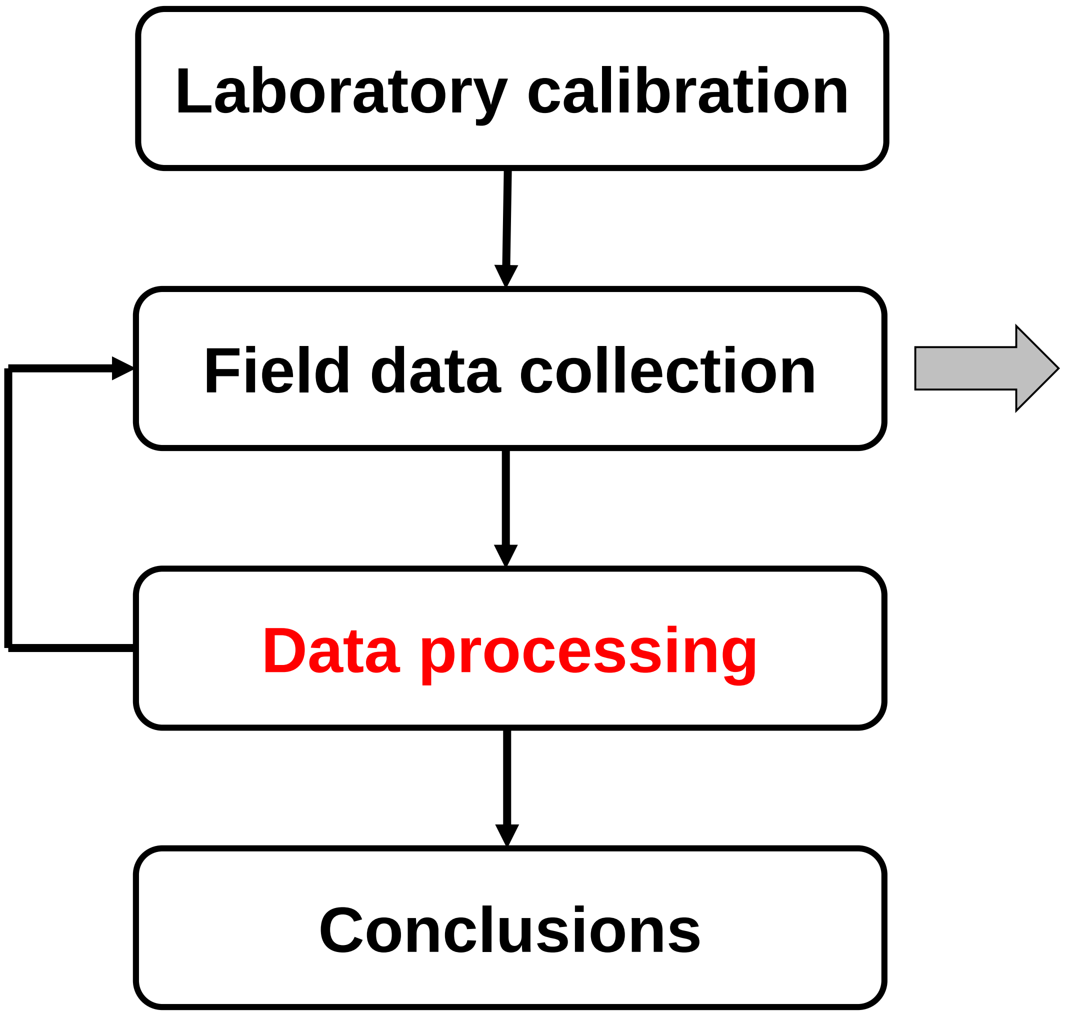


Example Bending Moment Signal (Gauge C)

- Multiply strain by calibration factor to convert to moment



Project Approach



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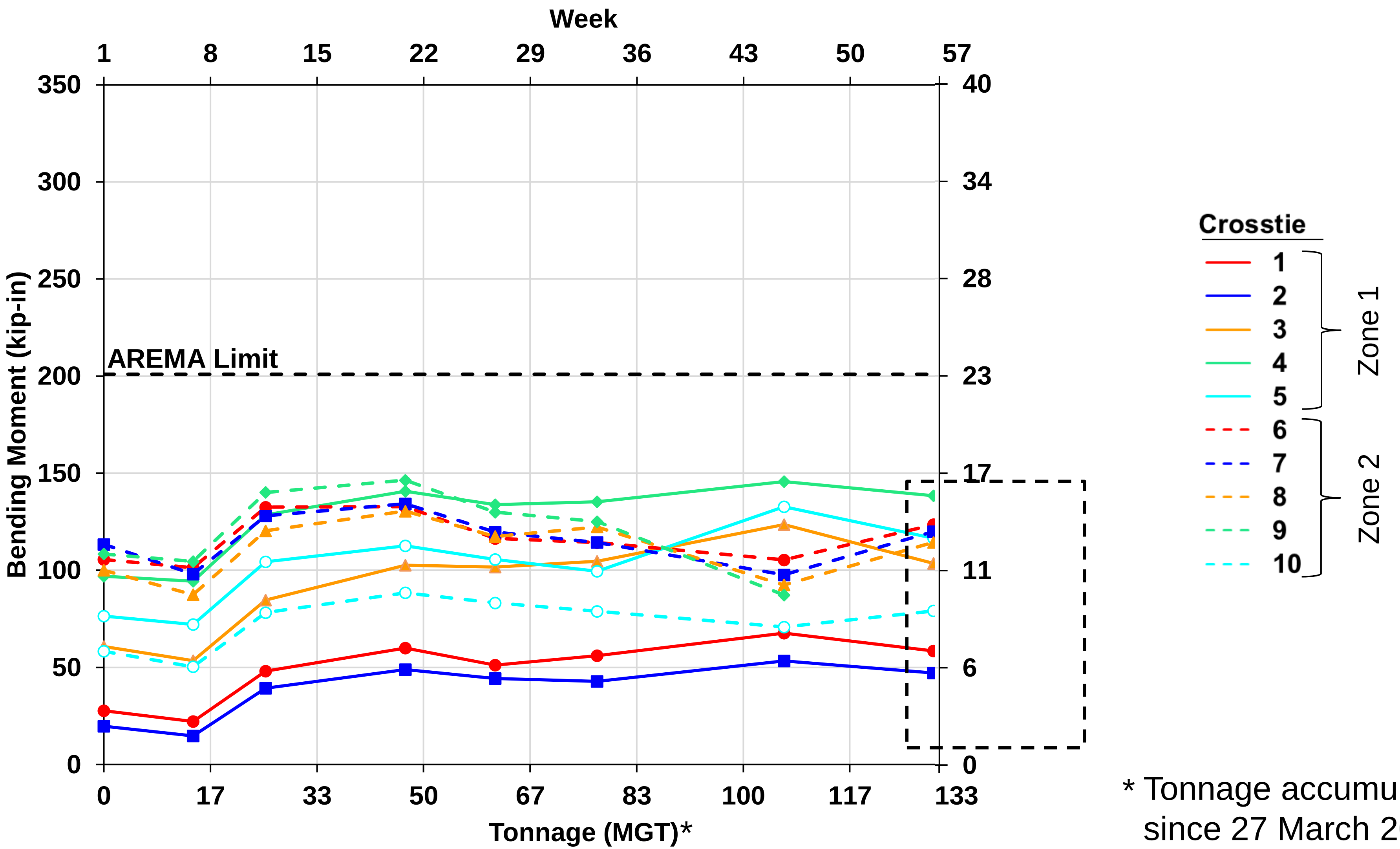
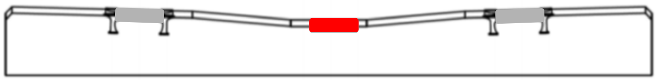
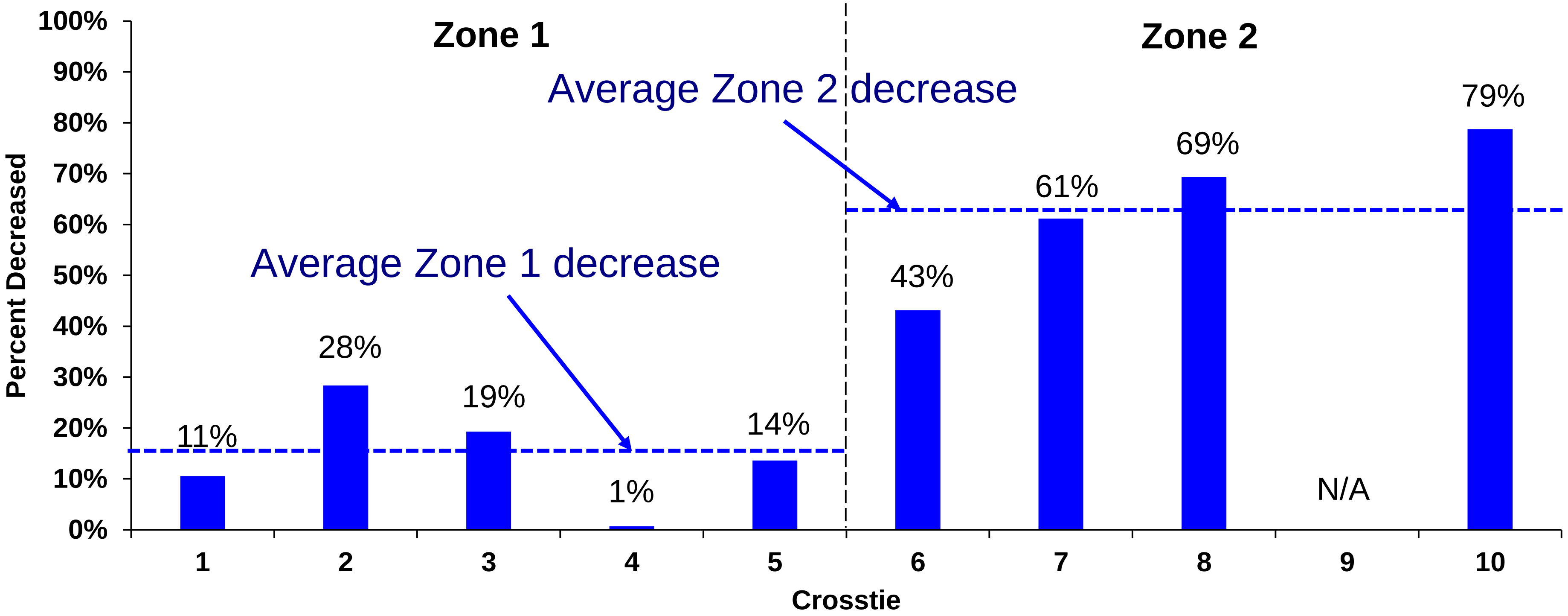
Average Center Negative Bending Moment vs. Time/Tonnage (Gauge C)



* Tonnage accumulated since 27 March 2015

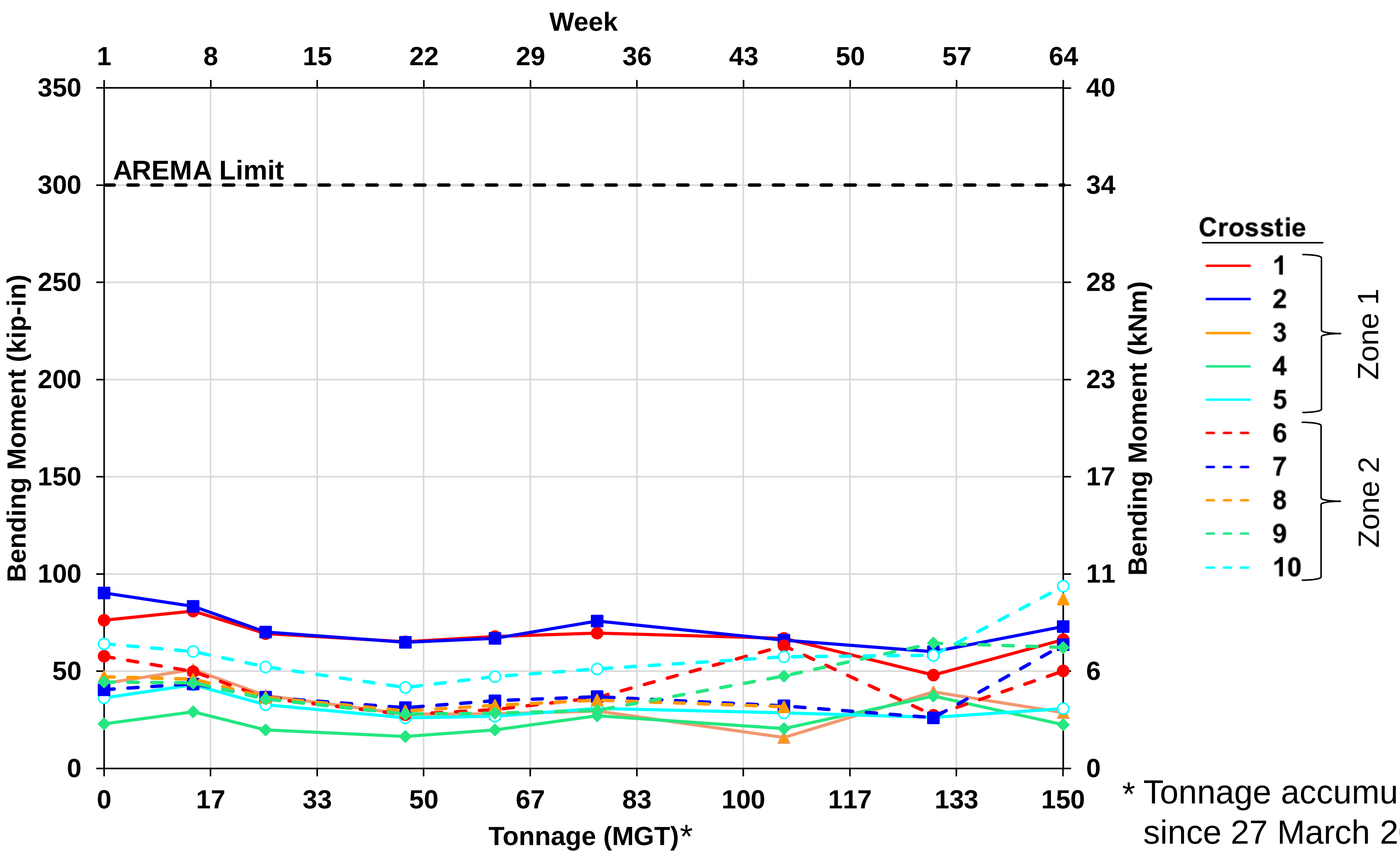


Change in Average Center Negative Bending Moments after Tamping (Gauge C)



- Average center moment of all crossties decreased, but those in Zone 2 (tamped zone) decreased more significantly

Average Center Negative Bending Moment vs. Time/Tonnage (Gauge A & E)



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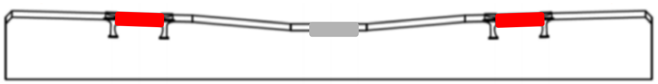
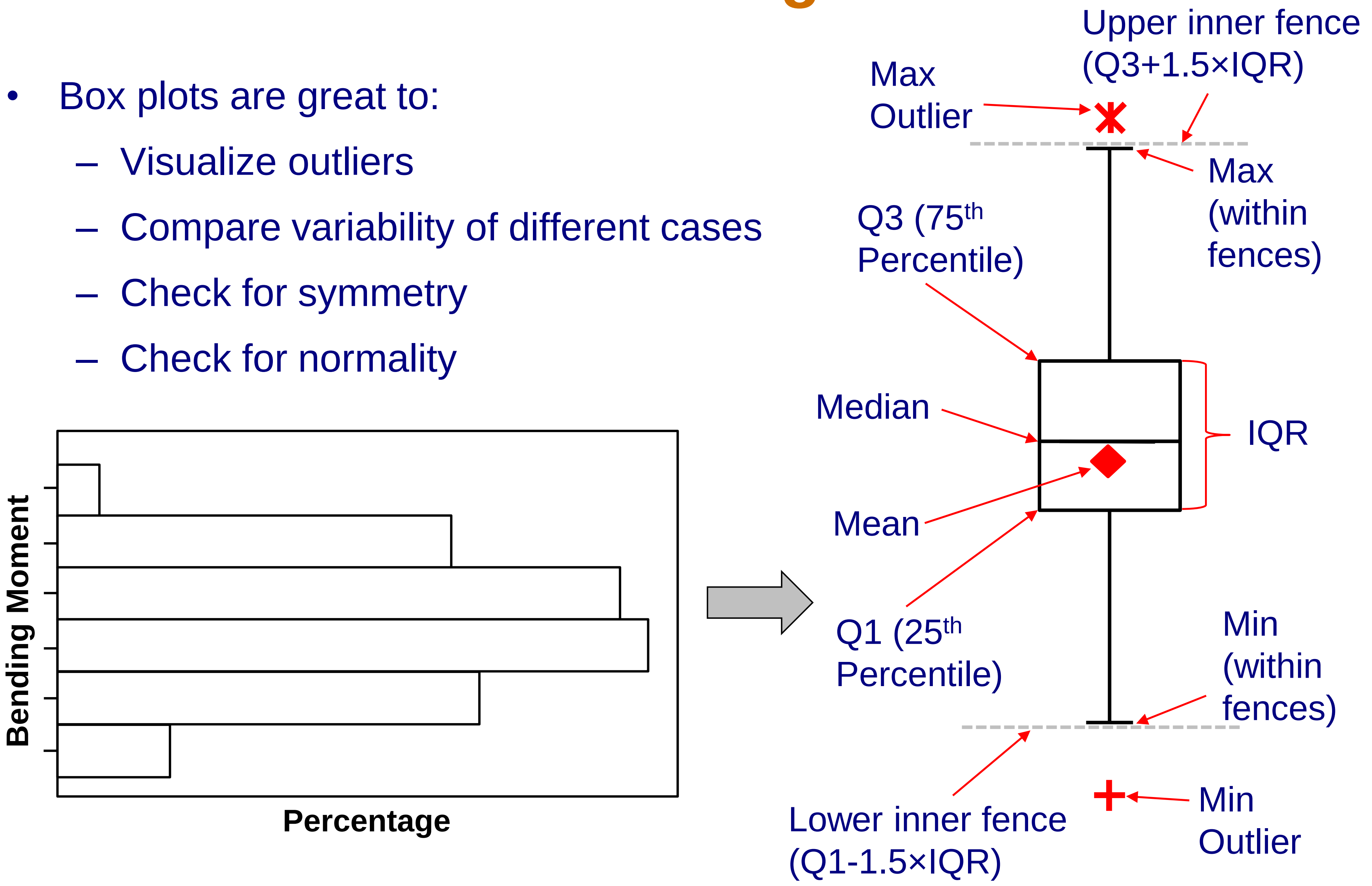
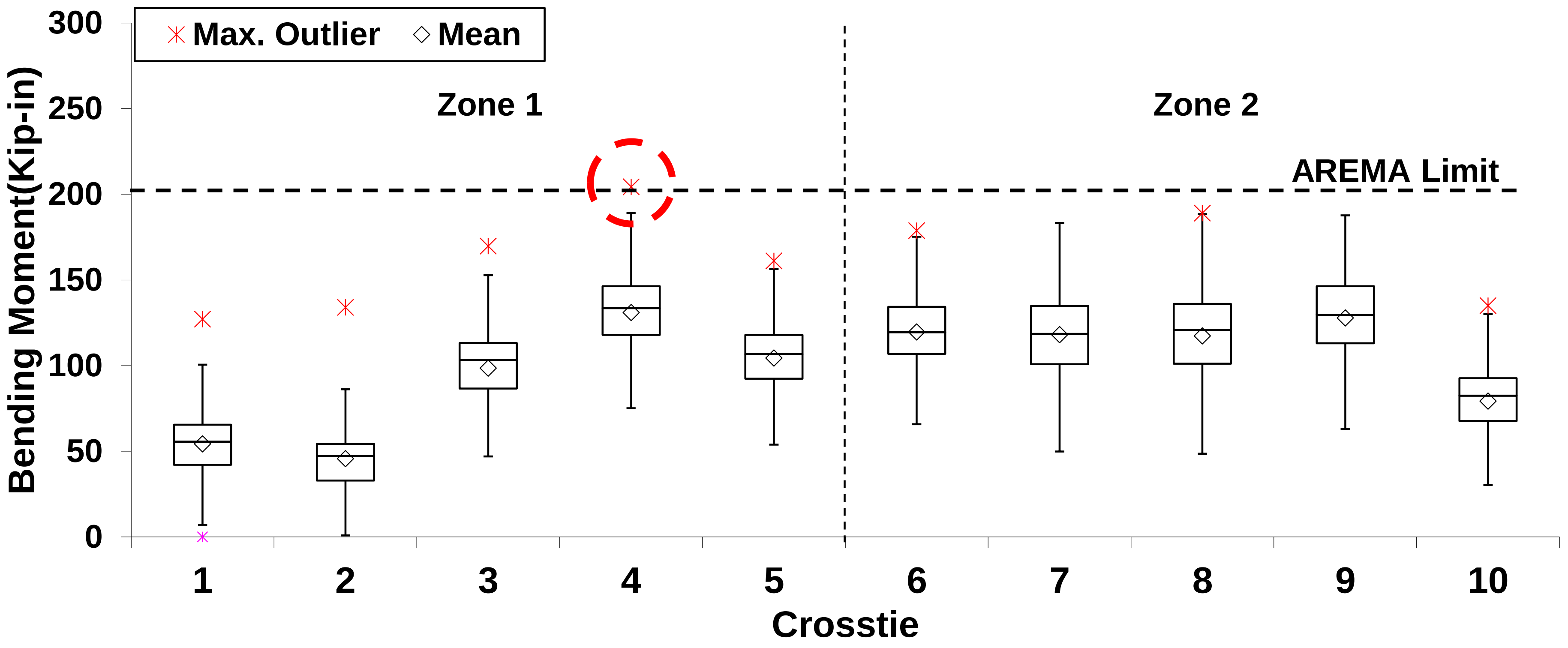


Box Plot Background

- Box plots are great to:
  - Visualize outliers
  - Compare variability of different cases
  - Check for symmetry
  - Check for normality

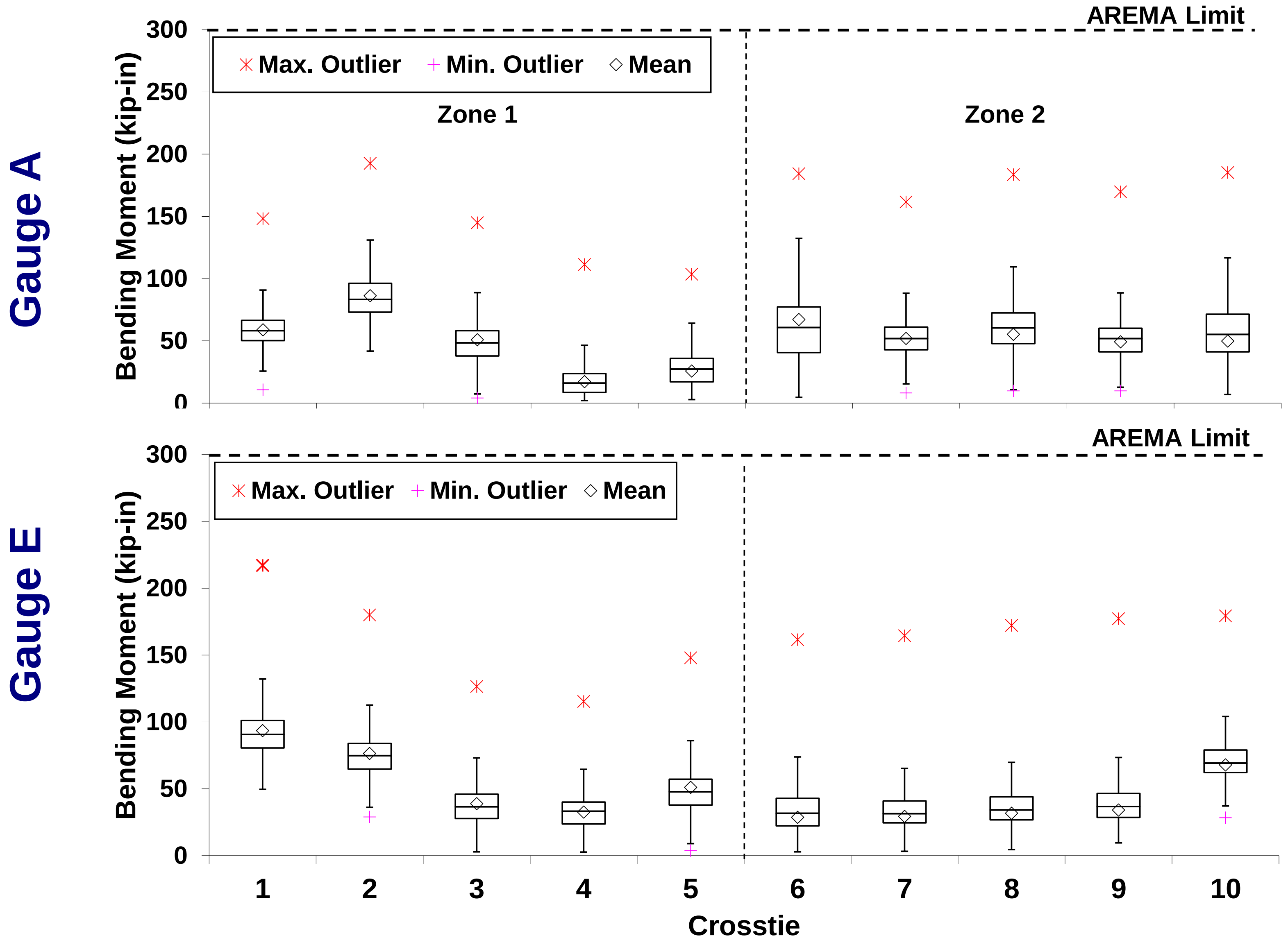


Box Plot for Center Negative Bending Moment (Gauge C)

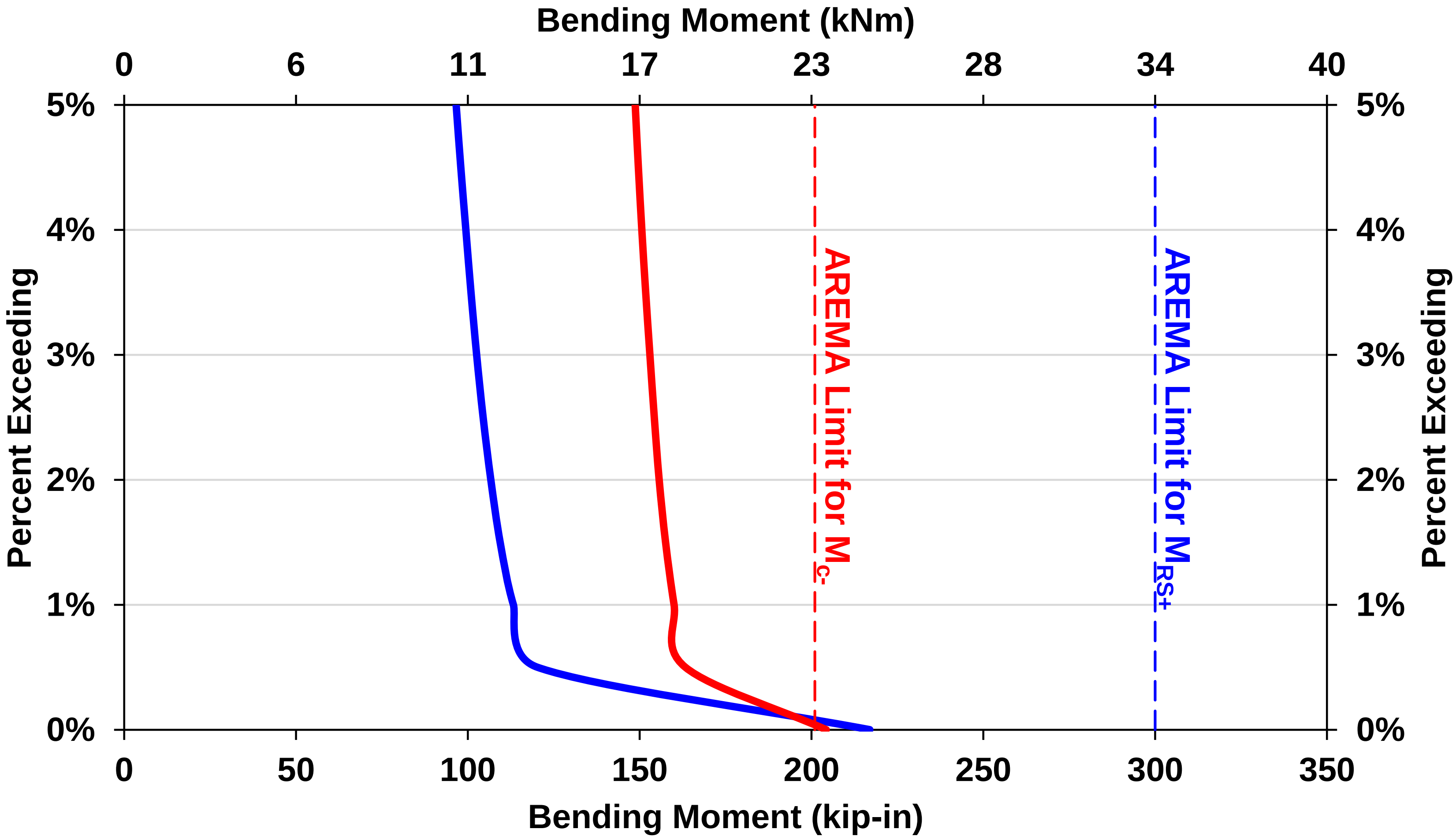


- However, only 2 of 41,098 loaded axles exceeded the AREMA limit
  - 0.005% exceedance probability for Crosstie 4 and 0.0005% for all 10 crossties

Box Plot for Rail Seat Positive Bending Moment (Gauge A & E)



Percent Exceedance Plot for Center and Rail Seat Bending Moments (Gauge C, Gauge A & E)



Preliminary Conclusions

- Instrumentation is robust and has not failed over the past 14 months and approximately 150 MGT
- Instrumentation is measuring true bending behavior of crosstie
- There is a variability in support conditions in this site, which causes variability in crosstie bending moments
- In general, center bending moment remained relatively constant over around 150 MGT of train passing
- Center negative bending moments increase while rail seat positive moments decrease over accumulated tonnage
- Center negative bending moments approached AREMA recommended design limits

Path Forward

- Continue collecting field data
  - Analyze effects of tamping on crossties' flexural performance
  - Monitor crossties within untamped zone
  - Install automated data collection system to capture train signals on daily basis
- Compare bending behaviors of crossties at different locations (under different traffic and track conditions)
- Further improve the design methodology of concrete crossties

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FRA Tie and Fastener BAA Industry Partners:

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U.S. Department of Transportation Federal Railroad Administration

Marcus S. Dersch
Senior Research Engineer
email: mdersch2@illinois.edu

Zhengboyang Gao
Graduate Research Assistant
email: zgao9@illinois.edu

David A. Lange
Professor
email: dlange@illinois.edu

J. Riley Edwards
Senior Lecturer and Research Scientist
email: jedward2@illinois.edu

Yu Qian
Research Engineer
email: yuqian1@illinois.edu

Matt Csenge
Manager of Experimentation
email: csenge2@illinois.edu