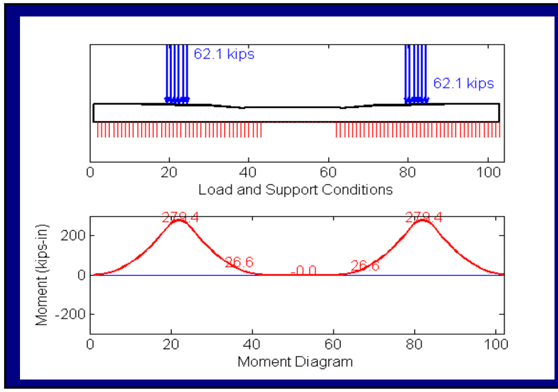
Use of Crosstie Bending Moment Data for the Development of a Support Condition Back-calculator



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Zhengboyang Gao, Riley Edwards, Marcus Dersch, Yu Qian, and Matt Csenge

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

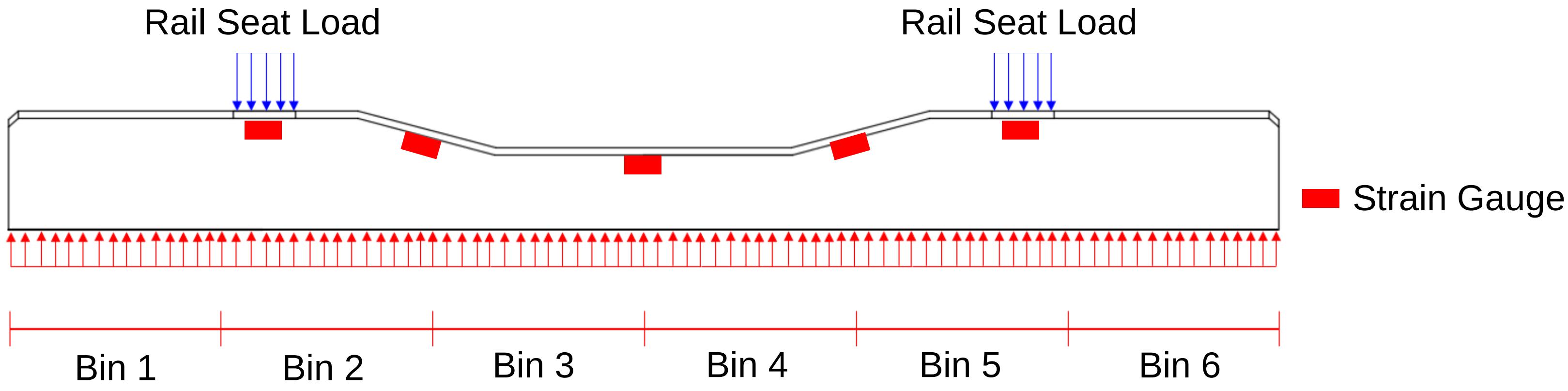
- Problem statement and research objective
- Back-calculator development
- Preliminary results
  – Lab experimentation
  – Field experimentation
- Preliminary conclusions
- Future work

Problem Statement and Research Objective

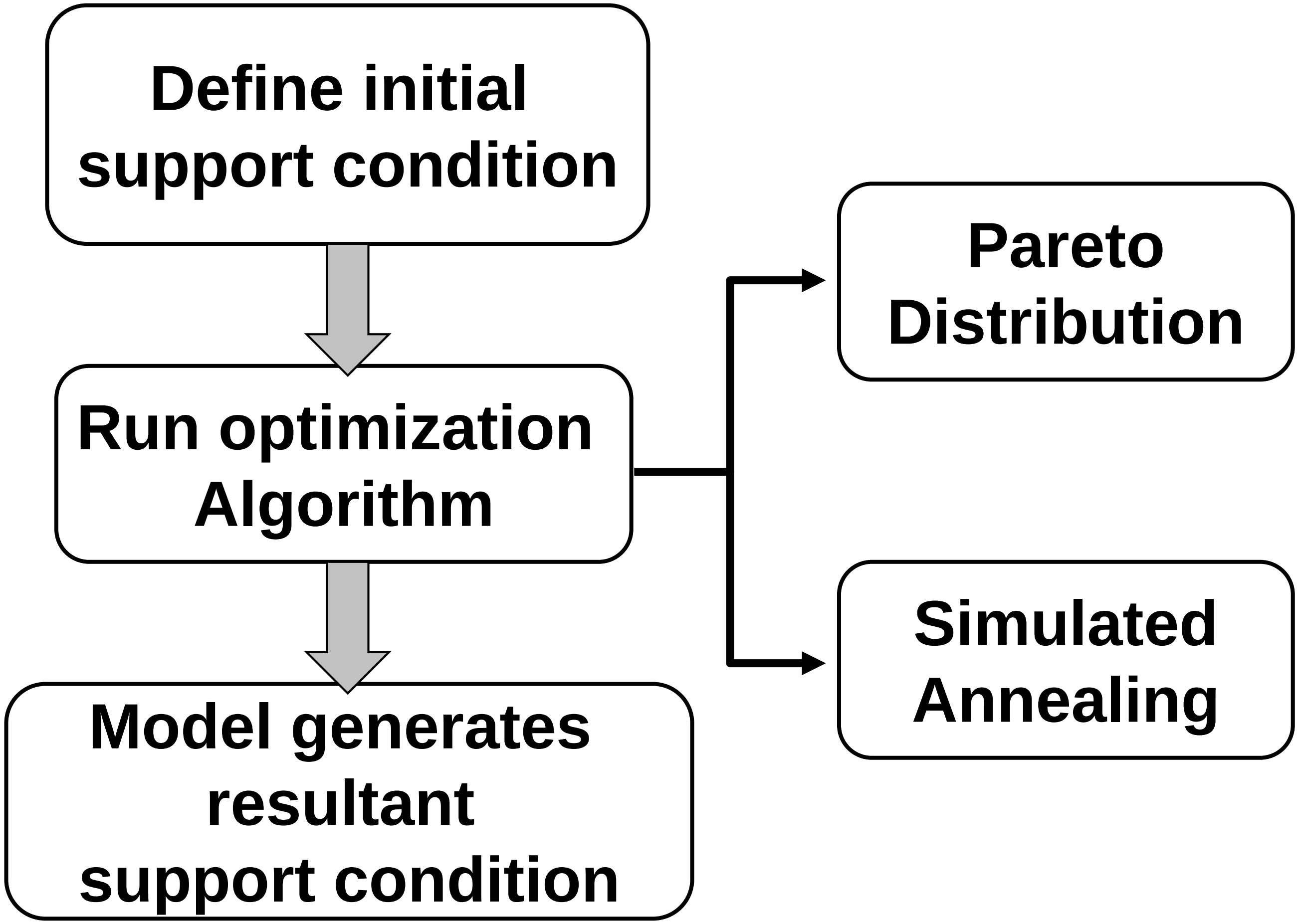
- **Challenge:** It is inherently difficult to quantify the pressure distribution at the crosstie-ballast interface
- **Objective:** Develop a non-intrusive method to quantify support conditions and their variation over time/tonnage
- **Approach:** Back-calculate ballast support conditions from measured bending moments

2-D Crosstie Bending Model

- Assume rail seat load is uniformly distributed across rail seat
- Crosstie divided into 6 bins:
  - Each bin consists a percentage of total reaction force
- 9 model inputs:
  - Known bending moments from 7 locations
  - 2 approximated rail seat loads
- 2 boundary conditions:
  - Force equilibrium (all bins should sum to approximately 100%)
  - Force value for each bin should not be negative

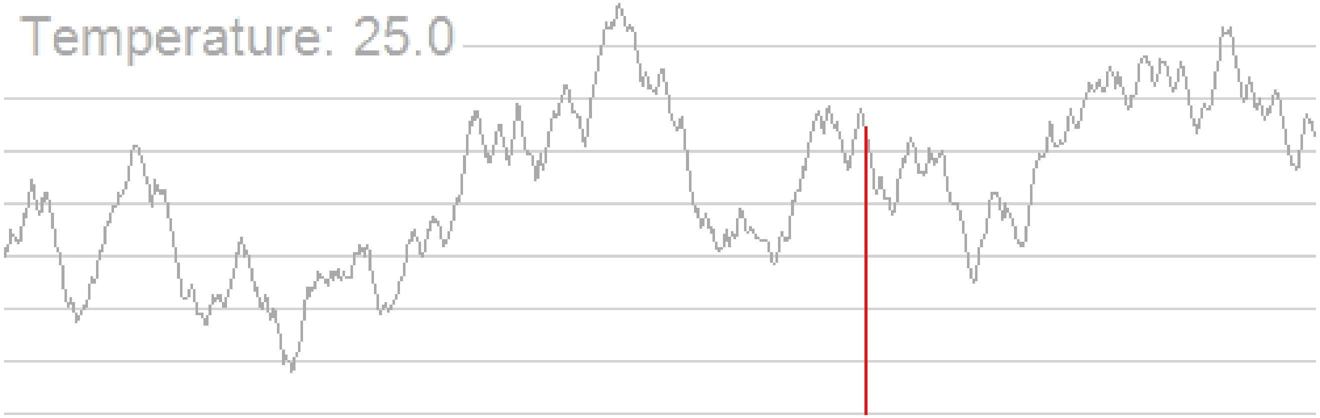


Framework for Support Back-calculator



Optimization Algorithm

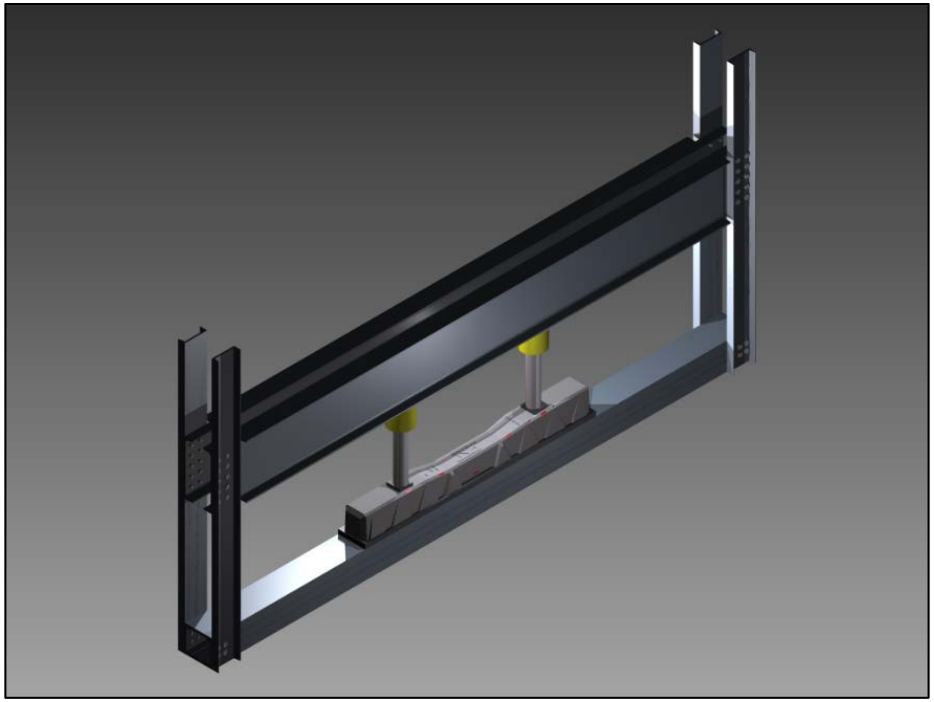
- Pareto distribution is chosen as random variable generator
- Simulated annealing (SA) is a probabilistic technique for approximating the global optimum of a given function
- Has a probability of accepting a “worse” solution
- Avoids stopping at a local optimum

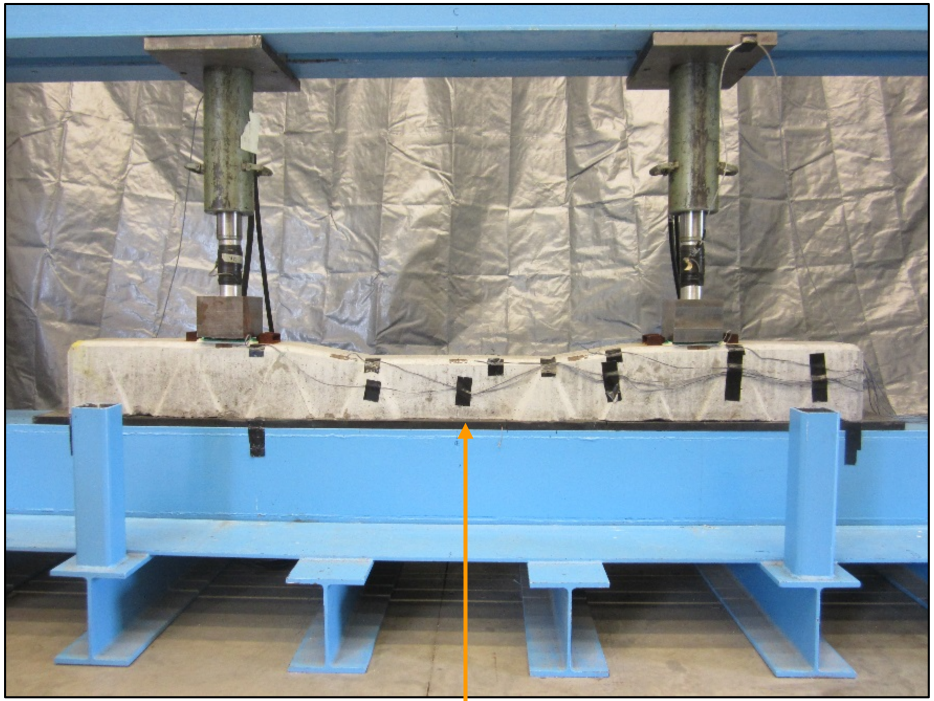


Wikipedia: Simulated Annealing

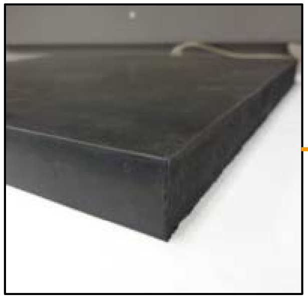
Laboratory Experimentation Equipment

- **Loading frame - Static Load Testing Machine (SLTM) at RAIL**



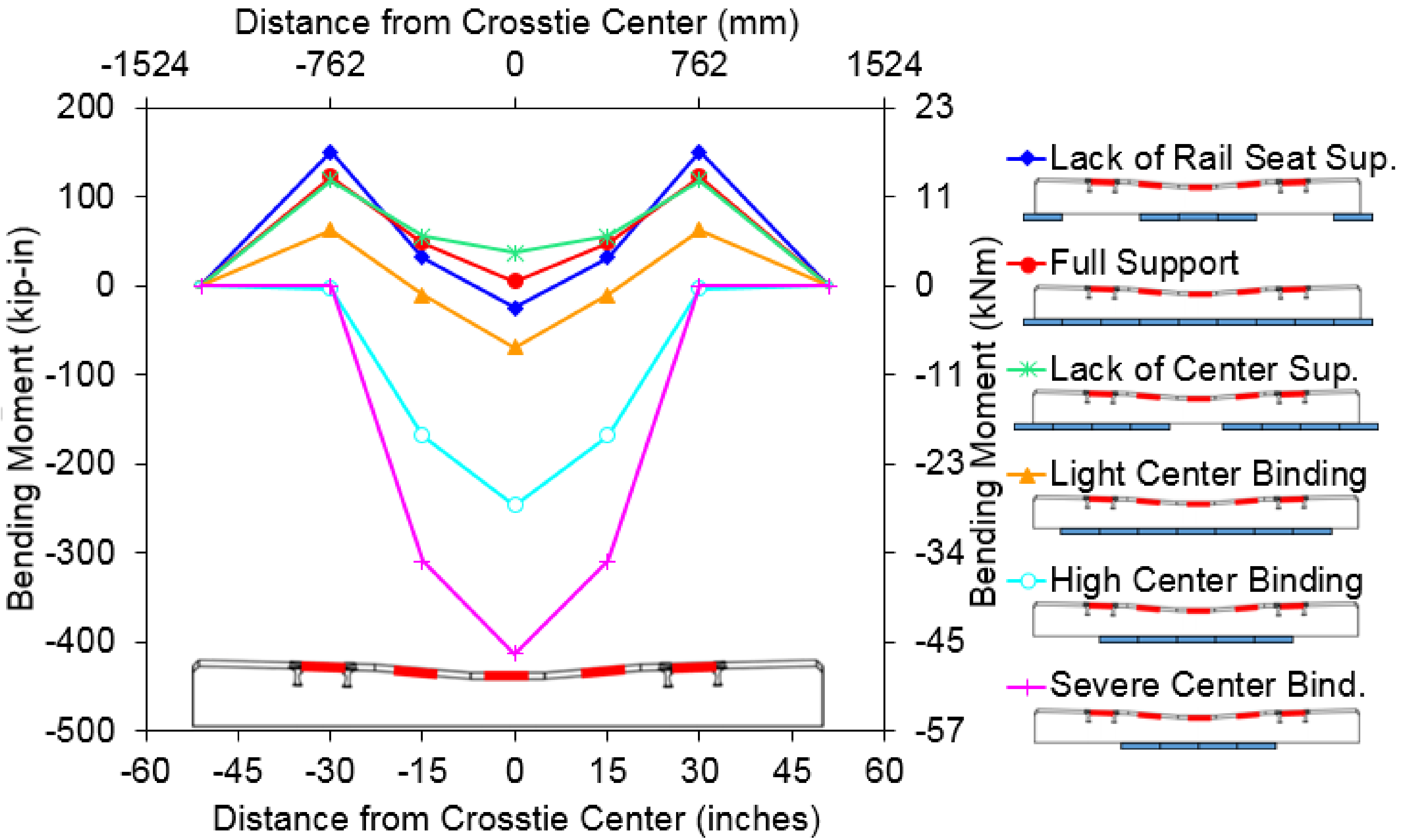


- **Supporting rubber pads**



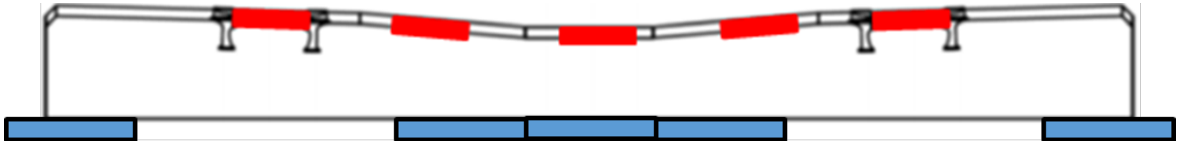
Flexural Performance under Different Support Conditions

Rail Seat Load: 20 kips (89 kN), Healthy Crosstie

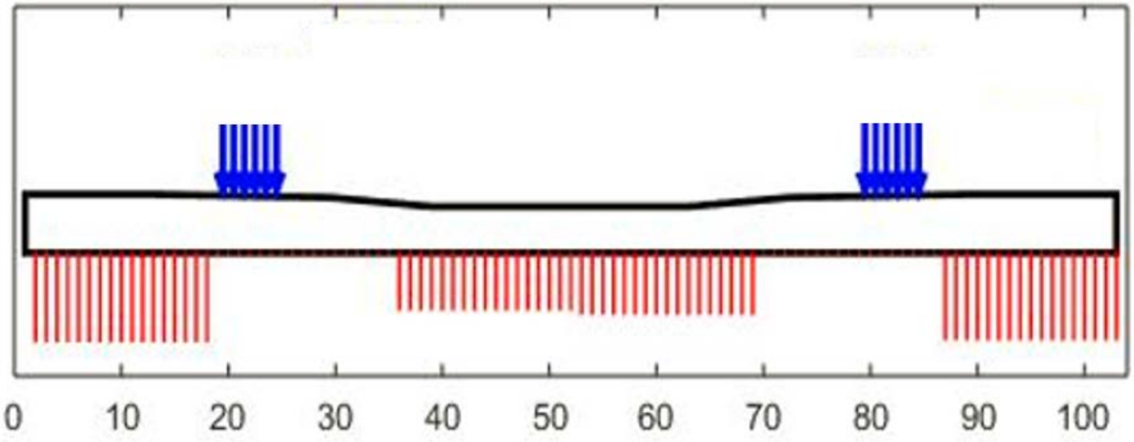


Lack of Rail Seat Support Condition: *Lab Setup and Back-calculator Result*

Lab Setup

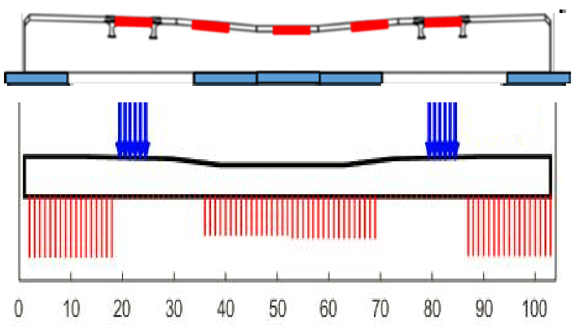


Back-Calculator Result

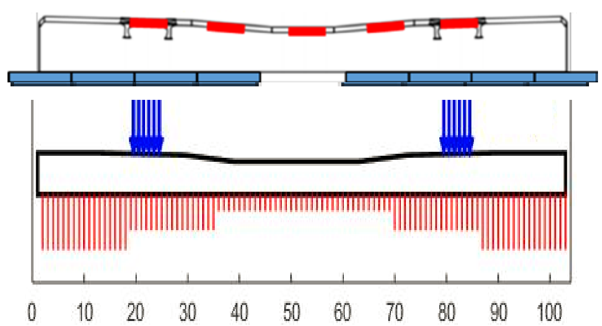


Comparison between Lab Support Conditions and Back-calculator Results

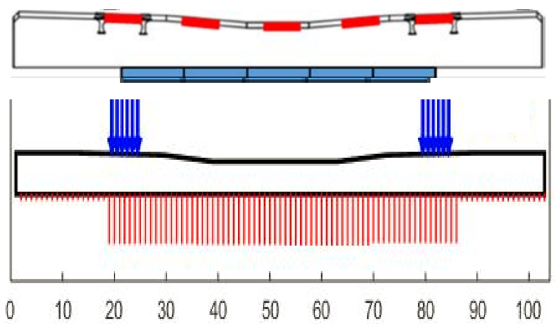
Lack of Rail Seat Sup.



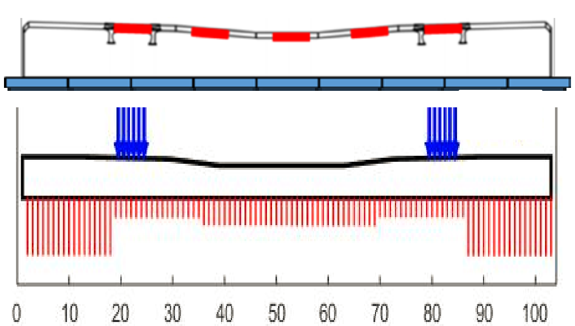
Lack of Center Sup.



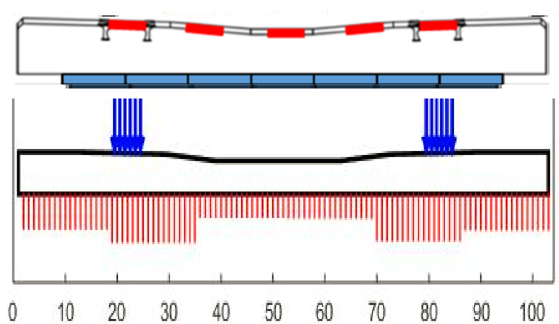
High Center Binding



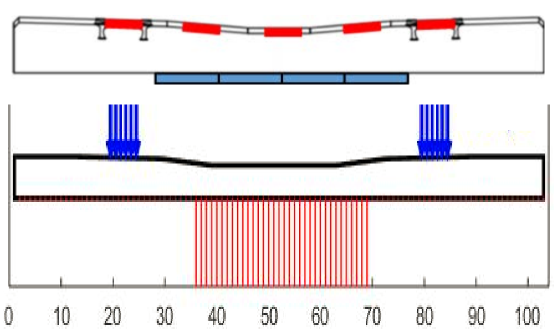
Full Support



Light Center Binding



Severe Center Binding

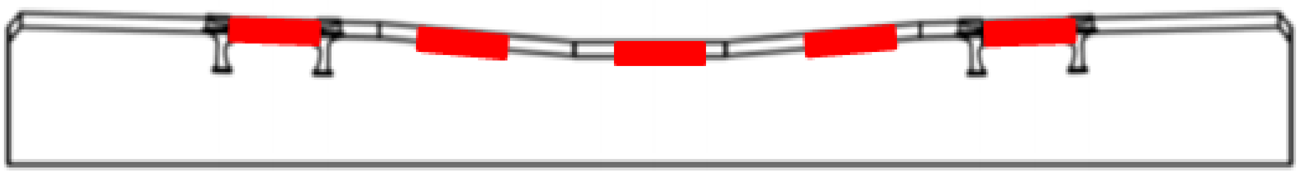


Field Experimentation

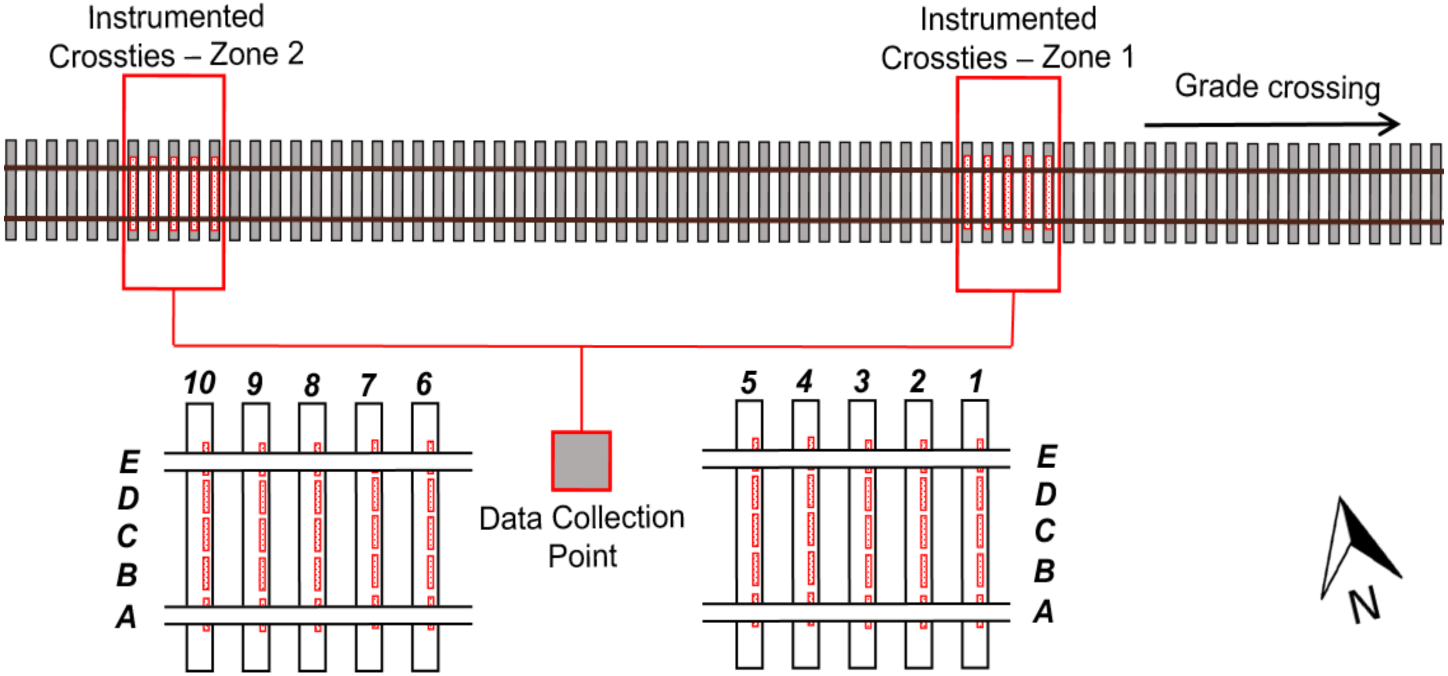
- A Class 1 heavy haul location was selected that had recently experienced multiple cross level deviations in geometry car measurements
  - Tangent track with loaded coal traffic (~220 MGT in 2014)
  - Constructed in 1999 with concrete crossties and elastic fasteners
  - Near Lemoyne, NE (1 hr west of North Platte, NE)

Field instrumentation: *Site Layout*

- 50 surface strain gauges installed on 10 crossties



- Nearby Wheel Impact Load Detector (WILD) sites provide wheel load data



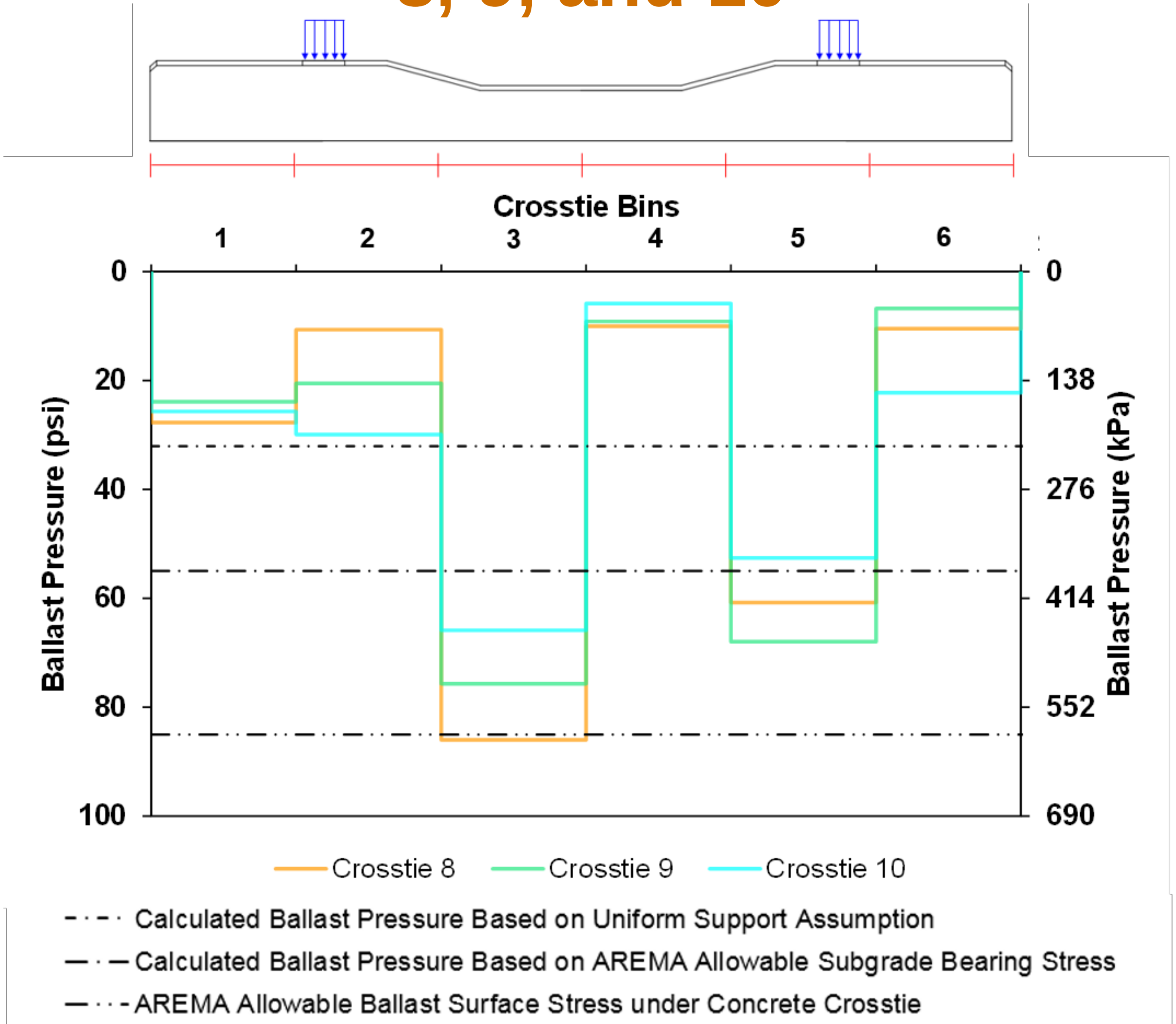
Ballast Pressure Limit States

- Ballast pressure calculated based on uniform support condition: **32 psi**
- AREMA allowable ballast pressure under concrete crossties: **85 psi**
- Ballast pressure calculated based on AREMA allowable subgrade bearing stress (25 psi) using Talbot equation: **55 psi**

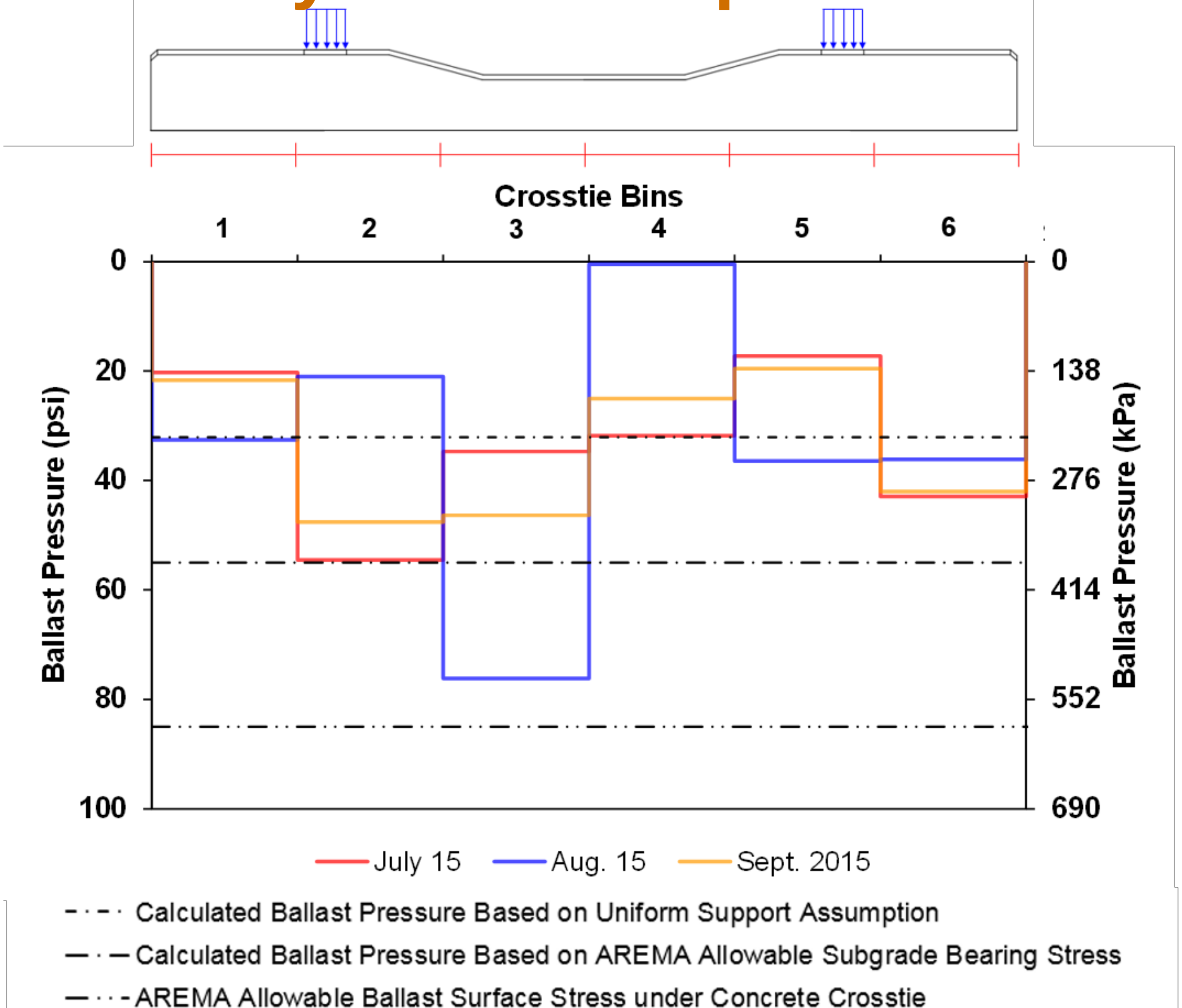
$$h \qquad \frac{p_a}{p_c} \; 4 \;\; 5$$

Where, h = Support ballast depth
p_a = Stress at bottom of tie (top of ballast)
p_c = Allowable subgrade stress

Distribution of Ballast Reaction for Crossties 8, 9, and 10



Distribution of Ballast Reaction for Crosstie 3 from July 2015 to September 2015



Preliminary Conclusions

- Results from back-calculator are comparable to lab experimentation data
- Back-calculator can provide quantitative assessment of ballast support conditions
- Ballast pressures below crossties within the field test site were highly variable
- Allowable subgrade bearing stress and ballast surface stress were exceeded at times, thus indicating the potential for accelerated ballast deterioration

Future Work

- Conduct lab experimentation dedicated to further validation of the back-calculator
  - Use rubber pads with the same width as bins from the crosstie model
- Continue collecting field data to monitor the ballast behavior over time
- Install additional strain gauges along the crosstie to generate results with higher resolution
- Determine feasibility of quantifying support through crosstie displacement

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Any Questions?

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

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

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

Yu Qian
Research Engineer
email: yuqian1@illinois.edu

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