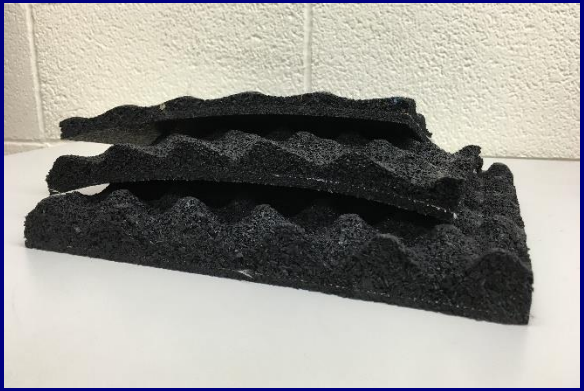
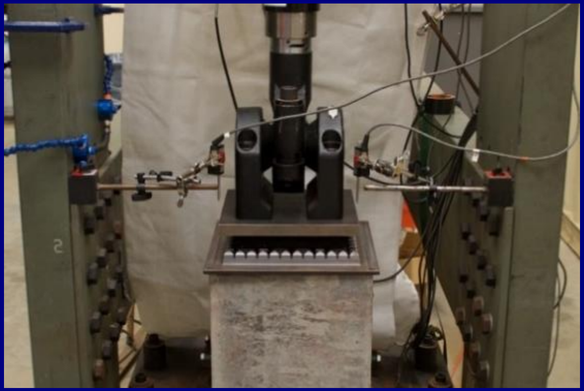
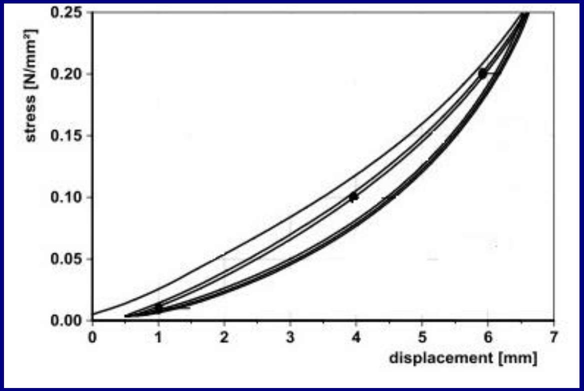
Comparison of Ballast Mat Performance with Different Support Conditions







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RAILTEC
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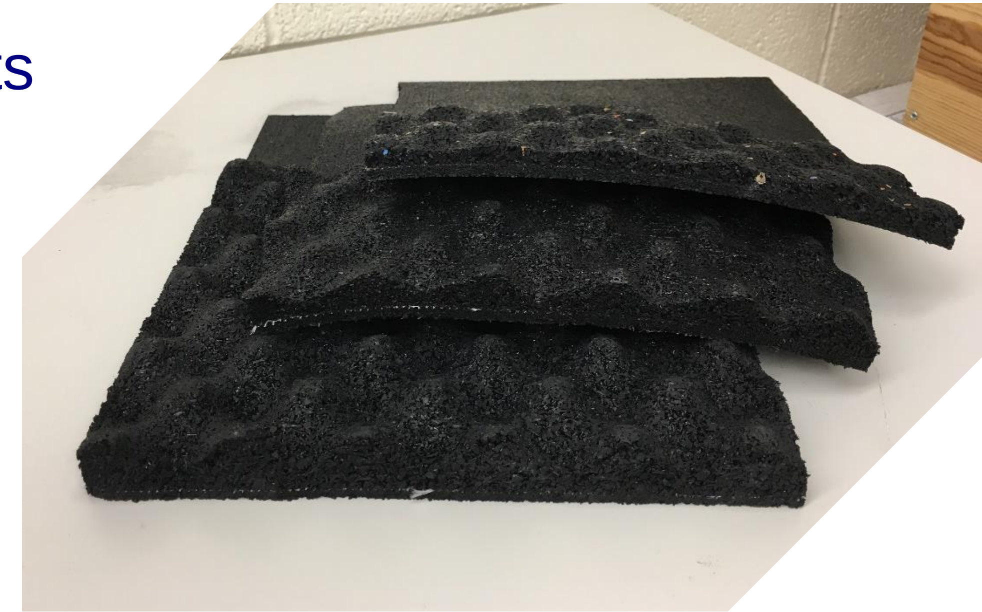
Progress Rail
A Caterpillar Company

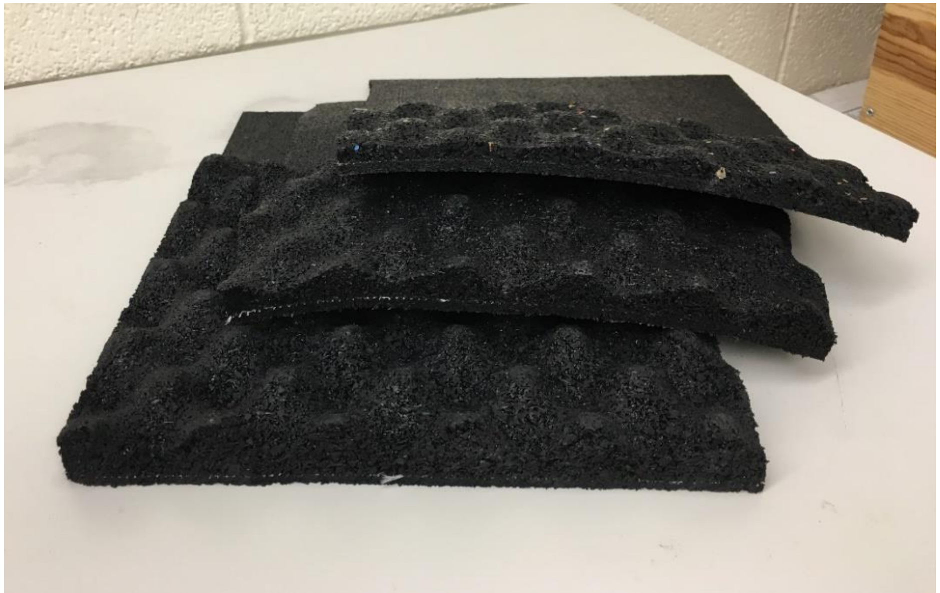
Outline

- Introduction
- Background and Motivation
- Goals for Research
- Laboratory Experiment Program
- Results from Laboratory Tests
- Conclusions
- Future Work



Background and Motivation

- Ballast mats (under-ballast mats) are elastic pads installed under the ballast layer or concrete slab, depending on the type of track structure
- Typically manufactured using natural rubber, recycled tire rubber, or EPDM synthetic rubber



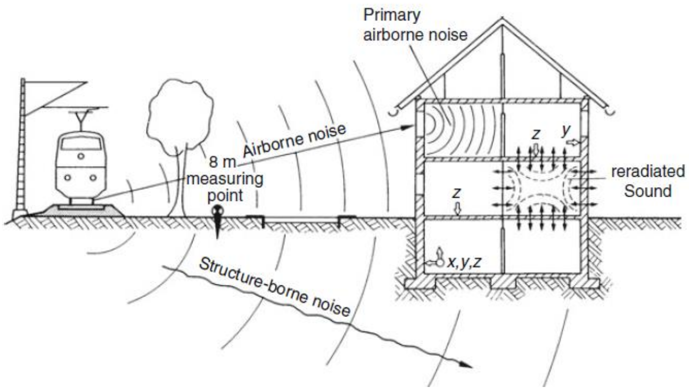
Mademann, C. and D. Otter. 2013. *Effects Of Ballast Depth And Degradation On Stresses In Concrete Bridges*. Transportation Technology Center, Inc.

Background and Motivation

- The study of ballast mats were started in the 1960's by the Japanese Railways for use in the Tokaido Shinkansen line
- European passenger and freight services have also used/studied ballast mats since early 1980's
- North America, Class I railroads have primarily used ballast mats on ballast deck bridges and tunnels with limited research being conducted to date
- Globally, the German DIN 45673-5 is the only standardized testing procedure available for determining component properties of ballast mats
- The growing interest in North America for this component has established a demand for the development of uniform and representative testing procedures

Goals for Research

- Major benefits from the use of ballast mats are dependent on its application environment:
  - **Transit: reduction of ground-borne noise and vibrations**
  - Freight: reduction of ballast degradation and track stiffness in transition zones
- The main objectives of this research are to:
  - Quantify ballast mat properties
  - Quantify ballast mat benefits
  - Study the effect of test variables (support, loading, etc.)

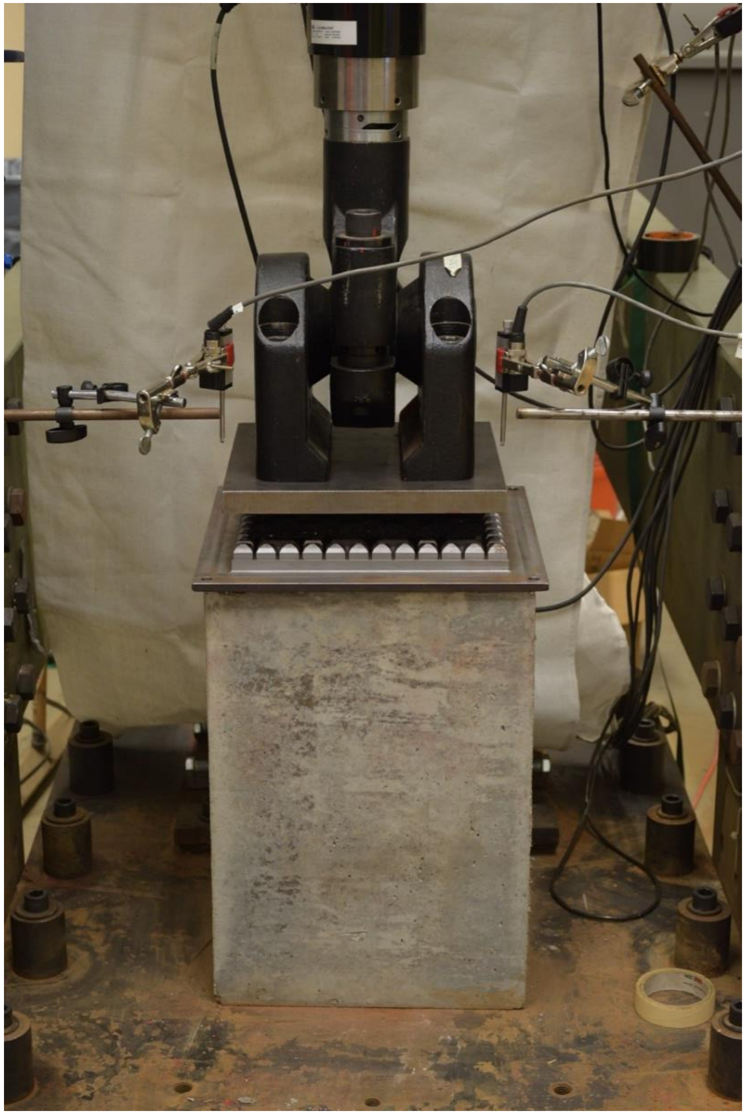


Müller, G. & M. Möser (Eds.). 2013. *Handbook Of Engineering Acoustics*. Springer Berlin Heidelberg, Berlin, Heidelberg.

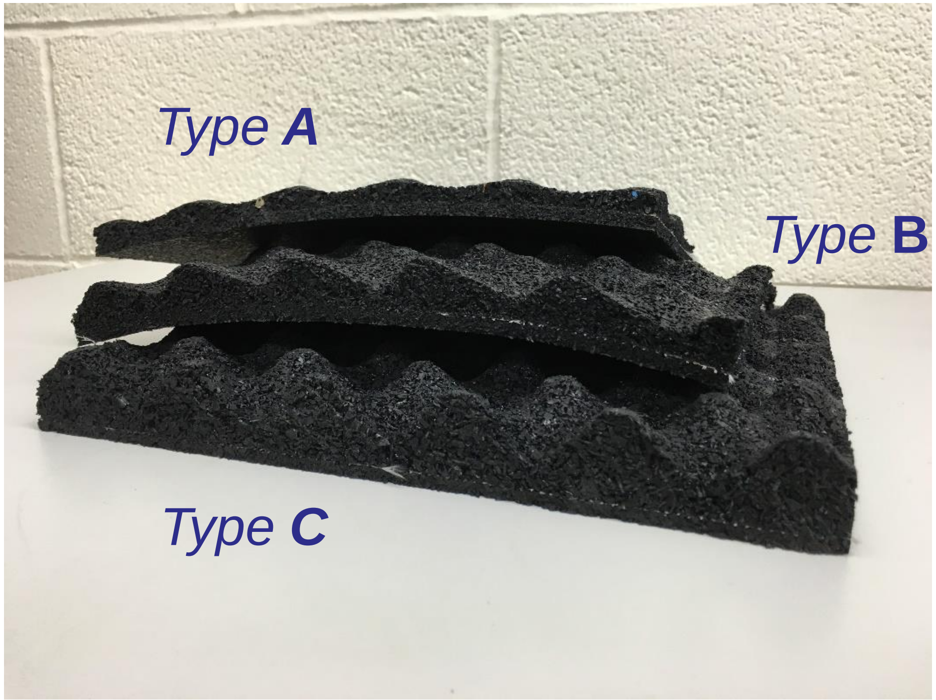
Mademann, C. and D. Otter. 2013. *Effects Of Ballast Depth And Degradation On Stresses In Concrete Bridges*. Transportation Technology Center, Inc.

Laboratory Experiment Program

- **Objective:** To determine component properties of ballast mats in controlled laboratory setting using **various support conditions**
- **Instrumentation:** Potentiometers deployed to capture vertical ballast mat displacement at multiple locations
- **Loading:** servo hydraulic actuator used to apply vertical load to ballast mat



Ballast Mat Sample Types



- Ballast mat samples
  - Size : 10” x 10” (254 x 254 mm)
  - Thickness (Min / Max)
    - Type A:
      - 0.197” / 0.394” (5/10 mm)
    - Type B:
      - 0.315” / 0.670” (8/17 mm)
    - Type C:
      - 0.275” / 0.984” (7/25 mm)

Support Conditions

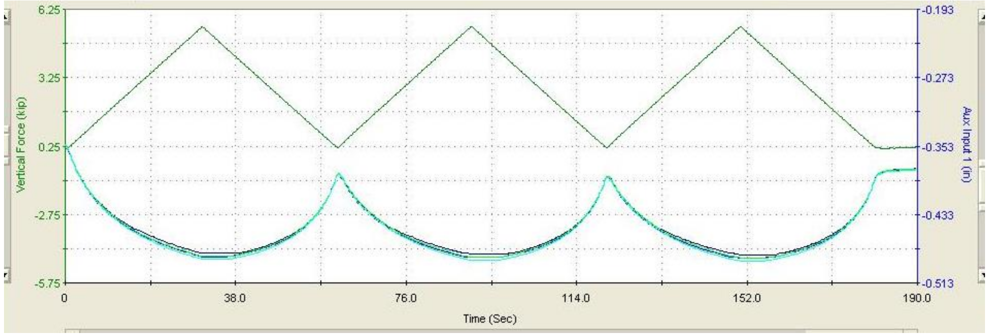
- **Geometric Ballast Plate (GBP)**
  - Standardized European apparatus (EN 16730:2016)
  - 12” x 12” (300 x 300 mm) aluminum profiled plate that simulates ballast profile
- **Concrete**
  - 14” x 14” (356 x 356 mm) Concrete block
- **Steel**
  - 12” x 12” (305 x 305 mm) Steel plate placed over concrete block

Important Definitions

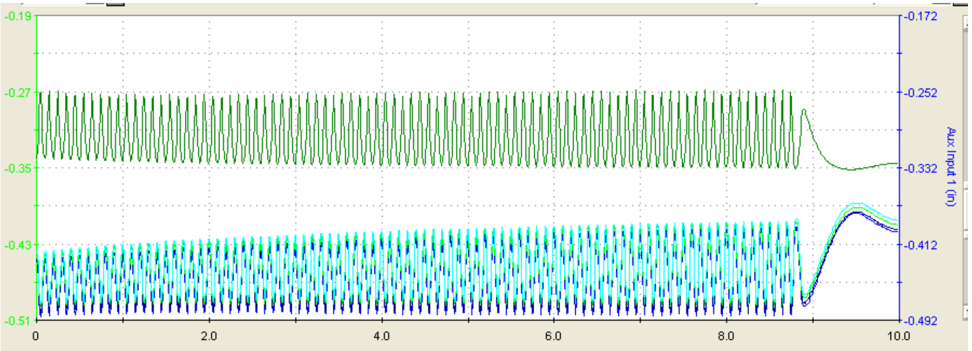
- **Bedding Modulus:**
  - The amount of force required to cause unit deflection in a unit area sample (lbs/in^3 or N/mm^3)
    - Static
    - Dynamic
- **Insertion Loss:**
  - Ratio of signal levels (vibration amplitudes) before and after the installation of a filter (i.e. ballast mat)
    - $\Delta L = 20 log\left(\frac{V_1}{V_2}\right)$

Bedding Modulus Test Protocol

- Procedure heavily based on German standard DIN 45673 – Part 5
- **Static Tests:**
  - Quasi-static
  - Load
    - 0.2 - 3.8 kips (0.9 – 16.9 kN)
    - 3 cycles
- **Dynamic Tests:**
  - Frequencies: 5 Hz and 10 Hz
  - Loading
    - 0.4 - 3.8 kips (1.8 – 16.9 kN)
  - 10 sec. of sinusoidal loading
  - Data collected for last 10 cycles

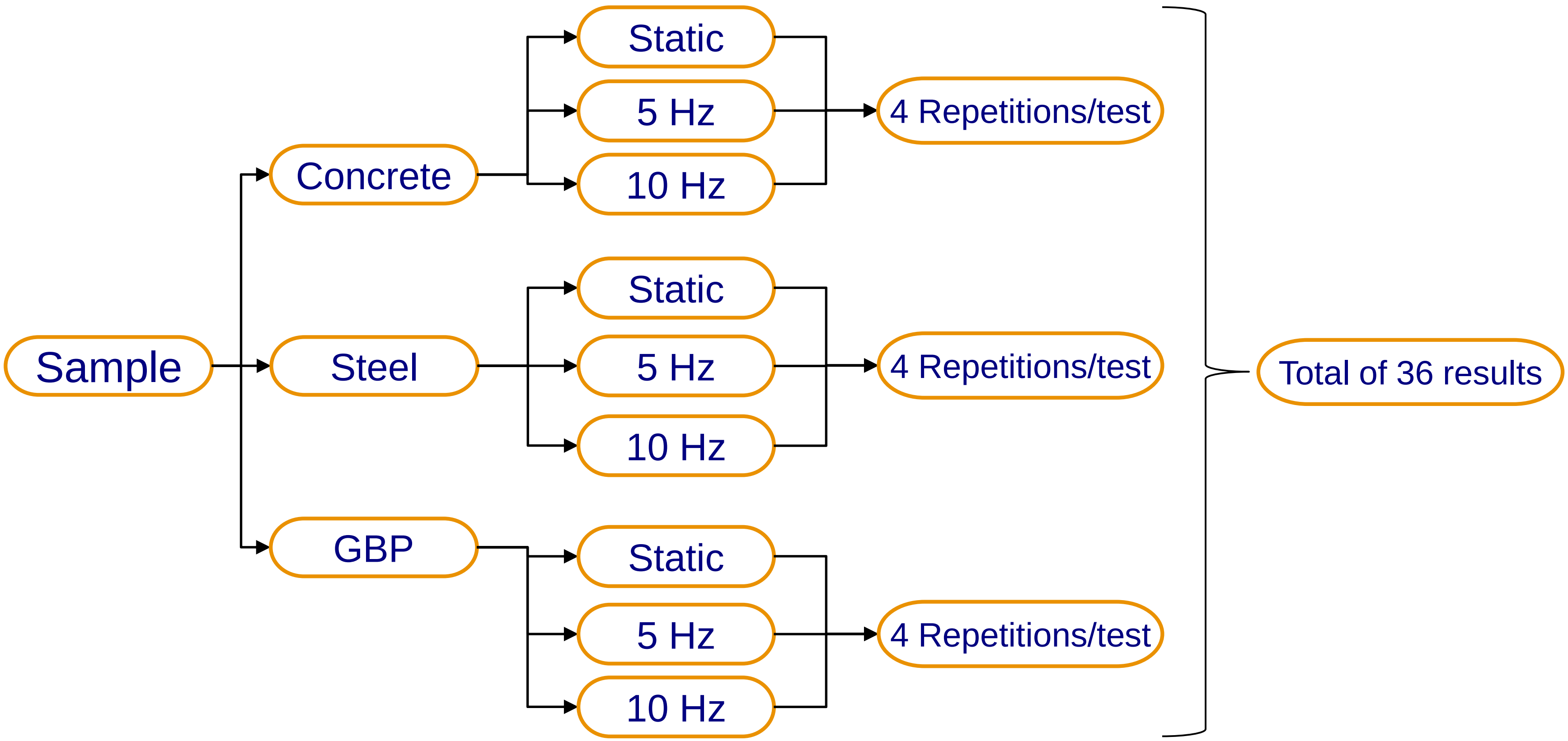


Static loading waveform (triangular) with associated displacement



Dynamic 10 Hz loading waveform with associated displacement

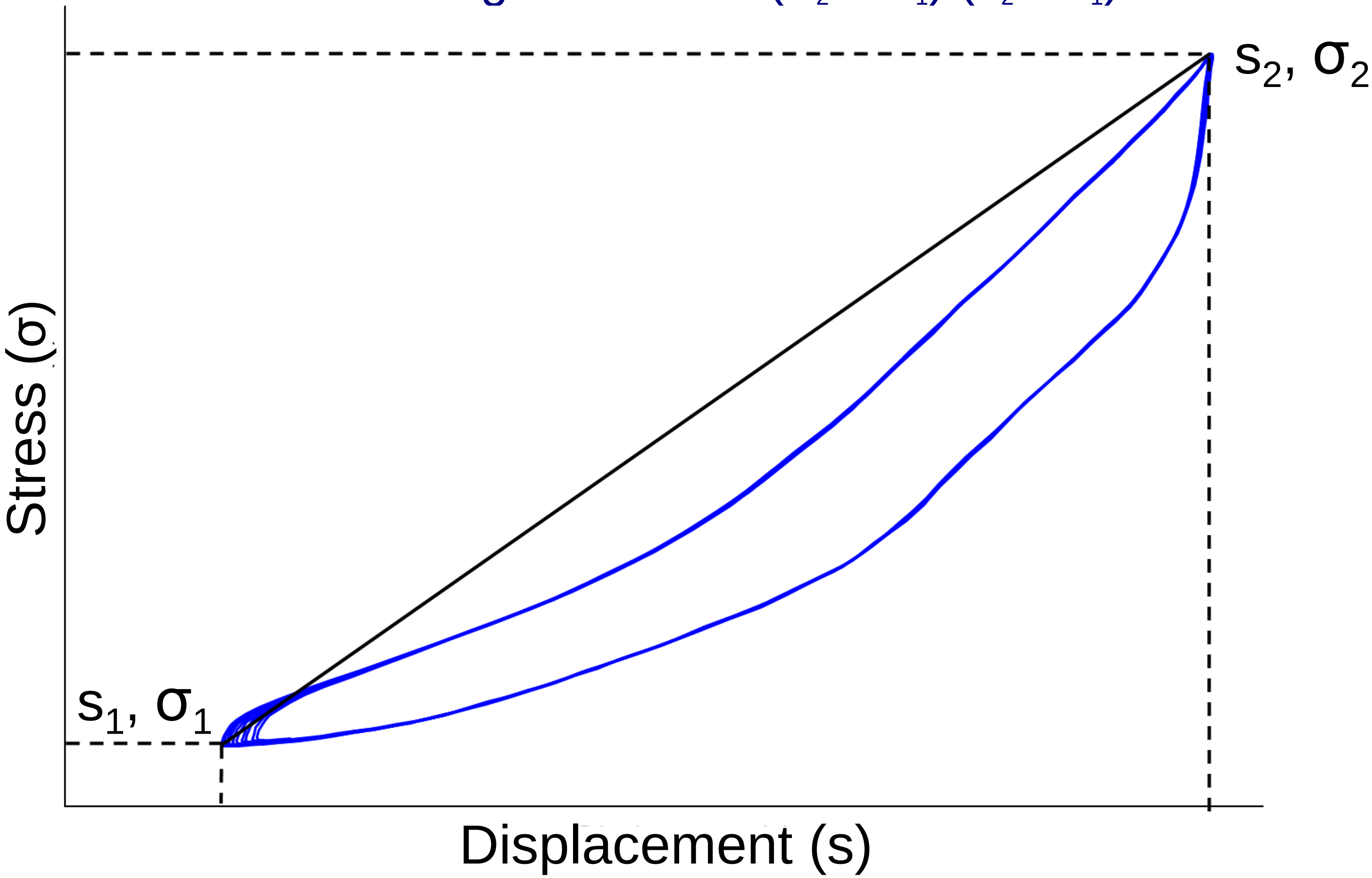
Laboratory Experimental Matrix



Results from Laboratory Tests
Bedding Modulus

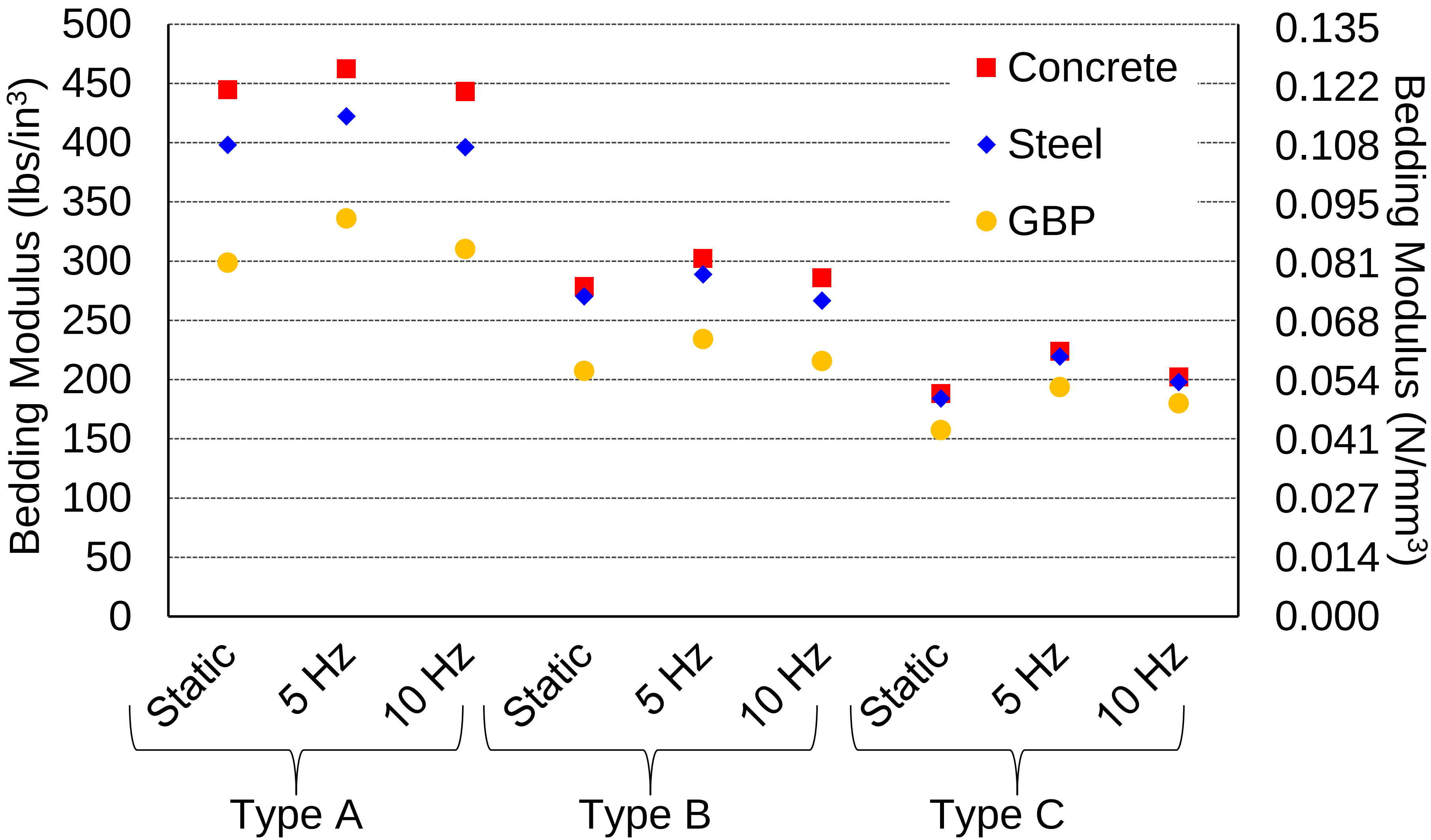
- Static and dynamic bedding modulus calculated using **secant modulus**

Secant Bedding Modulus = $(\sigma_2 - \sigma_1)/(s_2 - s_1)$



Results from Laboratory Tests

Summary of Bedding Modulus Tests



Results from Laboratory Tests

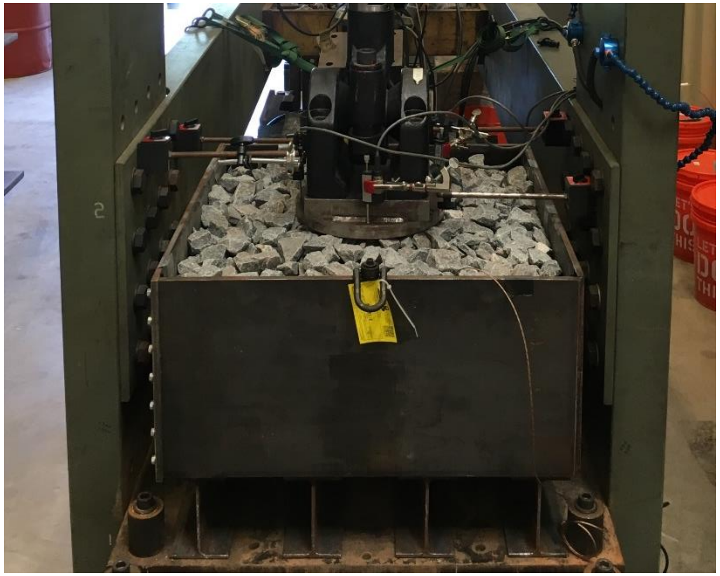
- Consistency of testing was supported by a maximum 4.0% deviation from the mean for a single test procedure
- Results obtained using the GBP were 30% and 21% lower than their corresponding tests conducted with concrete and steel support respectively
- Bedding modulus values obtained with concrete support as a support were highest for all cases
- Effects of different test frequencies could not be investigated due to uncertainties with the results obtained for higher frequencies (i.e. 10 Hz)

Conclusions

- The bedding moduli of a ballast mat is dependent on the support condition with which it is tested
  - GBP typically resulted in lowest values
  - Steel and Concrete yielded similar values
- The statistical analysis of the results corroborated the visual analysis of the results as to the difference between the bedding modulus values obtained from each support condition
- Sensitivity analysis provided a better understanding of the importance of standardizing the support condition used to obtain the dynamic bedding modulus values to be input in the prediction models
  - Maximum insertion loss difference between all support conditions of:
    - 3.0 dB for Type A
    - 2.4 dB for Type B
    - 1.2 dB for Type C

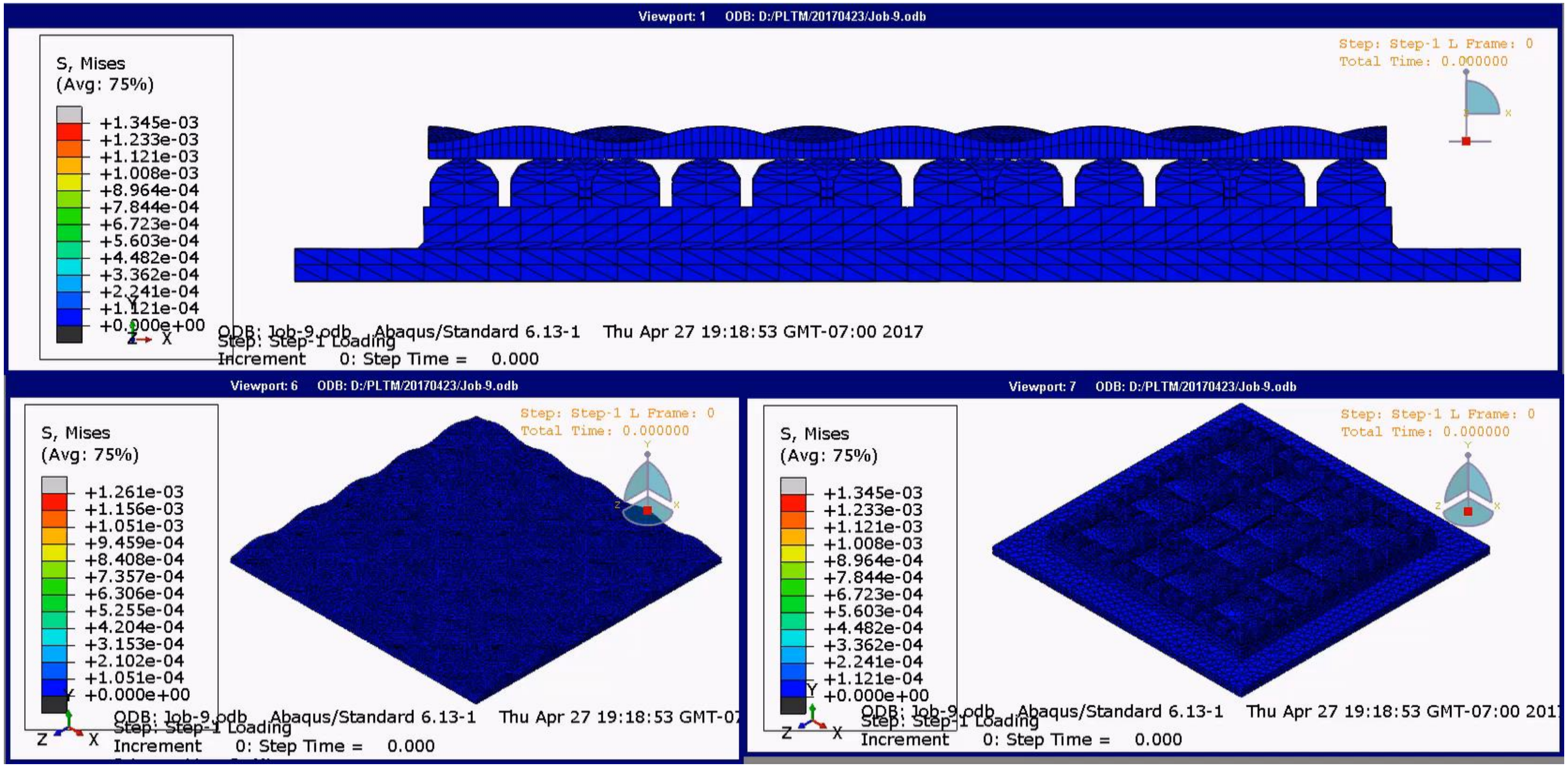
Future Work

- Mechanical fatigue strength tests
  - Ensure survivability
    - Comparison of bedding modulus before and after repeated load cycles
  - Quantify effect on ballast deterioration
    - Gradation
    - Ballast surface characteristics
    - Ballast geometry
  - Quantifying ballast mat's effects to the vertical transient deformations of a ballast structure over a rigid support
- Investigation into the impacts and viability of using the GBP setup as a substitute for the ballast box mechanical fatigue testing of ballast mats



Future Work

- Numerical Simulation
  - Calibrate simulation parameters based on laboratory tests
  - Predict ballast performance under different scenarios
    - Loading frequency / Loading magnitude / Different structures



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Thank You

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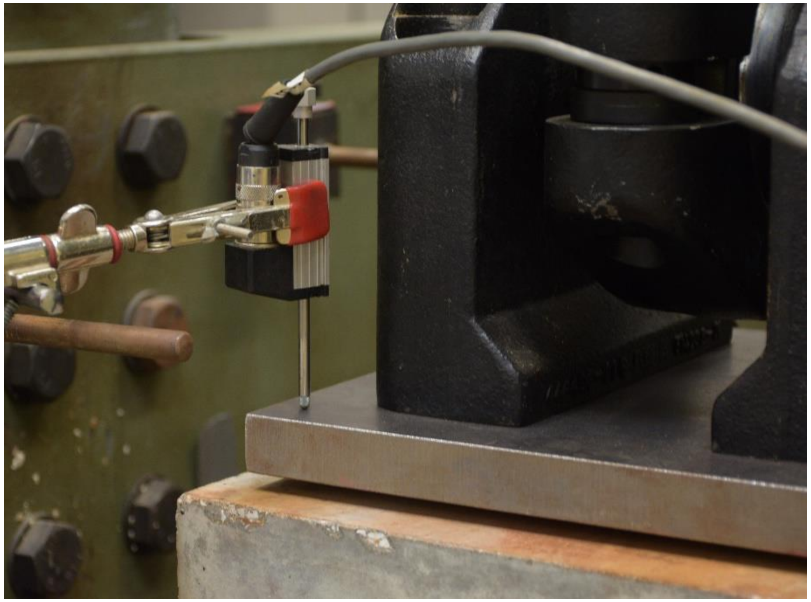

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