Quantification of Ballast Deterioration Performance With and Without Ballast Mats - A Laboratory Study

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Progress Rail
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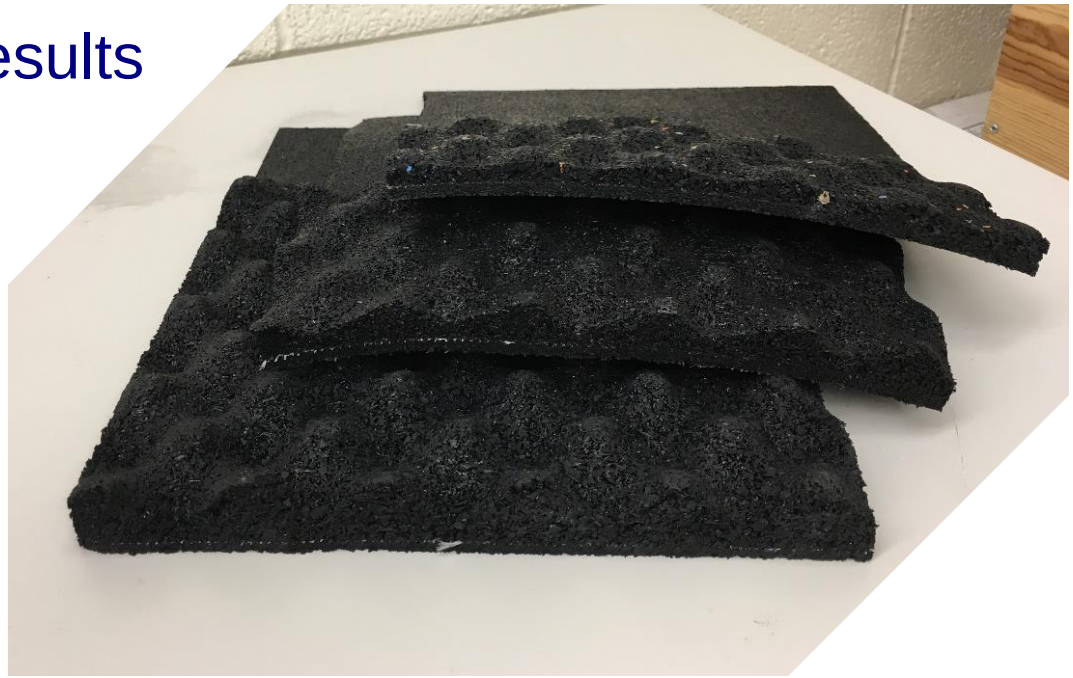
Outline

- Introduction
- Motivation and Goals for Research
- Laboratory Experimental Program
- Ballast Deterioration Results
- Conclusions
- Future Work

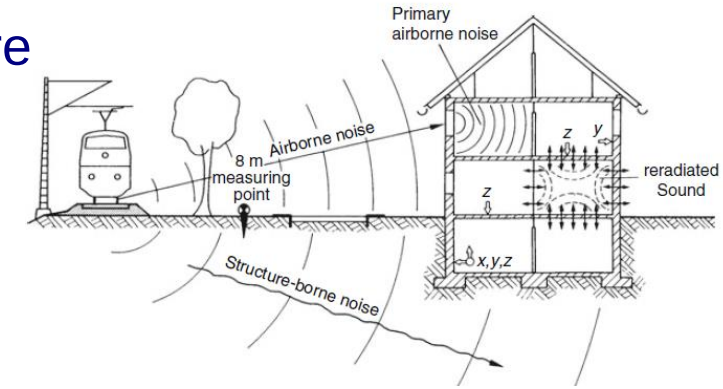


Introduction

- Ballast mats (or under-ballast mats) are elastic pads installed under the ballast layer or concrete slab, depending on the type of track structure
- The component is typically manufactured using natural rubber, recycled tire rubber, or polyurethane foam
- The study of ballast mats was initiated in the 1960's by the Japanese Railways for use in the Tokaido Shinkansen line
- European passenger and freight railways have also employed/studied ballast mats since early 1980's
- In the last decades in North America, Class I railroads have primarily utilized ballast mats on ballast deck bridges and tunnels, but limited research has been conducted to date

Motivation and Goals for Research

- Major benefits from the use of ballast mats are dependent on its application environment:
  - Transit: reduction of ground-borne vibrations
  - Freight/Passenger: reduction of ballast degradation and track stiffness in bridges
- 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.)
  - Develop tools to predict track behavior



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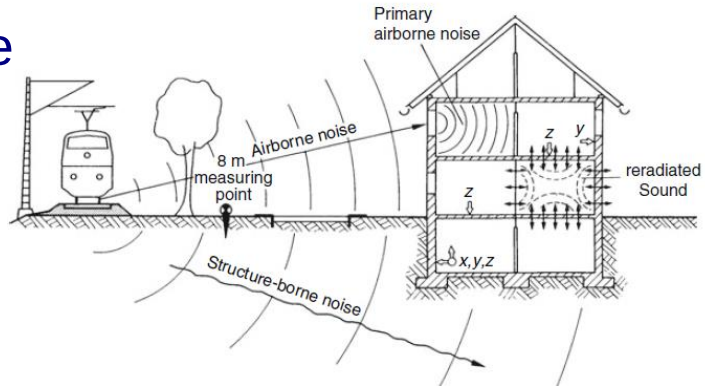

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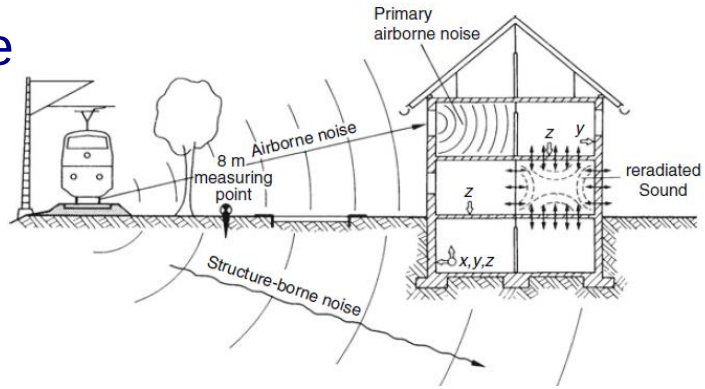

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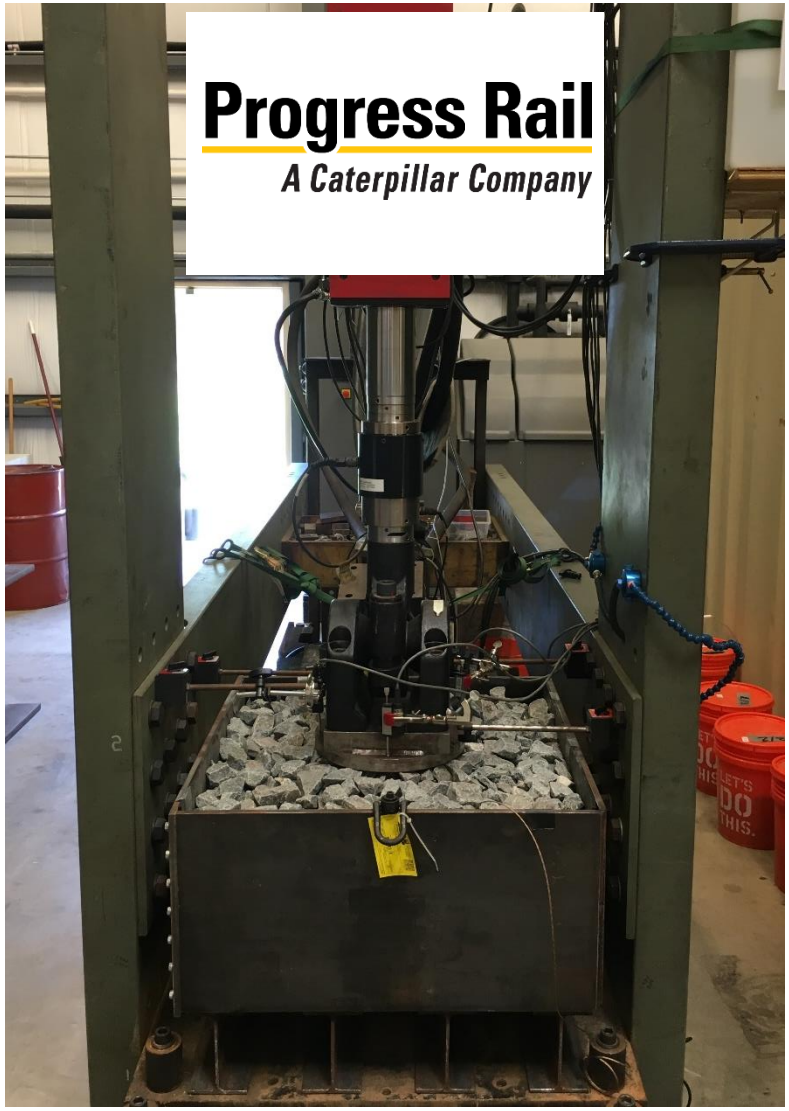
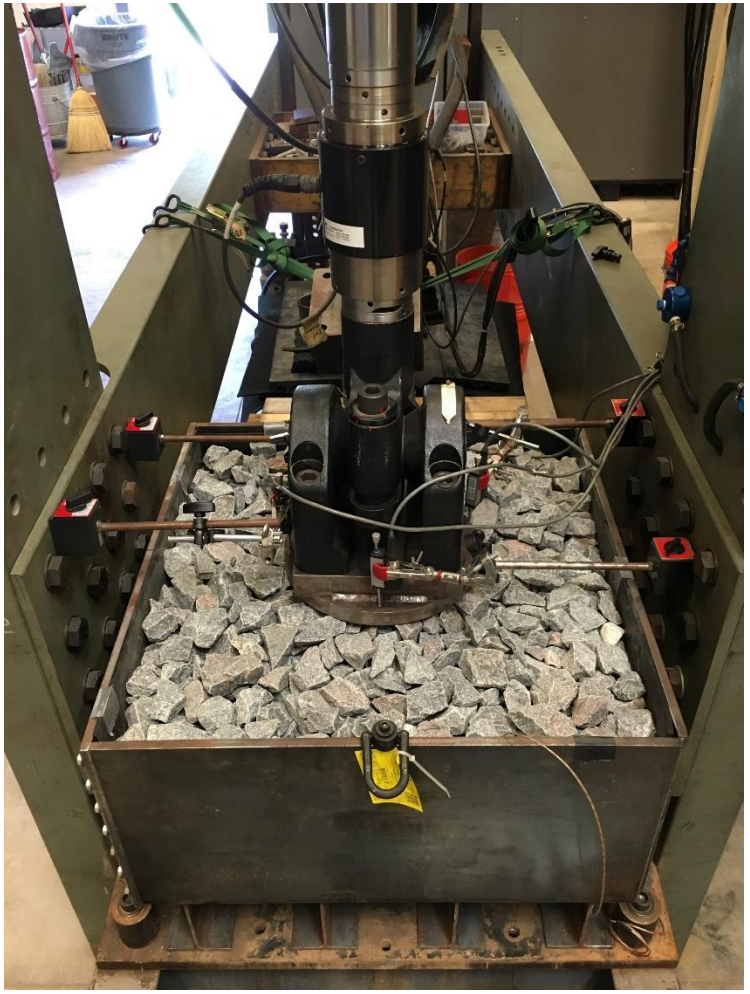
Laboratory Experimental Program

- **Objective:** Quantifying ballast mat's effects to the degradation of ballast material in a controlled laboratory settings
- **Location:** Research and Innovation Laboratory (RAIL) at Schnabel, UIUC
  - Pulsating Load Testing Machine (PLTM): Biaxial loading frame owned by Progress Rail
- **Instrumentation:** Potentiometers deployed to capture vertical displacement at multiple locations
- **Loading:** Servo hydraulic actuator used to apply vertical load



Test Apparatus

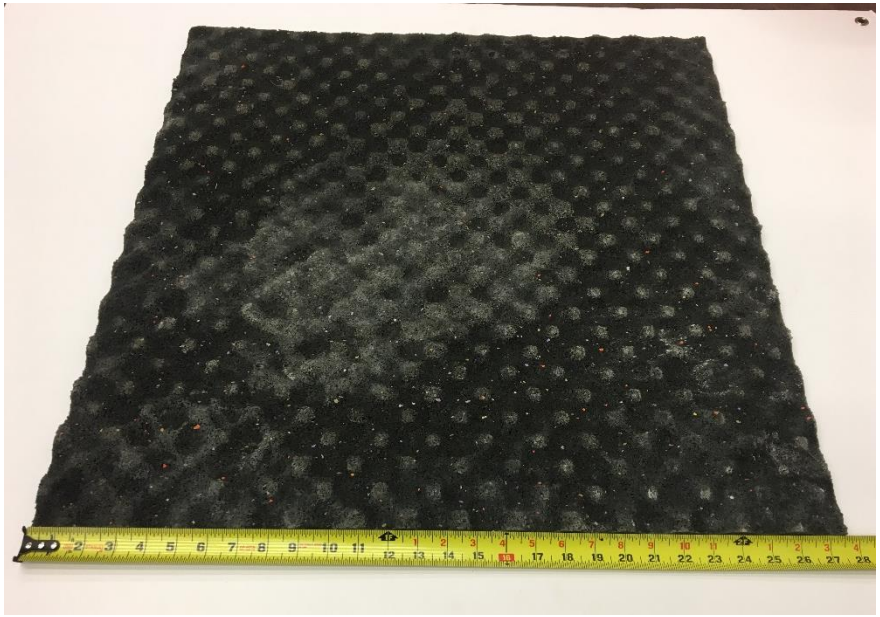
- **Ballast box:**
  - Adapted design from German DIN 45673 – Part 5 standard for testing of mechanical fatigue performance of ballast mats
  - Standard 12” ballast layer

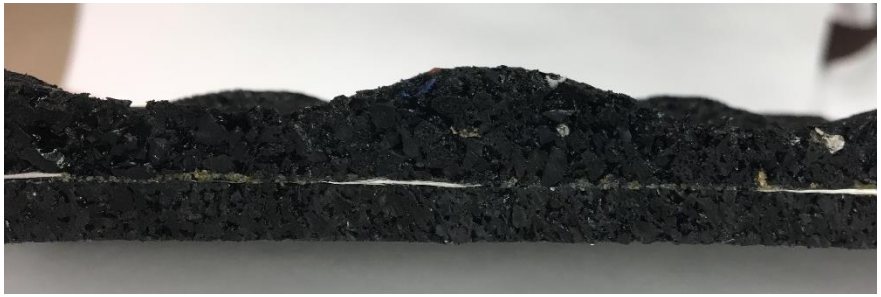


Test Setups

- **Ballast Box Constructions:**
  - With Ballast Mat
  - Without Ballast Mat

Ballast Mat Sample Characteristics





- Ballast mat sample
  - Type 4
  - Size: 27.5” x 27.5”
  - Construction
    - Profiled mat bonded to flat protective layer
  - Mat Thickness (Min. / Max.)
    - 0.197” / 0.394”

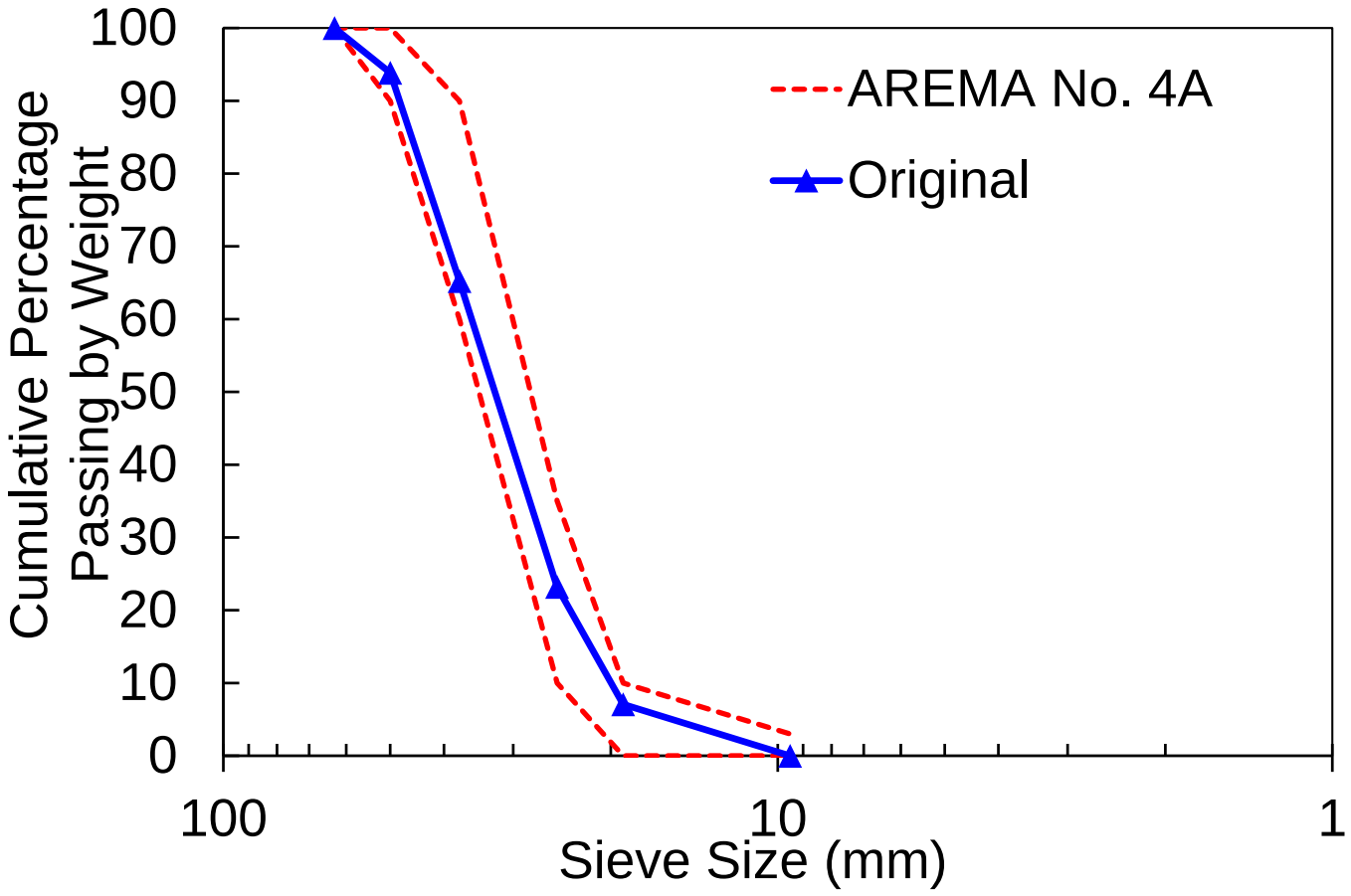
Ballast Gradation

- Washed gradation was obtained prior to testing
  - Ballast was found to be consistent with AREMA Size No. 4A gradation
  - Content passing the $\frac{3}{8}$" size sieve was considered as fines

Size No. (See Note 1)	Nominal Size Square Opening	Percent Passing									
		3"	2½"	2"	1½"	1"	¾"	½"	d"	No.4	No. 8
24	2½" - ¾"	100	90-100		25-60		0-10	0-5	–	–	–
25	2½" - d"	100	80-100	60-85	50-70	25-50	–	5-20	0-10	0-3	–
3	2" - 1"	–	100	95-100	35-70	0-15	–	0-5	–	–	–
4A	2" - ¾"	–	100	90-100	60-90	10-35	0-10	–	0-3	–	–
4	1½" - ¾"	–	–	100	90-100	20-55	0-15	–	0-5	–	–
5	1" - d"	–	–	–	100	90-100	40-75	15-35	0-15	0-5	–
57	1" - No. 4	–	–	–	100	95-100	–	25-60	–	0-10	0-5
Note 1: Gradation Numbers 24, 25, 3, 4A and 4 are main line ballast materials. Gradation Numbers 5 and 57 are yard ballast materials.											

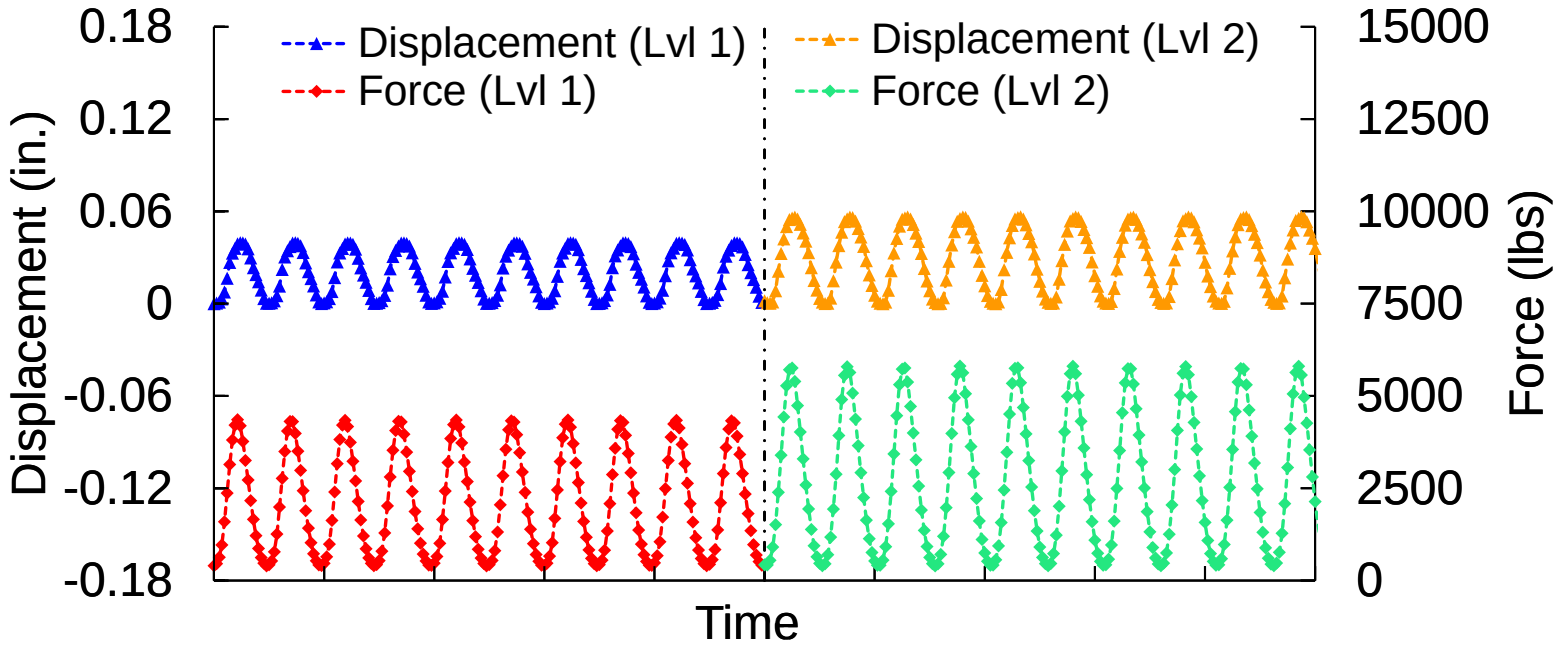
AREMA Recommended Ballast Gradations

Original Ballast Gradation



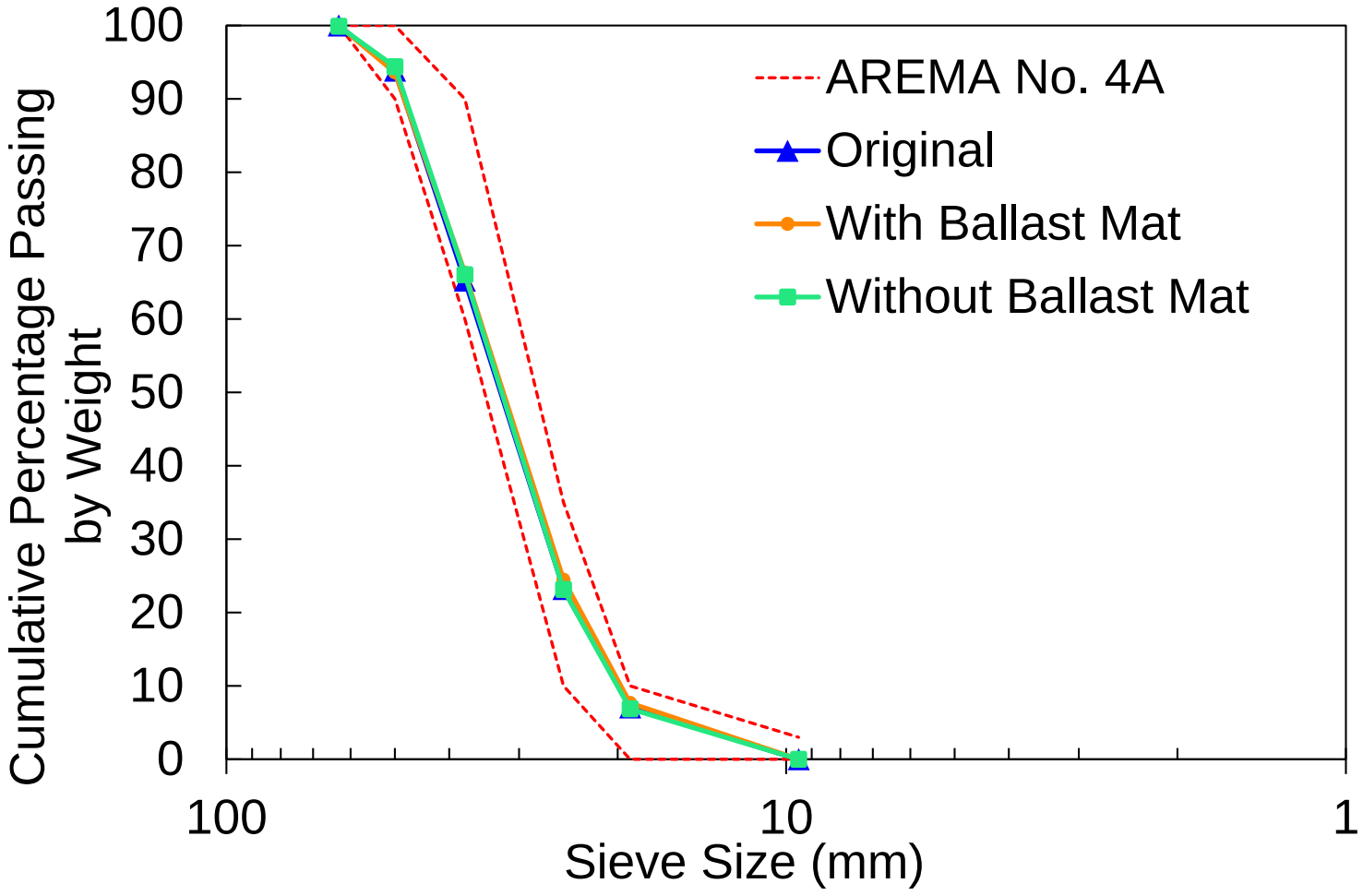
Testing Protocols

- Cyclic sinusoidal loading at 5 Hz
  - Load Level 1 (0.4 - 4.4 kips)
    - 10 Million Cycles
  - Load Level 2 (0.4 - 5.8 kips)
    - 2.5 Million Cycles



- Ballast characteristics obtained before and after complete testing

Final Ballast Gradations



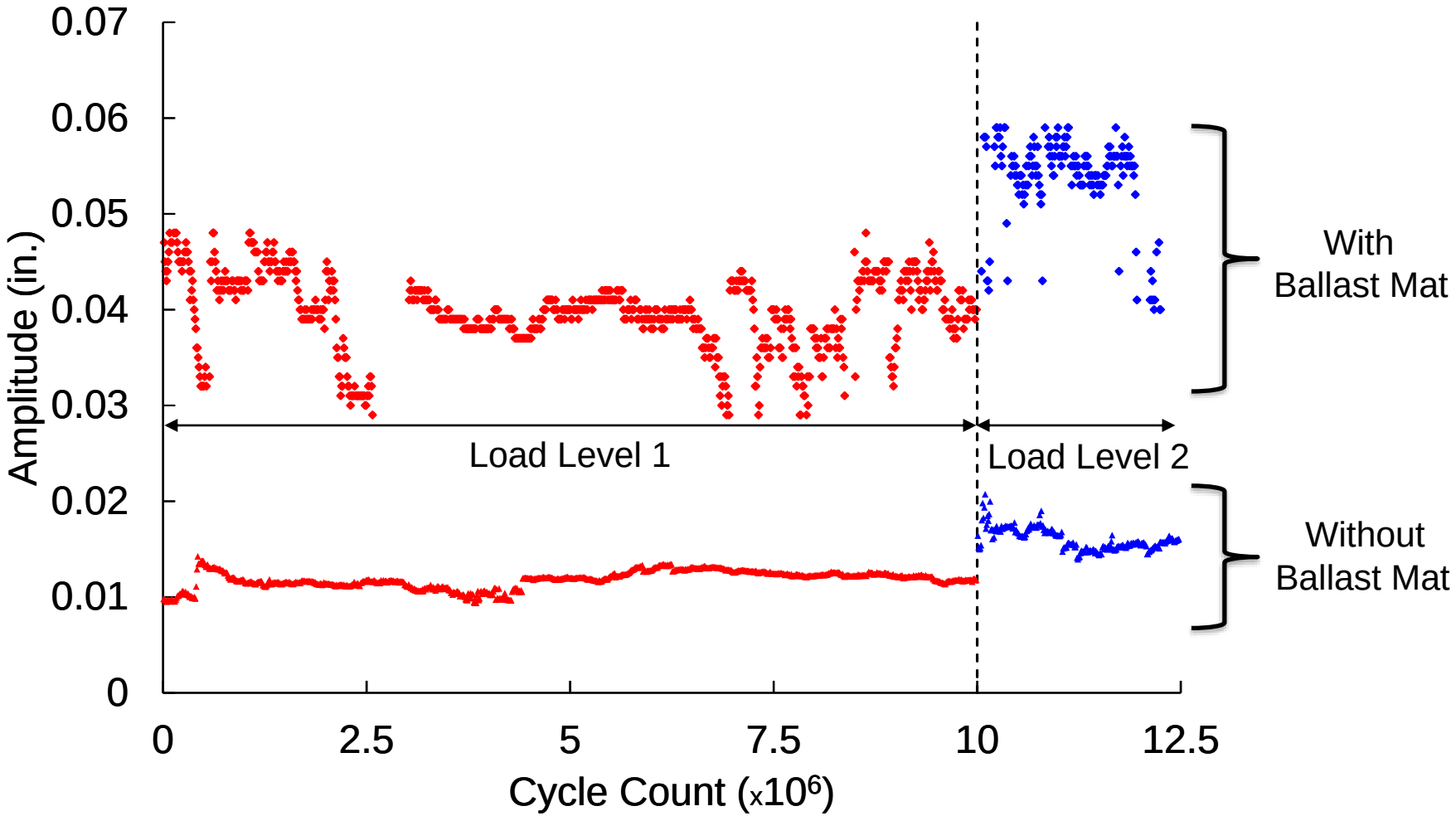
Material Weight Retained by Size

Sieve Size [in]	Original	With Ballast Mat	%Δ	Without Ballast Mat	%Δ
2.5	0.0	0.0	*0.0*	0.1	*0.1*
2	6.1	6.4	*0.3*	5.6	*-0.5*
1.5	28.6	27.3	*-1.3*	28.4	*-0.3*
1	42.0	41.8	*-0.2*	42.9	*0.9*
0.75	16.1	16.8	*0.7*	16.2	*0.1*
0.375	7.1	7.7	*0.6*	6.9	*-0.2*

Note: All values in % retained by weight

- No particle breakage could be observed

System Vertical Transient Deformation



Conclusions

- Ballast gradation results shown small changes in particle size distribution
  - Slight shifts in the gradation demonstrated by increase in retained material weight in smaller sieves
- Attrition is seen as the sole mechanism of ballast degradation for this experiment
  - This phenomenon results from the relative movement between particles occasioning in frictional wear of particle surface characteristics

Conclusions

- Important field degradation mechanism of particle breakage could not be observed in either test case
  - Changes to testing procedures are to be considered in order to more realistically simulated field degradation conditions
  - This would provide better insights into the effects of ballast mats to the protection of ballast installed over rigid structures

Future Work

- Considering evaluating additional metrics of ballast degradation
  - Loss of material
  - Surface Texture
  - Angularity
  - Shape
- Explore changes in test procedures
  - Increase load
  - Modification of loading waveform

Future Work

- Further investigate the effects of ballast mats to the vertical transient deformations of a ballast structure over a rigid support
  - This is important when assessing its effectiveness in mitigating transition zone problems
- Conduct similar experimental matrix on two other ballast mat sample types intended for transit applications

Acknowledgements

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Thank You
Questions?

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