Concrete Material Improvements to Mitigate the Adverse Effects of Abrasion Mechanism in Rail Seat Deterioration (RSD)

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Amogh A. Shurpali, Emily J. Van Dam, Ryan Kernes, Sujing Zhao,
J. Riley Edwards, and David A. Lange

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Objectives
- Proposed Improvements to the AREMA Manual
- Small-Scale Test for Abrasion Resistance (SSTAR)
- Abrasion Mitigation Approaches
- Experimental Results
- Conclusions
- Ongoing and Future Research

RSD Research Objectives

- Propose methods for mitigating critical failure modes (abrasion mechanism of RSD) in concrete ties
  - Quantify abrasion resistance of various concrete mix designs, curing conditions, and surface treatments
- Evaluate ability of high performance concrete mix designs to increase crosstie durability

Rail Seat Abrasion
AREMA Chapter 30 - Section 4.1.6

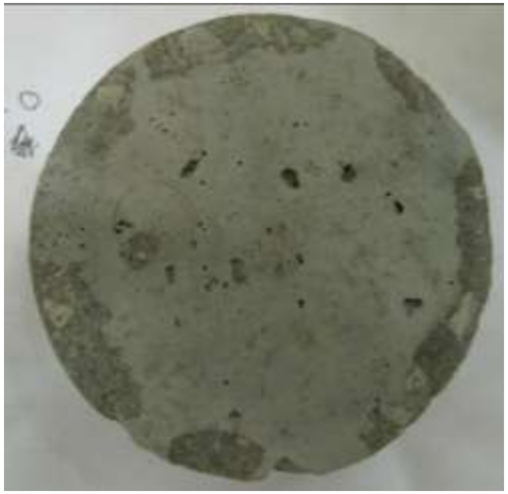
- **Existing Content**
  - Several approaches for mitigating RSD are listed, including steel augmented rail seat and metallic aggregate topping
- **Proposed Improvements**
  - Further investigate the effects of metallic aggregates on RSD and rail pad wear
  - Include other RSD prevention approaches such as surface coatings
  - Better define mitigation techniques and explain uses
  - Further discussion on benefits of using mineral admixtures
- **Methodology**
  - Small-Scale Test for Abrasion Resistance (SSTAR)
  - Continued mechanistic study using intermediate-scale test setup at UIUC
  - Comprehensive testing regime on a variety of mix designs using mineral admixtures
- **Timeline**
  - Present ballot proposal to AREMA Subcommittee 4 (C-30 Spring 2013)

Small-Scale Test for Abrasion Resistance (SSTAR): Test Setup

- In general, similar to other international industry standard abrasion tests
- Consists of a powered rotating steel wheel with 3 lapping rings
  - Lapping rings permitted to rotate about their own axis
  - Vertical load applied using the dead weights (4.5 pounds)
  - Abrasive sand and water dispensed during testing

SSTAR: Test Protocol and Example Specimens

- Three specimens tested in each repetition (2-3 repetitions)
- Test duration - 100 minutes
- Data collection frequency
  - Every 5 minutes for the first 45 test minutes
  - Every 20 minutes for the remainder of the test
- Revolution rate - 60 RPM
- Discharge rates
  - Water: 150 milliliters/minute
  - Sand: 40 milliliters/minute
- Abrasive material used - Ottawa 20-30 sand



Before

After

4 inch x 1 inch

Abrasion Mitigation Approaches

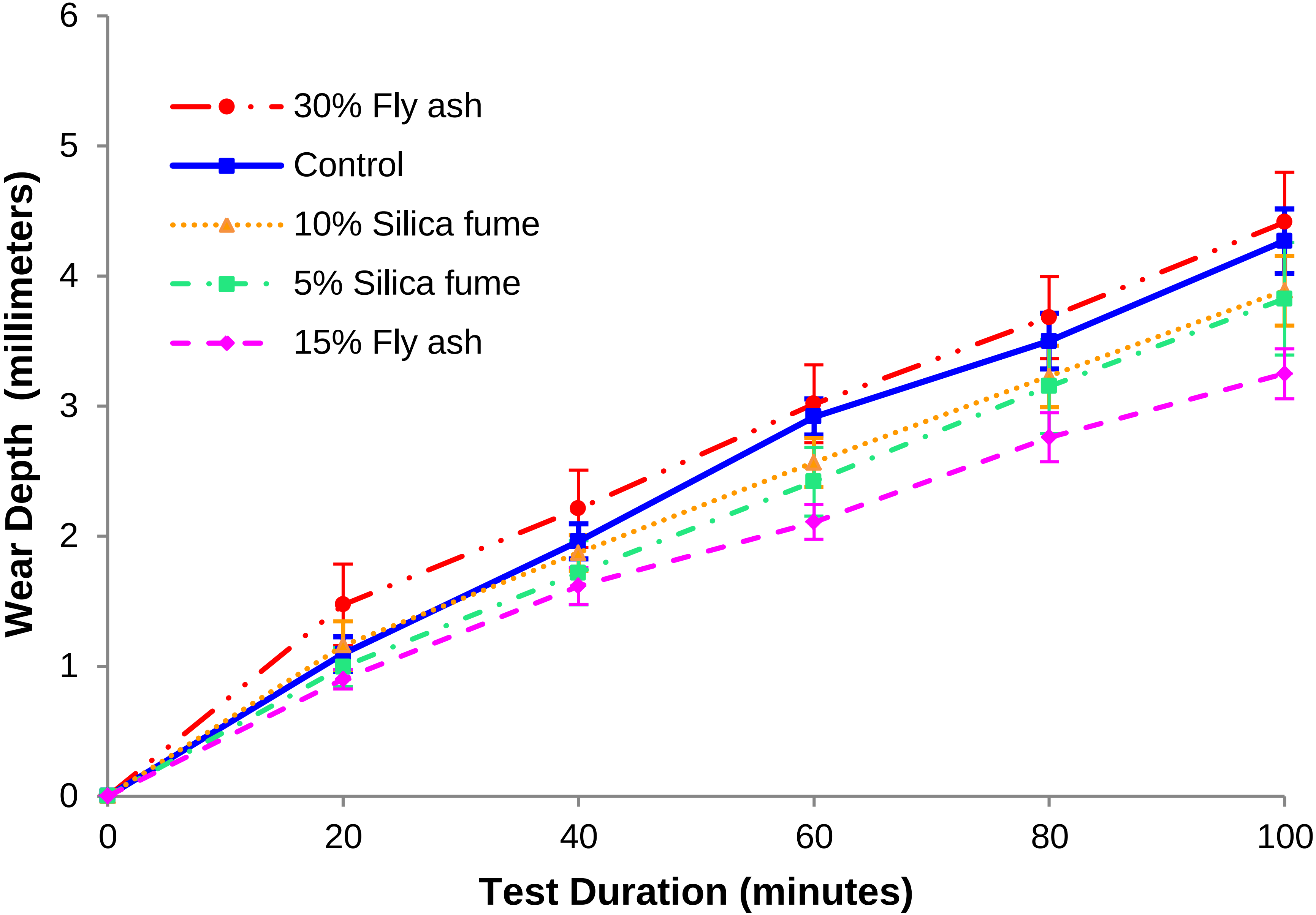
Phase I: UIUC Manufactured Specimens

- Mineral admixtures
  - Silica fume (5%, 10%)
  - Fly ash (15%, 30%)
- Surface treatments
  - Grinding
  - Epoxy coating

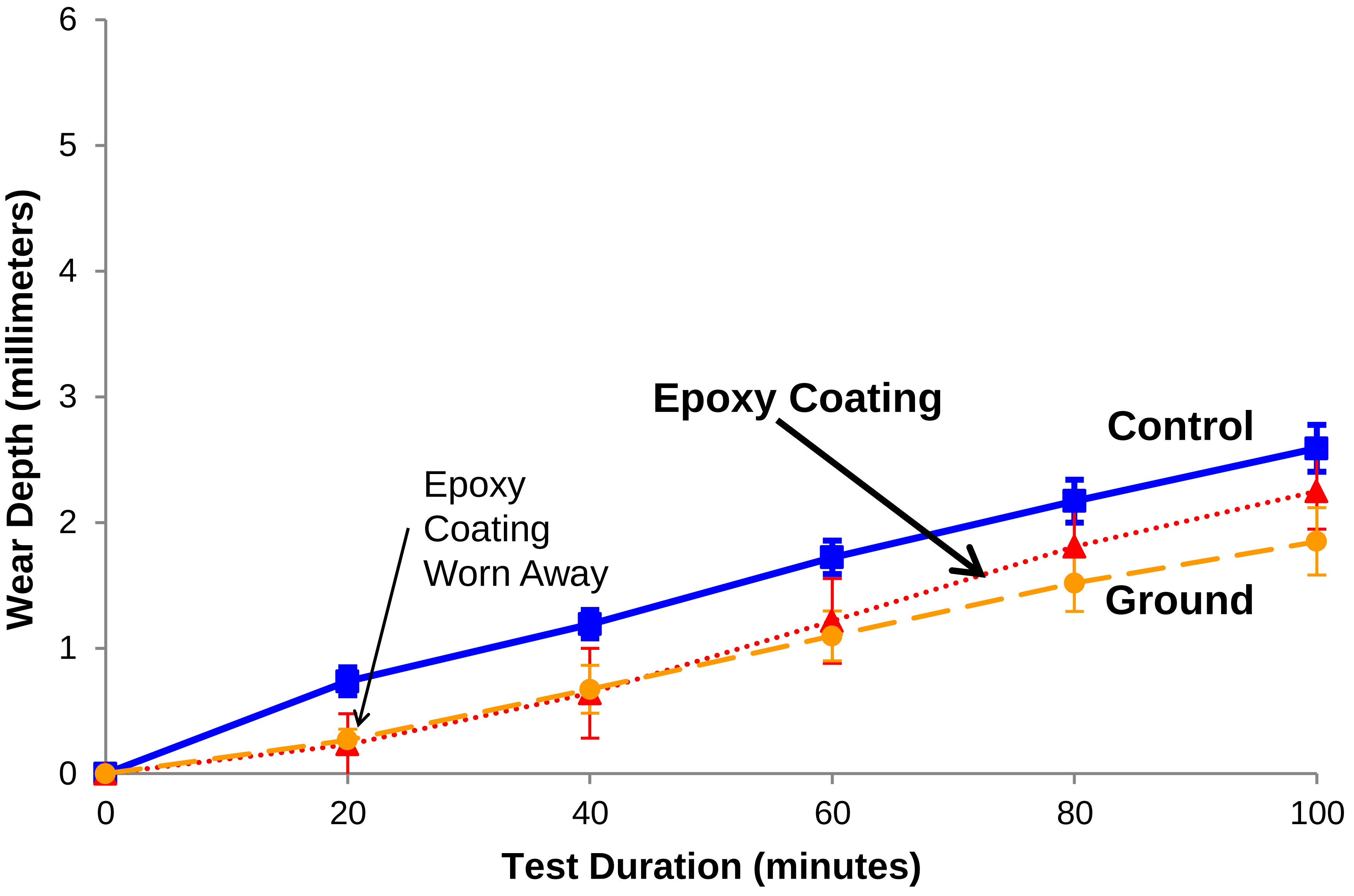
Phase II: Industry Manufactured Specimens

- Varying quantity of air entraining admixture (AEA)
  - 2.2 % Air (No AEA)
  - 3.5 % Air (Control)
  - 6% Air
- Surface treatments
  - Epoxy coating
  - Polyurethane coating
- Other approaches
  - Self-consolidating concrete (SCC)
  - Fiber reinforced concrete (FRC)
  - Metallic fine aggregates (MFA)

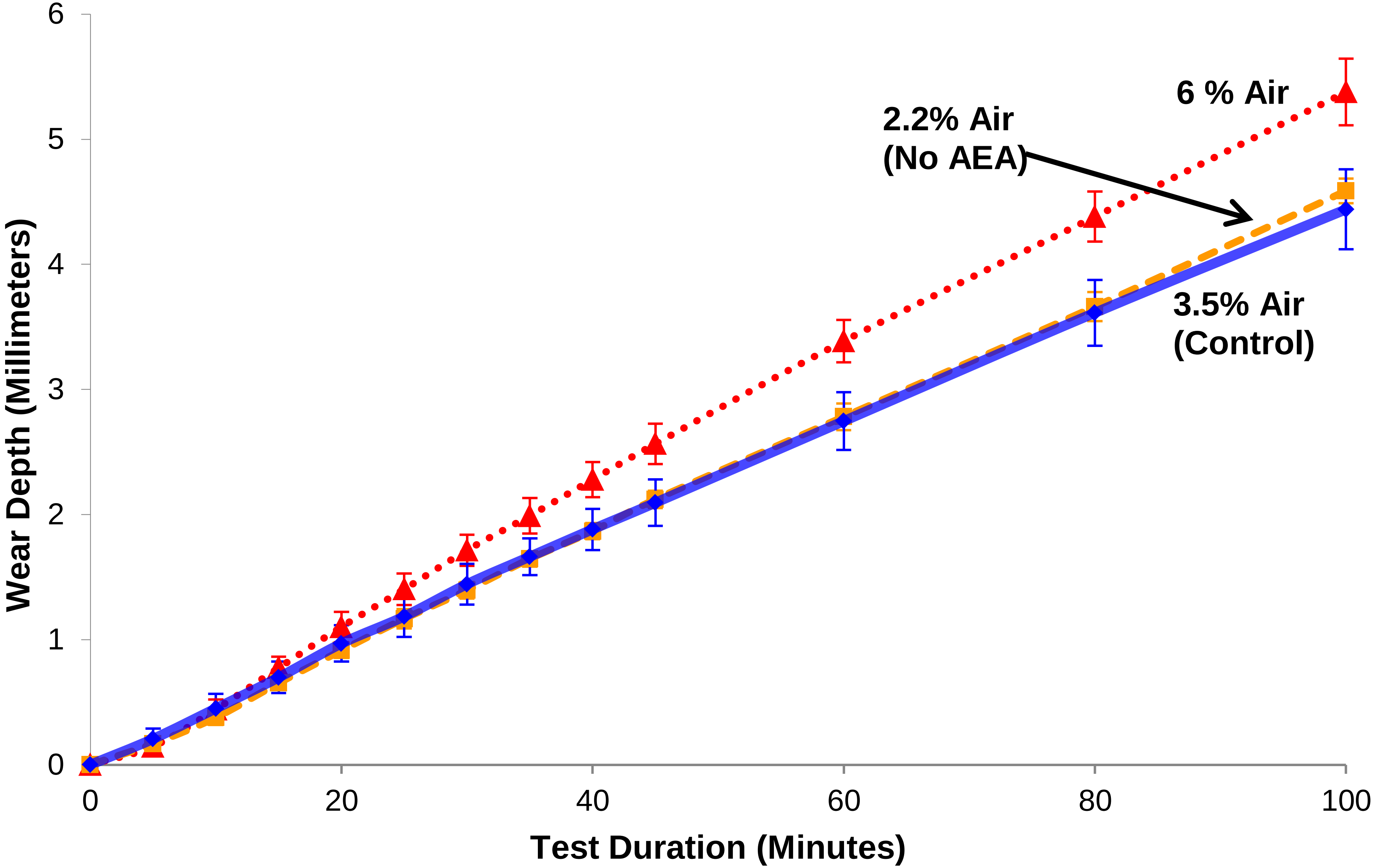
Effect of Mineral Admixtures



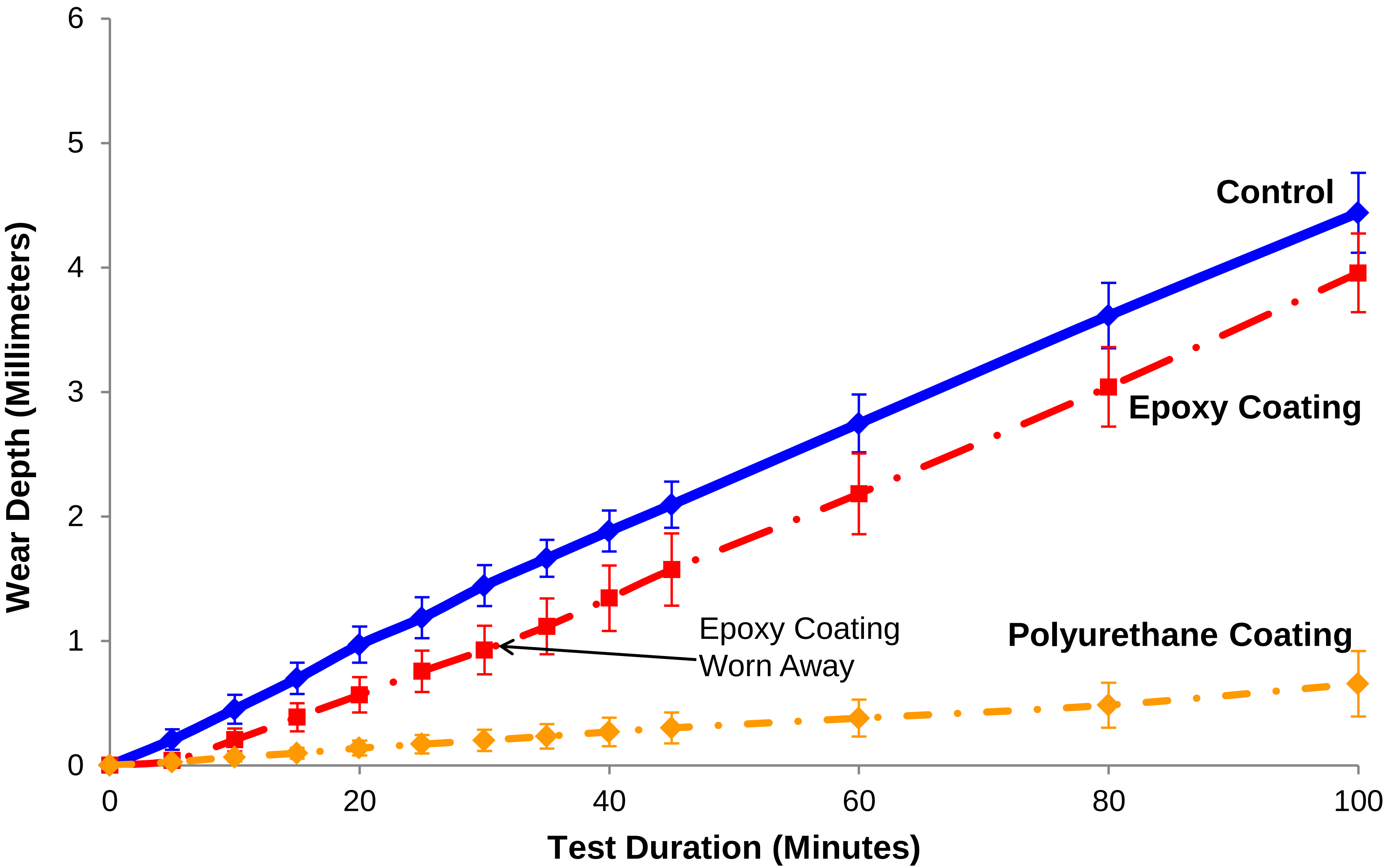
Effect of Surface Treatments



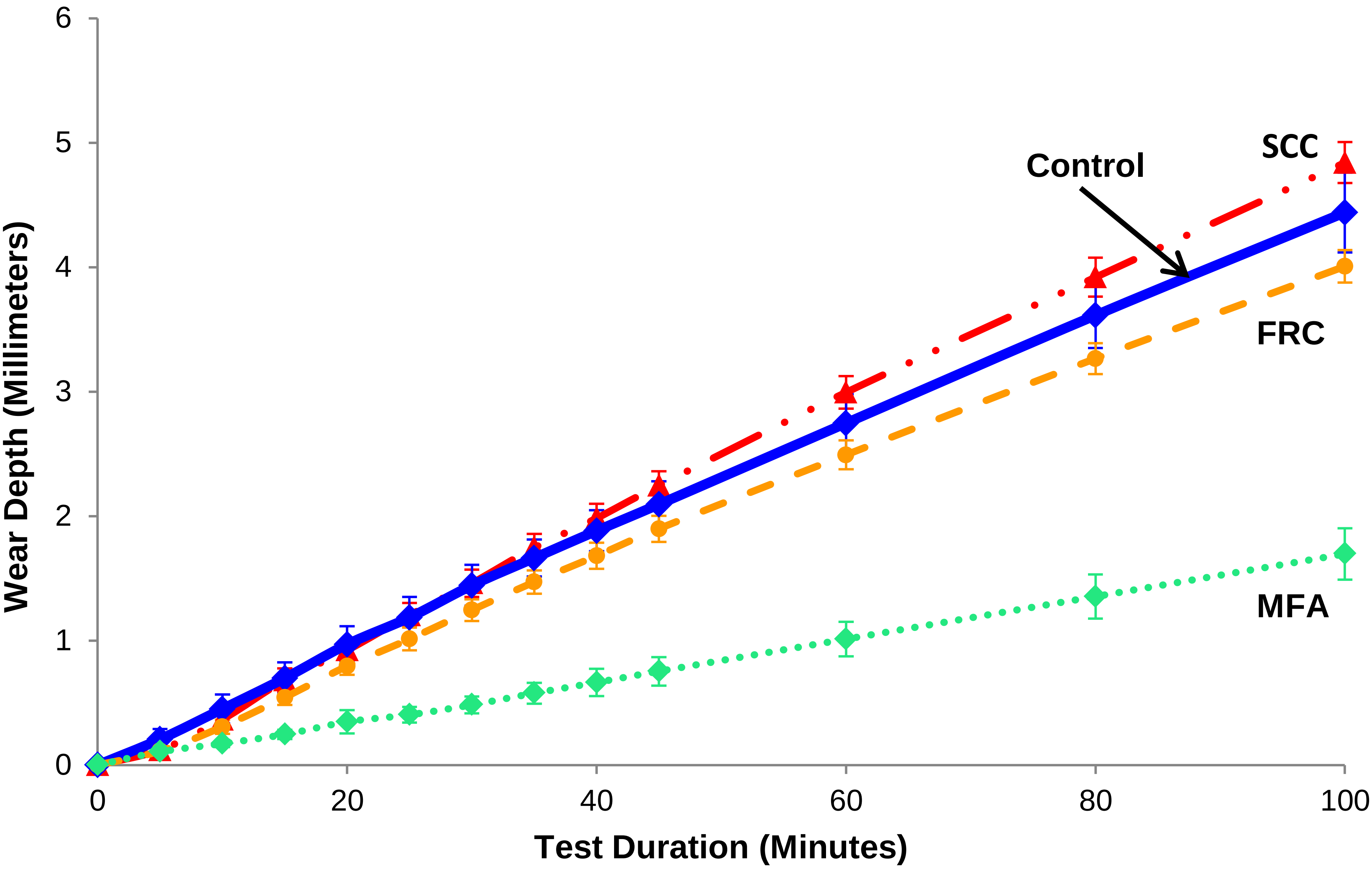
Effect of Air Entraining Admixture (AEA)



Effect of Surface Treatments



Effect of Other Variations in Mix Design



Conclusions

- SSTAR:
  - Proved to be a reliable abrasion resistance test providing repeatable data (with low variability)
  - Capable of causing quantifiable abrasion of concrete specimens in accelerated environment
- Abrasion resistance of concrete improved with:
  - Optimal amounts of fly ash, silica fume
  - Metallic fine aggregates (MFA) and surface coatings
- Polyurethane coating performed better than epoxy coating in this study
  - Cracks in epoxy coating propagated quickly
  - Wear rate of epoxy specimens after coating is deteriorated resembles that of control specimens
- MFA specimens appeared to performed the best
  - Minimal wear in some cases and no coarse aggregate was exposed
- Increasing air content appeared to have a negative effect on the abrasion resistance of concrete

Ongoing and Future Research

- Testing currently underway on a new test matrix to supplement results of the previous research
  - Test matrix focuses on using various mineral admixtures to make high performance concrete (HPC)
  - Comprehensive array of tests will be performed on these mixes including abrasion, permeability,freeze-thaw resistance, short and long term strength
- Goal is to optimize concrete mix design to maximize its ability to resist RSD and other durability failures

Tests for HPC Mixes

Standard Tests	
ASTM C39	Compressive strength at 1, 7, 28, 56,and 90 days
ASTM C232	Bleed of fresh concrete
ASTM C157	Free (unrestrained) shrinkage (cured in lime solution and air)
ASTM 496	Split tensile strength at 28 days
ASTM 666	Freeze-thaw resistance (F/T) for concrete at mature ages
ASTM 1202	Rapid Chloride Penetration Test (RCPT) for permeability
ASTM 1260	Alkali Silica Reactivity (ASR) test
AASHTO Ring Test	Test for restrained shrinkage strain

Non-Standard Tests	
Heat of Hydration	Record the internal temperature of the concrete for the first 72 hours
SSTAR	Small-Scale Test for Abrasion Resistance
SEM	Use a scanning electron microscope to look at cured specimens to study microstructure

High Performance Concrete Mixes

- All mix designs will have water to cementitious (w/c) ratio of 0.3, target air content of 6% and target slump of 8-10''
- Zero (control), one, two, or three different mineral admixtures will replace cement content in each mix
- Using mineral admixtures to replace cement content
  - 3%, 7%, and 15% silica fume
  - 18% fly ash
  - 23% and 43% slag
- Possibly achieve synergistic effects with different combinations of mineral admixtures
  - Mitigate multiple failure modes related to durability
- Highly experimental mixes

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Questions?

Amogh Shurpali
Graduate Research Assistant
email: ashurpa2@illinois.edu

Emily Van Dam
Graduate Research Assistant
email: vandam1@illinois.edu

Rail Transportation and Engineering Center RailTEC
University of Illinois at Urbana-Champaign UIUC