Development and Evaluation of a UHPC-based High-Friction Surface Treatment for Pavement and Bridge Surface Rehabilitation

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Research-in-Progress Session 2
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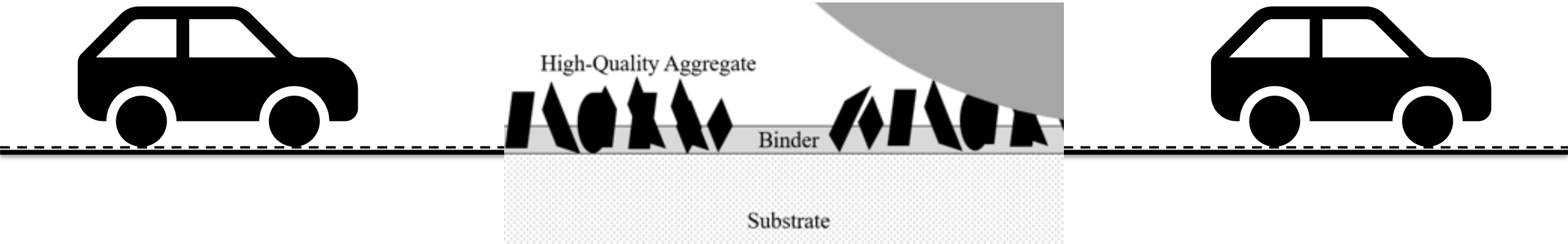
Agenda

1. Introduction
2. Material Selection
3. Continuous Particle Packing
4. Surface Properties
5. Future Work

Introduction

Without HFST

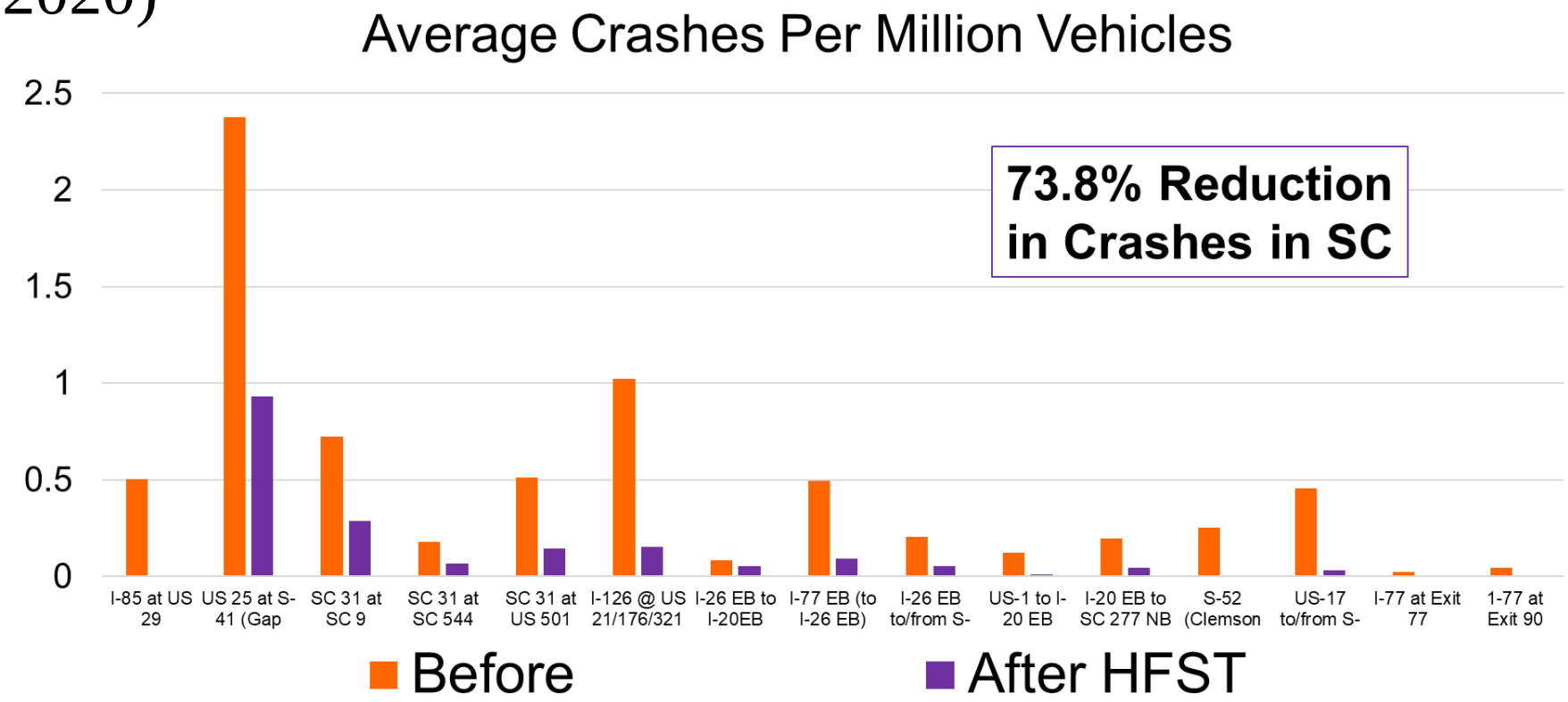
With HFST



Introduction

HFSTs

- Recent FHWA studies estimate that HFST's "**reduce wet crashes by 83 percent and total crashes by 57 percent** (FHWA 2023)"(Merritt, David K. et al. 2020)



*Timespan for collection of data varied by section from 2003 to 2016, data is normalized by traffic count to account for this

Introduction

UHPCs

- Class of cementitious composite characterized by its high compressive strength, enhanced toughness, high fluidity, and high bond strength.
  - Typical Composition: Portland Cement, Silica Sand, Steel Fibers, Silica Fume, High Range Water Reducer, and a low w/b ratio.

Necessary for HFST binder to be effective:

- High Bond Strength √
- Low Shrinkage/Cracking √
- High Abrasion Resistance √

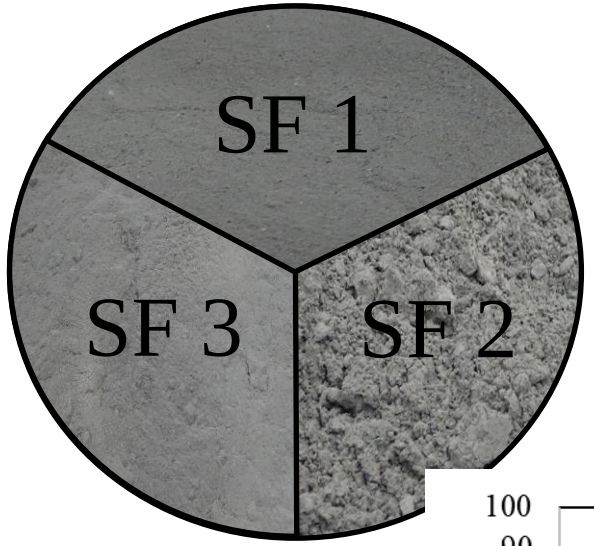
Good for HFST Binder:

- *Ultra-High Compressive Strength ✓*

Materials

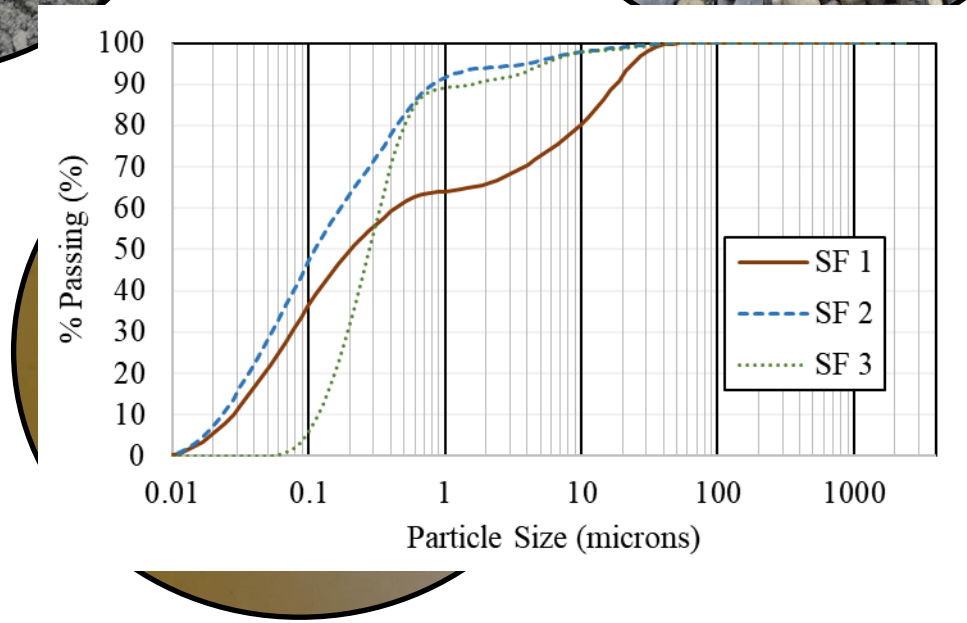
Type III PC

Silica Fume



Calcined Bauxite

Man. Sand

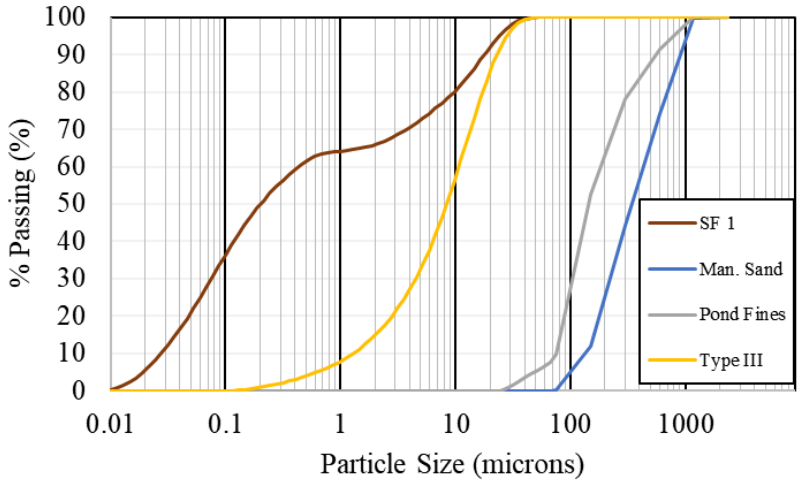


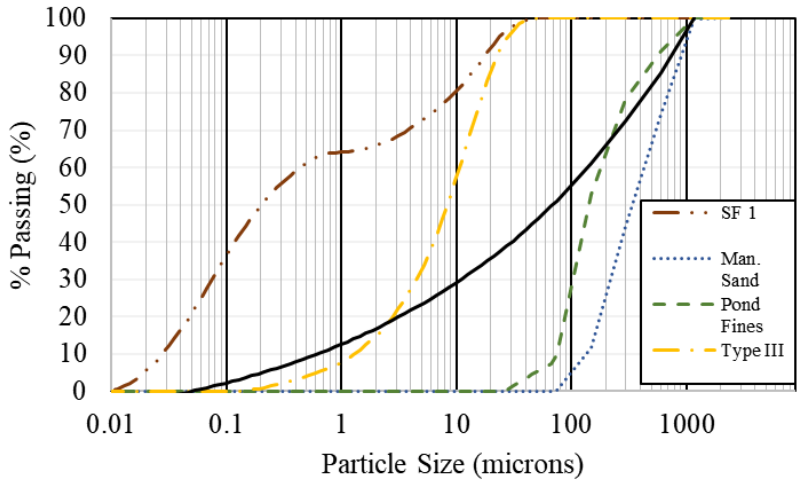
Continuous Particle Packing

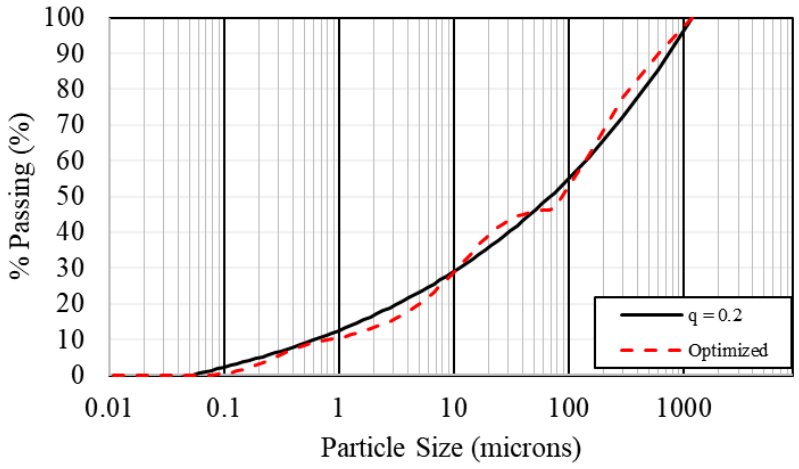
- Method of densely arranging particles.
- Modified Andreasen and Andersen Method

$$CPFT = \frac{d^q - d_{min}^q}{D_{max}^q - d_{min}^q} * 100$$

- For UHPC an optimal q-value is between 0.2 and 0.37







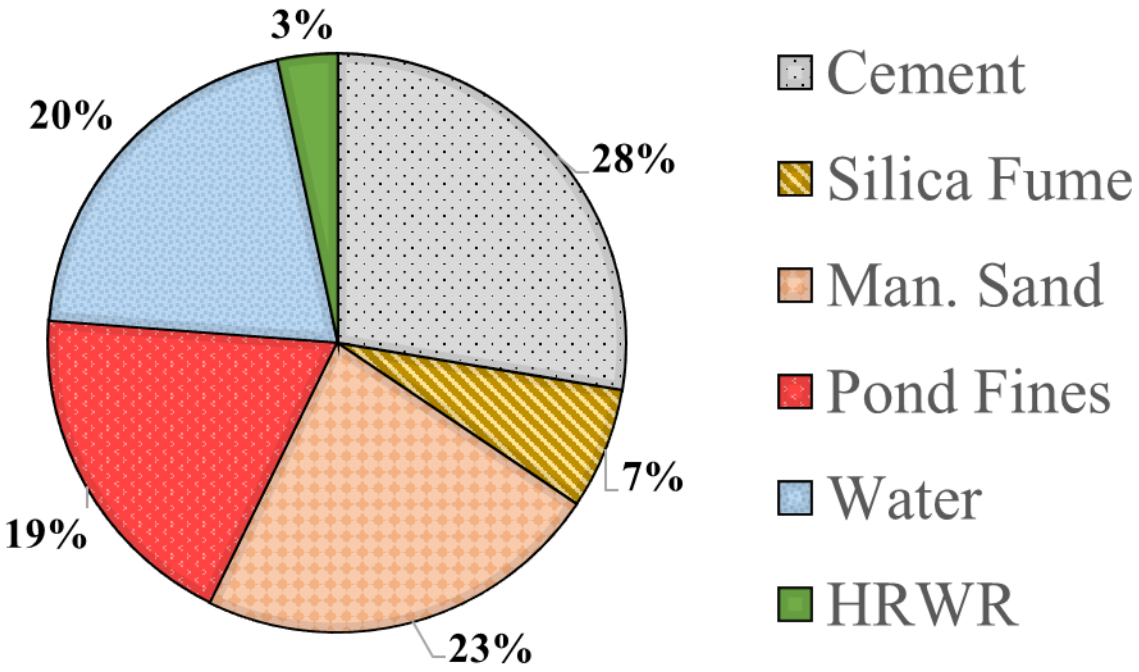
Mix Proportions of UHPC

	SF1-3.5	SF1-4.5	SF2-3.5	SF2-4.5	SF3-3.5	SF3-4.5
C/CM	0.8	0.8	0.8	0.8	0.85	0.85
SF/CM	0.2	0.2	0.2	0.2	0.15	0.15
W/CM	0.2	0.2	0.2	0.2	0.2	0.2
S/CM	0.7	0.7	0.6	0.6	0.6	0.6
PF/CM	0.4	0.4	0.4	0.4	0.5	0.5
HRWR/CM	0.035	0.045	0.035	0.045	0.035	0.045
CB/CM	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*

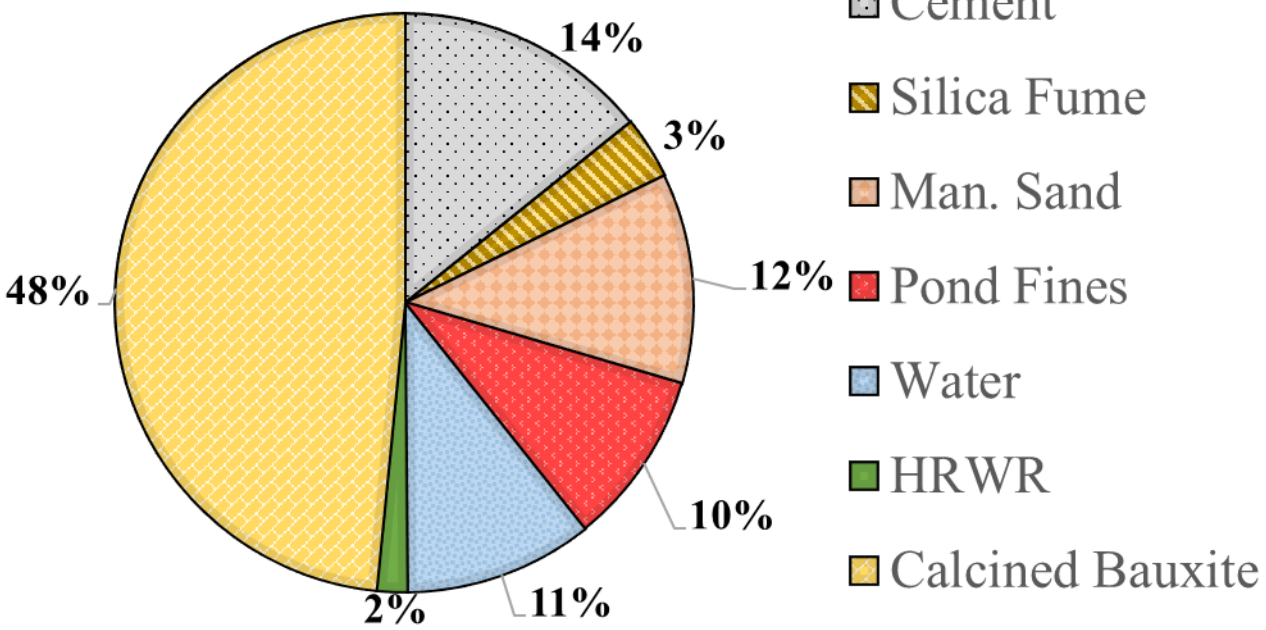
C: Cement
SF: Silica Fume
W: Water
S: Sand
PF: Pond Fines
HRWR: High Range Water Reducer
CB: Calcined Bauxite
CM: Cementitious Material

Composition by Volume

UHPC



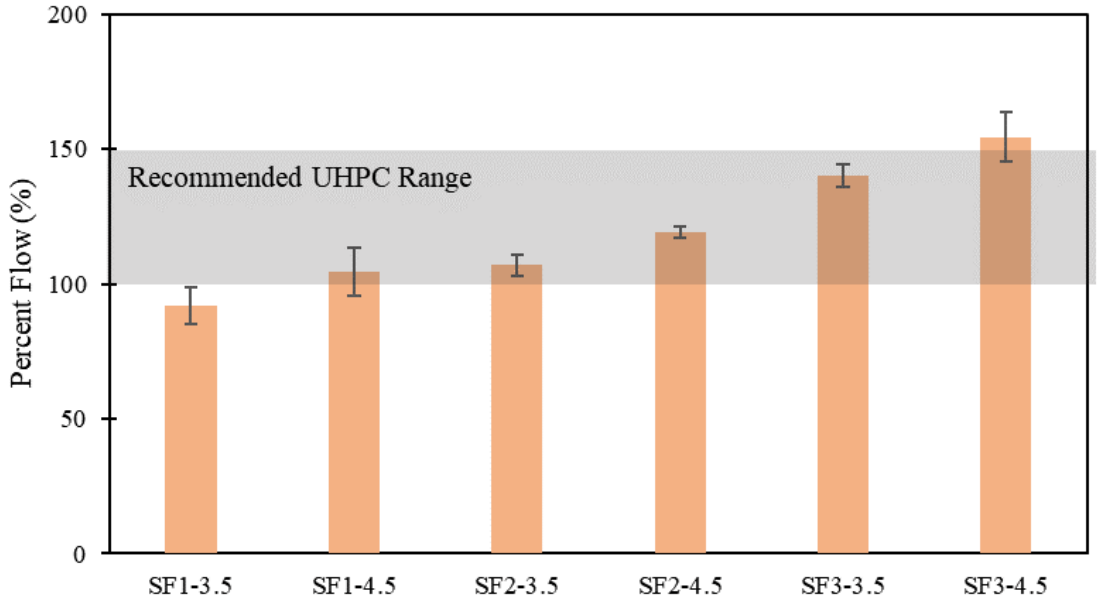
Intermixed CB



Workability

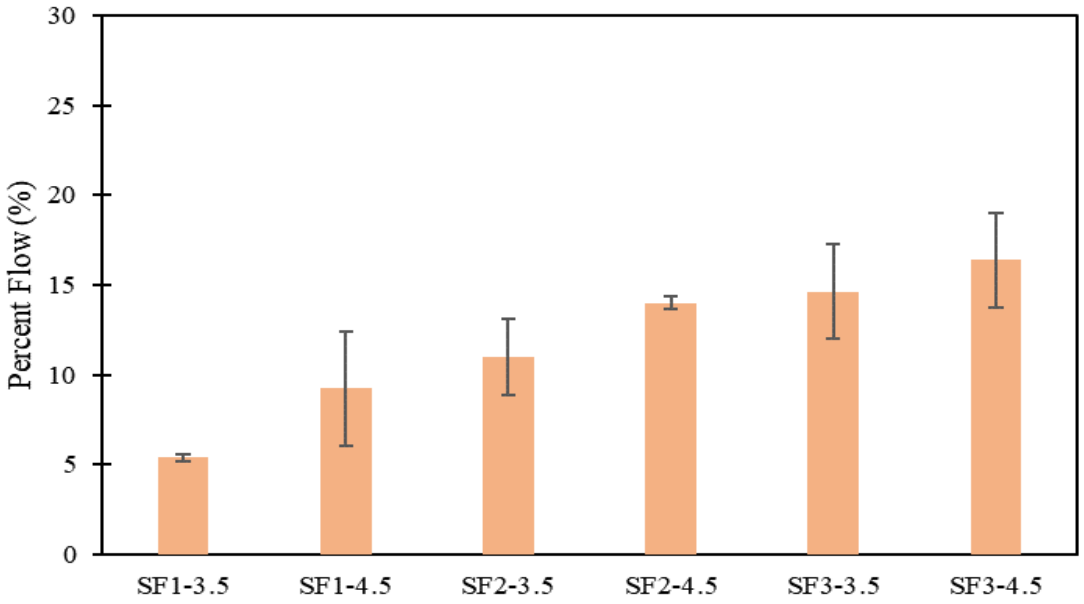
UHPC

Modified Flow Table Test



Intermixed CB

Flow Table Test



Pull Off Tensile Strength

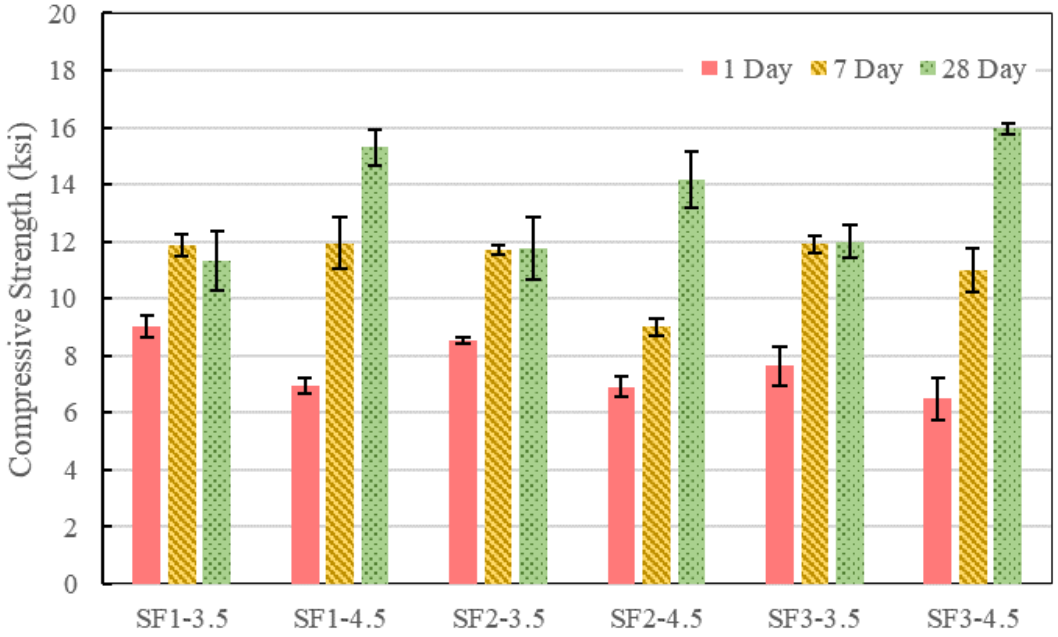
SCDOT HFST Spec: 250 psi at 7 Days

7 Day Results (psi)

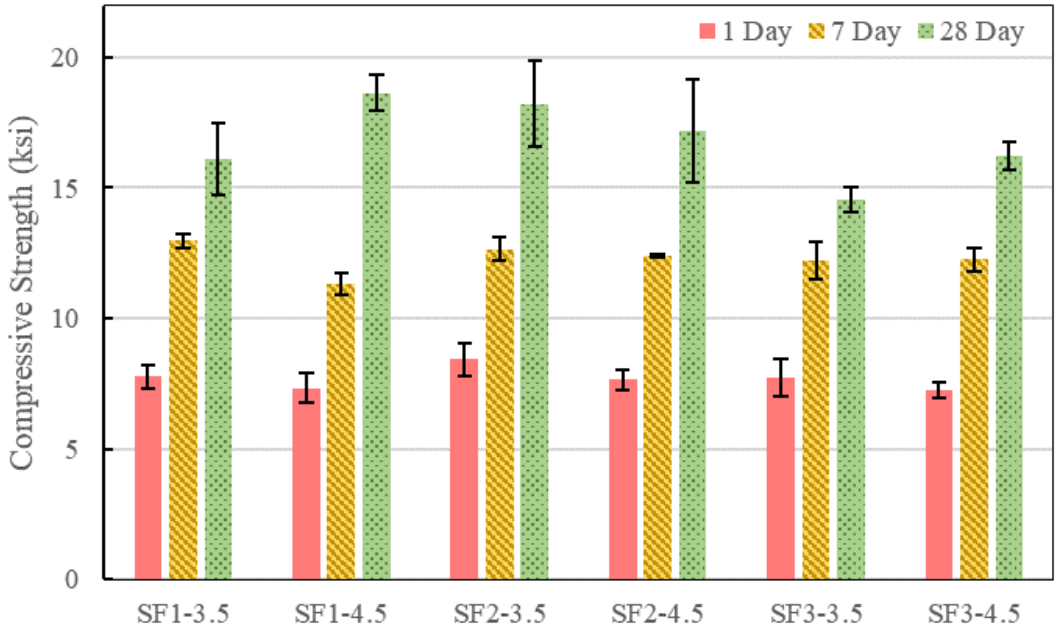
	UHPC	Intermixed	% of Binder
SF1-3.5	424	252	60%
SF1-4.5	415	284	68%
SF2-3.5	329	277	84%
SF2-4.5	303	253	83%
SF3-3.5	308	231	75%
SF3-4.5	323	193	60%
Epoxy	315	---	---

Compressive Strength

UHPC



Intermixed CB



American Concrete Institute
Always advancing

Spring 2024 – New Orleans

Surface Method Comparison

SMART CENTER
Sustainable Materials Research and Technology Center
CLEMSON
GLENN DEPARTMENT OF CIVIL ENGINEERING


Resin Based

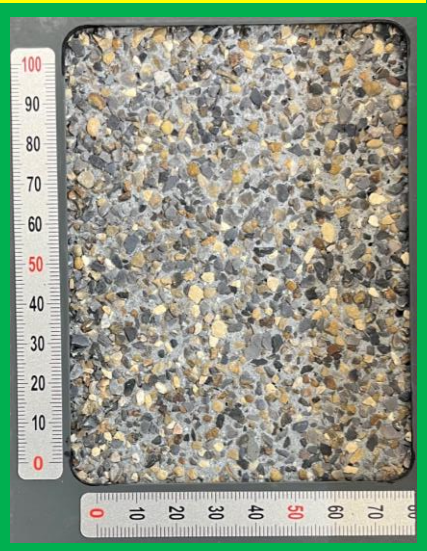

SSD Broadcast


SSD Vibrated

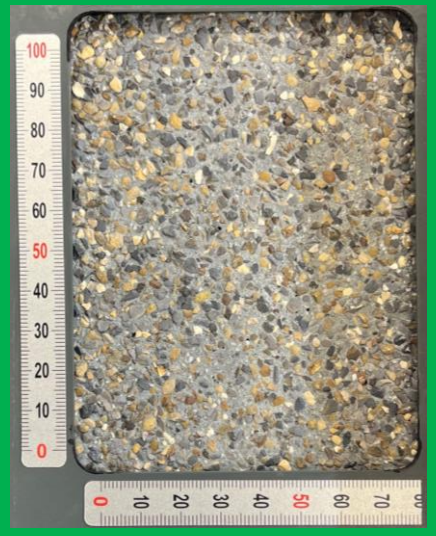

OD Broadcast


OD Vibrated


No Retarder w/Wash


VE-15


VE-25


SE-25

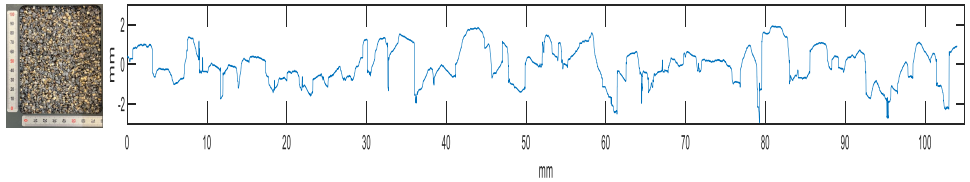

SE-50


SE-125

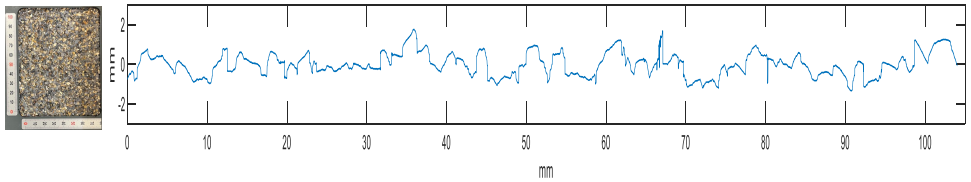

SE-200

Surface Method Comparison

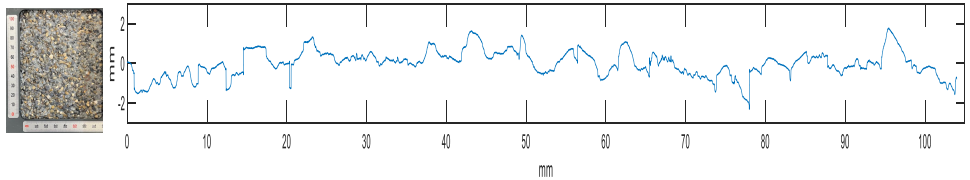
Resin Based



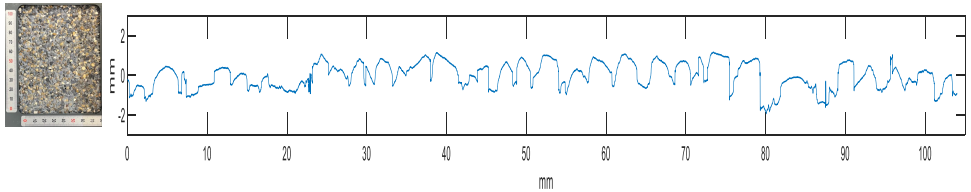
OD Vibrated



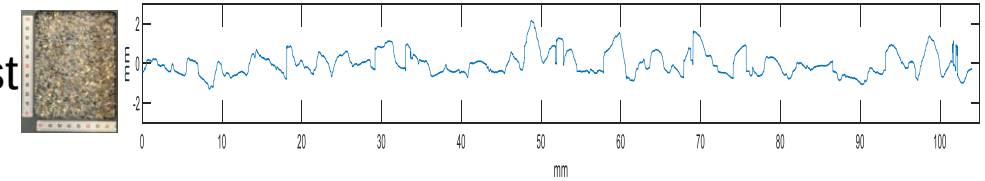
SE-200



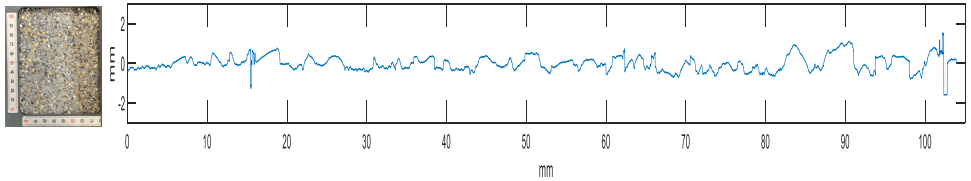
SE-50



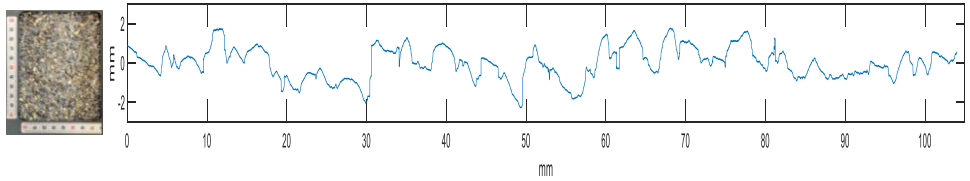
SSD Broadcast



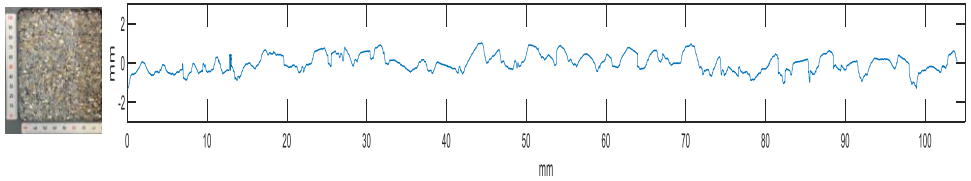
SE-25



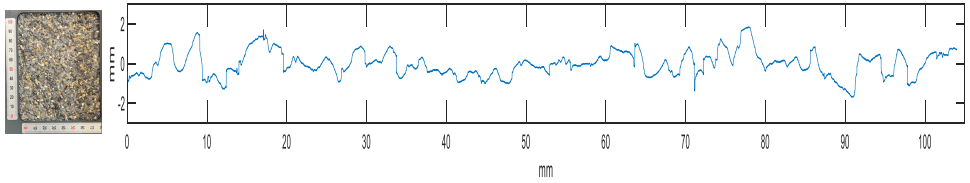
SE-125



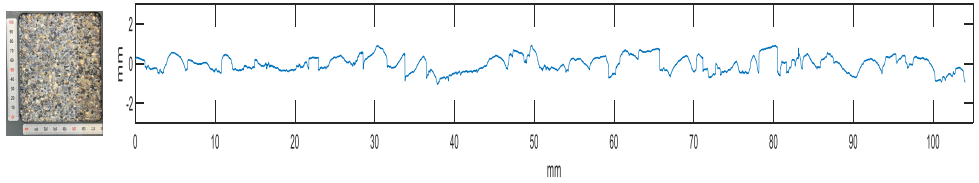
No Retarder



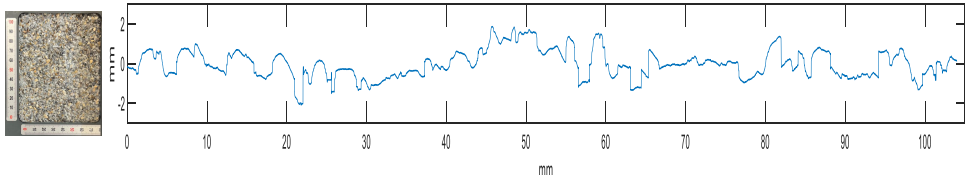
OD Broadcast



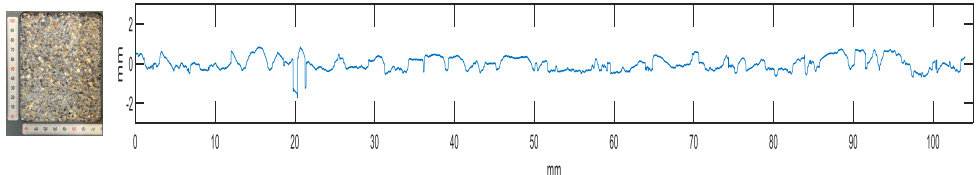
VE-15



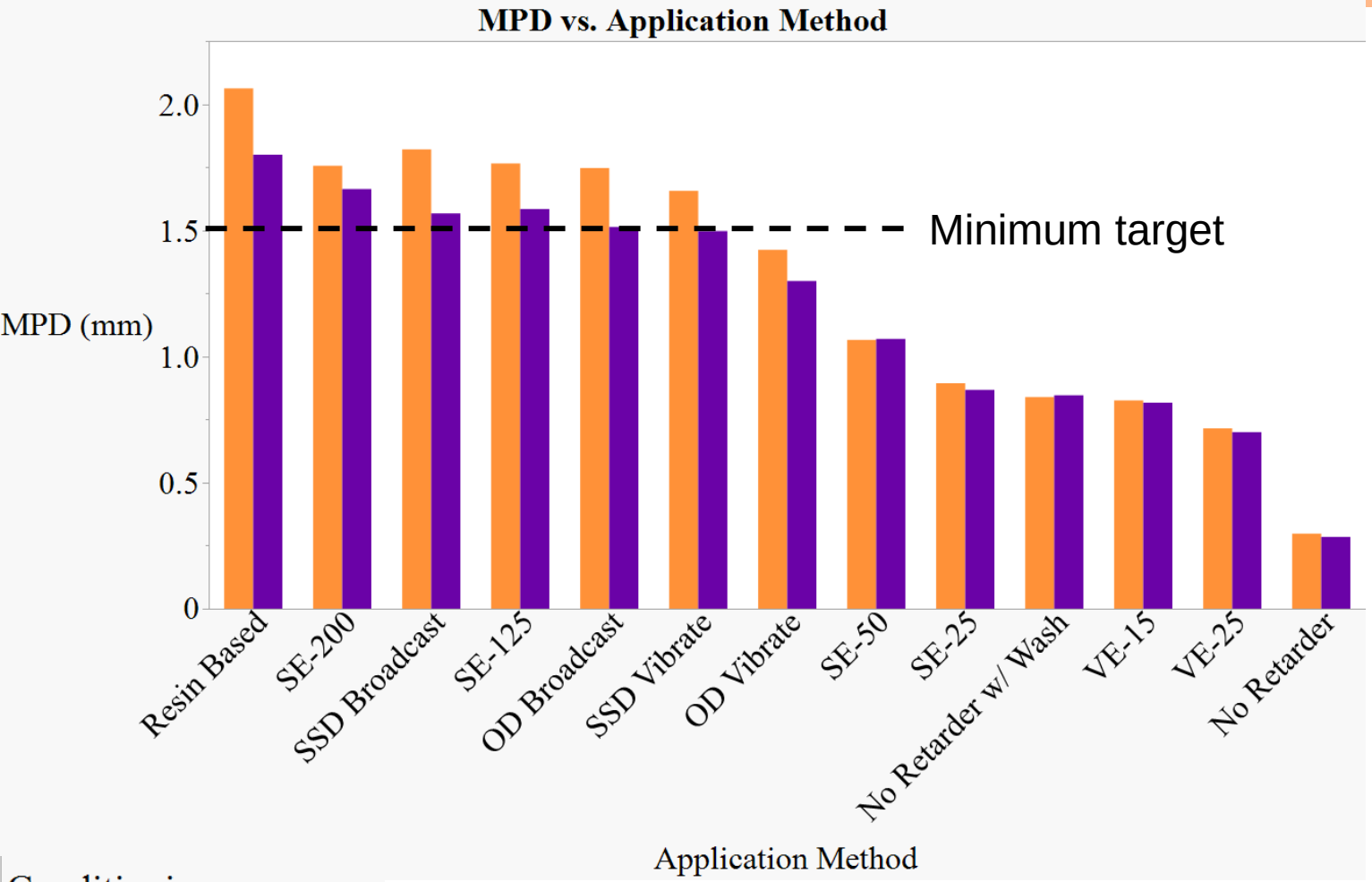
SSD Vibrated



VE-25



Macrotexture of Surfaces (MPD)



Tukey's HSD of Mean Profile Depth After Conditioning

Application Method							Least Sq Mean
Resin Based	A						1.799
SE-200	A	B					1.664
SE-125		B					1.584
SSD Broadcast		B					1.567
OD Broadcast		B					1.513
SSD Vibrate		B					1.497
OD Vibrate			C				1.300
SE-50				D			1.070
SE-25					E		0.867
No Retarder w/ Wash					E		0.846
VE-15					E		0.817
VE-25					E		0.700
No Retarder						F	0.285

Methods not connected by same letter are statistically significantly different

Preliminary Conclusions

- UHPC has the potential to act as a HFST binder, but additional testing is needed.
- Continuous Packing Methods provide comparable results between mixes.
- Intermixed CB results in a decreased bond strength.
- UHPC and Epoxy provide comparable bond strengths.
- Intermixed CB Mixes provide comparable MPD to epoxy when the correct surface retarder is used.

Ongoing and Future Work

- Continuous Packing
  - Abrasion Resistance
  - Shrinkage
- Discrete Packing
  - Bond Strength
  - Shrinkage
- Shrinkage
  - Shrinkage + Crack Risk
  - Fiber Addition
- Surface Study
  - Three-wheel polishing testing
  - LTS + DFT

Abrasion Testing

ASTM C944

Thin-Layer Shrinkage

Dynamic Friction Tester

Questions?

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Acknowledgements

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  - Argos, Sika, Brickform, SpecChem, Ferroglobe, Elkem, Martin Marietta, Vulcan, FX minerals, Sunrock, Levy, Skidabrader

Mix Procedure

- 20 Quart Tabletop Hobart Mixer
  - Low Speed: 40 rpm
  - Medium Speed: 75 rpm
  - High Speed: 135 rpm