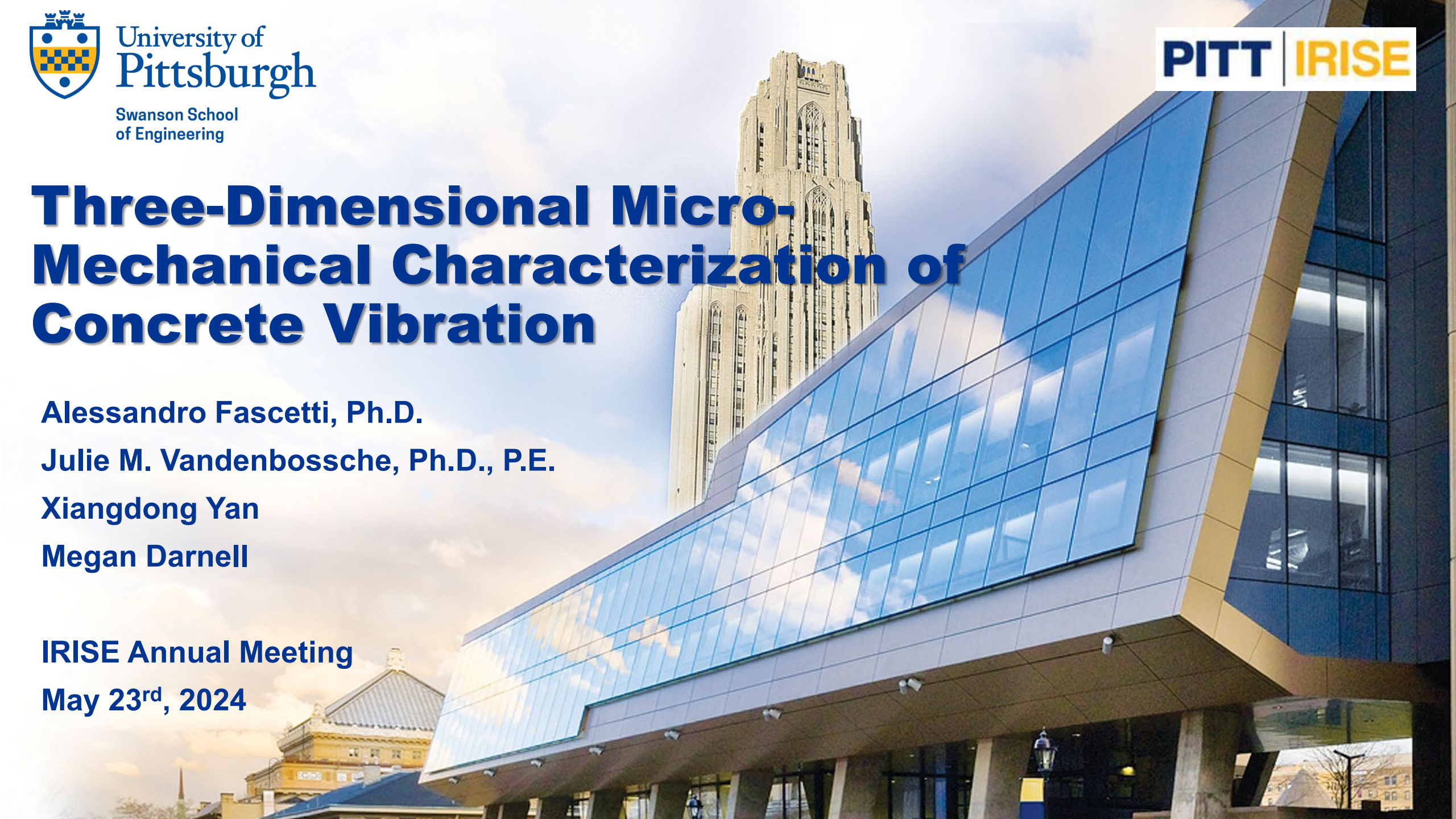

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Three-Dimensional Micro-Mechanical Characterization of Concrete Vibration

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Julie M. Vandenbossche, Ph.D., P.E.

Xiangdong Yan

Megan Darnell

IRISE Annual Meeting

May 23rd, 2024

The Problem

Slipform Paver

Vibration Array

Vibrator element

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Resources: 1. GOMACO GP3; 2. GP3 Slipform Paver; 3. Vibrating and bar insertion element;

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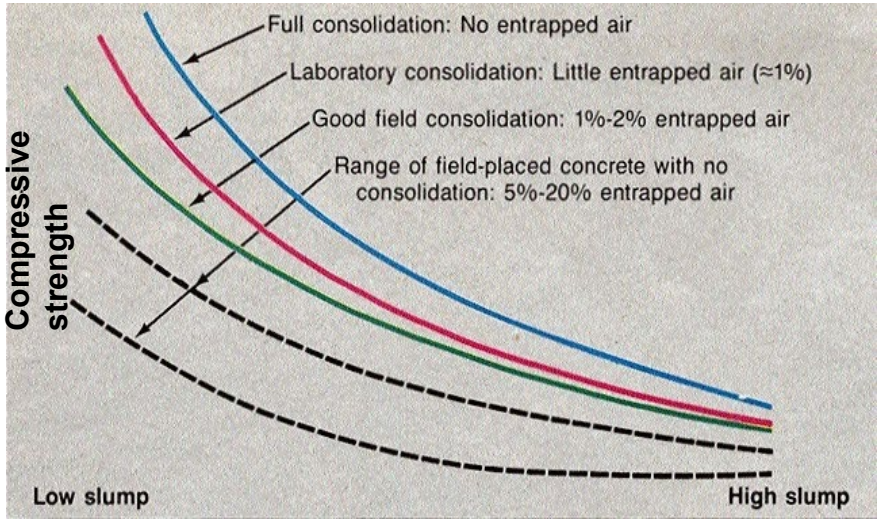
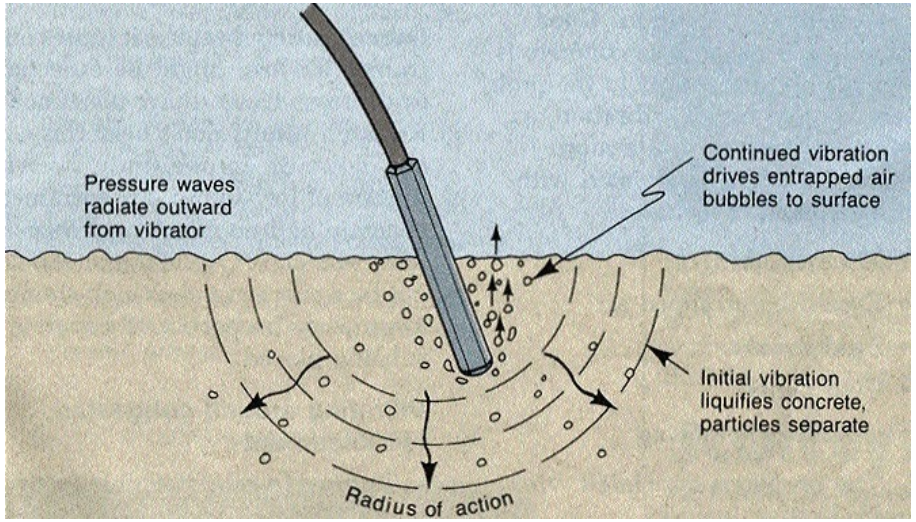
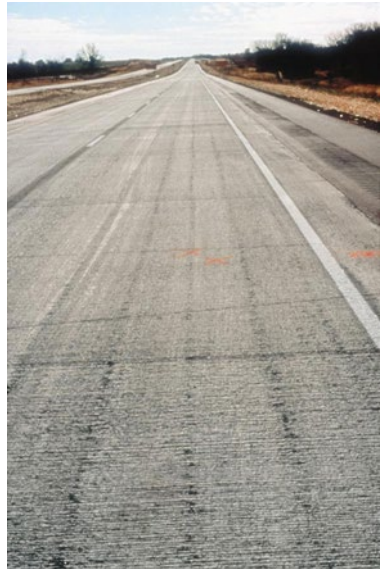
The Problem

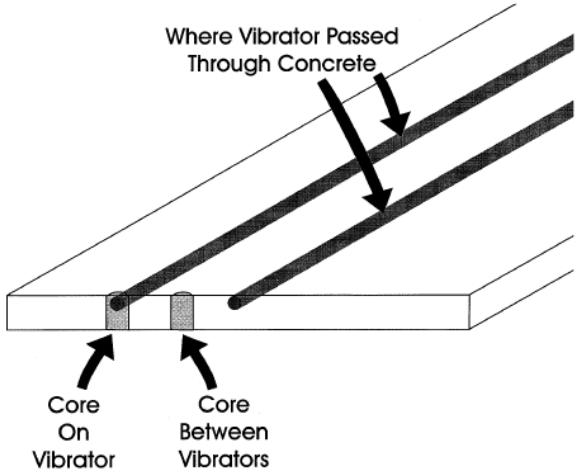


The effect of consolidation on compressive strength



The function of vibration includes liquefy the fresh concrete and release entrapped air bubbles





Excessive vibration vibrates out the entrained air which reduces freeze-thaw protection

Specification of vibratory speed and vibration frequency*4			
#	**Agency**	**Vibration frequency** (Vibrations Per Minute)	**Specification**
1	Illinois DOT	5,000 - 9,000	D&E-02, 2020
2	Iowa DOT	4,000 - 8,000	SERIES 2023
3	Minnesota DOT	3,600 - 7,000	EDITION 2020
4	New York DOT	6,000-10,000	Vol 2, 2023
5	Pennsylvania DOT	Minimum of 6,000	PUB 408, 2020

Resources: 1. Concrete Vibration by Prof.Dr.Bruce A.Suprenant; 2. Vibrator of slip-form paver. 3. Shane Tymkowicz and Robert F. Steffes, 1997, Vibration Study For Consolidation Of Portland Cement Concrete; Bob Steffes, 2000, Headed For The End Of The Trail; 4. State specification.

Project Objectives

1. **Investigate the affects of paving components.** To explore how different combinations of vibrator frequency, paver speed, and concrete workability impact the quality of consolidation.

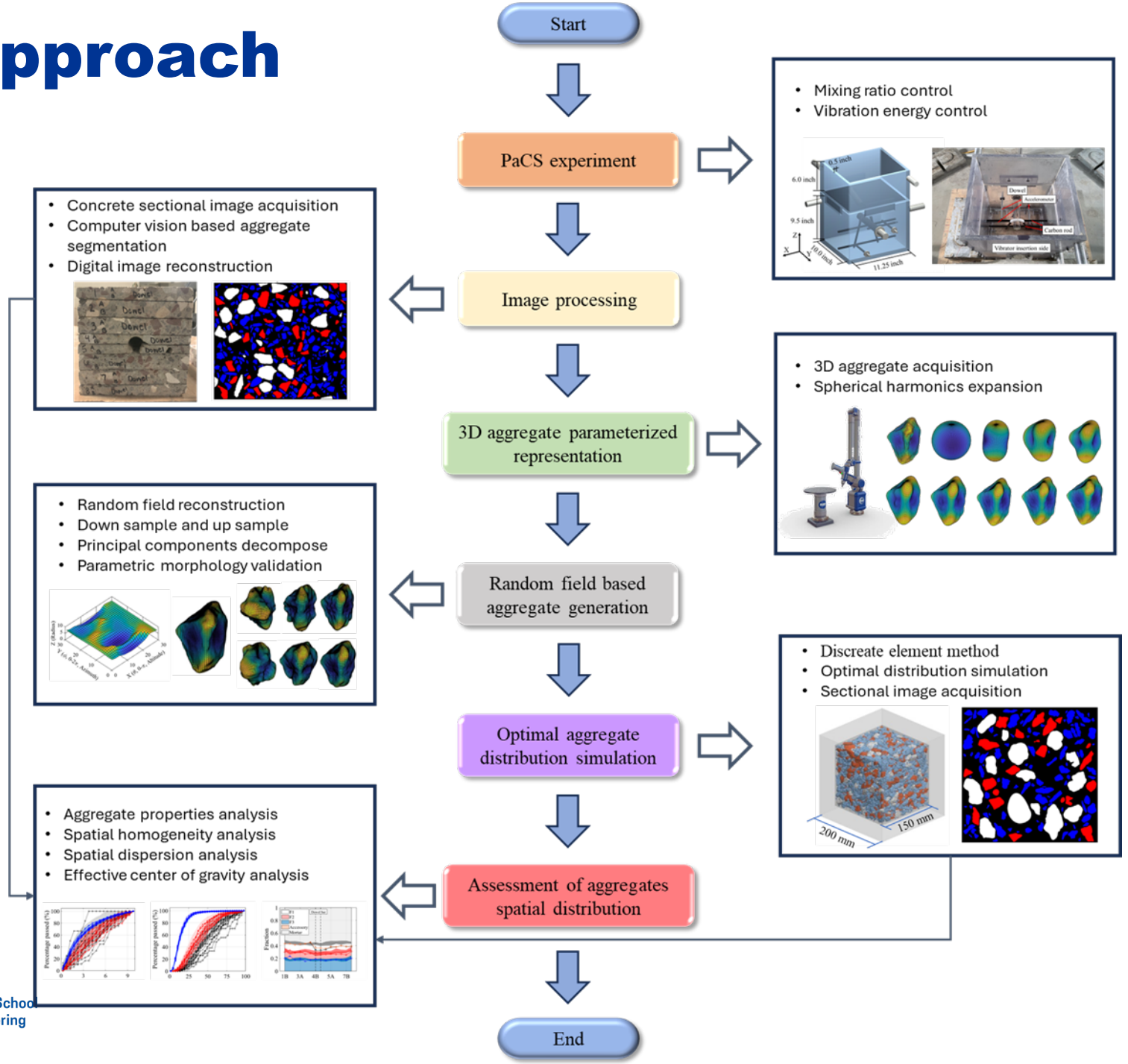
2. **Develop a novel experimental setup to replicate actual paving process.** A novel and small-scale experimental setup is used to quantify the consolidation of fluid concrete as a function of key paving parameters, then to measure the quality of consolidation.

3. **Develop a comprehensive assessment system.** Utilize Computer Vision (CV) and Discreate Element Method (DEM) to characterize the distribution of air, coarse aggregate, and mortar, then reconstruct a meso-scale model to find a optimal spatial distribution of concrete components to build a benchmark.

4. **Provide a practical guidance.** Results from this study will allow the researchers to determine the optimal amount of vibration energy needed based on the workability of the concrete mixture.

5. **Improve the service life of concrete pavement.** Eventually, this method will be useful for assisting paving contractors in selecting appropriate vibration frequencies that will result in the construction of long-life, durable concrete pavements based on the concrete workability and paver speed.

Project Approach



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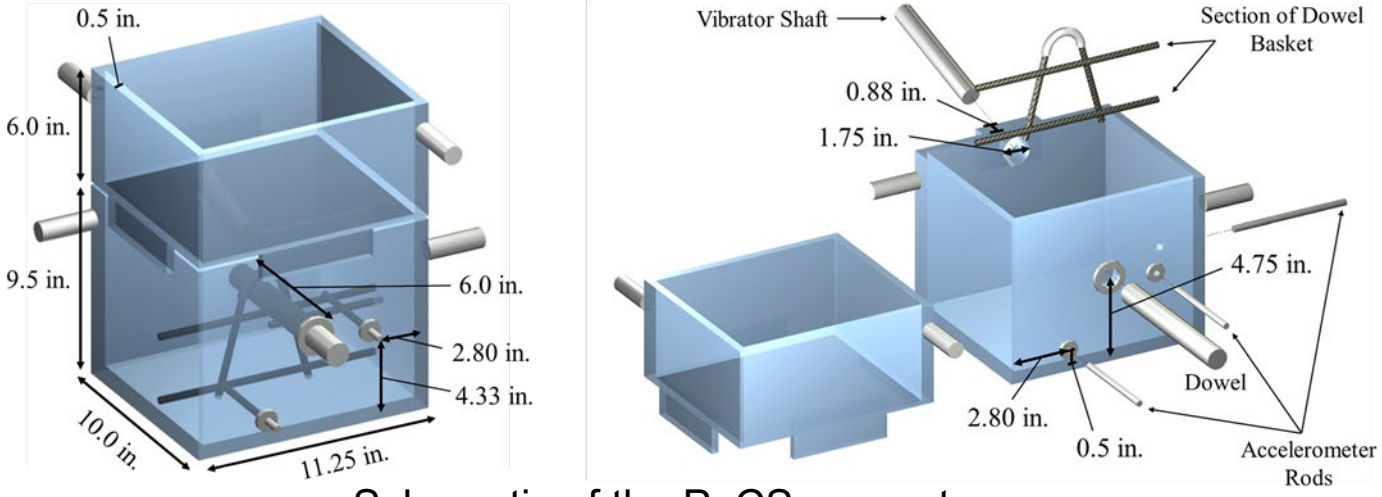
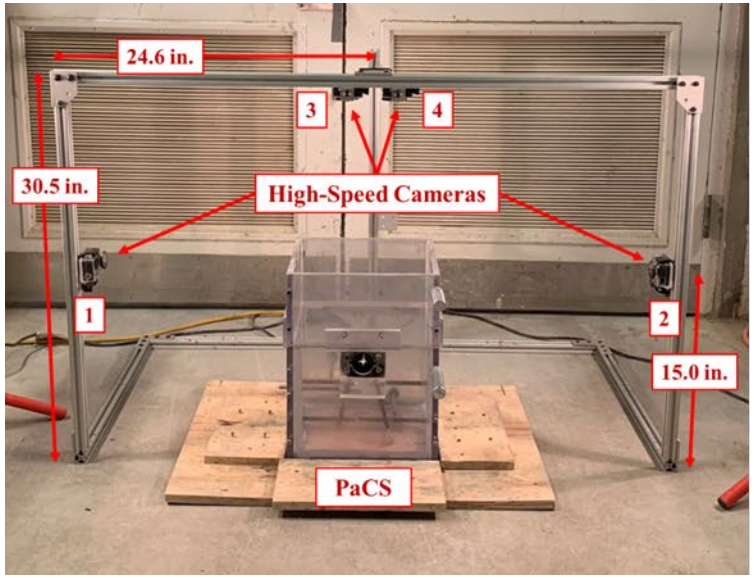
Paver Consolidation Simulation (PaCS)



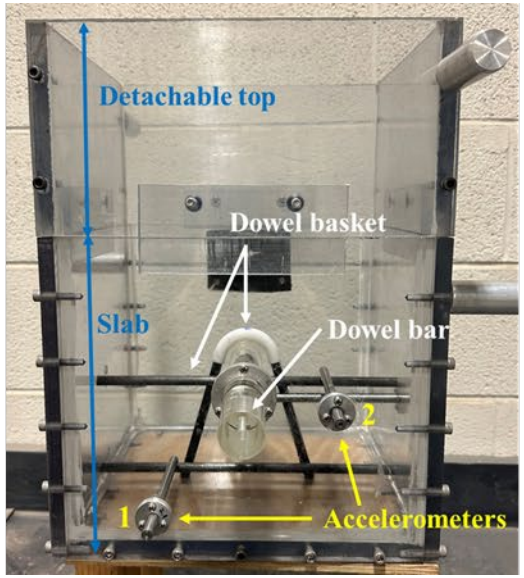
Schematic of the PaCS apparatus

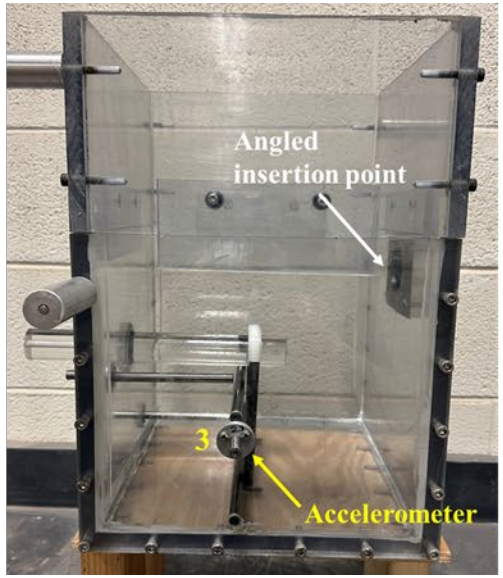
Table. Vibration frequency, paver speed of experiments.

Paver speed (ft/min)	Vibrator Frequency (Hz)		
	67	83	133
3	Slump: 1.25 in Air: 5.3 %	---	Slump: 1.00 in Air: 5.0 %
5	---	Slump: 1.25 in Air: 5.5%	Slump: 1.50 in Air: 5.5 %
8	---	Slump: 2.00 in Air: 6.0%	Slump: 1.25 in Air: 5.3 %



Experimental setup of the PaCS

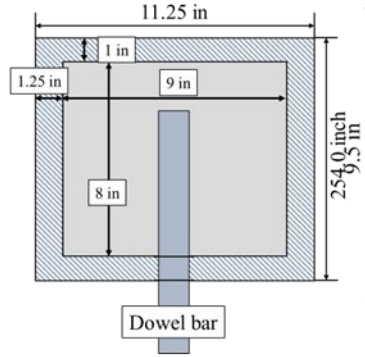


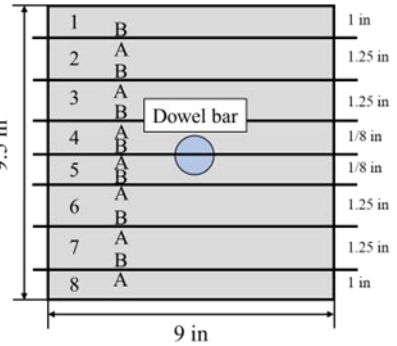


Detail of the PaCS experimental setup

Image recognition and processing

Coarse aggregate selection





Slicing to acquire concrete images

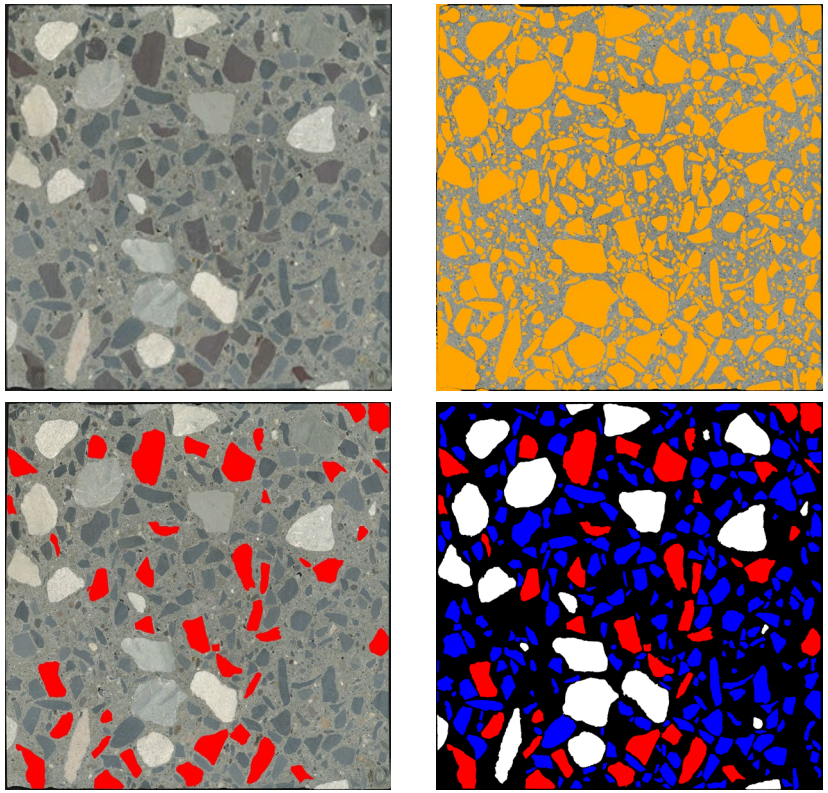
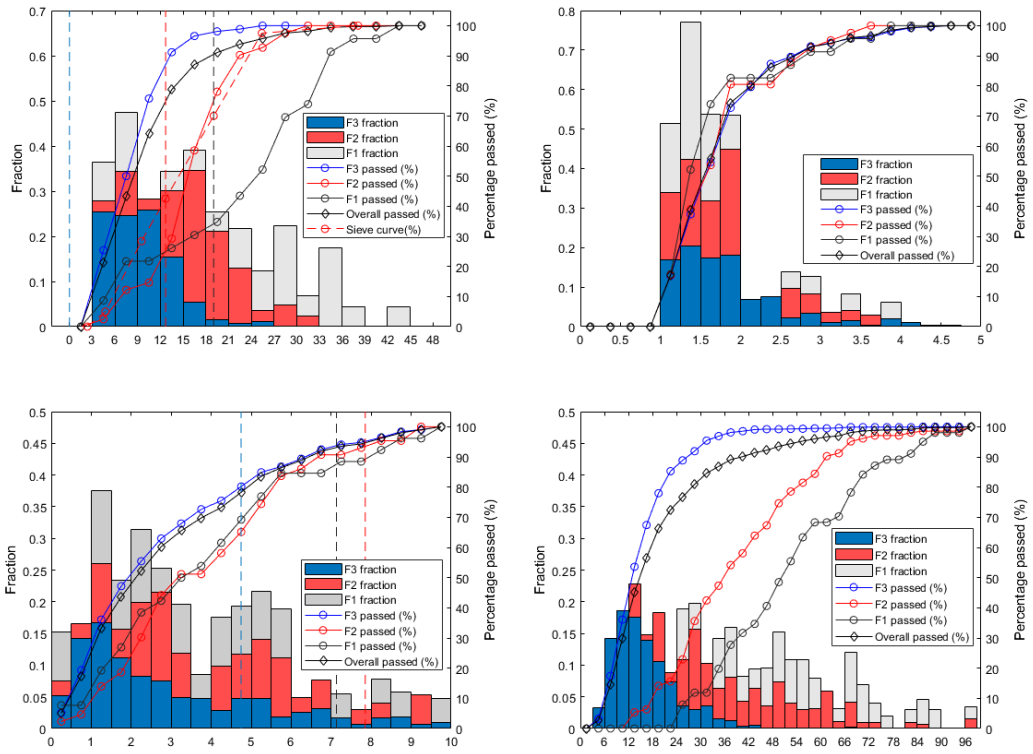
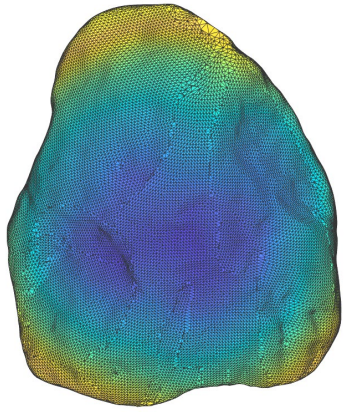


Image recognition based on CNN

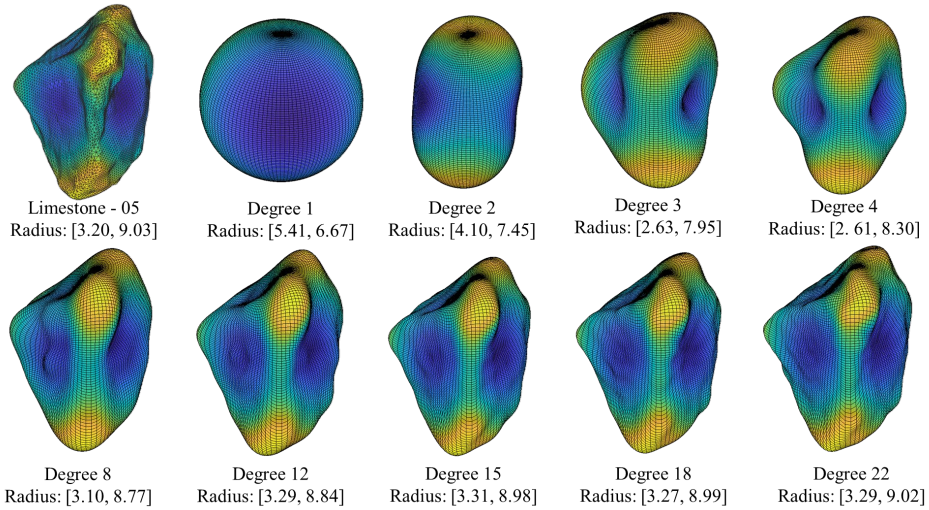


Assessment of concrete consolidation

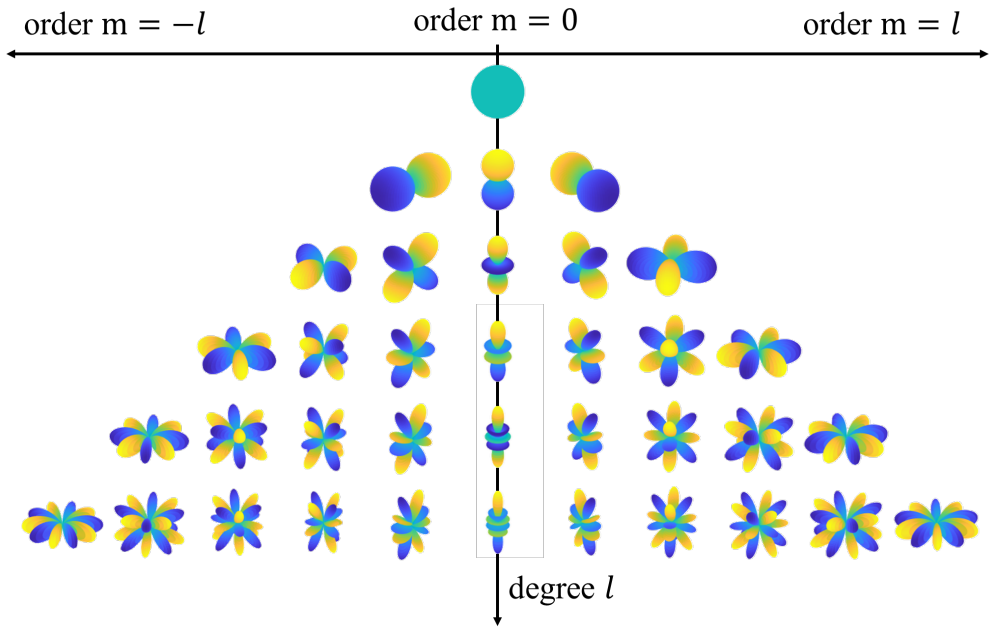
3D aggregate mathematical representation



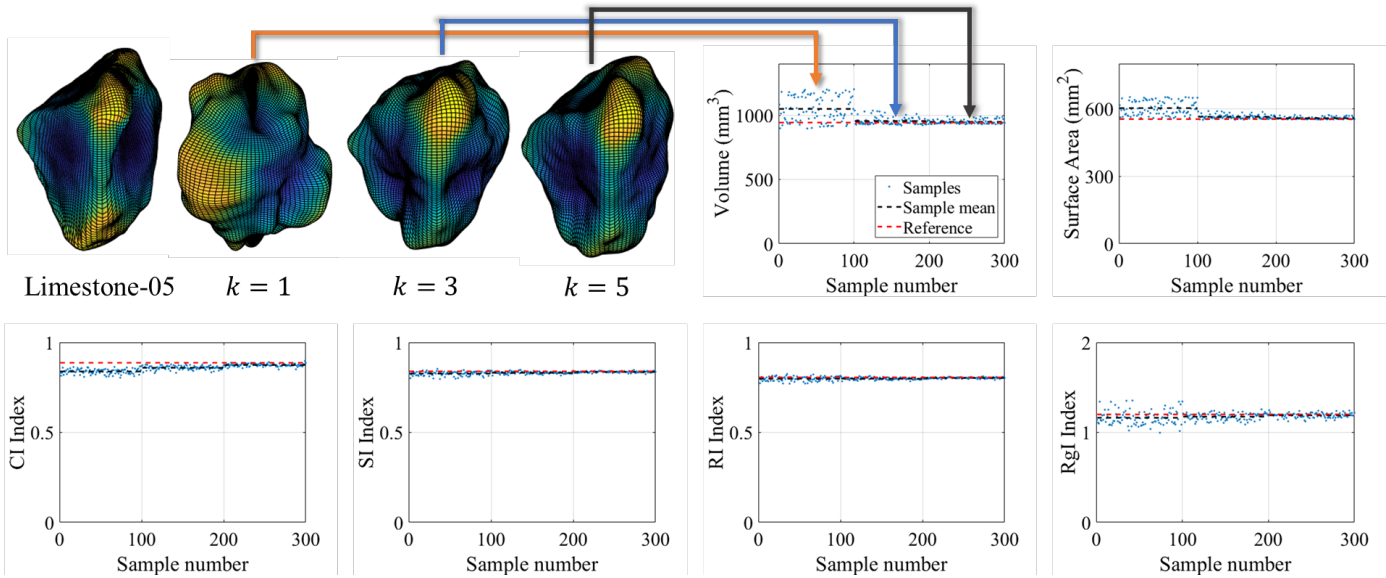
Utilize laser scanner to capture aggregate morphology



Mathematical representation with Spherical harmonics

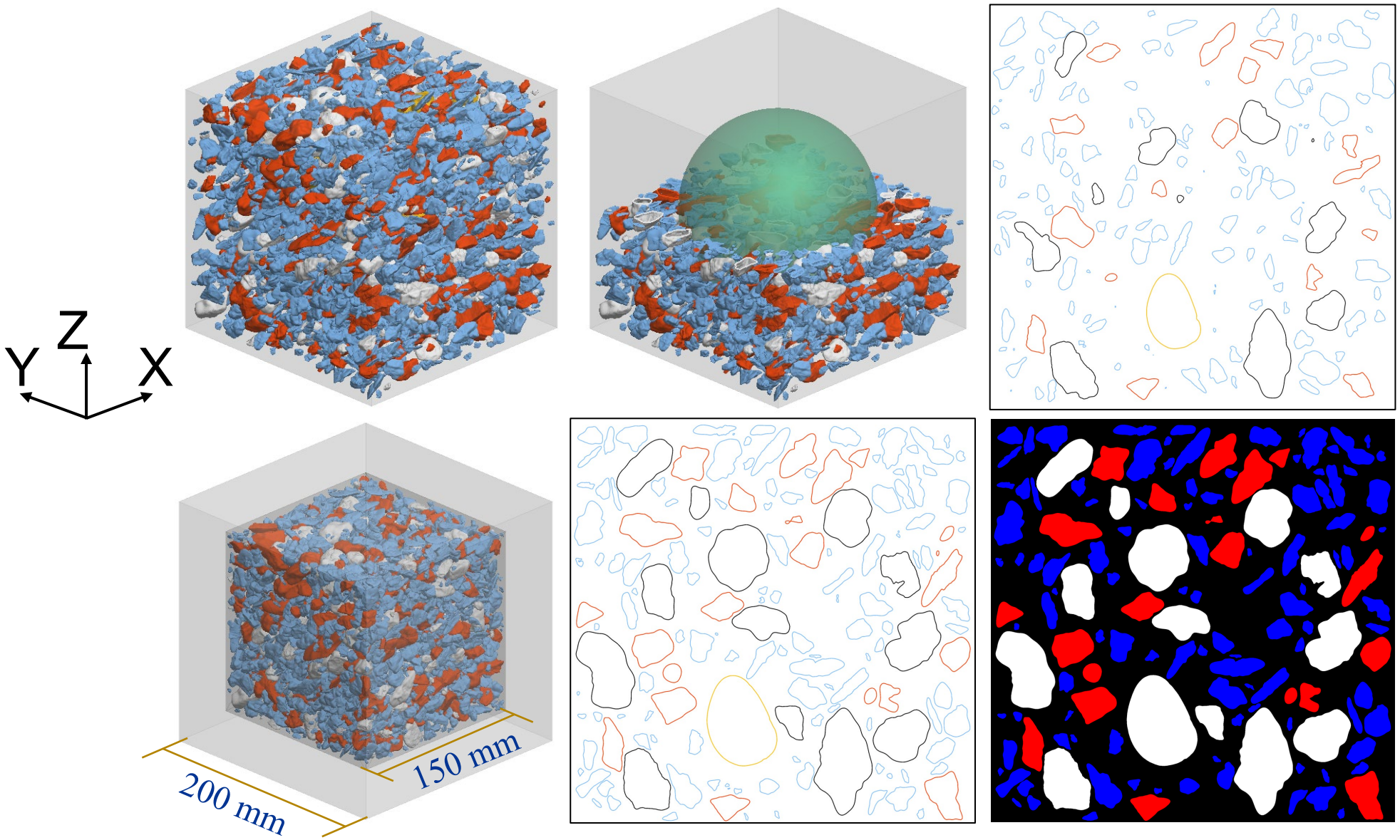


Spherical harmonics expansion



Generate numerous digital aggregate particles with random field theory

Optimal distribution simulation



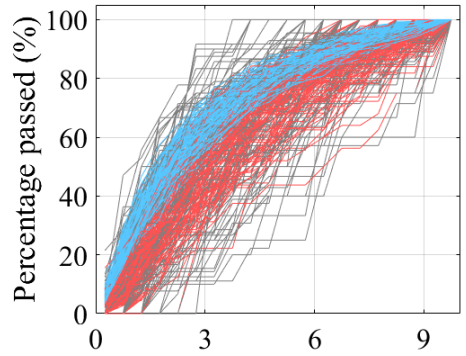
Utilize DEM to get optimal spatial distribution of coarse aggregate

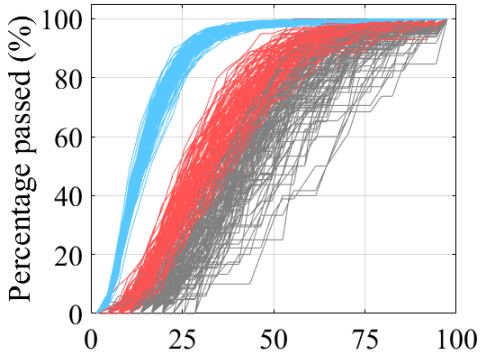
Assessment of concrete consolidation

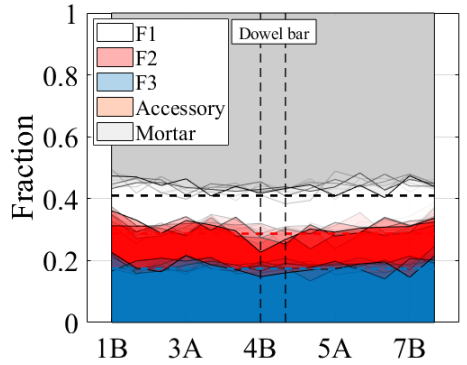
Monte Carlo simulation

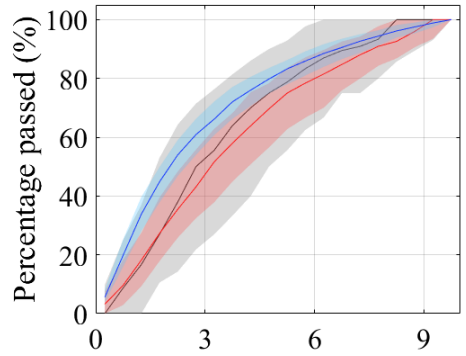
Build a benchmark

Compare with actual concrete experiment

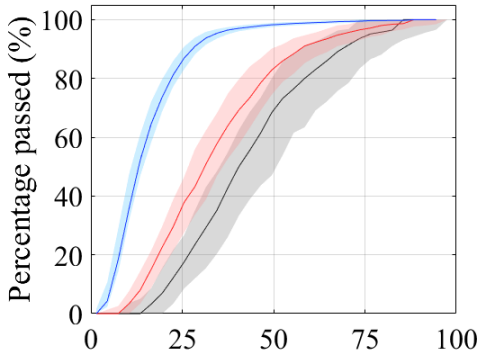




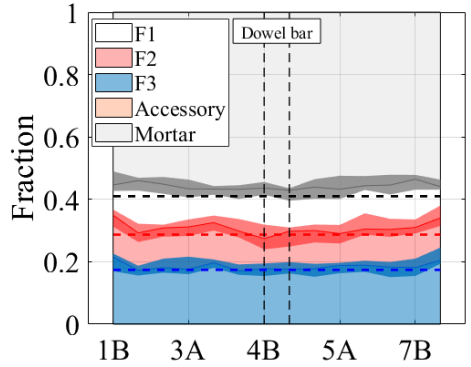




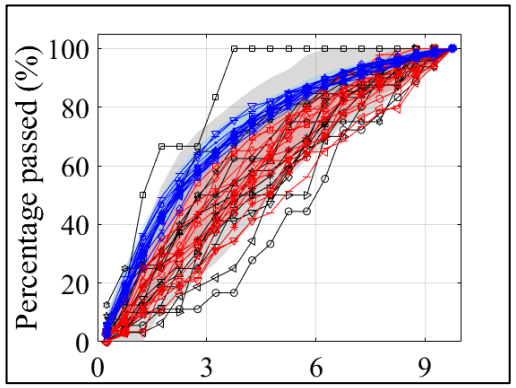
Mortar to agg ratio

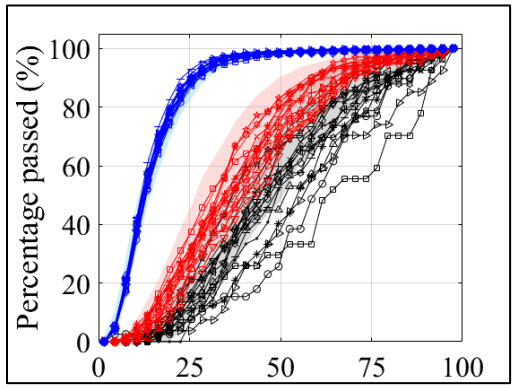


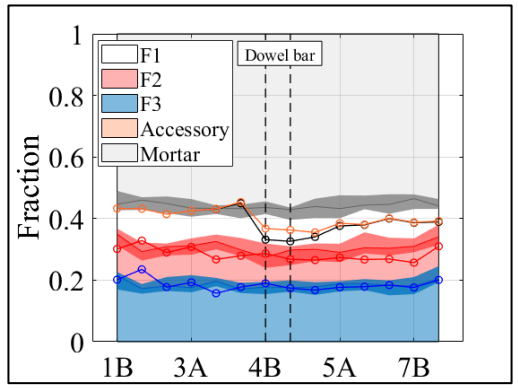
Agg distance (mm)



Area share

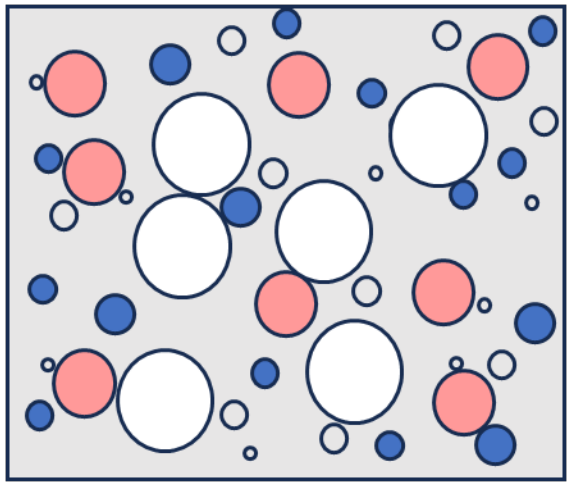






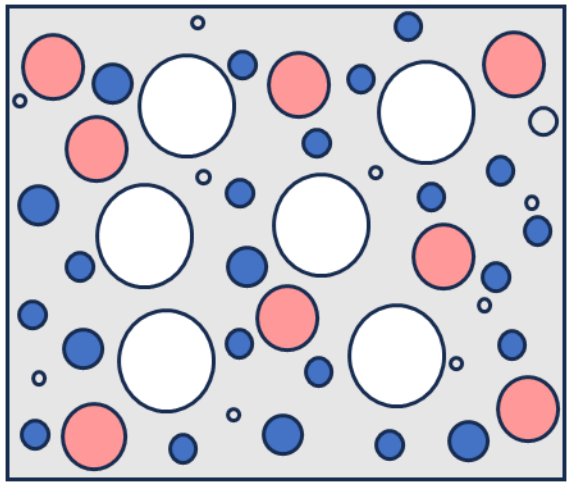
Characterize the quality of consolidation

Summary



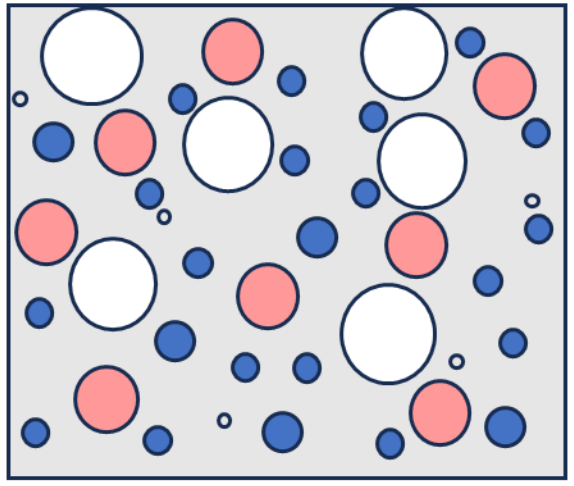
Under consolidation

1. Large entrapped air
2. Granular arches
3. More average mortar around small aggregate



Good consolidation

1. Entrapped air released
2. Granular arches broken
3. Amount of small aggregate increase
4. Average mortar around small aggregate decreases, with an increase in large aggregate
5. Variation of middle aggregate slightly increase



Over consolidation

1. Entrained air released
2. Large aggregate lift-up
3. Average mortar around large aggregate and variation increases significantly
4. Amount of middle aggregate is decreased, with a slight improvement in stability
5. Insignificant change in small aggregate distribution, and even a better stability

Thank you

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- DISCOVER Lab: https://www.fascetti.org