

Early Age Strength Enhancement via Nucleation Seeding: *Role of C-S-H Seeds*

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Philadelphia, PA



imgflip.com



Macro



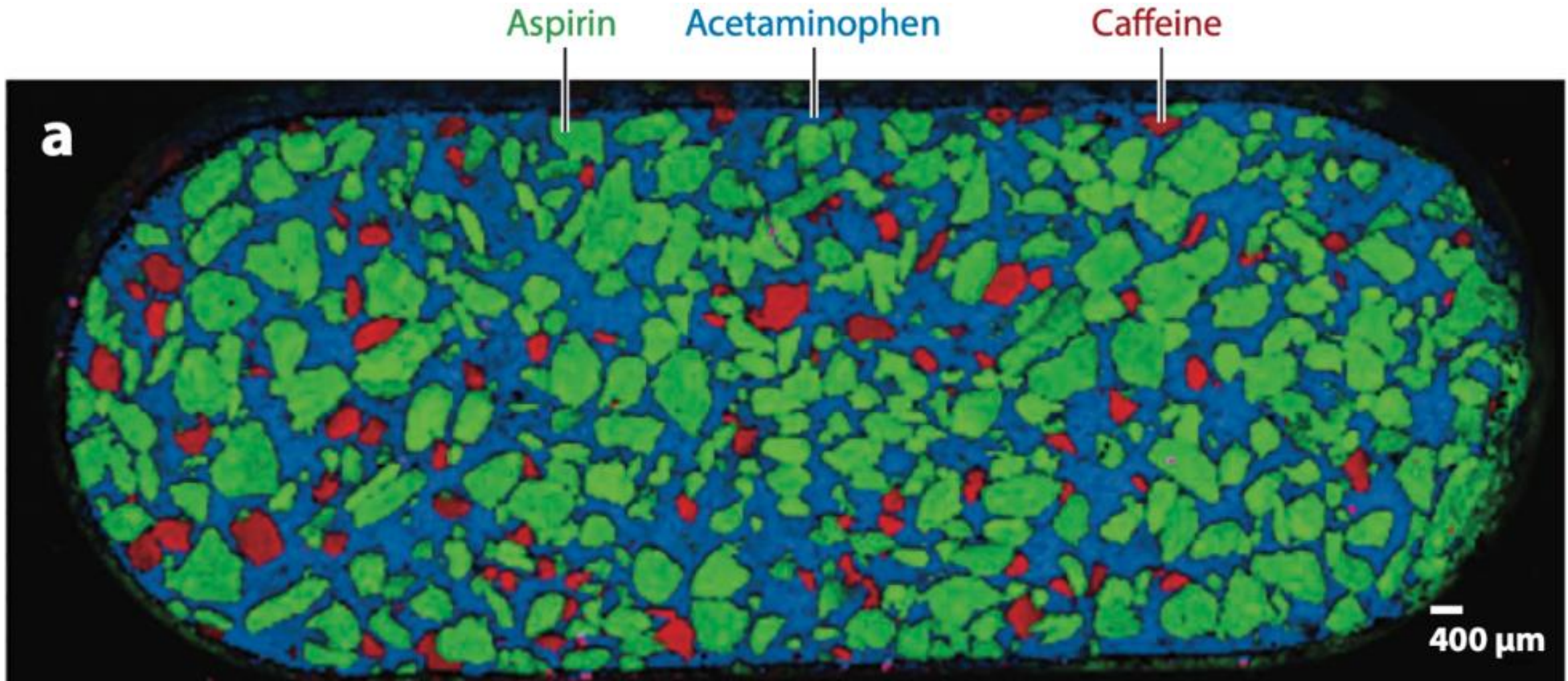
Micro



Nano

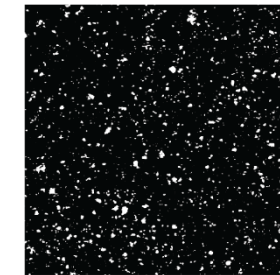
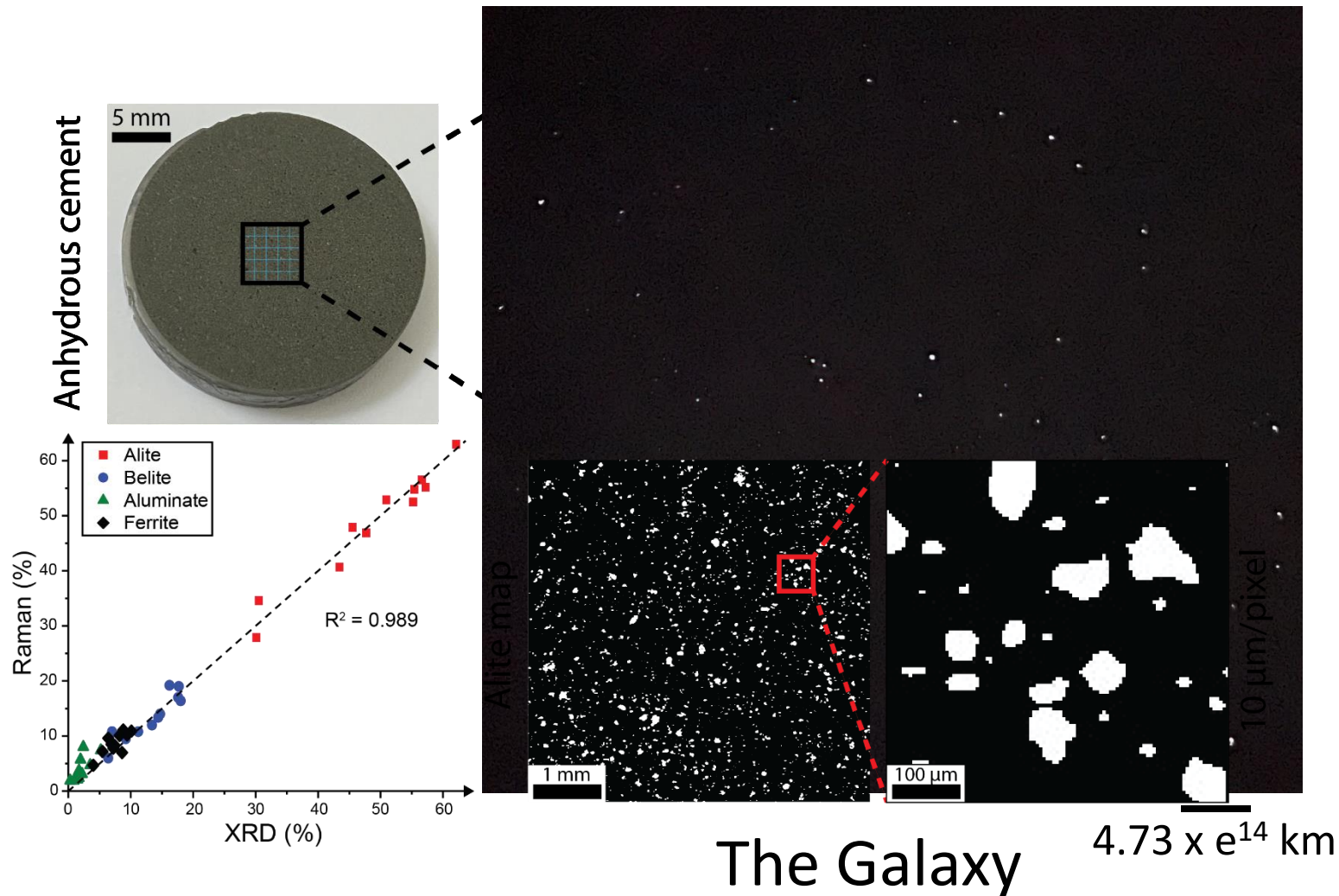


Raman Imaging for phase mapping of composite materials

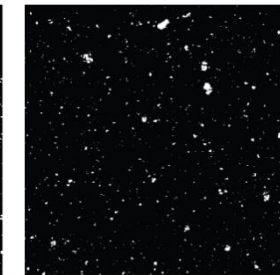


Stewart et al., *Ann. Rev. Anal. Chem.* **2012**

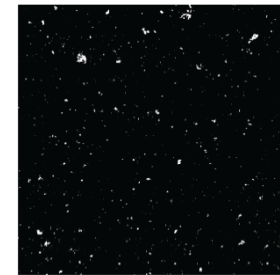
Ordinary Portland Cement – Raman Imaging Results



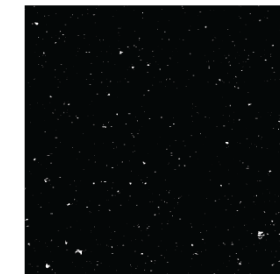
Alite (55.5 %)



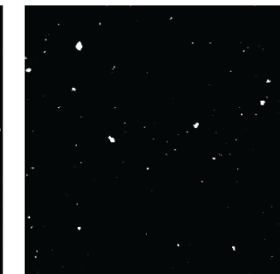
Belite (17.2%)



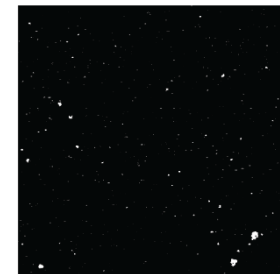
Ferrite (10.0 %)



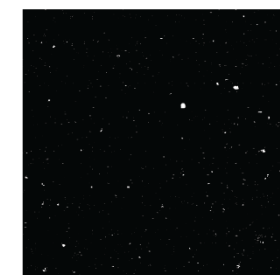
Aluminate (3.3 %)



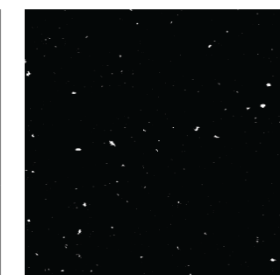
Anhydrite (3.0 %)



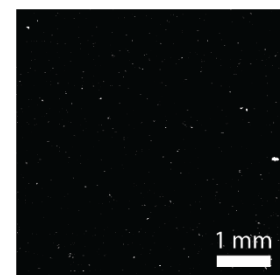
Calcite (2.8 %)



Gypsum (2.4 %)



Dolomite (1.1 %)



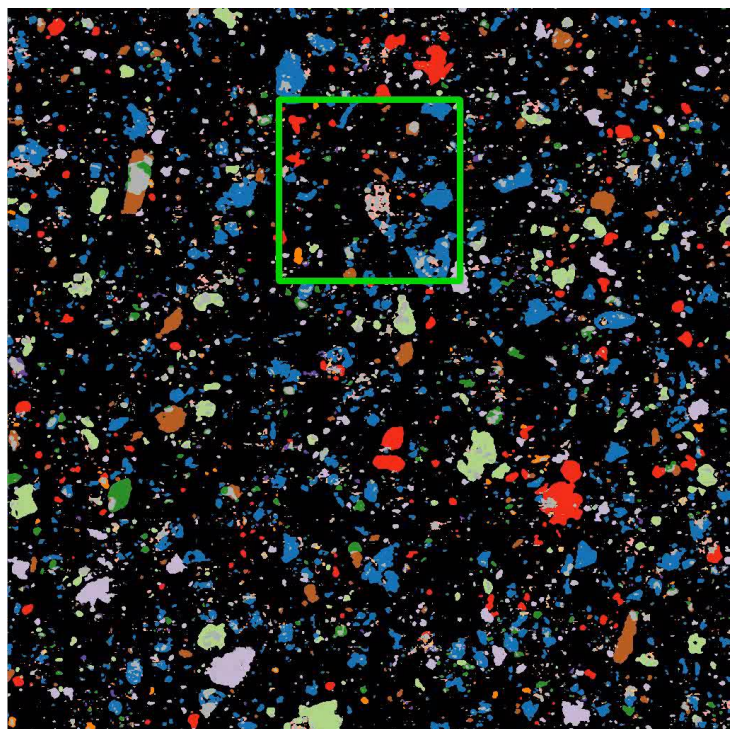
Quartz (1.0 %)

Polavaram and Garg, *Cem. Concr. Res.* **2021**

Size and Shape Distribution of Individual Clinker Phases

Anhydrous Cement

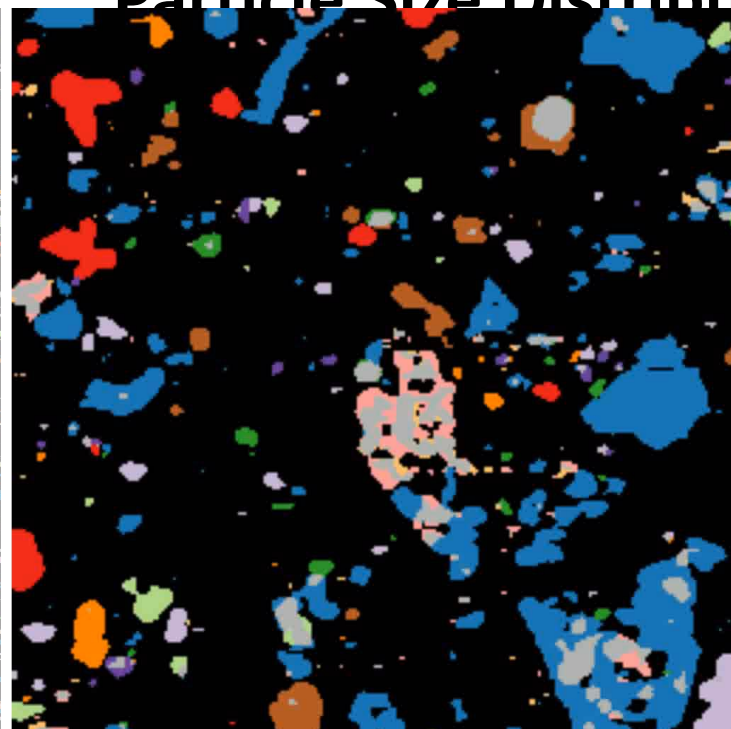
Raman Image



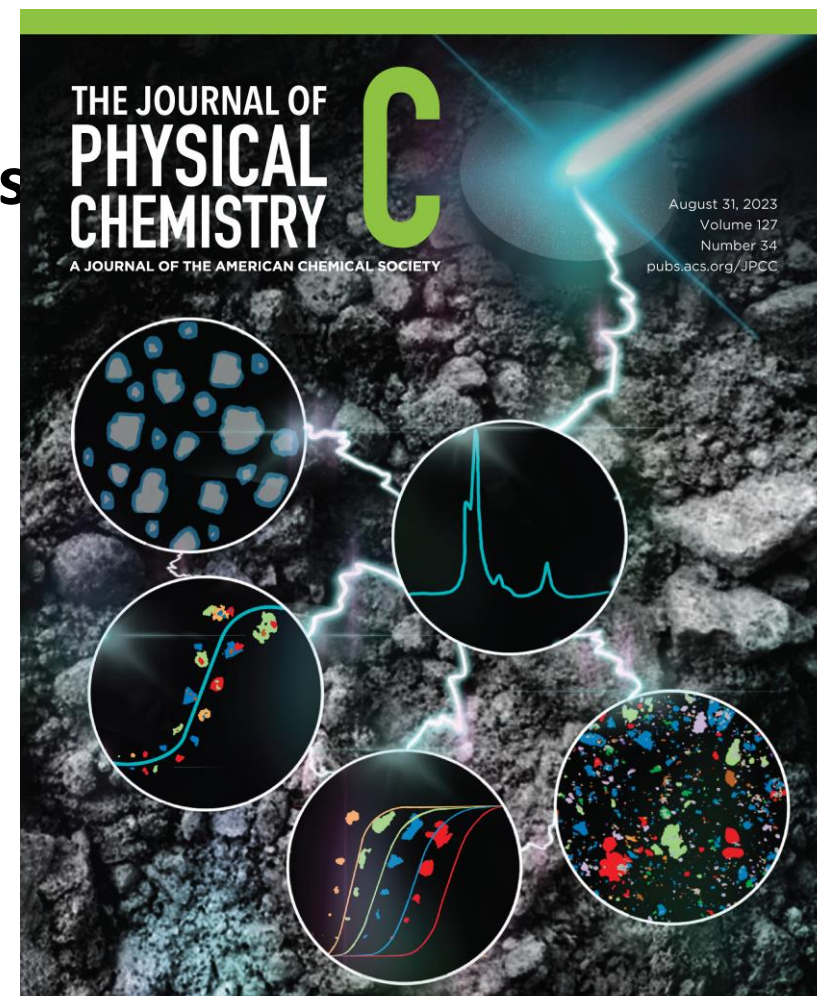
100 μm



Raman Image - Inset
Phase-Specific
Particle Size Distributions



10 μm



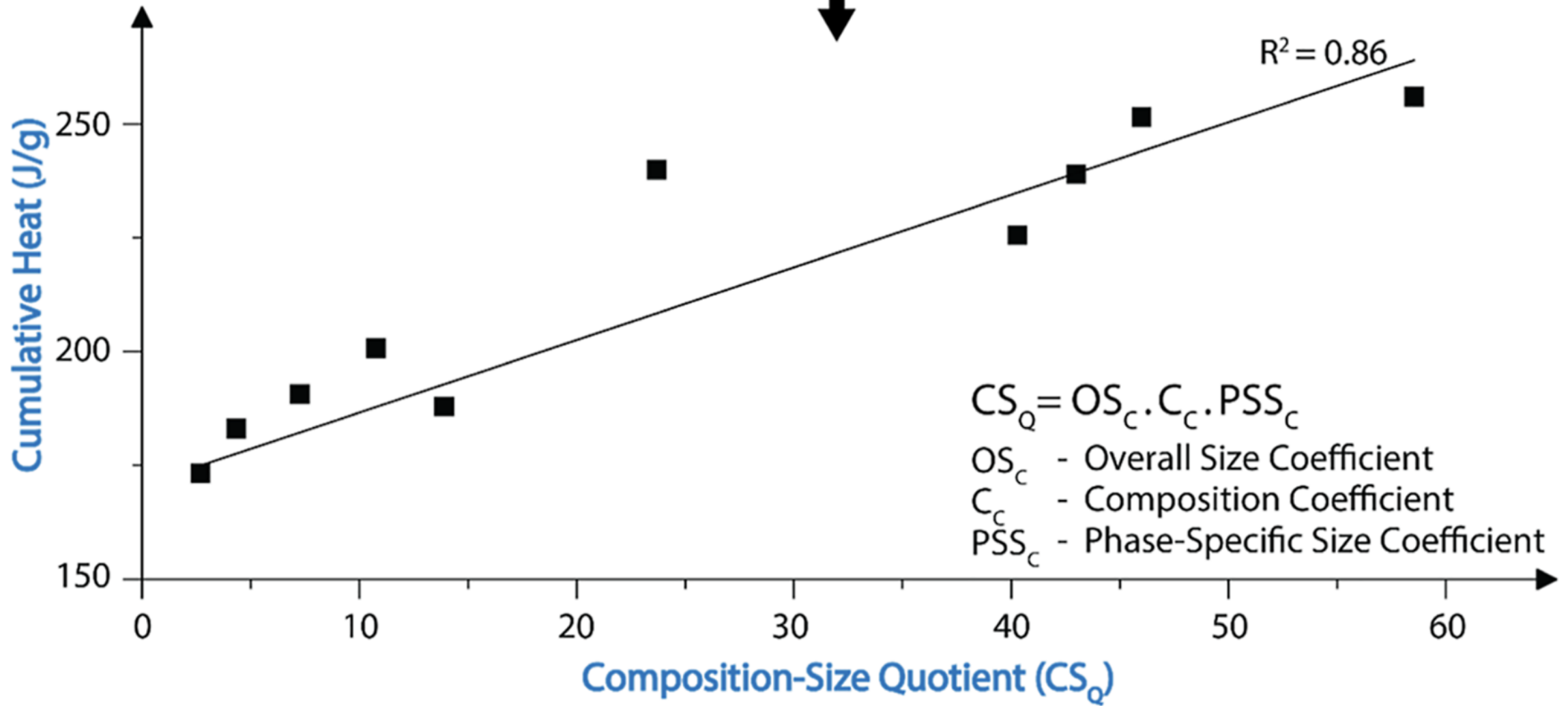
ACS Publications
Most Trusted. Most Cited. Most Read.

Elucidating the Size and Shape of Individual Clinker Phases via Raman Imaging: Impact on Cement Hydration

Krishna C. Polavaram and Nishant Garg

www.acs.org

Polavaram and Garg, *J. Phys. Chem. C*. 2023

d Raman Imaging - (Size + Composition)



Macro



Micro

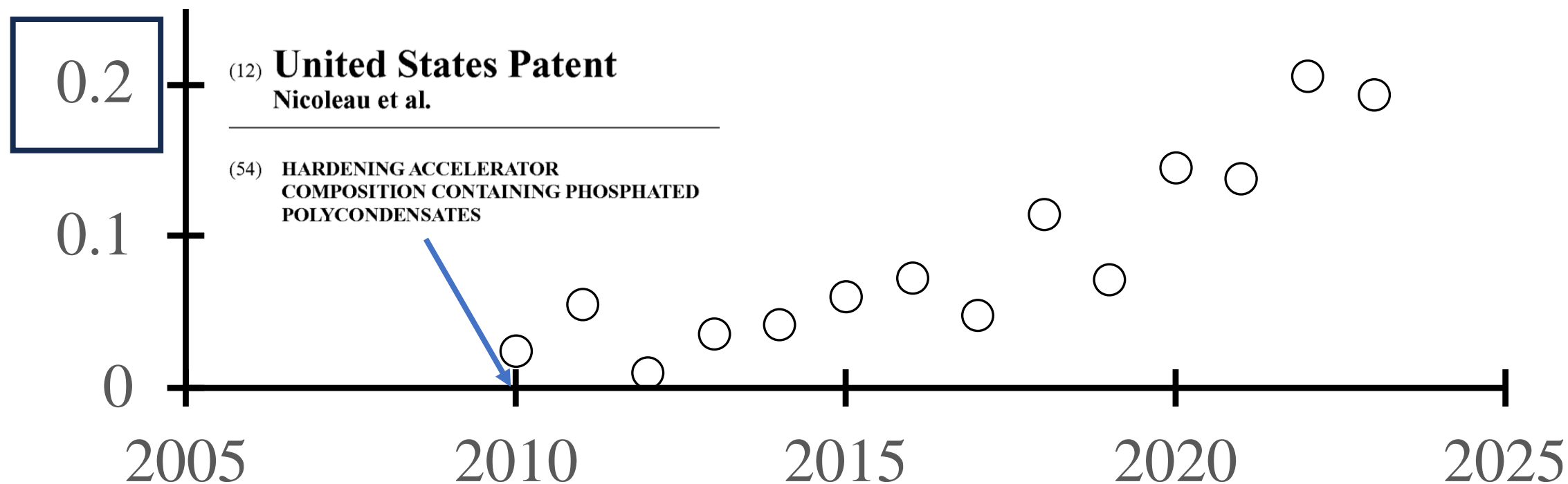


Nano



C-S-H Seeds – Prevalence in Literature

Normalized Data (%)

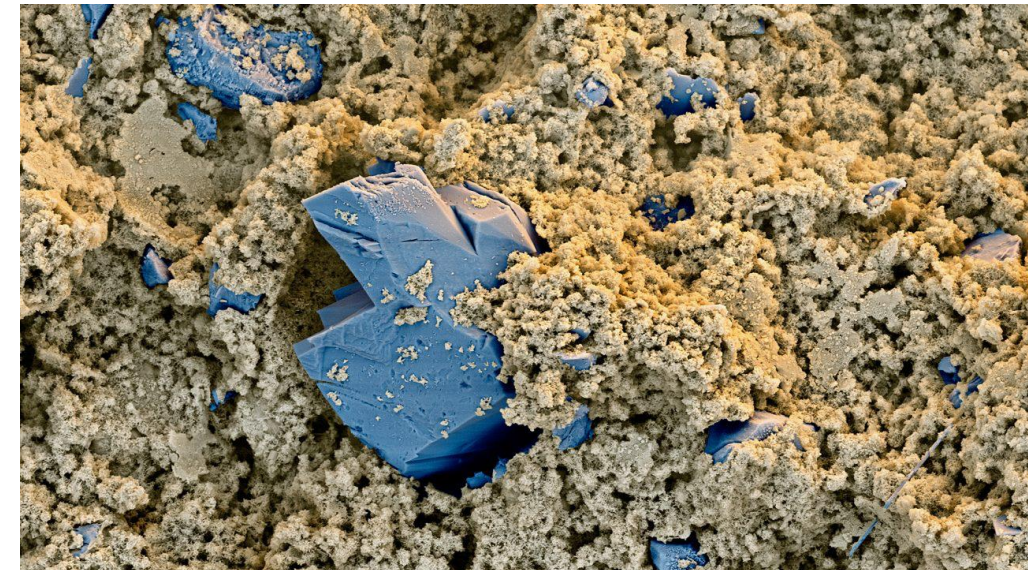


Research Objectives:

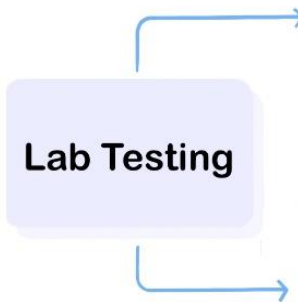
- 1) How do commercial C-S-H seeds influence hydration kinetics?
- 2) What's their impact on strength as well as porosity?
- 3) What new insights can be obtained via systematic microstructural investigations?

Master X-Seed[®]

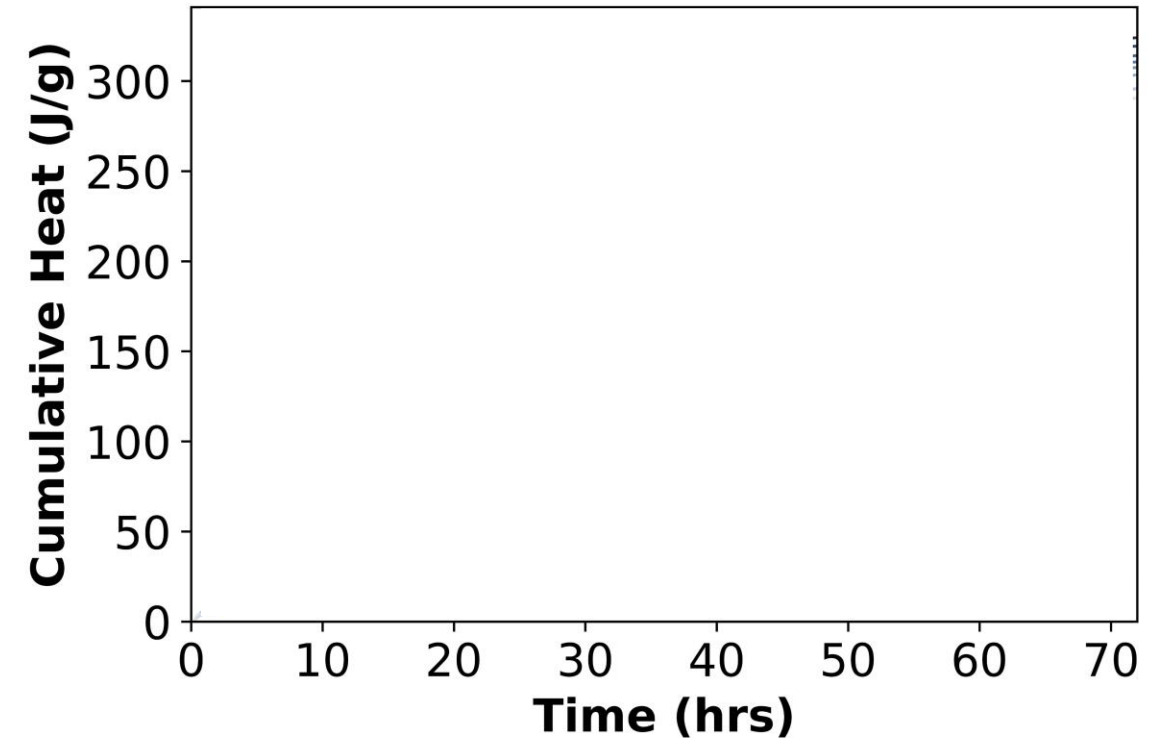
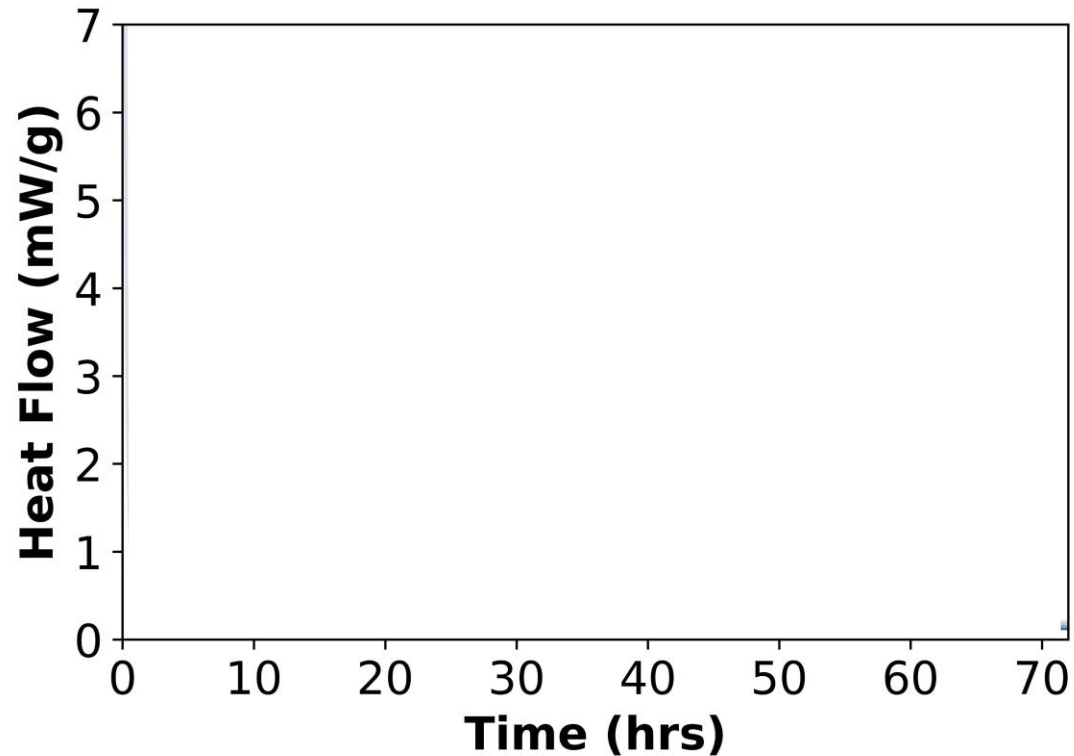
A commercial hardening accelerator from Master Builders



Materials and Methods



Kinetics – Isothermal calorimetry

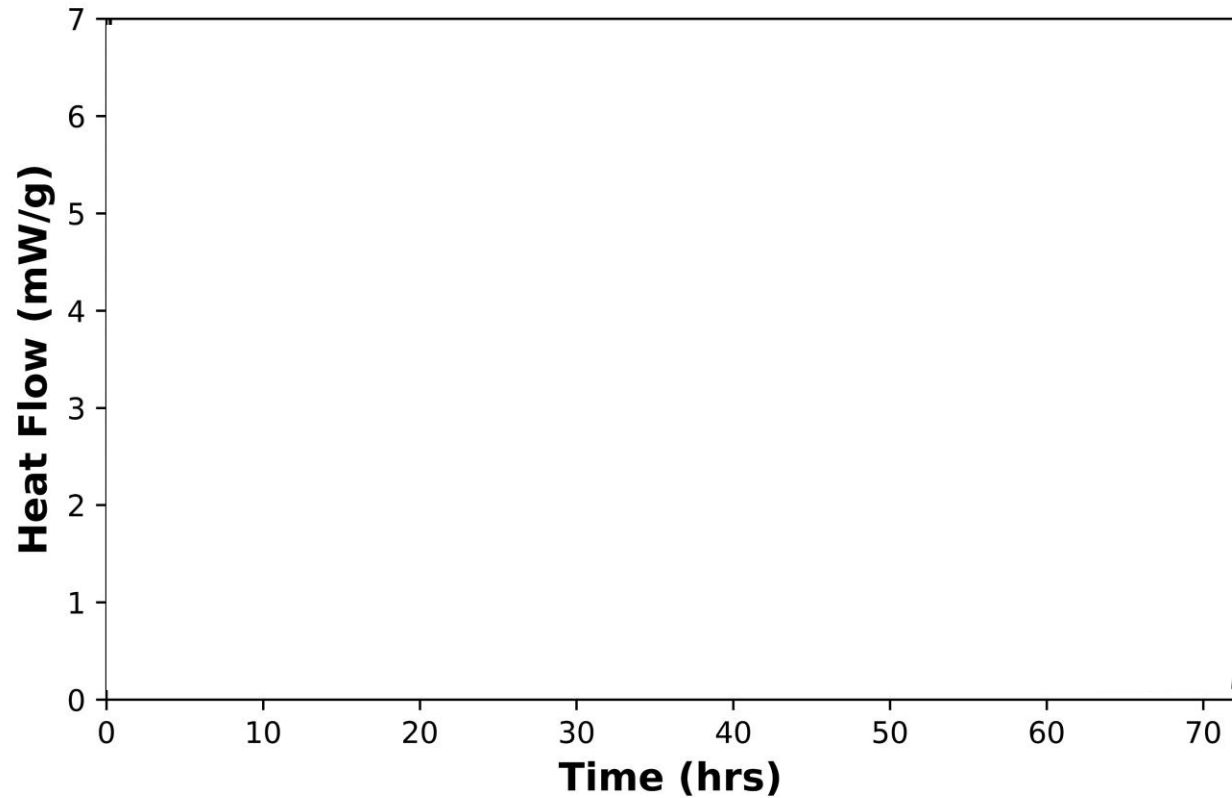


- Acceleration takes place
- Increases the degree of hydration

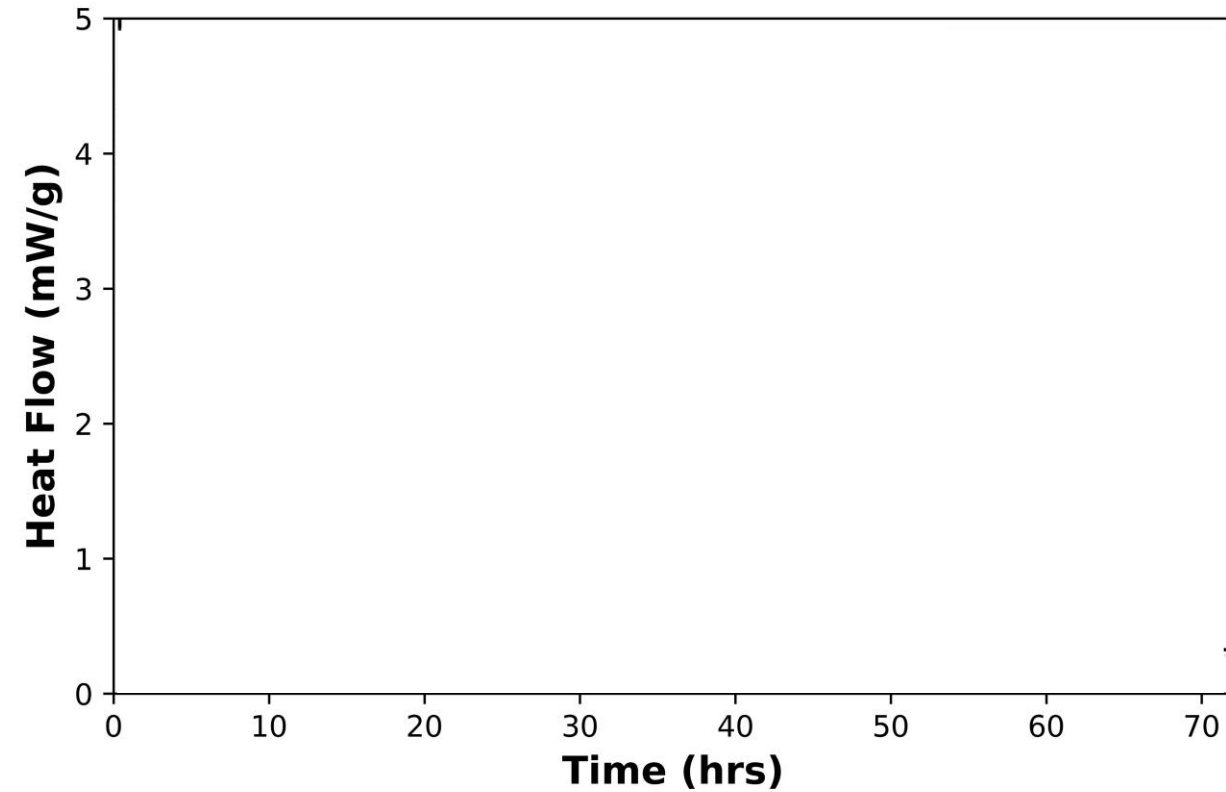
Qadri et al., *Mat. Today Com.* **2024**

A tale of two admixtures

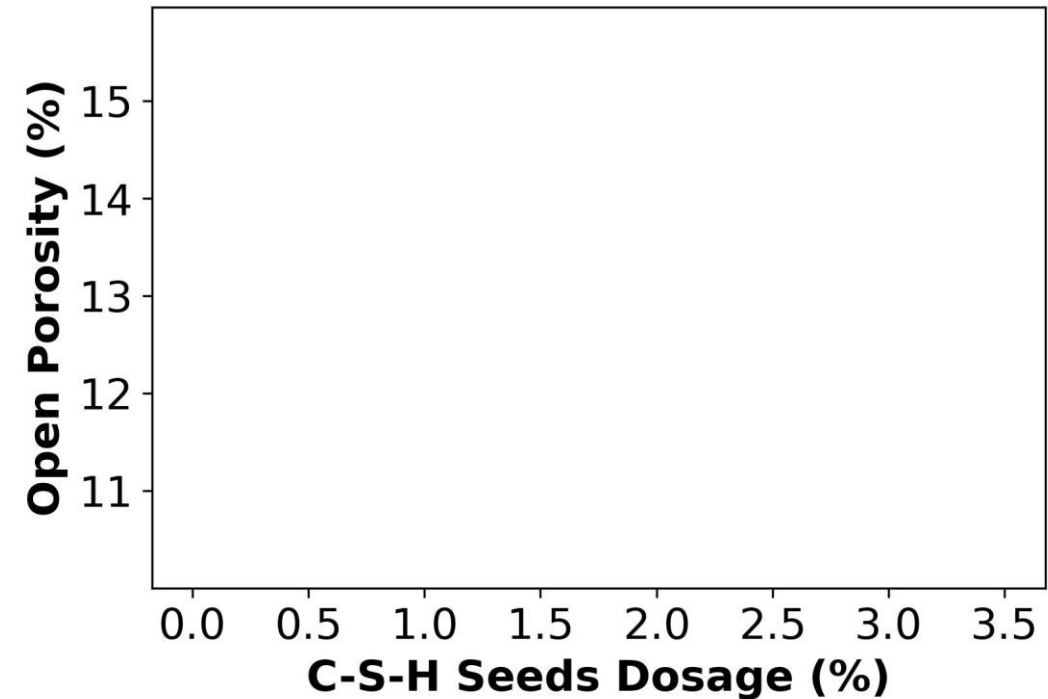
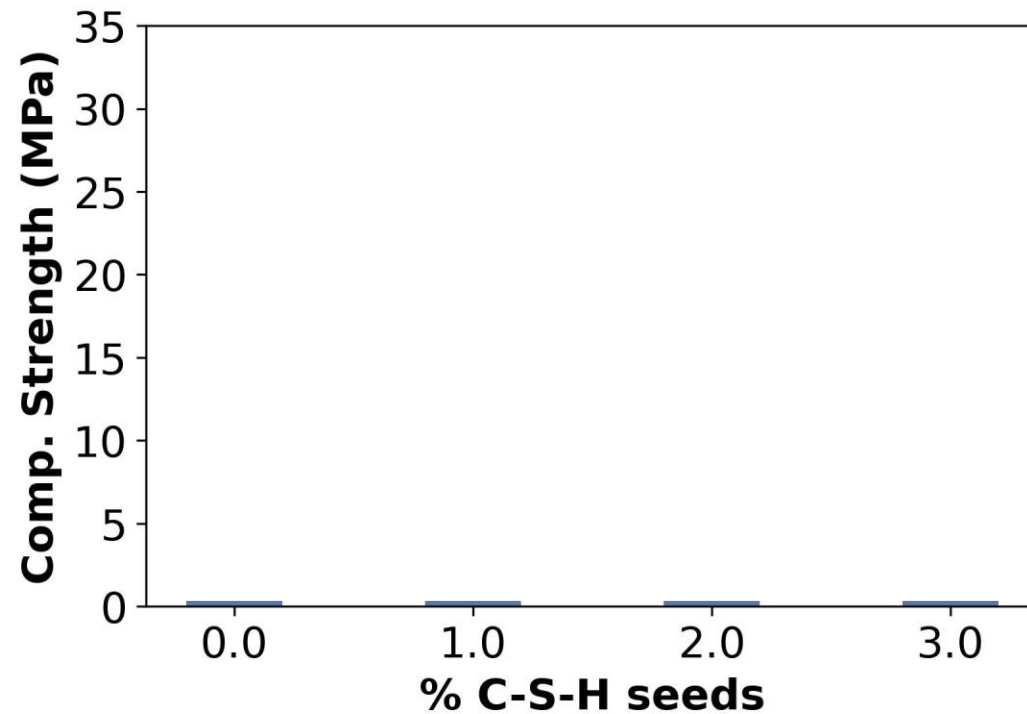
X-Seed 44



X-Seed 55



Enhancement in strength and open porosity

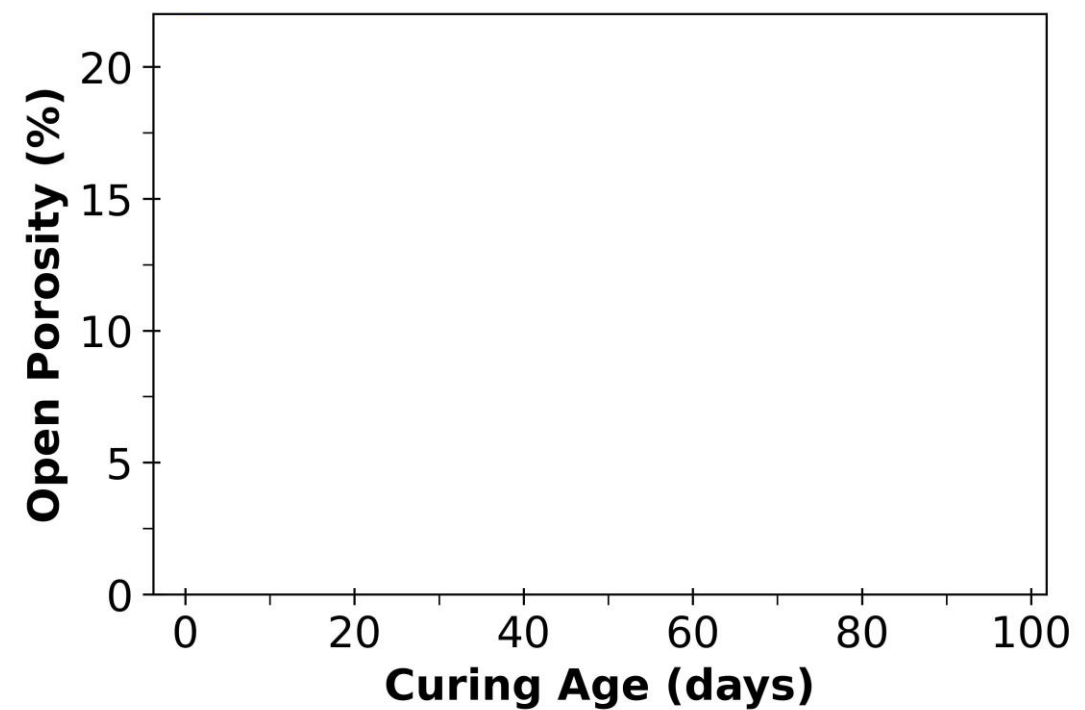
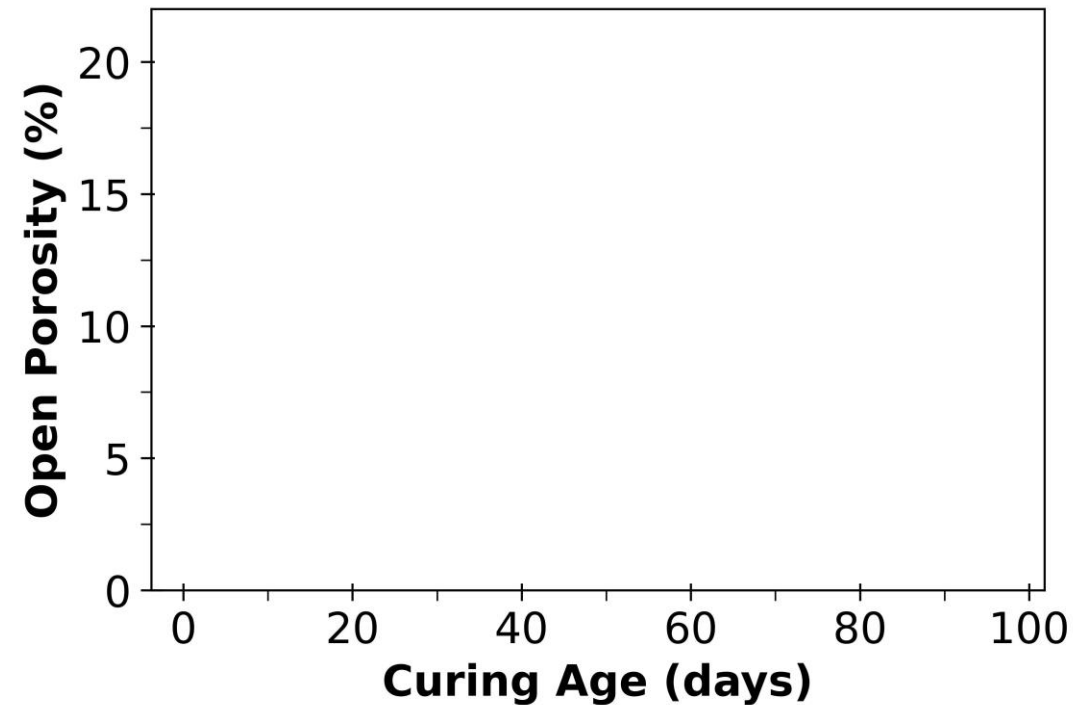


With C-S-H seeds:

- Strength increases
- Open porosity decreases

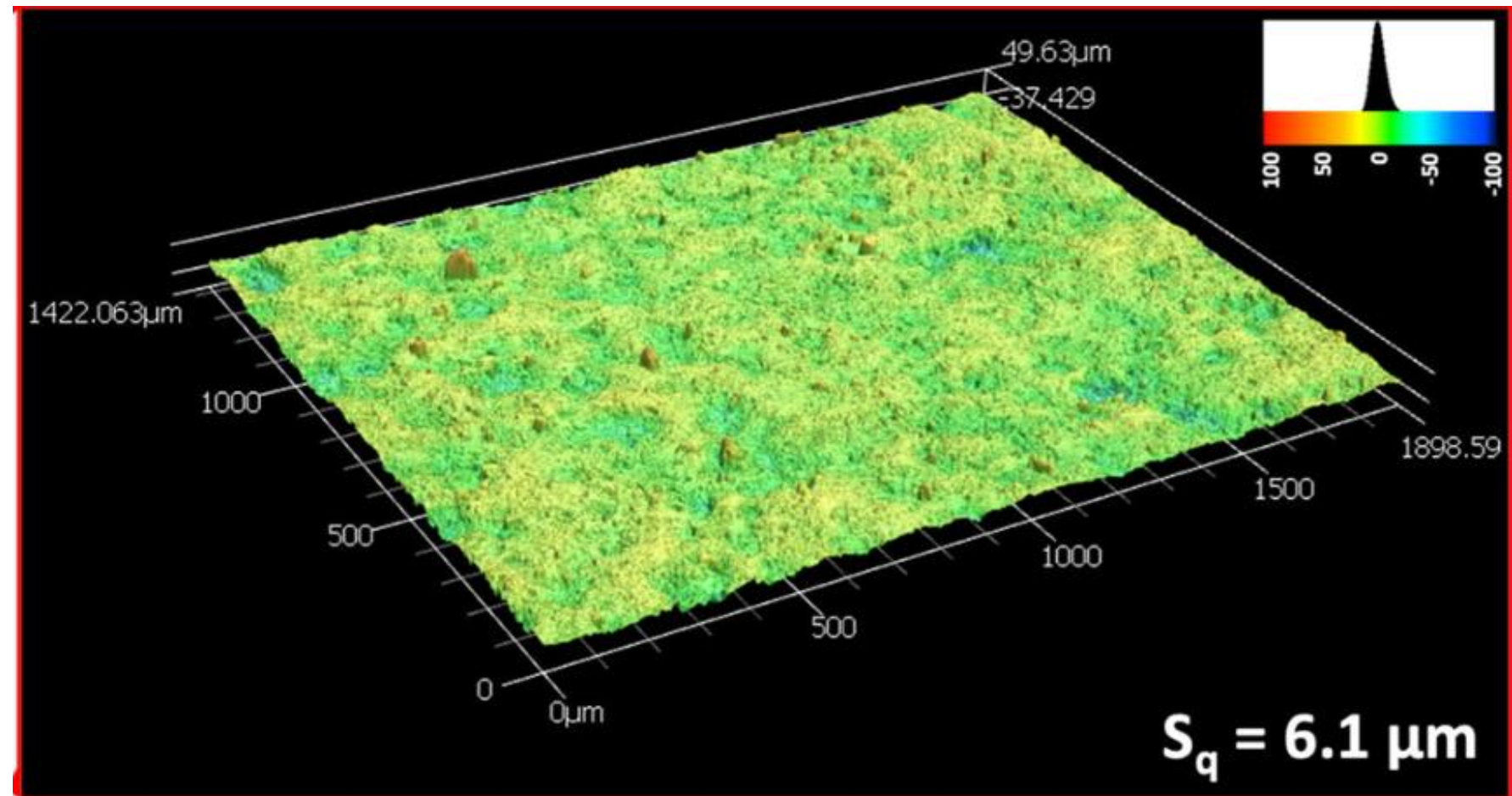
Qadri et al., *Mat. Today Com.* **2024**

Microstructure refinement – blended cement



Porosity decreases at all ages

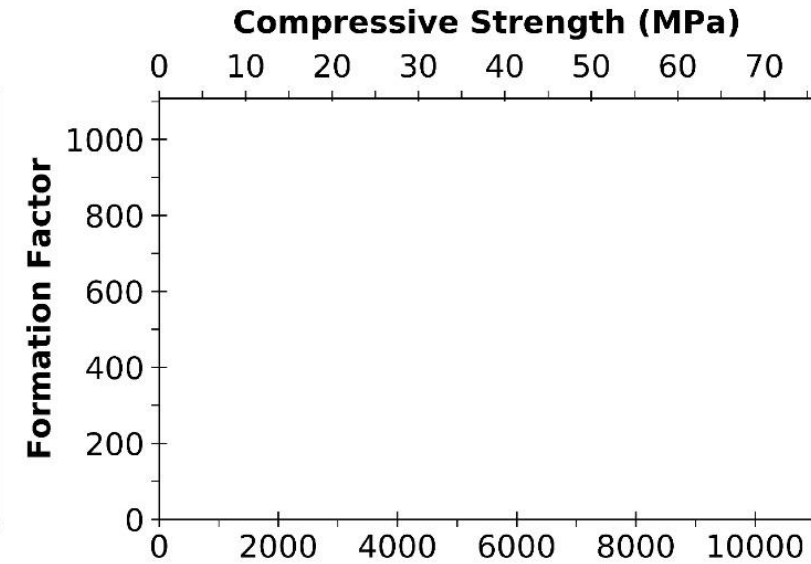
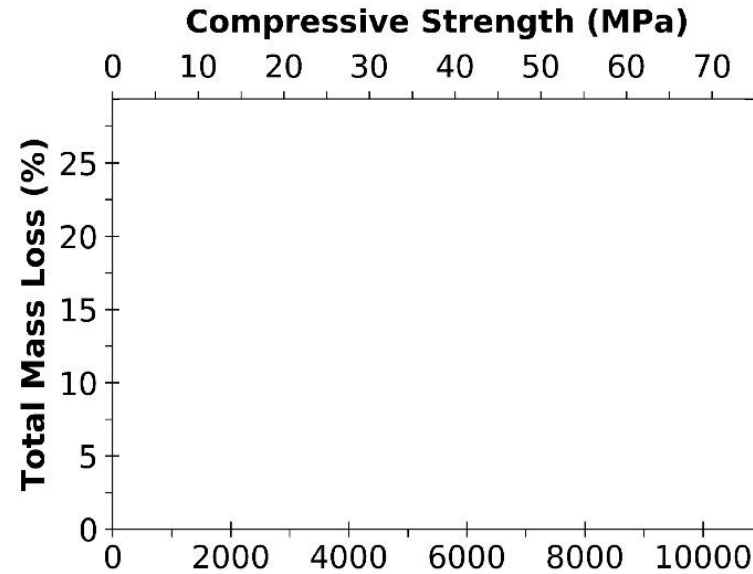
Microstructure refinement – surface roughness via Laser Profilometry



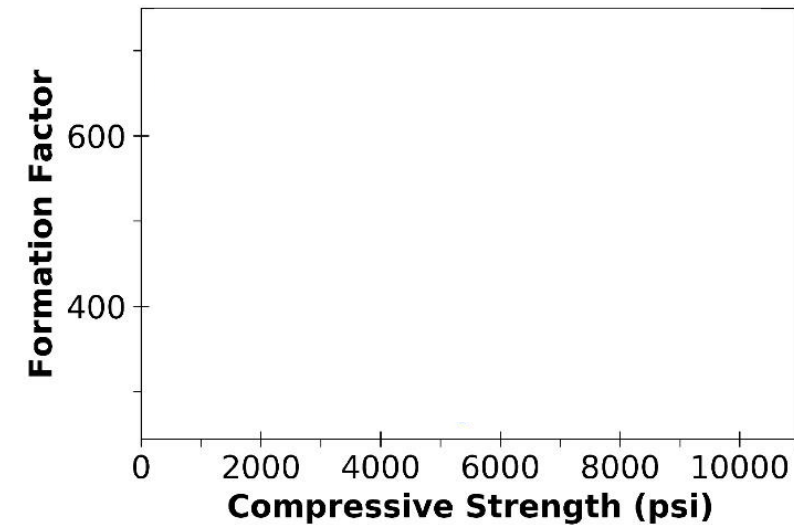
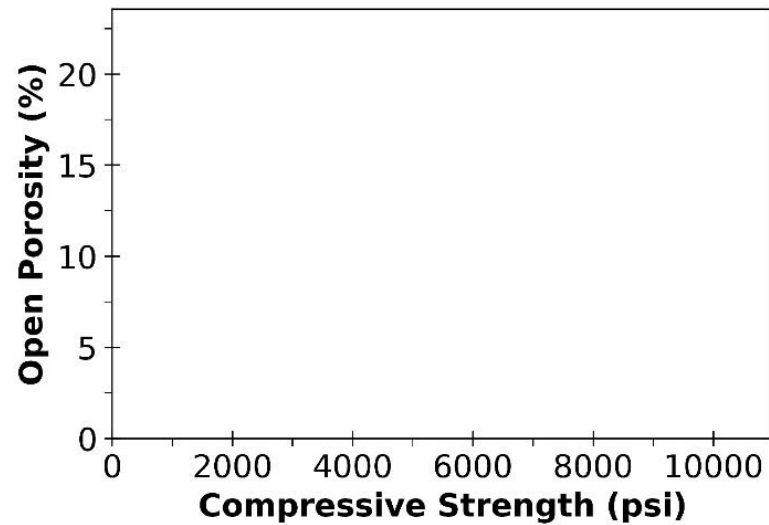
Qadri et al., *Mat. Today Com.* **2024**

Kabir & Garg, *npj Mat. Deg.* **2023**

Correlations



From the lab

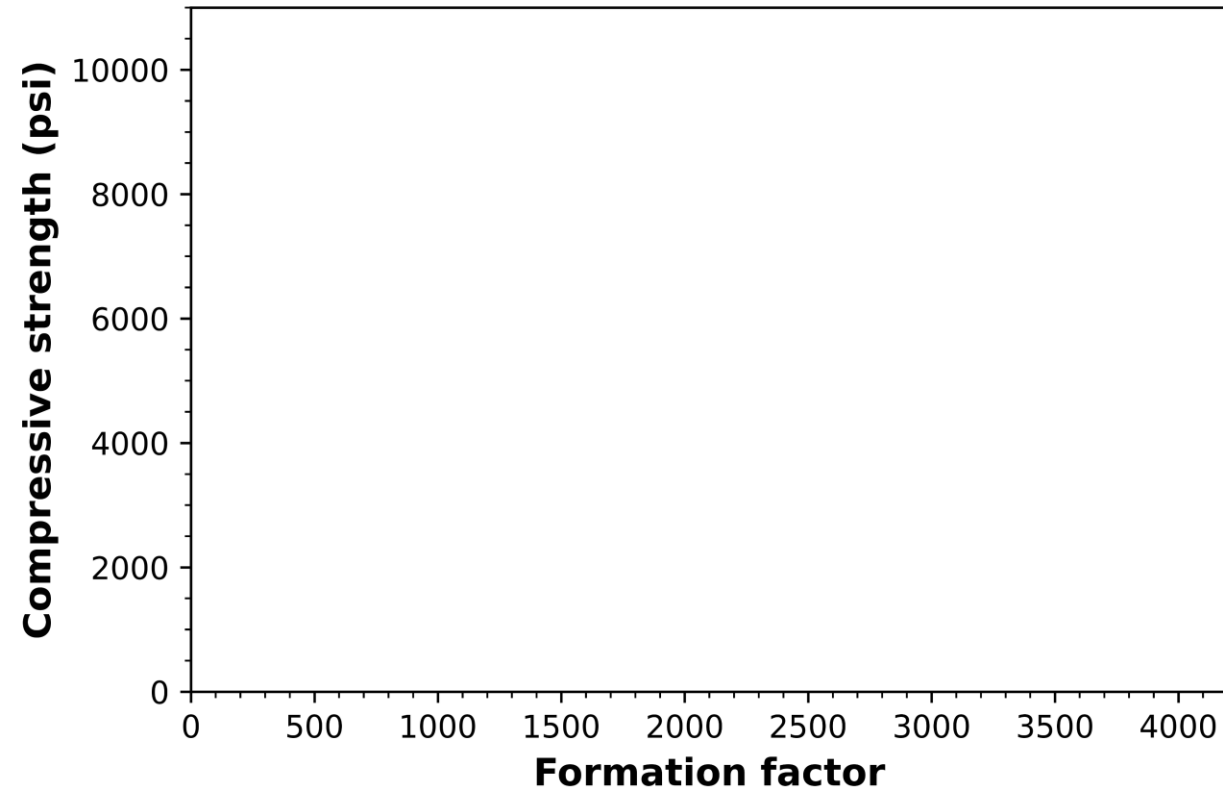


From the field

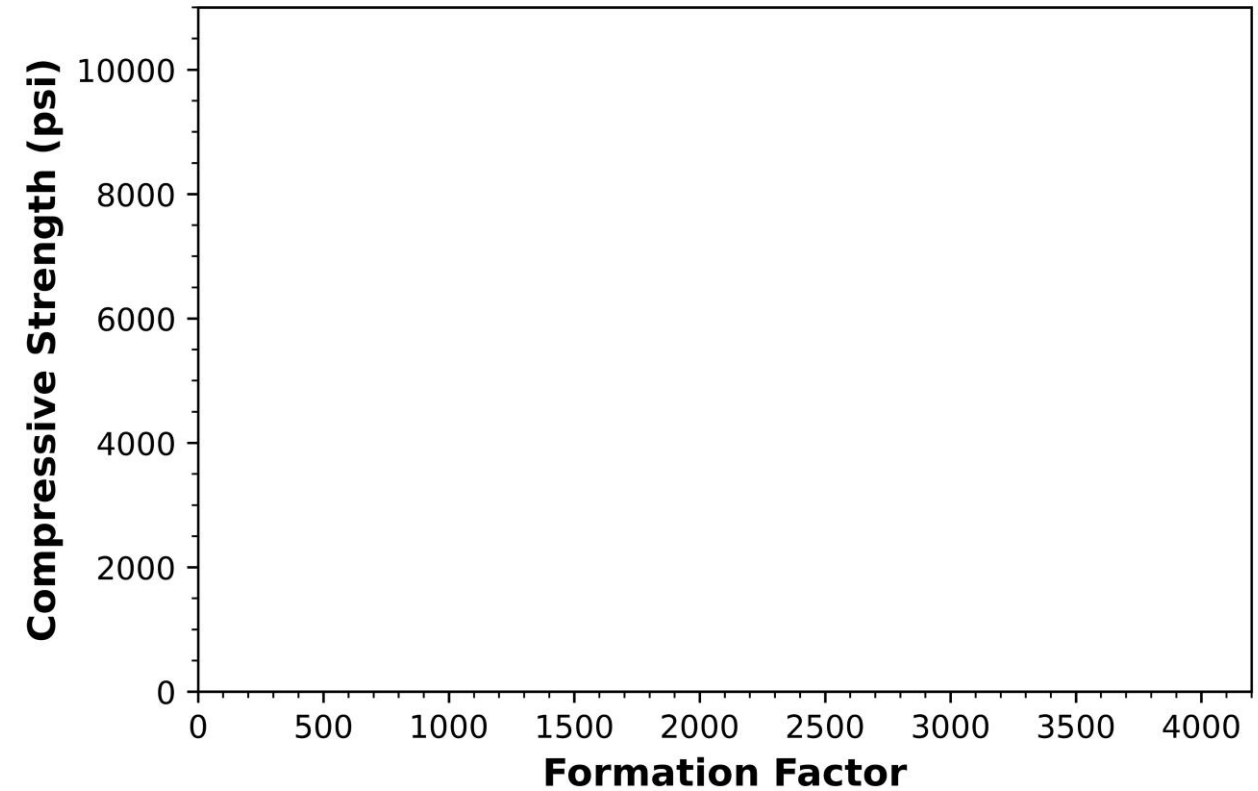
Qadri and Garg, *Case Studies of Con. Mat.* 2023

Formation factor vs. compressive strength

Lab data



Field data



Field Implementation in Illinois

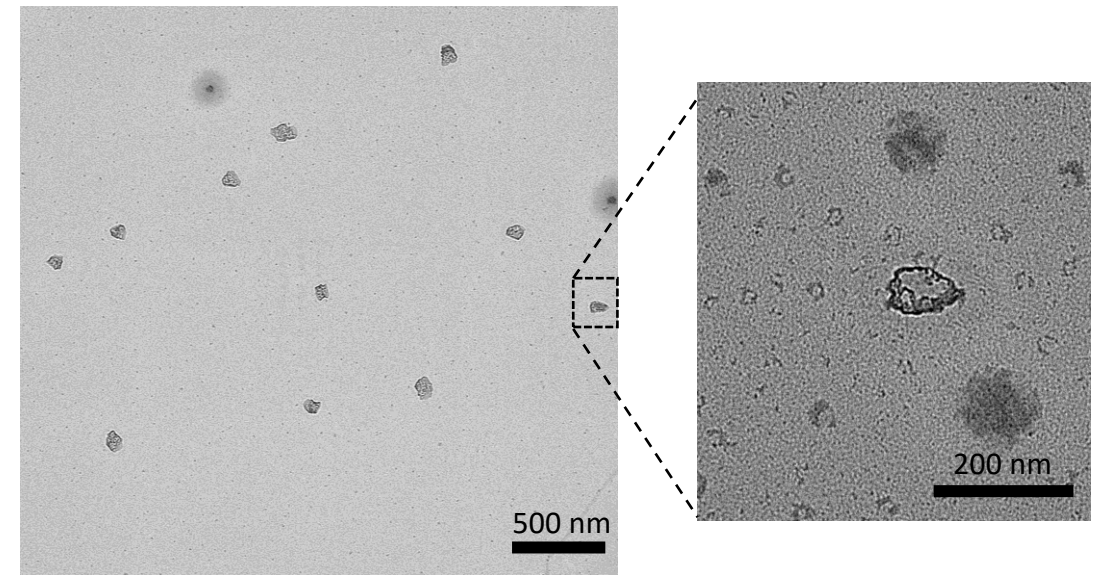
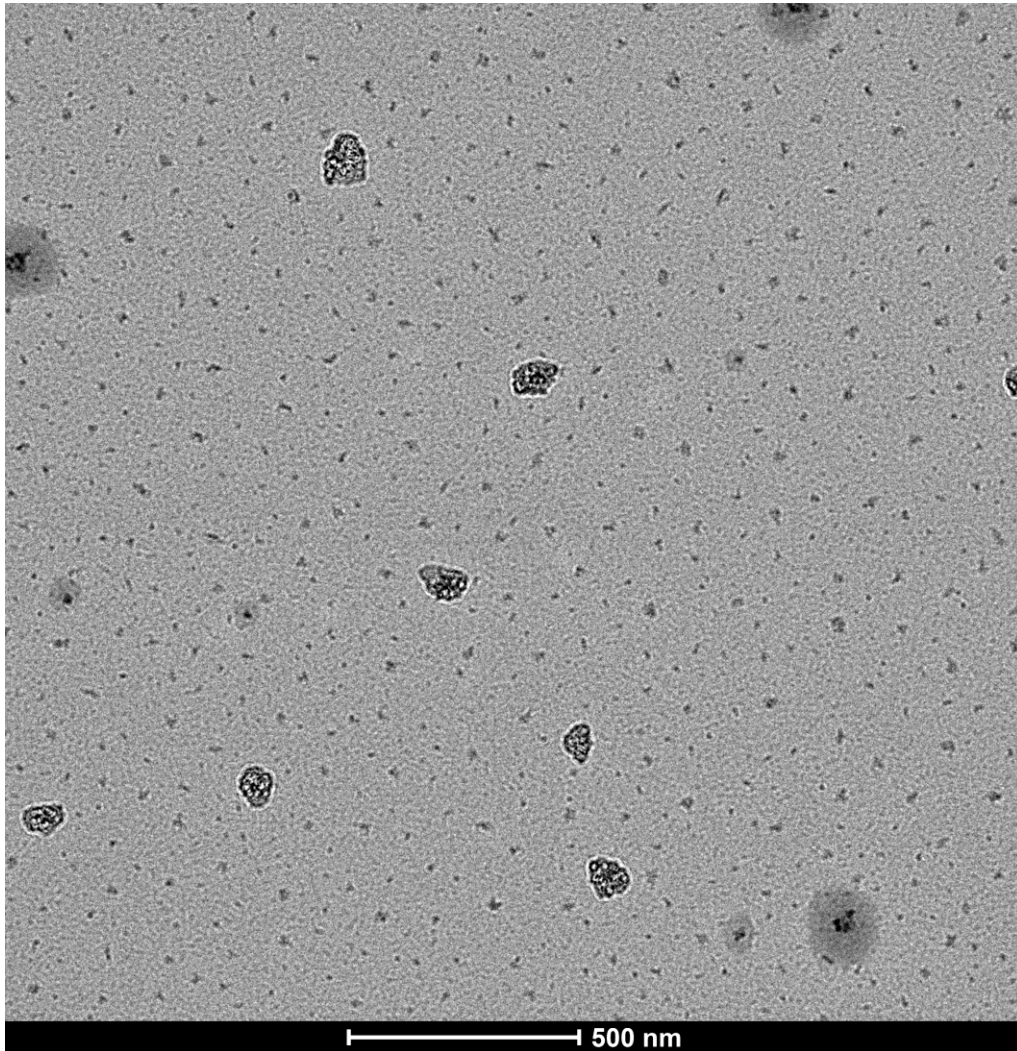
State of Illinois in the US



● Armstrong in Vermilion County



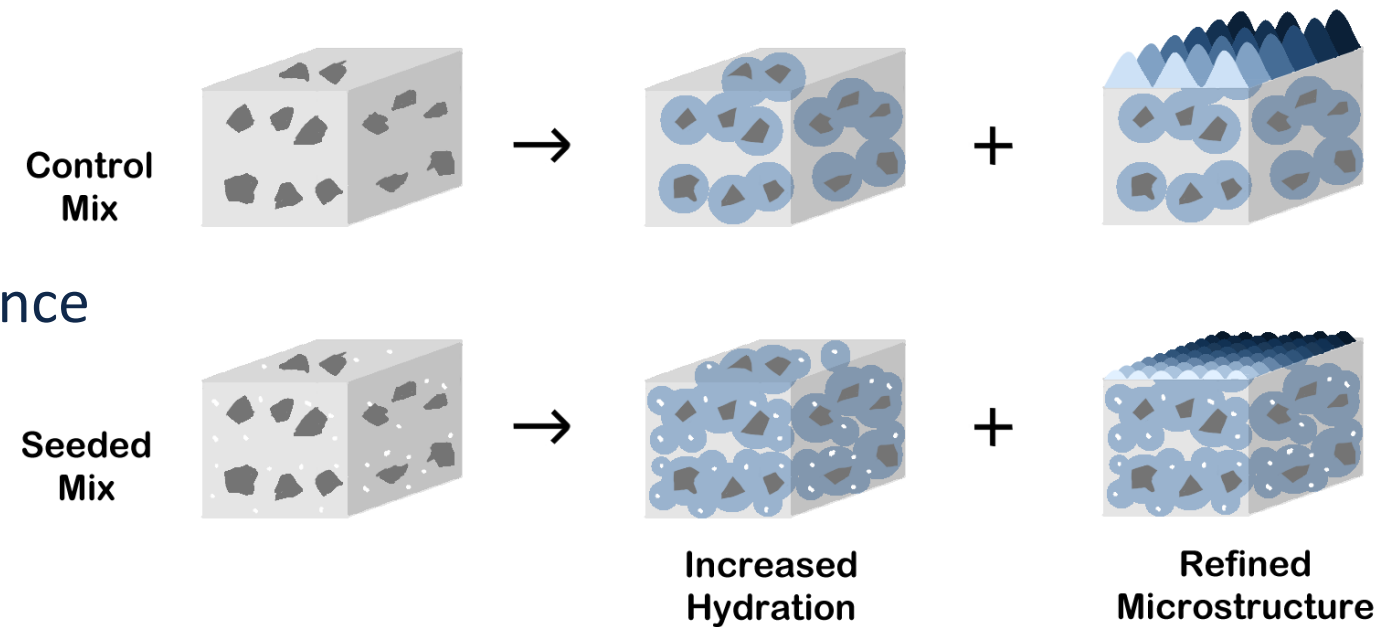
Some TEM images



Contributions

- C-S-H seeds affect the kinetics depending on the dispersion medium. Excess of PCE may cause set time retardation.

- Based on the Helium pycnometry and laser profilometry, there's evidence that C-S-H seeds refine the microstructure



- An application in the field proved the efficiency of using these seeds.

Qadri et al., *Mat. Today Com.* **2024**
Qadri and Garg, *Case Studies of Con. Mat.* **2023**

Acknowledgements

