

Experimental Investigation of Fracture Toughness in Coal Combustion Ash Concrete Using 4D X-ray CT

Student: Soniya Tiwari
Advisor: Laura E. Dalton

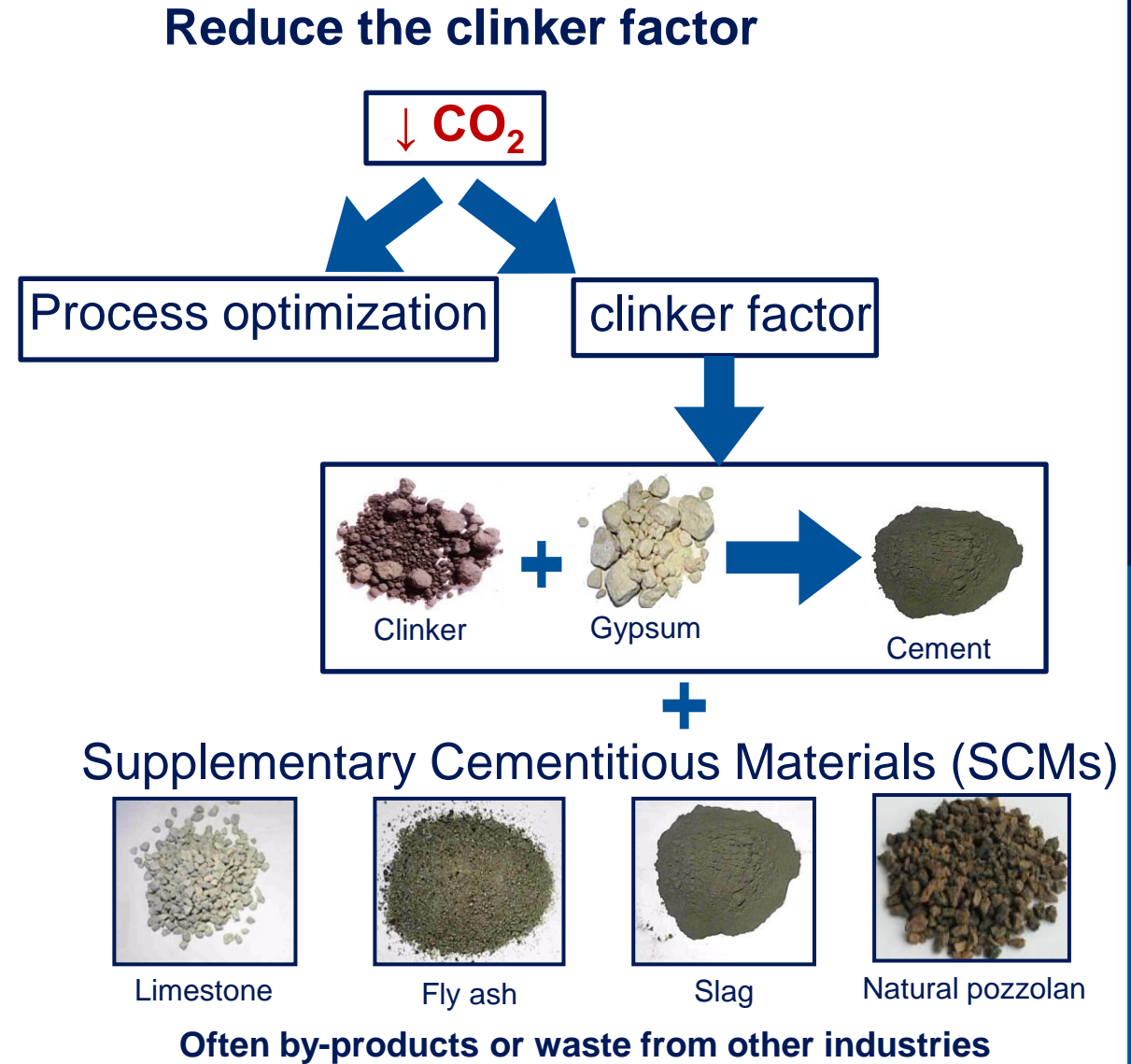
**Department of Civil and Environmental Engineering, Duke University,
Durham, NC**

Outline

- **Background**
- **Research Motivation**
- **Methods**
- **Ongoing Results**
- **Next Steps**

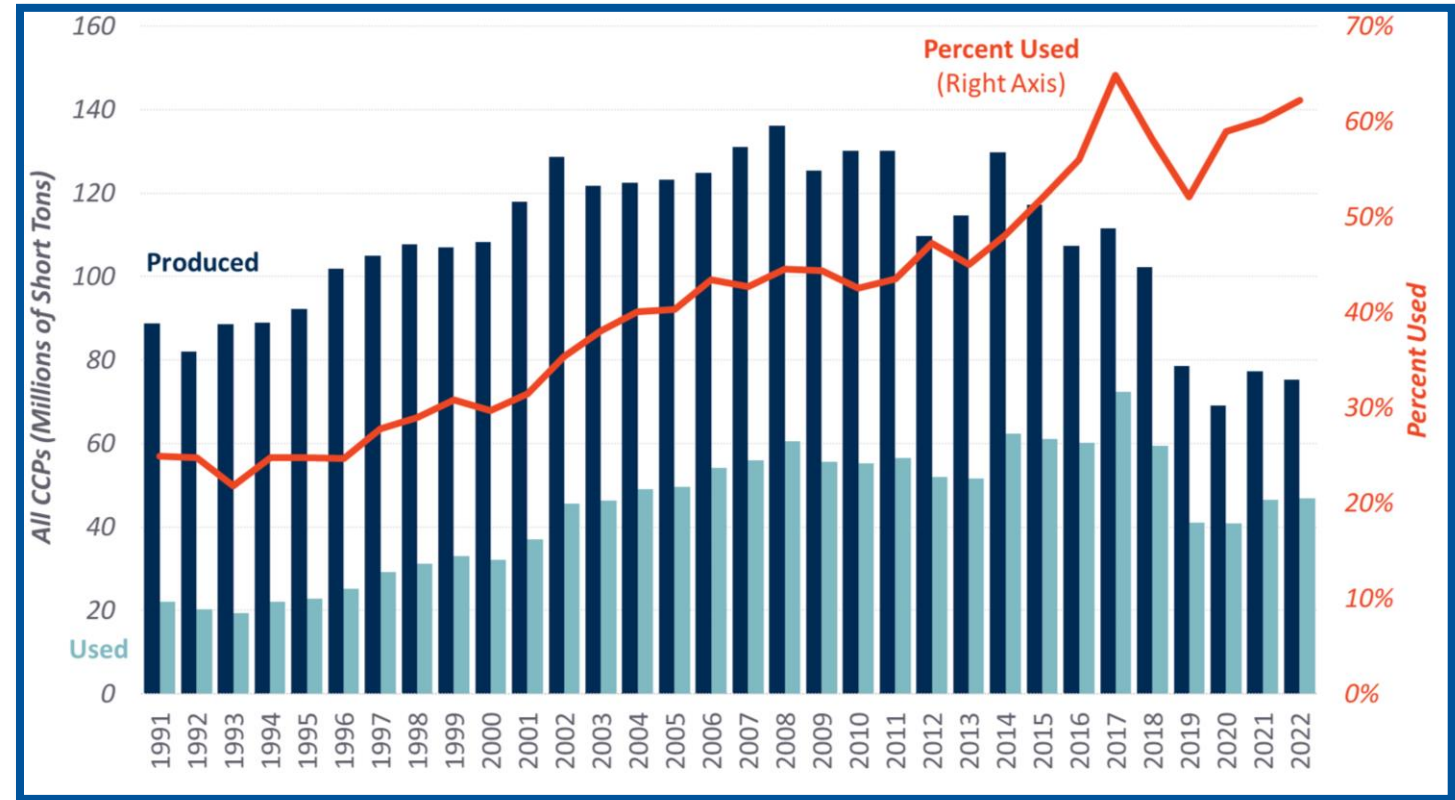
Background

- Portland cement contributes 8-10 % global CO₂ emissions
- Common solution - Supplementary Cementitious Materials (SCM)
- ASTM C618 - Class C and Class F fly ash



Research Motivation

- Dwindling supply of coal combustion ash and environmental exposure from past disposal
- ASTM C618-23
- Research Goal: Can we link the CCA oxide composition to mechanical properties to guide performance-based construction?

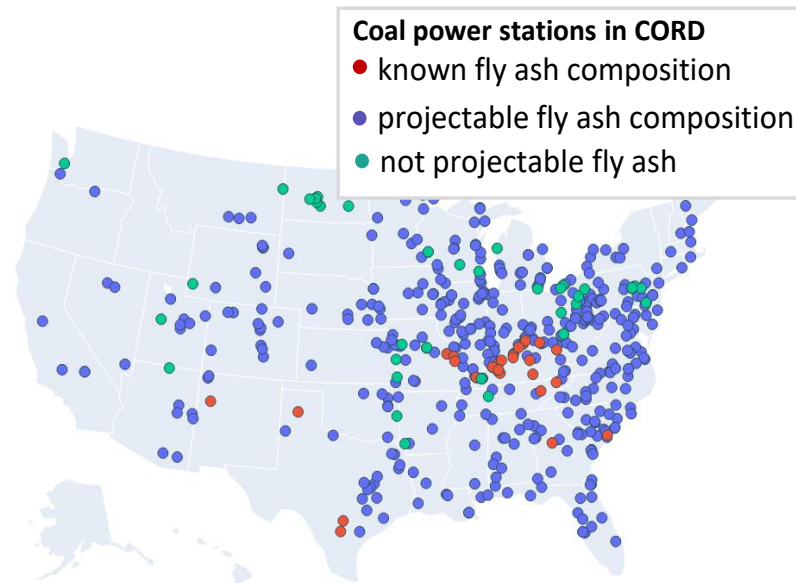
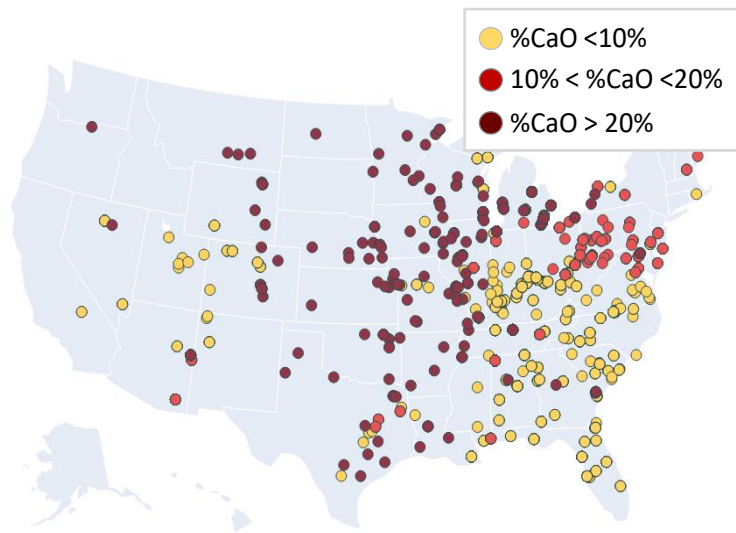
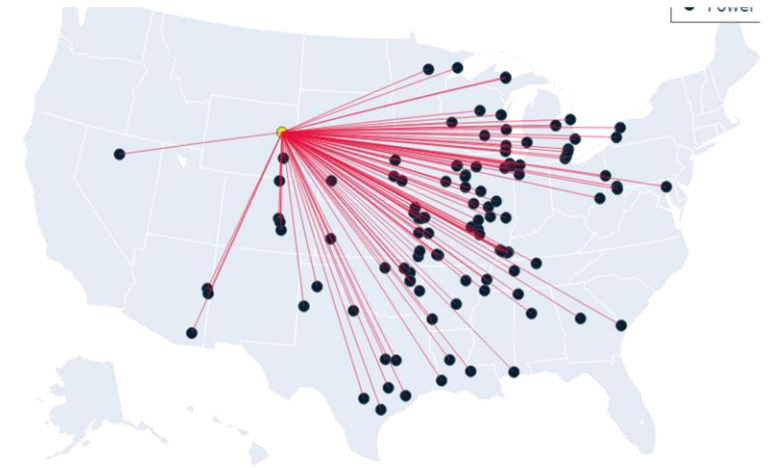


Coal Combustion Products: Production and Use

[American Coal Ash Association](#)

Methods: Chemical Composition

- CCA accumulated for decades
- Carbon Ore Resources Database (CORD)
 - > Working collection of 399 data files
 - > CCA batches from different US plants
 - > Percentage composition of various oxides



Methods: Fly Ash Performance Calculator

- Prediction of fly ash substituted concrete performance
- Depends on chemical composition
- Limitation: specified range for data

Home
LEAVE COMMENTS
ABOUT
CONTACT
LOOK UP TABLE APPROACH

Fly Ash Performance Calculator

**Chemical Components
(by mass %)**

SiO ₂	<input type="text" value="Type values from 18 to 70"/>
Al ₂ O ₃	<input type="text" value="Type values from 14 to 32"/>
Fe ₂ O ₃	<input type="text" value="Type values from 0 to 24"/>
CaO	<input type="text" value="Type values from 0 to 38"/>
MgO	<input type="text" value="Type values from 0 to 11"/>
SO ₃	<input type="text" value="Type values from 0 to 8"/>
Na ₂ O	<input type="text" value="Type values from 0 to 14"/>
K ₂ O	<input type="text" value="Type values from 0 to 6"/>
TiO ₂	<input type="text" value="Type values from 0 to 4"/>
P ₂ O ₅	<input type="text" value="Type values from 0 to 4"/>
SrO	<input type="text" value="Type values from 0 to 4"/>
Total	<input type="text"/>

Compressive Strength

Fly Ash Replacement by Mass	20%	40%
3d	TBA	TBA
7d	TBA	TBA
14d	TBA	TBA
28d	TBA	TBA
56d	TBA	TBA
90d	TBA	TBA
180d	TBA	TBA

Diffusion Coefficient

Fly Ash Replacement by Mass	20%	40%
45d	TBA	TBA
90d	TBA	TBA
135d	TBA	TBA
200d	TBA	TBA
250d	TBA	TBA
500d	TBA	TBA
700d	TBA	TBA

Heat of Hydration at 48 h

Fly Ash Replacement by Mass	20%	40%
	TBA	TBA

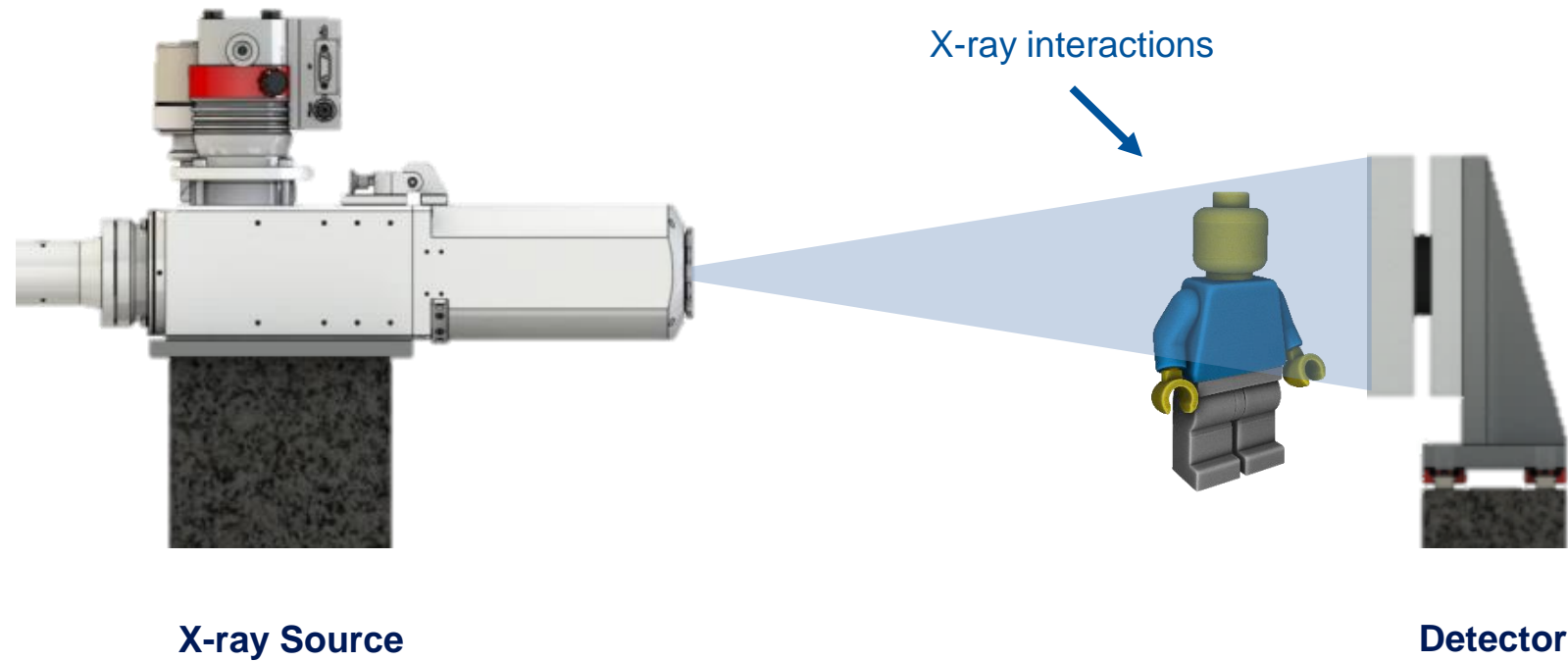
Methods: Compressive Strength Tests

- Started with fly ash available in comparatively more amount
- Concrete with 0 - 40% fly ash substitution
- 2 x 2 inch cube and 2 x 4 inch cylinder specimens
- Material Testing System (MTS) for 1, 3, 7 and 28 days
- X-ray computed tomography (CT) mechanical testing



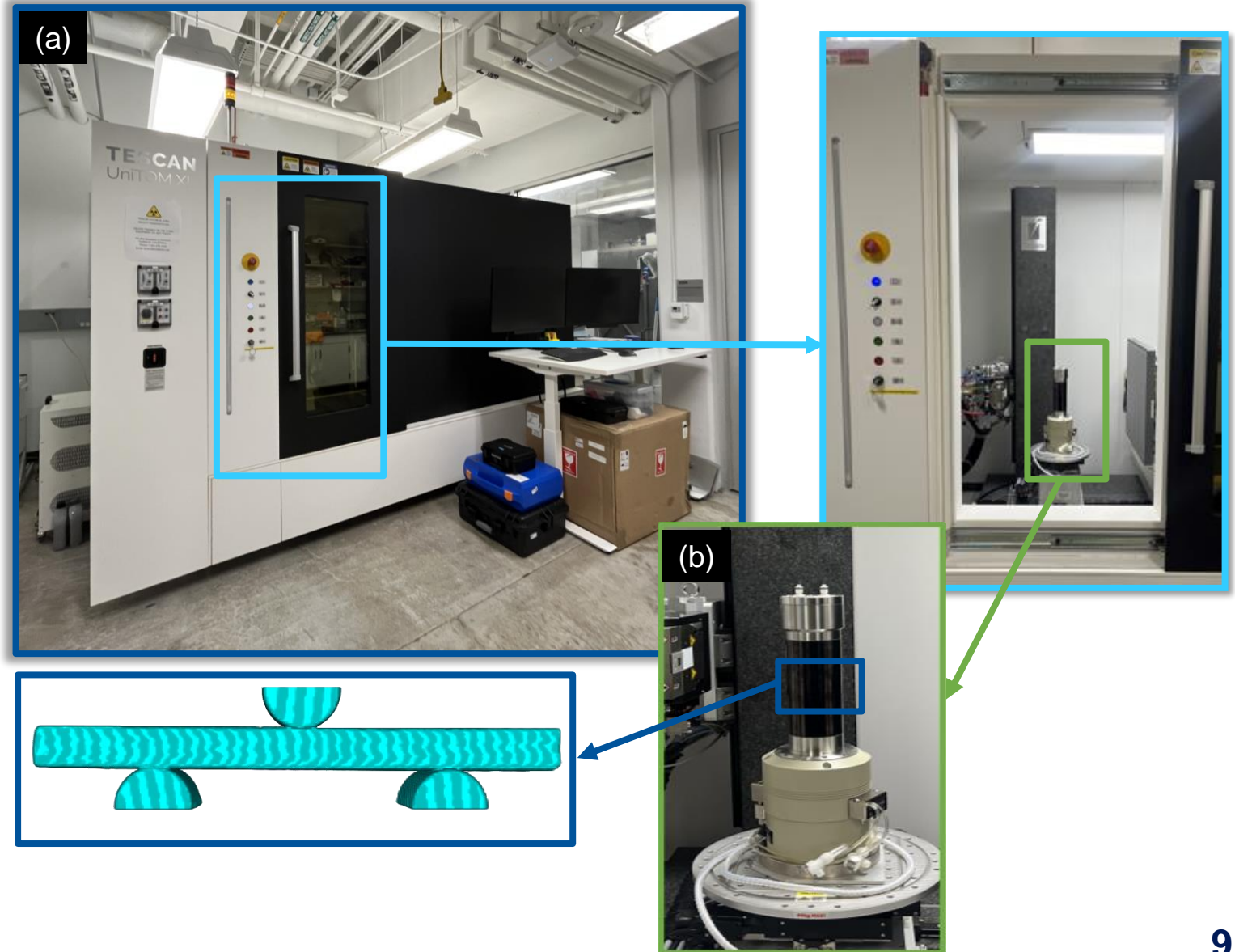
Specimen setup in MTS

Method: X-ray Computed Tomography



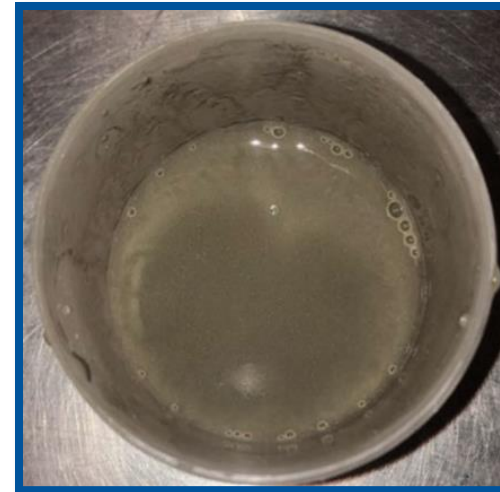
Methods: Three-Point Bending Test

- Flexural strength test
- DEBEN in-situ loadcell
- Small specimens
- 4D X-ray CT scan of crack propagation

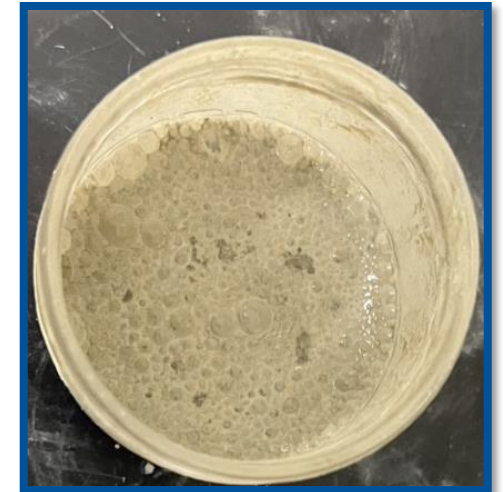


Methods: Foam Index Test

- Volume of air entraining admixture as per CCA substituted
- ASTM C1827
- Overcome reduction in air content due to fly ash substitution
- Ensure workability and durability
- Comparison of results in hardened concrete

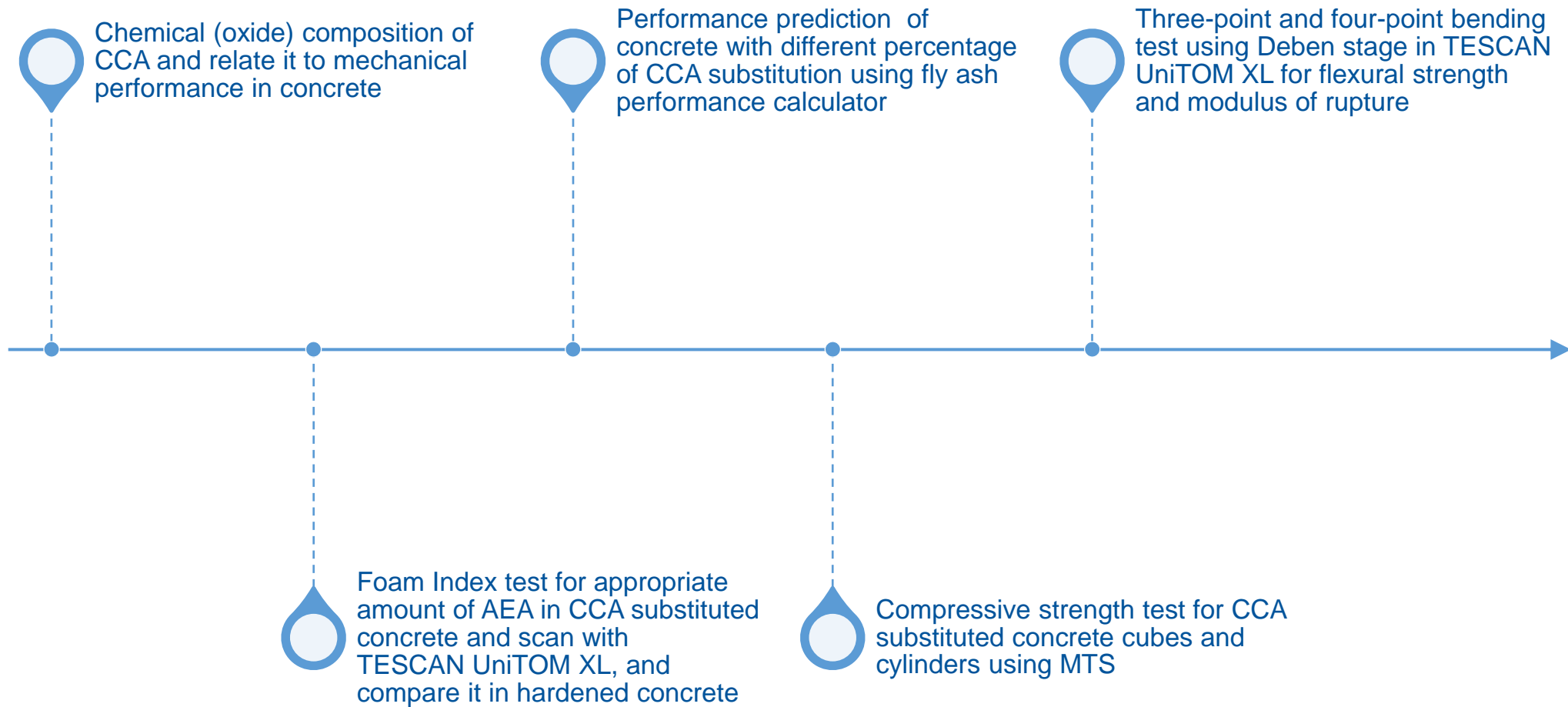


Unstable foam



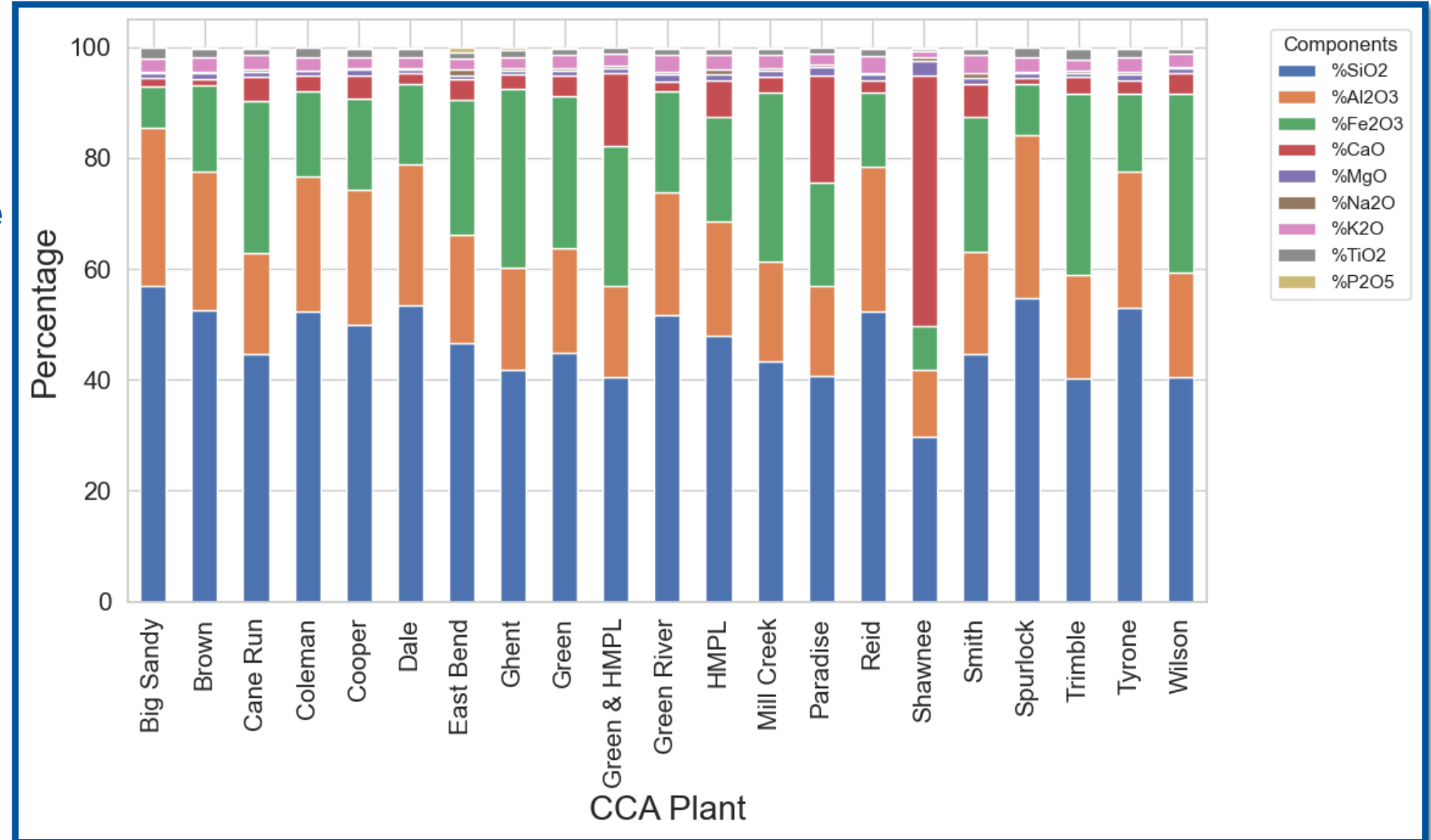
Stable foam

Summary of Methods

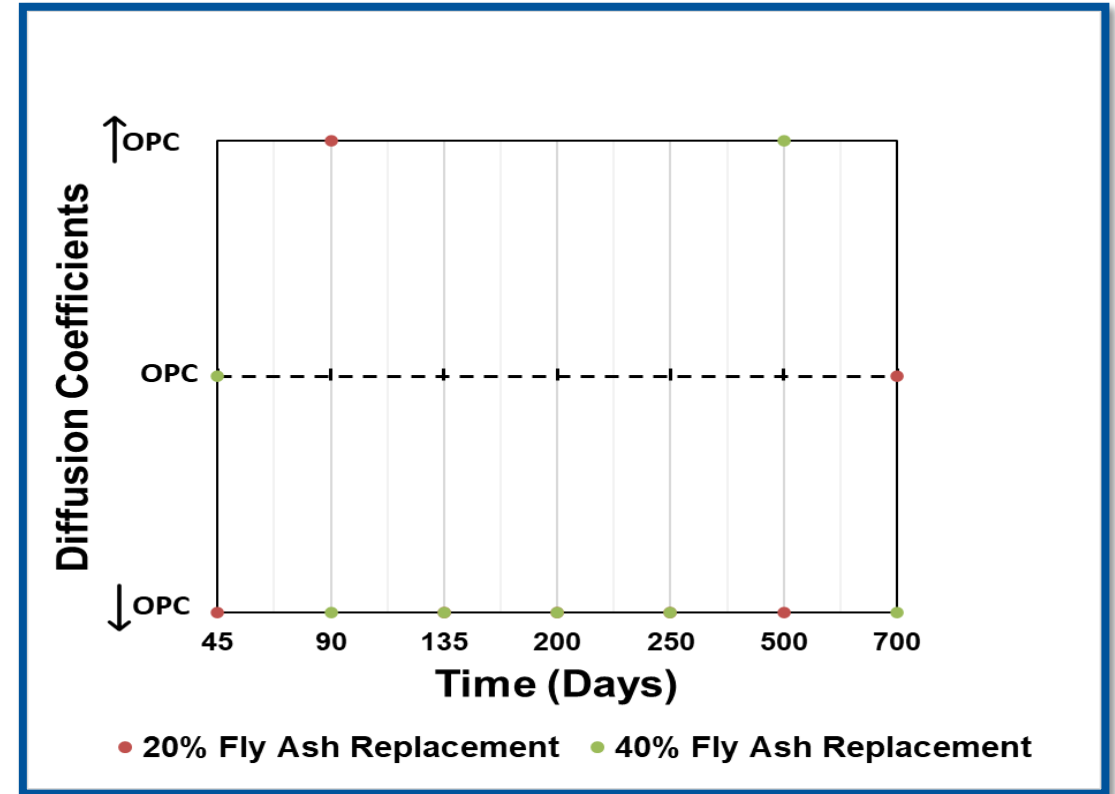
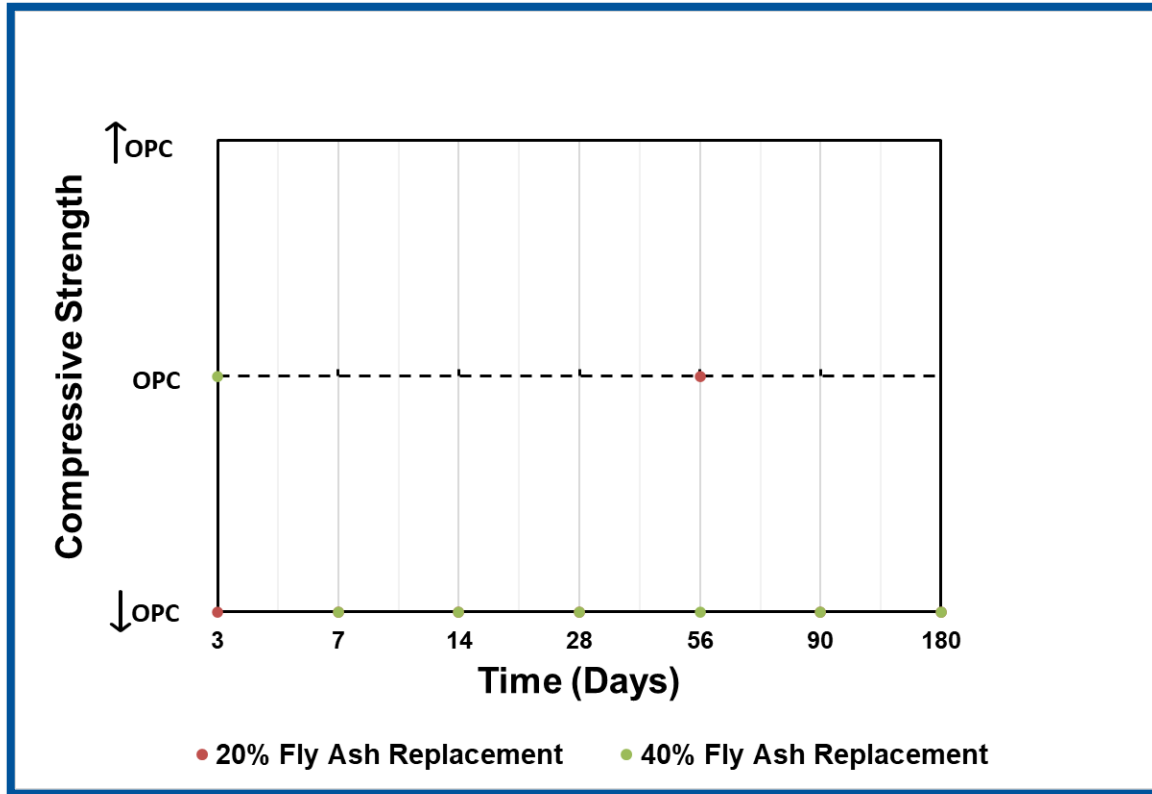


Results: Chemical Composition

- Oxide composition
- Relate performance of hardened concrete to oxide components

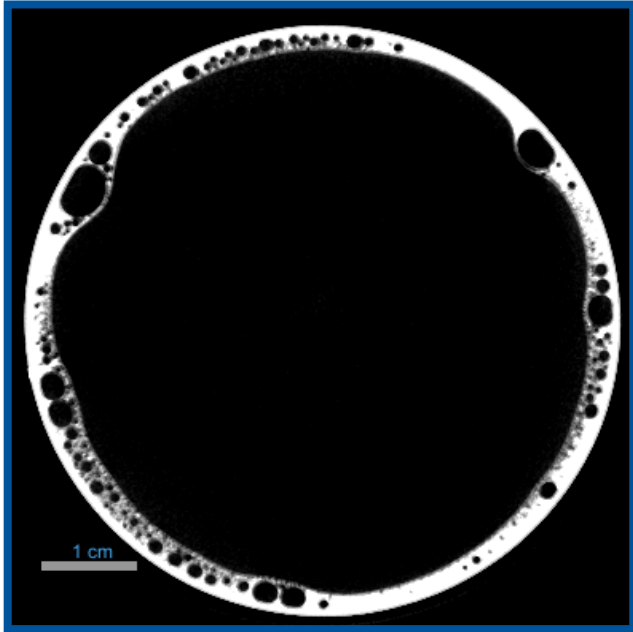


Results: Fly Ash Performance Calculator

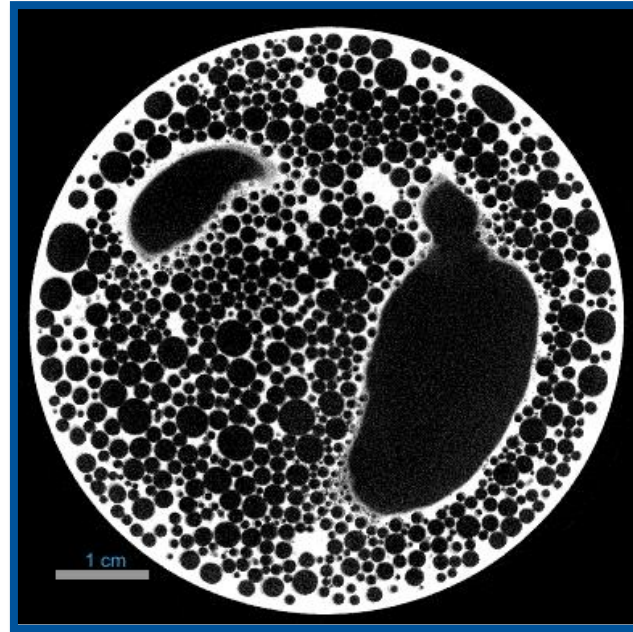


Prediction of compressive strength and diffusion coefficients of fly ash substituted concrete compared to Portland cement concrete

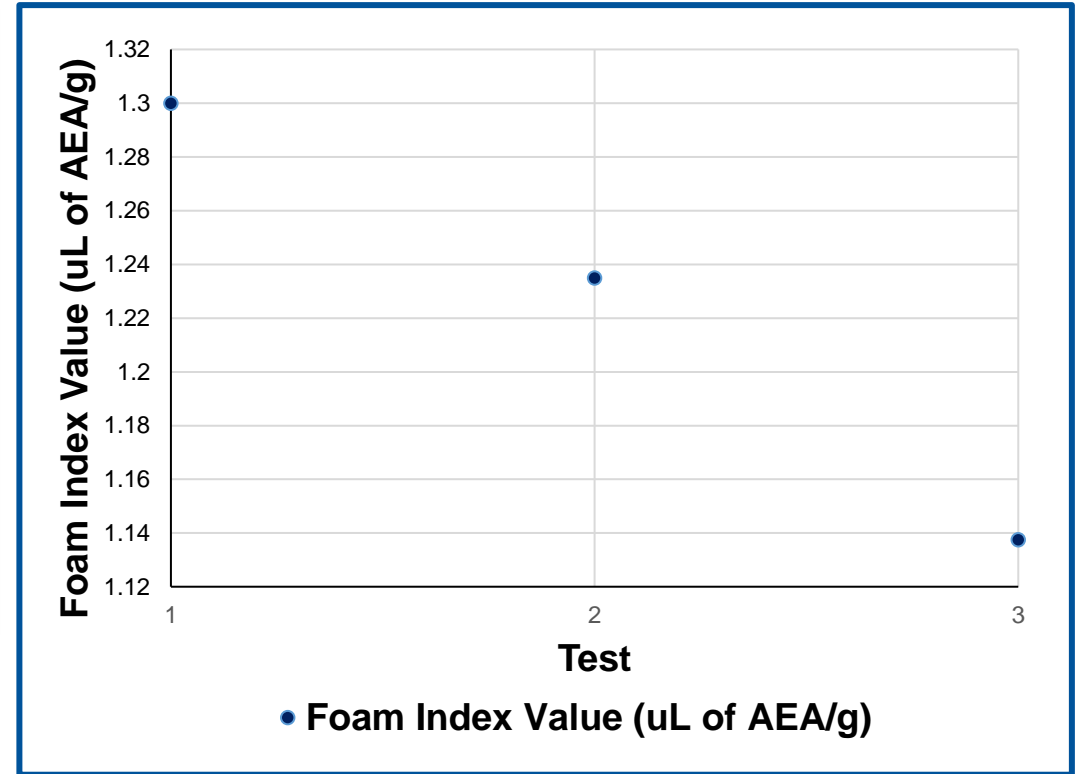
Results: Foam Index Test (4D X-ray CT)



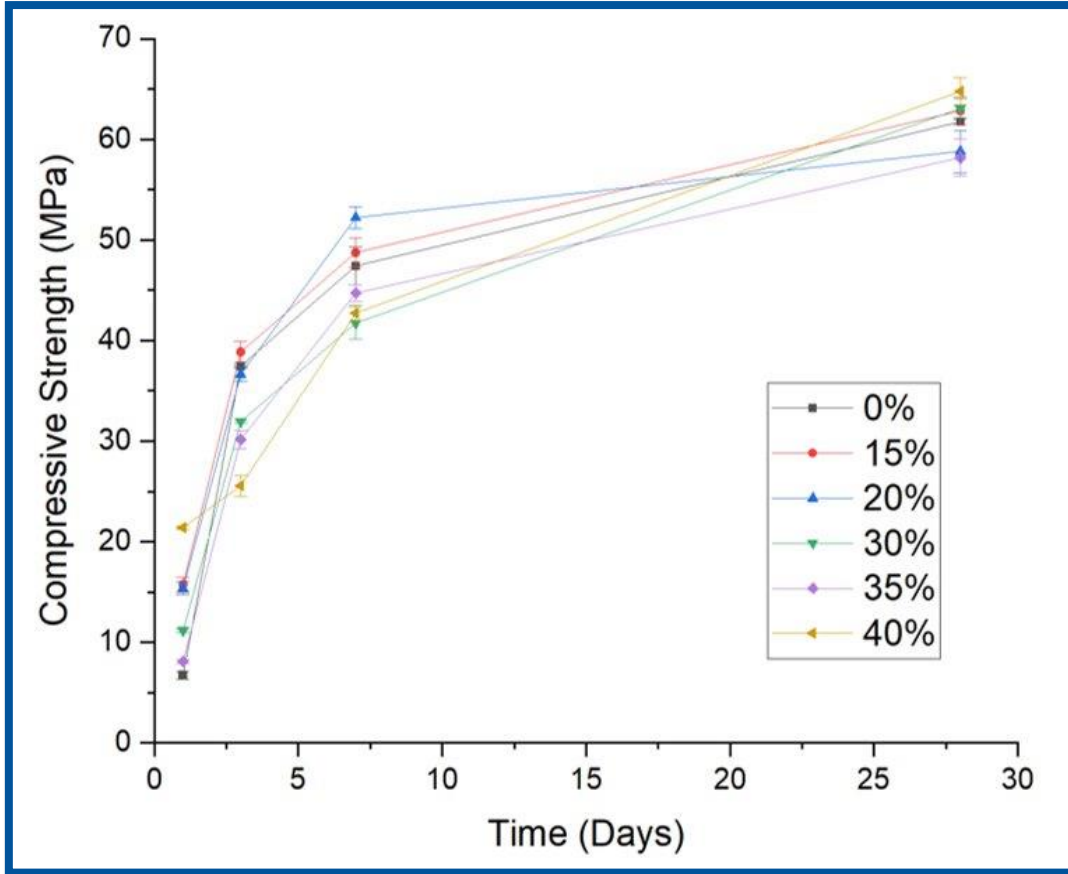
Unstable foam



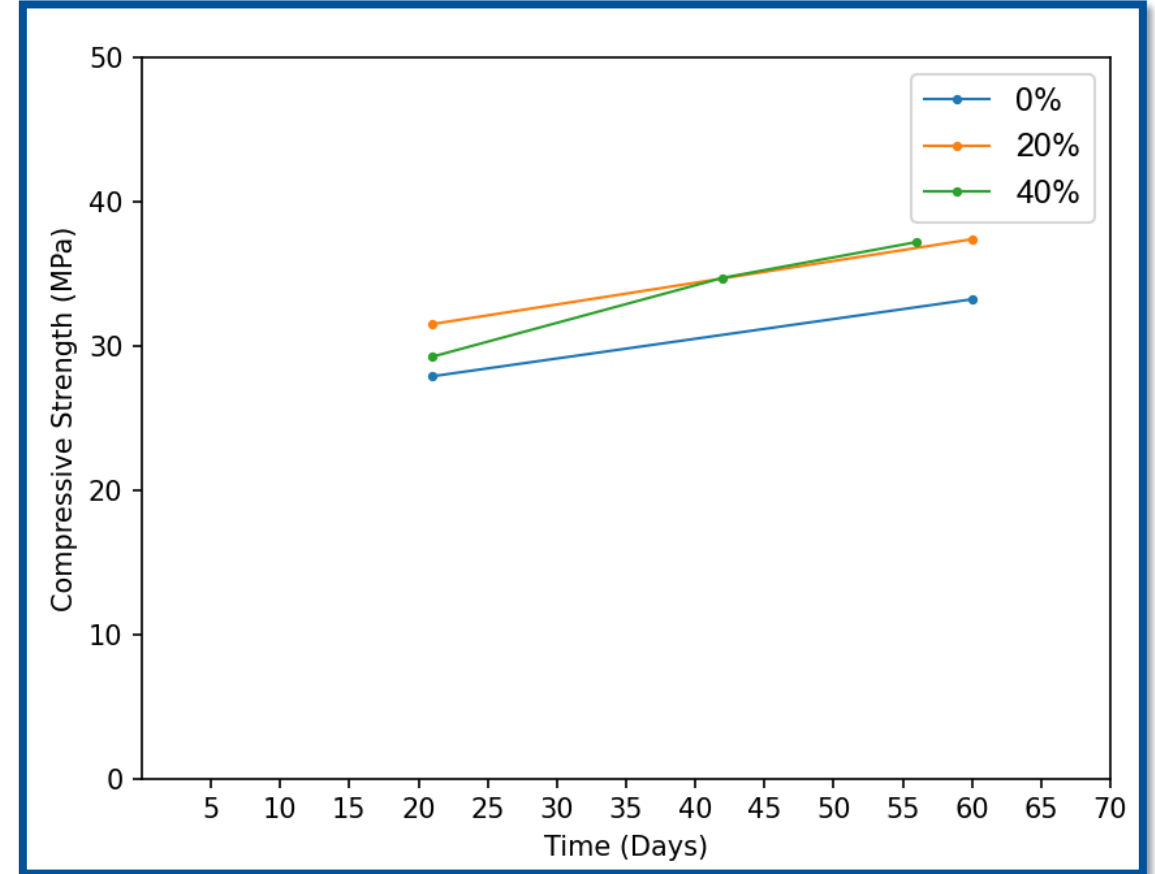
Stable foam



Results: Compressive Strength Test



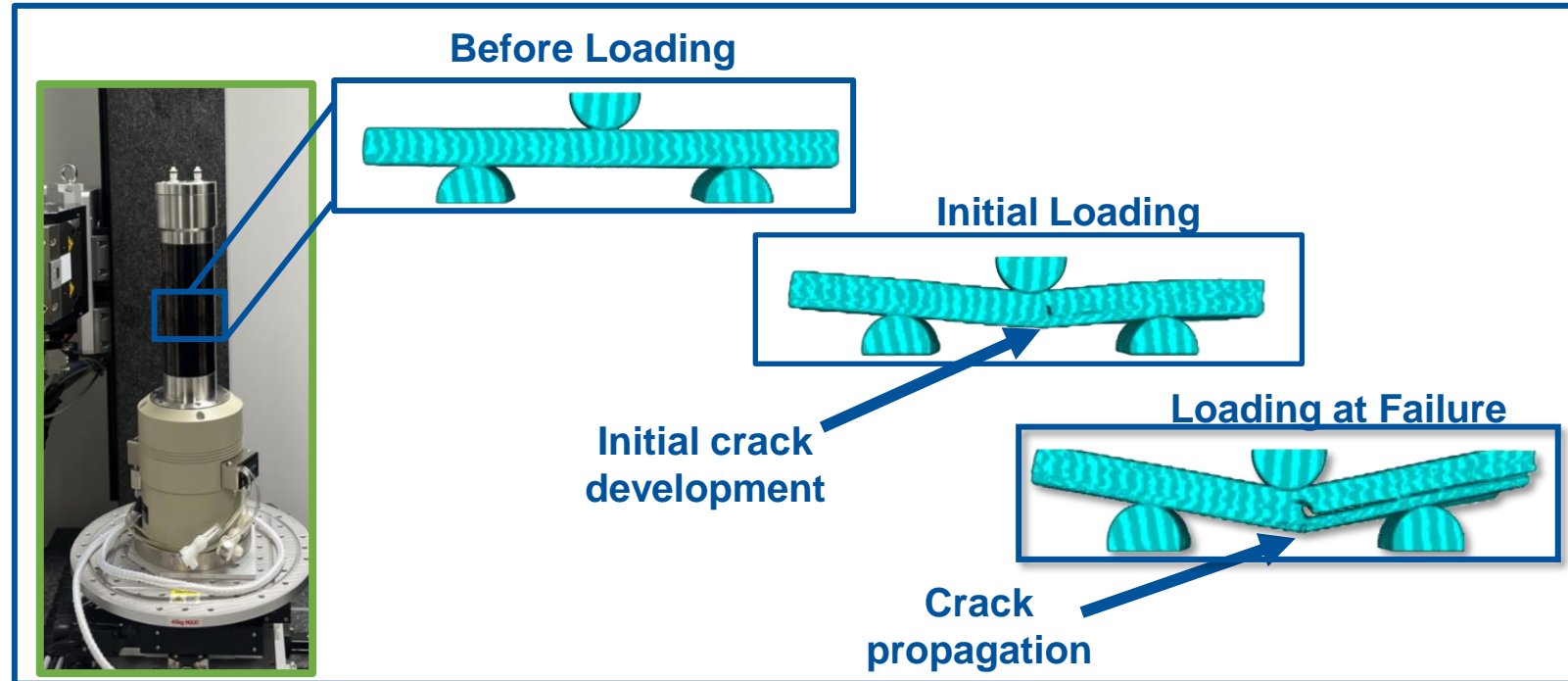
Compressive strength graph for cube



Compressive strength graph for cylinder

Ongoing and Next Steps

- Three-point bending test for flexural strength
- Four-point bending test for modulus of rupture
- ASTM C78

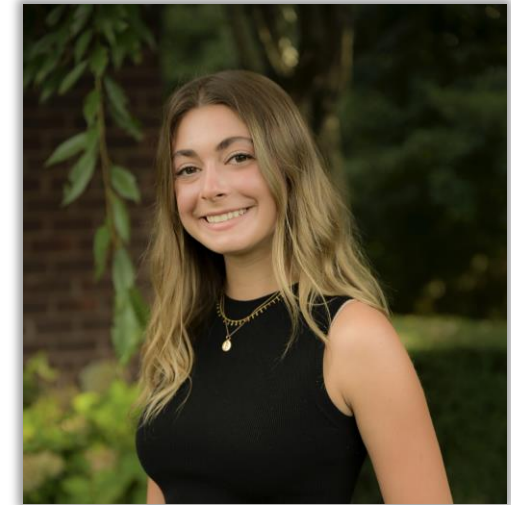


Setup for three-point bending



Molds used for preparing Samples

Acknowledgments



Thank you for your attention!

Questions?

Email: soniya.tiwari@duke.edu

Advisor Email: laura.dalton@duke.edu