Zeolite Concrete Research at the UW: An Overview

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UNIVERSITY of WASHINGTON

Zeolite Composites LLC

Introduction

- Brandon Lou
  - B.S., M.S. Materials Science and Engineering
  - University of Washington, Class of ‘22, ’23
  - Department of Materials Science and Engineering
  - Previous research in biological alternatives for cement in structural materials
  - Academic advisement from Professors Arola and Roumeli

- Zeolite Composites, LLC
  - Founded in March 2022
  - Co-founder Dan Uhm
  - Focusing on utilization of zeolite for environmental benefits
  - Exclusive access and rights to natural zeolite mine

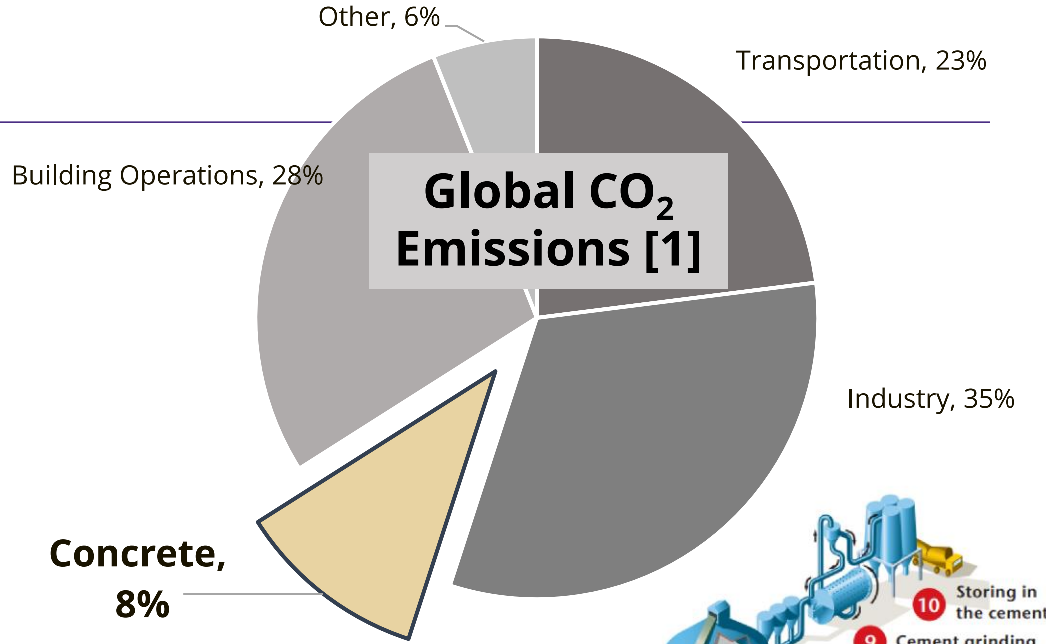
Introduction - Cement

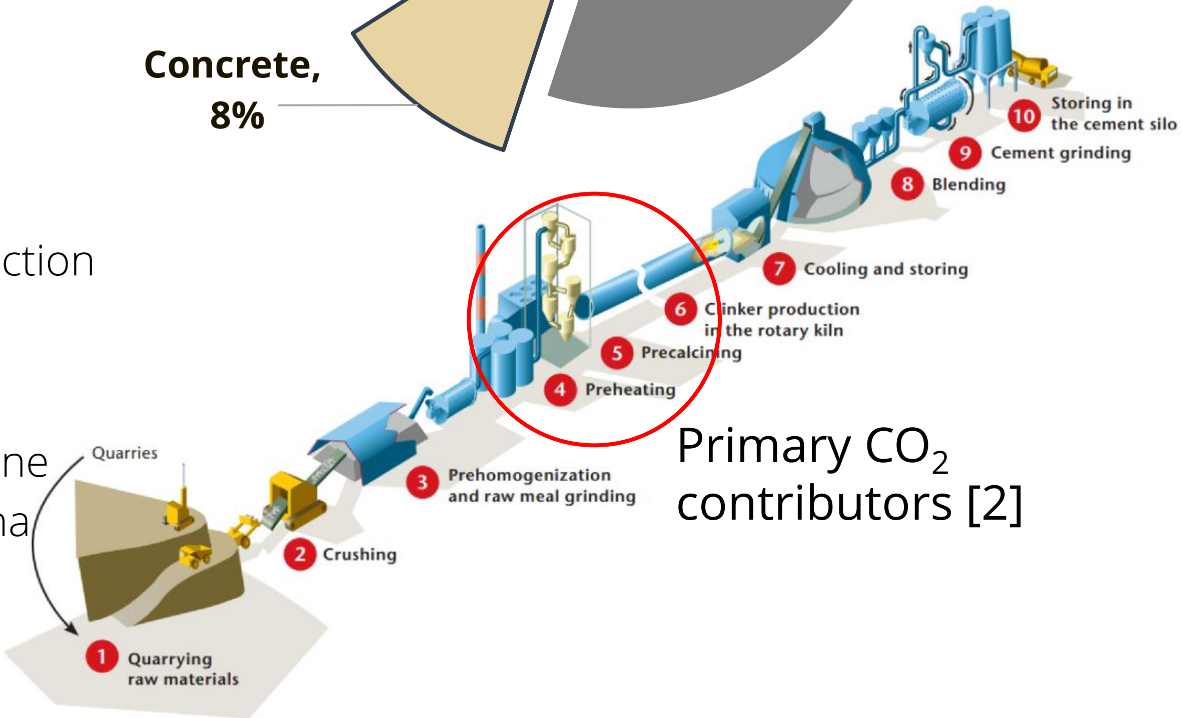
- Ordinary Portland Cement (OPC)
  - 7-15 wt% concrete
  - 1 kg cement emits ~1kg CO_2 [1]
  - Hydration reactions cause strength development

- Pozzolanic reaction:

  $Ca(OH)_2 + H_2O$ + pozzolan -> C-S-H + C-(A-)S-H
  - Densification/strengthening
  - Reduction of CO_2 emissions associated with cement production

- Cement replacement with pozzolans
  - Blast furnace slag, fly ash, silica fume, calcined clay, limestone
  - Reactivity classified by relative amounts of silica and alumina





Primary CO_2 contributors [2]

[1] https://psci.princeton.edu/tips/2020/11/3/cement-and-concrete-the-environmental-impact
[2] https://www.aceee.org/blog-post/2022/12/low-carbon-cement-could-be-sped-market-climate-law-funds

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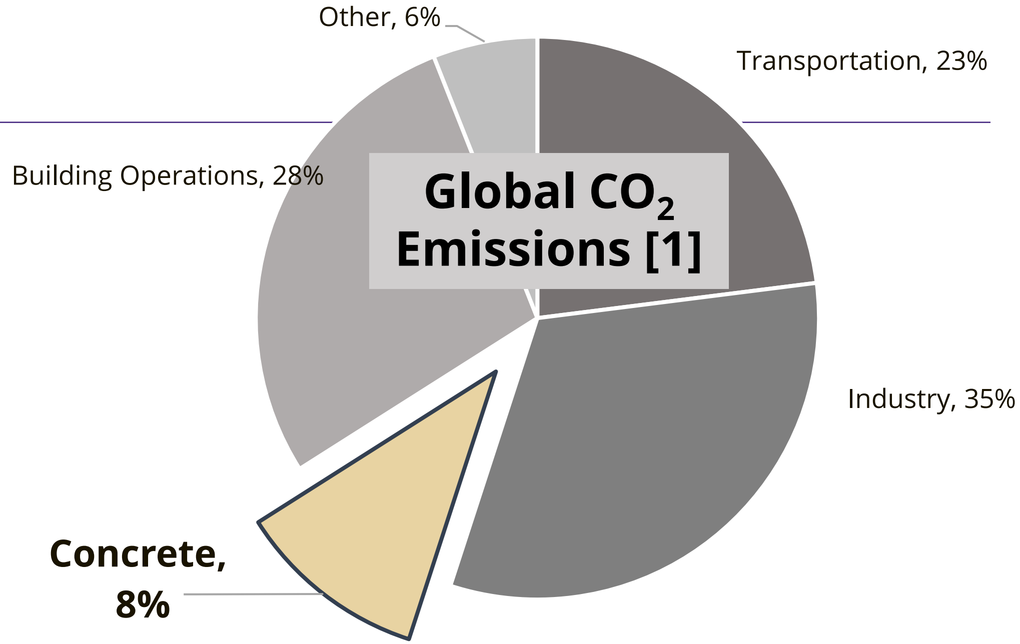

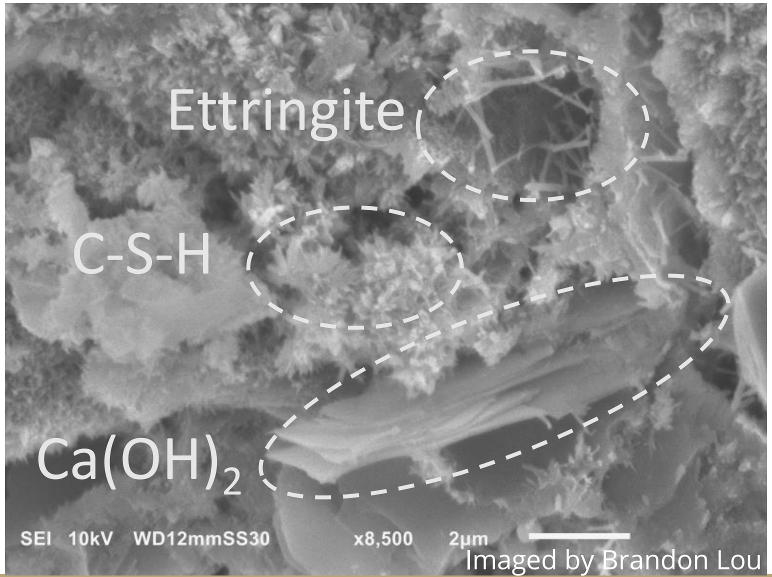

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Introduction - Zeolite

- What is zeolite?
  - Minerals composed of crystalline aluminosilicates
  - *Zéō* (“boiling”) + *líthos* (“stone”)
  - Used as detox agent, drying agent, water/air purifier, ingredient in detergents
  - Natural and synthetic options available

- Zeolite as a cement replacement
  - Pozzolanic -> viable supplementary cementitious material (SCM)
  - Clinoptilolite highly reactive due to high (>4) Si:Al
  - Microporous structure -> ability to capture molecules
  - Non-intensive processing reduces upfront carbon emissions

Material	Effectiveness in concrete	Environmental footprint
Cement	Very Good	Very Bad
Slag	Good	Very Bad
Silica fume	Very Good	Good
Zeolite	Very Good	Very Good

Introduction

Goal: Understand zeolite potential in concrete to reduce CO_2 emissions associated with cement production.

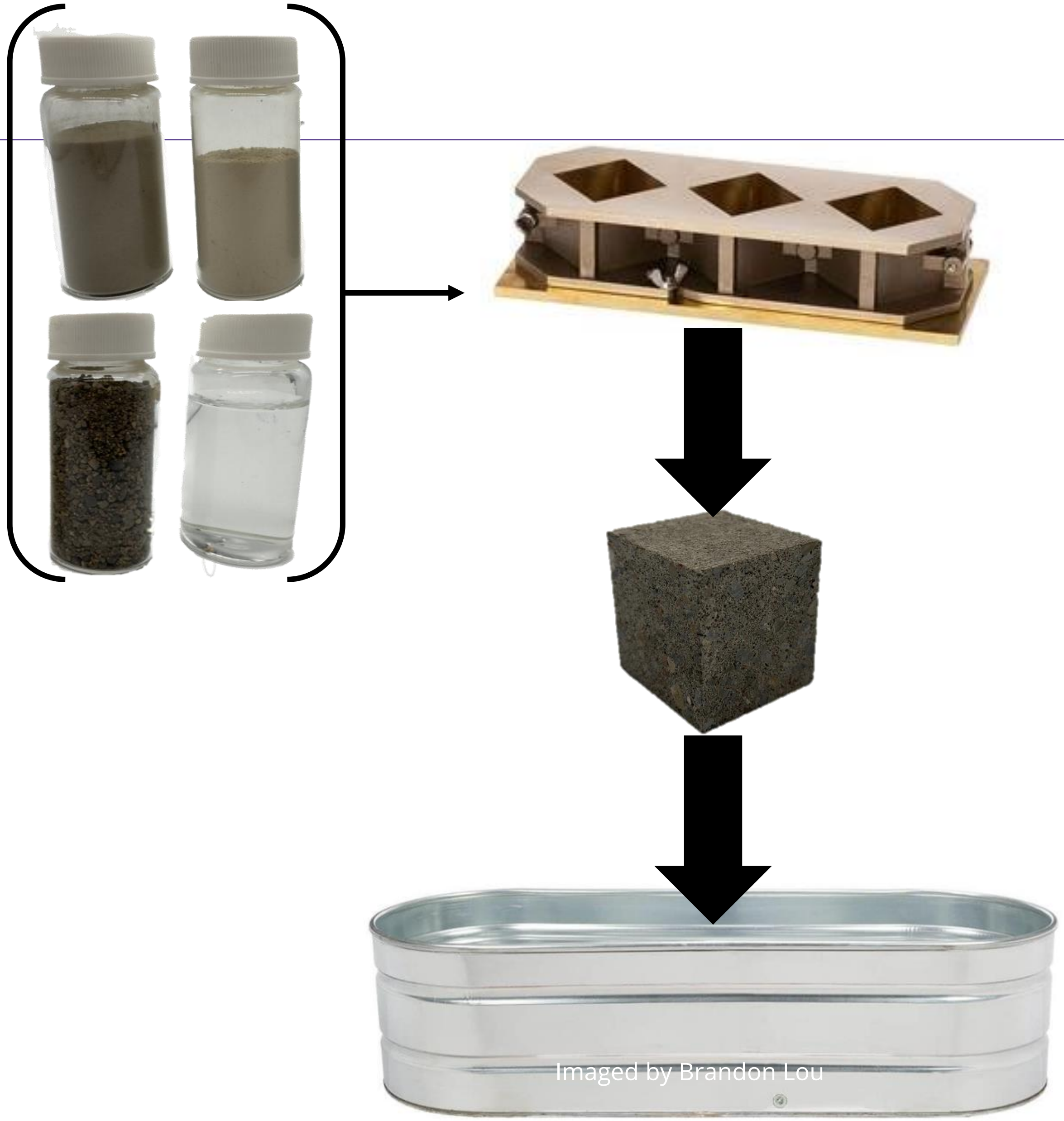
- Achieving this goal takes time and understanding:
  - Need to understand how zeolite effects the chemical reactions that take place in concrete
  - Does zeolite change the durability of concrete over time? In different environments?
  - Are there other ways that zeolite reduces carbon emissions?

Recent collaboration with Western Interlock to understand zeolite effect on pavers:

- Creating sample pavers with their materials, scientific lens for industrial work

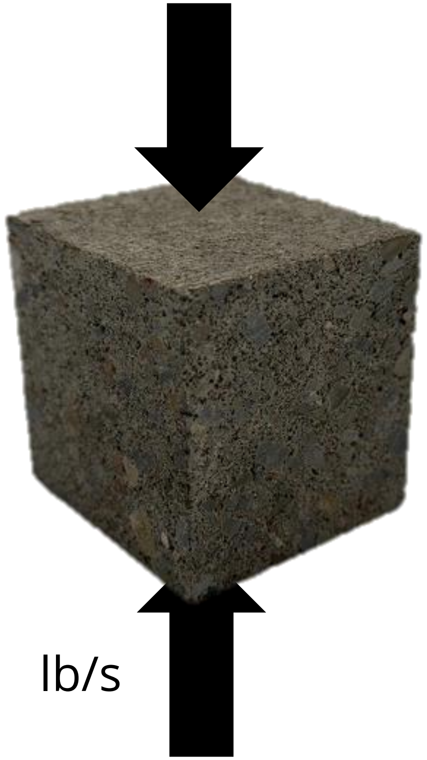
Experimentation

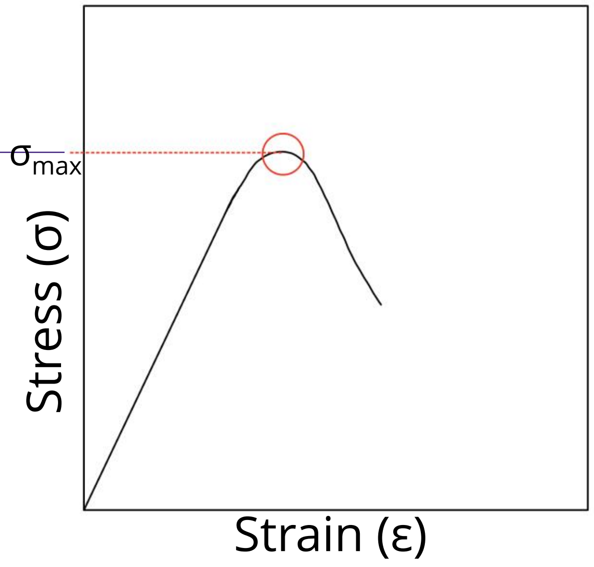
- Making samples
  - 2 in. x 2 in. x 2 in. cubic samples
  - Varying amounts of zeolite content



Experimentation

- Making samples
  - 2 in. x 2 in. x 2 in. cubic samples
  - Varying amounts of zeolite content
- Breaking samples
  - Compressive testing after specified times of curing (3, 7, 14, 28d)
  - Maximum load recorded, compared between samples





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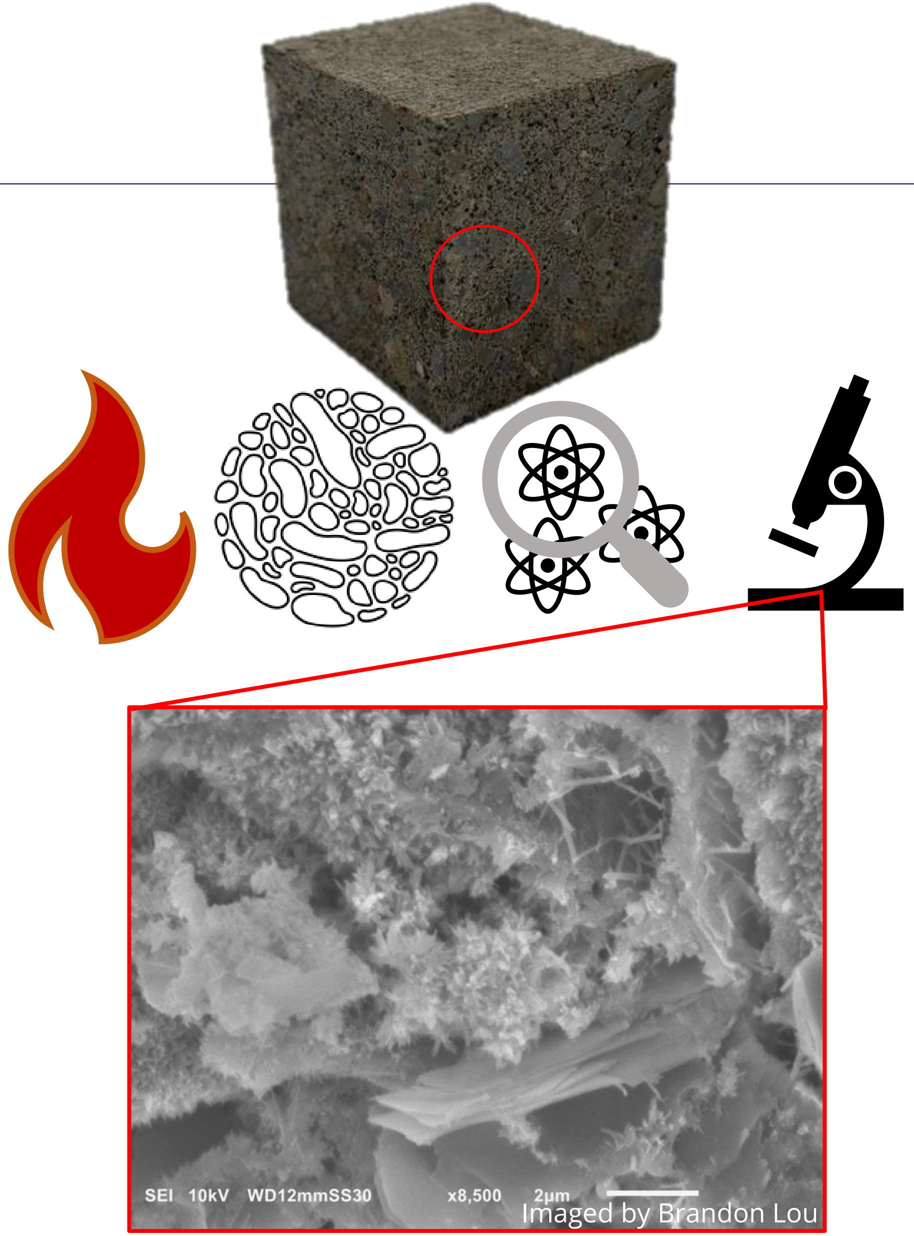
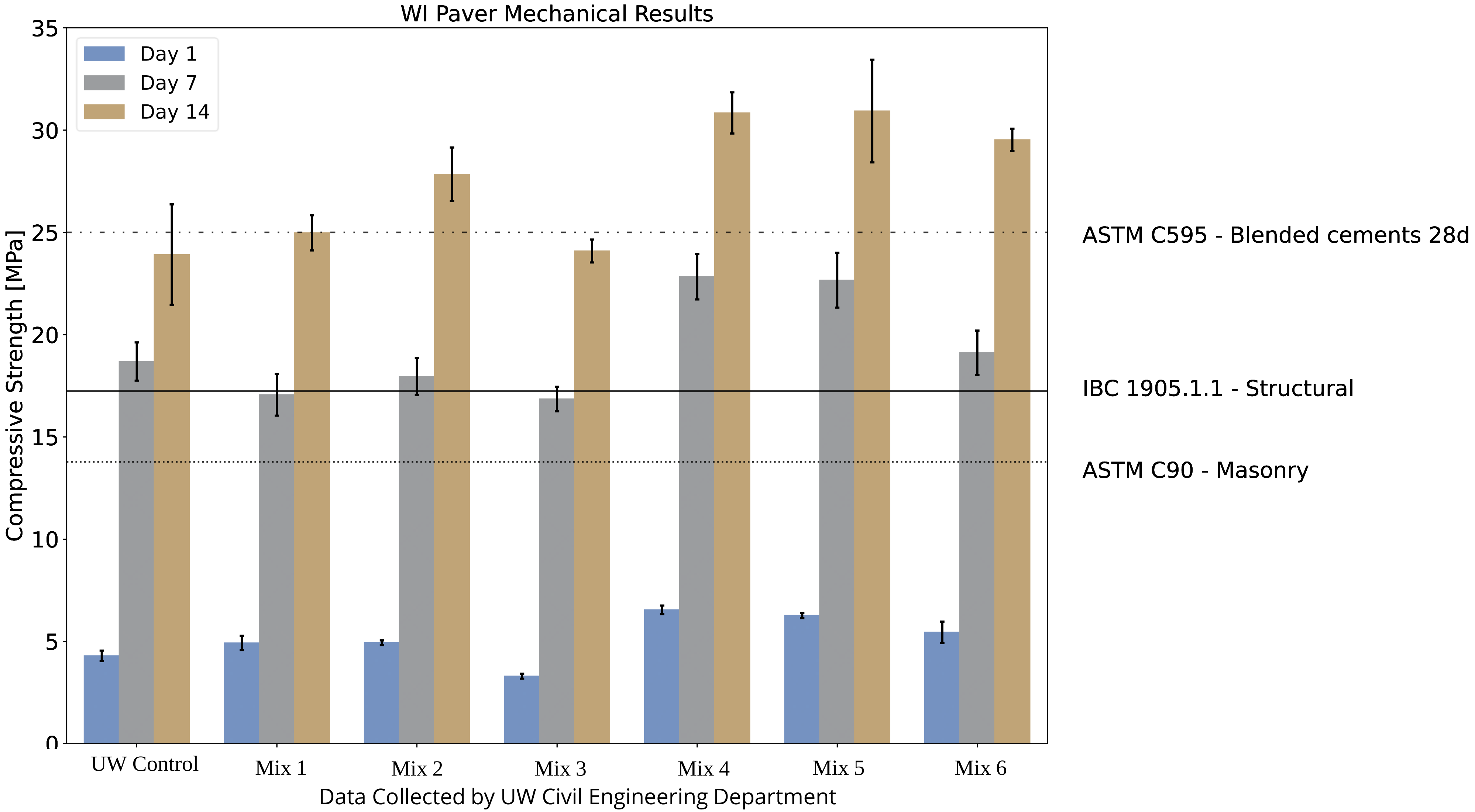
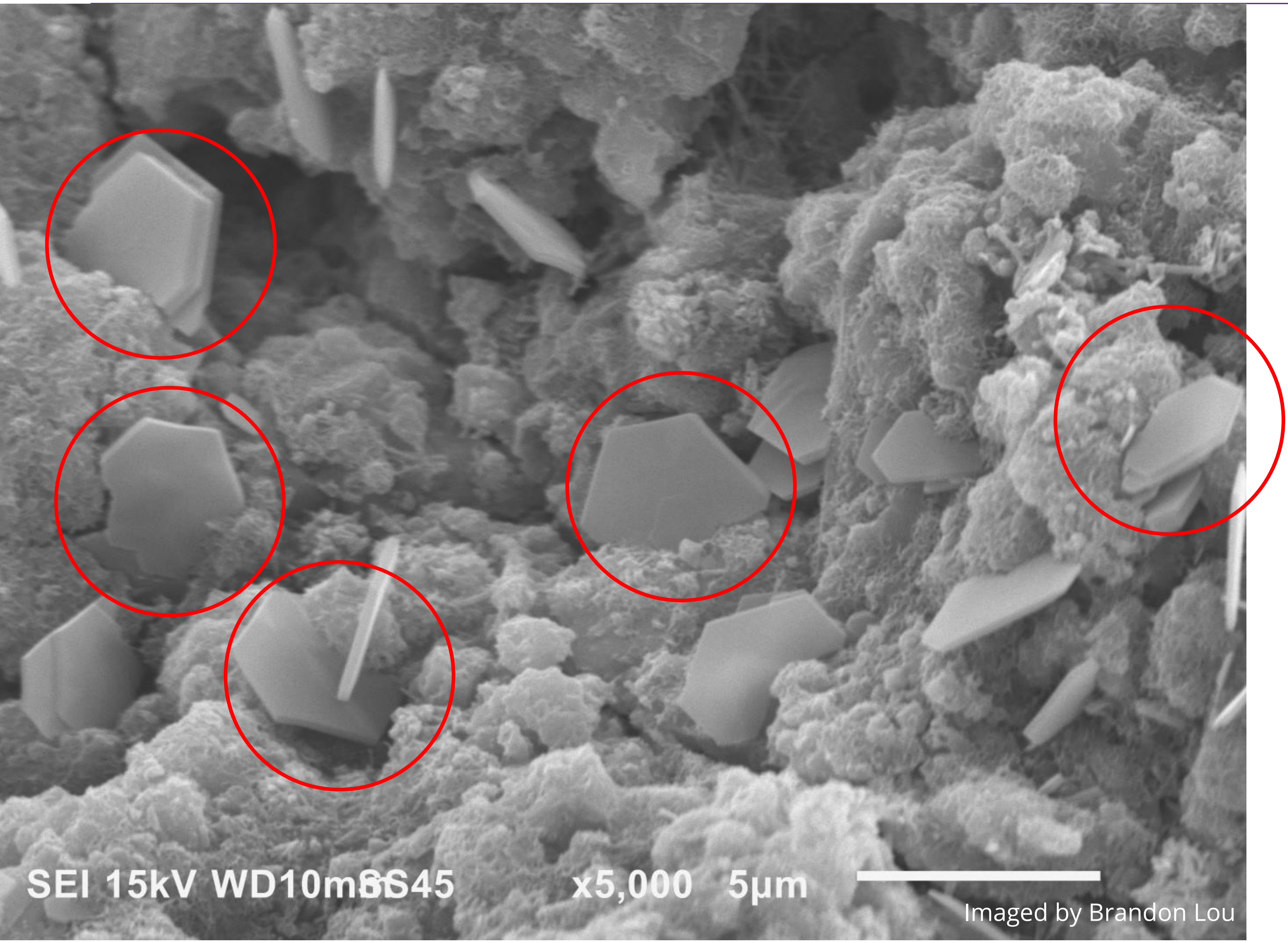
  - Compressive testing after specified times of curing (3, 7, 14, 28d)
  - Maximum load recorded, compared between samples
- Characterizing samples
  - Thermal degradation
  - Porosity
  - Elemental analysis
  - Microstructure observation



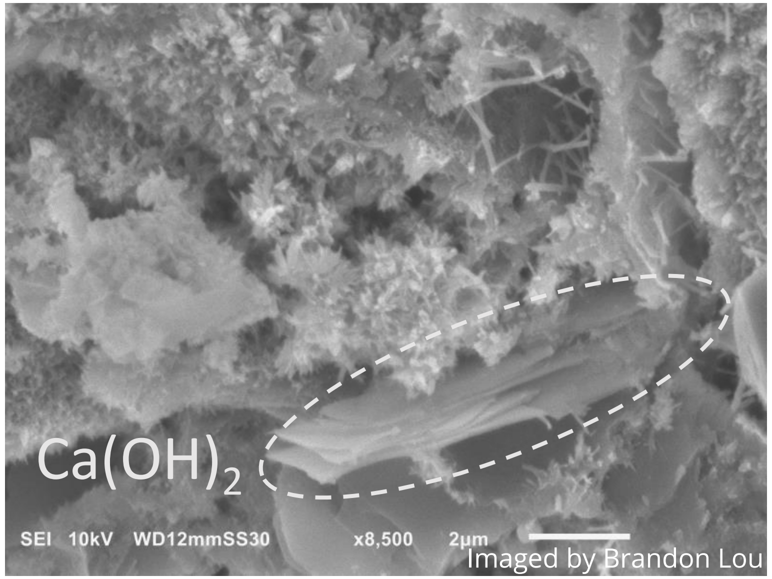
Mechanical results



$Ca(OH)_2$ growth



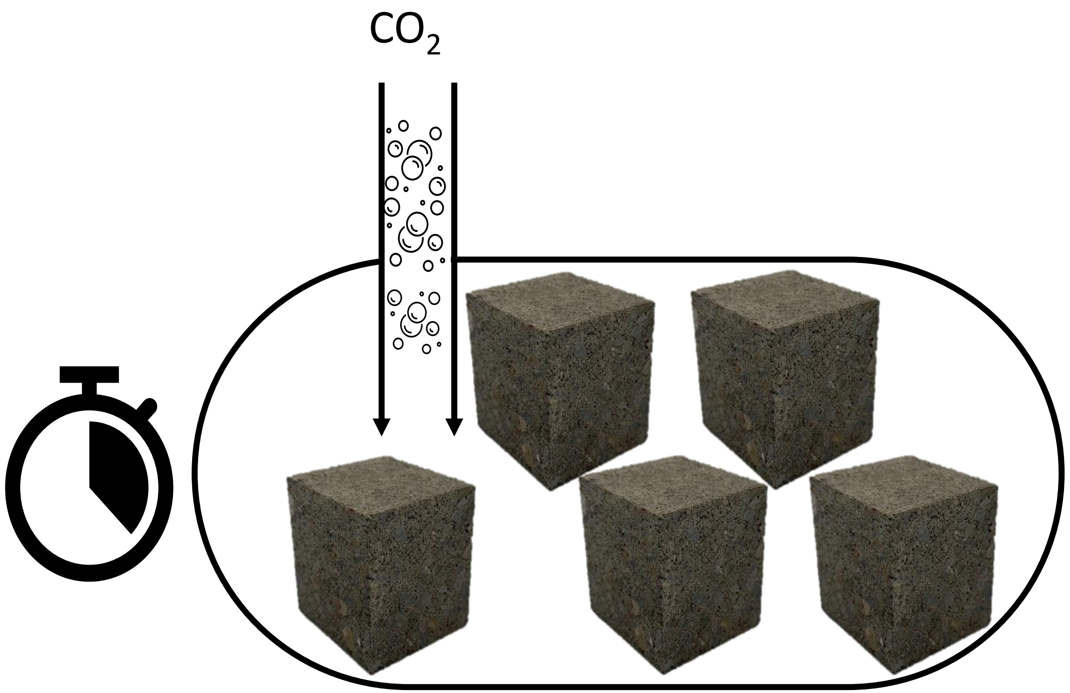
Mortar sample with zeolite powder added to composite



Recall the image from earlier!

Future Work

- Post-cure carbon capture
  - How will carbon capture work?
  - Expose samples to CO_2 rich environments for predetermined time intervals
  - Measure resultant change in properties and CO_2 captured
- Environmental exposure
  - Ex: seawater, humid, high temperature
- Long-term durability
  - Currently characterized to 28d, need to see effect over longer periods of time



Industrial Efforts

- 11/17/23 C-Crete collaboration
  - 100% OPC-free zeolite-based concrete mix
  - Poured at Commercial Project in Seattle
- 12/04/23 Western Interlock partnership
  - 1st low carbon zeolite paver production run
  - Manufacture and Distribute Low Carbon Hardscape Products (Retail Distribution and Big Box Retailers) in 2024
- Carbon credit recognition
  - 12/12/23 approved and registered with Climate Action Reserve
  - Zeolite Composites one of 12 global companies participating with VERRA protocol development for low carbon concrete
- January 2024
  - Mutual Materials collaboration for zeolite pavers
  - Alquist 3D, COBOD collaboration for low carbon concrete for 3D printing of concrete

Acknowledgement

Zeolite Composites LLC