Engineered Biological Construction Material: Self-healing Carbon Negative Enzymatic Construction Materials (ECM)

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Background

- In 2015, United Nations announced the Sustainable Development Strategy
- Buildings account for 40% of global energy consumption and 33% of greenhouse gas emissions.
- 8% global CO_2 emission from concrete production
- 1:1 Cement to CO_2

WPI

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Multiple Synergies Between Carbon footprint and Cement Production

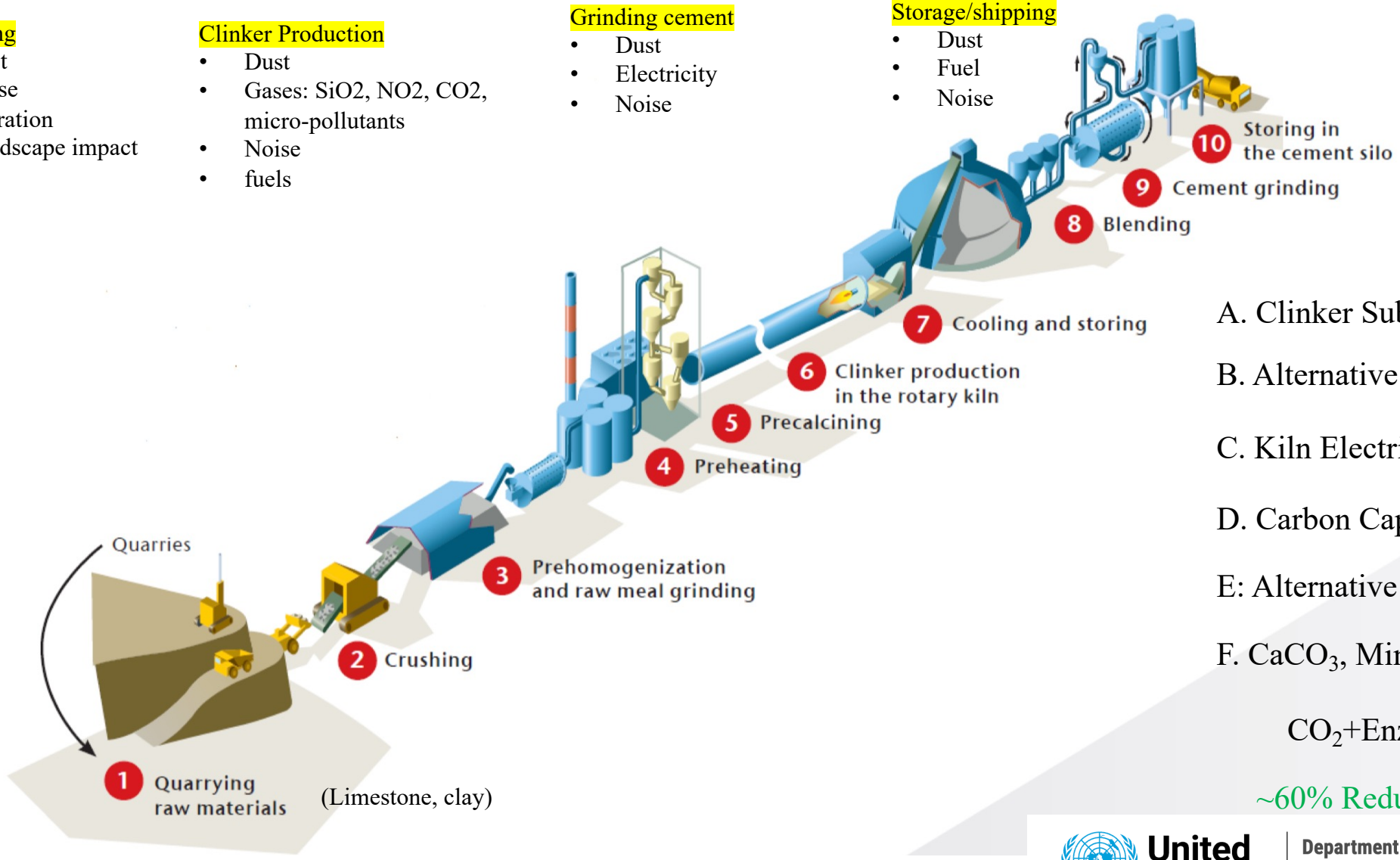
Quarrying
- Dust
- Noise
- Vibration
- Landscape impact

Clinker Production
- Dust
- Gases: SiO2, NO2, CO2, micro-pollutants
- Noise
- fuels

Grinding cement
- Dust
- Electricity
- Noise

Storage/shipping
- Dust
- Fuel
- Noise

Fuel Combustion Release ~40% CO_2



(Limestone, clay)

A. Clinker Substitution

B. Alternative Fuels

C. Kiln Electrification

D. Carbon Capture

E: Alternative cementitious Materials

F. $CaCO_3$, Mineralization

CO_2+Enzyme → $CaCO_3$

~60% Reduction in CO_2

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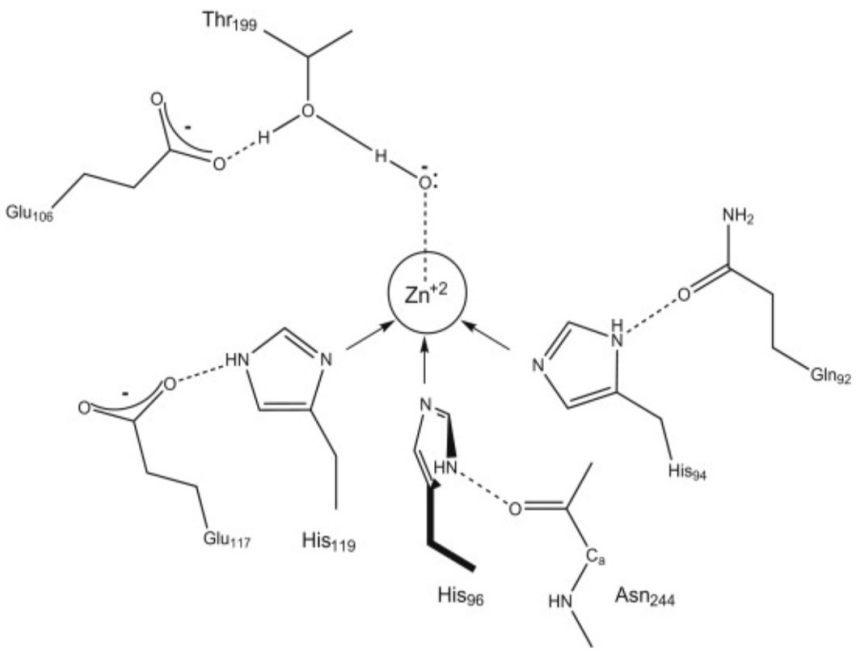
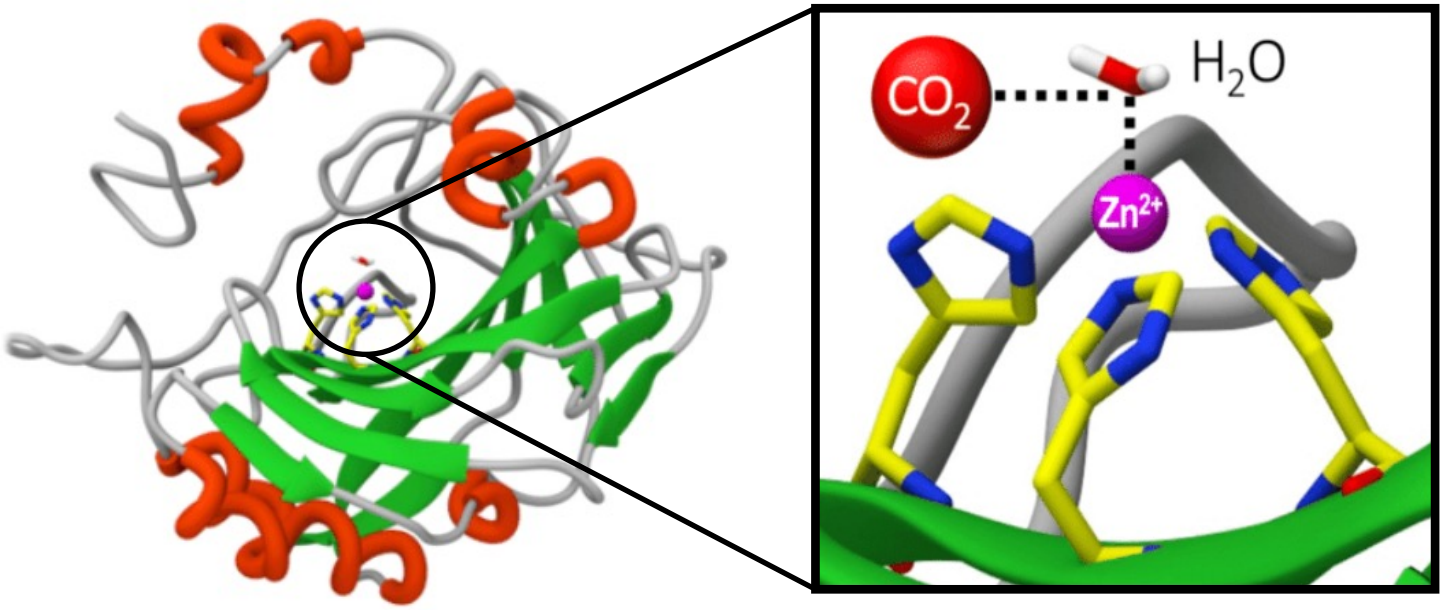
Carbonic Anhydrase (CA)





CA II from mammalian erythrocy

$$CO_2 + H_2O \longrightarrow H_2CO_3 \longrightarrow H^+ + HCO_3^-$$

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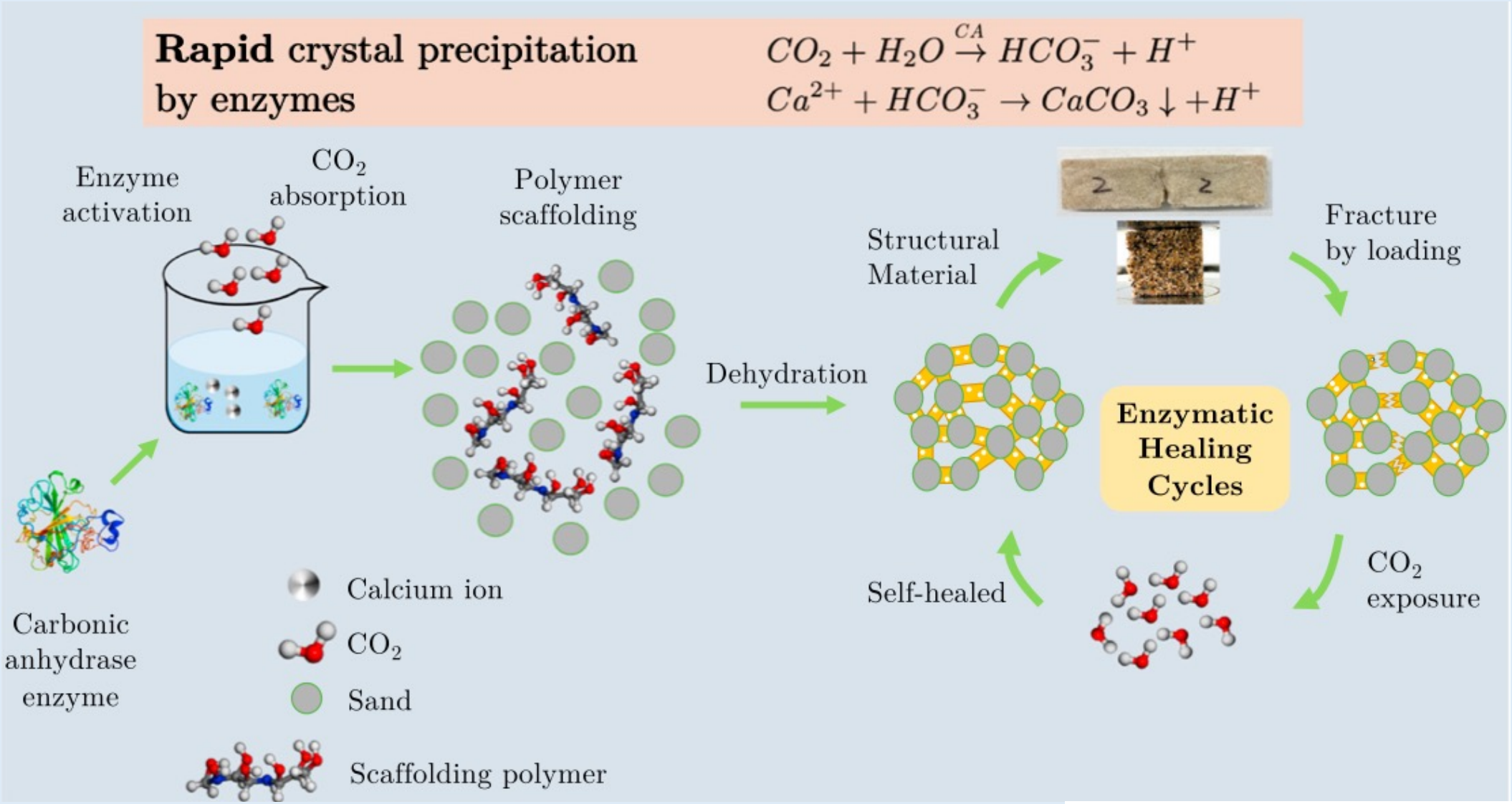
Enzymatic Construction Material (ECM)



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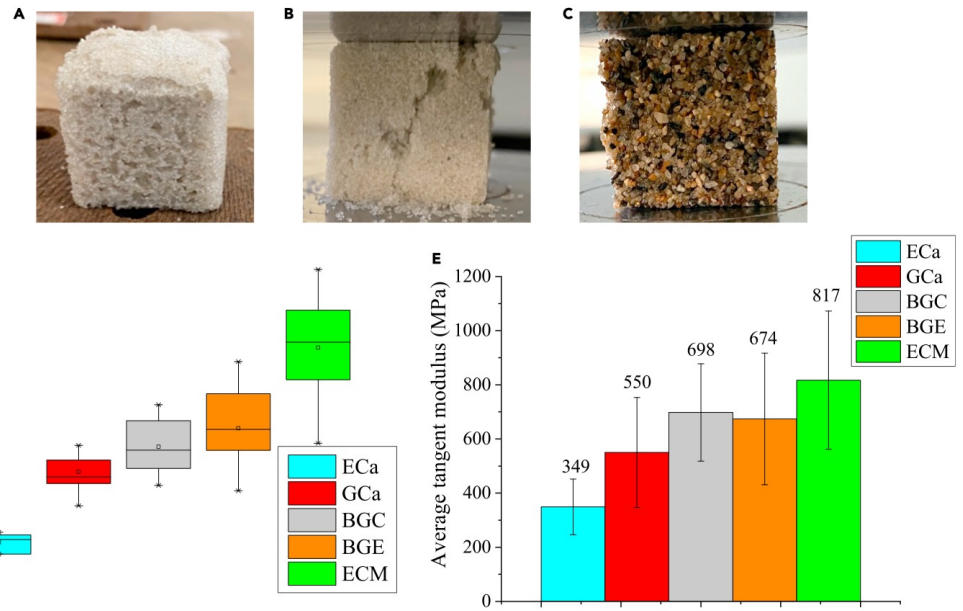
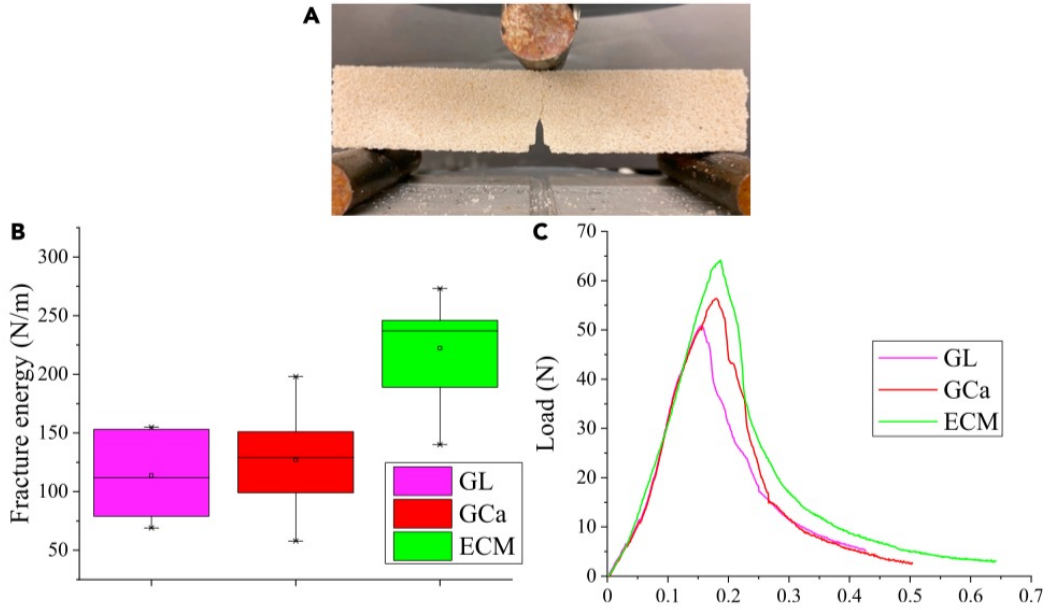
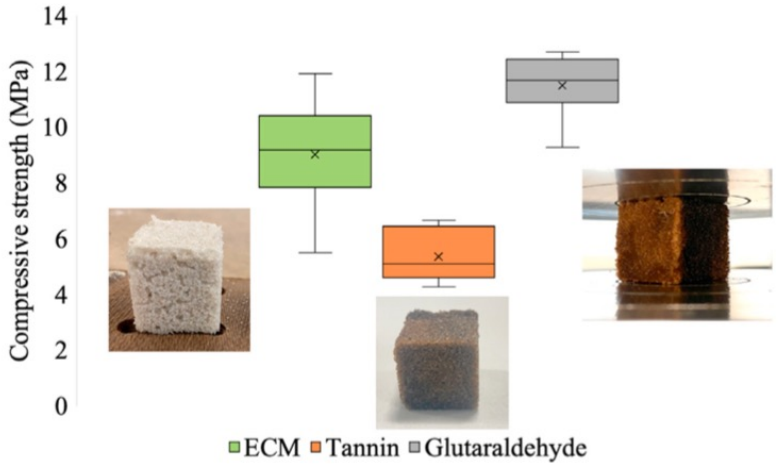
Mechanical Properties





Cross-linking agent-modified ECM

12 MPa
!!!



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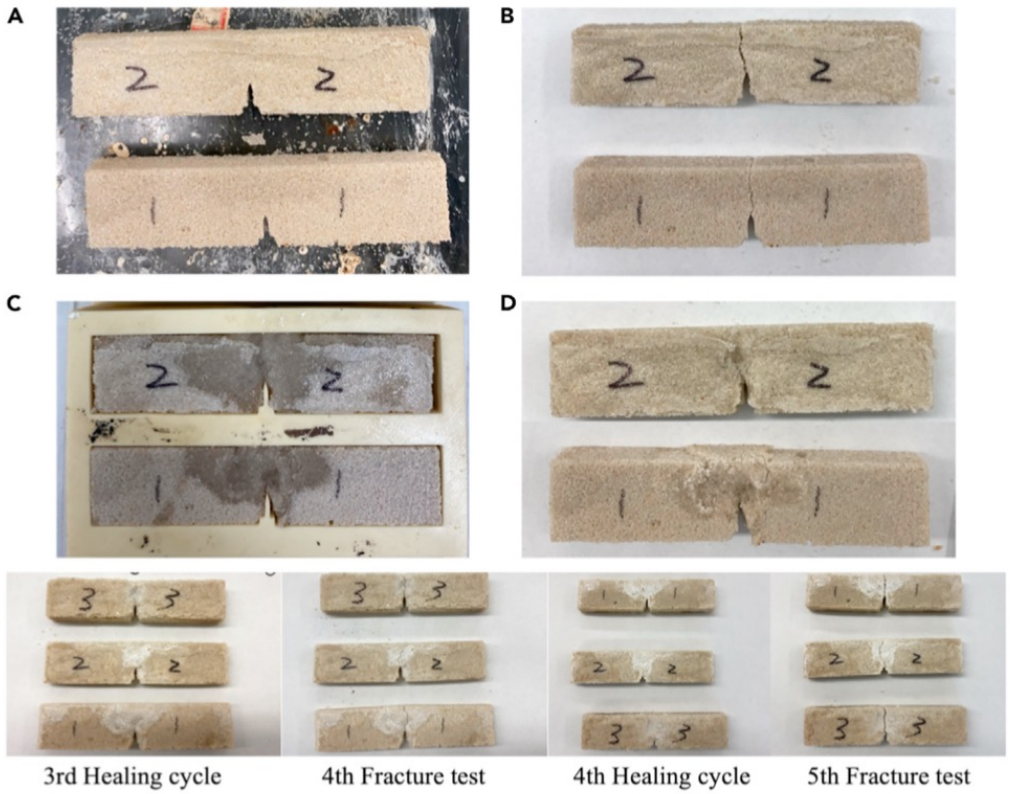
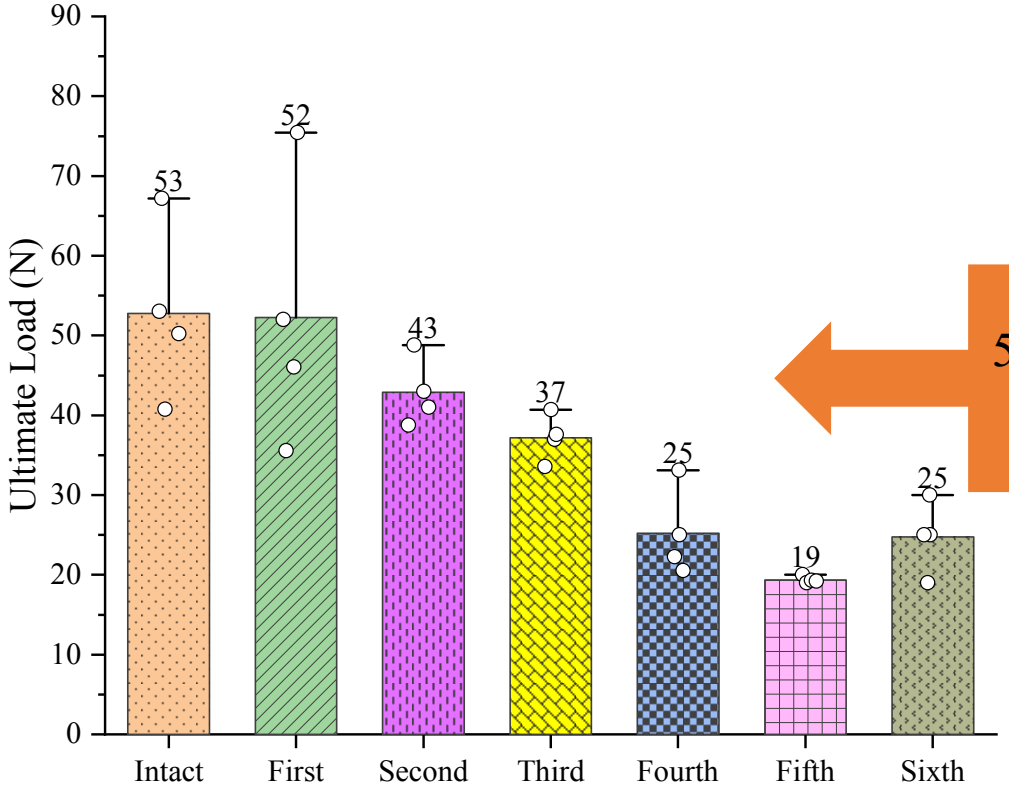
Self-healing Properties





50% of Original Strength

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Take home messages

- ECM possesses 12 MPa as a construction material, higher than any other biological construction material and is more than twice as high as the minimum acceptable strength for cement mortar.
- ECM is a ”living” material capable of self-healing for six cycles of fracture.
- ECM can be a viable method for carbon sequestration. **Producing 1kg will net consume 0.2 kg CO_2.**

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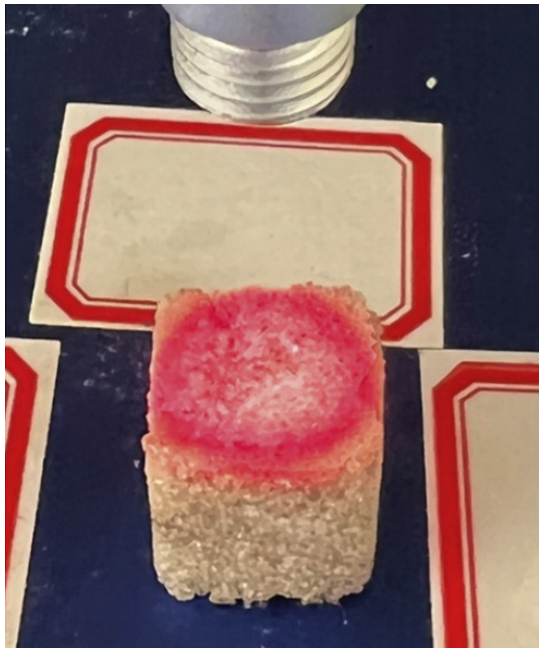
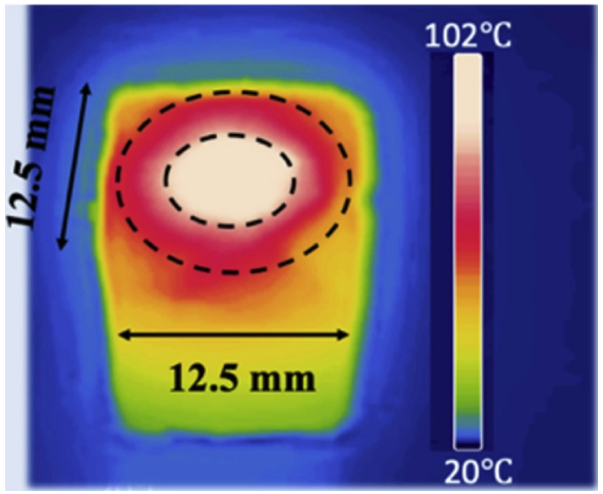
The Sustainable Future

ECM-n





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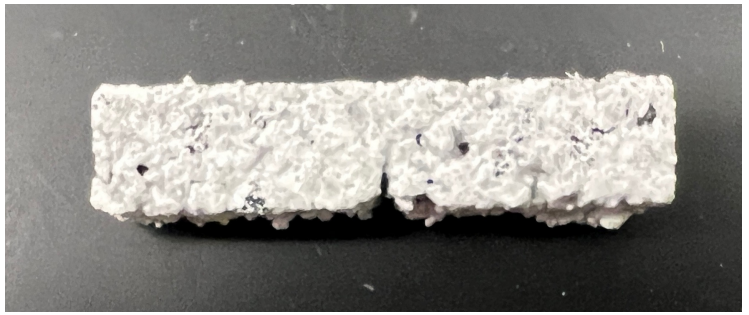
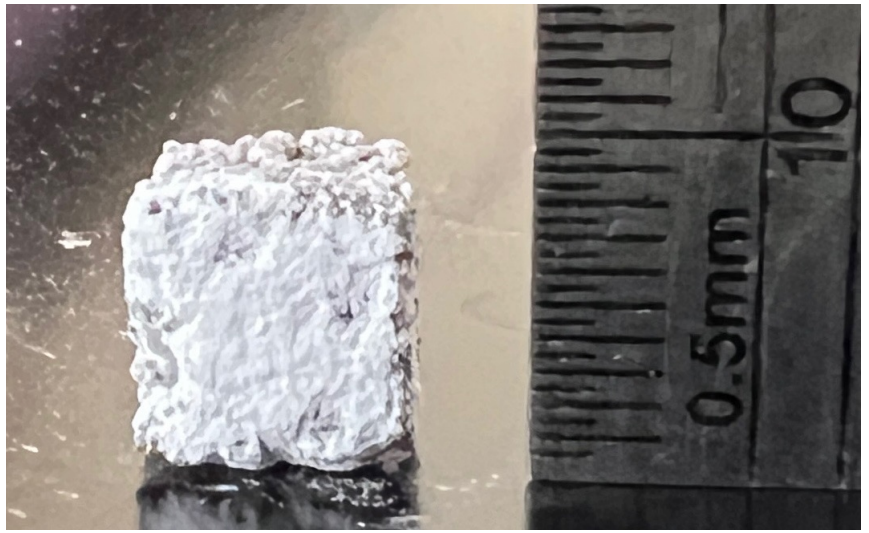
ECM-σ

1) 1 cubic yard consuming 51 kg CO_2
2) Longer Durability





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Acknowledgements

Advisor: Prof Nima Rahbar

Prof Suzanne Scarlata

Acknowledge funding sources: NSF

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THANK YOU!