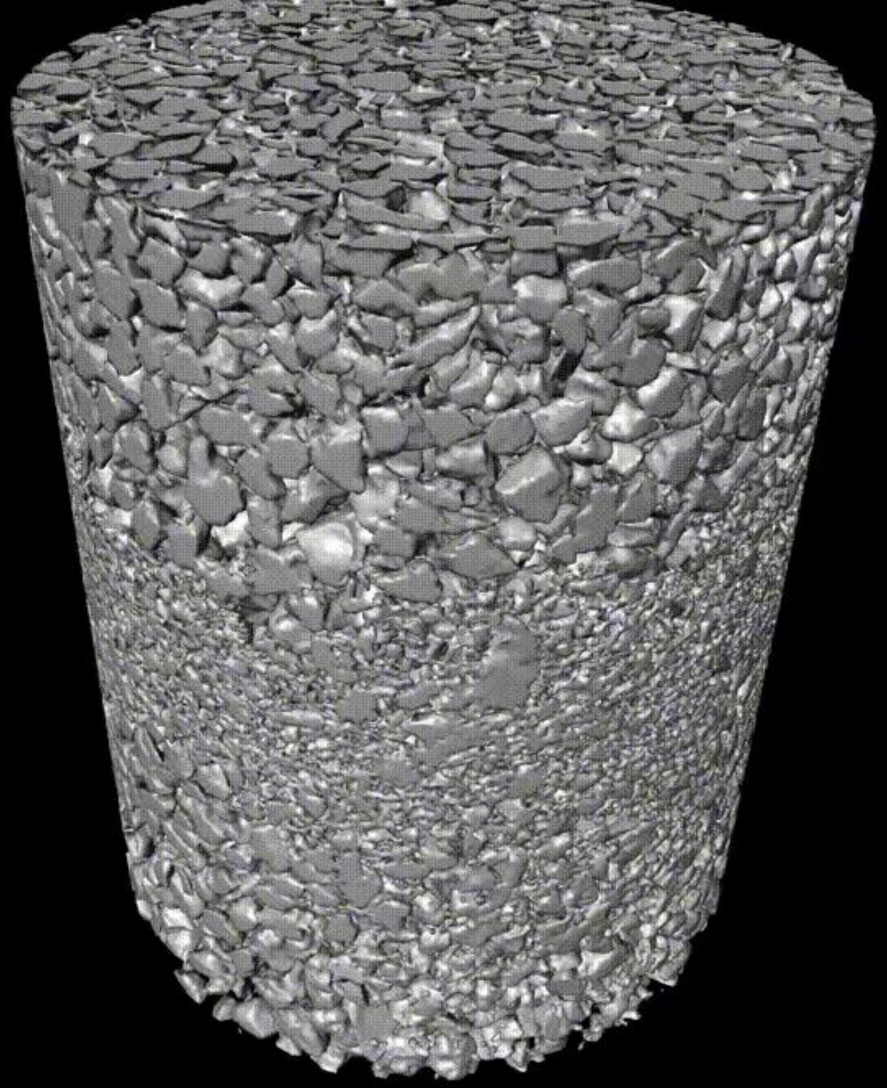
From Carbon Capture to Carbon-Negative Construction: The Journey to

Ureaka



About Me & My Journey with SCCS

Final-year PhD student specializing in **bio-cementation** using plant-based enzymes (EICP) and bacteria (MICP).

Three years of involvement with SCCS events, developing meaningful academic and industry connections.

Collaborating with **The Carbon Removers** to evaluate solutions for permanent storage of biogenic CO_2.

THE CARBON REMOVERS → Ureaka

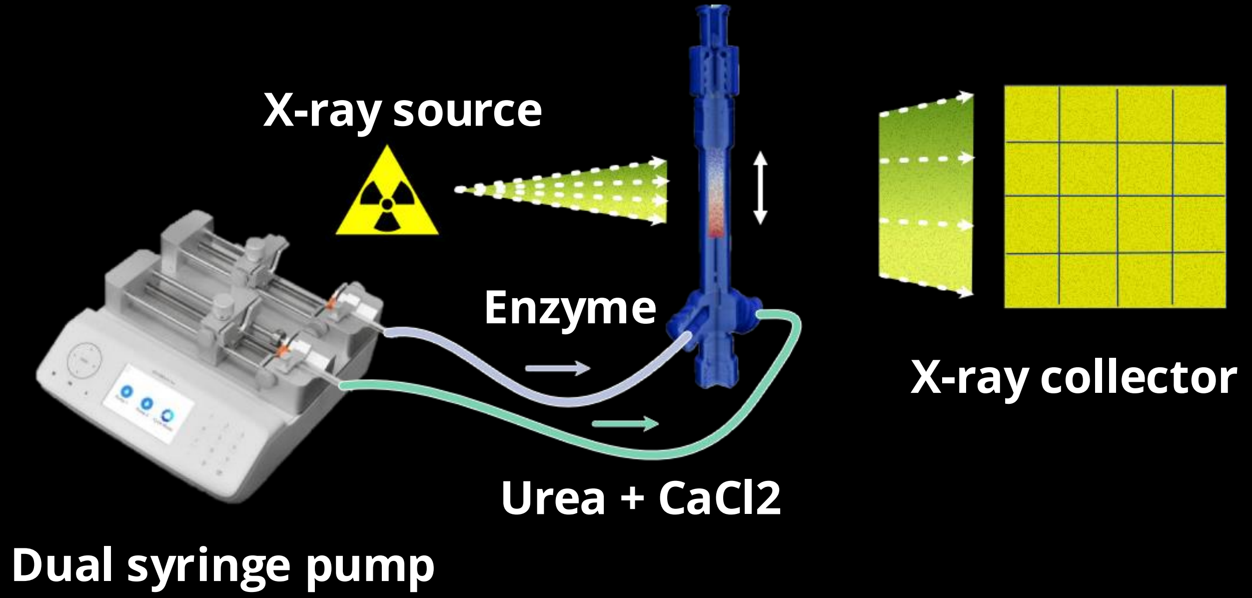
Passionate about translating **academic research** into **real-world solutions** to tackle climate change.

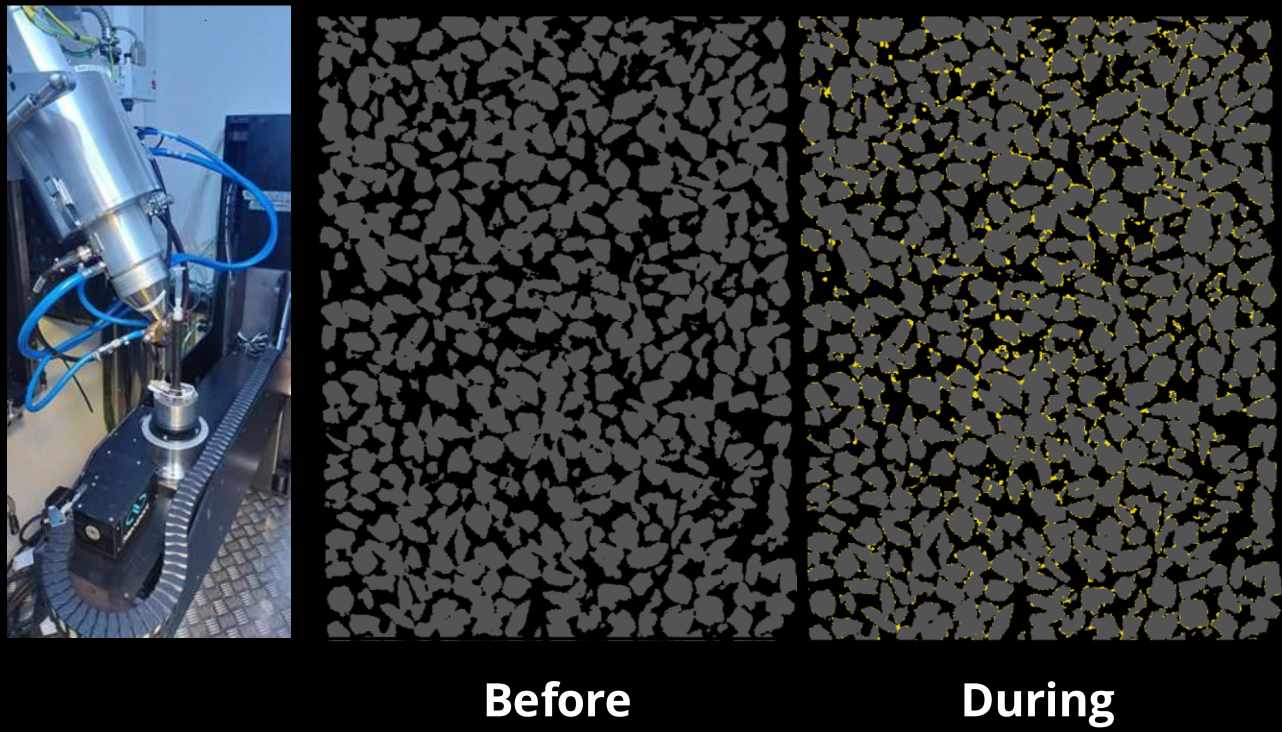
First 4D XCT Imaging of Enzyme-Induced Carbonate Precipitation

- High-speed X-ray computed tomography (XCT) visualized **multiphase** enzyme-induced carbonate precipitation (EICP).

- First-ever capture of real-time enzyme induced crystallization in 3D.

- Critical for advancing subsurface CO_2 storage and other applications.





How Crystallization Impacts Permeability and Flow

1. Crystallization Dynamics:

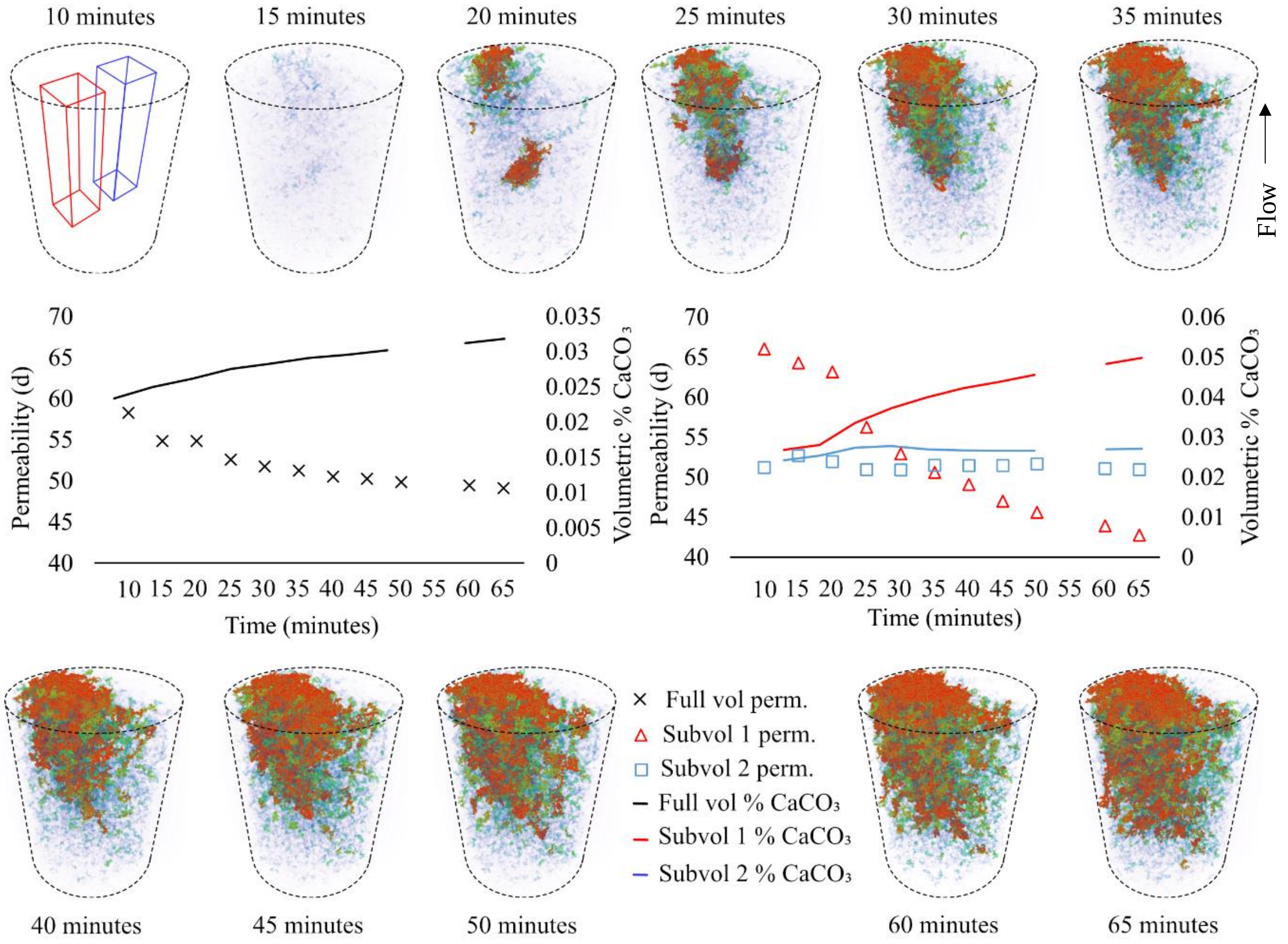
- Precipitation occurs along the mixing profile.
- Reduction in local flow velocity caused by crystal formation.

2. Impact on Permeability:

- Simulated permeability reduced by 37% in just 1 hour.

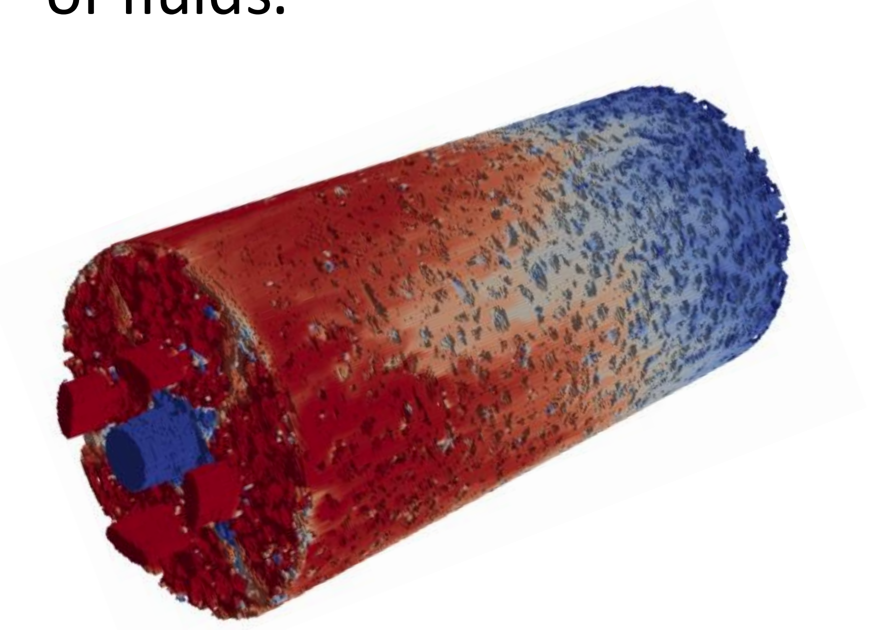
3. Key Insight:

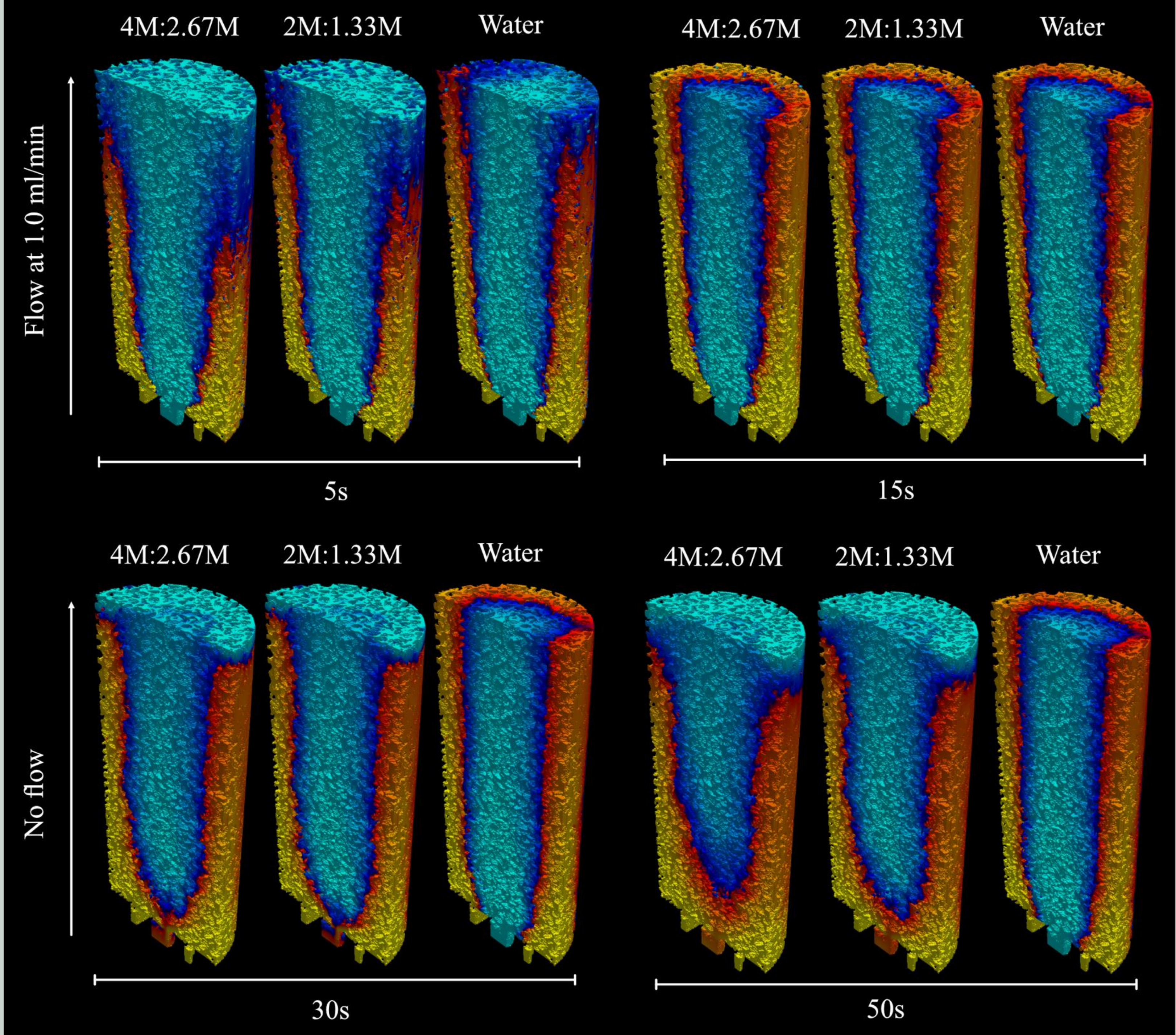
- Crystal location is independent of sand grain contact points.



Fluid Mixing Model to Explain Crystallization Dynamics

OpenFOAM was used to simulate the in situ mixing of fluids.



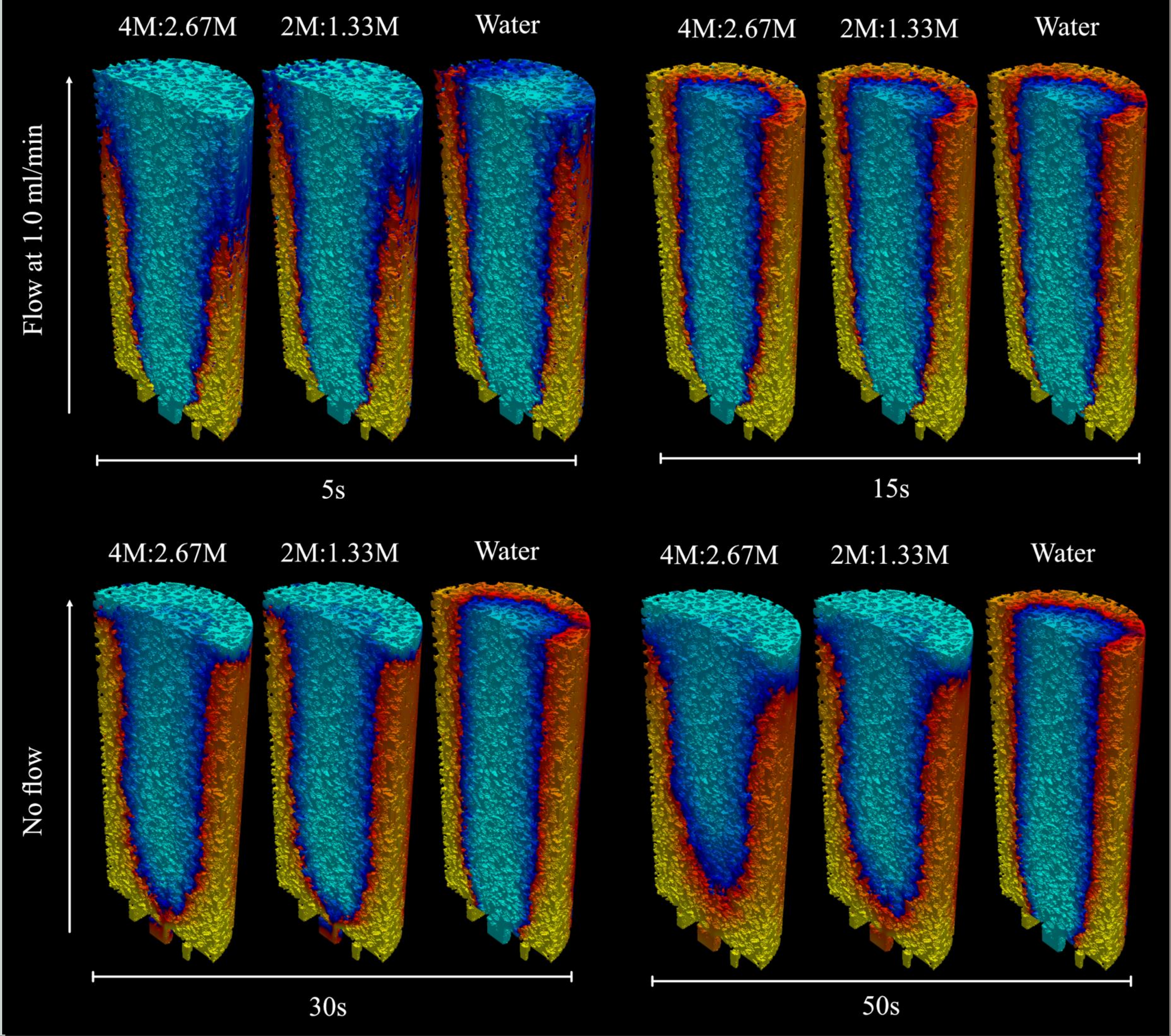


Fluid Mixing Model to Explain Crystallization Dynamics

- During flow viscosity and density differences limit effective mixing.

- Density currents drive crystal formation along gradients once flow turned off.

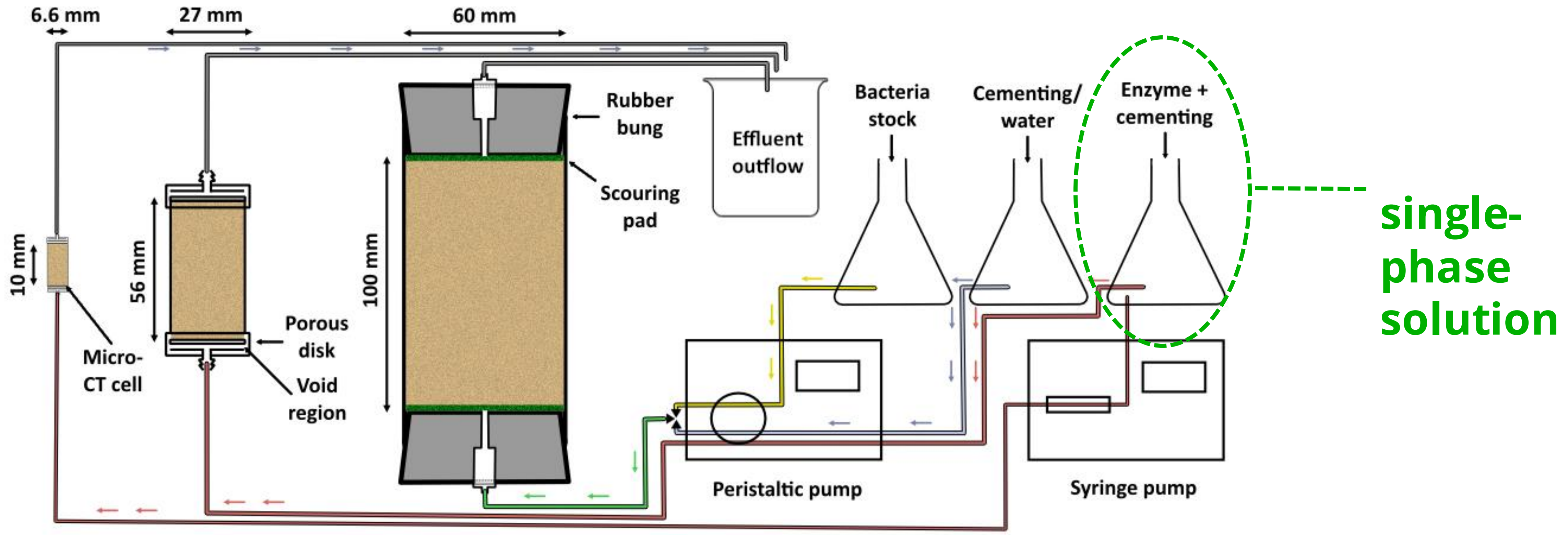
- **Fluid mixing in porous media remains a significant challenge!**



The Case for Single-Phase Injection Strategies

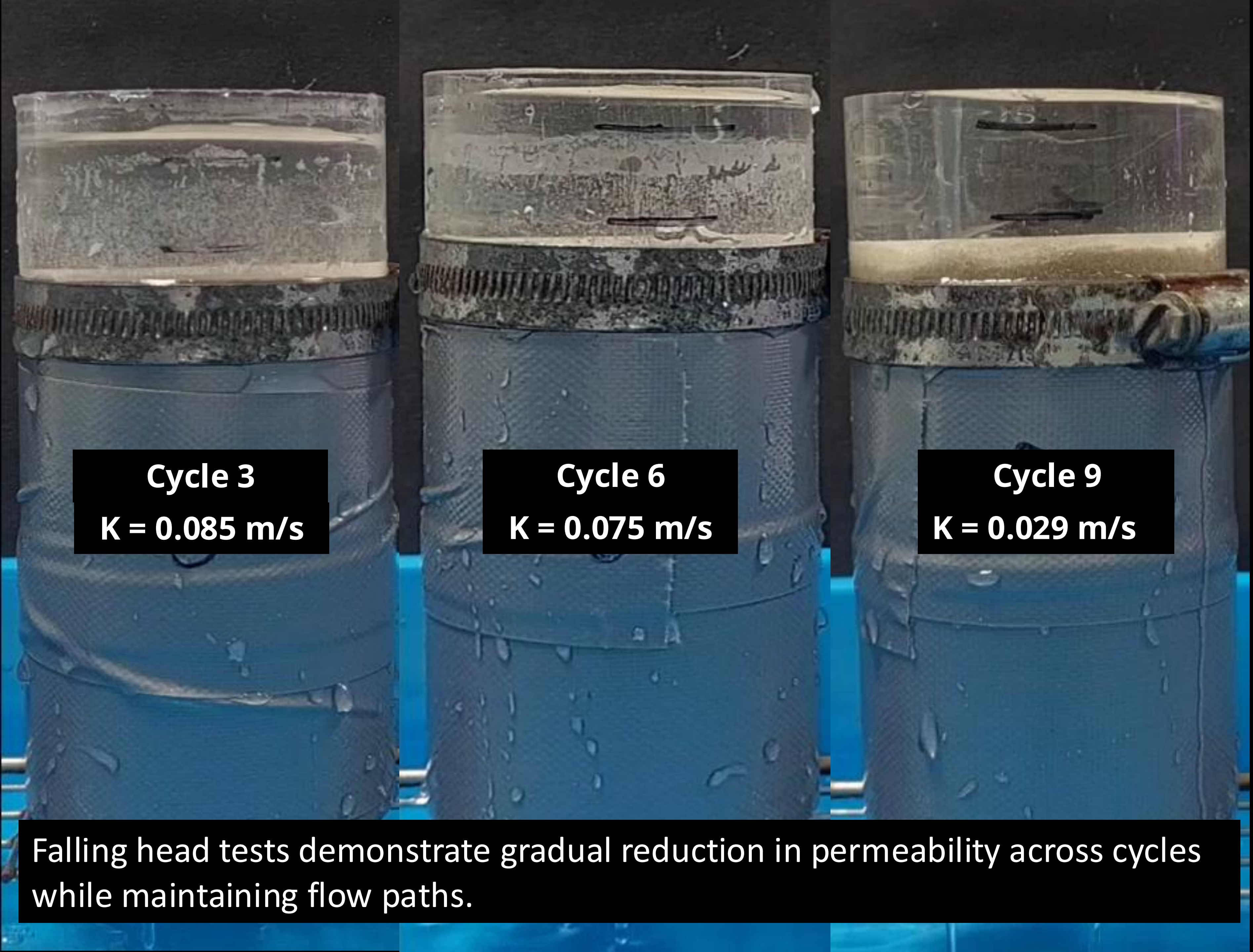
Traditional multi-phase injection faces challenges: **clogging, uneven distribution, and inefficiency.**

Single-phase injection combines crudely extracted **urease** (from jack beans or soya beans), **urea, and calcium chloride,** simplifying delivery and reducing operational costs.



Schematic of single-phase injection setup, combining enzyme and cementing solution in one phase.

Retaining Permeability with Soybean EICP

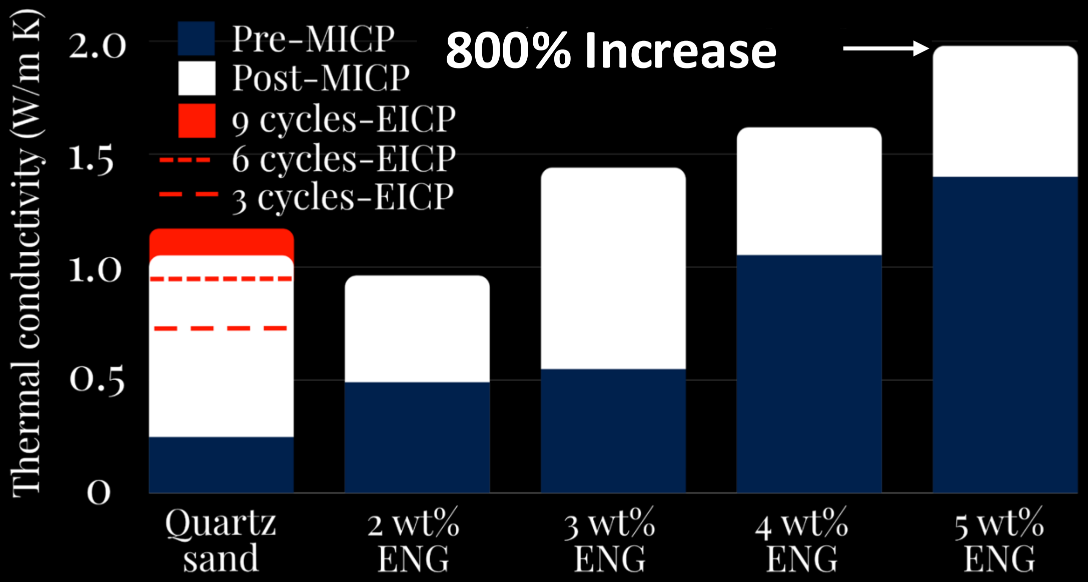


Falling head tests demonstrate gradual reduction in permeability across cycles while maintaining flow paths.

- Requires several cycles for significant permeability reduction.
- Hydraulic conductivity retained up to **25 cycles.**
- Applications in **sustainable drainage systems** and **fluid flow management.**

Boosting Thermal Conductivity in Bio-Cemented Materials

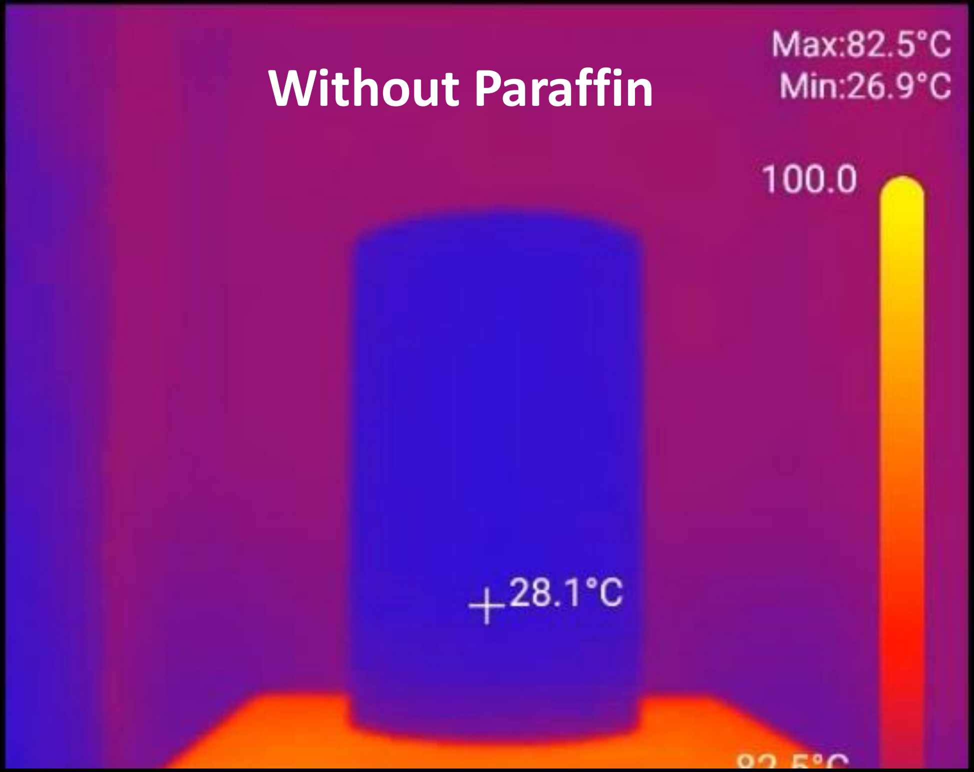
- Soya bean EICP increases thermal conductivity by **779%** after 25 cycles.

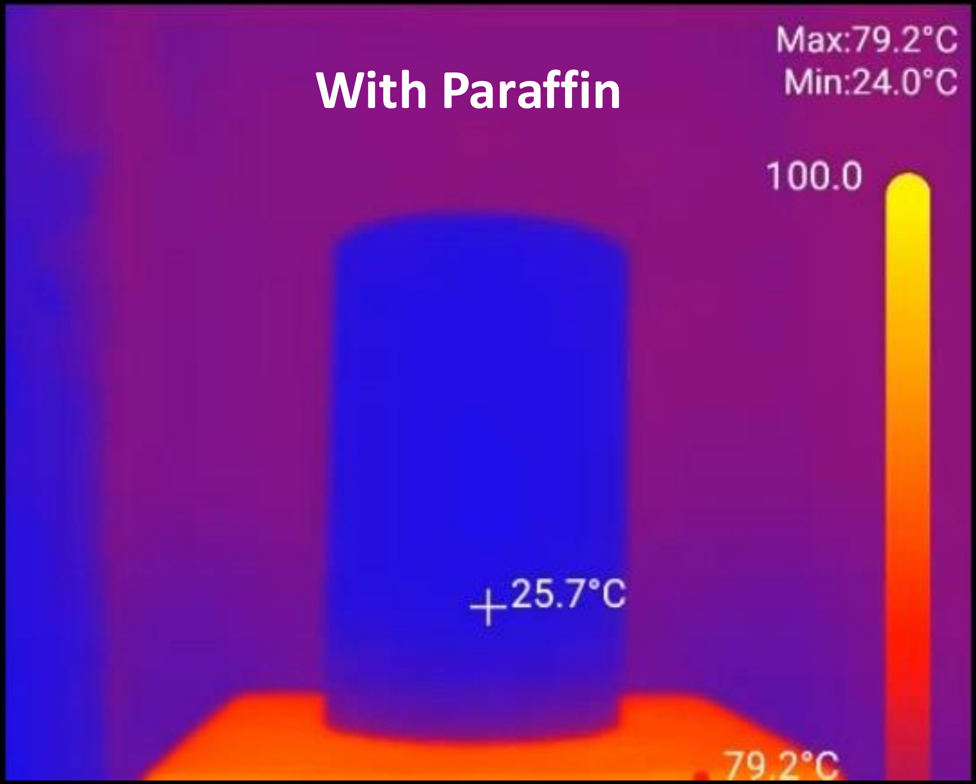


- Expanded natural graphite (ENG) enhances thermal conductivity (**800%** after 9 cycles) and enables **directional heat flow control**.

Thermal Energy Storage with Paraffin-Infused Expanded Graphite

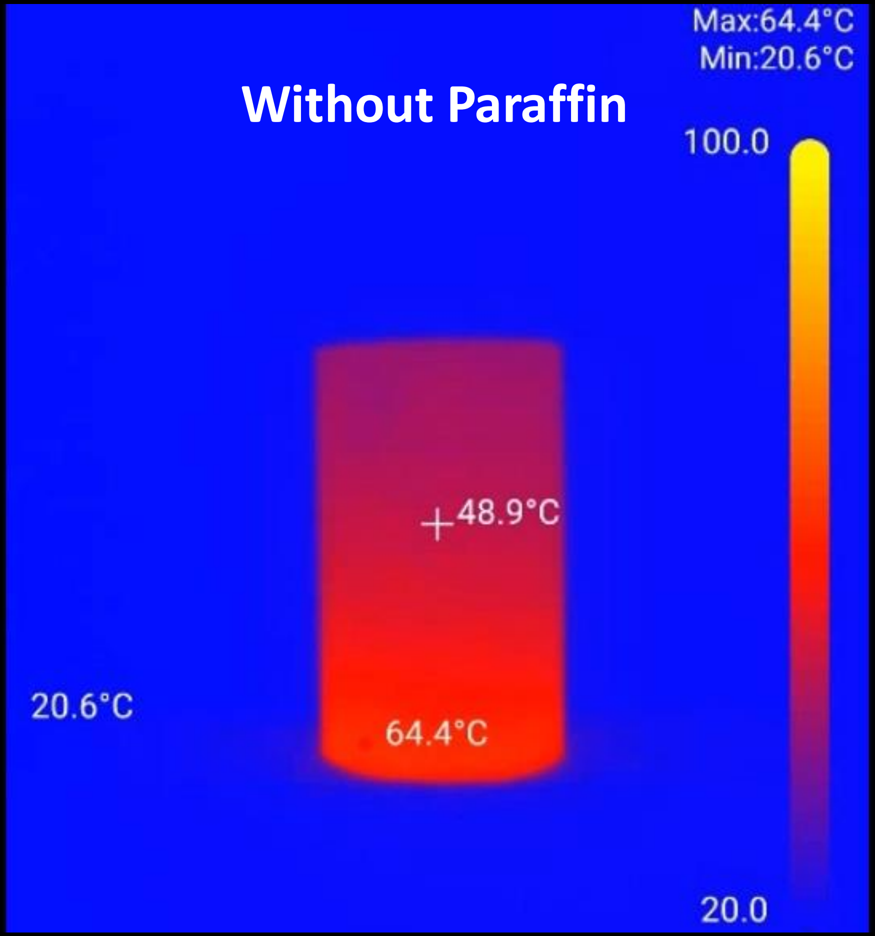
- Paraffin-infused EICP samples absorb latent heat during heating, slowing the temperature rise compared to non-paraffin-infused samples.
- Thermal buffering occurs within the phase change window (~40–50°C), significantly enhancing energy storage potential.

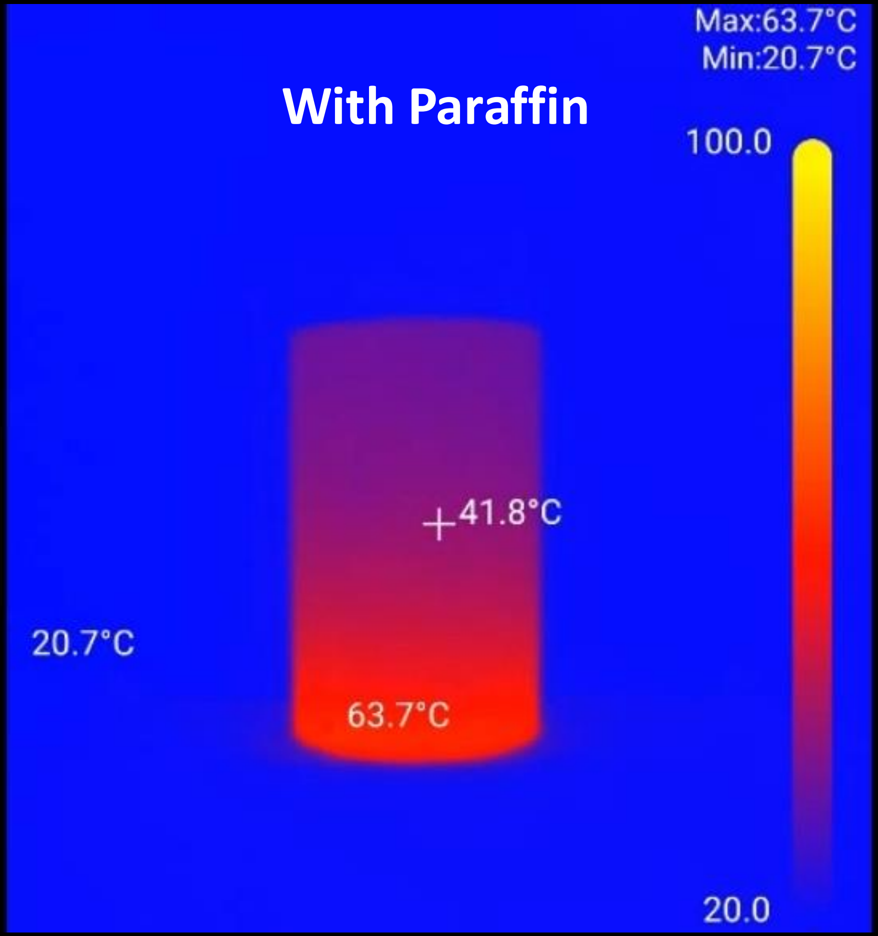


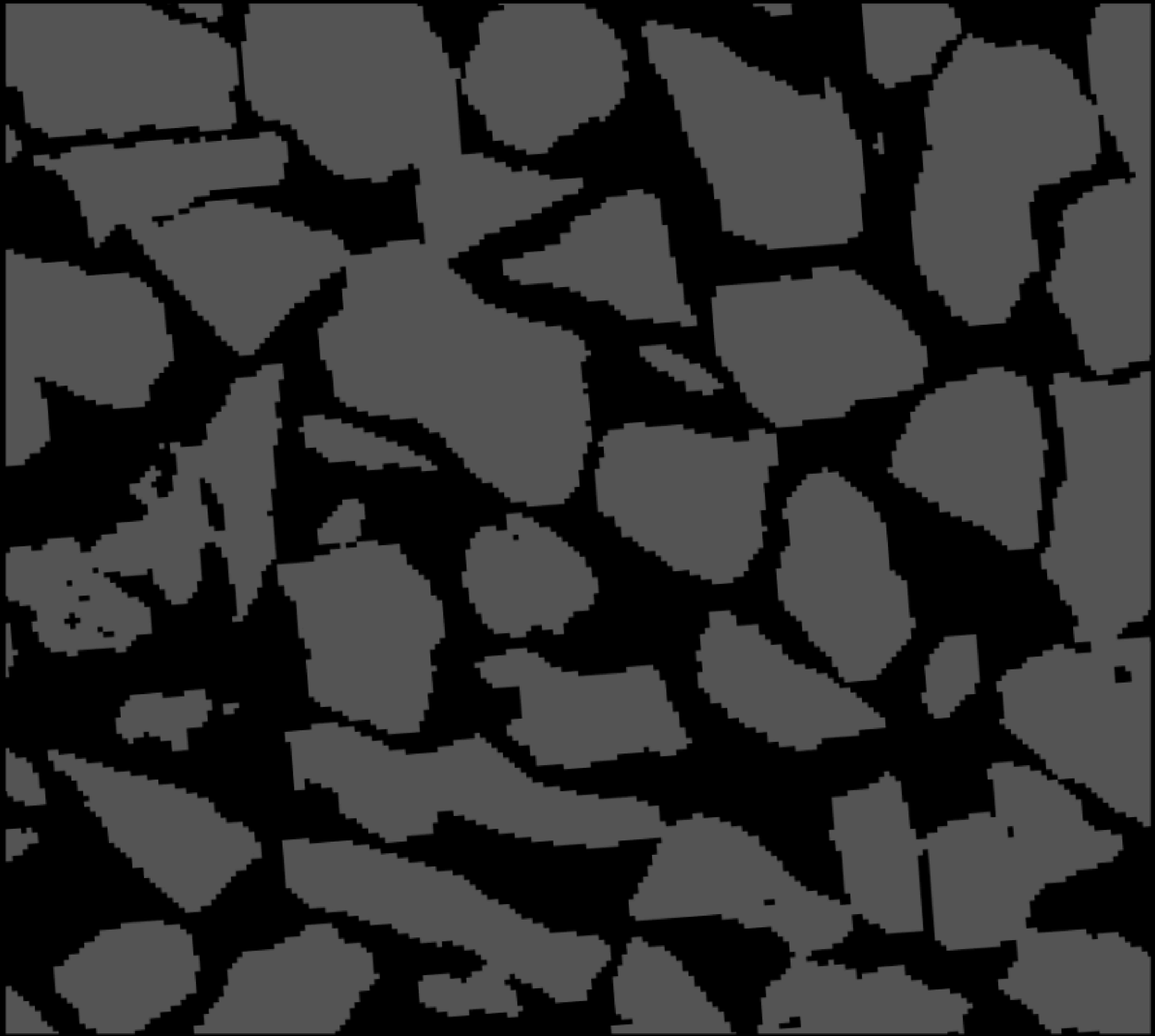


Thermal Energy Storage with Paraffin-Infused Expanded Graphite

- Paraffin-infused EICP samples release stored latent heat gradually, cooling significantly slower under ambient conditions



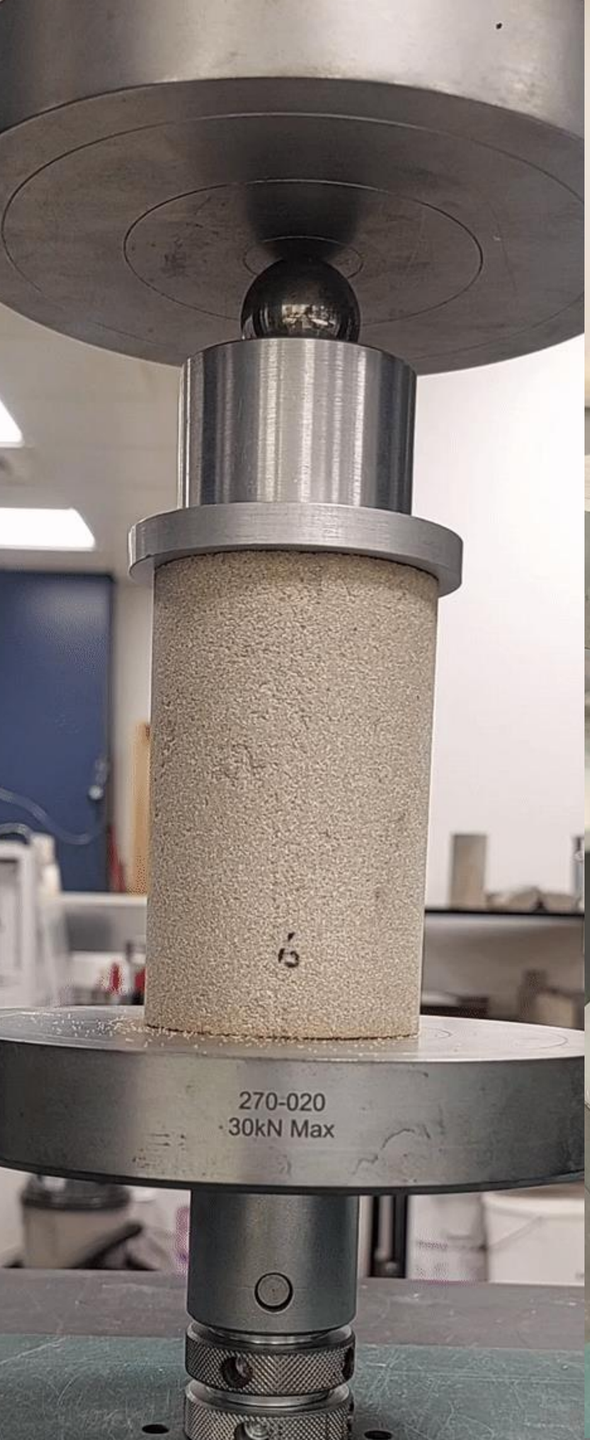




0 cycles

Tracking Carbonate Precipitation Over Time with Micro XCT

- **Uniform precipitation** of $CaCO_3$ over repeated soya bean EICP cycles.
- Precipitation predominantly forms at grain contacts, acting as **thermal** and **mechanical** bridges.
- **Retention of flow paths** enables continued bio-cementation, even after multiple cycles.



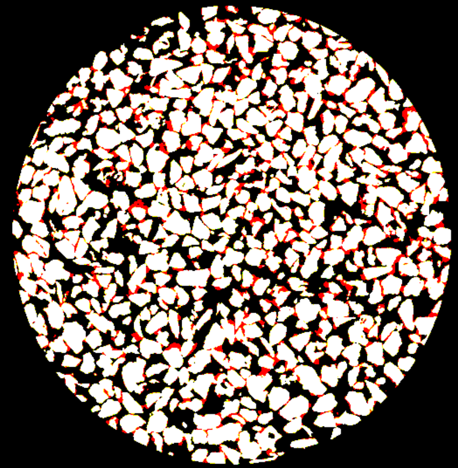
Compressive Strength Tests

3 cycles: 2.3 MPa at 7.5 wt% $CaCO_3$

6 cycles: 5.2 MPa at 12.7 wt% $CaCO_3$

9 cycles: **>8.8 MPa** at 16.2 wt% $CaCO_3$

Compressor maxed at 25,000N, failed to break sample!



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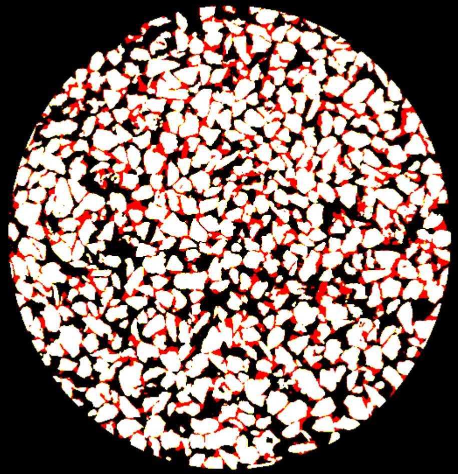

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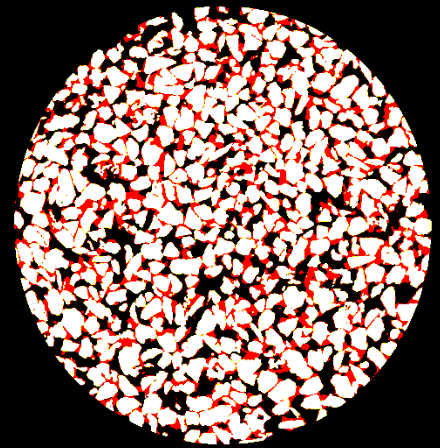

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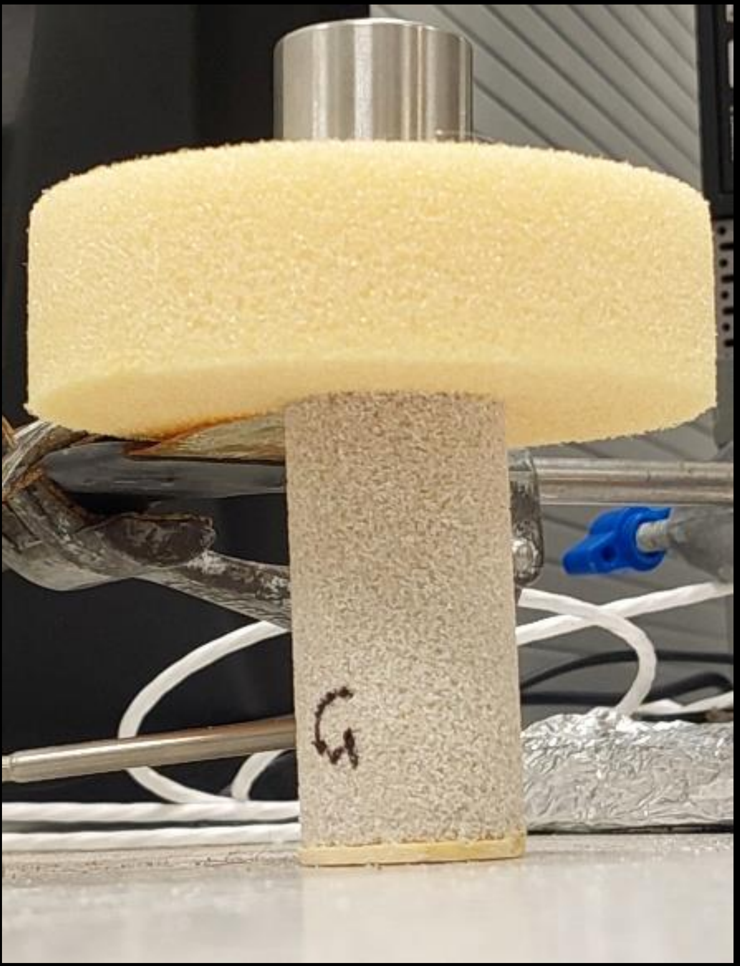
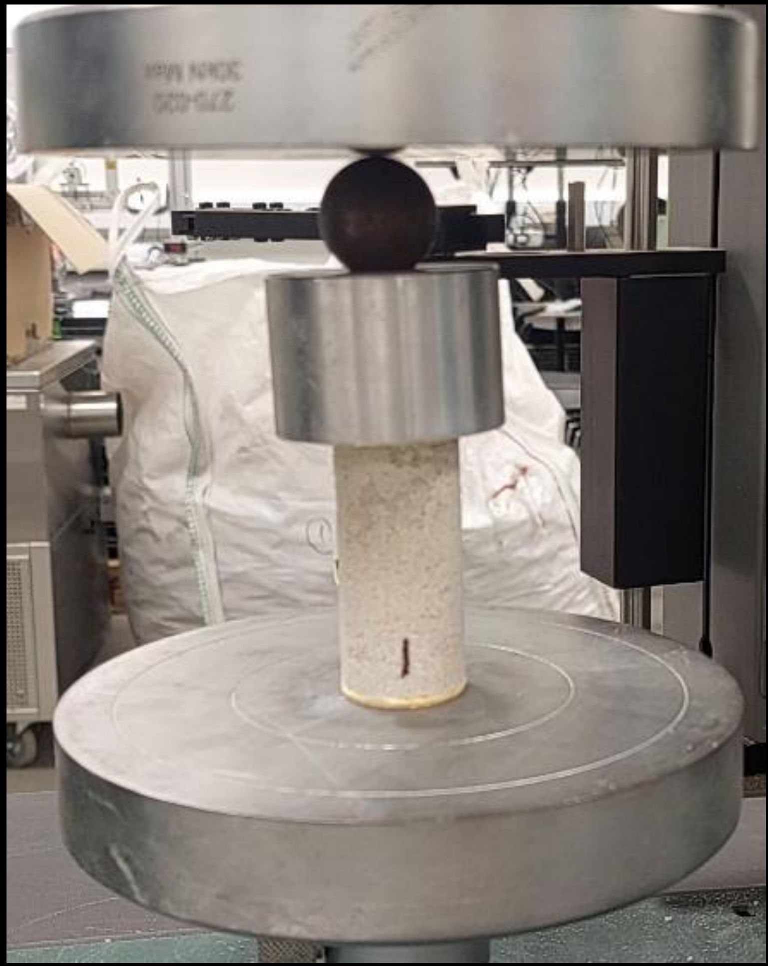
Soya Bean EICP for Hydraulic, Thermal, and Mechanical Optimization



Thermal conductivity increased by up to 779% (0.25 to **1.93 W/m ·K)**

Hydraulic conductivity is maintained up to 25 cycles of soybean EICP, enabling **greater bio-cementation than MICP**.



UCS reached **17.9 MPa at 26.6 wt% $CaCO_3$** after 25 cycles of soybean EICP

Ureaka

Building the leading bio-concrete solution
for the construction industry

The Construction Sector: A Major Source of Global CO_2 Emissions

Cement and concrete are responsible for 8% of global CO_2 emissions — nearly twice that of aviation.

Current materials rely on **energy-intensive processes and fossil fuel-based resources**, driving high emissions.

There is an urgent need for sustainable alternatives to conventional concrete.

Fact 1:
Traditional cement emits **~900 kg of CO_2 per ton** produced.

Fact 2:
By 2050, global cement demand is estimated to **grow by 12–23%**.

Cement free bioconcrete, Permanent CO_2 storage

Our **patent-pending process** combines carbon capture and bio-cementation, creating a closed-loop system where:

- CO_2 is stored in a **permanent, fully quantifiable,** and **mineralized form** within construction materials.
- The bio-cementation step **regenerates aqueous CO_2 sorbent** for **partnering capture companies**.
- **Utilizes CO_2** in high-value products, making permanent storage **economically viable**.

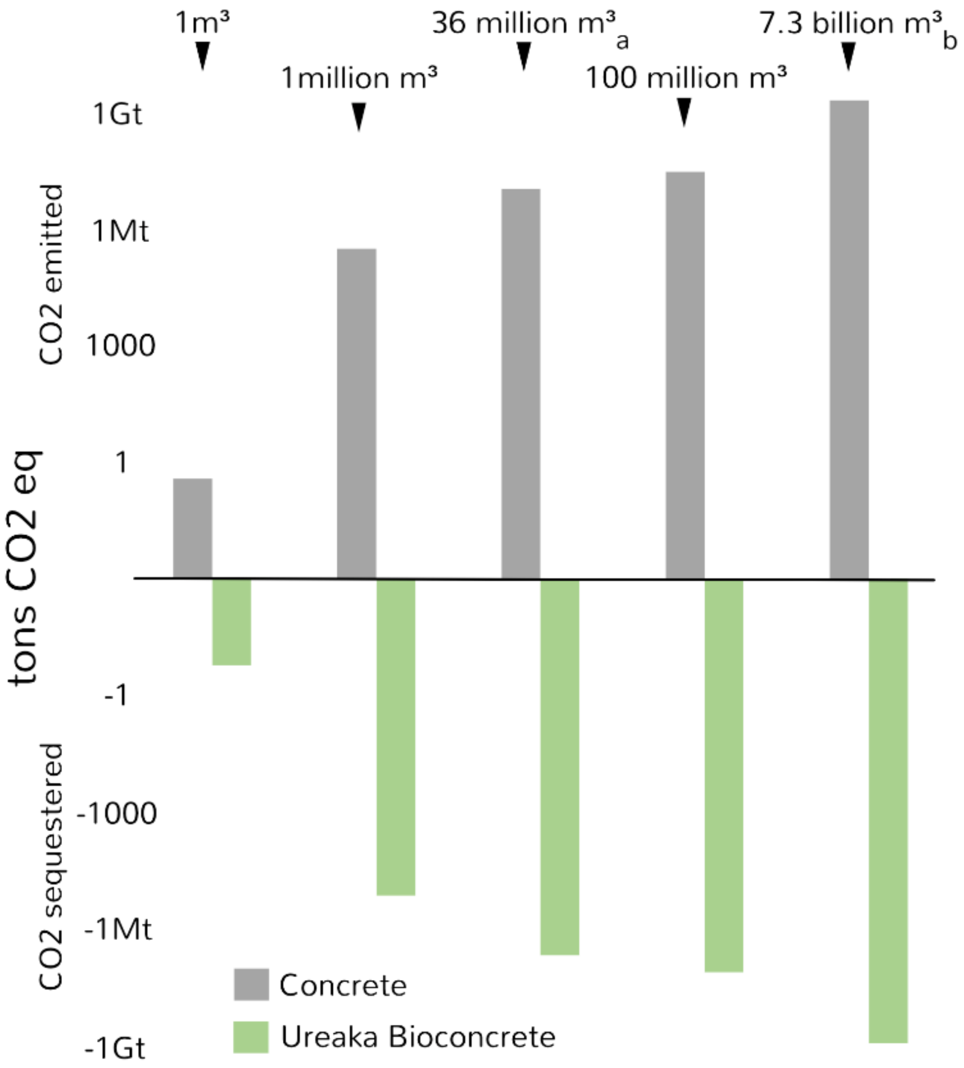
Ureaka bio-concrete

Impact

Replacing all UK concrete with Ureaka bioconcrete could avoid **14.8 Mt CO_2** and sequester **6.7 Mt of CO_2**.

This is equivalent to removing over 5 million petrol cars for 1 year.

CO_2 Comparison



a UK annual concrete use   b Global annual concrete use

Note: This comparison illustrates potential CO2 reduction if we reach target efficiencies in each step of our process

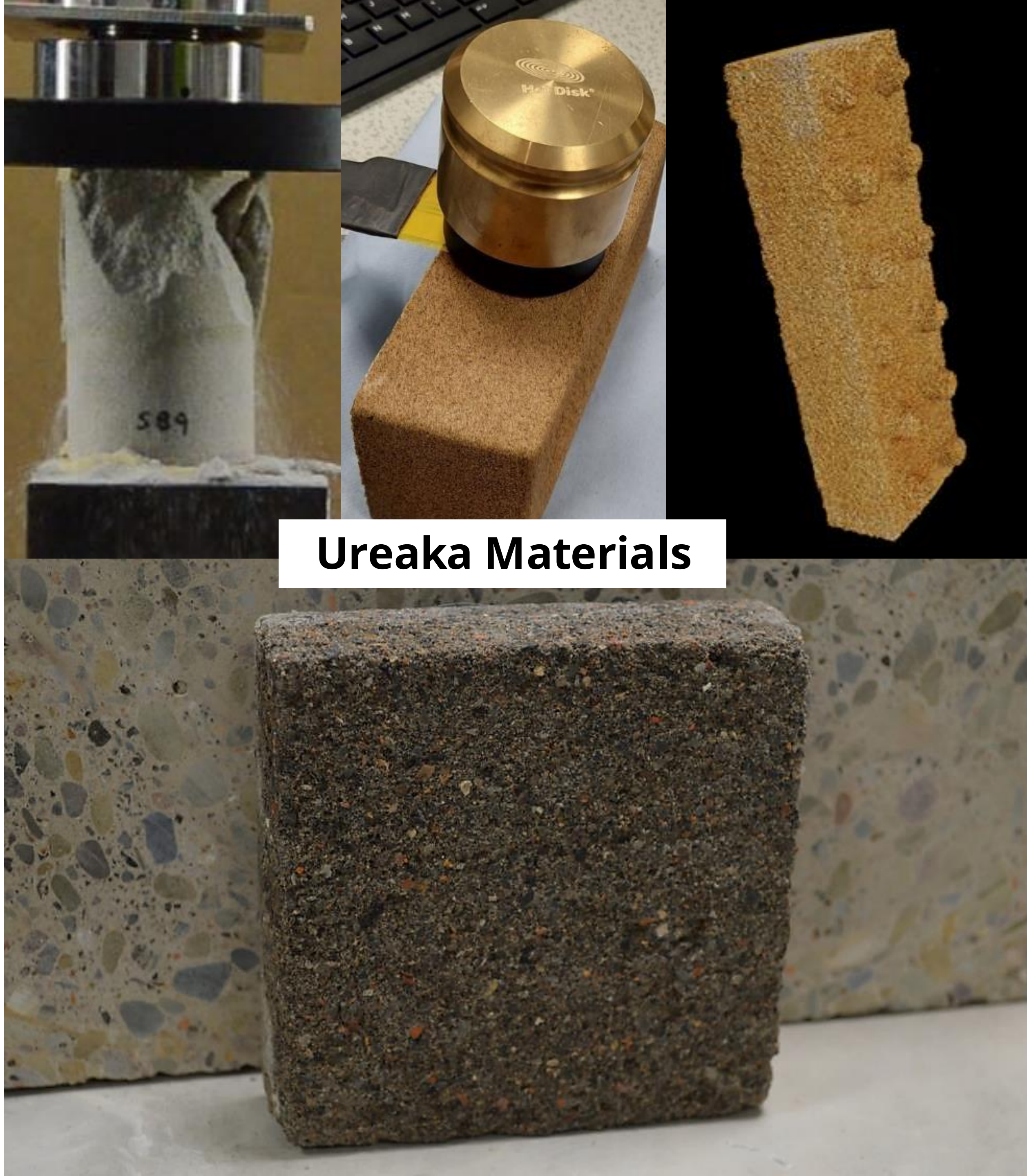
Material Properties

Structural: Up to 30% lighter than conventional concrete, with comparable compressive strength (3500 psi).

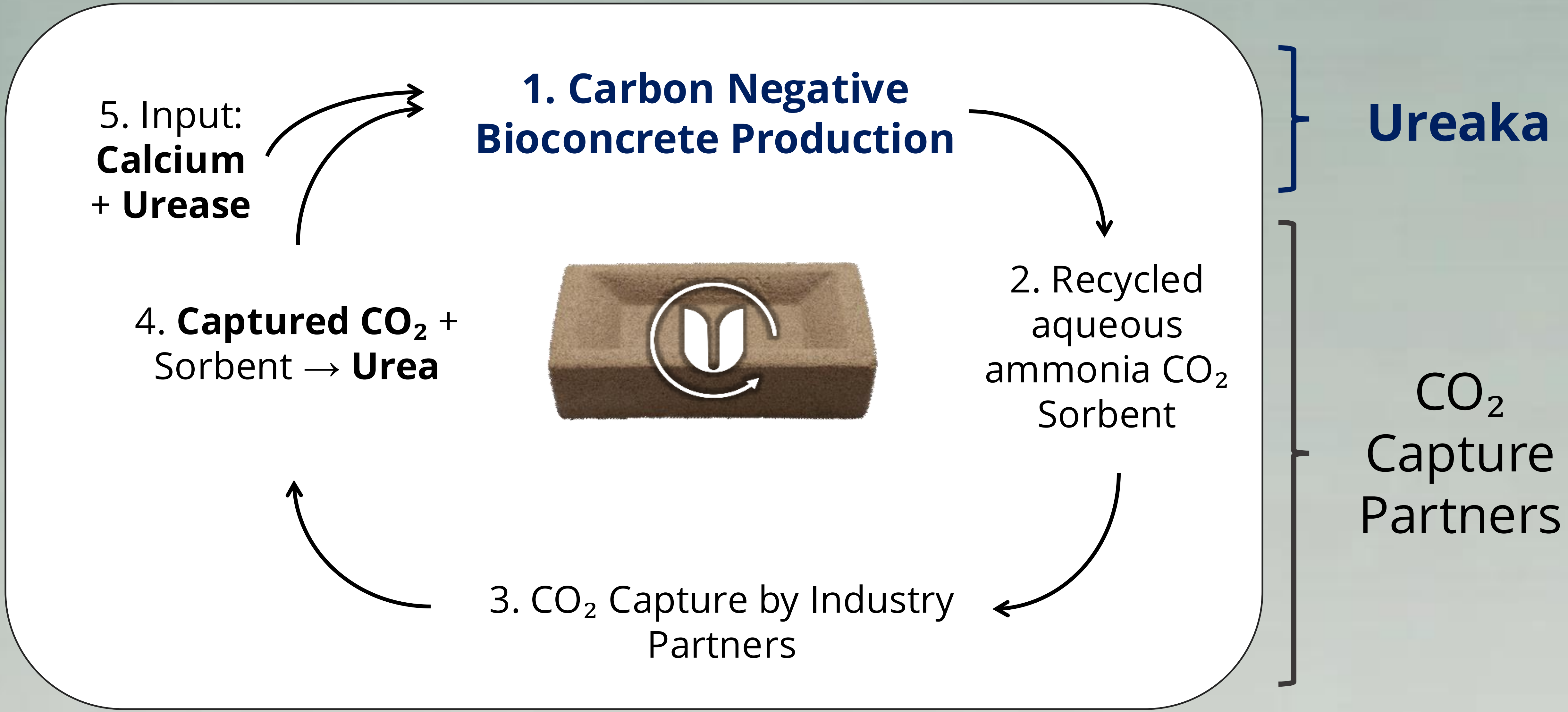
Measured CO_2 storage: ~117 kg of CO_2 per ton of bioconcrete, confirmed by acid dissolution and XCT.

Cost competitive: Priced to match or beat traditional concrete costs.

Tailored permeability: Allows use in drainage, coastal infrastructure, and masonry.



Ureaka's Closed-Loop Carbon Capture & Storage: A Circular Solution



Patent Pending: UK Patent Application No. 2411063.7

1a. Carbon Negative Bio-concrete Production

- Leverages the **urea hydrolysis** pathway for **controlled carbonate precipitation**.

$$(NH_2)_2CO + CaCl_2 + 2H_2O \rightarrow CaCO_3 + 2NH_4Cl$$

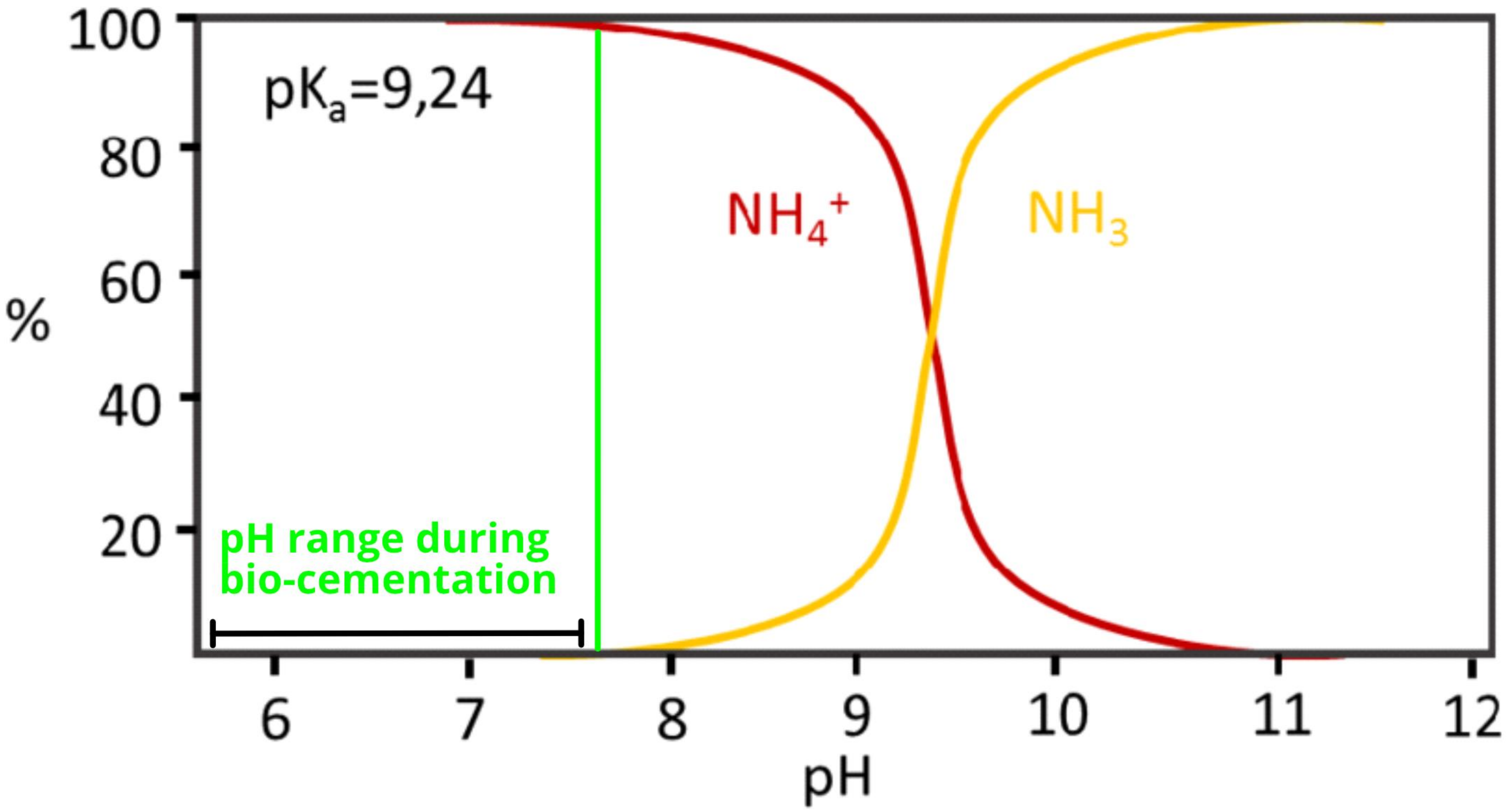
- Produces **$CaCO_3$** that binds aggregates into **high-strength bio-concrete.**
- Enables **permanent**, and **fully quantifiable** CO_2 sequestration.
- Uses sustainable urease sources, primarily **soybean waste**.
- Efficient ammonium chloride recovery supports **scalable**, **circular carbon capture.**

Cumulative $CaCO_3$ accumulation over multiple cycles

High strength bio-concrete (3500 psi)

Patent Pending: UK Patent Application No. 2411063.7

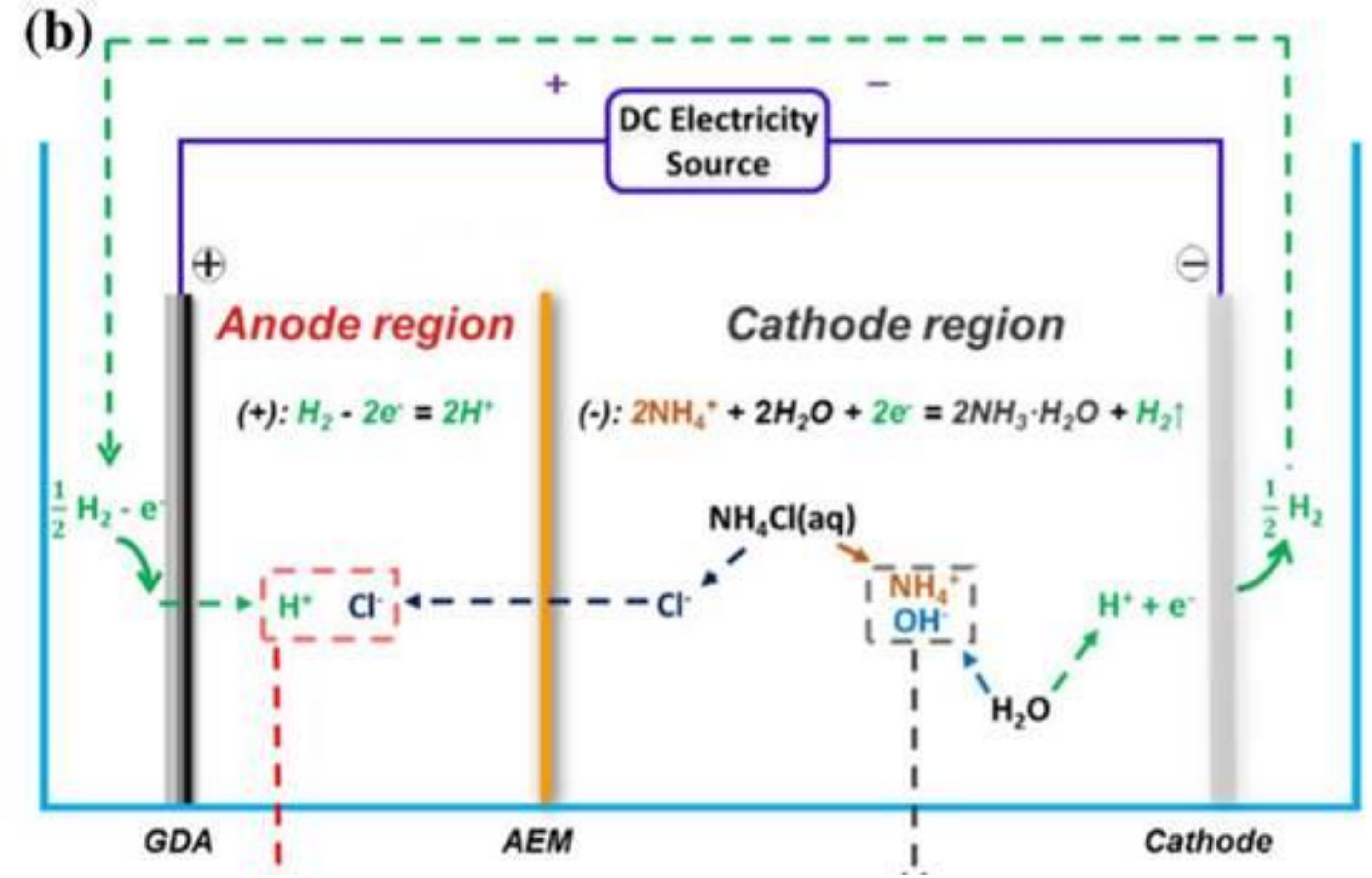
1b. Recovering Ammonia Efficiently



1. "Waste" effluent (NH_4Cl) is recovered at pH 7.5, minimizing ammonia losses.

Patent Pending: UK Patent Application No. 2411063.7

2. Recycled CO_2 Sorbent: Innovative Electrochemistry



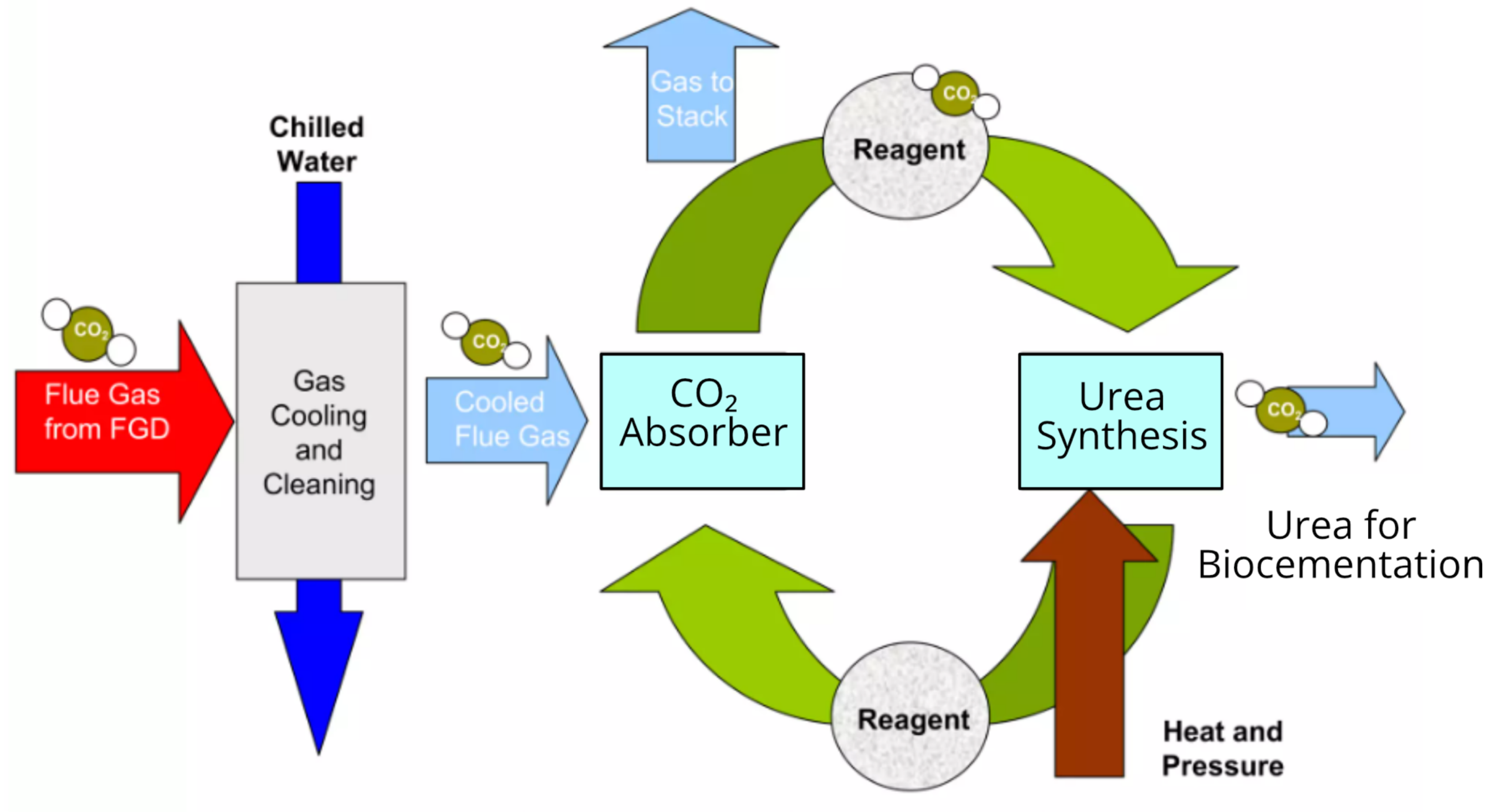
2. Membrane Electrolysis is used to break down NH_4Cl into **$NH_3.H_2O$** and **HCl**.

$NH_3.H_2O$ is given to the partnering **capture company**.

Adapted from: Xie, H., Wang, F., Wang, Y., Liu, T., Wu, Y. & Liang, B. (2018). CO2 mineralization of natural wollastonite into porous silica a nd CaCO3 powders promoted via membrane electrolysis. Environmental Earth Sciences, 77.

Patent Pending: UK Patent Application No. 2411063.7

3. CO_2 Capture & Urea Resynthesis (Partner Company)



3. $NH_3.H_2O$ is used as a sorbent to **Capture CO_2** and resynthesise **Urea (4)** via the well established **Chilled Ammonia Process (CAP).**

Adapted from web: https://www.slideshare.net/slideshow/ccs-projects-integration-workshop-london-3nov11-aep-integration-of-a-commercial-scale-co2-capture-facility-into-a-host-plant/10314387#5

Patent Pending: UK Patent Application No. 2411063.7

Sources of Alkalinity: Recovering $CaCl_2$

Long-Term Strategy: Use HCl from step 2 to extract Ca^{2+} from calcium silicate-rich rocks (e.g., basalt, wollastonite) to **resynthesize $CaCl_2$** for step 1.

$$CaSiO_3 + 2HCl \rightarrow CaCl_2 + H_2O + SiO_2$$

Abundant Resources: These materials are globally available, enabling **scalable applications** in sustainable construction and mineralization.

Initial Approach: Ureaka will purchase $CaCl_2$ as a **zero-carbon waste stream**.

Supply Chain

Raw materials

Industry emitter
CO_2 Capture + Conversion

Supplier 1
Zero carbon calcium source

Supplier 2
Enzyme: from food/drink waste

Supplier 3
Aggregate

Manufacturing

By-product recycled for additional CO_2 capture

At Ureaka, we make carbon-negative bio-concrete using CO_2 captured by industry partners.

Revenue

1. Carbon negative Bio-concrete

2. Carbon credits
Shared with capture company

3. UK ETS free allowance
Unused allowances sold for additional profit

Market Opportunity

The green construction material market is expected to grow at 12% CAGR from 2024 to 2029

TAM $325B

Global green construction materials market

SAM $69B

UK + Europe + US

SOM $70M

Estimated obtainable market with a 5% UK market share

Source/calculation: Green market assumed at 19% of global construction market of which we use numbers only for bricks and pre-cast concrete blocks (statistics from https://market.us/report/construction-materials-market/ and https://www.statista.com/outlook/cmo/diy-hardware-store/hardware-building-materials/worldwide)

This is how UREAKA distinguishes itself

		BIOMASON	Paebbl™	PROMETHEUS MATERIALS	Made of Air	Biozeroc
Carbon capture and sequestration	✓	✗	✓	✗	✓	✗
Carbon storage	✓	✗	✓	✗	✓	✗
Structural building materials	✓	✓	✗	✓	✗	✓
Versatility across applications	✓	✓ (in progress)	✗	✓	✓ (in progress)	✓ (in progress)
Technical performance and strength*	✓	✓	✓	✓	✗	✓
Certifications or compliance	✗	✓	✗	✓	✗	✗
Manufacturing cost**	Medium	Medium	Low	High	Low	Medium

Note: (*) Compared to traditional building materials; (**) Based on assumptions processes costs
Source: Publicly available information, UREAKA analysis

Legend
✓ Currently available ✓ (in progress) In progress ✗ Not available

Next Steps (12 months)

Regulatory approval:

Securing regulatory approvals under British Standards, BBA, BREEAM, and Puro Earth.

Market Validation:

Secure customer demand and commitments for our carbon-negative materials.

Product Development:

Complete development + testing of our pilot product line, including masonry blocks, facing bricks and porous paving slabs.

Partnerships:

- **Formalize CO_2 supply and industry collaborators**
- **Academic partnerships**
- **Reuse of industrial hubs**
- **New Scottish jobs!**

Thank You! Any Questions?

GeoNetZero
Geoscience Solutions to address the Net Zero Challenge

UNIVERSITY of STRATHCLYDE INSPIRE

University of Strathclyde Glasgow

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