Towards Using Microbes for Sustainable Construction Materials: A Feasibility Study

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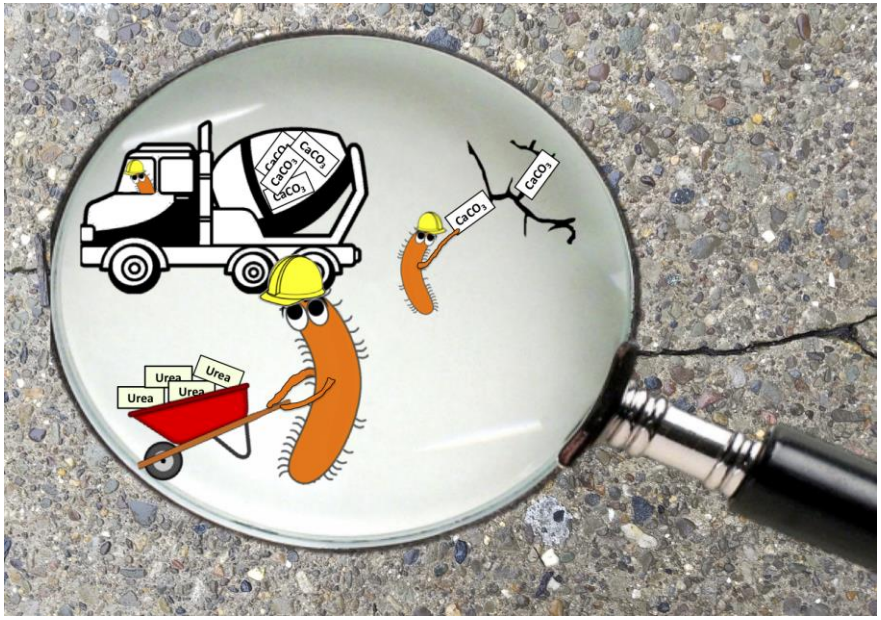

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Preventing & fixing damage to reinforced concrete is a major challenge

- Cracks reduce lifetime of structures and **cost $21 billion** annually to repair
- Current remediation strategies are expensive, temporary, and environmentally hazardous
- Bioinspired design may be the solution to making reinforced concrete more environmentally friendly

Bioinspired sustainable concrete repair: Microbially induced calcium precipitation

$$Substrate + \boldsymbol{Bacteria} \rightarrow Metabolites + \boldsymbol{CaCO_3}$$


https://www.flickr.com/photos/earthguardianangel/36478302441

- A wide range of organisms can produce $CaCO_3$
- Ureolytic microbes offer the most promise
  - Live in aerobic and anaerobic environments
  - Does not produce harmful byproducts
  - Fast production of $CaCO_3$
- MICP has been used to restore limestone and marble structures but its application for reinforced concrete has been largely unexplored.

Project Objectives

A. Conduct a literature review to identify ureolytic microbes which can be used for MICP

B. Isolate microbes that can be used for MICP that exist in reinforced concrete in-situ.

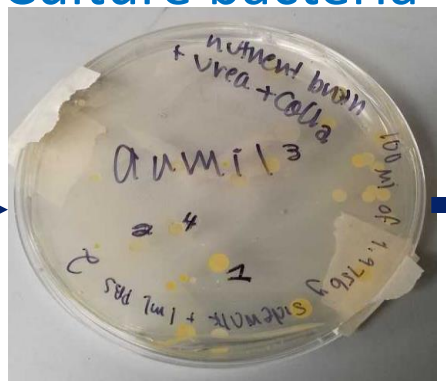
C. Evaluate the mechanical properties of concrete mix design which incorporate nutrients for MICP

D. Evaluate the self-healing and leaching properties of pre-cracked bench-scale concrete specimens developed in C

Isolation of ureolytic MICP microbes from real reinforced concrete maximizes future success

Swab concrete

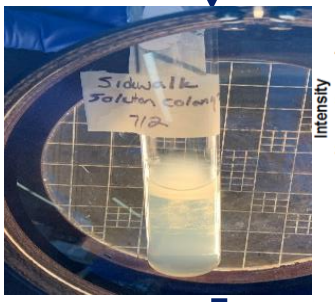
Culture bacteria

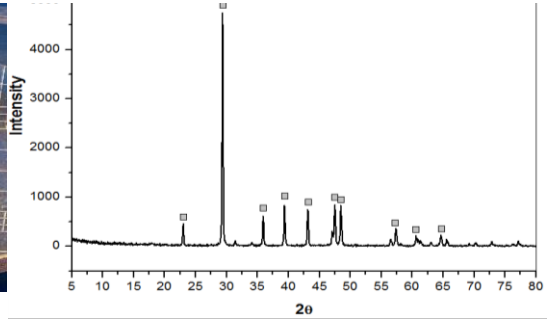


Subculture bacteria which fulfilled MICP traits

Assessing Potential MICP microbes

- Ability to form precipitate
  - agar column injection & XRD
- Speed of growth
  - growth kinetics



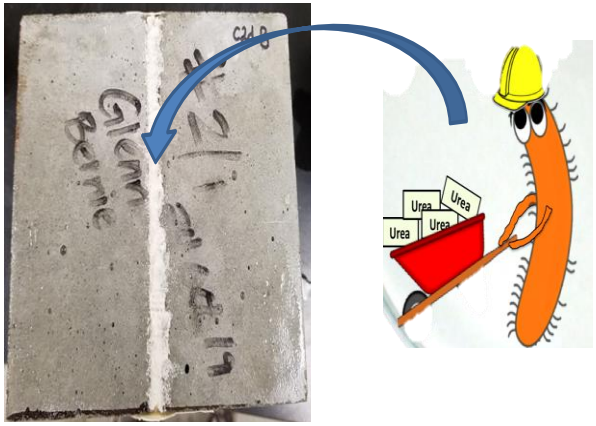


- Overall 22 microbes isolated capable of MICP
- 5 best taken on for biomortar and cracked concrete testing

MICP Biomortar is a sustainable option to repair cracked concrete

- Tested various MICP biomortar mixtures
  - 3:8 mixture of 7 day old MICP (1.4 x 10^7 cfu/ml) and sterile sand.
  - 5:2:0.4 mixture of sterile sand, 7 day old MICP and binder

- Preliminary results show water ingress reduced by 15-30%
  - Bacteria from I-70 deck most effective
  - Currently repeating using 17 more blocks.



- Biomortar application is stable >4 months & no harmful products leach out (still monitoring)

Conclusions and Future Directions

- Isolated 22 bacteria capable of MICP from pre-existing concrete

- Develop a biologically active mortar using environmental isolates to repair cracked surfaces *(Testing ongoing)*
  - Best isolate reduced water ingress by 30%
  - No harmful byproducts are leached out by strategy.

- Developed new concrete formations (containing urea) which promote MICP and don't impact structural characteristic of concrete

Future directions

- Test new MICP concrete formulation with MICP microbes encapsulated within concrete – *prevent cracking before it begins.*

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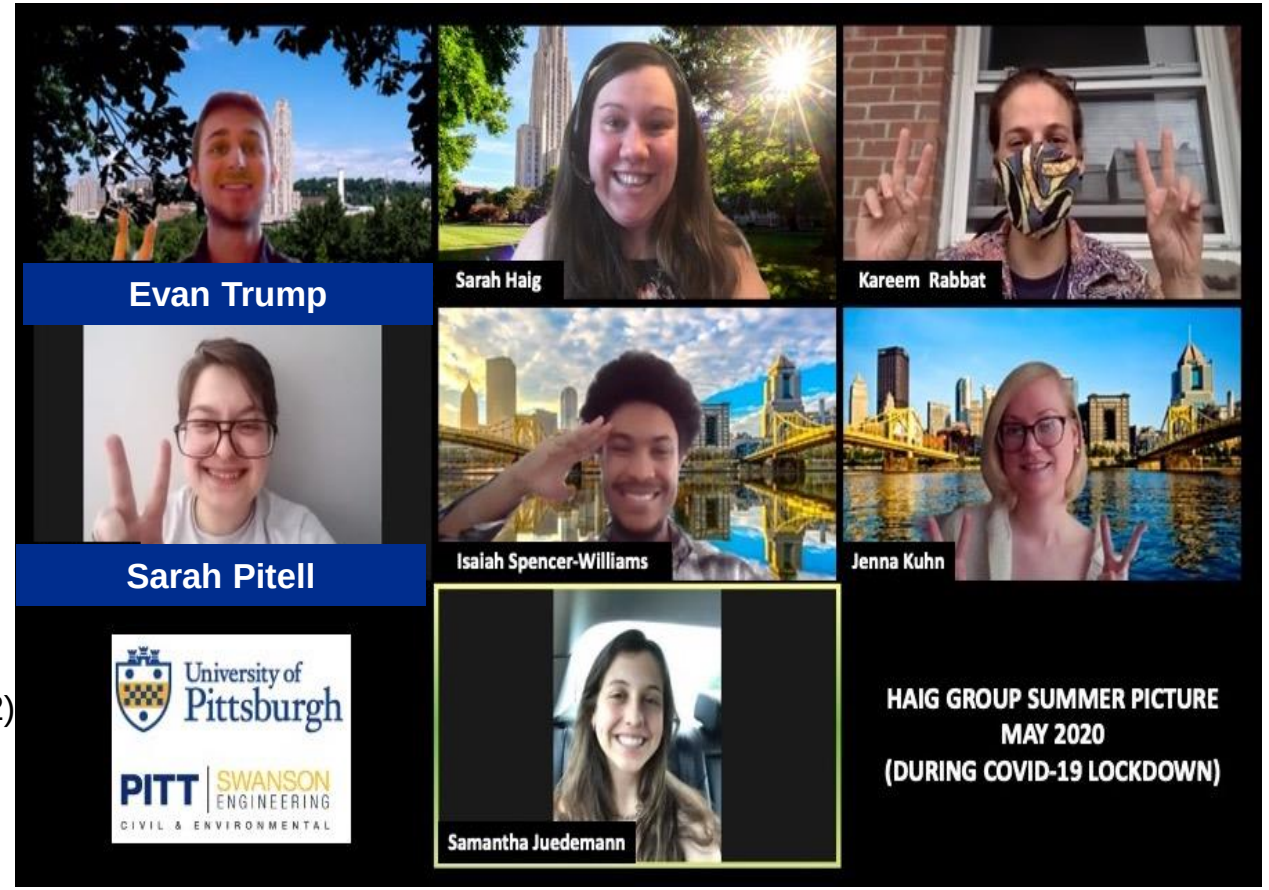

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