The class will start at 16h15

Also part of :

Enterprise for Society

Schweizerischer Ingenieur- und Architektenverein
Société suisse des ingénieurs et des architectes
Società svizzera degli ingegneri e degli architetti
Swiss society of engineers and architects

Innovation for construction & the environment

Dr. Dimitrios Terzis

26/11/2024

The program of the semester

Innovation for construction and the Environment class Fall 202

Mondays 08:15-10 am	Lectures
Mondays 10:15 - 11 pm	Project discussions and continuous reporting
Office hours:	Tuesdays morning (upon email request and confirmation)

Room GCD0386

			Title
Week 1	25.Sep	45 mins	Introduction to the course
		45 mins	Disruptive, Incremental Innovation and Research, Projects from last year and takeaways
Week 2	02.Oct	08h15	Cement-free concrete
		09h15	Cement-free concrete
Week 3	09.Oct	08h15	Circular economy, Impact and Life Cycle Assesement
		09h15	Sustainalytics
Week 4	16.Oct	08h15	Traffic Operations, Unmanned Aerial Systems (UAS) and Data Science for smart mobility
		09h15	Traffic Operations, Unmanned Aerial Systems (UAS) and Data Science for smart mobility
Week 5	23.Oct	08h15	Data-driven structural health monitoring and damage detection for smart infrastructure and buildings
		09h15	Data-driven structural health monitoring and damage detection for smart infrastructure and buildings
Week 6	30.Oct	08h15	Project preparation / Paper reading
		09h15	Project preparation / Paper reading
Week 7	06.Nov	08h15	Parametric design
		09h15	Robotic construction
Week 8	13.Nov	08h15	Sustainalytics
		09h15	
Week 9	20.Nov	08h15	Industrial innovation from the perspective of a construction giant
		09h15	Industrial innovation from the perspective of a construction giant
Week 11	27.Nov	08h15	Harnessing renewables for buildings
		09h15	Harnessing geo-energy for buildings
Week 12	04.Dec	08h15	Monitoring and surveillance
		09h15	GIS and BIM for construction and risk management
Week 13	11.Dec	45 mins	Project presentations - schedule to be announced
		45 mins	Project presentations - schedule to be announced
Week 14	18.Dec	45 mins	Synthesis of Innovation project and takeaways
		45 mins	Synthesis of Innovation project and takeaways

Next week →

Today's class

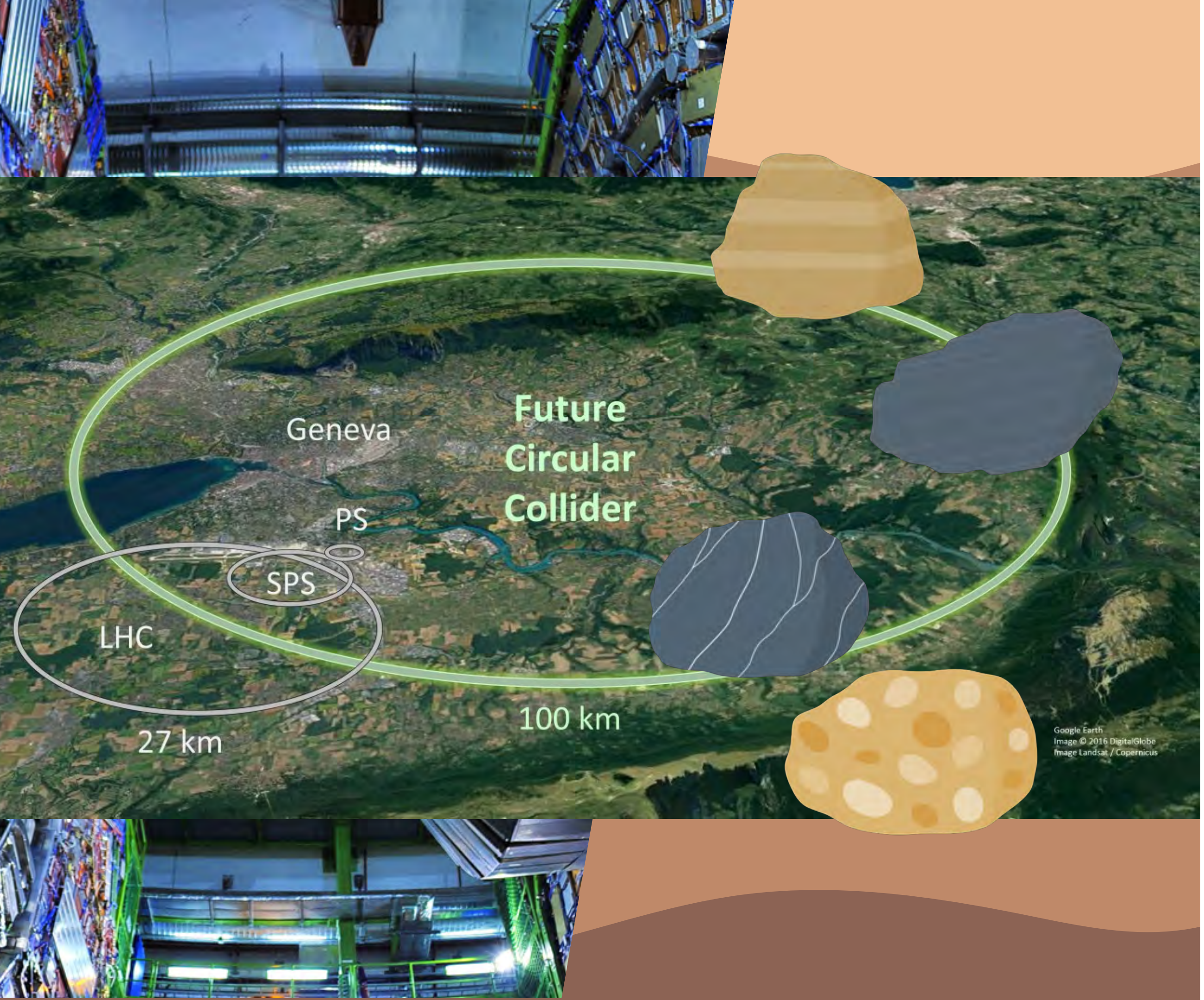
1) A recent case study that showcases the need for innovation (CERN FCC 2022)

2) Biocementation: a hands-on example of creating a new material

Today's class

1) A recent case study that showcases the need for innovation (CERN FCC 2022)

2) Biocementation: a hands-on example of creating a new material



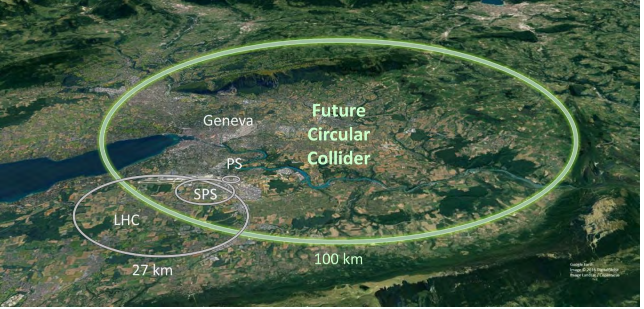
FUTURE CIRCULAR COLLIDER

FCCIS – Future Circular Collider Innovation Study

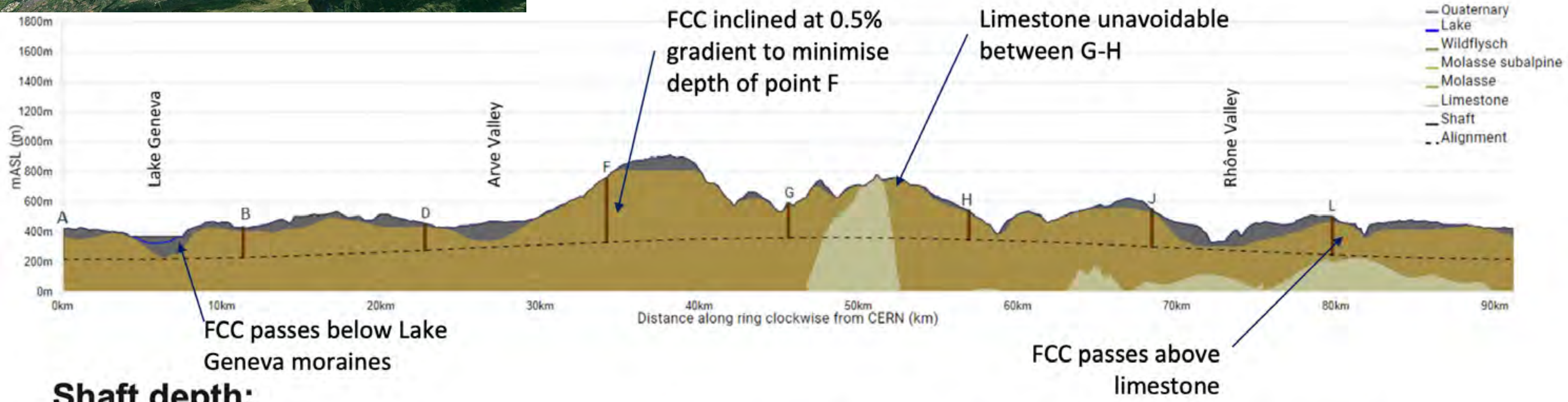
(EU – Horizon 2020)

CERN³
RECYCLE
REINVENT
REVALORISE

medusoil
HOLCIM
bilger+partner
V-S-H-
AMBERG ENGINEERING
pagani lanfranchi



Michael Benedikt
27/09/2022, Mining the Future, CERN

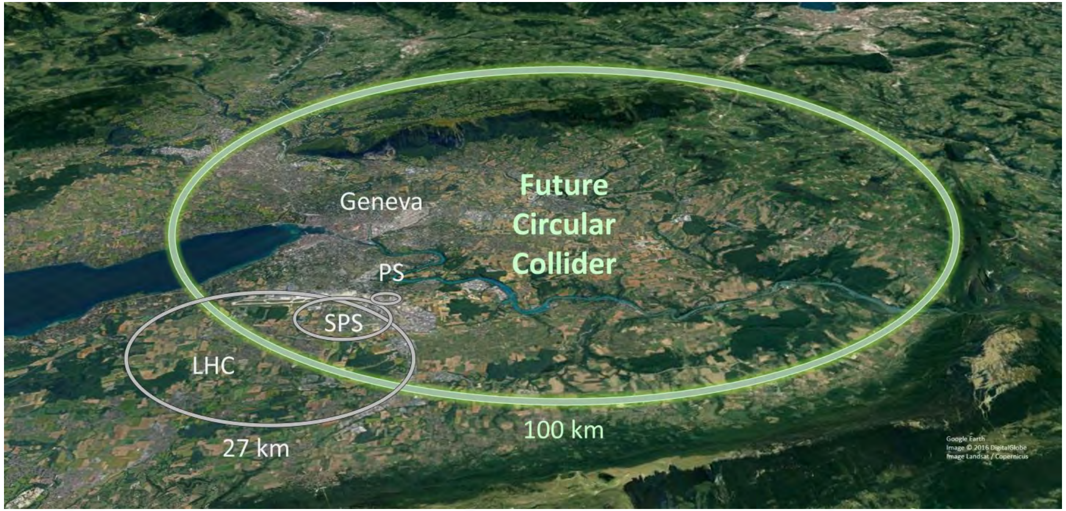


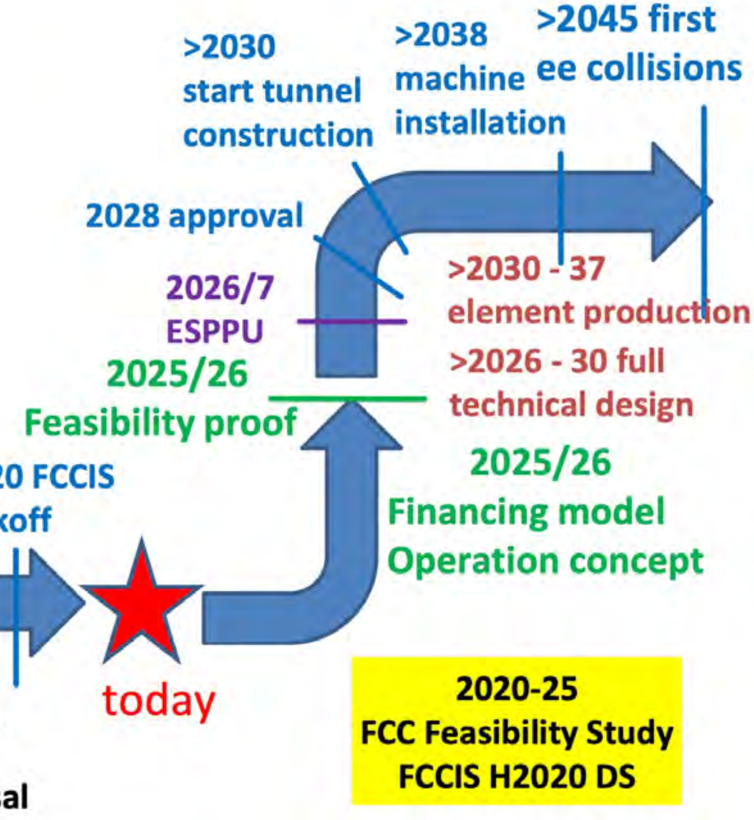
Shaft depth:

A: 202 m B: 200 m D: 177 m F: 399 m G: 228 m H: 139 m J: 251 m L: 253 m

Tunnelling mainly in molasse layer (soft rock), well suited for fast, low-risk TBM construction.

Site investigations campaign planned for 2024 – 2025: ~40-50 drillings, 100 km of seismic lines





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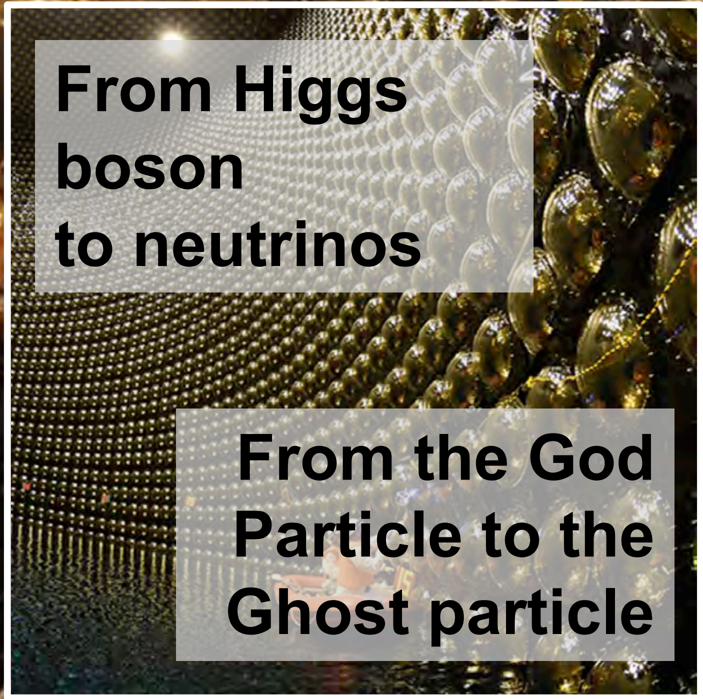
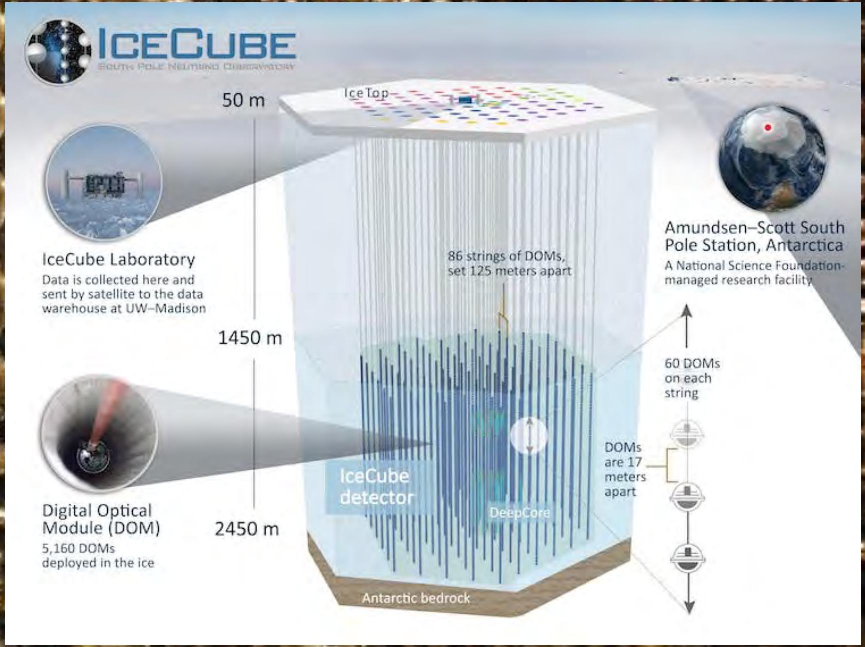


From Higgs boson to neutrinos

From the God Particle to the Ghost particle



Today **80%** of the mass of the universe is unknown.
What is the rest of the universe made of?

Why is the universe composed only of **matter**? Where has the **anti-matter** gone that was produced simultaneously in the **Big Bang**?

Proof of concept

Preliminary investigations

i. Material composition and properties
Laboratory sieving, Point load tests & Petrography

ii. Workability of the aggregates
Sorted Material used as an aggregate for concrete tests

iii. Aggregate handling and Sorting method for industrial Scale
Plant design for required quantities and quality

Figure 2. Sample of washed molasse from Gubrist Tunnel and iron residues

RECYCLE
REINVENT
REVALORISE

medusoil HOLCIM AMBERG ENGINEERING bilger+partner V-S-H- pagani lanfranchi

Proof of concept

Preliminary investigations – Results

iii. Plant design for required quantities and quality

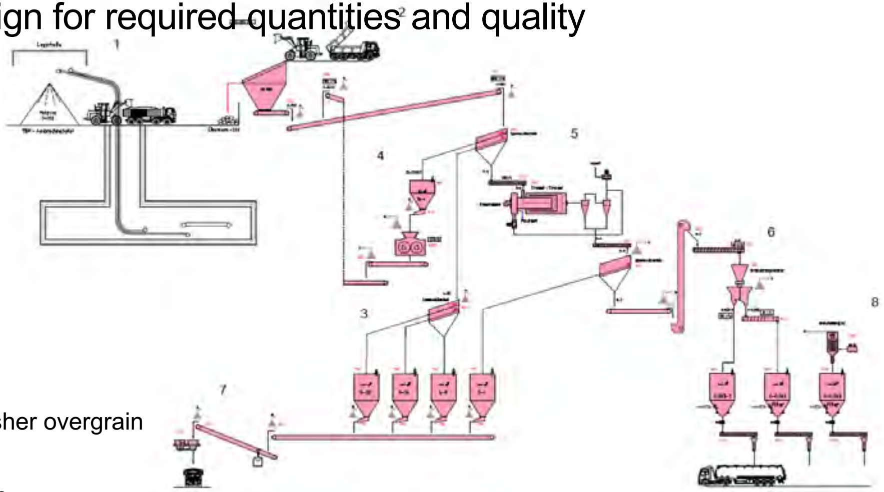
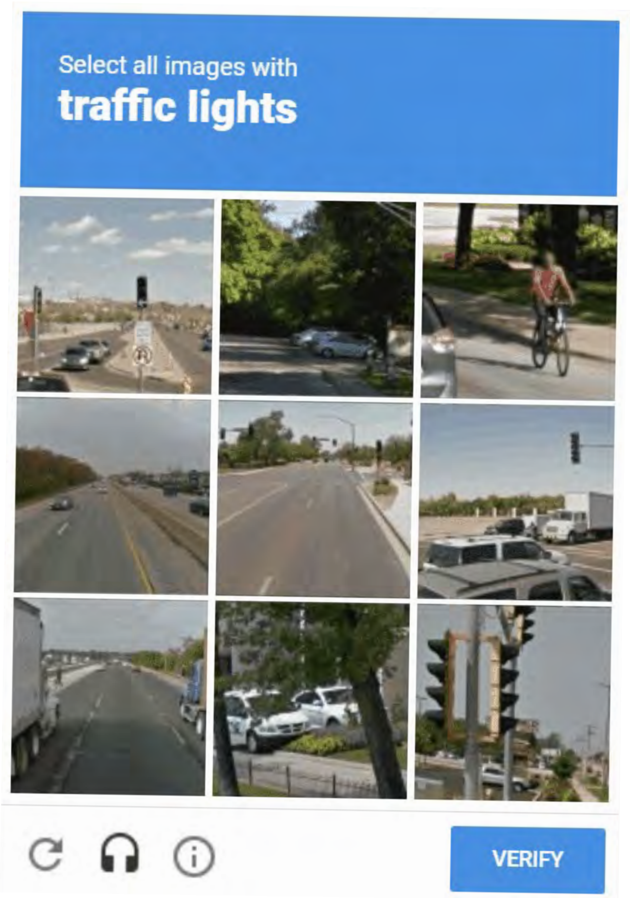


Figure 5. Overview of the overall sorting process

1. Material input
2. Pre-sorting
3. Final sorting
4. Secondary crusher overgrain
5. Material drying
6. Air classification
7. Loading
8. Dedusting

Figure 6. Crossbelt elemental analyser

- Assessing and classifying material on the basis of geochemical composition
- Minute by minute composition analyses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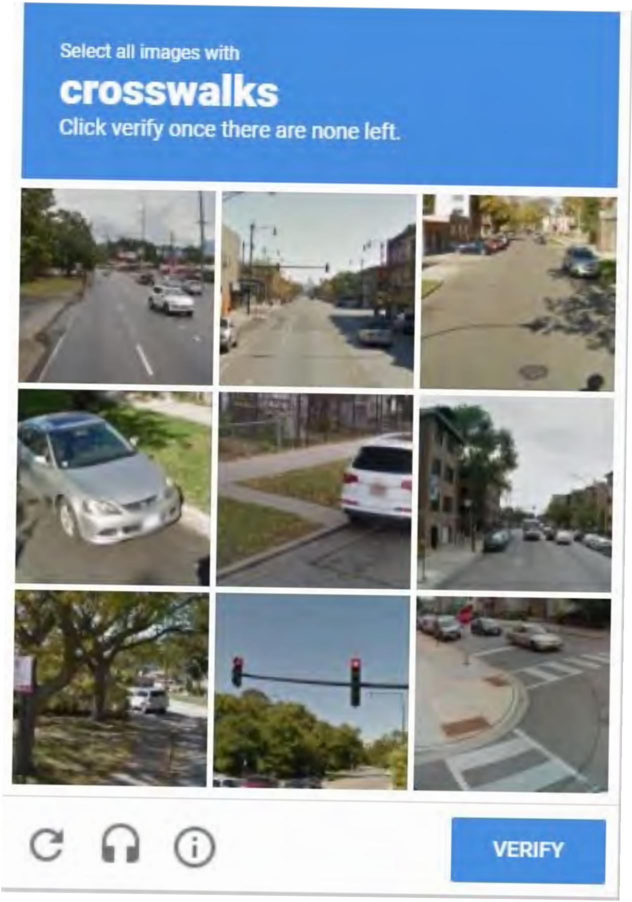
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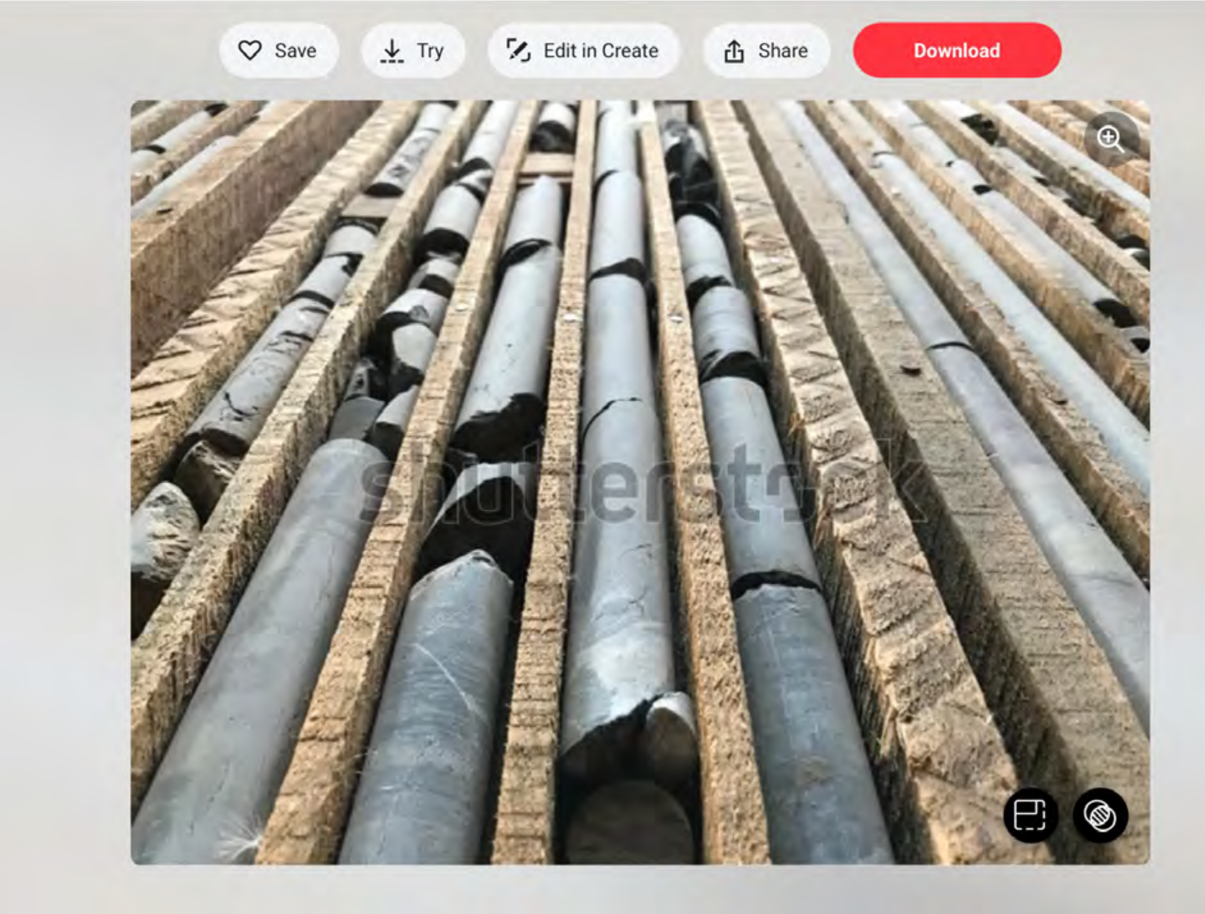
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Proof of concept
Preliminary investigations - Results

CERN[3] RECYCLE REINVENT REVALORISE

i. Laboratory sieving, Point load tests & Petrography

Grain sizes	Zurich Molasse	Geneva Molasse
< 2 mm	63.70%	77.00%
2 - 8 mm	4.10%	4.60%
> 8 mm	32.20%	18.40%

Zurich Molasse	Geneva Molasse
6.3 N/mm^2	2.6 N/mm^2

Zurich Molasse
81% Quartz and Feldspar
18% Agglomerates
1% Schist silicates

Figure 3. Sample of washed molasse (left) and wet molasse material (right) from Gubrist Tunnel

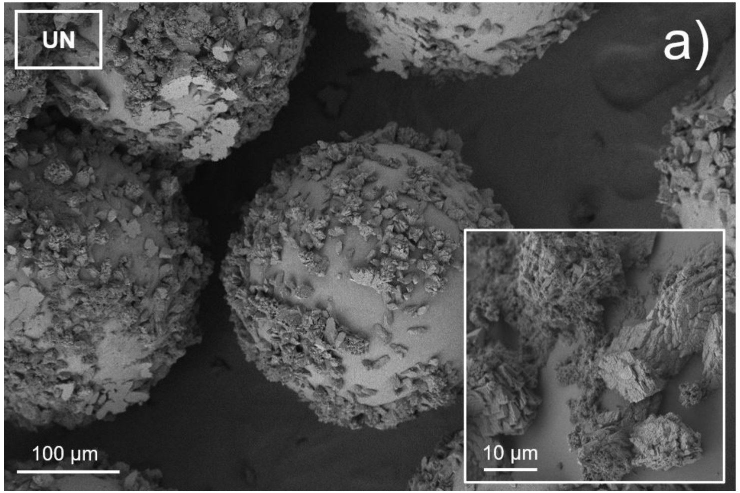
ii. Concrete tests

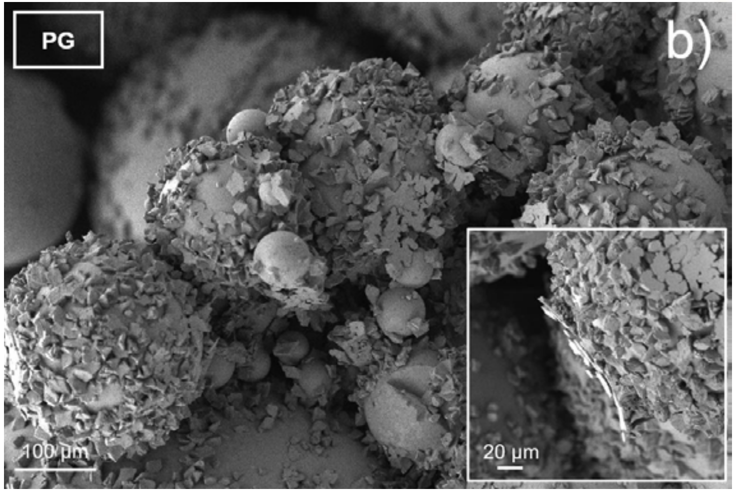
Cube	Name	Aggregates	Cement	Compressive Strength (7 days) in N/mm^2
Mix 1	Reference	100% of 0/8 mm from gravel pit Holcim in Aigle	330 kg/m^3 Optimo 4 (Holcim)	26.7 (100 %)
Mix 2	Molasse 100	100% of raw molasse from the Gubrist construction site		7.0 (26 %)
Mix 3	Molasse 55	55% of 4/8 mm washed molasse (mainly sandstone)		14.8 (55 %)
		45% of 0/4 mm from gravel pit Holcim in Aigle		

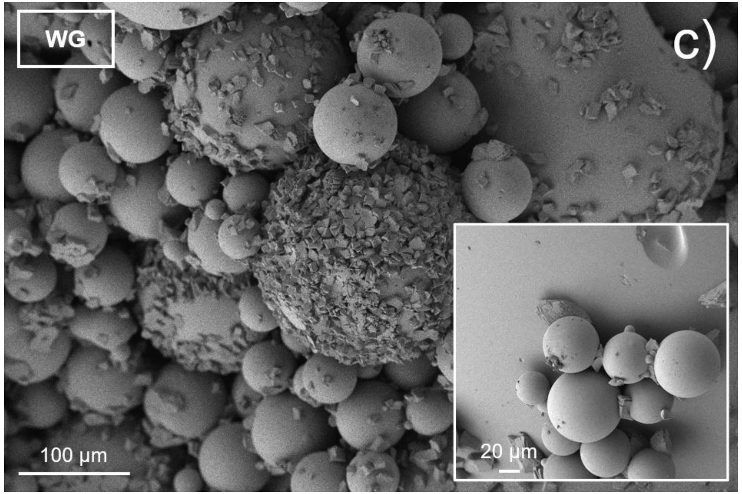
Figure 4. Sample of washed molasse (left) and wet molasse material (right) from Geneva Basin (Cern)

medusoil HOLCIM AMBERG ENGINEERING bilger+partner V-S-H- pagani lanfranchi

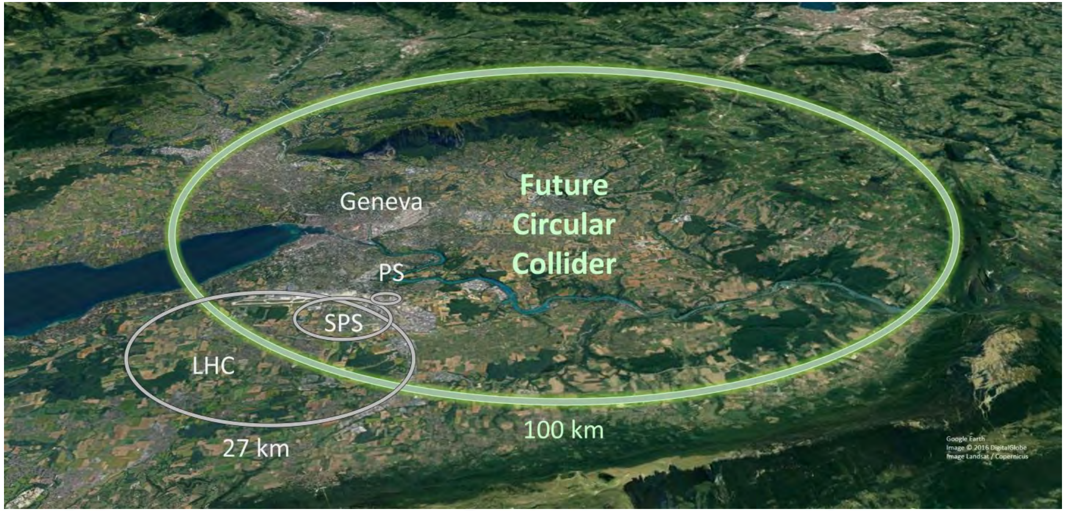
Proof of concept

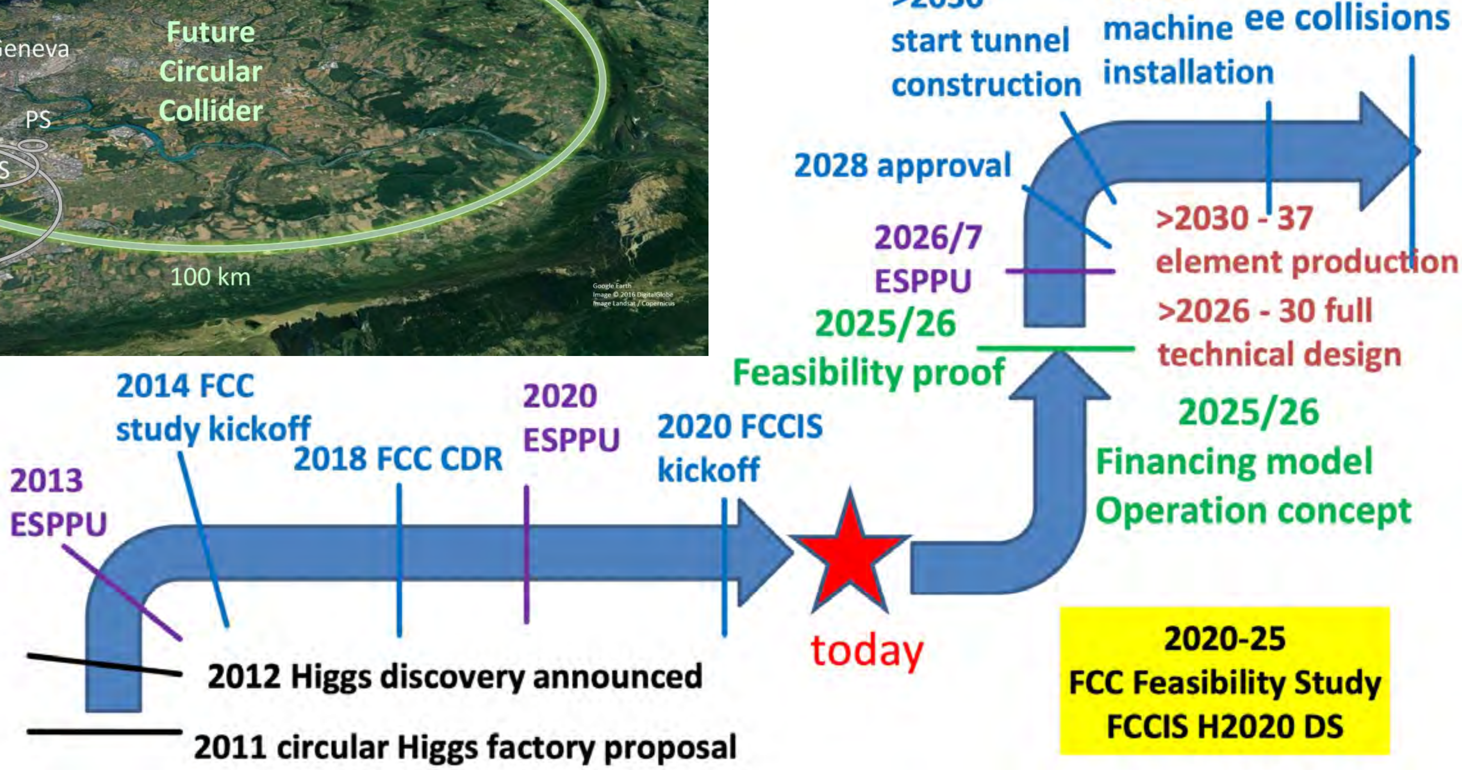






	UN	PG	WG
D_{10} [mm]	0.22	0.23	0.11
D_{90} [mm]	0.29	0.57	1.10
C_u [-]	1.27	1.78	7.50
C_c [-]	0.94	0.95	2.24
n [-]	0.36	0.31	0.22





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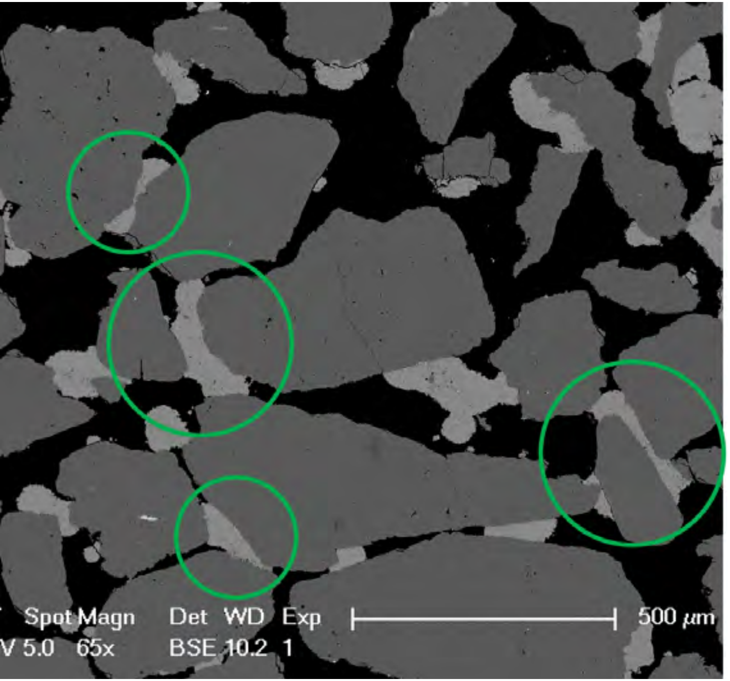
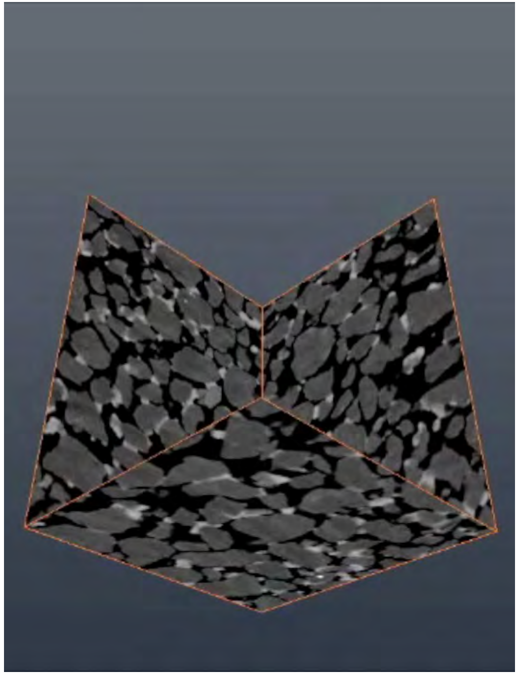
1) A recent case study that showcases the need for innovation (CERN FCC 2022)

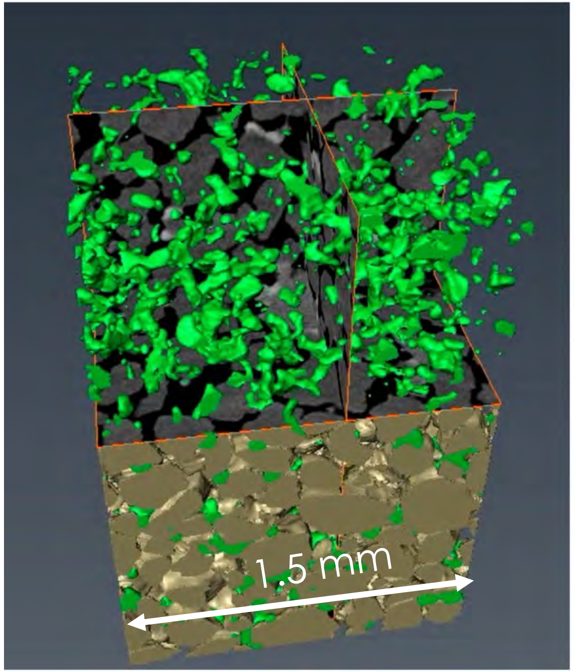
2) Biocementation: a hands-on example of creating a new material

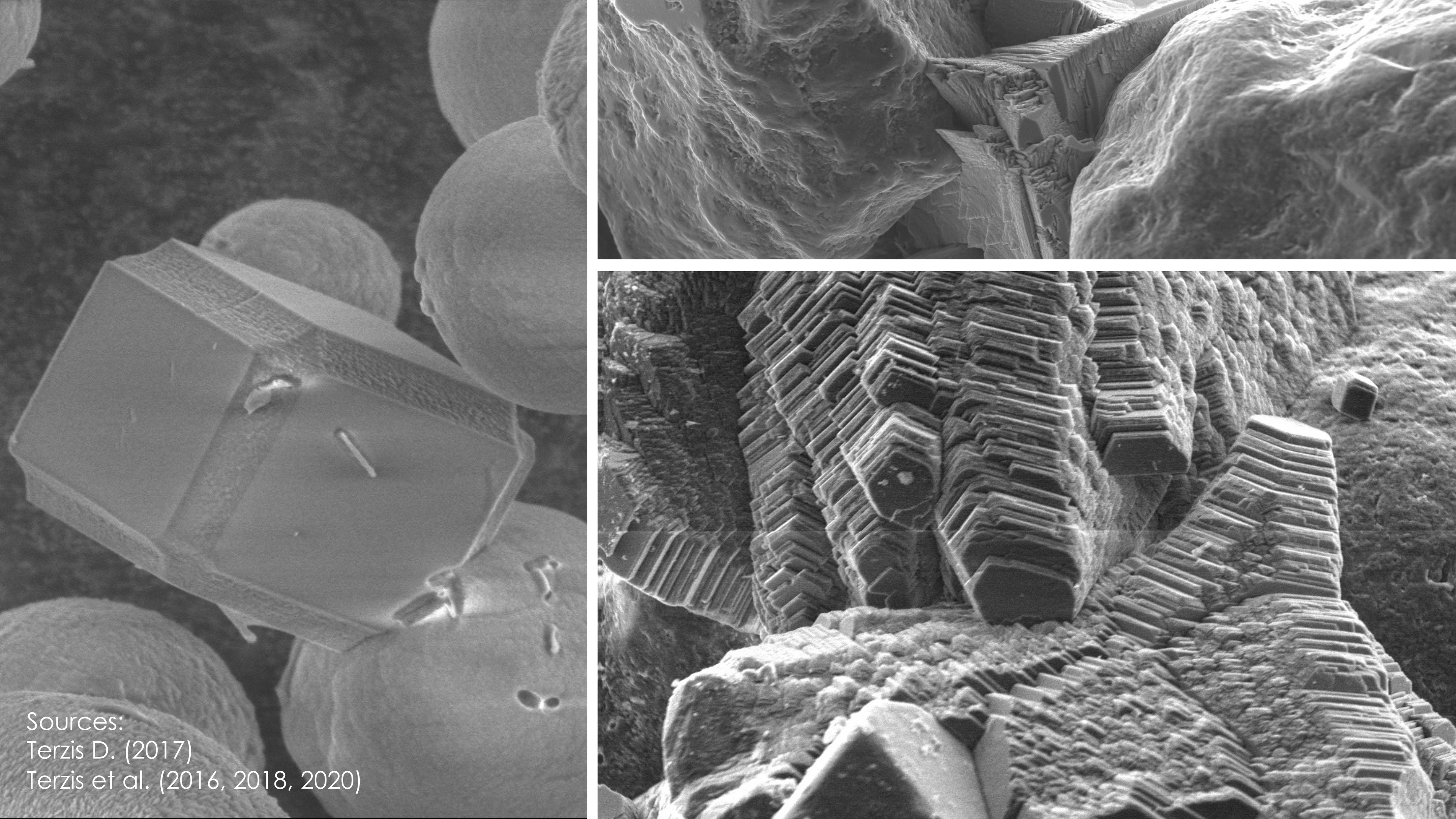
Dr. Dimitrios Terzis

Bio-cementation: Mineralizing calcite binders

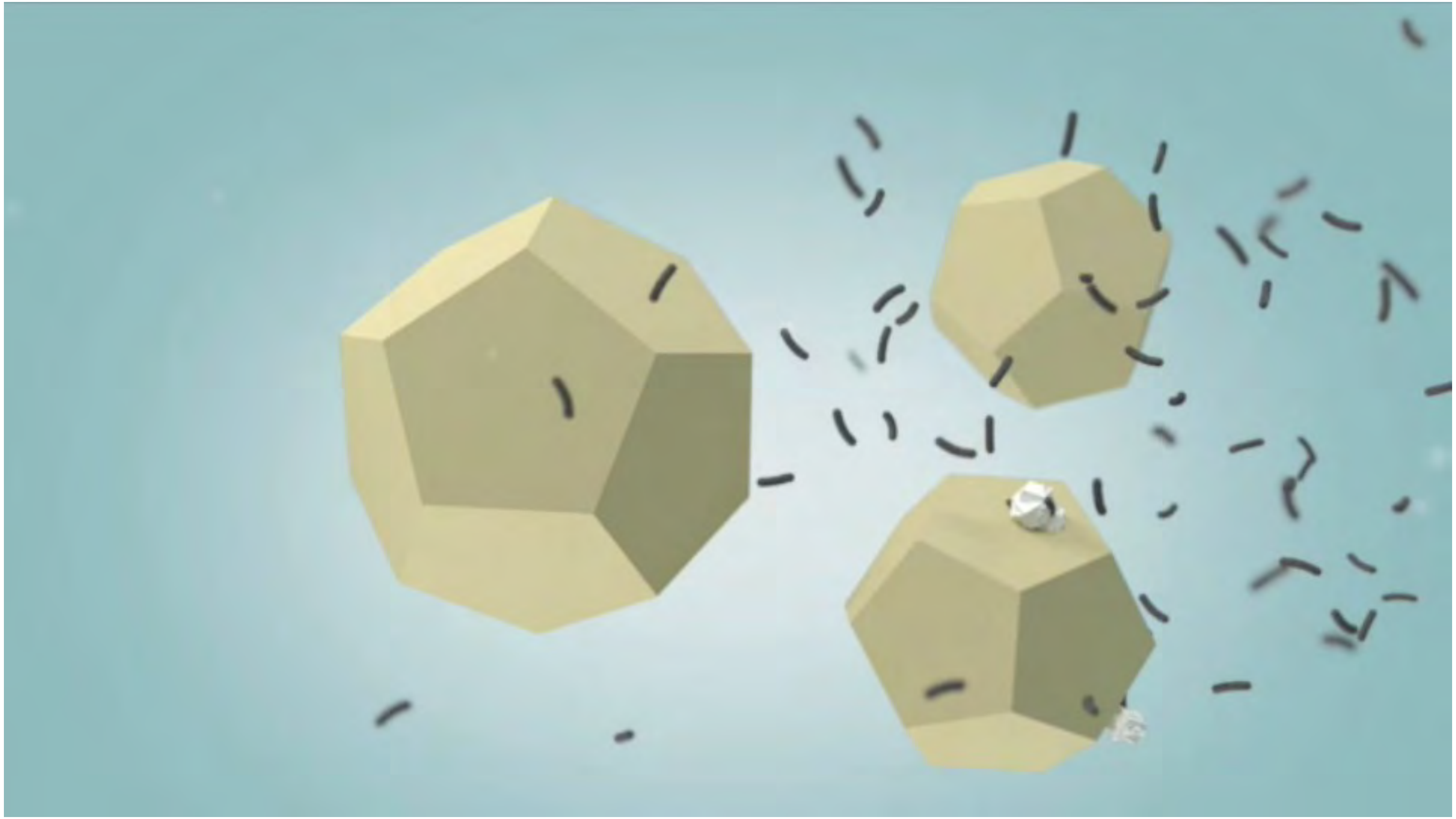







Sources:
Terzis D. (2017)
Terzis et al. (2016, 2018, 2020)

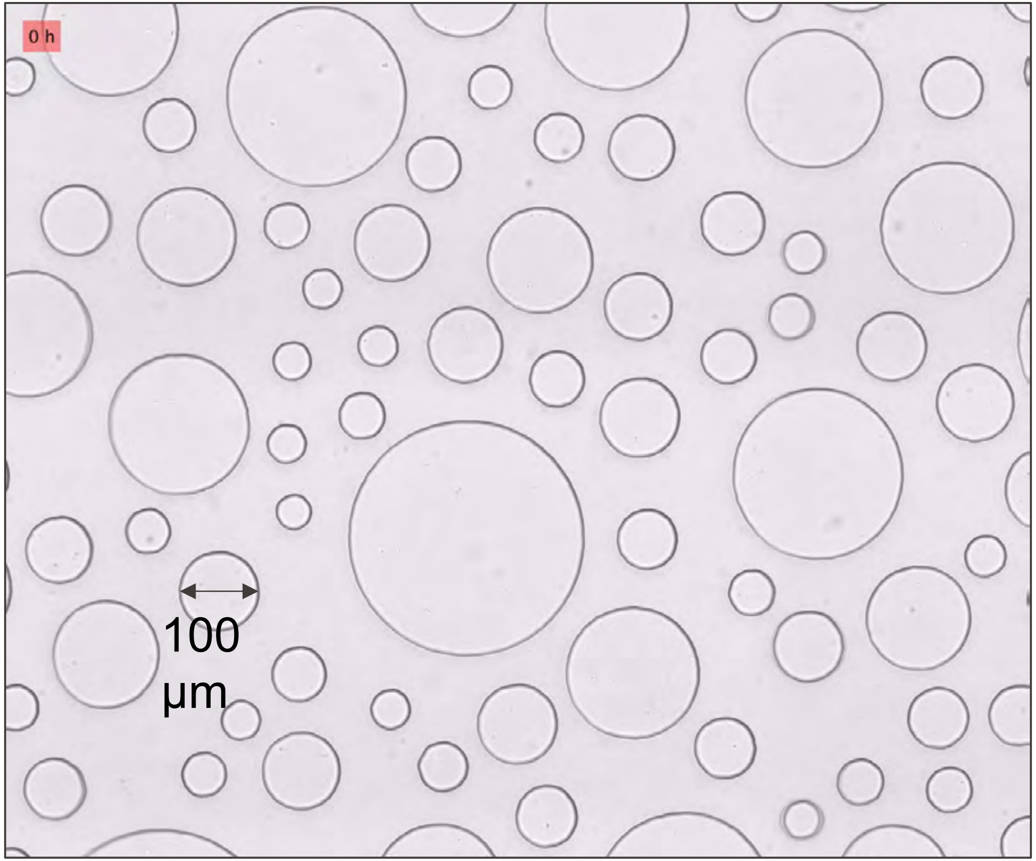
Bio-cementation: Mineralizing calcite binders



Terzis, D. and Laloui, L., 2019. A decade of progress and turning points in the understanding of bio-improved soils: A review. *Geomechanics for Energy and the Environment*, *19*, p.100116.

Bio-cementation: Mineralizing calcite binders

- Real-Time Monitoring
- 1 meter-long propagation
- Spatio-temporal and hydro-chemical process understanding



More info: Elmaloglou, A., Terzis, D., De Anna, P., Laloui, L., Mahé, S. and Miele, F., 2020, February. Microfluidic-Based Study on the Activation and Evolution of Calcite Bio-Mineralization for Geotechnical Applications. In *Geo-Congress 2020: Biogeotechnics* (pp. 74-82). Reston, VA: American Society of Civil Engineers.

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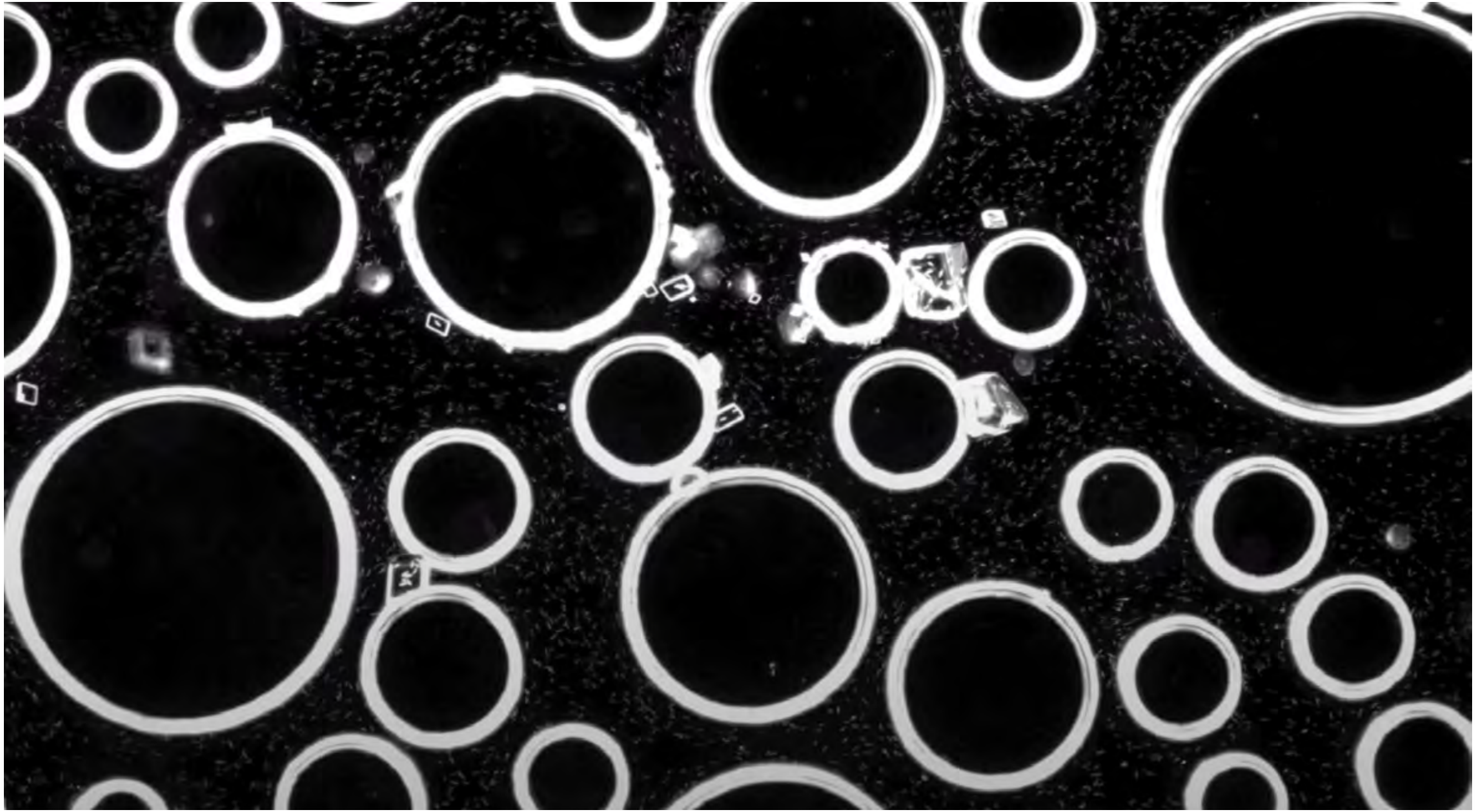

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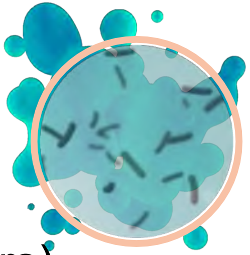
What's the magic? Stimulating an organic reaction in 4 steps

Freshwater calcite microbialites at Pavilion Lake, British Columbia, Canada

Step 1:
Carbamide (carbon source)

Step 2:
Groundwater/soil microorganisms (enzymatic catalyzers)



Step 3:
High carbonate production of known quality and stability

Step 4:
Mineralization

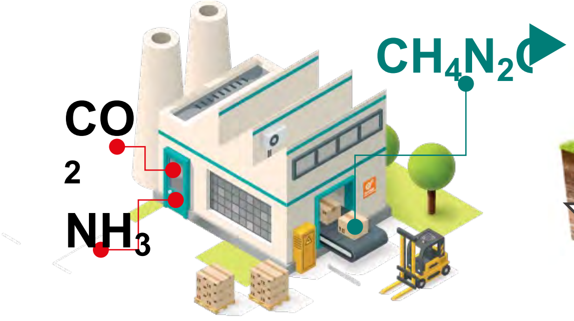
$$\mathbf{CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3\ (\downarrow)}$$

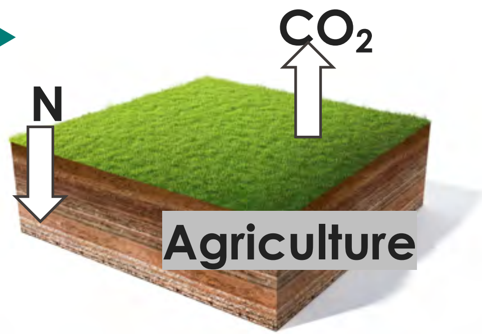
Mineral calcite precipitation

Dr. Dimitrios Terzis

Steps 1,2 : From carbamide (carbon source) to $CaCO_3$

1) Carbamide is an organic soil fertilizer:





Carbamide supply vs. demand rate

2) Carbamide is used in biocementation to mineralize $CaCO_3$

Dr. Dimitrios Terzis

Nitrogen is shaking up the construction industry

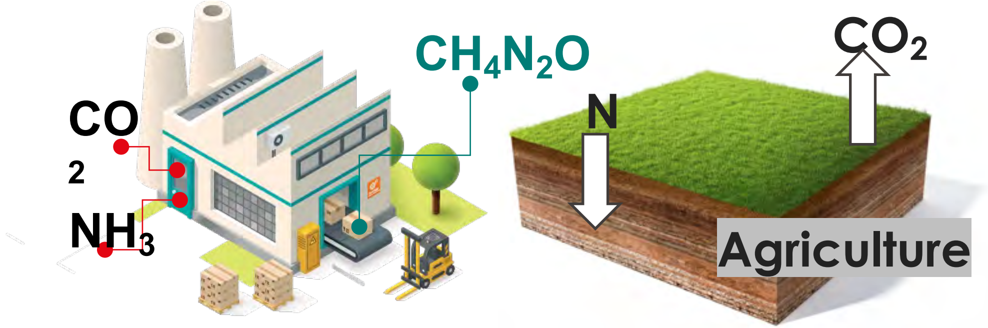
Source: Science AAAS

A Dutch high court decision in May 2019 **suspended permits for construction projects that pollute the atmosphere with nitrogen compounds and harm nature reserves. […]** Also blocked are plans for new homes, roads, and airport runways, because construction machinery emits nitrogen oxides. **All told, the shutdown puts some €14 billion worth of projects in jeopardy, according to ABN AMRO Bank. "It has really paralyzed the country," says Jeroen Candel, a political scientist at Wageningen University & Research.**

Dr. Dimitrios Terzis

Steps 1,2 : From carbamide (carbon source) to $CaCO_3$

1) Carbamide is an organic soil fertilizer:



2) Carbamide is used in biocementation to mineralize $CaCO_3$

What about Nitrogen/Ammonium?

- source: FR1250397A·**2012**-01-16

«…Consolidating soil in situ comprising the following steps: a) injecting a solution of calcifying bacteria, prepared from powdered bacteria, into the volume of soil to be treated; b) injection of a calcifying solution; c) ***washing the volume of treated soil with water; d) measuring the concentration of ammonium ions in the washing water and in the treated soil; e) recycling the wash water to the process***.»

- source: Lee et al. (**2019**) *Investigating Ammonium By-product Removal for Ureolytic Bio-cementation Using Meter-scale experiments.*

This **dilution** approach requires at least 10 times the pore volume of soil in fresh water to dilute Nitrogen which remains still in the surrounding soil or groundwater

- PCT/IB2019/054532 - **SYSTEM AND METHOD FOR GROUND CONSOLIDATION**

EPFL

Results

Improves parameters, e.g.:

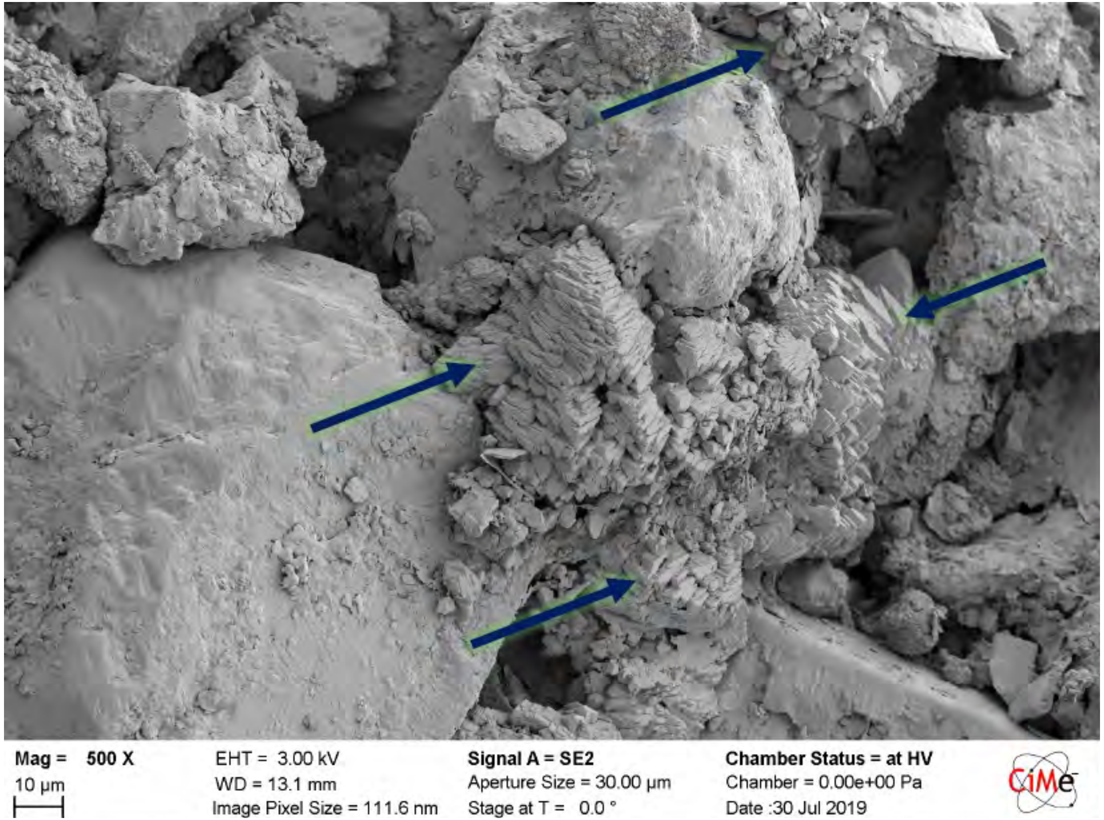
- Cohesion, c → **400 kPa**
- Friction angle, φ → **42°**
- S-wave velocity → **2'000 m/s**

Maintains

- permeability → drainage capacity

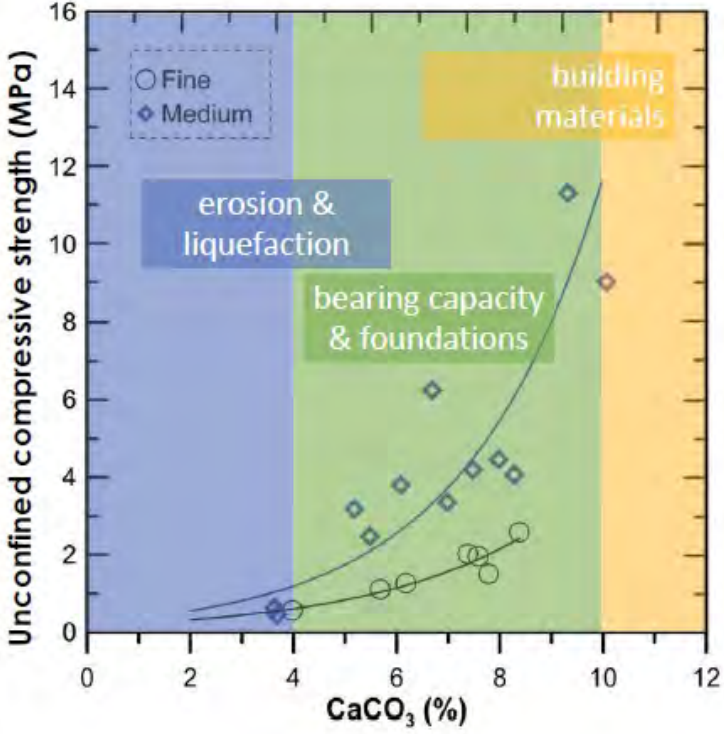
Permits

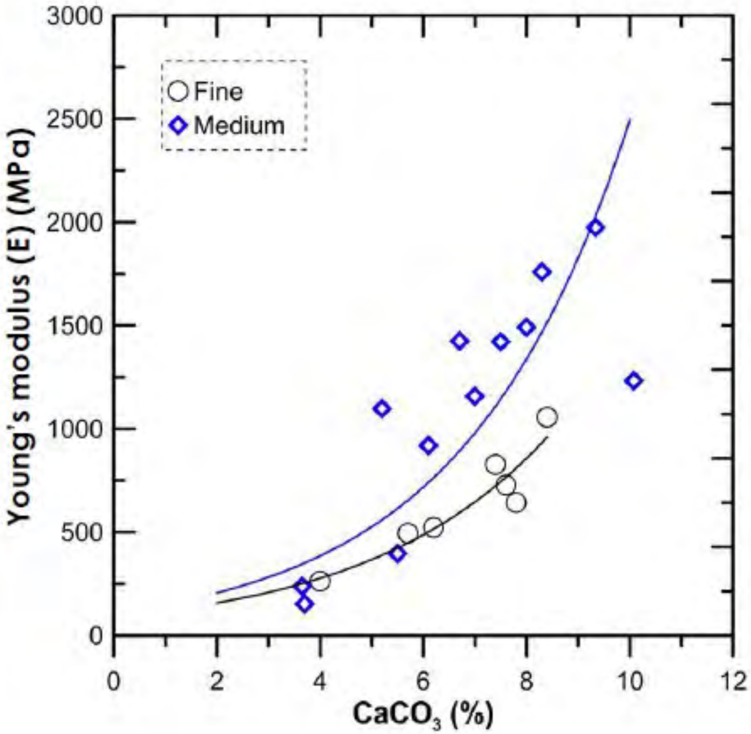
- re-injections



Results

Strength and stiffness in relation to the mineral content

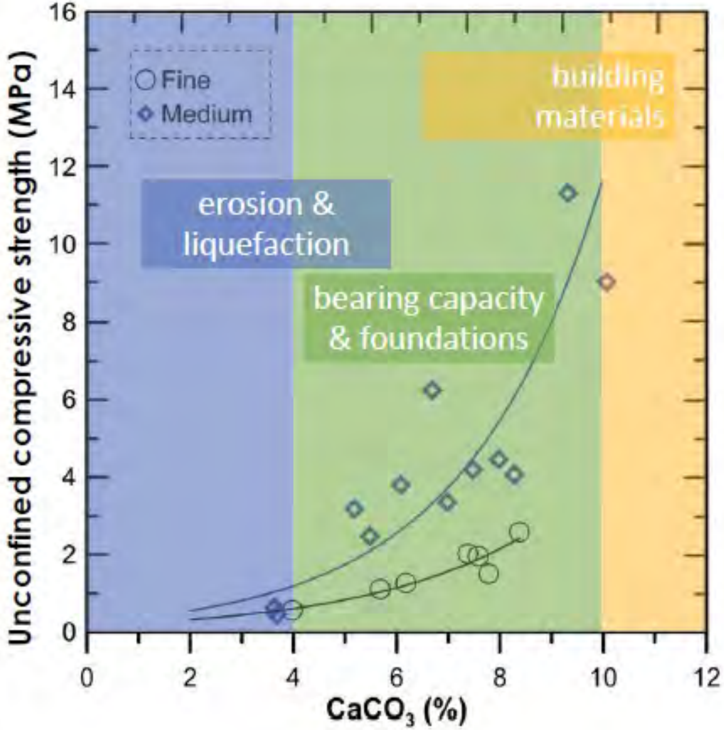


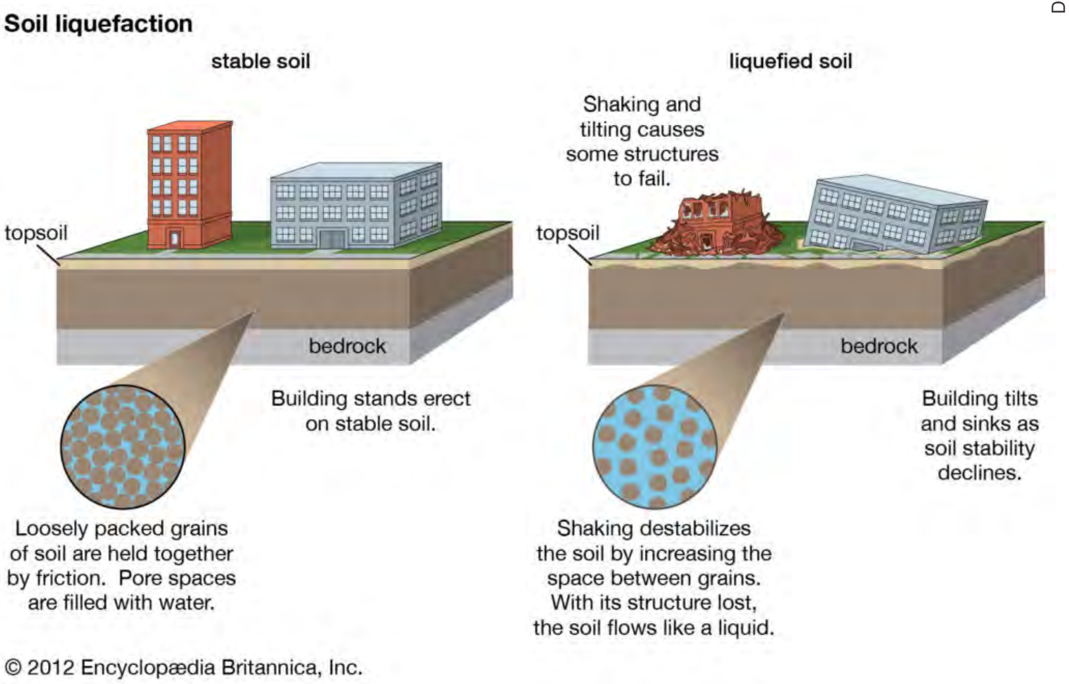


→ Design of a fit to purpose solution ←

Results

Strength and stiffness in relation to the mineral content





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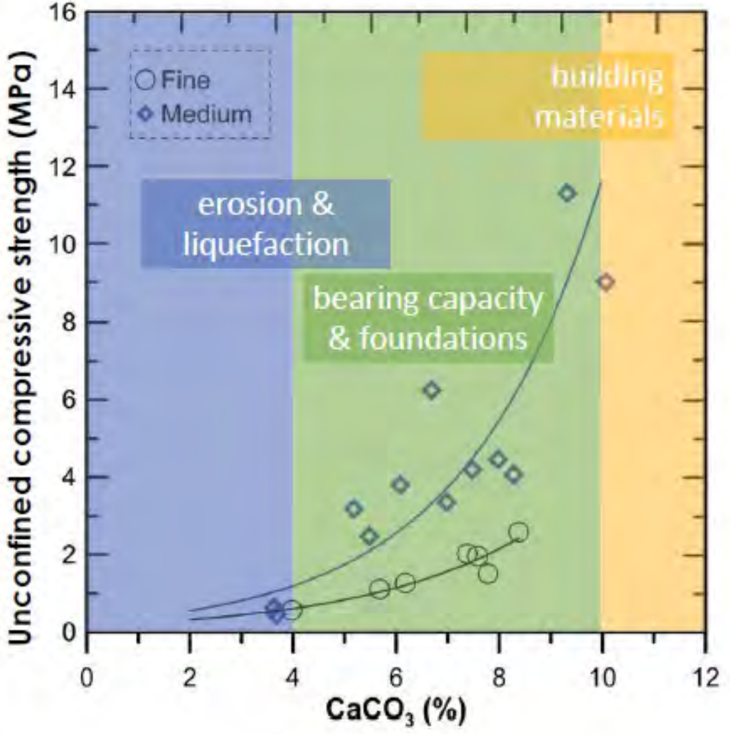
Results

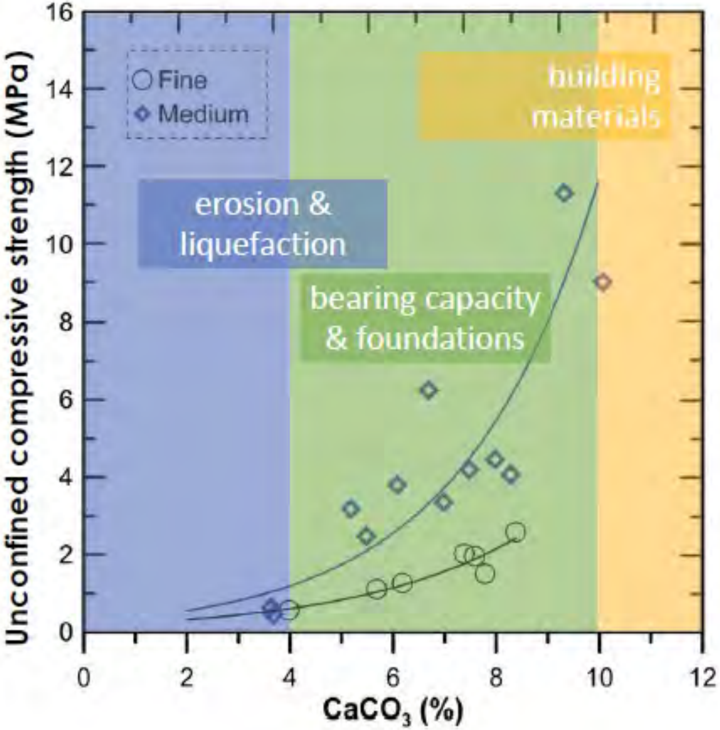
Strength and stiffness in relation to the mineral content



→ **Design of a fit to purpose solution** ←

Results

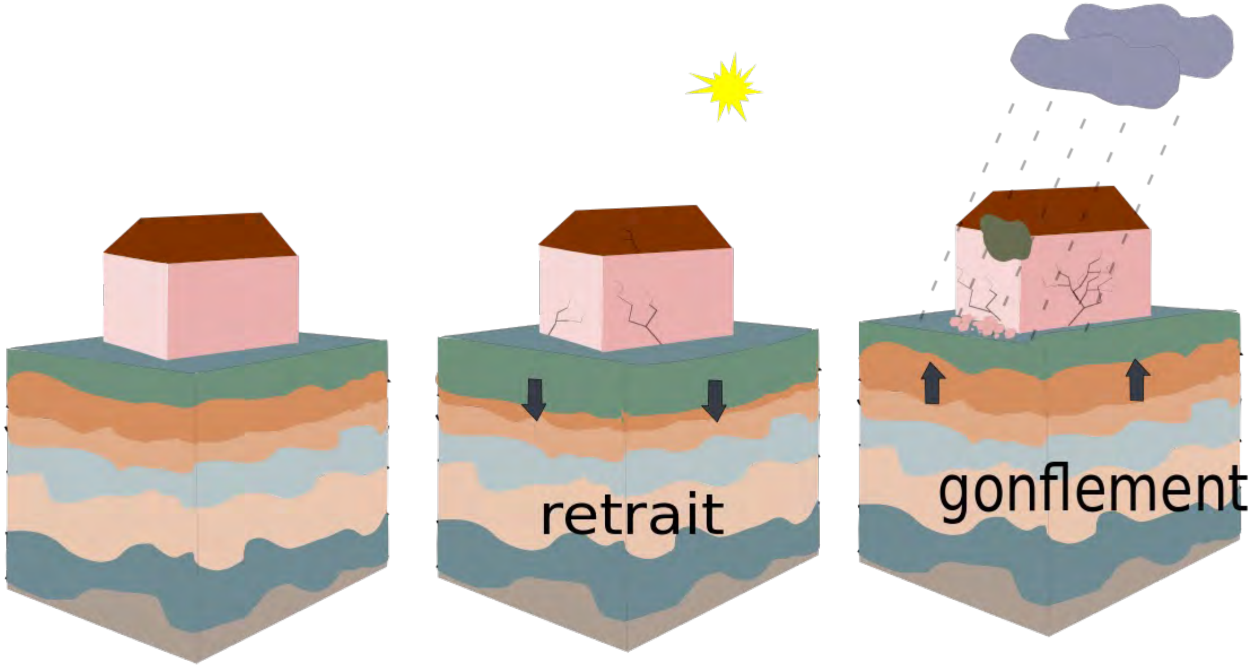
Strength and stiffness in relation to the mineral content

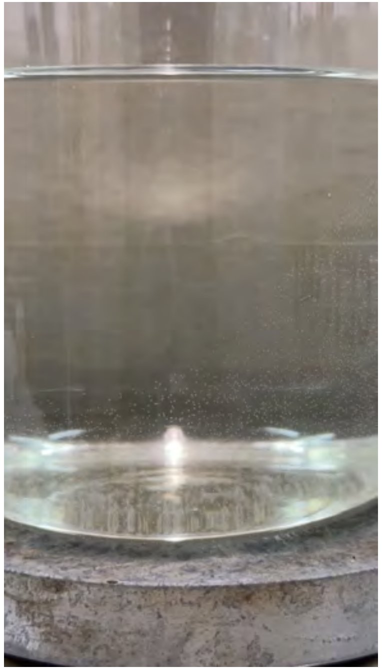


→ Design of a fit to purpose solution ←

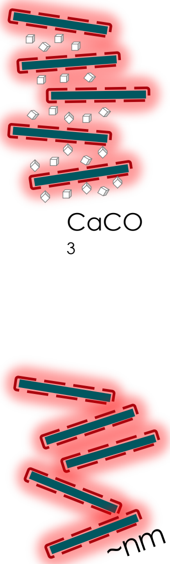
More emerging challenges

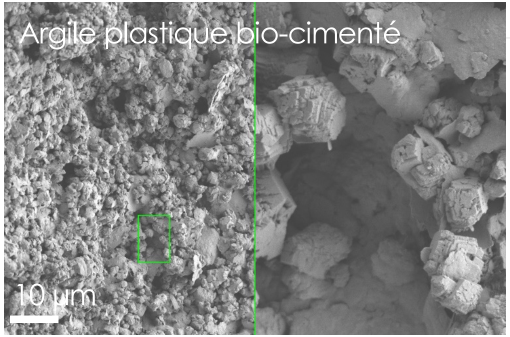
Dr. Dimitrios Terzis

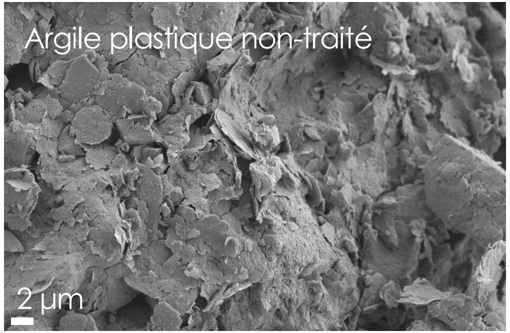


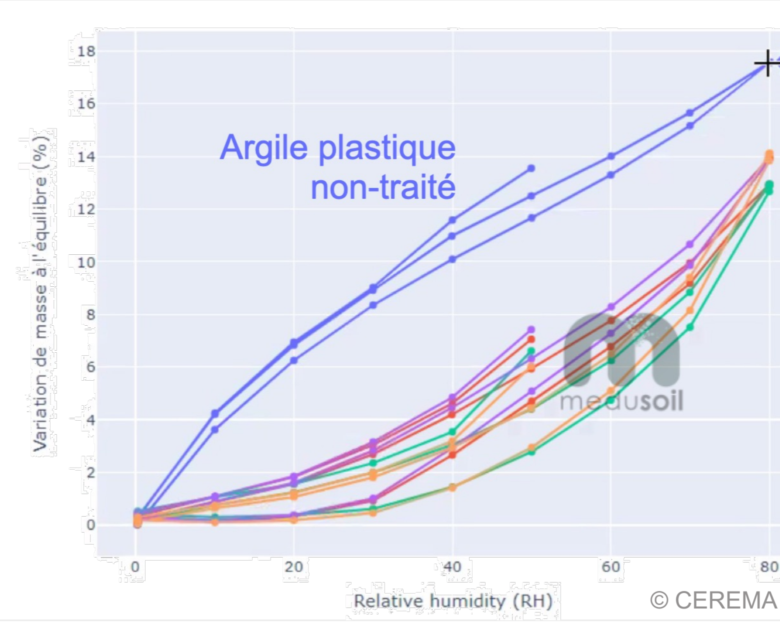


More emerging challenges



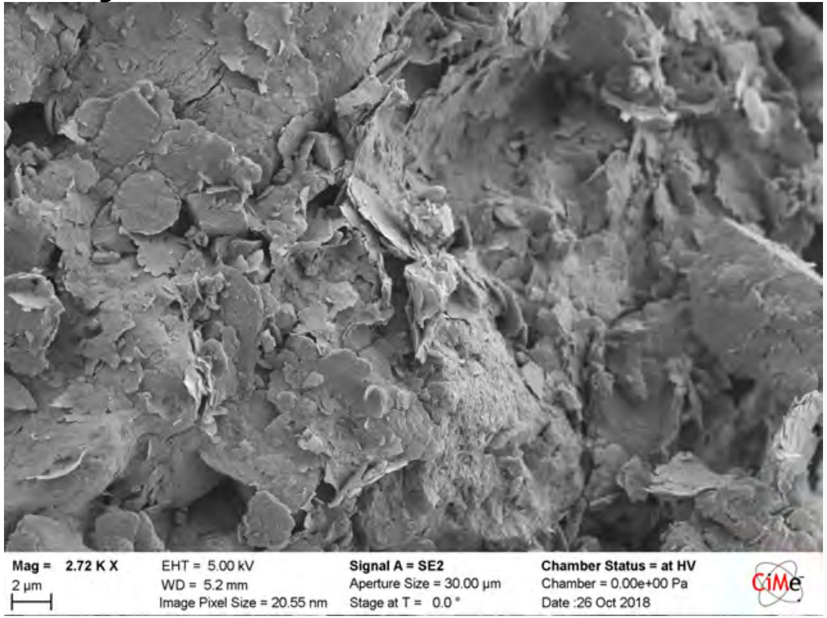




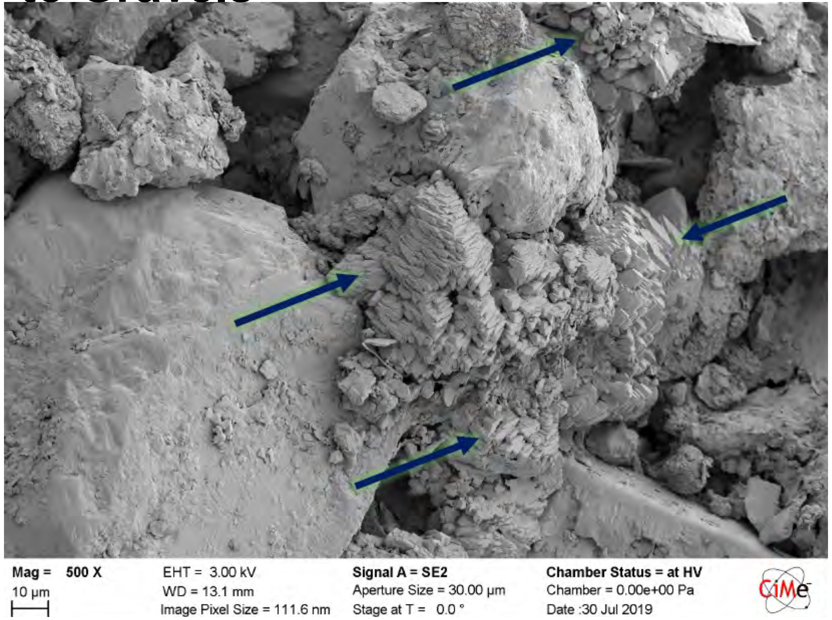


Injectability and Applicability limitations

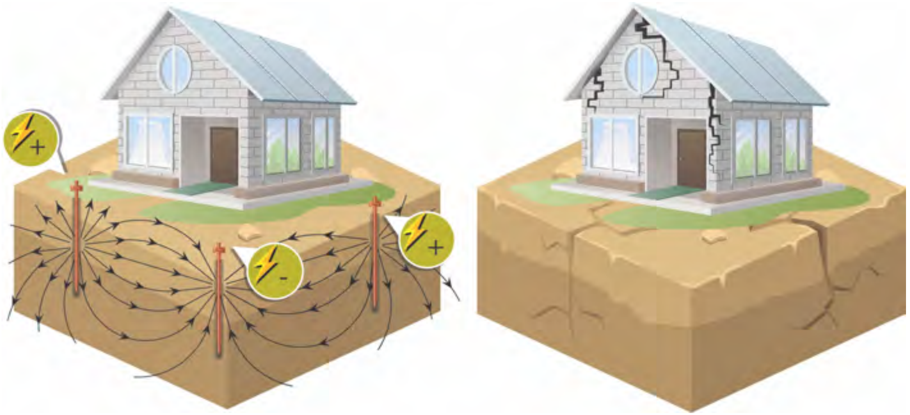
Clays



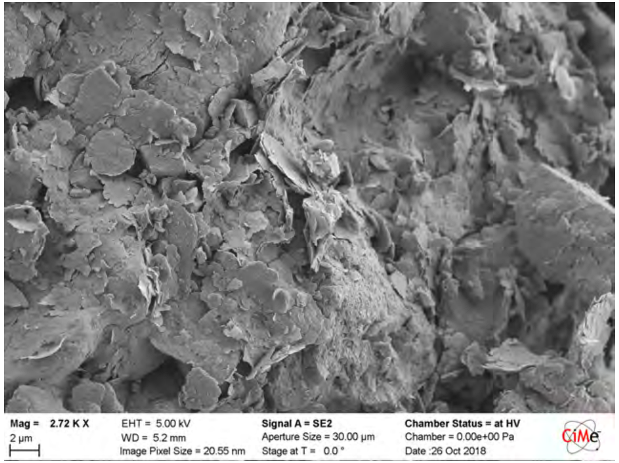
to Gravels

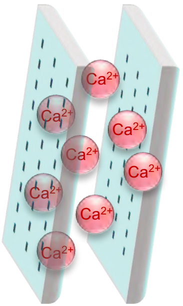


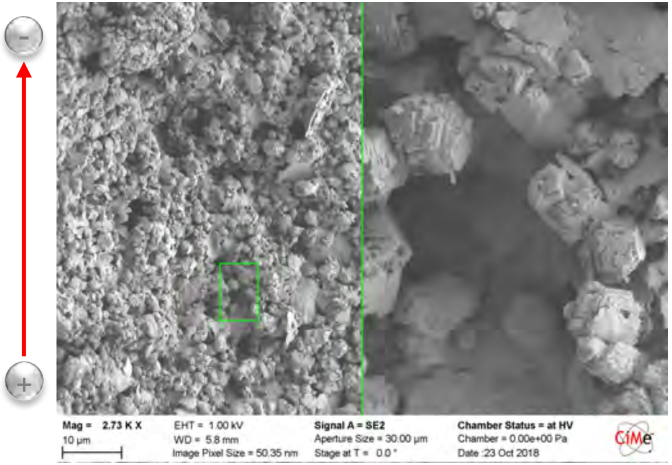
Direct current assisted bio-cementation



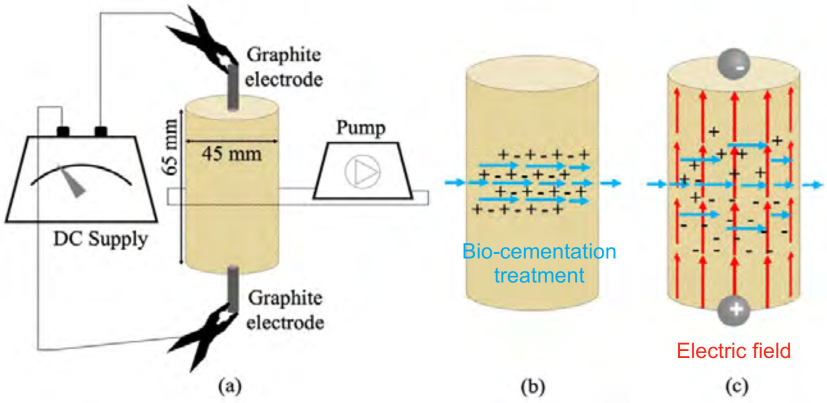
Source: https://actu.epfl.ch/news/using-electric-current-to-stabilize-low-permeabili/

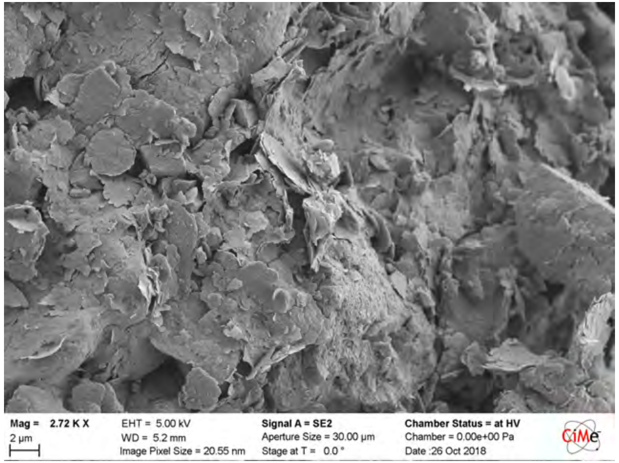


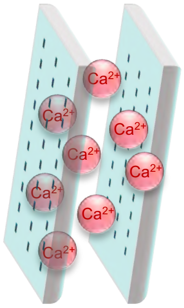


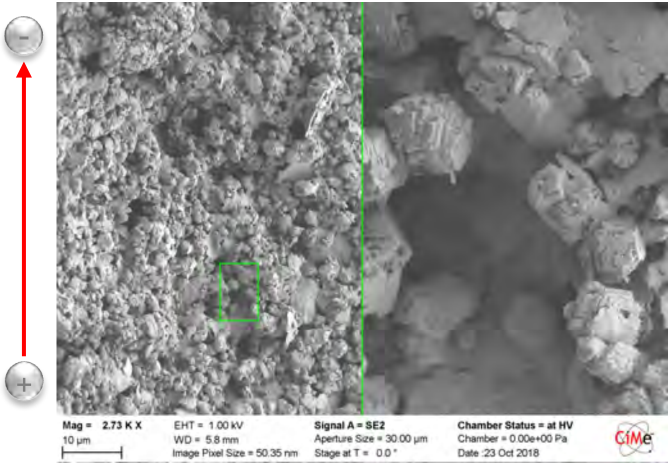


Direct current assisted bio-cementation

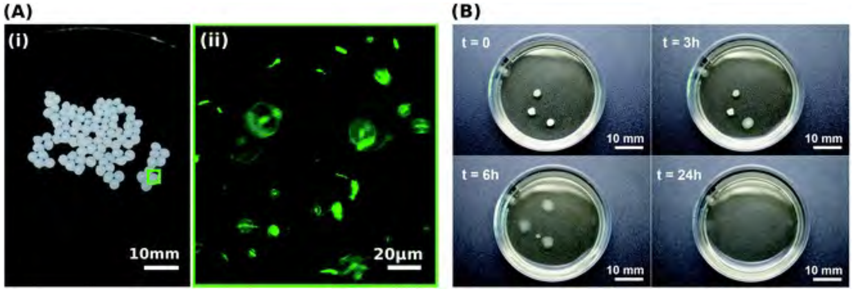


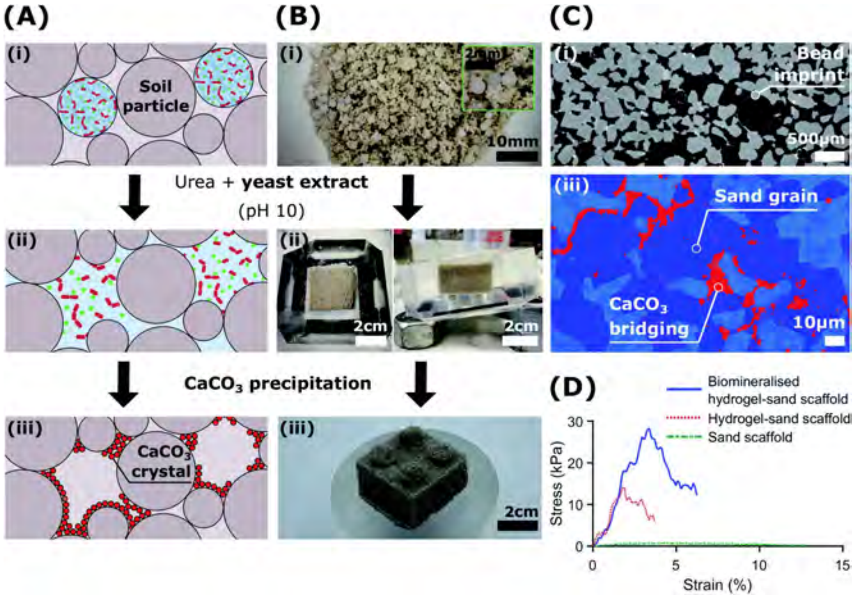


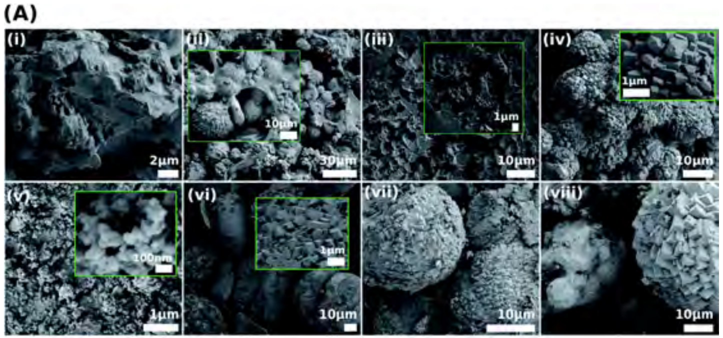




Microencapsulation assisted bio-cementation







Saracho, A.C., Lucherini, L., Hirsch, M., Peter, H.M., Terzis, D., Amstad, E. and Laloui, L., 2021. Controlling the calcium carbonate microstructure of engineered living building materials. *Journal of Materials Chemistry A*.

"Nature is our laboratory"

LABIOTECH.eu NEWS LONG READS MULTIMEDIA REFRESH EVENTS JOBS BIOTECH MAP

This Biotech Makes Self-Healing Concrete Using Bacteria

JONATHAN SMITH - 03/05/2019 3 MINS - BIOTECH OF THE WEEK

Imagine walls and buildings that heal themselves just like your skin does. The Dutch biotech Green Basilisk is making this idea a reality by embedding special limestone-producing bacteria into concrete.

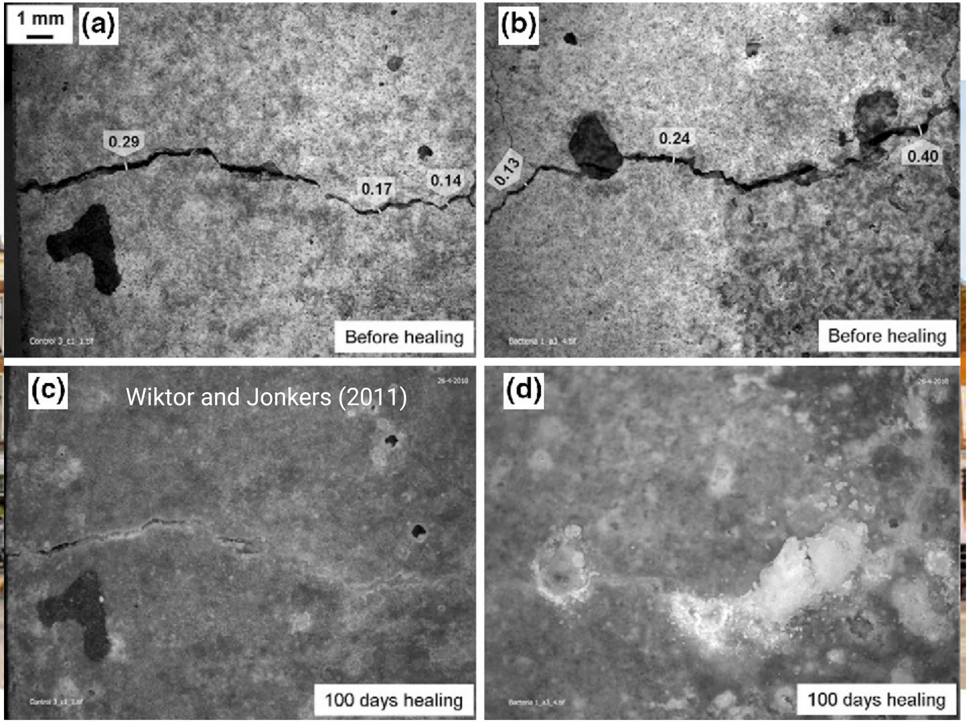
“Nature is our laboratory”

This Biotech Makes Self-Healing Concrete Using Bacteria

JONATHAN SMITH

Basilisk
self healing concrete

TU Delft



Wiktor and Jonkers (2011)

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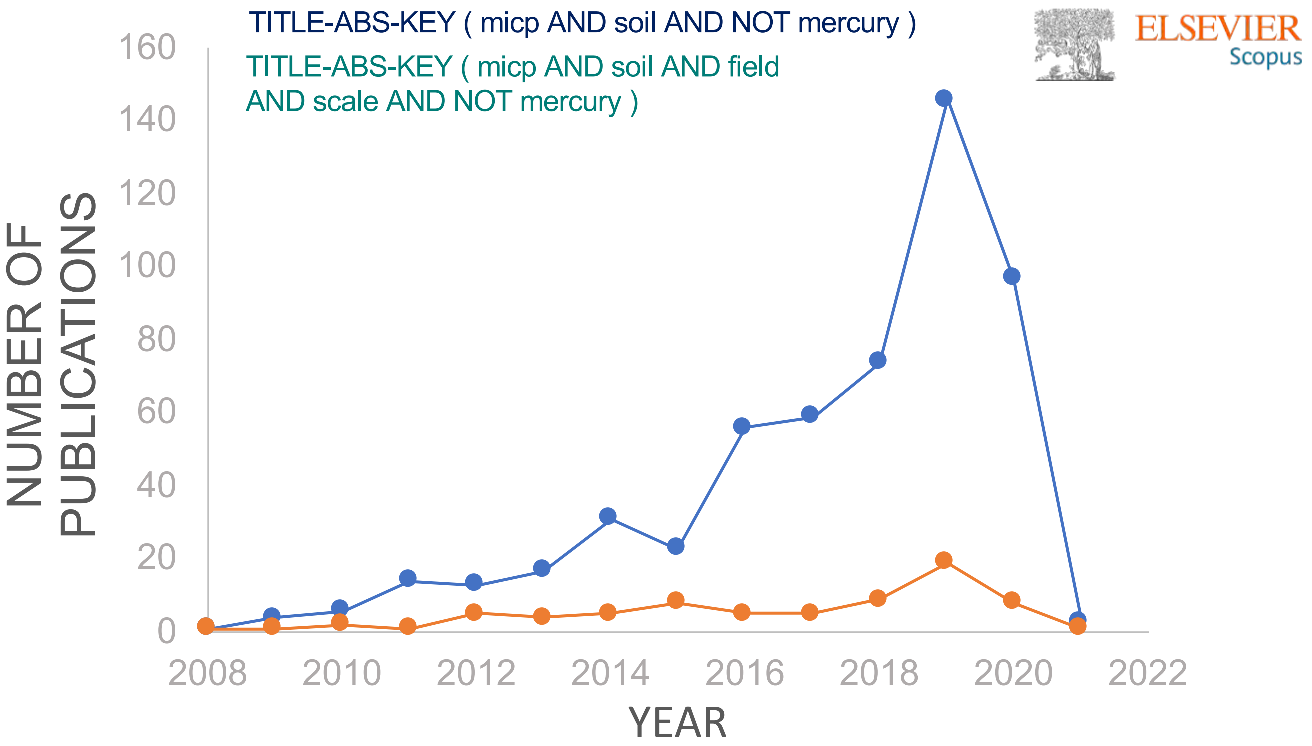
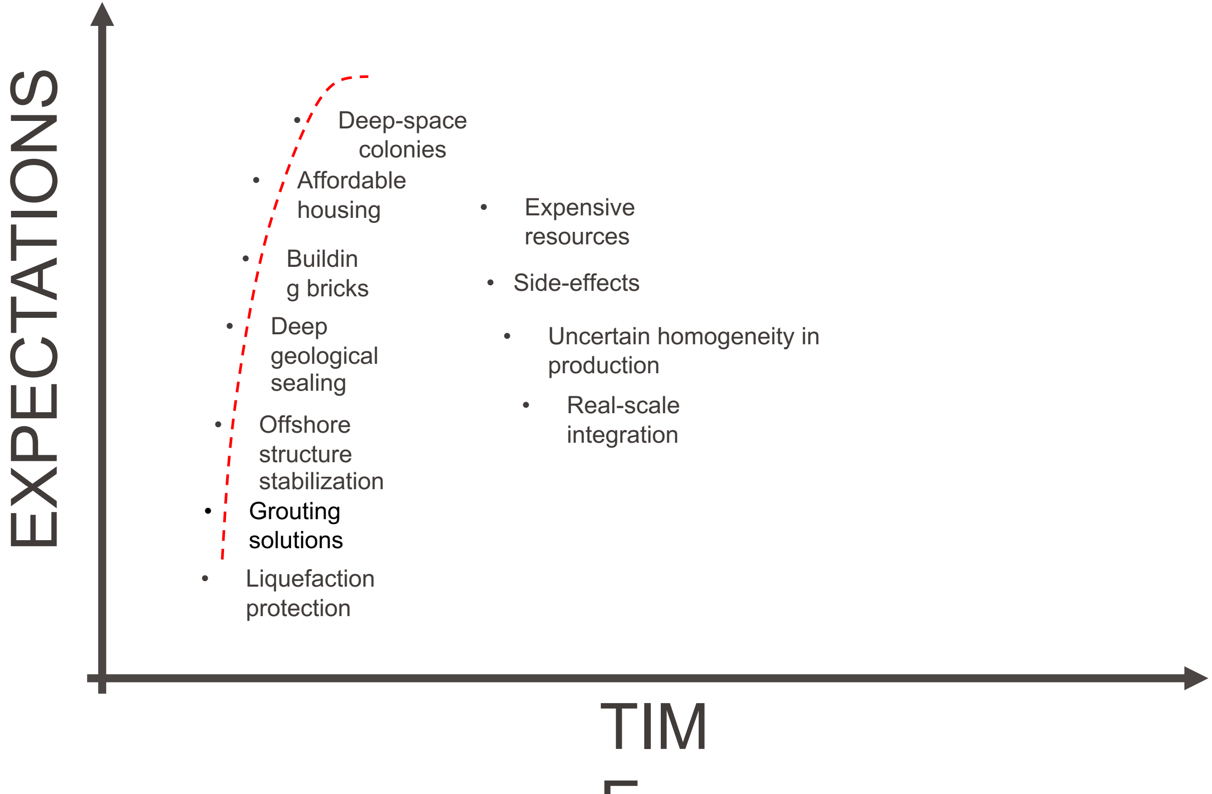
The hype cycle / expectations theory



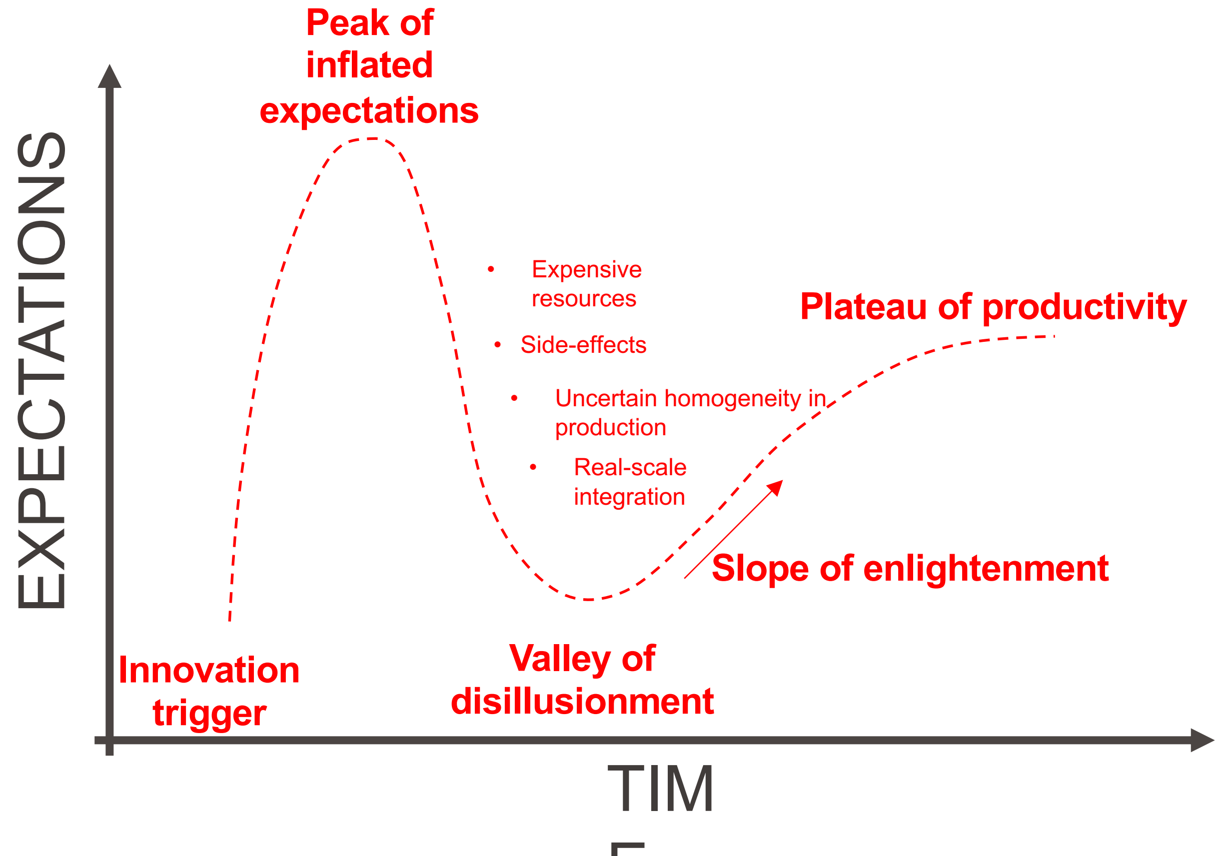
Terzis, D. and Laloui, L., 2019. **A decade of progress and turning points in the understanding of bio-improved soils**: A review. *Geomechanics for Energy and the Environment*, *19*, p.100116.

The hype cycle / expectations theory



Hype cycle by Gartner

The hype cycle / expectations theory



Hype cycle by Gartner

Technology Readiness Level

Technology readiness levels (**TRLs**) estimate the **maturity** of technologies. The European Commission advised EU-funded research and innovation projects to adopt the scale in 2010.

PoC

- TRL **1** – basic principles observed
- TRL **2** – technology **P**roof **of** **C**oncept formulated
- TRL **3** – experimental proof of concept
- TRL **4** – technology validated in lab

Make or break

- TRL **5** – technology validated **in relevant environment**
- TRL **6** – technology demonstrated **in relevant environment**
- TRL **7** – system prototype demonstration in operational environment

Likely failure in integration

- TRL **8** – system **complete and qualified**
- TRL **9** – actual system proven in operational environment (**competitive manufacturing**)

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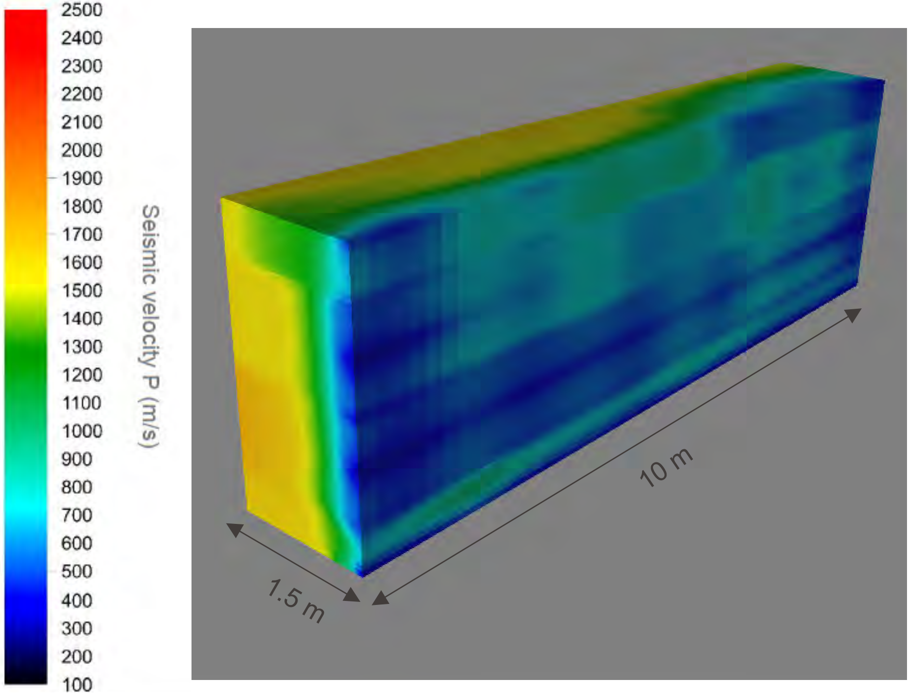
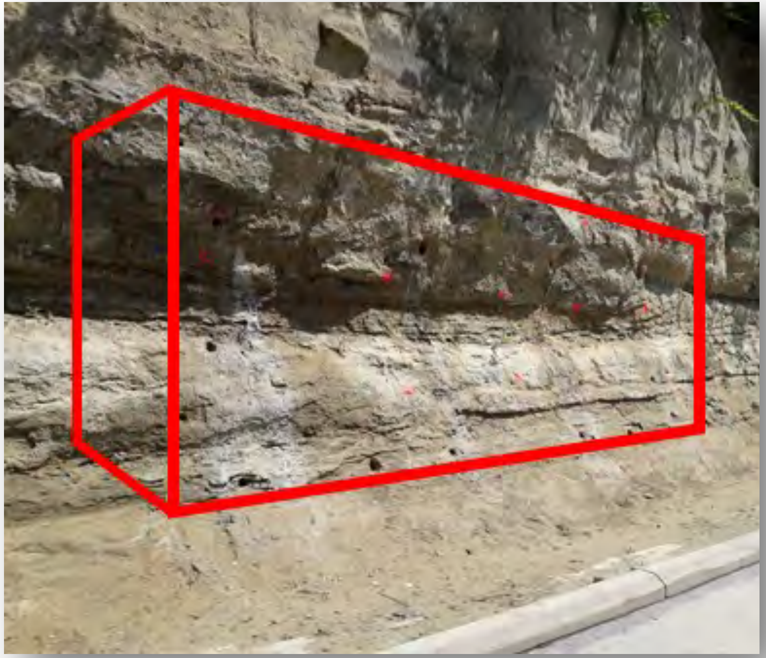
300 m

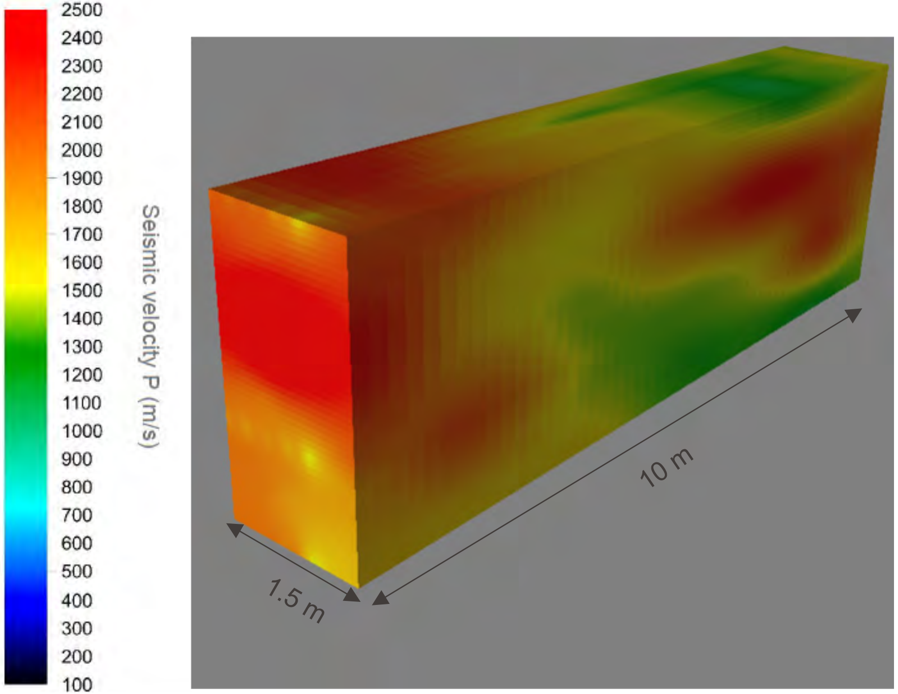
Sandstone cliff bio-stabilization

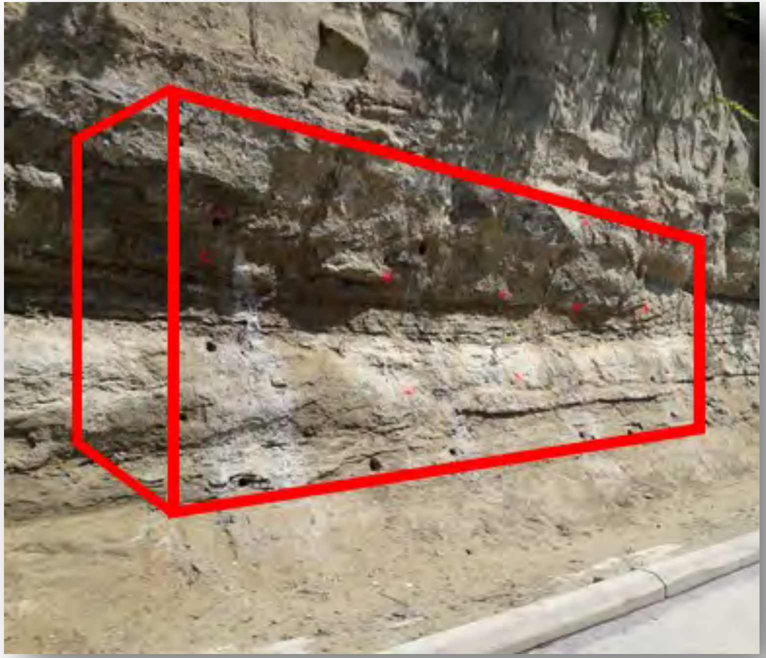
Dr. Dimitrios Terzis





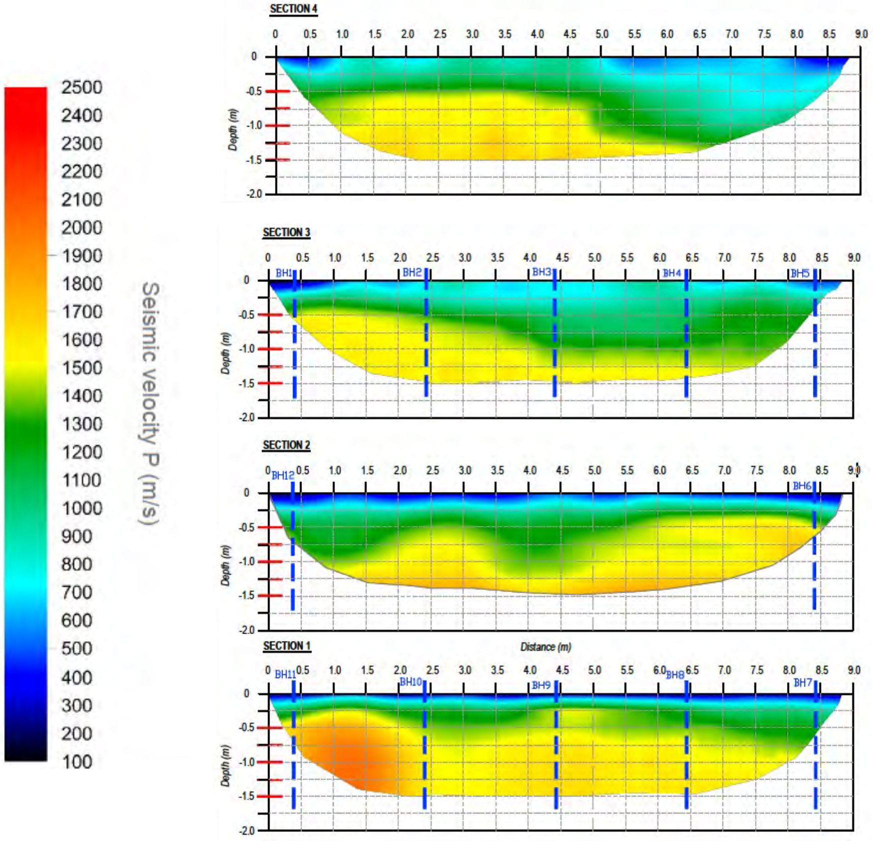
Sandstone cliff bio-stabilization

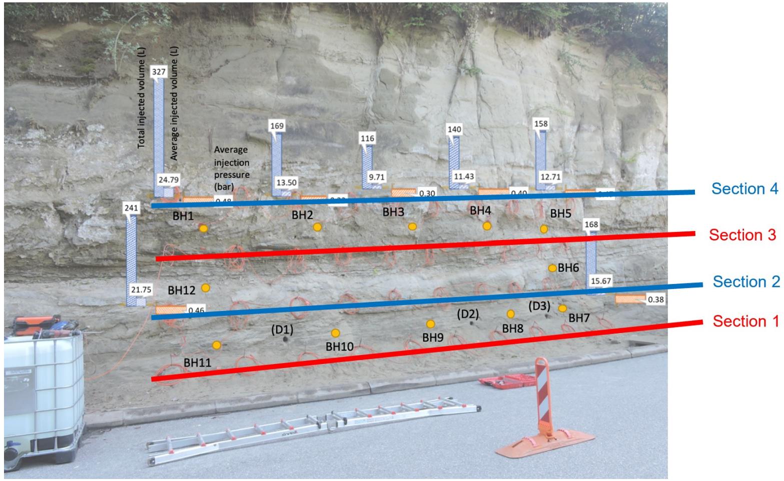




Dr. Dimitrios Terzis

Sandstone cliff bio-stabilization

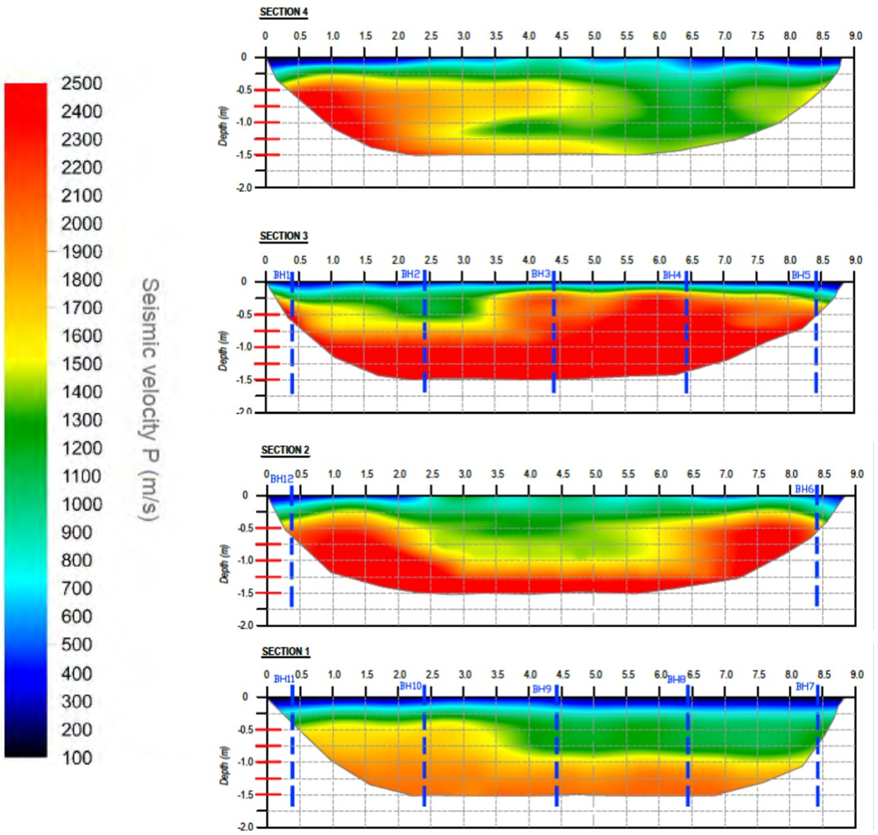


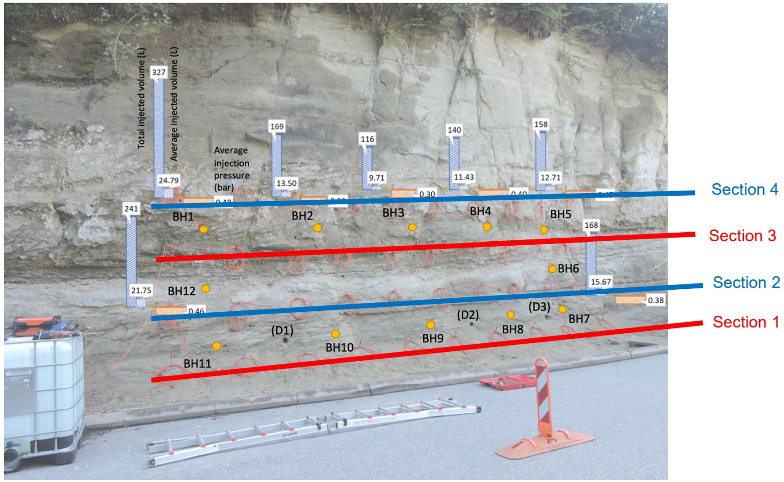


Material	P-wave velocity (m/s)
Air	330
Water	1450
Sands and clays	300-1900
$CaCO_3$	1700-3000
Strong Limestone	3000-6500

Source: M Aziman *et al* 2016 *J. Phys.: Conf. Ser.* **710** 012011

Sandstone cliff bio-stabilization





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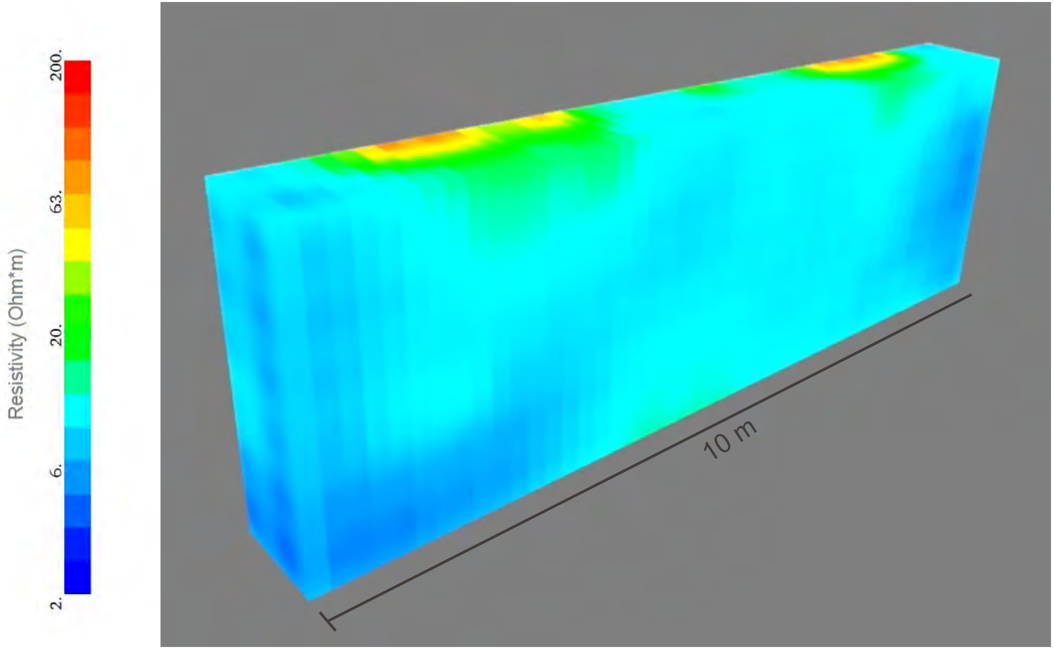

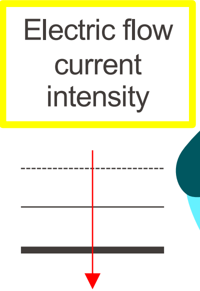

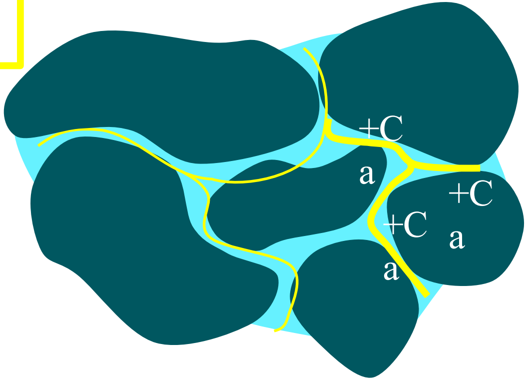

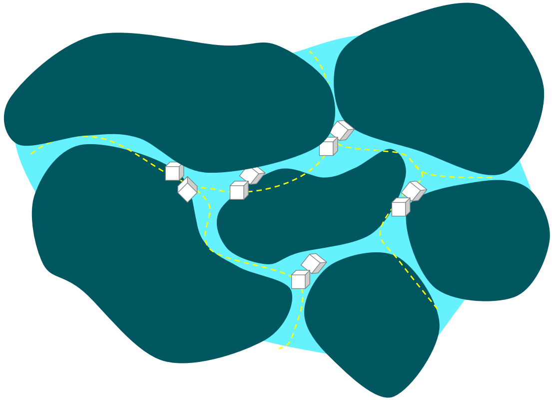

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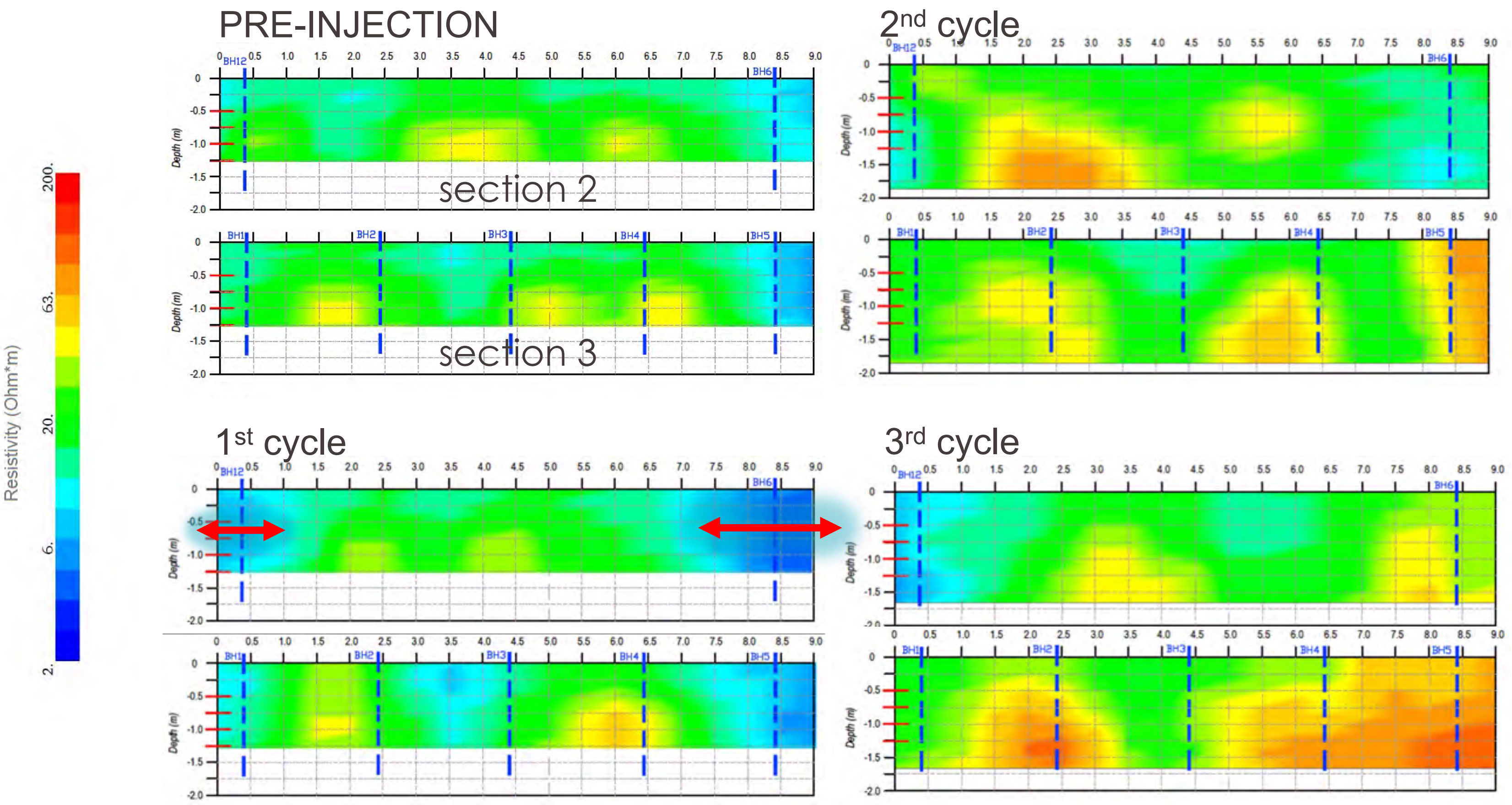

Sandstone cliff bio-stabilization

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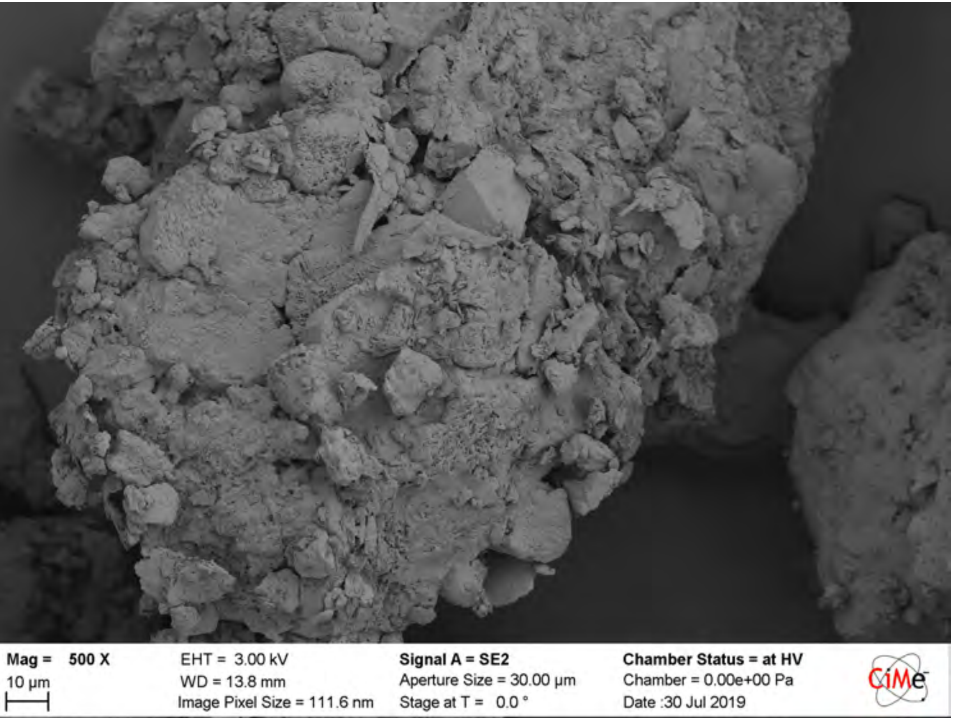
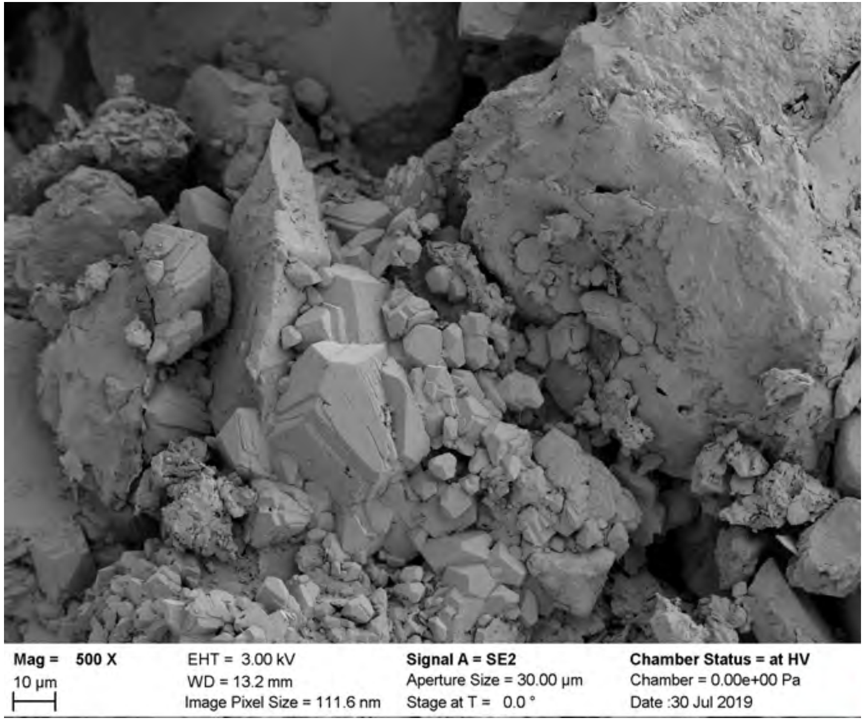


PRE-INJECTION



POST-INJECTION

Innovation for construction & the environnent

Dr. Dimitrios Terzis

26/11/2024

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