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NAME EVENT / NAME PRESENTATION

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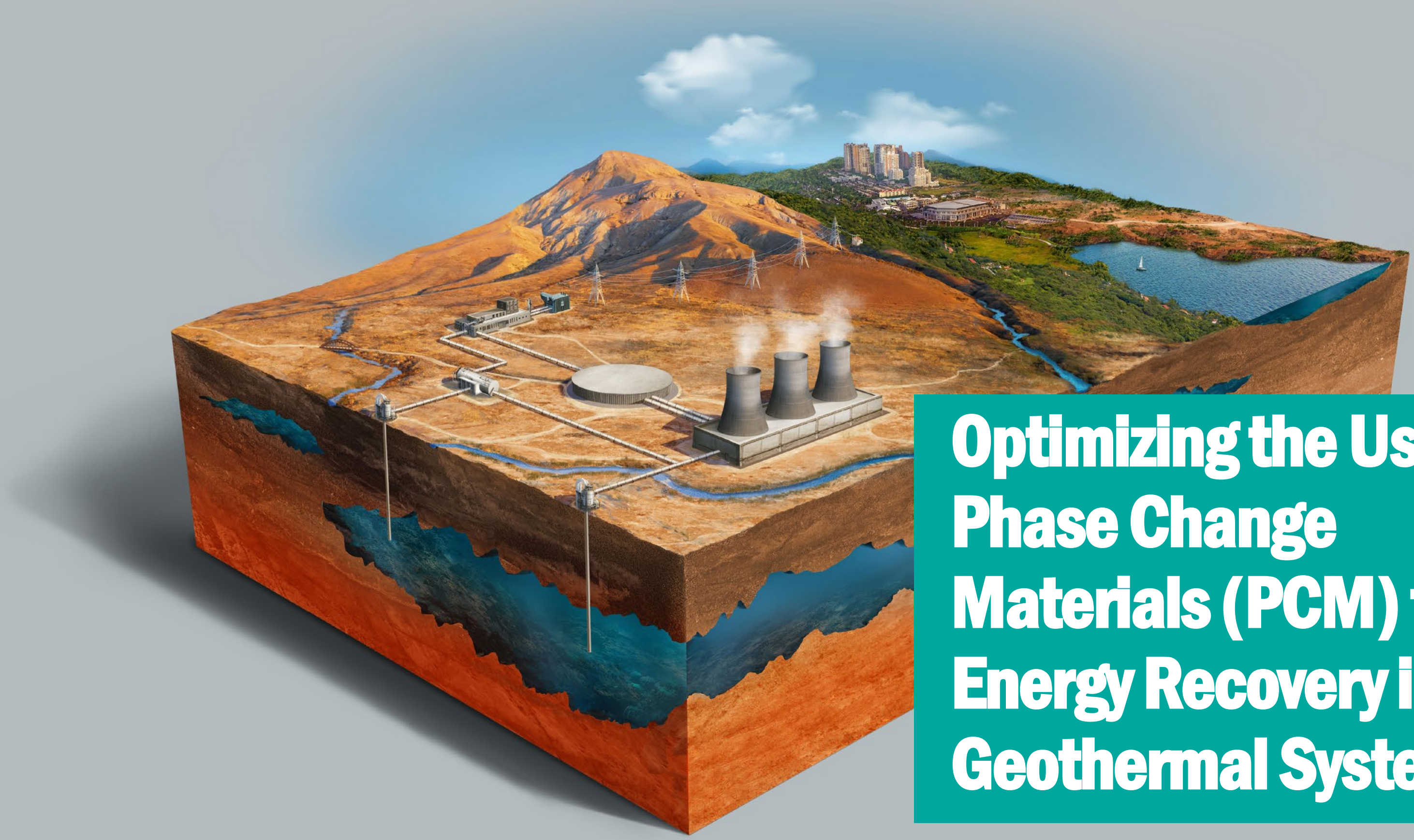
Projects at LMS 2024 - 2025



Optimizing the Use of Phase Change Materials (PCM) for Energy Recovery in Deep Geothermal Systems

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Optimizing the Use of Phase Change Materials (PCM) for Energy Recovery in Deep Geothermal Systems

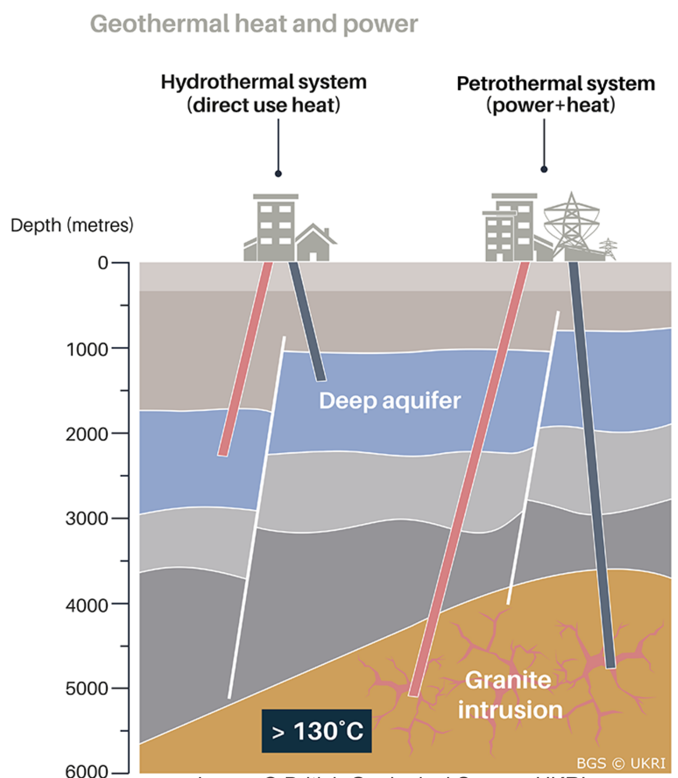


Image © British Geological Survey, UKRI

Why This Matters

Deep geothermal energy offers a sustainable, low-carbon solution for reliable, year-round energy in Switzerland and worldwide, driving energy independence and reducing emissions. Deep **geothermal energy is underutilized** due to challenges like low rock permeability and inefficient heat transfer.

Innovative Project

You will optimize **Phase Change Materials (PCM)** – currently used as thermal storage solutions - to improve heat transfer, **enhance geothermal efficiency, and preserve rock integrity**, unlocking the full potential of geothermal energy.

Optimizing the Use of Phase Change Materials (PCM) for Energy Recovery in Deep Geothermal Systems

Methodology

- Laboratory experiments (mechanical and thermal tests)
- Numerical simulations (MATLAB, COMSOL)
- Data Analysis and Reporting

Timeline for key results

- 6-months

Resources

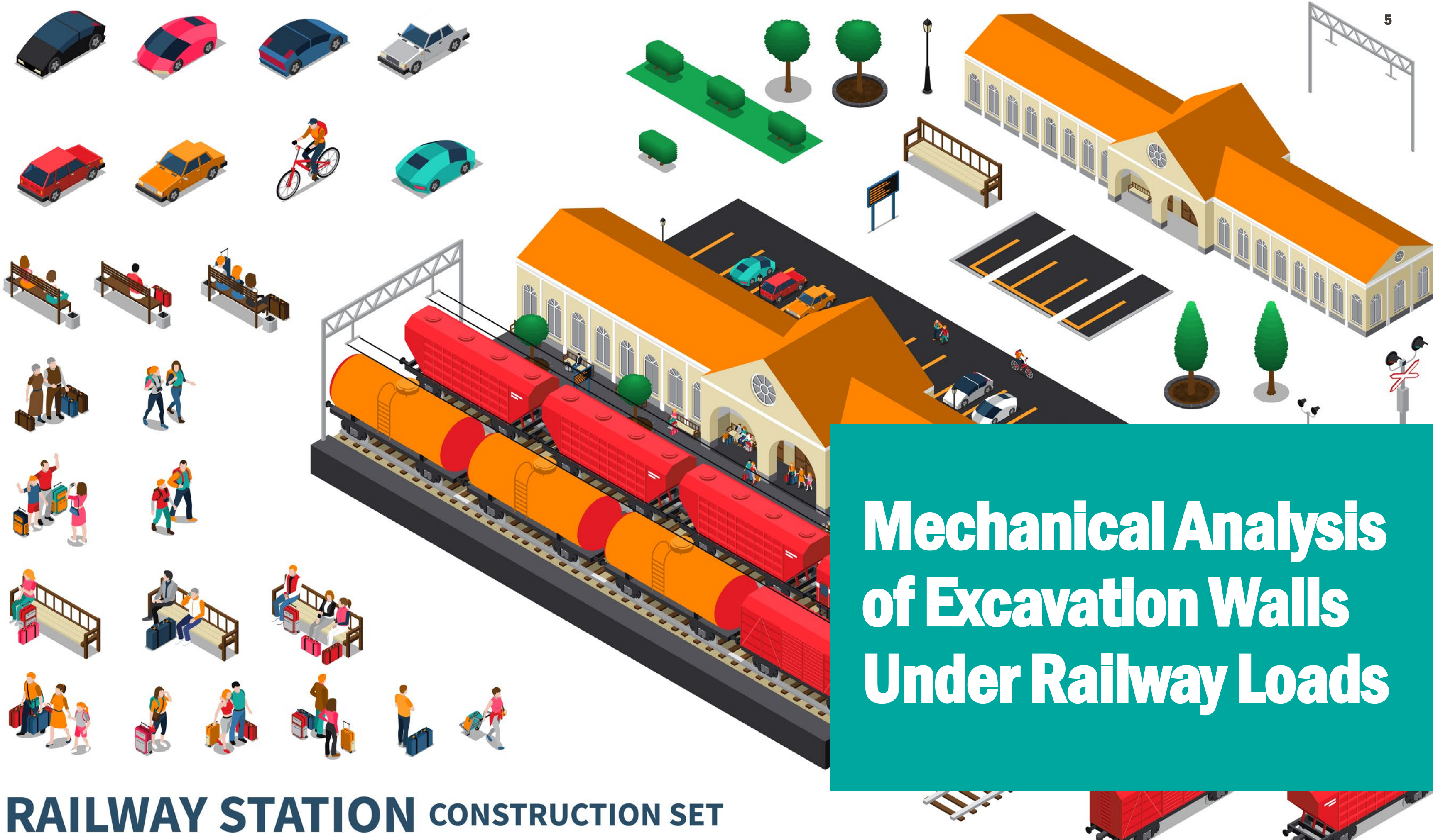
- Fully equipped laboratory
- Advanced software
- Multidisciplinary team

Project Lead

Dr. Angelica Tuttolomondo
angelica.tuttolomondo@epfl.ch

Key goals

- Identify PCM suitable for high temperatures
- Characterize PCM properties and rock-fluid interaction
- Develop numerical models
- Propose design guidelines for geothermal systems



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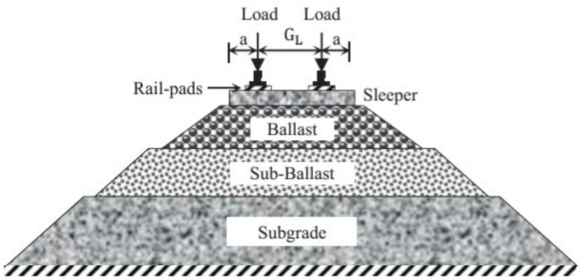
Mechanical Analysis of Excavation Walls Under Railway Loads

Mechanical Analysis of Excavation Walls Under Railway Loads

Gotthard Railway (Wikipedia)

Why This Matters

As **transportation demands grow**, expanding train stations and rail infrastructure often requires **excavations near active railways**, where static and dynamic train loads pose significant safety risks.



Kumawat et al., 2019

Innovative Project

You will develop **advanced analytical and numerical methods** to analyze the mechanical behavior of excavation walls, **ensuring safe and optimized designs.**

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Mechanical Analysis of Excavation Walls Under Railway Loads

Methodology

- Analytical approach
- Numerical simulations (e.g., Abaqus)
- Validation and Optimization

Timeline for key results

- 6-months

Resources

- Advanced simulation tools
- Support from railway and geotechnical experts
- Multidisciplinary team

Project Lead

Dr. Angelica Tuttolomondo
angelica.tuttolomondo@epfl.ch

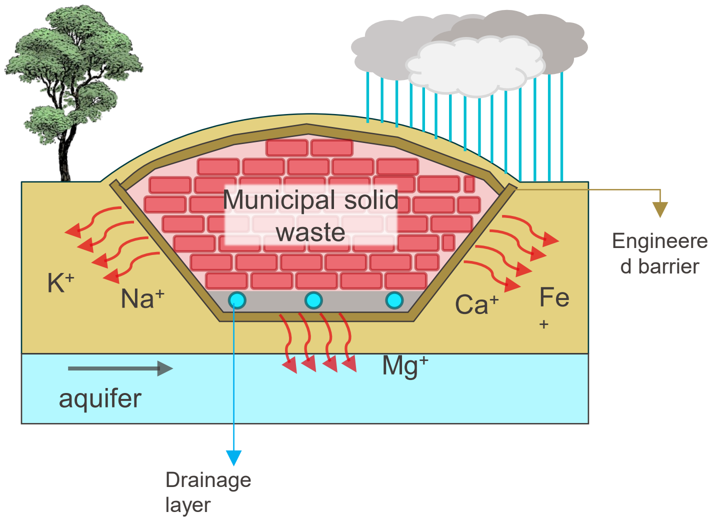
Key goals

- Detailed understanding of excavation wall performance
- Validated models for reliable design
- Comprehensive guidelines for excavations in expanding railway infrastructure

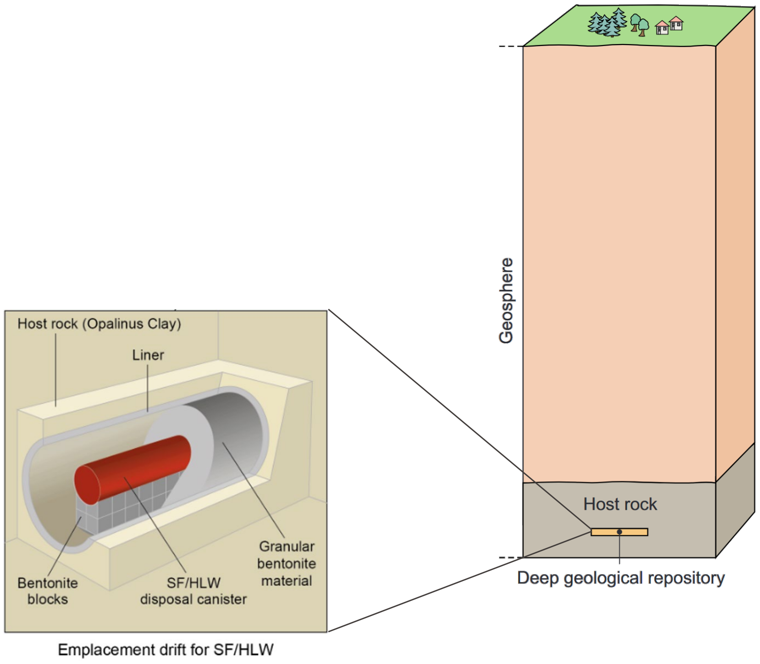
Municipal and nuclear waste storage

Municipal and Nuclear waste disposal

Landfills (municipal waste)



Deep geological repository (nuclear waste)



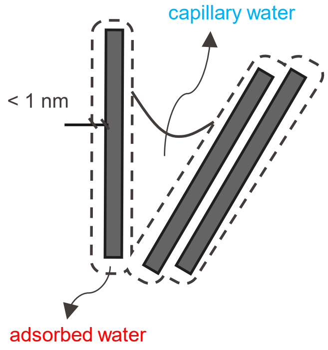
Leupin et al., 2014

Use of bentonite in engineered barriers

Bentonite is mainly composed by active clay minerals.

The most important features:

- ❑ Swelling behaviour
- ❑ High water retention capacity
- ❑ High chemical retention capacity
- ❑ Self healing capacity
- ❑ Low hydraulic conductivity $(10^{-14} - 10^{-13}\ m/s)$



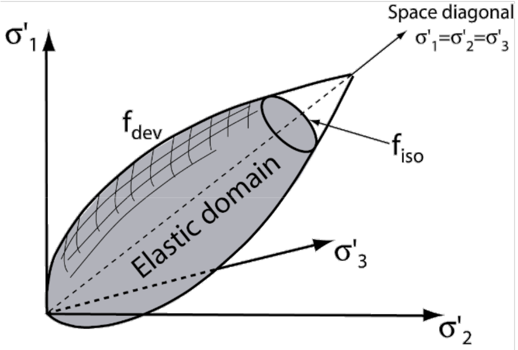
Bentonite is used in different forms:

- Granular form
- Blocks
- Pellets
- Geosynthetic Clay liners (GCLs)

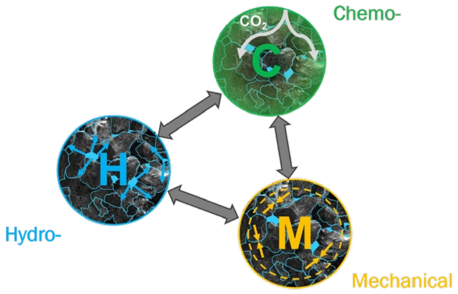
Constitutive modelling of bentonite

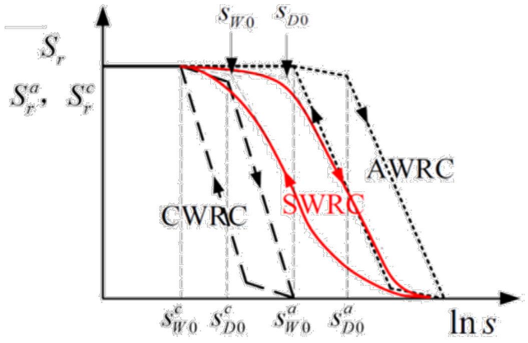
Contact: alessandro.parziale@epfl.ch

- Understanding of the model formulation
- Calibration of the model using available experimental data
- Simulation of chemo-hydro-mechanical stress-paths



François, 2008





Qiao et al. 2021

Constitutive modelling of bentonite

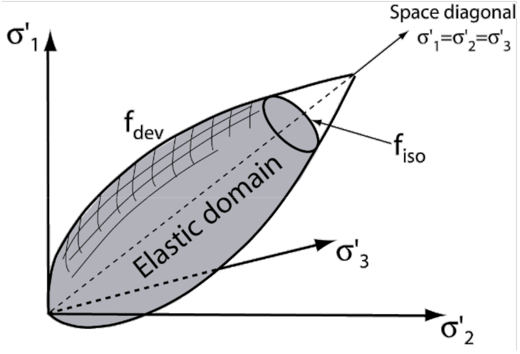
Contact: alessandro.parziale@epfl.ch

Requirements:

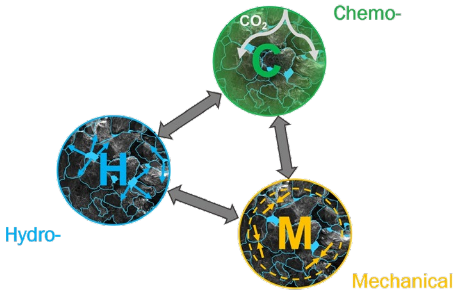
- Basic Geomechanics knowledge
- Basic Python knowledge

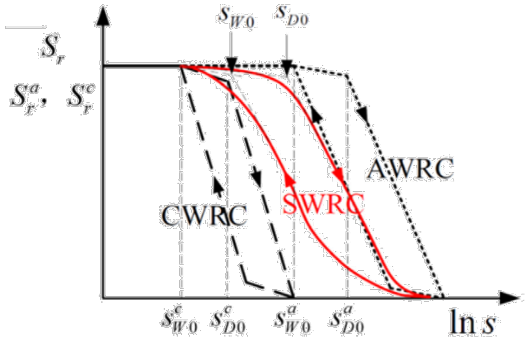
Objective:

Simulation of many stress-paths using an advanced stress-strain framework



François, 2008





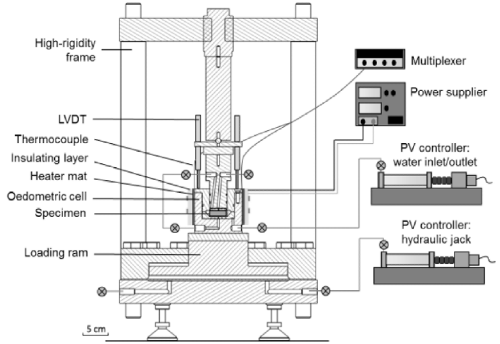
Qiao et al. 2021

Chemically-induced strains on bentonite (experimental work)

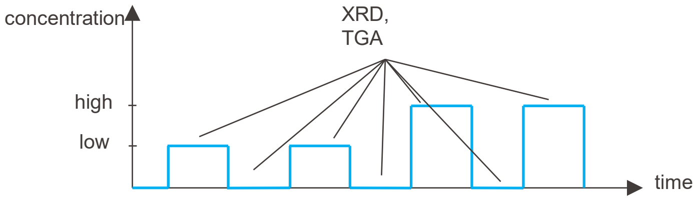
Contact: alessandro.parziale@epfl.ch

- Free swelling under different chemical concentrations (NaCl)
- Thermogravimetric analysis (TGA)
- X-Ray diffraction (XRD)

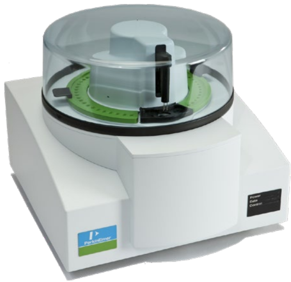
High pressure oedometer cell



Fuselier, 2024

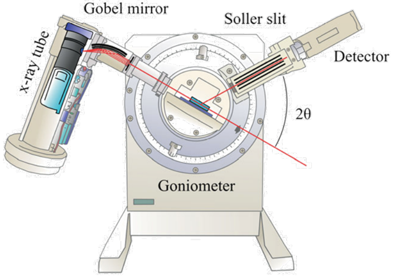


TGA apparatus



http://www.thermal-instruments.co.uk

X-Ray diffractometer



Stefanov, 2015

Chemically-induced strains on bentonite (experimental work)

Contact: alessandro.parziale@epfl.ch

- Free swelling under different chemical concentrations (NaCl)
- Thermogravimetric analysis (TGA)
- X-Ray diffraction (XRD)

Requirements:

- Basic Geomechanics knowledge

Objective:

Understand the mechanisms underlying chemically-induced strains on bentonite

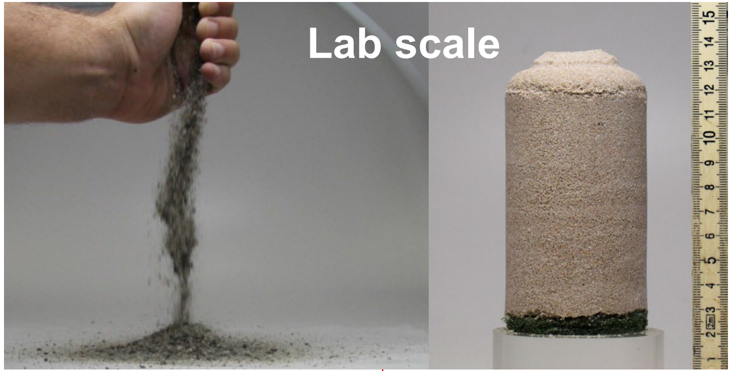
Bio-improved soils

Biocementation

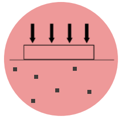
Sofie ten Bosch

Context

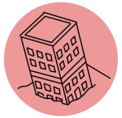
- Field-scale application of **biocementation**
- Numerical modelling



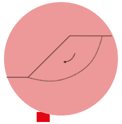
Example of applications



Securing necessary bearing capacity



Liquefaction protection



Increasing slope stability

Erosion protection

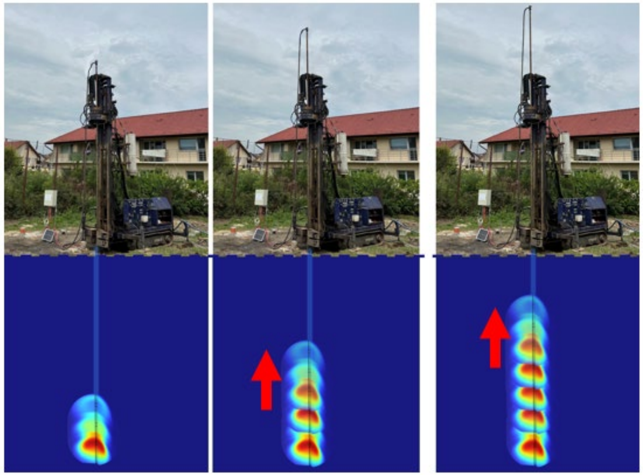
Biocementation: demonstrate field-scale performance

Sofie ten Bosch

Objectives

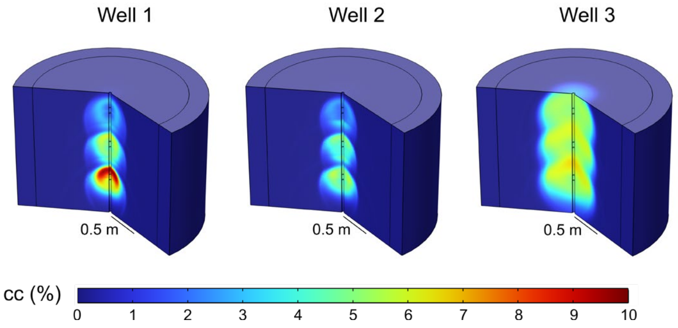
Primary goal: Simulate the **biocementation treatment** applied in a **recent field-scale experiment** using a bio-chemo-hydro framework.

Reflect on model capabilities to capture treatment monitored with an extensive monitoring campaign.



Activities

- Familiarizing with current modelling framework & field-scale application details
- Simulate the treatment to obtain calcite precipitation patterns
- Reflect on model capabilities based on monitoring data



calcite content

Biocementation: going from model to a design tool

Sofie ten Bosch sofie.tenbosch@epfl.ch

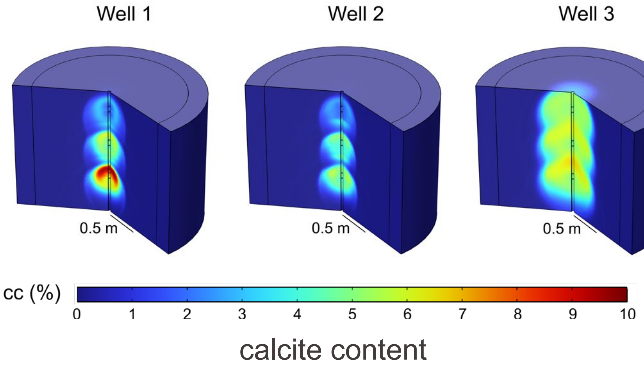
Objectives

Primary goal: Numerical model for biocementation → Design tool biocementation

How …? open for discussion!
But for example can think of developing an **application** or **design curves** for certain scenarios.

Activities

- Familiarizing with current modelling framework & inspiration from design approaches other technologies
- Determining most influential design parameters and ranges
- Developing design tool

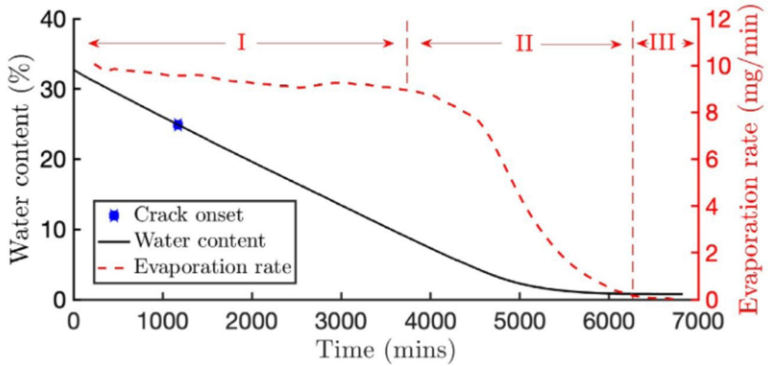


Desiccation crack mitigation

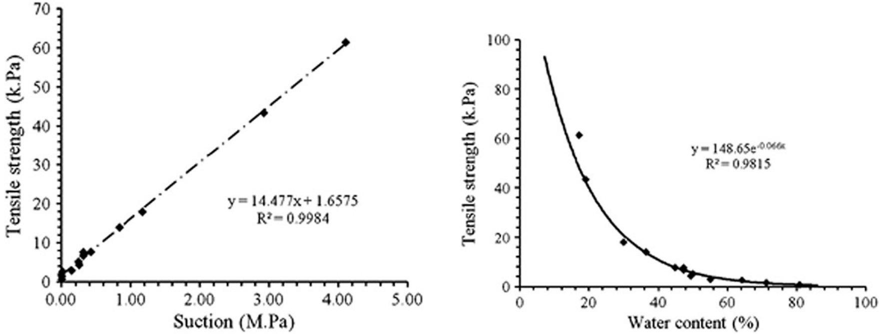
Ziad Sahlab – ziad.sahlab@epfl.ch

Mechanisms of desiccation cracking

- Drying
  - Soil water retention properties
- Shrinkage
  - Volumetric response
- Cracking
  - Tensile behavior



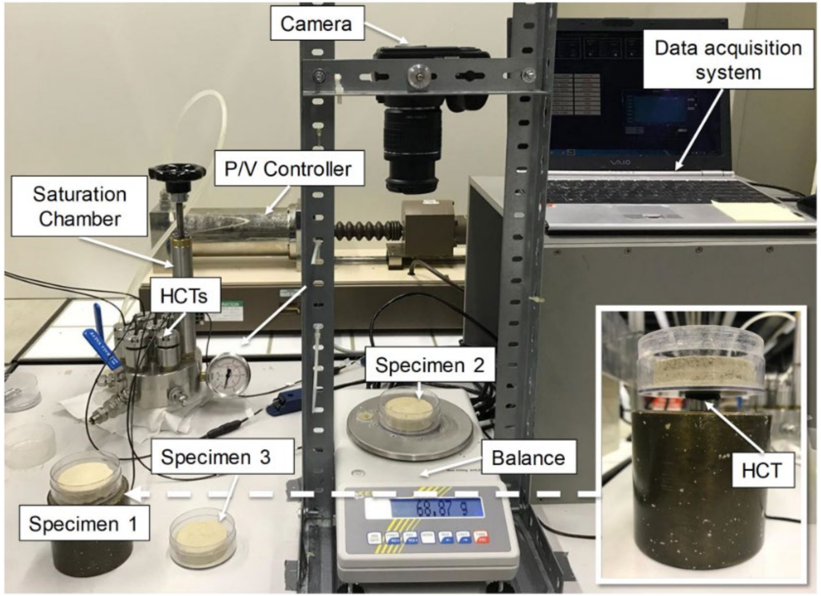
(Chen et al., 2023a)



Trabelsi et al. 2012

Water retention and volumetric behavior

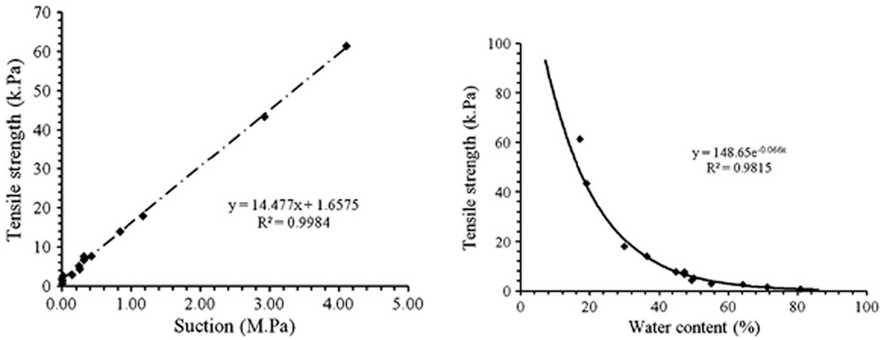
- Using setup from Speranza (2020) we can determine:
  - Suction
  - Gravimetric water content
  - Radial deformations

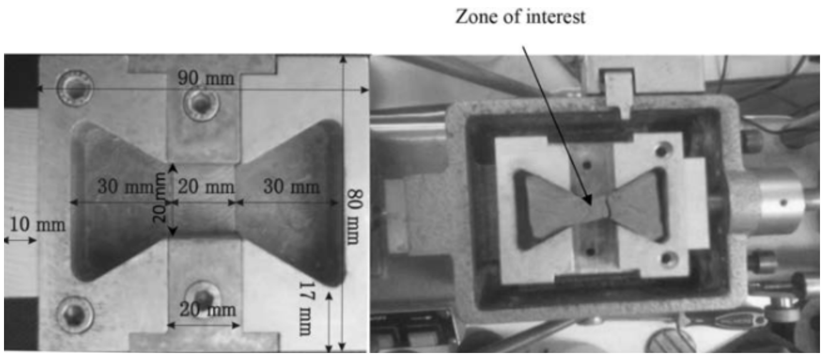


Tensile behavior

- Evaluate evolution of tensile strength with water content and calcite content

Trabelsi et al. 2012





Trabelsi et al. 2018

CO_2 sequestration

Geological CO_2 storage (GCS)

Contact: eleni.stavropoulou@epfl.ch

DR. ELENI STAVROPOULOU

Context

Injection and permanent storage of captured CO_2 for net zero carbon emissions

A. CO_2 sequestration in deep saline aquifers

→ Stratigraphic CO_2 trapping thanks to overlaying caprock (HM barrier)

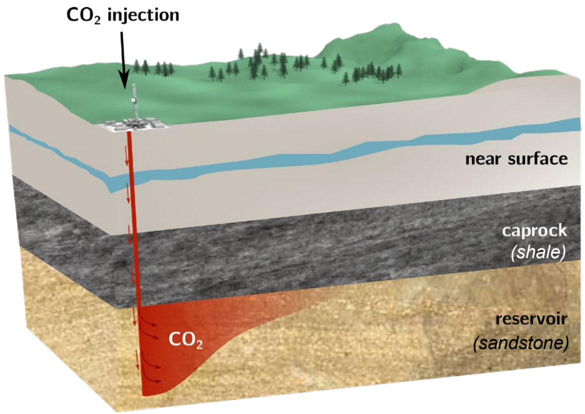


Illustration of GCS concept in deep porous reservoirs

B. CO_2 sequestration in basalts

→ Mineral CO_2 trapping

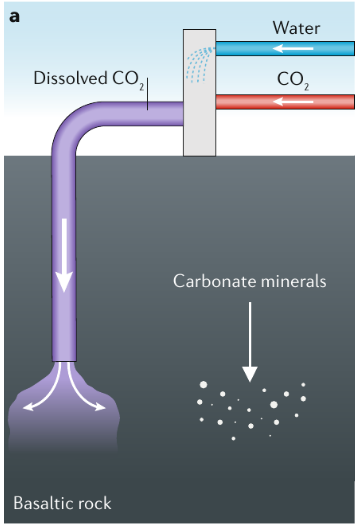
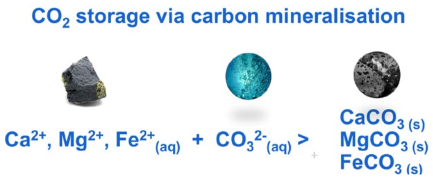
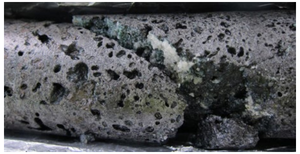


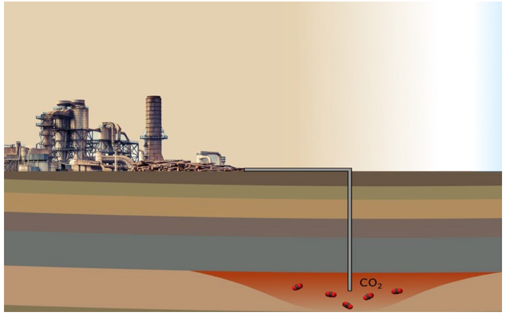
Illustration of GCS concept in basalts



Basalts + CO_2 dissolved in water = Carbonates



A. CO_2 sequestration in deep saline aquifers



Net-zero CO_2 emissions through GCS

Engineering challenges

- Caprock integrity and sealing
- Fracture generation
- Surface uplift

Scientific Objectives

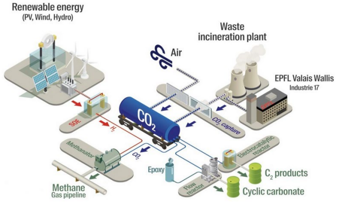
- Link lab-scale results to field-scale application
- Identify potential CO_2 escape paths (breakthrough) through the caprock
- Investigate the CO_2 injectivity of sandstone reservoirs for efficient storage

Methodology and Tools

- Micro-to-macro behaviour with in-situ x-ray tomography and optical fibres
- Constitutive and numerical modelling of the geomechanical response during CO_2 injection

Related Projects

- Solutions 4 Sustainability (EPFL) – collaboration with the EPFL Carbon team

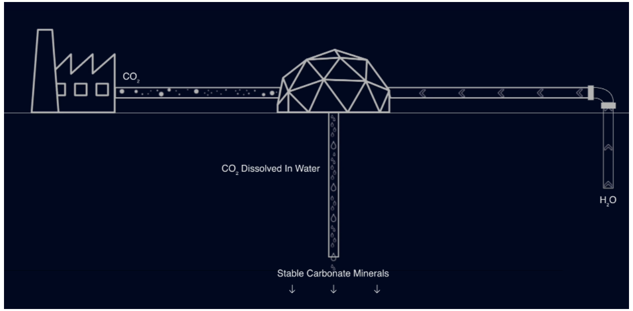


S4S demonstration pilot

B. CO_2 sequestration in basalts

Engineering challenges

- Seawater impact on mineralisation
- Storage efficiency
- Long-term storage and safety



Carbfix injection concept (Iceland)

Scientific Objectives

- Characterise the flow properties of the material
- Simulate the reactive transport properties of the material
- Evaluate long-term storage efficiency (e.g. pore clogging etc.)

Methodology and Tools

- Pore network modelling for hydraulic flow and reactive transport characterisation
- Advanced image analysis and micro-structural characterisation of basaltic cores

Related Projects

- CHRONOS pilot project for long-term synchrotron testing

ESRF synchrotron (France)