A Novel Technique to Investigate Effects of Thermal Shocks on Cement for CCS Well Integrity [PPT]

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A Novel Technique to Investigate Effects of Thermal Shocks on Cement for CCS Well Integrity

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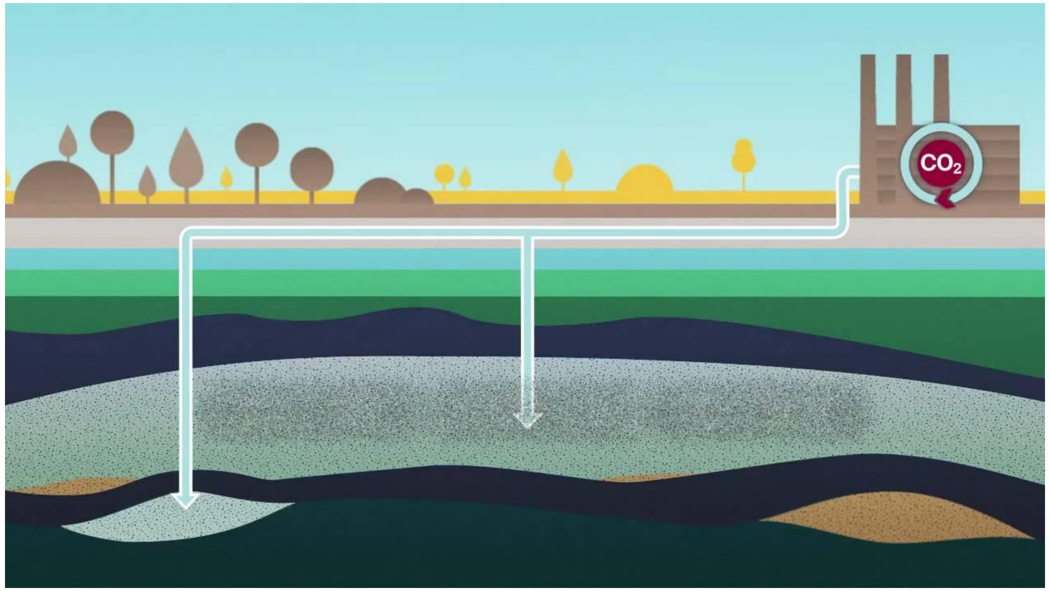
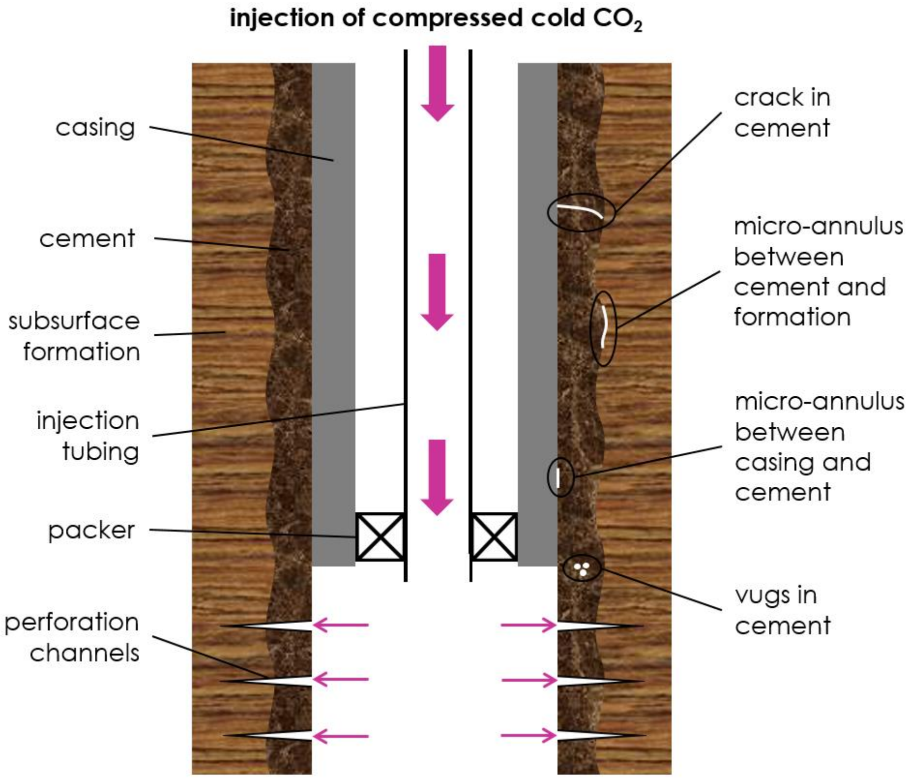
May 31, 2022

Introduction - Effects of thermal stresses on cement integrity





← Potential leakage pathways due to thermal stresses during CO_2 injection and storage in CCS.

<u>What happens to the subsurface wellbore and formation?</u>

→ Reservoirs 1-4 km deep in the subsurface

→ Wellbore and subsurface formations cyclically contract and expand

- ❑ **We investigate the thermal effects on the integrity of cement under in-situ conditions for CCS wells.**
- ❑ To begin with, we present a novel technique to study effects of thermal shock under in-situ conditions.

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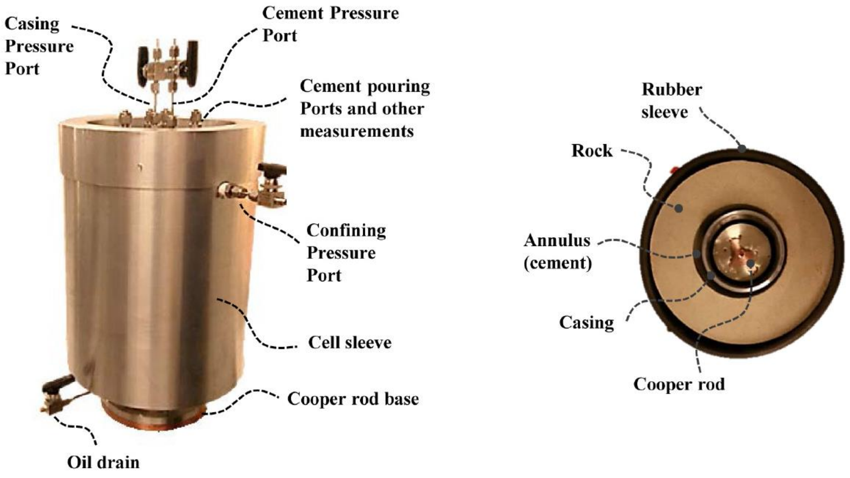
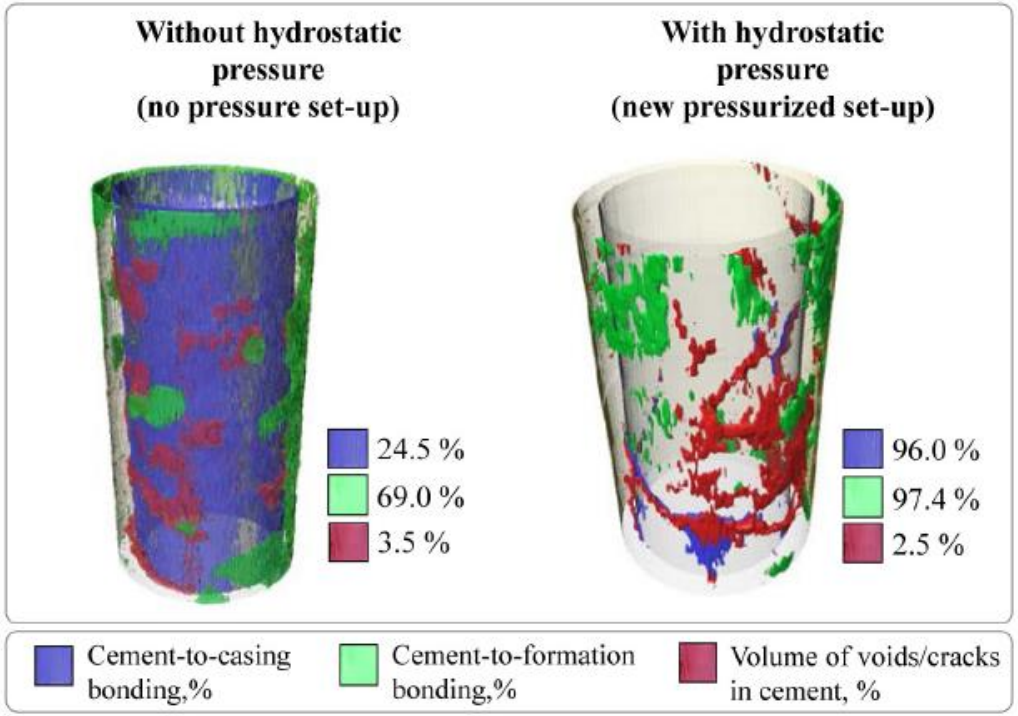
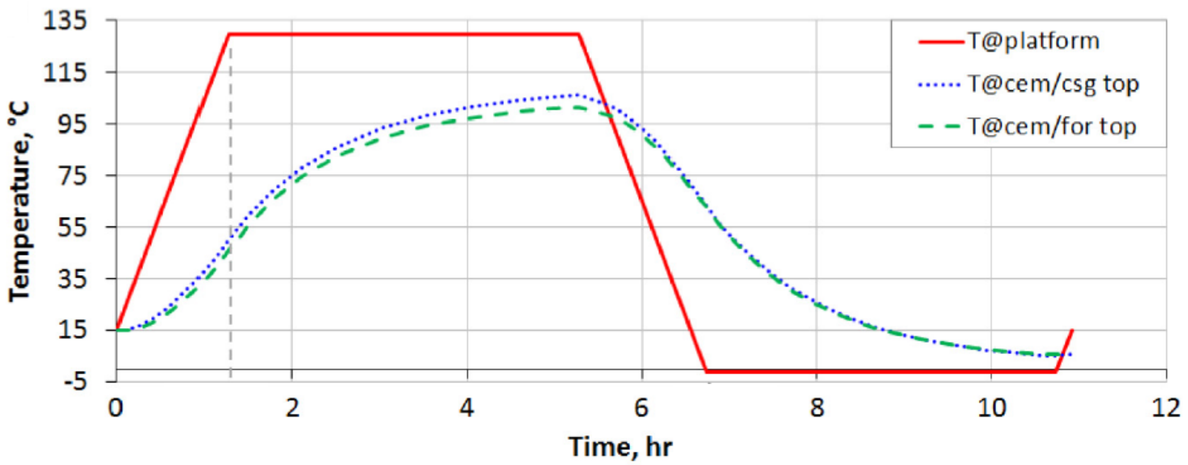
In-situ conditions governs thermal-induced de-bonding

De Andrade et al, 2015



A setup with maximum pressure of 35bar ,temperature up to 150°C.





Heating and cooling (1.5°C/min) with steel rod in wellbore.

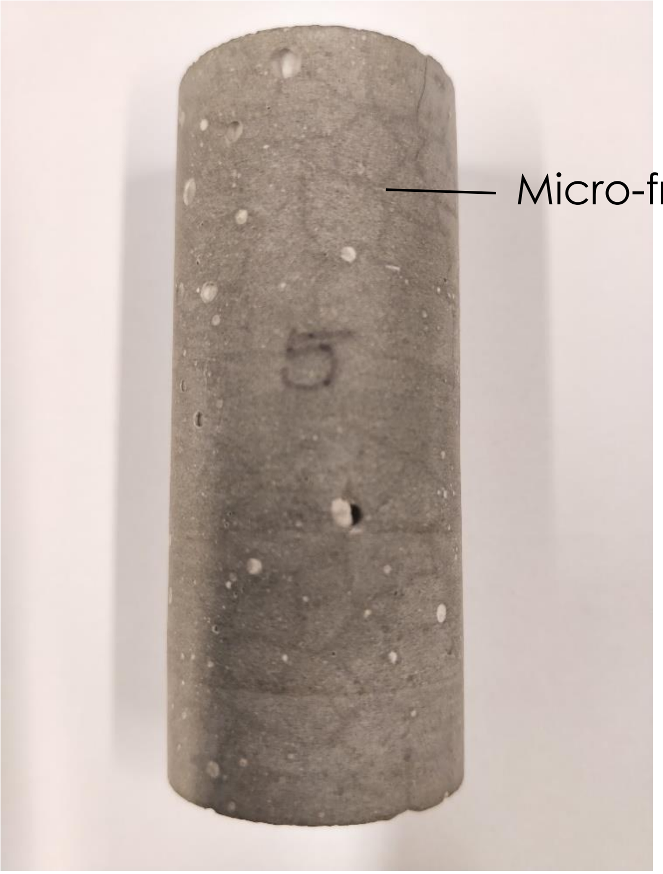
See also:
Albawi et al., 2014
Torsæter et al., 2016.

Preliminary work: thermal effects without confinement

Quenching is a common practice to achieve thermal shocks on rock and cement samples under no confinement.

- Portland CEM I 42.5, water-to-cement ratio: 0.3, cured at 96% humidity, 20°C, and ambient pressure for 28 days.
- ϕ3 x 7 cm cement sample. Density 2.34 g/cm^3.
- Heat the sample to 120°C.
- Quench it in 20°C water.
- Repeat the heating and quenching for 6 cycles.

Intact sample



Micro-fractures

After thermal shocks

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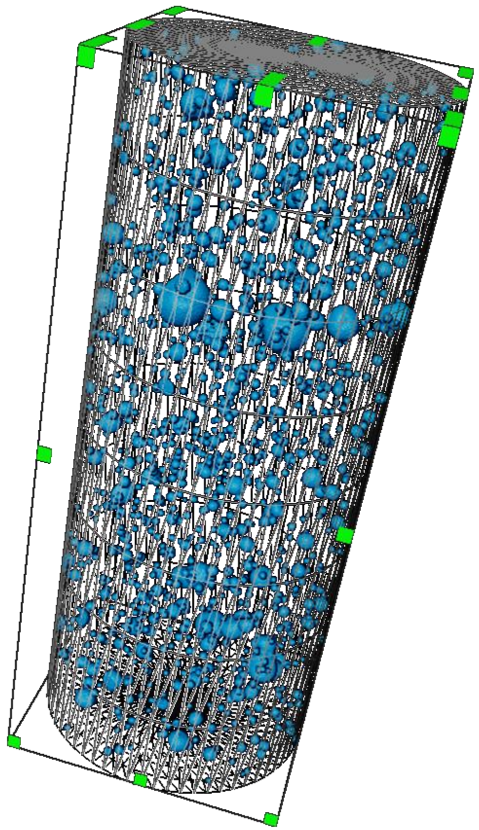
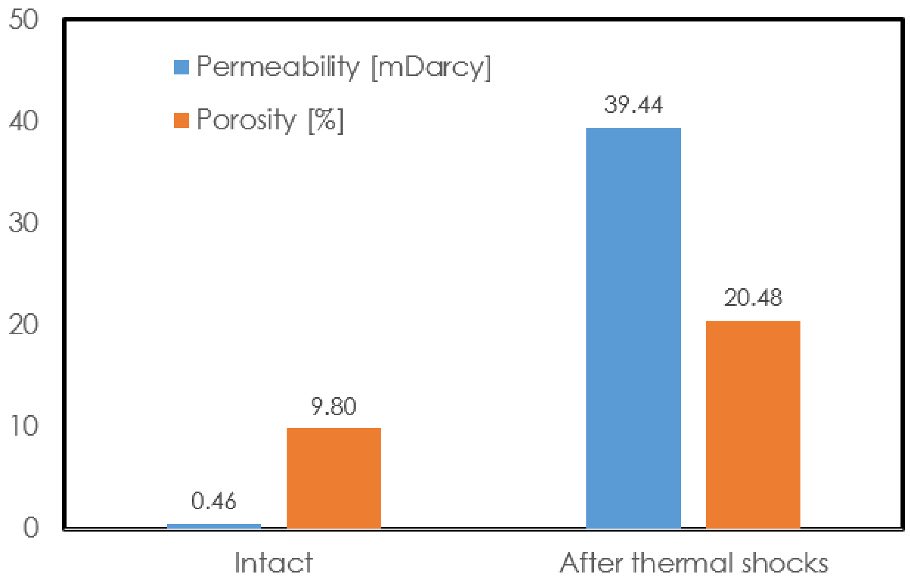
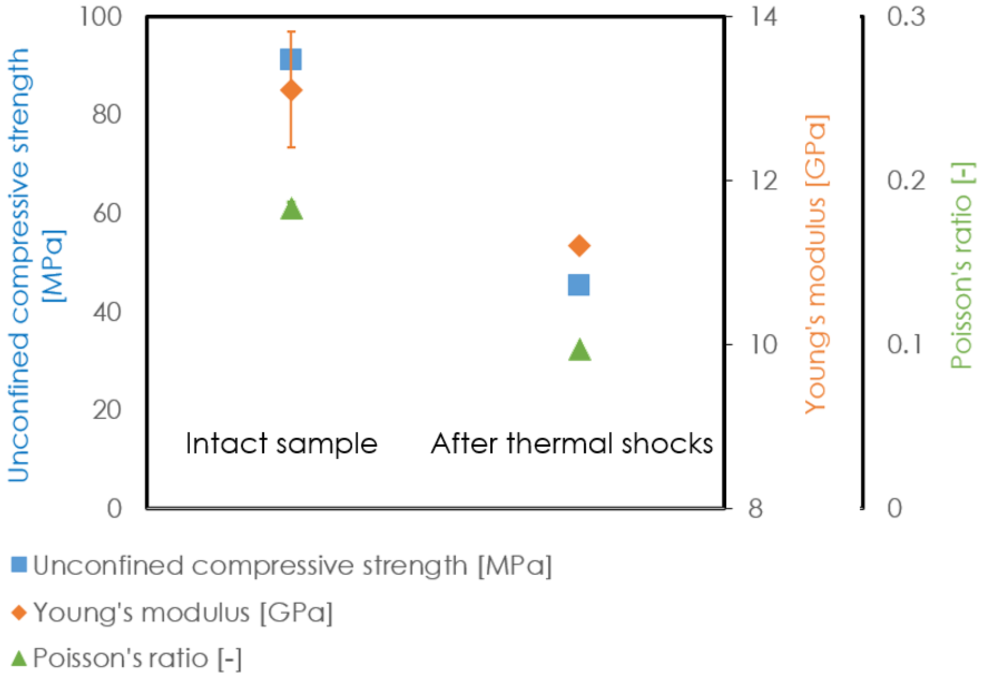
Thermal effects without confinement



X-ray CT scan on intact sample. Pores shown in blue.





After thermal shocks, under no confinement:

- Micro-fractures develops and voids in cement are enlarged.
- We are working on reconstructing the microstructures of the cracks (aperture smaller than 30 μm) in images.

Thermal shocks impair the cement integrity.

- Conductivity increases.
- Cement weakens.

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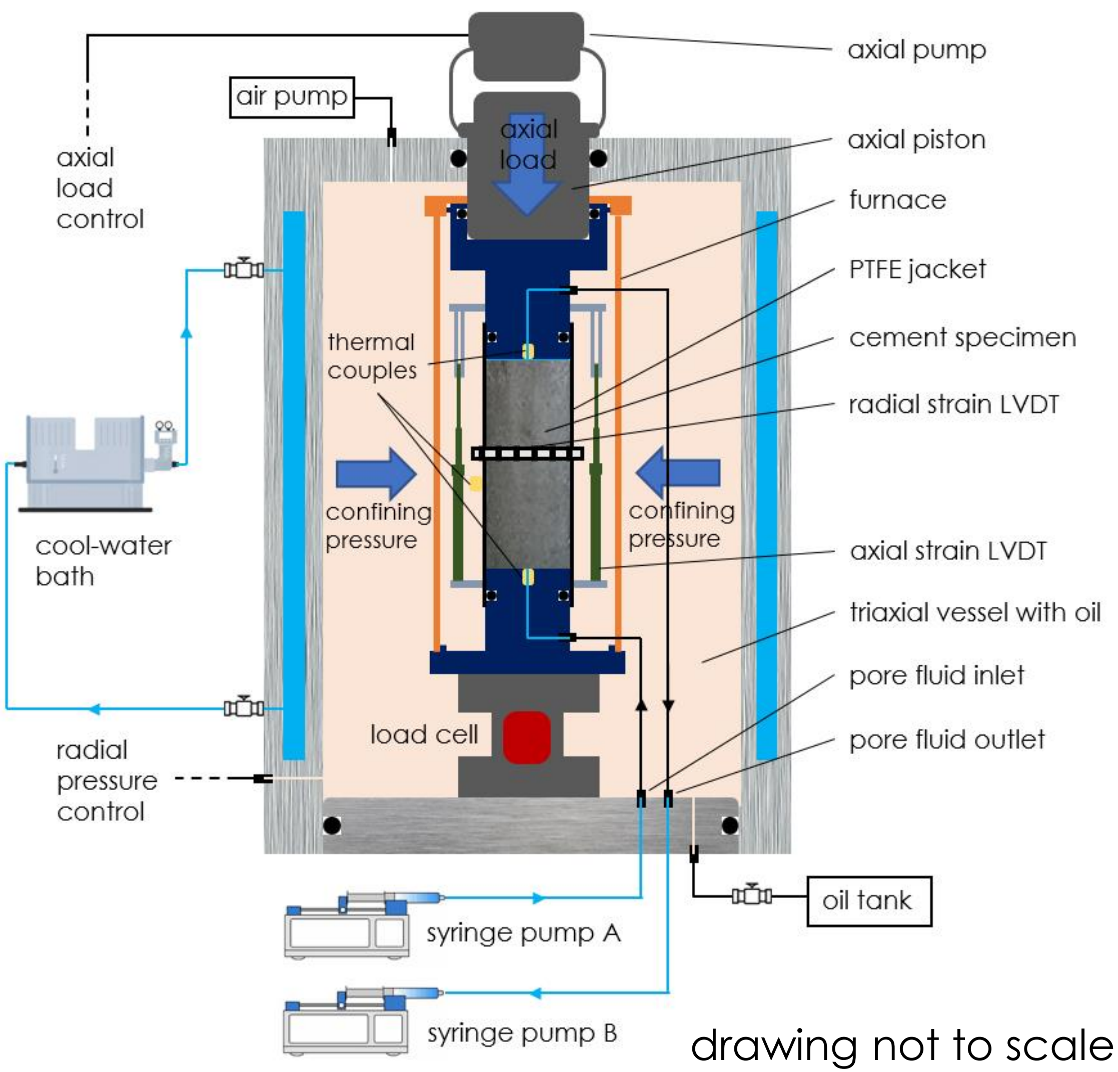
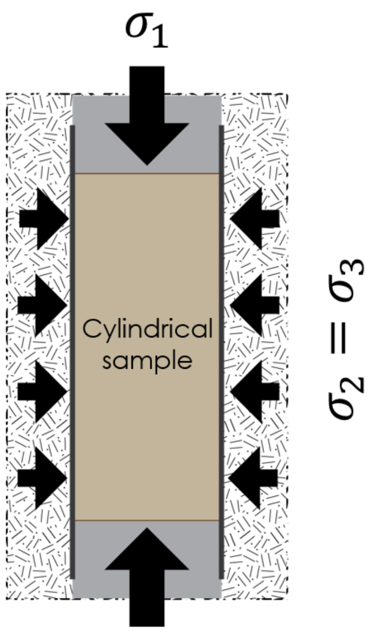
Novel technique: triaxial deformation setup to study thermal shocks on cement under <u>in-situ stresses and temperature</u>



drawing not to scale



- Confining pressure up to 70 MPa, axial stress up to 424 MPa.
- Internal furnace for temperature up to 150°C.
- Triaxial vessel filled with heat-resistant oil that provides the confining pressure.

- Cold water through the sample using two pumps.
- Three linear variable differential transducers (LVDT) measure axial and radial deformation.
- Three thermocouples measure temperature.

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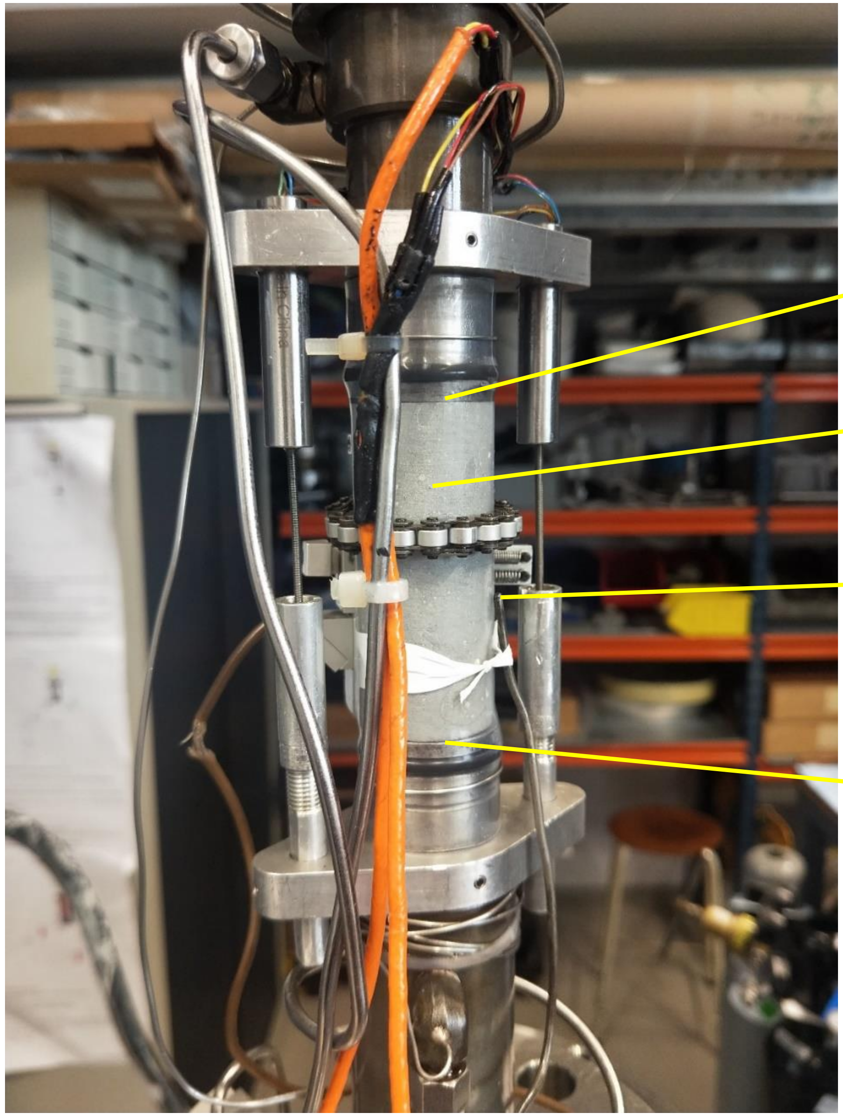
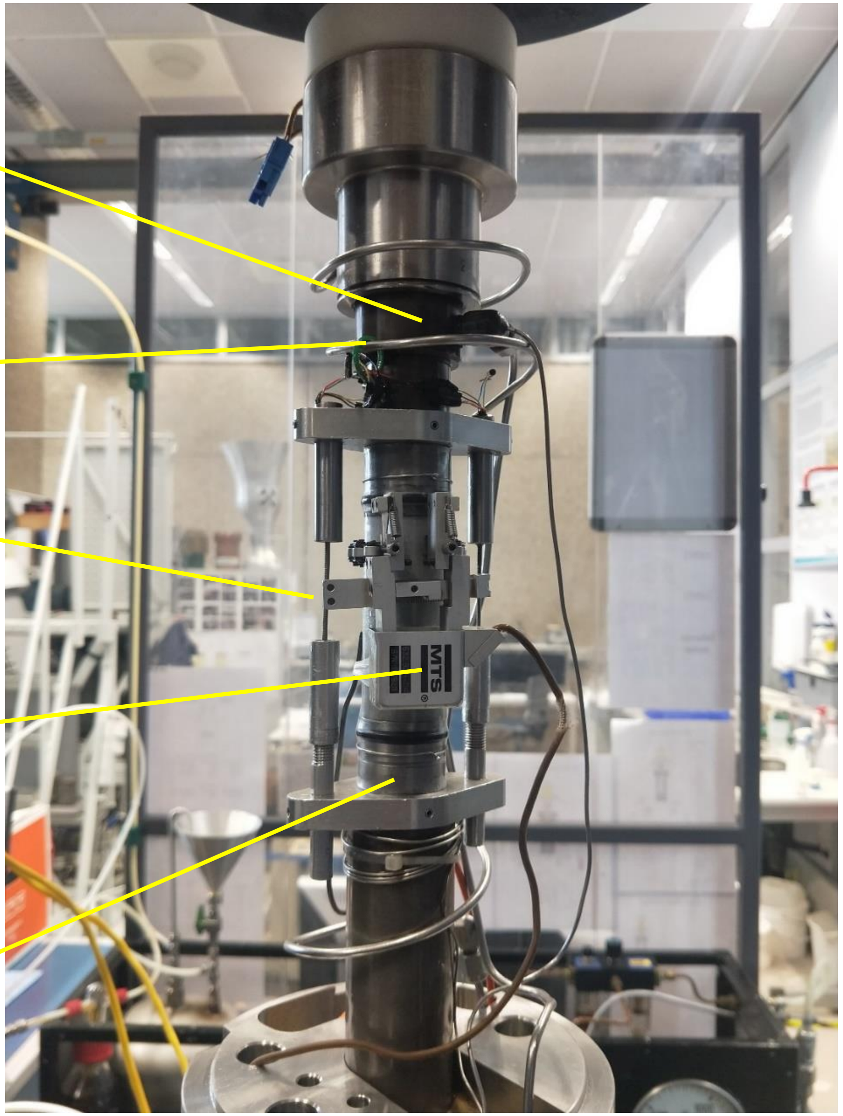
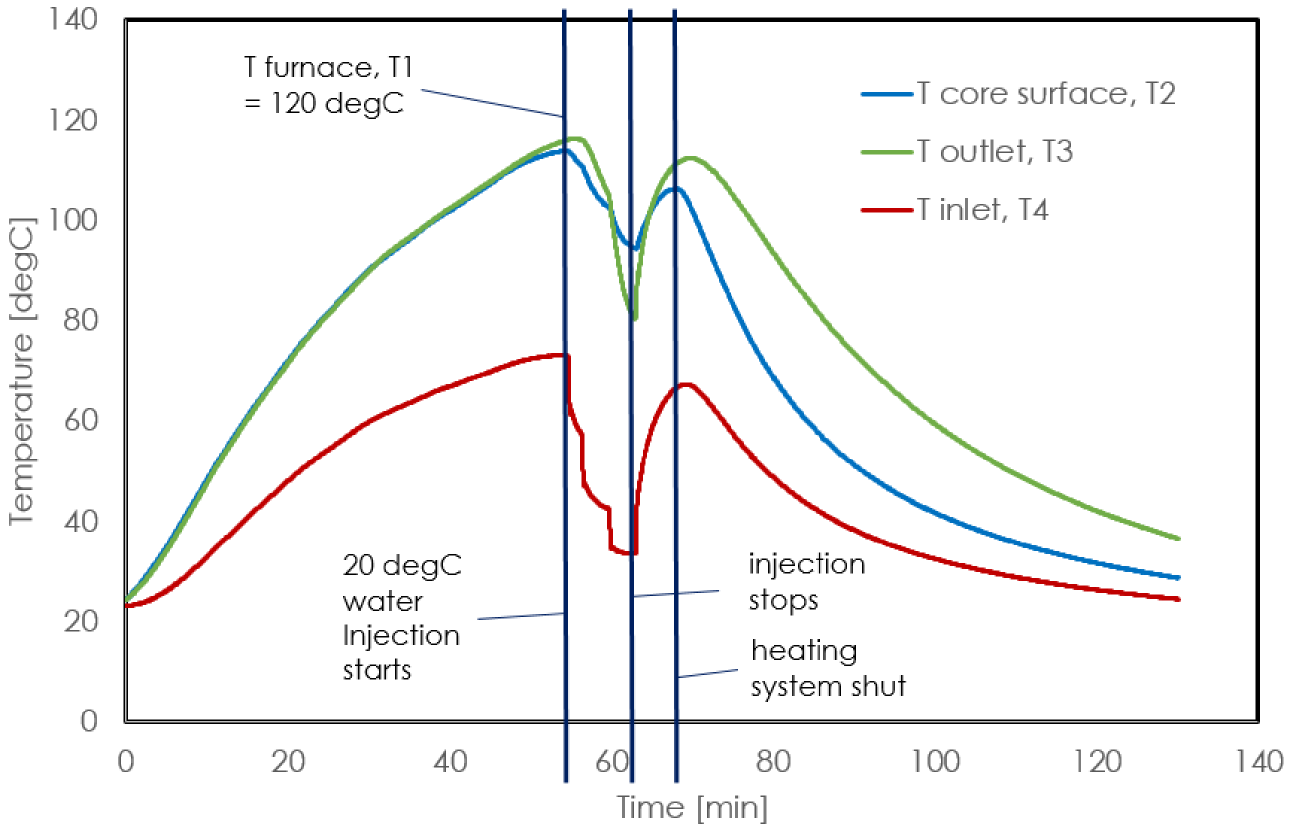
- The sample assembly will be placed inside the triaxial vessel with in-situ stresses and temperature.





Proof-of-concept test

Injection of 20°C water through red Pfaelzer sst core for 8 mins. Hydrostatic stresses of 15 MPa.



ΔT at inlet	40°C
ΔT at outlet	36°C
ΔT at core surface	19°C

- Temperature drops significantly at all locations.
- ΔT/time is important - Cracks happen because cement shrinks that create thermal stresses.
- ΔT/time depends on flow rate and T of injected water. SST is okay by increasing the flow rate. **How about cement – to drill a hole for flow-through.**
- Thermal expansion coefficient, thermal conductivity of the sample also affect on the cracking behavior.

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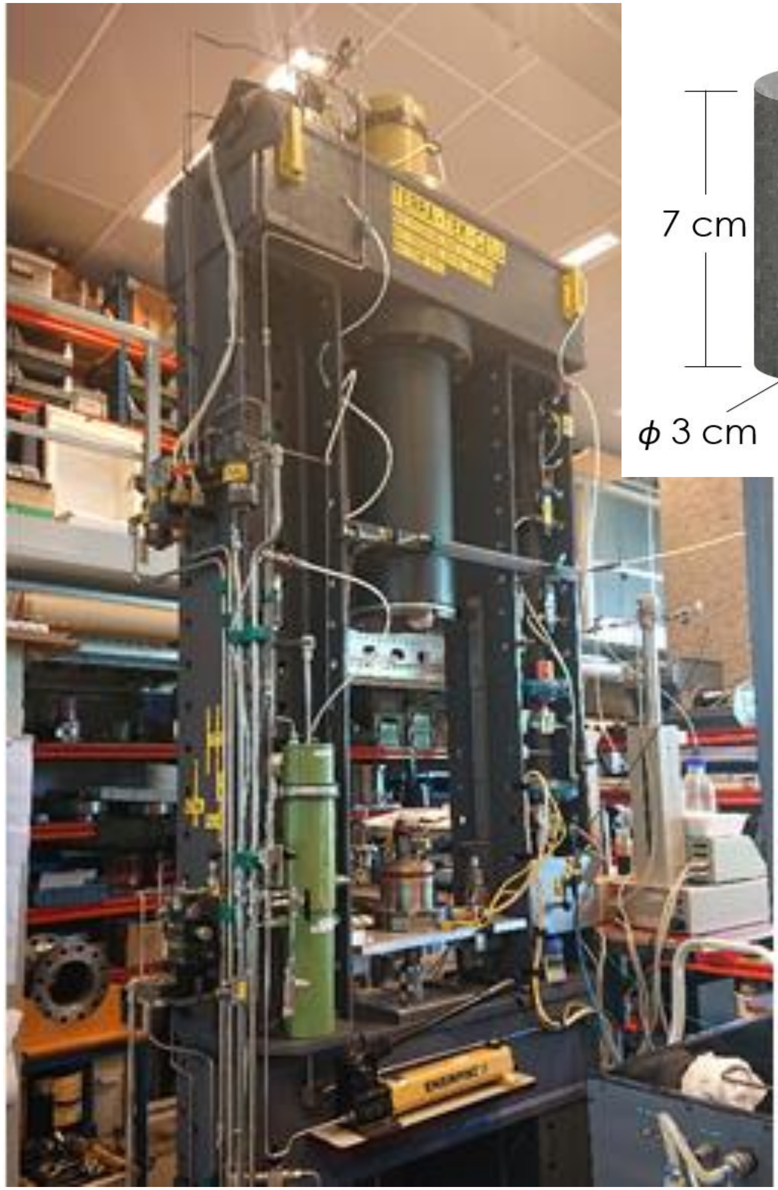
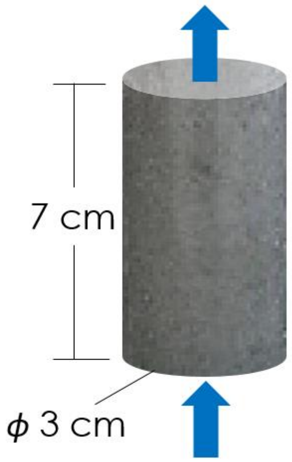
Plan: Effects of thermal shocks on cement integrity





Procedure

- Investigate microstructure before experiments
- Measure initial permeability and mechanical properties
- Mount sample in triaxial pressure vessel (confining pressure 15 MPa, hydrostatic stress/high-overburden conditions)
- Heat up the vessel to 80 / 100 / 120°C
- Inject cold water (5 / 20°C) cyclically
- Take sample out and measure permeability and mechanical properties after leakage pathways form
- investigate microstructure after experiments

Possible parameters to vary:

- Sample compositions
- ΔT (80 - 120°C)
- State of stress: confining pressure + axial load
- Flow rate (changes T profile)

Future work

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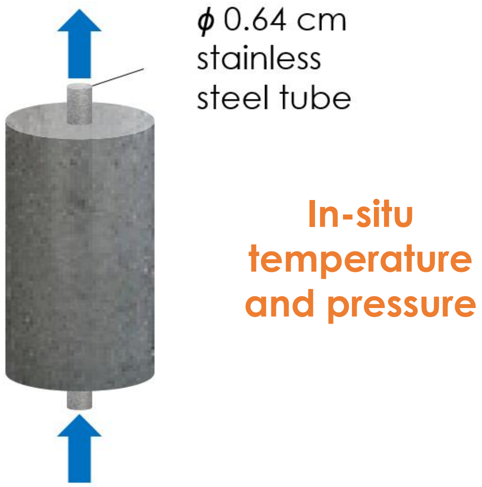
- Effects of in-situ conditions (temperature profile, state of stresses).
- Exposure of intact cement samples **of different compositions** to thermal shocks under in-situ conditions.

Cement	TRL	Description
S1	7: Proven technology	1.92 SG class G cement with 35% BWOC silica flour
S2	7: Proven technology	1.90 SG ultra low permeability class G cement with 35% BWOC silica flour
S3	3: Prototype tested	1.90 SG class G cement with 35% BWOC silica flour with CO2 sequestering agent
S4	7: Proven technology	1.80 SG calcium aluminate based blend
S5	3: Prototype tested	1.90 SG Rock-based (Feldspar rich type of rock as a precursor) geopolymer for CCUS

- Exposure of composite cement samples (cement and casing) to thermal cycles under in-situ conditions.
  - Study of crack formation and de-bonding (micro-annulus) development.

Composite sample with steel tubing as ↗ the simulated casing. Flow cold water through model casing.



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THANK YOU

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