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Investigating hydromechanical and geochemical processes in swelling clay-sulfate rocks – presentation of a new experimental setup

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BACKGROUND

Natural groundwater flow paths can be disturbed due to engineering activity, such as the construction of tunnels and bridges as well as in geothermal projects. Within regions with clay-sulfate rocks, e.g. in Southern Germany and Switzerland („Gipskeuper“) as well as in Spain („Red Clay“), engineering activity can lead to the swelling of such rocks (Fig. 1). As a result, damage to buildings and other infrastructure in their vicinity can be triggered.

Until today, the planning of countermeasures that would minimize or prevent the swelling is difficult, and it is hardly possible to predict the swelling behavior of clay-sulfate rocks connected with geotechnical constructions. One reason is the **limited knowledge of coupled geochemical, hydraulic and geomechanical processes taking place during rock swelling**.

Fig. 1: Ground heave due to swelling in the Gipskeuper formation (Chienberg tunnel, Switzerland)

EXPERIMENTAL SETUP

Fig. 2: Existing swelling apparatuses at TU Bergakademie Freiberg

Tab. 1: Technical data of the swelling apparatuses

oedometric cells	6
dimension of rock samples	Ø = 70 mm h = 35 … 45 mm
load	3.5 MPa (max.)
swelling pressure	12 MPa (max.)
swelling expansion	20 mm (max.)
temperature	21°C to 40°C

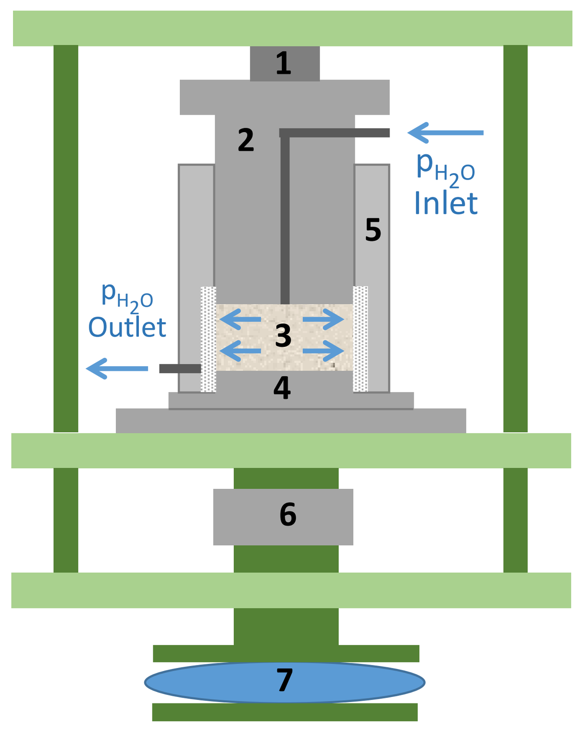

Fig. 3: Extended experimental setup for flow-through swelling experiments (under construction)

1. load cell
2. loading piston (top) with fluid inlet
3. rock sample
4. loading piston (bottom)
5. oedometric ring with integrated sinter ring and sampling port
6. locking screw to block the load piston
7. pneumatic cylinder to apply the load
8. displacement measuring sensor

SAMPLE MATERIAL

- ***natural clay-sulfate rocks*** of the Grabfeld formation (Gipskeuper)
  - fresh, unaltered material
  - fine grained anhydrite
  - clay content around 15%
  - dry preparation of cylindrical test specimen
- ***synthetic fluids***:
  - deionized water
  - synthetic $CaSO_4$ – solution with a concentration of 2 g/L

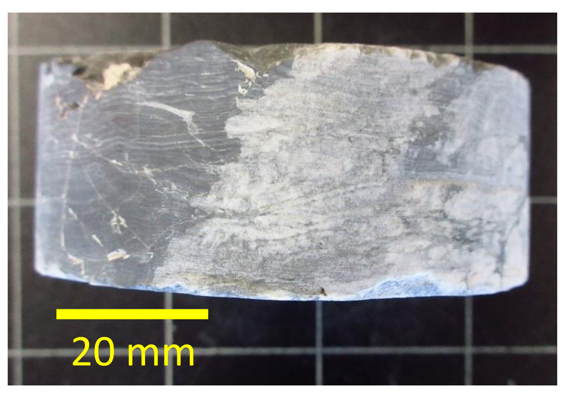

Fig. 4: Cylindrical test specimen (side view)

FIRST RESULTS UNDER CONDITIONS WITHOUT FLOW

- natural clay-sulfate rocks (Gipskeuper; Southern Germany)
- deionized water
- temperature: 22°C ± 0.4 K
- increase in swelling pressure: ~ 40 kPa per week
- no detectable swelling extension until now

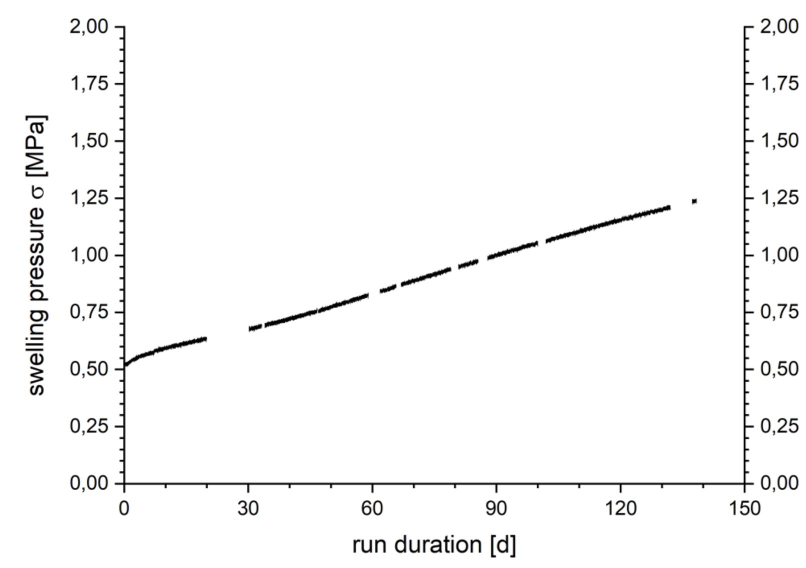

Fig. 5: Swelling pressure development under oedometric conditions without flow

FUTURE WORK

- describing reaction processes during swelling regarding:
  (1) the geochemistry and mineralogy/petrology of rock samples and their effects on the geomechanical behavior
  (2) hydraulic conductivity changes of the rock sample (flow-through swelling experiments)
- experimental verification of conceptual swelling models proposed in the literature (Fig. 6)
- define new swelling laws as a result of coupled hydromechanical-chemical (HMC) processes

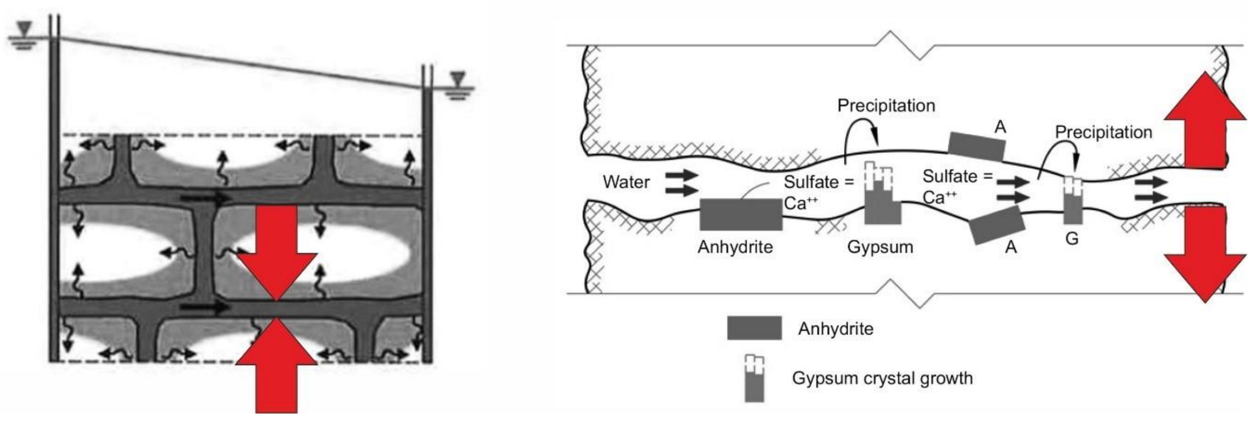

Fig. 6: Conceptual models of swelling in clay-sulfate rocks: *left*: Sealing model (after Wittke and Wittke (2004)); *right*: Bulking model (after Alonso (2011))

ACKNOWLEDGEMENT

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