Master Research Topic

Progressive failure around a large-diameter borehole simulating structurally-controlled tunnel overbreaks in Opalinus Clay Shale (PF Experiment, Mont Terri URL)

Project Framework

Opalinus Clay is the target rock formation for a nuclear waste repository in Switzerland. Rock mass characterisation experiments at the Mont Terri underground research laboratory (MT URL), situated in Opalinus Clay, have shown that tunnel excavation leads to formation of Excavation Damage Zones (EDZs) or at places where tunnels are cut by faults or fracture zones to much larger structurally-controlled overbreaks around the underground galleries (Fig. 1). Large overbreaks and associated damage may lead to a reduction of the effective thickness of the geological barrier. In addition, the required repository space may increase if wastes cannot be placed in repository drifts with faults and or fracture zones. The progressive formation of extensive damage zones and their properties in and around acute angled fault zones and their long-time behaviour have not been investigated under in-situ conditions

To investigate structurally-controlled overbreak formation the ETH Chair of Engineering Geology conducts in-situ field and laboratory tests in the so-called PF experiment Progressive Failure of Structurally-Controlled Overbreaks under the umbrella of the Mont Terri project. The PF experiment is funded by the Swiss Federal Nuclear Safety Inspectorate (ENSI) and the Swiss Federal Office of Topography (Swisstopo). The PF experiment aims at i) a detailed analysis of the properties of highly damaged EDZ and overbreaks around acute angled fault zones, ii) investigation of the kinematic and structural evolution of highly damaged overbreaks, and iii) evaluation of fault zone hazard scenarios on repository long-term safety.

Figure 1. left. Deep overbreak of the EZ-A niche (09/2003) excavated parallel to bedding and to a tectonic fracture zone (Bossart 2003, Nussbaum et al. 2004). right. Borehole damage zone in Opalinus Clay shale simulating the behaviour of an unsupported tunnel reveiled deep shear (F1, F3) and buckling-type (F2) fracturing (Kuperschmied et al. 2015).
Research Goals and Methods

The goal of this MSc project is to investigate the spatial and temporal evolution of damage (i.e., overbreaks) of a large-diameter borehole that simulates a repository tunnel cut by a steep fault or fracture zone (Fig. 2). The experiment will be conducted at the MT URL. Borehole failure will be monitored by means of a photogrammetric unit that repetitively records the inner geometry of the environmentally-controlled borehole in 360° (Fig. 3). Photogrammetry allows to calculate the radial extents and locations of borehole overbreaks, and at the same time allows to qualitatively investigate the fractures that led to the collapse. The thesis will focus on the investigation of the visible evolution of the borehole overbreak. The results will be discussed and interpreted within a broader perspective (rock mass heterogeneity, state of saturation, stress around the fault/fracture zone, etc.). A set of monitoring boreholes around the large-diameter experiment borehole will also be installed and will provide a broad range of rock mass properties and their changes during progressive failure and overbreak (note the analyses of these datasets are not part of the MSc thesis). Structural data from monitoring boreholes, i.e., core and borehole logs, will be used in the MSc thesis to constrain the rock mass structures of the experiment.

Figure 2. Sketch of the 1:10 scale experiment conceptual layout with large-diameter (red) and monitoring boreholes (black) at Niche 6 of the extension of the Mont Terri Underground Research Lab (Renz et al. 2019).

Figure 3. Sketch of the 1:10 scale large-diameter experiment borehole. a) photogrammetric monitoring unit, b) environmental control unit, and c) monitoring boreholes for seismic and resistivity tomographies (Renz et al. 2019).
Tasks

- Develop a structural rock mass (fault) model of the experiment site
- Conduct photogrammetric surveys and process 4D data
- Study temporal and spatial damage evolution from the obtained data
- Optional investigate spatial damage evolution with a 2D fracture mechanics code (Fracod)
- Support PF experiment in the Mont Terri laboratory

Required Student Skills

We are looking for a student with a background in engineering or natural sciences. A background in geology or rock mechanics is very helpful but not required. The successful candidate should have good computer skills. No background in optional numerical simulation is necessary; a simulation code can be learned during the course of the thesis. The candidate should have the willingness to work in a team and travel to the MT URL.

Collaboration

You will be part of the PF experiment and will be supported to present your M.Sc. results to a broader audience (e.g., conference poster etc.).

Thesis Supervisors

- Dr. Martin Ziegler, ETHZ (martin.ziegler@erdw.ethz.ch)
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References


