

# PREDICTIVE MODELLING OF AN EXCAVATION TEST IN INDURATED CLAY

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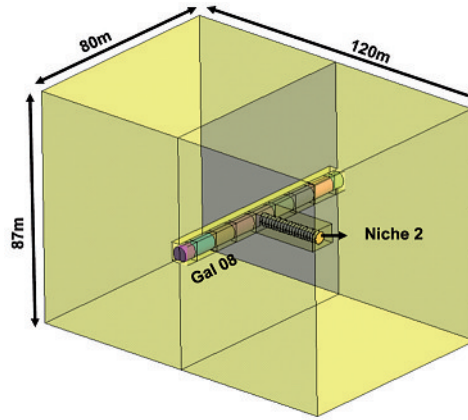
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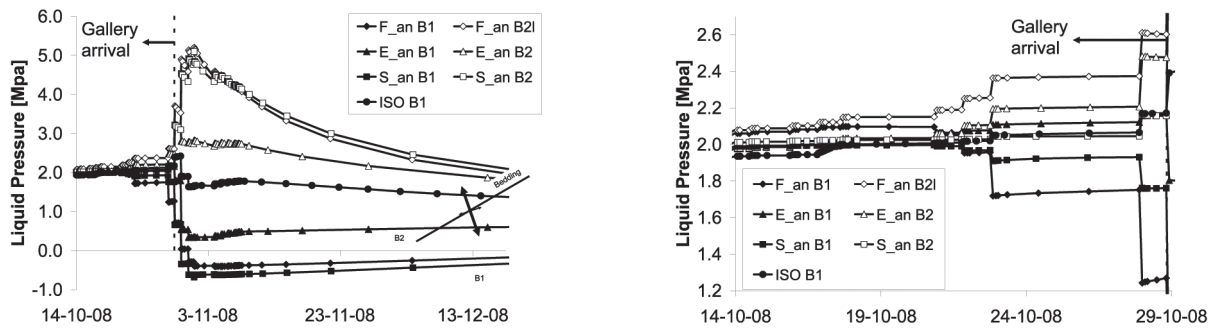
This Abstract presents the predictive hydromechanical (HM) modelling of an excavation performed in Opalinus clay in the Mont Terri underground laboratory (Figure 1). Niche 2 was excavated in the shaly facies of Opalinus clay from gallery 08. The area surrounding the gallery was intensively instrumented. The geology of Mont Terri is described in Thury and Bosssart (1999) and the parameters used in the analysis were taken from Bock (2009). The stress state is derived from Martin and Lanyon (2003). Gallery 08 is horseshoe shaped and has a mean radius of 2.25m. It was excavated with a road header at a mean velocity of 1m/day starting on January 30<sup>th</sup> 2008 (Gallery chainage 43.8) and ending on June 30<sup>th</sup> 2008 (Gallery chainage 123.8) with a stop from March 18<sup>th</sup> to April 24<sup>th</sup> to instrument the area of niche 2. Niche 2 was excavated by successive blastings 1.3m deep until reaching a distance of 24m from the gallery 08 wall. Advance was continuous from October 13<sup>th</sup> to November 7<sup>th</sup> with the exception of three stops of 3, 5 and 4 days. The niche has an average diameter of 4.5m and has a slight upward slope of 0.98%. The excavation of gallery 08 from chainage 43.8 to chainage 123.8 and of the niche was simulated by relaxing the normal total stress and water pressure from the value before excavation to 0. The gallery advance rate was simulated in an approximate manner by applying successively the excavation procedure to 9m long gallery sections. In the case of the niche, the blasting scheme and the application of the shotcrete was closely reproduced. The three dimensional geometry used in the simulation is shown in Figure 1.

The coupled hydromechanical formulation used for the analysis is based on the simultaneous solution of the balance equation for solid mass, water mass and momentum (equilibrium). In accordance with field observations, it has been assumed that the medium remains saturated throughout. The formulation was completed with a number of constitutive laws that describe the various phenomena under consideration. The density of the solid and the density of the water are dependent on the total mean pressure and the water pressure, respectively and the advective water flux is described by an anisotropic Darcy's law. Finally, the mechanical behaviour is modelled using an anisotropic linear elastic constitutive law that relates the medium deformation with the effective stress ( $\sigma' = \sigma - b \cdot p_w$ , where  $\sigma$  is total stress,  $b$  is the Biot coefficient and  $p_w$  the water pressure).

The simulated pore water pressure evolution is presented in Figure 2 for two points at 1m from the niche wall, in a transversal section at 16.5m from the gallery centre (points B1 and B2) for 4 different computations. B1 lies in the direction of the major stress and B2 in the direction of the minor stress. F\_an is a "full" anisotropic computation, considering anisotropy of stress, stiffness and permeability ( $E_1 = 1.33 \cdot E_2 = 4000 \text{MPa}$ ). ISO is an isotropic simulation. In E\_an and in S\_an, all properties are considered isotropic except the mechanical constitutive law ( $E_1 = 2 \cdot E_2 = 6000 \text{MPa}$ ) and the stress state, respectively. Long before the arrival of the gallery, ISO and S\_an do not predict significant pore water pressure changes in contrast to the computations that consider an anisotropic constitutive model. The changes are strongest in the case of F\_an and are consistent with observations in similar tests performed in Callovo-Oxfordian Clay. After the passage of the shaft, pore water pressure keeps increasing in the minor stress direction whereas it decreases in the major stress direction. A future stage of modelling must incorporate the reduction of stiffness and the increase in permeability cause by rock damage. The result will likely be a lower magnitude of the pore water pressure increments and an acceleration of drainage processes.



**Figure 1:** Three dimensional model geometry incorporating Gallery 08 and Niche 2.



**Figure 2:** Simulated pore water pressure evolution. The picture on the right is an enlargement showing the pore water pressure evolution before gallery arrival.

### References:

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- Bock, H. (2009, in review) RA Experiment: Updated Review of the Rock Mechanics, Properties of the Opalinus Clay of the Mont Terri URL based on Laboratory and Field Testing *Mont Terri Report TR 2008-04*.
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