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NUMERICAL ANISOTROPIC MODELLING OF A DEEP DRIFT AT THE MEUSE/HAUTE-MARNE URL

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Abstract

The development of nuclear energy raised the issue of radioactive waste disposal in deep geological formations. Clay formations in their natural state show very favorable confining conditions as repositories for radioactive waste due to their generally low values of hydraulic conductivity and significant retention capacity for radionuclides. Three clay formations in Europe are currently being studied in details as potential host rocks for high level radioactive waste disposal, i.e. the Boom Clay in Belgium, the Opalinus Clay in Switzerland and the Callovo-Oxfordian Claystone (COx) in France. Lastly, the French national radioactive waste management agency (Andra) started building the underground research laboratory (URL) at Bure in the Meuse district. Several specific in situ experiments were carried out with the main objectives in term of underground civil engineering to: (a) evaluate the geological environment of the future Deep Geological Repository (DGR), (b) collect data from the clay formation in order to assess the performances of the future DGR, (c) test and demonstrate the feasibility of the future DGR. The feedback of these experiments and in situ measurements as well as the numerous theoretical analyzes and numerical modeling works undertaken on the COx allowed to identify the key mechanisms (mainly in the framework of THM processes) governing the behavior of the COx [1]. In addition to the THM processes and the associated parameters, it appears necessary to consider the anisotropies (mechanical, hydraulic and thermal) of such rock, but also its time-dependent behavior. This paper deals with these issues.

Saturated hydromechanical coupling was investigated on a circular experimental gallery of radius 2.6 m (GCS drift) excavated following the principal major stress and without rigid lining at the URL. The plane strain assumption is considered. Then a cross section of the GCS drift with a drainage condition along its wall, was modeled with COMSOL Multiphysics software. The initial pore pressure and in situ stress fields at the main level (-490 m) are given in figure 1. The model geometry and the poromechanical properties are presented in figure 1 and table 1, respectively. For simplicity, the creep of COx is described by a power law ($A=1.26\times10^{-26}$ $Pa^{1/n}$ s^{-1} and $n=1.98$).

The instantaneous (t=0+) response induced by excavation leads to overpressures with a maximum value of 1.3 MPa in the horizontal direction (i.e. direction of initial minor stress) and underpressures in the vertical direction (i.e. direction of initial major stress) with respect to the GCS section (figure 2). These pore pressure distributions are in good agreement with a poroelastic analysis presented by [2]. Moreover, with time and in the horizontal direction, the pressure peak, shift towards the interior of the rock mass and decreasing with time at a very small rate due to the low permeability of the COx. This remains in agreement with the in-situ observations [3].

It is observed that the evolution of the pore pressure around drift, is not influenced by creeping (figure 2), in accordance with the creep model used (not dependent on the mean stress). Conversely, the creep relaxes the von Mises stress until a distance of 2 diameters (depending on the used creep model and associated parameters) from the wall (figure 3 b) at 100 years. The radial displacement (figure 3 a) highlights a significant increase in magnitude from 10 years. These results will be compared with the in-situ measurements.

Parameter	Unit	Value
E_x / E_y	(GPa)	5.2 / 4
v_{xz} / v_{yx}	(-)	0.2 / 0.3
G_{xy}	(MPa)	1740
b	(-)	0.6
k_x / k_y	(m^2)	4/1.33 ($x10^{-20}$)
ϕ_0	(-)	0.18

Table 1. Poromechanical properties.

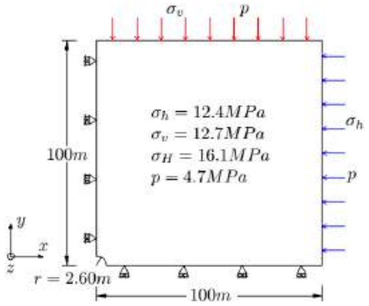

Figure 1. Geometry and boundary conditions.

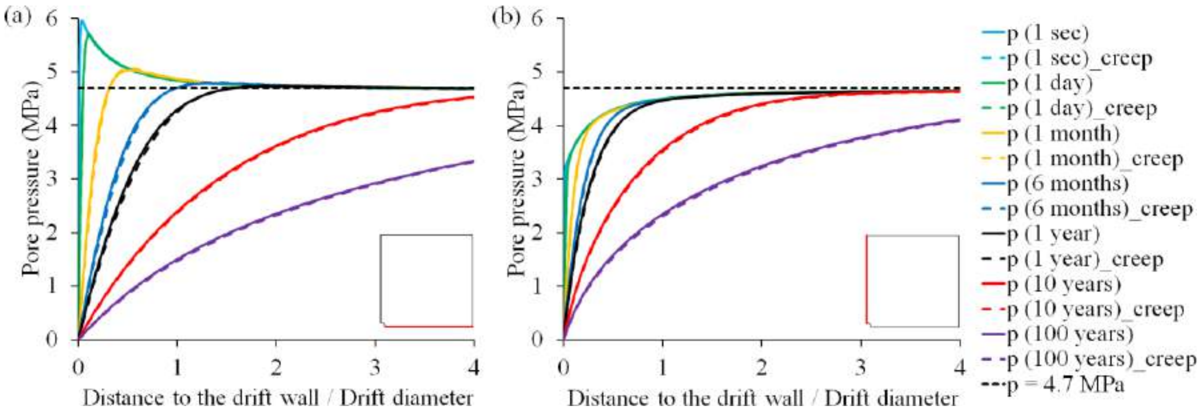

Figure 2. Pore pressure profiles (a) horizontal direction (b) vertical direction (continue = poroelastic, dashed = poroviscoplastic).

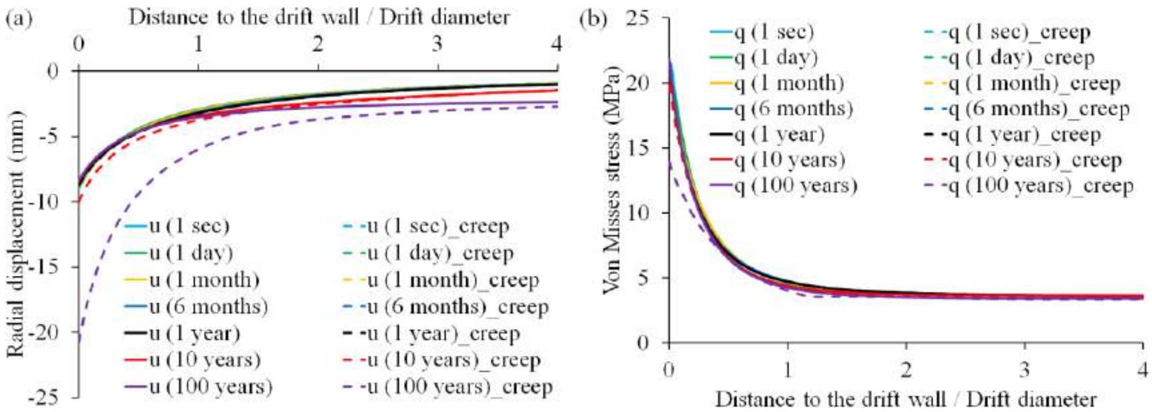

Figure 3. (a) Radial displacement and (b) von Mises stress in the horizontal direction (continue = poroelastic, dashed = poroviscoplastic).

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