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Influence of creep on water pressure measured from borehole tests in the Meuse/Haute-Marne Callovo-Oxfordian argillites

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Abstract

Porewater pressure is an important parameter for use in safety assessment of underground waste disposal. In order to measure porewater pressure in the Callovo-Oxfordian argillites, ANDRA has performed several in-situ tests, which consist in measuring time evolution of water pressure in an almost closed chamber. This was accomplished using an in-place pressure sensor coupled with an electromagnetic transmission device (called an EPG probe). The measured values show a small hydraulic overpressure (0.1 MPa) compared with the estimated value at the corresponding depth. In the framework of a scientific cooperation agreement between Andra and Ineris, a study was undertaken to examine whether all or a part of this overpressure could be attributed to the hydro-mechanical coupled processes linked with the creep of argillites and the stress relaxation in the experimental measuring chamber-nearby. In the whole, the numerical results were in good agreement with the measured results. Poroviscoplasticity can explain the increasing pressure in the borehole. The measured overpressure can be reached with adequate viscoplastic model parameters.

Keywords: Numerical modelling; Hydro-mechanical; Porous; Waterflow; Creep; Porewater

1. Introduction

ANDRA has over several years performed in-situ monitoring of Callovo-Oxfordian argillites in order to provide the required data for assessing the feasibility of a deep geological waste repository in this type of geologic media.

In this regard, ANDRA has performed (Delay and Cruchaudet, 2004) water pressure measurements in several boreholes in the Callovo-Oxfordian argillites at different depths (about 420, 443 and 533 m). This is achieved using an in-place pressure sensor coupled with an electromagnetic transmission device called EPG probe, in which the water pressure is continuously monitored as it evolves naturally with time until a steady-state is reached. Pore pressure measured in-situ at a given depth in this geology increases with time, and on achieving steady-state shows a overpressure (a value greater than expected at the depth of the sensor). In all cases this overpressure is small and does not exceed 0.1 MPa.

Laboratory tests have been performed on several Callovo-Oxfordian argillites samples and they show that this material exhibits a time-dependent behavior that is well described by Lemaitre viscoplastic model without any threshold. In other words, the behaviour of the argillites is time-dependent and strongly non-linear, being a function of the intensity of the deviatoric stress. The material creeps while deviatoric stress is not zero.

The scope of this study is to investigate whether this viscoplastic behaviour may explain the measured overpressure in the boreholes.

The geomechanical problem characterised by a borehole in a saturated argillite is clearly a coupled or hydro-mechanical problem (Wang, 2000). Porewater pressure

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evolution leads naturally to changes in the effective stress field values until the steady-state is reached. However, due to the very significant viscosity of the rock, there are two interacting processes that act in opposing directions. These are the inflow or outflow of water within the borehole and the evolution in time of the borehole wall due to the viscoplastic strains.

In order to understand the meaning and the origin of the water overpressure, several numerical computations have been done. This was principally achieved with FLAC^{2D} software, complementary computations were made using a finite element code (VIPLEF).

Due to the size of the EPG probe and its position, the hydro-mechanical computations were performed on a reduced size problem and assuming axisymmetric conditions. It is shown numerically and analytically that in cases where the rock behaviour is poroelastic or if the mechanical behavior is not coupled with the hydraulic behaviour that the measured overpressure is not linked to the borehole creep. Moreover within a saturated viscoplastic media, the steady-state can only be reached when the boreholes void space is totally closed.

2. Context

The figure below shows the geological formations examined and the position of EPG probe inside these argillites, for the monitored site, located in Northeastern France (Fig. 1).

The three EPG sensors are located at 419.23 m, 442.60 m and 532.83 m depth respectively. The corresponding hydraulic heads are respectively equal to 400 m, 423.1 m and 514 m. The water pressure inside these boreholes has been monitored since 1996, 2002 and 2004 respectively.

3. Assumptions of the numerical modelling

This study is intended to provide an accurate numerical simulation that considers the different steps of the experiment (the drilling history, the geometry of the device and boundary conditions). All the currently recognized mechanisms involved, before, during and after the EPG probe installation are taken into account. The model used for the computation is depicted in Fig. 2.

Lemaitre's constitutive model (Lemaitre and Chaboche, 1988), (a viscoplastic creep model), is used without any threshold in order to describe the time-dependent behavior of Callovo-Oxfordian argillites. The hydraulic behavior is also time-dependent, but all hydraulic and mechanical properties are assumed to be constant. This means that the damaged zone adjacent to the borehole walls is ignored in this model. In fact, it is known that within a damaged zone, the permeability may increase, however because of

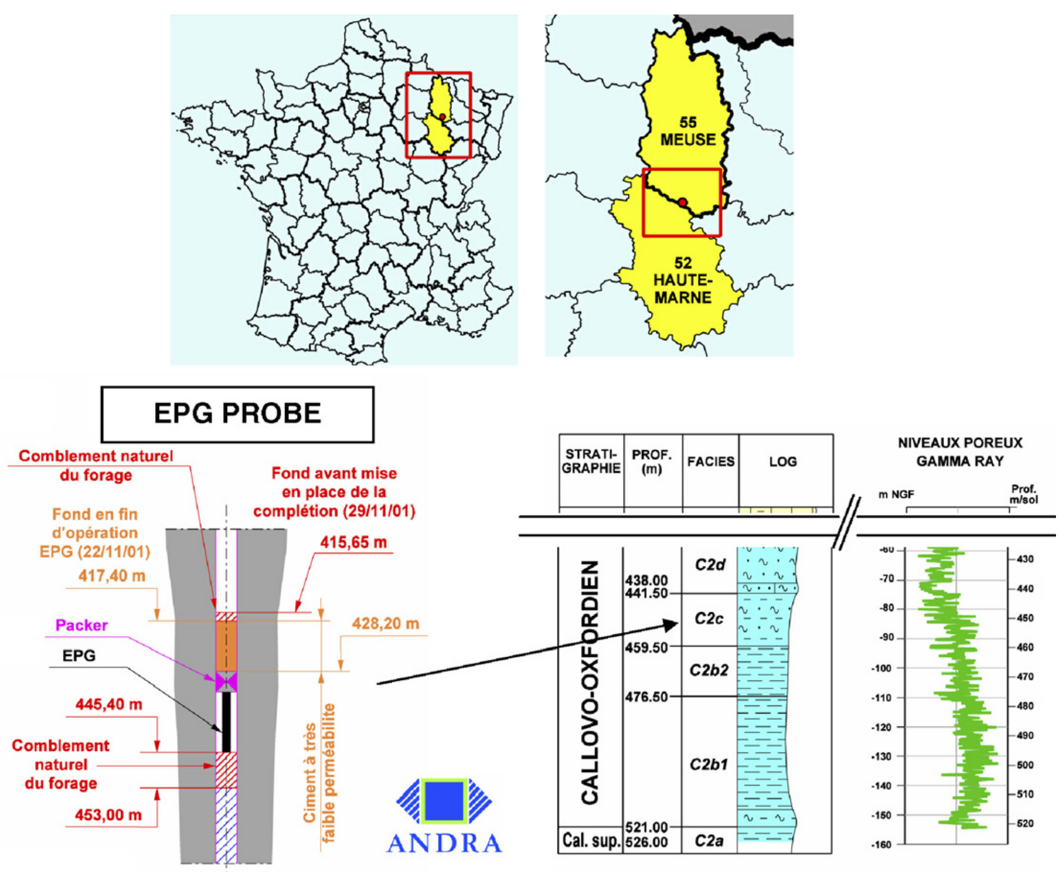

Fig. 1. Example of stratigraphic-log, gamma ray and situation of the EPG probe.