LONG TERM BEHAVIOUR OF THE BOOM CLAY: INFLUENCE OF VISCOSITY ON THE PORE PRESSURE DISTRIBUTION

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Introduction

Boom clay formation has been selected as a potential host rock formation for the geological disposal of radioactive waste in Belgium. An Underground Research Facility (URF) called HADES in Boom Clay formation at a depth of about 223m at Mol site was built successively to study the feasibility of HLW disposal (figure 1). The excavation of the connecting gallery from the second shaft towards the existing URF HADES provided a unique and original opportunity to monitor the hydromechanical responses of the Boom Clay ahead of the excavation front thanks to the European CLIPEX instrumentation programme (Bernier et al. 2002). The most important observations are that the zone disturbed by excavation extends very far in the massif, especially the pore pressure variation, and that it cannot be replicated by a classical elastoplastic constitutive law, which gave however reliable blind predictions in terms of instantaneous convergence and pressure on the lining (Li et al. 2006).

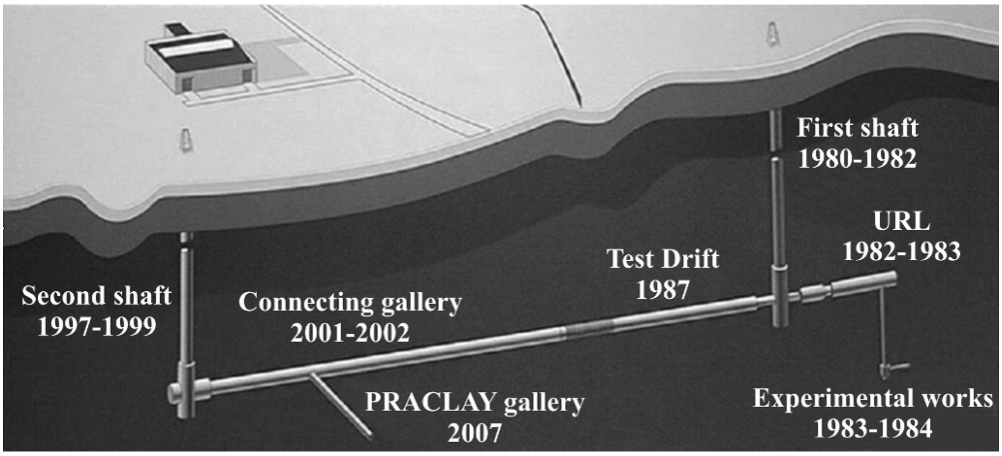

Figure 1. Construction history of the underground research facility HADES.

The present project aimed at investigating the long term behaviour of the Boom clay and studying if it has an effect on the variation of pore water pressure in the far field during the excavation. Preliminary works (Barnichon, 2003) has indeed showed that viscosity could be an explanation for far field pressure drop during excavation process. The project is composed of two parts:

- An experimental study, which includes mainly creep tests under isotropic stress and deviatoric stress in axisymetric and oedometric conditions.
- A numerical study, which includes the development of two viscoplastic models, their implementation in a finite element code and the modelling of a gallery excavation.

The deep complexity of the clay behaviour and its sensitivity to the initial state of the clay sample (water content, porosity) make difficult the experimental study. Nevertheless, all the tests performed highlight the creep potential of Boom Clay (overall under isotropic stress) and the coexistence of at least two mechanisms: consolidation and creep. The experimental works allow us to define some aspects viscous behaviour of the Boom Clay and to calibrate the constitutive models described in the next part. This paper focuses mainly on the numerical study results.

The numerical works consist in the development of a viscoplastic constitutive model and the modelling of the excavation of the connecting gallery with this model. In order to have comparison results, elastoplastic modellings were also performed.
In a first step, we developed thus an elastoviscoplastic model (named EVP model), which is composed of two mechanisms: a friction mechanism (dilatant) and a cap mechanism (contractant), both with hardening. This model is a viscous reference surface, being the limit between the elastic and the viscoplastic domain. Viscoplastic strains, formulated in the framework of the Perzyna's theory, are proportional to the distance between the actual stress state and the viscous reference surface. The EVP model is implemented in the FEM code Lagamine, calibrated on the basis of laboratory tests and used to simulate the excavation of a gallery in plane strain condition. The numerous simulations evidenced the limit of the EVP model. Actually the model failed in reproducing both short term and long term behaviour of Boom Clay. At short term an elastoplastic model appears to be more suitable. At long term, the behaviour of the rock mass becomes rapidly elastic and thus viscosity effects are limited. Moreover, the behaviour is mainly influenced by a mechanism of consolidation even in the far field.

In a second step, we have developed a viscoplastic-elastoplastic model (VPEP model), which aims at reproducing correctly the short term response of the rock mass and at studying the influence of viscosity at long term. Such a model is suitable in order to distinguish the influence of viscosity from the effect of consolidation by comparing the response of the VPEP with the response of an EP model.
The VPEP is composed of an EP yield surface (internal friction mechanism coupled with a pore collapse mechanism) and of the VP reference surface developed in the first step. Such a model gives a similar response than an EP model at short term if the strain rate is sufficiently high to neglect the influence of viscosity.

This model has been used to simulate the excavation of a gallery in plane strain conditions. The results showed that the only viscosity effect is not able to explain the pore pressure drop at large distance from the gallery. Indeed, the modelling exhibits that the contact between the clay and the liner tends to unload the host rock and the time effects are then limited. However, a constitutive model coupling viscosity and damage showed better qualitative results in terms of pore pressure. This model has thus been applied on the Clipex gallery in an axisymetric bidimensional modelling. The results are promising in terms of pore pressure predictions and seem to show the importance of damage process in the behaviour of the host rock.

Reference

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