Numerical modelling of thick-walled hollow cylinder tests on Boom Clay samples cored parallel and perpendicular to bedding

F. Peguiron[a*] and V. Labiouse[a]

[a] School of Engineering and Architecture of Fribourg HEIA-FR
HES-SO, University of Applied Sciences and Arts Western Switzerland

[*] florence.peguiron@hefr.ch (corresponding author's E-mail)

Introduction

The disposal of high-level radioactive waste is a complex issue due to the very strict requirements to achieve a long-term security. Their storage in deep geological formations is considered as a highly promising solution. Due to its low permeability and self-sealing capability, Boom Clay is a particularly adequate formation. The stress release occurring during the excavation of galleries in Boom Clay induces an Excavation Damaged Zone (EDZ). During the excavation of the underground laboratory HADES at Mol (Belgium), a higher convergence was measured horizontally (i.e. parallel to the bedding planes) and the damaged zone was as well larger in the horizontal direction (Bastiaens and al. 2003). This could be related to mechanical anisotropy (strength and/or deformation) as well as to hydraulic anisotropy. The initial anisotropic stress field in the clay formation could also play a role.

Hollow cylinder tests

Thick-walled hollow cylinder experiments have been carried out in the framework of TIMODAZ project (Labiouse and al. 2014). After recovery of the in situ stress conditions, the inner confining pressure was decreased in 70 minutes to reproduce tunnel excavation under laboratory conditions. Medical scans have been carried out before and a few hours after the unloading to observe the displacements occurring in the sample. Tests conducted on Boom Clay samples cored parallel to bedding show an anisotropy of convergences similar to the one observed in situ, while an isotropic behavior is observed for samples cored perpendicular to bedding. Further experiments are underway at HEIA-FR. The deformation of the clay over time is observed by means of several high-resolution scans taken after mechanical unloading. The effect of the unloading rate is also investigated.

Numerical modelling

In parallel to the laboratory work, numerical simulations are performed in order to assess the capability of existing constitutive models to adequately reproduce the experiments and to gain further understanding. Hollow cylinder tests on samples cored perpendicular to the bedding planes are first simulated with an isotropic linear elastic perfectly plastic constitutive law. Then, tests on samples cored parallel to the bedding planes are modeled considering the inherent anisotropy of Boom Clay. For this purpose, among the various constitutive models taking into account the mechanical anisotropy of geomaterials (e.g. François and al. 2014), a rock mechanics oriented failure criteria is adopted using ZSoil Multilaminate model. In addition to the matrix which is modelled as an isotropic linear elastic perfectly plastic continuum with a Mohr-Coulomb failure criteria, weak planes with reduced Mohr-Coulomb strength parameters are considered in the specific orientation of the bedding. The model however does not consider elastic anisotropy.

Results and discussion

Results provided by the isotropic model are in accordance with the measurements on samples cored perpendicular to bedding. Computations were performed to investigate the influence of the inner confining pressure unloading rate on the radial displacement and on the extent of the plastic zone. Due to Boom Clay low permeability, a strong hydro-mechanical coupling occurs during the unloading. The pore water pressure redistribution that follows produces additional displacements after the unloading. (Fig. 1).

With respect to the samples cored parallel to the bedding planes, both experiments and modelling (when the anisotropy is considered) show an average larger convergence of the clay around the central hole. However, numerical models considering strength and/or hydraulic anisotropy predict a larger displacement and extent of the plastic zone in the direction perpendicular to the experimental and in situ observations (Fig. 2). This statement is not software dependent as similar results were obtained using the finite difference program FLAC with both strength (i.e. Ubiquitous Joint model) and hydraulic anisotropies (Kivell 2015).

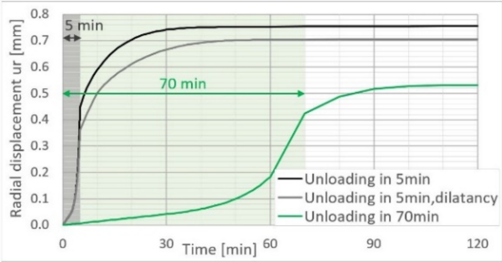

Fig. 1.Influence of the inner pressure unloading rate on the evolution of central hole convergence

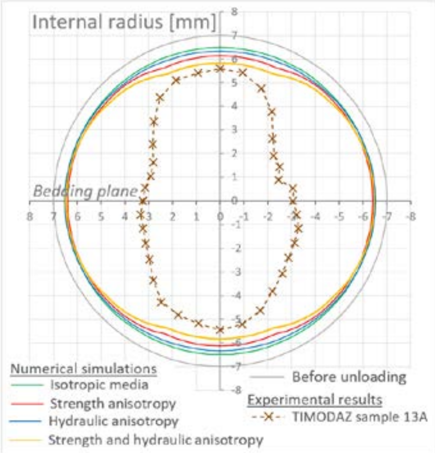

Fig. 2. Measured and predicted hole convergence for samples cored parallel to bedding

Conclusion

Hollow cylinder tests performed in the framework of the TIMODAZ project and in-situ observations at Mol URL have underlined a significant influence of bedding on the development and the orientation of the damaged zone. Numerical simulations with standard constitutive models considering strength and/or hydraulic anisotropy show a significant discrepancy with these observations. Upcoming work will be carried out with a model including as well elastic anisotropy (Souley and al. 2017).

Acknowledgements

This work is part of a research project funded by the Belgian National Agency for Radioactive Waste and enriched Fissile Material ONDRAF/NIRAS.

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