Introduction

Nuclear energy is strategically considered as an important contributor in different industries for instance generating the electricity. It inevitably produces some amount of potentially highly hazardous wastes. The long-term safety of the radioactive waste disposal is advisable storing them in the deep geological repository with low permeability. Boom Clay which is characterized by low hydraulic conductivity and the self-sealing capacity is known as one of the potential host rock for this geological disposal process.

The gallery excavation in deep geological host rocks is expected to create a perturbed zone around the underground structures in rock masses triggering the damage propagation. This zone in which the significant irreversible deformations and significant properties changes can be occurred is called as Excavation Damaged Zone (EDZ). Modelling of the fracturing system and extension of the EDZ zone as an essential issue is focused in this study using the strain localization approach as a classical mode of failure of geo-materials. The experimental works also showed clearly the localized rupture in geo-materials (Lenoir et al. 2007).

Strain Localization Method

Numerical modelling of strain localization within the framework of classical finite element depends on the mesh size and orientation (Collin et al. 2009). Therefore, an enhanced technique introducing an internal length scale is needed to adjust this problem. Among the different regularization methods, the second gradient model (Chambon et al. 1998 & 2001) is used to overcome this practical problem. The continuum is enriched by microstructure effects in the second gradient method. So the kinematics includes macrokinematics as well as microkinematics (Toupin 1962, Mindlin 1964, Germain 1973, Collin et al., 2006).

Numerical Analysis of a Gallery Excavation

Coupled numerical modelling of a gallery excavation in the underground research laboratory (URL) in Boom Clay host rock close to the city of Mol, Belgium is performed in two-dimensional plain strain state taking into account the initial anisotropic stress. The simulation provides information about the strain localization in shear bands mode accomplished by the evolution of EDZ during the gallery excavation. In addition, the evolution of pore water pressure is focused particularly presenting the effect of strain localization.

The constitutive mechanical law (first gradient law) used for the clayey rock is an elasto-plastic model with a Drucker Prager yield surface. It includes friction angle hardening and cohesion softening as a function of the Von Mises equivalent plastic strain. The second gradient law is used to correctly model the strain localization process. In such local second gradient model, the width of the shear band is proportional to the parameter D of the second gradient model (Chambon et al. 1998).

Several simulations have been done to study the influence of the second gradient elastic modulus D. Since the numerical results show the effect of this parameter on the width of the shear strain localization bands, it should be chosen carefully based on the mesh element size. In addition, the calculations emphasize the role of cohesion softening for initiating the strain localization process. Figure 1-2 show the evolution of strain localization bands after the excavation of galley through the increment of deviatoric strain and plastic zone. The material anisotropic stress state is obvious in the fractures' pattern.

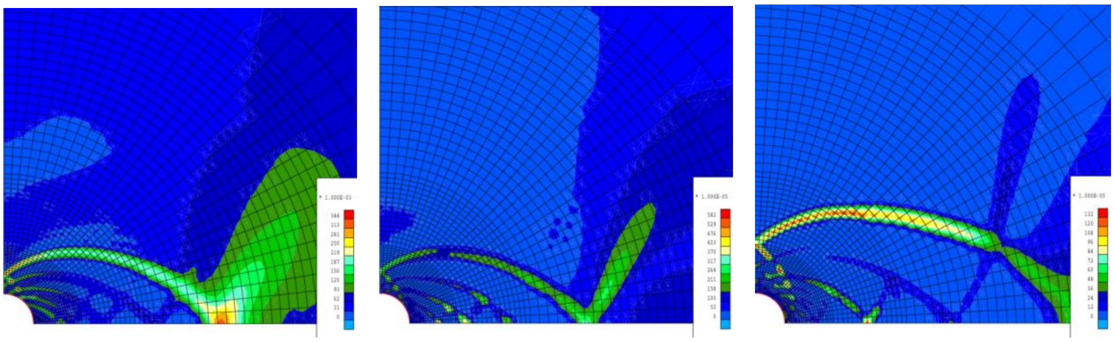

Figure 1 *Evolution of strain localization bands: Increment of deviatoric strain after a) 1 day of excavation phase; b) 100 days and; c) 1277.5 days=3.5 years.*

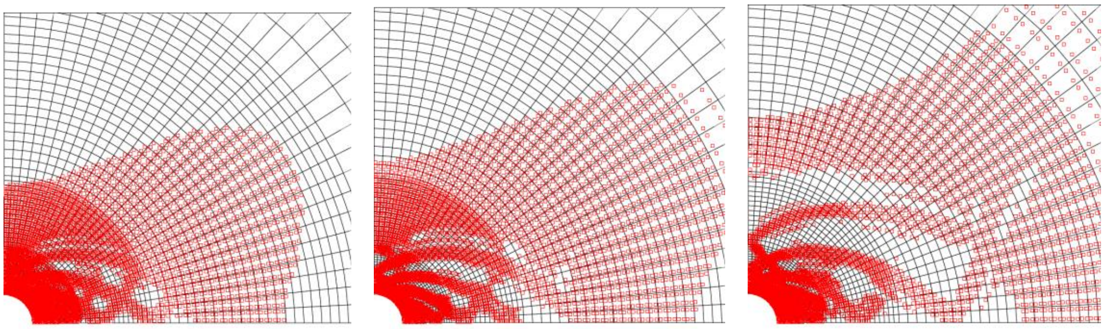

Figure 2 *Evolution of strain localization bands: Plastic zone after a) 1 day of excavation phase; b) 100 days and; c) 1277.5 days=3.5 years.*

Conclusions

Since Boom Clay was selected as a potential host rock formation for the deep geological disposal of the nuclear waste in Belgium, the excavated damaged zone in Boom Clay has been numerically modelled in the framework of strain localization. Studying the evolution of fracture network subsequent to rock's damage may also allow a better understanding of the rock's hydraulic conductivity changes since the EDZ is considered as a zone with significant irreversible deformations and changes of hydro-mechanical properties.

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