VISCOPLASTIC BEHAVIOUR INCLUDING DAMAGE FOR DEEP ARGILLACEOUS ROCKS: FROM IN SITU OBSERVATIONS TO CONSTITUTIVES EQUATIONS

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Keywords
Claystone, long term behaviour, constitutive equations, in situ observations, measurements, numercial implementation, numerical modelling.

ABSTRACTS

In order to demonstrate the feasibility of a radioactive waste repository in claystone formation, French national radioactive waste management agency (ANDRA) started in 2000 to build an underground research laboratory CMHM) at Bure located at nearly 300 km East of Paris. The host formation consists of a claystone (Callovo-Oxfordian argillites) and lies between 430 m and 550 m deep.

On the basis of numerous campaigns of laboratory tests (uniaxial/triaxial, mono/multi stage creep and relaxation) undertaken for characterizing mechanical and hydromechanical short-term or long-term behaviour of these argillites, several constitutive models were developed in the framework of MODEX-REP European project and scientific cooperations between ANDRA and national institutions.

Moreover, more than 400 m horizontal galleries at the main level of -490 m at CMHM laboratory have been instrumented since April 2005 with the aim to understand the rock behaviour (especially the long term behaviour) needed for the repository design. The continuous measurements of convergences of the galleries are available contributing to better understand the time-dependent response of the argillites at natural scale (see Figure 1 for example). Analysis of convergence data over a period of 2 years leads to the following conclusions: (a) viscoplastic strains are anisotropic and depend on the gallery orientation with regard to the initial stress anisotropy in the investigated formation; (b) the viscoplastic strain rates observed in the undamaged area far from the galleries walls are in the same order of magnitude as those obtained on samples, whereas those recorded in the damaged or fractured zone near to the walls are one to two orders of magnitude higher; indicating the damage and created macroscopic fractures influences on the viscoplastic strains. This influence has not been taken into account in the previous constitutive models.

From these observations, a macroscopic viscoplastic model which aims to improve the viscoplastic strain prediction in the EDZ (Excavated Damaged Zone) is proposed by introducing damage variable in Lemaître's model. The mains characteristics of the model are: (a) the short-term behaviour is based on a generalized Hoek-Brown model; (b) the long-term behaviour is based on the modified Lemaître's model, the changes of viscoplastic strain rates due to damage (in pre peak phase) and failure (post-peak and residual phases) are taken into account by varying the creep activation energy and the strain-hardening as a function of the current damage rate. In addition, in order to prevent the overestimation of volumetric strain the associated flow rule initially assumed is revisited for the short term behaviour.

The proposed model is implemented in FLAC$^{3D©}$. In order to verify both constitutive equations and their implementations, several simulations of classical laboratory tests (uniaxial/triaxial, mono/multi stage creep and relaxation) are performed.

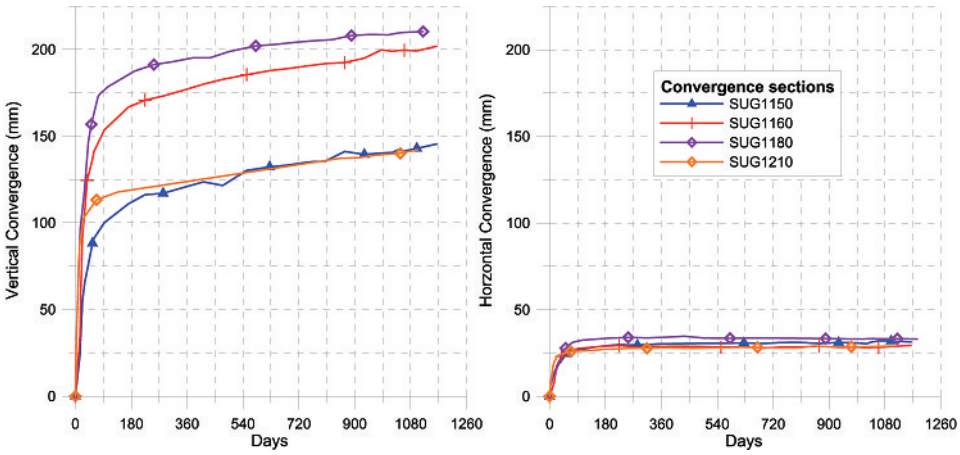

Figure 1: Examples of vertical and horizontal convergences measured in drift parallel to σ_h.

As practical applications, the proposed model has been used to predict the behaviour of two galleries of the laboratory (at -490 m level): parallel and perpendicular to the major horizontal stress. Comparison between predicted results and the in situ meaurements are then presented and discussed

Finally the model limitations as well as possible improvements are discussed in this paper.