Modeling the influence of water content in Callovo-Oxfordian argillite compression test

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Abstract:A unified elastic–plastic model is presented for argillites in this paper. Emphasis is put on the description of hydromechanical behavior of argillite under saturated and unsaturated condition in compression test. Base on the experimental investigation, the material's behavior is characterized by important plastic deformation coupled with damage on the short-term scale. Furthermore, the water content has an important impact on mechanical behavior of argillite at different saturation degree. Using the unified approach proposed by Matallah and Christian La Borderie (2016), a general constitutive model is proposed for the poromechanical behavior of argillites in both saturated and unsaturated conditions. Main features observed in experiments are taken into account, particularly the elastic degradation due to microcracks, coupling between plastic deformation and induced damage and influence of water content on plastic flow on different time scales. The performance of the model is examined by simulation of plasticity tests with different hydraulic states. Finally, the model is applied to study the hydromechanical coupling in a resaturation–desaturation test.

KEY WORDS: Elastoplasticity, Damage, Callovo-Oxfordian Argillite, Unsaturated rock, Hydromechanics

1.Introduction

Stiffer sedimentary clays are widely studied as potential host geological barrier for underground repositories of high-level radioactive wastes. In France, an underground research laboratory has been constructed by the French Radioactive Waste Management Agency (Andra). It is located in one layer of hard clay formation, called Callovo–Oxfordian argillite, in the eastern France. From the excavation to subsequence backfilling/sealing of underground repository, the geological barrier will be subjected to coupled hydromechanical processes for a very long term. Getting a good knowledge on the long-term responses of rock material subjected to these coupled processes is necessary in the framework of feasibility study of underground repositories. Therefore, it is very important to have reliable and predictive constitutive models which take into account various coupling phenomena, especially the hydromechanical coupling. In the Callovo–Oxfordian argillite, it is known that water content variation affects its microstructure and mechanical properties. Such effects have been widely reported as regards uniaxial and triaxial compression tests (Andra, 2005). In particular, uniaxial compression strength decreases significantly with water content rise. But, to the best of our knowledge, as regards the influence of capillary pressure upon elastic Young's modulus and its long-term behavior, few validated constitutive models are available. In the present work, a special attention is paid on the description of these two mentioned phenomena. The short-term behavior of argillites has been deeply investigated by a series of experimental programs (Andra, 2005). It is generally characterized by important irreversible deformations and degradation of mechanical properties. Influence of water content on short-term behavior of argillite has also been studied (Chiarelli, 2000; Hoxha and Auvray, 2005; Pham, 2006). The argillite exhibits an increase of mechanical strength and Young's modulus as well as a more important dilatancy phase with decrease of applied relative humidity. However, the emphasis of these laboratory tests is put on the influence of water saturation degree upon their multi-axial behavior. Moreover, the experimental data is so limited that it is difficult to identify clearly the general tendency of elastic properties and uniaxial compression strength in function of hydraulic state. In order to correctly capture this dependence, Zhang et al. (2010) have carried out some uniaxial compression tests under different relative humilities. The elastic properties are determined quantitatively by using the linear part of strain–stress curves.

However, the most research is limited for the saturated material and the influence of water saturation on the mechanical behavior of material is not dealt with. The emphasis of this study is put on the influence of water content on the mechanical behavior of argillite, In the first part, we present a synthesis of experimental study on the poromechanical behavior of argillite. Particular attention is paid to the coupling between the mechanical behavior and the desaturation/resaturation processes. Then, a new coupled elastoplastic damage model is proposed to describe the mechanical behavior of argillites under different water contents and loading conditions in the framework of partially saturated porous media. The constitutive model will be validated by simulating the experimental data. Finally, the proposed model is used to analyze some creep tests realized under different relative humidities. The numerical results help us to get a good understanding of the water content impact on the mechanical behavior of argillites.

2.Figures and table

In the framework of a feasibility study of underground nuclear waste disposal in France, the Meuse/Haute-Marne Underground Research Laboratory (URL) (Figure1) is being built in eastern France since 2000. The laboratory contains the main shaft and the auxuliary shaft. At a depth of about 490m exoerimental galleries were excavated (Rémi de La Vaissière et al. 2014).

The site of the MHM-URL is located within the Paris geological basin. The host formation consists of a clayey rock called Callovo-Oxfrdian gagillites, which is over- and under-laid by relatively impermeable carbonate formations. The argillaceous formation is located at a depth of approximately 400m and has a thickness of 130m. The upper part of the Callovo-Oxfordian formation is investigated during the construction of the laboratory (Chun-Liang Zhang et al. 2002).

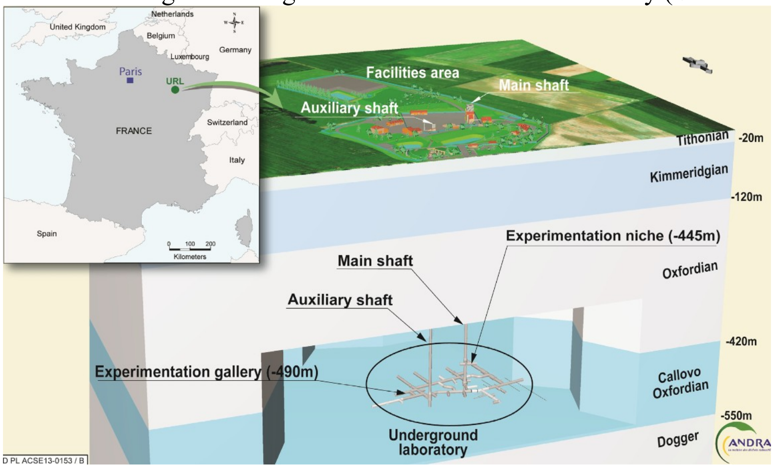

Figure 1. Meuse/Haute-Marne Underground Research Laboratory: location and geology

Core samples of 100 mm diameter and 320 mm length (Fig. 2) Zhang et al. (2004)were taken at different depths between 434 and 506 m below the surface from the drillcore of the borehole EST205 drilled at the axis of the auxiliary shaft of the MHM-URL (ANDRA, 2005)

Figure 2: Cores taken from the Callovo-Oxfordian argillite at MHM- URL

Rheological zone	A' - Upper	B'- Middle	C'- Lower
Thickness (m)	35	60	35
Density	2.42±0.05	2.42±0.05	2.46±0.05
Water content (%)	6.1±1.5	7.1±1.0	5.9±0.7
Young's modulus (MPa)	5837±2455	4723±1218	6118±1550
Uniaxial comp. strength (MPa)	27.0±9.5	19.0±3.2	21.0±3.6
Porosity (%)	17.8	18.2	16.8
Degree of saturation (%)	93	98.7	99.7
Poisson's ratio		0.29 ± 0.05	
Tensile. strength (MPa)		1.0	
Biot coefficient		0.6	
fracture energy		119	

Table 1. Parameters from experiments of different Callovo-Oxfordian argillite layers

Table 1. shows the fundamental hydro-mechanical parameters of Callovo-Oxfordian argillite from plenty of experiments (Andra, 2005; Armand, 2017 et al).

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