An Insight into the Water Retention Behaviour of MX-80 Granular Bentonite

Ali Seiphoori, Alessio Ferrari, Lyesse Laloui

Ecole Polytechnique Fédérale de Lausanne (EPFL), School of Architecture, Civil and Environmental Engineering (ENAC), Laboratory for Soil Mechanics (LMS). EPFL-ENAC-LMS, Lausanne, Switzerland

Abstract

The use of MX-80 bentonite is foreseen in the radioactive waste repositories of high level nuclear wastes (HLW) as compacted blocks or in granular form around the canisters. Bentonite will function as buffer under confined condition in the repository. An improved understanding of the water retention behaviour and the microstructural evolution of the buffer material is required to predict and interpret the repository behaviour. This study aims at investigating the retention and the microstructural evolution of compacted MX-80 granular bentonite during cycles of wetting and drying. A new technique called 'Micro-cell' is used to obtain the retention curve in wetting and drying cycles.

Tests are performed on compacted MX-80 (Wyoming) granular bentonite at a void ratio e = 0.53 corresponding to a dry density of 1.5 Mg/m^3. MX-80 bentonite is a highly swelling material which contains about 85 % of smectite mineral. A liquid limit of 420, and a specific surface of 523 m^2/g are obtained for this material (Plötze and Weber, 2007; Seiphoori in prep., 2014). The granular material is produced by breaking down and rounding of highly compressed bentonite units. For specimen preparation, different grain size fractions of the granular material are selected and mixed thoroughly in order to get always the same apparent grain size distribution.

In Figure 1, the Pore Size Density (PSD) functions of a single grain and the compacted specimen are shown. It is seen that the single bentonite grain shows a single porosity mode and does not have inter aggregate pores, while the as compacted specimen exhibits a clear bimodal pore size distribution.

The Micro-cell is a constant volume cell used in combination with a dewpoint potentiometer to obtain the points along the water retention curve. In this method, the degree of saturation is controlled and the total suction is measured. The technique provides an accurate evaluation of the the degree of saturation and air-entry value of highly swelling bentonite at a given compaction dry density (Seiphoori in prep, 2014). Figure 2 depicts the hydraulic domain obtained with a main wetting and a main drying path in terms of water content versus total suction at constant volume condition. Results are compared with others available in the

literature and highlight the accuracy of the proposed method in assessing the retention behaviour of highly swelling materials.

On the other hand, the Micro-cell provides representative samples for microstructural investigations by means of MIP analysis. Tested samples can be freeze-dried directly in the device. In this way, it is possible to investigate the microstructural evolutions of the saturated sample under a given swelling pressure and avoid porosity changes due to the possible stress release. The water retention curve obtained for the studied material suggests that during the first wetting the material underwent a significant and irreversible alteration in the retention behaviour. To investigate this behaviour from microstructural point of view, the other application of Micro-cell is used to prepare representative samples in the retention path. Results indicates a permanent change of structure to a single mode after the fully saturation state. This structural modification has a notable remark on the evaluation of the water retention behaviour of buffer at different points of the repository life time. The change of structure due to the saturation in constant volume conditions converts the initial double structure porosity of the compacted granular bentonite into a single mode pore size distribution. This structural modification is found irreversible and remains permanent for the next drying and wetting cycles. Consequently, the retention capacity of the material significantly increases. This feature has an important impact on the design and modeling of the buffer material for long term performance assessment of the HLW repositories.

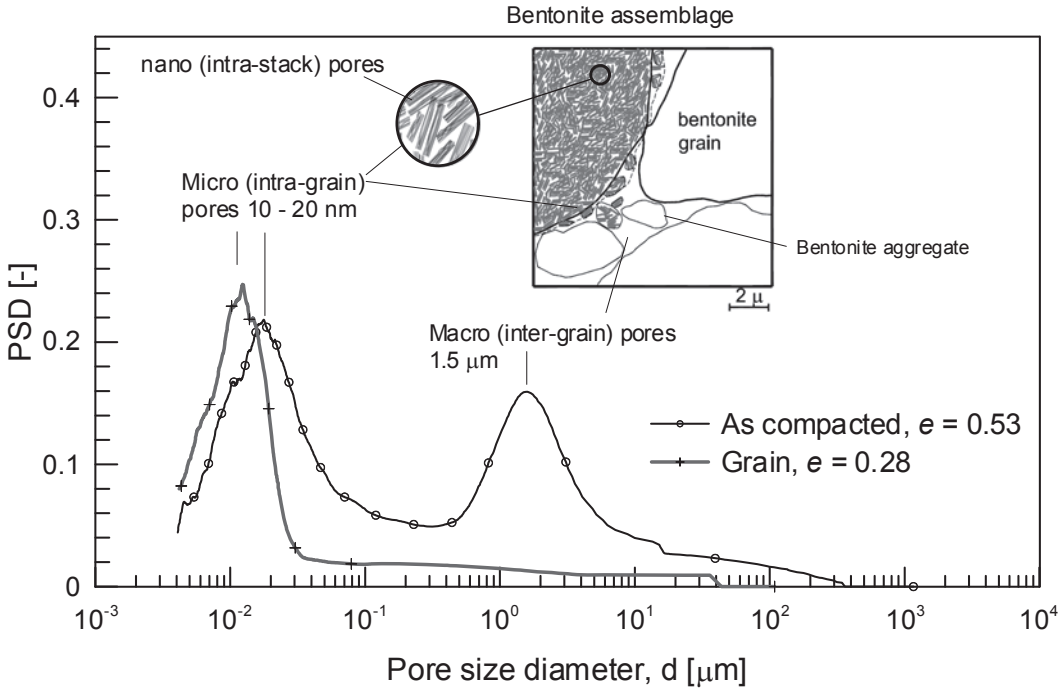

Fig. 1: Different microstructural levels in as compacted MX-80 granular bentonite

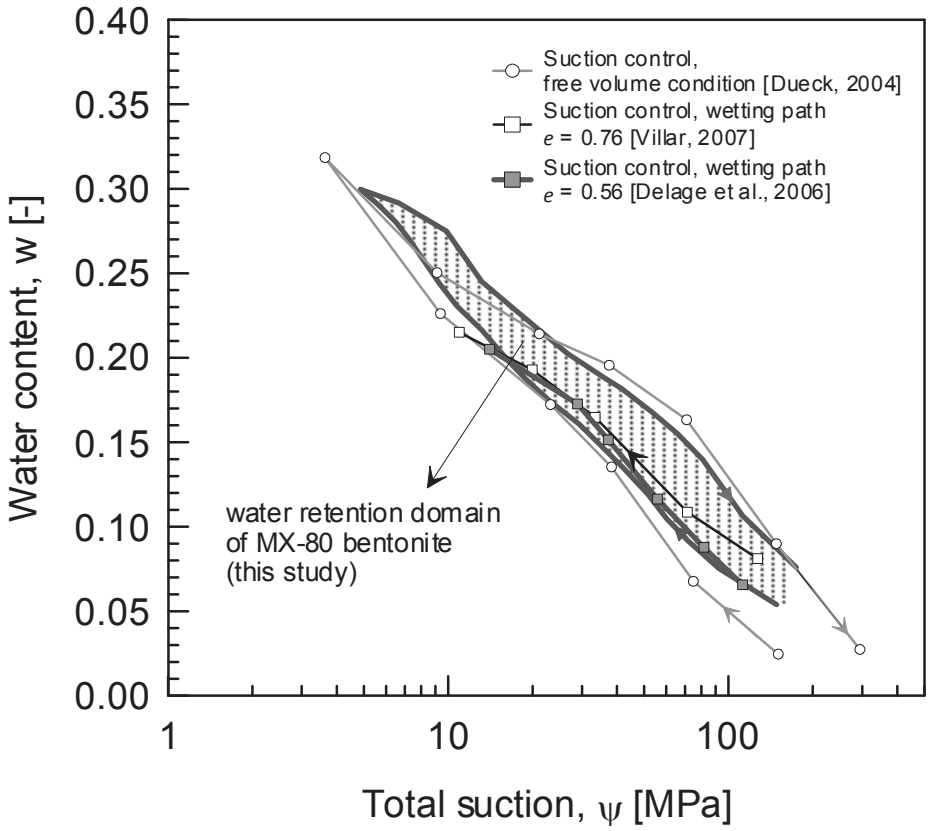

Fig. 2: Comparison of water retention curves obtained by Micro-cell with other techniques of total suction control

References

Plötze, M. & Weber, H. P. (2007): ESDRED: Emplacement tests with granular bentonite MX-80. Laboratory results from ETH Zürich. Nagra Working Report NAB 07-24. Nagra, Wettingen.

Seiphoori, A. (2014): Characterization and constitutive modelling of the behaviour of MX-80 granular bentonite during Thermo-Hydro-Mechanical processes. PhD Thesis. EPFL. In prep.