ABSTRACT

At present, atomic energy corresponds to the 16% of the energy produced worldwide. One of the most pressing challenges for this industry is to find a long-term solution to store the long-lived nuclear waste during its active life.

One of the most studied and an accepted solution is the construction of underground repositories to keep the radioactive waste isolated from the surrounding environment (ENRESA, 2000; Reseal, 2000; PRACLAY, 1998). Most conceptual designs for these repositories envisage placing the canister (metallic cylinder) containing the waste in horizontal drifts or vertical boreholes. The empty space surrounding the canister is filled by an engineer barrier often made of swelling clay. Because of it properties, bentonite materials are the most studied candidates for sealing elements.

The Engineered Barrier Emplacement Experiment (EB Project) aims to study a new concept for the construction of HLW repositories. The principle of the new construction method is based in the combined use of a lower bed made of compacted bentonite blocks, and an upper backfill made with a material based on bentonite pellets (AITEMIN 2001a, 2001b). Both sealing materials, blocks and pellets, are made of the same Febex bentonite, (ENRESA, 2000). The bentonite pellet material is placed using pneumatic projection techniques, which facilitate the backfilling operation and minimise air gaps. In this way, a better contact between the canister and the liner is ensured from the very beginning, as well as between the buffer and the irregular surface of the competent clay formation. This better union improves the heat transfer to the clay formation and minimises the initial preferential paths for water and gas flow.

The PhD thesis here presented is related to the experimental work performed for the hidromechanical characterization of the bentonite pellet material. Pellets are fabricated by compaction of preheated bentonite powder (NAGRA 2001). This results in very high density granules (ρ_d=1.95 Mg/m^3), with a very low initial water content (approximately 3-4%) and an initial suction of nearly 250 MPa. Because of this very low initial water content, a hydration process will start after its emplacement in a humid environment. Material characteristics and hydration conditions used in the real scale test have to be specially considered in order to perform the experimental programme and to explore the

most important features of the material behaviour. Different testing devises and experimental techniques have to be specially adapted for these purposes (Romero 2001).

This thesis is presented following the chronological order of the work performed. Three different stages can be defined:

> The first stage involved the study of structural characteristics of the different bentonite pellets material characterization. Mercury intrusion porosimetry (MIP) tests were performed to characterize the multiple-porosity network of the artificially prepared packing at different dry density values, as well as some infiltration tests.
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> Secondly, an extensive laboratory test programme was defined and the different tests were performed. In order to characterize the hidromechanical response of the material under reliable conditions, different suction control techniques and testing devices were specially adapted. Experimental results are presented divided in three groups. The first includes the hydraulic characterization tests. In the second, wetting under constant volume, constant load and loading at constant suction tests are presented. Finally, the influence of the wetting rate and water transfer type in the material response is shown.
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> In the last stage of the thesis, a constitutive model suited for expansive materials is presented, (BExM model; Gens & Alonso, 1992 y Alonso *et al.* 1999). Proposed ideas were specially adapted to reproduce the main features of bentonite pellet behaviour, model parameters were inferred and model predictions were compared against real behaviour. The model was implemented in a finite difference code programmed in MATLAB.

At the end of this thesis, a series of hydro-mechanical small-scale tests were performed, with a view to reproducing the hydration conditions in a more reliable way and minimize the scale effects. Special care is placed in controlling boundary conditions and monitoring the different test variables.

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