(1) Introduction

The long term performance of clay based sealing systems is being studied in the SEALEX experiments at the Tournemire Underground Rock Laboratory (URL). One of the SEALEX experiments, involving a 70/30 mixture of MX80 bentonite and sand, has been chosen as the focus of a coupled-modelling task in DECOVALEX-2015 (www.decovallex.org). The ultimate aim of the task is to represent the coupled hydro-mechanical behaviour of the chosen SEALEX experiment; this task has been broken down into stages to enable models to be built and calibrated against simpler laboratory data sets. This poster discusses the development of models to represent the hydro-mechanical behaviour of the bentonite in two of the laboratory tests, an oedometer test at different suction and a 1/10th scale mock-up of the SEALEX experiment, and compares results from different models.

The work discussed here has been carried out by a team working for the UK’s Radioactive Waste Management Limited (RWM) and represents the work of one of the teams participating in this DECOVALEX-2015 task.

(2) Model description

Modelling philosophy

- Use the simplest model that will adequately reproduce the data that is available from experiments.
- Reduce the number of free parameters by linking hydraulic and mechanical behaviour to observations and avoid arbitrary calibration.

Modelling work has been carried out in Quintessa’s in-house software, QPAC, in which different process models can be easily implemented.

Observations

Experimental data (Wang et al., 2012) show that the swelling pressure is a function of the dry density for samples of the same bentonite (Figure 1).

The curve that fits these data also fits the water retention data (Figure 2) and the virgin consolidation curve (Figure 3) of oedometer test data (Wang et al., 2013a), allowing parameterisation of these curves with two constants.

Mechanical model

The mechanical model is based on the Modified Cam Clay (MCC) model (Roscoe and Burland, 1968):

Elastic deformation is represented by

\[ \psi = \kappa \ln \rho - m \ln \rho \]

Plastic deformation is represented by a failure surface (2) and the virgin consolidation curve (3).

\[ \frac{\Delta \lambda}{\lambda} + p (p - p_c) = 0 \]

The swelling model assumes the bentonite grains are uniformly distributed in all directions and calculates swelling in axial directions. Suction equilibrium is enforced in the axial directions and the amount of swelling is calculated from the volume of water added in each direction to account for the change in water content.

Hydraulic model

Water movement is represented by vapour diffusion and calibrated to an infiltration test.

(3) Oedometer test

Oedometer tests were carried out on samples of the bentonite/sand mixture at different suctions (Wang et al., 2013a).

The model was able to reproduce the broad shape of the results, only requiring calibration of the elastic deformation.

Some additional calibration was required to fit the 1/10th scale mock-up as discussed below.

(4) 1/10th scale mock-up

The 1/10th scale mock-up experiment consists of three phases (Wang et al., 2013b):

1. Initial saturation under confined conditions, with swelling into the technological void (1 year);
2. Recovery of the void, in which the sample was allowed to swell (~50 days);
3. Confinement.

The data show some interesting plastic behaviour during phase 1, related to the sample swelling into the technological void. The model is able to capture all the major features of the experimental data.

(5) Alternative models

A number of alternative models have been set up in QPAC to represent the hydro-mechanical properties of the bentonite/sand mixture in the experiments. Results from a model based on the Barcelona Basic Model (BBM) are shown here for comparison.

It is possible to get reasonable fits to the experimental data with a range of different models for the mechanical and hydraulic behaviour of the bentonite/sand mixture. However the models differ in the prediction of spatial variation of properties such as dry density, which, with the appropriate data, will make it possible to determine which models best represent the relevant processes.

(6) Conclusions

Using measured properties of bentonite/sand mixtures, a model for deformation of bentonite has been proposed which explicitly links the mechanical and hydraulic properties and has fewer free parameters than other commonly used models, so requires less calibration.

A range of models has been built which predict different bentonite behaviour within the sample, so with appropriate data, it will be possible to distinguish between the models.

References


Barcelona Basic Model. Available at: http://www.bbm.eu (accessed 16 December 2015). This model represents swelling in oedometric tests and is calibrated against water retention data from Quintessa’s instrumentation.

