Prediction of Inflow and Wetting Behaviors of Bentonite in Deposition Hole Under In-Situ Geological Features

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1. Introduction

Äspö Task Force is a forum of the international organizations for modeling of groundwater flow and transport of solute (GWFT) in fractured rocks. SKB Task 8 primarily focuses on the evaluation of the hydraulic interaction between the bentonite backfill material and near-field host rock [1]. The objective of this study is to calculate inflows into 30 cm diameter open boreholes and to evaluate the resulting wetting of the bentonite installed in the borehole.

2. Approach

Numerical model development is based on the use of TOUGH2 and FLAC3D. A lot of computer resources are generally required in TOUGH2 and FLAC3D with regard to application of smeared fracture model to all the elements in model domain. Equivalent permeability, therefore, is estimated from fracture statistics around TASO tunnel by application of an imaginary tunnel (2×2×20 m) into model domain. Equivalent permeability is obtained by assuming that the inflow estimated from TOUGH2 code is same to that from FLAC3D code in which site-specific DFN is evaluated by applying the smeared fracture model with regard to the hydraulic properties. Three deterministic large fractures and small-scale fractures with large transmissivity (log10(T) > -11.6) intersecting probing borehole are directly embedded to the model geometry. They are assumed to have a thickness of 5 cm

3. Model setup

The mode geometry is presented in Fig. 1 below. In contrary to Task 8c, additional monitoring boreholes surrounding probing borehole and site-specific small fractures intersecting probing boreholes are further embedded in Task 8d. Material properties used in TOUGH2 analysis and other input parameters including initial & boundary conditions are same to those used in Task 8c. Total mesh number in Task 8d is 74,184 within a domain of 40x40x40 m (Fig. 1).

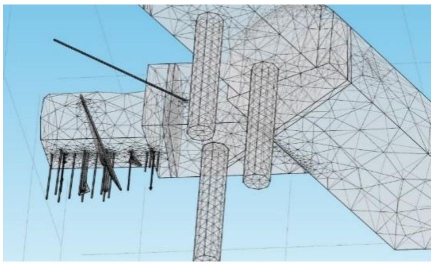
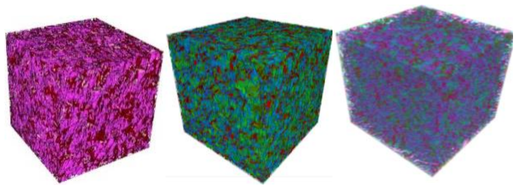


Fig. 1. Model geometry for Task 8d.

Site specific-stochastic fracture statistics are given as intensity, size and orientation data, and serve as the basis for the hydraulic properties. DFN generated from FracMan is applied to FLAC3D for equivalent permeability calculation (Fig. 2).



(a) FracMan (b) FLAC3D (C) EPM

Fig. 2. DFN generation and EPM (Equivalent Porous Medium).

4. Main Results

4.1 Estimation of groundwater inflow into probing holes

When the permeability of intact rock is assumed to be 1.02×E-21 m^2, the inflow into an imaginary tunnel is calculated as 1.652E-7 kg/sec from FLAC3D. While the inflow from TOUGH2 code is calculated to be 0.911E-7 kg/sec. It should be noted that some difference is found in the estimated flow between TOUGH2 and FLAC3D codes even under the identical input condition without discrete fractures. The value from FLAC3D is consistently 1.81 times larger than that from TOUGH2 code in this study.

Therefore, the calibration factor between two codes should be taken into account with regard to inflow estimation when using TOUGH2 code. Equivalent permeability of 1.125E-19 m^2 is selected to be used in this study.

Based on this information, the inflow into borehole is calculated from TOUGH2 code and listed in Table 1. In the borehole of BEN18, relatively large difference is found at inflow estimation between simulation and BRIE data. It is likely that there are some geological features or processes such as impermeable zone around the BEN18 (KO018). As more data became available, the model should be adjusted to better reproduce the observations made in probing boreholes.

Table 1. Inflow into boreholes after excavation at 0.1 yr

Borehole	KO20	BEN18 (KO18)	BEN17 (KO17)
Inflow (ml/min)	0.48	1.00	0.95
BRIE (ml/min)*	0.01	0.0 (0.01-0.03)**	1.0 (0.12-0.25)**

* inflows from short duration test (approx. 15 min)

** values in parenthesis indicate inflow into 300 mm diameter open boreholes

4.2 Variations in saturation and pressure around TASO tunnel

The required time for full saturation of bentonite is around 100 years or more. These values are much longer than the time from Task 8c (less than 5 years).

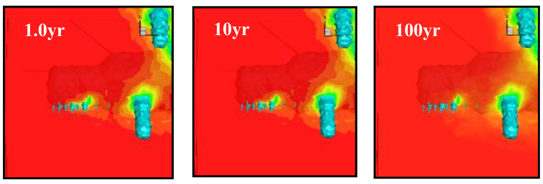


Fig. 3. Saturation distribution at the middle of probing hole.

Pressure distribution around TASO tunnel is presented in Fig. 3 with time. The pressure does not show substantial difference with time and remains relatively low value around the boreholes.

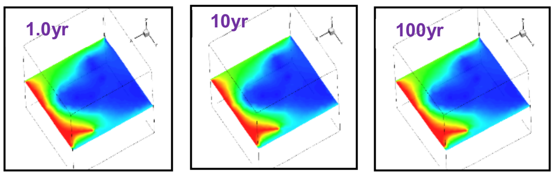


Fig. 4. Pressure distribution at the middle of probing hole.

5. Discussion

The time required for the full saturation of benonite in Task 8d is estimated to be much longer than that in Task 8c although additional fractures are taken into account and the inflow is larger. It is likely that additional boreholes and fractures intersecting tunnel and boreholes results in slow saturation in Task 8d. In particular, various monitoring boreholes surrounding each probing borehole give rise to low pressure distribution.

It is worthwhile to notice that the borehole KO17 shows very slow saturation profile (Fig. 2). Even after 100 years, some location does not show fully saturated. This is attributable to the fact that a large fracture is intersected with the tunnel inside which has a constant atmospheric pressure. Subsequently, more information on the geological features near the deposition holes, such as interconnection of fractures is also required for improving prediction of inflow as part of deposition hole characterization.

6. Conclusion

Better prediction of the hydraulic interaction between the near-field rock and bentonite depends on how well the site-specific features around the deposition are identified. Subsequently, more information on the geological features near the deposition holes, such as interconnection with man-made structures is also required for improving prediction of inflow. In addition, model adjustment and calibration based on the available data measured in situ are necessary to better reproduce the observations.

REFERENCES

[1] SKB (2012), Task 8-Modelling the interaction between engineered and natural barriers: An assessment of a fractured bedrock description in the wetting process of bentonite at deposition tunnel scale, SKB report P-16-05, Stockholm.