Hydromechanical characterization around an excavated cavern

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1. Introduction

Disturbance caused by excavation of cavern or tunnel is usually described by the term 'Excavation Disturbed (or Damaged) Zone (EDZ). Excavation-induced change of hydraulic properties represented by a hydraulic conductivity can mainly be caused by opening or sliding of pre-existing fractures in the EDZ resulting from stress-redistribution in the vicinity of the excavated cavern. In order to predict the excavation-induced change of hydraulic conductivity of the EDZ, stress or deformation dependent hydraulic transmissivity of individual fractures should be included.

In-flow rate into a disposal cavern can be increased according to the excavation-induced hydraulic conductivity change and may enhance the corrosion rate of sealing material for the wastes and increase the transport potential of radionuclides released out of the radioactive wastes in a geological repository. In this paper, it is introduced both to numerically predict a hydraulic conductivity change due to excavation-induced disturbance and to experimentally evaluate hydraulic characteristics of disturbed zone around the excavated cavern.

2. Excavation-induced permeability change of a rock fracture and fractured rock mass

2.1 Excavation-induced permeability change of a single rock fracture

Anisotropic permeability change of a single rock fracture with rough surfaces due to shear deformation was investigated using an analytical approximation. The permeability approximation of a single fracture was represented by a function of the spatial correlation of the aperture as well as the statistical moments (: mean and standard deviation) of the aperture distribution.

$$\overline{K}_{ij}^{\text{eff}} = C\overline{A}^3\left[\left(1+3\frac{\sigma^2}{\overline{A}^2}\right)\delta_{ij} - 9\alpha_{ij}\frac{\sigma^2}{\overline{A}^2} + 9\left(\alpha_{ij} - 3\alpha_{ij}^2 + 9\gamma_{ij}\right)\frac{\sigma^4}{\overline{A}^4}\right] \tag{1}$$

where, C: constant determined by water properties, $\overline{A},\sigma$: mean and standard deviation of aperture distribution, α,γ : coefficients dependent on the autocorrelation function of aperture distribution.

The present method could well explain the significant increase of permeability due to shear deformation and its gradual approach to an asymptotic upper bound of the permeability. The anisotropy in the permeability was also induced by the shear deformation as well. It was also noticeable that the shear-induced anisotropic permeability became more isotropic as the shear displacement exceeded the characteristics correlation length of surface asperities.

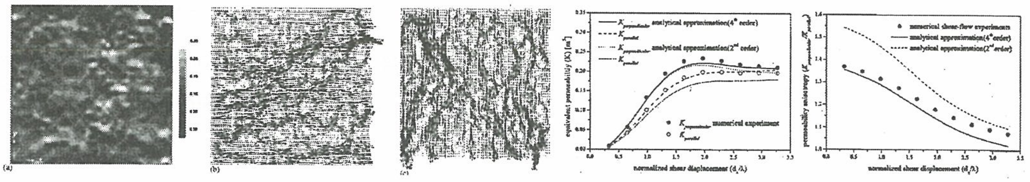

Fig. 1 Flow through a single rock fracture and numerical as well as analytical solutions for fracture permeability (Kim and Inoue, 2003)

2.2 Excavation-induced hydraulic conductivity of a fractured rock mass

Underground excavation can induce significant deformation of pre-existing fractures in rock mass. Due to the sliding and opening of the fractures, subsequent changes in the hydraulic properties of a fractured rock mass would be anticipated. The effect of excavation on the flow properties of a fractured rock mass can be predicted by including excavation-induced permeability change of individual fractures. This can be accomplished in a numerical manner that initially prescribed fracture permeability (; transmissivity) of Discrete Fracture Network (DFN) model is modified into excavation-induced value depending on both normal stress and shear displacement obtained by pre-performed mechanical stress analysis (Kim et al., 2003; Park et al., 2007). The calculation of the excavation-induced permeability involves the distributions of shear displacements and normal stresses around the excavation, and implicitly takes into account the effect of surface geometric roughness as well.

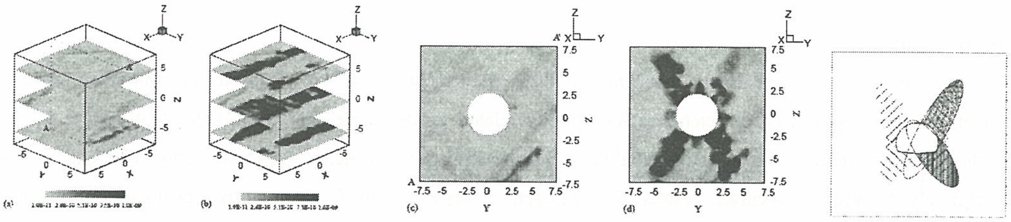

Fig. 2 Numerical prediction of excavation-induced hydraulic conductivity change in a fracture rock mass

3. Borehole hydraulic test in EDZ

EDZ is usually formed at the limited regions around the excavated cavern. A conventional borehole hydraulic test system with several m scales of interval length may not always be applicable in identifying hydraulic conductivity change in the EDZ. Specially designed borehole hydraulic test system was employed in-situ and hydraulic conductivities of EDZ were evaluated. Since this system provides a short test interval length of approximately 10cm, comparatively continuous variation of hydraulic conductivity along the distance from the cavern could be measured and estimated. And DFN model around the tested boreholes was constructed and flow model was verified so as to increase the precision of hydraulic conductivity estimation.

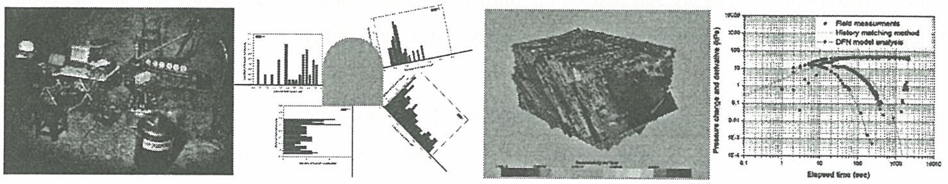

Fig. 3 Specially designed borehole hydraulic test system for EDZ and DFN model analysis for a flow model verification

4. Conclusion

In order to predict and evaluate hydraulic conductivity change due to excavation-induced disturbance, both numerical methods and in-situ testing system were introduced in this paper. The proposed system may help in identifying hydraulically significant EDZ and increase the precision of hydraulic conductivity evaluation around the EDZ.

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