Fracture Stress Condition and its Relationship With Hydraulic Conductivity in the KURT Site

Yeonguk Jo*, Kyung-Woo Park, and Sung-Hoon Ji
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil Yuseong-gu, Daejeon, Republic of Korea
*joy@kaeri.re.kr

1. Introduction

The hydraulic conductivity of a rock fracture generally depends on the aperture size, surface roughness and contact area, all of which are functions of the stress which acts on the fracture plane [1]. Thus the stress condition on the fractures is an important factor affecting hydraulic properties of fractured rock mass. In this study, we investigated the stress conditions of the natural fractures in KURT site based on the reviewed in situ stress states and fracture observations, and compared them with estimated from a series of in situ borehole tests to observe relationship between the stress condition and hydraulic conductivity.

2. Fracture Stress Conditions and Hydraulic Conductivity

2.1 Fracture observation

We investigated distributions of natural fractures, which cross boreholes at KURT site, using borehole images from acoustic and optical image wireline-loggings. Natural fractures are ubiquitously distributed with depths, and randomly oriented. The fracture density is defined as number of all fractures at a 9.2-10 m interval, which corresponds to interval length of the hydraulic tests.

2.2 Stress condition on the fracture plane

The condition of stress on the fracture plane are generally described as slip tendency (μ), which is the ratio of effective normal stress (σ_n) to shear stress (τ). The stress components, normal and shear stress, are a function of in-situ stress states and fracture orientations (Fig. 1).

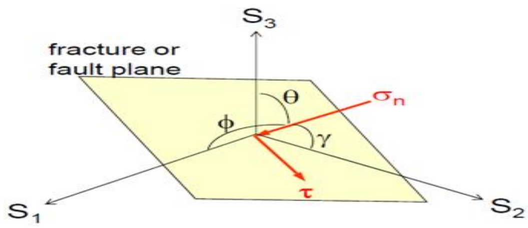

Fig. 1. Effective normal and shear stress conditions on the fracture plane.

The S_1, S_2 and S_3 are maximum, intermediated and minimum principal stress, respectively. Since the stress regime at KURT site is favored to thrust-faulting [2], the S_1 should be maximum horizontal principal stress (S_{Hmax}). Then S_2 and S_3 are minimum horizontal principal stress (S_{hmin}) and vertical stress (S_v), respectively.

About the poles of individual fractures, direction cosines of normal vectors are given below:

$$n_1 = \cos\phi, \quad n_2 = \cos\gamma, \quad n_3 = \cos\theta \qquad (1)$$

Effective normal stress (σ_n) and shear stress (τ) can be calculated in terms of principal stresses, normal vectors and formation pore pressure (P_P):

$$\begin{aligned} \sigma_n &= n_1^2 S_1 + n_2^2 S_2 + n_3^2 S_3 - P_P \\ \tau &= \sqrt{(n_1 S_1)^2 + (n_2 S_2)^2 + (n_3 S_3)^2 - \sigma_n^2} \\ \mu &= \tau / \sigma_n \end{aligned} \qquad (2)$$

All natural fractures have slip tendency, a range between 0.1-0.5 with its value significantly varying with their orientations (strike and dip).

2.3 Hydraulic conductivity

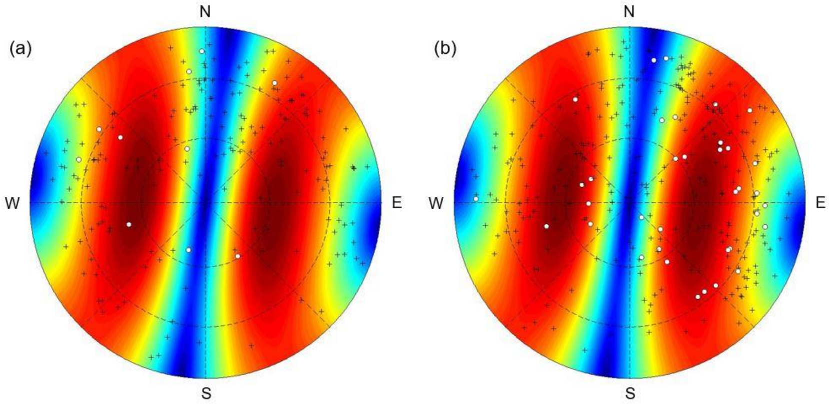

Fig. 2. Streonets showing poles of natural fractures in the intervals of HRD (a) and HCD (b). White-circle and cross symbols denote fractures with aperture > 5 mm and all other fractures, respectively. Background color expresses slip tendency (ratio of shear to effective normal stress) acting natural fractures in different orientations.

The hydraulic conductivity was determined by a series of constant head injection tests in the boreholes (YS-area) located in the KURT site. Double packer system with an interval length of 9.2 to 10 m was used in the in situ borehole tests. Estimated hydraulic conductivities (K) at individual intervals have a range between 10^{-6} and 10^{-12} m/sec. Then we classified HRD as the interval where log K values are less than -10, and HCD as the intervals where intervals of log K are relatively higher.

2.4 Fracture distribution characteristics in HRD/HCD intervals

To observe relationship between fracture distributions and hydraulic conductivity, we plotted natural fractures in the stereonets showing slip tendency of individual fractures (Fig. 2).

All natural fractures, which are quite randomly oriented, have significantly different slip tendency depending on their geometry. There are some wide natural fractures (aperture size > 5 mm) in HCD intervals and they especially have relatively high slip potential under the in situ stress conditions.

3. Conclusion

In this study, we observed fracture distribution features and their stress conditions in the HRD and HCD intervals. We think that fracture types and fracture stress conditions are important factors affecting water flow in fractured intervals.

ACKNOWLEDGEMENT

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