Correlations Among Fracture Distribution, in Situ Stress States and Hydraulic Conductivity of Fractured Rock Mass

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1. Introduction

It is an important issue to investigate groundwater flow in fractured bedrock, in a wide range of rock engineering, such as deep geological radioactive waste disposal. The fluid flow in fractured rock mass tends to be influenced by geometrical features of fractures and their distributions. The KURT is located in a crystalline bedrock, which is fairly homogeneous, but intermittently fractured, and the results of site characterization works indicate that the hydraulic characteristics of the KURT site were affected by presence of permeable structures and its distributions [1].

One of known factors controls permeability of a fracture is that intrinsic shape of fracture in terms of aperture size and types (open or closed). The open-type fracture showing relatively wide aperture and loosely closed due to infilling materials such as weathered rock fragments, is considered as a dominant permeable structure.

It is also proposed that the hydraulic conductivity of fractured rock domain can be altered by in situ stress states, because the aperture of fracture can be changed due to stress condition leading to variation of its permeability. Therefore, the influence of stress on permeability should be properly investigated.

In this context, we attempt to compare the hydraulic conductivity in part of KURT research area, with fracture distribution and stress states there, in order to understand how the fracture distributions and stress conditions influence the hydraulic characteristics of fractured rock mass.

2. In-Situ borehole tests

2.1. Borehole Image Loggings

We identified natural fractures and its distributions which cross the boreholes using a borehole acoustic televiewer (BHTV). We classified the types of individual fractures into open, semi-open, and closed, based on the reflected amplitude and travel time. The spatial distributions of fracture frequency are defined as number of fractures at a 10 m interval. The natural fractures are ubiquitously distributed with depths, but intermittently highly concentrated at several sections.

2.2. Constant Head Injection Tests

The hydraulic conductivity was determined by constant head injection tests, using a double-packer system with an interval length of ~10 m [1]. There are two methods, what we used, to estimate hydraulic conductivity from the test results: Moye [2] and Horner [3] to steady state and transient phase, respectively.

The determined hydraulic conductivities from two individual interpretations, are qualitatively comparable, and have a range between 10^{-8} and 10^{-10} m/sec, representing general value for granitic rock, and a log-normal distribution.

2.3. Stress estimations

The states of in-situ stress were evaluated using hydraulic fracturing tests and borehole wall stress indicators [4]. Local stress condition at KURT research site represents the S_{Hmax} orientation of ESE-WNW, averaging N97ºE, with prevailing lateral compression, indicating thrust-faulting favored stress regime.

3. Influence of fracture distribution and stress states on permeability of fracture

3.1. Relationship between fracture distribution and hydraulic conductivity

The relationship between fracture distribution and hydraulic conductivity shows that some intervals, where natural fractures, especially open-type fractures, are relatively abundant (i.e., high frequency

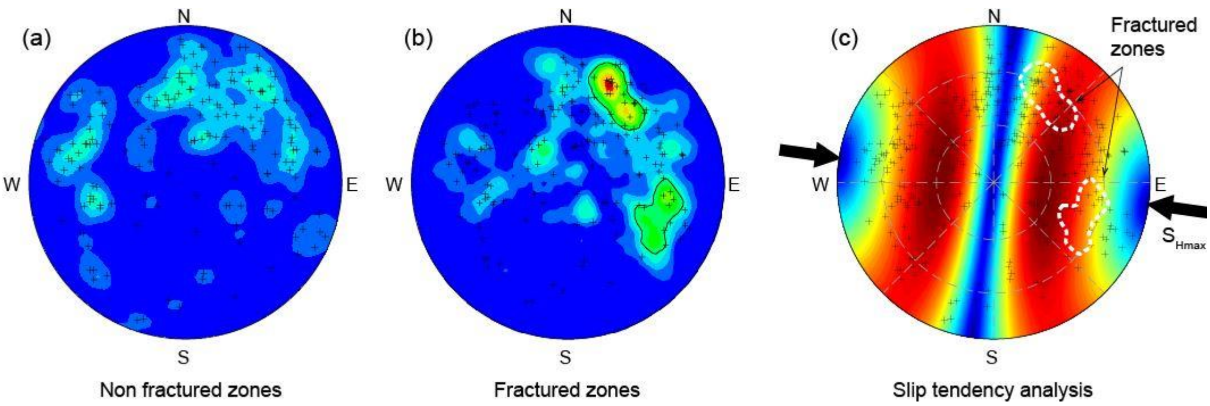

Fig. 1. Streonets representing pole of natural fractures in non-fractured zones (a) and fractured zones (b). All natural fractures are quite randomly oriented. But the fractures in fractured zones tend to be clustered in area of where slip tendency is relatively high (c).

of the fracture), are relatively highly permeable. It suggests that the presence of open-type fracture has a proper relation with hydraulic conductivity, as we expected. There are, however, relatively high conductivity intervals, although no distinct permeable structure exists.

3.2. Influence of stress states on fracture water conductivity

In some boreholes, we observed somewhat unexpected correlations between the fracture distribution and hydraulic conductivity. Several intervals, where no open-type fracture crosses there but fracture frequency is relatively high due to presence of numerous closed-type fractures, show relatively high hydraulic conductivity.

To understand the origins of this phenomenon, we analyzed slip tendency of the structures. All natural fractures have significantly different slip potential depending on their orientations. But some fractures in the concentrated zones have relatively high slip tendency under in situ stress states of KURT site.

It is reported that stress condition (especially, shear stress) on the fracture plane can derive dilation of fracture aperture due to slip, which leads to not only increase in permeability of the individual fractures, but also channeling effects [5]. Thus, we interpret that the high water conductivity zone where no open-type fracture exists is influenced by in situ stress.

4. Conclusion

In the present study, we consider both the fracture distributions and in situ stress states as influence factors on permeability of fractures. The relationship between stress and permeability suggests that the stress condition can significantly affect groundwater flow in fractured bedrock.

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