Considering the effect of water pressure at the analysis of a hydraulic test in a fractured rock

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1. Introduction

Groundwater flow through fractures is one of major pathways for radioactive contaminants from a subsurface repository to the biosphere. From the cubic law the transmissivity of a fracture is proportional to the cube of the aperture, which introduces that a small change of the aperture can make a big change in the flow rate thus the transmissivity of a fracture –if the aperture increases by 50 %, the transmissivity of a fracture increases by 338 %. It is known that a sufficiently large water pressure makes a change in a fracture aperture thus a fracture transmissivity (e.g. hydro-fracturing), and a small change in water pressure, which is often occurred during the hydrogeologic characterization works, maybe affect a fracture aperture thus the well test result.

In this study, we evaluate the influence of the water pressure on the fracture aperture and the fracture transmissivity with a series of field experiments. For the experiments, a borehole is installed in the KURT, and the test interval is determined through the analyses of borehole logging and hydraulic tests. Then, a double packer system, which is able to observe the change of an aperture due to the water pressure change directly, is developed and installed in the test borehole. Using the double packer system the aperture of a fracture in the test interval and the flow rate are observed directly under various water pressures, and the relation between the water pressure and the aperture thus the fracture transmissivity during a hydraulic test is quantified.

2. Test borehole

The test borehole named as TB-5 is located in the KURT, which is in Daejeon, middle-western area of the Korean peninsula. The KURT, whose maximum depth is 90 m from the ground surface, is a small scale underground research facility with 180 m long access tunnel and two research modules. Fig. 1 shows the layout of the KURT and the location of the TB-5 borehole. The length and radius of the TB-5 are 30 m and 4 in, respectively, and its host rock is two-mica granite.

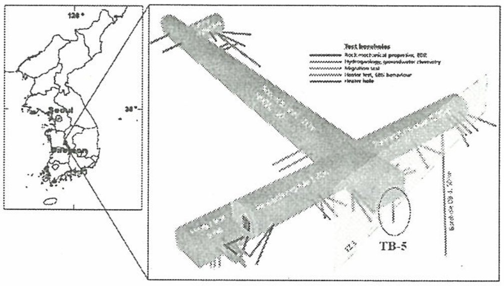

Fig. 1. Layout of the KURT and the location of the test borehole, TB-5

To determine the test interval, fractures crossing the TB-5 are logged using an acoustic televiewer. The total number of them is 78, and thus the P10 defined as the number of fractures per unit length of the borehole is 2.6. The fractures can be classified to 3 fracture sets, and the fracture set with 233 and 74 degrees of the mean trend and plunge, respectively, is the most dominant one. Based on the borehole logging data, the packed-off section 28.2 – 29.1 m depth from the top of the casing (TOC) is selected as the test interval because it has 1 fracture that is not connected to other boreholes thus the intensive observation and analysis for the target fracture are possible.

3. Results

3.1 Hydraulic test

In the test interval, preliminary hydraulic tests such as a constant head withdrawal and recovery tests are conducted. During the constant head withdrawal test, the hydraulic head in the test interval instantaneously decreases from the initial head to the assigned head, and is kept constant. The out-flow rate is initially at maximum, and converged to a value. The recovery test begins by stopping the groundwater outflow, and the hydraulic head is restored to the initial one. The constant head withdrawal test results are analyzed with the Moye, Jacob-Lohman and straight line model while the recovery test results Horner models. Table 1 shows the estimated transmissivity for the test interval. The difference between the estimated transmissivities from the constant head withdrawal test and those from the recovery test is about 1 order.

Table 1. The estimated interval transmissivities from the constant withdrawal and recovery tests conducted at the test interval in the TB-5 borehole

Estimated interval transmissivity [m^2/sec]			
Constant head withdrawal test			Recovery test
Moye analysis method	Jacob-Lohman analysis method	Straight line analysis method	Horner analysis method
3.6E-9	4.8E-9	5.2E-9	2.7E-8

3.2 Developed double packer system

For direct observation of the fracture aperture during a hydraulic test, a special double packer system is designed. It is composed of three parts: outer pipe, inner pipe and acrylic pipe. Eight rubber packers to isolate the specific zone in a borehole are attached to the outer packer, and there is an observation window, which is located at the zone isolated by the packers, in the outer pipe. The inner pipe is coupled with the acrylic pipe for direct observation of a fracture using a borehole camera. It is a passage for a borehole camera and cables and a barrier to shut out the influence of the assigned water pressure to the test zone on the camera. It is placed inside the outer pipe. Note that the outer and inner pipes are made of the stainless steel.

3.3 Water pressurizing tests

To check the performance of the developed double packer system and confirm the experimental set up, a preliminary test for quantifying the relation between water pressure and a fracture aperture is conducted. The pressurized water is injected to the target interval through the space between the outer and inner pipes using a constant pressure injection pump, and a borehole camera such as the borehole image processing system (BIPS) is inserted into the inner pipe to record the change of the target fracture aperture. Transducers for measuring the established water pressure and the injection rate into the target zone are installed between the injection pump and the injection hole in the outer pipe.

The target fracture and the injection rate into the test zone are observed while a hydraulic head of 50 m is applied to the test zone. After the water pressure is imposed, the aperture of the fracture in the test zone is increased, which means that the effect of water pressure change should be considered when the estimated hydraulic parameter from a field test is applied to the safety assessment of the repository.

4. Acknowledgement

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5. References

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