Study on the Evaluation Method of Aperture Distribution of Fractured Rock

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1. Introduction

The safe disposal of high-level radioactive waste (HLW) has been a major challenge for many countries operating nuclear power plants. Deep geologic repositories is being considered as a final disposal method to permanently isolate high-level radioactive waste, including spent nuclear fuel, from the ecosystem.

During the operation of the disposal system, if the radioactive material in the disposal container leaks out due to an external impact, the cracks in the rock will become the main migration pathway for the radioactive material.

In this study, the size of the aperture in the fractured crack was evaluated by dipole test for the rock used as a natural barrier material for deep disposal of high-level radioactive waste, and the evaluation method of the aperture distribution was verified using CFD analysis.

2. Methods and Results

This chapter describes the results of the hydraulic test of the fractured rock, the evaluation of the aperture distribution and the flow analysis using the calculated aperture.

2.1 Dipole Test

On the top of the test rock with cracks, nine test holes were drilled to the crack surface as shown in Fig. 1, and a mechanical packer was installed to inject and discharge fluid. A dipole test was performed to measure the water head between test holes while injecting flow from one test hole and discharging it from another test hole.

2.2 Aperture Distribution Evaluation

Using the head data obtained from the dipole test, the transmissivity was calculated using Equation (1) [1].

$$T = \frac{Q}{2\pi \mathrm{h}} \ln\left(\frac{2d}{r}\right) \quad (1)$$

where, Q is the flow rate, h is the head, r is the radius of the test hole, and 2d is the distance between the inlet and outlet.

Using the relationship between the transmissivity and the aperture, the aperture in the fractured rock was obtained using Equation (2).

$$b = \left(\frac{12\mu T}{\rho g}\right)^{\frac{1}{3}} \quad (2)$$

where, μ is the viscosity coefficient of the fluid, ρ is the density of the fluid, and g is the acceleration of gravity.

A grid was constructed for the fracture plane to be evaluated as shown in Fig. 2, and the size of the aperture at each grid point was calculated using an iterative method. The size and distribution of the calculated aperture and a three-dimensional wireframe graphic are shown in Figure 3.

Fig. 1. Photographs of experimental rock with crack

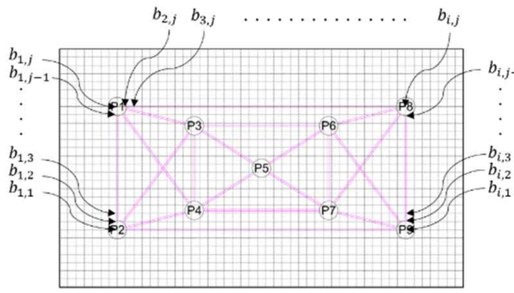
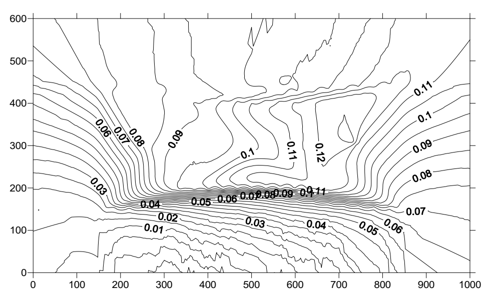
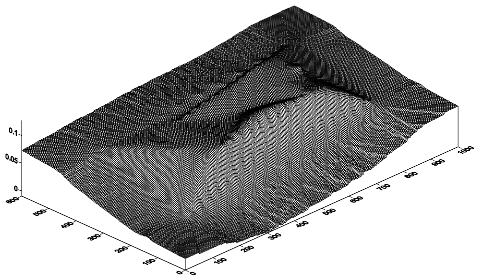


Fig. 2. Grid system for evaluating aperture distribution (from Jang [2])



(a)



(b)

Fig. 3. (a) Contour of aperture distribution; (b) Wireframe graphics of aperture distribution (Unit: mm).

2.3 CFD Analysis

The three-dimensional aperture distribution calculated from the dipole test results was used to form a grid for the flow analysis. The flow field was defined as incompressible, steady flow, and laminar flow, and the SIMPLE scheme was applied. The residual fraction calculated for each variable was set to 1E-6 or less to ensure convergence of the analysis. The test results and analysis results are shown in Fig. 4. Except for the large head (P2), we found that the test results and analysis results were similar.

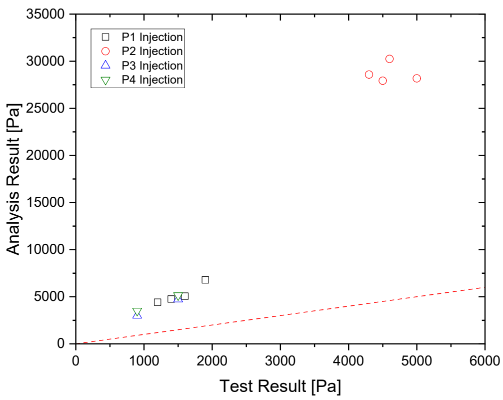


Fig. 4. Test results and CFD analysis results

3. Conclusions

In this study, testing device including mechanical packers and pressure sensors for dipole testing was constructed on rocks with natural cracks, and the size of the aperture in the rock was calculated using the test results. To verify the aperture distribution evaluation method, CFD analysis was performed and compared to the test results.

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