Estimation of the Magnitude of Excavation Damaged Zone at KURT

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1. Introduction

A geological repository would be located in a bedrock at a depth of several hundred meters below the ground surface, and be expected to be of a room-and-pillar design. During the construction of a geological repository in a crystalline rock such as granite, the excavation does considerable damage to the rock close to the tunnel wall. An excavation damaged zone (EDZ) is a zone around the tunnel where the rock properties and conditions have been changed owing to the excavation. In EDZ, the new fractures are created and pre-existing fractures are opened. Therefore the EDZ has influence on the stability of rock mass resulting in the decrease of deformation modulus, which deteriorates the long-term performance of underground rock cavern. The EDZ has also influence on the groundwater flow characteristics. In the EDZ, the permeability of the rock increases. The annular EDZ surrounding the tunnel may act as a continuous and high-permeable pathway for the groundwater flow, which accelerates the intrusion of groundwater into the repository and increases the release of radionuclide into the biosphere from the repository. Therefore an investigation on the magnitude of the EDZ has been important from the viewpoint of mechanical stability and radiological safety for a geological repository.

In this study, two in-situ measurements were performed at the KURT (KAERI Underground Research Tunnel) to investigate the magnitude of the EDZ.

2. KURT

KURT (KAERI Underground Research Tunnel) is located in a mountainous area at the Korea Atomic Energy Research Institute (KAERI). KURT consists of two main parts, namely an access tunnel and research modules [1]. The access tunnel has a -10% downward slope to place the research modules as deeply as possible with a limited length of the access tunnel. The length of the access tunnel is 180 m, and the turning shelter is installed at the location, 70 m from the entrance. Two research modules are located at each side of the access tunnel at the tunnel dead end. The lengths of the research modules are 45 m (research module 1) and 30 m (research module 2), respectively. The research modules are located 90 m below the surface in a hard granite formation. The access tunnel and research modules are all horseshoe shapes, and their tunnel size is 6 m x 6 m. A controlled blasting technique was applied for the excavation of the tunnel to minimize the disturbance of the rock around the tunnel.

3. In-situ Experiments

3.1. Goodman Jack Test and Permeability Test

Two in-situ experiments to investigate the magnitude of the EDZ were carried out at KURT. The Goodman jack test was conducted to measure the deformation modulus of rock mass. Total 19 boreholes were drilled into the wall of access tunnel, turning shelter, and research module to measure the change of rock properties due to an excavation, and the maximum depth of borehole is 35.0 m. The deformation modulus was measured at 0.3 m, 0.5 m and 1.0 m interval for the distance range of 0 to 3.0 m, 3.0 to 5.0 m, and above 5.0 m from the tunnel wall, respectively.

The permeability test was conducted to investigate the change of permeability in the EDZ. Total 6 boreholes were drilled into the wall of research module 1. Because the EDZ is limited to a narrow range of a few meters from the tunnel wall surface, an in-situ permeability measuring system using nitrogen gas was developed to measure the permeability in the EDZ. In the borehole, two inflatable rubber gaskets sealed the both ends of the test interval with a length of 0.2 m. In the borehole, the permeability of rock in the test interval was measured consecutively at up to a 4 m distance from the tunnel wall.

3.2. Results and Discussion

The deformation modulus of rock in the four test zones as a function of the distance from the tunnel wall is shown in Fig. 1. In EDZ, the deformation modulus was decreased, and the magnitude of EDZ can be estimated from the range of rock with lower deformation modulus compared with that of undisturbed rock

The EDZ was formed to 0.6 to 0.9 m from the tunnel wall surface in the test zone 1. In the test zone 2, the magnitude of EDZ is about 0.6 m due to relatively good rock property. In zone 3, the magnitude of EDZ is 0.6 to 0.9 m and in zone 4, the magnitude of EDZ is 1.5 to 1.8 m which is relatively large. In general, the magnitude of EDZ measured at the KURT is in the range of 0.6 to 1.8 m, and the value of deformation modulus in the EDZ is about 40% of those in undisturbed zone.

The typical permeabilities as a function of the distance from the tunnel wall are shown in Fig. 2.

Although the variation in the permeability is large, the general trend shows that the permeability decreases with an increasing distance to a location about 2 m deep from the tunnel wall and then maintains at a nearly constant value. The symbols ◐ and ▽ in Fig. 2 represent that the gas flow was not detected in the test intervals, and the intervals can be considered as impermeable.

Tsang et al. [2] defined an EDZ as a zone in which hydromechanical and geochemical modifications induce significant changes in the flow and transport properties. The EDZ can be estimated to be about 2 m from the viewpoint of permeability, and the permeabilities in the EDZ seem to be increased at up to 2 orders of magnitude compared with those in the intact rock. The excavation generates new fractures and enlarges the pre-existing fracture to increase the overall fracture connectivity.

These results suggest that the magnitude of EDZ estimated based on the permeability is larger than that from the Goodman jack test.

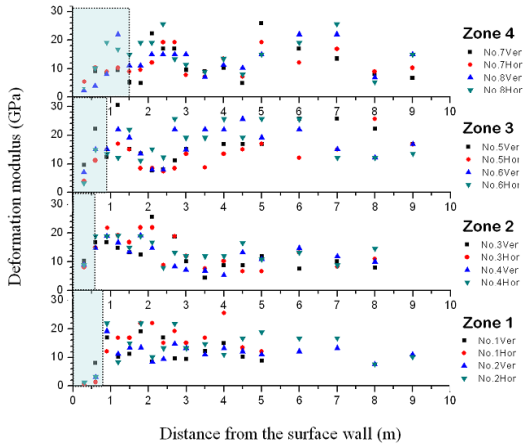

Fig. 1. The change of deformation modulus of rock versus the distance from the tunnel wall at four test zones in KURT

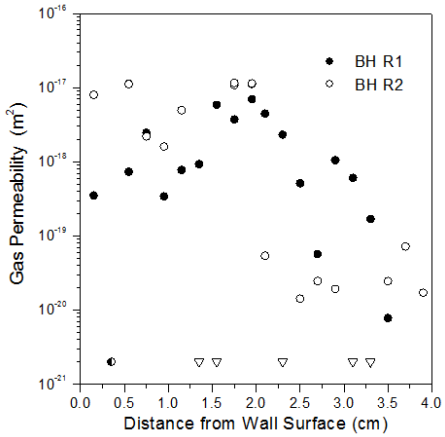

Fig. 2. Gas permeabilities measured in the test interval versus the distance from the tunnel wall (borehole R1, R2, ◐(R1), ▽(R2): impermeable)

4. Conclusions

The magnitude of EDZ was estimated to be 0.6 to 1.8 m from the tunnel wall on the basis of the deformation modulus, and the value of deformation modulus in the EDZ is about 40% of those in undisturbed zone. The magnitude of EDZ can be estimated to be about 2 m from the viewpoint of permeability, and the permeabilities in the EDZ seem to be increased at up to 2 orders of magnitude compared with those in the intact rock. The magnitude of EDZ estimated based on the permeability is larger than that from the Goodman jack test.

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