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Hydrogeological properties of Excavation Damage Zone (EDZ) in deep geological repository

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1. Introduction

The Excavation Damage Zone (EDZ) is notably influenced by localized stresses, which increase with depth. The EDZ substantially affects thermal, hydraulic, and mechanical rock properties near the disposal tunnel and deposition hole [1]. Consequently, in the context of a deep geological repository constructed at a depth of approximately 500 meters below the surface, alterations in rock properties induced by the EDZ can profoundly impact the stability of the geological repository. This study examines the hydrogeologic characterization of the EDZ encountered when constructing a deep geologic repository and how the hydrogeologic characteristics of the EDZ should be input when considering the safety of disposal.

2. Methods and Results

2.1 In-situ hydraulic test

To understand the hydrogeological changes caused by the excavation of the disposal tunnel or deposition hole, the diameter of borehole is expanded assuming the drilling of the deposition hole or construction of the disposal tunnel by TBM (Tunnel Boring Machine), and the hydrogeological characteristics of the damaged zone due to borehole expansion are derived from the in situ hydraulic test.

The borehole (BDZ-1) for this study was drilled to a depth of 20 m in KURT and expanded from three-inch to four-inch of diameter. When drilling boreholes with three-inch, the core drilling method was used. When expanding the diameter of borehole from three inches to four inches, a rotary drilling method was used in consideration of the excavation method of the deposition hole or disposal tunnel by TBM. In other words, the three-inch-diameter borehole drilled in KURT focused on obtaining original data on the hydrogeological properties of the crystalline rock. The four-inch-diameter borehole, which was expanded from the three-inch-diameter borehole, aimed to analyze the changes in hydrogeological properties due to the expanding the diameter of the borehole.

After drilling and expanding the borehole, sequential hydraulic tests were conducted to identify the hydrogeological properties of the crystalline rock (Fig. 1). Hydraulic tests performed before and after borehole expansion were instantaneous water level change test and constant head test. Slug and pressure pulse tests were performed for the instantaneous water level change test, and a constant head withdrawal test was conducted for the constant head test. The same test methods were applied to compare the hydrogeological properties before and after borehole diameter expansion. In this paper, the results from slug and pressure pulse tests were used for understanding hydrogeological properties, because constant head test were not conducted in entire test section.

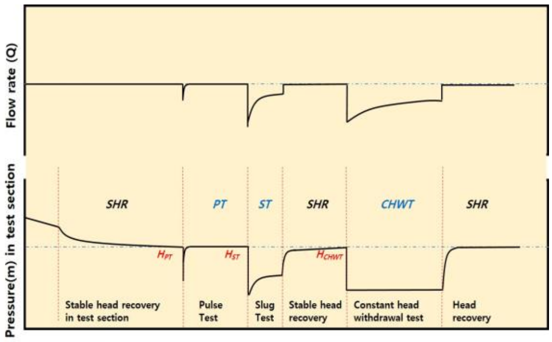


Fig. 1. Sequential hydraulic test, which is performed in the BDZ-1 borehole [2]

2.2 Transmissivity

Based on the pressure pulse test results, the transmissivity of each test section increased overall after borehole expansion. The results of the slug test were very similar to those of the pressure pulse test, and it was found that the permeability increased in all test sections. Similar to the results of the pressure pulse test, the transmissivity increased significantly by more than ten times in Section 5 and Section 10 from the slug test (Fig. 2).

In brief, the hydraulic test results indicate a notable change in the permeability of the test section attributable to the borehole damage zone following borehole diameter expansion. This change resulted in an overall increase in permeability within the borehole damage zone. Also, after expanding the diameter of borehole, the heterogeneity in transmissivity distribution by depth decreased, although variations persisted, spanning up to two orders of magnitude. Nevertheless, this study uncovered depth-dependent variations in permeability after borehole diameter expansion.

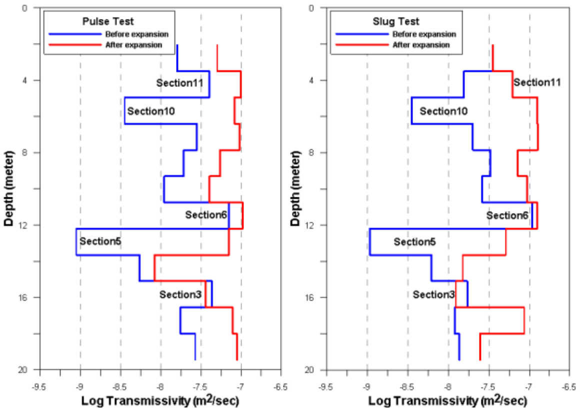
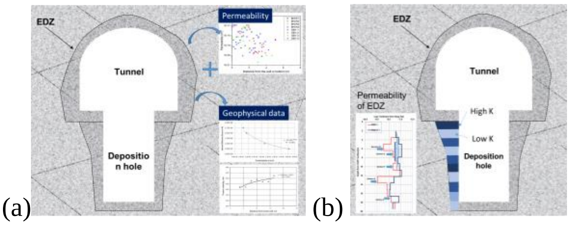


Figure 1 Transmissivity profile from hydraulic tests (pulse test and slug test) with depth in BDZ-1 before and after expanding the diameter of the borehole

2.3 Hydrogeological properties of EDZ

The findings of these experiments advocate adopting more nuanced approaches in inputting uniform hydraulic conductivity for the EDZ. Instead, a preferable methodology involves establishing correlations between the outcomes of geophysical surveys determining the EDZ depth distribution and the corresponding permeability values. Subsequently, the EDZ distribution along the tunnel or deposition hole from correlation should be inputted into the numerical model for groundwater flow simulation around a geological repository to conduct a comprehensive evaluation of disposal safety Consequently, we can suggest a reasonable approach for assigning the hydrogeological properties of EDZ. That is, the variable hydrogeological property should be applied to EDZ based on the indirectly derived through geophysical investigation (Fig. 3). To illustrate it, if the depth distribution of the Excavation Damaged Zone (EDZ) in a tunnel is determined through methods like electrical resistivity surveys or elastic wave surveys, establishing a correlation between factors derived from these geophysical surveys and permeability allows for the acquisition of data on the permeability of the EDZ.



(a) (b)

Fig. 3 Suggested procedure for determining the hydraulic conductivity of EDZ around disposal tunnel and deposition hole (a) identifying the correlation between geophysical data and permeability of EDZ (b) assigning the hydraulic conductivity based on the geophysical data to EDZ

3. Conclusions

From a disposal safety perspective, assessing the EDZ during the investigation of a disposal tunnel or deposition hole in the site characterization process is imperative. The permeability distribution results from this study underscore the significance of refraining from treating permeability in the EDZ as a singular, constant value. Instead, it highlights the necessity of acknowledging it as a variable distribution contingent upon the original permeability of the medium. Therefore, when incorporating the hydraulic conductivity of the EDZ into a numerical model for groundwater flow simulation of a geological repository, it becomes essential to establish the relationship between the distribution range obtained from indirect methods, such as geophysical surveys, and the permeability of the EDZ.

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