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Evaluation of the Hydraulic and Mechanical Characteristics of Bentonite-Sand mixed Backfill for Engineered Barrier System

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1. Introduction

SKB and Posiva Oy define the backfill material to be located in the deposition tunnel and upper part of the deposition hole. It serves two safety functions: 1) keeping the buffer in place and 2) limiting advective mass transfer [1]. These functional requirements necessitate performance targets based on hydrogeological and mechanical behavior, demanding a hydraulic conductivity of 10^{-10} m/s and a swelling pressure of 0.1 MPa as limiting conditions. Due to the early saturation phase's uneven swelling, technical design requirements are defined at 10^{-10} m/s hydraulic conductivity and 1 MPa swelling pressure [2]. Technical design requirements encompass swelling pressure, hydraulic conductivity, as well as backfill mass and deformation, and impurity-related characteristics.

The reference material for the backfill should be selected based on dry density [3], considering performance criteria. From the perspective of bentonite costs, the use of mixed backfill in central and access tunnels is suitable [4]. Therefore, this study measured the swelling pressure and hydraulic conductivity of a mixed bentonite-silica backfill at different mix ratios and dry densities, and the compliance of the backfill with technical requirements was assessed.

2. Experimental programs

Bentonite swelling in a confined volume generates resistance against swelling pressure. Thus, swelling pressure and hydraulic conductivity can be measured by applying pore pressure to a cell that can constrain volume. We manufactured cells capable of simultaneously measuring swelling pressure and hydraulic conductivity and set up a pressure controller and logger system (Fig. 1) in the laboratory of the Korea Atomic Energy Research Institute (KAERI). Swelling pressure and hydraulic conductivity were measured using an experimental procedure designed based on the conventional triaxial compression test method.

The bentonite-silica mix ratio is presented in two types: 3/7 and 4/6, with a bulk dry density ranging from 1.5 to 1.85 g/cm³ at a water contents of 15%. The bentonite used is called Bentonil-WRK, a Ca-bentonite, with a montmorillonite content of approximately 70%. The mixed silica has sizes ranging from 1.6 to 2.5 mm with a nominal diameter (i.e., *D50*) of 1.8 mm.

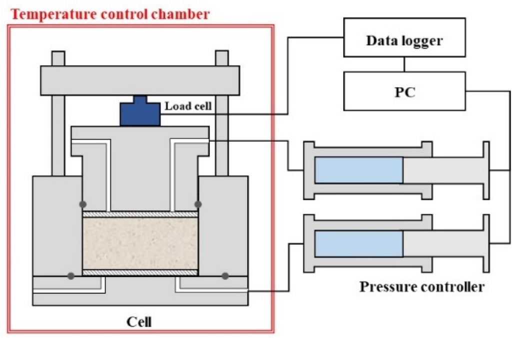

Fig. 1. Experimental setup for measuring swelling pressure and hydraulic conductivity.

The compacted mixture block volumetrically consists of bentonite and silica, and the sealing capacity bases on the properties of bentonite alone [5]. The performance of the mixed backfill should be evaluated based on the effective dry density (ρ_{db}; Eq. 1), which is the dry density of bentonite alone.

$$(1)\ \ \rho_{db} = m_b \Big/ \left(\left(\frac{\pi}{4} D^2 H - \frac{(1-R) m_b}{\rho_s} \right) \cdot (1 + w_b) \right)$$

where, m_b is the mass of bentonite (g), w_b is the water contents on bentonite (0.00%), D and H are the sample diameter and height (cm) respectively, ρ_s is the specific gravity of silica sand (g/cm³), and R is the mixing percentage (0.00%).

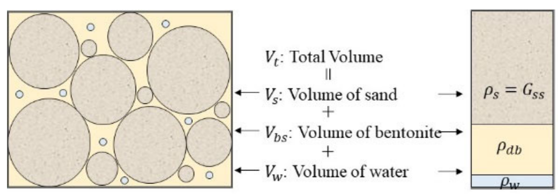

Fig. 2. Conceptual diagram of bentonite-sand mixed backfill composition.

3. Experimental results

Figure 3 depicts swelling pressure in terms of bulk dry density and effective dry density respectively. The higher the mass ratio of bentonite mixing, and the higher the dry density, the higher the swelling pressure. Even at low dry densities, swelling pressures approach or exceed 1 MPa.

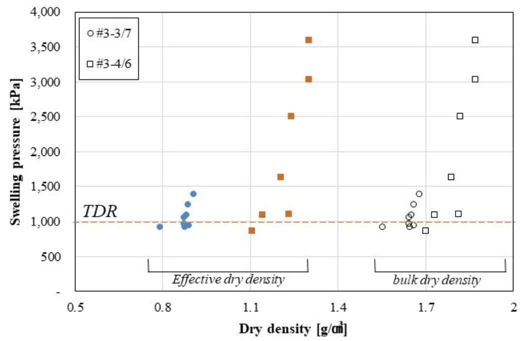

Fig. 3. Swelling pressure for different mix ratios based on dry density

Figure 4 represents hydraulic conductivity concerning bulk dry density and effective dry density. The hydraulic conductivities of the 3/7 mixing ratio mostly greater than 10^{-10} m/s.

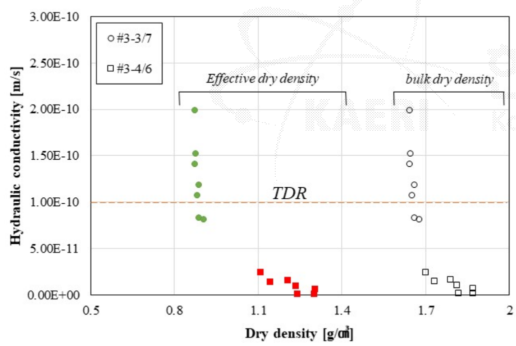

Fig. 4. Hydraulic conductivity for different mix ratios based on dry density

4. Conclusions

We measured swelling pressures and hydraulic conductivities according to variable combinations of bentonite-silica sand mixed backfill. We reviewed the performance concerning mix ratio and dry density, and compared it with the requirements. The results of this study will be utilized in the evaluation of material properties for the design guidelines of mixed backfill and are expected to contribute to the development of an engineered barrier material for the Korean disposal system.

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