Temperature Effect on the Swelling Pressure of Bentonite-Sand Mixtures

Deuk-Hwan Lee[a*], Seok Yoon[a]
[a]*Korea Atomic Energy Research Institute, Advanced Disposal Technology R&D Division*
[*]*Corresponding author: leedh21@kaeri.re.kr*

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1. Introduction

Bentonite-based buffer materials are widely considered as key components of the engineered barrier system (EBS) in deep geological repositories for the disposal of high-level radioactive waste (HLW). The buffer must provide low permeability and high swelling capacity to ensure long-term safety by limiting radionuclide migration and sealing technological voids. In repository conditions, however, the buffer is exposed to heat generated from HLW, which may influence its hydro-mechanical performance. Among these, the swelling pressure is particularly important because it governs the sealing capability of the buffer against groundwater flow [1].

To improve the overall performance and constructability of buffer materials, mixtures of bentonite with sand have been studied as alternatives to pure bentonite [2]. The inclusion of sand not only facilitates the handling and compaction of buffer blocks but also modifies their mechanical response under thermal and hydraulic conditions. Nevertheless, systematic evaluation of how temperature affects the swelling pressure of bentonite–sand (B-S) mixtures remains limited.

This study aims to investigate the swelling pressure behavior of B-S mixtures under different thermal conditions. The findings are expected to provide fundamental insights into the thermo-hydro-mechanical performance of B-S mixtures and contribute to the design of engineered barrier systems in deep geological repositories.

2. Materials and Methods

The bentonite used in this study was Bentonil WRK, a calcium-type bentonite supplied by Clariant Korea. Its main mineralogical component is montmorillonite, accompanied by small amounts of accessory minerals. The additive material was silica sand (99% pure silica sand), which was mixed with the bentonite at weight ratios of 0, 10, 20, and 30% to prepare the B-S mixtures.

Swelling pressure was measured using a custom-built swelling pressure measurement apparatusequipped with a load cell. The B-S mixtures were compacted to the target dry density and then mounted in the testing cell. After installation, a constant hydraulic pressure of 100 kPa was applied at the inlet side, while the outlet was kept open to allow free drainage. Deionized waterwas supplied from the bottom of the specimen under these conditions.

To evaluate thermal effects, the entire apparatus was placed in a temperature-controlled oven, and the tests were conducted at three constant temperatures: 25 °C and 60 °C. Each test was continued until the swelling pressure reached a stable value with time.

3. Results and Discussion

2.1 Effect of Sand Content

Figure 1 presents the swelling pressure of B-S mixtures at room temperature (25 °C) as a function of dry density. The results indicate that the swelling pressure decreases consistently with increasing sand content. This trend reflects the reduced proportion of expansive clay minerals in the mixture, which directly lowers the overall montmorillonite content responsible for crystalline swelling.

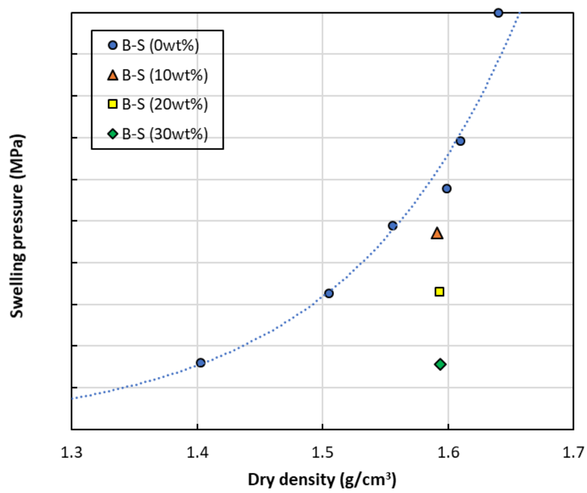

Fig. 1. Swelling pressure versus dry density at 25 °C for sand contents of 0, 10, 20, and 30%.

2.2 Effect of Temperature

Figure 2 shows the swelling pressure of B-S mixtures under different thermal conditions (25 and 60 °C). For all sand contents, the swelling pressure measured at 60 °C was lower than that at 25 °C. The reduction was more pronounced in mixtures with higher sand contents, suggesting that the combined effects of reduced clay fraction and elevated temperature significantly limit swelling development. The observed temperature dependence can be explained by the migration of pore water from micropores to macropores under heating, which induces lattice contraction and consequently reduces the swelling capacity of montmorillonite.

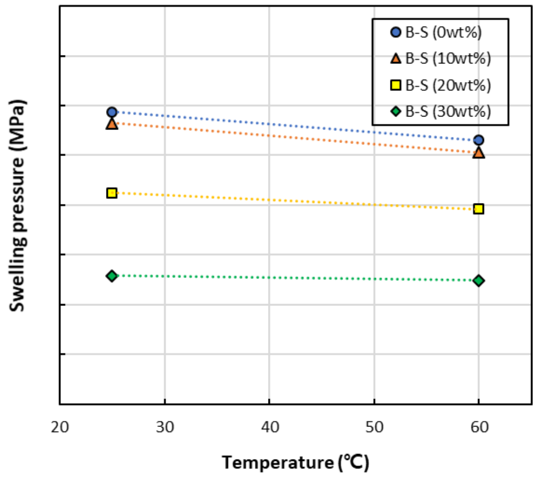

Fig. 2. Swelling pressure at 25 °C and 60 °C for different sand contents.

4. Conclusions

This study investigated the swelling pressure of calcium-type Bentonil WRK bentonite mixed with different proportions of silica sand under thermal conditions. The results showed that the swelling pressure decreased as the sand content increased, due to the reduced fraction of expansive clay minerals in the mixtures. In addition, a clear temperature dependence was observed, with swelling pressure at 60 °C consistently lower than that at 25 °C. These findings highlight that both sand addition and elevated temperature significantly influence the sealing capability of B-S mixtures, providing useful implications for the design and performance evaluation of buffer materials in deep geological repositories.

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