Effect of Temperature on Swelling Pressures During Saturation of Kunigel-V1 Bentonite

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1. Introduction

In deep geological disposal project, which was selected to deal with high level radioactive (HLW) by massive countries, a multi-barrier system would be constructed deeply underground to prevent the leakage of nuclide waste. Buffer material was paid great attention by many scholars and bentonite was chosen as candidate buffer material because of its low hydraulic conductivity and high self-healing capacity. Swelling pressures are crucial factors to evaluate self-healing capacity and were proved being affected by many elements (e.g., *Komine et al. 2009*), such as dry density, saturation liquid and concentration.

Besides above mentioned factors, the temperature effect on swelling pressures of bentonites should be taken into consideration. Among desporisitory period, the nuclide waste would decay continuously, inducing a great amount of heat. As *JNC (1999)* reported that, the temperature in buffer material is around approximate. 20°C to approximate. 90°C. Therefore, it is necessary to research the temperature effect on swelling pressures of bentonites.

2. Material, Equipment and Procedure

This study used a bentonite designated as Kunigel-V1 from Tsukinumo Mine, Yamagata, Japan. Kunigel-V1 was selected as candidate buffer material for Japanese deep geological project. The swelling characteristics of Kunigel-V1 had been investigated by plenty of researchers (e.g., *Komine et al. 2009*). The physical parameters and their values are listed in Table 1. It can be seen from Table1, the Na^+ ion dominates the cations of bentonite. Thus, Kunigel-V1 is considered as sodium type bentonite.

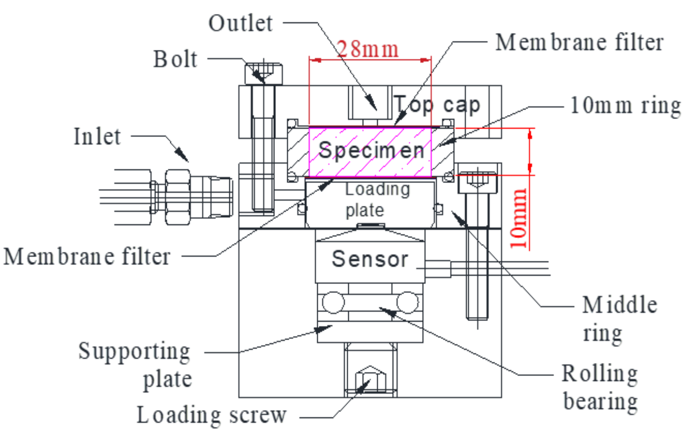
Table 1 Physical parameters and their values

Physical property		
Specific gravity, G_s (g/cm^3)		2.78
Montmorillonite content, C_m (%)		48
Total cation exchangeable capacity (CEC) and number of extractable cations (EXC)	CEC (meq/g)	1.043
	EXC_{Na} (meq/g)	0.613
	EXC_{Ca} (meq/g)	0.404
	EXC_{Mg} (meq/g)	0.02
	EXC_{K} (meq/g)	0.01

Table 2 Specimen details

Height (mm) × Diameter (mm)	10 × 28
Dry density, ρ_d (g/cm^3)	1.2–2.0
Temperature, T (°C)	25, 50 and 80

Figure 1 Swelling pressure apparatus



Oven dried Kunigel-V1 powders were compressed in the ring (10 mm, height × 28 mm, inner diameter) and installed together in the swelling pressure apparatus (Fig. 1). Then, swelling pressure apparatus was putted into the oven with the water supply container. The apparatus was placed in the setting temperature for approximate. 4 hours in order to let specimen reach target temperature. Finally, the distilled water was supplied by the inlet in the middle ring.

3. Testing results

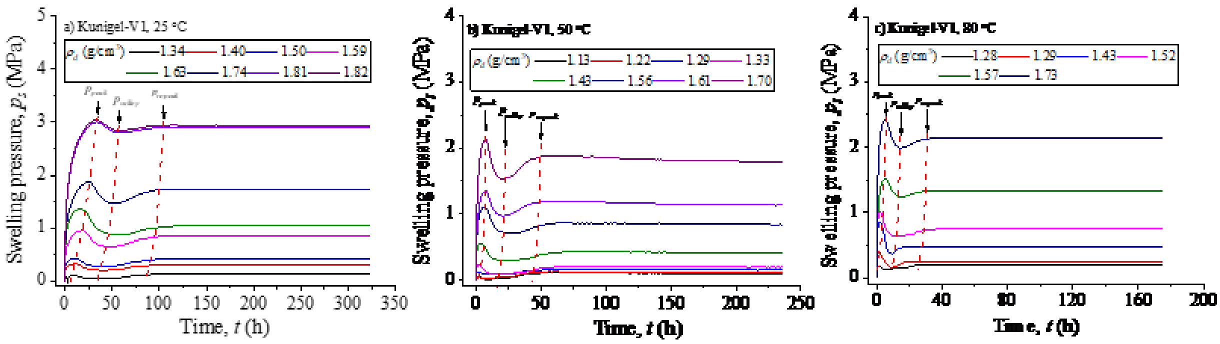


Figure 2 Swelling pressure evolution curves of Kunigel-V1 bentonite at different temperatures

Key word: Bentonite; Swelling pressure; Temperature
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Numerous studies (e.g., *Wang et al. 2021*) reported traditional swelling pressure evolution curve for compacted bentonite at room temperature, suggesting the following: First, in the early stage of saturation, the swelling pressure rises quickly to a peak point. After reaching the peak point, the swelling pressure drops continuously to a valley point. Then, following another increase of swelling pressure, the swelling pressure progresses to a re-peak point. Later, the swelling pressure remains at a stable value until reaching an equilibrium point. Figure 2 reveals swelling pressure evolution curves of Kunigel-V1 at different temperatures. It might be apparent from Fig. 2(a), (b) and (c) that, for Kunigel-V1 at different temperatures, almost all swelling pressure evolution curves are similar with the traditional curve described above. Additionally, as might be found from Fig. 2, the times needed for bentonites to reach peak points and re-peak points decrease with increasing temperature. As might be apparent from Fig. 2(a), (b), and (c), times for Kunigel-V1 bentonite to arrive peak points are approx. 25 h, approx. 10 h, and approx. 5 h, respectively, at 25 °C, 50 °C, and 80 °C. From 25 °C to 50 °C to 80 °C, the times in the re-peak points decrease from approx. 100 h to approx. 50 h to approx. 30 h.

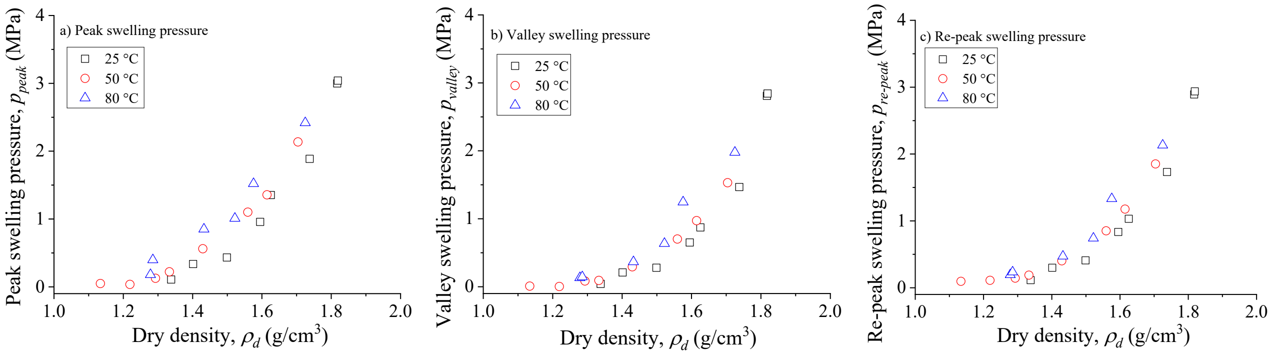
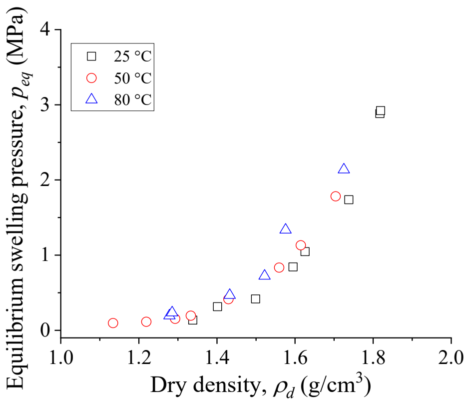


Figure 3 Peak, valley and re-peak swelling pressures of Kunigel-V1 bentonite at different temperatures



Peak swelling pressure (p_{peak}), valley swelling pressure (p_{valley}) and re-peak swelling pressure ($p_{re\text{-}peak}$) of Kunigel-V1 bentonite at 25 °C, 50 °C, and 80 °C are indicated in Fig. 3(a), (b), and (c), respectively. It can be easily found from Fig. 3(a), (b), and (c) that, p_{peak}, p_{valley} and $p_{re\text{-}peak}$ increase as the rise of dry density. Same phenomenon was pointed out by *Wang et al. (2021)* for Kunigel-V1 bentonite with different specimen thickness. Meanwhile, another interesting conclusion can be draw from Fig. 3(a), (b), and (c) that, p_{peak}, p_{valley} and $p_{re\text{-}peak}$ increase with the increase of testing temperature at the same dry density. Equilibrium swelling pressures (p_{eq}) of Kunigel-V1 at different temperatures are revealed in Fig. 4. It is a general truth from Fig. 4 that, when the dry density is the same, p_{eq} grows as the increase of temperature.

Figure 4 Equilibrium swelling pressures of Kunigel-V1 bentonite at different temperatures

Figure 5 presents $(p_{eq}-p_{valley})$ changing with dry density at different temperatures. It is apparent from Fig. 5, $(p_{eq}-p_{valley})$ increases as the increasing dry density. Additionally, $(p_{eq}-p_{valley})$ reduces with the increase of the testing temperature. This founding is different from the trend for p_{peak}, p_{valley} and $p_{re\text{-}peak}$ at different temperatures.

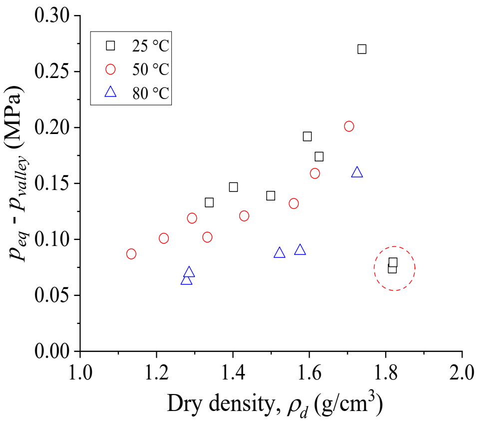


Figure 5 $(p_{eq}-p_{valley})$ of Kunigel-V1 bentonite at different temperatures

4. Conclusion

Peak, valley, re-peak and equilibrium swelling pressures of Kunigel-V1 bentonite increase with the rise of experimental temperature. $(p_{eq}-p_{valley})$ of Kunigel-V1 bentonite decreases as the temperature increases and rises with increasing dry density.

Reference

JNC 1999. Technical reliability of the geological disposal for high level radioactive waste in Japan geological disposal research and development. Second compiled General report. Japan Nuclear Cycle Development Institute, JNC TN1400 99–120. (in Japanese) Komine, H., Yasuhara, K., and Murakami, S. 2009. Swelling characteristics of bentonites in artificial seawater. Canadian Geotechnical Journal, 46: 177–189. Wang, H.L., Ruan, K.L., Harasaki, S., and Komine, H., 2021. Effect of specimen thickness on apparent swelling pressure evolution of compacted bentonite. Soil and Foundation, 62(1): 101099.