Evaluation of Relative Hydraulic Conductivity for Bentonil-WRK bentonite Buffer Material

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1. Introduction

The bentonite buffer material is a crucial component in the engineered barrier system to dispose high-level radioactive waste. The bentonite buffer materials becomes saturated by the inflow of groundwater over hundreds of years; therefore, it is highly important to investigate the water retention curve (WRC) as well as the unsaturated and saturated hydraulic conductivities of compacted bentonite buffer materials as these properties are closely related with saturated conditions [1]. The relative hydraulic conductivity can be defined as unsaturated hydraulic conductivity divided by saturated hydraulic conductivity, and potential law is widely used. In Korea, new reference bentonite which is called Bentonil-WRK is being studied since 2021. As there has been no studies to evaluate relative hydraulic conductivity for Bentonil-WRK bentonite, this study derived relative hydraulic conductivity of Bentonil-WRK bentonite.

2. Materials

Table 1 shows basic geotechnical properties of the Bentonil-WRK bentonite. The specific gravity value of Bentonil-WRK was marginally smaller than previous bentonite (KJ-II) and was classified as MH (highly plastic silt) based on the unified soil classification system. The initial water content and swelling index of the Bentonil-WRK bentonite were 13–14% and 5 ml/2g. Especially, the swelling index was 30% smaller than KJ-II bentonite. Furthermore, The Bentonil-WRK has a final montmorillonite content of 69–73 wt.%, and other minerals include 15 wt.% albite, 2 wt.% quartz, and 13 wt.% cristobalite..

3. Relative hydraulic conductivity

3.1 Theoretical background

Water in unsaturated soils does not flow through the air in the voids, but rather the water only flows along a flow path consisting of continuous water. Accordingly, water flow is dependent on the degree of saturation of the soil, and the hydraulic conductivity of an unsaturated soil is closely related to WRC(water retention curve) properties. The Eq. (1) represents an relative hydraulic conductivity function ($K_r(H_p)$) using WRC [1].

$$K_r(H_p) = \left[\frac{\left\{ 1-(aH_p)^{n(1-\frac{1}{n})}\left[1+(aH_p)^n\right]^{-(1-\frac{1}{n})} \right\}^2}{\left[1+\left(aH_p\right)^n\right]^{(1-\frac{1}{n})/2}} \right] \quad (1)$$

where α is the fitting parameter related to the air entry value and n is the fitting parameter related to the pore size distribution of bentonite. The relative hydraulic conductivity can be also expressed by the potential law of Eq. (2).

$$K_r = \left(\frac{S-S_r}{S_s-S_r}\right)^L \quad (2)$$

S, S_r, and S_s refer to the current, residual, and maximum liquid degree of saturation. L is the power coefficient.

3.2 Derivation of relative hydraulic conductivity

Once the WRC experiment on bentonite buffer material is completed, fitting parameters can be obtained.

Table 1 Basic properties for two kinds of bentonites

	Specific Gravity	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	USCS	Swelling Index (ml/2g)	Initial water content (%)	Specific surface area (m^2/g)	Grain-size distribution < 2 μm (%)
KJ-II	2.71	146.7	28.4	118.3	CH	6.5	11-12	61.5	48.4
Bentonil-WRK	2.548	97.1	42.4	54.7	MH	5	13-14	51.74	30

The relative hydraulic function (Eq. (1)) can be obtained with α and n values. Table 2 represents L values in Eq.(2). As power coefficient value is large, the relative hydraulic conductivity becomes small. The bentonil-WRK showed higher L value than KJ-II and MX-80 bentonites. It is because that MX-80 and Bentonil-WRK bentonites possess greater amounts of montmorillonite than KJ-II bentonite. It is thought that pore size increases more readily in KJ-II bentonite due to its lower swelling tendency, which is likely to lead to higher hydraulic conductivity under similar dry density condition.

Table 2. Power coefficient *L* values in Eq. (2)

Bentonite type	Power coefficient *L*	Dry density (g/cm^3)
Bentonil-WRK	3.335	1.6
KJ-II	2.644~2.756	1.59
MX-80 [1]	2.819	1.57

4. Conclusions

This paper derived power coefficient of relative hydraulic conductivity for the Bentonil-WRK bentonite buffer material, and this value can be used as an input parameter in the numerical simulation for the performance assessment of disposal system.

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REFERENCES

[1] S. Yoon, M. S. Kim, G. Y. Kim, S. R. Lee. Contemplation of relative hydraulic conductivity for compacted bentonite in a high-level radioactive waste repository, Annals of Nuclear Energy, Vol. 161, p. 108439, 2021.