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Swelling and Relative Hydraulic Conductivities of transformed Ca-bentonite with various Na-cemicals

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Abstract

To investigate the effect of solution pH and particle size of Na-bentonite on swelling characteristics and relative hydraulic conductivity, four kinds of acids and two alkali were selected. The results showed that the swelling was decreased to half of the original Na-bentonite's swelling index. Also the decrease in SI was most distinctive in pH 3.5 of HCl. But changes of swelling index between initial and stabilized were minimal in alkali treatment, compared to the change by acid treatment. No flux was detected under atmospheric pressure although there was drastic decrease in swelling. However, leaching started after application of 1.5 bars of air-pressure equivalent to 15 m of water head.

Key word : Swelling, Hydraulic Conductivity, Ca-bentonite, Activation,

1. Introduction

The swelling of smectite aggregate plays an important role in the microstructural evolution of bentonite. Bentonite is widely used as barrier material for waste disposal since bentonite possesses a remarkable swelling due to water absorption and therefore restricts the migration of water and contaminants through it. The origin of the swelling effect of bentonite has been widely studied by many researchers, in the effort to reach a fundamental approach to relate swelling potential to basic particle-water-cation interactions (Low 1987, Quirk 1997). These processes are highly complex and include fluid flow, heat transport, interaction between water/solution and bentonite, as well as mechanical reaction of the bentonite itself (Gens et al. 1998).

Bentonite swells and shrinks due to a change in water content, which can lead to cracking of the liner. Subsequently, the liner becomes more permeable. Hydraulic conductivity of a soil generally depends on electrolyte concentration and the hydraulic conductivity decreases due to swelling and dispersion of soil. Hydraulic conductivity testing, however, may take several months to perform, especially at higher bentonite contents. An alternative approach is to use mathematical models to predict the hydraulic conductivity based on the properties of the sand and the bentonite (Chapuis, 1990; Abichou, 1999). However, the effect of solution pH on swelling and relative hydraulic conductivity of bentonite has scarcely been investigated. The objective of the present study is to investigate the effect of pH and particle size on swelling characteristics and relative hydraulic conductivity of Na-bentonite, assuming that changes in pH can be occurred by decomposition of waste in a landfill site.

2. Materials and Methods

Wyoming Na-bentonite (Table 1) which contains greater than 95 % of smectite were used to measure swelling characteristics and relative saturated hydraulic conductivity according to changes of solution pH ranging from 3.5 to 8.5 adjusted with acids (HCl, Phosphoric acid, Citric acid, and Oxalic acid) or Alkaline (KOH and NaOH). To measure the swelling indexes(SI) of the bentonite, bentonite samples were sieved to separate into four different sizes of particles (60-80 mesh, 80-100 mesh, 100-120 mesh, and 120 mesh or greater). 2.00 grams of each separated bentonite were slowly added to 100 mls of different pH solution in a graduate cylinder and left it over until there were no more changes in swelling. Hydraulic conductivity was measured with powdered Na-bentonite manufactured by Sudco, Inc. As a mixing material, clean commercial sand was purchased and soil (clay loam) collected from upland located at Gongjoo Chungnam, Korea was air-dried and ground to pass 2 mm sieve before use (Table 2).

Table 1. Properties of Na-bentonite.

Property	Value
Liquid limit (%)	487
PI (%)	450
#200 Sieve (%)	65
Specific Gravity	2.55
SiO_2 (%)	63.97
MgO (%)	15.66
Na2O (%)	4.51
CaO (%)	3.46

Table 2. Chemical properties of a mixing material

Property	Value
Soil texture	Clay loam
pH	6.15
EC (dS m^{-1})	1.74
OM (%)	2.52
CEC(cmol kg^{-1})	2.55
K (cmol kg^{-1})	0.012
Na (cmol kg^{-1})	0.011
Ca (cmol kg^{-1})	0.010
Mg (cmol kg^{-1})	0.005

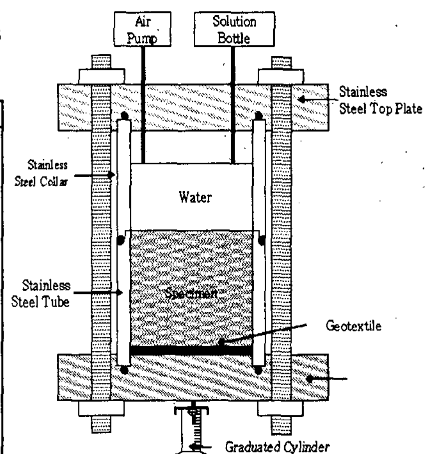

Fig. 1. Diagram of Rigid Wall Permeameter

The bentonite content was from 0 % to 100 % with 10 % increment by weight for sand or clay soil. The hydraulic conductivity tests were performed on compacted sand (or clay)-bentonite mixtures in a modified rigid wall permeameter equipped with an air pump to apply pressure over the top of the specimens (Fig. 1). After saturating the specimens with deionized water, hydraulic conductivity was measured while maintaining 5 cm hydraulic head with different pH solution for each column. Also additional air pressure in addition to hydraulic head was applied over the water surface of the column if effluent from the bottom of the column was not collected for 3 days after starting experiment. The air pressures applied by air pump were 150, 300, and 500 kpa. Each pressure was continued until steady hydraulic conductivities of the specimens were obtained.

3. Results and Discussion

In Fig. 2 through 6, we observed the swelling characteristics of four different sizes of bentonite particles influenced by acidic or alkaline conditions. The swelling of Na-bentonite treated with distilled water was approximately 110. As shown in Fig. 2, the swelling of 60-80 mesh size of bentonite particle was gradually increased with increasing retention time and the maximum swelling indexes (SI) ranged from 35 to 43 for pH 3.5 and 4.5, respectively. However, the increase in SI was retarded after 72 hours in pH 4.5 while SI still gradually increased in pH 3.5. This indicated that the pH was significantly reduced the swelling compared to that of original Na-bentonite. For changes in SI depending on the particle size, SI decreased with increasing particle size although the maximum SI was increased with increasing particle size. Compared the effect of acid type on the swelling of bentonite, HCl was most effective in reduction of swelling and lower pH was slightly effective in reduction of swelling. The order of reduction for the acids was as follows: HCl > Phosphoric acid > Citric acid ≈ Oxalic acid. For the effects of neutral and alkalinity on swelling, the results showed that the maximum SI was slightly higher by 5 for the Na-bentonite treated with pH 8.5 solution of NaOH than those of Na-bentonite observed from acid treatments. The changes in SI were not distinctive throughout the experiment except pH 8.5 solution of NaOH. Figure 2. Comparisons of swelling for 60-80 mesh particles in pH 3.5 and 4.5 (left) and 7.5 and 8.5 (alkali) adjusted with different chemical sources

For pH 8.5 solution of NaOH, SI rapidly approached to the maximum SI till 72 hours and then stabilized. Although the maximum SI treated with alkaline solution was less than half of the original Na-bentonite, the maximum SI observed from alkaline solution was similar to the results observer from pH 4.5 of citric acid. From these results we could assume that the types of chemical are important in changes of SI.

Hydraulic conductivities (HS) were measured with a modified rigid wall permeameter by treating distilled water and three different pH solution adjusted with oxalic acid and KOH (Fig. 6). The results showed that there was flux detected from the bottom of the permeameter under atmospheric pressure although the swelling was poor. However, the effluent was collected as air pressure was added through the air nozzle over the water surface. The highest initial HS obtained from distilled water head was approximately 8 x 10^{-3} cm day while HS's from treatments of pH 3.5, 6.5, and 8.5 were 4.2 x 10^{-3}, 5.01 x 10^{-3}, and 3.45 x 10^{-3} cm day-1, respectively. However, the HS's were rapidly stabilized to around 1 10^{-3} cm day-1, respectively. In this we could not find any air-pressure effect on the stabilized HS. But there were distinctive differences in HS before HS reached to the stabilized HD observed in this experiment.

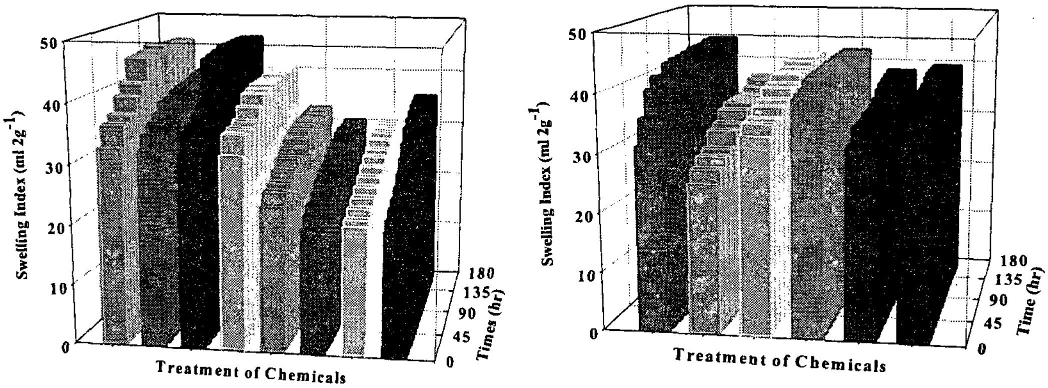

Figure 2. Comparisons of swelling for 80-100 mesh particles of bentonite in pH 3.5 and 4.5 (left) and 7.5 and 8.5 (alkali) adjusted with different chemical sources

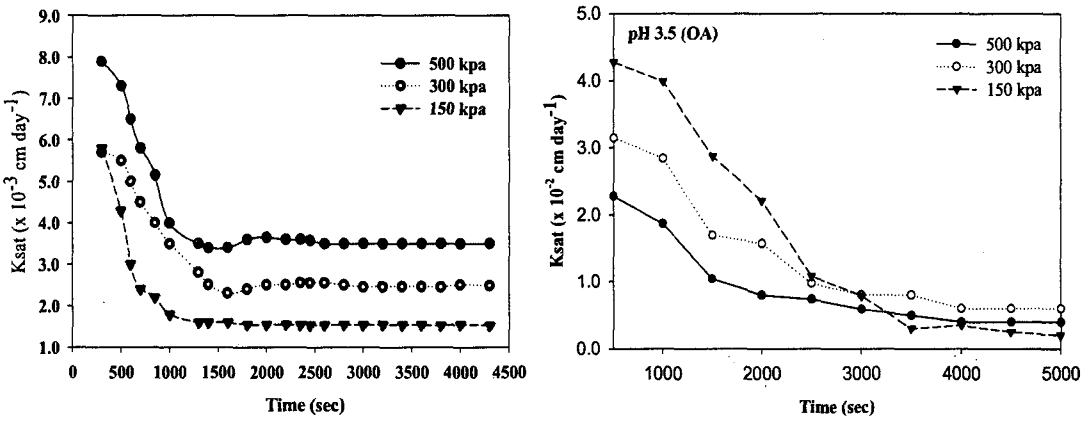

Figure 3. Hydraulic conductivities of Na-bentonite by different pH solution through the permeameter

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