토목건축재료용 벤토나이트 겔의 팽윤 메카니즘

전한용
인하대학교 나노시스템공학부

Swelling Mechanism of Bentonite Gels for Civil and Architecture Materials

Han-Yong Jeon
Division of Nano-Systems Engineering, Inha University, Incheon, Korea

1. Introduction

Geosynthetic clay liners of bentonite gels have been used as a barrier to migrating liquids in civil and architecture fields, because it gives the excellent expand and sealant property at wet stage. Swelling procedure of sodium bentonite happens due to the sodium carbonate through ion exchange equilibrium process. Then, due to the flow of water, the micro structure is changed from smaller, finely distributed clay mineral flakes to larger clay mineral crystals with giving lesser permeability. Also, swelling of bentonite gels is generally attributed to the volume of water molecules that are bound to the clay surface, size and valence of cation and pH values of permeant liquids. In this study, we analyzed the swelling of bentonite gels of powder and granular types in mono-valent and bi-valent cation solutions.

2. Experimental

Sodium bentonites of powder and granular types were used in this study. NaCl, KCl, $CaCl_2$ and $MgCl_2$ were used as permeate liquids. Free swell tests were carried out in accordance with ASTM. D5890. Approximately 90 ㎖ of 0.1 mol/ℓ solution (NaCl, KCl, $CaCl_2$ or $MgCl_2$) or distilled water was poured into a clean 100 ㎖ graduated cylinder. And then, it was placed the cylinders in water baths under room temperature (approximately 16°C), 30°C, 40°C, 50°C and 60°C. After this, swollen volume of bentonite was measured by direct reading the cylinder scale (㎖) in every 24 hours. In order to observe the effect of pH on bentonite swelling, HCl and NaOH solutions with different pH values were used. In addition, the effect of pH on bentonite swelling was investigated in HCl ($1<pH<6$) and NaOH ($8<pH<12$) solutions were used under mentioned temperatures and swelling volume was measured in every 24 hours till come to a stable volume.

3. Results and Discussion

Swelling behavior of bentonite in types of powder and granular in NaCl solutions under different temperatures. It is clearly seen that swelling volume is depend on the bath temperature till 7^{th} experimental day. After that, swelling of bentonite lies at a constant level of 14㎖. Thus, higher temperatures rapidly bring the bentonite to a stable swelling volume. Also, powder bentonite rapidly comes to a stable swelling volume at higher temperatures. During swelling, bentonite stays at constant level/s for certain period before come to a stable volume, but powder bentonite at 60°C is an exceptional case. $CaCl_2$ (+2 ions) solution gave lower swelling volumes to powder and granular bentonite compared to the swelling volumes given by NaCl and KCl solutions. The pH value cannot be affected on this change, because, we maintained the pH values approximately in same range (about 7) in all above mentioned solutions. Thus, they also show the temperature dependency of bentonite swelling. Hence, higher temperature gives higher swell volumes and quickly came to a highest state. Meanwhile, powder bentonite indicate higher swell volumes than with granular bentonite. Swelling behavior of powder and granular bentonite in $MgCl_2$ (+2 ions) solution under different temperatures showed the lowest swelling volumes under all temperatures tested. Even though solution pH value is slightly higher than other cases, it is hard to think its' significant effect on the lowest swell volume. Distilled water gives highest swelling volumes to both powder and granular bentonite with experimented temperatures, compared with other solutions. We hypothesized the reason for this as that distilled water does not possess any valent ions to attract inner crystalline layers of bentonite compared to mono-valent(; +1 ion) or bi-valent(; +2 ions) solutions. Thus, powder form gave slightly higher swell volume than granular form of bentonite. Thus, bentonite swells in distilled water is also temperature dependence reaction and higher temperatures bring bentonite (both forms) quickly come to a stable swell volume. For swelling behavior of Sodium bentonite powder and granular forms with different pH values (using HCl and NaOH solutions) under different temperatures. We changed the pH values from 1 to 12, without considering 13 and 14, because these pH values were not familiar to leachate. It is clearly seen that $pH<3$ and $11<pH<12$ show a greater influence on swelling of bentonite. Specially, with lower pH values increase and higher pH values decrease the swell volume, in concern of active pH ranges. Usually, a higher temperature and powder bentonite (compared to granular form) leads to higher swell volumes

4. Conclusion

Swelling behavior of bentonite gel depends on permeate liquids. Solutions with mono-valent(; +1 ion) cations swell the bentonite highly than bi-valent(; +2 ions)cation solutions. Thus, swell volume also depends on the reactive power of these cations. Distilled water gave highest swell volumes among all tested solutions. Hence, swell volume depends also on the temperature of solutions as higher the temperature higher the swelling rate. Powder bentonite showed comparatively higher swell volumes than their granular form. The pH value also effect on swelling volumes of bentonite as lower pH values ($pH<3$) increased and higher pH values ($11<pH<12$) decreased the swell volume of powder and granular sodium bentonite.

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