# THE STUDY ON SWELLING INDEX OF SODIUM BENTONITE UNDER DIFFERENT CONDITIONS

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## ABSTRACT

Sodium bentonite is the most important material in geosynthetic clay liners. The anti-leakage capacity of geosynthetic clay liner directly depends on the swelling index of sodium bentonite. According to the practical application of geosynthetic clay liners, this paper studies the swelling index of sodium bentonite in solutions with different PH value such as --1, 3, 5, 7, 9, 11, and 13, and in salt solution similar to sea water. It also presents the swelling index of sodium bentonite in acidic, neutral, alkaline and sea-water-like salt solutions under different temperatures such as 10℃, 20℃, 30℃ and 40℃. The experimental results shows that the swelling indexes of sodium bentonite are lower in PH=1 and sea-water-like solutions than in others, but different temperatures have little effect on the swelling index of sodium bentonite in all solutions. The results have been analyzed and discussed.

*Keywords: Sodium bentonite, geosynthetic clay liners, solution, swelling index*

## INTRODUCTION

Geosynthetic clay liners are new environment friendly and efficient water-proof materials, which can be used in urban construction, irrigation works, landfills, public garden, petrochemical, mining and many other areas for leak-proof[1]. Sodium bentonite is the most important material in geosynthetic clay liners. The anti-leakage capacity of geosynthetic clay liners directly depend on the swelling index of sodium bentonite. In practical engineering applications, geosynthetic clay liners often have to meet the needs of blocking acidic and alkaline filtrate. In some coastal areas, it is also needed to block sea water. In addition, the temperatures differ when laying geosynthetic clay liners in different regions or in different seasons, so studying the effects of temperature on the swelling index of sodium bentonite also has some practical significance.

## PRELIMINARY ANALYSIS

Bentonite is a kind of sticky mineral with montmorillonite minerals as the main components. The strong cation exchange capacity, dilatability, absorbability, dispersivity, cohesiveness, colloidal and suspension property are the typical advanced performances that the bentonite possesses. According to the reported work, under the laboratory conditions, the swelling ratio of a bentonite particle could achieve 10 to 30 times of its original volume after treated by water. Furthermore, the bentonite particle was dispersible in an aqueous medium, and presented a colloidal suspension, which had strong cation exchange capacity and adsorbability.

The montmorillonite which composed by the crystallized mineral, belongs to the monoclinic system. It is closely related to the layer silicate mineral, with the theoretical chemical formula as $Na_x(H_2O)_4\{Al_2[Al_xSi_{4-x}O_{10}](OH)_2\}$. Its structural unit is composed of two silicon-oxygen tetrahedron $[SiO_4]$ and one alumina octahedral sheet $[AlO_2(OH)_4]$ in between of them. In the tetrahedral crystal structure, tetrahedrons are connected by three angles with each other in the same plane, which compose a hexagonal symmetry with the fourth angle pointing to the center of the structural layer. The tetrahedrals and octahedrals are connected by the oxygen atoms which are on the top of the shared tetrahedrals, and overlapped along the direction of the c-axis. Because the connecting force between the oxygen atoms in different crystal layers are quite small, water and other polar molecules could easily enter the crystal layer, which causes the variability of the distance between the structural layers on the c-axis.

If the replacement ions don't exist in the betonite, the positive and negative electric charges are balanced. In fact, in the montmorillonite crystal structure, the Si4+

in the silicon-oxygen tetrahedron is partially replaced by $Al^{3+}$ and $P^{5+}$, and the $Al^{3+}$ in the octahedron was partially replaced by the $Mg^{2+}$ 、 $Fe^{3+}$ 、 $Zn^{2+}$. This kind of omorphism replacement causes the excess negative charges in the crystal unit cell. The cations such as $Na^{+}$、$Ca^{2+}$ are kept being absorbed into the crystal layers in order to compensate the excess negative charges until the charges are balanced. The absorbed cations are able to be replaced by other cations. And due to the hydrability of the cations, there are hydrated cations absorbed in between the montmorillonite crystal unit layers, which also causes the crystal expansion on the c-axis. Thus, the betonite is much favoured due to its good dilatability, adsorbability, and cation exchange capacity.

Depending on the different adsorbed ions in the montmorillonite, the bentonite was defined as sodium bentonite, calcium bentonite, and hydrogen (aluminum) based bentonite. The linkage between the crystal unit layers and the sodium bentonite is quite weak. Moreover, due to the small diameter and the low ionic valence of the sodium ion, it's easy for the water to enter the crystal unit layers, which cause the lattice expansion[2-4] .

## MATERIALS AND APPARATUS

Sodium bentonite taken from geosynthetic clay liners was used in this study as raw material. Sulfuric acid, sodium hydroxide, sodium chloride, magnesium chloride, anhydrous calcium chloride, potassium sulfate and deionized water were used to prepare solutions with different value-1, 3, 5, 9, 11, 13, and sea-water-like solution, the component of which is NaCl 26.75g/l, $MgCl_2$ 2.25g/l, $CaCl_2$ 1.25g/l, $K_2SO_4$ 2.25g/l. A temperature test chamber provides conditions of different temperatures, and also the means to dry the bentonite.

## TEST METHODS

Grind the sodium bentonite sample to passing a 200 mesh U.S. Standard Sieve with a mortar and pestle. Place the bentonite sample in the temperature test chamber and maintain it at 105±5℃ for 14 to 16h. Weigh 2.00g of dried and finely bentonite sample of each part. Add 90ml solutions prepared above, PH value=1, 3, 5, 9, 11, 13, deionized water and the sea-water-like solution, to 100-ml graduated cylinders. Add each part of bentonite sample, not more than 0.1g increment each time, into the graduated cylinders carefully. Allow the bentonite sample to wet, hydrate and settle to the bottom of the graduated cylinders for a minimum period of 10 min. Raise the solution volume to 100-ml mark after the entire 2.00-g samples have been added. Record the volume levels in milliliters (ml) at the top of the settled benotonite after 24h, which is the swelling index of sodium bentonite in the solutions.

Repeat the steps above but replace the graduated cylinders with PH value=1, 5, 9, 13, deionized water and the sea-water-like solutions in the temperature test chamber under 10 ℃ , 20 ℃ , 30 ℃ and 40 ℃ respectively for 24h, then record the volume levels in milliliters (ml) at the top of the settled benotonite.

## RESULTS AND DISCUSSIONS

### Swelling Behaviors of Sodium Bentonite in Solutions with Different PH Value and Deionized Water

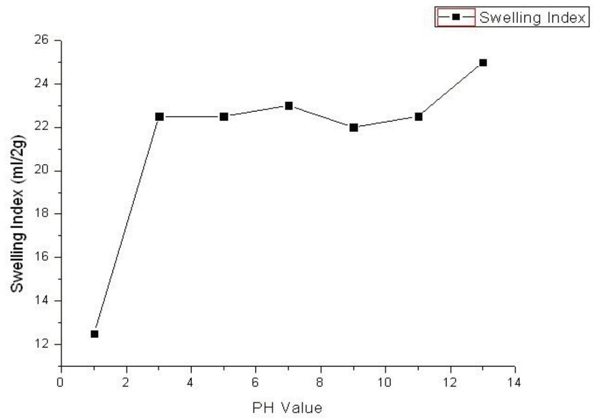


Fig.1 Swelling index of sodium bentonite in solutions with different PH value and deionized water

From Fig. 1 it can be seen that in the solution with PH = 1, the swelling index of the sodium bentonite is lower than in other solutions. The swelling indexes in solutions with PH=1, 3, 5, 9, 11 are similar as it is in pure water. The solution with PH = 13 has a slightly larger swelling index than most others. This shows that the acidic solutions and alkaline solutions within a certain range of concentrations have little effect on the swelling index of the sodium bentonite. But if the PH value is less than 3, the swelling index declines significantly. We also found that in the process of adding the samples, the bentonite in solutions of PH=1, 3, 13 wet very fast and settle to the bottom with a short time. When the bentonite fully expanded, the solutions of pH = 1, 3, 13 are very clear and have barely soil particles suspended. While soil particles suspend in other solutions and pure water, making which looked muddy.

The cause of the phenomenon and the results of the experiments above, is generally believed that it is possible due to that the radius of $H^{+}$ is less than $Na^{+}$'s. And $H^{+}$ has more positively charged. When the $H^{+}$ concentration in solution exceed a certain value, the presence of great number of $H^{+}$ tend to replace the $Na^{+}$ absorbed in the tetrahedron of montmorillonite. The vacancy of $H^{+}$ in the ion orbit is less than $Na^{+}$'s, so $H^{+}$ could combine with less number of water molecules than $Na^{+}$. Less water molecules entering the crystal layer, less the c-axis expands. When the $OH^{-}$ concentration is greater than a certain value, a large number of $OH^{-}$ reduced the $H^{+}$ concentration of the solution, $Na^{+}$ could hydrate more easily. On the other hand, when $Na^{+}$

contact with some $OH^-$, the c-axis expands larger than $Na^+$ contact with H-O-H, of which bond angle is 104.5° .

The basic structure unit of layered silicate is silicon-oxygen tetrahedron and aluminum octahedron. The octahedron containing aluminate will hydrolyze in acidic or alkaline conditions. The higher the concentration of $H^+$ or $OH^-$ is, the greater the degree of hydrolysis is, and the solution is clearer. In the solution close to neutral, the degree of hydrolysis is small. The swelling montmorillonite will continue to be suspended in the solutions.

**Swelling Behavior of Sodium Bentonite in Seawater-like Solution**

In the seawater-stimulated solution which contains several halides and sulfates, the swelling index of the sodium bentonite is only 7ml/2g, which could hardly be observed. Additionally, the bentonite was moistened quite fast in the process of being added in to the solution. There is no soil particles suspended observed in the clear solution after 24 h standing.

According to some reported work, the bentonite could be modified by the salts. In the halides such as the sodium, magnesium, and potassium or the sulfate, the metal cations with low valence and large diameter balanced the negative charges on the silicon-oxygen tetrahedron, thus the force between the ion and the structural unit layer is very week. These structure characters cause the replacement of the cations in different layers. Moreover, because the bentonite could be peeled off and separated into even thinner single crystal layers under the effect of the solution between the layers, the bentonite possesses a large internal surface area. The huge and charged specific surface area causes the strong adsorbability, which result in the fast moistening of the soil particles in the water[7]. Furthermore, the existing of variety cations could lead to the interaction between the cations, which greatly reduce the crystal structure of the layered silicate. The water molecules are difficult to enter the crystal layer, which greatly reduce the swelling index.

**Swelling Index Comparison of the Sodium Bentonite in Acidic, Alkaline, Sea-water-like Solutions and Water under Different Temperatures**

As shown in Table 1, along with the change of temperature, the swelling index of the bentonite in different solutions did not change significantly. Although the reading numbers on the cylinder could be affected slightly by the temperature, we considered this minor deviation hardly effected on the results. According to the references, the water molecular activeintense activity in a higher temperature, which cause the soil particles smaller in the vertical direction of the crystal. Additionally, the change of temperature also have an impact on the inorganic salt[8]. However, under normal natural environment and temperature, this effect is not obvious.

Table 1 The swelling index comparison of the sodium bentonite in various solutions under different temperatures. (ml/2g)

| | PH=1 | PH=5 | water | PH=9 | PH=13 | sea-wat e-like |
|---|---|---|---|---|---|---|
| 10℃ | 12.0 | 23.0 | 23.0 | 23.5 | 23.0 | 7 |
| 20℃ | 12.5 | 22.5 | 23.0 | 22.0 | 25.0 | 7 |
| 30℃ | 12.5 | 22.0 | 23.0 | 23.0 | 24.0 | 6 |
| 40℃ | 13 | 22.0 | 22.0 | 23.0 | 23.0 | 6 |

## CONCLUSIONS

a) The PH value of solutions has an effect on the swelling index of the sodium bentonite. Swelling index significantly decreased when in solution with PH value under 3. The concentration of $OH^-$ could increase swelling index of bentonite in a certain extent.

b) The adsorption of sodium bentonite will enhance when a variety of metal ions coexisting in solution., but the swelling index will greatly decline. It is recommended that when laying geosynthetic clay liners in the coastal areas, it would be better to spray some water on it before laying.

c) The normal natural temperature has little effect on the swelling index and adsorption properties of the sodium bentonite.

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