Swelling Pressures of an Untreated and a Na-treated Bentonite

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One of the major functions of buffer in a high-level waste repository is to play a role of self-sealing. The bentonite, which is widely favored as a buffer material because of high swelling capacity, closes any voids and cracks in the repository thereby to prevent the intrusion of ground water into the repository. However, the bentonite should be designed to have a swelling pressure as low as possible to avoid excessive load to container and the surrounding rock when used for the buffer of repository. It, in this connection, is of essence to investigate the swelling pressure of the bentonite. This study presents the swelling pressures of an untreated bentonite taken from Jinmyeon mine and a treated bentonite which is obtained from its contact with 10 % of Na_2CO_3 solution in a commercial plant (hereafter referred to as a Na-treated bentonite). The swelling pressures are also presented as a function of the dry density of compacted bentonites.

The X-ray diffraction pattern of the untreated bentonite is shown in Fig. 1. The bentonite was found to be of Ca-type and its mineralogical composition was 64.7% montmorillonite, 34.3% feldspar, and 1.00% quartz. Its chemical composition was 56.8 % SiO_2, 20.0 % Al_2O_3, 6.0 % Fe_2O_3, 2.6 % CaO, 0.8 % MgO, 0.9 % K_2O, 1.3 % Na_2O, 0.2 % FeO, 1.3 % SO_3, and 0.8 % TiO_2. The cation exchange capacity was 57.6 meq/100g. Compacted bentonites were prepared as follows: Bentonite sample was oven-dried at 105 ℃ and weighed in a given mass; The water was added to the weighed sample using ultrasonic sprayer to adjust a desired water content; After the adjustment of water content, the sample was put into a polyethylene zip-bag and kept in a desiccator for overnight to give uniform distribution of the sprayed water in the sample; Then, the known mass of sample was compacted uniaxially into a stainless steel cylindrical mold to a given dry density and again was left in a desiccator for 24 hours to reach equilibrium. The swelling pressures were measured using an experimental apparatus shown in Figure 2. The main test section consists of a stainless steel cylindrical cell of which the dimension was 5×10^{-2} m in height and 5×10^{-2} m in diameter, porous metal filters to avoid the loss of bentonite particles, and swelling pressure sensors. Swelling tests start with feeding the pressurized water after the zero point of pressure sensor was adjusted, and the swelling pressures sent from the sensor were collected in a given time interval using personal computer. The swelling pressures are effective ones which are obtained by subtracting an applied pressure from the collected swelling pressures. These tests are performed at 20℃, and proceed until the swelling pressure reaches steady-state. Fig. 3 is an example to represent the change of swelling pressures with the contacting time of sample and water. As shown in the figure, the swelling pressures develop rapidly until they reach a peak in a few days. Subsequently, the swelling pressures start to decline gradually to a constant value. These tests ended in 30 days because the time-dependent behavior of the swelling pressure was regarded as reaching steady-state.

The swelling pressures obtained are plotted in Figure 4. The swelling pressures are in the range of 10 Kg/cm^2 to 143.5 Kg/cm^2 for the untreated bentonite and 3.7 Kg/cm^2 to 92.4 Kg/cm^2 for the Na-treated bentonite. They increase with increasing the dry density of compacted bentonites. The dependence of the swelling pressure upon the dry density is more sensitive at higher dry densities. There is a slow increase of the swelling pressure up to a threshold dry density between 1.6 Mg/m3 and 1.8 Mg/m3. Above the threshold dry density, the swelling pressure rises at a much steeper gradient. Such a behavior of the swelling pressure was also reported in Gray et al.'s experiment [1], in which the threshold dry density was found to be between 1.6 Mg/m3 and 1.7 Mg/m3. The steep increase of the swelling pressure beyond the threshold dry density is supposed to be due to the anisotropic nature of the compacted bentonite. SEM analysis offered an explanation for the anisotropy. The bentonite at lower dry densities consists of randomly arranged aggregates of bentonite particles (micropeds), while, at the dry densities above the threshold value, interparticle voids are mostly eliminated, the micropeds become fused, and the topography is relatively uniform. This suggests that the micropeds of bentonite particles beyond the threshold dry density are arranged in a nearly parallel orientation and thus the corresponding swelling pressures increase steeply. On the other hand, Pusch [2] put out for this phenomenon the explanation that the force of hydration on the surface of particles or their interlamellar layers may be of significance in the swelling pressure of highly compacted bentonite with the densities of 2.0 - 2.1 Mg/m3.

1. M. N. Gray, S. C. H. Cheung and D. A. Dixon, "Swelling Pressures of Compacted Bentonite/Sand Mixtures," AECL TR-350, pp. 776-785, Canada (1985).

2. R. Pusch, "Water Uptake Migration, and Swelling Characteristics of Unsaturated and Saturated Highly Compacted Bentonite," SKBF/KBS Teknisk Rapport 80-11 (1980).

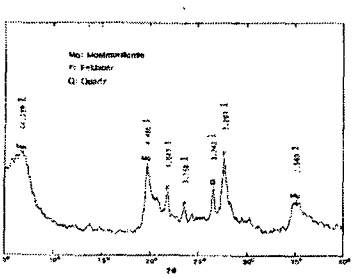

Figure 1 XRD pattern of untreated bentonite.

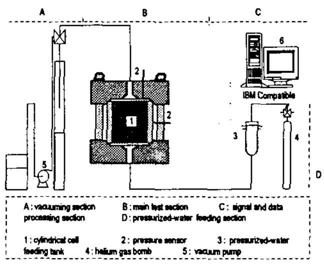

Figure 2 Swelling Test Apparatus

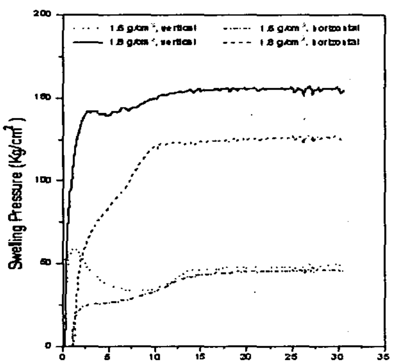

Figure 3 Development of swelling pressure versus elapsed time

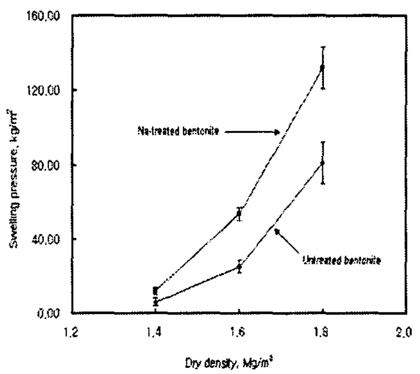

Figure 4 Swelling pressures of an untreated and Na-treated bentonite.