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Approach for Measuring Swelling Stress of Buffer Backfilling Material

Ming Zhang, Huyuan Zhang, Suli Cui and Lingyan Jia
Key Laboratory of mechanics on Disaster and Environment in Western China,
Lanzhou University, China

Abstract: The characteristics of swelling stress of buffer backfilling material have been studied by force-balance method and constant volume test method in this paper. The constant volume test apparatus was designed by the authors. Results show that swelling stress changing with time is a little different between the two methods. The value of swelling stress measured by constant volume test is more accurate; besides, uptaking water with time could also be monitored by constant volume test. The constant volume test method is more suitable for measuring the swelling stress of buffer backfilling material.

Keywords: Bentonite, swelling stress, buffer backfilling material, high-level radioactive waste, measuring approach

INTRODUCTION

GMZ bentonite mixed with sand is often considered as possible buffer backfilling materials in deep High-Level Radioactive waste disposal in China (Wang *et al*., 2006; Dixon *et al*., 1985). Bentonite swells by taking in water between the layers of Montmorillonite in it. The pressure applied to a confining structure by expanding montmorillonite is the swelling pressure (Liu *et al*., 2001; Sridharan *et al*., 1986). However, the stress applied on the confined boundary surface when a bentonite specimen is infiltrated with water is not always equal to the swelling pressure and so the applied stress on this confined boundary surface is defined here as the ”swelling stress” (Nakano *et al*, 1984; Furuichi *et al*., 1998). The characteristics of swelling stress of buffer backfilling material have been studied by force-balance method and constant volume test method in this paper to find out the more suitable method.

MATERIALS AND METHODS

Materials: The constituents of the mixtures evaluated in this research included a processed sodium bentonite and a kind of fine sand. The GMZ bentonite (powder), obtained from Inner Mongolia northwest in China, was supplied by CNNC Beijing Research Institute of Uranium Geology. The physical and chemical properties and miner alogical composition of the bentonite are summarized in Table 1 (Liu and Wen, 2003; Zhang *et al*., 2009). Its high montmorillonite content assures a high swelling potential even at low dry density. This important swelling capacity (higher than calcium bentonite) is attributed to the big hydrated radius of Na^+ (Mitchell, 2005). In addition, the particle density of Fulong quartz sand used in this research is 2.65 g/cm^3 and particle diameter ranges from 0.5 to 1.0 mm. The sand has always assumed hydration inert due to its old origin and long contact with water coming from river.

Methods: Figure 1 and 2 show the equipment used for measuring the swelling stress. For test apparatus WG high-pressure triple combination consolidometer, the swelling stress was performed by using the force-balance principle. Specimens (D61.8 mm×H20 mm) in stainless ring to prevent corrosion, covered with two porous stones at upper and lower surfaces, respectively. The piston of the cell, adjoined to the upper porous stone, was kept in contact with the loading ram, whose displacement can be accurately measured by a dial gauge. The specimen was submerged by water injecting into the container from its bottom to top. As soon as the specimen started to swell, suitable weights were loaded to the loading ram to make the pointer of the dial gauge return to its initial note. With this system, the load applied was recognized as the swelling stress.

For constant volume test apparatus of measuring swelling stress, the compacted samples (diameter 60 mm, height 40 mm) were set in stainless steel cell and covered with two porous stones at upper and lower surfaces, respectively. The middle part of porous stone was excavated firstly, so that the pressure transducer (diameter 17 mm) could be settled in the middle of porous stone. The sample was confined in the stainless steel clamp without volume changing when the water was supplied to the sample from the bottom. The YJ-35 statically resistance strain gauge, connected with BX-1 soil pressure transducer, were used to monitor the micro-strain (less than 1/104) at water inletting surface of samples during test process. With the Existing correlation coefficient, the

Corresponding Author: Huyuan Zhang, Key Laboratory of mechanics on Disaster and Environment in Western China Lanzhou University, China, Tel.: 15002659551

Fig. 1: Apparatus A: WG high-pressure triple combination consolidometer

Fig. 2: Apparatus B: Constant volume test apparatus for swelling stress

swelling stress could be calculated quickly. Besides, the weight of stainless steel clamp, including sample and two designed by the authors could monitor the water in taking

Table 1: Characteristics of GMZ bentonite and quartz sand used

GMZ bentonite				
Particle diameter	Bentonite content	Specific surface	Air-dried water content	Plastic limit
Main<2mm	74%	570 m^2/g	10.53%	32.43%
Fulong sand				
Liquid limit	Specific gravity	Particle diameter	Silica content	Specific gravity
228%	2.71	main 0.5~1.0 mm	99.45%	2.65

process easily. As shown in Fig. 4, in the initial stage of test, the swelling stress increased rapidly, due to the absorbing a lot of water. Then, the swelling stress increased slowly, because the speed of absorbing water decreased. That is to say, the swelling stress development process of bentonite with time shows phase characteristics. It becomes clear that the microscopic structure of buffer changed from drastic to stable in the water infiltration process. It is known that there are three methods to measure swelling stress (Sridharan *et al*., 1986; Ye *et al*., 2007). The path of the two methods in this paper could be expressed in Fig. 5. The specimen was submerged by water injecting into the container from its bottom to top. As soon as the specimen porous stones, was measured in the test process. The layout of the

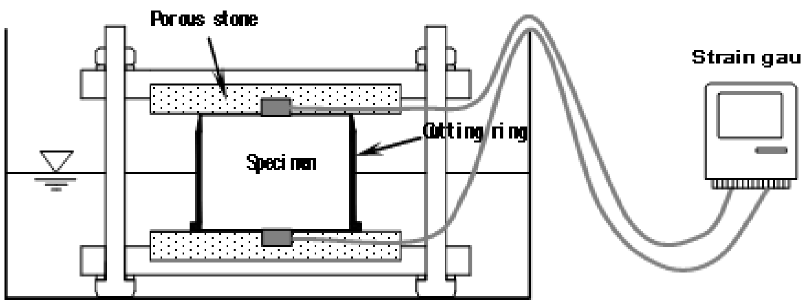

Fig. 3: Layout of the constant volume test apparatus

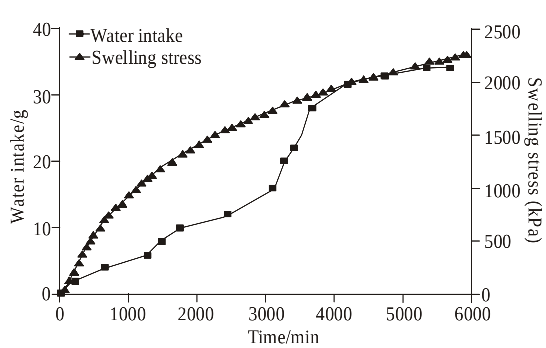

Fig. 4: Water intake and swelling stress evolution in the test

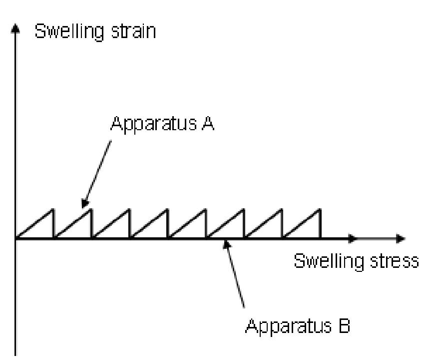

Fig. 5: Paths of the two methods for measuring swelling stress

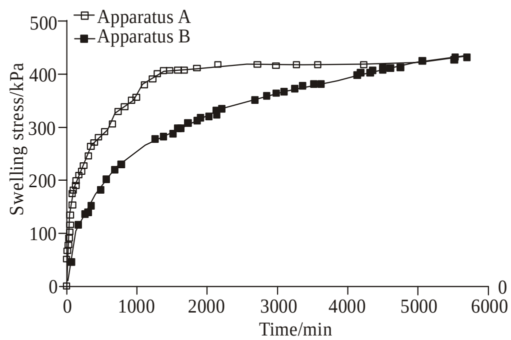

Fig. 6: Change processes of swelling stress with time

constant volume test apparatus for swelling stress is showed in Fig. 3.

RESULTS AND DISCUSSION

Figure 4 shows the evolution of water intake in the constant volume test performed with distilled water. The dry density of sample is 1.70 g/cm^3, sand ratio is 0%. It becomes clear that the water intake capacity at the middle stage of test was higher, what reveals a higher permeability. The water intake process does not is not linear increase. The test confirmed that the apparatus designed by the authors could monitor the water in taking process easily.

As shown in Fig. 4, in the initial stage of test, the swelling stress increased rapidly, due to the absorbing a lot of water. Then, the swelling stress increased slowly, because the speed of absorbing water decreased. That is to say, the swelling stress development process of bentonite with time shows phase characteristics. It becomes clear that the microscopic structure of buffer changed from drastic to stable in the water infiltration process.

It is known that there are three methods to measure swelling stress (Sridharan *et al*., 1986; Ye *et al*., 2007). The path of the two methods in this paper could be expressed in Fig. 5. The specimen was submerged by water injecting into the container from its bottom to top. As soon as the specimen swelled a little, which could be observed by dial gauge, suitable weights were loaded to the loading ram to make the pointer of the dial gauge return to its initial note. The test process was made of a lot of circulating from swelling a little to swelling zero. It is easy to understand that this process could influence the microstructure of bentonite, ultimately effect the result of the swelling strain. For constant volume test apparatus designed by the authors, the maximum strain is less than $1/10^4$, which could be recognized as no strain compared with the other method. So it could be indicated that the swelling stress measured by constant volume test apparatus could be more accurate.

Figure 6 shows the evolution of swelling stress both using consolidometer apparatus and constant volume apparatus. The initial dry density of the two samples is 1.70g/cm^3, the initial water content is 12.4% and the sand ratio is 50%. The results shows, swelling stress changing with time is similar, increased rapidly firstly, then increased slowly. Besides, the maximum swelling stress measured by the constant volume test apparatus is a litter more than swelling stress measured by consolidometer.

CONCLUSION

The value of swelling stress measured by constant volume test is more accurate; besides, uptaking water with time could also be monitored by constant volume test. It is clear that this method is more suitable for measuring the swelling stress of buffer backfilling material.

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REFERENCES

Dixon, D.A., M.N. Gray and A.W. Thomas, 1985. A study of the compaction properties of potential clay-sand buffer mixtures for use in nuclear fuel waste disposal. Eng. Geol., 21: 247-255.

Furuichi, M., K. Okutsu, T. Tanaka and K. Tanai, 1998. A Study of the sealing concept of High-Level Radioactive waste repository. J. Geotech. Engine. Japan Soc. Civil Eng., 594: 21-33 (in Japanese).

Liu, Y., G. Xu, S. Liu and Z. Chen, 2001. Study on compatibility and swelling property of buffer/backfill material for HLW repository. Uranium Geol., 17(1): 44-47 (in Chinese)

Liu, Y.M. and Z.J. Wen, 2003. Study of clay-based materials for the repository of high level radioactive waste. Mineral Petrol, 3(4): 42-45 (in Chinese).

Mitchell, J.K., 2005. Fundamentals of Soil Behavior. John Wiley and Sons, New York.

Nakano, M., Y. Amemiya, K. Fujii, T. Ishida and A. Ishii, 1984. Infiltration and expansive pressure in the confined unsaturated clay. Tran. Japanese Soc. Irrigation Drainage Reclamation Engine., 112: 55-66, (In Japanese).

Sridharan, A., A.S. Rao and P.V. Sivapullaiah, 1986. Swelling pressure of clays. Geotech. Test. J., 9(1): 24-33.

Wang, J., R. Su, B. Chen, Ju, W., S. Rui, C. Weiming, G. Yonghai, J. Yuanxin *et al*., 2006. Deep geological disposal of high-level radioactive wastes in china. Chinese J. Rock Mechanics Engine., 25(4): 649-658 (in Chinese)

Ye, W.M. T. Schanz, L.X. Qan, *et al*., 2007. Characteristics of swelling pressure of densely compacted Gomiaozi bentonite GMZ01. Chinese J. Rock Mechanics Engine., 26(12): 3861-3865 (in Chinese).

Zhang, H.Y, J. Liang and J.S. Liu, 2009. Compaction properties of bentonite-sand mixture as buffer material for HLW disposal. Chinese J. Rock Mech. Eng., 12(12): 2585-2592 (In Chinese)