Soil-water characteristic curve of a Ca-bentonite-sand mixture at wide suction range

Tomoyoshi NISHIMURA [1] *, Sachie ISO [2], Takayuki MOTOSHIMA [2]

[1] Department of Civil Engineering, Ashikaga University, Tochigi, JAPAN
[2] Civil Engineering Department, Nuclear Facilities Division, Taisei Corporation, Tokyo, JAPAN
* email address of the corresponding author: tomo@ashitech.ac.jp

Introduction

Swelling clay materials having low hydraulic conductivity in high level radioactive waste disposal system is relevant to the engineered barriers (Hoffman et al. 2007). Long-term life time, the safety designs experience cycle drying and wetting in hydro phases, which correspond to increasing and decreasing in suction. Suction describe the observed features of unsaturated soil behavior under stress paths involving hydration efforts. The hydration impact induced by changing of suction modify, develop the accumulation of expansion or shrinkage in deformation. Also, engineered barrier experience strong stress (i.e. external load) during several construction stages. The description of stress-strain behavior of swelling clay has been closely linked with efforts to suction and total stress as suitable stress frameworks.

This study focused on soil-water characteristic curve of bentonite-sand mixture material. The bentonite was named as Kunibondo, which was classified as Ca-bentonite. Many reports to investigate, and estimate the swelling properties of bentonite or bentonite-sand mixture on reaching saturation were described (Komine & Ogata 1996, Cui et al. 2002, Sun et al. 2009 and Lee et al. 2010). Almost of these reports in experimental works were Sodium type, and experimental activity of hydro-mechanical properties of Ca type bentonite was slightly, and was limited with comparison to Sodium bentonite. SWCC was measured using vapor pressure technique using different salt solutions and pressure plate technique by high air-entry ceramic disk that by combining two suction controlling methods leaded to describe the SWCC at entire wide suction ranges. Also, swelling phenomena of the material was masured under constant volume that was of maintaining initial height of specimen during swelling pressure test.

Swelling pressure

The specimen was prepared to swelling pressure test which had a diameter of 6.0 cm and a heoght of 2.0 cm. The dry density and compaction water content were 1.65 Mg/m^3 and 20 %, respectively. Modified unsaturated soil oedometer apparatus having high air entry value ceramic disk was used which was possible to suction control up to 1.0 MPa. While swelling test, specimen in steel mold remained constat height (i.e. volume constant). Absorbed water was supplied from bottom surafce, which was due to capillary forces by specimen own. The growing of swelling pressure was measured on upper side. Figure 1 showeed absorbed water increased with time, increment of absorbed water was actively at begining of test. Till elapsed time was ten hours, increment of absorbed water indicated straight line with time. Subsequently, absorbed water increased smoothly, and peak value was obserbed at sixty hours. The test was continued till time was 180 hours, and chnaging of absorbed water was hardly. An arrow in vertical direction in figure indicated end of test. The degree of saturation was calculated using water content at end of test that specimen became to saturation completely. Measured swelling pressures on absorbed process were described as shown in Fig. 2. Increment of swelling pressure was so clear and rapidly at early portion of test. Siginificant growing proceed till elapsed time was ten hours, and subsequently ratio of increment reduced or lost (i.e. no increment of swelling pressure). The increment, however, was repeatted beyond thirty hours that was gradual. At sixty hours swelling pressure was into stability that was possible to evaluate as equilibrium. At least specimen not described changing of swelling pressure till end of test. Maximu swelling pressure was around 3.0 MPa.

SWCC on wetting process

Suction of 800 kPa was applied to compacted bentonite using pressure plate technique, and vertical stress of 120 kN/m^2 was remained during SWCC test. Suction was decreased gradually due to decreaing of pore-air pressure, and suction controlled to 10 kPa at end of test. Then, calculated degree of saturation were described in

Fig. 3. The change of degree of saturation due to reduction of suction was hardly at range from 800 kPa to 100 kPa. When suction was less than 100 kPa degree of saturation increased according to suction that was small incrrement. Its value was around 86 % at suction of 10 kPa.

SWCC at high suction ranges using vapor pressure technique

Vapor pressure technique was conducted out to detemine soil-water characteristic curve of compacted bentonite-sand mixture sample that was possible to appreicate controlling high suction ranges. Suction was larger than 2.8 MPa at least. Various salt solutions were prepared in this testing which there were seven different salt solutions. The suction range had from 2.8 MPa to 296 MPa that relative humidity range had from 98 % to 11 % on thermo-dynamic conversion theory (i.e. Kelvin law). Suction of 2.8 MPa was applied at beginig of test, and suction increased up to 296 MPa on drying process. Subsequently wetting process was performed in accordence with suctions required in drying process. Water content was larger than initial water content till suction was 9.8 MPa on drying that occurred swelling as shown in Fig. 4. Behind suction was 9.8 MPa water content decreased straightly. At end of drying water content indicated 8.0 % roughly. Water content increased due to decrease suction that existed hystersis between drying and wetting. The hystersis was obserbed in relationship between suction and degree of saturation.

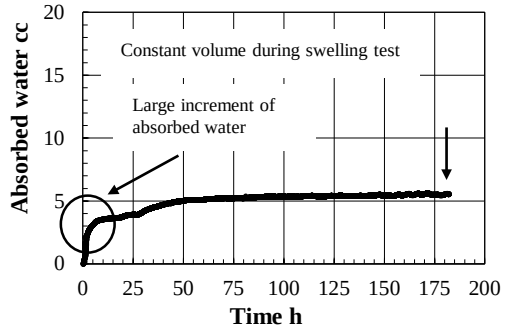

Fig. 1: Absorbed water with time.

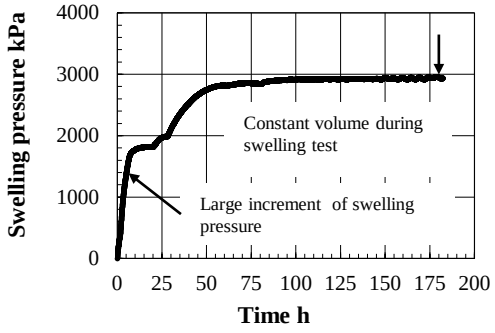

Fig. 2: Swelling pressure with time.

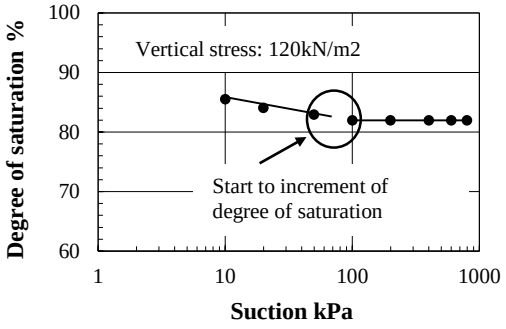

Fig. 3: Increment of Sr on wetting process.

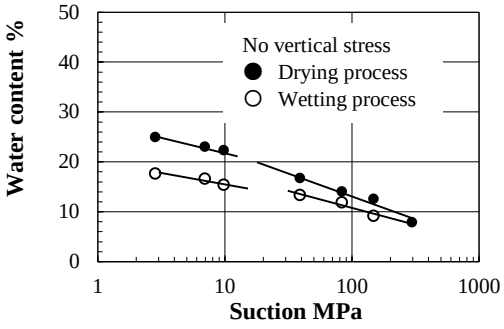

Fig. 4: SWCC under high suciton range.

References

Cui Y J, Yahia-Aissa M, Delage P. (2002) A model for the volume change behaviour of heavily compacted swelling clays, Engineering Geology, 64, 233-250.

Hoffman C, Alonso E E, Romero E. (2007) Hydro-mechanical behaviour of bentonite pellet mixtures, Physics and Chemistry of the Earth, 32, 832-849.

Komine H, Ogata N. (1996) Prediction for swelling characteristic of compacted bentonite, Canadian Geotechnical Journal, 33, 11-22.

Lee J, Lee M, Choi H, Choi J. (2010) Temperature effect on the swelling pressure of a domestic compacted bentonite buffer,Journal of Korean Radioactive Waste Society, 8(3), 207-213.

Lee J O, Lim J G, Kang I M, Kwon S. (2012) Swelling pressures of compacted Ca-bentonite, Engineering Geology, 129-130, 20-26.

Sun D, Cui H, Sun W. (2009) Swelling of compacted sand-bentonite mixtures, Applied Clay Science, 43, 485-492.