Proceedings of the XVIII ECSMGE 2024
GEOTECHNICAL ENGINEERING CHALLENGES
TO MEET CURRENT AND EMERGING NEEDS OF SOCIETY

ISBN 978-1-032-54816-6
DOI 10.1201/9781003431749-114

ECSMGE 24
XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

Accumulated axial strains for bentonite sand mixture due to cyclic loading with low confining pressures

Déformations axiales accumulées pour le mélange de sable bentonite en raison d'un chargement cyclique avec de faibles pressions de confinement

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ABSTRACT: A certainly design, construction, management and observation of geological repositories is crucial key to address the safety disposal of radioactive waster including LLWs and HLWs. This study focused on dynamic properties for unsaturated-saturated bentonite sand mixture used as one of engineered barrier system, which composed sodium bentonite and silica sand. Cyclic triaxial apparatus is used for determination of reduction amplitude stress, stress-strain behaviour and changing of cyclic stress ratio. Also, shear strength parameters are measured from monotonic loading tests for unsaturated-saturated bentonite sand mixture, which are angle of shear resistance and apparent cohesion, and failure envelopes are estimated, proceeding of faire conditions are observed in between principal means stress and principal deviator stress. Specimens used in this study are unsaturated condition and saturated condition, and unsaturated specimens are applied high suction controlling by vapor pressure technique in order to prepare variety of soil moisture and various of dry density. Owing suction control by vapor pressure technique, it proves that specimens have hydration effect associated to strength parameters and stress-strain properties in dynamic loading. Also, it is found out that accumulated axial strains for unsaturated bentonite sand mixture with various of high suctions verified the influence of initial cyclic stress ratio and suction value, and accumulated axial strains are slightly when suction is over 83 MPa. Other hands, specimens are decrement to the resistance in cyclic loading due to increment of soil moisture induced by relative humidity of 98%, and strains in compression side.

RÉSUMÉ: La conception, la construction, la gestion et l'observation de dépôts géologiques sont certainement essentielles pour assurer l'élimination en toute sécurité des déchets radioactifs, y compris les déchets de faible activité et les déchets de haute activité. Cette étude s'est concentrée sur les propriétés dynamiques d'un mélange de sable de bentonite insaturé-saturé utilisé comme système de barrière technique, composé de bentonite de sodium et de sable de silice. L'appareil triaxial cyclique est utilisé pour déterminer la contrainte d'amplitude de réduction, le comportement contrainte-déformation et la modification du rapport de contrainte cyclique. En outre, les paramètres de résistance au cisaillement sont mesurés à partir d'essais de chargement monotones pour un mélange de sable de bentonite insaturé-saturé, qui sont l'angle de résistance au cisaillement et la cohésion apparente, et les enveloppes de rupture sont estimées, les conditions de déroulement sont observées entre la contrainte moyenne principale et la contrainte déviatrice principale. Les spécimens utilisés dans cette étude sont en condition insaturée et saturée, et les spécimens insaturés sont soumis à une aspiration élevée contrôlée par une technique de pression de vapeur afin de préparer une variété d'humidité du sol et diverses densités sèches. Grâce au contrôle de l'aspiration par la technique de pression de vapeur, il prouve que les éprouvettes ont un effet d'hydratation associé aux paramètres de résistance et aux propriétés contrainte-déformation en chargement dynamique. En outre, il a été découvert que les déformations axiales accumulées pour un mélange de sable de bentonite insaturé avec diverses succions élevées ont vérifié l'influence du rapport de contrainte cyclique initial et de la valeur de succion, et que les déformations axiales accumulées sont légères lorsque la succion est supérieure à 83 MPa. D'autre part, les éprouvettes subissent une diminution de la résistance en chargement cyclique en raison de l'augmentation de l'humidité du sol induite par une humidité relative de 98% et des déformations axiales côté compression.

Keywords: Bentonite; unsaturated soil; suction; dynamic properties; vapor pressure technique.

1 INTRODUCTION

The aspect of high-level radioactive waste (HLW) repository commonly includes environmental engineering artificial barrier system. The system has compacted bentonite blocks with some sand mixture are established around the strong waste canister, which Sellin and Leupin, (2013) mentioned detail. It is generally accepted that after construction the high-level radioactive waste (HLW) repository, the compacted bentonite become gradually absorb or hydration with groundwater at deeply place to recognize essential buffer functions such as sealing some gaps due to swelling, subsequently supporting the canister with steady. The mathematical models regard to artificial barrier have been suggested including thermal-hydration-mechanical-chemical couple phenomena (Villar et al. (2010), Yong-Gui Chen at al. (2015), Yong-Gui Chen et al. (2017), Yong-Gui Chen et al. (2019)) that contribute accuracy simulations in swelling processes. The cyclic strength and deformations are generally a problem in liquefaction for loose sand and few refreshes are report clay material and unsaturated soils. This study focused on dynamic properties for unsaturated-saturated bentonite sand mixture used as one of engineered barrier system. The controlling suctions have a range from 2.8 MPa to 148 MPa and three different suction are required that translated relative humidity are 98%, 75% and 33%. The maximum cyclic of number is 10 times, and loading-unloading frequency is 0.1 Hz, which is not so large cyclic application. Furthermore, this study has more consideration that both heating application and chemical effort to bentonite sand mixture specimen. 80 degree Celsius and 100 degrees Celsius are controlled to the specimen heating application accomplish.

2 TESTING PROCEDUE

2.1 Soil material and specimens

Considering, Kunigel V1, a sodium bentonite, is used in some series of testing programs to confirm cyclic loading properties in experimental laboratory studies. Owing to its high montmorillonite content, the bentonite has a fines content greater than 95%. In this testing program all of specimens mixed a silica sand, named Iitoyo No.4, into the sodium bentonite, which has a uniformity grain size distribution.

All specimens had a diameter of 38 mm and a height of 76 mm for all of series of testing programs that are statically compacted using a hydraulic oil jack. The bentonite sand mixture is put into the stiffness steel mold with an inner diameter of 38.0 mm, a thickness of 18.0 mm and a height of 76.0 mm. The initial specimens have the following physical properties: a dry density of 1.600 Mg/m^3, void ratio of 0.710, and degree of saturation of 65.6%.

2.2 Apparatus and programs

This study used cyclic triaxial test apparatus for investigation of axial deformations for unsaturated specimen and saturated specimens. This testing program has majority two parts that one is

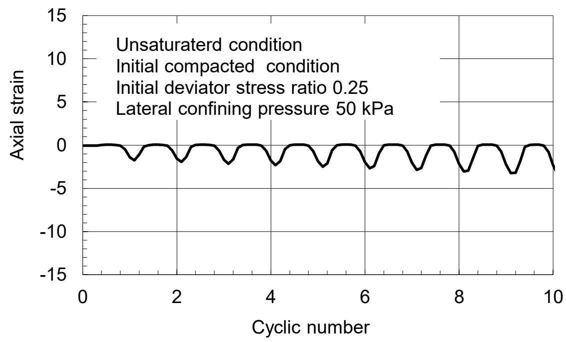

Figure 1. Initial condition at compaction.

unsaturated specimens cyclic loading test and other one is saturated specimen cyclic loading test. Furthermore, unsaturated specimens cyclic loading test divided as followings; the specimens are prepared with and without suction controlling. Suction controlling is performed using vapor pressure technique, which is used salt solutions and have a range from 2.8 MPa to 2986 MPa. This testing program attempt three suction (i.e., 98%, 75% and 33% in relative humidity), which are 2.8 MPa, 39 MPa and 148 MPa. Then, saturated specimens are prepared due to soaking. The salinity water has concentration of 0.85% or 1.2%. After the specimens approach to be fully saturation, and saturated specimens placed on the pedestal and the cyclin triaxial apparatus is set up. It is common between unsaturated specimen test and saturated specimen test that lateral confining pressure is 50 kPa and loading frequency is 0.1 Hz. End of cyclic loading test is determined till cyclic number is ten.

3 TEST RESULTS

3.1 Compacted bentonite sand mixture

Axial strains in both compression side and expansion side are described as shown in Figure 1. Compression side is positive value and expansion side is negative value. During cyclic loading, compression strain and expansion strain are further small, which are less than 0.2%. The specimen has steady small strain with cyclic number, the increment is not found. The difference between compression axial strain expansion strain remain the same.

3.2 Unsaturated bentonite sand mixture subjected to suction

Comparing the axial strain behaviour during cyclic loading through as shown in Figs. 2, 3 and 4 that the different phenomena is clear. When the specimen has equilibrium to RH 98%, the specimen has a suction of 2.8 MPa, and the axial strain through cyclic

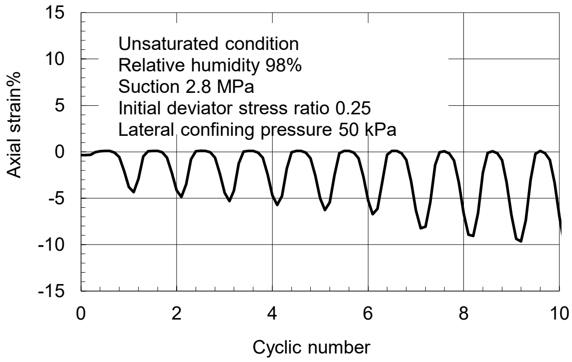

Figure 2. Unsaturated specimen for suction of 2.8 MPa.

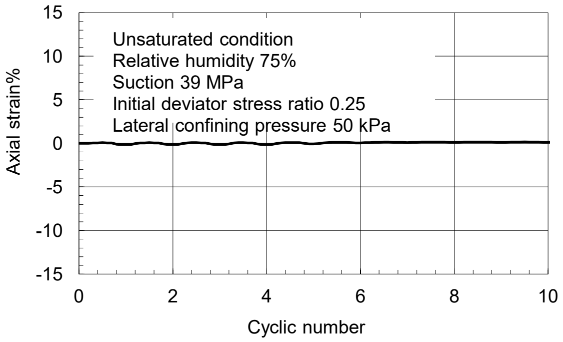

Figure 3. Suction of 39 MPa.

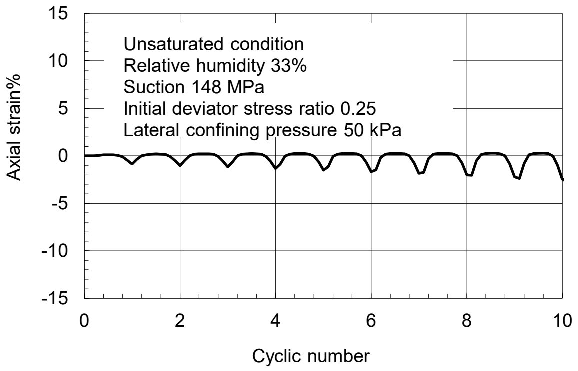

Figure 4. Suction of 148 MPa.

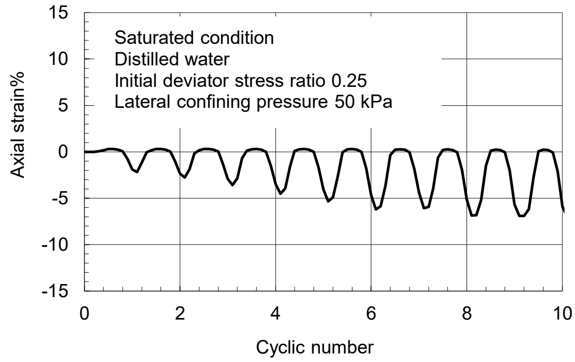

Figure 5. Saturated specimen (Distilled water).

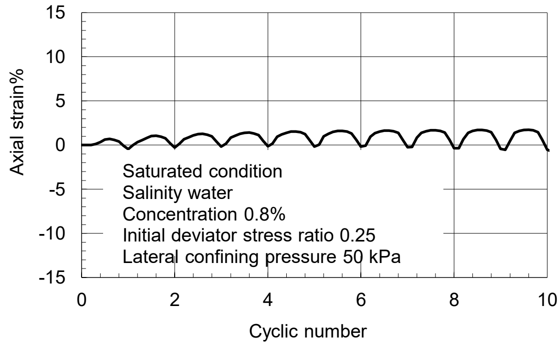

Figure 6. Saturated specimen (0.8%).

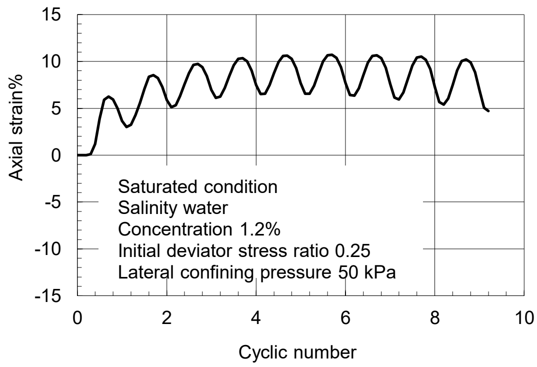

Figure 7. Saturated specimen (1.2%).

loading is measured as shown in Figure 2. Expansion axial strain is occurred at beginning of loading and unloading which is -4.3%. Processing compression loading and expansion loading, the deformations are employed toward to expansion side. The failure for specimen with suction of 98% is impossible to observed through the test. Other hands, the specimen is applied relative humidity of 75% corresponding to 39 MPa that two times difference between two relative humidity value for suction value. Similar cyclic loading is required, changing of axial strain is verified as shown in Figure 3. Providing that small axial strain is measured for both compression side and expansion side during cyclic loading, which each strain is 0.15%.

3.3 Saturated bentonite sand mixture

Saturated specimen due to distilled water indicate the axial strains with vibration as shown in Figure 5, and almost of deformation are occupied in expansion side that compression deformations are less than 0.2%. According to expansion deformations increase with cyclic number, and approach to 7.0% at end of test. In case of absorbed water change to salinity water, Figure 6 shows the compression side deformations are advantage compare to expansion deformation for salinity water with concentration of 0.8%. Maximum axial strain in compression side is 1.5%. Furthermore, significant different properties are measured as shown in Figure 7. The specimen occurred large compression deformation, and the compression deformation remine the increment of axial strain with number.

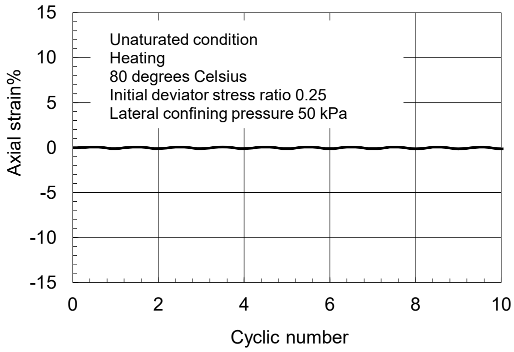

Figure 8. 80 degrees Celsius.

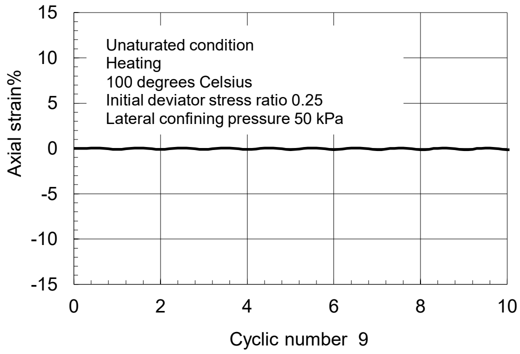

Figure 9. 100 degrees Celsius.

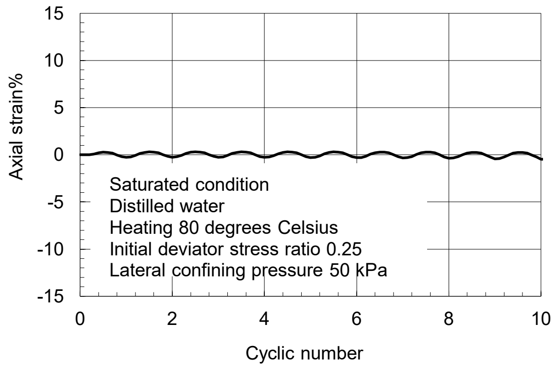

Figure 10. Saturated specimen at 100 degrees Celsius.

Expansion axial strains are not measured. Also, the deference between compression axial strain and expansion axial strain are almost 5% through the cyclic numbers.

3.4 Influence of heating action on deformations

Unsaturated bentonite sand mixture specimens have conductive under 80 and 100 degrees Celsius and subsequently cyclic loading test are conducted. The relationship between cyclic number and axial strain are shown in Figs. 8 and 9. The measured axial strains are less than 0.2% and expansion side that the occurrence of axial strains is resist through the test. Saturated bentonite sand mixture specimen subjected to heating application (i.e. 80 degrees Celsius) that the strains are similar to the result in Figures. 8 and 9. A few axial strains are measured as shown in Figure 10.

4 CONCLUSIONS

This study focused on dynamic properties for unsaturated-saturated bentonite sand mixture with variety functions. The obtained summaries are as followings: The unsaturated bentonite sand mixture specimen subjected to suction control that the further small axial strain is measured for both compression side and expansion side during cyclic loading. Its tendency related to increase the suction that is relative humidity decrease. Saturation specimen due to distilled water verify the large expansion axial strains, and it is obviously that saturated specimens in salinity water with concentration of 1.2%.

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