Suction Controlled Triaxial Apparatus for Saturated-unsaturated Soil Test

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1 Introduction

The main problem in conducting unsaturated soil test is due to its difficulties, time consumed and costly. In nature, unsaturated soil is located at between ground surface and ground water table. This area experience drying and wetting process due to change in climate. This process leads to hysteresis phenomena on unsaturated soil properties. A suction controlled triaxial apparatus (Fig. 1) has been developed in Geotechnical Engineering Laboratory of Kyushu University which able to conduct shear test to obtain strength properties as well as hydraulic properties of unsaturated soil. Multistage test method was adopted to obtain properties as many as possible using single specimen will be presented. This method is expected to be able to reduce test time as well as the cost.

2 Triaxial Apparatus and Its Characteristics

Several instruments for control /measurement purposes are equipped in the apparatus, such as: external and internal load cell to measure deviator load; pressure transducer to measure cell pressure, pore water pressure at bottom of the specimen and pore air pressure at the top of specimen; Pressure Differential Transducer to measure drained water volume changes and total volume changes, LVDT to measure axial large strain range externally, LDTs and Pi-gauges to measure axial and radial small strain range internally.

Pore air pressure is applied at the top of the specimen through normal porous disk, while pore water pressure is applied at bottom through high air entry ceramic disk. The air entry value of ceramic disk is about 3 bars (300 kPa). High air entry ceramic disk was glued and completely sealed at the pedestal and connected with water channel at the bottom. At the middle of ceramic disk, metal porous disk is installed, mainly used to saturate specimen in unsaturated test condition or to apply back pressure and measure specimen volume change during saturated triaxial test.

Total volume change and drained water volume change can be measured by using pressure differential technique. Open ended inner cell is used to measure total volume change of soil. The fluctuation of water level inside the inner cell represents the change of total volume change. Drained water volume change is calculated by measuring the amount of water drained in or out of specimen.

During shearing, strain of deformed specimen is measured externally and internally. Linear Variable Differential Transformer (LVDT) (range 0-20% strain) is placed outside the chamber to measure large strain range of specimen during shearing. Internally, two LDTs are attached at the specimen to measure axial strain, while other three instruments so called pi-gauge are attached horizontally to measure lateral strain. The maximum displacement can be measured by LDT is about 1.5 mm (1.5% of strain).

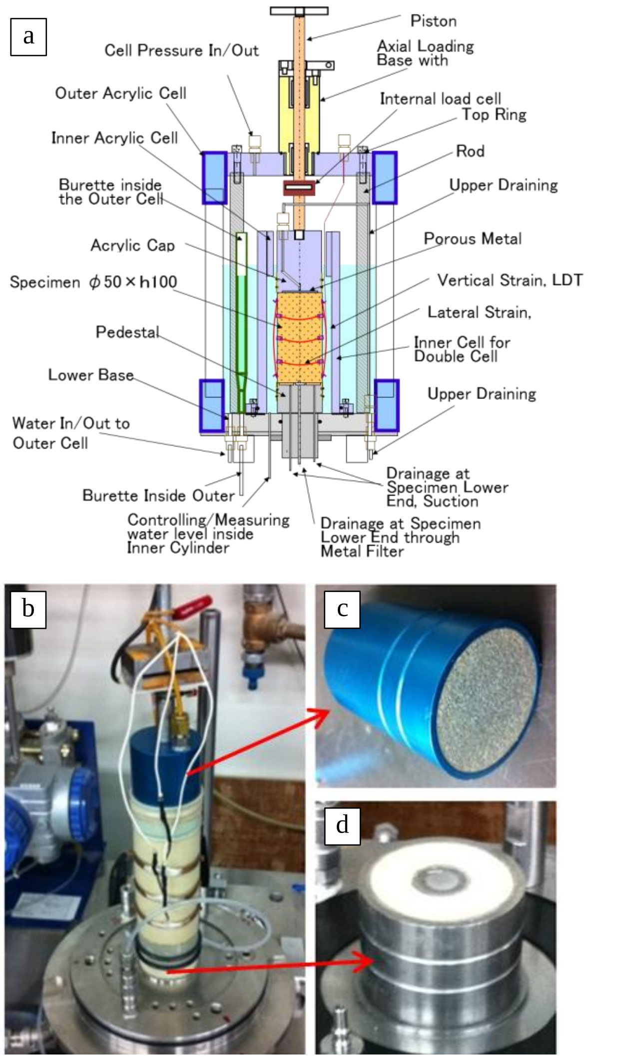

Figure 1 Suction controlled triaxial apparatus, a) schematic diagram, b) photo, c) normal porous disk (top of specimen) and d) high air entry value disk and porous metal filter (bottom of specimen)

3 Materials and Method

Two types of soil were used in the tests; they are low plasticity silt called Red Soil from Okinawa Perfecture, Japan and sand soil called Toyoura sand. Red soil was prepared to conduct soil water retention test, while Toyoura sand was prepared for shearing test. Specimen dimension prepared in the apparatus is 10 cm in height and 5 cm in diameter for shearing test. To reduce the time consumed in soil water retention test, specimen height was reduced to be 5 cm height, while the diameter is same.

Multistage test procedure (Ho and Fredlund, 1982) was adopted by increasing suction in each stage. Using this method, it is possible to obtain many data, such as shear

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strength, stiffness and SWRC from single specimen; therefore time and cost could be reduced. Even though it is possible to obtain hydraulics and mechanics properties by using single soil specimen, in this test, to evaluate the performance of the apparatus, two different tests were conducted Water retention test on Red soil and shearing test on Toyoura sand were conducted.

For water retention test, the specimen test was started from saturated condition. Pore air pressure and cell pressure was increased in the same value to maintain destined matric suction and to keep constant value of net normal stress. Pore water pressure was set constant about 25kPa. Net normal stress was also set constant about 50kPa. Matric suction was varied from 3kPa, 10 kPa, 30kPa, 100kPa, 170kPa, 250kPa, 100kPa and 30kPa.

For shearing test, consolidated drained condition was chosen with shear rate about 0.01 mm per minutes. The specimen was tested initially from saturated condition. After being saturated, the specimen was sheared until reaching peak value and then unloading. After shear loading and unloading was finished, consolidation for next stage predetermined matric suction started, and then sheared again after reaching equilibrium state. This condition was repeated for subsequent stage.

4 Test Results

SWRC of red soil can be drawn in Fig. 2. This figure shows the hydraulic hysteresis of red soil due to different process of drying and wetting path. At the same matric suction, wetting process will give lower water content than drying process. Boundary condition of specimen during soil water retention test in triaxial apparatus is more similar with field condition by applying radial pressure (cell pressure) at the specimen. This is one of the advantages of using triaxial apparatus to measure soil water retention curve compared with other apparatus.

The stress-strain relationships for 4-stages (different matric suction) shearing test is shown in Fig. 3. It shows that the strength of soil increases as the increasing of matric suction. Similar result could be observed on the steepness of the stress-strain curves, means that stiffness is also increasing. At the early shearing test (matric suction = 0kPa), the curve seems to be incorrect. This problem might occur when the LDT was not attached properly. In this test, the LDTs were attached manually by using bare hand, and may unstable. There are two LDTs attached at the specimen, so the expected correct result can be drawn easily from the other LDT with correct result, shown in dashed line. Smaller strain range (below 0.01%) of stress-strain diagram and related elastic moduli at small strain are presented in Fig. 4. These figure more clearly show the stiffness of soil at small strain range. It shows that in small strain range, the stress-strain relationship can be represented by linear line. Elastic moduli of soil changes depend on the applied matric suction.

5 Conclusion

Suction controlled triaxial apparatus has been developed to conduct both shear test (saturated-unsaturated condition) and SWRC test. Multistage test has been adopted to obtain much properties from single specimen, and to reduce time and cost consumed. The apparatus has ability to control stress path and suction in high performance. Results on

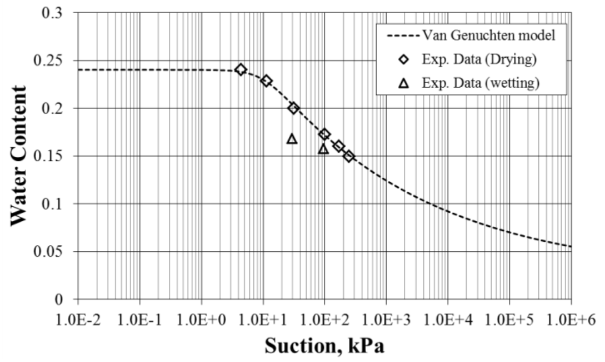

Figure 2 SWRC experiment data fitted with Van Genuchten fitting curve

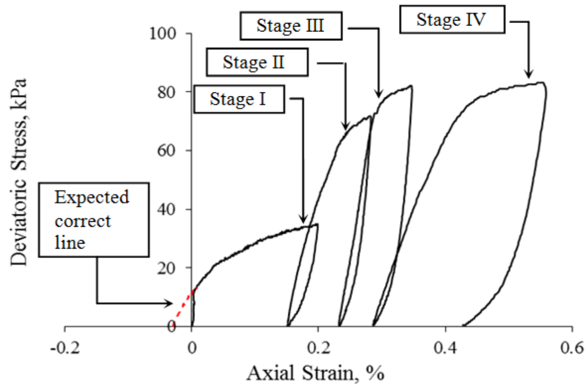

Figure 3 Stress strain relationship of 4-stages multistage triaxial test

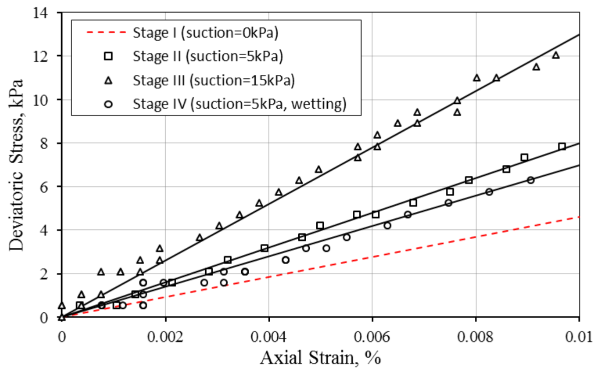

Figure 4 Stress-strain diagram in small strain range of each stage

SWRC and stress-strain diagram has been presented and discussed.

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