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Determination of Soil-Water Characteristic Curves of Unsaturated Sandy Soils Using Membrane Filter with Stainless Wire Mesh

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Soil-water characteristic curve (SWCC) is an important soil function in an unsaturated soil mechanics field for design and analyses of any unsaturated earth structures. Determination of SWCC is not easy and more so time consuming. Generally, ceramic disc with high air-entry value has been used in the pressure plate apparatus for this purpose by many people. Now-a-days membrane filter is being used as a suitable alternative to ceramic disc. However, experience shows, it has disadvantage of breakage after one time use especially with coarse grain soils (sandy soils). In this study, membrane filter with stainless wire mesh was used to solve this problem and the SWWC was compared with the results obtained without wire mesh. Results showed that membrane filter with stainless wire mesh can be used to determine the SWCC for coarse grain soils.

Key words: *SWCC, Unsaturated sandy soils, Membrane filter, Stainless wire mesh*

1 INTRODUCTION

The relation between soil water content (volumetric water content or gravimetric water content or degree of saturation) and soil suction (matric potential or negative pressure head) is a fundamental part of the characterization of the hydraulic properties of a soil (Klute, 1986). This relation is called by several names such as: 1) the soil-water characteristic curve (SWCC), 2) the water retention curve (WRC), or 3) the capillary pressure curve. The SWCC defines a soil's ability to store and release water. This curve presents the basic characteristics of a partially saturated soil. The water flow and storage characteristics of an unsaturated soil are closely related to the amount of water contained in the pores. The amount of water can be related to the negative pore-water pressure (i.e. soil suction) in the soil. SWCC is the base of the engineering behavior of unsaturated soil because it is a measured soil property that is used to derive other soil functions (permeability, shear strength and volume change) and provides a common reference to stress state at which other properties are calculated. It is also a key function of unsaturated soils and has been used for numerical analyses of any unsaturated earth structures.

There are several numerical methods for obtaining a SWCC for a particular soil. Brooks and Corey Model (1964) and Van Genuchten Model (1980) are more commonly used methods for obtaining SWCC.

However, the most accurate way to determine a SWCC is through laboratory experimentation. Many experimental tests had been performed to obtain the SWCC for different types of soil and under different conditions. It is commonly determined by the pressure plate apparatus test (e.g., Richards 1941). Determination of SWCC is not easy and time consuming.

Generally, researchers have been using ceramic disc in the pressure plate apparatus to determine SWCC. Now-a-days membrane filter is being used as a suitable alternative to ceramic disc. For that reason membrane filter has been used as a suitable alternative to ceramic disc in this study. However, experience shows, it has disadvantage of breakage after one time use especially with coarse grain soils (sandy soils). In this study, membrane filter with stainless wire mesh was used to solve this problem.

2 MATERIALS AND PROPERTIES

Two types of granite soils taken from Okayama and Hiroshima areas of Japan were used in this study. These soils named are: Sample-1and Sample-2. The soil masses passed through No. 2 sieve were used for all experiments. The grain size distributions of the soils and basic properties are presented in Figure 1 and Table 1 respectively.

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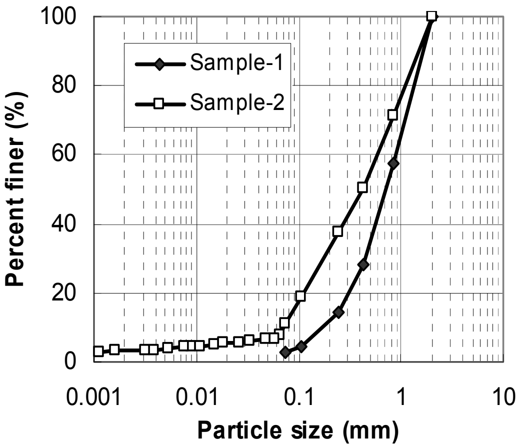

Fig.1 Particles size distribution curve of used soils

Table 1 Basic property of soils

Properties	Sample-1	Sample-2
Specific gravity, G_s	2.63	2.64
Maximum dry density, (g/cm^3)	1.85	1.79
Optimum water content, (%)	14.7	15.5
Grain size analysis		
D_{60} (mm)	0.90	0.58
D_{30} (mm)	0.44	0.17
D_{10} (mm)	0.17	0.08
Coefficient of uniformity, C_u	5.29	7.25
Coefficient of curvature, C_c	1.26	0.62
Soil properties used in SWCC		
Dry density, (g/cm^3)	1.63	1.60
Void ratio, e	0.61	0.65
Porosity, n	0.38	0.39
Saturated permeability, K_s (cm/s)	2.2E-3	9.4E-4

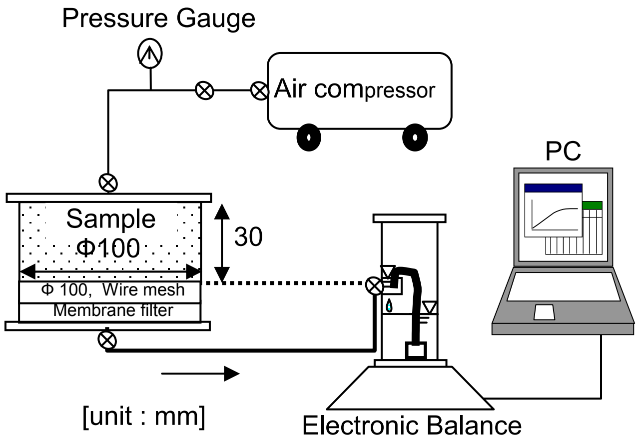

Fig.2 The schematic diagram of Tempe pressure cell

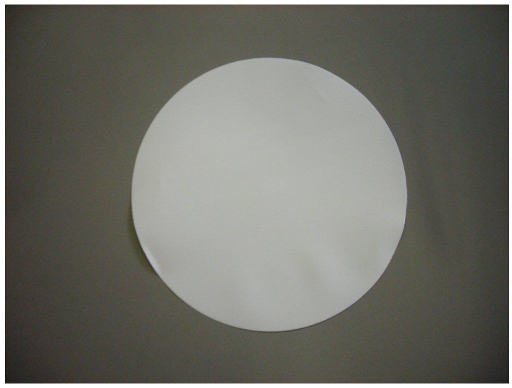

Photo 1 Picture of the membrane filter

3 PROCEDURE TO DETERMINE THE MATRIC SUCTION OF USED SOILS

Matric suctions were determined using a Tempe pressure cell which operates on the same principle as the conventional pressure plate apparatus. The schematic diagram of Tempe pressure cell is shown in Figure 2.

The membrane filter from commercial company in America was used in this study (Photo 1). The air-entry value, thickness and pore size of the filter were 2 bars, 142 μm and 0.45 μm respectively. There were two procedures for the specimen preparation: 1) membrane filter was saturated and then a required dry soil (for specific porosity) placed on the membrane filter inside the Tempe pressure cell, and 2) a stainless wire mesh of 75 μm thicknesses placed on saturated membrane filter and after that a required dry soil (for specific porosity) placed on stainless wire mesh inside the Tempe pressure cell.

The membrane filter in the Tempe pressure cell allowed water to flow but disallowed air flow when saturated. An outlet was provided in the water compartment below the membrane filter where water could drain from the soil specimen. Therefore, the water pressure was maintained at atmospheric throughout the test and an air pressure was applied through the inlet tube on the top cap. The top and bottom plates were fastened with bolts. O-ring seals kept the cell air tight during the test.

Before the start of the Tempe pressure cell test, the soil was oven-dried and cooled for 12 hours at room temperature 20^{0}c and then the required soil mass was placed in the Tempe pressure cell and compacted to the required density (Table 1). After that, the bolts of the cell were tightened and the specimen inside was saturated by allowing water to flow through the bottom valve while the water head was kept higher than the specimen's height. It took about 2-3 days for complete saturation. The Tempe pressure cell was placed on a support and the water level maintained at the bottom of the soil specimen. When the air pressure was set to desired matric suction, water started to drain from the soil specimen through the membrane filter until equilibrium was attained. The outflow of water from the soil specimen was measured by an electronic balance. The procedure was repeated at higher applied air pressures until the degree of saturation less than 0.70 was obtained. A plot of degree of saturation against corresponding matric suctions gave the soil-water characteristic curve (SWCC).

4 RESULTS AND DISCUSSION

The SWCCs were determined by Tempe pressure cell: firstly using only membrane filter and secondly membrane filter with stainless wire mesh for both sample-1 and sample-2. The obtained SWCCs are presented and compared in Figures 3 and 4. The experimental results show that both methods gave the same results for both soils. A maximum of 8.5 kPa air pressure was applied in the cell when membrane filter was used exclusively. This gave the required degree of saturation (for stability analyses purpose) of less than 70%. Within this pressure the membrane filter was safe and SWCCs were obtained. However, the membrane filter could not be used for the second time as a result of damage to the filter. The damage could be caused by sand particles due to sharp edges thus piercing the membrane filter. Another experiment was conducted using sample-1 to determine the critical pressure of membrane filter. The pressure was found to be 15.5 kPa. Photo 2 shows the broken membrane filter under 15.5 kPa air pressures.

On the other hand, when stainless wire mesh of 75 μm thicknesses was placed on the membrane filter, similar results were obtained as in the case when membrane filter was used exclusively. No breakage of the membrane filter was observed after several usage of the membrane filter with stainless wire mesh. Therefore, the stainless wire mesh could be used with membrane filter to determine SWCC for course grain soils. The combination of the two (membrane and wire mesh) promotes durability and reuse of membrane filter.

The possible soil - wire mesh - membrane filter interaction is: during compaction to prepare the specimen, the soil particles at the bottom whose diameters are less than 75 μm pass through the wire mesh and rest on membrane filter shown in Photo 3. The coarser particles can not enter through the wire mesh therefore the membrane filter becomes safe from breakage.

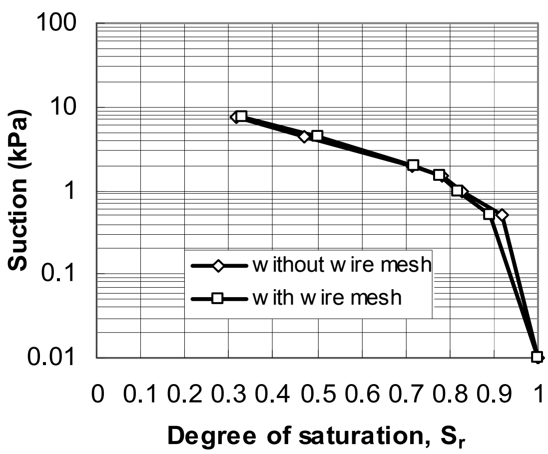

Fig.3 Soil-water characteristics curves using membrane filter with and without stainless wire mesh (for Sample-1)

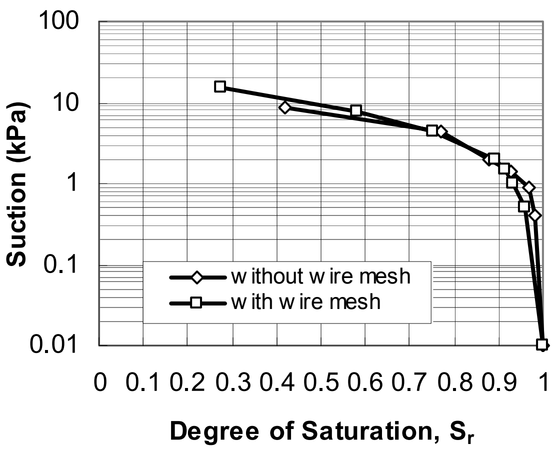

Fig.4 Soil-water characteristics curves using membrane filter with and without stainless wire mesh (for Sample-2)

Photo 2 Picture of broken membrane filter

Photo 3 Picture of top of membrane filter after the experiment

5 CONCLUSION

The purpose of this study was to investigate how the membrane filter could be reused for determining SWCC of coarse grain soils. From this study, it was observed that when the stainless wire mesh was placed on top of membrane filter, it protected the filter from breakage of filter and gave good SWCC. Therefore, the membrane filter with stainless wire mesh could be used to determine SWCC with coarse grain soils. The technique also ensures reuse of the membrane filter.

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