LOCAL MEASUREMENT OF THE PERMEABILITY OF SANDS USING PIN-TYPE SENSORS IN THE TRIAXIAL APPARATUS

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1. INTRODUCTION

Permeability of soils is measured in the laboratory by using JIS A 1218: Test Methods for Permeability of Saturated Soils. The code specifies an apparatus with standard rigid mold with height of 12 cm and diameter of 10 cm. It is supposed that since the mold is rigid, the water flows faster on the gaps between the mold and the specimen interface than in between particles (Fig. 1). Hence, attempts were made to use a flexible confining wall, such as rubber membrane on triaxial apparatus (Hatanaka et al, 1997, Wang 2014) to reduce the gaps between specimen and confining wall by adjusting the confining pressure (Fig. 2).

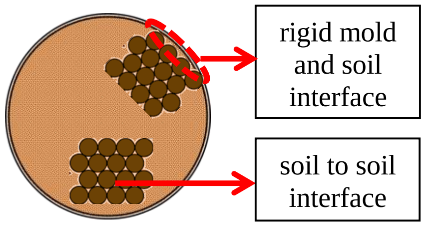

Fig.1 Schematic Cross Section of Rigid Mold using JIS A 1218

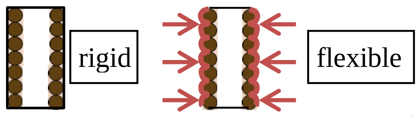

Fig.2 Schematic representation of rigid and flexible wall due to confining pressure

2. EQUIPMENT AND MATERIALS

In this study, a special type of tank was utilized to maintain constant head for permeability test using triaxial apparatus. Fig. 3 schematically shows the testing system. In Fig.3 indicated by *x*, the total head supplied to the specimen is maintained by opening valve, V1 so that the water from Water tank 1 can supply constant head to water cell in Water tank 2. Water from the water cell will flow through the system. The water enters through the top end of the specimen, permeating through the bottom of the specimen. The water receiver in Fig. 3 indicated by *y* collects the water that flowed through the system through burette, B1. System *y* bears two functions: to maintain constant head at burette, B1 (with respect to water cell in system *x*) while at the same time, the overflow of B1 is collected at pipe, P1. The volume in the overflow is measured by using a differential pressure transducer (DPT) between pipe, P1 as it increases, with burette, B2 as reference elevation.

The total head supplied cannot be all applied to the specimen due to head loss such as friction on the flow path. Hence, a pin-type sensor inserted at the top of the specimen, and at the bottom of the specimen was innovated in order to measure the head difference between the two points directly (Fig 3, indicated by *z*). The pin-type sensor is made of stainless steel, with cut on the side to allow flow of water, and is connected to a tube up to the DPT.

The pin-type sensor was used in this study for two types of sand: Toyoura and Inagi. The Toyoura sand has specific gravity (G_s) of 2.652, median diameter (D_{50}) of 0.16 mm, maximum void ratio (e_{max}) of 0.989 and minimum void ratio (e_{min}) of 0.611. Inagi sand is a type of silty sand with 30% fines which has G_s = 2.656, D_{50} = 0.115 mm, and maximum dry density (ρ_d) of 1.66 g/cm^3.

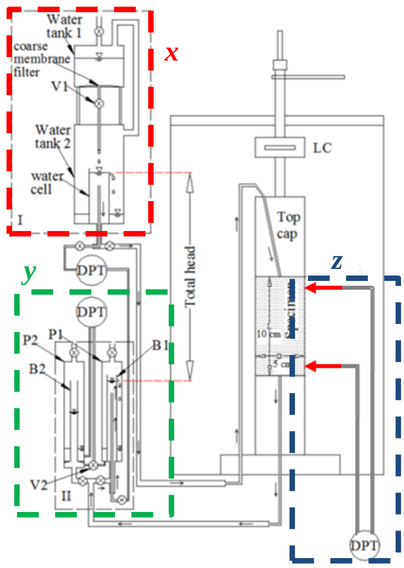

Fig.3 Schematic Diagram of Triaxial Apparatus with Confining Stress at the specimen

3. SPECIMEN TESTS AND METHODOLOGY

3.1 Permeameter Tests (Standard and Modified)

For comparison purpose, experiments on Toyoura sand were also conducted using the permeameter test (Fig.4) while adding special inner cylinder(s) to increase the possible effect of the rigid mold and soil interface. Four specimen of Toyoura sand were prepared by air pluviation. The first specimen was conducted by using the standard set-up (diameter, ϕ = 10 cm). The second specimen included cylinder *a* (ϕ = 7.5 cm). The third specimen was composed of cylinders *a* and *b* (ϕ = 5.0 cm). Lastly, the fourth specimen involved cylinders *a*, *b*, and *c* (ϕ = 2.5 cm). The specification in conducting constant head from JIS A 1218 was followed in performing the experiment.

Measurement was performed using three different heads: 3 cm, 6 cm, and 12 cm, which correspond to hydraulic gradients of 0.25, 0.50, and 1.00, respectively. For each head,

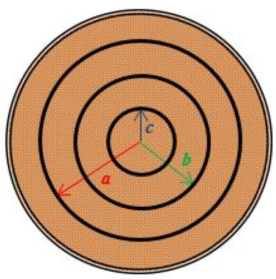

Fig.4 Schematic Cross Section of Rigid Mold using various cylinder diameters.

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nine trials were conducted (three trials each for time, t=30 sec, t=60 sec, and t=120 sec). This implies that 27 data points were obtained for every specimen. The relative density (D_r) of the specimen ranged from 71% to 78% in Toyoura sand.

3.2. Local Measurement using Pin-Type Sensor

The specimen has height of 10 cm, prepared by 1-D mold compression. The pins were inserted 1 cm away from the top and bottom of the specimen. Five different heads were carried out with Total Head equal to 5 cm, 20 cm, 35 cm, 50 cm, and 65 cm. The specimens were all subjected to 100 kPa confining stress. The D_r of Toyoura sand was 75% to 78% while the degree of compaction, D_c of Inagi sand was 72%.

4. RESULTS AND DISCUSSIONS

4.1 Permeameter Tests (Standard and Modified)

Fig. 5 shows the semi-log plot of the data points obtained from performing the permeameter tests. The four specimens are symbolized by their respective shapes, with the average permeability coefficient (k_{avg}) obtained from each curve for each hydraulic gradient (i). Except for the standard set-up (indicated by square), it can be observed that the trials conducted at t=30 sec resulted to less pronounced difference in permeability than those obtained at t=60 sec and t=120 sec. Another thing that could be observed is that except the third specimen (indicated by upright triangle), the permeability at lower i yielded higher k than that at higher i. One possible reason affecting the two abovementioned observations is due to filter clogging. The data points also evidenced increase in permeability as the cylinders were added. It can be said that the gaps between the soil and cylinder interface affected the flow of water into the specimen.

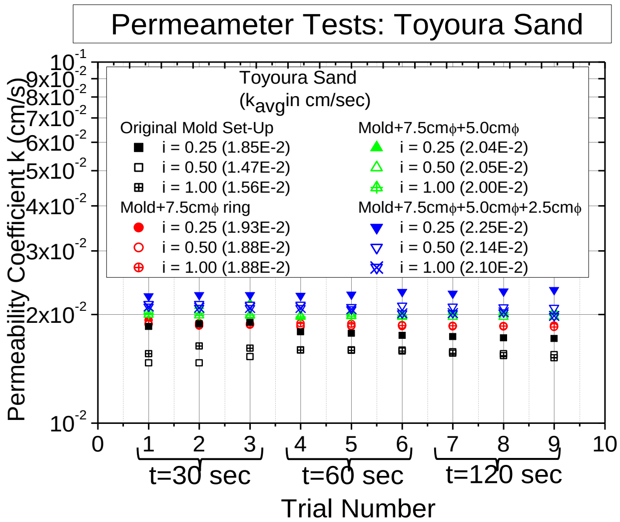

Fig.5 Permeameter Test Results of Various Cylinders

4.2 Triaxial Apparatus using Pin-Type Sensor

The permeability of the specimen was also determined by using the triaxial apparatus. Fig.6 summarizes the results, comparing the permeability of the specimen by permeameter tests to triaxial apparatus using pin-type sensor. In Toyoura sand (indicated by square), the permeability using the permeameter test ranged from 1.5 x 10^{-2} cm/s to 2 x 10^{-2} cm/s while the triaxial apparatus with pin-type sensor ranged from 3 x 10^{-3} cm/s to 5 x 10^{-3} cm/s. In Inagi sand (indicated by circle), the permeability using the standard test was about 5 x 10^{-4} cm/s while the triaxial apparatus using pin-type sensor ranged from 1 x 10^{-4} cm/s to 8 x 10^{-4} cm/s. In both cases, the values of permeability coefficients obtained using the triaxial apparatus with pin-type sensors were generally less than the values obtained using permeameter test.

Other factors that need to be verified, which could affect the permeability of the specimen obtained from the permeameter test and triaxial test are: (1) The permeameter test does not take into account the head loss incurred by the filters and porous stone, and (2) the confining pressure of the specimen using triaxial apparatus.

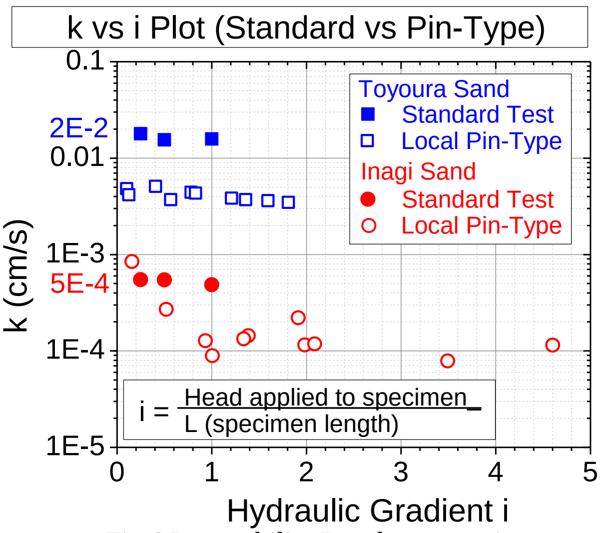

Fig.6 Permeability Results comparing Permeameter Test and Triaxial Test w/ Pin-Type

5. CONCLUSIONS

The number of cylinders inserted in the Standard Test resulted to increase in permeability, which imply that the gaps between the soil and cylinder interface affected the flow of water into the specimen.

The permeability values of Toyoura and Inagi obtained from triaxial apparatus with pin-type sensors are in general lower than the values obtained from permeameter tests. The head loss effects and confining pressure effects must be verified.

6. REFERENCES

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Wang, H. (2014). Evaluation of Liquefaction Potential of Partially Saturated Heap of Iron Ore Fines during Maritime Transportation. PhD thesis, Dep. of Civil Engineering, The University of Tokyo

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