EFFECT OF PIN-LENGTH AND CONFINING PRESSURE ON THE 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. It was found out that the gaps between the soil and cylinder mold interface affected the flow of water into the specimen (Tan Tian et al, 2016). In contrast, a flexible confining wall such as rubber membrane on triaxial apparatus (Hatanaka et al, 1997, Wang 2014) reduces the gaps between specimen and confining wall by adjusting the confining pressure (Fig.1). In this paper, further investigations were conducted to determine the effect of pin length, and to study the effect of confining pressure (σ_c) on the coefficient of permeability (k) using triaxial apparatus.

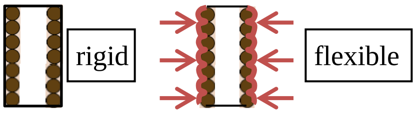

Fig.1 Schematic representation of rigid and flexible wall due to confining pressure

2. EQUIPMENT AND MATERIALS

In this study, a special type of tank was utilized to maintain constant head for the permeability test using triaxial apparatus. Fig.2 schematically shows the testing system. In Fig.2 indicated by *x*, the total head supplied to the specimen is maintained by the overflow of the water cell. This is done 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.2 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 overflow volume 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 cylindrical specimen (height, h = 10 cm; diameter, φ = 5 cm) due to head loss such as friction on the flow path. Hence, two sets of pin-type sensors inserted near the top of the specimen at opposite sides, and near the bottom of the specimen at opposite sides were innovated in order to measure the local head difference between the two points directly (Fig 2, 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 length of the long pins were 2.5 cm, which intersected the centerline of the specimen, while the short pins were 0.5 cm to measure the permeability near the edge of the specimen (Fig.3).

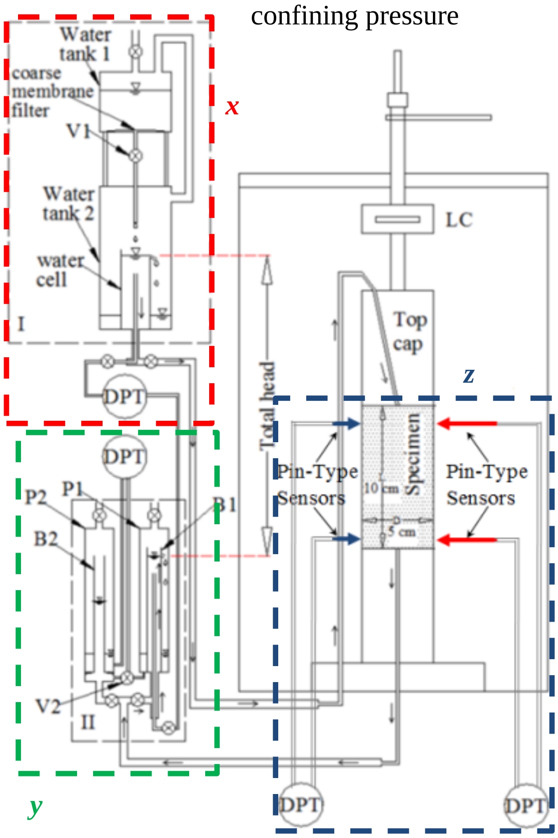

Fig.2 Schematic Diagram of Triaxial Apparatus w/ two sets of pin-type sensors

The pin-type sensors were used in this study for two types of sands: Toyoura and Inagi. Toyoura sand has specific gravity (G_s) of 2.652, median diameter (D_{50}) of 0.16 mm, max. void ratio (e_{max}) of 0.989 and min. 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 ($\rho_{d,max}$) of 1.66 g/cm^3.

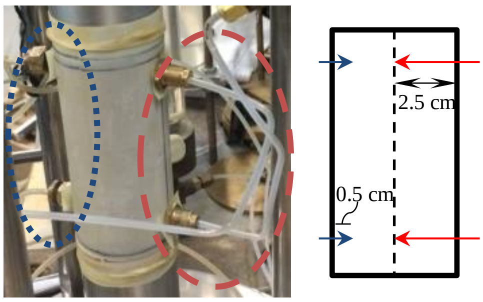

Fig.3 Two sets of pins, one set at 2.5 cm length while another is 0.5 cm

3. SPECIMEN TESTS AND METHODOLOGY

3.1 Local Measurement using two sets of Pin-Type Sensors

The specimen was prepared by 1-D mold compression. The pins were inserted 1 cm away from the top and bottom of the specimen. Seven (7) different head tests were carried out with Total Head equal to 5 cm, 10 cm, 15 cm, 20 cm, 35 cm, 50 cm, and 65 cm. The relative density, D_r of Toyoura sand was 75% to 78% while the degree of compaction, D_c of Inagi sand was 72%.

Keywords: Permeability, Pin-Type Sensor, Local Measurement, Triaxial Apparatus, Confining Pressure
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3.2. Confining Pressure

The specimens were initially subjected to σ_c of 30 kPa. Then, the seven different total heads were implemented to the triaxial apparatus. After conducting tests for each total head, the confining pressure was increased to 60 kPa, in which the same process was repeated. It was finally incremented to 100 kPa, before decreasing the pressure to 60 kPa, and then 30 kPa again. Then on, it was decreased every 5 kPa until the final confining stress was 5 kPa.

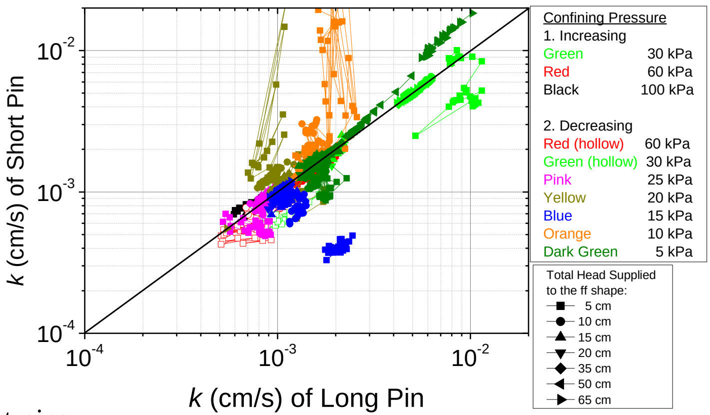

Fig.4 Comparison of *k* of long and short pins

4. RESULTS AND DISCUSSIONS

4.1 Comparison of *k* of the Long and Short Pins

Fig.4 shows the *k* obtained by the long pins and the short pins. The *k* values obtained at total head supply of 5 cm were significantly different from the others. This is due to the low head measured that was affected by the natural electric impulses supplied by the DPT. The *k* values obtained at total head supply of 10 cm to 35 cm were in agreement to each other, while those of 50 cm and 65 cm were generally higher in the short pins.

4.2 Effect of Confining Pressure

Fig.5 shows the initial σ_c of 30 kPa corresponded to higher *k* values (i.e. up to 1 x 10^{-2} cm/s) for every total head supplied. The *k* values gradually decreased as the σ_c was increased up to 100 kPa. It can be noticed that upon decreasing the σ_c from 100 kPa to 20 kPa, the *k* values were rather consistent with *k* of around 1 x 10^{-3} cm/s. This suggests that although elastic rebound may be present, it was minimal, hence small change in the void ratio. The *k* values increased at σ_c values lower than 20 kPa. This is due to the rubber membrane wrinkle, causing the water to flow faster through the specimen.

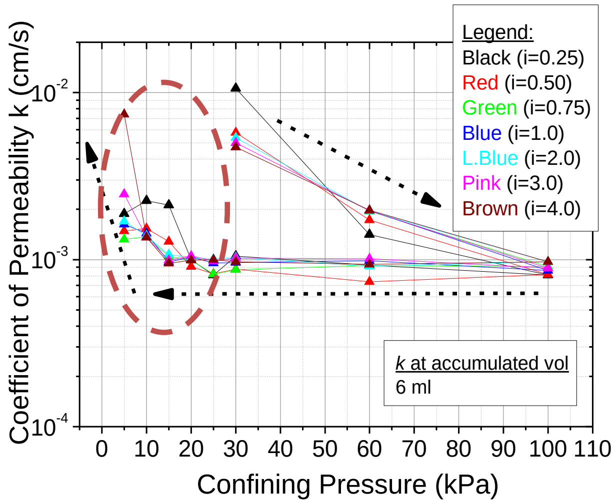

Fig.5 Effect of Confining Pressure on *k*

4.3 Comparison of Permeameter Test and Triaxial Test

Fig.6 summarizes the results, comparing the *k* values of the specimen by permeameter tests to triaxial tests using pin-type sensors. In Toyoura sand (indicated by square), the *k* values using the permeameter test ranged from 1.5 x 10^{-2} cm/s to 2 x 10^{-2} cm/s while the triaxial test 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 *k* values using the permeameter test was about 5 x 10^{-4} cm/s while the triaxial test using pin-type sensor ranged from 1 x 10^{-4} cm/s to 1 x 10^{-2} cm/s. The values obtained for Toyoura sand were less at pin-type while for Inagi sand, the results were inconclusive.

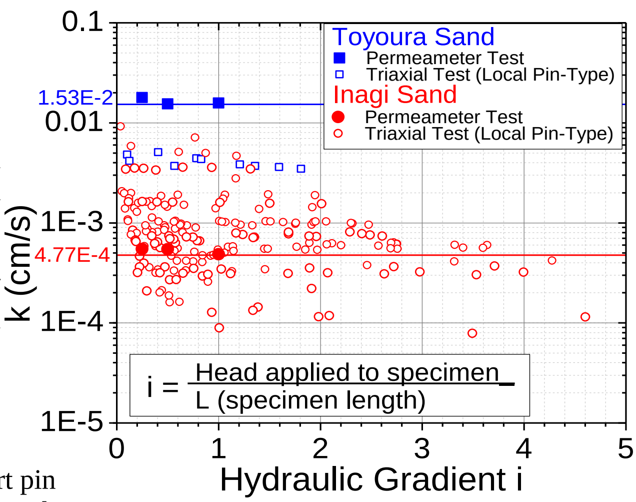

Fig.6 Comparison of *k* between Permeameter Test and Triaxial Test (Local Pin-Type)

5. CONCLUSIONS

Effect of Pin Length – the local permeability of long pin and short pin are comparably the same at confining pressures (σ_c) > 20 kPa with total head supply between 10 cm to 35 cm.

Effect of confining pressure – permeability is affected by the increase of σ_c due to the change of voids. Increasing σ_c resulted to decreasing coefficient of permeability values (*k*), while decreasing the pressure resulted to consistent *k* values until less than 20 kPa due to membrane wrinkle.

6. REFERENCES

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