Evaluation on Drainage Capacity of Cylindrical Drain with Different Core Shapes
코아형식에 따른 원통형 배수재의 구멍막힘에 의한 배수능력 평가비교

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SYNOPSIS : Various core shapes of cylindrical drains are used for accelerating primary consolidation for soft clay deposits, but serious harmful disadvantages on drainage capacity may occur on cylindrical drains due to confining pressure when they are installed in that soil. In this study, two different core shapes of cylindrical drain are used to evaluate the drainage capacity with consideration of clogging effects on their filter jackets for an applied confining pressure. Column tests with radial drainage system were conducted under confining pressure of 50 kPa for 13 days. Two parameters which are discharge and accumulated volume of water drained were measured as the time elapsing. From this experimental study, the results showed that at the initial stage before the clogging developed enough, the cylindrical drain with angular-type-plastic-core could produce discharge twice higher (maximum) than those with round-type. After 13 days had passed on, cylindrical drain with angular-type-plastic-core could produce discharge only 20% higher than those with round-type one. Eventually, there is a possibility that the efficiency of using angular-type-cylindrical-drain will be similar to the round-type one as the clogging develops more.

Key words : Clogging, Core shape, Cylindrical drain, Drainage capacity

1. Introduction.

Vertical slotted plastic drain pipe (referring to cylindrical drain) is one recent innovation for providing drainage (Rollins et al 2003). This type of drain material can provide more space for water to flow due to the excess pore pressure developed from the surrounding soil. In contrast to conventional PVDs, which have very limited flow capacity (2.83 x 10^{-5} m^3/sec for a gradient of 0.25), a 100 mm diameter of cylindrical drain can flow 0.093 m^3/sec of water (K. Rollins and J. Anderson, 2003). This volume is also more than 10 times greater than that provided by a typical 1 m diameter of stone column which is about 6.51 x 10^{-3} m^3/sec (Rollins, et al, 2004).

Cylindrical drain is usually used when the demand of water to be drained must be dissipated in a large amount and rapidly such as being used for liquefaction mitigation to prevent the excess pore pressure develops beyond the confinement pressure of the soil (Rathje, et al, 2004). In addition, this type of prefabricated vertical drain has also been being used to accelerate the primary consolidation of embankment test on Busan New Port area (Choi, et al, 2005). Moreover, selecting cylindrical drain instead of ordinary PVD is dependant on the amount of excess pore pressure due to surcharge and allowable consolidation time available in a project to get the required soil strength.

Clogging is another long term effect which may control the dissipation of porewater. However, at the initial stage of primary consolidation, hydraulic gradient generated from the surcharge will control the dissipation of porewater (Bergado, et al, 1996). On this paper clogging effect has been evaluated by comparing the drainage capacity (discharge and accumulated volume of water drained) of cylindrical drain with two different shapes of plastic cores (round and angular types).

2. Experimental study.

2.1 Materials and properties.

The main materials of the current column tests are clayey silt soil and cylindrical drain samples. Clayey silt soil had been taken from west coast of South Korea and remade until 60-70 % of water content could be obtained. Table 1 shows the engineering properties of clayey silt soil used in the tests. In addition, the cylindrical drain samples which are distinguished by their PE-core shapes (round and angular types) with the same filter jacket (non-woven geotextile) are depicted in Figure 1. Detail geometries of cylindrical drain samples also can be seen in Figure 2. Table 2 gives the engineering properties of non-woven geotextile filter jacket used on the cylindrical drain samples.

Table 1. Engineering properties of soil.

Properties		Value
ω (%)		64.56
G_s		2.67
LL (%)		36.43
PL (%)		23.96
Particle Content (%)	Sand	5.10
	Silt	86.40
	Clay	1.53
	Colloid	6.97
C_u		4.50
C_c or C_z		0.80
USCS		CL

Table 2. Engineering properties of non-woven geotextile filter jacket.

Properties	Value	Remarks
Mass	177.8 gram/m^2	KSK 0514
AOS	85.2 μm	ASTM 6767
Tensile Strength	551.0 kgf/m	KSK 0520
Crossed Plane Permeability	2.5 x 10^{-1} cm/sec	KSF 2322

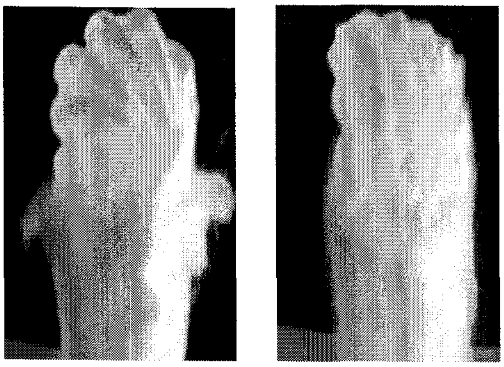

Figure 1. PE cores of cylindrical drain samples (left = round type ; right = angular type).

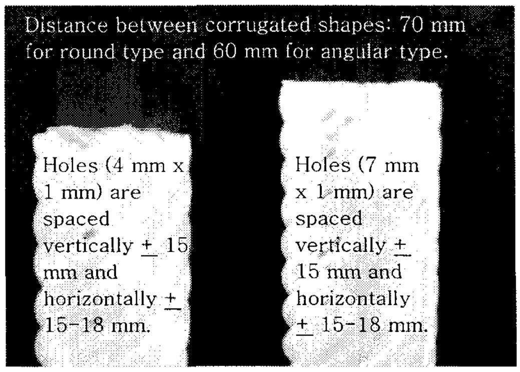

Figure 2. Geometry of two different plastic cores (left = round type ; right = angular type).

2.2 Test set up and procedure.

Using the same geotextile filter jacket, the cylindrical drain samples were cut until 15 cm long. Afterwards, one of their edges was closed and tightened with a membrane and o-ring while another edge was embedded in the styrofoam layers as depicted in Figure 3. Due to the embedment in the styrofoam layers and impermeable confinement by the rubber membrane, the effective drained surface area on the cylindrical drain was only 9 cm times the perimeter of the drain. Two different thicknesses of soil layer were tested (15 and 20 cm). After all chambers had been filled with water, they were closed and air pressure was applied until 50 kPa to each chamber at the same time to generate hydraulic gradient in the clayey silt soil and confining pressure of on the cylindrical drain samples.

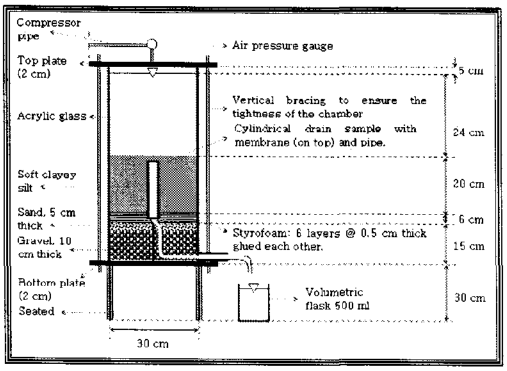

Figure 3. Schematic diagram of testing apparatus.

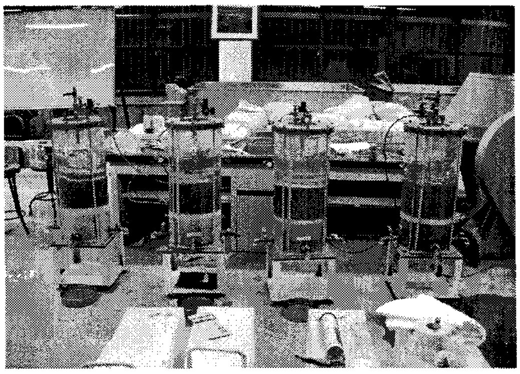

Figure 4. Photo of column tests.

3. Result and discussion.

The maximum discharge difference of cylindrical drain with angular-type-plastic-core is about twice greater than that of cylindrical drain with round-type-plastic-core (Figure 5). However, the discharges become smaller and smaller after their peak values are transcended. The maximum discharge difference of 30% occurs at elapsed time 210 hours and 20% occur at elapsed time 312 hours. The difference might still be smaller as clogging develops with time. In addition, the accumulated volume of water drained depicted in Figure 6 are curving at elapsed time 90 hours, means smaller discharges were being obtained at that time. Furthermore, Figure 6 and 7 enables some estimation for the later drainage capacity (discharge and accumulated volume). Figure 8 gives the overall increase of drainage capacities in using cylindrical drain with angular-type-plastic-core normalized with those with round-type one. Moreover, at the end of the tests, there is an indication for the normalized drainage capacity (discharge and accumulated volume) to become unity after some more hours. That means that the later discharges of all cylindrical drain samples are more or less equal independent on the type of plastic core. Hydraulic gradient in the clayey silt soil can be estimated by dividing the total water head with the distance from the surface of water to the middle of drained surface area). It was found that the estimated hydraulic gradient was 34.77 for 20 cm thick soil layer and 51.33 for 15 cm thick soil layer.

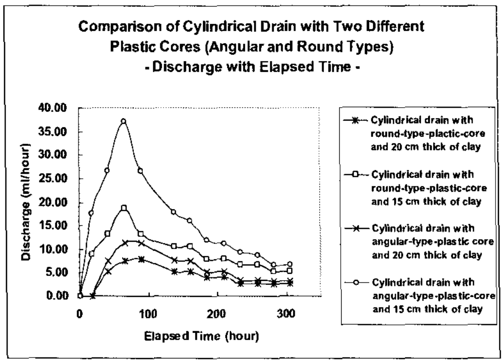

Figure 5. Discharge with time.

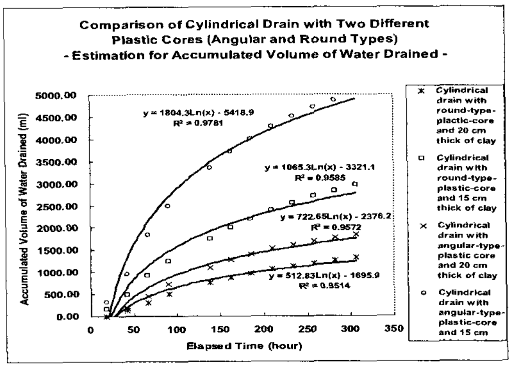

Figure 6. Accumulated volume with time.

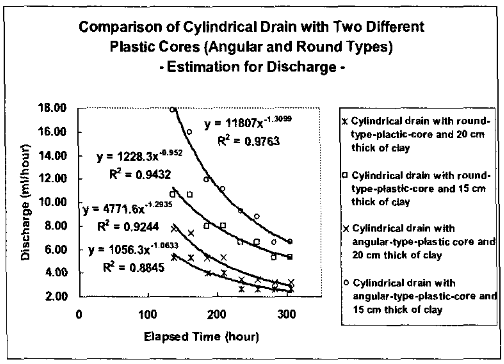

Figure 7. Estimation of discharge with time.

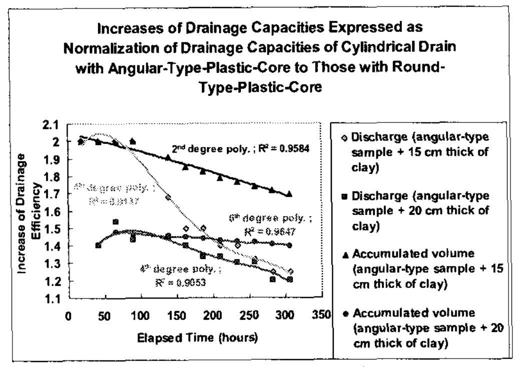

Figure 8. Increases of drainage capacities expressed in normalization.

$$\text{Accumulated volume } = A\ln t + B \quad (1)$$

$$\text{Discharge } = Ct^{D} \quad (2)$$

From the experiment, as the accumulate volume tend to curving to make asymptote, the relation between accumulated volume and elapsed time can be expressed by logarithmic-type-equation (Equation 1) which may give a good approximation ($0.95 < R^2 < 0.98$). Assuming that the discharge may not become zero or even negative, power-type-equation (Equation 2) will be reasonable (0.88 < R^2 < 0.98) to relate the discharge with elapsed time. In addition, it is also possible to use exponential equations to relate the discharge with elapsed time; however, they will give lower R^2 values. Eventually, t (in hour) in Equation 1 and 2 represents elapsed time and constants A to D are experimental values dependant on hydraulic gradient and confining pressure.

4. Conclusion.

Drainage capacity of cylindrical drain with angular and round types of plastic core was evaluated by measuring their discharge and accumulated volume. Furthermore, the following conclusions have been derived from the tests:

- At the initial stage, the maximum discharge difference produced by cylindrical drain with angular-type-plastic-core is twice greater than those with round-type one at elapsed time 66 hours and only 20% greater at elapsed time 312 hours. Furthermore, as the clogging develops with time, the cylindrical drain samples with angular-type-plastic-core produce less discharges and seem to get close to the ones with round-type-plastic-core.
- Angular-type-plastic-core can resist well the surrounding confining pressure so that the space available for water to flow is bigger and wider than that of round-type one.

Finally, using cylindrical drain with angular-type-plastic-core has been proved to be advantageous for draining more volume of porewater compare to those with round-type-plastic-core at initial stage, hence, also the later one. However, further studies for long term behavior of cylindrical drain with angular-type-plastic-core are still necessary especially with very high confining pressure.

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