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CONSOLIDATION CHARACTERISTICS UNDER CYLINDER TEST, CENTRIFUGAL TEST AND OEDOMETER TEST

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ABSTRACT

A several laboratory tests have conducted to investigate the self-weight consolidation characteristics on Ariake washed. They are self weight consolidation by cylinder test and centrifuge test, while incremental loading by oedometer test as well. All the samples were used have passed through a 425 µm siever to remove the granular particles. For cylinder test series, we adjust the suspension for each sample in initial water content range from 103 % to 1000 %, corresponding to liquid limit start from 1. Then let the self-weight consolidation process occurred. After the final process, we measured the final water content and maximum settling rate. Next for centrifugal test, we adjust the sample in liquidity index (IL) equal 1.5. The initial height specimens were 6, 4, 2, and 1 cm. All the specimens were played in centrifuge device. For 5 and 6 cm initial height specimen we adjust the velocity 850 rpm, and 800 rpm for 1 and 2 cm initial height specimen. The settling was recorded on elapsed time ranging from 15 to 1440 minute randomly. As for oedometer test, we adjusted the samples under 0.75, 1.0, 1.25, and 1.0 in liquidity index.

Key words: self weight consolidation, settlement, centrifuge, sediment

1. Introduction

The utilization of dredge materials as land reclamation becomes widely spread nowadays. Besides to fulfill the needs of materials embankment, to solve the silting river, seabed and other deposits problems as well. However the characteristics of slurry soil mainly clay deposits that has known poor geotechnical properties. They are high initial water content, high compressibility, low shear strength and low bearing capacity. Therefore the consolidation characteristics investigation, need to be done to understanding the settling behavior of slurry soil for further soft ground improvement works.

Particle settling is important and ubiquitous phenomenon. Settling is called sedimentation in system with low or intermediate particle content and consolidation when system has a high solid content. Sedimentation and consolidation have been studied extensively in chemical engineering for solid liquid separation, and in civil engineering for the construction.

The characteristics of self-weight consolidation on slurry marine clay have reported by Kondo et al. 1999. However there has not been theory that reporting a relationship among self-weight consolidation under the wide range initial water content of slurry clay. Based on that theory therefore we investigated the characteristic of self-weight consolidation on Ariake washed deposit under cylinder test, centrifugal test and oedometer test. That investigation is needed for design-analysis the geo-engineers works to soft clayey ground improvement, mainly for using the dredged material for embankment.

2. Materials

Ariake creek sediment samples were collected in Higashi Yoka in the intertidal zone at low tide on latitude 33°12'57.65. The Ariake creek specimens used for the experiments were prepared by removing shells and coarse particles from the sample by using 425 µm strainers. Some properties of Ariake washed are presented on table 1 and grain size distribution (Fig.1.) as well.

3. Experimental Methods

Cylinder Test

The preparation of sedimentation experiment was conducted using a 1 L plastic bottle for each test series with the appropriate initial water content (w_c) which range 106, 133, 200, 300, 400, 500, 750, and 1000 %. The values of liquidity index corresponding to that initial water content were 1.0, 1.5, 2.8, 4.6, 6.5, 8.4, 13.2, and 17.83 respectively. After these suspensions were left for one day, the soil was removed into a 6 cm diameter and 26 cm high acrylic cylinder which was then filled to 20 cm with the appropriate suspensions. For samples with initial water content ranging from 500 to 750%, the settling processes were monitored for 14 days, while the specimens with initial water content ranging from 106 to 400 % it takes place 28 days for finished the self-weight consolidation processes, then data was recorded to the 20 cm graph paper which was pasted into the cylinder.

Centrifugal Test

Ariake washed sample was adjusted on 1.5 liquidity index. The water content on liquid limit, plastic limit and present sample state were, 106.2,53.1, 132.75 respectively. The sample then filled up on the plastic bottle with 10 cm in height 3 cm in diameter and the cone shape on the bottom edge of the bottle. The sample height in the bottle was adjusted 1, 2, 4, and 6 cm. Each height was prepared on the 2 bottles then put on the centrifuge device on symmetric position for balancing. The capacity of centrifuge equipment is 4 samples every played. The sample on the face to face direction should be equal on weight. For 1 and 2 cm sample in height were played together with 800 rpm in rotation velocity, while for 4 and 6 cm sample heights were 850 rpm in rotation velocity. From 30 minutes to 1440 minutes elapsed time randomly, the heights of the sample was recorded.

Oedometer Test

The odometer test was performed on Ariake washed specimens with different initial water contents. They were 92.93, 106.2, 119.48, and 132.75 % initial water content. The liquidity index corresponding with those initial water contents were 0.75, 1.0, 1.25, and 1.5 respectively. The test was done in accordance with the procedure of the Japanese Geotechnical Society (JSF T 411-1990). The consolidation pressures applied were 0.05, 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, and 12.8 kgf/cm^2.

Table 1. Soil Properties Analysis

Kind of properties	Original sample	Air dried sample
Ignition loss	11.7	
Particle density	2.54	
CEC (meq/100g)	33.6	
Water content (%)	150-200	
Plastic Limit (%)	w_P = 53.1	
Liquid Limit (%)	w_L = 106.2	
Grain size distribution		
Sand (> 0.075mm) (%)	2	2
Silt (0.05-0.075mm) (%)	37	22
Clay (<0.05mm) (%)	61	76

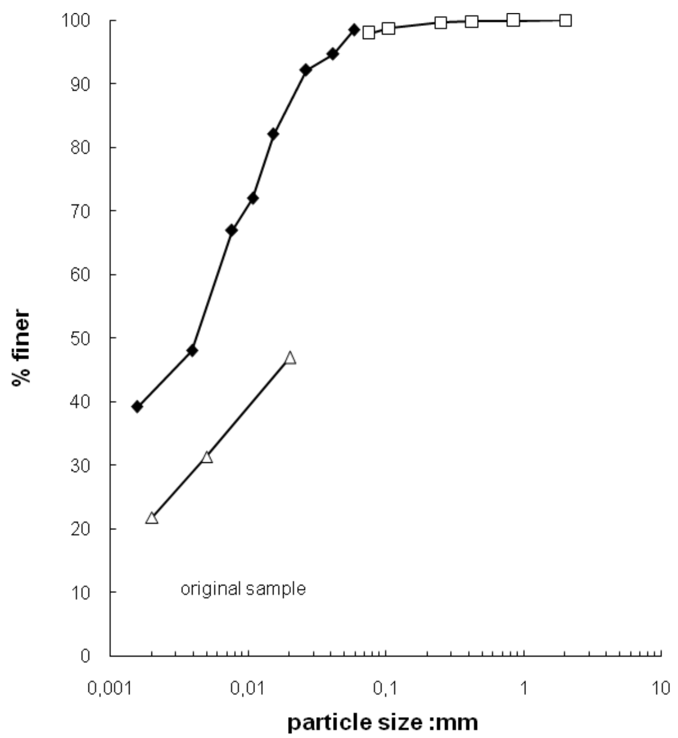


Fig.1. Grain size distribution

4. Result And Analysis

The fundamental mechanism of settling characteristics on the higher solid concentration than zone settling state was successfully interpreted by Mikasa (1963) with his consolidation theory for very soft clay. The volume ratio (*f*) definition was presented in this report where *f=1+e*, which is represent the volume of soil, and some report using volume ratio than the void ratio in settlement calculation for convenient (Kondo et.al. 1999). Some calculation relationships for settling rate, coefficient of permeability, volume ratio and effective stress are presented.Then the volume ratio-effective stress relationship and coefficient of permeability relationship were presented.

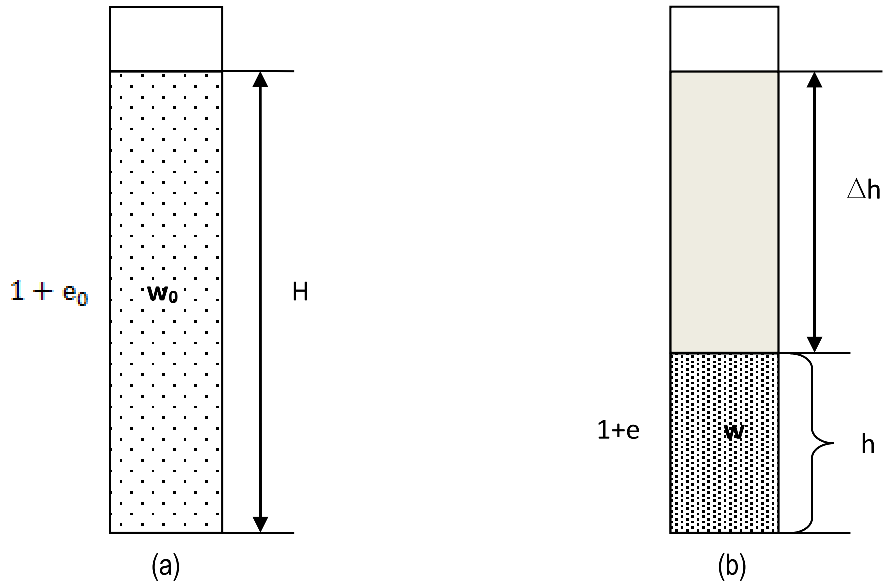


Fig. 2. Sketch solution on sedimentation (a) before sedimentation (b) after sedimentation

As for the formula from its condition :

$$H = h + \Delta h \qquad (1)$$

$$h = H - \Delta h$$

$$\frac{H}{1+e_0} = \frac{h}{1+e}$$

$$h + h\,e_0 = H + H\,e$$

$$H\,e = h + h\,e_0 - H$$

$$e = \frac{h}{H} + \frac{h}{H}e_0 - 1$$

$$e = \frac{h}{H}(1+e_0) - 1$$

$$e = \frac{H-\Delta h}{H}(1+e_0) - 1$$

$$e = \left(1 - \frac{\Delta h}{H}\right)(1+e_0) - 1 = 1 + e_0 - \frac{\Delta h}{H} - \frac{\Delta h}{H}e_0 - 1$$

$$= e_0 - \frac{\Delta h}{H} - \frac{\Delta h}{H}e_0$$

$$e = \left(1 + \frac{\Delta h}{H}\right)e_0 - \frac{\Delta h}{H} \qquad (2)$$

$$e_0 Sr = G_s w_0 e_0 = \frac{G_s - w_0}{Sr} = \frac{G_s w_0}{100} = \frac{G_s w}{100} \qquad (3)$$

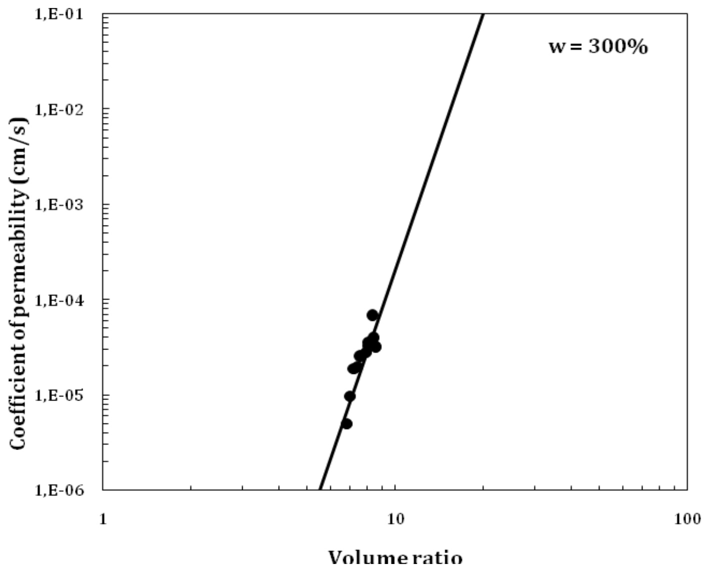
In which, *e, Sr, Gs, w*, and *H* are void ratio, degree of saturated, specific gravity, water content and height of solution respectively. The subscript *0* shows the initial state.

The equivalency inclination slope was shown from the coefficient ofpermeability-volume ratio plot under cylinder test (Fig.1). The linear relationship between coefficient of permeability and volume ratio can be used to predict the coefficient of permeability at any given point of volume ratio. This condition valid only on self-weight consolidation settling stage, under settling zone (w = 1000%) the data shift randomly and irregularly. In this case, the settling rate mostly influenced by degree of particle's interaction which is determined by mixture's solid concentration. The effective stresses at any given point of the void ratio are constant. This condition can be explained as the void ratio decrease followed by submerged unit weight increase, the sediment thickness decrease also.

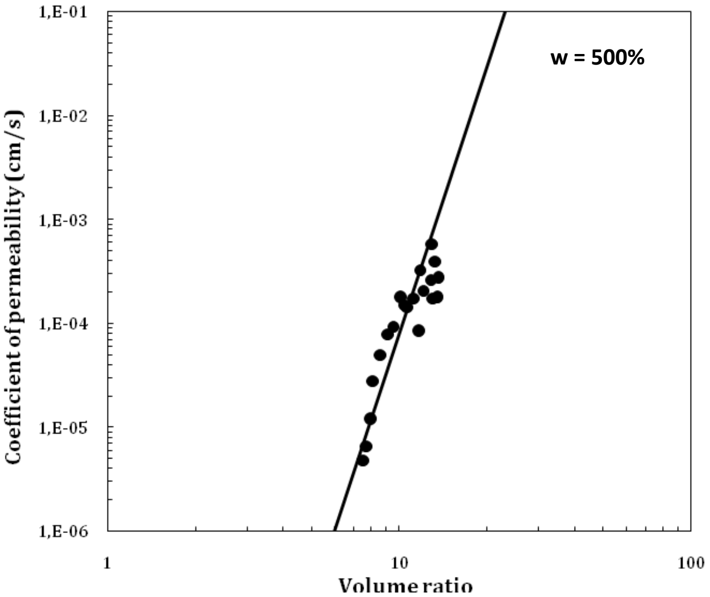
While in the centrifugal test results, the settling rate was very slowly, the coefficient of permeability was presented in cm/year unit in relationship to the volume ratio (Fig.2). For the thinner initial height, the settling rate slower than the thicker initial height. Additionally, in the thicker initial data the more data could be recorded. As on the cylinder test result, the coefficient of permeability-volume ratio curve, shows the linear relationship hence, the coefficient of permeability at any given point can be predicted. The effective stress constant at every single point, this condition has been explained previously. In the centrifugal test, the *k-f* relationships were determined from the initial settling rates of self-weight consolidation using various initial water contents under single drainage condition. The coefficient of permeability was calculated using :

$$k = \frac{v.\gamma_w}{n.\gamma_0'} \quad \text{...} \quad (4)$$

Where *v* denotes the settling rate of the specimen surfaces, denotes the unit weight offluid, and denotes the submerged unit weight in the initial state respectively. In the oedometer test, the *k-f* relationships (fig.3) were determined from the coefficient of consolidation (c_v) by a conventional manner according to the Terzaghi's theory. The inclination slope plot from the coefficient of permeability-volume ratio curve tend linear and similar for any liquid limit condition. The graph plot can be used to predict the final settling rate as well. On the opposite direction the volume ratio-effective stress relationship shows the linear in semi logarithmic plot also (fig.4). As the effective stress increase, the volume ratio decrease. The more the volume ratio decrease shows the faster of the settling rate and shows the higher the compressibility.

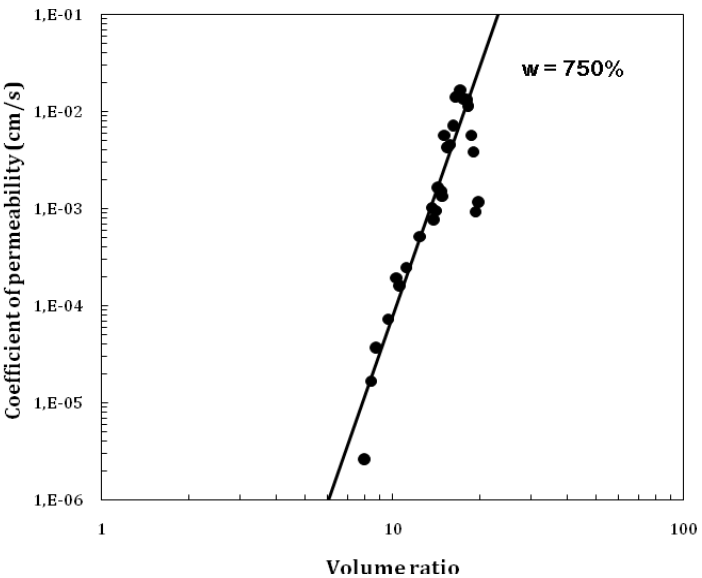


(a)

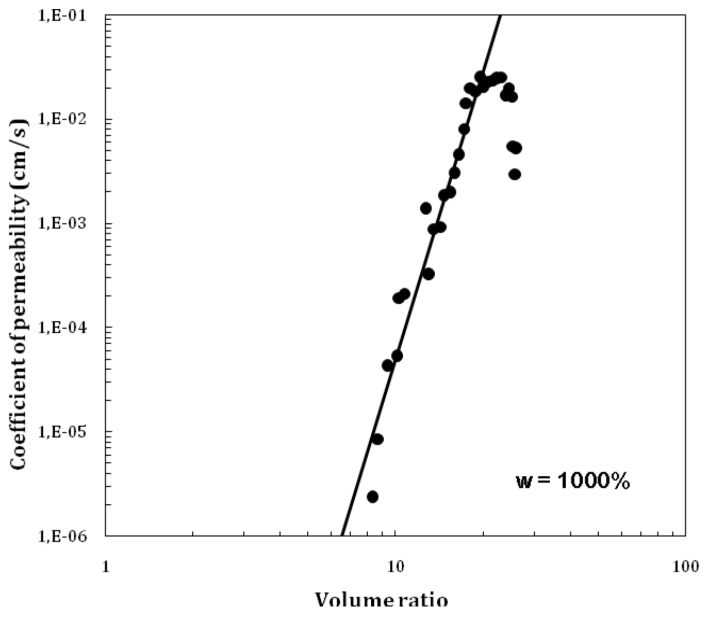


(b)

Fig. 3. Coefficient of permeability and volume ratio relationship determined by cylinder test,
a) w = 300% ; b) w = 500%

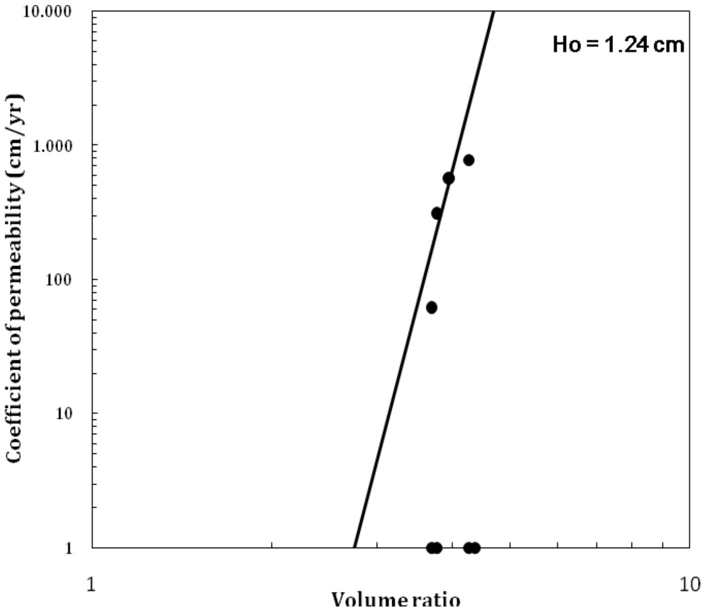


(c)

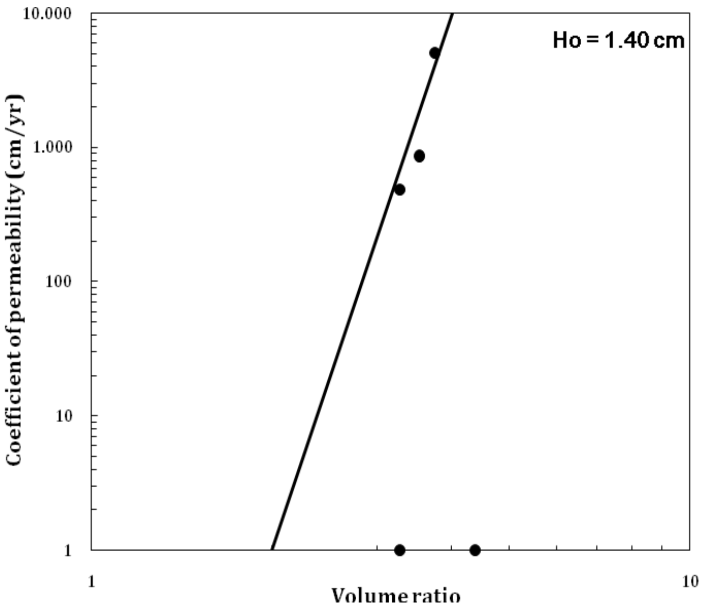


(d)

Fig. 4. Coefficient of permeability and volume ratio relationship determined by cylinder test, c) w = 750% ; d) w = 1000%



(a)



(b)

Fig. 5. Coefficient of permeability and volume ratio relationship determined by centrifugal test,
a) Ho = 1.24 cm ; b) Ho = 1.40 cm

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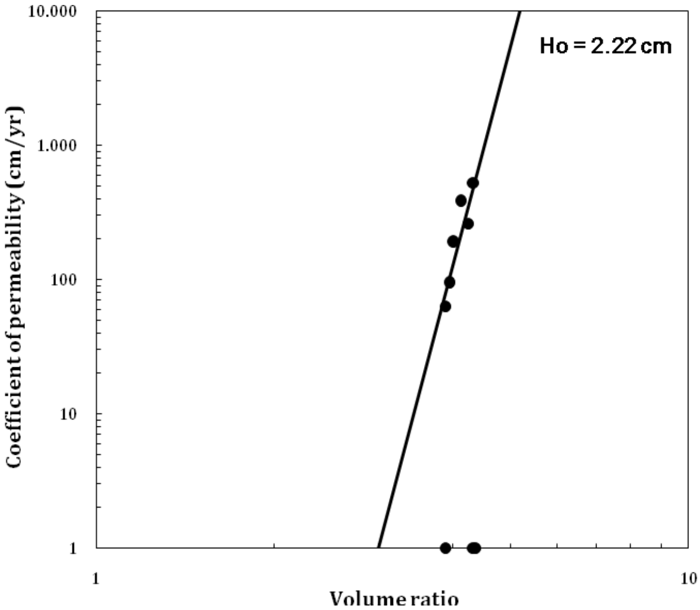

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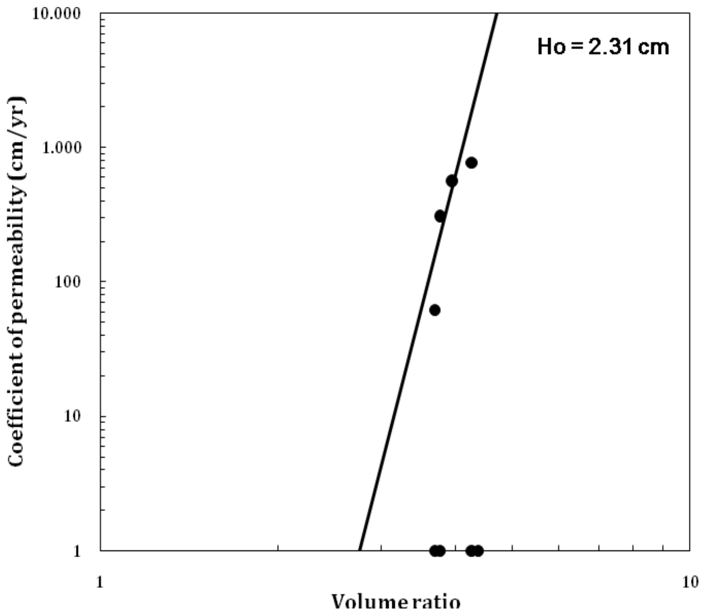
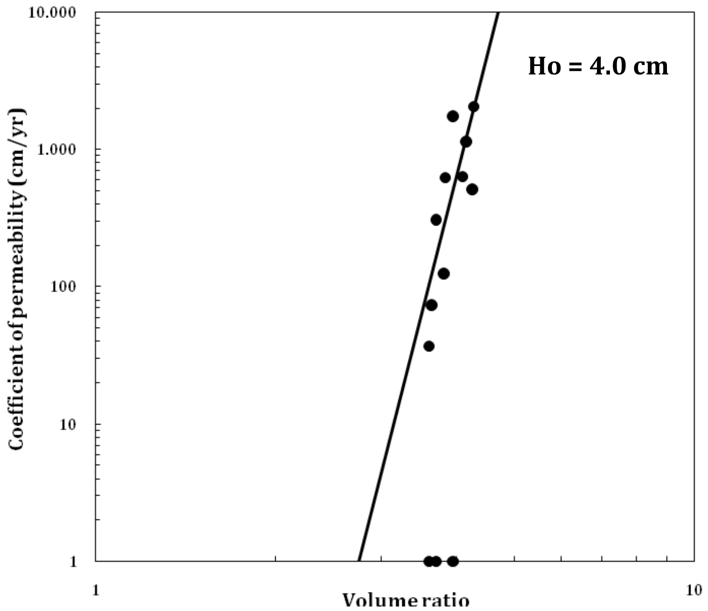
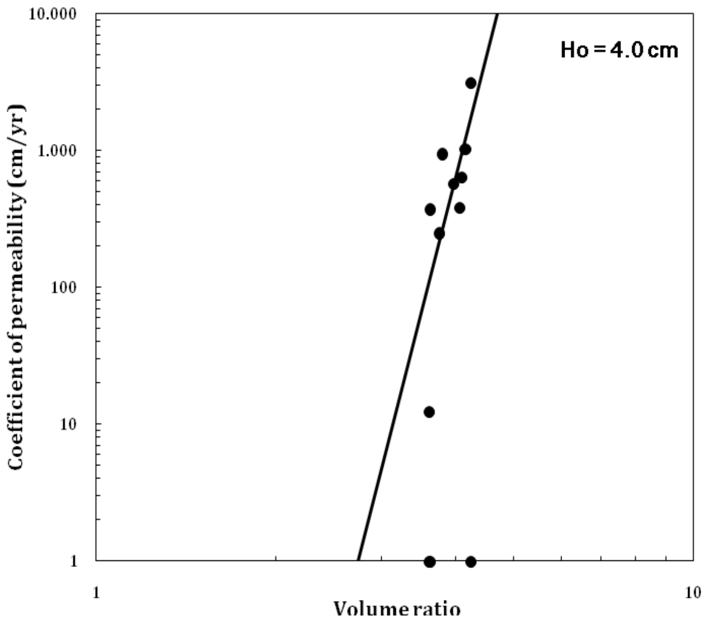


(d)

Fig. 6. Coefficient of permeability and volume ratio relationship determined by centrifugal test, c) Ho = 2.22 cm ; d) Ho = 2.31 cm

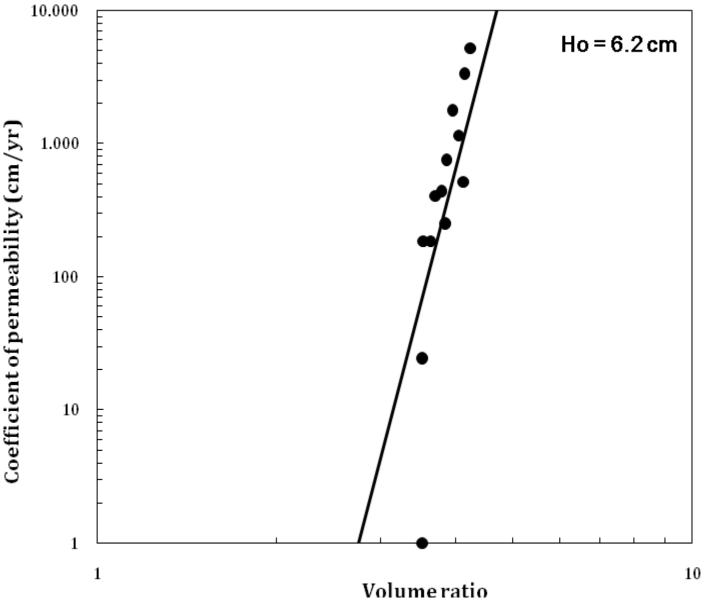


(e)

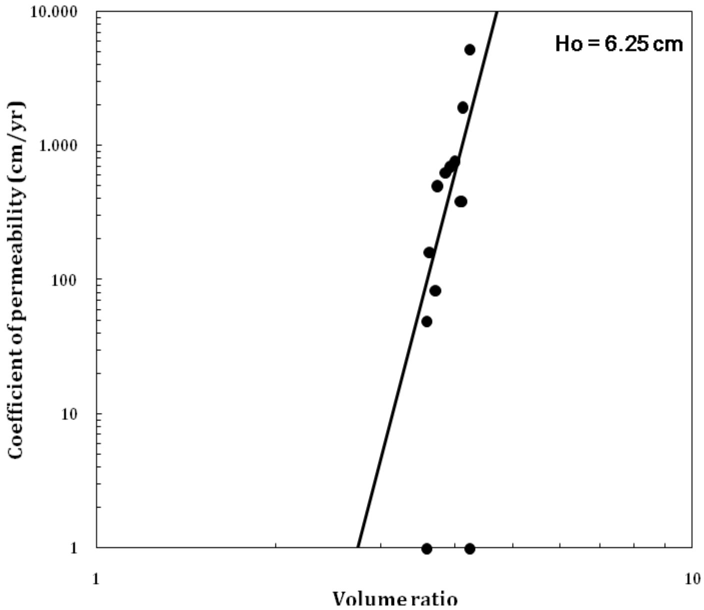


(f)

Fig. 7. Coefficient of permeability and volume ratio relationship determined by centrifugal test,
e) Ho = 4.0cm sample 1 ; f) Ho = 4.0 cm sample 2

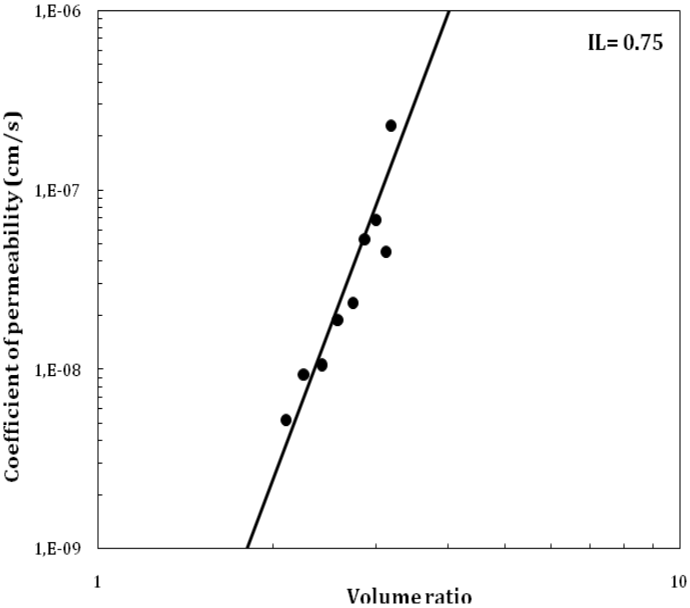


(g)

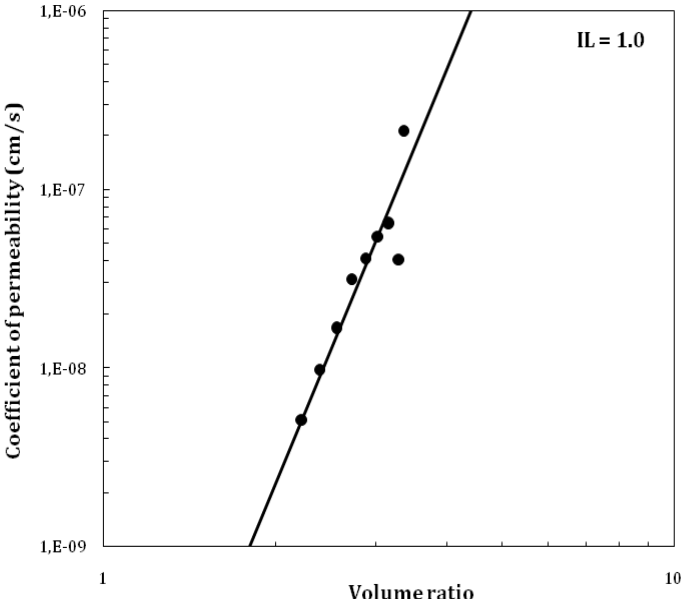


(h)

Fig. 8. Coefficient of permeability and volume ratio relationship determined by centrifugal test, g) Ho = 6.2 cm ; h) Ho = 6.25 cm

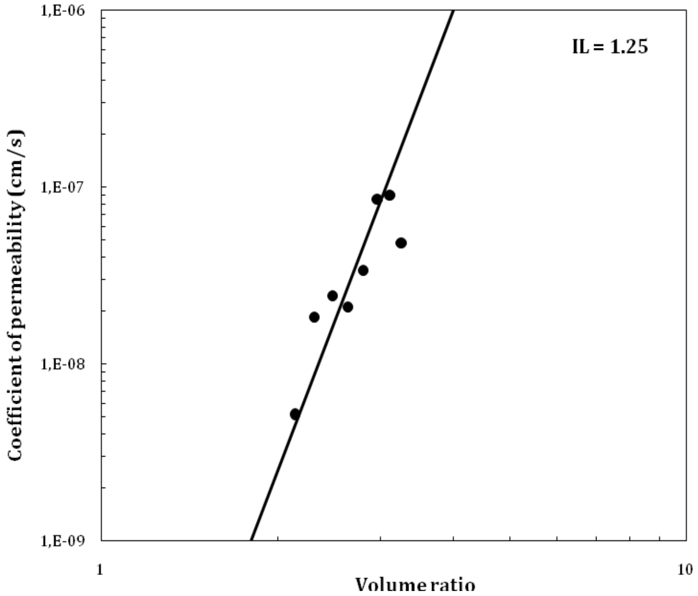


(a)



(b)

Fig. 9. Coefficient of permeability and volume ratio relationship determined by oedometer test, a) IL = 0.75 cm ; b) IL = 1.0 cm



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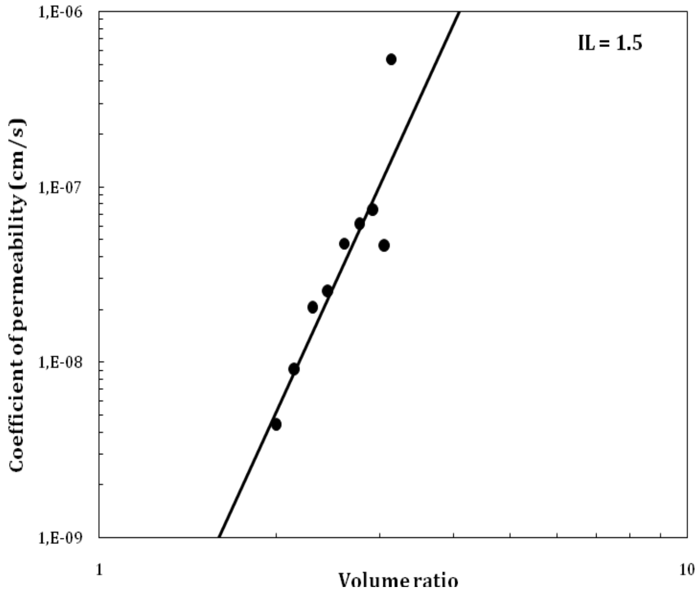
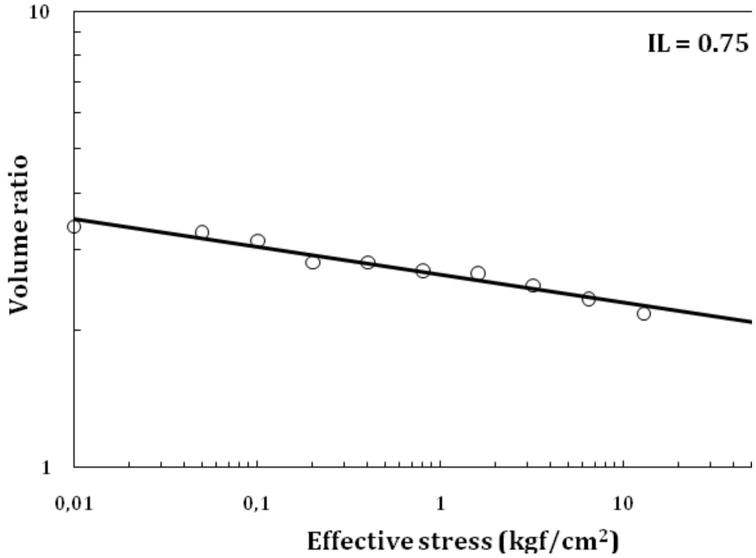
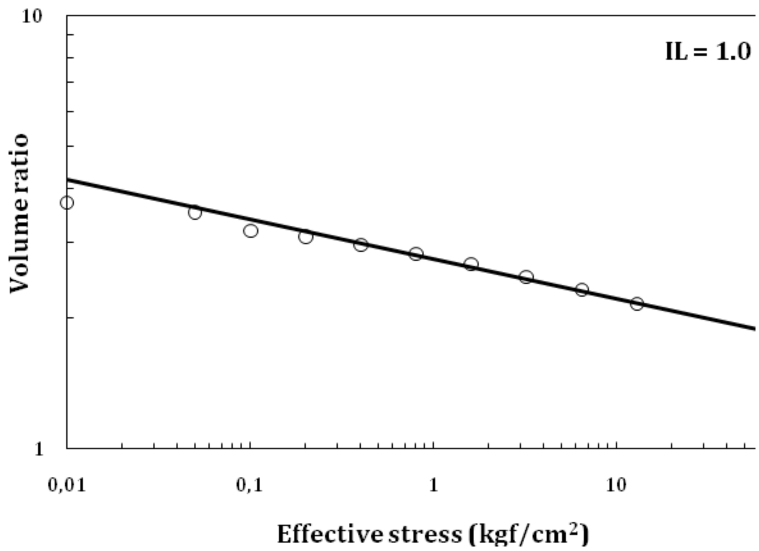


(d)

Fig. 10. Coefficient of permeability and volume ratio relationship determined by centrifugal test, c) IL = 1.25 ; d) IL = 1.5

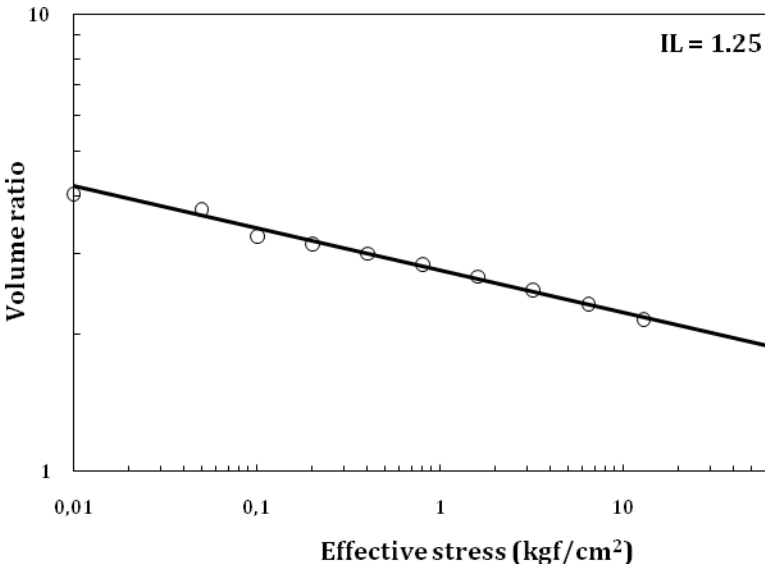


(a)



(b)

Fig. 11. Volume ratio and effective stress relationship determined from oedometer test
a). IL = 0.75 ; b). IL = 1.0



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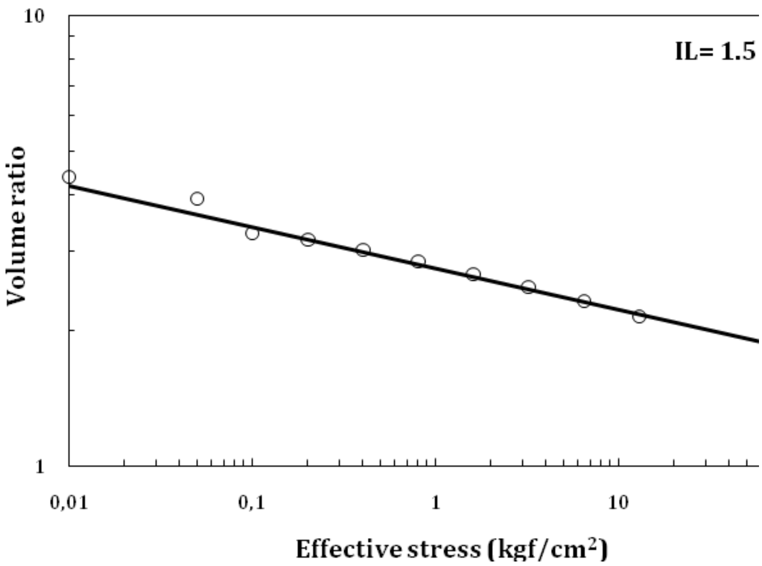

(d)

Fig. 12. Volume ratio and effective stress relationship determined from oedometer test, b).IL = 1.25 ; c). IL = 1.5.

5. Conclusion

Under cylinder test, centrifugal test and oedometer test, the coefficient of permeability-volume ratio relationship tend similar in the linear and at the slope inclination plot. This phenomenon also shows on the volume ratio-effective stress relationship under oedometer test on the opposite direction. Those plot curves can be used for predicting the final settling rate of the slurry clay in the wide range initial water content.

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