SETTLEMENT AND STRENGTH CHARACTERISTICS OF UNSATURATED SILTY SOILS WITH DIFFERENT DEGREES OF COMPACTION

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1. INTRODUCTION

From a practical viewpoint, collapse settlement due to water infiltration into the soil affects fills or road bases that are developed by compacted unsaturated soils. The compacted soil is frequently assessed based on the degree of compaction ($D_c=\rho_d/\rho_{d\max}$*100%)[1]. Furthermore, no consideration has yet been given to the mechanical properties of compacted soils as a criterion for determining the effect of compaction, or to the condition of soil immersed in water, the most dangerous state for the soil[2]. In this study, collapse settlement tests were conducted on three different types of soils (Kanto loam, DL clay and Kaolin clay) which are silty loam, silty and clayey soils using the initial degree of saturation, initial dry density and overburden pressure as parameters[3]. Then, simple direct shear tests have been conducted under the same conditions as collapse settlement tests to investigate changes in shear parameters (c and ϕ).

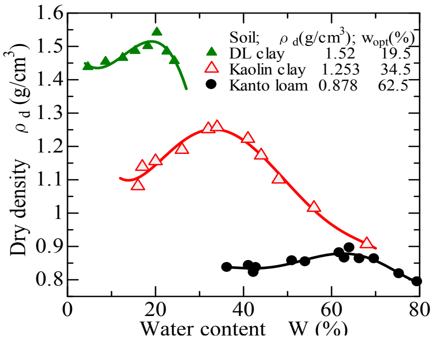
2 SAMPLES AND TEST PROCEDURE

2.1 Samples

The Kanto loam was taken directly from construction field inside Tokai University in Hiratsuka city and the other two types provided by factory. Table.1 shows the physical properties of tested soils and Fig. 1 shows the compactions curves which obtained from compaction tests (JIS A1210) result to choose the initial conditions for the tests specimens. According to the result of compaction tests using three kinds of oven-dried soils, amount of soil and water for both collapse and shear tests were calculated. After mixing the soil with water and placing in oedometer ring, static compaction was used to make the specimens.

Table1. Physical Property of DL clay

Sample	ρ_s (g/cm^3)	WL (%)	Wp (%)	Grading (%)		
				Clay	Silt	Sand
DL clay	2.65	NP	NP	4.7	95.3	0
Kanto loam	2.65	NP	NP	4	51	45
Kaolin clay	2.67	73.1	36.7	96.8	3.2	0



ils

2.2 Test procedure

Firstly the specimens for all types of soils have developed based on method of Kamei et al[3] in order to investigate collapse settlement. The collapse settlement tests were conducted using an odometer apparatus. Eight different overburden pressures p (5-640kPa) applied on unsaturated specimens and the amount of compressive deformation was measured for 24 hours. Then, water was absorbed through the bottom surface of the specimen and the influence of water in collapse was monitored for another 24 hours. After that, the specimens were dried in the oven at 110 $C°$ for 24 hours. Totally 160 collapse tests were performed on three types of soils which the initial conditions shown in table 2.

Table 2. Initial Conditions of the Tests

Type of soil	Dry density ρ_d (g/cm^3)	Degree of saturation S_r (%)	Pressure p (kPa)
DL clay	1.1, 1.2, 1.3, 1.36	20, 40	5, 10, 20,
Kanto	0.5, 0.6, 0.65	25, 40	40, 80, 160,
Kaolin	1, 1.1, 1.2	30, 60	320, 640

Secondly, under the same initial condition as collapse test, direct shear tests were performed to investigate the changes of shear parameters (c and ϕ). For each condition, two specimens were tested separately to compare the results of unsubmerged specimen with submerged one. After the specimens made, the designated vertical pressure applied on one of the specimen and then waited for one hour, while settlement occurred, the specimen was sheared. Then the same procedure followed for the second specimen, but after settlement and before soaking, the specimen soaked by water via its bottom surface. While collapse settlement occurred, shear stress has applied.

3 TEST RESULTS AND DISCUSSIONS

3.1 Collapse settlement test

A literature review has shown that nearly all types of compacted soils are subjected to collapse under certain conditions[4]. It is important to note that even clean sand, pure clays (including pure montmorillonite), and soils containing substantial gravel fractions can also collapse[5]. Fig. 2 through Fig. 4 shows the relationships between void ratio e and overburden pressure p of collapse tests. The filled circles indicate the loading process of unsubmerged specimens and opened circles show the loading process of submerged specimens for all types of soils. Fig. 2 indicate the result of DL clay at S_r=20 %, and ρ_{d0}=1.1 and 1.36 g/cm^3, void ratio started decreasing when p exceeded up to 40 kPa at ρ_{d0}=1.1g/cm^3 in Fig. 2(a). With increasing overburden pressure, the void ratio started decreasing and settlement has occurred. At ρ_{d0}=1.36g/cm^3, hardly any settlement occurred Fig. 2(b). Fig. 5(a) shows the relations between axial strain ε and vertical pressure p. The result shows that strain increased with p, peaked and then gradually decreased at ρ_{d0}=1.1 g/cm^3 and 1.2 g/cm^3. Fig. 5(b) shows the e-p relations of Kanto loam. This results also indicates that strain increased with p, peaked and then decreased continuously at ρ_{d0}=0.5 and 0.6 g/cm^3. The Kanto loam result is near with the result of DL clay.

The collapse results indicated that DL clay and Kanto loam which are silty and silty loam soils, tend to collapse more than Kaolin which is a clayey soil Fig. 2 and Fig. 3. Decrease of void ratio in DL clay and Kanto loam shows compressions and volume reduction of specimens than as initial compacted conditions. The Kaolin clay results show both collapse and swelling depend on vertical pressures and dry densities and the collapse only occurred at higher pressures p=320 and 640 kPa. Incre-

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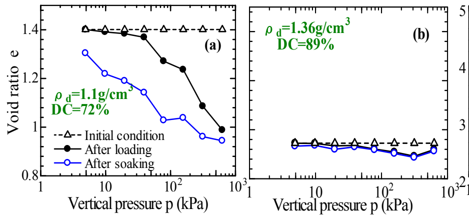

Fig. 2. e– p Relation of DL clay at Sr=20%

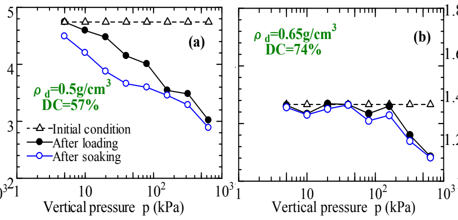

Fig. 3. e– p Relation of Kanto loam at Sr=25%

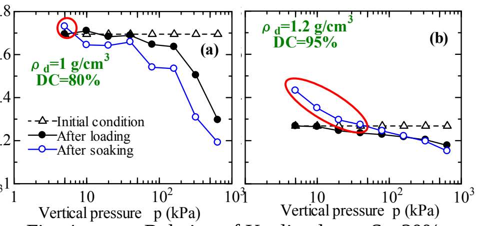

Fig. 4. e– p Relation of Kaolin clay at Sr=30%

ment in volume (Swelling) gradually increased with increase of dry densities at overburden pressures lower than 320 kPa. Negative strain indicates that the wetted specimen has a bigger volume than the as-compacted specimen. At stress level where the strain differences are negative, the soil is considered to be susceptible to wetting-induced collapse.

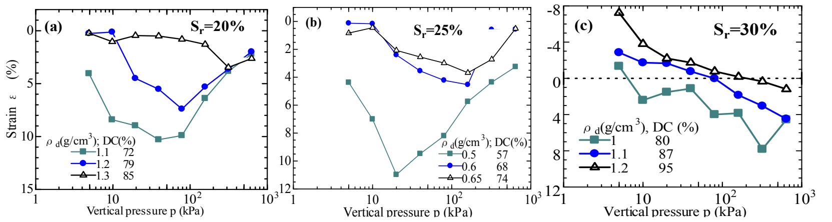

Fig.5. ε–p Relations after Soaking, (a) DL clay, (b) Kanto loam, (c) Kaolin clay

The result indicated that by increasing of $\rho_{d0,}$ swelling also will be increased Fig. 5(c). This result can be matched with the mechanism of collapse that for any given set of conditions, the amount of collapse generally decreases with increasing pre-collapse moisture content, increasing pre-collapse dry density, and decreasing overburden pressure[6]

3.2 Simple constant pressure single shear test

Fig.6 through Fig.9 indicate the relationships between shear stress τ and vertical stress p of DL clay, Kanto loam and Kaolin clay at S_r=20%,25% and 30% respectively which obtained by direct shear tests. The results indicate that after soaking, small changes occurred in ϕ (decreased), but c has significantly reduced especially for Kaolin clay in Fig. 6(c). Regardless of S_r, c has decreased after soaking in all tests conditions Fig. 7(a) 8(a) and 9(a). The outstanding changes of ϕ occurred in Kaolin clay and the result of Kanto loam shows both decrease and increase of ϕ after the specimens soaked.

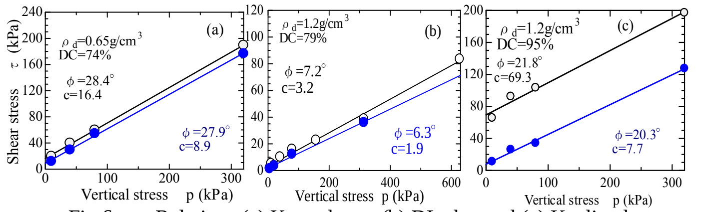

Fig.6. τ-p Relations (a) Kanto loam, (b) DL clay and (c) Kaolin clay

The results of direct shear tests after soaking in comparison with before soaking, indicate that the changes of cohesion c, is more considerable (decreased) than internal fraction angle ϕ. The changes of c in Kaolin clay, is higher than Kanto loam and the change of c in Kanto loam is higher than DL clay. It resulted that whatever the practical size of soil be smaller, the shear parameters will be more changed after the specimens soaked. Increasing of dry density has not affected significantly on changing of cohesion.

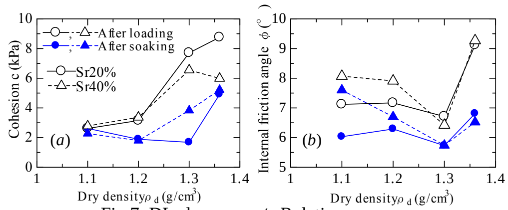

Fig.7. DL clay ρ_d-c, ϕ Relations

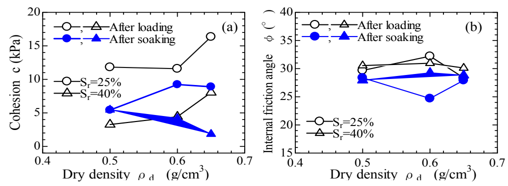

Fig.8. Kanto loam ρ_d-c, ϕ Relations

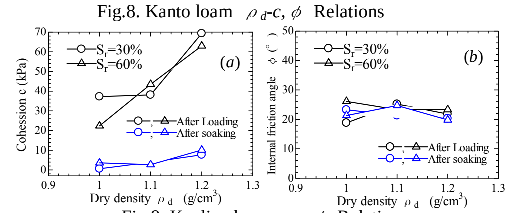

Fig.9. Kaolin clay ρ_d-c, ϕ Relations

4. CONCLUSION

Three different types of unsaturated compacted soils (Kanto loam, DL clay and kaolin clay) which are silty loam, silty and clayey soils were used to investigate the influence of the initial dry density on collapse settlement and shear parameters to compare their changes before and after soaking. The collapse results indicate that silty soils tend to collapse more than clayey soils but clayey soils shown both swelling and collapse depend on overburden pressure. The result of direct shear tests shown that changes of c is more outstanding than ϕ when specimen soaked, cohesion c is willing to decrease more in clayey soils than silty soils. Increase of dry density didn't affect significantly on cohesion after the specimens soaked.

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