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COMMON GROUND 07

Tube sampling disturbance effects on geotechnical properties of a soft clay

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Keywords: clays, sample disturbance, shear strength, compressibility, permeability

ABSTRACT

Influence of tube sampling disturbance on geotechnical properties of normally consolidated soft Dhaka clay was investigated. Reconstituted samples of soft clay were prepared in the laboratory by K_0-consolidation of slurry in a large cell. “Block” samples were prepared by hand trimming of small blocks to investigate the undisturbed behaviour of the clay. “Tube” samples were obtained by pushing sampling tubes of different cutting shoe designs into the large diameter sample in the consolidation cell. In unconsolidated undrained triaxial test and unconfined compression test, compared with the “block” sample, undrained shear strength and initial tangent modulus of the “tube” samples decreased considerably. The values of axial strain at peak strength of the “tube” samples, however, increased. Compared with the “block” sample, initial void ratio, compression index and expansion index of the “tube” increased significantly. Coefficient of volume compressibility and coefficient of consolidation of the “tube” samples either increased or decreased. Little change in the values of coefficient of permeability between “tube” and “block” samples has been observed. The findings of this investigation clearly demonstrated that the design of a sampler tube has profound influence on sample disturbance.

1 INTRODUCTION

The behaviour of foundation soil is usually predicted on the basis of soil parameters obtained from laboratory investigation of the sampled soil. This disturbance can be significant, such that the behaviour of the soil in the laboratory differs markedly from its behaviour in situ. Regarding the extent of sample disturbance in clays, one of the most important contributory factors is the precise design of the cutting shoe of the sampler being used (Siddique 1990, Clayton et al. 1998, Siddique & Clayton 1998).

Clay soil samples can be obtained by hand at the bottom of excavations (block samples) or from down a borehole (tube samples). With regard to block samples, the major forms of disturbance are those associated with the excavation, stress relief, transportation and storage, sample preparation and testing. With tube sampling, sample disturbance occurs due to drilling, tube penetration, stress relief, transportation and storage, sample preparation and testing. Because of the difference between these two approaches, block samples are taken as bench-mark against other technique for comparison. Block sampling can be simulated in the laboratory by releasing and trimming blocks from large oedometer samples.

This paper presents the effects of tube sampling disturbance on strength-deformation-stiffness, compressibility, expansibility and permeability properties of a reconstituted normally consolidated soft clay. Attempt has also been made to examine the effect of the design parameters of a tube sampler, namely area ratio, external diameter to thickness on the measured soil parameters of the clay.

2 SOIL USED AND PREPARATION OF RECONSTITUTED SAMPLE

Red Dhaka clay of high plasticity has been used in this investigation. Liquid limit, plasticity index and activity of the clay are 52, 34 and 1.26, respectively. Reconstituted samples of Dhaka clays were prepared in the laboratory by K_0-consolidation of uniform slurry of the clay in a large cylindrical consolidation cell. Initially the slurry was allowed to consolidate by the self-weight of the sample and then gradually increased to 100 kN/m^2. The average water content and bulk density of the reconstituted normally consolidated soil samples were 35 $\pm$ 1% and 19.4 $\pm$ 0.07 kN/m^3, respectively.

3 DIMENSIONS AND CHATACTERISTICS OF TUBE SAMPLERS

Eight open-drive samplers of different area ratios but identical outside cutting edge taper angle (OCA) were fabricated. Sampler designations T with numeral subscript have been used to indicate sampler tubes for obtaining samples to conduct unconsolidated undrained (UU) triaxial compression tests and unconfined compression tests. Sampler designations TT with numeral subscript have been used to indicate sampler tubes for retrieving samples to perform one-dimensional consolidation tests. Sampler designations and the dimensions and characteristic of the tube samplers are presented in Table 1. Each sampler had no inside clearance and outside clearance.

Table 1: Dimensions and characteristics of the tube samplers used

Sampler designation	t (mm)	D_e (mm)	D_i (mm)	D_e/t Ratio	Area ratio (%)	OCA (Degree)
T1	1.5	41.0	38.0	27.3	16.4	5
T2	3.0	44.0	38.0	14.7	34.1	5
T3	4.5	47.0	38.0	10.4	53.0	5
T4	6.0	50.0	38.0	8.3	73.1	5
TT1	1.5	66.5	63.5	44.5	9.7	5
TT2	3.0	69.5	63.5	23.2	19.8	5
TT3	4.5	72.5	63.5	16.1	30.4	5
TT4	6.0	75.5	63.5	12.6	41.4	5

4 TYPES OF TEST SAMPLES

After extruding the reconstituted soil block from consolidation cell, the large soil block was sliced into small blocks. The small blocks were trimmed by using piano wire, soil lathe and a split mould to prepare sample of nominal dimensions of 38 mm diameter by 76 mm high for unconsolidated undrained (UU) triaxial compression test and unconfined compression test. These samples have been termed as “block” samples. To prepare a “block” sample for one-dimensional consolidation test, initially small slabs of clay were obtained out of reconstituted samples from large consolidation cell. Then a sample ring of 63.5 mm diameter by 25.4 mm high having its internal surface well covered with silicon grease was gradually and in stages pushed into the clay, which was continuously being trimmed away from the cutting edge of the ring with a knife.

At first the reconstituted soil cakes were prepared from the disturbed samples in a large consolidation cell. Then sample tubes having respectively 38 mm and 63.5 mm inner diameter but of different area ratios as mentioned in Table 1 were steadily pushed into the reconstituted soil cake. The samples were then extruded manually from the tubes. These samples have been termed as “tube” samples. Islam (2003) reported details of sample preparation, procedures for various tests and equipment.

5 TEST RESULTS AND DISCUSSIONS

5.1 Undrained strength, deformation and stiffness properties in UU triaxial compression test and unconfined compression test

From the stress-stain data, the values of undrained shear strength (s_u), axial strain at peak strength (ε_p) and initial tangent modulus (E_i) of “block” and “tube” samples were evaluated which are summarised in Table 2. Table 2 shows that in both UU triaxial test and unconfined compression test, compared with the “block” sample, the values of $s_{u,}$ and E_i of the “tube” samples decreased considerably due to disturbance caused by penetration of sampling tube. The values of ε_p of the “tube” samples, however, increased. In UU triaxial compression test, the values of $s_{u,}$ and E_i decreased up to about 61% and 71%, respectively while in unconfined compression test the values of $s_{u,}$ and E_i decreased up to about 62% and 76%, respectively. Compared with the “block” sample, the values of ε_p increased up to 200% and 167% in UU triaxial compression test and unconfined compression test, respectively. Compared with “in situ” sample, reductions in the values of $s_{u,}$ and E_i and increase in the value of ε_p of “tube” samples have been reported for reconstituted normally consolidated coastal clays from Chittagong (Siddique et al. 2000, Bashar et al. 2000).

Table 2: Comparison of undrained shear properties of “block” and “tube” samples from uu triaxial and unconfined compression test

Sample designation	s_u (kN/m^2)		ε_p (%)		E_i (kN/m^2)	
	UU triaxial test	Unconfined compression test	UU triaxial test	Unconfined compression test	UU triaxial test	Unconfined compression test
“Block”	25.5	19.3	2.0	1.5	9423	5126
T1	21.1	16.1	4.0	2.0	8758	4679
T2	19.7	13.4	4.6	2.5	8199	2516
T3	17.8	8.4	5.3	3.0	6665	2289
T4	9.9	7.4	6.0	4.0	2726	1243

5.2 Compressibility and expansibility characteristics of “block” and “tube” samples

The compressibility and expansibility characteristics of “block” and “tube” soft clay samples undergoing incremental loading in an oedometer are presented in Figure 1 and Figure 2. In Figure 1, void ratio (e) at the end of each loading and unloading stages have been plotted against logarithm of vertical effective consolidation pressure. Figure 2 shows the plotting of coefficient of volume compressibility (m_v) and coefficient of volume increase (m_s) as a function of logarithm of vertical effective consolidation pressure. Table 3 shows a summary and comparison of the compressibility and expansibility properties of “block” and “tube” samples.

It can be seen from Table 3 that, compared with the “block” sample, the values of initial void ratio (e_0) of the “tube” samples are relatively higher (about 15% to 54%). It can be seen from Table 3 that compared with the “block” sample, the values of C_c increased between 13% and 30%. These results agree with those reported by Okumura (1971) who found an increase in C_c due to tube sampling disturbance. Farooq (1995) found that compared with “in situ” samples, the values of C_c either increased or decreased for “tube” samples of reconstituted normally consolidated soft coastal clays of Chittagong. It was found that compared with the “block” sample, the changes in the values of C_s of the “tube” samples are insignificant. Farooq (1995) also reported similar results for reconstituted soft samples of Chittagong coastal clays. It is evident from the plots of Figure 2 that up to value of preconsolidation stress (i.e., 100 kN/m^2), the values of coefficient of volume compressibilty (m_v) of the “tube” samples are generally higher than the “block” sample. Beyond the preconsolidation stress, however, there is insignificant changes in the values of m_v between the “block’ and “tube” samples. Farooq (1995) reported similar results reconstituted soft samples of Chittagong coastal clays.

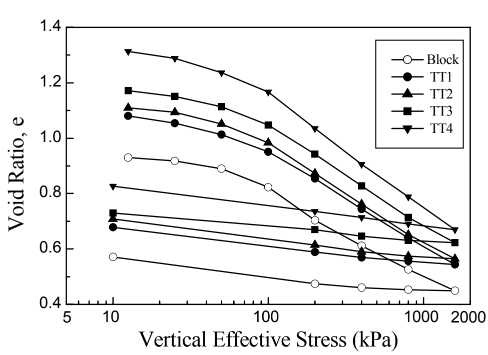

Figure 1: Comparison of void ratio versus vertical effective stress plots of “block” and “tube” samples

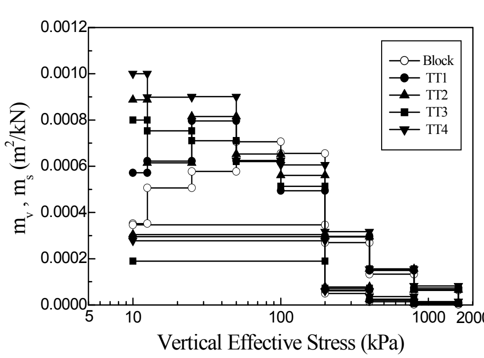

Figure 2: Comparison of m_v and m_s versus vertical effective stress plots of “block” and “tube” samples

Table 3: Comparison of initial void ratio, compression index and swelling index of "block" and "tube" samples

Sample designation	Initial void ratio, e_o	Compression index, C_c	Swelling index, C_s
"Block"	0.94	0.30	0.05
TT1	1.08	0.34	0.06
TT2	1.13	0.37	0.06
TT3	1.22	0.38	0.06
TT4	1.45	0.39	0.07

5.3 Permeability properties of "block" and "tube" samples

Coefficient of permeability of the samples was determined indirectly from one-dimensional tests. In Figure 3, the coefficient of vertical permeability (k) of "block" and "tube" samples has been plotted against vertical effective consolidation stress. It can be seen from Figure 3 that there is little change in permeability between "tube" and "block" samples up to preconsolidation pressure of 100 kPa. Beyond preconsolidation pressure of 100 kPa however, there is practically no change in permeability in relation to changes in vertical effective consolidation stress. Disturbance due to tube sampling has practically insignificant effect on the permeability characteristics of reconstituted soft clay samples of Dhaka clay. A comparison of the plots of void ratio (e) versus logarithm of coefficient of vertical permeability of the "block" and "tube" samples is presented in Figure 4. It can be seen from Figure 4 that coefficient of vertical permeability increases with the increase in void ratio of the "block" and "tube" samples and that at a particular void ratio coefficient of vertical permeability of the "tube" samples are less than the "block" sample.

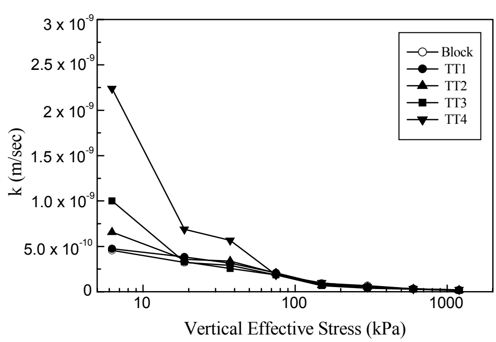

Figure 3: Comparison of coefficient of permeability versus vertical effective stress plots of "block" and "tube" samples

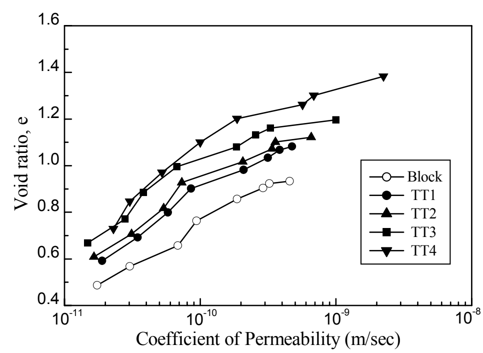

Figure 4: Comparison of void ratio versus coefficient of permeability plots of "block" and "tube" samples

5.4 Effect of Cutting Shoe Design

5.4.1 Effect of Area Ratio and D_e/t ratio on undrained shear properties

Figures 5 and 6 show changes in s_u, ε_p and E_i in UU triaxial tests and unconfined compression tests, respectively, due to increase in area ratio (or decrease in D_e/t ratio) of the samplers. Table 4 summarizes the changes in undrained shear parameters. Compared with the "block" sample, the following effects have been observed:

(i) Values of s_u decreased by 17% to 61% and 17% to 62% in UU triaxial compression and unconfined compression test, respectively due to increase in area ratio of sampler from 16.4% to 73.1% (or decrease in D_e/t ratio from 27.3 to 8.3).

(ii) Values of ε_p increased by 100% to 200% and 33% to 167% in UU triaxial compression and unconfined compression test, respectively due to increasing area ratio (or decreasing D_e/t ratio).

(iii) Values of E_i were reduced by 7% to 70% and 9% to 76% in UU triaxial compression and unconfined compression test respectively due to about 4.5 times increase in area ratio (or about 70% reduction in D_e/t ratio).

Changes in the experimentally measured values of s_u, ε_p and E_i between "in situ" samples and "tube" samples retrieved with different area ratios and D_e/t ratios have also been reported for reconstituted normally consolidated coastal soils of Bangladesh (Siddique et al. 2000; Bashar et al. 2000). IS (1986) recommends small area ratio (less than 10 %) for thin walled open-drive samplers for high quality sampling in clays.

Table 4: Influence of increasing area ratio (or decreasing D_e/t ratio) of sampler on undrained shear properties

Test type	Sample designation	Area ratio (%)	D_e/t ratio	$s_{u\text{"tube"}}/s_{u\text{"block"}}$	$\varepsilon_{p\text{"tube"}}/\varepsilon_{p\text{"block"}}$	$E_{i\text{"tube"}}/E_{i\text{"block"}}$
UU triaxial compression	T1	16.4	27.3	0.83	2	0.93
	T2	34.1	14.7	0.77	2.3	0.87
	T3	53.0	10.4	0.70	2.65	0.71
	T4	73.1	8.3	0.39	3.00	0.30
Unconfined compression	T1	16.4	27.3	0.83	1.33	0.91
	T2	34.1	14.7	0.70	1.67	0.49
	T3	53.0	10.4	0.43	2	0.45
	T4	73.1	8.3	0.38	2.67	0.24

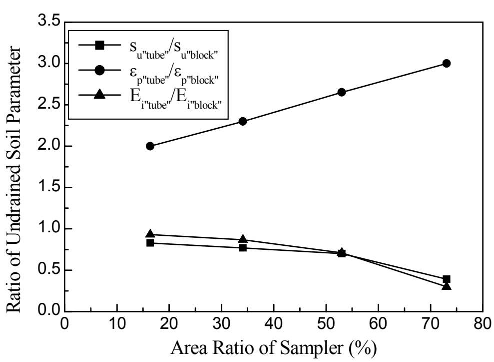

Figure 5: Influence of area ratio on undrained soil parameters from UU triaxial compression test

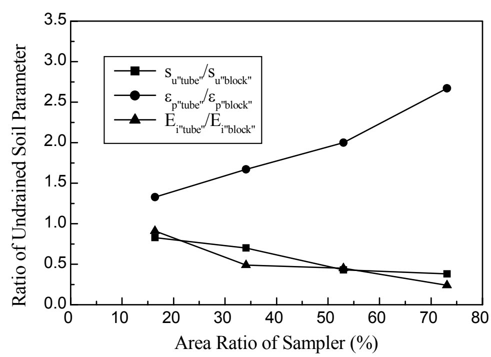

Figure 6: Influence of area ratio on undrained soil parameters from unconfined compression test

5.4.2 Effect of area ratio and D_e/t ratio on compressibility, expansibility and permeability properties

Changes in the e_0, C_c and C_s due to changes in area ratio and D_e/t ratio of the samplers are presented in Figure 7 and Figure 8, respectively. The following effects have been observed on the measured consolidation properties:

(i) Values of e_0 increased by 16% to 55% due to increase in area ratio of sampler from 9.7% to 41.4% (or decrease in D_e/t ratio from 44.5 to 12.6).
(ii) Values of C_c increased by 13% to 30% to increase in area ratio (or decrease in De/t ratio).
(iii) Values of C_s also increased by 20% to 40% due to about 4.25 times increase in area ratio (or about 72% reduction in D_e/t ratio).

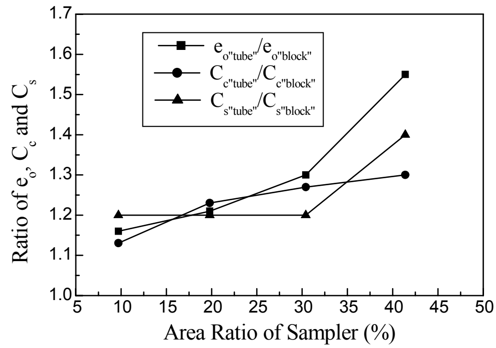

Figure 7: Influence of area ratio on e_0, C_c and C_s

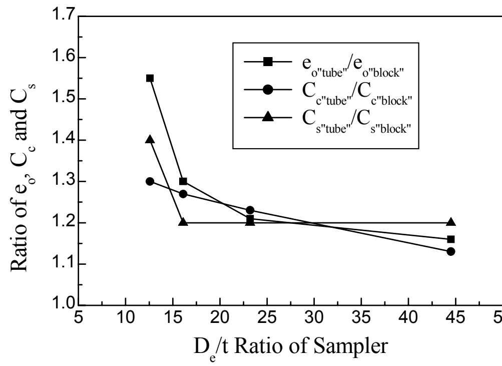

Figure 8: Influence of D_e/t ratio on e_0, C_c and C_s

6 CONCLUSIONS

The main conclusions of the present investigation can be summarised as follows:

- The values of s_u, and E_i decreased considerably due to tube sampling disturbance. The values of ε_p , however, increased. Values of s_u and E_i decreased due to increase in area ratio (or decrease in D_e/t ratio). Values of ε_p, however, increased due to increasing area ratio (or decreasing D_e/t ratio). The findings of present investigation on Dhaka clay clearly demonstrate that the design of a sampler tube has profound influence on sample disturbance.
- Compared with the "block" sample, the values e_0 and C_c of the "tube" samples are relatively higher. The values of m_v and m_s of the "tube" samples either increased or decreased compared with the "block" sample.
- Little change in the values of coefficient of permeability between "tube" and "block" samples has been observed. It has been found that coefficient of vertical permeability increases with the increase in void ratio of the "block" and "tube" samples. At a particular void ratio coefficient of vertical permeability of the "tube" samples are less than the "block" sample.

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