

Effect of in-situ disturbance within the soil mass on the stress-strain behaviour of silty soil

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Abstract. To date, different techniques have been evolved to collect soil in undisturbed condition so that the in-situ soil behaviour can be determined by carrying out laboratory tests. For the same reason, the execution of undisturbed soil sampling in practice is given a lot of efforts. However, this study brings the fact into consideration that the in-situ soil condition may not remain constant, rather it might vary time to time, because of different internal or external reasons. For example, the internal stress state of soil layers, existing below or above the swelling soil layer, become modified during shrinking and swelling resulting from drying and wetting of swelling clay, respectively. Further, foundations of building may transfer cyclic loads (generated by vibration installed in the building) to the soil below the foundation. Therefore, this study investigates the effects of stress-strain behaviour due to the disturbances on the shear strength of the soil with respect to that of undisturbed specimens. The shear strength of disturbed soil shows deviation from that of undisturbed specimen depending on the different parameters defining the severity of disturbance.

1. Introduction

To date, problematic soils, such as liquefiable soil, sensitive clay, collapsible soil and expansive clay, have drawn the attention of researchers, as the performance of foundations on them is severely affected due to a change, such as occurrence of cyclic loading, variation in moisture content, etc. [1-4]. After 2018-Taiwan and 1995-Kobe earthquakes, structures were found to collapse due to bearing capacity failure of foundations. The disturbance that changes in-situ soil stress-state, might cause reduction in soil shear strength and accordingly such catastrophic failures. However, in the design of foundation, the stress-strain behaviour and shear strength parameters of soil in undisturbed condition (in-situ and before construction) are considered. Previous studies investigated the effect of disturbances during sampling [5], but the disturbances that might occur after construction has not been investigated in previous studies.

The effect of internal soil stress has significant influence on different aspects of geotechnical properties of soil [6-7]. The present study focuses the disturbances of soil condition (in-situ) that is not during sampling but while supporting the foundations of structures due to different internal or external reasons. The internal stress state of soil layers, existing below or above the expansive soil layer, becomes modified during shrinking and swelling of expansive soil resulting from drying and wetting, respectively. Further, foundations of building may transfer cyclic loads (generated by vibration installed in the building) to the soil below the foundation. Disturbances might be due to cyclic freezing and thawing during change in ambient temperature. Some research attempts regarding the



investigation of cyclic freezing and thawing are found in the literature but mostly dealt with clayey soils [8-10].

The objective of the present study is to investigate the effect of disturbances on the shear strength, of the silt soil with respect to that determined in its undisturbed state. The severity and time dependency of disturbances in influencing strength reduction are considered in the experimental investigation carried out in this study.

2. Experimental Program

The present study conducts experimental investigation to study the soil shear strength in disturbed condition with respect to that of undisturbed soil.

2.1. Soil

Undisturbed grey soil samples were collected in Shelby tubes (open drive) from Ex-Marine Workshop ship building area in Barisal, the southern district of Bangladesh, while conducting standard penetration test. The depth of sampling was 4 m (approximately). Figure 1 shows the undisturbed soil in tube.



Figure 1. Undisturbed soil in the tube sampler

The soil was identified to be clayey silt with traces of sand. The soil properties, determined in the laboratory, are given in table 1. The soil is classified as low plastic silt (ML), according to Unified Soil Classification System (USCS).

Table 1. Soil properties

Variables	Value
Percent smaller than No. 200 sieve	> 90 %
Liquid limit (%)	32.5
Plastic limit (%)	28
Plasticity index (%)	4.5
Specific gravity	2.64 – 2.66
Natural moisture content	28 - 34 %
Bulk unit weight (kN/m^3)	17.3
Void ratio	0.51
Compression index	0.18

2.2. Methodology

In order to investigate the effect of disturbances on soil shear strength, the stress-strain behaviour and Mohr-Coulomb failure envelopes of disturbed specimens with respect to those of undisturbed specimens were examined. Therefore, the shear strength parameters of both undisturbed and disturbed

specimens were tested by conducting consolidated undrained (CU) Triaxial tests according to ASTM standard. The CU Triaxial tests were conducted on three undisturbed and three disturbed soil specimens. All the specimens were initially undisturbed and identical. Table 2 gives the details of the experimental program.

The disturbed specimens were prepared by cyclic freezing and thawing, and thus the degrees of disturbances were controlled. During freezing phase, the tube containing the soil that was collected in undisturbed condition, was kept in freeze (below 0° C) for 8 hrs. Further, the tube was left outside the freeze at room temperature of 22° C for about 5 hours. When some delay periods before testing or inducing further cycles of freezing and thawing were necessary according to the experimental plan, the tubes were kept in the refrigerator (temperature around 10°C).

Table 2. Experimental Program

Borehole No.	No of Test	Type of Specimen	Test Detail
01	2	Undisturbed	Failed by static loading by CU type test
02	1		
03	1	Disturbed	7 cycles of freezing & thawing, failed by static loading immediately after last thawing
	1		7 cycles of freezing & thawing, failed by static loading on 20 th day after last thawing
	1		7 cycles of freezing & thawing, left for 20 days, again 5 cycles of freezing and thawing, then immediately failed by static loading

3. Results and Discussion

The deviator stress versus strain behaviour of both the undisturbed and disturbed specimens is compared at two different effective confining pressures (200 kPa and 300 kPa) in figures 2 and 3, respectively. The disturbance effects on the deviator stress at failure are found significant in both cases.

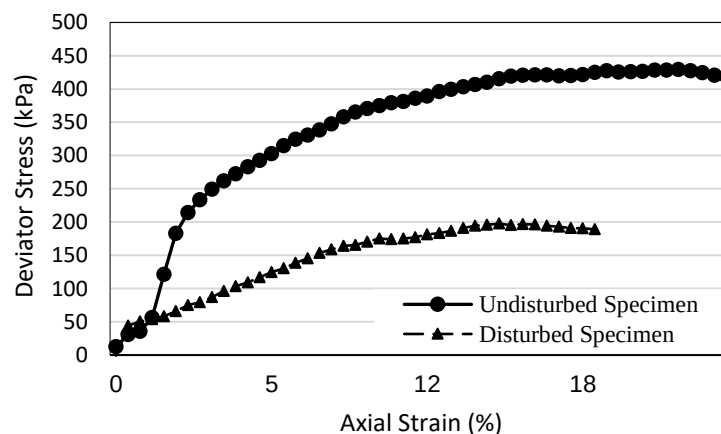


Figure 2. Effect of disturbances: Deviator stress versus strain at effective confining pressure of 200 kPa

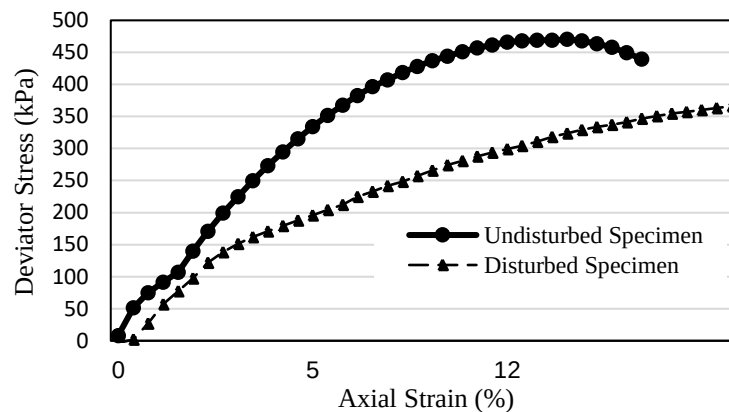


Figure 3. Effect of disturbances: Deviator stress versus strain at effective confining pressure of 300 kPa

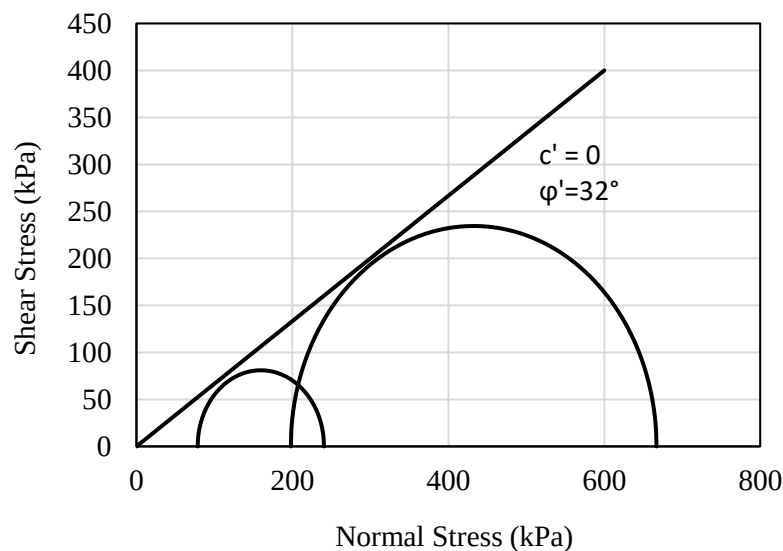


Figure 4. Mohr-Coulomb Failure Envelope in Undisturbed Condition

Further, the disturbance effects on the shear strength parameters are studied with respect to those of undisturbed soil. The Mohr-Coulomb failure envelope of the undisturbed soil used in this study is presented in figure 4. The effective angle of internal friction and the effective cohesion are obtained 32° and 0 kPa, respectively.

The Mohr circle of each disturbed specimen was separately compared with those, along with Mohr-Coulomb failure envelope, of undisturbed specimens in figures 5-7. It can be noted that reduction in shear strength parameters are greatly dependent on the degree of disturbances. Significant reduction in the effective angle of internal friction is observed especially when the specimen was tested after 20 days since last thawing (figure 7), while the effect of disturbance on shear strength parameter is found insignificant immediately after thawing (figure 5 and figure 6).

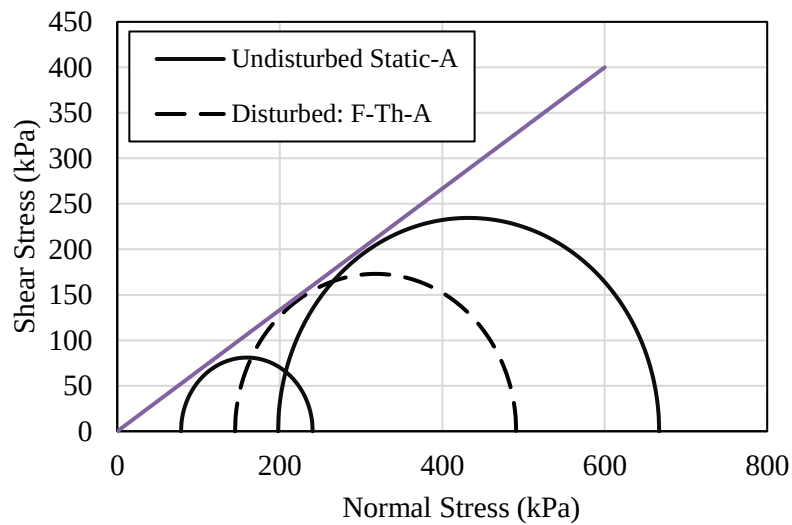


Figure 5. Effect of 7 cycles of freezing & thawing, Triaxial test conducted immediately after thawing

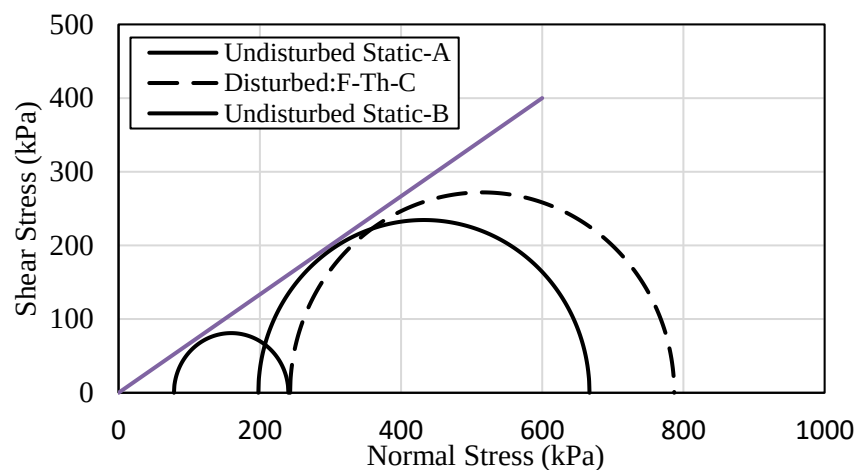


Figure 6. Effect of 7 cycles of freezing & thawing, then 20 days later again freeze and thawed 5 times, Triaxial test conducted immediately after thawing

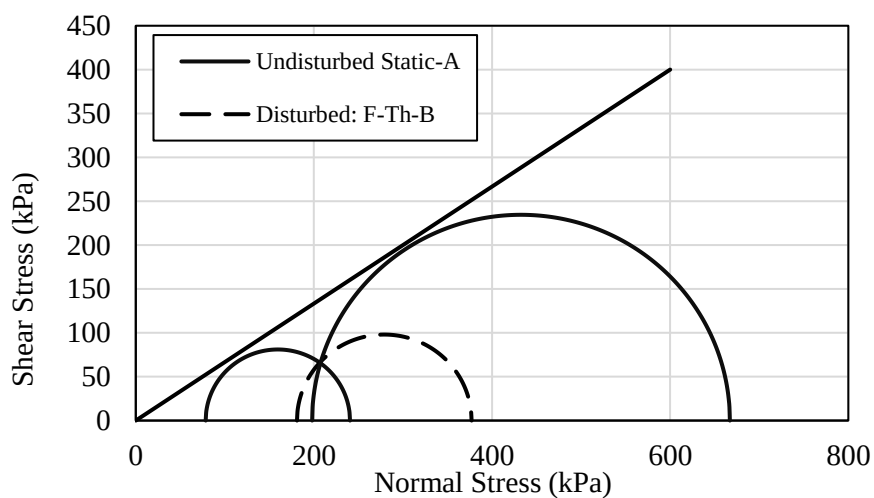


Figure 7. Effect of 7 cycles of freezing & thawing, Triaxial test conducted 20 days after thawing

Table 3: Effect of disturbance on effective angle of internal friction

Variable of disturbances		ϕ' (°)
No of cycles	Time elapsed between last disturbance and test begins	
0	-	32
7	-	32
7-delay-5	-	27
7	20 days	18

The effect of different degrees of disturbances on the effective angle internal friction is summarized in Table 3. It is found that the greater the degree of disturbances, the greater the reduction of ϕ' is. It can also be noted that the strength reduction continues with time to some extent. This implies that the structure will survive till the reduced soil strength could develop bearing capacity equalled the stress transferred to the soil from the foundation. The structure will collapse, when the strength reduction further continues beyond this point.

4. Conclusions

The paper explores the effects of in-situ natural disturbances on the shear strength of the soil supporting the foundation of structures. In this study, only low plastic silt soil was considered. Based on the experimental results and analysis, the conclusions of the study is summarized as below:

- i. The greater the degree of disturbance, the greater the reduction of strength is.
- ii. The time dependency of the strength reduction, caused by the disturbances within the soil mass, has been observed. Thus, the consequence of disturbances might not be hypothesized based on the stress-state observed immediately after the disturbances occurred.

Further investigation is necessary to explore other sources of natural disturbances with different variable parameters and time dependency of strength reduction of different types of soil.

Acknowledgments

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