[Monteiro* 4(4): April, 2017] ISSN 2349-4506
Impact Factor: 2.785

Global Journal of Engineering Science and Research Management

ANALYSIS OF SOIL EFFECTIVE SHEAR STRENGTH PARAMETERS CONSIDERING DIFFERENT SPECIMEN DIAMETERS IN TRIAXIAL TESTS

Fernando Feitosa Monteiro*, Yago Machado Pereira de Matos, Mariana Campos Fontenelle, Beatriz Rodrigues Soares, Icaro Rodrigues Marques
* Department of Civil and Environmental Engineering, University of Brasilia, Brazil
Department of Hydraulic and Environmental Engineering, Federal University of Ceará, Brazil
Department of Technological Sciences, University of Fortaleza, Brazil
Department of Technological Sciences, University of Fortaleza, Brazil
Department of Technological Sciences, University of Fortaleza, Brazil

DOI: 10.5281/zenodo.496160

KEYWORDS: Triaxial Tests, Specimen Diameter, Effective Shear Strength Parameters.

ABSTRACT
The aim of this paper is to analyze effective shear strength parameters measured with triaxial tests on remolded sand soils specimens with 50mm e 38mm diameters. A laboratory testing campaign of twenty-one consolidated undrained (CU) tests were carried out on remolded specimens. Those triaxial tests were performed applying confining pressures of 100, 200, and 300 kPa. The results indicated that the angle of internal friciton of the 50mm e 38mm specimens presented the value of 33º and 29º.While the results for the cohesion intercept presented values of 18,25 and 68,12 kPa. Analyzing the results that were obtained on this study, it is possible to indicate that the variation of the specimen diameter can influence on effective shear strength parameters. The results show that the specimen diameter influence on effective shear strength parameters for triaxial tests on different diameters specimens is small regarding the internal friction angle. On the other hand, soil cohesion presented a significant variation.

INTRODUCTION
Conventional triaxial test involves subjecting a cylindrical soil sample to radial stresses (confining pressure) and controlled increases in axial stresses or axial displacements. In this type of test, the shear strength parameters of soils are obtained, which are crucial and useful for design work to produce safe and economic geotechnical structure design. The shear strength of soil is the maximum resistance to shear expressed as a stress. Soil shear strength derived from two main components: internal friction angle and cohesion [1]. Movement of wedge soil behind a retaining wall or sliding in an earth embankment are some of the forms of shear failure [2]. An improper estimation can constitute a serious damage to both property and life. Cohesion is a component of the shear strength, which is independent of the normal stresses applied, the origin of this phenomenon is due to the grouting between the particles, chemical attraction between clay particles, residual stresses from the original rock and ionic attraction [3].

The triaxial compression test is one of the most used tests when it comes to the evaluation of the shear strength of the soil, and obtaining its parameters. The test offers a range of possibilities in its conduction, as the option to control the load applied to the sample or the deformation suffered by it. The principle of triaxial compression test is versatile, and procedures may be related to various practical problems such as the investigation of slope stability and the design of retaining walls and foundations optimization [4]. The test can simulate real situations of the field by providing better understanding of the behavior of soils and their properties. On the test, the cylindrical specimen is sealed by a rubber membrane, and confined in a cell with water, which can be subjected to pressure. An axial load is thrown on top of the sample via a piston, which controls deviator stress. The connections allow the cell to drain both water and air in the soil voids, or the measurement of pore pressure on condition of undrained test [5].

MATERIALS AND METHODS
Disturbed silty sand soil samples were collected from a trench next to the Civil Construction building at the Federal Institute of Ceará. The soil was excavated with a shovel at a depth of 1.5 m below the ground surface, removing the layer of humus and roots, placed in wood boxes, and transported to the geotechnical laboratory of

ISSN 2349-4506
Impact Factor: 2.785
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Federal Institute of Ceará. Soil index properties tests such as moisture content, specific gravity, particle size distribution, plastic limit, and liquid limit were carried out according to the Brazilian Standard [6]. The triaxial tests were performed on remolded soil specimens. The remolded specimens for the triaxial tests were prepared using static compaction at a specified moisture content and density. The soil samples were compacted in a cylindrical mold with moisture content of 10,5% and 19,17 kN/m³ density as shown in Figure 1.

Figure 1: Cylindrical specimen

The CU triaxial tests were performed under three different cell pressures of about 100, 200, and 300 kPa using specimens of 50mm e 38mm diameter. The specimens in the CU triaxial test were sheared with a strain rate of 0.083 mm/min.

RESULTS AND DISCUSSION

The soil subjected to the tests was classified as a SM-SC (silty sand), according to the Unified Soil Classification System. Table 1 shows the basic properties of the studied soil.

Table 1: Basic properties of studied residual soil

Moisture Content (%)	Specific Gravity	Particle Size Distribution				Atteberg Limits		Soil Classification (USCS)
		Clay (%)	Silt (%)	Sand (%)	Gravel(%)	Plastic limit (%)	Liquid Limit (%)	
10,5	2,48	14	3	83	0	0	0	SM-SC

Many tests were performed to obtain consistent results. Because of the relative complexity of the test, some samples were lost, others, presented inconsistent values. For the selection of compatible values, it was held a careful analysis of the various results. Table 2 and Table 3 present results of the performed triaxial tests with 50mm e 38mm diameter samples.

Table 2: Triaxial results for 50mm diameter samples

Specimen #	σ3 (kPa)	σd (kPa)	σ1 (kPa)	u (kPa)	σ'1 (kPa)	σ'3 (kPa)
1	100	712	812	-163	975	263

2	100	698	798	-171	969	271
3	200	860	1060	-114	1174	314
4	200	758	958	-147	1105	347
5	200	791	991	-2	993	202
6	200	804	1004	-110	1114	310
7	300	1143	1443	-139	1582	439
8	300	1120	1420	-137	1557	437

Table 3: Triaxial results for 38mm diameter samples

1,4" diameter samples						
Specimen #	σ3 (kPa)	σd (kPa)	σ1 (kPa)	u (kPa)	σ'1 (kPa)	σ'3 (kPa)
9	100	609	709	-131	840	231
10	100	501	601	-137	738	237
11	100	386	486	-103	589	203
12	100	395	495	-109	604	209
13	200	718	918	-124	1042	324
14	200	547	747	0	747	200
15	200	734	934	-7	941	207
16	300	699	999	-83	1082	383
17	300	849	1149	-109	1258	409
18	300	611	911	-62	973	362
19	300	948	1248	-84	1332	384
20	300	759	1059	-53	1112	353
21	300	973	1273	-78	1351	378

From the triaxial test results, it was possible to determine the specimens that presented the most consistent results for each diameter. The failure envelope was composed with the more consistent results, therefore, specimens 1, 6 and 7 showed the best adjustments for the 50mm diameter samples. Meanwhile, the specimens 12, 15 and 19 presented the best fit for the 38mm diameter samples. From the best set of specimens, both Mohr-Coulomb failure envelopes were computed as shown in Figures 2 and 3. Figure 2 shows the Mohr-Coulomb failure envelope for the 50mm diameter samples. From this adjustment, it was found that cohesion intercept has a value of 18, 25 kPa and the internal friction angle of 33º. As for the Mohr-Coulomb failure envelope for the 38mm diameter samples, the determined adjustment resulted in a cohesion intercept with a value of 68,12 kPa and the internal friction angle of 29º as shown in Figure 3.

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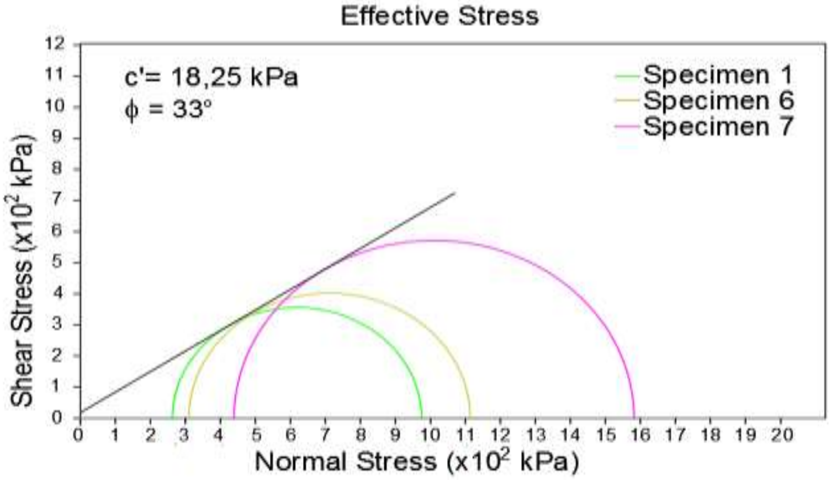

Figure 2: Mohr-Coulomb failure envelope for the 50mm diameter samples

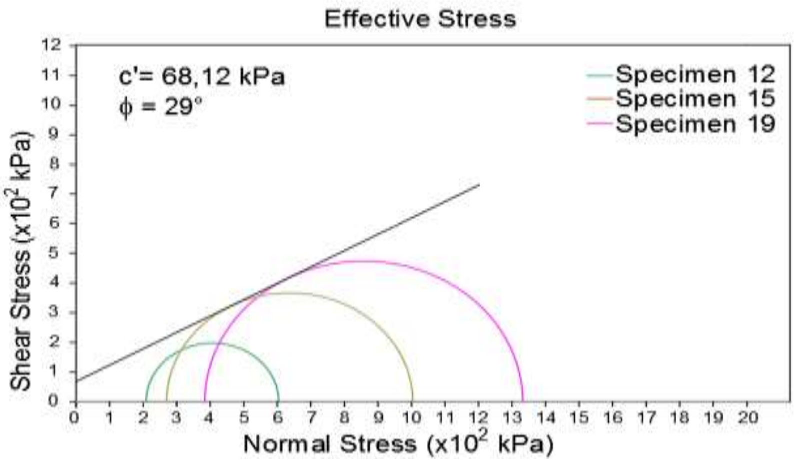

Figure 3: Mohr-Coulomb failure envelope for the 38mm diameter samples

Table 4 presents the effective shear strength parameters from triaxial tests and inclination of the failure plane of 50mm and 38mm diameter samples comparison. The results indicate that the effective shear strength parameters for triaxial tests on different diameters specimens are not identical, although, the internal friction angle presented similar results. The internal friction angle showed a 12,12% difference between the different diameter specimens. On the other hand, the specimens cohesion presented a 73,20% discrepancy, which is a considerable variance. The shear strength of the soil is affected by the quality of the sample. Remolded samples will usually present lower values of effective shear strength parameters than undisturbed samples because residual soils are sensitive to disturbances and disruptions incurred during sampling that affect the results of the tests [1]. Disruptions in the stability of the soil samples gave a lower value for shear strength due to the collapse of the soil structure as well as increase the value of effective friction angles [7]. During the tests performance, it was noted a great difficulty on working with the 38mm diameter samples, due to its fragility. Some samples were ruined during the use of rubber sheath, to a point that the test would not proceed, because the specimen was damaged. Thereat, the number of triaxial tests needed to achieve consistent results was higher.

Table 4. 50mm and 38mm diameter samples comparison

Specimen Diameter (mm)	c' (kPa)	' (º)
50	18,25	68,12
38	33	29

CONCLUSION

The results show that the specimen diameter influence on effective shear strength parameters for triaxial tests on different diameters specimens is small regarding the internal friction angle. On the other hand, soil cohesion presented a significant variation. The results of the triaxial tests showed that 50mm diameter samples presented a cohesion intercept of 18, 25 kPa and the internal friction angle of 33º. Meanwhile, the 38mm diameter samples presented a 68,12 soil cohesion and a 29º internal friction angle. The internal friction angle exposed a 12,12% difference between the different diameter specimens. The specimens cohesion showed a 73,20% divergence, which is a considerable variance. The usage of 38mm diameter specimens is not recommended due to its fragility when testing silty sand soils, which can be easily damaged during the rubber sheath handling, in that way, possibly occasioning inconsistent results.

ACKNOWLEDGEMENTS

The authors thanks CNPq and FUNCAP for the financial support

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