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Determination of Drained Residual Shear Strength Parameters of C-ϕ Soil Using Ring Shear Apparatus

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Abstract: Shear strength parameters such as cohesion and angle of internal friction of soil are very important for the design of foundation of the structures and soil structures. Many tests such as direct shear, Tri-axial, UCC are available to determine the shear strength parameters of soil. Specifically, Residual Shear strength plays a major role in slope stability analysis and Earthquake analysis. The Residual Cohesion (Cr) and Residual angle of internal friction (Φr) are used for slope analysis. In this study, the soil used is c-Φ soil collected from Anaikatti, Coimbatore district and the residual shear strength was determined using Ring shear apparatus. In Ring shear test, the sample undergoes different stages such as consolidation and shearing for varying applied pressures of 100kPa, 200kPa and 300kPa. A plot drawn between normal stress and residual shear stress gives the residual shear parameters and the values of Cr and Φr are respectively 6kPa and 18^0.
Keywords: Residual strength, Landslides, Slope stability, Laboratory tests.

I. INTRODUCTION

The residual strength of cohesive soils is of importance in geotechnical engineering. The concept of residual strength has contributed enormously to the understanding of the behavior of soils subjected to large displacements under both drained and untrained conditions. It plays a major role in the behavior of old landslides, in the assessment of engineering properties of soil deposits which contain pre-existing shear surfaces and in the assessment of the risk of progressive failure in stability problems. The approach to the residual state of an over consolidated soil can be considered as taking place in two stages. First, after peak strength is passed, the strength decreases to the critical state value due to an increase in water content. Then, strength decreases at large displacements due to reorientation of soil particles parallel to the direction of shearing. The strength of the soil once this condition has been reached will be a minimum and is termed as residual strength. The friction angle corresponding to this strength is the residual friction angle.

II. MATERIALS USED

In this Torshear apparatus we take an annular soil sample 5mm thick with inner and outer diameters of 70 and 100mm respectively and confined it radially between concentric rings. It is consolidated vertically between porous bronze loading plates by means of a counter balanced 10:1 ratio lever loading system. A rotation is imparted to the base plate and lower platen by means of a variable speed motor. This causes the sample to shear, forming a shear surface close to the upper platen which is artificially roughened to prevent slip at the platen soil interface. The settlement of the upper platen during consolidation or shear can be monitored by means of sensitive dial gauge bearing on to top of the load hanger.

Table 1. Properties of soil

Description	
Diameter of Inner Ring(mm)	70
Diameter of Outer Ring(mm)	100
Specimen Thickness (mm)	5

A. Cement

The soil sample collected from Anaikatti, Coimbatore district for the slope studies was initially prepared and subjected to laboratory investigation. The soil samples are tested for its natural moisture content, organic content, specific gravity, Waterberg's limit, grain size distribution and Standard proctor compaction test. The soil is classified as SM (SILTY SAND). The results obtained from laboratory tests are presented in Table 2.

Table 2. Properties of soil

S. No	PROPERTIES	RESULTS
1.	Specific gravity	2.65
2.	Sieve Analysis a) % Gravel b) % Sand c) % Fines	 5.1 60.7 34.2
3.	Waterberg's limit a) Liquid limit (%) b) Plastic limit (%) c) Plasticity Index (%)	 26.75 22.86 3.89
4.	Classification	SM
5.	Optimum moisture content (%)	12
6.	Maximum dry density(g/cc)	1.859
7.	Unconfined compressive strength (kPa)	60.84
8.	Cohesion (kPa)	30.42

III. METHODOLOGY

A. Direct Shear

The direct shear test was conducted as per IS 2720 (Part 3) – 1986 to determine the angle of internal friction and cohesion of the soil sample. A graph was plotted between stress and shear stress. From the plot the angle of internal friction and cohesionwas obtained.

B. Sample Preparation

The Ring shear test was conducted as per ASTM D6467 – 06 to determine drained residual shear strength of soil sample. The lower porous plate and sample container assembly are removed from the machine by undoing the two knurled retaining nuts and lifting this assembly clear of the two locating studs. This is facilitated by swinging the proving ring turrets and load hanger clear of water bath. A remolded sample can then be kneaded evenly into the annular cavity using a small spatula. The top of the sample is then struck off level with the top of the confining rings, and the assembly placed in position, on the locating studs. The upper platen is then fitted, this locates on the centering pin, which is given a light smear of oil. The water bath needed not be removed during this operation. The settlement dial gauge is then mounted to bear on the top of the loading yoke screw adjuster. If a very soft sample has been prepared, it is important to allow time for it to come into equilibrium under the load of the upper platen, and then subsequently the load of the lever loading system. When the soil is fully consolidated it may be sheared at the appropriate rate. During both consolidation and shearing, the sample should be flooded to prevent it drying out.

Figure 1. Ring shear test

IV. RESULTS

A. *Direct Shear Test*

The direct or box shear test is one of the laboratory techniques that identifies a soil's shear strength as well as its angle of internal friction. According to ASTM International, this approach can be used to assess a soil's consolidated drained shear strength when it is subjected to direct shear boundary conditions. The Ottawa sand, which was produced by four groups through compacting using wooden tampers providing 10 blows per layer for five layers, was used in the direct shear test for C- soils according to ASTM D3080. Since pore pressure cannot be determined during a direct shear test, the normal stress is employed as the effective stress and a zero-pore pressure assumption is made. Figure 3 shows the samples' peak shear stress and normal stress to have a positive relationship. The soil exhibits a larger peak shear stress as higher normal pressures are applied. The Mohr-Coulomb relation, which is a theoretical definition of Equation, is used to describe a soil's shear strength (Sullivan, 2011).The specimens are tested on 7,14 and 28 days and the loads are noted.

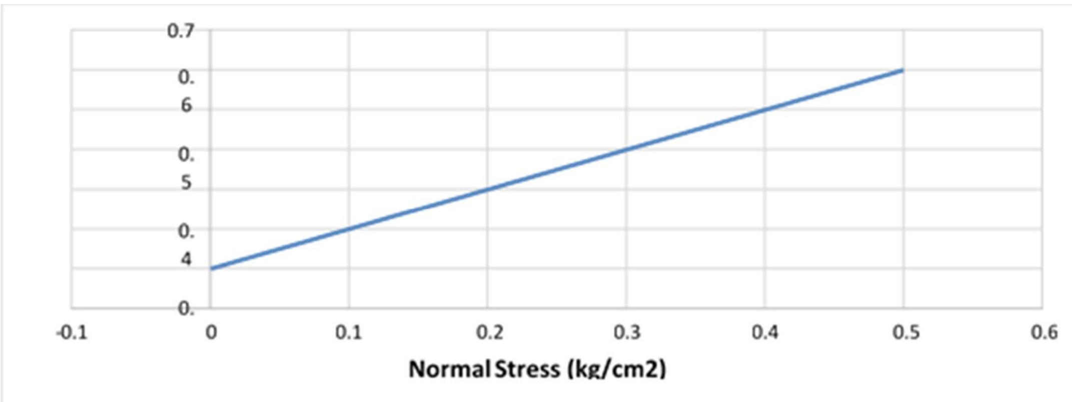

Figure 2. Ring shear test

$$\tau = \boldsymbol{c} + \boldsymbol{\sigma}\ \boldsymbol{tan\phi}$$

According to the equation, the amount of shear stress depends on the amount of effectively applied normal stress. The failure envelope of the soil samples was thus represented by the regression line that appeared in the figure. Additionally, the angle of internal friction can be calculated using the line's slope. The soil's cohesiveness serves as the line's y-intercept in the Mohr-Coulomb failure envelope. Since the soil sampled was from the C-soil Anaikatti in the Coimbatore district, cohesion c can be equated to zero and the line is anticipated to be drawn over the origin. The peak friction angle along the trend line was 290. The line, however, has a y-intercept of 30.42 kPa according to the trend line drawn from the experimental data.

Table 3. Results of Direct shear test

Shear Strength parameters	Results
Angle of internal friction(ϕ)	29^0
Cohesion(c)	30.42kPa

B. *Ring Shear Shear Test*

Pre-consolidation of the specimen is performed in a water bath with applied normal stresses of 25 kPa, 50 kPa, 100 kPa, 200 kPa, and 400 kPa at a load increment ratio of 1. It was made sure that main consolidation was finished for each load increase. The specimen was pre-shared at a constant rate of displacement of 18mm/min to lower the amount of horizontal displacement needed to obtain a residual state.

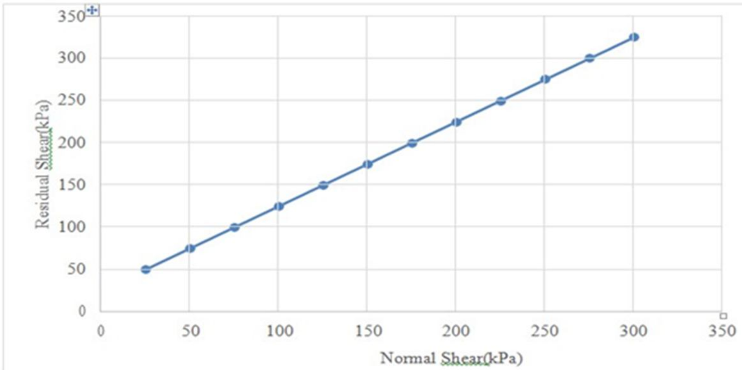

Figure 3: Ring shear test

After completing the prior distribution, identical soil samples were sheared at different normal stresses and very slow displacement rates. A displacement rate of0.58 mm/min was chosen for the current test. The slow displacement velocity dissipates pore pressure and helps maintain realistic shear strength values during drainage. Since the analysis focuses on failures on shallow slopes, we discuss results obtained at lower normal stresses when simulating field conditions.

Table 4. Results of Ring shear apparatus

Residual Shear Strength parameters	Results
Angle of internal friction(ϕr)	18^0
Cohesion(cr)	6 kPa

The slope is found to be unstable at drained cohesion of 6kPa and drained friction angle of 18^0 as show in Table 4.

V. DISCUSSIONS

Torsion ring shear tests were performed on the ground at Anakatti, Coimbatore. Typical test results showing soil peak and residue values are shown in Table 4. The test results showed that when the normal stress is low, the cohesion force approaches 6 kPa and the contraction angle of the internal friction angle approaches 180, as shown in Table 4. It can be seen that the slope is unstable with a drainage cohesive force of 6 kPa and a drainage friction angle of 180 degrees. Slope stability studies have shown a safety factor of less than 1 in dry areas. Therefore, plans were made to strengthen Anaikatti soils by adding admixtures to the soil.

VI. CONCLUSIONS

By assuming that the shear strength mobilized on the slip surface of a landslide is equal to the residual shear strength based on laboratory-drained multiple-reversal direct shear, or ring shear tests independent of the time after reaching the residual condition, the stability, even the movement, of reactivated landslides has been successfully evaluated and interpreted. Long-term landslides with a residual slip surface rarely remain still and can move at a pace of 2 to 50 millimeters per year (e.g.,Skempton and Hutchinson 1969; Skempton at al. 1989). When clay particles in the shape of plates are sheared, the residual condition is obtained when, to the greatest extent feasible under the operating effective normal stress, the clay particles are orientated face to face and parallel to the direction of shearing. The effective normal stress under which the residual condition is obtained through shearing determines the secant residual friction angle; as effective normal stress rises, a greater degree of particle alignment and orientation is made feasible, and as a result, lowers. Further shearing is needed to reach the residual condition under the new effective normal stress when effective normal stress on a shear plane at the residual condition is increased or decreased following compression or swelling. Depending on how much the effective normal stress has changed.

There may be a peak before reaching the new residual condition, depending on the size of the change in effective normal stress and the type of compression or swelling.

In the field, variations in effective normal stress due to functions of groundwater pressure may have some impact on short-term movement of the slope, but it is unwise, as Chandler (1997) pointed out, to place any reliance on this peak since it is frequently lost after small shear displacements. In the drained multiple reversal direct shear experiments described here, every effort was made to maintain the slip surface in the gap between the upper and lower portions of the shear box at residual condition. After 7 to 30 days of ageing under five different effective normal stresses for two distinct clay compositions, the peak and increases in residual strength were seen after reshearing.

1) It was discovered that the cohesion and angle of internal friction for normal shear strength were, respectively, 29.5kPa and 29^0.
2) It was discovered that cohesiveness and the angle of internal friction, two residual shear strength parameters, were, respectively, 6kPa and 18^0.
3) Studies on slope stability revealed a failure in the parched zone with a safety Factor.

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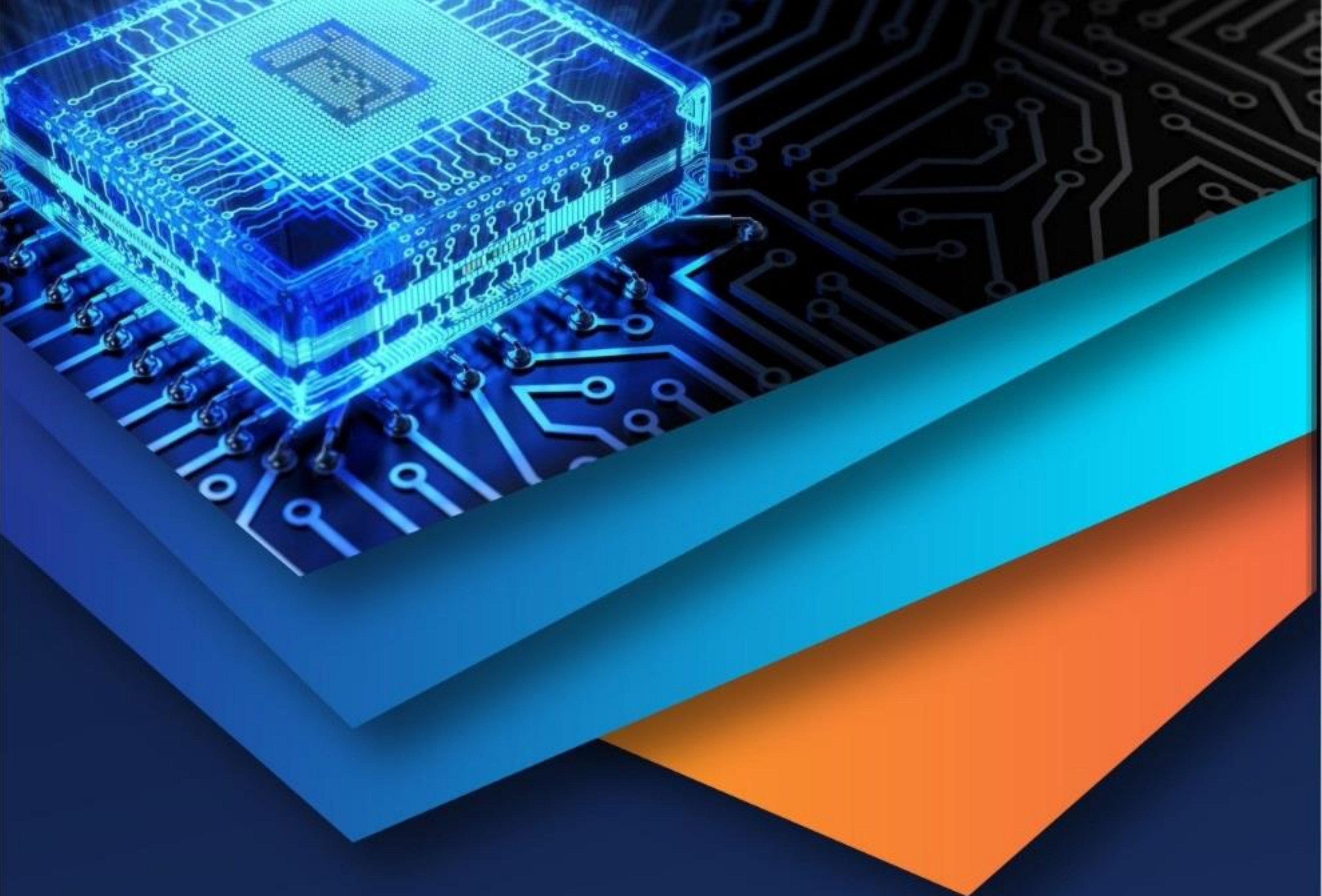

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