UNDRAINED SHEAR STRENGTH OF COHESIVE SOILS AT CONSISTENCY LIMITS

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***Abstract*—Shear strength of cohesive soils at consistency limits is considered to be constant and various apparatus are designed based on this, for easy determination of consistency limits. But there is a significant difference in the shear strength values quoted by different researchers. This study mainly deals with the systematic approach of determining the undrained shear strength of cohesive soil at consistency limits. The density and shear strength variation of the soil with variation of water content between consistency limits has been evaluated. Based on which it is under stood that the shear strength and density decreases with increase in water content of a soil-water mixture. The values of shear strength at consistency limits are observed to be within the range suggested in literature.**

***Key words*— Consistency limits, Undrained shear strength, Vane shear test, Dry density**

I. Introduction

Consistency limits plays an important role in defining the behavior of cohesive soil. Efforts are made by various researchers to propose correlations between consistency limits and other index properties of soil [1, 2]. Researchers on other hand worked to device various instruments for easy and accurate determination of consistency limits. These instruments works based on the shear strength of the soil at consistency limits. The undrained shear strength of soils at consistency limits plays a significant role in devising the mechanism of these instruments. But literature suggests a range of shear strengths 0.5-5.6 kPa and 20-320 kPa for soils at liquid limit and plastic limit respectively [3, 4, 5, 6]. An attempt is made in this study to determine exactly the shear strength of soil between consistency limits in a systematic manner.

II. Materials and Methods

Two locally available cohesive soils having plasticity index 20 and 33 were selected for this study. The various geotechnical properties of selected soils are summarized in table 1 and the grain size distribution of the soils are depicted in figure 1. The undrained shear strength of these soil are determined using laboratory vane shear test as specified in [7]. A range of water contents is selected between the consistency limits (Liquid and Plastic limits) of the soil and is placed in a cylindrical mould of 38mm Ø x 76mm, with a small 1mm hole at its bottom.

TABLE 1. Various Geotechnical properties of selected soils.

Properties	Red soil	Black soil
Specific Gravity (G)	2.69	2.635
Hygroscopic Water Content (%)	5	12.5
Liquid limit (LL)	40	66
Plastic limit (PL)	20	33
Plasticity Index (%)	20	33

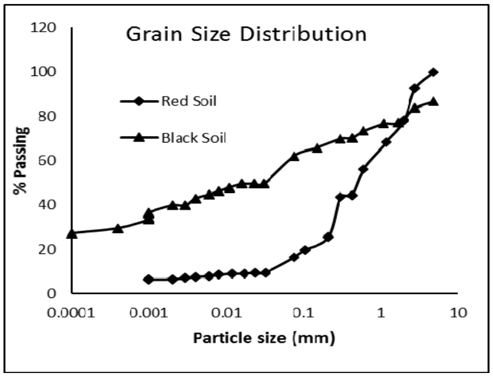

Figure 1. Grain size distribution of selected soils.

The soil mixed at selected water content is placed in three layers and every time it is tamped 25 times to remove air voids present in the soil, which creates a slight compactive effort that densifies the soil to an extent. This density mainly depends on the type of soil and has its effect on the strength characteristics determined using vane shear. Hereafter the variation in dry density is also considered significant in this study.

III. Results and Discussion

Figures 2 and 3 depict the variation of shear strength and bulk density of red soil respectively with variation of water content between consistency limits. Corresponding values are summarized in table 2. From figures, it can be observed that the shear strength and the bulk density decreases with increase in water content of the soil sample. Similar variations are observed in case of black soil as depicted in figures 4 and 5 and are summarized in table 3. Decrease in shear strength is obvious as the increased water has no resistance to shear force. And the decrease in density is a result of low specific gravity of high water content soil mixture. Similar results are observed in case of [8].

It can be observed that the shear strength of soils considered in this study, at liquid and plastic limit fall in the range of 0.5 – 5.6 kPa and from 20 – 320 kPa respectively as reported by [3, 4, 5, 6]. The variation of shear strength observed in figures 2 and 4 follows an exponential manner and the fitting the trend result in equation as shown in (1). Using this equation the strength of soil can be predicted at any water content between consistency limits. The values of shear strength, the constants of exponential equation and accuracy of exponential fitting R2 are reported in table 4.

$$S_u = c\,e^{-mw} \qquad (1)$$

where,Su= undrained shear strength

c & m = constants depending on soil type

w = water content between consistency limits

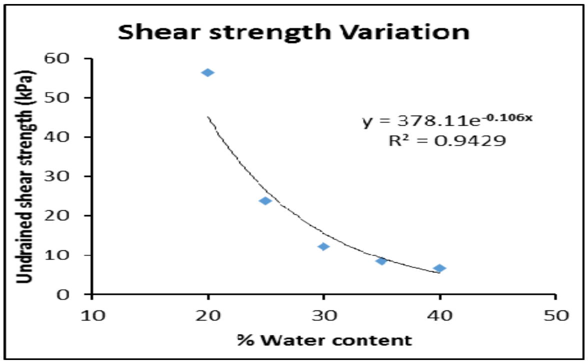

Figure 2. Shear strength variation of Red soil.

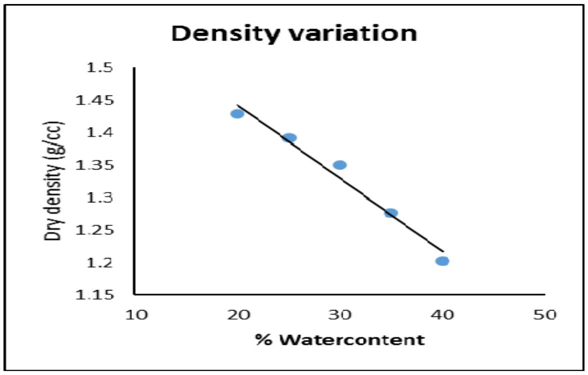

Figure 3. Density variation of Red soil.

TABLE 2. Summary of shear strength and density results of Red soil.

% Water content	Shear strength (kPa)	Dry density (g/cc)
20	56.291	1.429
25	23.932	1.391
30	12.152	1.351
35	8.477	1.276
40	6.6346	1.203

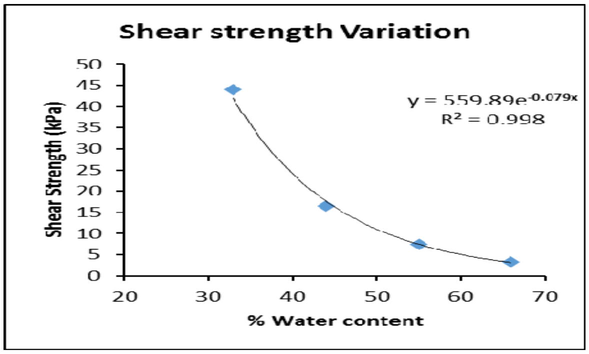

Figure 4. Shear strength variation of Black soil

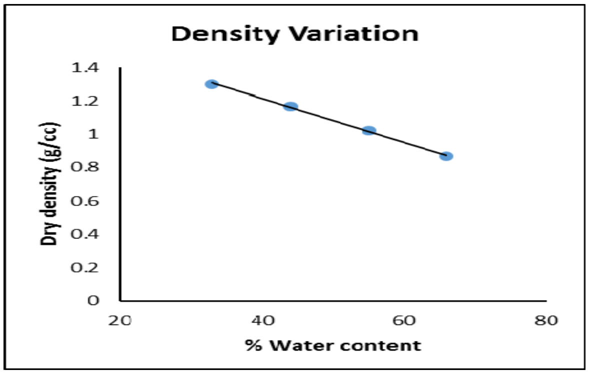

Figure 5. Shear strength variation of Black soil

TABLE 3. Summary of shear strength and density results of Black soil.

% Water content	Shear strength (kPa)	Dry density (g/cc)
33	43.97	1.3
44	16.5	1.17
55	7.46	1.022
66	3.22	0.867

TABLE 4. Summary of exponential fitting for shear strength variation

Soil type	S_u Liquid limit (kPa)	S_u Plastic limit (kPa)	constant 'c'	constant 'm'	R^2 value
Red soil	6.635	56.291	378.11	0.106	0.943
Black soil	3.220	43.970	559.89	0.079	0.998

Conclusions

Within the limited work done in this study, the following conclusions are drawn:

- The shear strength of a given soil between consistency limits depends on soil type and lies in the limits as suggested in literature.
- The variation of shear strength of soil between consistency limits follow an exponential trend and corresponding fitting equation helps in estimating strength at any corresponding water content.

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