EFFECT OF DRAINAGE CONDITIONS ON SHEAR STRENGTH OF SWOLLEN EXPANSIVE SOILS

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SYNOPSIS

Swelling behaviour of expansive soils is extensively discussed in literature but not their shear strength behaviour. Katti et. al. (1979) reported bilinear strength envelopes for expansive soils instead of the traditional linear envelopes. Babu Shanker et. al. (1990) have confirmed the bilinear effective strength envelopes for swollen expansive clays only for certain initial moulding (pre-swollen) void ratios.

This paper presents the results of triaxial and direct shear tests on swollen Black Cotton Soils of Warangal. Two types of Swell paths were chosen prior to shearing samples under varying drainage coditions like UU, CU and CD. The results point out that total stress strength envelopes are not bilinear while the corresponding effective stress strength envelopes are. Even the effective stress envelopes could still be linear if the initial moulding void ratios are larger than the terminal void ratio (Babu Shanker and Saikrishna, 1989).

INTRODUCTION

For a given consolidation stress history, the relationship between the effective normal stress and the shear strength is linear for clays requiring a maximum of two shear strength parameters. However, Katti et.al. (1979) reported bilinear relationship between effective normal stress and the shear strength for expansive clays which requires two additional shear parameters. Based on the results of drained shear tests, Babu Shanker and Sai Krishna (1989) and Babu Shanker et. al. (1990) confirmed bilinear effective strength envelopes for swollen Black Cotton soils of Warangal. However, they further stated that effective stress strength envelopes may not be bilinear if the initial moulding (pre-swollen) void ratio of the expansive soil exceeds a certain value called as 'Terminal void ratio'. One of the aims of the present study is to confirm the validity of the concept of Terminal void ratio.

EXPERIMENTAL STUDY

The Black Cotton soil used in this study was obtained from the campus of Regional Engineering College, Warangal which had the following properties : LL = 63%, PL = 24%, SL = 10%, Free Swell Index = 132%, Sand content = 31%, Silt content = 28% and Clay content = 41%. Natural soil was air dried and -2mm fraction of it was used. Samples were prepared by static compaction with an initial moisture content of 10% both for direct shear and triaxial shear tests. Initial moulding void ratios were 0.8 and 1.2 for direct shear tests and only 0.8 for triaxial test.

Soil samples were allowed to absorb moisture and swell freely (FS) under a confining pressure of 0.07 kg/sq.cm. in triaxial tests. Some of the samples in direct shear tests were allowed to absorb moisture and swell freely (FS) under a normal load of 0.07 kg/sq.cm. and some more were allowed to absorb moisture initially under constant volume (CV) conditions and water allowed to swell freely uder a normal load of 0.07 kg/sq.cm. The swollen samples were then subjected to shear tests under UU, CU and CD conditions both in direct shear and triaxial shear. Rates of shear testing were 1.25mm/minute for undrained tests and 0.025mm/minute for drained tests. No attempt was made to measure the pore pressures developed during undrained shear process.

PRESENTATION AND DISCUSSION OF RESULTS:

The undrained (UU) tests on swollen soil samples indicated linear horizontal envelopes with uu = 0 as is the case for non - expansive clays. These results are summarised below:

TABLE-I

Results of UU tests ($\varphi_{uu} = 0^{o}$)

Sr. No.	Type of shear test	Swell path	Moulding void ratio	Void ratio after swelling	Undrained cophesion(kg/cm^2)
1	DS	FS	0.8	1.05	0.37
2	DS	CV	0.8	1.92	0.65
3	TA	FS	0.8	1.08	0.40
4	DS	FS	1.2	1.21	0.20
5	DS	CV	1.2	1.15	0.35

It may be observed that as the failure void ratio increases, the undrained strength decreases as expected.

The total strength envelopes obtained from CU tests are also linear and the strength parameters so obtained are tabulated below:

TABLE-II

Results of CU tests

Sr. No.	Type of tests / swell path	e_i = 0.8		e_i = 1.2	
		C cu (kg/cm^2)	φ_{cu} (degrees)	C cu (kg/cm^2)	φ_{cu} (degrees)
1	DS (FS)	0.17	17.7	0.10	16.4
2	DS (CV)	0.14	19.5	0.07	17.0
3	TA (FS)	0.07	17.0	–	–

It is seen that cu value is more or less constant (with a value of 17.5 degrees) while the C cu varies with moulding void ratio, swell path and type of test. Samples behaved as over consolidated samples (with C cu O) due to the compactive efforts needed in preparing the samples initially.

Typical results of CD direct shear tests are shown in Fig. 1. The most striking conclusion of Fig. 1 is that, while the effective strength envelope for samples moulded with an initial moulding void ratio of 1.2 is linear, the envelope corresponding to initial moulding void ratio of 0.8 is bilinear (the second straight line is much flatter than the first straight line). This confirms the concept of Terminal void ratio (Babu Shanker and Saikrishna 1989). The bilinearity occurs at an effective normal stress roughly corresponding to the swell pressure of the smaple (Katti et. al., 1979). The vertical dial gauges used in CD direct shear tests to measure the volume changes during shearing stage have indicated that the samples expand under effective normal stress less than the swell pressure (Fig.2). These secondary volume changes are probably responsible for the bilinear trends. Other reasons of bilinearity are discussed by Nageshwar Rao (1989) and the implications of bilinearity are discussed by Babu Shanker and Sai Krishna (1989).

All the results of traixial tests are shown in Fig. 3. It is seen that while the total stress strength

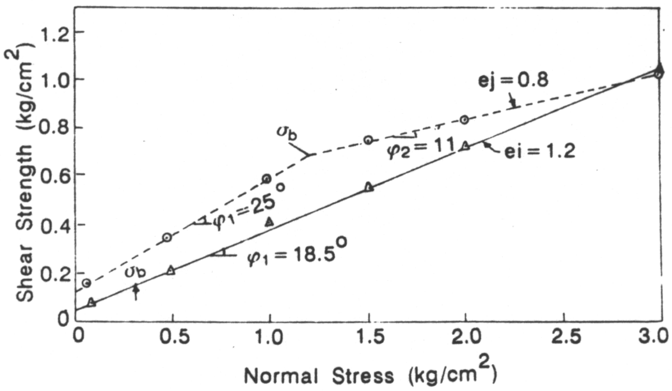

Fig. 1: Strength Envelopes obtained from Drained Direct Shear tests (Constant Volume Stress path)

TABLE-III
Bilinear effects from CD tests

Sr. No.	Type of test	Swell path	Initial void ratio	φ_1 (degrees)	φ_2 (degrees)	$\frac{\tan\varphi_2}{\tan\varphi_1}$
1	DS	FS	0.8	23	14	0.59
2	DS	CV	0.8	25	11	0.42
3	TA	FS	0.8	24	15	0.60
4	DS	FS	1.2	18	18	1.00
5	DS	CV	1.2	18.5	18.5	1.00

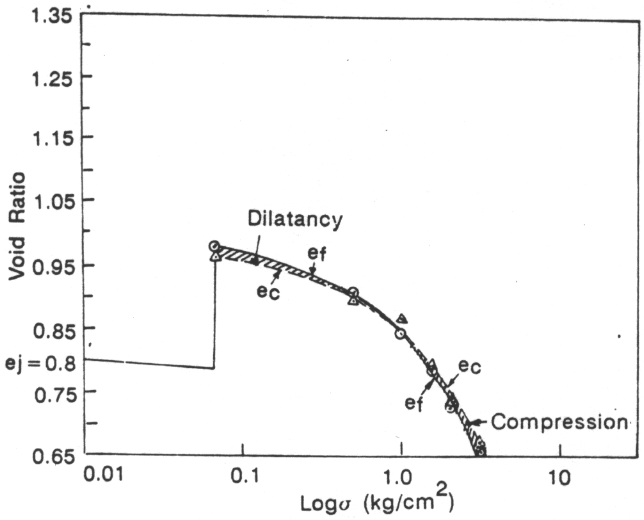

Fig. 2: Variation of Void Ratio with Normal Stress in Direct Shear test (Constant Volume Stress path)

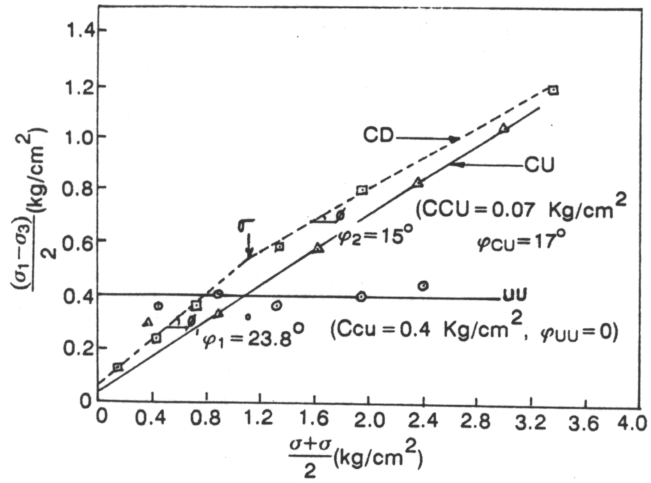

Fig. 3: Failure Envelopes from Triaxial Shear tests (Free Swell Stress path)

envelopes obtained from UU and CU tests are linear, the effective strength envelope obtained from CD test is bilinear. Thus it is the effective stress and not the total stress which distinguishes the strength behaviour of expansive soils from that of non-expansive soils. The degree of bilinearity is seen from the results of Table III.

CONCLUSIONS

1. Total stress strength envelopes (obtained from undrained tests) do not show bilinear trends in expansive soils.
2. φ_{uu} = O hypothesis is also valid for saturated expansive soils.
3. Effective stress strength envelope may be bilinear in (Swollen) expansive soils provided the initial moulding void ratio is less than certain critical value (known as Terminal Void Ratio).
4. Further research is needed into all the aspects of bilinearity, particularly the reasons behind it and its wider implications.

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