Short Communication

Swelling Behaviour of Undisturbed and Remoulded Samples of Black Cotton Clay

by

N. Babu Shanker*

A. Srirama Rao**

A. S. R. Swamy***

Introduction

Extensive research work has been carried out in this country on the swelling behaviour of black cotton soils (Satyanarayana, 1966, Katti, 1969). But, the researches so far have emphasis on the study of remoulded samples to analyse factors influencing swell though, some work has been done on undisturbed samples and in situ measurment of swelling pressure.

An attempt is made in the present work to study the swelling behaviour of undisturbed samples of black cotton soils so that they may be of use for direct applicattion in foundation design. Results of tests on undisturbed samples are compared with those of the same samples in remoulded state to bring out the effect of soil structure. This study also includes determination of the effect of the initial water content, the surcharge pressure and the testing technique adopted on the free swell and the swelling pressure of undisturbed and remoulded samples.

Swelling pressure may be defined and determined in the following ways :

(*i*) By the Constant Volume Method : the pressure required to prevent a soil from undergoing swell (disignated as s_0)

(*ii*) By the free Swell Method : the pressure required to bring back a swollen soil to its initial volume (designated as s_1).

Experimental Programme

Two sites in the regional Engineering College Campus, Warangal were selected for collecting the soil samples. At location-1 near the Government Tourist Home, the soil samples were collected from an average depth of 0.85m and and at location-2 near the College Guest House from an average depth of 1.25 m. Undisturbed samples were collected in 100 mm dia thin-walled sampling tubes in vertical and horizontal directions. Samples were extracted from these sampling tubes into Oedometerrings

*Assistant Professor
**Research Scholor
***Formerly Post Graduate Student
} Geotechnical Engineering Section, Department of Civil Engineering Regional Engineering College, Warangal-506004, India.

This paper was received in June 1981 and is open for discussion till the end of October 1982.

of 76 mm dia and 19mm thickness. Disturbed soil samples were also collected from these locations and remoulded specimens were prepared with them by static compaction in Oedometer rings to the field moisture and density conditions. Specimens designated as L_1 VU, L_1HV and L_1R indicate respectively the undisturbed sample collected in the vertical direction, undisturbed sample in the horizontal direction and remoulded sample from location-1. Correspondingly, numeral 2 (in place of 1) indicates similar sampless collected from location-2.

The index properties of the soil tested are as indicated below :

Property	Location-1	Location-2
Sand content (%)	23	17
Silt content %	25	27
Clay contents (%)	52	56
Liquid Limit (%)	106	71
Plastic Limits (%)	32	30
Shrinkage Limited (%)	12	10
Natural Water Content (%)	28.0	22.0
Free Swell Index (%)	120	190
Base Exchange Capacity (m eq/100g)	15	19

Test Procedure

The undisturbed and remoulded soil samples were tested for the determination of swelling pressure by adopting the free swell and the constant volume methods using the consolidation test apparatus and the triaxial bench with a proving ring. In the free swell method, soil samples were allowed to swell to full capacity (to record the maximum percentage swell, ϵ_v) under known surcharge pressures (q) by admitting water. They were then brought back to their original volumes in various stages by applying loads in double increments and allowing consolidation for 24 hours under each load increment in the consolidation test apparatus and in one single stage only while testing on the triaxial bench using proving ring to record the swelling pressure.

In the constant volume method, the sample was inundated with water and was prevented from undergoing increase in volume. This was accomplished by operating a screw jack from the top whenever there was a heave of about 0.02mm in traxial bench set up and the resulting compression of the proving ring gives the pressure applied to prevent volume change. This was continued until their was no further change in the volume and the final reading of the proving ring dial gauge gives the swell pressure (s_0). In the consolidation test apparatus, this was done by applying extra weights whenever there was a heave of about 0.02mm, on admitting water in to sample.

Effect of Soil Structure

In order to study the effect of soil structure, undisturbed samples collected from location-1 and location-2 in vertical and horizontal directions and remoulded samples were tested by the free swell method in the consolidation apparatus with identical initial conditions of dry density, water content and surcharge pressure. Thus each soil sample was allowed to swell fully to record the maximum percentage swell (ϵ_v) and then loaded back in stages to its original volume to yield the swelling pressure (s_1). Samples were tested for the study of the above effect by the constant volume mehode also.

Effect of Surcharge Pressure

It is common knowledge that when sufficient surcharge is applied, the swell of a soil can be arrested. However, to study the effect of surcharge pressure on the swelling pressure, undisturbed samples collected in vertical direction and remoulded samples for locations 1 and 2 with near identical initial dry density and water content values were tested under different surcharge pressures in the consolidation test apparatus by the free swell method.

Effect of Initial Water Content

Expansive soils are subjected to volume increase due to increas in the moisture content. Thus, the amount of swell is a function of the initial moisture content with the swell being more in respect of a drier soil than a wet soil. An attempt is made in this study to determine the effect of initial moisture content on the swelling characteristics of expansive soils. For this purpose, remoulded soil samples from the two locations, compacted statically to the same initial dry density but with different moisture contents were tested by the free swell method in the consolidation test apparatus under the same initial surcharge. Tests on the samples were conducted using the constant volume method also.

Summary and Discussion of Results

Table—I illustrates the effect soil structure on the maximum percentage swell and the swelling pressure as determined by the free swell method in the consolidometer apparatus. Typical test results obtained for sample L_1HU are shown in Figure 1. Results presented in table-1 indicate that the maximum percentage swell (ϵ_v) and the swelling pressure (S_1) are higher for undisturbed soil samples extracted in the vertical direction than those

TABLE 1

Effect of Soil Structure on Swelling Characteristics (Free Swell Method)

Property	Location-1			Location-2		
	L_1VU	L_1HU	L_1R	L_2VU	L_2HU	L_2R
Density (r_d) gm/cc	1.52	1.48	1.52	1.61	1.61	1.61
Water content (w) %	28.00	28.00	28.00	22.00	21.00	22.00
Surcharge Pressure (q) kg/sq. cm	0.15	0.15	0.15	0.25	0.25	0.25
Max. Swell (ε_1) %	9.97	7.00	6.10	11.60	8.90	4.05
Swelling Pressure (S_1) kg/sq. cm	3.00	2.30	1.50	7.50	5.50	2.90

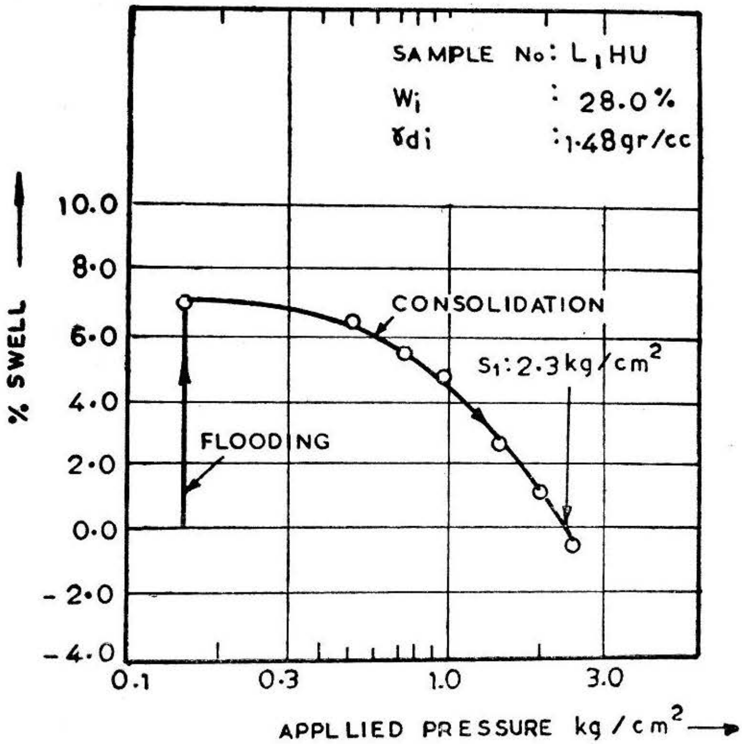
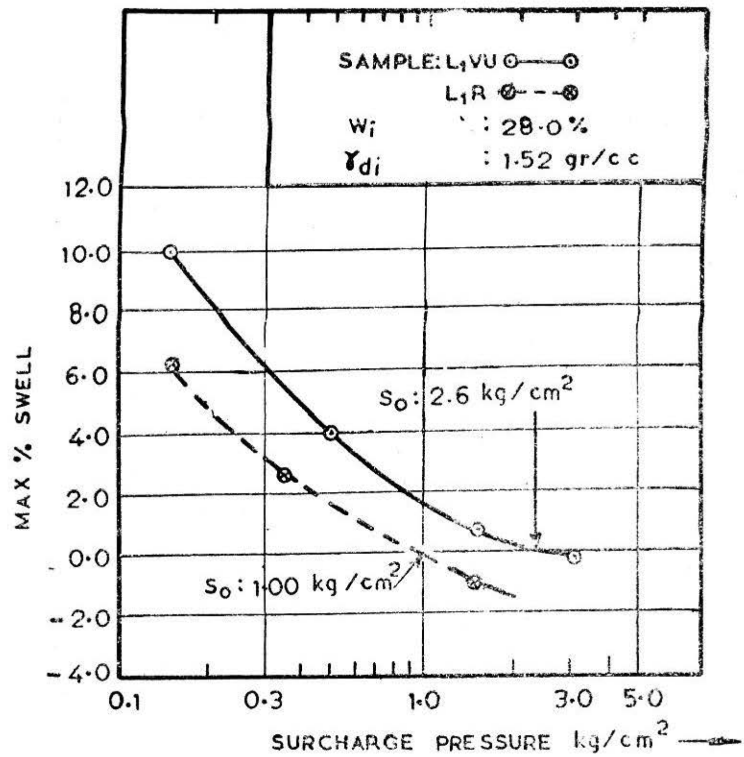


FIGURE 1 : Swell pressure (S_1) and maximum swell (ε_v) from consolidation method

in the horizontal direction under the same initial conditions. Similar observations were made by Novais Ferreire and J.A.H de silve (1973). Thus, the in-situ swelling behaviour seems to be anisotropic in nature.

Another observation that can be made from the results presented in Table-1 is that the undisturbed samples exhibited greater percentage swell and recorded higher swelling pressures than the remoulded samples under identical initial conditions. Thus. the undisturbed swelling behaviour is found to be different from the remoulded swelling behaviour. Similar results were obtained when swelling pressures were determined by the constant volume method, where in the swelling pressures (S_o) correspond to the no volume change condition.

Typical results of the tests conducted to study the effect of initial sucharge pressure (q) on the swelling behaviour of vertical undisturbed soil samples at location-1 are shown in Table 2. While increase in surcharge pressure results in the reduction of free swell, the swelling pressure (S_1) for the same initial conditions remains unaffected, as shown in Figure 2. similar trend was observed in the resuets of tests conducted on undisturbed samples collected at location-2 as also on the remoulded samples from the two locations. This trend is quite in agreement with the findings of Chen (1973).



FIURE 2 : Swell pressure (S_o) from consolidation method

TABLE 2

Effect of Surcharge Pressure on Swelling Characteristics (of vertical undisturbed samples from Location-1 by free swell methods)

Property	Sample No. 1	2	3	4
Surcharge pressure (q) kg/sq. cm	0.15	0.50	1.50	3.00
Density (r_d) gm/cc	1.52	1.48	1.51	1.52
Water content (w) %	23.00	26.50	25.00	27.00
Max. swell (ϵ_v) %	9.97	4.10	0.82	—0.05
Swelling Pressure (S_1) kg/sq. em	3.00	2.70	2.70	—

The effect of initial water content on the swelling characteristics of remoulded samples from location-1 can be seen from Table-3. With increase in the initial water content, the percentage swell (ϵ_v) decreases, but the swelling pressure (S_1) is insensitive to changes in the initial water content. The same trend was noticed in respect of the samples obtained

TABLE 3

Effect of Initial Water Content on Swelling Characteristics or Remoulded Samples (Free Swell Method) (From Location 1)

Property	Sample Number 1	2
Water content (w) %	7.00	28,00
Density (r_q) gm/cc	1.52	1.52
Surcharge (q) kg/sq. cm	3.15	0.15
Maximum swell (ε_v) %	10·10	6.10
Swelling pressure (S_1) kg/sq. cm	1.56	1.50

from Location-2. Swelling pressures (S_o) obtained by the constant volume method revealed the same trend.

Thus, while the percentage swell is sensitive to changes in the initial surcharge pressure and the initial water content, the swelling pressure has been found to be insensitive. Similiar observations were made by Kassiff and Baker (1971) Chen (1973) and Brackley (1973).

Another aspect of interest in the above study is the effect of the technique adopted in the determination of swelling pressure. As indicated earlier, swelling pressures were determined by the constant volume method (S_o) and the free swell method (S_o) both in the consolidations test apparatus and on the triaxial bench. Under of swelling pressure (S_o) and (S_1) obtained in the consolidation test apparatus and in the triaxial bench on the undisturbed soil samples collected in the vertical direction and the corresponding remoulded soil samples from the two Locations, for the same initial conditions, are presented in Table-4. Values of swelling pressure (S_1) determined by the free swell method in the consolidation test apparatus are more than the swelling pressure values (S_o)

TABLE 4

Comparsion of swelling pressures Determined by Different Techniques

Sample Designation	Swelling pressure in kg/sq. cm: By consolidation test apparatus		By triaxial bence with proving ring	
	S_0	S_1	S_1	S_0
L_1VU	2.60	3.00	1.33	—
L_1R	1.00	1.50	0.95	0.76
L_2VU	2.70	7.50	3.19	—
L_2R	0.75	2.90	1.96	0.87

indicating that more pressure is needed to bring back a swollen sample to its initial volume than that required to prevent a soil from undergoing swell. This underscores the importance of the stress path that is followed in determining the swellinging pressure.

The opposite trend is seen (i.e. s_1 being less then s_0) in respect of the samples tested on the triaxial bench with proving ring attachment. This may be due to the fact that enough time was not allowed for the sample to attain equilibrium in the free swell method as the sample was brought back to its initial volume in one single stage as against the number of stages adopted and the time allowed at each stage in bringing the swollen sample back to its initial volume in the consolidation test apparatus. Pore pressure changes may be responsible for this difference. s_1 values obtained in the consolidation test apparatus refer to (long term) effective pressures, whereas the time allowed to developed s_1 in the triaxial bench was much smaller. This underlines the need for allowing enough time for the soil to attain equilibrium under each load intensity.

However, the swelling pressures obtained by the standard free swell method in the consolidation test apparatus 1.5 : 2720—Part XL1) are higher than those obtained by the standard constant volume procedure in the triaxial bench by about 1.5 times to 2.4 times.

Conclusions

The following conclusions may be drawn from the results presented in this paper :

(*i*) In-situ swelling behaviour is likely to be anisotropic, with the free swell and the swelling pressure being more in the vertical direction than in the horizontal direction.

(*ii*) Swelling behaviour of undisturbed soil samples is different from that of remoulded soil samples, swelling pressure and free swell of remoulded specimens being less than those of undisturbed soil specimens for the same initial conditions.

(*iii*) While increasing initial moisture contents and surcharge pressures result in a decrease of the maximum percentage swell, the swelling pressure remains unaffected by them.

(*iv*) Swelling pressure value depends on the technique adopted for its determination. The pressure necessary to bring back a swollen sample to its initial volume is more than that necessary to prevent the sample from undergoing swell on absorption of water.

Acknowledgement

The senior auther thanks the Government of India for sanctioning a research project under which the above work has been carried out. The authors thank Sri S. M. Panse, formerly, M. Tech. Student, for his help in carrying out a part of the experimental work.

References

BRACKLEY, I. J. A(1973) "Swell Pressure and free Swell in a compacted clay" *Proc. of 3rd Int. Conf. on Expansive Soils*, Haifa, Israel, pp 169-176.

CHEN, F. H. (1973) "The Basic Physical Properties of Expansive Soils" *Proc. of 3rd Int. Conf. on Expansive Soils*, Haifa, Israel, pp 17-25.

I. S. 2720 (Part XL1)-1977, "Measurment of Swelling Pressure of Soils".

KASSIFF, G AND BAKER R (1971) "Aging effects on swell potential of Compacted clay" *Jrl. of the Soil Mech. and Foundations Division* Proc. of ASCE, March, 1971 pp 529-540.

KATTI, R. K. et al (1969) "Studies on Mechanism of Expansive Soil Media and on its application to Field Problems" *Proc. of the Symposium on Characteristics of and construction techniques in Black cotton soil*, Puna pp 49-64.

NOVAIS FERRIERA, H AND DA SILVA, J. A. H, (1973) "Luanda Expansive Clays and Laboratory Appreciation Criteria" *Proc, of 3rd Int. Conf. on Expansive Soils*, Haifa, Israel pp 53-59.

SATYANARAYANA, B.(1966) "Swelling Pressure and related Mechanical Properties of Black Cotton Soil" Ph. D. thesis, Department of Civil Engineering, Indian Institute of Science, Bangalore, India.

SWAMY, A. S. R. (1980) "A Laboratory Study on the Swelling Characteristics of undisturbed and remoulded Expansive Soils" M. Tech. Thesis, Geotechnical Engineering Section, Department of Civil Engineering, Regional Engineering College, Warangal, India.