Determination of Swelling Pressure of Black Cotton Soil — A Method

Méthode pour déterminer la pression de gonflement dans le sol dénommé «black cotton»

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Summary

A method of measuring the swelling pressure of heavy plastic clays is described and the results of some preliminary results are given.

Sommaire

Méthode pour mesurer la pression de gonflement dans les argiles plastiques lourdes suivie des résultats de quelques essais préliminaires.

Introduction[1])

A typical heavy plastic clay called Black cotton soil occurs in large parts of mid-western India. The soils owe their origin to the Deccan Trap which is an extensive volcanic formation of basaltic rocks. This type of soil has a number of characteristics comparable to the tschernosem soil group. From the pedogenic considerations these soils have been tentatively termed as "immature tropical tschernosem" by *Basu* and *Sirur* (1938), "immature because the leaching process has not proceeded as far as in the proper tschernosem and tropical because of the evidences of the breakdown of the silicate complex in certain soils". Black cotton soils also contain much less humus than the tschernosem soils.

When buildings are founded on black cotton soil, it is generally found that they suffer damage, unless special precautions are taken. The causes for such damage are the excessive swelling and shrinkage of the soil that take place when moisture finds its way into the subsoil under the foundations and subsequently dries up during the hot period. Damage to structures due to these reasons may be avoided if the following methods are adopted:—

(*a*) The foundation is carried down to a depth, not affected by seasonal moisture variations.

(*b*) The foundation load is such that the pressure on the soil under dead load itself equals or exceeds the swelling pressure of the soil.

The former method as in (*a*) may not be always practicable especially in case of roads and runways, and a knowledge of the value of the swelling pressure of soil would be considered a necessary pre-requisite wherever the second method is to be adopted.

It is obvious that the amount of swelling pressure of a soil will depend on the type and percentage of clay it contains, the initial density and moisture content, the final degree of saturation attained and the depth of the soil layer. This paper describes a laboratory method of test by which swelling pressure of an undisturbed or remoulded sample of soil can be determined, and an apparatus to carry out such tests. The presentation also includes results of experiments carried out with a representative sample of black cotton soil remoulded in the laboratory.

Apparatus

The apparatus for carrying out the test consists of the following:—

A *swelling pressure testing apparatus* as shown in Fig. 1. It consists of a device by which the remoulded or undisturbed soil sample in a mould is confined between two porous stones covered with water. The water bath containing the mould is placed on the base of the frame work. A plunger piece is placed on the top porous stone and the ram attached to the proving ring is adjusted so that it comes in contact with the plunger piece. Pressure exerted by the soil sample is transmitted to the proving ring, the deflection of which is recorded in the dial gauge. The relationship between load and deflection of the

[1]) Since the completion of the first phase of investigation under report, author's attention has been drawn to a paper entitled "Suggested method of test for expansion pressures of remoulded soils" by *F. N. Hveem*, "Procedure for testing soils"—A.S.T.M. Committee D–18, describing a similar method.

proving ring being known, the applied pressure due to swelling can be determined.

Moulds—This is a hollow cylinder 3 inch in inside diameter and 4 inch in length. It is fitted with a perforated base plate. The clearance between the cylindrical wall of the mould and the porous stone or plunger piece must be sufficient to prevent

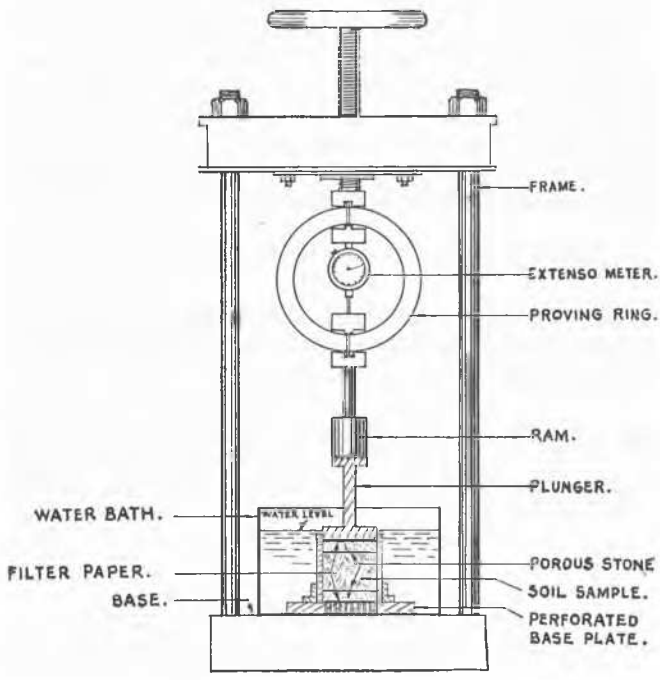

Fig. 1 Apparatus for Swelling Pressure Measurements
Appareil pour mesurer la pression de gonflement

friction, yet small enough to keep the soil from being squeezed out. Moulds of different dimensions may be used as necessary. For undisturbed samples, a mould with cutting edge is used.

Preparation of the Test Specimen

Remoulded sample—The soil is first dried in the sun and then pulverised and passed through a $\frac{3}{16}''$ sieve. The exact quantity of dry soil required to make a sample of definite height in the mould at its A.A.S.H.O. or any other required density is calculated and the corresponding weight of sundry soil is taken in a basin and mixed with the requisite amount of water to bring the soil to optimum moisture content (O.M.C.) or any other desired moisture content. The soil is mixed thoroughly and then compacted in the mould which gives pressure by means of a hydraulic jack fitted in a sturdy framework. The height of the sample is accurately measured by means of an extensometer suitably fitted to the frame. The base plate and the plunger are then separated from the mould and porous stones are fitted on the top and bottom of the sample. The sample is then ready for the test.

Undisturbed samples—The soil is first excavated up to a depth below which the sample is to be taken. The surface of the soil at the required depth is made level and a mould of required height and diameter, and provided with a cutting edge, is pushed into the soil. It is then removed and the soil is trimmed from both ends of the mould and the surfaces made level. The mould is then interposed between two porous stones with filter paper and is ready for the test.

Experimental Procedure

The mould with the soil sample, porous stones and plunger is put inside a water bath and the whole is placed on the base of the frame under the ram of the testing apparatus in such a way that the top of the plunger comes directly under the ram.

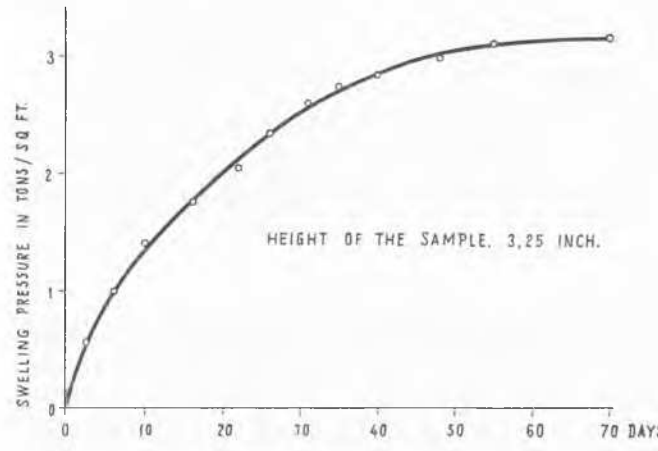

Fig. 2 Swelling Pressure vs. Time
Pression de gonflement en fonction du temps

The ram is then manipulated to touch the plunger. The bath is then filled with water so that the whole sample is under water. As the sample begins to absorb water it tends to swell and deflection occurs in the proving ring indicating the pressure it exerts. The readings in the extensometer is taken daily until maximum constant reading is obtained.

Results

Experiments have been carried out with remoulded samples of black cotton soil (characteristics see Table 1) of 3 inch in diameter and of different heights, compacted at optimum moisture content to its A.A.S.H.O. density. A typical set of results is given in Fig. 2, where the sample height is 3.25 inch. Fig. 3 give the results of experiments with different heights of the soil samples.

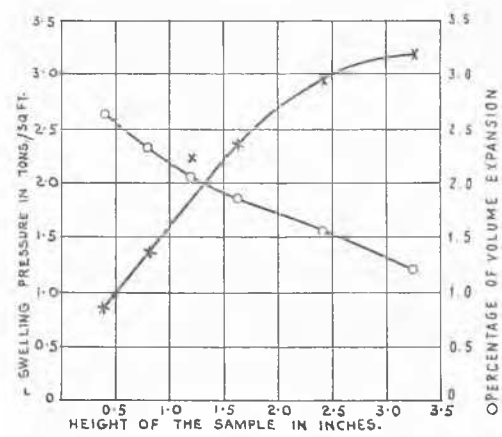

Fig. 3 Relation between Swelling Pressure, Volume Expansion and Height of the Samples
Relation entre la pression de gonflement et l'expansion du volume et la hauteur de l'échantillon

Table 1 Chemical and Mechanical Characteristics of the Material Used

Acid insoluble	59.53%		Liquid limit	96.5%
Fe_2O_3	9.29%	No. 40	Plastic limit	40.4%
Al_2O_3	13.68%	sieve	Plastic index	56.1%
CaO	6.11%	oven	A.A.S.H.O.	24.2%
MgO	3.98%	dried	optim. moist. cont.	
Org. matt	1.53%		A.A.S.H.O. maximum density	103 lbs./cu.ft.
Gravel	2.40%		Shrinkage limit	8%
Coarse sand	4.40%		Volumetric shrinkage	63%
Fine sand	7.40%		Shrinkage ratio	2.07
Silt	19.00%		Specific gravity	2.706 g/cm³
Clay	65.80%		C.B.R. value (modified A.A.S.H.O.) at saturated condition	2.3%

Discussion

In the tests described above, swelling pressure is measured at virtually constant volume, the deformation of the proving ring itself being extremely small. The swelling which is allowed to take place can be neglected for practical purposes. The stronger the proving ring used, the less will be the swelling effect.

From the results it may be seen that the increase of swelling pressure is not directly proportional to the increase of height, though increase of the swelling pressure does take place with increase of height of the test sample at optimum moisture content and maximum density.

It will be noticed that the curve in Fig. 3 tends to become flat thus leading to an ultimate value of constant swelling pressure. However, in order to arrive at a method of determining the working stress due to the swelling pressure in a foundation soil, for the total thickness of the expansible layer from small scale laboratory tests, further experimentations are warranted on the lines indicated in this paper. Further investigations are being carried out both with remoulded and undisturbed soil samples, with variable cross section but with constant height, with a view to study the influence of the width of the soil sample on its swelling pressure.

Acknowledgment

This work has been carried out as a programme of research on Indian Soils in the Engineer Research Wing of the College of Military Engineering, Poona, India.

References

Basu and *Sirur* (1938): The Indian Journal of Agricultural Science, Vol. VIII, Part V.