ANISOTROPIC SWELLING IN BLACK COTTON SOIL

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ABSTRACT.

The influence of initial moisture content and the nature of granular material on the anisotropic swell behaviour in black cotton soil has been examined. It was observed that the amount and rate of swelling are guided by the initial particle orientation. For samples compacted with moisture below the optimum value, the variation in swelling trends in vertical and horizontal directions is a result of the particle arrangement, the pressure exerted by the air in the voids and also the subsequent expulsion of the same. In samples compacted with moisture content above the optimum, the initial dispersed state of the particles guides the anisotropy. The swelling in such samples is considerable in directions transverse to the particle orientation. At optimum moisture levels, because of the minimal differences in the particle arrangement for samples in vertical and horizontal directions, the swelling is similar in both cases and as such no anisotropic behaviour was noticed. Increasing presence of granular component in the soil reduces the rate of swelling, protracts the time for completion of swelling and also reduces the anisotropic behaviour. Reduction in the grain size of the granular material facilitates quick swelling. The variations in such samples for vertical and horizontal directions are explained on the basis of packing in the system and the constraints imposed by sand grains on osmotic swelling. Since similar variables exist in field conditions, the present study enables an understanding of their role in the anisotropic swell behaviour of black cotton soils.
INTRODUCTION.

Black cotton soil is the prevalent type in Central, Western and South Western parts of India. Foundations in this soil are of great concern to engineering geologists and civil engineers due to the extensive swelling and shrinkage exhibited causing settlements in the field down to considerable depths. Typical ground movements in black cotton soil for some areas in India have been indicated by Dinesh Mohan (1966). Montmorillonite is the dominant constituent in the soil existing with granular material (sand and silt). Such a soil was visualized as a multicomponent clay-sand system and the shrinkage characteristics for the system were reported by Das, Ananda Krishnan and Gokhale (1969) and Gokhale and Ananda Krishnan (1970).

Montmorillonite adsorbs water due to charge deficiencies in its lattice. Role of physico-chemical parameters in clay swelling has been investigated in detail by several workers (Bolt, 1956, Holtz and Gibbs, 1956, Lambe, 1958, Seed and Chan, 1959, Ladd, 1960, Seed, Michell and Chan, 1962 and Sorochan, 1970). Because of the direction expansion (in the 001 direction) of the montmorillonite lattice and the specific orientation of the clay particles in a soil, the swelling in the system is different in different directions. Data on anisotropic swell behaviour is limited. Engineering studies on the anisotropic swelling in expansive clays and soils have been reported by a few workers (Means, 1959, Ward, Samuleo and Butler, 1959, Warkeintin and Bozozuk, 1961, Parish and Liu, 1965). Their results revealed that swelling was dominant either in vertical or in horizontal direction in the soil which was correlated to specific situations. Rogatkina (1967) observed that the maximum swelling was in the direction perpendicular to bedding and the rate of swelling was appreciably greater when the direction of the water flow coincided with the bedding direction.

In an expansive soil, the behaviour of the soil would largely be controlled by the particle orientation and the composition of the cohesive constituent (clay) as also by the percentage and the grain size of the granular component (sand or silt). The present study attempts to explain the role of these parameters on anisotropic swelling with various moulding water contents.

EXPERIMENTAL PROCEDURE.

Black cotton soil from Baroda (India) was used. The grain size analyses for the same revealed the presence of 63% of clay, 27% of silt-sized particles and 10% of sand. The maximum dry density (as obtained from the standard Proctor's test) was 1.54 g/cm³ and the optimum moisture content around 24.5%. X-ray diffraction analysis carried on General Electric unit with XRD-6 diffractometer using filtered copper K-alpha radiation indicated the clay mineral to be montmorillonite. The soil was compacted in standard Proctor mould with a metal rammer, in three layers with 25 blows for each layer. From such a compacted specimen, two samples (one in vertical and the other in horizontal directions) were taken, as indicated in figure 1, in the oedometer ring of 3” diameter and 1” height. The bulk densities were maintained identical. If there were any differences the entire sampling procedure was repeated. The samples were subjected to a preload of 1 pound per square inch in the oedometer. All the tests were carried out on Amil oedometer. Continuous supply of water was maintained to the sample during swelling.

RESULTS AND DISCUSSION.

a) Effect of moulding water content on swell anisotropy:

The samples were compacted at three moisture levels: dry of optimum, at optimum and wet of optimum moisture. For each of the Proctor specimens, the samples in vertical and horizontal directions were obtained as described earlier. Measurements for swelling were taken on four identical sets at any moisture level to ensure the consistency of operations.

Figure 2 represents the swelling behaviour for such samples. All the samples indicated slightly greater swelling in the horizontal direction than in the vertical one during the first 60 minutes due to rapid initial penetration of the moisture along the layers (created in the samples during compaction). For the remaining period of time, the swelling for the sample in the vertical direction was always greater than for the one in the horizontal direction. Anisotropic swelling behaviour was noticed in the samples compacted with moisture below and above the optimum level. However, the anisotropy was greater for the samples with moulding water contents below the optimum level (curves 5 and 6 of figure 2). It is well known that the arrangement of the particles is influenced by the mode of compaction and the moulding water content. Lambe (1958) has indicated the nature of particle arrangement in a clayey soil under different moisture levels of compaction (figure 3). Samples with low moisture content have a random particle orientation which slowly improves with increasing moulding water contents. Above the optimum moisture range, the samples would have a partially oriented structure. The higher swell values for the samples at low initial moisture is due to the flocculated nature of the fabric. In case of greater dispersion of particles, the swelling is less due to the decrease in the natural desire for the soil to imbibe water to satisfy adsorptive and double layer pressures (Seed, Michell and Chan, 1962). Seed and Chan (1959) have shown that parallel particle orientations exhibit lower swelling characteristics than the random orientations. Thus the values for swelling shown by samples compacted either at optimum or below the optimum moisture content (curves 3, 4, 5 and 6) are greater than the values for samples compacted with high moisture (curves 1 and 2 of figure 2).

The anisotropic behaviour in samples compacted with moisture above the optimum can be explained as follows: Due to the partial orientation of the particles in dispersed state, the oedometer samples taken from the Proctor mould in vertical direction (figure 1) would have particles aligned on their basal planes while the samples taken in the horizontal direction would have them partially parallel to the oedometer sample axis. As such, the