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LATERAL SWELL PRESSURES IN EXPANSIVE SOILS

PRESSION LATERALE DE DILATION DANS DES SOLS EXPANSIF

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SYNOPSIS : The lateral and vertical swelling pressures and the relationship between them are investigated using a thin wall oedometer in the laboratory using compacted specimens of an expansive soil. Constant volume swell tests and swell overburden tests were conducted. The influence of initial water content and surcharge on the swelling behavior and the lateral swell pressures is presented. It is found that lateral swell pressures increase rapidly to attain a peak value and gradually decrease to an ultimate value under constant normal stress. The range of the ratio between lateral and vertical swelling pressures is reported.

1. INTRODUCTION

Any structure, located or burried in expansive clay, may be subjected to large magnitudes of lateral pressures due to development of lateral component of the swelling pressure as a result of an increase in water content. In some cases replacement of these types of clays may not be feasible; and structures like tunnels, underground conduits, canal linings, retaining structures etc. located in expansive soils may be designed to withstand high lateral swelling pressures (Kassiff and Zeitlen 1962, Katti et.al. 1987). The current research on the subject indicate that the saturated expansive soil behaves unconventionally with respet to development of lateral pressure both at active and at rest conditions (Katti et.al. 1987).

Several techniques are available for direct measurements of lateral swell pressures, including triaxial and oedometer testing (Fourie 1989; Keskin et.al. 1992; Edil et.al. 1992) and in situ probes (Ofer 1985). In the present investigation a thin wall oedometer ring is manufactured and calibrated to measure lateral swell pressures. Constant volume swell (CVS) and swell overburden (SO) tests were conducted on statically compacted specimens. The variables considered in the testing program included initial water content and surcharge (vertical) pressure. Drained and undrained triaxial tests were also performed on samples that reached equilibrium swell to investigate the mechanism of yielding observed in constant surcharge swell tests.

2. SOIL INVESTIGATED

A clay soil from the Egean Coast of Turkiye has been used. The soil has the following characteristics:

Liquid Limit : 110%
Plasticity Index : 85%
Clay Content ($<2\mu$) : 61%
Standard Proctor :
Optimum Water Contend 43%
Max.dry density 11.7 kN/m^3

The soil was dried, crushed and sieved through No.40 sieve. After mixing with required amount of water, the samples were placed into special molds to attain a constant dry density of 12 kN/m^3 by static compaction.

3. TESTING TECHNIQUE

The apparatus used in this investigation is similar to the one developed by Ofer (1981) and, Edil and Alanazy (1992). It allows the measurement of small lateral strains and therefore lateral pressures in a thin wall steel oedometer ring. The ring has a wall thickness of 0.35 mm, and horizontally oriented strain gages are glued outside of the thin wall at diametrically opposite points. The calibration of the ring was performed by sealing the bottom and top of the ring with fixed plates; and measuring the lateral strains under application of known air or water pressure (Ertekin, 1991). Calibration process were repeated for few loading/unloading cycles and no hysterisis were observed within the working pressure range of 1000 kPa.

Two different techniques of performing one dimensional swelling were investigated on 63.5 mm diameter and 50 mm high specimens:

i. Constant Volume Swell Tests (CVS): In this technique the compacted specimen was placed into the ring and kept in the ring to relax for some time. It was then inundated with water. This causes vertical deformations to develop; however the deformations were prevented by gradually increasing the vertical pressure. The test continued until no swelling was registered. Continuous records of lateral pressures were obtained throughout the experiments. At the equilibrium stage the registered vertical and lateral stresses are defined as swell pressures. After this stage the vertical pressures were reduced in decrements to obtain the rebound characteristics.

ii. Swell Overburden Tests (SO): In these tests a predetermined surcharge pressure was applied to the specimen in dry, and kept for one hour for equilibrium. Then the sample was inundated with water and allowed to swell while registering the lateral pressures continuously. The ultimate swell percent under particular surcharge and variations in the lateral stresses were obtained.

4. EXPERIMENTAL RESULTS

4.1 CVS Tests

Typical data trends reflecting the development of lateral stresses with respect to vertical pressures in CVS tests are shown in Fig.1. In these tests the dry density of the samples were identical (12 kN/m^3) and initial water contents varied from 27% to 43% being in the slightly wet and mainly dry side of optimum moisture range.

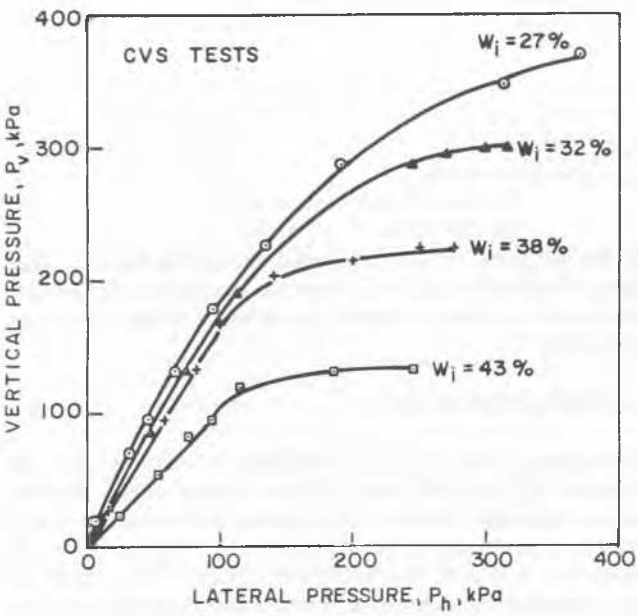

Fig.1 Development of vertical and lateral stresses in CVS tests

It is noted that rate of development of vertical swell pressures is fast as compared to lateral swell pressures at early stages of the test. However, the lateral stresses continue to increase at faster rates after the development of vertical pressures slowes down; and reach values in excess of vertical swell pressures. This behavior is more pronounced at higher water contents.

The swell pressure ratio, K_s, is defined as the ratio of lateral to vertical swell pressures at the equilibrium stage. The variation of K_s and both the vertical and horizontal swell pressures with initial water contents are shown in Figures 2 and 3, respectively.

The data indicate that both the vertical (P_v) and the lateral swell pressures (P_h) decrease with increasing initial water content in a linear manner. However the rate of decrease in P_v with respect to water content is faster as compared to P_h. Thus, the resulting K_s is higher with higher initial water content, as shown in Fig.2. The K_s value varies from 1.00 to 1.55 for the water content range investigated.

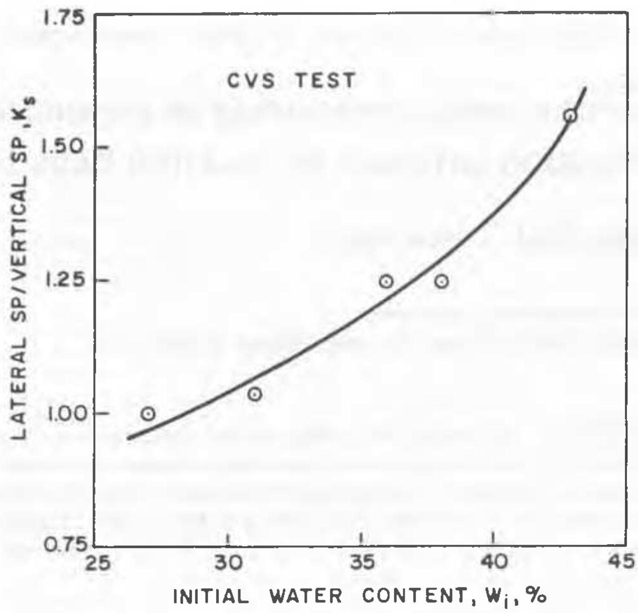

Fig.2 Swell pressure ratio v.s. initial water content in CVS tests

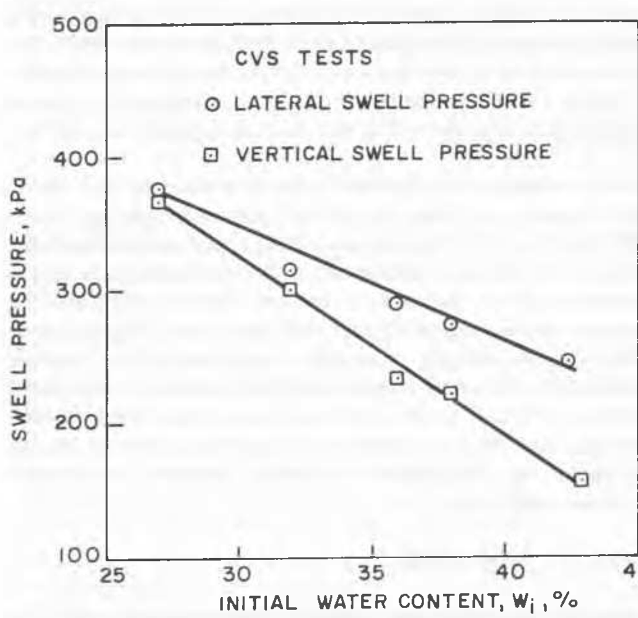

Fig.3 Reduction in swell pressures at higher water contents

4.2 SO Tests

Typical behavior showing the development of the lateral pressures with increasing vertical swell deformations under constant surcharge pressures of 50, 100, 150 and 200 kPa is shown in Fig.4. The initial water contents and the dry densities of these samples were identical. It is noted that under constant surcharge load, the lateral pressure increases rapidly with time at the beginning of the saturation phase, and attains a peak value. With further increase in time and the vertical swell deformation lateral pressures decrease and reach an ultimate value. Similar behavior has been reported by other investigators (Chen et al 1987; Keskin et.al. 1992).

Chen and Huang (1987) propose that the reduction in the lateral pressures may be attributed to gradual changes in the soil structure and clay particle orientation associated with the saturation process. On the other hand Blight and Williams (1971) suggest that this reduction is due to passive failure of specimens under peak value of the lateral swell pressure.

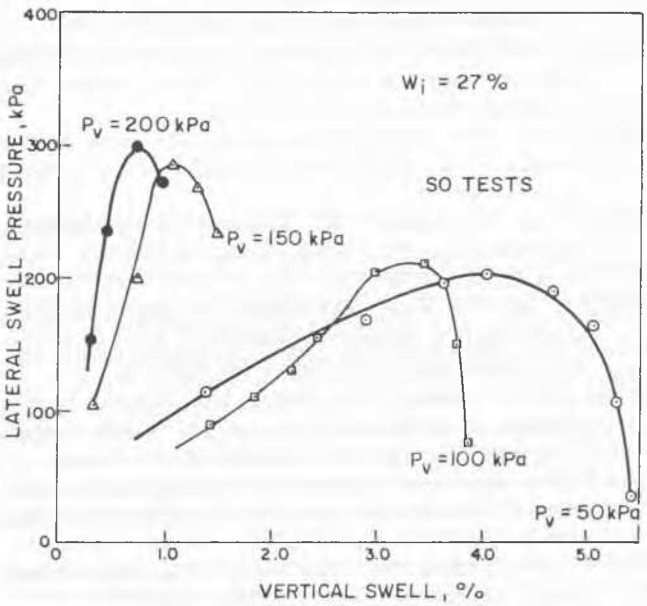

Fig.4 Typical lateral pressure v.s. vertical swell behavior in SO tests

The peak and ultimate lateral swell pressures under various surcharge loads are shown in Fig.5. The data trends indicate that the difference between the peak and ultimate values of the lateral pressures is much higher at the surcharge pressures 100 kPa and less, and the reduction in the lateral stresses is not significant (i.e. 15% or less) under surcharge pressures of 150 kPa or more.

The undrained shear strength of the specimens was determined after the equilibrium swell is attained in the SO tests through unconsolidated undrained triaxial tests. The triaxial specimens were trimmed from the samples of SO tests. The test results are shown in Fig.6.

The UU triaxial test results indicate that the average undrained shear strength of the specimens after being saturated under the specific surcharge loads is 100 kPa. This implies that an undrained failure under increasing lateral stresses is to be expected when the peak principle stress difference (i.e. P_h-P_v in SO tests) reaches 200 kPa. The peak principle stress differences in the SO tests are recorded within the range from 101 kPa to 124 kPa, being higher under the smaller surcharges.

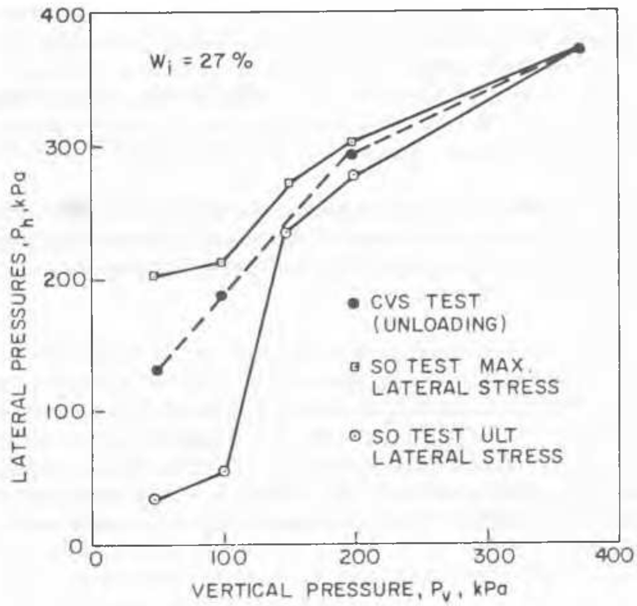

Fig.5 Peak and ultimate lateral stresses in SO tests

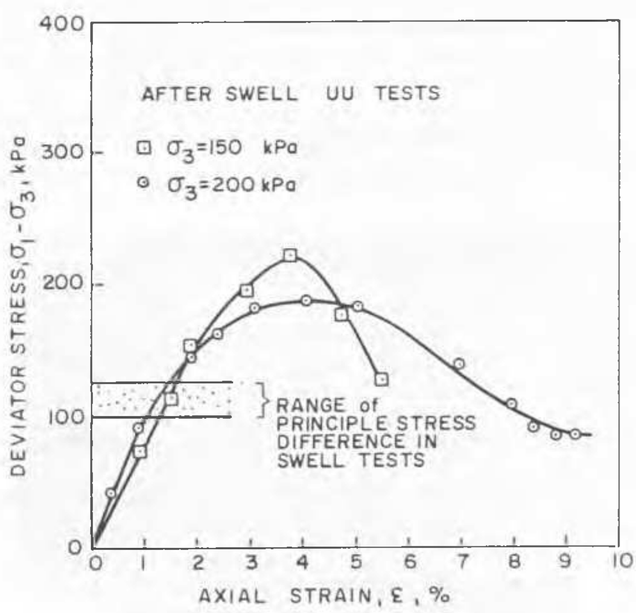

Fig.6 Undrained shear strength of SO test samples

These results indicate that the specimens tend to yield under increasing lateral stress, under the shear stresses lower than the undrained shear strength. This implies that a creep mechanism is in action during gradual wetting and softening of the swelling soils, and the creep rates and the deformations are higher in magnitude under low surcharge pressures.

It is also noted that, while unloading the specimens in CVS tests the equilibrium lateral stresses attain intermediate values between the peak and the ultimate lateral swell pressures measured at SO tests, as shown in Fig.5.

The vertical swell measured in the SO tests are compared with the swell observed in unloading phase of the CVS tests in Fig.7. It is found that at relatively higher surcharge pressures (i.e. more than 150 kPa), the magnitude of swell is comparable in both tests. However, at smaller magnitudes of the surcharge pressure higher swell deformations occur in the SO tests. This behavior is also related to yielding of the specimens under the higher lateral stresses.

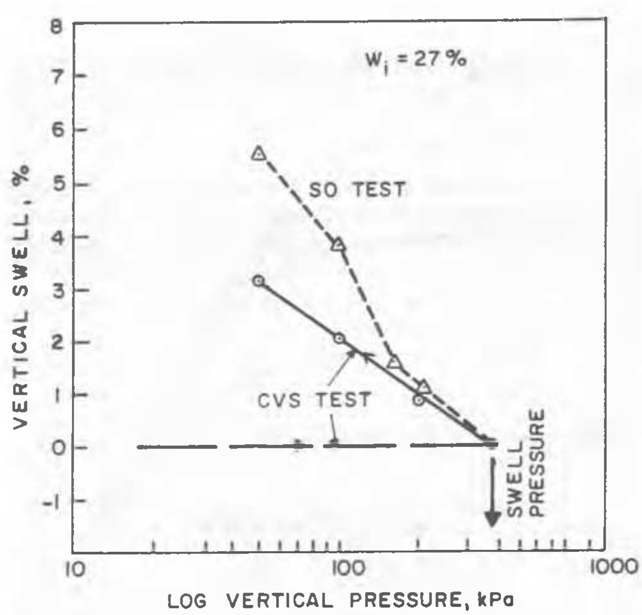

Fig.7 Comparison of swell in CVS and SO tests

5. CONCLUSIONS

The following conclusions can be reached from the experimental results:

i. The magnitude of lateral swell pressures developed in CVS tests are equal or in excess of the vertical swell pressures, and the swell pressure ratios vary over a range from 1.0 to 1.55 in the moisture content range investigated.
ii. Both lateral and vertical swell pressures decrease with increasing initial water contents and reveal larger swell pressure ratios at higher water contents.
iii. The magnitude of lateral swell pressures depends on the surcharge pressure acting on the soil during SO tests. For the particular clay at relatively low surcharge pressures (i.e. 100 kPa or less) the lateral pressures are reduced drastically after attaining a peak value. The difference between the peak and ultimate lateral pressures is not significant under higher surcharge pressures.
iv. In practical applications both the peak and the ultimate values of lateral swell pressures must be considered depending on the overburden stress level.

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