Effect of apparatus deformability on swelling pressure

L'effet de la déformabilité sur les pressions de gonflement

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SYNOPSIS: Numerous methods have been proposed and described in the literature for the measurement of swelling pressure. It was noticed that these methods produce either too high or too low predictions compared to what realy occur in the field. Therefore no laboratory technique is yet established. This could be due to the interrelated factors affecting the measurement of swelling pressure. In this paper, the effect of deformability of apparatus is investigated. It is indicated that, in the one dimensional oedometer test, the measured axial displacement is affected by apparatus deformability. This effect which should be added to the measured swelling pressure varies with the method adopted and sample diameter.

1 INTRODUCTION

While dealing with the problem of expansive soil, the major concern of the design engineer is to predict as accurately as possible the stress-volume change behaviour of this soil when subjected to change in stress and environment. As a result, numerous methods have been proposed and described in the literature for the measurement of swelling pressure. It has been realized that some methods consistently produce predictions which are far too high or too low of what realy occur in the field. Therefore, no laboratory technique is yet established. The complexity of the subject is due to the interrelated factors affecting the measurement of swelling pressures. Among these factors are the different stress paths that are used in the various methods, the boundary or environmental conditions under consideration and the deformations of the several parts of the apparatus system.

The purpose of this paper is to investigate some of the factors affecting the measurement of swelling pressure while the effect of other factors is isolated. Therefore the effect of deformability of the apparatus on the measurement of swelling pressure is studied. In this study the relationship between the deformability and the sample dimensions is considered rather than the relationship between the swelling pressure and sample dimensions which is the purpose of other study.

The methods presented in the literature for the measurement of swelling pressure are numerous, some of them have been used quite extensively, while others have been used very little since the time they have been proposed. A review of current practice indicates that the conventional one-dimensional oedometer test is the most widely used. Therefore, in the present research work, emphasis is given to methods based on that test. In the conventional one dimensional oedometer test, the axial pressures are directly measured and the axial displacement are measured by a dial gauge or displacement transducer. With this technique the measured displacement includes not only the soil deformation but also the deformability of the several parts of the system. The major subject of the present investigation is to determine the value of these deformations to be deduced or added by calibration rather than eliminating their effect.

2 MEASUREMENT OF SWELLING PRESSURE

Using the oedometer, three methods were considered in the present work for measuring the swelling pressure; they may be summarized as follows:

2.1 Different pressures method (denoted method 1)

In this method, three or more identical samples are loaded by different loads and allowed to swell until the swelling ceases. The final percentage swelling is drawn versus the vertical applied pressure. Then the pressure corresponding to zero swelling percent is the swelling pressure (El-Ramly, 1965; El Ramly and El-Demery, 1973; Rabba, 1975; El Sohby and Mazen, 1980).

2.2 Preswelled sample method (denoted method 2)

In this method, sample is first allowed to completely swell under a light load, then it is consolidated by the increase of loads until the sample reaches its initial volume. The pressure required for this is the swelling pressure (Youssef et al, 1957; Zacharias and Ranganathan, 1972; El-Sohby and Mazen, 1980; Tisot and Aboushok, 1983).

2.3 Constant volume method (denoted method 3)

The swelling pressure in this method is determined by increasing the load gradually on the sample when it swells in order to maintain its deformations. At a certain stage the sample has not further tendency to swell under the applied pressure. This pressure is denoted as the swelling pressure (Holtz and Gibbs, 1956; Thomson and Ali, 1969; Brackly, 1973; David et al, 1973; Tarek, 1980; Tisot and Aboushok, 1983).

3. MATERIAL USED

The soil samples used in the present work were taken from an arid newly developed satellite city in the suburb of Cairo known as Madinet Nasr. Samples were taken from an open pit at a depth of 2.0 m from ground surface. The soil is light grey indurated silty clay (claystone) with laminated bedded fabric of smooth texture. Determined engineering and mineralogical properties were as in the following table :

Table 1. Engineering and minerological properties of tested soil

Engineering properties :	
Liquid Limit	78%
Plastic Limit	31%
Plasticity Index	47%
Natural water content	14.23%
Dry unit weight	1.80 gm/cm^2
Clay percent	51%
Silt percent	43%
Sand percent	6%
Mineralogical compositions:	
Clay mineral: calcium mont-verm. 42% + Kaolinite 17%	
Non clay mineral: 24% silicate minerals + 17% salt and metal minerals	

4. APPARATUS AND TESTING TECHNIQUE

The convential consolidation apparatus was utilized by using swelling cells in the oedometer which contains brass moulds of different diameters and heights.

Remoulded prepared samples were used. The soil was firstly oven-dried at constant temperature 105-110°C for 24 hours then pulverized and passed sieve No. 40 (425 µm). The required weight of the oven dried soil was calculated to get the required initial dry density and calculated amount of water was added and mixed carefully to get the required initial water content. Then the mixed soil was kept in airtight container for 24 hours to allow for uniform distribution of moisture. The swelling mould was lubricated by high vacuum grease and the sample was carefully poured into the swelling mould at three layers and then statically compacted to the required height. The filter papers and the porous plates were put above and below the specimen ends inside the mould. The swelling mould has been lubricated by high vacuum grease before putting the soil sample to eliminate the effect of side friction. This was found very efficient by Rabba, 1975; Tarek, 1980.

In order to measure the oedometer deformation, steel disc was used instead of the soil sample and the loads were applied in a similar technique used for sample loading. The steel disc was used as the elastic deformations of its material is negligible in the range of the applied loads. Therefore the registered strains could be considered the elastic deformations of the parts of the oedometer system.

5. APPARATUS DEFORMABILITY MEASUREMENT

In order to study the effect of oedometer deformability on the measured swelling pressure, four steel discs of diameter 6.30, 8.88, 12.68, and 17.74 cm were used. These diameters were the same as those of soil samples used in the present work. Figure (1) shows the deformability of the apparatus at different applied pressures and for different steel disc diameters. From this figure it is noticed that the oedometer deformability increases with the increase of steel disc diameter.

To investigate the effect of the porous plates and the filter papers on the magnitude of the total deformation values, the deformability of oedometer was measured without using them and by the same previous technique. It was found that the deformations of the porous plates and filter papers represent 14.40%, 25%, 32.90%, and 37.70% of the predetermined deformations when using steel discs of diameter 6.30, 8.88, 12.68 and 17.74 cm respectively and these values were measured at the maximum applied pressure for each diameter. However, the deformability of the apparatus will be considered, in this work, as the value of the total deformation of the measuring system.

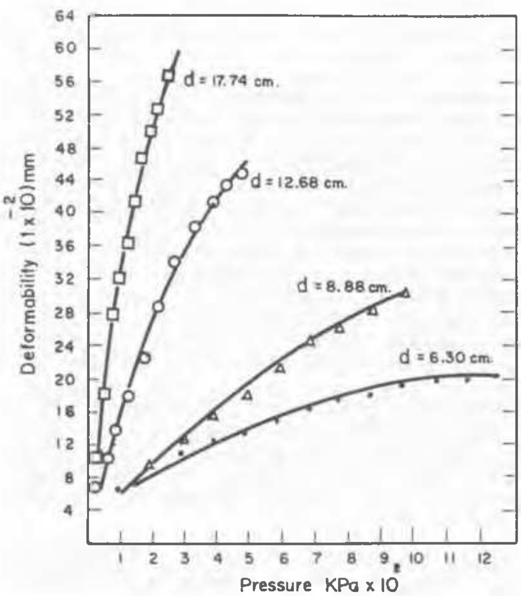

Figure 1. Deformability of the apparatus for different steel disc diameters.

6. APPARATUS DEFORMABILITY AND CALIBRATION

The effect of oedometer deformability on the swelling pressure is in excees of its measured value as indicated in figures (2a) and (2b). This could be explained as follows:

At the consolidation stage, (in case of preswelled sample method) the sample is exposed to high increments of pressure. The dial reading represents the measured height decrease between two successive points and its value includes a reading of deformability of the apparatus itself. Therefore, the actual compression of the sample is the difference between the dial reading and the deformability of the apparatus corresponding to each load increment as shown in fig. (2a).

At the swelling stage, (in case of different pressures method) two opposite deformations occur simaltaneously, the swelling of the sample and the deformability of the apparatus. Assuming that the dial reading registered a swelling of the sample under the applied load as shown in fig. (2b). This reading is the difference between actual sample swelling and the deformability of the apparatus. Therefore, the actual swelling of the sample is the summation of apparatus compression value plus the dial reading.

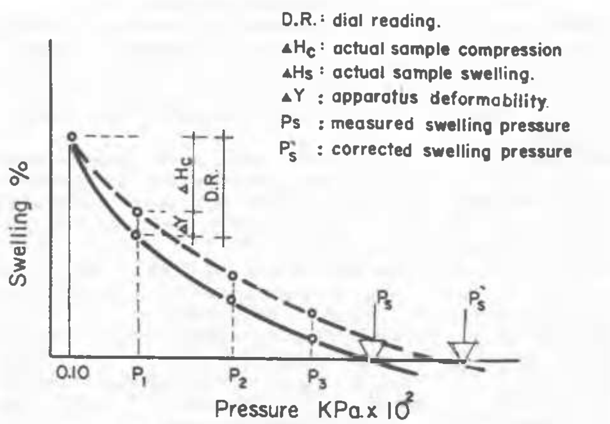

Figure 2a. Effect of oedometer deformability on the measured swelling pressure using "preswelled sample method"

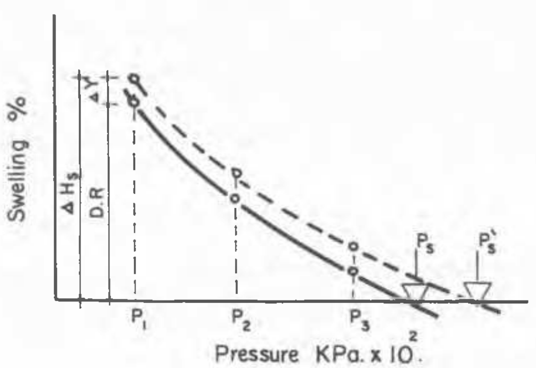

Figure 2b. Effect of oedometer deformability on the measured swelling pressure using "different pressures method".

In case of constant volume method, the soil sample is only allowed to have very small deformations at each stage of loading which is canceled simultaneously by the load increment. Therefore the effect of apparatus deformability is not allowed to develop significantly.

7. APPARATUS DEFORMABILITY AND METHODS

Using standard specimens of diameter 6.30 cm and height 3.00 cm, the swelling pressure was measured using methods 1, 2, and 3 then the measured values were corrected for method 1 and 2 due to the effect of apparatus deformability as shown in figure (3). It was found that the measured swelling pressure represents 91.97% and 94.35% of the corrected one using method (1) and (2) respectively. As indicated before the effect of apparatus deformability on method 3 is negligable i.e. no correction is made.

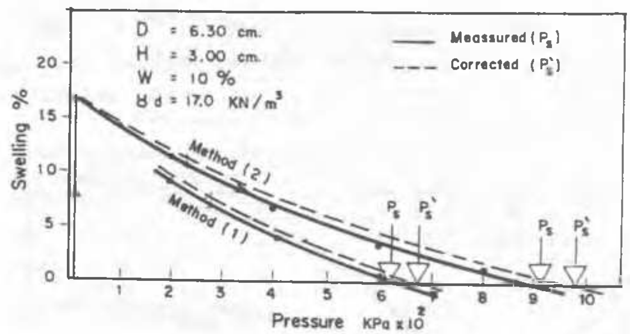

Figure 3. Measured and corrected swelling pressure using standard specimens.

8. APPARATUS DEFORMABILITY AND SAMPLE DIAMETER

Swelling pressure was measured for different sample diameter using the three mentioned methods. Then the results were corrected due to the oedometer deformability (in method 1 and 2) as shown in figure (4) which shows that:

1. Method (3) gives the least values of swelling pressure and no apparatus formability is added.
2. Small diameter is less affected by the apparatus deformability than large diameter This could be due to bedding error and plate rigidity
3. The measured swelling pressure represents about 88.50% as average value of the corrected one.
4. The swelling pressure decreases as sample diameter increases using method (1) and (2). However this effect decreases in the corrected value when compared with the measured value.

9. APPARATUS DEFORMABILITY AND SAMPLE HEIGHT

Swelling pressure was measured for different sample heights using the three mentioned method. Then the results were corrected due to the oedometer deformability (in method 1,2) as shown in figure (5) which shows that the effect of oedometer deformability on sample height is less significant, and the swelling pressure (measured and corrected) increases as the height increases.

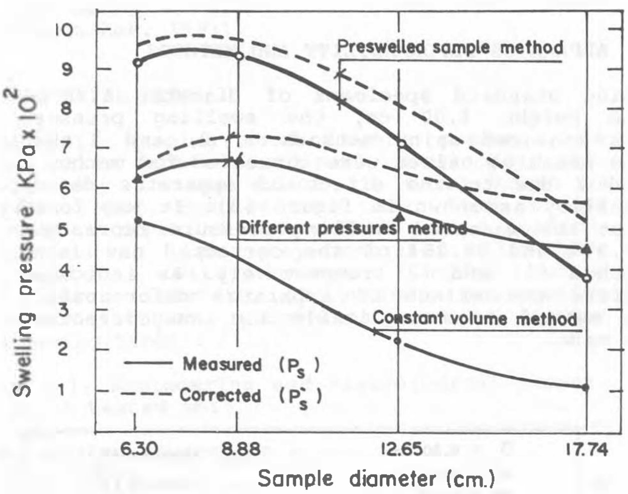

Figure 4. Measured and corrected swelling pressure for different sample diameter

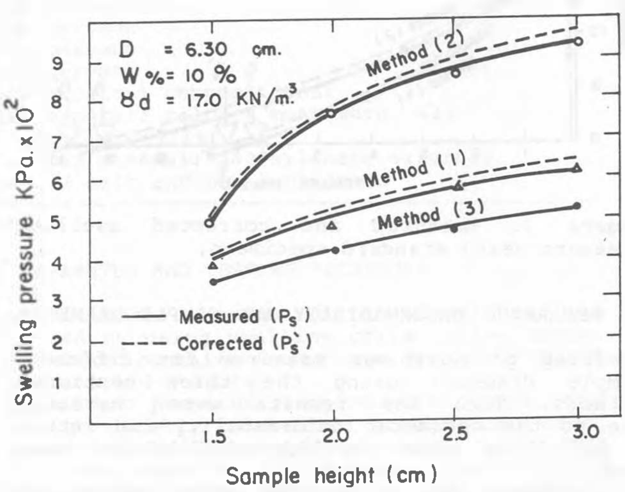

Figure 5. Measured and corrected swelling pressure for different sample height.

10. CONCLUSIONS

1. In the convential one dimensional oedometer test, the measured axial displacement is affected by apparatus deformability and this effect should be added to the measured swelling pressure.
2. The portion of apparatus deformability taken by filter paper and porous plate in the system was found to be 14.40%, 25.0%, 32.90%, and 37.70% for diameter 6.30, 8.88, 12.68 and 17.74 cm respectively.
3. Apparatus deformability varies with the method adopted, however its effect could be neglected in case of constant volume method.
4. Apparatus deformability is affected with sample diameter. it increases as the diameter increases, while the study indicated that the effect of apparatus deformability on sample height is not significant.

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