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An Alternate Method of Saturating Sand Specimens in Triaxial Tests

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***Abstract*—Pore pressure and volume change measurements in undrained and drained triaxial tests are performed after ensuring saturation of the specimen, through the B parameter checking. For sand specimens, with high permeability, an alternate method is suggested in this paper, which involves incorporation of certain modified triaxial testing attachments to ensure complete saturation of the specimen. Theoretical validation of the experimental results are checked with standard geotechnical theories. It has been found that saturation of sand samples using the attachments described, is reliable and simpler,**

***Keywords*—degree of saturation,pore pressure parameters, B parameter checking, triaxial test.**

I. INTRODUCTION

A triaxial shear test is a common method to measure the mechanical properties of soils. In a number of problems involving the undrained strength of soils , such as earth dams, the change in pore pressure Δu occurring under changes in total stress must be known. To simulate these conditions in laboratory, triaxial tests are performed on saturated soil specimens to measure the pore pressure response and volume changes undergone by the specimen. Complete saturation is extremely difficult to ensure if the sample is placed in the dry condition first and subsequently flooded. Conventional methods employed to facilitate saturation include the use of a more soluble gas such as ammonia to displace the air before passing water through the sample [1].However, control of effective stress during this operation is difficult and there are chances of a modified φ' value being obtained. A simplified method for sample preparation has also been suggested which involves deposition of sand specimens through a funnel into the rubber membrane, filled with de-aired water and tightly housed inside the split sand former [2] However, this method had some inherent drawbacks especially in case of fine and medium sands, in which the deposition lead to segregation of particles. The heavier particles settled at the bottom whereas the lighter ones, floated at the top. Conventional methods of preparing saturated samples involve moist tamping, air pluviation and water pluviation techniques. Some studies on samples prepared using moist tamping suggest that they are not homogeneous and are less suitable for triaxial testing (Vaid et al., 1999, Frost and Park, 2003, DeGregorio, 1990, Vaid and Sivathayalan, 2000). Ladd (1974) proposed the method of undercompaction in which each layer is undercompacted to its successive layer. Air pluviation is yet another technique, that is shown to produce reconstituted sand specimens with the least degradation in soil structure. (Cresswell et al., 1999). Air pluviated samples strain softens to a lesser extent when compared to moist tamped specimens (DeGregorio, 1990, Vaid and Sivathayalan, 2000). Amini and Chakravrty (2004) prepared homogeneous sand samples using dry pluviation technique. However, when the soil contained silt in excess of 20 %, air pluviation resulted in soil segregation because, the fines lagged behind on account of their lower velocities within the fixed height. In wet pluviation, preferred fabric can develop which behaves similar to that of natural alluvial deposits (Ghionna and Porcino, 2006, Oda et al., 1978). Vaid et al. (1999) showed that these samples are uniform with depth and have small deviation in the relative

density. In this paper, a new method for saturating sand samples has been outlined, which overcomes the practical difficulties associated with specimen preparation and ensuring full saturation. The B parameter method of ensuring full saturation has been briefly described, followed by the new method. Theoretical and experimental saturated weights have been compared and a strong correlation has been obtained among the two.

II. DEGREE OF SATURATION

In soil mechanics, degree of saturation is defined as the ratio of volume of water to the volume of voids.

$$S = \frac{V_w}{V_v}$$

For a perfectly dry soil mass, S=0 and for a fully saturated soil specimen, S=1.

Triaxial tests on saturated sand specimens are essential in simulating the worst field conditions that a soil specimen might be subjected to, in the field. The main objective of the saturation phase of triaxial testing is to fill all voids in the specimen with water without undesirable pre stressing of the specimen or allowing the specimen to swell. Conventionally, saturation is accomplished by applying back pressure to the specimen pore water to drive air into solution after saturating the system. This can be achieved in two ways:

a. Applying vacuum to the specimen and dry drainage system (lines, porous disks, pore-pressure device, filter-strips or cage, and disks) and then allowing de-aired water to flow through the system and specimen while maintaining the vacuum;

b. Saturating the drainage system by boiling the porous disks in water and allowing water to flow through the system prior to mounting the specimen. It should be noted that placing the air into solution is a function of both time and pressure. Accordingly, removing as much air as possible prior to applying back pressure will decrease the amount of air that will have to be placed into solution and will also decrease the back pressure required for saturation. In addition, air remaining in the specimen and drainage system just prior to applying back pressure will go into solution much more readily if de-aired water is used for saturation. The use of de-aired water will also decrease the time and back pressure required for saturation.

III. Back Pressure Application

The application of back pressure to saturate the specimen involves simultaneously increasing the confining and back pressure in increments, keeping the specimen drainage valves opened so that de-aired water from the burette connected to the top and bottom of the specimen may flow into the specimen. To avoid undesirable pre stressing of the specimen while applying back pressure, the pressures must be applied incrementally with adequate time between increments to permit equalization of pore-water pressure throughout the specimen. The size of each increment may range from 35 kPa up to 140 kPa, depending on the magnitude of the desired effective consolidation stress, and the percent saturation of the specimen just prior to the addition of the increment. The difference between the cell pressure and the back pressure during the process should not exceed 35 kPa unless it is deemed necessary to control swelling of the specimen during the procedure. The difference between the chamber and back pressure must also remain within 65 % when the pressures are raised and within 62 % when the pressures are constant. To check for equalization after application of a back pressure increment or after the full value of back pressure has been applied, the specimen drainage valves are closed and change in pore-pressure over a 1 min interval is measured

IV. Ensuring Full Saturation by B Parameter Checking

If the change in pore pressure is less than 5 % of the difference between the cell pressure and the back pressure, another back pressure increment may be added or a measurement may be taken of the pore pressure parameter B to determine if saturation is completed.

Specimens shall be considered to be saturated if the value of B is equal to or greater than 0.95, or if B remains unchanged with addition of back pressure increments. The pore pressure Parameter B is defined by the following equation:

$$B = \frac{\Delta u}{\Delta \sigma_3}$$

where, Δu is the change in the specimen pore pressure that occurs as a result of a change in the chamber pressure when the specimen drainage valves are closed, and

Δσ3 is the change in the chamber pressure.

The method as discussed above is quite useful for soils of medium to low permeability such as silty sands and clays. For sands, however due to its large pore spaces, the permeability is of the order of 10^{-4} to 10^{-2} cm/s. Hence, sand specimens take up lesser time for full saturation compared to clay specimens.

V. Theoretical Saturated Weight of Soil

The water content required for 100% saturation of a given mass of dry sand with a particular void ratio and specific gravity can be calculated as:

$$w = \frac{eS}{G}$$

where, w is the water content

e= void ratio of the sample

S=degree of saturation (=0 for perfectly dry sand and 1 for fully saturated sample)

G=specific gravity of soil solids.

Hence, theoretical weight of saturated sample= $w_1\left(1+\frac{w}{100}\right)$

where, w_1 represents dry weight of sample.

VI. Experimental Validation

Sand samples were prepared on the triaxial cell pedestal by mixing with 5% water and placing in 10 layers using the under compaction technique. Once the samples were prepared, they were immersed in water for 24 hours, after which the weights were compared with the theoretical saturated weights. The experimental procedure is outlined in the following section. The split sand former, used in triaxial test, is utilized to confine the sand samples enclosed in a rubber membrane. The sample, along with the porous disc, is enclosed in the rubber membrane and fastened on to the brass pedestal using O-rings. The brass pedestal serves as the base where the sample is placed in the triaxial cell. Once the sample is filled in the dry state in different layers and compacted to achieve the relative density, the top surface is levelled and a saturated porous disc is placed on its top. The dry weight of the sample along with its attachments are noted. The sample, enclosed inside the split sand former is now lowered into a tank. A dial gauge is fixed beside the container, with its needle set to just touch the top of porous disc. The container is now filled with water, the water level being allowed to stay slightly above the top porous disc. Dial gauge readings are noted every hour to check for swelling or shrinkage and the corresponding reduction in sample volume is noted. After 24 hours, the sample is taken out from the tank and weighed. The result is cross checked with theoretical values and full saturation is ensured. The different stages involved in the procedure are shown in Fig. 1 and 2.

Fig.1.Preparation of samples enclosed in rubber membrane, confined by the split sand former.

VII. Results and Discussions

Sand was oven dried, sieved and separated into coarse, medium and fine fractions .Sand fractions were filled in the split sand former at three different relative densities viz. 30%, 45% and 65%. Table 2 gives the comparison between the experimental and theoretical saturated weights of the sand fractions. A vernier caliper was used to check for changes in the sample dimensions, if any. It was found that the variations in dimensions of the sand samples under study, was within a maximum of 5 percent. The results obtained from laboratory tests are plotted against the theoretical values, in Fig.3. It is evident that the plotted points lie close to the 45^0 line, implying that the theoretical and experimental value lie very close to one another. The coefficient of correlation has been obtained as 0.99, implying perfect compliance between the two values. From the results, it is clear that an soaking sand specimens in water is a viable alternative to the B parameter method of ensuring full saturation in sand samples. However, certain modifications are to be performed in the triaxial cell, for ensuring minimum disturbance to samples. The complexities related with the B parameter check can thus be avoided.

TABLE I. Comparison of Theoretical and Actual Saturated Weights of Sand Specimens at Variying Relative Densities

SAND FRACTION	Dr	W_{th} (g)	W_{act} (g)
Medium	30	359.82	357.88
Medium	45	364.07	363.25
Medium	65	369.88	367.56
Fine	30	364.65	362.89
Fine	45	368.57	367.11
Fine	65	373.11	371.94
Coarse	30	345.87	343.02
Coarse	45	348.29	347.14
Coarse	65	405.91	404.57

Fig.2.Immersing the samples under water and attaching the dial gauges to the center of the porous discs

VIII. Modifications to the Conventional Triaxial Cell Setup

The conventional triaxial cell is slightly modified so as to use it for sample saturation. The clamping pipes are removed from their position. The ring is permanently clamped on to the base using threaded mild steel bars of 8mm diameter. The top cap is separated from the perspex cylinder, and the cylinder removed, for preparing the sample, as shown in Fig.4 and 5.

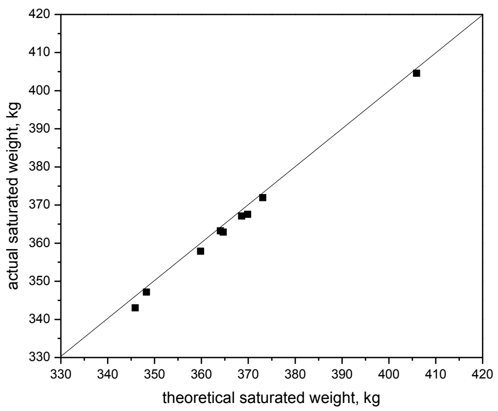

Fig.3. Plot of actual vs saturated weights of sand fractions, at varying relative densities.

The sample, enclosed in the rubber membrane is assembled on the brass pedestal and fastened with O-rings. At the top, the rubber membrane is left open and a porous disc, after saturation, is placed on top of the sample. The perspex cylinder is now placed around the sample and the cell is filled with water, enabling saturation. The sample is kept immersed for 24 hours in water. To enable easy removal of the split mould thereafter, a small hinge attachment along with two protruding levers is fabricated on the split mould. These levers help in fastening or loosening the split mould from the top itself, without physically holding the mould. This ensures minimum disturbance to the sample after saturation.

Fig.4. Removing clamping pipes from the triaxial cell and replacing with threaded MS rods

Fig.5.Permanently fixing the cell ring to the base using threaded MS rods and nuts.

IX. CONCLUSIONS

Triaxial tests involving pore pressure measurements, often require the preparation of fully saturated soil specimen. Preparation of saturated sand samples by conventional method involves methods such as moist tamping, air pluviation and water pluviation techniques. However, these conventional methods often require complex connection mechanism and are often troublesome. To overcome these difficulties, a new concept of sample preparation and saturation is described in this paper. The triaxial cell is modified suitably so as to double up as a saturation cell. The water content during mixing is maintained at about 5% and the sample is prepared by under compaction. Saturation is ensured by validating experimental saturated weights with the theoretical saturated weights. A high R^2 value suggests that the results are in perfect agreement with each other. The sample dimensions were also checked and was found to vary within 5% margin. Thus, the method can be adopted successfully for saturating sand samples in the triaxial cell itself.

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