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Calibrations for volume change measurements using osmotic suction control technique

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Abstract Evaluation of the volume change behavior of expansive soils under controlled suction and boundary conditions is important for the proper design of different geotechnical systems. Osmotic technique was used by several researchers for suction controlled testing of expansive soil specimens. This technique involves circulating polyethylene glycol solution (PEG) over a semi-permeable membrane underlying a test specimen. Different suction controlled testing apparatuses incorporating osmotic techniques were developed included triaxial and oedometric testing conditions to simulate different boundary conditions. This paper describes a series of calibration performed on suction controlled modified oedometer and triaxial equipment used for testing expansive soil. The modified oedometer, developed by the authors, comprises of thin-wall oedometer ring instrumented with strain gauges to measure the lateral stresses evolving during the test. The first part of this paper introduces the errors that arise during osmotic suction testing, concerning the device flexibility and PEG solution losses. The second part of the paper highlights the calibration procedure for estimating lateral stresses in modified oedometer from instrumented strain gauges as well as introduces a correction for the temperature fluctuation. Finally, the effect of triaxial cell flexibility on the volume change measured during osmotic suction controlled testing as well as temperature effect on volume change measurements were evaluated and correction procedures were introduced.

Introduction

Suction control using osmotic technique is a common method used for studying the effect of suction on the behavior of unsaturated soils. Osmotic suction testing is typically used to apply suction in the range of (0–10) MPa [1,2]. Kassiff and Ben Shalom [3] was the forerunner to apply the osmotic technique for controlling suction in geotechnical engineering.

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Various research groups over the world used, improved and adopted such technique to impose suction in oedometer, triaxial and direct shear testing [4,5,1,6–8]. The osmotic suction technique was imposed on the top and bottom of test specimen by connecting the semi-permeable membrane to the top cap and the base of the device membrane behind which an aqueous solution of large sized polyethylene glycol (PEG) molecules is circulated. Several researchers have used osmotic suction control testing for the evaluation of swelling characteristics of expansive soils [7,2,9,10]. The authors are currently undergoing research to investigate the effect of suction on the swelling behavior, of a locally available expansive soil, in vertical and lateral directions. Motivation for this research stemmed from cases reported in the technical literature where lateral swelling is the main contributor to observed damages [11,12]. These tests are performed using suction controlled triaxial testing and thin-walled oedometer devices.

Polyethylene glycol solution (PEG) calibration is a mandatory task for osmotic control testing. This calibration provides a relationship between the PEG solution concentrations and imposed suction. Techniques and procedures for PEG calibration have been extensively discussed in the technical literature [13,1,14], and is out of the scope of this paper. Depending on the device used (whether oedometer or triaxial), other calibrations may be needed to assess measurement errors. These errors need to be quantified and accounted for in experimental data to obtain accurate representation of soil behavior. In particular, this paper investigates the errors that may rise during expansive soil testing using osmotic suction controlled technique including axial deformation due to device flexibility and PEG solution losses due to evaporation and circulation. Furthermore, device specific calibrations needed for the proper interpretation of the volumetric behavior of expansive soils are presented.

Components of osmotic suction technique and devices used

The osmotic suction technique considered in this research, Fig. 1, comprised of polyethylene glycol solution (PEG) – with a molecular weight of 6000 (PEG 6000) – filled in a one liter conical flask, a semi-permeable membrane, flexible tubing, peristaltic pump for PEG circulation and an electronic balance for monitoring the change in weight of the PEG solution. The semipermeable membrane used was Spectra/Por® 3 regenerated cellulose dialysis membrane with a molecular weight cut off (MWCO) value of 3500 Daltons that is compatible with the molecular weight of PEG used (MW = 6000).

PEG solution is circulated in a closed loop with all connections well sealed to prevent probable leaks. Moreover, the surface of the PEG is sealed by a thick layer (10 mm) of light silicon oil to prevent potential evaporation of the PEG. The position of PEG surface was maintained in the flask neck to reduce the solution surface area exposed to evaporation. The flask neck was plugged with a stopper with three holes. Two glass tubes with inside diameter of 1.50 and 3.00 mm were fitted in two of these holes. The 1.50 mm tube is used to allow the flow of PEG from the peristaltic pump to the flask, while the 3.00 mm tube is used to transfer the flow from the flask to the tested specimen. The third hole was used to maintain atmospheric pressure on the top surface of the PEG solution.

The peristaltic pump was installed and rotated in a manner that permit PEG solution to be pulled, rather than pushed, under the membranes in the testing device, see Fig. 1. The solution was sucked from the centric hole of the lower part of testing device and enters to testing device from the outer hole of its upper part, Fig. 1. PEG returns back to the flask by pumping through the 1.5 mm glass tube. Pulling the solution from the device lower part, which is connected to the upper part, leads to circulate PEG solution on both sides of tested sample by sucking the solution from the outlet glass tube (3.0 mm). The lower level of the outlet tube (3.0 mm) was positioned to be lower than that of the inlet tube (1.5 mm) by 30.0 mm to keep sucking fresh solution and avoid sucking any air bubbles. It is aforementioned that PEG circulation by sucking reduces the possibility of air bubble formation and cancels the possibility of PEG leakage along the membrane edges.

During suction application, PEG solution is circulated behind the semipermeable membrane in contact with a specimen causing water to be extracted or added to the sample to

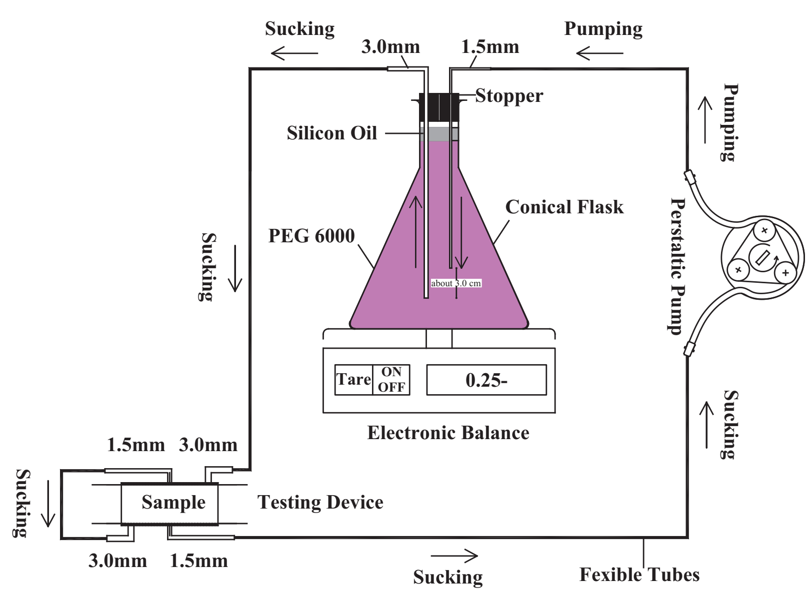

Fig. 1 Schematic layout of osmotic suction system.

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