Mechanism and Techniques of Measuring of Suction

[1]Adje Kpie Janvier De Thales , [2]Prof. Anoosheh Iravanian

[1]Master Student, Department of Civil Engineering, Near East University, Yakın Doğu Üniversitesi / Yakın Doğu Bulvarı Lefkoşa, KKTC, Cyprus

[2]Professor. Dr, Department of Civil Engineering, Near East University, Yakın Doğu Üniversitesi /Yakın Doğu Bulvarı Lefkoşa, KKTC, Cyprus

Abstract: Dealing with unsaturated soil is one of the difficulties encountered by Civil Engineer. A State in which voids between particles are occupied with air and water at the same time. Water content in the voids reduces the shear strength of a soil that leads to suction called negative pore pressure. This clearly indicates that the soil-moisture contain governs the shear strength of the unsaturated soil. In fact, there is an evidence of how the phenomenon of water pressure is important in determining soil's behavior; therefore, there is a necessity of accurate methods to measure and interpret soil suction that is crucial to understand unsaturated soils behavior. This paper briefly reviews the concepts of soil suction, explain its components: the matric and the osmotic suction and present methods of measuring soil suction.

KEYWORDS: Unsaturated Soil, void spaces, particle, shear strength, negative pressure, suction, soil-moisture.

DOI of the Article: https://doi.org/10.46501/IJMTST0707017

Available online at: http://www.ijmtst.com/vol7issue07.html

As per UGC guidelines an electronic bar code is provided to seure your paper

To Cite this Article: Adje Kpie Janvier De Thales and Prof. Anoosheh Iravanian. Mechanism and Techniques of Measuring of Suction. *International Journal for Modern Trends in Sceicen and Technology* 2021, *7*, 0707053, pp. 99-104. https://doi.org/10.46501/IJMTST0707017

Article Info. Received: 9 June 2021; Accepted: 11 July 2021; Published: 16 July 2021

1.INTRODUCTION

Unsaturated soil is the most encounter in practice where soil contains at the same time water and air. In this case, soil properties differs and is characterized by the SWCC. In fact, the important state for establishing swcc, which is a fundamental constitutive relationship for soil, for partly saturated, is matric suction or total suction depending on the techniques used. As stored water or suction helps in decision-making in civil Engineering field, therefore it is important to know the techniques, which helps in determining the suction. This paper present a brief reviews on suction mechanism firstly and secondly some of the techniques used for estimating or controlling suction of the soil and their limitations either in laboratory or on the field.

2. LITERATURE REVIEW

1. Mechanism of suction

Soil suction occurs above the water table in unsaturated pores where the space between soil particles is occupied by some water through capillary action. Water is pull out from the water table and held within the pores with an energy. The surface tension of that water creates meniscus and force that binds the soil particles together and creates an apparent cohesion in the soil, which is beyond the attraction between solid particles. In fact, the mechanism of suction is based on adhesion and cohesion forces: adhesion force is a molecular attraction created when the molecule of water and soil meet each other. This force pulls the water up into meniscus whereas the cohesion force is the molecular attraction existing between water particles (like particles) causing surface tension in the water.

The polarity of water molecules allows it to create this surface tension and pulls the water up but in pulling up the water, water itself has to be in tension. Due to the surface tension, water molecules pull each other up into the soil. These two molecular forces raise water up against the gravity and hold it in the soil voids and the fluid pressure is less than the atmospheric. This is due to the negative pore water pressure that exists within these droplets of water. The ability for soil to generate soil suction or generate negative pore water pressure is a function directly proportional to the particle sizes within the soil.

Soil suction can be expressed in in terms of SWCC or WRC that is a function of moisture content and suction.

2.2.1 Matric suction

This is due to the capillary action generated due to the removal of moisture under pressure or under evaporated circumstances. The matric suction is linked to the air-water interface. In fact, this energy suck out water into the soil pores the energy. According to some researchers, the shear strength of the soil is increaseddue to the presence of matric suction in an unsaturated soil, provided there is sufficient contractile skin present in the soil. Matric suction is subject to environment changes and vary from time to time. In fact, it increases in dry season and decreases in wet season, the overall equilibrium of soil is affected by any change in suction.

2.2.2 Osmotic suction

This is due to salt or ionic concentration, hence osmotic suction prevails only in saline or Marin or chemically contaminated soil soils. Osmotic suction plays a role that is equally applicable to both saturated and unsaturated soils. Osmotic suction depends on the salt content and hence whenever the salt content in the soil sample is subjected to a change automatically the soil properties change as well.

Total suction = Osmotic suction + Matric suction

3. METHODS OF MEASUREMENT OF SUCTION OR CONTROLLING SUCTION

3.1 Tensiometer

This is commonly use method in unsaturated soil mechanics and soil science for measuring the suction value. It consists of a sensing probe, which is connected to the water-filled body tube. The body contains full water; there should not be any vapor or air component in it. The water body is connected to the sensing probe and a pressure gauge at the same time. A service cap is provided to fill the de-aired water and remain closed during the measurement. When the sensing probe and water are in contact, which is at negative pressure, the negative pressure is transmitted through this tube, to the water. Hence, thepressure gauge attached to it measures the pressure. The measured pore water

pressure in a tensiometer is approximately limited to negative 90 kpa.
The matric suction is equal tomeasured negative pore-water pressure when the pore air pressure is atmospheric.

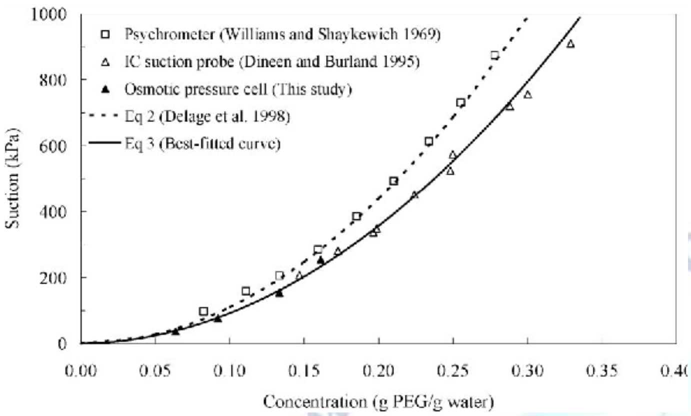

Figure 1: Curve from axis translation and suction

3-1-2 Limitations

The limitation of this method is the air entry disk, because if the soil contains negative pore water pressure of more than 100 kpa or less 500 kpa but the air value of the high entry disk is only 100 kpa , water enters through the high entry disk pores and goes into the body. Then, there is a negative pressure within the soil mass, which is in contact with the high air entry disk. The negative pressure may be as high as 1000 kpa. Therefore, in this particular case, if the high-air-entry disk capacity is 100 kpa, then the air enters into the high air entry. The sustainable air water interface or sustainable pressure at the air water interface is only up to 100 kpa. As the high airentrydisk capacitydictates the maximum value that can be measured by the tensiometer hence, the entry of air into the system does not allow the pressure gauge to read the values.

3.2 Axis-translation technique

This technique takes inspiration from the tensiometer; the name itself indicates the principle behind the technique. A high air entry disk in a closed chamber with the top is linked to the air pressure valve and the bottom connected to the water valve. Air pressure is maintained at elevated values may be as high as high values can be maintained and water pressure is maintained at lowest values. The sample soil is placed over the saturated air entry disk, in such a way that soil in good contact it and water in the pore and water in the high air entry disk both are in good contact and form a good channel. When we start increasing the air pressure, water pressure is constant and pressure in air that is the positive value is increased, that indicates the matric suction. As the matric suction ($u_a - u_w$) increases, water start bleeding from the soil and come out from the bottom of the chamber. When matric suction increases the amount of water coming out is known. At equilibrium water stop coming out which means the sample soil reached equilibrium with the matric suction. Total stressis increased together with air pressure at the same amount so the net stress σ-$u_a$remains unchanged. Stresses in unsaturated soil in the field are total stress, both pore air and water pressures. When applying the axis translation technique, total stress, both pore air and water pressures increased (generally positive gauge pressure).Thematric suction ($u_a - u_w$) andthe net stress (σ-u_a) remain unchanged. This process is referred as 'axis-translation'. Matric suction variable can be controlled based on the axis translation principle, over a range far greater than the cavitation limit for water under negative pressure.

3.2.1 Limitation

This method cannot be used on the field. As cavitation occurs, water phase becomes discontinuous and makes the measurements unreliable and sometimes impossible, because it is required to control the matric suction variable over a range far greater than 1atm for some soils and their applications. Alternatives to measurement or control of negative water pressure are desirable.

3.3 Osmotic technique

This is based on the osmosis. A soil sample is taken into a small column with a semi-permeable membrane at the top and porous stones placed after the membrane. The whole is connected to a reservoir. When some solute is maintained, for example, PEG (polyethylene glycol) solution is put in the column at the right hand side; the PEG molecule size is much larger than the filter size or the pore size of the semi-permeable membrane. PEG molecules is filtered to pass through. If initially the soil is saturated then, water will be taken out from the soil to dilute the PEG solution to maintain the chemical equilibrium. With time PEG, solution concentration starts decreasing and reaches a steady-state value. This concentration corresponding to one particular suction, a graph can be drawn with the PEG concentration versus suction and base on the graph the corresponding suction can be read. The soil sample is weighed to measure its water content then, we can establish water content versus suction. At equilibrium, suction in peg solution equal to the suction in the soil pore water. This help in establishing the suction in the soil mass. This method is used to control suction.

3.4 Filter paper

This is commonly used in laboratory. This cheap technique could be used for obtaining the SWCC. We have two different techniques such as contact filter technique, which is used to estimate the matric suction, and non-contact filter paper technique that estimates the total suction.

Filter papers used in laboratory have uniform pores, which vary depending on the types. If the SWCC of the filter paper is known then when this filter paper and soil are in contact, we obtain the moisture equilibrium with the soil. Then if we measure the water from the filter paper, the chemical potential of the filter paper and the soil will be same at the equilibrium at steady state. Suction in the soil is indicated by the measuring of the water contentof the filter paper.

3-4-1 Contact Filter paper

Several filter paper like whatman size 42 or Schleider and Schuell589 or white robbon or fisher, which is support by fisher scientific, fisher 9-790 A, are the most commonly used types. Using axis translation technique, the filter paper is placed and suction sill be maintained to obtain swcc. The filter paper is placed in a way that the soil and the filter are in contact with for 7 days. Three filters papers are inserted in the soil with two papers as sacrificing paper. The middle one is does not touch the soil and used for further measuring the water content. Initially the chemical potential of soil is high that the filter's, hence, there is equilibrium. Water inters in the filter paper until the both chemical potentials become equal. Several test may be perform in which one test is chosen. Carefully take out the filter paper and weighed up to 2-3 decimal points. As the swcc of filter paper is known therefore the suction can be obtained with the corresponding measured water contain using the calibration curve.

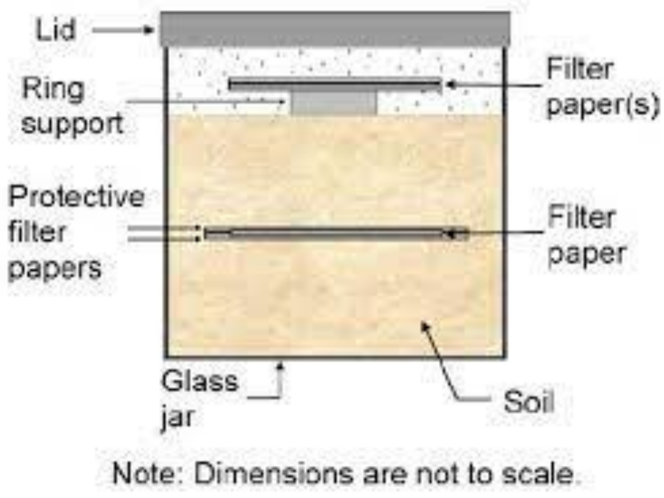

Figure 2: Contact Filter paper-

Limitation

Filter paper does not filter the solutes like salt, therefore only matric suction is obtain in this case.

3-4-2 Non-contact Filter paper

In this methodology, unsaturated soil is put in a closed chamber where the ambient vapor pressure is maintained. The oven-dried filter paper is kept above without any physical contact with the soil. The filter paper gets slowly wet due to hydration from the available vapor, hence, water content in filter paper increases. The filter Paper and the vapors of the soil pore water come in equilibrium. If we have salt, the vapor pressure decreases and is reflected in the filter paper as the same moisture content. The filter paper is taken out after some time and is weighed then we can obtain the suction that indicates the chemical potential of the ambiance. This technique estimate the total suction.

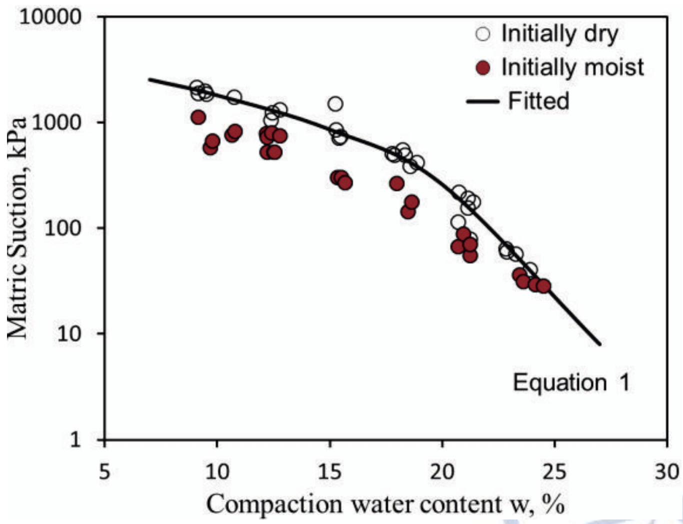

Figure3: Swcc with n0n-contact filter paper method

3.5 Dew-point potentiometer

This technique is a laboratory technique and used to measure the suction rather than controlling. This is also called WP4, which is developed by Decagon USA. It consists of a sample holder, where the soil sample is kept. Generally, there is a cup similar to shrinkage cup, but this is a smaller size where sample of soil can be fill to half or less of its height. The cup is placed in the drawer and close in a closed chamber. The principle of this method is to estimate the soil's relative humidity or soil's pore space and from that, we estimate the total suction. The equipment consist of thermoelectric cooler with a mirror on the top connected to a LED which send ray that can be detected by a photo detector. The point at which water condenses from the air in the chamber into the mirror is recorded by the photoconductor. This is the dew point and is the temperature at which the water vapor in the air is enough to saturate the air. Relative humidity is the ratio of the saturated vapor pressure of water at the dew point to the saturated vapor pressure of water above a flat surface at the air temperature. The device has a control for setting up the temperature of the soil sample to that at which the relative humidity is to be measured.

Figure 4: Dew-point potentiometer

3.5.1 Limitation

This technique is a laboratory technique only and helps in measuring the suction rather than controlling. In fact, estimation of the suction is done indirectly.

3-6 Hanging water column

This is also called as Negative column method in which a container containing the soil sample is placed on a porous stone connected to a flexible pipe with water in the column. At equilibrium means at a steady state, soil is completely saturated. Whenever the water level is increased, water flows from the soil. In the same way if the water level is reduced in the column or if the column is reduced, soil will try to retain water within the pores due to the capillary action. Depending on the air entry suction of the soil, the contact betweenwater and soil may remainand the U tube may be completely filled with water. Then pressure in the water is negative pressure because soil is completely saturated under negative head. When the negative head start increasing, the water content may decrease, hence, matric suction measurement is possible.

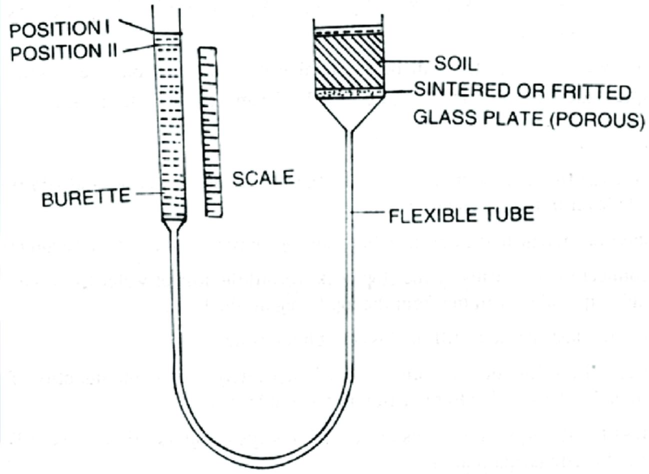

Figure 5: Hanging water column

4-CONCLUSION

This paper has gone through some of the techniques to measure and control suction and presented their limitations, explain how suction occurs. All this should be taken into consideration. In fact, it is recommended that care should be taken in the manipulation of the instruments in all the steps in measuring and controlling the suction for the good determination of the WSCC.

REFERENCES

1. Behzad Fatahi, Hadi Khabbaz, in Ground Improvement Case Histories, 2015
2. Stacey Vorwerk, Gunnar Keppel, in Ground Improvement Case Histories, 2015
3. Jahangir Abedi-Koupai, Jahangir Abedi-Koupai 1 and Hasan Mehdizadeh, Estimation of Osmotic Suction from Electrical Conductivity and Water Content Measurements in unsaturated Soils, Isfahan University of Technology
4. Yulian Firmana Arifin & Tom Schanz, Osmotic suction of highly plastic clays.
5. Eng-ChoonLeong, Hossam Abuel-Naga, Contribution of osmotic suction to shear strength of unsaturated high plasticity silty soil, pubished in Elsevier
6. Debora J. Miller, Ph.D., P.E; and John D. Nelson, Ph.D., P.E. Osmotic Suction in Unsaturated Soil Mechanics, published in ASCE library.
7. Chao Zhang, A.M.ASCE; and Ning Lu, F.ASCE, Unitary Definition of Matric Suction
8. Charles W.W. Ng and Bruce Menzies, Advanced Unsaturated soil mechanics and Engineering. First published 2007 by Taylor & Francis
9. Pierre Delage, Yu Jun Cui, An evaluation of the osmotic method of controlling suction Ecole Nationale des Ponts and Chaussées, Paris, France, CERMES (department of Geotechnical engineering) – Institut Navier.
10. E.J. Murrary and V, Sivakumar, unsaturated soils, a fundamental interpretation of soil behavior. A John Wiley & Sons, Ltd., Publication
11. Gerald A. Miller, Claudia E. Zapata, Sandra L. Houston and Delwyn G. Fredlund, Geotechnical special publication, 2006 volume one.
12. D. G. Toll, Unsaturated Soil Concepts and Their Application in Geotechnical Practice University of Durham, School of Engineering, Durham, UK.
13. D.G. Fredlund, Ph.D. and H.Rahardjo, Ph.D. Soil mechanics for unsaturated soils
14. Mohammed Y. Fattah, Asma Y. Yahya , Maysam Th. Al-Hadidi and Balqees A. Ahmed effect of salt content on total and matric suction of unsaturated soils.