Hysteresis of Filter Paper Method on Laterite Soil

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Abstract- Hysteresis is one of the nature for soil water characteristic curve that was ignored in the most routine during laboratory test. The soil hydraulic parameters were next estimated by using data from both the infiltration and redistribution phases for cases in which hysteresis was considered but restricted to the simplifying assumption. The paper reports on an evaluation of hysteresis suction of filter paper method. Matric suction was proven as a parameter in this study for soil mechanics for unsaturated soil. The hysteresis curve and relationship result are also discussed. The filter paper method duration was 20 days for drying and wetting path. Soil matric suction range from 768.45 kPa to 42,714.37 kPa and with higher moisture content from drying curve 32.43 percent and fro wetting curve starting moisture content 8.94 percent, filter paper method can be used to determine hysteresis for unsaturated soil, especially laterite soil.
Keywords – Filter Paper Method, Hysteresis, Drying, Wetting, Matric Suction

I. INTRODUCTION

Hysteresis in soil is characterised as the distinction in connection between water substance of the comparing water potential acquired under wetting and drying process. Shear strength is an essential material property that is required to address an assortment of building issues running from incline solidness to bearing limit. Shear strength of an unsaturated soil is emphatically identified with the measure of water in the voids of dirt, and in this manner to matric suction, it is proposed that the shear quality of an unsaturated soil ought to likewise tolerate a relationship to the dirt water trademark bend. This paper portrays the connection between the soil-water characteristic curve of an unsaturated soil as for matric suction. To ensure that anticipated soil property capacities speak to soil conduct sensibly well, fitting choice of the parameter that controls the execution of these expectation conditions ends up noticeably basic. The plan influences utilisation of soil-water characteristic curve and the immersed shear quality parameters are from research centre test. This investigation assessed the exactness of channel paper strategy device for measuring soil water maintenance and hysteresis result. It, at that point, gives an itemised portrayal of an option viable anxiety parameter, and demonstrates its viability in foreseeing shear quality over the whole scope of suction. As of late, various examinations have concentrated on the shear quality of unsaturated soils (Fredlund et al, 1996; Khallili et al, 1998; Lu et al,2004; Oberg et al,1997;Vanapalli et al, 1996)

Some of these examinations have demonstrated that shear quality can be characterised regarding a straightforward Bishop sort effectives tress, which is exceptionally speaking to honing engineers.[8] Water retention curve is used in the estimation of properties of the unsaturated soil and in order to predict the permeability function by using empirical method simply by the application of the soil water characteristic curve as well as the saturated coefficient of permeability (Kalatehjari *et al*, 2014). This investigation points on impact on shear quality because of suction on unsaturated soil. Geotechnical building has generally been considered utilising the standards of soil mechanics to explain soil quality, porousness and strain examination. In current geotechnical science, the anxiety variable approach is turning into the methods for exchanging unsaturated soil conduct. Unsaturated soil behaviour is essential in different undertakings, geotechnical and ecological building. It is trusted that with the introduced strategies a portion of the issues owed of slants can be tended to by a more reasonable slant strength analysis (Kalatehjari *et al*, 2014). Sample preparation, testing procedure, and the required calibrations of the system components are presented. The filter paper method and device is described in detail. In addition, the devices and techniques were used in the determination of water soil characteristic (SWCC) test for drying and wetting curve.

II. METHODOLOGY

2.1 Material And Method :

The total suction (k) of a soil was made up of two components, matric suction $(u_a - u_w)$ and osmotic suction $\underline{\pi}$:

$$k = (u_a - u_w) + \underline{\pi} \qquad (1)$$

where u_a = pore-air pressure and u_w = pore-water pressure. Matric suction is relative to the partial pressure of the water vapour in equilibrium with a solution identical in composition with the soil water and the equivalent suction derived from the measurement of the partial pressure of the water vapour in equilibrium with the soil water. Osmotic suction is the equivalent suction derived from the measurement of the partial pressure of the water vapour in equilibrium with a solution identical in relative to the partial pressure of water vapour in equilibrium with free pure water, composition with the soil water (Aitchison *et al*, 1964). Definition of matric suction to the affinity a soil has for water in the absence of any salt content gradients and osmotic suction arises from the salt content in the soil pore-water, and osmotic potential arises from variation in salt content from one point to another (Houston *et al*, 1994). Filter paper can be used to measure the total or matric suction. The filter paper method is based on the equilibrium with respect to moisture flow with a soil having a specific suction and when the filter paper is placed in direct contact with the soil, water will flow from the soil into the filter paper until equilibrium is achieved and when the filter paper is not in contact with the soil, only water vapour flow will occur. The filter paper method measures suction indirectly and the measurement accuracy is dependent on the moisture-suction relationship of the filter paper used. Additionally, the influence of the applied matric suction on unsaturated laterite soil was studied by performing with the rate of a given relation is as shown in the following Formula 2 and Formula 2(Greacen *et al*, 1987) and Whatman No. 42 filter paper was used for the test, as a shown Figure 1.

$$\text{Log } \psi = 5.327 - 0.0779 \text{ wf} \quad (2)$$

$$\text{Log } \psi = 4.945 - 0.0673 \text{ wf} \quad (3)$$

Where ψ suction = in kpa; wf = filter paper water content in %.

Figure 1. Whatman No.42

The main drying curve and wetting curve of the expansive soil are tested by using the filter paper method. The water content of sample is 31.84%. The prepared sample was placed in a humidity chamber with temperature 25^0C degree. Samples were naturally dried to simulate a drying path and to simulate the wetting path a watering can was used to spray the surface of the samples to simulate the natural rainfall. Measure the moisture content for both condition from time to time and take sample with different moisture content to be loaded. Put the filter into drying oven for about 24 hours to ensure its water content is zero and measure the paper mass. Also put three dried filter papers in the middle of the sample. Place the samples into a humidity chamber and adjust the temperature to 250C for 20 days to ensure exchange equilibrium between the soil sample and water filter in Figure 3 and Figure 4. Sealed container glass was used as a sealing divide for salt calibration and laterite soil for filter paper method. The basic classification properties of laterite soil are summarised with previous reseacher by using laterite from Balai Cerap Skudai in Table 1. Then remove the middle filter paper and measure mass then dry the filter paper by using drying oven for 24 hours.

Table 1. Physical Properties

Physical Properties (Laterite)	**Values**	**Nima, 2013**
Specific Gravity	2.765	2.69
Liquid Limit, LL (%)	73.313	75
Plastic Limit, PL (%)	36.500	41
Plasticity Index, PI	39.300	34
Maximum Dry Density	1.37	1.31
Optimum Moisture Content (%)	31.85	34

Figure 2. Sealed Container Glass for soil sample

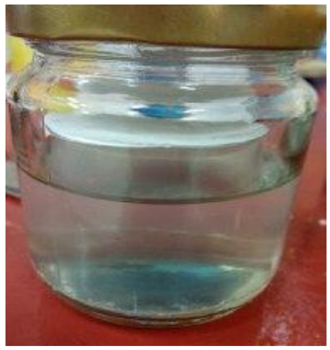

Figure 3. Sealed Container Glass for salt (calibration)

III. EXPERIMENT AND RESULT

3.1 System Calibration For The Suction Wetting Curve

Calibration for the suction wetting curve for filter paper by using salt solutions depends on the thermodynamic relation between the total suction (or osmotic suction) and relative humidity, resulting from a specific concentration of a salt in distilled water. In this study, NaCl was selected as an osmotic suction source for the filter paper calibration. Salt concentrations from 0 (distilled water) to 2.0 molality were arranged and filter papers were essentially put above salt solutions (in a non-contact manner) in fixed containers. The filter paper and salt solution setups in the sealed containers were placed in a steady temperature condition for balance equilibrium. Temperature variances were kept as low as possible during a two weeks equilibration period. A water bath was utilised for this reason, in which temperature variances did not surpass 25 ^{o}C.

A wetting curve was produced from the filter paper test outcomes by following the procedure defined above. There may be an inverse relationship between total suction and relative humidity at a consistent temperature. Alternatively, total suction will become very huge when relative humidity decreases, however the change in relative humidity may be very small with respect to the change in total suction. Considering that the total suction values in engineering practice are frequently represented in logarithmic scales (i.e., pF or log kPa), the total suction values in log kPa units as opposed to relative humidity are plotted in Figure 5 with a purpose to see the impact of the logarithmic scale on the relationship. From the figure, it is visible that total suction decreases dramatically when relative humidity approaches 53.67%. Distinct concentrations of sodium chloride solutions were plotted towards corresponding osmotic (or total) suction values both in kPa and log kPa units at 25^{o}C in Figure 6 and Figure 7 , respectively with osmotic suction value 9757 kPa with molality 2 and osmotic suction in log is 3.989 also with molality 2. For instance, a high concentration salt solution at a consistent temperature in a closed container has low relative humidity above its surface.

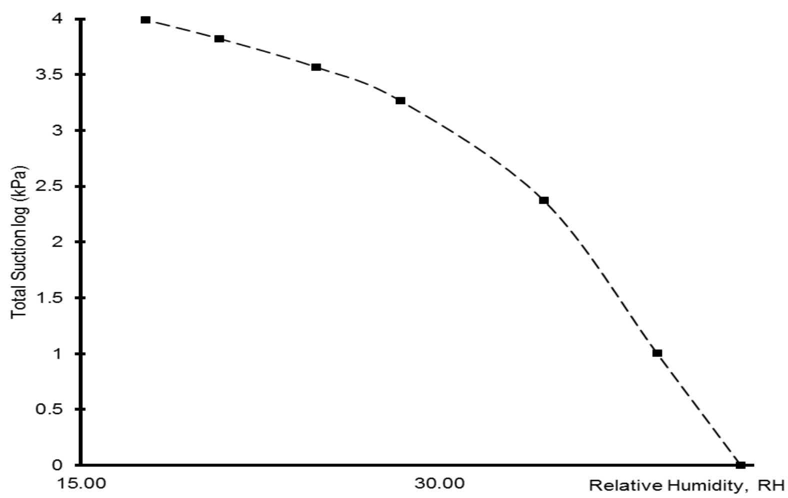

Figure 4. Total Suction and Relative Humidity Relationship

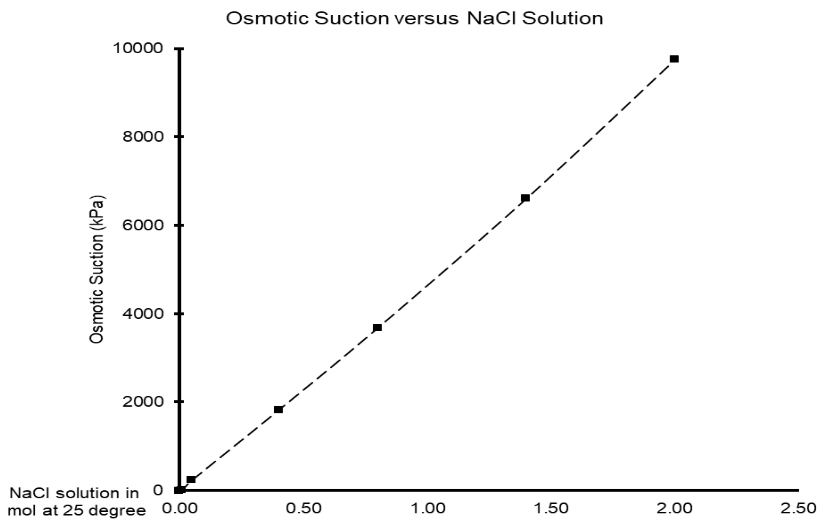

Figure 5. Osmotic Suction versus NaCl Solution

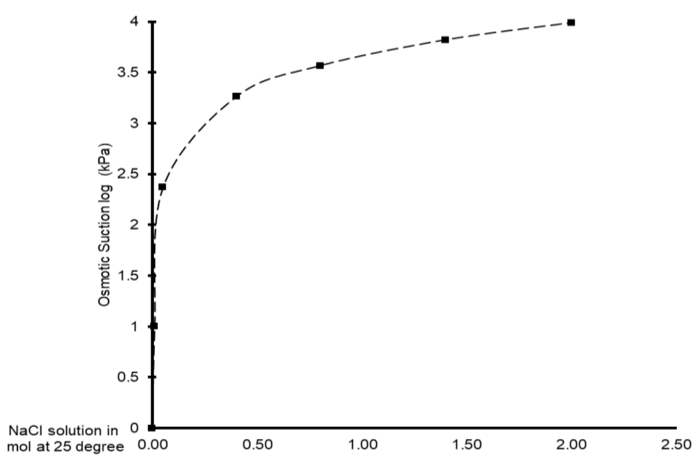

Figure 6. Osmotic Suction in log (kPa) versus NaCl Solution.

Figure 7 depicts a plot of the wetting curve in kPa units versus filter paper water contents obtained in this study with starting water content 53.67% in 21.53 kPa and end with water content 17.01 percent in 6312.87 kPa. From the figure, the sensitivity of the filter paper water contents and total suction relationship can absolutely be visible at very low suction values. From the relationships among total suction and relative humidity (i.e., Figure 4), total suction and salt solutions, and total suction and filter paper water contents (i.e., Figure 5) it can be concluded that the dramatic decrease in total suction at excessive water contents relies upon on the character of the relationship between total suction and relative humidity from Kelvin's equation and on the use of the logarithmic scale for total suction. Further, soils have a tendency to soak up more water for a small change in suction at very low suction values (Baver et al. 1972), and for the reason that filter papers, like soils, are porous materials they may be very sensitive for soaking up water at low suction values.

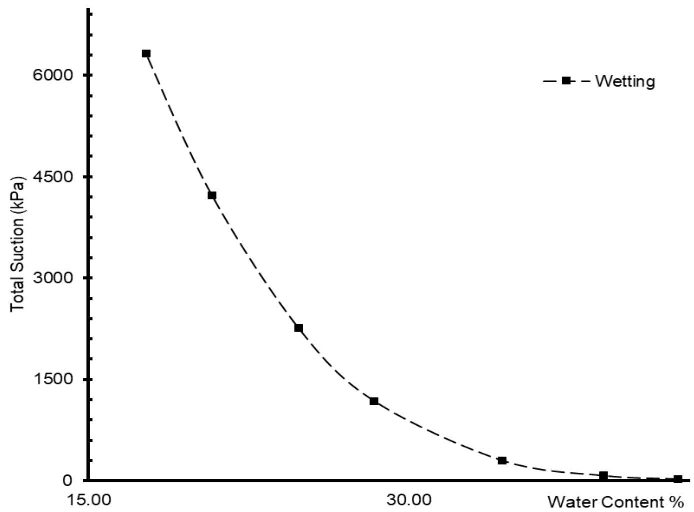

Figure 7. Filter Paper Wetting Calibration Curve in kPa

3.2 Filter Paper Method for Laterite Soil:

Based on the Figure 8 result for drying and wetting curve or called hysteresis curve by using sealed container glass for filter paper method with reference to the duration of time where it is being observed and the graph shows the result for laterite soil within 10 days for drying part and another 10 days for wetting part, as shown in Figure 9 used same sample with duration 20 days. Whatman No.42 filter paper was used for the test and five laterite soil samples were included for each test.

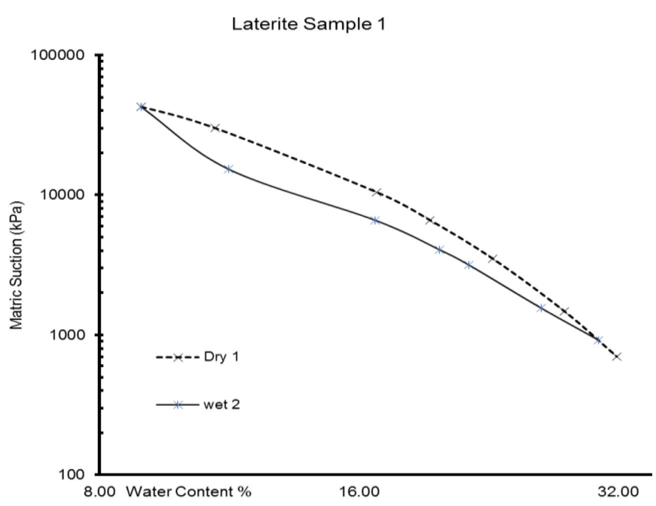

Figure 8. Filter Paper using Laterite Soil for test 1 (Hysteresis)

The equilibration times of the filter paper was dependent on suction source, contact condition and suction level (Baver *et al*,1972). Started drying curve was from natural water content for two samples. First sample result water content 32.43% and second sample 31.34%. The result of drying curve for laterite soil for Sample 1 decreased slowly from Day 1 to Day 3, which was from 32.43 percent to 27.73 percent with difference 4.70 percent with matric suction for Day 3 was 1,468.36 kPa. Apart from that, difference moisture content for Day 3 to Day 4 was 4.84% and for Day 8 was 10.89% with matric suction 30,107.11 kPa and for Day 10 for drying curve are 8.94% with matric suction 37,809.59 kPa with difference 1.95 percent from day 8.

Drying curve result for Sample 1 from Day 1 started from Day 10 drying curve results, which was 8.94% and decreased slowly from Day 1 to Day 10, which was 23.49% and to simulate the wetting curve, a watering can was used to spray the sample surface to simulate natural rainfall and wetting path, and measure the moisture content from time to time by using Formula 4.7 to get the matric suction result. Difference in moisture content for wetting curve result from Day 1 to Day 3 was 2.36% with matric suction for Day 3 was15,293.61 kpa. On Day 6 and Day 7 the moisture content appeared to slowly increase from 19.83% to 21.46%. As for Day 8 to Day 10 the moisture content was increased along the 2 days from 26.02 % to 30.32 % with matric suction for Day 10 at 802.54 kPa.

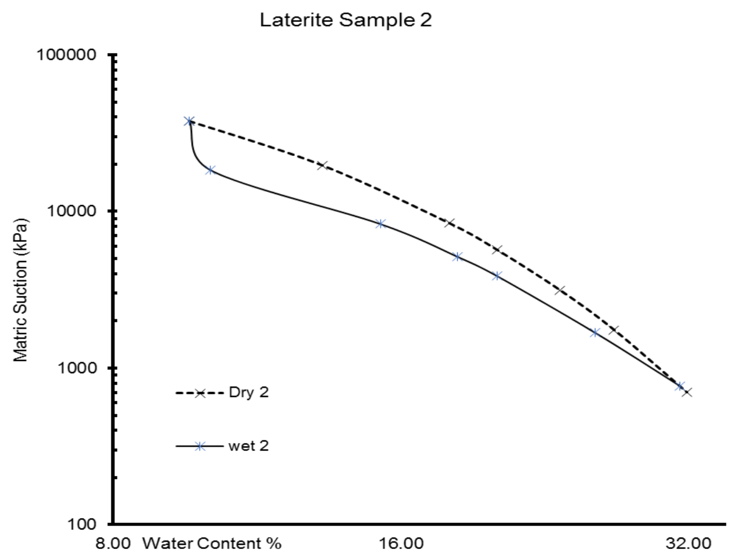

Figure 9. Filter Paper by using Laterite Soil for test 2 (Hysteresis).

Figure 9 shows the result of drying curve for sample 2 with water natural content for Day 1 was 31.84% with matric suction 702.53 kPa also the moisture content gradually decreased to 26.74% with increased matric suction to 1,753.69 kPa. Drying curve result of Sample 2 for Day 8 to Day 10 the moisture content showed a slow decrease with difference 3.62% with Day 10 matric suction was 37809.59 kPa. Wetting curve result by using the same method with Sample 1 result Day 10 for drying curve was 9.62% was a result wetting curve for Day 1 with same moisture content and matric suction. For Day 3 wetting curve result is 10.12% was slowly increased moisture content and with matric suction 18362.17 kPa. Difference in moisture content for Day 6 and Day 7 was 1.86%. For Day 8 and Day 10 the difference in moisture content was 5.78% with Day 10 matric suction was 768.45 kPa. The difference between last result for drying and wetting curve was 0.5% for moisture content for a 20-day duration.

IV.CONCLUSION

The conclusion is to extend the approach for the simulation of hysteresis over time cycle, in the unsaturated zone and in the vicinity of soil. Time varying boundary conditions and hysteresis effects were also considered in the simulation. Filter paper method is widely applicable to measure drying and wetting path , especially for laterite soil. Drying and wetting curve were clearly defined by the experimental programme. The proposed sample should be easy to use, such as soil suction. Soil matric suction is ranged at 100-100,000 kPa for filter paper test as compared to pressure plate at 0-1500 kPa and Double Triaxial wall at 0-600 kPa. The change in matric suction can influence the soil slope stability , especially for laterite soil. Calibration by using salt solution is most important to know the thermodynamic relation between total suction and relative humidity, also equilibrium time for each soil sample. Equilibrium for each sample is different and must control the sample with care to avoid cracking.

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