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Characteristics of Soil Suction with Filter Paper Test Method

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Abstract—Soil suction is the ability of the soil to absorb water. Type of soil in this research was peat soil and clay soil. The soil samples had been used were taken from Village III Banyu Urip, Banyuasin Regency, South Sumatera Province. Laboratory testing with Filter Paper test method. The filter paper used is Whatman Filter Paper No.42. The Scanning Electron Microscope (SEM) had been used to analyze the orientation of fiber content. Energy Dispersive Spectroscopy (EDS) also to analyze the chemical elements. Characteristics of peat soil are water content value (ω) is 294.30 %, acidity (pH) value is 3.000, and peat soils classified as fibrous peat soils. While the characteristics of clay soil are water content value is (ω) 62.05 %, acidity (pH) value is 5.000, and clay soils classified as A-7-5 (AASHTO) and OH (organic clay) based on USCS. The result of the test paper filter test on peat soil obtained from the value of suction is (Ψ) 3.2432 kPa-17.5230 kPa. The results of testing the Filter Paper test method on the clay obtained the value of suction is (Ψ) 61.8733 kPa-100.3421 kPa. The value of suction from clay soil is more than a value of suction peat soil based on Filter Paper test method.

Keywords— soil suction; peat soil; clay soil; filter paper; characteristics soil.

I. INTRODUCTION

South Sumatra Province has a soil type with varying conditions such as peat and clay soil. Peat soil is a mixture of organic fragments derived from vegetation that has been transformed into fossils chemically. Clay soil is a mineral particle with fine grain size and has the potential for shrinkage. The characteristic of peat soil containing water content is quite high, causing peat soil to have a low of suction soil. The soil suction is directly connected with the released energy in the pores of water content in the soil. Based on clay soil characteristics influenced by moisture content it also affects the occurrence of soil suction on clay soil. The higher the groundwater content, the soil suction ability will be lower.

Soil suction is the capability of the soil to absorb water. Therefore, to determine the value of soil suction done laboratory testing by testing the soil suction. There are several methods to measure soil suction in the laboratory, among others tensiometer, thermal conductivity, and filter paper. In this research, laboratory testing is done using a filter paper method. Filter paper method is a simple test method whose main media is a filter paper by measuring the water content of filter paper. The filter paper used in this research is Whatman filter paper No. 42 [1] – [5]. Research from [2] using the filter paper method. This method is used to analyze suction matrix suction and total suction. The results show higher water content in the compacted soil.

The relationship between water content and soil suction is the definition of the Soil Water Characteristic Curve. Water content states the amount of water contained in the pores of the soil. Some critical parameters in SWCC are Air Entry Value (AEV), slope curve function for negative or positive pore water pressure (MW), and residual water content (θv) or saturation (Sr). Soil Water Characteristic Curve (SWCC) is used as an estimate or estimate of soil properties in measuring its suction [3], [6]-[8]. The specific of Soil Water Characteristic Curve (SWCC) can be seen in Fig. 1 [6].

Reference [3] analyzes the effect of the Soil Water Characteristic Curve (SWCC) on kaolin samples. The kaolin sample had been used in the compacted condition. Based on the test it is found that density value and initial water content value influence to SWCC characteristics. [7] stated that the Soil Water Characteristic Curve (SWCC) affects the characteristics of unsaturated soil conditions. Parameters such as residual water content, Air Entry Value (AEV), and slope of the graph affect SWCC analysis. A simple method to estimate the Soil Water Characteristic Curve (SWCC) is examined by [8]. Soil types used are fine-grained soils and coarse-grained soils. The result of the research shows that data analysis using the simple method used is better than the one point method.
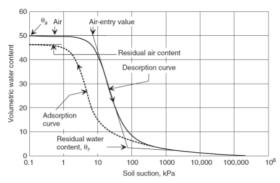
Fig. 1 SWCC characteristic [6]

II. MATERIAL AND METHOD

The research methodology used is the laboratory testing method conducted in Soil Mechanics Laboratory of Civil Engineering Department of Sriwijaya University. This research started with a survey of the research location. The location of the soil sampling is in Banyuasin District, South Sumatra Province. Soil samples taken are peat and clay soil. Soil sampling is undertaken in disturbed and undisturbed condition. Before testing the ability of peat soil and clay soil of the filter paper method, first testing soil properties.

Soil properties testing of peat soil are: (1) water content (ω) ASTM D 2974-87; (2) acidity of peat soil (pH) ASTM D 2976-71; (3) specific gravity (Gs) ASTM D 854-14; (4) fiber content (FC) ASTM D 1997-13; and (5) organic content (OC) and ash content (AC) ASTM D 2974-14. While the testing of soil properties for clay soil is consists of several tests, among others: (1) water content, ASTM D 2216; (2) Specific Gravity, (Gs) ASTM D 854; (3) Sieve Analysis, ASTM D 422; and (4) Atterberg Limits ASTM D4318. Soil classification using a soil classification system based on AASHTO (American Association of States Highway and Transportation Official) and USCS (Unified Soil Classification System).

Soil suction testing for peat soil and clay soil in this research using measurement techniques with filter paper test methods. Soil suction testing using the filter paper method is based on ASTM D 5298-03. The filter paper used is Type II Whatman No. 42. The filter paper used in this research is shown in Fig. 2.

Fig. 2 Filter paper Whatman no.42

After peat soil sampling and soil properties, soil testing, then proceed with the preparation of making a sample of the specimen. The making of this specimen was done in Soil Mechanics Laboratory of Civil Engineering Department of Sriwijaya University. Using a piece of pipe measuring 57 mm in diameter and about 50 mm in height, the soil sample used was compacted on the compacted pipe. In this research, we used two pieces of pipe mold soil samples. The soil mold of each piece of pipe will be used as a sample of the test material for soil suction measurement. At least more than two pieces of pipe are required to print the soil sample to be used in the soil suction test. In the peat soil and clay soil measurement test using the filter paper method, six samples were used as a sample of the suction test. Research from [2] had been used compacted samples with height (h) 70 mm and internal diameter (d) 85 mm for the filter paper test method.

The data obtained from the test results are data soil properties (soil characteristics), data of soil test suction with a filter paper method, and water content data every seven days. Soil suction test obtained data weight of dry filter paper and water in filter paper. From the data obtained value of filter paper water content. The soil suction value was obtained by calibrating the moisture content of the ASTM standard Whatman filter paper 42. From the data of the water content can be obtained the value of a degree of saturation (Sr, %) and volumetric water content (Θv, %). In soil suction testing that has been done can be known Soil Water Characteristic Curve (SWCC) which describes the relationship of soil water with moisture content (□), a degree of saturation (Sr), and volumetric water content (Θv).

III. RESULTS AND DISCUSSION

The type of soil had been taken was peat soil and clay soil. Soil properties testing has been done on this soil samples. The test was conducted at Soil Mechanics Laboratory of Civil Engineering Department of Sriwijaya University. The results of the laboratory tests are shown in Table 1 and Table 2. The water content (ω) from peat soil in Table 1 is 294.30 %. The acidity (pH) value of peat soil samples obtained from field testing is 3.00 and from laboratory testing is 3.16. The pH results indicate that the peat soils contain high levels of acid and are included in the category of highly acidic. Based on the Von Post classification, peat soils are included on the H4 scale where peat soils decay slightly and emit dark and very turbid water. So that the characteristics of peat soil from Village III Banyu Urip, Banyuasin regency are included in the type of fibrous peat soil. The characteristics of peat soil in Ogan Ilir Regency, South Sumatera Province were also classified as fibrous peat soil. The value of water content (□) in the range 409.09 % - 493.01 % [9]. Based on the results from [10], the value of acidity (pH) of peat soil which is taken from Indah Kiat Pulp and Paper, Perawang, Riau Province is 3.20.

The value of water content in clay soil (Table 2) from Village III Banyu Urip, Banyuasin regency in the amount of to 62.05 %. Based on testing the degree of acidity (pH) obtained pH value of 5.00. Classification of clay soils based on AASHTO to the classification in A-7-5. Based on the AASHTO soil classification system, it is known that soil samples are more than 35 % of the grained soil sieve pass No. 200. So it is categorized as a clay soil with the level of general rating as subgrade fair to weak. While based on USCS obtained the liquid limit value of more than 50 % and

percentage of grains passed 200 more than 50 % sieve. So the soil including the classification of OH (organic clay with moderate to high plasticity).

TABLE I
CHARACTERISTICS OF PEAT SOIL

No.	Tests	Results
1.	Water Content (ω ,%)	294.300
2.	Specific Gravity (G_s)	1.799
3.	Acidity (pH)	3.160
4.	Organic Content (OC, %)	77.400
5.	Ash Content (AC, %)	26.610
6.	Fiber Content (FC, %)	70.450
7.	Void Ratio (e)	3.092
8.	Wet Unit Weight (γ_b, kN/m^3)	17.335
9.	Dry Unit Weight (γ_d, kN/m^3)	4.396
10.	Cohesion (c, kPa)	7.649
11.	Internal Friction (ϕ, °)	24.000
12.	Shear Strength (τ, kPa)	8.720
13.	Von Post Scale	H$_4$

TABLE II
CHARACTERISTICS OF CLAY SOIL

No.	Tests	Results
1.	Water Content (ω, %)	62.050
2.	Specific Gravity (G_s)	2.594
3..	Liquid Limit (LL, %)	65.200
4.	Plastic Limit (PL, %)	42.870
5.	Index plastic (IP, %)	22.330
6.	Wet Unit Weight (γ_b, kN/m^3)	17.531
7.	Dry Unit Weight (γ_d, kN/m^3)	10.818
8.	Void Ratio (e)	1.396
9.	Acidity (pH)	5.000
10.	Cohesion (c, kPa)	18.000
11.	Internal Friction (ϕ, °)	22.835
12.	Shear Strength (τ, kPa)	26.521
13.	Classification AASHTO	A-7-5
14.	Classification USCS	OH

The fiber content can be examined under a Scanning Electron Microscope (SEM). Fig. 3 and Fig. 4 shows the typical fiber orientation obtained by Scanning Electron Microscope (SEM) for soil obtained from Village III Banyu Urip, Banyuasin, South Sumatra Province. Based on test results conducted on the SEM peat in the Chemical Laboratory of Chemical Engineering Department of the Sriwijaya Polytechnic visible pores and fibers contained. The sample used in this test was a sample which is cut horizontally with a magnification up to 10.000x.

Testing of EDS (Energy Dispersive Spectroscopy) also performed for peat soil and clay soil sample from Village III Banyu Urip, Banyuasin, South Sumatra Province. EDS test was done to analyze the chemical elements contained in the peat soil and clay soil. The results of the testing of EDS can be seen in Fig. 5 and Fig. 6. Research [11] reported the results from a Scanning Electron Microscope (SEM) and Energy Dispersive Spectroscopy (EDS) tests. Based on the results of the EDS test showed that element C has the highest content.
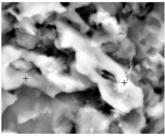

Fig. 3 Result of sem 10000x peat soil sample in village iii banyu urip, banyuasin regency
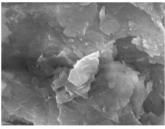

Fig. 4 Result of sem 10000x clay soil sample in Village iii banyu urip, banyuasin regency
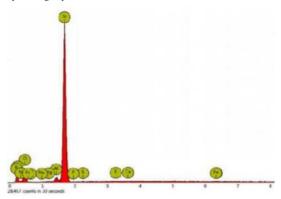

Fig. 5 Result of eds from peat soil in Village iii banyu urip, banyuasin regency
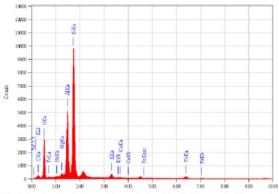

Fig. 6 Result of eds from soil sample in village iii banyu urip, banyuasin regency

Soil suction testing using filter paper method on clay soil and peat soil from Village III Banyu Urip, Banyuasin regency had been done at Soil Mechanics Laboratory of Civil Engineering Department of Sriwijaya University based in ASTMD5298-03. Soil suction tests conducted as many as six samples on peat soil and clay soils. In this research, the soil suction value was obtained from the amount of water content on the Filter Paper calibrated by using a calibration curve or with an equation for Whatman Filter Paper No. 42.

Table 3 shows the peat soil peat result from P1 sample testing. Table 4 shows the clay soil result from C1 sample testing. Based on Table 3, peat soil under the Degree of Saturation (Sr) condition is 100 % obtained water content (ω) 149.4095%, Volumetric of water content (Θv) 85.3882 %, and Soil Suction (Ψ) 1.000 kPa. While in clay soil (Table 4) for Degree of Saturation (Sr) of 97.7485 % obtained water content (ω) 42.5407%, Volumetric of water content (Θv) 56.9463 %, and soil suction (Ψ) 1.000 kPa.

The result of soil suction in Table 3 and Table 4 can be seen that the change of the suction value occurring on the peat and clay soils is related to the value of water content and the degree of saturation possessed by soil samples. The relationship of moisture content, a degree of saturation, and volumetric water content with soil suction occurring on peat soil samples can be seen in Fig. 7, Fig. 8, and Fig. 9. While Fig. 10, Fig. 11, and Fig. 12 shows the relationship of moisture content, a degree of saturation, and volumetric water content with suction on clay soil.

The graph of the relationship between water content (ω) peat soil and soil s suction value as shown in Fig. 7 shows some points of initial value of soil sucking test, AEV value point, and residual water content. From the figure results the soil suction Ψ = 1,000 kPa with ω = 149.4095 % as the initial value of soil suction test, $\Psi 1$ = 6,632632 kPa with $\omega 1$ = 127.0030 % as the AEV value, and $\Psi 2$ = 16.7062 kPa with $\omega 2$ = 87.9751 % as value of residual water content.

The graph of the relationship between the degree of saturation (Sr) of peat soil and soil suction value in Fig. 8 shows some points of initial value of soil suction test, AEV value point, and residual water content. Based on the Fig. 8 results soil suction Ψ = 1.000 kPa with Sr = 142.5387 % as the initial value of soil suction testing, $\Psi 1$ = 6.63263 kPa with Sr1 = 141.1450 % as AEV values, and $\Psi 2$ = 16.7062 kPa with Sr2 = 137.6341 % as residual water content.

Fig. 9 shows a graph of the relationship between volumetric water content (θv) of peat soil and soil suction value. Fig. 9 shows some points of initial value of ground suction testing, Air Entry Value, and residual water content. The results is soil suction Ψ = 1 kPa with θv = 85.3882 % as the initial value of soil suction testing, $\Psi 1$ = 6.6326 kPa with $\theta v 1$ = 78.9674 % as AEV values, and $\Psi 2$ = 16.7062 kPa with $\theta v 2$ = 64.4148 % as residual water content.

The relationship between soil suction clay with water content can be seen in Fig. 10. From the graph, it can be known that the starting point of the test on soil suction value Ψ = 1.0000 kPa with a degree of saturation ω = 42.3292 %. While the soil suction value, $\Psi 1$ = 48.9050 kPa with $\omega 1$ = 40.8399 % shows the value point Air Entry Value and value $\Psi 2$ = 103.5342 kPa with $\omega 2$ = 37.9294 % as residual water water content.

The result of the filter paper test on clay soil obtained the graph of soil saturation relationship with a degree of saturation (Fig. 11). From the graph, it can be seen the starting point of testing on soil suction value Ψ = 1.0000 kPa with a degree of saturation, Sr = 97.4560 %. While the soil suction value, $\Psi 1$ = 48.9050 kPa with Sr1 = 93.6319 % shows the point value of AEV (Air Entry Value) 103.5342 kPa with Sr2 = 87.4753 % residual water content. Fig. 12 illustrates the soil suction graph with volumetric water content. From the graph it can be seen the starting point of testing on soil suction value Ψ = 1.0000 kPa with volumetric water content, Θ = 56.7759 %. While the soil suction value, $\Psi 1$ = 48.9045 kPa with $\Theta 1$ = 54.5481 % shows the value point AEV (Air Entry Value) and value $\Psi 2$ = 103.5342 kPa with $\Theta 2$ = 50.9613 % as residual water content. The value of AEV (Air Entry Value) from [13] in the range 3kPa- 200 kPa.

TABLE III
RESULTS OF PEAT SOIL SUCTION FROM SAMPLE P1

No.	Water Content (ω, %)	Degree of Saturation (Sr, %)	Volumetric of Water Content (Θ_v, %)	Soil Suction (Ψ, kPa)
1.	149.4095	100.0000	85.3882	1.0000
2.	137.7388	99.9000	82.1750	3.8826
3.	127.0030	99.0000	78.9674	6,6326
4.	106.5902	95.8970	72.4620	7.7614
5.	97.3758	91.2470	68.9482	9.3663
6.	95.9804	90.1480	68.1180	10.0358
7.	91.3841	87.4720	66,0961	13.1782
8.	90.0128	86,4600	65,3315	13.4625
9.	87.9751	85.2470	64,4148	16.7063
10.	87.2716	84.1747	63.6042	23.9449
11.	85.8190	83.1140	62.8027	34.8745
12.	84.6429	82.2577	62.1556	55.5056
13.	84.3120	81.7230	61.7520	421.9588
14.	83.9462	81.1560	61.3232	798.5424

TABLE IV
RESULTS OF CLAY SOIL SUCTION FROM SAMPLE P1

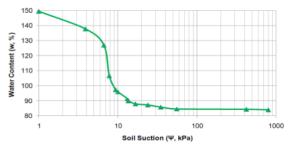| No.	Water Content (ω, %)	Degree of Saturation (Sr, %)	Volumetric of Water Content (Θ_v, %)	Soil Suction (Ψ, kPa)
1.	42.5407	100.0000	56.9463	1.0000
2.	41.9737	96,5143	56.2273	14.0080
3.	41.1994	94.6953	55.1676	19.7394
4.	40.4207	93.0846	54.2292	27.1052
5.	39.9430	91.7572	53.3172	31.5157
6.	39.0946	90.4190	52.6762	41.6312
7.	38.0377	88.4253	51.5148	49.9796
8.	37.3970	87.1340	50.7625	61.8733
9.	36.8482	85.9830	50.0920	129.2291
10.	36.4787	85.1767	49.6222	207.0814

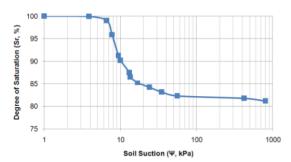Fig. 7 Graph of water content versus peat soil suction from sample p1

Fig. 8 Graph of degree of saturation versus peat soil suction from sample p1
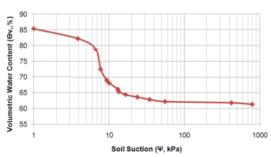

Fig. 9 Graph volumetric of water content versus peat soil suction from sample p1

As shown in the graph above shows that the value of water content indicated by the soil may affect the value of saturation degree and volumetric water content which will then also affect the value of suction produced by the tested peat soil. Each graph of the three samples shows three different points in each sample. The points on each graph show the amount of value at the beginning of the occurrence of soil suction, the value of the Air Entry Value, and the value of the value at the beginning of the residual water content.

The initial value of the occurrence of soil suction, the magnitude of the AEV value, and the value of the initial value of residual water content shown on the graph are the parameters that form the Soil Water Characteristic Curve(SWCC). The points that lie between the AEV point and starting point of the residual water content are the slope points of the moisture ($\square$). The results of peat soil suction with a filter paper test method are shown in Table 5. Table 6 shows the results of clay soil suction. Fig. 12 and Fig.13

illustrate the graph of the relationship between Soil Water Characteristic Curve (SWCC) with peat soil and clay soil.
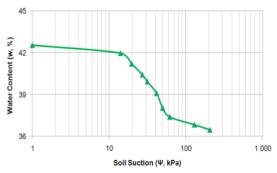

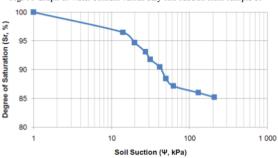Fig. 10 Graph of water content versus clay soil suction from sample c1

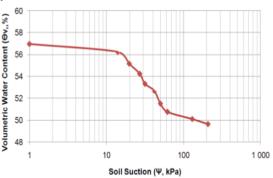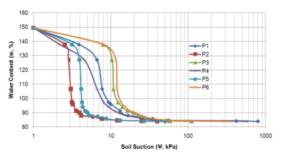Fig. 11 graph of degree of saturation versus clay soil suction from sample c1

Fig. 12 Graph volumetric of water content versus clay soil suction from sample c1

Based on Table 5, the peat soil suction (Ψ) values in the range of 3.2432-17.5230 kPa. The clay soil suction (Ψ) in Table 6 was in the range 61.8733-100.3421 kPa. In Fig. 13 and Fig. 14 it can be seen that SWCC is comparing the suction value of all peat soil and clay soil samples. Soil Water Characteristic Curve (SWCC) above shows the existence of parameters that influence it. The comparison of the Soil Water Characteristic Curve (SWCC) from Fig. 13 shows the amount of AEV (Air Entry Value) in each peat soil sample having a value of soil suction less than 20 kDa. Whereas based on Fig. 14 the value of AEV in each clay soil sample has a soil suction value of less than 110 kPa.

In soil suction testing conducted with peat soil samples indicated that peat soil has a low suction to water with a soil suction value of no more than 1000 kPa. The clay has a relatively small percentage of pore volume. The amount of Pressure required on soil sucking is related to the pores of a land. The larger the pores of the soil, the pressure required to suction the water gets smaller because the soil that has a larger pore can be easier in passing water. The research of [12] describes the matrix suction of 10 and 500 kPa on coarse-grained soils and fine-grained soils. The results show that the Grained soils and fine-grained soils. The results show that the sensitivity analysis obtained a good SWCC curve.

Fig. 13 Soil water characteristic curve (swcc) peat soil suction

TABLE V
RESULTS OF PEAT SOIL SUCTION WITH FILTER PAPER METHOD

Parameters		Peat Soil Suction		
		Initial Value of Suction	Air Entry Value (AEV)	Residual Water Content
Sample P1	ω, %	149.4095	127.0030	95.9804
	Sr, %	100.0000	99.0000	90.1480
	Θ, %	85.3882	78.9674	68.1180
	Ψ, kPa	1.0000	6.6326	10.0358
Sample P2	ω, %	149.4095	127.0030	95.9804
	Sr, %	100.0000	99.0000	84.2890
	Θ, %	83.5066	77.4935	67.0247
	Ψ, kPa	1.0000	2.8320	3.2432
Sample P3	ω, %	149.4095	127.0030	91.3841
	Sr, %	100.0000	99.1000	85.7510
	Θ, %	84.6304	78.3499	65.5933
	Ψ, kPa	1.0000	10.3836	16.2930
Sample P4	ω, %	149.4095	127.0030	95.9804
	Sr, %	100.0000	99.3000	90.1500
	Θ, %	80.8882	74.4674	63.6180
	Ψ, kPa	1.0000	4.5326	9.3580
Sample P5	ω, %	149.4095	127.0030	95.9804
	Sr, %	100.0000	99.4500	84.8750
	Θ, %	87,3066	81,2935	70,8247
	Ψ, kPa	1.0000	3,9320	4,3432
Sample P6	ω, %	149.4095	127.0030	91.3841
	Sr, %	100.0000	99.2160	85.5750
	Θ, %	88.4804	82,1998	70,8247
	Ψ, kPa	1.0000	11.6136	17.5230

TABLE VI
RESULTS OF CLAY SOIL SUCTION WITH FILTER PAPER METHOD

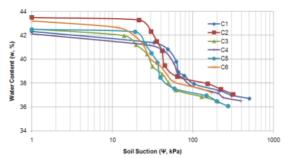| Parameters		Clay Soil Suction		
		Initial Value of Suction	Air Entry Value (AEV)	Residual Water Content
Sample C1	ω, %	42.3292	40.8400	37.9294
	Sr, %	97.4560	93.6319	87.4753
	Θ, %	56.7759	54.5481	50.9613
	Ψ, kPa	1.0000	48.9050	103.5342
Sample C2	ω, %	43.3412	42.3106	38.53392
	Sr, %	99.2137	96.4817	89.20705
	Θ, %	57.7999	56.2083	51.97024
	Ψ, kPa	1.0000	30.4006	64.1832
Sample C3	ω, %	42.5407	41.1994	37.39659
	Sr, %	97.7485	94.6953	87.1339
	Θ, %	56.9463	55.1676	50.7625
	Ψ, kPa	1.0000	19.7394	61.8733
Sample C4	ω, %	42.1292	38.7500	35.7440
	Sr, %	95.2546	91.5225	85.3675
	Θ, %	55.6750	53.2543	49.8768
	Ψ, kPa	1.0000	46.768	100.3421
Sample C5	ω, %	42.5057	41.1065	37.5467
	Sr, %	98.2150	95.3750	88.1354
	Θ, %	56.6581	55.1768	50.8554
	Ψ, kPa	1.0000	29.3756	63.1205
Sample C6	ω, %	43.2168	42.4510	38.5545
	Sr, %	99.7685	96.9753	89.2500
	Θ, %	57.6560	56.1895	51.9432
	Ψ, kPa	1.0000	20.8250	62.4457

Fig. 14 Soil water characteristic curve (swcc) clay soil suction

Based on the soil suction capability generated in soil suction testing, it is found that the greater the value of water content of a soil type, the greater the degree of saturation and volumetric moisture value of the soil type. Conversely, the water content of land will affect the absorption or puffing of the soil with the higher the value of moisture content, a degree of saturation, and volumetric water content of the soil will be smaller the value of suction produced by the soil. So from the results of research that has been done can be concluded that clay soil has a high soil suction ability compared with the suction be possessed by peat soil.

IV. CONCLUSION

The value of water content (ω) from peat soil is 294.30 %. The pH value of peat soil is 3.00. Peat soils are included on the H4 from Von Post classification. So, peat soils are classified as fibrous peat soils. The value of peat soil suction (Ψ) is 3.2432 kPa -17.5230 kPa. Peat soils have a fairly low suction capability. This is because the amount of soil suction value (Ψ) on peat soil obtained from the suction test with paper test does not reach more than 1000 kPa. The water content of clay soil is 62.05 %. pH value about 5.00. Classification of clay soils based on AASHTO is A-7-5. Moreover, based USCS is OH (organic clay). The value of peat soil suction (Ψ)= 61.8733 kPa-100.3421 kPa.

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