Laboratory Investigation Of The Suction Of Peat Soil In Drying And Wetting Process

Yulindasari Sutejo, Anis Saggaff, Wiwik Rahayu, Hanafiah

Abstract: The suction of peat soil illustrate the characteristics of peat soil. This research aimed to investigate the peat soil suction (drying and wetting condition). Filter Paper testing (Whatman42) has been used for testing. The peat soil sample was acquired in village III Banyu Urip, Regency of Banyuasin, South Sumatera province. The percentage values of optimum water content in this study are: W1=41 %, W2=42 %, W3= 43 %, W4=44 %, W5=45 %, W1=46 %, W1=47 %, W1=48 %, and W1=49 %. The results of the test such as: the average water content (□) = 263.538 %, average of acidity (pH) = 3.353, the value of optimum water content value ($□_{opt}$) = 45 %, the value of optimum dry content weight value (γdopt) = 0.954 kN/m3. The results of peat soil suction value (Ψ) due to the influence of wetting and drying are: P = 321.860454 kPa, W1 = 46.75611 kPa, W2 = 56.67991 kPa, W3 = 43.48429 kPa, W4 = 65.56742 kPa, W5 = 37.42705 kPa, W6 = 32.04885 kPa, W7 = 37.86667 kPa, W8 = 35.74133 kPa, and W9 = 28.58823 kPa. The results in the drying condition were greater when compared to the wetting condition.

Index Terms: Peat Soil, Suction, Soil Water Characteristics Curve (SWCC), Drying, Wetting

1. INTRODUCTION

Peat soil is the result of a mixture of fragmented organic matter formed in wetlands under climatic conditions and topography. The behavior of fibrous peat soil is very different from clay soil due to fiber in soil. The suction of peat soil can describe the behavior of peat soil. In the field of geotechnical, soil suction is a magnitude of groundwater that is absorbed by cations. Suction on the ground is directly related to the free energy in the pore in the soil [1]. Many methods can be used to quantify the value of soil suction. One technique or method that can be used in the calculation of suction, both soil suction and Soil Water Characteristics Curve (SWCC) is filter paper method. SWCC is a method of filter paper on dry soils, an extensive soil of the matric is up to 1 million kPa, and a zero value on the soil is fully saturated. The matric suction can be likened to negative pore water pressure. Soil Water Characteristics Curve (SWCC) is a curve describing the relationship between the amount of water in the soil and suction [3,4,5]. The amount of water here is Gravimetric water Content (GWC) (W), Volumetric Water Content (VWC) (θ), or degree of saturation (S). The testing method on this research used the laboratory Filter Paper testing as a passive sensor. These tests to evaluate soil matric and potential totals of soil suction. Paper Filter Type is Whatman42 [2,12]. Suction total is related to free energy in groundwater. While the suction of the matric and the osmotic suction is a component of free energy. In the form **of equations can be written as follows:**

$$\Psi = (U_a - U_w) + \pi \quad (1)$$

Where: (Ua – Uw) = matric suction (kN/m^2), Ua = air pore pressure (kN/m^2), Uw = water pore pressure (kN/m^2), π = osmotic suction (kN/m^2) The soil suction measured from relative moisture is typically called total suction. In which, the total suction consist of the matric suction and the osmotic suction. Some environmental conditions that affect the absorption of matric are ground conditions, climatic or weather conditions, and groundwater-surface. In geotechnical knowledge, it is difficult to determine whether the land is in the drying process or the wetting process when in the field. The difference between drying and wetting from the SWCC is seen in terms of soil suction. The curve chart plots between the matric suction with moisture content for the drying process and the wetting shown in Figure 1. This graph illustrates the hysteresis effect of drying and wetting. [6] determined the process of drying SWCC. The sample for the test is the compacted Khon Kaen soil. The characteristic of an expansive soil had been studind by [7]. The research was studied the cycles of wetting and drying of the expansive soil.

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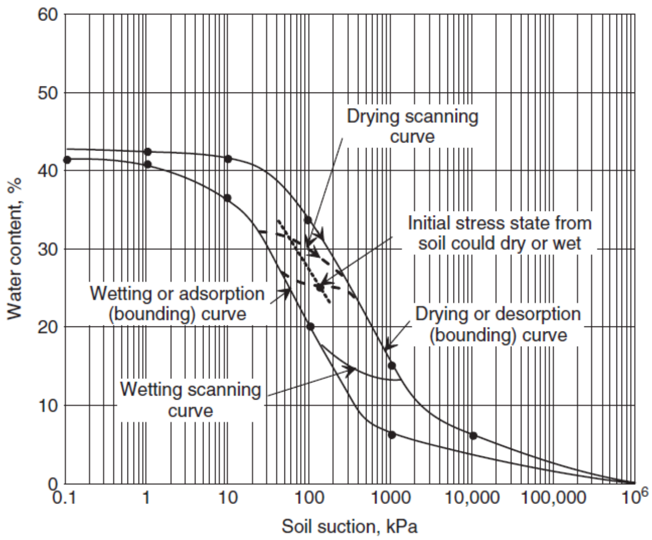


Fig. 1. *The scanning curves and designation of the initial stress state of wetting and drying process (Fredlund et al., 2012)*

2 RESEARCH METHODOLOGY

2.1 Peat Soil

Samples of peat soil were taken at shallow depths. The methods of sampling were using the block sampling method. The location of the peat soil sample is in village III Banyu Urip, Regency of Banyuasin, South Sumatera province. Peat soil samples and research locations can be views in Fig. 1, and Fig. 2. Undisturbed peat soil samples had been used for the testing of index properties such as moisture content, density, void ratio, unit weight, and acidity levels are performed to obtain the behavior of peat soil. Von Post classifies peat soil or the degree of humification (H1-H10), fiber content (FC, %), organic content (OC, %), and ash content (AC, %). In this study, characteristics/mechanical properties in peat soil were testing using filter paper testing equipment. Types of peat soil samples are disturbed soil samples. Modeling of peat soil behavior in Banyuasin Regency, South Sumatra Province in the condition of drying and wetting with testing SWCC (Soil Water Characteristics Curve).

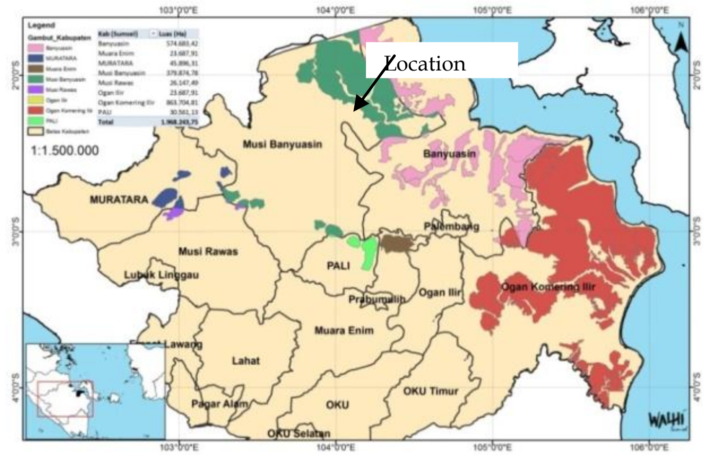
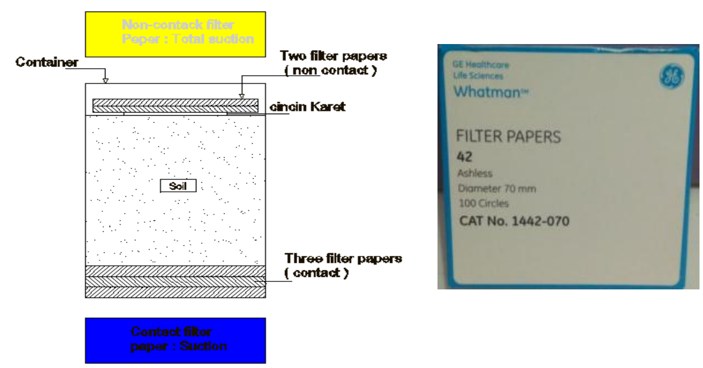


Fig. 2. *Research location (Walhi, 2015)*

2.2 Laboratory Test

Standard Proctor Compaction Test function to define the relationship between moisture content (□□□%) and soil density (γd, kN/m^3). Results obtained from the Standard Proctor Compaction Test are optimum water content ($\square_{opt}$) and optimum dry content weight (γ_{dopt}). The parameter of the optimum water content value is used for suction soil testing. This test is to determine the effect of the drying process or the wetting process on peat soil suction value. ASTM D 5298-03 is a standard testing method for measuring soil suction using filter paper (Fig 3). The Whatman42 filter paper type is used for this test.



(a) (b)

Fig. 3*. Filter paper test*

The paper filter method of this research is a testing technique that takes advantage of filter paper or paper filter as the primary medium of suction power measurement in soil suction testing. Filters paper filter paper first in oven for at least 16 hours. Then filter paper filters are placed in plastic boxes and stored in a desiccator until use. After preparing the filter paper to be used, the suction measurement can be performed, including two measuring ways: the total suction measurement and the measurement of suction matric. 200-400 grams of peat soil samples were placed on sample containers. Soil sample filling in the sample container is fully cultivated to reduce equilibrium time and minimize the suction change in the soil. The equilibrium suction when the suction measurement is performed by closing the sample container and sealing it with an elastic and adhesive plastic electrical insulation. Then save the sealed sample container into the insulated chest or closed insulation box, which is placed in the room temperature 20℃ with a variation in temperature 3℃. This suction equilibrium is done at least 7 days. Samples for testing of soil absorption of peat are molded from the Standard Proctor Compaction test results. The standard for the Standard Proctor Compaction test is ASTM D558-82. The Standard Proctor Compaction testing is used to knowing the value of optimum water content ($□_{opt}$) of peat soil. The percentage value of optimum water content used to know the value of the suction of peat soil that has having drying then rewetting process: 41% (W1), 42% (W2), 43% (W3), 44% (W4), 45% (W5), 46% (W6), 47% (W7), 48% (W8), and 49 % (W9). Several sample test items for each percentage of six samples. All tests were performed at the Soil Mechanics Laboratory of Civil Engineering, Faculty of Engineering, Sriwijaya University.

3 RESULTS AND DISCUSSION

3.1 Index Properties Test Results

The beginning identification of peat soil is based on the index properties and classification testing. The location of the soil sample is derived from the village III Banyu Urip, Regency of Banyuasin, South Sumatera province. The properties of the index and classification include determination of water content, density, soil weight, pore numbers, and classification. The index properties and classification results are presented in Table 1. The average water content (□) obtained from laboratory testing is 263.538%. Peat is known to have a low pH value, and its acidity tends to decline with depth. The test results showed that the average pH value was 3.353. Further, the result of other parameters of peat soil is the void ratio (eo) of 3.296, the average weight of a wet unit of 3,771 kN/m3 ranges between 8.30-15.50 kN/m3, and the weight of the average dry unit is 4.125 kN/m3. The type of peat soil is determined using the standard Mac Farlane and Von Post. Based on Mac Farlane, peat soil is classified as a fibrous peat soil. Meanwhile, according to Von Post, peat soil is including in the H4 category.

3.2 Standard Proctor Compaction Test Results

The standard compaction test curve for the village III Banyu Urip, Banyuasin Regency, South Sumatera Province can be seen in Fig. 4. Based on Figure 4, it can see the standard compaction test result for village III Banyu Urip peat soil obtained the optimum water content value ($□_{opt}$) and the optimum dry content weight value (γ_{dopt}) of 45 % and 0.954 kN/m^3.

TABLE 1

RESULT OF PEAT SOIL INDEX PROPERTIES AND CLASSIFICATION

No.	Results Test	Village III Banyu Urip
1	Water Content (□, %)	294.300
2	Specific Gravity (G_s)	1.799
3	Acidity pH)	3.160
4	Void Ratio (e_0)	3.092
5	Wet Unit Weigh ($□_b$, kN/m^3)	15.050
6	Dry UnitWeigh ($□_d$, kN/m^3)	4.132
7	Organic Content (OC, %)	77.400
8	Ash Content (AC, %)	22.610
9	Fiber Content (FC, %)	70.450
10	Von Post	H_4
11	Mac Farlane	Fibrous peat

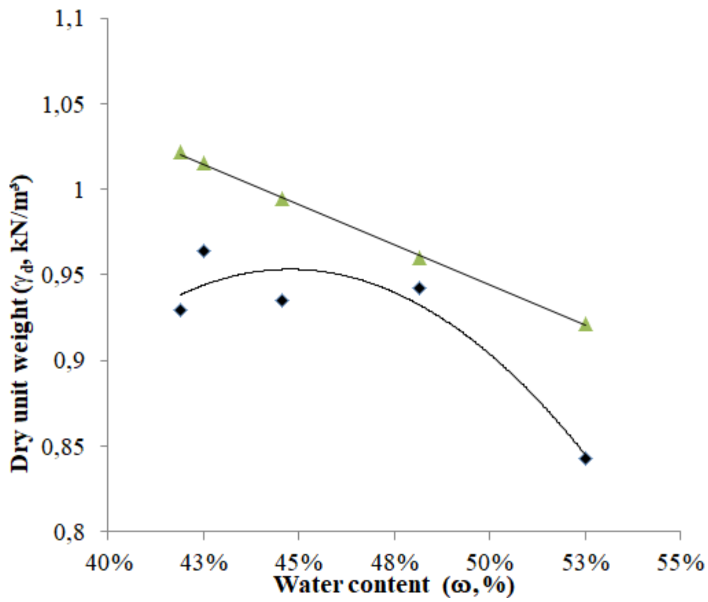


Fig. 1. *The standard compaction test result of a Dusun iii banyu urip peat soil*

3.3 Soil Suction Test Results

Soil suction testing on peat soil in this study was conducted under the reference of ASTM D 5298-03. To find out how much suction value is obtained in soil suction testing, then the sum of water content (□) on the filter paper Whatman42 in the calibrating. The ground suction value of the percentage of optimum water content ($□_{opt}$) of 45 % is shown in Table 2. As well as Fig. 5, Fig. 6 and Fig. 7 that illustrates the graph of ground relationship to water content □□□□□□□ degrees of saturation (Sr, %), and volumetric water content (θ, %) Result of peat soil suction testing.

TABLE 2

RESULT OF PEAT SOIL SUCTION AT AN OPTIMUM WATER CONTENT OF 45 % (W5 SAMPLE)

No.	Water Content (w, %)	Degree of Saturation (S_r, %)	Volumetric Water Content (Θ_v, %)	Soil Suction (Ψ), kPa
1	83.9358	100.0000	89.09749	1.00000
2	79.4616	98.2496	87.49121	5.02057
3	72.2390	94.2303	81.70075	8.207490
4	66.4797	90.5703	76.44218	10.70071
5	59.6024	84.8604	70.70827	15.40667
6	55.5171	82.0977	67.55780	20.19592
7	51.0965	79.1729	65.23885	37.42705
8	49.5082	78.3136	64.31393	60.38867
9	48.7259	78.0496	63.60220	92.43854
10	48.5171	78.0069	63.07263	119.08912
11	48.0965	78.0000	62.92672	128.93242
12	47.9082	77.9364	62.72133	139.57481
13	47.7259	77.9074	62.53531	160.32707

14	47.6287	77.8136	62.63928	194.00529

The resulting parameters of peat soil suction test are obtained, such as the degree of saturation (Sr) is 100% with the moisture content □□□□ of 83.93583%, volumetric water content (θ □□□□□□of 89.097498%, and soil suction value (ψ□) of 1,000 kPa. Figure 6 explains the graph of the relationship between the moisture content (□) of peat soil and the soil suction value (Ψ) for the W5 sample. Based on these graphs can be seen some points of the initial value of soil suction. The points are the AEV (Air Entry Value) value and the residual water content. From the figure of Ψ soil suction of 1.000 kPa with moisture content (□□ of 83.93583 % as the initial value of soil suction, Ψ1 of 8.207490 kPa with □1 is 72.23904 % as the AEV value, and Ψ2 amounted to 92.438541 kPa with □2 of 48.72590 % as residual water content value. Fig.7 shows a relationship degree of saturation (Sr) and peat soil suction (Ψ) of W5 samples. The parameters obtained are the initial value of soil suction. AEV (Air Entry Value) and volumetric water content value. Based on Fig. 7, Ψ (soil suction) results of 1.000 kpa with Sr of 100.00000 % as the initial value of soil suction testing. Ψ1 of 8.207490 kPa with an Sr1 of 94.23036 % as the AEV value and Ψ2 of 92.438541 kPa with Sr2 amounted to 78.04964 % as a residual water content value. The graph of the relationship between the volumetric water content (ϴv) and the peat soil suction (Ψ) of the W5 sample is described in Fig. 8. Fig. 8 shows a few points of initial ground suction testing: AEV (Air Entry Value) and residual water content. The result is that the Ψ soil is hissed at 1.000 kPa with ϴv by 89.097498 % as the initial value of soil suction testing, Ψ1 of 8.207490 kPa with θv1 of 81.700750 % as AEV value and Ψ2 of 92.438541 kPa with ϴv2 by 63.602206 % as the moisture content of residue. The result of peat soil suction with the filter paper testing method due to the effect of drying and wetting is shown in Table 3. According to Table 3, the Peat soil suction value (Ψ) ranges 28.58823-65.56742 of the kPa.

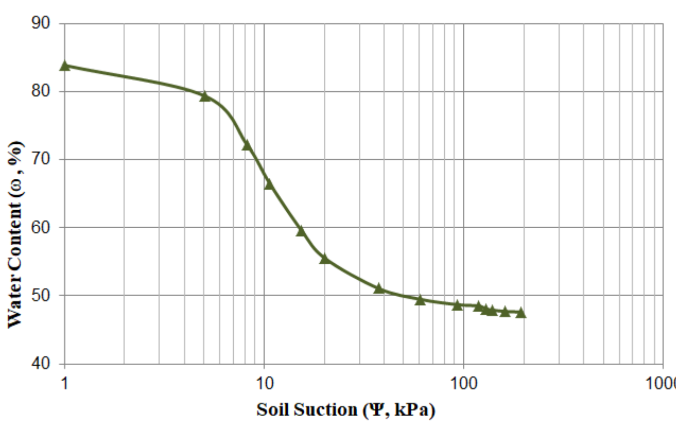


Fig. 5*. Graph of moisture content and peat soil suction in the W5 sample*

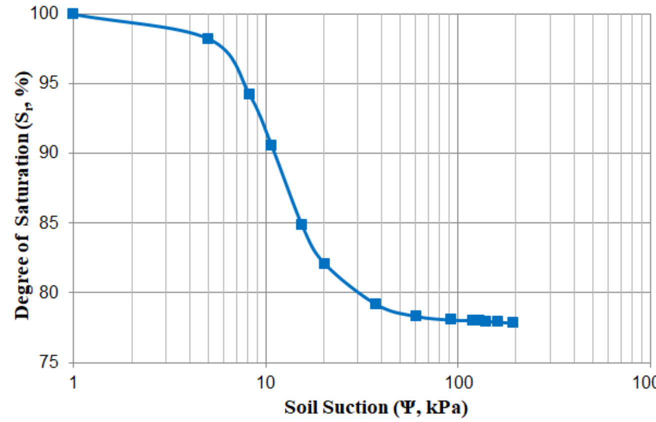


Fig. 6*. Graph of saturation and suction degree of peat soil on the W5 sample*

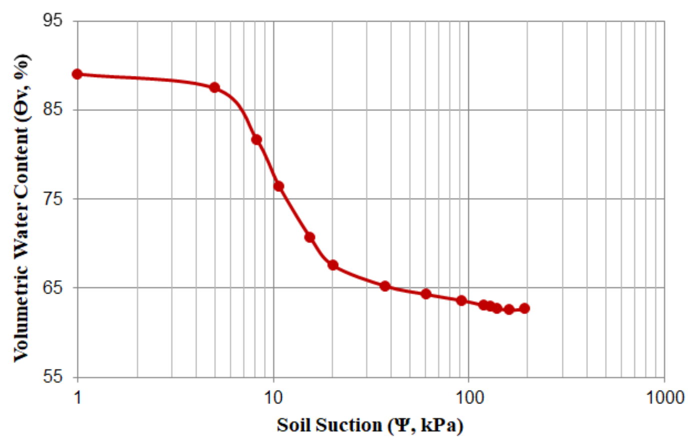


Fig. 7*. Graph of volumetric water content and peat soil suction link on w5 samples*

TABLE 3

RECAPITULATION OF PEAT SOIL SUCTION TEST DUE TO THE EFFECT OF DRYING AND WETTING

Sample		Soil Suction		
		Soil Suction Initial	Air Entry Value (AEV)	Residual Water Content Value
W1	□, %	74.7926	65.8574	46.3367
	Sr, %	100.000	92.8452	78.4965
	$ϴ_v$,%	84.0865	77.2255	62.2653
	Ψ, kPa	1.00000	9.3898	46.7561
W2	□, %	76.1031	67.2191	47.1485
	Sr, %	100.000	89.1341	79.0507
	$ϴ_v$,%	84.6347	77.7290	62.6712
	Ψ, kPa	1.00000	10.5039	56.6799
W3	□, %	78.9801	72.4658	48.9310
	Sr, %	100.000	94.2674	85.7510
	$ϴ_v$,%	84.6304	78.349	65.5933
	Ψ, kPa	1.00000	9.0014	43.4842
W4	□, %	82.5326	72.4658	49.5817
	Sr, %	100.000	92.9998	77.5059

	Θ_v,%	84.8891	77.9626	62.0559
	Ψ, kPa	1.00000	8.6120	65.5674
W5	□, %	83.9358	72.2394	51.0965
	Sr, %	100.000	94.23036	79.1729
	Θ_v,%	89.0975	81.70075	65.2388
	Ψ, kPa	1.00000	8.2074	37.4270
W6	□, %	85.5739	75.2425	53.4847
	Sr, %	100.000	94.4637	79.4109
	Θ_v,%	89.9765	83.0404	66.9537
	Ψ, kPa	1.00000	7.0329	32.0488
W7	□, %	86.0296	74.7845	53.2983
	Sr, %	100.00000	95.9096	80.3065
	Θ_v,%	90.9333	83.5137	67.3352
	Ψ, kPa	1.00000	8.3045	37.8666
W8	□, %	88.0030	77.1369	54.5209
	Sr, %	100.000	93.1052	78.4345
	Θ_v,%	90.5134	83.1286	67.0243
	Ψ, kPa	1.00000	8.0298	35.7413
W9	□, %	87.9598	77.094	54.4942
	Sr, %	100.000	89.4652	75.3590
	Θ_v,%	91.0444	83.6175	67.4175
	Ψ, kPa	1.00000	7.0538	28.5882

The suction graph with volumetric water content as well as the moisture content suction graph due to the wetting and drying influence on peat soil for sample P and W5 samples are shown in Fig. 8 and Fig. 9. In Figure 8, the value of the absorption of peat soil due to the wetting influence is higher than drying. As well as Fig. 9 shows the value of a peat soil suction due to smaller wetting influence than drying. The relationship between suction value and volumetric water content due to the wetting and drying influence on all peat soil samples is described in Fig. 10. Whereas Figure 11 shows the graph between the suction value and the moisture content due to the wetting and drying influence of all peat soil samples. Based on the figure, it can be concluded that the higher the water content is added then the suction value will be smaller. This condition is due to an empty cavity in peat soil pores.

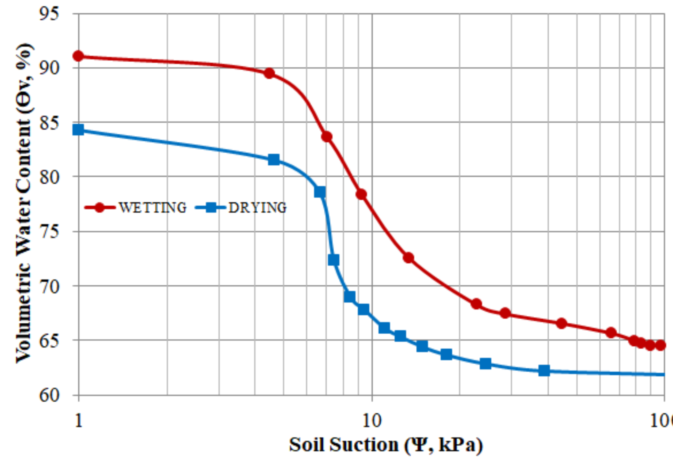


***Fig. 8**. Suction graph with volumetric water content due to the influence of wetting and drying on peat soil (sample P and W5 samples*

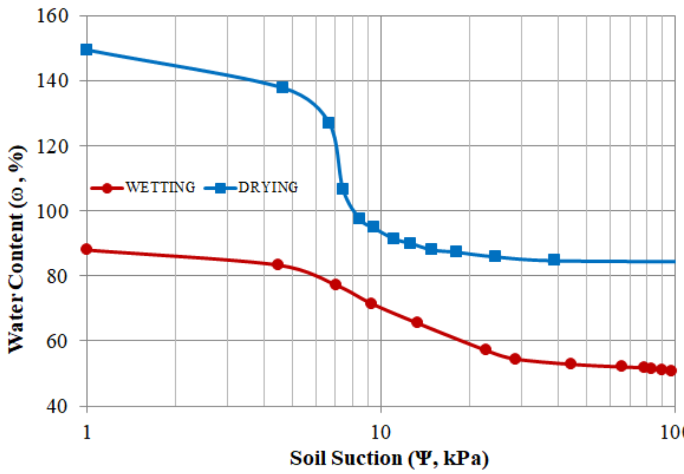


***Fig. 9.** Suction graph with moisture content due to wetting and drying effect on peat soil (sample P and W5 samples)*

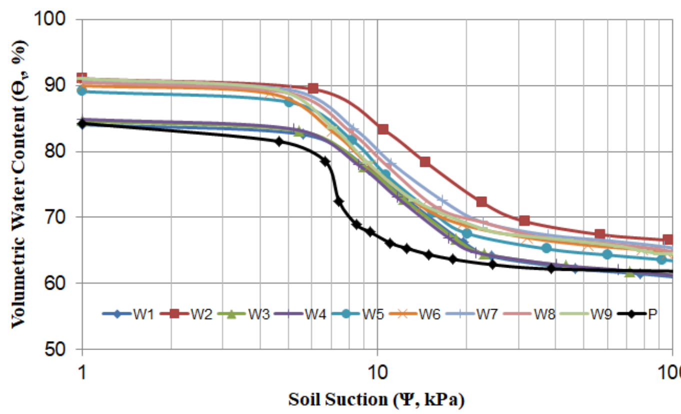


***Fig. 10**. Suction graph with volumetric water content due to wetting and drying influence on all peat soil samples*

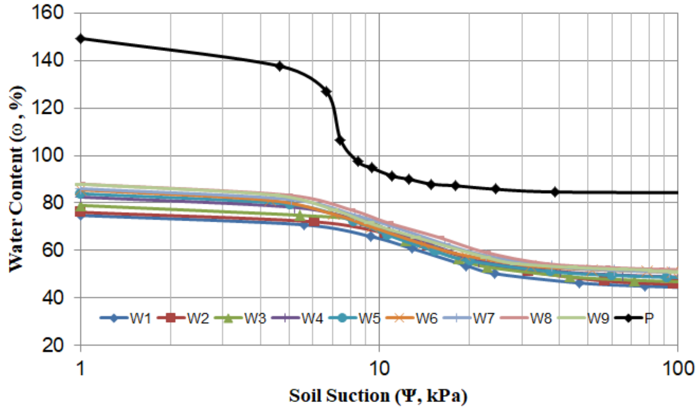


Fig. 11. *Suction Graph with moisture content due to wetting and drying influence on all peat soil samples*

Fig. 12 shows a graph of peat soil suction value due to the influence of wetting and drying. Based on Figure 10, the results of peat soil suction value (Ψ, kPa) are: sample P of 321.860454 [8], W1 sample of 46.75611, W2 sample of 56.67991, W3 sample of 43.48429, W4 sample of 65.56742, W5 sample of 37.42705, W6 sample of 32.04885, a W7 sample of 37.86667, a W8 sample of 35.74133, and a W9 sample of 28.58823. The absorption rate of peat soil due to drying is higher when compared to the absorption rate of peat soil due to wetting. Peat soil suction value is also obtained based on the calibration curve for Whatman42 Filter Paper. The suction rate of peat soil (Ψ, kPa) for W1 samples are 2.42196 (Yulindasari), 1.82786 (ASTM D5298), 0.15864 (Chandler and Gutierrez), 1.99227 (Chandler et al.,), 1.90365 (Oliveira and Marinho). The recapitulation of calculated results according to the calibration curve can be seen in Table 4. The research result from [9], is about FPM. FPM is a method to use to get the parameter matric suction for soils in a range of suction. The parameter using the value of dry density = 95 % MDD. Another results from [5] also using the filter paper method. This technique had been used for soil-suction measurement. The results shows the value of suction with an inflection point occurring at 60 kPa < s < 100 kPa.

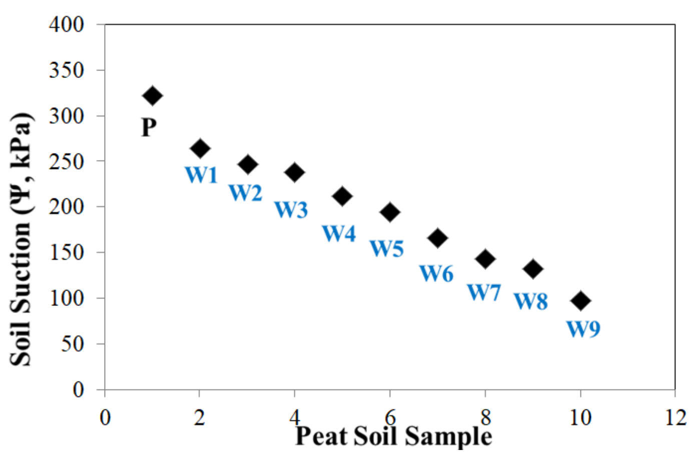


Fig. 12. *Graph of peat soil suction value based on wetting and drying process*

TABLE 4

COMPARISON OF PEAT SOIL SUCTION VALUE BASED ON A CALIBRATION CURVE FOR WHATMAN42 FILTER PAPER

Soil Suction (Ψ, kPa)	Yulindasari (2018)	ASTM D5298	Chandler, et. al.	Oliveira and Marinho
P	2.2221	1.2787	1.2784	1.2772
W1	2.4219	1.8278	1.9922	1.9036
W2	2.3914	1.8176	1.9336	1.8919
W3	2.3762	1.7951	1,9336	1.8663
W4	2.3261	1.7674	1.8862	1.8346
W5	2.2878	1.7690	1.8888	1.8365
W6	2.2199	1.7366	1.8360	1.7996
W7	2.1544	1.7401	1.8415	1.8035
W8	2.1183	1.7246	1.8170	1.7859
W9	1.9860	1.7250	1.8176	1.7863

Table 4 explains the comparison of soil suction values based on the Whatman42 Filter Paper curve. The value of peat soil suction in the sample P was obtained: 2.2221 kPa (Yulindasari), 1.2787 kPa (ASTM D5298), 1.2784 kPa (Chandler et al.), and 1.2772 kPa (Oliveira and Marinho). Based on this table, it can be concluded that the suction value of the P sample is higher when compared to the others.

4 CONCLUSION

Conclusions that can be taken from the research results on the suction of peat soil as follows:

1. The value of suction (Ψ, kPa) of peat soil due to the influence of wetting and drying is obtained at sample P of 321.860454 kPa, the W1 sample of 46.75611 kPa, the W2 sample of 56.67991 kPa, the W3 sample of 43.48429 kPa, the W4 sample of 65.56742 kPa, the sample W5 37.42705 kPa, a W6 sample of 32.04885 kPa, a W7 sample of 37.86667 kPa, a W8 sample of 35.74133 kPa, and a W9 sample of 28.58823 kPa.
2. The absorption rate of peat soil due to drying is higher when compared with the absorption rate of peat soil due to wetting.

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