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# HYDRAULIC CONDUCTIVITY AND COMPRESSIBILITY CHARACTERISTICS OF FIBROUS PEAT

Yulindasari Sutejo
*PhD Student*
*Civil Engineering Departement, Faculty of Engineering,*
*Universitas Sriwijaya, 30662 Ogan Ilir, Indonesia*
*Email: yulindasari@unsri.ac.id*

H. Anis Saggaff, MSCE.
*Corresponding author*
*Civil Engineering Departement, Faculty of Engineering,*
*Universitas Sriwijaya, 30662 Ogan Ilir, Indonesia*
*Email: anissaggaff@yahoo.com,*

Wiwik Rahayu, DEA.
*Civil Engineering Departement, Faculty of Engineering,*
*Universitas Indonesia, 16424 Depok, Indonesia*
*Email: wrahayu@eng.ui.ac.id*

Hanafiah, MS.
*Civil Engineering Departement, Faculty of Engineering,*
*Universitas Sriwijaya, 30662 Ogan Ilir, Indonesia*
*Email: hanafiah_dr@yahoo.com.sg,*

## ABSTRACT

*This research was studying the mechanical characteristics of fibrous based on hydraulic conductivity/permeability and compressibility tests. The samples of the test were obtained by the block sampling method. The location of sampling was on Banyuasin Regency, South Sumatra. The permeability tests using constant head method was used for hydraulic conductivity parameter of fibrous peat soil. And consolidation tests using Oedometer test was also used to find out compressibility characteristics of fibrous peat soil. The hydraulic conductivity test results are horizontal hydraulic conductivity ($k_h$)=6,13x10$^{-4}$ cm/s and vertical hydraulic conductivity ($k_v$) = 3.76.10$^{-4}$ cm/s. The ratio of $k_h/k_v$ (20$^o$C) about 2.04. The coefficient of $k_h$ is greater than $k_v$, this is due to the effect of fiber arrangement such as the roots of peat soil. Beside of that, the consolidated test results based on compression index parameters ($c_c$) are 1,428 and 1,215. The consolidation coefficient parameters ($c_v$, m$^2$/year) were 13,671 (50 kPa), 11,511 (100 kPa), 8,268 (200 kPa), and 3,312 (400 kPa) from the Banyu Urip Dusun III sample. The results of parameter $c_v$ can be affected by applied the pressure where the greater the pressure the smaller the value of $c_v$.*

Keywords: Hydraulic conductivity, compressibility, fibrous peat.

## INTRODUCTION

Peat is a soils that have a lot of organic content, in cold and humid environments where dead hygrophytes have been deposited over a long period of time without fully decomposing. In fact, there are about 1.6 million Ha is deposit in the East of South Sumatera. The distribution of peat in the Banyuasin regency is 200.000 Ha. The characteristics of peat soil such as: low shear strength, large high ground water level, and high compressibility. These characteristics become problems with civil engineering structures of peat deposits. The construction of structures of peat deposits to tend to result in sliding failure or dramatic settlement of substrata. Peat soil can be characterized as various technique depending on the objectives for which the peat soil is being explained. Changes and shrinkage of peat land deposit from time to time is always happening. Changes in the hydraulic conductivity/permeability and compressibility properties of peat soil can be found in the Banyuasin regency area of South Sumatra province. Therefore the research issues and research problems with this research were to study the behaviour of peat as results from the term hydraulic conductivity/permeability and compressibility test results.

The hydraulic conductivity of the soil is a function of three components: (1) ground water pressure, (2) water content, and (3) soil moisture retention. The hydraulic conductivity of the soil is needed for understanding transport processes, water to balance, and irrigation (Sarki, 2014). The hydraulic conductivity/ permeability of peat is controlled by the original structure, engineering characteristics, high of decomposition, and density (Huat, 2014). The results of hydraulic conductivity (k) of peat soil can be as sand: 10$^{-5}$-10$^{-4}$ m/s. The value of initial coefficient of vertical hydraulic conductivity from 10$^{-5}$-10$^{-8}$ m/s (Wong, 2009). The permeability of peat soil can be affected by mineral content, the presence of gas, degree of decomposition, chemistry, and void ratio. Previous researcher (Huat, 2011) reported the physical properties and hydraulic properties of peat soil. The results of this research describe that peat soil impacted by the presence of soil pores so the permeability of peat soils is medium.

Two permeabilities testing methods is: (1) the falling head tests method, and (2) the constant head test method. The falling head test method is used for soil types that are less permeable. If the soil belongs to a permeable type so the permeability test can be used constant head method. The peat soil is permeable. So the permeability testing for this soil suggested use constant head method. According to Sutejo (2016) the coefficient of vertical permeability ($k_v$) is $5.86.10^{-4}$ m/s and the coefficient of horizontal permeability ($k_h$) is $8.19.10^{-4}$ m/s. Yulindasari (2006) reported fibrous peat has horizontal permeability ($k_h$) more than vertical permeability ($k_v$) from Ogan Ilir sample. The hydraulic conductivity of the soil describes the nature of water flow through the soil. Parameters of hydraulic conductivity of the soil are commonly used to analyze seepage in construction eg: (a) sheet pile walls, (b) earth dams, (c) ponds, and (d) landfills. Commonly, the permeability of the deposit decreases to increasing depth (decreasing void ratio), and the state of bio degradation (Kelly, 2013). From previous researcher stated that coefficient of horizontal permeability ($k_h$) usually more than in coefficient of vertical permeability ($k_v$) for fibrous peat (Huat, 2014).

The constant head method had been used in this research. A steady state head condition on permeability tests using constant head method can make water flow in the soil. The volume of flow water can be calculated based on period of time. Parameter of hydraulic conductivity (k) using constant head method has been calculated using the following equation:

$$k = \frac{Q\ .\ L}{A.\ t.\ h} \tag{1}$$

Where Q = the volume of water discharged, A = the cross-sectional area, L = distance, h = the head difference, t = the total time of discharged.

The vertical coefficient of hydraulic conductivity ($k_v$) can be estimated based on the analysis of the consolidation test. The formula $k_v$ is:

$$k_v = c_v.\ m_v.\square\square_w \tag{2}$$

Where, $m_v$ is coefficient of volume compressibility and $c_v$ is coefficient of rate of consolidation.

Furthermore, compressibility of clay soil characteristics is not same with fibrous peat soil. In fibrous peat soil, Compressibility generally divided into two processes: (1) primary consolidation, and (2) secondary consolidation. Peat soil compressibility behavior is influenced by several things such as water content, void ratio, the fiber content, and permeability. Peat soil parameters such as weight units have the same value as water. The value of effective stress ($\square'_p$) usually small. So, at the time of consolidation testing, these parameters are sometimes difficult to analyze. In addition, to analyze parameters such as time of beginning of secondary compression ($t_p$) was also very difficult. This is because the consolidation process is usually occuring quickly. The parameters obtained from the consolidation test are: compression index ($c_c$), coefficient of volume compressibility ($m_v$), recompression index ($c_r$), and coefficient of axial compressibility ($a_v$).

The consolidation parameters can be determined from consolidation test (Oedometer test). The consolidation parameters such as: compression index ($c_c$), the starting time of secondary compression ($t_p$), the ending time secondary compression ($t_s$), the rate of secondary compression ($c_\square$), and coefficient of rate of consolidation ($c_v$). In the consolidation test (Oedometer test), the fitting graph method is used to obtain the coefficient of rate of consolidation ($c_v$) parameter. The $c_v$ parameter was obtained based on the analysis of Cassagrande's (the logarithmic time) and Taylor's (the square root time) method. Terzaghi consolidation theory is basic theory of data analysis so that the results obtained in accordance with the tests performed. The curve of Oedometer tests results is shown in Figure 1.

Publish data on $c_c$ ranges of 2-15. Ajlouni (2000) reported the decrease in $c_v$ that was affected by the load during the consolidation testing so that the permeability results was reduced. Beside of that, Yulindasari (2006) determined the results from Oedometer test such as: $c_c$=3.253, $c_v$=2.074 $m^2$/year (under consolidation pressure 25 kPa), and $c_v$ =0.850 $m^2$/year (under consolidation pressure 400 kPa). Generally, peat samples for testing in the soil mechanics laboratory are disturbed samples and undisturbed samples. This research had been used a block sampling procedure for undisturbed samples based on ASTM D 7015-04 standard. This peat soil sample was taken at shallow depth. Undisturbed block samples had been used to determine the hydraulic conductivity/permeability and compressibility characteristics of fibrous peat.

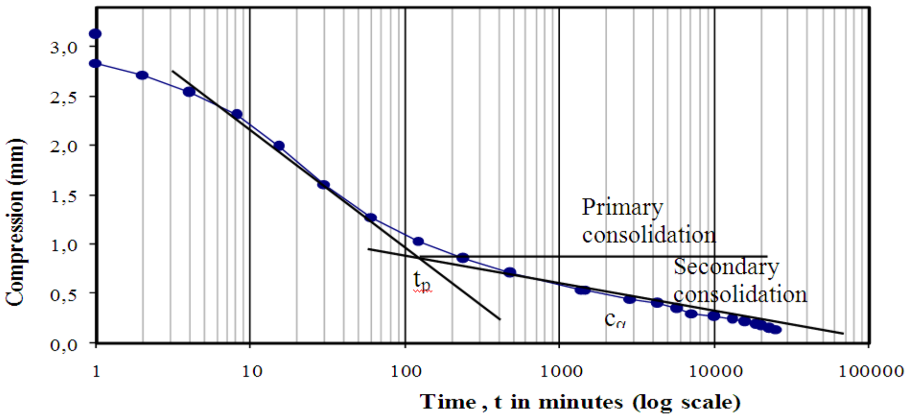



**Figure 1: The time versus compression curves**

**METHODOLOGY**

Laboratory soil tests are performed to determine the engineering characteristics of peats. Generally tests use the disturbed samples of peat soil are physical and chemical properties. The test such as natural water content (w, ASTM D 2974-87), unit weight (g), specific gravity ($G_s$, ASTM D 854-14), initial void ratio ($e_o$), and acidity (pH, ASTM D 2976-71), fiber content (FC, ASTM D 1997-13), organic content (OC, ASTM D 2974-14), and ash content (AC, ASTM D 2974-14). The results of physical and chemical properties of fibrous peat soil are derived from the results of previous studies (Sutejo, 2017).

And for this research, an extensive laboratory testing will be conducted on undisturbed samples using block sampling method of peat deposits for the purpose of studying hydraulic conductivity and compressibility characteristics of fibrous peat. Block sampling method is selected because peat deposits to extend over the groundwater level and the water content is high. The properties of hydraulic conductivity/permeability and fibrous peat soil compressibility were analyzed in this research. Consolidation tests to help determine characteristics of consolidation settlement. Permeability or hydraulic conductivity tests had been use to know the process of the water in the fibrous peat soil either through the pores of macro and micro pores either in the horizontal or vertical direction.

Location of fibrous peats soil sampling in Banyuasin Regency, South Sumatra, Indonesia. The location of hydraulic conductivity samples is KTM Telang Mulya Sari, Dusun I Banyu Urip, Dusun III Banyu Urip, and Desa Gasing Tanjung Api-Api. And the locations of compressibility samples are Dusun I Banyu Urip and Dusun III Banyu Urip. Figure 2 shows the location of peat soil sampling.

**Figure 2: Location of sampling**

In this research, the block sampling method had been selected. The size of tube for the test Consolidation test isdiameter (D) = 15 cm diameter and height (h) = 30 cm). Beside of that, the size of tube for the test hydraulic conductivity/permeability tests are diameter (D) = 15 cm diameter and height (h) = 15 cm). Hydraulic conductivity measurements were carried out on a sample using constant head method. Parameter of horizontal permeability ($k_h$) and vertical permeability ($k_v$) obtained from this method. The following is the procedure of examination of hydraulic conductivity of peat soil in accordance with ASTM D 2434-68 standard.

Hydraulic conductivity testing conducted in laboratory of soil mechanic of Civil Engineering Department of the Polytechnic Sriwijaya Palembang. The sample of permeability tests height (H) 93.5 cm high by permeameter tests tube (L) 15 cm. The temperature will increase the viscosity decrease and increase permeability. Standard temperature in determining the permeability coefficient is 20˚C. The parameters results from hydraulic conductivity test such as vertical coefficient of hydraulic conductivity

($k_v$) and horizontal coefficient of hydraulic conductivity ($k_h$). From the results of consolidation testing, permeability parameters will be obtained ($k_v$).

Moreover, the parameters of compressibility of peat soil characteristics can be estimated by consolidation testing (Oedometer test). Consolidation tests in laboratory of soil mechanic of Civil Engineering Department of Universitas Sriwijaya. Procedures on consolidation testing according to ASTM D 2435-96 standard. Sample size on Oedometer test were sample height (h) = 2 cm and sample diameter (d) = 5 cm. The load increment ratio (LIR) in this test was one. As well as the pressure (P, kPa) given in the test were 50, 100, 200, and 400. At each load given for one sample will be maintained for two weeks (based on standard). But in this tests, changed to for 1 week. The time intervals had been used during the reading of test data were as follows (minutes): 0.25, 0.50, 1, 2, 8, 15, 30, 60, 120, 240, 480, 1440, 2880, 4320, 5760, 7200, 8640, and 10080. The number of samples for one location is 6 samples.

There are two relationship curves can be analyzed from consolidation test results. The first curves of the relationship between time and compression. The second curve describes the results of the analysis of the logarithmic pressure and the void ratio (e-log p' curve). Based on the logarithmic curve of time-compression curve methods, the compression parameter of the coefficient of rate of consolidation ($c_v$) is obtained. The methods had been used to obtain the parameter were (1) the square root time method (Taylor's method), and (2) the logarithmic time method (Cassagrande's method). The compressibility parameters derived from other consolidation tests such as: (a) the beginning of secondary compression ($t_p$), (b) the time of secondary compression ($t_s$), (c) the rate of secondary compression ($c_{\square}$), and (d) compression index ($c_c$).

**RESULTS AND DISCUSSION**

Soil properties testing and peat soil classification have been done in this research. The results of this test were taken from previous researcher. Table 1 presented the average results of index properties, and classification tests from Banyuasin regency. The average water content (□) obtained from laboratory tests is 258.100 %. The value of average specific gravity ($G_s$) obtained 1.80. The average organic content of peat is found at 78.70 % and the average fiber content 73.60 %. According to Von Post scale, peat soils are classified as fibrous peat. Based on Von Post, the degree of decomposition was $H_4$ scale. While, the classification of peat based on ASTM D 4427-84 is highly acidic. If compared with the results of previous research, all the results of the index properties and classification on peat soils result is still in range of publication data.

**Table 1: Summary of index properties and classification**

| No. | Parameter | Range Published Data | Average Results |
|---|---|---|---|
| 1. | Water Content (□) | 200-700 % | 258.100 % |
| 2. | Acidity (pH) | 3.0-4.5 | 3.26 |
| 3. | Specific Gravity ($G_s$) | 1.38-1.90 | 1.80 |
| 4. | Dry unit weight ($\square_d$) | - | 4.10 kN/m$^3$ |
| 5. | Void Ratio ($e_0$) | 3-15 | 3.22 |
| 6. | Organic Content (OC) | > 80 % | 78.70 % |
| 7. | Fiber Content (FC) | > 20 % | 73.60 % |
| 9. | ASTM D 4427-84 | less than 4.5 | highly acidic |
| 10. | Von Post | $H_1$- $H_4$ | $H_4$ |

The summary of permeability of peat soil showed in Table 2. And the value of coefficient hydraulic conductivity results from Dusun III Banyu Urip can be seen in Table 3. From the Table 2, the average of hydraulic conductivity coefficients from four locations was $3.76.10^{-4}$ cm/sec ($k_v$ 20$^o$) and $6.13.10^{-4}$ cm/sec ($k_h$ 20$^o$). Dusun I Banyu Urip has the highest value pore size that is equal to 1470 nm according to Scanning Electron Microphotograph (SEM) analysis and also has the highest of void ratio value that is 3.445. Because if pore size is large and void ratio is high then the value of permeability coefficient is high too. Therefore, peat soil classification was categorized having medium hydraulic conductivity. With this behaviour, it can be concluded that peat soil has good drainage. Figure 3 and 4 shows the graph horizontal hydraulic conductivity ($k_v$ and $k_h$) with hydraulic gradient (i).

**Table 2: The summary of hydraulic conductivity of peat soil**

| Parameter (average) | KTM Telang Mulya Sari | Dusun I Banyu Urip | Dusun III Banyu Urip | Desa Gasing Tanjung Api-Api |
|---|---|---|---|---|
| $k_v$ (cm/s) (.10$^{-4}$) | 6,07 | 3,40 | 3,10 | 4,52 |
| $k_v$ (cm/s) 20$^o$C(.10$^{-4}$) | 5,28 | 2,92 | 2,86 | 3,96 |
| $k_h$ (cm/s) (.10$^{-4}$) | 8,40 | 6,68 | 6,80 | 7,04 |
| $k_h$ (cm/s) 20$^o$C(.10$^{-4}$) | 7,07 | 5,69 | 5,86 | 5,91 |

**Table 3: Hydraulic conductivity results from Dusun III Banyu Urip**

| Parameter | H (cm) | L (cm) | i | T (°C) | ηT (g/cm.s) | Q (cm$^3$) | T (s) | $k_V$ (cm/s) .10$^{-4}$ | $k_{20}$ (cm/s) .10$^{-4}$ |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Vertical Hydraulic Conductivity ($k_v$) | 93.5 | 15 | 6.233 | 26 | 0.00874 | 250 | 3578,82 | 2,54 | 2,21 |
| | 93.5 | 15 | 6.233 | 26 | 0.00874 | 250 | 4116,00 | 2,21 | 1,92 |
| | 93.5 | 15 | 6.233 | 26 | 0.00874 | 250 | 4806,82 | 1,89 | 1,64 |
| | 93.5 | 15 | 6.233 | 27 | 0.00855 | 250 | 1843,46 | 4,93 | 4,19 |
| | 93.5 | 15 | 6.233 | 27 | 0.00855 | 250 | 2006,81 | 4,53 | 3,85 |
| | 93.5 | 15 | 6.233 | 27 | 0.00855 | 250 | 2100,59 | 4,32 | 3,68 |
| Parameter | H (cm) | L (cm) | i | T (˚C) | ηT (g/cm.s) | Q ($cm^3$) | T (s) | $k_h$(cm/s) $.10^{-4}$ | $k_{20}$ (cm/s) $.10^{-4}$ |
| Horizontal Hydraulic Conductivity ($k_h$) | 93.5 | 15 | 6.233 | 27 | 0.00855 | 250 | 566.32 | 1.60 | 1.60 |
| | 93.5 | 15 | 6.233 | 27 | 0.00855 | 250 | 2056.24 | 4.42 | 3.76 |
| | 93.5 | 15 | 6.233 | 27 | 0.00855 | 250 | 1564.93 | 5.80 | 4.94 |
| | 93.5 | 15 | 6.233 | 26 | 0.00874 | 250 | 1573.15 | 5.77 | 4.91 |
| | 93.5 | 15 | 6.233 | 26 | 0.00874 | 250 | 2563.00 | 3.54 | 3.01 |
| | 93.5 | 15 | 6.233 | 26 | 0.00874 | 250 | 2006.81 | 4.53 | 3.85 |

Based on the research of Kelly (2013), the values of the coefficient of hydraulic conductivity for biodegraded ($H_4$) peat material was $10^{-9}$-$10^{-10}$ m/s. This result is lower than the value in the field. The calculated hydraulic conductivity coefficient was founded comparative to the effective stress on a logarithmic plot. Sutejo (2016) reported the range of value permeability coefficient were $k_v$= 5.30x$10^{-4}$-6.24x$10^{-4}$ cm/sec and and $k_h$= 7.14x10-4-9.93x$10^{-4}$ cm/sec. The coefficient of permeability based on Wang (2015) were k=2.99x$10^{-6}$ cm/sec (depth 6.2-6.4 m) and k=6.88x$10^{-6}$ cm/sec (depth 8.8-9.0 m). The result of permeability coefficient from the present study is greater than previous researcher.

The mechanical characteristics based on consolidation tests had been done using Oedometer test. The standar procedures outlined in ASTM D 2435-96. A consolidation test had been used to estimate the effect of loading processes on fibrous peat soil samples. Figure 5 shows the results of the consolidation tests in Dusun III Banyu Urip. Based on the figure, it can be seen that the primary consolidation process takes place in a short time but still influences the compressibility result of the characteristics of fibrous peat soil. Consolidation parameters obtained by using Cassagrande's method based on the time-compression curves were: (a) the end of primary consolidation ($t_p$), (b) the coefficient of secondary compression ($c_{\square}$), (c) the end of secondary compression ($t_s$), and (d) the coefficient of rate of consolidation ($c_v$). The average value of the coefficient of rate of consolidation ($c_v$) for each pressure show in Table 4.

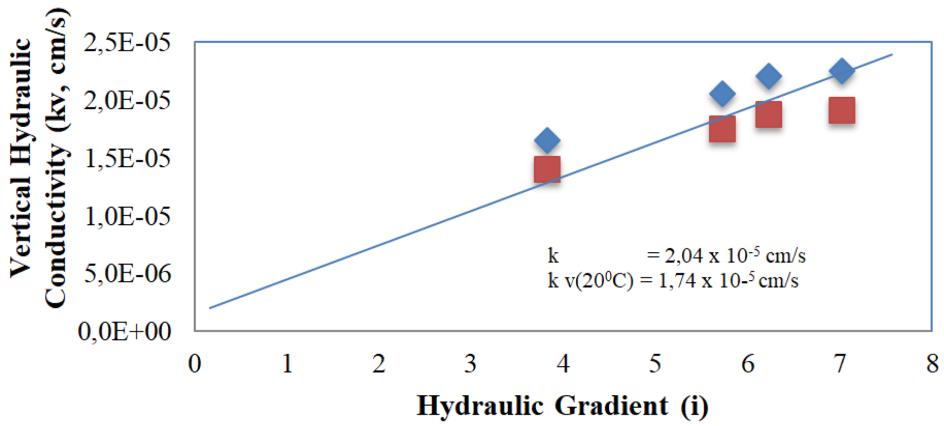



**Figure 3: Vertical hydraulic conductivity ($k_v$) versus hydraulic gradient (i) from Dusun III Banyu Urip sample**

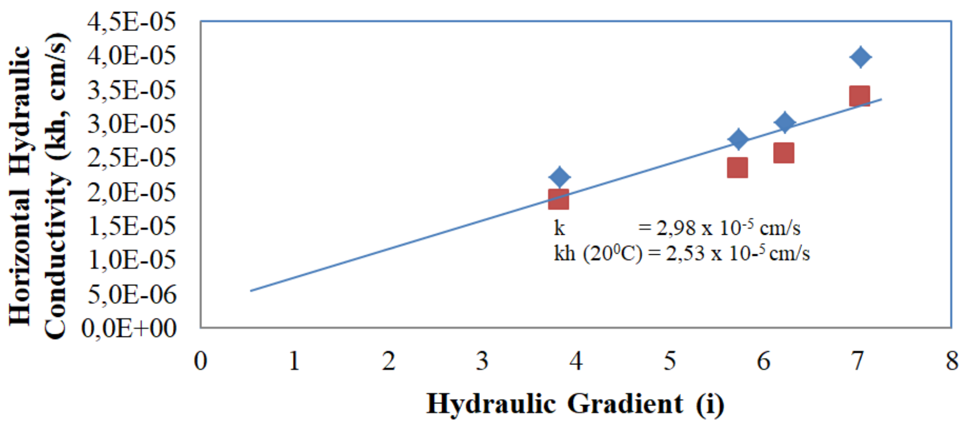



**Figure 4: Horizontal hydraulic conductivity ($k_h$) versus hydraulic gradient (i) from Dusun III Banyu Urip sample**

Based on the research of Kelly (2013), the values of the coefficient of hydraulic conductivity for biodegraded ($H_4$) peat material was $10^{-9}$-$10^{-10}$ m/s. This result is lower than the value in the field. The calculated hydraulic conductivity coefficient was founded comparative to the effective stress on a logarithmic plot. Sutejo (2016) reported the range of value permeability coefficient were $k_v$= 5.30x$10^{-4}$-6.24x$10^{-4}$ cm/sec and and $k_h$= 7.14x10-4-9.93x$10^{-4}$ cm/sec. The coefficient of permeability based on Wang (2015) were k=2.99x$10^{-6}$ cm/sec (depth 6.2-6.4 m) and k=6.88x$10^{-6}$ cm/sec (depth 8.8-9.0 m). The result of permeability coefficient from the present study is greater than previous researcher.

**Table 4 The average value of $c_v$ for each pressure**

| Pressure (p', kPa) | Rate of consolidation ($c_v$, $m^2$/year) | | | |
|---|---|---|---|---|
| | Cassagrande's Method | | Taylor's Method | |
| | Dusun I Banyu Urip | Dusun III Banyu Urip | Dusun I Banyu Urip | Dusun III Banyu Urip |
| 50 | 12.260 | 13.671 | 18.048 | 18.098 |
| 100 | 9.725 | 11.511 | 10.271 | 8.615 |
| 200 | 8.425 | 8.268 | 8.911 | 7.226 |
| 400 | 3.522 | 3.312 | 3.318 | 3.086 |

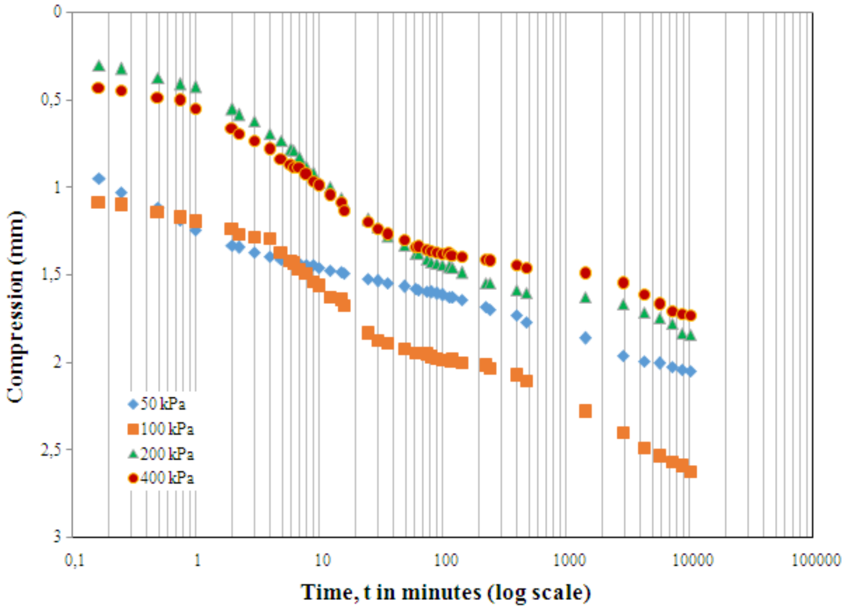



**Figure 5: Relationship curve between compression-logarithmic of time from consolidation test based on Cassagrande's method (Dusun III Banyu Urip)**

Table 5 described the compressibility parameters obtained from consolidation curves. Figure 6 shows the results of analysis based on Cassagrande's method. Figure 7 is an analysis of Taylor's method. Figures 6 and 7 were taken from the location of Dusun III Banyu Urip sample. The coefficient of rate of consolidation ($c_v$, $m^2$/year) based on Cassagrande's method from Dusun III Banyu Urip were 3.671 (50 kPa), 11.511(100 kPa), 8.268 (200 kPa), and 3.312 (400 kPa). Figure 6 (Cassagrande's method) explains that the Rabbee (2012) had been studying the compressibility parameter. These study about reversed again organic peat soil in Khulna region (Bangladesh). The variation of the coefficient of rate of consolidation ($c_v$) with the increase of applied pressure for varying organic contents was evaluated. The value of coefficient of rate of consolidation ($c_v$) increases: 0.0135 to 0.1200 $cm^2$/s for the organic content of 35 % (consolidation pressure from 25 to 800 kPa). Gofar (2007) show the results $c_v$ decreases because of increasing consolidation pressure.

**Table 5: Results of consolidation test based on Cassagrande's method**

| Parameter | Pressure (p', kPa) | Cassagrande's Method | |
|---|---|---|---|
| | | Dusun I Banyu Urip | Dusun III Banyu Urip |
| End of primary consolidation ($t_{100}$ = $t_p$, minutes) | 50 | 50 | 55 |
| | 100 | 36 | 44 |

| | | | |
|---|---|---|---|
| | 200 | 29 | 31 |
| | 400 | 24 | 20 |
| Coefficient of secondary compression (c□) | 50 | 0.064 | 0.114 |
| | 100 | 0.135 | 0.212 |
| | 200 | 0.248 | 0.376 |
| | 400 | 0.119 | 0.187 |
| End of secondary compression ($t_s$, minutes) | 50 | 2613 | 4025 |
| | 100 | 2058 | 2825 |
| | 200 | 1800 | 2183 |
| | 400 | 1438 | 1800 |
| Compression Index ($c_c$) | | 1.428 | 1.215 |

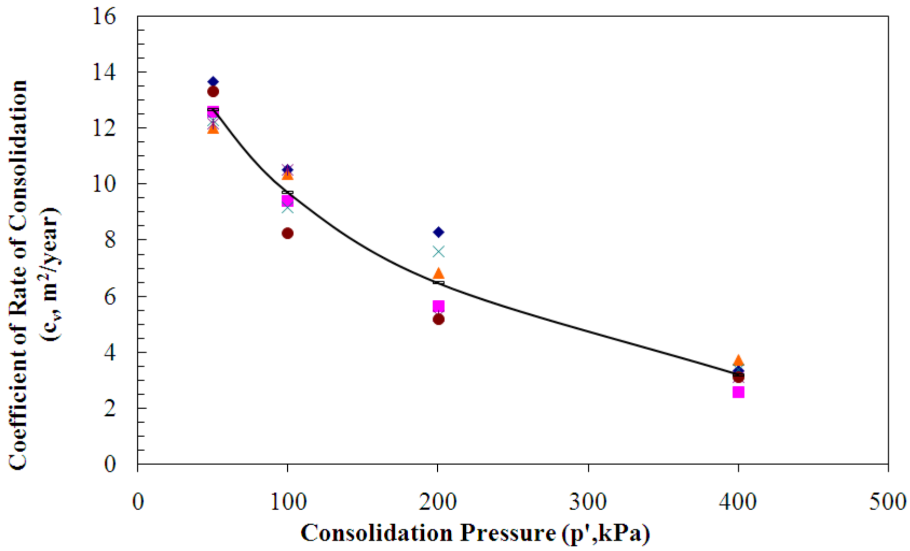



**Figure 6: Relationship curve between consolidation pressure - coefficient of rate of consolidation based on Cassagrande's method (Dusun III Banyu Urip)**

The value of $t_p$ is decreasing nonlinearly with the consolidation pressure. Beside of that, the average value of this $t_s$ versus pressure based on Table 5, also show the value of this $t_s$ is decreasing with the consolidation pressure. The average compression index ($c_c$) in the Dusun I Banyu Urip 1.428. And the average $c_c$ in the location of Dusun III Banyu Urip is 1.215. The value obtained from the Oedometer test conducted on fibrous peat soil from Banyuasin is slightly lower than published is in the range 6-9 (Ajlouni, 2000). Johari (2016) reported the value of the compression index ($c_c$) was 2.68 for peaty soil from Parit Nipah Darat, Johor. This test uses the undisturbed sample and 1-D Oedometer consolidation tests. High compression index ($c_c$) values explain that the settlement was also high. The parameter of compression index ($c_c$) based on Oedometer test has been performed by researchers Duraisamy (2011). The results of this test follow: (a) fibric ($c_c$ = 1,453-3,211), (b) hemic ($c_c$ = 1,290-2,780), and (c) sapric ($c_c$ = 1,150-2,440). Based on the study literature, the range of values for cc is 5-10. Thus if this parameter compared with the study Duraisamy (2011), then the $c_c$ result was smaller. The parameters of the coefficient of secondary compression (c□) were in the range of 0.08-0.09 for fibric, hemic and sapric peat soil. This range of values explains that at the time of the consolidation process, peat soil has high secondary compressibility.

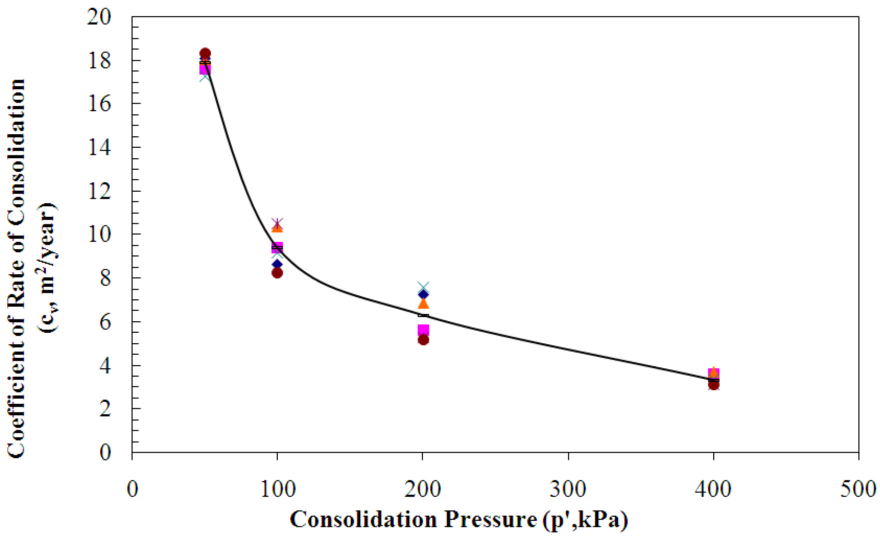
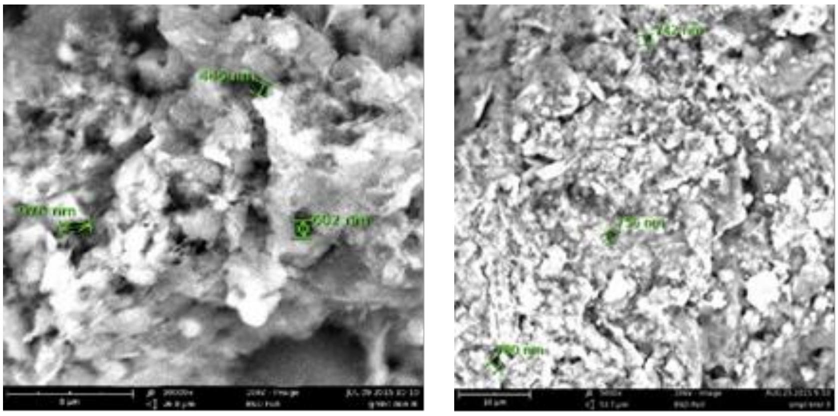



**Figure 7: Relationship curve between consolidation pressure - coefficient of rate of consolidation based on Taylor's method (Dusun III Banyu Urip)**

Analysis of the composition of fibrous peat soil structure is an important factor for determining the orientation of the fibers. The presence of fibers in fibrous peat soils is affected by several factors: rootlets, fractures, pockets, and fissures of organic material. These factors may result the parameter of hydraulic conductivity/permeability in larger value. The addition of load to the consolidation process also affects the presence of peat soil fiber orientation so it can reducing the pore size of the peat soil. In addition, it also causes the value of the vertical permeability coefficient is reduced.

Figure 8 shows the results of Scanning Electron Microphotograph (SEM). This result based on consolidation pressure before and after test. The fibrous peat soil sample was taken from Dusun III Banyu Urip. From Figure 8 it can be seen that there are differences in SEM results before and after the test. Before the test, the arrangement of fiber from peat soil was larger. When compared after the test, the pores on the fibrous peat soil become more closely. Wong (2009) concluded that compressibility of peat soil can be influenced by the soil consist (macropores and micropores) in the photomicrographs of the peat soil. Also, SEM images based on Ali (2010) show uninterrupted peat soils with fibrous structure characteristics and coarse organic particles.



(Before) (After)

**Figure 8: Results of analysis of SEM under consolidation pressure (a) Before test and (b) After test**

Compressibility characteristic be related with hydraulic conductivity characteristics. The coefficient of hydraulic conductivity in vertical direction ($k_v$) was obtained from the result of consolidation test. Table 6 shows the results of the $k_v$ parameters below the 50 kPa-400 kPa pressure range. The relationship between pressure giving and the vertical coefficient of hydraulic conductivity was described in Figure 9. The applied of pressure on the consolidation test affected the results of the $k_v$ values.

**Table 6: Average value coefficient of vertical hydraulic conductivity for each consolidation pressure**

| Parameter | Pressure (p', kPa) | Dusun I Banyu Urip | Dusun III Banyu Urip |
|---|---|---|---|
| Coefficient of volume compressibility | 50 | 0,0026233 | 0,0034000 |
| | 100 | 0,0015133 | 0,0022967 |

| | | | |
|---|---|---|---|
| ($m_v$, 1/kPa) | 200 | 0,0004733 | 0,0002633 |
| | 400 | 0,0004467 | 0,000170 |
| Coefficient of Vertical Hydraulic Conductivity ($k_v$ , cm/s) | 50 | $1{,}07.10^{-9}$ | $1{,}37.10^{-9}$ |
| | 100 | $4{,}86.10^{-10}$ | $7{,}03.10^{-10}$ |
| | 200 | $1{,}04.10^{-10}$ | $4{,}63.10^{-11}$ |
| | 400 | $4{,}44.10^{-10}$ | $1{,}69.10^{-11}$ |

It can be seen from the Table 6 the average value coefficient of vertical hydraulic conductivity ($k_v$) under consolidation pressure 50 kPa are $1{,}07.10^{-9}$ cm/s (Dusun I Banyu Urip) and $1{,}37.10^{-9}$ cm/s (Dusun III Banyu Urip). The value of hydraulic conductivity in vertical direction ($k_v$) of Figure 9 appears to decrease. This is a result of pressure (p‘, kPa) of 50, 100, 200, and 400. So it can be concluded that the greater the pressure value (p’), the $k_v$ value obtained will be smaller.

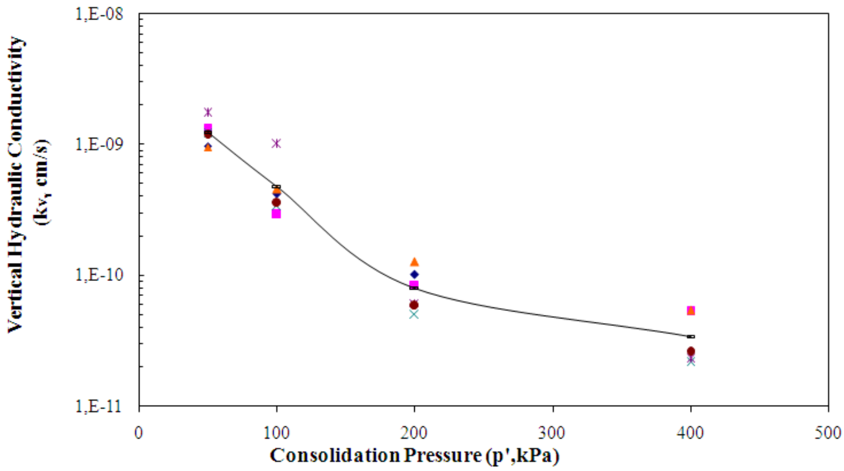



**Figure 9: Variation coefficient of vertical hydraulic conductivity with consolidation pressure (Dusun III Banyu Urip)**

## CONCLUSION

The hydraulic conductivity/permeability and compressibility of fibrous peat soil affected by the behaviour of fibrous peat soil as: (a) depth, (b) water content, (c) void ratio, and (d) classification. The peat soil in Banyuasin Regency was categorized as fibrous peat soil. This research gave the information that the peat soil is one of the typical peat soil, which is can be found in South Sumatera. Based on hydraulic conductivity test (constant head method), the average coefficient vertical hydraulic conductivity coefficient ($k_v$ 20°) was $3.76.10^{-4}$ cm/s. And the average coefficient of the horizontal hydraulic conductivity coefficient (kh 20°) was $6.13.10^{-4}$ cm/s. Results show that the ratio of $k_h/k_v$ (20°C) was 2.04 (Dusun III Banyu Urip). The value of horizontal coefficient hydraulic conductivity ($k_h$) is more than the value of vertical coefficient hydraulic conductivity ($k_v$). This is because in the horizontal direction, peat soil has a larger pore size.

The hydraulic conductivity/permeability parameters also obtained from consolidation test. The average value coefficient of vertical hydraulic conductivity ($k_v$) from Dusun I Banyu Urip was $1{,}07.10^{-9}$ cm/s (for consolidation pressure 50 kPa). The analysis of compressibility characteristics of fibrous peat soil had been done using Oedometer test. The results from consolidation test were the average compression index ($c_c$) in the Dusun I Banyu Urip 1.428 and the average compression index ($c_c$) on the location of Dusun III Banyu Urip is 1.215. The coefficient of rate of consolidation ($c_v$) based on Cassagrande’s method from 13.671 from 3.312 under consolidation pressure in range of 50 to 200 kPa (Dusun III Banyu Urip). The results of coefficient of rate of consolidation ($c_v$) can be affected by applied the pressure which is the greater the pressure the smaller the value of coefficient of rate of consolidation.

The results of this research were very useful for the development of peat deposit for fibrous peat soil in Banyuasin Regency, South Sumatra province as construction material and foundation. Data collected from this research were carried on hydraulic conductivity/permeability and the compressibility parameters of fibrous peat. The science on the hydraulic conductivity/permeability and the compressibility is necessary as it enables designers to comprehend the response to the fibrous peat soils to load and to recommendation proper engineering solutions to overcome the problem. Hydraulic conductivity/permeability is one of the most important properties of fibrous peat soil. This is because the parameters of the permeability test can be used to control the consolidation rate and increase the shear strength of the soil. Fibrous peat soil hydraulic conductivity/permeability coefficient ($k_v$ and $k_h$) can be used to find out of dam problem, embankment, infiltration wells, irrigation channel, and others. Beside of that the compressibility parameters of fibrous peat evaluated for evaluation of prediction of settlement of embankments and road construction over peat deposit. Therefore, for a new construction project on peat deposit, the information on the characteristics (hydraulic conductivity/permeability and compressibility) of fibrous peat soils very importance.

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