Advances in Engineering Research, volume 187
Third International Conference on Sustainable Innovation 2019 – Technology and Engineering (IcoSITE 2019)

Acceleration of Decomposition Process by Lignocellulolytic Bacteria and Its Effect on the Physical and Engineering Properties of Kalimantan Fibrous Peat

1st Dwiaji Ari Yogyanta
Department of Civil Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
ariyogyanta@gmail.com

2nd Noor Endah Mochtar
Department of Civil Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
noormochtar@gmail.com

3rd Enny Zulaika
Department of Biology
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
enny@bio.its.ac.id

***Abstract*—Peat is an organic soil which has very low bearing capacity and very high compressibility; its organic content is higher than 75%. Peat is classified into two categories, amorphous granular peat and fibrous peat (fiber content > 20%). Fibrous peat has higher bearing capacity compared to the amorphous one due to its fiber content. When the fiber undergoes decomposition, however, its bearing capacity drops, and bigger compression takes place. For this reason, decomposition process of fibrous peat has to be accelerated before the construction starts in order to prevent the change of its properties. In this study, lignocellulolytic bacteria was used to accelerate the fiber decomposition. The results show that 10% of bacteria with 28 days of curing period had the optimum results. The fiber content decreased from 50% to 36.67% in 28 days of curing period. The coarse and medium sizes of fiber decreased 5.13% and 22.03%, respectively; but the fine fiber increased 27.16% because of the change of coarse and medium fiber. Its unit weight and specific gravity decreased 6.83% and 7.89%, respectively. The peat compression increased 22.95% compared to the initial one; but the internal friction angle decreased 27.29%.**

***Keywords*—acceleration, fibrous peat, fiber decomposition, lignocellulolytic bacteria**

I. INTRODUCTION

About 14.9 million hectares of land in Indonesia are peat spreading on Sumatra, Kalimantan and Papua [1]. In Indonesia, a lot of infrastructure must be built in areas where the soil conditions are peat. As a result, the infrastructure is often damaged due to very low bearing capacity and very high compressibility. This can occur because peat has an organic content greater than 75% and very large void ratio [2]. The organic content of peat comes from fragments formed by weathering or decomposition of plants.

Peat can be classified based on its fiber content, namely amorphous granular peat with fiber content of less than 20% and fibrous peat with fiber content of more than 20% [3]. Peat in Indonesia is classified as tropical peat which contains a lot of lignin and cellulose fiber derived from weathering wood or plants. In general, fibrous peat soil has smaller compressibility than non-fibrous peat soil; nevertheless, in case of decomposition of the fibers happen, the compressibility that occurs is usually very large. Therefore, the decomposition process should be completed before construction is built. From this aforementioned background, this study is conducted to looking for the percentage of decomposer bacteria (lignocellulolytic endogenous bacteria) which can break down all types of fibers (cellulose and lignin) in order to accelerate decomposition process. The results of this study are reported in this paper.

II. LITERATURE REVIEW

Studies on soil improvement of peat with stabilization method using 10% of lime $CaCO3$ + pozolan (mixture of rice husk ash or fly ash) have been conducted [4-6]. The results show that in 20-45 days of curing period, the behavior of stabilized fibrous peat soil improved. However, in 45-90 days of curing period, peat has decreased in physical properties and engineering properties where compression increased, and the bearing capacity decreased. This was caused by the decrease in the water content in peat as a result of chemical reaction of water absorption by lime for the process of forming $CaSiO3$ jelly. The decrease in water content in the sample caused acceleration of the peat decomposition process which resulted in the increase in compression of the relevant peat [7].

Based on the description above, it can be known that peat with high degree of decomposition (dominated by fine fiber content) is more commonly chosen as the subgrade of a construction. For this reason, study on the acceleration of the fiber decomposition process on peat has been conducted by adding cellulolytic type aerobic decomposer bacteria obtained from the studied peat (endogenous) [8]. The use of bacterial solution of 10% of the weight of wet peat provided optimum results. However, the type of fiber that was successful in accelerating the decomposition process was only cellulose fiber (cellulolytic); this acceleration process didn't occur in lignin fiber. This means the potential of peat decomposition process still exists. Therefore, the study was continued by using decomposer bacteria which can break down all types of fibers (cellulose and lignin), namely lignocellulolytic endogenous bacteria.

III. METHODOLOGY

The materials used in this study are fibrous peat and decomposer bacteria. Fibrous peat samples were taken in Bareng Bengkel Village, Palangkaraya, Central Kalimantan. The type of sample is disturbed sample taken at a depth of 0.5-1.0 m. The decomposer bacteria used are taken from disturbed peat samples (endogenous) which can decompose lignin and cellulose fibers (lignocellulolytic). The bacteria are a consortium solution with an initial density of 480,000,000

Copyright © 2019, the Authors. Published by Atlantis Press.
This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

CFU/ml. The process of retrieving, identifying, and breeding endogenous bacteria were carried out in the Laboratory of Microbiology and Biotechnology, Department of Biology, Institut Teknologi Sepuluh Nopember.

In this study, 4 (four) samples were made with a weight of 2500 grams; each was placed in a container measuring 19x12x11cm3. Then, each sample was mixed with decomposers in the form of a consortium of lignocellulolytic endogenous bacteria with various percentage of wet peat weight, namely 0% of bacteria (B0), 10% of bacteria (B10), 20% of bacteria (B20), and 30% of bacteria (B30). Observations of the decomposition process were carried out by testing the fiber content, decomposition rate, fiber distribution, and bacterial viability during 0, 14, 28, 42 and 56 days of curing period. From the results of these tests, the percentage of bacteria and the optimum of curing period can be determined.

The next step was making 3500 grams of new sample placed in a container measuring 27x27x5cm3 and then mixed with the optimum percentage of bacteria. The changes of physical and engineering properties of samples were observed until optimum curing period. The physical properties of peat observed were water content (wc), specific gravity (Gs), unit weight (γ), void ratio (e), fiber content, fiber distribution, and pH. Standards and methods of physical properties testing were conducted based on Peat Testing Manual (1979) [9]. Later, the engineering properties of peat observed were total compression and internal friction angle (ϕ). Compression testing method was conducted based on Gibson and Lo [10], while the internal fiction angle (ϕ) testing was based on ASTM D-3080 [11].

IV. Result & Analysis

A. Physical Properties and Engineering Properties of the Studied Fibrous Peat

The results of testing the physical and engineering properties of initial peat are listed in Table I. Based on these data, the peat soils studied can be classified into hemic with high acidity.

TABLE I. Initial Physical and Engineering Properties of Peat

Soil Parameters	Unit	Fibrous Peat Studied
Water Content (Wc)	%	554.77
Specific Gravity (Gs)	-	1.311
Unit Weight (γ)	gr/cm3	1.010
Void Ratio (e)	-	7.496
pH	-	4.4
Fiber Content	%	50.00
Fiber Distribution - coarse fiber - medium fiber - fine fiber	 % % %	 10.89 60.51 28.60
Total Compression	mm	4.75
Internal Friction Angle (ϕ)	°	24.81

B. Percentage of Lignocellulolytic Bacteria and Optimum Curing Period

The effect of adding lignocellulolytic bacteria to the reduction of fiber content can be seen in Fig. 1. The greatest decrease in fiber content occurred in samples with 10% of bacteria (B10) which occurred in 14 days of curing period. Nevertheless, starting in 28 days of curing period, the decrease in fiber content that occurred wasn't significant and tended to be constant. Thus, the greatest decomposition rate occurred in 14 days of curing period for samples with 10% of bacteria (B10) as seen in Fig.2.

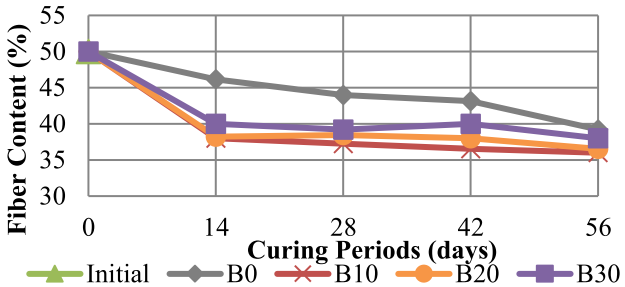

Fig. 1. Fiber content of peat from various addition of bacteria

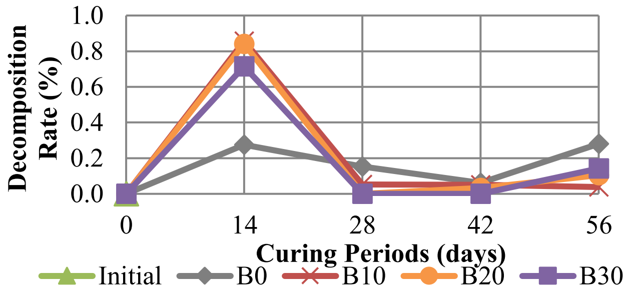

Fig. 2. Decomposition rate of peat from various addition of bacteria

The decrease in peat fiber content that occurred was followed by the decrease in the amount of coarse fiber and medium fiber. The largest decrease in the amount of coarse fiber and medium fiber occurred in a sample of 10% of bacteria (B10). Fig. 3 shows the largest decrease in the amount of coarse fiber that occurred until 28 days of curing period. Meanwhile, in Fig. 4, the amount of coarse fiber and medium fiber had decreased in 14 days of curing period and started constant in 28 days of curing period. The decrease in the amount of coarse fiber and medium fiber caused an increase in the amount of fine fiber as shown in Fig. 5.

In Fig. 6, it can be seen that at the beginning of bacteria addition, bacterial viability increased compared to the initial condition. In 14 and 28 days of curing period, a sample 10% of bacteria (B10) had the greatest bacterial viability compared to other samples, although all samples tended to decrease along with reduced nutrition (fiber) for bacterial metabolism.

In peat samples with 20% of bacteria (B20) and 30% of bacteria (B30), more addition of bacteria didn't cause significant decrease in fiber content compared to 10% of bacteria (B10) (see Fig. 1). Besides, decomposition rate and bacterial viability from sample of 10% of bacteria (B10) was a little bit greater than samples with 20% of bacteria (B20) and 30% of bacteria (B30). This is due to the large number of bacteria aren't as equal as the amount of lignin and cellulose fibers that become "food" of lignocellulolytic bacteria. This condition results in competition between bacteria, so that the number of bacteria that lived in 14 days and 28 days of curing period weren't as many as in the sample of 10% of bacteria (B10).

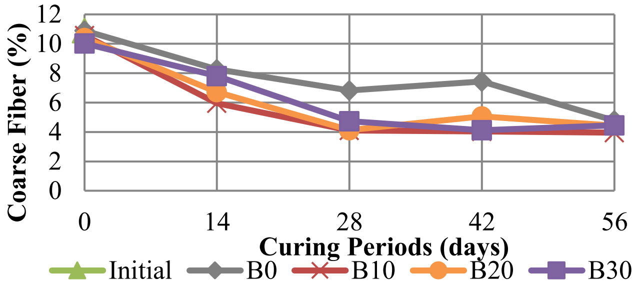

Fig. 3. The amount of coarse fiber from various addition of bacteria

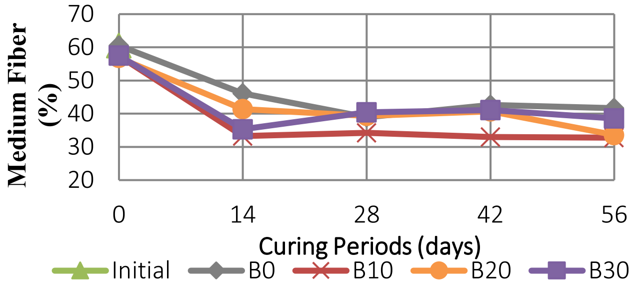

Fig. 4. The amount of medium fiber from various addition of bacteria

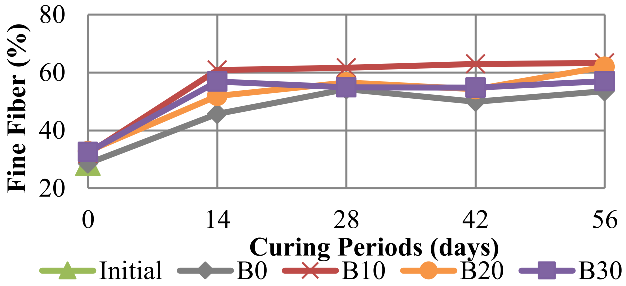

Fig. 5. The amount of fine fiber from various addition of bacteria

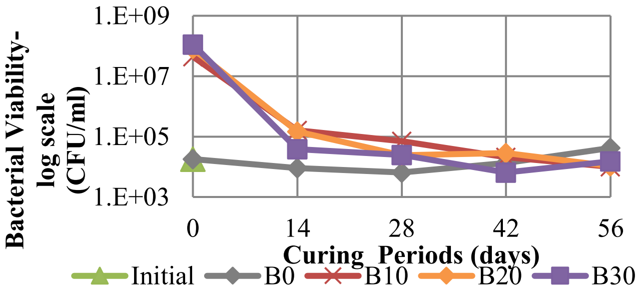

Fig. 6. Bacterial viability from various addition of bacteria

Based on the decomposition rate, decrease in fiber content and bacterial viability that are explained above, it can be known that sample with 10% of bacteria (B10) shows optimal results in 14 days of curing period and start being constant in 28 days of curing period. For this reason, the use of 10% of lignocellulolytic bacteria with 28 days of curing period is the percentage of bacteria and optimum curing period for the acceleration of fiber decomposition in peat.

C. Effect on the Physical and Engineering Properties of Peat Due to the Acceleration of Decomposition by 10% of Lignocellulolytic Bacteria

The peat sample which would be determined by its physical properties and engineering properties was first mixed with lignocellulolytic bacteria at 10% of the wet weight of peat. Afterwards, the sample of 10% of bacteria (B10) was tested in 0, 14, and 28 days of curing period in order to determine the physical and engineering properties of peat during the process of accelerating decomposition.

In 0 days of curing period, the water content (wc) and void ratio (e) were greater than the initial conditions of peat as shown in Fig. 7 and Fig. 8. This occurred because the consortium of lignocellulolytic bacteria added to the peat formed in solution or liquid that can fill pores in peat. As a result, the value of water content (wc) and void ratio (e) increased and tended to be constant until 28 days of curing period.

Until 28 of days curing period, the additional of bacteria resulted decrease in the specific gravity (Gs) and unit weight (γ) as shown in Fig. 9 and Fig. 10. If it is compared to the initial conditions, the specific gravity (Gs) decreased 7.89% from 1.311 to 1.207, and the unit weight (γ) decreased 6.83% from 1.010 gr/cm^3 to 0.941 gr/cm^3. This was caused by the decomposition of coarse fiber into smaller fiber that occurred during the decomposition process.

The sample with 10% of bacteria (B10) underwent decrease in the value of fiber content (Fig. 11), from initial conditions of 50% to 36.67% in 28 days of curing period. Fig. 12shows the changes in the size distribution of coarse, medium and fine fibers. The amount of coarse fiber decreased 5.13% from the initial condition of 10.89% to 5.76% in 28 days of curing period. Meanwhile, the number of medium fibers decreased 22.03% from the initial conditions 60.51% to 38.48% in 28 days of curing period. As a result of the decrease in the amount of coarse fiber and medium fiber, it caused an increase 27.16% in the amount of fine fiber from the initial conditions of 28.60% to 55.76%.

The addition of bacteria resulted on increase in pH values from initial conditions as seen in Fig. 13. In 14 days of curing period, the pH values decreased because there was a formation of carbonic acid (H2CO3) due to CO2 gas from bacterial decomposer metabolic activities. At the next curing period, pH values tended to increase along with the availability of nutrients needed by bacteria for metabolism.

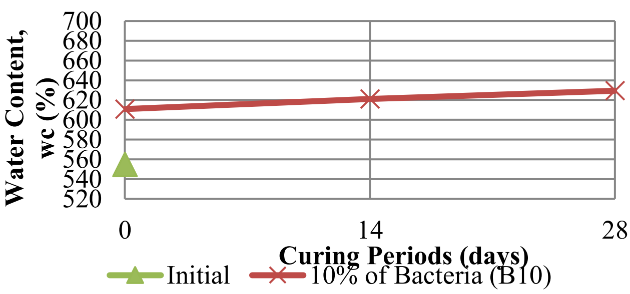

Fig. 7. Water content of peat with 10% of bacteria (B10)

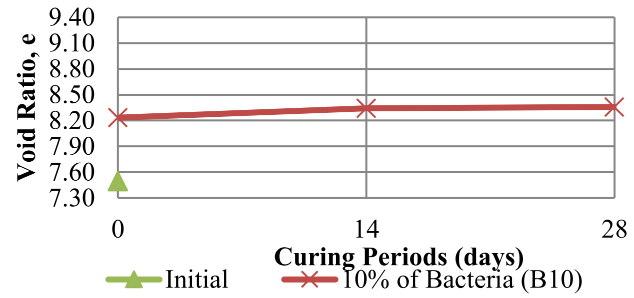

Fig. 8. Void ratio of peat with 10% of bacteria (B10)

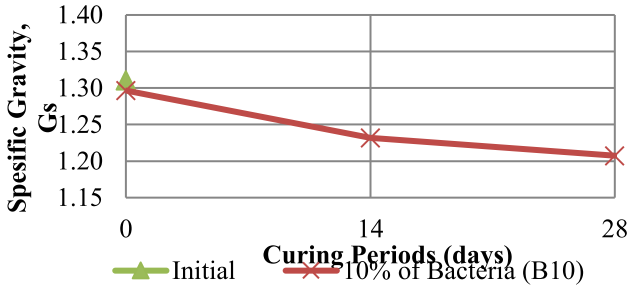

Fig. 9. Specific gravity of peat with 10% of bacteria (B10)

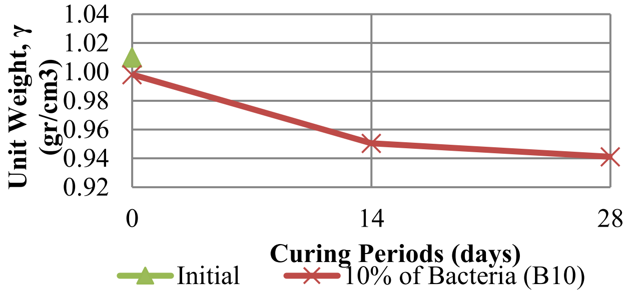

Fig. 10. Unit weight of peat with 10% of bacteria (B10)

Based on the physical properties testing results that are previously explained, the acceleration of decomposition by 10% of bacteria (B10) resulted to the changes in physical properties of peat. These changes in physical properties included decrease in specific gravity of 7.89%, unit weight of 6.83%, fiber content of 13.33%, coarse fiber of 5.13%, and medium fiber of 22.03%. This shows that the decomposition process caused peat fibers decrease during the curing period; thus it affected the physical properties of peat.

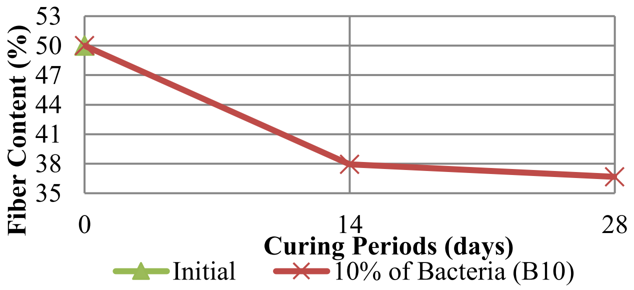

Fig. 11. Fiber content of peat with 10% of bacteria (B10)

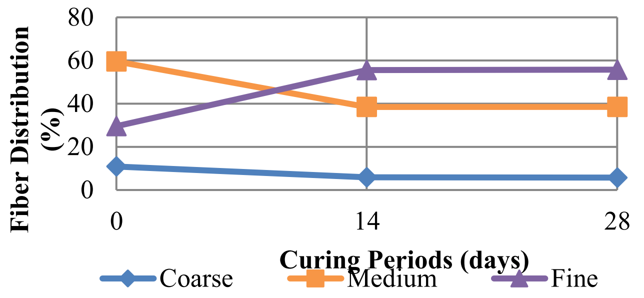

Fig. 12. Fiber distribution of peat with 10% of bacteria (B10)

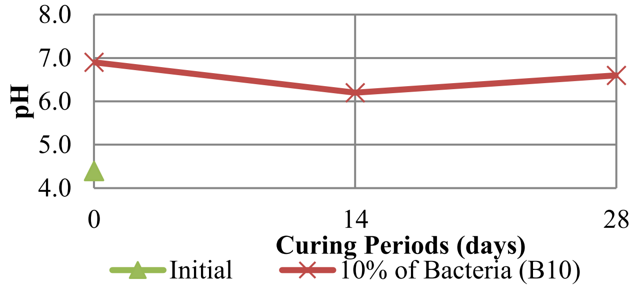

Fig. 13. pH values of peat with 10% of bacteria (B10)

The addition of bacteria to peat also affects the engineering properties. In Fig. 14, it can be seen that the total compression had increased 22.95% from the initial conditions of 4.75 mm to 5.84 mm in 28 days of curing period. Based on the compression curve shown in Fig. 15, it can also be known that the vertical strain that occurred was getting bigger as the increase in curing period. This is in line with the results of a study conducted by Mochtar and Yulianto [6].

In Fig. 16, it is known that the internal friction angle (ϕ) had decreased by 27.29% from the initial conditions of 24.81° to 18.04°. This occurred because the shear strength of peat soil is strongly influenced by the size of the fiber. The decomposition process causes the peat fibers decompose become smaller, so that the peat soil is dominated by fine fiber which causes decrease in the internal friction angle (ϕ).

Based on the engineering properties testing results during the curing period as described earlier, it was shown that the acceleration of decomposition by 10% of bacteria (B10) had an effect on the engineering properties of peat. Decreased peat fibers due to accelerated decomposition caused the changes in engineering properties as increase in total compression of 22.95% and decrease in internal friction angle (ϕ) of 27.29%.

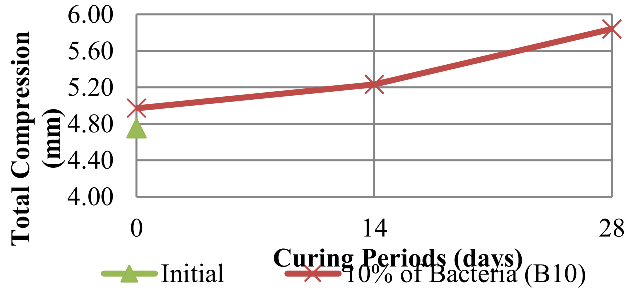

Fig. 14. Total compression of peat with 10% of bacteria (B10)

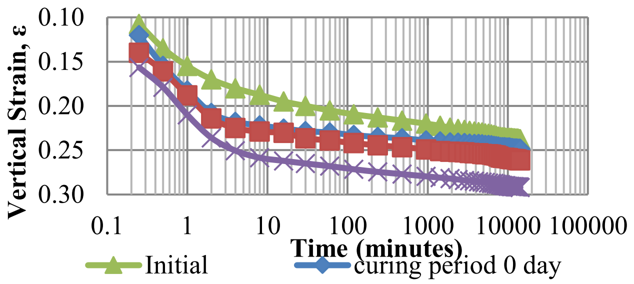

Fig. 15. Compression curve of peat with 10% of bacteria (B10)

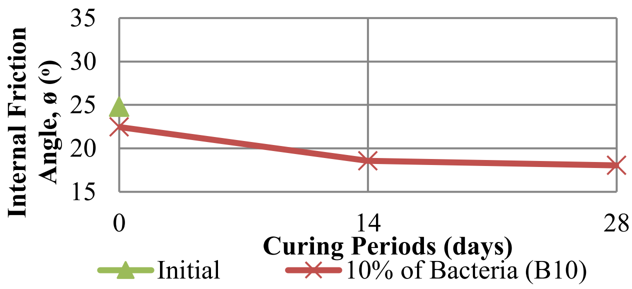

Fig. 16. Internal friction angle of peat with 10% of bacteria (B10)

V. Conclusion & Recommendation

Based on the results of the test and the explanations given above, it can be concluded that: 10% of lignocellulolytic bacterial solution of the wet weight of peat in 28 days of curing period shows optimum results to accelerate the process of peat decomposition. The acceleration of decomposition results on the change of the physical properties of peat in the decrease in: fiber content, the amount of coarse and medium fiber, unit weight (γ), and specific gravity (Gs). The acceleration of decomposition also affects the change of the engineering properties of peat in the increase in compression and the decrease in internal friction angle (ϕ).

References

[1] S. Ritung et al., "Indonesian peatland map at the scale 1:250,000 (Peta lahan gambut Indonesia skala 1:250,000)," Balai Besar Litbang Sumberdaya Lahan Pertanian, Bogor, Indonesia, 2011.

[2] ASTM, Standard classification of peat samples by laboratory testing (D4427-84), ASTM Section 4, vol 04.08 Soil and Rock, pp. 883-884, 1984.

[3] I.C. MacFarlane, N.W.A. Radforth, "Study of physical behaviour of peat derivatives under compression," Proceeding of The Tenth Muskeg Research Conference, National Research Council of Canada, 1965.

[4] N.E. Mochtar, F.E. Yulianto, and T.R. Satrya, "The effect of curing period on fibrous peat soils stabilized with mixed of CaCO3 and pozolan (Pengaruh usia stabilisasi pada tanah gambut berserat yang distabilisasi dengan campuran CaCO3 dan pozolan)," Jurnal Teknik Sipil, vol. 21(1), pp. 57-64, 2014.

[5] F.E. Yulianto and N.E. Mochtar, "The effect of curing period and thickness of the stabilized peat layer to the bearing capacity and compression behaviour of fibrous peat," ARPN Journal of Engineering and Applied Sciences, vol. 11(19), pp. 11615-11618, 2016.

[6] N.E. Mochtar and F.E. Yulianto, "Compression behavior of fibrous peat stabilized with admixtures of lime CaCO3+rice hush ash and lime CaCO3+fly ash," International Journal on Advanced Science Engineering Information Technology, vol. 8(3), pp. 792-798, 2018.

[7] S. Pichan and B.C. O'Kelly, "Effect of decomposition on the compressibility of fibrous peat". ASCE GeoCongress, pp. 4329-4338, 2012.

[8] A. Prativi, N.E. Mochtar, and E. Zulaika, "Peat soil stabilization by adding solution of endogenous aerobic decomposer bacteria consortium," 12th International Conference on Building Design, Materials, Civil and Transportation Engineering, pp. 77-83, 2018.

[9] J.H. Day, P.J. Rennie, W. Stanek, and G.P. Raymond, Peat testing manual, Sponsored by: Muskeg Subcomitee, Technical Memorandum No 125, 1979.

[10] R.E. Gibson and K.Y. Lo, "A theory of consolidation of soil exhibiting secondary compression," Acta Polytechnica Scandinavica. 1961.

[11] ASTM, Standard test method for direct shear test of soils under consolidated drained condition (D3080-72), 1972.