

Comparison of Shear Strength Properties for Undisturbed and Reconstituted Parit Nipah Peat, Johor

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Abstract. Shear strength of soil is required to determine the soil stability and design the foundations. Peat is known as a soil with complex natural formations which also contributes problems to the researchers, developers, engineers and contractors in constructions and infrastructures. Most researchers conducted experiment and investigation of shear strength on peat using shear box test and simple shear test, but only a few had discovered the behavior of peat using triaxial consolidated undrained test. The aim of this paper is to determine the undrained shear strength properties of reconstituted peat and undisturbed peat of Parit Nipah, Johor for comparison purposes. All the reconstituted peat samples were formed with the size that passed opening sieve 3.35 mm and preconsolidation pressure at 100 kPa. The result of undrained shear strength of reconstituted peat was 21kPa for cohesion with the angle of friction, 41° compare to the undisturbed peat with cohesion 10 kPa and angle of friction, 16°. The undrained shear strength properties result obtained shows that the reconstituted peat has higher strength than undisturbed peat. For relationship deviator stress-strain, σ_{\max}^d and excess pore pressure, Δu , it shows that both of undisturbed and reconstituted gradually increased when σ' increased, but at the end of the test, the values are slightly dropped. The physical properties of undisturbed and reconstituted peat were also investigated to correlate with the undrained shear strength results.

Keywords: Reconstituted peat, using triaxial consolidated undrained (CU- Test), undrained shear strength, preconsolidation pressure, cohesion, angle of friction.

1. Introduction

Peat soil is organic soil with organic content more than 75% or ash content less than 25% by dry weight [1]. Peat and organic soils commonly occur as extremely soft, wet, unconsolidated surficial deposits that are an integral part of wetland systems [2]. In natural condition, peat contains of decomposed plant and organic material with close to no measurement strength [3]. Islam and Hashim [4] stated that the presence of high ground water table and woody debris has caused the low bearing capacity. Whitlow [5] and Razali et al. [6], have mentioned that peaty soil consists of high moisture content reached up to 1000%



(depending on soil compositions), high organic content (exceed >75%), high compressibility with initial void ratio in the scale of 5 – 15, high fiber content and low bearing capacity in the range of 5 – 20 kPa. These properties can contribute to geotechnical problems in term of strength, settlement and stability.

Peat is agglomerated when the ground condition is fully undrained and the rate of decay is slower than the rate of addition [7]. As plants remained to assemble, the ground surface levels were raised. This condition called as a formation of peat, which has low of clastic sediments (ombrogenous peat) and highly acidic [2]. CREAM [8] describes peat is a natural sponge, retaining moisture when low rainfall but since it is in waterlogged condition, so the capacity to absorb additional heavy rainfall is very limited.

Poulos [9] stated that factors that influence strength properties of soils are divided into four categories which are soil compaction, structure, state (initial) and loading methods. Shear strength of a soil mass is classified as the internal resistance per unit area where the soil mass can offer to resist failure and sliding along any plane inside it [10]. The strength of soil leads to the resistance to the movement (failure) of molecules associated together, thus failure is relevant to the shear strength where it is one of the foremost important soil engineering properties [11]. The soil shear strength is the maximum burden that can be bolstered by the mass of the soil before it faced failure. Huat [1] notified the undrained friction angle in West Malaysia is in the range from 3° to 25°. O'Kelly and Orr [12] postulated that the cohesion value of fibrous peat is higher than zero.

Effective friction angle of peat is typically determined in triaxial consolidated undrained compression test. To obtain the effective strength parameters such as effective cohesion (c') and effective angle of shearing resistance (ϕ'), consolidated undrained test with measurement of the pore pressure is suitable for highly organic peat [12][8]. Zhang and O'Kelly [13] identified that triaxial testing is one of the most often methods in practice because its repeatability result is generally good. In triaxial analysis test, the stress-strain relationship is developed by the failure criteria in the shear strength. The magnitude of the strain in the soil depends on the parameters, for example; the magnitude of applied burden, the structure of the soil, past stress experience, void ratio, and also on the approach manner in which the stress is applied [14].

In this paper, the influence of reconstituted peat size passing 3.35mm sieve was measured to determine the shear strength properties. In addition, undisturbed peat samples were also tested as controlled specimen. Hence, a comparison between undisturbed and reconstituted peat samples related to shear strength properties were made to measure whether the reconstituted peat can provide more shear strength than the undisturbed peat.

2. Materials and Methods

2.1 Peat Sample

Peat samples were taken from Parit Nipah Darat, Batu Pahat, Johor in two conditions which are undisturbed and disturbed at the depth of 0.3 to 1.0 m below the ground surface. Von Post classification was done at the field and it is defined as hemic peat since the fresh peat passed through finger about one-third and the actual colour was very muddy dark brown. Thus, peat at Parit Nipah is classified as H5 (moderately decomposed). All the undisturbed samples were obtained using PVC tube with a sharp edge at the end of the tube with 50 mm of diameter and 150 mm height and then they were placed into the box sealed with wax and aluminum coil to maintain the properties of undisturbed peat like moisture content. For disturbed sample, it was placed directly into the box to form reconstituted sample at the laboratory and to define the physical properties of peat.

2.2 Reconstituted Peat Sample

For reconstituted peat, disturbed peat was sieved using 3.35 mm passing opening size of the sieve with the aid of some water to produce a wet sample. The peat which was passed 3.35 mm opening size was selected for this study. After that, peat samples were prepared by using large strain consolidation equipment under initial consolidation pressure of 100 kPa and then completed when there is no water coming out from the bottom tube. The preconsolidation pressure for undisturbed peat soil was 26 kPa. So in this research, the higher loading is needed to give more overburden pressure to the reconstituted peat soil. In addition, a higher preconsolidation was required to form the specimen which was able to stand during the triaxial test. Then, the 50 mm of diameter and 150 mm height of PVC tube was used to form the reconstituted peat samples and was extruded and trimmed using trimming equipments as shown in Figure 1. The remaining peat samples were collected to conduct physical properties for reconstituted peat for comparison purposes.

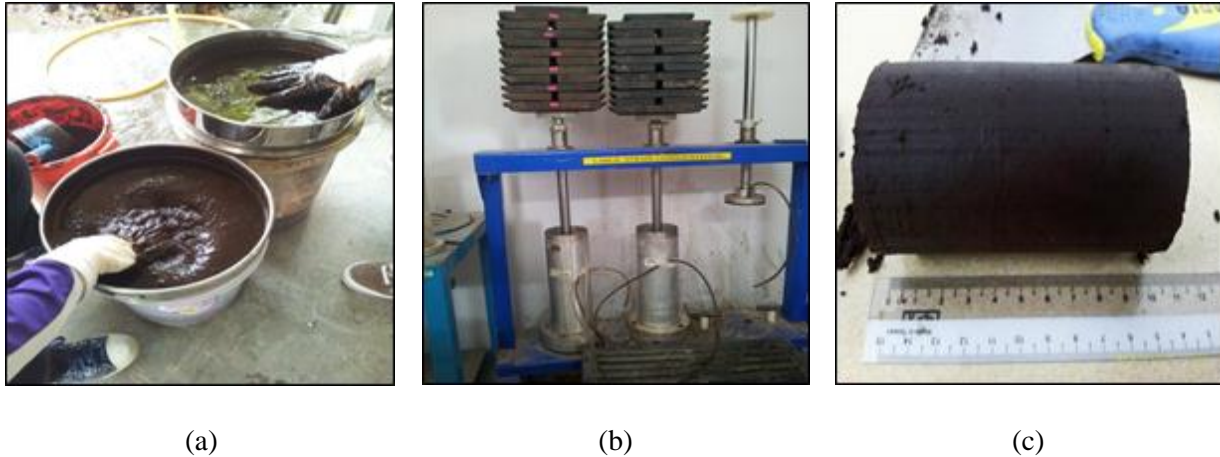
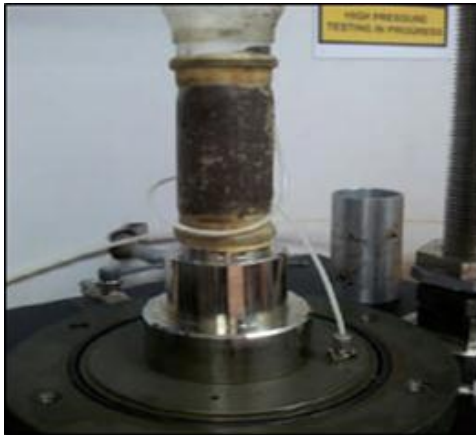


Figure 1. (a) Wet Sieving of Disturbed Peat, (b) Large Strain Consolidation Apparatus for Obtained Reconstituted Peat Sample (c) Reconstituted Peat Sampler

2.3 Consolidated Undrained Test

All the undisturbed and reconstituted peat samples were tested under triaxial consolidated undrained test with an excess pore water pressure measurement according to BS1377: Part 8: 1990 [15] as shown in Figure 2. The confining pressure 25, 50 and 100 kPa were used with the constant strain rate of 0.1mm/min. In consolidated undrained test test, there have three major stages which are saturation, consolidation and shearing stage. In saturation stage, the sample was filled with water until it reached the value of B-check of 0.95. Then, the sample was consolidated isotropically within 24 hours. While, in the last stage, the sample was applied with cell pressure until it failed and reached 20% axial strain.



(a)



(b)

Figure 2. (a) Peat Sampler on Bottom Cap (b) Peat Sampler During Testing on Triaxial Test Machine

3. Results and Discussions

3.1 Peat Properties

The moisture content for undisturbed and reconstituted Parit Nipah peat were 545 % and 328 %, respectively. For liquid limit, undisturbed peat shows the highest value which was 360 % followed by reconstituted peat at 326 %. Kolay and Pui [16] stated that sample contains a lot of fibers resulted in high water absorption capacity. The specific gravities of undisturbed peat were 1.49 and 1.33 for reconstituted peat. The fiber content of undisturbed peat was 66.56 % while for reconstituted peat was 51.12 %. The result of physical properties is within the range of the previous study as shown in Table 1.

Table 1. Physical Properties of Typical Peat

Parameter	Undisturbed Peat	Reconstituted Peat Passing 3.35mm	Past Researcher [1], [17], [18], [19]
Moisture Content (%)	545	328	200-1000
Liquid Limit (%)	360	326	190-360
Specific Gravity (mg/m^3)	1.49	1.33	1.38-1.80
Fiber Content (%)	66.56	51.12	33-77

3.2 Consolidated Undrained Analysis

Soil failure is commonly considered to be found at around 15 % to 20 % strain. In this case, the shear strength of peat can be defined as the maximum stress applied on any plane in a peat mass at some strain considered as a failure. By plotting stress- strain relationship and pore water pressure relationship, the Mohr- Coulomb Circle can be determined. Hence, the effectiveness of shear strength properties (c' and ϕ') can be measured.

3.2.1 Mohr Coulomb Circle of Effective Stress Failure Envelope

Figure 3 (a) and (b), show the Mohr-Coulomb circle for undisturbed and reconstituted peat. In this graph, the shear strength properties (c' and ϕ') were gained. The reconstituted peat has recorded the highest value of cohesion which is 21 kPa with the angle of friction 41° . Meanwhile, the undisturbed peat has recorded the lowest value of cohesion which is 10 kPa with the angle of friction 16° . The reconstituted peat recorded higher shear strength properties because the 100 kPa preconsolidation pressure made the peat structure changed and particle bound well to others particles. Mesri and Ajlouni [20] and O'Kelly et al. [21] stated the compressibility of peat can affect the fabric and the arrangement of the constituent fibers and inter- particle of chemical bonding in the soil.

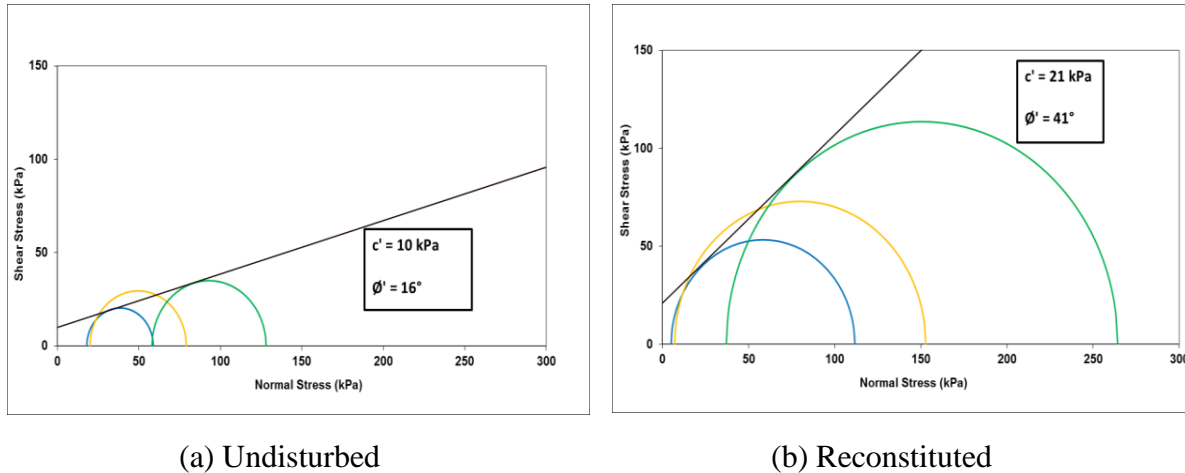


Figure 3. (a) Graph of Mohr Circle of Effective Stress Failure Envelope for Undisturbed Peat
(b) Graph of Mohr Circle of Effective Stress Failure Envelope for Reconstituted Peat

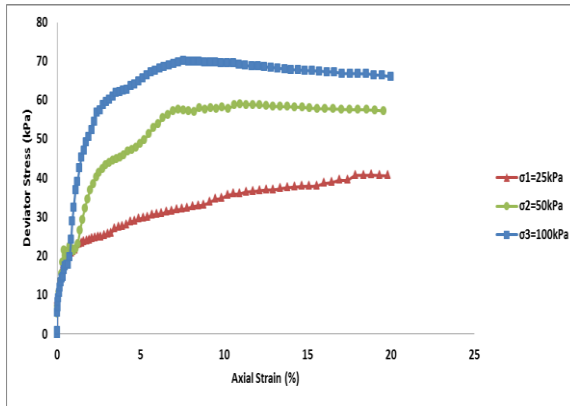
3.2.2 Stress- Strain Relationship and Variation of Excess Pore Water Pressure vs. Axial Strain

Figure 4 (c) and (d), show the stress- strain relationship that has been performed between undisturbed (UD) and reconstituted peat to determine the maximum value of deviator stress, σ_{\max}^d versus axial strain, ϵ_a during the shearing stage. The σ_{\max}^d for undisturbed and reconstituted gradually increased when σ' increased. On the other hand, excess pore water pressure, Δu versus axial strain was performed in Figure 5 (e) and (f) for undisturbed and reconstituted. Based on the results, the Δu increased along with σ' but in the end of the test, the values are slightly dropped. Das [10] diagnosed and explained on the variation of Δu versus ϵ_a for loose sand which is gradually increased and maintained or slightly dropped at the end of the test.

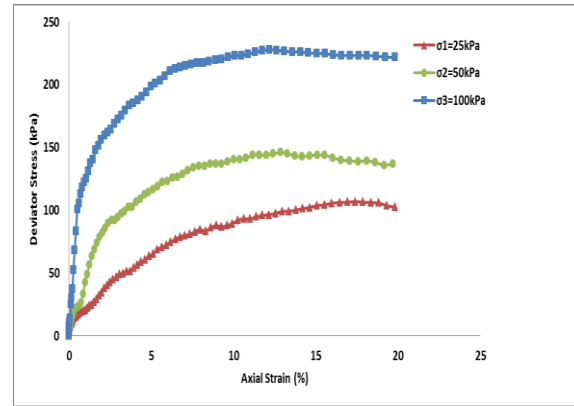
The result from graphs illustrated in Figure 4 and 5 are scheduled in Table 2 below, the σ_{\max}^d and the Δu increased with the increment of σ' for both sample conditions. The undisturbed peats have lower values of σ_{\max}^d as compared to reconstituted peats. This result is influenced by the origin and characteristics of the soil that may have undergone by agricultural activities or machinery [22]. Cola and Cortellazo [23] have also concluded that the deviator stress for peat is increased with the increment of effective shear stress.

Table 2. Triaxial Value for Undisturbed Peat and Reconstituted Peat

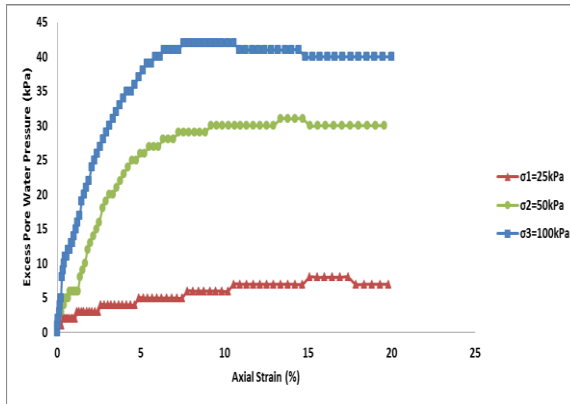
Sample	Principal Stress, σ' (kPa)	Axial Strain, ϵ_a (%)	Deviator Stress, σ^d_{max} (kPa)	Excess Pore Water Pressure, Δu (kPa)
Undisturbed peat	25	18.8305	40.8068	7
	50	10.9527	59.0867	30
	100	7.5624	70.0752	42
Reconstituted peat	25	17.4003	106.7058	20
	50	12.8483	145.8429	43
	100	12.6206	227.3029	63



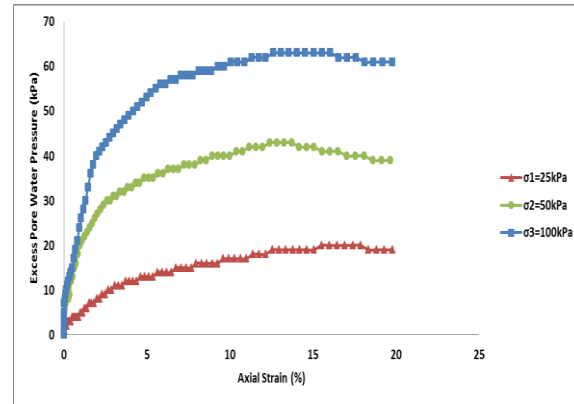
(a) Undisturbed



(b) Reconstituted

Figure 4. (a) Graph of Stress- Strain Relationship for Undisturbed (b) Graph of Stress- Strain Relationship for Reconstituted

(a) Undisturbed



(b) Reconstituted

Figure 5. (a) Graph of Excess Pore Water Pressure vs. Axial Strain for Undisturbed (b) Graph of Excess Pore Water Pressure vs. Axial Strain for Reconstituted

Table 3 shows the value of effective shear strength properties (c' and ϕ'). The cohesion values for undisturbed and reconstituted peats are 10 kPa and 21 kPa, respectively. Besides, the angles of friction value for undisturbed (UD) and reconstituted <R3.35mm are 16° and 41° respectively. As shown in the table, the result of undrained shear strength properties for reconstituted peat is higher than undisturbed peat (UD). This condition happened because of the peat size and shape particle and also preconsolidation pressure that was impacted to the reconstituted peat structure where it affected the initial void and moisture content.

The moisture content, initial void ratio and fiber content for undisturbed peat were higher than reconstituted peat which had recorded the value of 545 %, 8.36 and 66.56 %, respectively. Meanwhile, the moisture content, initial void ratio and fiber content for reconstituted peat were recorded at 328 %, 5.74 and 51.12 %, respectively. Yusoff et.al. [24] stated that the strength of soil specimen texture was affected since the sample was compacted. Edil and Wang [25] declared that the increasing fiber content in the soil will influent increment of the moisture content and void ratio, at once effect the shear strength of soil.

Wong et.al. [26] stated that size of peat, shape, fabric and packing of the soil particles give impact on the soil permeability, compressibility and shear strength. Based on Mitchell [27], the size and shape of soil particles, the arrangements and the forces between particles are the factors that contribute to the determination of the values of properties such as strength, permeability and compressibility [28]. Thus, it can be concluded that the size and shape of peat can affect the water content, void ratio and fiber content, and thus affect the shear strength properties [29][30]. However, for comparison purposes, the shear strength properties for reconstituted peat were higher than undisturbed peat if the reconstituted peat has passed 3.35 mm opening size of a sieve and compressed with 100 kPa preconsolidation pressure.

Table 3. Triaxial Summary Results

Sample	Initial Water	Initial Void	Fiber Content	Undrained Shear Strength	
	Content w (%)	Ratio, e_0	(%)	c' (kPa)	ϕ' (°)
Undisturbed peat	545	8.36	66.56	10	16
Reconstituted peat	328	5.74	51.12	21	41

Conclusion

In this paper, the reconstituted peat samples which passed 3.35 mm opening size of a sieve were used as a comparison with undisturbed peat samples. The undrained shear strength properties for reconstituted peat are higher than undisturbed peat. This condition may happen because of the peat size and preconsolidation pressure that were used to form the reconstituted peat has increased the strength of the peat. The results of shear strength properties for reconstituted peat samples are 21 kPa for cohesion and 41° for the angle of friction. At the same time, the results of shear strength properties for undisturbed peat samples are 10 kPa for cohesion and 16° the angle of friction. The different values of cohesion and angle of friction that obtained in this study between reconstituted peat samples and undisturbed peat samples were affected by a few factors. The factors that contribute to the differences are preconsolidation pressure, initial void ratio, size and shape of peat and physical properties such as moisture content, fiber content and liquid limit. Thus, it can be concluded that reconstituted peat with the passing size sieve of 3.35 mm and preconsolidation pressure 100 kPa can increase shear strength properties of peat soil.

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References

- [1] Huat, B.B.K., 2004 Organic and Peat soil Engineering. University Putra Malaysia, Serdang, Malaysia.
- [2] Huat, B. B., Prasad, A., Asadi, A., and Kazemian, S., 2014 Geotechnics of Organic Soils and Peat. London, UK: Taylor & Francis Group.
- [3] Munro, N., 2005 Dealing With Bearing Capacity Problems on Low Volume Roads Constructed on Peat. ROADDEX II Northern Periphery.
- [4] Islam, S. and Hashim, R., 2008 Engineering Properties of Peat Soils In Peninsular Malaysia. J. Appl. Sci., 8 (22).
- [5] Whitlow, J.R., 2001 *Basic Soil Mechanics*. 4th Ed. England: Pearson Education Ltd.
- [6] Razali, S. N. M., Bakar, I., and Zainorabidin A., 2013 Behaviour of Peat Soil in Instrumented Physical Model Studies, *Procedia Engineering*, Volume 56, Pp 145 – 155.
- [7] Bell, F.G., 2000 Engineering Properties of Soils and Rocks. Malden, MA, Blackwell Sci., pp. 202-221.
- [8] CREAM, 2015 Guidelines for Construction on Peat and Organic Soils in Malaysia. Kuala Lumpur, Malaysia: Construction Research Institute of Malaysia (CREAM).
- [9] Poulos, S. J., 1989 Jansen, R. B., ed., “Liquefaction Related Phenomena”, *Advance Dam Engineering for Design* (Van Nostrand Reinhold): 292-320.
- [10] Das, B. M., 2010 *Principles of Geotechnical Engineering, 7th Edition*. Stamford, USA: Cengage Learning
- [11] Salih, A.G. and Kassim, K.A., 2012 Effective Shear Strength Parameters of Remoulded Residual Soil. *Electronic Journal of Geotechnical Engineering*, 17, 243- 253.
- [12] O’Kelly, B.C. and Orr, T.L.L., 2014 Briefing: Effective Stress Strength of Peat in Triaxial Compression. *Proceedings of the Institution of Civil Engineers*. Institution of Civil Engineers (ICE). pp. 417-420
- [13] Zhang, L. and O’Kelly, B. C., 2014 The Principle of Effective Stress and triaxial compression testing of peat. *Proceedings of the Institution of Civil Engineers*. Institution of Civil Engineers (ICE). pp. 40-50
- [14] Anggraini, V., 2006 Shear Strength Improvement of Peat Soil Due To Consolidation. Master Dissertation, Universiti Teknologi Malaysia.
- [15] British Standard Institution (BSI)., 1990 *British Standard Methods of Test for Soils for Civil Engineering Purposes. Part 8: Shear strength Tests (effective stress)*. BS1377.
- [16] Kolay, P.K. and Pui, M.P., 2010 Peat Stabilization Using Gypsum and Fly Ash. *Unimas E Journal of Civil Engineering*; Vol 1.Issue 2.
- [17] Zainorabidin, A, Wijeyesekera, D.C., and Mohd Masirin, M.I., 2007 Comparative Study of British and Malaysian Peat Soils Pertaining to Geotechnical Characterizatics.
- [18] Rahman, J. A. and Chan, C. M., 2013 Influence of Temperature on the Mass Losses of Tropical Peat at Different Decomposition Level, *Soft Soil Engineering international Conference*.
- [19] Razali, S. N. M., Bakar, I., and Zainorabidin A., 2013 Behaviour of Peat Soil in Instrumented Physical Model Studies, *Procedia Engineering*, Volume 56, Pp 145 – 155.
- [20] Mesri, G. and Ajlouni, M., 2007 Engineering Properties of Fibrous Peats. J. Geotech. Geoenviron. Eng., 133(7): 850-866.

- [21] O'Kelly, B.C., Pichan, S.P., 2013 Effects of Decomposition On The Compressibility of Fibrous Peat- A Review, *Geomech. Geoeng.* 8(4), 286-296
- [22] Zainorabidin, A. and Bakar, I., 2003 Engineering properties of in-situ and modified hemic peat soil in Western Johor. *Proc. of 2nd International Conference on Advances in Soft Soil Engineering and Technology*, Putra Jaya, Malaysia, pp. 173-182.
- [23] Cola, S. and Cortellazo, G., 2003 The Shear Strength Behaviour of Two Peaty Soils," *Geotechnical and Geological Engineering*, pp. 679-695
- [24] Yusoff, S.A.N.M, Bakar, I., Wijeyesekera, D.C., Zainorabidin, A., Madun, A., 2015 Comparison of Geotechnical Properties of Laterite, Kaolin and Peat. *Applied mechanics and material* 773, 1438-1442.
- [25] Edil T.B and Wang, X., 2000 *Shear Strength and K_o Of Peats and Organic Soils Geotechnics of High Water Content Materials*, ASTM STP 1374, West Conshohocken, PA.
- [26] Wong, L.S., Hashim, R. and Ali, F.H., 2009 A Review On Hydraulic Conductivity And Compressibility of Peat. *Journal of Applied Sciences*, 9: 3207-3218.
- [27] Mitchell, J.K, 1993 *Fundamentals of Soil Behavior*. J. Wiley & Son Inc.
- [28] Norhaliza W., Ismail B, Azhar A T S & Nurul N J, Shear Strength of Remoulding Clay Samples Using Different Methods of Moulding, *IOP Conference Series: Materials Science and Engineering*, 136 1-6.
- [29] Ling J H, Sabarudin M , Saiful A A T , Syazie N A M, Ismail B, Mohd I M M, Adnan Z & Ali A W M, 2016 Construction of Infrastructure on Peat: Case Studies and Lessons Learned, *MATEC Web of Conferences*, 47 03014.
- [30] Ali A W M, Sabarudin M , Mohd I M M , Saiful A A T , Ismail B , Adnan Z , Azrul Z K & Ling J H, 2016 Construction of Buildings on Peat: Case Studies and Lessons Learned, *MATEC Web of Conferences*, 47 03013.