© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Chemical Stabilization of Amorphous Peat Using Cement and Fly Ash at Different Water Additive Ratios

S. N. L. Taib[1*], I. Afiqah[2], G. J. Galvinov Indit[3]

[1]Faculty of Engineering,
Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, MALAYSIA

[2]KTA (Sarawak) Sdn Bhd, 93350 Kuching, Sarawak, MALAYSIA

[3]Jabatan Kerja Raya Sarawak, Sibu 96000, Sarawak, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2023.15.06.001
Received 8 May 2023; Accepted 1 September 2023; Available online 28 November 2023

Abstract: Peat is a very problematic soil as it is poor in strength. However, previous researchers have proven that the compressive strength of peat can be improved by using various methods of soil improvement including chemical stabilization method. In this study, cement and fly ash and lime were additives used and were mixed with amorphous peat at various water additive ratios. To replicate actual stabilization on site, water additive ratio is proposed as to allow stabilization to be performed at natural water content of the peat. Peat samples were collected from Kampung Endap, Samarahan and mixed at its natural moisture content with cement and with fly ash and lime at different water additive ratios of 3.0, 3.5, 4.0, 4.5 and 5.0. The compressive and bearing strengths of the samples were obtained by the unconfined compressive strength (UCS) test and California Bearing Ratio (CBR) test respectively. The results of the study have shown that there is marginal strength gained after 28 and 56 days of air curing period. The peat samples stabilized with cement at 3.5 water additive ratio recorded the highest value with UCS value of 69.48 kPa after 56 days of curing and 0.52 % for CBR test after 28 days curing period. These strength values obtained are lower compared to published data from previous studies. Different technique of mixing in the laboratory that is mixing peat at its natural water content with varied amount of additives at selected water additive ratio as opposed to mixing at maximum dry density and optimum moisture content that is mostly performed in laboratory contributes to the outcome. However, this study has proven that there is an increase in compressive and bearing strengths of stabilized peat in its natural water content compared to original peat without stabilizer.

Keywords: Peat, soil stabilization, CBR, UCS

1. Introduction

Malaysia is one of the countries that has peatland area of about more than 8% of total land around the world. Davies et al. [1] indicated that about 2.45 million ha (7.45%) of total land area in Malaysia is covered with peat or organic soils and out of this, Sarawak holds the largest area with about 1.7 million ha (69%) peatland area, 0.6 million ha (26%) in Peninsular Malaysia while 0.1 million ha (5%) of peatland area in Sabah. With the large area of peat is located in Sarawak, development is inevitable in such area and therefore, improvements to peatland must be made.

Various methods are available namely displacement and replacement method, preloading, deep stabilization method, pile support method, chemical stabilization, lightweight fill method, thermal precompression and reinforced overlay [2]. There have been many researches on different types of chemical stabilizers or admixtures used to improve the strength of peat. Fly ash, pond ash, cement and lime are the common chemical stabilizers used. Several researchers have also

*Corresponding author: tlinda@unimas.my

studied the stabilization of peat using combined additives such as cement with lime [3], quicklime and fly ash [4] and also lime with rice husk ash [5].

Peat is very poor in bearing capacity and subject to long term settlement. Therefore, construction methods and improvement applied on peat must be able to counter such problem, though constructions in peat area can be avoided altogether. There is high demand for development in Sarawak and is unavoidable. One of the promising methods to solve this problem is to increase and improve the strength of peat via chemical stabilization by adding the most suitable and optimum mixing quantity. In addition, laboratory mixing should replicate field stabilization mainly done via deep mixing method, wet mixing method, dry mixing method and mass stabilization method. According to Makusa [6], stabilization method involves mixing procedures to improve soil on site which is by applying stabilizing agents without removing the bulk soil. To add, the abundance of fly ash produced from burning of coal ash or industrial wastes in Sarawak is another factor leading to the study due to the large amount of fly ash produced which cause disposal problems. Hence, fly ash is of interest in this study.

This study concentrates on the stabilization of peat obtained from Samarahan, Sarawak with cement and fly ash and lime at different water additive ratios to replicate field stabilization whereby the studied peat was stabilized in a laboratory condition, yet maintaining the moisture content of the original peat sample. As a result, the water to additive ratio is varied in the mixing (at maintained peat water content). The geotechnical properties of stabilized peat such as water content, specific gravity and dry density obtained were then utilized in performing the stabilization and later be tested in California Bearing Ratio (CBR) test and Unconfined Compressive Strength (UCS) Test.

2. Methodology

All experiments were conducted in the Geotechnical Laboratory, Faculty of Engineering, Universiti Malaysia Sarawak. The study begins with gathering information from the literature on peat stabilization, the behaviour of peat especially their physical properties and the best mix proportion based on the best strength results obtained in previous studies. Water additive ratios of 3.0, 3.5, 4.0, 4.5 and 5 were chosen for this study.

Before sampling, the vane shear test was conducted to obtain the undrained shear strength of peat at site. Then, the samples collected were classified based on the degree of decomposition by Von Post classification. The physical properties of peat were also determined including organic content, fiber content moisture content, liquid limit, specific gravity and acidity. After all the basic properties were known, Unconfined Compressive Strength (UCS) test and California Bearing Ratio (CBR) test were carried out. The tests conducted in this study are according to BS 1377 and ASTM standards.

2.1 Sampling

Location where the peat samples are collected is at Kpg. Endap, Kota Samarahan as marked in Fig. 1(a). The site was surrounded by bushes and some pineapple and bamboo plants. The condition of the ground was very soft and the ground water table was approximately 15 cm from the ground surface as shown in Fig. 1(b).

The samples were collected on a sunny day, 21st March 2016 at 2.00 pm. The proposed peat type was amorphous peat and a peat auger was used to sample the peat as shown in Fig. 2(a). Von Post classification test was conducted on site to determine the humification scale of the peat sample. After the area where the amorphous peat was identified, the samples were dug and filled into two garbage bins and were kept airtight (Fig. 2(b)) to be brought back to the lab.

(a) (b)

Fig. 1 - (a) Location of sampling, and; (b) high ground water table at the site

(a) (b)

Fig. 2 – (a) Peat Auger sampling, and; (b) samples collected for further testing

2.2 Selected Admixtures

2.2.1 Cement

The production of Portland cement involves the burning of calcareous material (normally lime) and an argillaceous material (clay, silica and alumina) with iron oxide. The materials are crushed and mixed in ball mills, and then heated in a kiln to about 1500 ºC. The heating produced a clinker which consists of a number of compounds which set or harden when the clinker is ground to a fine powder (cement) and then mixed with water [7]. The type of cement used in this study was Ordinary Portland Cement (OPC) Type 1 from Cahya Mata Sarawak (CMS) Sdn. Bhd. The physical properties and chemical compositions of this OPC Type 1 manufactured by CMS Sdn Bhd are shown in Table 1 and Table 2 respectively.

Table 1 - Physical properties of type 1 OPC

Physical Properties	Type 1 OPC
Specific Gravity	3.15
Retained on 45 µm sieve	18%
Retained on 90 µm sieve	2%

Table 2 - Chemical composition of selected type 1 OPC

Components	Compositions (%)	Components	Compositions (%)
Calcium Oxide (CaO)	64.75	Magnesia (MgO)	1.44
Silicon Dioxide (SiO_2)	19.34	Potassium Oxide (K_2O)	0.47
Aluminum Oxide (Al_2O_3)	5.20	Sodium Oxide (Na_2O)	0.10
Loss on Ignition (LOI)	3.42	Free lime	1.39
Iron Oxide (Fe_2O_3)	3.41	Total Alkali	0.41
Sulphur Trioxide (SO_3)	2.85		

2.2.2 Fly Ash

Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. The fly ash used in this study is from Sejingkat Coal-Fired Power Station, Sarawak. The FA from this power plant is classified as ASTM Class F which is a low calcium fly ash. The chemical compositions are shown in Table 3.

Table 3 - Chemical composition of fly ash from Sejingkat Coal-Fired Power Station

Components	Compositions (%)	Components	Compositions (%)
SiO_2	58	TiO_2	1.05
Al_2O_3	24.8	P_2O_5	0.34
Fe_2O_3	7.17	Na_2O	0.30
K_2O	3.14	MnO	0.18
CaO	2.40	SO_3	0.08
MgO	1.95	LOI	0.32

2.2.3 Lime (CaO)

The type of lime or also known as calcium oxide (CaO) used in this study is of general grade Merck brand lime supplied by Robert Scientific Company Sdn. Bhd., Kuching. CaO has a molecular weight of 56.07 g/mol. The composition of CaO are 71.47 % calcium (Ca) and 28.53 % oxygen (O). The physicochemical information of CaO is shown in Table 4.

Table 4 - Physicochemical information on CaO

Specifications	Properties
Density	3.37 g/cm^3 (20°C)
pH value	12.6 (H_2O; 20°C) saturated solution
Bulk Density	800-1200 kg/m^3
Solubility	1.65 g/l(20°C)
Boiling Point	2850°C (100 mbar)
Melting Point	2850°C

2.3 Tests Performed

Properties tests performed to classify peat are degree of humification via the Von Post classification, loss on ignition or the organic content and the fiber content. Other relevant tests performed are moisture test, specific gravity, pH, liquid limit, linear shrinkage, the field vane shear test and the Unconfined Compressive Strength test (UCS). Description of sample preparation and results of mentioned tests are presented next.

2.4 Peat Properties

Table 5 presents the basic geotechnical properties of Kpg Endap, Samarahan peat. The type of peat to be stabilized in this study is amorphous peat which is widely found in the study area. The Von Post classification test was carried out by squeezing the peat in the hand. From the results, the sample was categorized as H8 to H9 according to the Von Post classification system. The description suited the classification made as the samples were very highly decomposed with a large quantity of amorphous material and about two thirds of peat escaped between the fingers. The ground water table on site was approximately 15 cm below ground level. Based on Malaysian Soil Classification System in [8], peat with Von Post classification of H7-H10 is categorised as amorphous peat.

Table 5 - Kpg. Endap peat properties

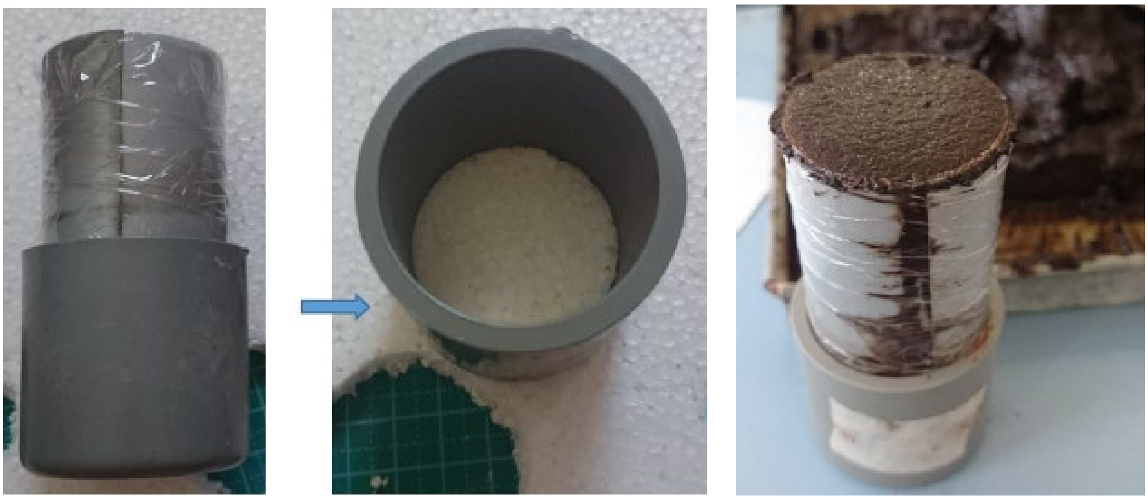
Properties	Kpg. Endap Peat
Von Post Classification	H8-H9 (Amorphous)
Moisture Content, w (%)	461
Liquid Limit, LL (%)	528.19
Linear Shrinkage (%)	19.29
Organic Content, OC (%)	92
Fiber Content, FC (%)	15.82
pH value	4.23
Specific Gravity (G_s)	1.47

2.5 Preparation of Sample for UCS Test

Samples were carefully prepared for the unconfined compressive strength of peat. The sample size used for the experiments was at different sizes due to the size of plastic pipes used for curing. The average size of the pipes is at 37 mm diameter and 77 mm length. Due to the unlevelled bottom of the pipe, a polystyrene was used to ensure the sample would have a smooth and levelled surface at both ends of the pipe. The pipes were also wrapped with plastic to avoid water from leaking out of the sample. The materials used for the preparation of samples are shown in Fig. 3(a) and Fig. 3(b).

The samples used for the stabilized peat UCS tests were peat samples at their natural moisture content. First, the peat sample was screened in order to remove the larger roots and fibers using a 6.3 mm sieve. Then, the specified amounts of cement, fly ash and lime were added to the peat sample, mixed well for their homogeneity, and placed in the plastic pipe mould in three layers. Each layer was pressed repeatedly using a round shaped stick until there was reasonably no visible voids present in the samples. This method was slightly different from the method used by Kalantari & Huat [9] where full thumb pressure of 10 seconds was used to compress the samples. The reason for not using this method is because large voids still exist in the samples after thumb pressed.

After the stabilized peat was placed in the mould, the samples were cured for 28 days. The curing technique used to cure the stabilized peat samples was air curing technique as described by Kalantari & Huat [9]. This technique involves wrapping the stabilized samples in plastic sleeves and kept in normal air temperature of 30 ± 2 ºC and out of reach from water intrusion during the curing period.



(a) (b)

Fig. 3 - (a) Plastic wrap and polystyrene used for sample preparation, and; (b) ready sample

2.6 Preparation of Sample for California Bearing Ratio Test (CBR)

In this study, tests were carried out on compressed peat at natural moisture content in unsoaked condition. The best water additive ratio result from the UCS test was chosen for the CBR test. Before the samples were placed into the mould, the compaction mould of 152mm diameter and 178 mm height was weighed. Then, the peat sample was compressed in three equal layers using a compression device as shown in Fig. 4. The collar of the mould was removed and the peat surface was levelled. The mould together with the sample was then weighed, sealed and air cured for 28 days. It is to mention here that samples were all prepared to the operator's best level to ensure no visible voids present in the samples and to allow similar condition as the UCS samples were introduced.

Fig. 4 - CBR peat sample compressed in 3 equal layers

3. Results and Discussion

3.1 Mix Design

Table 6 shows the water additive ratios used in preparing the peat samples. Based on previous study by Aminur et al. [10], the dosage amount of fly ash and lime recommended is 10% and 6% of dry mass respectively. For this study, based on the same principle, ratio of lime to fly ash was kept at 6:10 for the total admixture added. Mix proportions for cement only and combination of fly ash and lime samples together with their sample IDs are presented.

Table 6 - Mix proportions for all sample preparations

Moisture Content (%)	Water Additive Ratio	Mix Proportions (g) and Sample ID							
		Total Wet Soil	Dry Soil	Water	Cement Only	Sample ID	Lime +	FA	Sample ID
	3.0	1000	178.3	821.7	273.9	3.0 Cement	102.7	171.2	3.0 FA Lime
	3.5	1000	178.3	821.7	234.8	3.5 Cement	88.0	146.7	3.5 FA Lime
461	4.0	1000	178.3	821.7	205.4	4.0 Cement	77.0	128.4	4.0 FA Lime
	4.5	1000	178.3	821.7	182.6	4.5 Cement	68.5	114.1	4.5 FA Lime
	5.0	1000	178.3	821.7	164.3	5.0 Cement	61.6	102.7	5.0 FA Lime

3.2 Field Vane Shear Test

An in-situ shear strength was obtained by vane shear test conducted at a depth of 0.1 m to 1.5 m in the site. The vane shear strength profiles are represented in Fig. 5(a). The average undrained shear strength of peat obtained is 5 kPa for depth between 0.1 to 1.5 m. Since the results from the in-situ vane test is inaccurate as it tends to overestimate the shear strength of peat [11], a correction factor of 0.5 was suggested to be used for organic soils with liquid limit of more than 200 % [12], [13]. The corrected shear strengths are shown in Fig. 5(b). According to Huat [14], the average field vane shear strength of peat in Sarawak is only 10 kPa with sensitivity that ranges from 2 to 11. The low vane shear strength obtained in this study is most probably due to the high degree of humification of peat at the site. This is because as stated by Huat at el. [2], the shear strength parameters of peat are generally lower as the degree of humification increases.

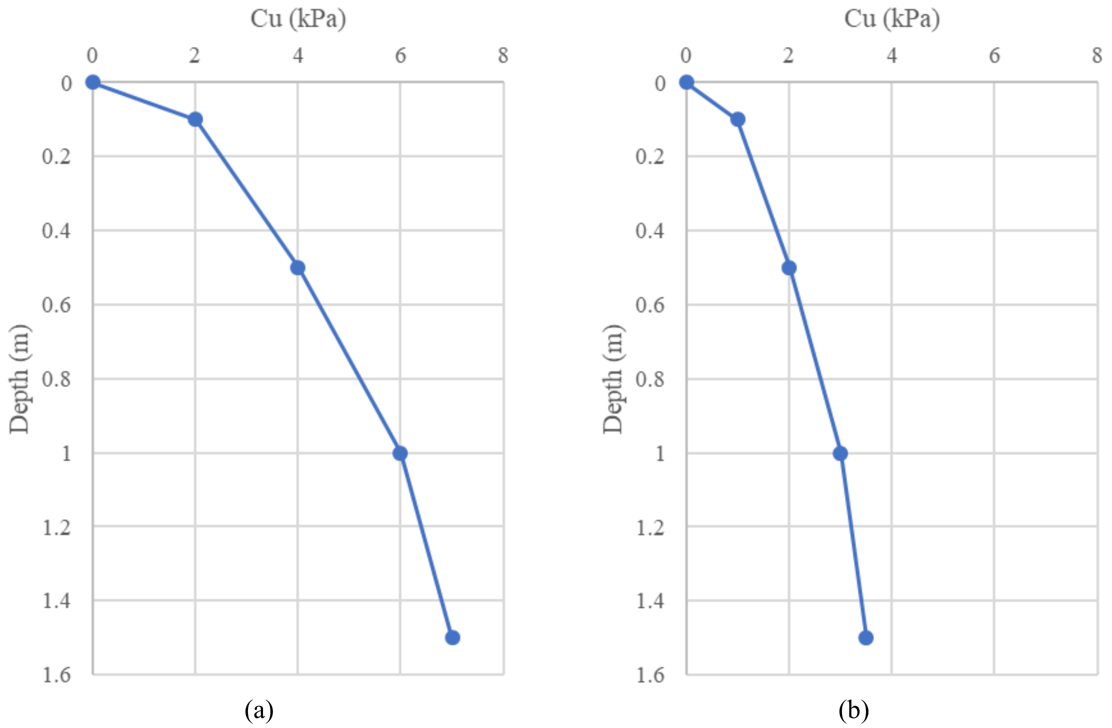
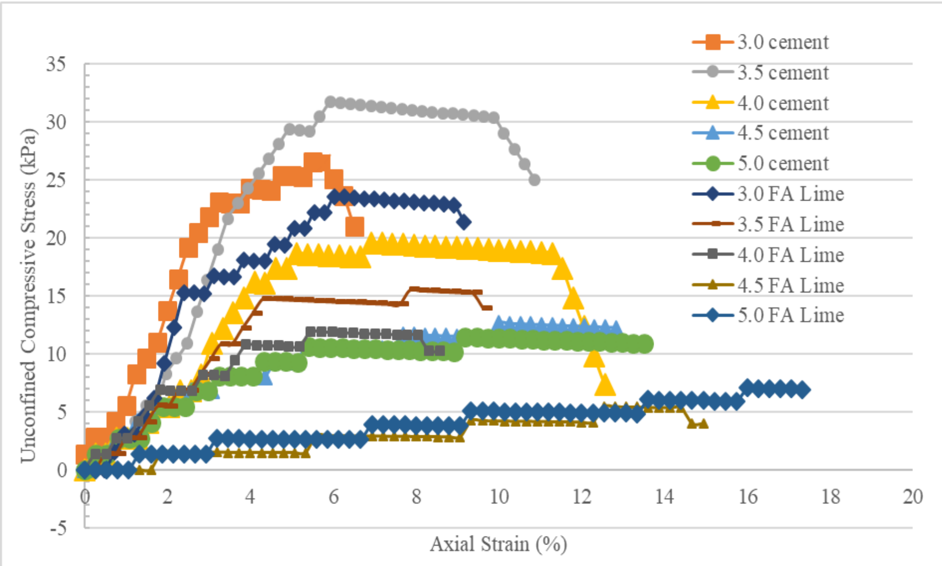


Fig. 5 - Vane shear strength for peat at Kpg. Endap (a) original, and; (b) corrected

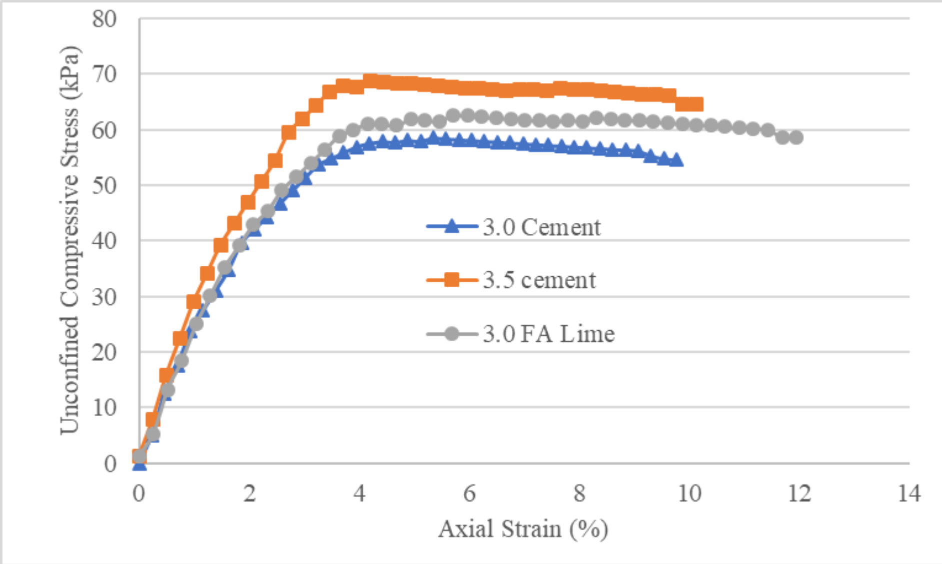
The results of the present vane shear test are also in agreement with a study conducted by Al Raziqi et al. [15] who has observed a decreasing trend between degree of humification and vane shear strength of peat where amorphous peats (H7-H10) obtained the lowest vane shear strength with an average of 5 kPa compared to fibric (H1-H3) and hemic peats (H4-H6) with 12 kPa and 9 kPa respectively. This shows that the higher the fiber content of peat, the higher the shear strength obtained. Al Raziqi et al. [15] had also observed the decreasing behaviour of peat shear strength with increasing moisture content and organic content with vane shear strength of 3 kPa to 6 kPa when the moisture content is between 400 to 550 % and organic content between 90 to 95% which is comparable with the results of the present study which are 461% moisture content and 92% organic content.

3.3 Unconfined Compressive Strength (UCS) Test

UCS tests were conducted at various water additive ratios of cement treated peat and also different water additive ratios for peat treated with fly ash and lime (refer Table 6). The amount of fly ash and lime used in this study was based on the finding of Aminur et al. [10] for optimum dosage rate that gave the highest UCS value. In addition, the UCS test was performed to investigate the most effective water additive ratio in both types of stabilizers. The stabilized samples were mixed initially with amorphous peat's natural moisture content of 461% and air cured for 28 days. The results of the UCS stabilized peat samples after 28 days of air curing are illustrated in Fig. 6(a) which shows that the higher the water additive ratio, the lower the UCS value in peat with both cement and lime and fly ash. These results agree with the data obtained by Kalantari & Huat [9] and can be explained as when more water content is present in the sample, the lower the strength value. In Fig. 6(b), UCS results of stabilized peat after 56 days of air curing are presented. Note that UCS after 56 days was only performed at water additive ratio of 3.0 for both stabilizers and at 3.5 only for sample mixed with cement as these water ratios are showing significant strength improvement as shown in Fig. 6(a).



(a)



(b)

Fig. 6 - (a) Unconfined compressive strength of stabilized peat after 28 days of air curing, and; (b) unconfined compressive strength of stabilized peat after 56 days of air curing

Based on the average UCS results after 28 days, peat samples that were stabilized with cement gave higher UCS results compared to peat stabilized with fly ash and lime. The highest UCS value obtained from the test was about 31.6 kPa for peat stabilized with cement at 3.5 water additive ratio followed by 26.4 kPa for peat stabilized with cement at 3.0 water additive ratio. The reason for the cemented peat with 3.0 water additive ratio was lower than 3.5 water additive may be due to the voids present in the earlier sample (Fig. 7) that affected the strength of the stabilized peat. However, for peat that was stabilized with fly ash and lime, the lowest water additive ratio gave the highest UCS value which then decreased as the ratio increased.

Referring to Fig. 8, the highest average UCS value obtained from the test after 28 days was 30.87 kPa which was for cement stabilized peat at 3.5 water additive ratio. In the case of cement stabilized peat, the results for 3.5 water additive ratio was higher compared to 3.0 water additive ratio. As for peat stabilized with fly ash and lime, the highest average UCS value obtained was at 3.0 water additive ratio and the lowest was at 4.5 water additive for peat stabilized with fly ash and lime with an average low value of 3.86 kPa. The overall results of the UCS test after 28 days of curing showed insignificant improvement in strength when the strength of all the compositions recorded are below 31 kPa which is around the same value obtained by Sing et al. [16] after 7 days of curing. However, as the water additive ratio decreases, the UCS values increases. In addition, the longer the curing period, the more strength it gains. Hence, it is observed that the UCS values increased by 2-3 folds when the curing period was longer (Fig. 6(b)) which is also shown in Fig. 8 for water additive ratio at 3 and 3.5 respectively. It is necessary to indicate here that the result for peat with cement only at 56 days for water additive ratio of 3.5 is higher than water additive ratio of 3.0.

Fig. 7 - Voids present in the cement stabilized peat at 3.0 water additive ratio

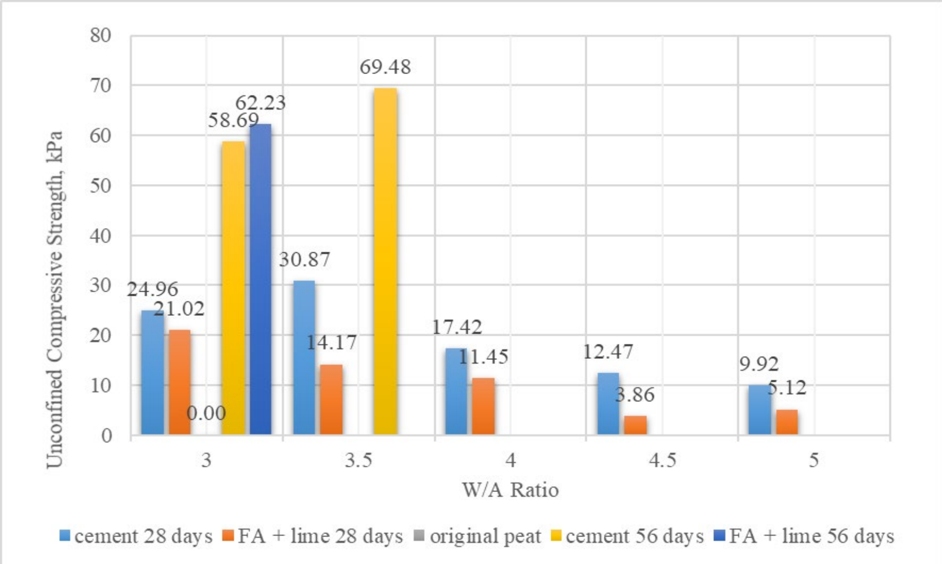


Fig. 8 - Unconfined compressive strength for peat stabilized at various water additive ratio for 28 and 56 days

FA and lime combination presents higher strength after longer curing. As noted by Kolay et al. [4] fly ash reacts with peat molecules after long curing period. In addition, the chemical reaction of lime and water as explained by Negi et al. [17] takes time to form cementitious products to bond and convert the soil into a stronger layer. This explains why it had developed more strength compared to cement at the same water additive ratio.

Nonetheless, all the UCS values obtained even after almost two months of curing were still low compared to other studies and was probably due to the high organic content of the present peat sample. According to Aminur et al. [10], peat that is highly organic and its acidic condition leads to lower UCS value upon stabilization. Besides, most studies are based on peat stabilized and compacted at their optimum moisture content. However, in this study, the amount of water in the sample was very high and most probably more than what was needed for bonding chemical reaction. Therefore, such condition affected the strength of the samples.

Based on the overall UCS results, peat stabilization with cement is more suitable compared to fly ash plus lime stabilization for this particular peat sample. The same trend was also observed in a study conducted by Aminur et al. [10]. Although the strength results obtained in this study does not give much satisfaction, nevertheless, the study shows strength development when the curing period was extended and water additive ratio was decreased. The increasing UCS values with increasing curing period was consistent with the findings observed by [9] in their study. Fig. 9 shows the failed samples at 3.0 water additive ratio of cement stabilized peat after 28 and 56 days curing. From all the tested samples, much profound brittle fractures are present in longer curing samples. Some samples of longer curing displayed clear shear band. Reduction in moisture content due to longer curing period increased the brittleness on samples.

(a)

(b)

Fig. 9 - Failure condition of 3.5 water additive ratio cement stabilized peat (a) after 28 days curing, and; (b) after 56 days curing

3.4 California Bearing Ratio (CBR) Test

The California bearing ratio (CBR) test was conducted only for peat with cement at water additive ratio of 3.5 which recorded the best ratio in the UCS test. The sample was cured for 28 days. The CBR test was also conducted on original peat and the reading maintained at 0 kN throughout the experiment for both top and bottom portions. The condition of the sample can be seen in Fig. 10 where some of the sample dripped at the side of the CBR mould after the top cover was removed.

On the other hand, Fig. 11 shows the CBR test results for peat stabilized with cement at 3.5 water additive ratio after 28 days. From the results, it can be said that the bottom portion of the sample could sustain more load than the top portion. This may be due to the bottom portion was more compressed under its own weight than the top portion. The same trend was also observed in a study conducted by Rahman et al. [18] where the bottom portion of CBR sample recorded higher values compared to the top portion.

Fig. 10 - Condition of original peat during CBR after 28 days

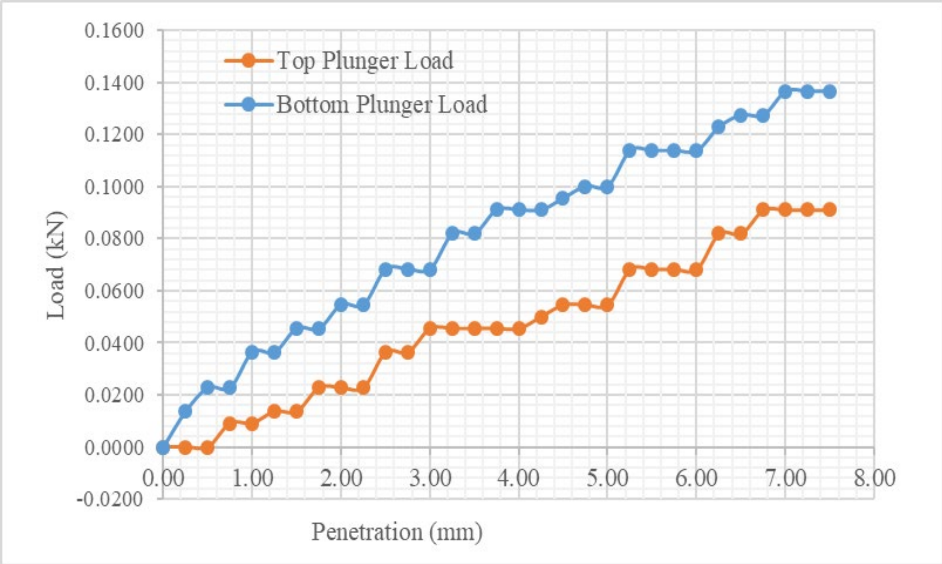


Fig. 11 - CBR test results for cement stabilized at 3.5 W/A ratio after 28 days

From the results of the test, the CBR value at both 2.5 mm and 5 mm penetration for the bottom portion is higher than the top portion which is 0.52 % and 0.50 % respectively while the top portion is 0.28 % for 2.5 mm penetration and 0.27 % for 5 mm penetration. It can be said that the overall CBR values are very low which may be due to high water additive ratio and insufficient curing time. Kalantari & Huat [9] had also studied on the CBR test of air cured stabilized peat mixed at natural moisture content of 200% with water additive ratio of at least 0.5 and found that the CBR values was up to 38 % after 90 days of curing which is very much higher than the values obtained in this study.

According to Bowles. [19], three months of air curing increases the general rating of in situ peat that is from very low to good. Besides, using the air curing technique instead of normal moist curing contributes to the increasing strength as it keeps lowering the moisture content while the stabilized sample increases in strength [2]. This proves that 28 days of curing is not enough for air curing technique.

4. Conclusions

The peat sample used in this study was from Kpg Endap, Samarahan and was classified as amorphous peat based on ASTM classification. The amorphous peat was also classified as H8-H9 based on Von Post scale which is highly decomposed peat with high amount of organic content and moisture content but with very less fiber content. The peat sample was stabilized using cement and fly ash plus lime combination at various water additive ratios; 3.0, 3.5, 4.0, 4.5 and 5.0.

The undrained shear strength of the peat sample at site recorded an average value of 5 kPa which is very low due to high moisture content and organic content. From the results of UCS test, water additive ratio of 3.5 for peat stabilized with cement recorded the highest value for both samples cured at 28 and 56 days which is 30.87 kPa and 69.48 kPa respectively. However, all the UCS values increased as the curing period increased. Since the water additive ratio of 3.5 for cement stabilized peat recorded the best UCS results, a CBR test was conducted for this mix ratio and cured for 28 days. The results from the CBR test were very low which was only up to 0.52 %. The findings of this study also showed that cement stabilized peat at 3.5 water additive ratio is the best mix proportion as it gives the highest strength value among all samples.

To add, since the water content of the sample was high, the 28 and 56 days curing periods were inadequate for the stabilized sample to gain strength as the results obtained were quite low than previous studies. A curing period of at least 90 days using the same air curing technique may give significant results based on the findings by previous studies [19], [2].

From the conclusions derived from the study, it is observed that not much strength was gained which is probably due to high water additive ratio used. The strength test on amorphous peat should be carried out further with more varying water additive ratio and longer curing periods. By doing so, a more comprehensive results can be obtained. In addition, the low results obtained may also be due to the acidity of peat sample that affects the strength of stabilized peat. It is recommended that the peat sample should be first treated with an additive sodium hydroxide (NaOH) reagent to remove the organic coating in order to increase pH and reduce hydrophobicity behavior of peat before mixing the peat sample with the desired chemical stabilizer. By this way, the strength of stabilized peat can be further improved [4].

Furthermore, it is recommended that further study involving field investigation on amorphous peat can be carried out to justify the laboratory investigation on the peat sample from this study. This is because the results obtain from the field may differ from laboratory results due to the controlled environment in the laboratory. Nonetheless, this study had successfully treated peat in its natural moisture content which may be extended further with more variations of natural water content, admixture dosages and types and extended curing period.

Acknowledgments

Authors wish to acknowledge Universiti Malaysia Sarawak for the laboratory and financial supports and colleagues for the assistance and encouragement throughout the project.

References

[1] Davies J., Matthew U., Aikanathan S., Chik N. Y. & Chong G. (2010). A quickscan of peatlands in Malaysia. Wetlands International.
[2] Huat B. B., Prasad A., Asadi A. & Kazeiman S. (2014). Soil improvement and construction method. In Huat B. P. (Ed.), Geotechnics of organic soils and peat. Taylor &Francis Group, pp. 121-168.
[3] Said J. M. & Taib S. N. (2009). Peat Stabilization with Carbide Lime. UNIMAS E-Journal of Civil Engineering, 1(1), 1-6.
[4] Kolay P. K., Aminur M. R., Taib S. N. & Mohd Zain M. I. (2011). Stabilization of tropical peat soil from Sarawak with different stabilizing agents. Geotechnical and Geological Engineering, 29(6), 1135-1141.
[5] Vishwanath G., Pramod K. R. & Ramesh V. (2014). Peat soil stabilization with rice husk ash and lime powder. International Journal of Innovation and Scientific Research, 9(2), 225-227.
[6] Makusa G. P. (2012). Soil stabilization methods and materials: In engineering practice. Lulea University of Technology.
[7] Gani M. S. (1997). Cement and concrete. Chapman & Hall.
[8] Jabatan Kerja Raya Malaysia & Jarret P. M. (l995), Geoguide 6: Site investigation for organic soils and peats. JKR Document 20709-0341, Jabatan Kerja Raya Malaysia.
[9] Kalantari B. & Huat B. B. (2010). Improving unconfined compressive strength of peat with cement, polypropylene fibers, and air curing technique. Global Journal of Researches in Engineering, 9-15.
[10] Aminur M. R., Kolay P. K. & Taib S. N. L.(2009). Effect of admixtures on the stabilization of peat soil from Sarawak. Indian Geotechnical Conference. Indian Geotechnical Society, pp. 410-414.
[11] Hanrahan, E. T. (1967). Shear strength of peat. Proceedings - Geotechnical Conference, Olso, pp. 399-403.
[12] Noto S. (1991). Peat engineering handbook. Civil Engineering Research Institute, Hokkaido Development Agency.
[13] Hartlen J. & Wolsky W. (1996). Embankments on Organic Soils. Elsevier Science, 80, 4-20.
[14] Huat B. B. (2004). Organic and peat soils engineering. Universiti Putra Malaysia Press.
[15] Al-Raziqi A. A., Huat B. B. & Munzir H. A. (2003). Potential usage of hyperbolic method for prediction of organics soil settlement. Proceeding of 2nd International Conferences on Advances in Soft Soil Engineering and Technology. University Putra Malaysia Press, pp. 439-445.
[16] Sing W. L., Hashim R. & Haji Ali F. (2009). Unconfined compressive strength of cemented peat. Australian Journal of Basic and Applied Sciences, 3(4), 3850-3856.
[17] Negi A. S., Faizan M., Siddharth D. P & Singh, R. (2013). Soil stabilization using lime. International Journal of Innovative Research in Science, Engineering and Technology, 2(2), 448-453.
[18] Rahman M. A., Kolay P. K. & Taib S. N. L. (2011). Utilization of fly ash in local Sarawakian peat soil stabilization. Australian Geomechanics, 46(3), 63-68.
[19] Bowles J. E. (1978). Engineering properties of soil and their measurements. McGraw-Hill.