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Impact of Sugarcane Bagasse Ash (SCBA) and Cement to the Strength Improvement of Hemic Peat

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Abstract: Peat soils are derived from organic deposition consisting of dead trees. Peat soils have low shear strength and cannot afford large loads. Various treatment methods are used to stabilize peat soils and most of them use cement as a main binder to increase the strength of peat soils. However, the use of large quantities of cement is not environment friendly due to the release of carbon dioxide (CO_2) and wastage of energy consumption by the cement production industry. Therefore, the introduction of SCBA as a substitution binder for some cement dosage is good as well as reducing the degradation of dumping waste which is increasingly uncontrollable. The objective of this study is to identify the basic and physical properties of peat soil from Pontian, Johor. In addition, this study was also conducted to identify the impact of SCBA on peat soil stabilization with cement. There are 5 different mixtures for cement and SCBA which are C100, C95S5, C90S10, C85S15 and C80S20 used in this study. Sample C95S5 with mixtures 95% cement and 5% SCBA were the optimum samples for this study based on unconfined compression strength (UCS) tests. The C95S5 sample successfully achieved the maximum strength of the whole sample with a strength of 190 kN/m^2, 209 kN/m^2, and 219 kN/m^2 recorded for wet curing periods of 7,14 and 28 days. Therefore, the use of SCBA materials in the stabilization of peat soils with cement and calcium chloride ($CaCl_2$) is seen to have a positive effect in increasing the shear strength of Hemic peat soil samples.

Keywords: Peat soil, cement, Sugarcane Bagasse Ash (SCBA), Unconfined Compressive Strength (UCS)

1. Introduction

Generally, peat soils are derived from organic deposition consisting of dead trees and so on. Apart from having high organic content, peat soils are also known as high acid acids and no microorganism's activity. Peat soil also has a very low volume weight and can be clearly seen in dry conditions. There are various treatment methods that can be used to stabilize peat soils and most of them use cement as an additive to increase the soil bearing capacity of the peat. Cement acts as a binding agent for peat soils that are more porous when compared to other mineral soils. However, the use of cement as a whole in the stabilization of peat soils threatens our ecosystem as the production of cement products emits carbon dioxide (CO_2) which pollutes the environment.

Various efforts and studies conducted around the world to reduce the use of cement in various aspects. Sugarcane bagasse ash (SCBA) is one of the popular studies that being used as a partial replacement for some dosage of cement in organic soil improvement [1-6]. SCBA is produced from the process of burning sugarcane. In addition, SCBA contains high amounts of silicon and aluminum oxide [7]. Therefore, the use of this material can help to solve the environmental problems caused by cement. The peatlands are declared to have a total area of 2,457,730 ha or 7.45% of the total land in

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Malaysia. The distribution of peat soils in Malaysia showed that Sarawak was the largest peat area with 1,697,847 ha or 69.08% followed by Peninsular Malaysia with 642,918 ha or 26.16% and Sabah contributed 116,965 ha or 4.76% [8]. Peat also can cause geotechnical problems in the sampling area, deposition, stability, in situ testing, stabilization and construction [9]. The Von Post humidification scale can be used to classify peat soils. Referring to Fig. 1, the Von Posttest confirms the scale of humidity of peat soil based on condition of water and peat when peat samples are squeezed by hand.

Mass stabilization is a new method for maintaining and improving the strength of soft soils. The mass stabilization process is carried out by mixing a number of dry or wet binders in suitable quantities along the treated soil layer [10]. Mass stabilization methods can be combined with column stabilization methods to support basic loads as shown in Fig. 2 [11]. The equipment used in the mass stabilization method consists of a modified excavation engine arm, stabilizer tank, a compressor and a mixing tool. The compressor and mixing tools are installed in the modified excavation engine arm for the mixing process of binders with peat soils as shown in Fig. 3 [10].

Fig. 1 - Von Posttest during soil sampling

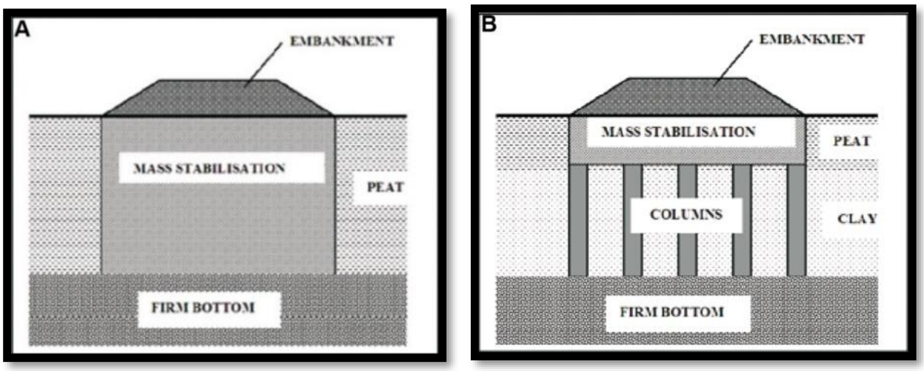

Fig. 2 - (a) Mass stabilization method; (b) combination of mass and column stabilization methods

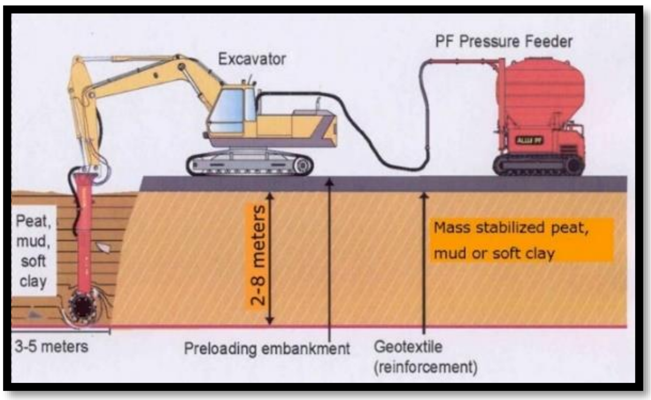

Fig. 3 - Mass stabilization method in peat soil

2. Materials and Methods

The main materials used in the sample preparation process is peat, SCBA and Ordinary Portland Cement (OPC). In addition to the main material, there are additional materials of calcium chloride used in this study to help the stabilization process. Peat soil sampling used in this study obtained from Benut, Pontian. The type of sample used in this study is a disturbed sample. The sampling method is manually using excavation method with a depth of 1 m from the ground surface. The soil at the first 10 cm depth should be removed because it is the top soil that does not represent the natural peat soil of the area. Cement is the main binder in the peat soil stabilization process even after the percentage reduction. The cement used in this study is the Ordinary Portland Cement (OPC) and is available from the construction material suppliers around the study area. For the size and physical content of the cement, it depends on the standards manufactured by the supplier.

SCBA is a substance used to replace the reduced percentage of cement in the sample preparation process. In this study, bagasse obtained from sugarcane traders around Parit Raja, Johor. The collected sugarcane bagasse should be dried first before grinding to facilitate the combustion process. The combustion process has been set at 500 ° C for 5 hours based on the previous study. Selection of temperature and time in the cane cracking process affects the quality of SCBA produced. Sample preparation for peat soils treated in this study was divided by different cement mix and SCBA ratio. Five different ratios of mixtures used in this study did not include untreated soil samples. Table 1 shows the abbreviation of the mixing bond ratio on peat soils with sugarcane bagasse ash represented by symbol (S) and the Ordinary Portland Cement represented by symbol (C).

Table 1 - Mixed ratio of SCBA and cement in treated samples

Ratio Binder Materials	Symbol
Cement 100%	C100
Cement 95% - SCBA 5%	C95S5
Cement 90% - SCBA 10%	C90S10
Cement 85% - SCBA 15%	C85S15
Cement 80% - SCBA 20%	C80S20

The proportion of the material ratio used in this study was based on the sample volume used i.e. 150 mm high and 50 mm diameter. The quantity of the substance used is the same as for wet storage for 7, 14 and 28 days. Peat soil quantities are calculated based on the bulk density value of peat soils of 10 kN/m^3. Bulk density values will be multiplied by 0.000295 m^3 specimen volume to obtain the required peat soil quantity for a specimen. The required OPC quantity for a specimen is 300 kg/m^3. The quantity value for each mix ratio varies according to the percentage of cement content as well as SCBA. For calcium chloride, the quantity required for each specimen is 3% of the cement quantity used. All the materials used in this study were weighed in grams (g) units as in Table 2.

Table 2 - Quantity of materials used for peat soil stabilization process

Sample Code	Peat Soils, (g)	Cement, (g)	SCBA, (g)	Calcium Chloride, (g)
C100	300	88	0	2.65
C95S5	300	84	4	2.52
C90S10	300	80	9	2.39
C85S15	300	75	13	2.25
C80S20	300	71	18	2.12

Sample preparation to be used for unconfined compressive strength (UCS) test based on predetermined mix ratio referring to ASTM-D 2166 standard. Study materials and apparatus that used were shown in Fig. 4. The sample preparation is used PVC pipe as a mold. The size of the mold was 50 mm in diameter and 150 mm in height. The sample size used for the UCS test is 50 mm in diameter and 100 mm in height, while the excess 50 mm in excess will be used for the consolidation test for further study. The first step in the preparation of the test sample is the preparation of materials such as cement, SCBA and sodium chloride. After all the ingredients are weighed according to the prescribed measure, all the ingredients are to be mixed for 1 minute of normal mixing machine to ensure all the ingredients are mixed when mixed with peat soil samples. Once the preparation of the material is complete, the peat soil samples weighing need to be mixed for 3 minutes using heavy-duty mixer. Mixing of peat soil samples is continued by mixing the binders which have been prepared into the same mixing machine and need to mix for 6 minutes until uniform for each sample.

Fig. 4 - (a) Study materials; (b) mixer; (c) sampling in mould

Samples that have been mixed are then put into molds as much as 3 layers and each layer is compacted using iron rod uniformed at a height of 10 cm in each layer of 20 bumps. Once the sample is inserted into the mold and compacted, the sample should be placed in a container containing water for a wet period of 7, 14 and 28 days. The soil samples that need to be tested are divided into two i.e. treated and untreated samples. The untreated sample is the original peat sample and has not been mixed with the binder. The treated sample is peat soils that have been mixed with binder material namely cement and SCBA to increase the bearing strength of the soil. Each test conducted in this study is carried out based on the established standards. Table 3 records the standards used for each experiment conducted in this study.

Table 3 - List of experiments and standards used in the study

Testing	Symbol	Standard
Moisture Content	MC	ASTM-D 2974
Organic Content	OC	ASTM-D 2974
pH Value	pH	ASTM-D 4972
Liquid Limit	LL	BS 1377 PART 2: 1990: 4.3
Specific Gravity	G_s	BS 1377 PART 2: 1990: 8.3
Fiber Content	FC	ASTM-D 1997
Unconfined Compressive Strength	UCS	ASTM-D 2166
Particle Size Analysis	PSA	ASTM-C 618

3. Results and Discussions

Table 4 shows a summary of the analysis results from the experiments conducted to identify the basic properties of peat soils. Based on moisture and organic content result, peat soil is a type of soil that contains a high percentage of moisture content. This is due to the fibers contained in peat soil structure having the ability to hold water. Therefore, the percentage of fiber content in peat soil will affect the moisture content of the tested sample. The percentage of the original moisture content and organic content obtained from the analysis was within the same range obtained by the previous researcher [6]. This high percentage of organic content proves that peat soils are derived from most deadly organic matter.

Table 4 - Analysis of the basic properties of Benut, Pontian peats

Laboratory Testing	Value
Moisture Content, %	533.33
Organic Content, %	92.69
pH Value	3.23
Specific Gravity. Gs	1.66
Fiber Content, %	48
Liquid Limit, %	189

The pH value obtained from the analysis proves that peat soils are acidic soils. According to previous studies, the pH values below 4.5 are classified as high acidity based on ASTM-D 4972 standards. Specific gravity test is carried out using pycnometer method to obtain the mean of the specific gravity value of 3 samples taken. The specific gravity value is influenced by the decomposition and mineral content of the tested soil samples. The specific gravity value of peat soil samples is usually below 2.0. The percentage of fiber content obtained showed the soil samples tested were hemic peat. Hemic peat has a modest decomposition stage. This condition can be seen in the preliminary sampling process which shows that most of the peat soil structure still contains still unpolished organic matter. Liquid limit tests performed using cone penetration method. The cone penetration graph against the percentage of moisture content should be plotted to obtain the percentage limit of the liquid. Fig. 6 shows the percentage of liquid limit obtained from the experiment is 189%.

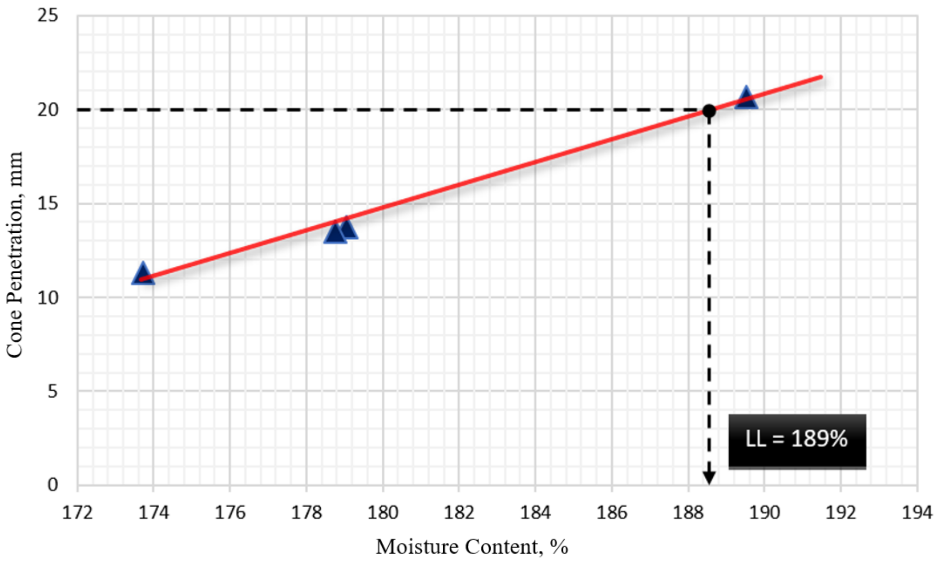

Fig. 6 - Graph cone penetration against moisture content

UCS test was conducted to determine the strength of peat soil before and after stabilization. The data obtained in this test has been analyzed to obtain the value of strain and stress. The result of the stress and strain values will be used to obtain UCS values for each tested sample. For peat soil samples before stabilization, only one specimen used to obtain UCS values to represent the original strength of peat soils. For samples after stabilization, there were 3 different curing periods tested i.e. 7, 14 and 28 days. Table 5 and Fig. 7 summarize the UCS values that have been analyzed. Peat soils are known as a soil that have a very low strength level compared to other soil types. This is evidenced by the results of an analysis of UCS test for natural peat soil for Benut, Pontian area which only reached 2.649 kN/m^2 of UCS value. The UCS value of untreated peat samples is based on the value of strain percentage which reaches 15%.

The 7-day curing period usually considered immature for most experiments involving the use of cement or concrete production. However, the use of calcium chloride (CaCl2) materials used in these experiments acts as accelerators which makes cement reactions in the sample faster or in other words the sample is able to reach the mature stage faster. This is evidenced by the results of the UCS test for the C95S5 sample which can achieve the average UCS value up to 190 kN/m^2.

Table 5 - The summary of unconfined compressive strength (UCS) results

No.	Curing Period	Mean Value of Unconfined Compressive Strength, (kN/m^2)					
		Untreated Peat	C100	C95S5	C90S10	C85S15	C80S20
1	7 Days	3.200	188	190	139	107	44
2	14 Days	3.200	207	209	175	133	69
3	28 Days	3.200	215	219	177	155	79

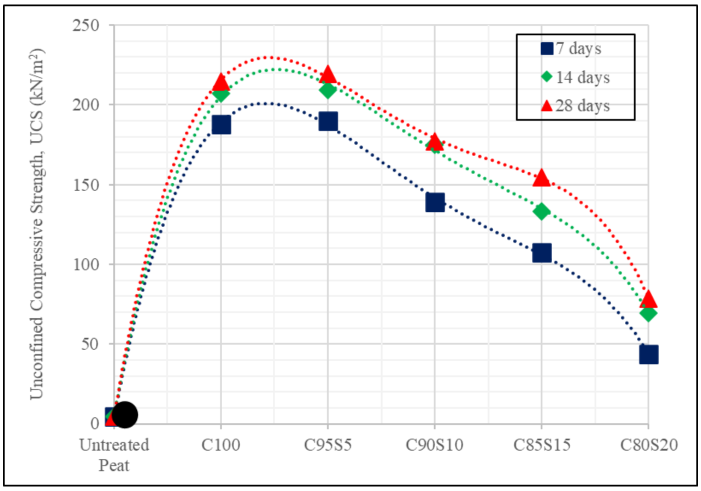

Fig. 7- Summary graph of unconfined compressive strength (UCS) result

UCS test for a 14-day wet curing period usually used to find the midpoint between 7 and 28 days. The midpoint between these two periods is important to get an overview of the increased strength of the treated sample. Typically, the sample for 28 days will reach the maximum strength of the tested sample. However, the use of additives such as calcium chloride (CaCl2) has made the earlier samples such as 7 and 14 days mature faster. The effect of using this additive will increase the strength of the sample for 28 days at a slight rate compared to the 7 and 14 day samples.

Referring to the ASTM 618 standard, quality pozzolana material is classified based on a finer percentage value more than 66% in particle size of 45μm. Based on Fig. 8, the finer percentage of SCBA materials is 60% on the particle size of 45μm. This shows that the SCBA material produced does not reach the level of quality pozzolana. This affects the strength of the treated peat sample where only 5% can be replaced by a portion of the cement dosage to achieve maximum strength after the stabilization process.

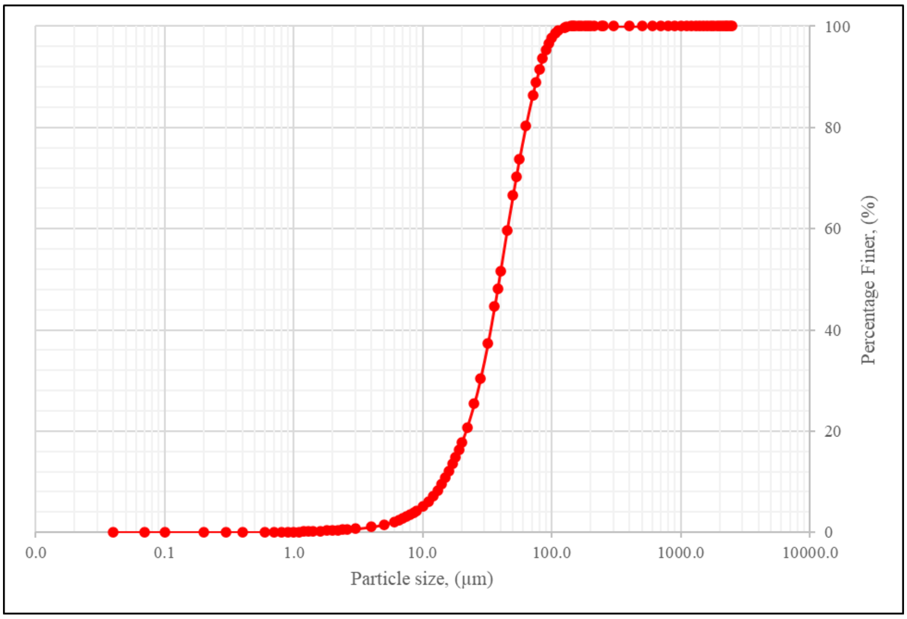

Fig. 8 - Particle size distribution graph for SCBA material

The samples used in this test were the original peat soil representing samples prior to stabilization, while C100 and C95S5 with a 7-day duration represented the sample after stabilization. The comparison between the pre and post-stabilization samples showed a significant change in terms of microstructure as shown in Fig. 9. By ensuring the same value on the lens focus, ground microstructure after stabilization is seen increasingly denser than the soil before stabilization.

Comparison between C100 and C95S5 samples shows that fiber particles and porous particles become denser as a result of SCBA and cement material responses that bind to the peat soil structure as a whole and make peat soils stronger. The SEM image of the C100 sample showed a more compact peat structure resulting from a uniform cement mixture.

For optimum C95S5 samples, peat soil microstructure was denser due to cement and SCBA reacted to produce pozzolanic reactions on peat soils and strengthened peat soil structure. The SEM image of the C95S5 sample showed an overly unobtrusive mixture of soil, cement and SCBA.

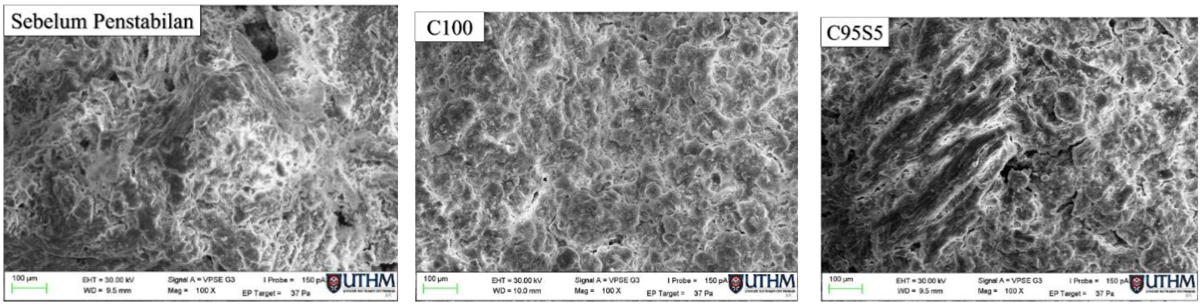

Fig. 9 - SEM images for samples before and after stabilization

4. Conclusions

Based on experimental results, peat soil in Benut, Pontian is a type of hemic peat. This was determined based on the test of fiber content and Von Post which showed peat soil samples used in H4 class based on Von Post scale table. The peat soil at Benut, Pontian has a high moisture content of 533.33%. For organic content, the results of the analysis recorded 92.69% organic content obtained for samples of peat soil tested. Peat soils in Benut, Pontian is a high acidic soil with a pH value recorded for the sample tested is 3.23. In addition to high acidity, peat soil samples for this study also recorded a liquid limit of 189% and specific gravity value of 1.66. The use of SCBA as a substitute for cement is shown to show positive results based on uncertainty compressive strength test (UCS). C95S5 samples with 95% cement mixtures and 5% SCBA were the optimum samples for this study. The C95S5 sample successfully achieved the maximum strength of the entire sample with a strength of 190 kN/m^2, 209 kN/m^2, and 219 kN/m^2 recorded for wet periods of 7,14 and 28 days. In conclusion, this 5% optimum reduction of cement material contributes to environmental sustainability by reducing the production of cement industry leading to various types of pollution, especially carbon dioxide emissions and high energy consumption rates. Therefore, the use of SCBA materials from sugarcane waste made into substitute parts for cement dosage needs to be further promoted and implemented by the construction industry in particular to promote the sustainable development concept in Malaysia.

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