Stabilization of peat using sugarcane bagasse ash (SCBA) and cement as a stabilizer

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Abstract. One of the main land types in Malaysia is peat, which has relatively soft soil with a high organic content, poor shear strength, and high compressibility. Therefore, in its natural state, peat is deemed unsuitable for supporting a construction site. Cement is one of the techniques used to stabilize peat. However, because so much cement is used, this process is not environmentally beneficial. at this work, the stabilization of peat was achieved by using Sugarcane Bagasse Ash (SCBA) at a ratio of 5% to 20% in lieu of Ordinary Portland Cement (OPC). To determine the strength of the soil and the differences in microstructure between treated and untreated soil, laboratory experiments on the physical, chemical, and mechanical properties have been carried out. Through testing unconfined compressive strength (UCS), the optimal mix of replacement SCBA with OPC, consisting of 15 PCBA, demonstrated enhanced strength. The microstructure of a sample of 100 PC with 15 PCBA that is hollow is reduced and becomes denser as a result of the filler material SCBA's reaction, as shown by a scanning electron microscope (SEM). The test Energy Dispersive X-Ray (EDX) with the lowered of carbon and calcium rise value shows the pozzolanic reaction. It may, indirectly, strengthen peat following stabilization.

1. Introduction

Peat soil is a prominent soil type in Malaysia and is characterized by a significant issue of having extremely low shear strength [1]. Peat soil is more precisely defined as a category of extremely soft soils containing a large proportion of organic matter derived from plant materials (75 percent or more). Additionally, peat soil is notorious for its extremely high compressibility and low bearing capacity [2]. Furthermore, the characteristics of peat soil are evident in its extraordinary natural moisture content, which can reach as high as 800% [3]. An attribute that distinguishes peat soil is its pigmentation, which typically ranges from brown to black. Civil engineering is a discipline that pertains to construction activities. When engaging in construction, it is critical to prioritize the capacity of the foundation on the construction site to sustain and accommodate the entire building structure. Consequently, the substructure of the site must be robust and capable of supporting the load, while the surrounding soil and the lowest stratum also significantly contribute to load bearing for the structure above [4]. Low-strength soil is unsuitable for construction purposes; therefore, it must be replaced or stabilized prior to use in order to prevent future complications. In accordance with previous research on how to increase the strength of peat soil, stabilization and modification of the soil constitute the majority of techniques. Stabilization of the soil entails augmenting its strength through the application of compaction techniques or an appropriate combination of compounds.

Among the additives used is such as increasing the quantity of cement along with peat soil, but this solution is not economical in terms of cost because it covers a large area, increasing the cost of cement and transportation to the site [5]. Therefore, several researchers had been conducted studies on agricultural waste such as SCBA as a cement partially replacement materials [6-9]. Nowadays the field of agriculture has grown rapidly all over the world. It has also invited an increasingly serious problem due to the handling and disposal of agricultural waste that is not carried out systematically and efficiently. Due to the disposal of agricultural waste, this has had a negative impact on the environment such as air pollution, water pollution and indirectly affecting the balance of the ecosystem. Among the world's continents in the field of agriculture, statistics show that sugarcane production is the main crop compared to corn, rice and others [10]. In the field of engineering, not many studies have been conducted using SCBA waste materials, especially in the stabilization of peat soil.

Therefore, this is one of the initiatives to reuse SCBA as a substitute for cement in the stabilization of peatland. This material can also be used for development beneficial to the environment and towards sustainable management. Referring to tropical areas of peat land in Southeast Asia, it is estimated that Malaysia has an area of peat land of 3 million hectares of which 8% covers the entire land area of the country [11]. The state of Johor has an area of 6,300 hectares of peat land found in areas such as Pontian, Batu Pahat and Muar [12]. Among the differences for each peat soil for different places is in terms of water content. This is dependent on agricultural background factors and also the frequency of rain in the area [13]. In addition, peat soil is one of the problematic soils because it has high compressibility and low shear strength [14]. This peatland is very unsuitable to be developed as an infrastructure development area due to its inability to support the foundation of the construction site or the ground naturally [15]. Most of the total area of peat land in Johor is used in agriculture such as palm oil. Problems faced in terms of transport challenges in the field due to the loose and soft nature of the soil.

Most of the ways to treat or stabilize the soil that are synonyms are used to replace the soil, but this method is not recommended because it is uneconomical. Therefore, the objective of this study is to see the results of mixed materials from SCBA with OPC used to increase the strength of peat soil after stabilization. In addition, being able to determine the optimal content of the design of mixed materials can also be known and can be used for the shallow foundation layer of peat soil to accommodate moderate loads such as road reclamation.

2. Laboratory Test Materials and Methods

The materials that had been used in this study are Parit Nipah Peat, OPC and SCBA (Figure 1). The method of peat soil sampling is disturbed method. The types of laboratory tests divided into physical and mechanical properties shown in Table 1 which following the standards by ASTM and BS.

Figure 1. Study Materials; Peat (Left), OPC (Middle), SCBA (Right)

The proportion particle size of SCBA is determined by the Particle Size Analysis (PSA) laboratory test. This test is crucial for characterizing the performance traits that arise from combining OPC and

SCBA materials. Chemical tests using SEM and EDX were performed to examine sample images of changes in soil microstructure as well as the characteristics of chemicals present in the soil both before and after stabilization. The values of the soil mixture, OPC, and SCBA as shown in Table 2 are followed in order to prepare the UCS test sample. A total of 36 samples are supplied for the purpose of lab mixing. Talib [7] states that SCBA can replace OPC by as much as 20%. Consequently, the percentage of SCBA used in this study ranges from 5% to 20%. Using a grinding machine, the sugarcane bagasse material will be reduced in size more quickly and effectively once the contaminants have been removed. Next, a furnace burner is used to burn the bagasse for three hours at 800ºC. It can be used as a cement substitute, however it must be sieved past 63 μm before usage.20 specimens with an interior diameter of 38 mm and a height of 80 mm are used to prepare cylindrical molds. Using a trowel, thoroughly mix the soil, cement, and SCBA with a quantity of water based on the optimum moisture content (OMC). Then, place it inside the mold and compact it using three times the force. The specimen is then submerged in water for a duration of seven to twenty-eight days as part of the wet curing process. The specimen is opened after curing and put through the UCS test, which involves applying the maximum load to the sample up until the point at which it is unable to compare the strength after stabilization.

Table 1. Type of laboratory test.

Test	References (Standards)
Moisture, organic and ash content	ASTM-D 2974
Liquid limits (L_L)	BS 1377 Part 2:1990: 4.3
Acidity (pH)	BS 1377 Part 3:1990: 9.4
Fibre content	ASTM D-1997
Specific gravity (G_S)	BS 1377 Part 2: 1990: 8.3
Standard proctor compaction	BS 1377 Part 4 :1990
Unconfined Compressive Strength (UCS)	ASTM-D 2166

Table 2. Mixture design of stabilized peat strength test.

Test	Curing duration (days)	Cement content (Kg/m^3)	Sample abbreviation	Cement (%)	SCBA (%)
Unconfined Compressive Strength (UCS)	7, 28	300	100 PC	100%	0%
			5 PCBA	95%	5%
			10 PCBA	90%	10%
			15 PCBA	85%	15%
			20 PCBA	80%	20%

3. Data analysis and discussion

The laboratory test results for the fundamental characteristics of peat soil are displayed in Table 3. According to the definition used in geotechnical engineering, the organic content of the soil from the Pt Nipah is greater than 75%, which indicates that the soil is categorized as peat soil. Because the pH test result is less than 4.5, it indicates that the peat soil is extremely acidic. Because the fiber content of the peat soil ranges from 33% to 67%, it is categorized as a hemic peat soil type and falls into the H6 group, which is the middle stage of decomposition. However, because the ash component is less than 5%, the soil type is considered low ash peat [16].The average size of the SCBA particles in the powder sample is what the PSA test is intended to measure. For a pozzolanic reaction, an ideal pozzolan material should have an average particle size more than 66% and a particle size lower than 45 μm

sieve size [17]. The average SCBA material value graph is displayed in Figure 2 and reveals that the material is 96% finer than 0.045mm, which is larger than the 325-sieve size. This demonstrates that the SCBA material is of a high enough quality for the pozzolanic reaction to take place during the stabilization of peat soil.With reference to Figure 3, the average UCS test value for the soil sample prior to stabilization is shown as 43 kPa on the data graph. On the other hand, after seven days of curing, the highest strengths for each mixture—which are 100 PC, 5 PCBA, 10 PCBA, 15 PCBA, and 20 PCBA—are 327.62 kN/m^2, 262.89 kN/m^2, 221.18 kN/m^2, 321.09 kN/m^2, and 320.69 kN/m^2.
Subsequently, compared to the 7-day curing period, the strength of the entire soil sample increased. This is due to the cement mixture's ability to observe the response during the 28-day curing period. After 28 days of curing with a mixture of 100 PC, 5 PCBA, 10 PCBA, 15 PCBA, and 20 PCBA, the total soil sample revealed that the average maximum strength for UCS for each mixture was 247.98 kN/m2, 242.82 kN/m^2, 350.06 kN/m^2, and 345.05 kN/m^2. When compared to other combinations, the 15 PCBA mixture has the best soil strength throughout the entire sample. When compared to cement alone, the soil strength of the 15 SCBA mixture was the highest. This is a result of the pozzolan material's reaction factor to the SCBA's chemical reaction on the soil's strength.

Table 3. Mixture design of stabilized peat strength test.

Laboratory test	Values
Moisture content, %	792.85
Ash content, %	1.6
Organic content, %	98.4
pH test	3.17
Specific Gravity, G_s	1.55
Fibre content, %	51
Liquid Limit (L_L), %	258
Standard proctor compaction	
i) Maximum Dry Density (MDD), Mg/m^3	0.58
ii) Optimum Moisture Content (OMC), %	36.67

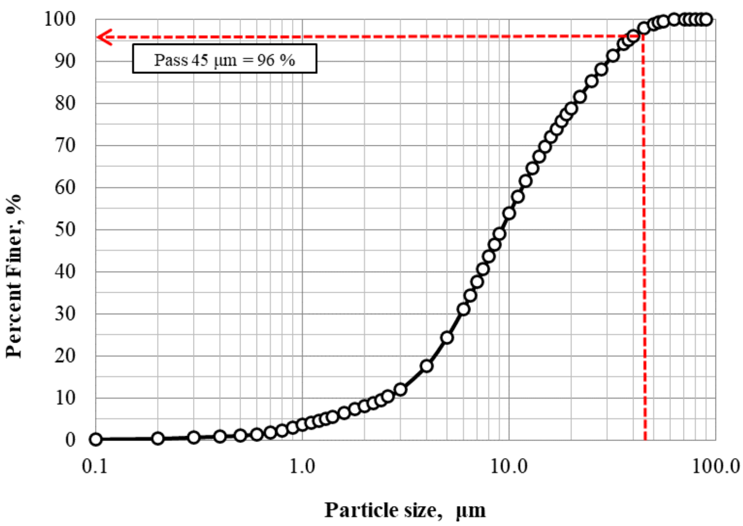

Figure 2. Particle size analysis of studied SCBA

In addition, the nature of the soil before stabilization is in a ductile state. In the mixture of 100 PC, it shows that it cracks more quickly, the nature of the soil failure is so fragile. However, in the mixture of 15 PCBA, the soil failure is more ductile due to the substitution of SCBA material for cement, this has an effect on the nature of the failure of the soil.

The findings of the scanning electron microscope (SEM) test are displayed in Figure 4 to further demonstrate the change in soil microstructure density following stabilization. The fiber content of the sample, which is composed of both coarse and fibrous particles in a loose condition, accounts for the discrepancy observed in the sample prior to stabilization. This component is also brought about by the soil's higher than average natural water content, which makes it more hollow. Following the stabilization of the 100 PC mixture with the ideal 15 PCBA combination, the sample exhibits less empty cavity space and a decrease in fibrous and porous particles, resulting in a denser structure. SCBA has served as a filler material in the hollow space because of the pozzolan substance's composition.

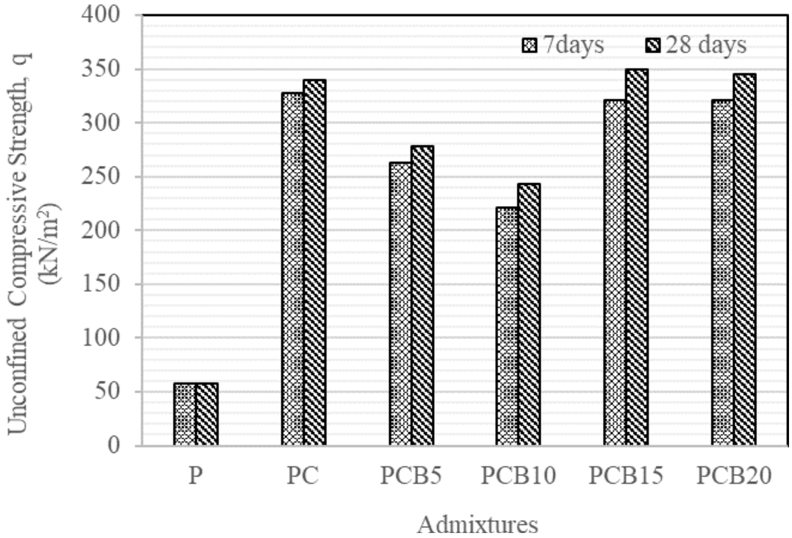

Figure 3. Unconfined compressive strength results of untreated and treated peat.

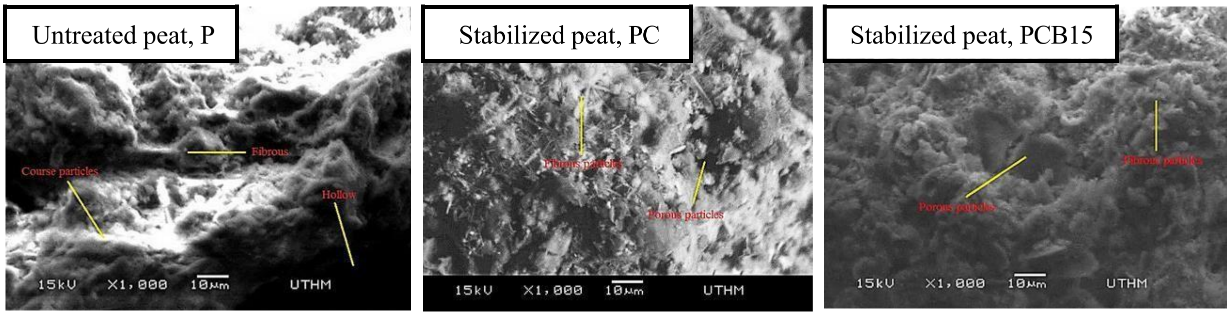

Figure 4. Microstructure results of untreated and stabilized peat.

Next, in terms of changes in chemicals, it can be seen in Table 4 that the difference in oxide compounds in terms of carbon (C) value is decreasing and soil strength is increasing due to increased calcium (Ca) value. The chemical reaction result equation between cement and pozzolan material (Al2O3 + SiO2 + Fe2O3) shows a higher value than before stabilization. Based on the optimal mixture of 15 PCBA, it can be seen that the strength is higher compared to 100 PC. This is because the SCBA material has produced a pozzolanic reaction because it contains a high content of silica and calcium. Indirectly it is a good pozzolan material to increase the strength of peat soil with cement.

Table 4. EDX test results of untreated and stabilized peat at 7 days curing.

Oxide composition	Untreated peat, P	Stabilized peat	
		PC	PCB15
C	57.79 ± 1.16	31.11 ± 6.17	28.02 ± 8.42
O	1.31 ± 0.05	39.26 ± 2.56	28.13 ± 5.27
Al	0.4 ± 0.05	1.06 ± 0.33	1.32 ± 0.15
Si	0.5 ± 0.1	2.68 ± 1.24	7.65 ± 0.96
Ca	0.5 ± 0.04	20.17 ± 3.29	27.44 ± 3.26
Fe	0.2 ± 0.1	0.66 ± 0.37	1.3 ± 0.38

4. Conclusions

Overall, the study's primary goal of comparing the soil's strength before and after stabilization with a mixture of SCBA as a partial replacement for OPC has been accomplished. Following laboratory testing on mechanical, chemical, and physical qualities, the summary is as follows:

I. The soil's basic characteristics prior to stabilization indicate a high moisture content and liquid limit. This peat soil's high acidity is revealed by a pH test. The peat soil's fiber concentration determines its classification as a hemic peat soil type, falling into the H6 group, which denotes the intermediate stage of decomposition. However, the soil type designated as low ash peat has a low ash component.

II. The mechanical properties test data show that the strength of peat soil can be increased with the stabilization method of mixed OPC and SCBA materials. Based on the UCS test, the strength of the peat soil is increasing at the optimal mix ratio of 15 PCBA with a value of 321.09 kPa at a curing time of 7 days compared to unstabilized soil which is 43 kPa. Meanwhile, at 28 days, the value for the 100 PC sample was 339.93 kPa, showing a lower value with the 15 PCBA sample, which was 350.06 kPa due to the pozzolanic reaction. In addition, the soil failure properties after stabilization also changed to ductile compared to the 100 PC mixture which cracked more quickly during the soil failure. This is due to the reaction of the pozzolan material to the filler material and chemicals have had an effect on the strength of the soil.

III. The change in the microstructure of the soil after stabilization also changed from the original nature of the peat soil which has reduced void space to become more dense with the reaction of filler material from SCBA with OPC.

IV. In terms of changing the composition of chemical substances with the carbon value (C) decreasing in addition to the calcium (Ca) value increasing will increase the strength of the soil.

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1) Muhammad Azri Bakhir is an undergraduate student at the Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia (UTHM). His role in this paper is focus on data analysis and writing a good manuscript. Writing – editing: Writing and editing paper based on suggestion from other authors.
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3) Aziman Madun is a professor at the Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia (UTHM), and the head of Civil Engineering Department. His contribution is writing – review and editing: Check the paper and gave a suggestion to improve the paper.
4) Mohd Firdaus Md Dan is a senior lecturer at the Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia (UTHM). His contribution is writing – review and editing: Asses the paper and conveyed a comment and feedbacks.
5) Faizal Pakir is a senior lecturer at the Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia (UTHM). His contribution is in investigation: Contribution in field work test such as sampling the samples.
6) Zeety Md Yusof is a senior lecturer at the Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia (UTHM). Her contribution is in investigation: Manage for field work arrangement such as transportation and additional worker.