



Stabilization of Johor Peat Soil using Sugarcane Bagasse Ash (SCBA)

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Abstract: Peat soil have been categorized as a problematic organic soil, because they have a high settlement rate when placed any structure on it. Therefore, the peat soil must first be stabilized using cement before it can be used. However, massive use of cement can lead to environmental pollution. Therefore, this study intends to use sugar cane bagasse ash as a substitute for cement in peat soil stabilization. The mix ratio of 5% to 20% was used to find the optimal mix ratio. Various tests were carried out on samples such as basic properties tests, Unconfined Compressive Strength (UCS) and Scanning Electron Microscope (SEM). After all the tests, the 5% replacement SCBA mix ratio gave the highest unconfined compressive strength if compared to the other mixtures ratio. Therefore, it is selected as the optimum mix ratio. The soil strength achieved by the SCBA 5% replacement ratio was found to be higher than cement stabilization alone due to the presence of secondary pozzolan reactions. The microstructure result from the SEM test had shown that the 5% replacement SCBA mix ratio filled in the hollow left by the peat soil. Hence, able to improve its soil structure and thus increasing its strength.

Keywords: Peat stabilization, sugarcane bagasse ash, cement replacement, peat strength

1. Introduction

In Malaysia, peat soil is estimated to reach up to three million hectares in area. Most can be found mainly in the southern region of the peninsular Malaysia as in Johor and also in Sarawak. Peat soil are less favored by civil engineers around the world especially those who work in geotechnical fields because the features contained in peat soil have made it difficult for construction work. Peat soils have been found to contain low bearing capacity and high settlement rates on any structure constructed above them. Peat also has very low shear strength within a range of 5 to 20 kPa. There have been numerous cases reported around the world on road damages due to peat soil instability. Peat soils represent an extreme form in the soft soils category as it could not be inhabited. Any infrastructures constructed on untreated peat soils is most likely to be settled in the long term [1]. Peat usually occurs in aqueous soils that lack oxygen supply which prevents natural microorganisms from decomposing dead plant materials. These conditions occur when dead plants are not decayed and accumulate for years as a peat layer. Peat forms slowly in this way, involving the accumulation of organic matter in water, and take about 10 years for 1 cm peat to form [2]. In Johor, most peat soil are located on the southern region of Malaysia like Pontian and Batu Pahat [3].

The use of cement and aggregate to make concrete has been used by civil engineers around the world to build many projects. In geotechnical areas, cement is widely used to stabilize unstable soil to provide a solid foundation of construction projects. However, massive use of cement in stabilizing peat soil can lead to some disadvantages of

various angles and aspects that should be taken into account by civil engineers [4]. The use of cement in small amount will have no significant effect on peat soil stabilization. In contrast to clay and mud, peat has much lower soil particle content and is easier to produce secondary pozzolanic reactions [5]. Cement manufacturing requires a considerable amount of energy because extreme heat is required to produce it. The production of one ton of cement requires about 4.7 million British Thermal Unit (BTU) of energy, generating nearly one ton of carbon dioxide (CO₂) [6]. This suggests that massive cement applications do not support the development of eco-friendly construction materials. The massive use of cement during the peat stabilization process contributes to the release of CO₂ due to concrete production. Cement is responsible for about 5 to 8 % of global carbon oxide emissions and expected to increase by 0.8 to 1.2% per annum to reach 4.4 billion tonnes production by 2050 [7]. Fig. 1 shows the process of CO₂ release during the cement production.

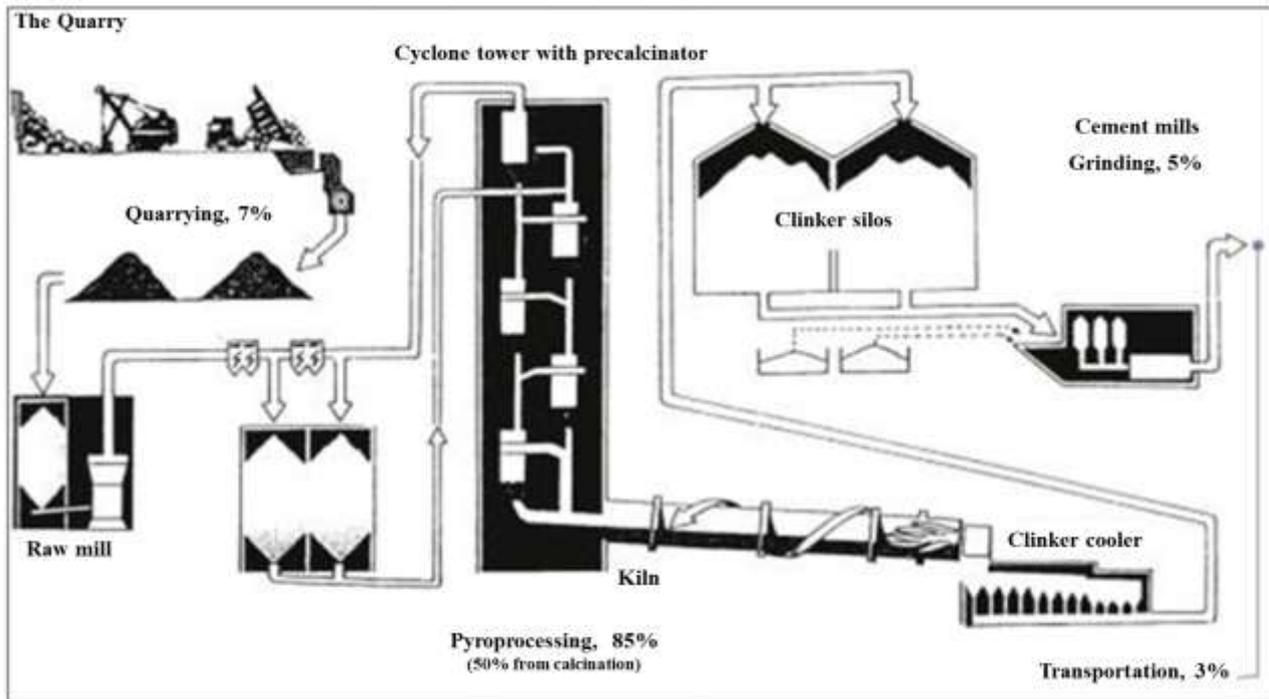


Fig. 1 - CO₂ emission process in cement manufacturing

Southeast Asia is among the world's largest sugarcane plantation industry in the world with Thailand, Malaysia, Philippines and Indonesia dominating the list of the top 10 with a total of 165.7 million tonnes per year. Sugarcane bagasse has surged to be amongst the major contributors of Malaysia's solid waste production behind palm oil, municipal and timber waste [8]. It's estimated around 1 ton of sugarcane produces 280 kg of bagasse after sugar extraction, equivalent to 30% of waste disposed [8]. Pozzolan is one of the additives that can partially replace cement in soil stabilization. Pozzolan material could be produced by combustion of agricultural waste. Pozzolan inclusions such as SCBA in soil cement mixtures can accelerate the curing hydration when pozzolan reacts with calcium hydroxide and water to form secondary calcium hydrate (CSH) along with calcium alumina silica hydrate (CASH). This process containing additional silica and activated cement alumina thus create an alkaline atmosphere that increases the secondary pozzolanic reaction in the treated soil [7]. Previous study indicates that with 20 % of cement replacement with SCBA have unconfined compressive strength (UCS) reaching 387 kPa. It was found this UCS value to be about 30 times better than unstable peat. This proves that the addition of sugar cane ash has a potential to produce a better product in terms of strength [7].

Mass stabilization is a modern ground-stabilization method for a soft soil. Soil stabilization is carried out by mixing a number of dry or wet binder material within the soft soil layer. This soil stabilization method is important as it has been shown to improve the peat structure characteristics and enhance the shear strength. It is a rapid method of improvement, and can be adapted to different soil condition and is economically efficient compared to removal and replacement method which require transportation and soil disposal area. Mass stabilization method in peat soil is adopted to overcome differential settlement. This is because this method is used when the material is very wet (peat, mud or soft clay) [9]. Fig. 2 shows the mass stabilization process on peat.

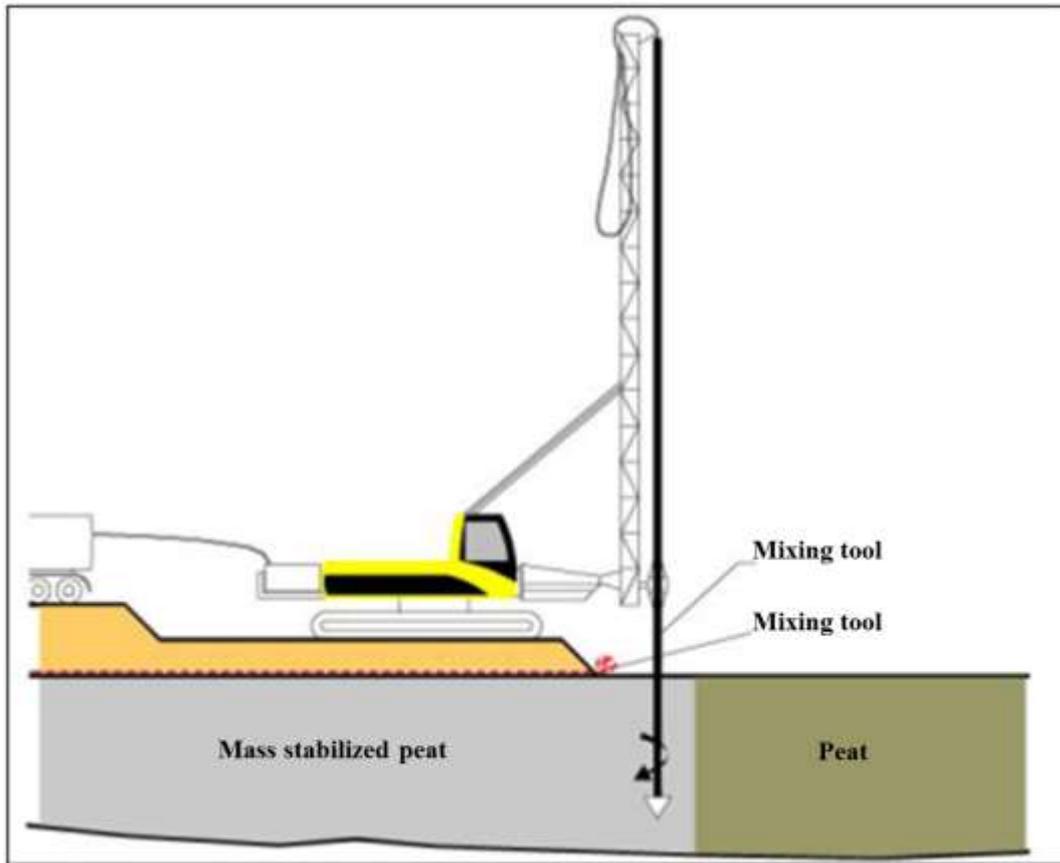


Fig. 2 - Mass stabilization process on peat

2. Materials and Methods

Referring to Fig. 3, peat soil samples used in this study were taken from the Research on Peat Station (REPEATS) at Parit Nipah, Batu Pahat, Johor. The disturbed samples were taken at 1 meter from the ground surface. The bagasse was grinded and burned using a furnace. The furnace temperature and the combustion duration were at 500 ° C and 5 hours, respectively. The purpose of the combustion is to remove the moisture. The sample then was sieved using a 63µm sieve to produce fine SCBA. The ordinary Portland cement (OPC) and SCBA were mixed at different mixing ratios as shown in Table 1. The binder dosage that adopted to stabilize peat in this study is 300kg/m³. The tests were divided into two parts namely index properties and mechanical testing as shown in Table 2.



Fig. 3 - Soil sampling at Parit Nipah

Table 1 - Laboratory mix design

Material mix ratio	Symbol
100% cement	C100
95% cement : 5% SCBA	C95 SCBA5
90% cement : 10% SCBA	C90 SCBA10
85% cement : 15% SCBA	C85 SCBA15
80% cement : 20% SCBA	C80 SCBA20

Table 2 - Index properties test

Testing	Symbol	Standard
Moisture Content	MC	ASTM-D 2974
Organic Content	OC	ASTM-D 2974
pH Value	pH	ASTM-D 4972
Liquid Limit	LL	BS1377 PART 2: 1990:4.3
Specific Gravity	G _s	BS1377 PART 2: 1990:8.3
Particle Size Analysis	PSA	ASTM D422

For mechanical testing, Unconfined Compressive Strength (UCS) was used to determine the treated and untreated samples strength by referring to the ASTM D-2166 standard. A 50mm diameter cylindrical mould specimen and 100mm height tested in compression. The samples were cured for 7 and 28 days. The microstructure of the samples was investigated by using Scanning Electron Microscopic (SEM) using JSM 6380LA model to understand the strength gain mechanisms. The samples used in this study were in non-liquid and dry conditions.

3. Results and Discussions

Table 3 shows the average of 3 samples results of index properties of the studied peat. The moisture content test was significantly high around 741%. The average value of organic content and ash content were 89.72% and 10.28% respectively. According to ASTM D2974, this sample is classified as a peat. The peat sample was highly acidic and low specific gravity at 3.35 and 1.55, respectively. With 57.5% of fibrous content and H6 of Von Post test, the peat samples is regarded as hemic peat. The average value of liquid limit test was 300%.

The particle size analysis on SCBA sample shows a finer percentage distribution reaching about 60% of 45µm in size. In general, pozzolan can act as a filler or secondary pozzolanic reaction. According to ASTM C618, one of crucial requirement of good pozzolan is to obtain at least 66% of pozzolan finer than 45µm. Therefore the SCBA produced can be categorized as low quality.

Table 3 - Index properties result

Test	Result
Moisture content, %	741.33
Ash content, %	10.28
Organic content, %	89.72
pH value	3.35
Specific gravity, G _s	1.55
Fibrous content, %	57.5
Liquid limit (LL), %	300

The UCS results for all samples were shown in Fig. 4 and Fig. 5. The UCS of untreated peat was 16 kN/m². It was observed that the maximum UCS of the treated samples after 7, 14 and 28 days curing were 185 kN/m², 233 kN/m² and 278 kN/m² respectively. All these maximum values occurred at 5% replacement of SCBA. Furthermore, these results indicates that the samples of 28 days curing show the highest values and about 17 times greater than untreated peat. However, compared to the maximum UCS of C100 (206 kN/m²), the UCS increment of 28 days curing sample was approximately only 35% and seems rapidly decrease after 5% of SCBA replacement. The possible reason of this outcomes due to quality of the SCBA that had been used which act only as a filler at early stage of strength gain in this study. However, 5% of cement replacement (C95SCBA5) was suggested since its still shows better improvement compared to without SCBA replacement (C100).

Electron scanning Microscope (SEM) tests have been carried out on samples before and after stabilization as shown in Fig. 6 to Fig. 8. Based on Fig. 6, SEM for untreated sample is seen to have many hollow conditions due to loose fibre with high water content in peat samples. Referring to Fig.7, the microstructure of C100 sample was

observed to be more compacted which indicates the reduction of voids compared to untreated sample. While for Fig. 8, the optimum mixture (C95SCBA5) shows the best microstructure condition amongst the other mixture as a result of SCBA inclusion within the pore spaces.

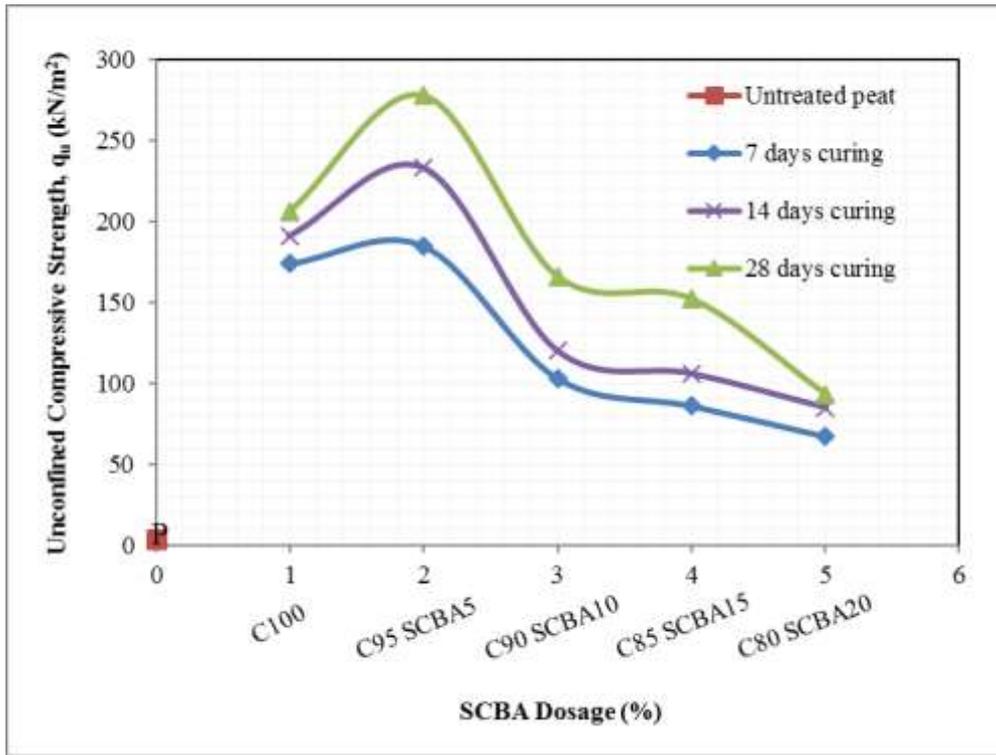


Fig. 4 - UCS vs mix ratio

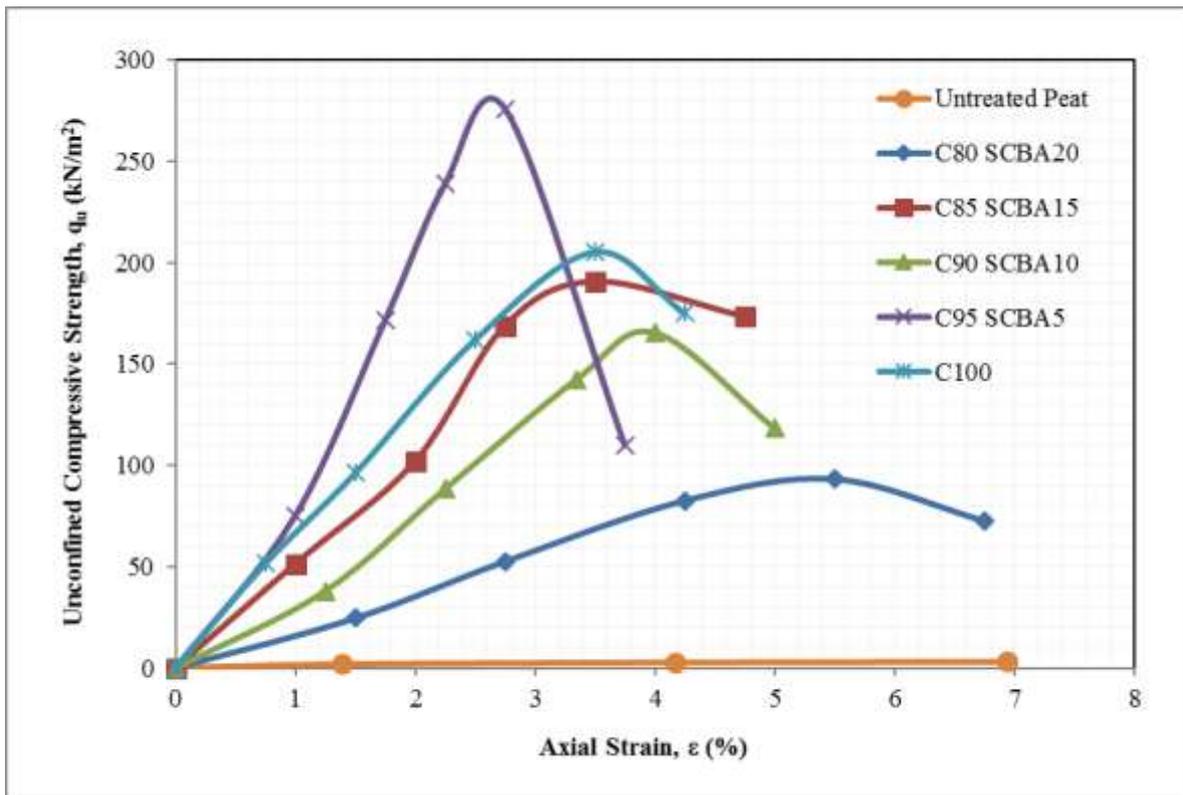


Fig. 5 - UCS Test for 28 days curing

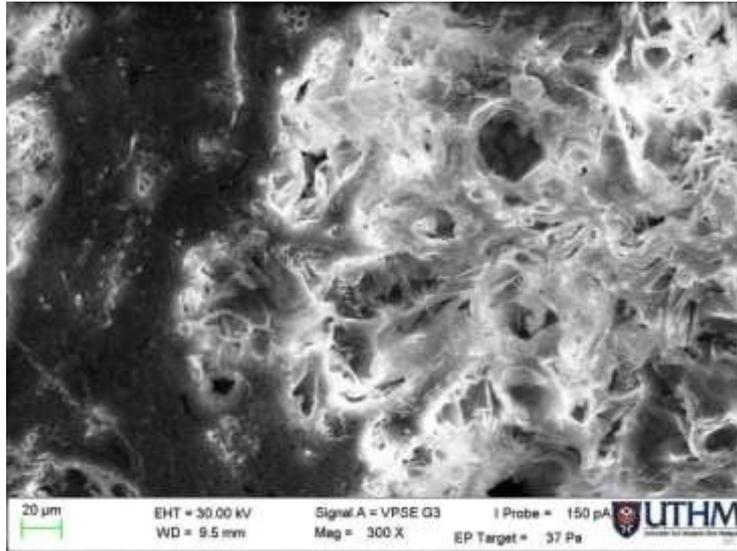


Fig. 6 - Microstructure image for untreated peat soil

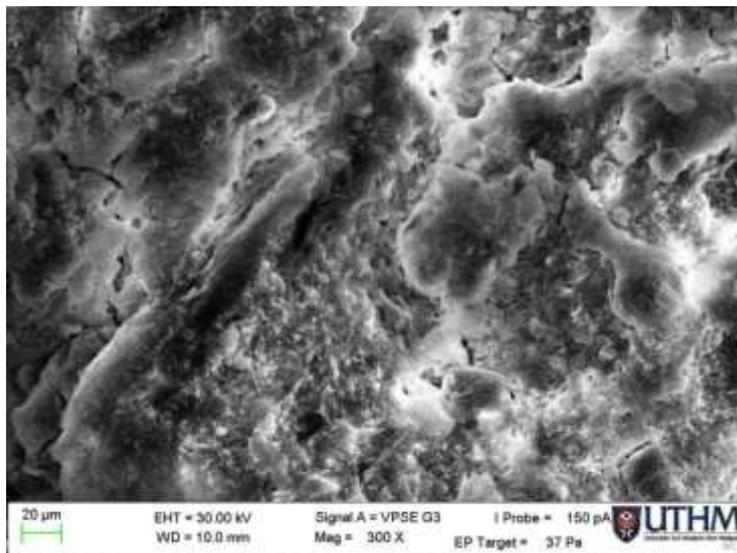


Fig. 7 - Microstructure image for sample C100

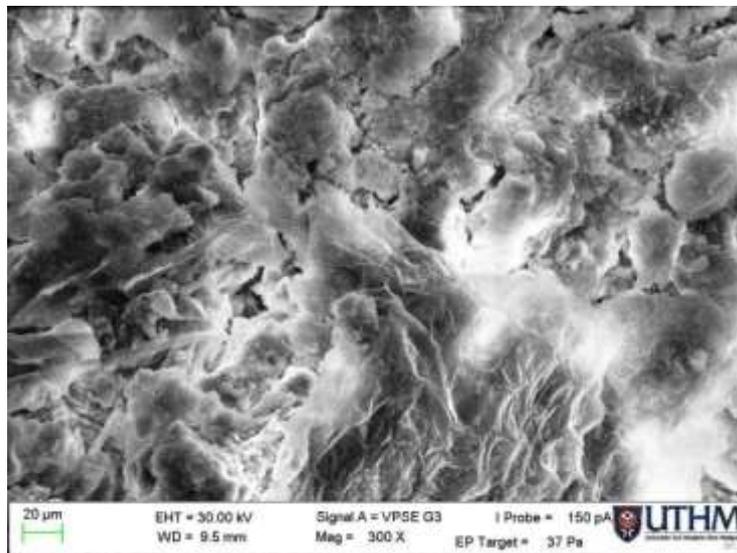


Fig. 8 - Microstructure image for sample C95SCBA5

4. Conclusions

The results of this study show the peat soil strength has proven to be greatly improved after stabilized with cement and SCBA mix ratio. It can be concluded that 5% partially replacement of cement by using SCBA shows the best mixture due to filler effect on the treated peat. This is supported by the maximum UCS of 7, 14 and 28 curing days at 5% SCBA replacement which were 185 kN/m², 233 kN/m² and 278 kN/m² respectively. The maximum UCS value was found about 35% greater than C100 mixture (100% cement) and 17 times better than untreated peat. The SEM test shows the microstructure of treated sample was visually observed to be more compacted which indicates the reduction of voids compared to untreated sample.

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