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Peat Stabilization by Using Ordinary Portland Cement (OPC) Mixed with Rice Husk Ash (RHA)

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Abstract

Peat generally consists of high organic and water content that causes the strength of peat soil to be very weak to bear any load. The strength of the soil can be increased by using binders like cement in peat soil stabilization techniques, but excessive cement use can pollute the ecosystem. This study aimed to determine the ideal proportion of rice husk ash (RHA) to be utilized in place of cement. A test of the basic characteristics of peat soil is carried out in order to identify the nature of peat soil. The strength of treated and untreated peat soil was determined through an unconfined compression test (UCS). By replacement at 15%, the result shows the replacement of 15% RHA in Ordinary Portland Cement (OPC) demonstrates the maximum strength with the value of 531 kN/m^2 and 580 kN/m^2 for 7 and 28 curing days respectively. The microstructure image shows the difference in total porosity between the untreated and treated samples through the Scanning Electron Microscopy (SEM) test. A chemical test via Energy Dispersive X-ray (EDX) shows that the strength of samples improves when the amount of carbon reduces and calcium content increases. The findings illustrate that the utilization of discarded agricultural waste can be used as an additive in reducing the consumption of cement to increase the strength of peat based on soil stabilization techniques.

1. Introduction

Peat soil is the top layer of the earth's surface that contains high organic matter. The use of the term organic for the soil group is the link between the soil and the decay of plants that go through the decomposition process, maintaining the original texture, color, or smell. Peat soil has a high organic content resulting from the process of decomposition and decay of plant waste. Peat soil has a high content of colloidal crystals such as humus that act in humid areas [1,2]. Soil that has organic properties is weaker than soil that is not organic because it goes through the decomposition process that occurs by the deposition of organic matter from thousands of years ago [3]. Through the process, organic matter that is submerged in water and receives low oxygen content helps the decomposition process to produce peat soil that is brownish to black and can be described as peat soil that contains at least 65% organic matter [4,5]. In addition, peat soil has very soft characteristics, as well as being easily flammable, making peat soil have different properties compared to clay and sandy soil [6]. Seeds, trees, and plants in marshy areas and wet areas in conditions that lack oxygen. This process of decay and decomposition results from the existence of soil microflora, bacteria, and fungi on the soil, but the rate of decomposition varies according to location based on the origin of the fiber, temperature, and humification [7,8]. In this situation, the collection results from plant waste will act as organic matter on the peat soil. Laboratory tests can be conducted to classify the peat by referring to the standards of the American Society for Testing and Materials (ASTM) demonstrated in Table 1.

Peat soil has poor properties to accommodate construction loads with high water content values that exceed 100%, high compressibility between 0.9-1.5, low strength between 5-20 kPa, and organic content that exceeds 75%[9]. The condition of peat soil that has a weak soil-bearing load causes problems with construction activities in peat land areas. The construction of peatland areas that have a low shear rate, high compressibility, and high-water content requires observation starting from the design stage until maintenance [10,11,12]. Failure in the construction of buildings and roads will result in more settlement if the load area is concentrated on the peat ground. Therefore, peat is considered not suitable as a foundation site for construction [9,13]. To meet the demand of the growing population, the exploration of new areas needs to be carried out and it will involve peatland areas that have an area of about 13% for the states of peninsular Malaysia out of the total area of 26000 km^2 in Malaysia [4]. Table 2 presents the distribution of the peat area in Malaysia.

Table 1 *Peat classification based on ASTM standards*

Parameters	Content	Range of Value	Standard
Fiber content	Fibric	Fibers > 67%	ASTM D1997
	Hemic	33% < Fibers < 67%	
	Sapric	Fibers < 33%	
Ash content	High	Ash > 15%	ASTM D2974
	Medium	5% < Ash < 15%	
	Low	Ash < 5%	
Acidity	High	pH < 4.5	ASTM D2976
	Moderate	4.5 < pH < 5.5	
	Slight	5.5 < pH < 7.0	
	Basic peat	pH > 7.0	

Table 2 *Peat land distribution in Malaysia*

Location (State)	Peat Area (Hectare)
Sarawak	1 697 847
Johor	143 974
Pahang	219 561
Selangor	164 708
Perak	69 597
Sabah	116 965
Terengganu	84 693
Kelantan	9 146
Negeri Sembilan	6 245
Wilayah Persekutuan	381
Total	**2 513 117**

Various methods can be employed to enhance the strength of the peat soil, but it depends on the suitability of the size of the construction and the construction cost. By using the mass stabilization method, increasing the strength of peat is able to be produced through the process of adding additives to peat soil [14]. The use of additives such as cement serves as an agent and binder between soils that will enhance the strength of peat soil [15,16,17]. The consumption of excessive amounts of cement, especially in large areas, is considered less environmentally and economically friendly [18,19]. Excessive use of cement will also contribute to the greenhouse effect [20,21]. The use of agricultural waste that has pozzolan material can replace the amount of cement considering agricultural waste that will pollute the environment if not managed perfectly [22,23,24,25]. Rice husk is produced from the separation of rice husk and rice with a value between 200 kilograms of rice husk from 1 ton of rice [8]. The total rice production for Malaysia in 2006 was 2,128,624 tons of rice with a rice husk value of 484 thousand tons per year in 2013 [26,27]. The nature of the chemical content found in rice husk ash (RHA) can be a good pozzolan material because it contains chemicals that contain high silica and alumina [15,28].

This study aims to find out the characteristics and behavior of peat soil shear strength as well as to identify the ability of RHA and cement mixture as a stabilization material for peat that can be used by engineers and developers for a project to ensure that the site of the area will be built to have enough strength to bear the load. The results of this study can add knowledge to engineers and researchers to find the best way to overcome the problem of peat soil strength and become a solution to agricultural waste management.

2. Materials and Method

The peat samples used in the study were obtained from the Research on Peat Station (REPEATS) area, Parit Nipah, Johor. The peat soil used was a disturbed sample as presented in Figure 1. The samples of peat were dug at a depth of 1 meter from the top surface with a manual digging method. The samples were stored in a container and left with a layer of cloth containing water to avoid disturbing the moisture content. Each soil sample that was undergone for laboratory tests was dried for a minimum period of 16 hours using an oven.

Fig. 1 *Collected peat samples*

Jelapang Selatan rice mill Sdn. Bhd., Muar, Johor, was the source of the rice husk (figure 2). The rice husk was burned at 700°C in an oven for 6 hours. To create RHA with a consistent ash size, the rice husk that was ready to be dried was allowed to cool to room temperature before being sieved through a 63 μm sieve.

(a) **(b)** **(c)**

Fig. 2 *(a) Raw rice husk; (b) Burnt rice husk; (c) Rice husk ash (RHA)*

The information in Table 3 shows the abbreviation of the ratio of the use of binding materials on peat soil representing a symbol consisting of RHA and OPC. Treated test samples for UCS test samples were conducted after the samples were cured by the wet curing method for 7 and 28 days.

Table 3 *Samples mixing ratio*

Sample Name	Material Ratio	
	OPC (%)	RHA (%)
C100	100	0
C95RHA5	95	5
C90RHA10	90	10

C85RHA15	85	15
C80RHA20	80	20

The unconfined compressive test used of a 38 mm diameter mold with a height of 80 mm. The weight of each additive in this study is determined depending on the composition of the additive ratio to the treated soil. The total density of the test material is used to calculate the weight of each additive and peat soil used on a single sample.

3. Result and Discussion

The sample test, which was split into groups of treated and untreated peat soil, provided the basis for the analysis and outcomes. Physical and chemical testing, such as the Particle Size Analysis, pH Value, Liquid Limit, Specific Gravity, Proctor Compression, Organic, Fiber, and Moisture Content tests, should be performed on untreated peat soil. The organic content value for the sample was obtained as much as 98.12%, the fiber content as much as 51% and the pH value is about 3 indicating that the peat soil is a hemic peat group with a high acidity value. Table 4 presents a summary of the results from the tests conducted based on ASTM and British Standards or British Standards (BS).

For the UCS test of the untreated sample, the sample strength was at a value of 43 kN/m^2. The optimal strength value for the 7-day curing sample was at the reduction of cement with the addition of RHA by 15% with a strength value of 531 kN/m^2. According to the finding by Rashid et al., [29], 13% of substitute additives achieved optimal strength value at 7-day curing indicating a similar finding to this study. At the same inclusion of 15% of RHA, the treated samples at 28 days of curing reached UCS value at 580 kN/m^2. Figure 3 shows the graph of UCS values against sample types at 7 and 28 days of wet curing. With the increase in the UCS value of the test sample, it can be seen the difference in the number of voids between the treated and untreated peat soil through Scanning Electron Microscopy (SEM) as shown in Figure 4. The void on the untreated and treated peat shows that the treated sample C100 and C85RHA15 shows a denser soil microstructure surface if compared to untreated peat.

Table 4 *Results of untreated peat*

Test Type	Standards	Unit	Values
Moisture Content		%	792.85
Organic Content	ASTM-D 2974	%	98.12
Ash Content		%	1.6
Fiber Content	ASTM-D 1997	%	51
pH	BS 1377 PART 2:1990:9.4	-	3.17
Liquid Limit	BS 1377 PART 2:1990:4.3	%	258
Specific Gravity (G_s)	BS 1377 PART 2:1990:8.3	-	1.54
Optimum Moisture Content	ASTM-D 698	%	36.67
Maximum Dry Density		mg/m^3	0.58

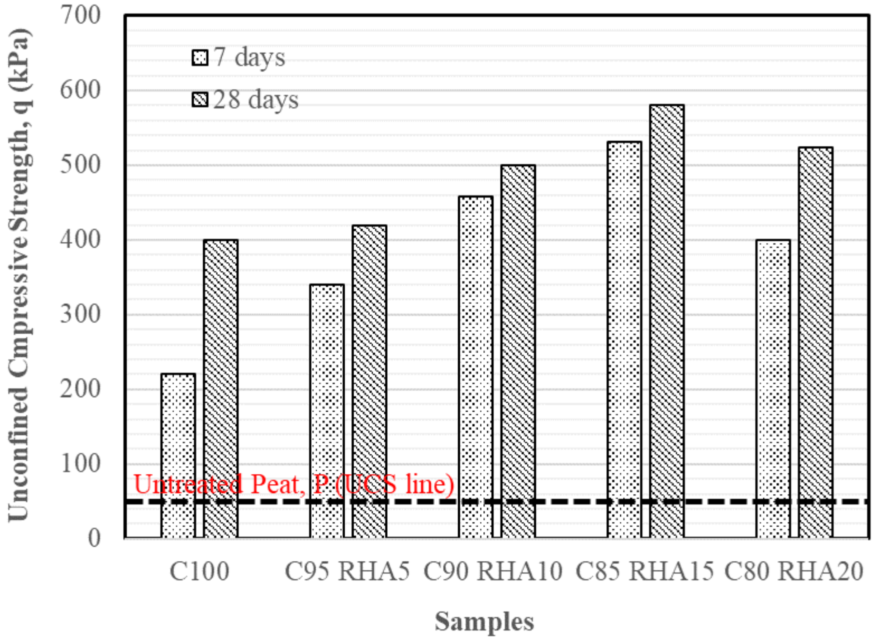
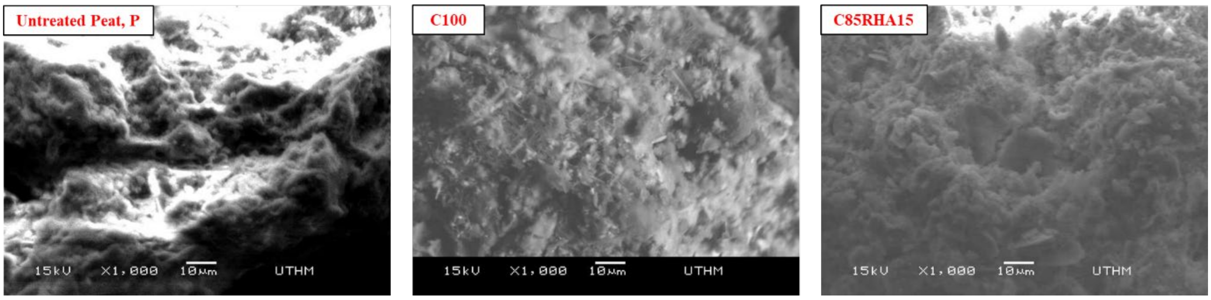


Fig. 3 *Results of UCS test for all samples*



(a) **(b)** **(c)**

Fig 4 *Microstructure images by using SEM: (a) Untreated; (b) C100; (c) C85R15*

Table 5 *Chemical composition from EDX test for untreated and treated peat*

Oxide Composition	Untreated Peat (%) P	Treated Peat (%) C100	Treated Peat (%) C85RHA15
C	57.64 ± 1.31	40.64 ± 0.17	32.63 ± 4.65
O	1.28 ± 0.08	11.48 ± 4.53	38.55 ± 3.27
Al	0.41 ± 0.04	0.49 ± 0.46	0.94 ± 0.45
Si	0.48 ± 0.11	3.98 ± 3.14	2.95 ± 0.97
Ca	0.51 ± 0.03	15.76 ± 3.63	18.70 ± 4.76
Fe	0.20 ± 0.09	0.85 ± 0.10	0.69 ± 0.34
$Al_2O_3+SiO_2+Fe_2O_3$	1.39±0.019	62.22±16.16	176.66±5.76

4. Conclusion

In conclusion, the use of waste materials from agricultural waste such as RHA can be utilized as an additive replacement for the utilization of cement in increasing the strength of peat soil. In addition to having properties as a good binding material in increasing the strength of peat soil, the use of RHA is also able to solve environmental problems when waste material can be utilized as a replacement material in the mixture of cement. The results of this study can be concluded that the organic content is over 70%, acid content is high with a value of 3.17 therefore the studied peat can be classified as hemic peat. Applying RHA as a substitution of cement is optimal at 15% during the 7-day and 28-day curing days. The reaction of pozzolana material and cement works well when the curing period of cement reaches maturity which is 28 days when the UCS value shows a high increase compared to the curing period of 7 days. In addition, the difference in the microstructure from SEM and EDX analysis shows the difference in terms of the number of voids, the decrease in carbon content, and the increase in calcium content indicating changes in the structure of the peat soil after treatment. In conclusion, the study on the use of RHA as a cement substitute material shows that the content of materials found in RHA can be used as an innovative material for peat soil stabilization methods.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mohd Khaidir Abu Talib, Adnan Zainorabidin;* ***data collection:*** *Mohd Khaidir Abu Talib;* ***analysis and interpretation of results:*** *Mohd Khaidir Abu Talib, Siti Nor Hidayah Arifin, Zeety Md Yusof, Kasbi Basri;* ***draft manuscript preparation:*** *Siti Nor Hidayah Arifin, Noorasyikin Mohammad Noh. All authors reviewed the results and approved the final version of the manuscript.*

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