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Research Article

Stabilizing Peat Soil Using Sawdust Ash

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Abstract

The aims of this research are to analyse the parameters of untreated peat soil and improve the engineering properties of the peat soil retrieved from MARDI Pontian in Johor, by using lightweight materials such as Sawdust Ash (SDA) so it meets the condition of construction. Due to rapid urbanisation, a large amount of saw dust is produced worldwide. The use of saw dust as ash in geotechnical applications is most likely a better solution compared to disposal in open areas or landfills. There were two types of soil used in this study such as organic peat soil (shallow) and mixed peat soil (moderate). In this investigation, sawdust ash (SDA) was employed as an admixture, and the stabilizer's percentage content was applied in 3.0% increments to both soils. Depending on the weight of the soil sample, the SDA has been applied in concentrations of 12%, 15% and 18%. Testing has been done on soil properties like bulk and dry density, moisture content, and the Atterberg limit. The optimum moisture content and maximum dry density of the soil samples were determined using the Standard Proctor test results in this investigation. Unconfined Compressive Strength has been used in determining the strength of this type of soil (UCS). The specific gravity ranged from 1.5 to 1.8 and the moisture content was 220% and 292% for untreated organic and mixed peat soil respectively, with an organic content of roughly 77% for both type of soil. The liquid Atterberg limit had a value of 230 and 240. By reason of the most of the peat does not satisfy the plastic limit, the test has been disregarded. The results of the compaction test indicated that adding SDA to peat soil decreased the maximum dry density (MDD), but increased strength. The study's findings show that adding 15% of Sawdust ash (SDA) to peat soil enhances its engineering qualities.

Keywords: Soils Stabilization, Peat, Sawdust Ash, Organic, Pyhsical Properties

Introduction

In modern terms, there is a limitation of stable land for the construction of new structures and the creation of new infrastructure due to population growth and desire for social reforms [1]. So, building new structures in weak and unstable soils is unavoidable [2]. As a result, employing various ground improvement techniques, it is required to enhance the qualities of problematic soils prior to building [3]. Peat soil has a low bearing capacity, is highly compressible and has a low shear strength. Therefore, construction on peat soil is extremely difficult due to its problematic nature. Organic soils are formed in the natural environment and do not allow for rapid decay of material. Organic soils have an organic content of more than 20%, while peat soils have an organic content of more than 75%.

Sawdust is a by-product of cutting wood and other wood-related activities and a form of fine wood particles. It is produced when timber is sawn into planks at saw mills located in almost every major town in the country such as Malaysia. This is a daily activity that generates heaps of saw dust at the end of each day. According to recent studies, fly ash and rice husk ash can be used to stabilise soil without the use of lime or cement, as well as in combination with them. Saw dust has little cementitious value on its own, but in the presence of moisture, it reacts chemically and forms cementitious compounds, which contribute to the improvement of soil strength and compressibility. Sawdust ash (SDA) primarily consists of silica, which controls the ash's reactivity. The presence of a high percentage of siliceous material in the SDA indicates that it has pozzolanic properties. Incineration is the most common method of converting saw dust to ash. The properties of SDA vary depending on whether the saw dust was completely burned or only partially burned.

Problem Statement

In order to improve the geotechnical properties and strength of peat soil, soil stabilisation is required. The common alteration of soil is done by the addition of different type of admixtures like (sawdust ash, cement, lime, etc.) to the soil [4]. To significantly reduce the cost of stabilising soils used in construction, it is necessary to analyse a cheaper materials or waste products [5]. Throughout the year, Malaysia has generates heaps of saw dust at the end of each day through industrial field and this somehow lead to industrial waste. The use of sawdust ash (SDA) as a soil stabiliser reduces construction costs and allows for the development of environmentally friendly binders that contribute to long-term management [6,7]. This will not only solve the waste disposal problem, but will also significantly improve the soil's strength characteristics.

Aim and Objectives of Study

This study investigated the improvement of soil strength by using locally available industrial wastes to reduce construction costs. The following are the objectives;

1. To determine the physical properties of untreated peat soils (organic and mixed).
2. To determine compressive strength of the treated peat soil by adding sawdust ash (SDA).

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Scope of Study

The research was carried out by using Peat soil collected from MARDI Pontian, Johor. Soil properties were determined in this study using laboratory experiments such as sieve analysis, Atterberg limit test, Proctor compaction test, unconfined compressive test. The soil characteristics were compared before and after the addition of sawdust ash based on the experiment results. Physical soil parameters that are primarily determined include moisture content, particle size distribution, loss on ignition, and the Atterberg limit, which consists of a liquid limit. To evaluate the soil's strength and compaction, two tests have been run. The typical Proctor test has been performed to measure the soil's maximum dry density (MDD) and optimum moisture content (OMC). An unconfined compression test was then carried out to determine the compressive strength. Figure 1 shows the location of peat soil were retrieved.

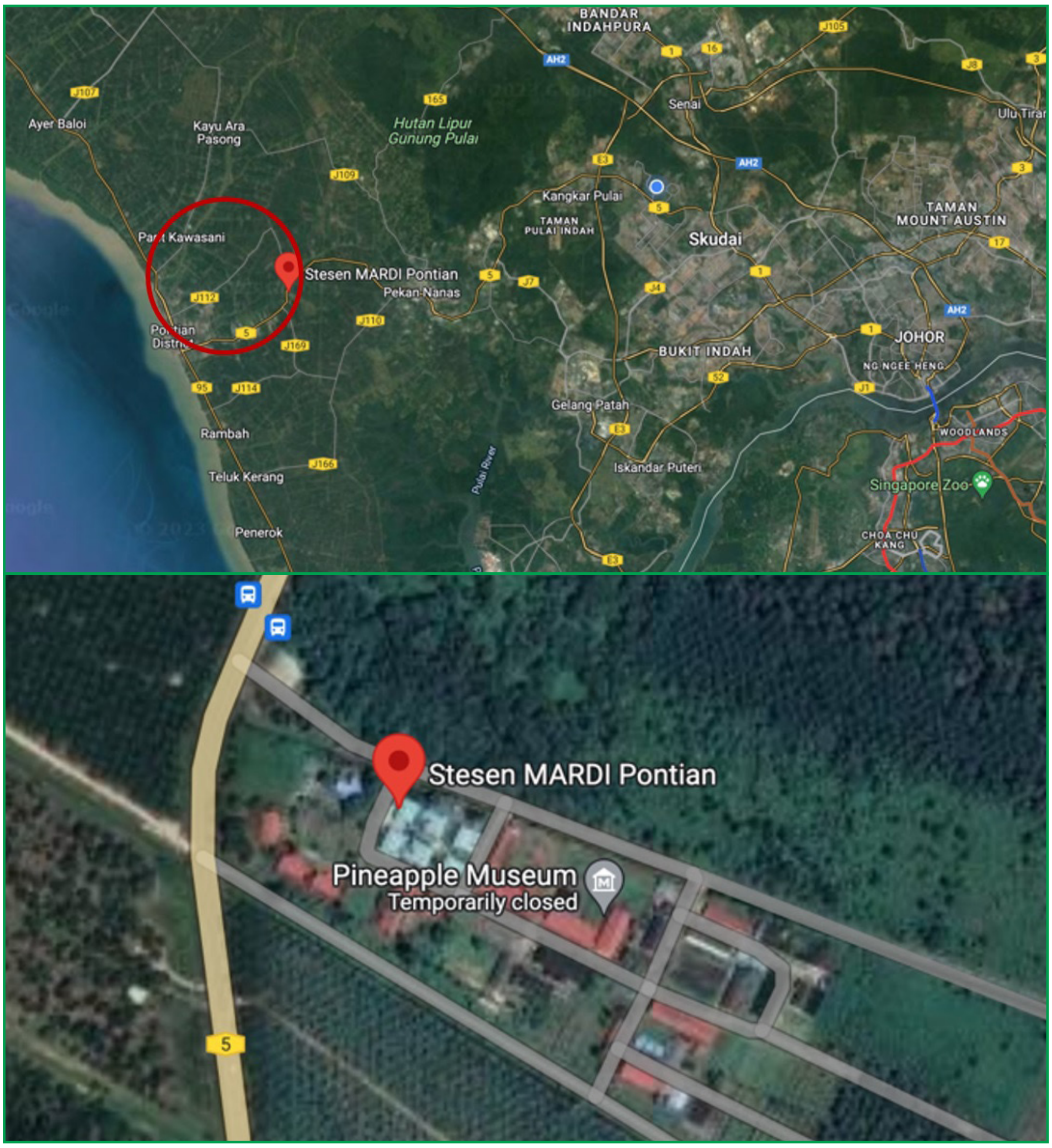

Figure 1. MARDI Pontian, Johor

Literature Review

Soil Stabilization

Civil engineering construction is one of the most important industry in every country. A good quality of soil underlaying beneath a building is required to ensure its safety and the quality [8]. In some cases, soil properties may not meet the required engineering specifications. Soil stabilisation is one of the primary techniques used to enhance the properties of the soil. Stabilization is accomplished by increasing a soil's shear strength and overall bearing capacity [9]. It is an alteration of one or more soil properties by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Stabilized soils provide a solid working platform, serving as the foundation for all other project components [10,11]. It performs mechanical, biological, physical, chemical, and electrical processes.

Classification of Soil

The type of soil used in this study was organic peat soil (shallow <1.0m) and mixed peat soil (moderate 1.0-1.5m). Peat soil forms naturally as a result of anaerobic decomposition of plant and animal constituents at low temperatures. According to the Von Post classification system, the experiment by Nurul et al. (2015) revealed that the peat soil in Pontian was categorised as H5. The experiment was classified as a Hemic-type (H5) peat with a 76.55% organic content, a 255% liquid limit, and an 898.91% water content [12]. During the rainy season, peat soil will be saturated with water, while in the dry season, peat soil will compress due to the loss of water from the pores. These factors are found to influence directly and indirectly on peat soil characteristics. According to Hashim and Islam (2008), the peat soil has a low bearing capacity because it is affected by the water table and woody debris on the subsurface [13]. Peat soil is distinguished by its high natural moisture content, high compressibility and water-holding capacity, low specific gravity, low bearing capacity, and medium-to-low permeability.

Properties of Peat Soil

From [13] found that the presence of underlying woody debris has an impact on the extremely poor bearing capacity of peat soil. Peat generally develops in dense layers in constrained locations, has a poor shear strength, and exhibits high compressive deformation, all of which pose challenges when carrying out building work, according to research by [13]. From [14] on the other hand, asserted that deep peat was a difficult material to work with because of its high compressibility, low permeability, low strength, and volume instability. According to [14], peat soils are challenging to work with because they contain more than 75% organic matter, have a low shear strength (5 to 20 kPa), a high moisture content (250 to 985.40%), and a high compressibility, which frequently causes problems when construction work is performed. A moderate load resulted in issues like long-term settlement or local sinking. In accordance with [7] the cohesion (c) ranges from 6 to 17 kPa and the angle of internal friction (ϕ) ranges from 3 to 25, respectively, as the indicator of shear strength of peat soil in Malaysia [1].

Table 1. Properties of Pontian peat soil (Razali et al., 2013) [14]

Properties	West Malaysia Peat and Organic Soil	East Malaysia Peat and Organic Soil	Johore Hemic Peat (MARDI-PRS, Pontian)	Pontian Peat Soil
Natural Water Content, W (%)	200-700	200-2207	230-500	848.7
Liquid Limit, LL (%)	190-360	210-550	220-250	-
Plastic Limit, PL (%)	100-200	125-297	-	-
Plasticity Index, PI (%)	90-160	85-297	-	-
Specific Gravity (Gs)	1.38-1.70	1.07-1.63	1.48-1.8	1.46
Organic Content (%)	65-97	50-95	80-96	99.20
Unit Weight (kN/m^3)	8.3-11.5	8-12	7.5-10.2	9.8
Refs.	Bujang (2004)	Bujang (2004)	Zainorabidin and Bakar (2003)	Author

Sawdust Ash (SDA)

Sawdust that has been used in this research was obtained from a factory that manufactures frames, doors, and windows (Figure 2). After collection, clean saw dust was air dried and burned at room temperature. The SDA was then sieved through 600 micron sieves to remove lumps, gravels, unburned particles, and other soil-damaging materials [15]. Incineration of sawdust reduced the moisture content of the sawdust and eventually increased the chemical composition of the sawdust ash which silicates. Sawdust ash contains a high proportion of silica, which has the most important component of cement replacement materials. Saw dust does not have much cementitious value on its own, but when moisture is present, it reacts chemically to form cementitious compounds that helped to improve the strength and compressibility of soils. Silica is the main constituent of sawdust ash (SDA), which oversees the reactivity of the ash. The majority of the earth's crust, or eight seven percent, is composed of silicon compounds, and soil is primarily composed of silica [16]. According to Elinwa and Abdulkadir's studies [17], SDA is a pozzolanic material that reduces porosity in addition to being effective at preventing reinforcement corrosion.

Methodology

The physical characteristics of the soil samples taken from Pontian regions have been examined, and their strength and stabilisation have been determined using admixtures. The soil's optimal geotechnical qualities, including their physical and engineering characteristics, have also been documented. The experiment was carried out in the Geotechnical and Rock Mechanics Laboratory, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia (UTM), Johor Bahru as can be seen in Figure 3.

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Figure 2. Sawdust ash after being undergone incineration process

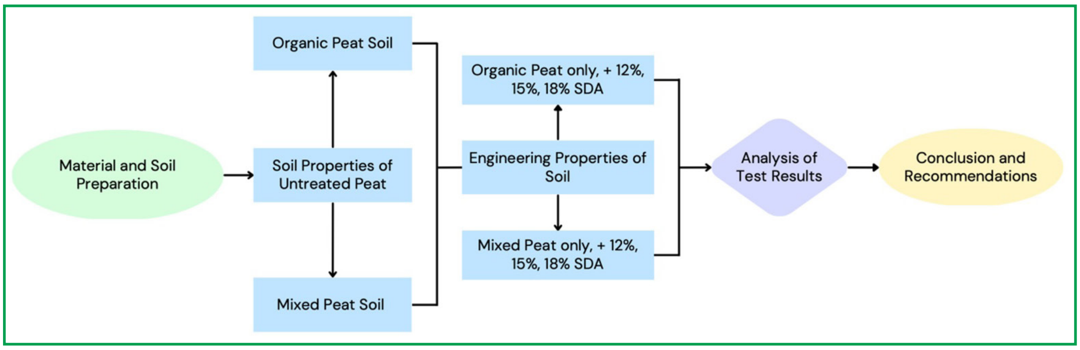

Figure 3. Research Methodology

Material Preparation

Laboratory testing for the study complied with British Standard (BS 1377:1990). Organic and mixed peat soil was oven dried and sieved. Peat soil that passed through 20 mm sieve were collected and used throughout the experiments. Sawdust ash (SDA) was applied in increments of 3% from 12% to 18%. To ascertain the engineering properties of soil, the peat soil was prepared with Sawdust ash (SDA) mixtures that mixed with an adequate amount of water.

Result and Discussion

This chapter covered the modifications to the physical and engineering characteristics of untreated and treated peat soil. The tests were carried out in the Geotechnical and Rock Mechanics Laboratory, Universiti Teknologi Malaysia, Johor. The experiment's findings are mainly concentrated on four kinds of peat: untreated (organic and mixed) and treated (organic and mixed) with SDA. The values of the fundamental, laboratory-tested characteristics of untreated peat soil are shown in Table 2.

Table 2. Basic properties of untreated soil

Soil Parameter	Organic Peat Soil	Mixed Peat Soil
Natural Water Content (%)	220	292
Organic Content (%)	77	77
Specific Gravity	1.50-1.80	1.50-1.80
Liquid Limit	230	240
Plastic Limit	np	np
Plasticity Index	-	-
Bulk Density (kg/m^3)	745.34	1014.49
Dry Density (kg/m^3)	743.60	1012.27

Particle Size Distribution Analysis

Dry sieve techniques were used to determine the particle size distribution of peat from fibre size 2,000 micron to 10 micron (Figure 4). These techniques were applied to generate the particle size distribution graph. The sieves ranged in size from 5 mm to pan. The percentage of grains that pass through sieves was represented by the untreated peat particle size distribution. Both of the untreated peat sample (organic and mixed) used in this investigation was categorised as fine-grained soils by BS 1377-2:1990:9.

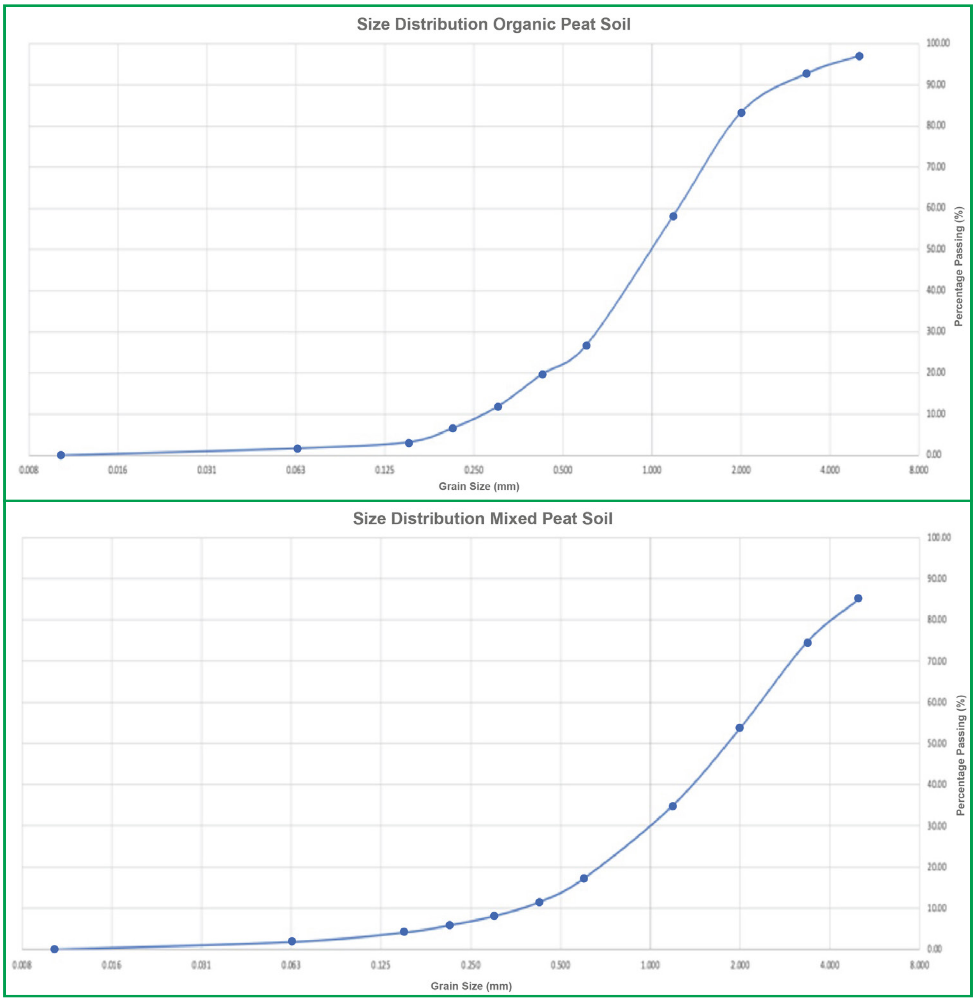

Figure 4. Particle size distribution for the organic and mixed peat soil

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Standard Proctor Test (Compaction Test)

Standard Proctor test has been conducted as per BS 1377:1990:4 by using 2.5 kg hammer to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the peat soil sample. By plotting the dry density values against the corresponding moisture contents yielded an optimum moisture content and maximum dry density for the soil samples. Figures 5, 6 and Table 3 depict the outcomes of the Standard Proctor compaction test on the organic and mixed peat soil + SDA samples.

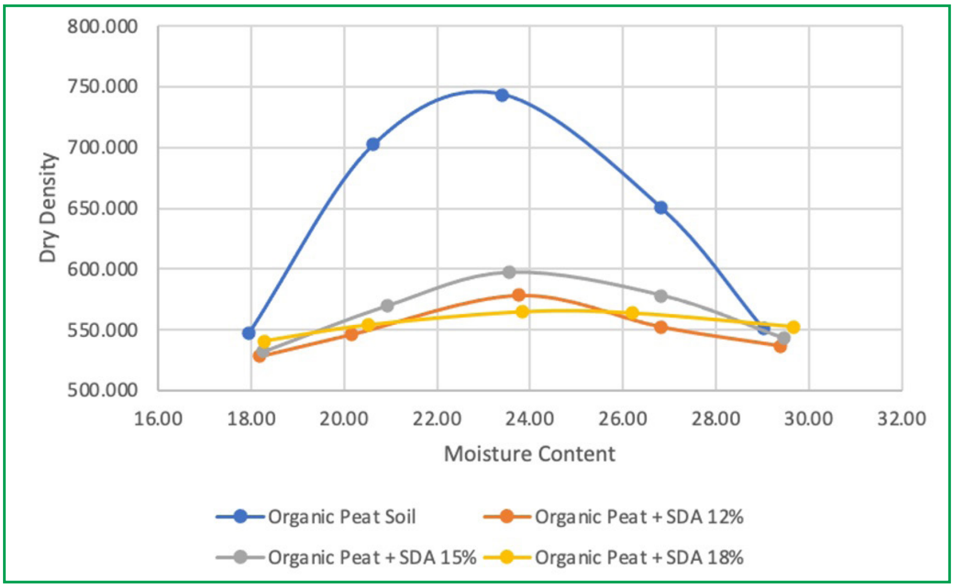

Figure 5. Standard Proctor test results for untreated organic peat and treated peat with SDA

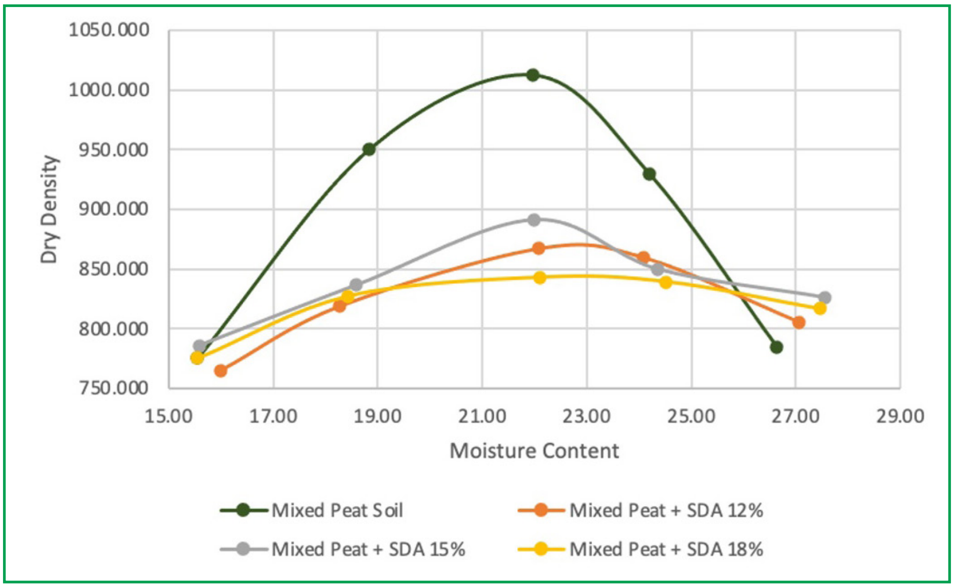

Figure 6. Standard Proctor test results for untreated mixed peat and treated peat with SDA

The studies done by [18] showed that the maximum dry density for the BSH compactive effort went from 1.54 g/cm^3 to 1.6 g/cm^3 with the addition of SDA in percentages ranging from 4% to 16% in black cotton soil. A further increase in SDA content to 20%, however, led to a rise in OMC rather than a decrease in OMC, as well as a fall in the MDD and CBR values. A significant change in the plasticity index (PI), specific gravity (Gs), or differential free swell was not also produced by the addition of 20% SDA.

Table 3. The values for each soil type, MDD and OMC

	MDD (kg/m^3)	OMC (%)
Untreated Organic Peat	743	23.41
Organic Peat + SDA 12%	578	23.76
Organic Peat + SDA 15%	597	23.55
Organic Peat + SDA 18%	565	23.82
Untreated Mixed Peat	1012	21.97
Mixed Peat + SDA 12%	867	22.07
Mixed Peat + SDA 15%	891	21.99
Mixed Peat + SDA 18%	843	22.09

Unconfined Compressive Test

The unconfined compressive strength was measured as the force per unit area at which a cylindrical soil specimen had been compressed in a standard compression test. Unconfined compressive strength was the main objective of the test, which was conducted in accordance with BS 1377:1990. In general, the specimen was prepared by extruding the soil sample from a standard Proctor test mould at a height that was roughly double the diameter. For all treated and untreated peat, a cylindrical specimen had been evaluated. 38.0mm diameter and 81.0mm height. UCS test will be carried out in accordance with BS 1377:1990 guidelines to ascertain the strength gain by the peat soil with stabilizer different percentage of mix design.

Figures 7 and 8 showed the plot of unconfined compressive strength as the percentage of SDA increased. The addition of additives to peat soil samples provided the objective of examining the effects of additive concentration and curing time. The stabilized peat specimens revealed a significantly higher UCS in 0 day compared to both original untreated peat soil, which only had a UCS of 10.72 kn/m^2 for organic peat and 12.30 kN/m^2 for mixed peat. The strength of peat and sawdust ash combinations was raised to 30.65 kN/m^2 with the addition of 15% SDA. However, the results revealed that the curing period affects the unconfined compressive strength of the soil samples. Likewise, samples that were cured for 0 days were stronger than ones that were cured for 28 days. Due to the biodegradability of both addictive materials, the value from the 28 days of treatment had decreased.

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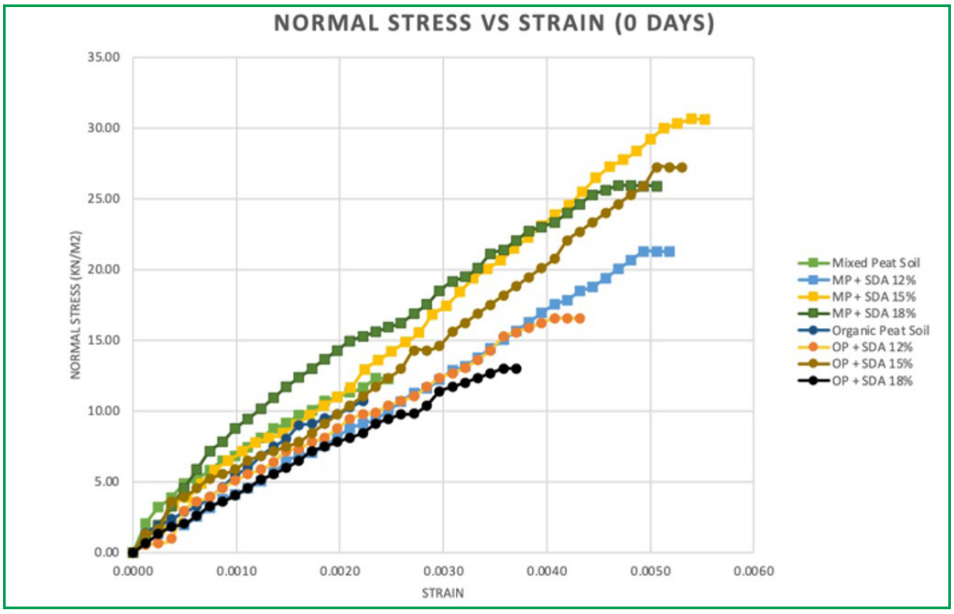

Figure 7. Stress-strain curves for original peat and as well as a mixture of peat and different amount of SDA and obtained from UCS tests in 0 day

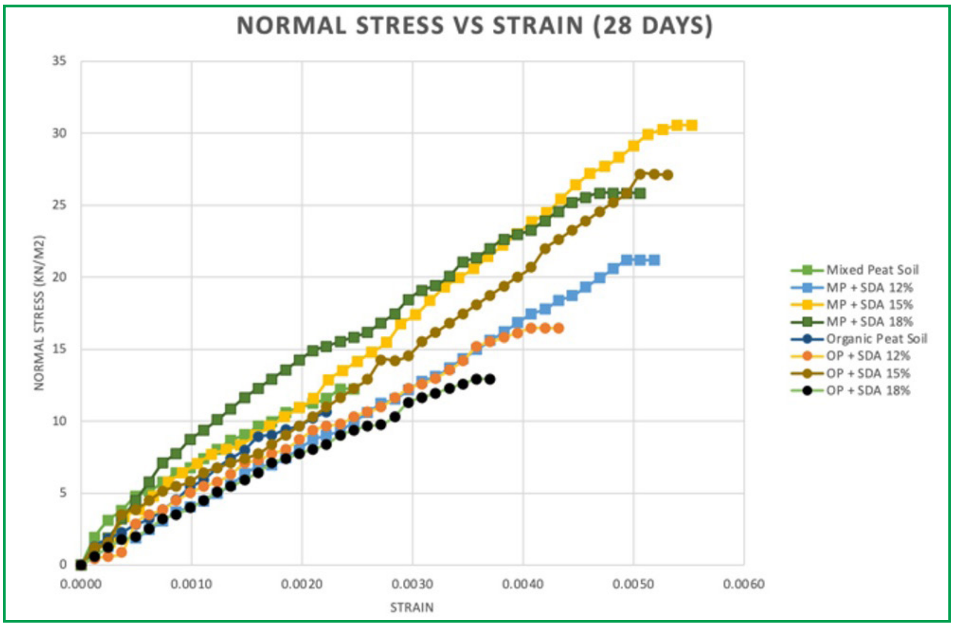

Figure 8. Stress-strain curves for original peat and as well as a mixture of peat and different amount of SDA and obtained from UCS tests in 28 days

Conclusion

The purpose of this study which to determine the characteristics of untreated peat soil and assess changes in the strength of treated peat soil after adding various amounts of sawdust ash (SDA) were determined. The general features of peat soil were improved by the use of sawdust ash as soil stabilizers. Results were marginally better with sawdust ash applied to peat soil than with peat that had not been treated. Peat with 15% of SDA had the lowest optimum moisture content and highest maximum dry density when compared to the other mix ratio.

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With the addition of SDA, unconfined compressive strength of the soil rose. This study found that the strength of treated peat was greatly increased by the addition of SDA to peat soil. Overall, the results are encouraging, with notable increases in the strength and economic capacity of stabilizing the soil using sawdust. In addition to resolving the issue of waste disposal has greatly enhance the strength properties of the soil.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

Nurul Hanis Hananni Mohd Anuar: writing, original draft preparation. **Dayang Zulaika Abang Hasbollah:** writing, reviewing and editing. **Azhani Zukri:** reviewing and editing.

Data Availability Statement

The data used to support the findings of this study are included within the article.

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