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Study of Various Soil Stabilization Techniques That Suitable for Parit Nipah Peat Soil

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Abstract: Peat soil is defined as soil with a high percentage of decomposed organic materials. The great majority of peatland lands have been redeveloped for agricultural purposes. Peat soil is categorised as problematic soils and dangerous for engineering structures because of geotechnical properties including high compressibility and weak shear strength. This paper presents various method of soil stabilizer by various type of admixture. In this study the method review were by the chemical stabilization method which by cement lime stabilization and envirotac stabilization and by the laboratory stabilization method that was done by electrokinetic stabilization. The research were carried out by analysing prior case studies conducted by other experts. The case study was taken at Prt. Nipah Johor Malaysia. In this study, the method of the soil stabilizer that taken from other state in Malaysia that have the same physical and mechanical properties of peat soil of study area were discuss in order to find the suitable method of peat soil stabilizer for Prt. Nipah Johor. Some engineering variables were compared with the physical and chemical properties of the peat soil at Prt. Nipah Johor including unconfined compressive strength (UCS), the liquid limit test, and moisture test result from the previous study of the untreated and treated peat soil. From the study, the suitable peat soil stabilization method has been identified which cement lime stabilization method. This is due to the condition that more suitable compared to the other two methods.

Keywords: Peat Soil, Peat Soil Stabilizer, Prt. Nipah

1. Introduction

Peat is a brownish-black soil created by the breakdown of organic material that has been degraded over thousands of years. [1]. In peat soil, plant disintegration in acidic settings without microbial activity produces highly organic materials [2]. Peat soils are weaker and more compressible than other soil types, resulting in greater geotechnical issues. Peat soil is a soft, water- and organic-rich soil with low shear strength, bearing capacity, mechanical, and biological characteristics that degrade over time. Construction on peat soils may be problematic for civil engineers. This is because of the soil type and

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its significant issue that can cause many problems. The water table and the presence of underlying woody debris appear to have an impact on peat soil's bearing capacity [3]. The physical characteristic of the soil is determined from the color of the peat soil, degree of humidification, water content and the organic content of the peat soil [4]. Mineral content, organic content, moisture content, and air content are all impacted by the main components of the formation [5]. The value of water content is determined by the peat soil's origin, degree of decomposition, and chemical makeup [6]. In order to sustain any building, peat soil requires some form of stability. Enhanced the bearing capacity, enhance the soil stability, and minimized settlement and lateral deformation are the major objectives of soil stabilization.

This problem also has become the major issue for the construction on Prt. Nipah Johor, where it has the same type of soil which is the peat soil. The common problem that normally happened on the building at Prt. Nipah peat soil is soil settlement, cracking and foundation subsidence. Therefore, in order to overcome the problem, any technological and geotechnical engineering method of improvement need to be done to the soil. This improvement is done in order to make the soil capable and safe to support the structure that is going to be built on it. Like other type of soil, peat soil also has its own physical, chemical and engineering properties. The primary components, such as mineral content, organic content, air content, and so on, have an impact on them. Changes in these components will result in changes in the peat soil's overall physical characteristics. [7]. Prt. Nipah peat is categorised as H5, or moderately decomposed peat, often known as hemic peat, due to its degree of decomposition. According to a prior study, organic content ranged from 78 to 93 %, with fibre level ranging from 40 to 67 % [8].

The aim of this research was to analyze various method of peat soil stabilizer and identify the suitable method for Prt. Nipah peat. Soil stabilization need to be done in order to improve the physical properties of the soil. As an outcome, the soil's bearing capacity and strength will both improve [9]. This research is based on a prior study by other researchers that focused on the method of peat soil stabilizer. The chemical and physical characteristics of the soil will be compared before and after the curing session. Various stabilizing methods are described in this study to improve soil strength. The method that are described in this study is by electrokinetic stabilization and by the chemical stabilization which by cement lime stabilization and envirotac stabilization method. This study can be used as a guide to help in order to select the suitable method for the peat soil stabilizer on problematic soil in Prt. Nipah, Johor, Malaysia.

2. Materials and Methods

The method used in this study was rather straight forward as it mostly requires a collective amount of reading and analyzing of past research papers. In this chapter, the method of peat soil stabilizer by using various method was discuss on order to full fill the objectives of the study. The data on the physical properties test on the moisture content and the Atterberg limit teat of the treated and untreated peat soil will be compared in the study. On the other hand, mechanical properties on the standard proctor compaction test and Unconfined compressive strength test also will be compared in order to find the suitable method of stabilizer for Prt. Nipah peat soil.

2.1 Electrokinetic stabilization

For electrokinetic stabilization method, the study has been done by Wahab et al. in 2018. From the research the sample was taken from Parit Haji Ali Johor [10]. This sample was put through a series of tests to assess its efficacy and performance as a stabilised peat soil. Moisture Content Test was used to determine physical characteristics. Using the oven-drying technique, the moisture content was determined using British standard procedures (BS1377: Part 2). The specimen was heated to 105°C to 110°C in an indoor dry oven for 16 to 24 hours. The liquid limits test was carried out also by referring to the British standard (BS1377: Part 2) by using the cone penetration method. The peat soil was sieved through 424 μm and then air-dried for 16 to 24 hours to achieve maximum moisture content. And the Compaction Test Standard Proctor compaction test was conducted according to (BS1377-1990: Part 4) to determine the maximum dry density (kg/cm^3) (MDD) and Optimum Moisture Content (OMC) of the peat. The soil was compacted in a mould and the mould was connected to a base plate in the typical proctor compaction test. The soil was combined with some water and compressed in three equal levels using a hammer that delivered 27 blows to each layer and had a 2.5 Kg hammer energy.

2.2 Cement lime stabilization

Cement lime stabilization method has been done by Rahman et al. in 2016. Ordinary Portland cement (OPC) was utilized as a binder agent to influence the mechanical behaviors of peat soil in this study, which was carried out at Kampung Tumbuk Darat Sepang Selangor[2]. Cement was utilized in construction not just for concrete but also for soil stabilization. Ordinary Portland Cement (OPC) is also known as a soil stabilizer in ground improvement since it is a combination of soil cement and water that reacts together. One of the most often utilized soil stabilizing methods is cement. The Atterberg limit, compaction, permeability, and strength of untreated and treated peat soils were all tested. Four sets of treated samples were made, with cement ranging from 0% to 40% of dry weight peat soil in each set. Because peat is non-plastic due to the significant incidence of plant remnants, determining the Atterberg limit, or plastic limit, of the peat soil was not achievable [10]. When dry, non-plastic peat soil has a very low strength and is quite fragile. As a result of the non-plastic condition of the peat sample, only the liquid limit LL was measured in this investigation. Using the Casagrande approach based on BS1377, the liquid limit, LL, was calculated. The goal of this test is to determine the maximum dry density (MDD) and optimum moisture content (OMC) values.

2.3 Envirotac stabilization

For envirotac stabilization method, the study has been done by Norazam et al. in 2017.The sample was obtained from Prt. Nipah Batu Pahat Johor [5]. Then the soil sample was mixed with the envirotac. The percentage of envirotac used is 40%, 60% and 80%. The study focused on a variety of tests to determine the sample's physical and chemical features. The peat soil sample will be combined with various concentrations of envirotac and distilled water at first. The data is then gathered on days 7, 14, and 21. This sample is subjected to a number of tests in order to measure the effectiveness and performance of stabilised peat soil. The unconfined compressive test UCS and the standard proctor compaction test SPC were used to collect data on treated peat soil, whereas the unconfined compressive test UCS and the standard proctor compaction test SPC were used to collect data on untreated peat soil. Unconfined compressive test is done in order to fine the soil strength. Where the cylindrical sample is subjected to the increasing axial compression until it fails. While for the standard proctor compaction test is done in order to fine the maximum dry density and the optimum moisture content of the sample.

3. Results and Discussion

The following chapter discuss on the comparison on the physical and mechanical test. The purpose of this research was to identify the soil's properties using tests such as moisture content and the Atterberg limit test. In addition, by comparing the results of the unconfined compressive test, the mechanical properties of the soil were studied in order to determine the optimum stabilizers for peat soil.

3.1 Results

i. Moisture content

Moisture content was used as the guideline to classify natural soil and as a control criterion in the classify of the peat soil. The data was collected and compared by the previous study by other researchers. The moisture content test was conducted by following BS13377-2:1990:3.2. The result was compared in order to see the peat sample is suitable to be compared or not in order to find the most suitable soil stabilization technique in this study. Moisture content of peat depends on the organic content in the soil [8]. The presence of substantial organic matter increases peat soil's water absorption capacity to rised [7]

Table 1: The average moisture content for untreated and treated peat soil

Type of soil stabilization technique	Average moisture content result *w*%				
	Untreated peat soil	Treated peat soil			
Electrokinetic	476.849	309.273			
Cement lime	470	0% 188	10% 185	20% 164	40% 135
Envirotac	465.67	-			

For electrokinetic stabilization method, the initial result shows the moisture content for Prt. Haji Ali untreated peat was 476.849%, as tabulated in Table 1. Before the electrokinetic procedure, a 50 kg weight was applied in the soil. The peat soil was compacted with low moisture content and compressibility when the load was removed from the electrokinetic cell. The moisture content was lower in the post electrokinetic with a 50 kg applied force than in the pre-electrokinetic with an untreated soil and a voltage difference of 110 V over a 3-hour operational time. The moisture content was observed 309.273%. The reduce of moisture content reduce for about 167.576%.

While for lime cement stabilization the method, the initial result shows the moisture content for Kampung Tumbuk Darat Sepang untreated peat was 470%, as tabulated in Table 1. Treatment of peat soil with different amounts of OPC where the percentage of OPC is 0%, 10%, 20% and 40% showed the values of *w* decrease with the increases in OPC contents. The moisture content reduce for the 0% percentage of OPC is 188% which the difference is about 282%. While for moisture content reduce for the 10% percentage of OPC is 185% which the difference is about 285%. And 20% percentage of OPC is 164% which the difference is about 306% and for 40% percentage of OPC is 135% which the difference is about 335%. The hydration of cement caused cementation between peat soil inter-particle gaps, lowering w values [11]. Previous research has found that cement-treated soils have a stronger soil structure than untreated soils, indicating that cement-treated soils have a denser soil structure.

For the envirotac stabilization test, the water content inside the soil was removed at a temperature of 110°C. The average moisture content for untreated peat soil is 465.67 %. The researcher did not calculate the average moisture content of treated peat soil using this approach. As a result, the typical moisture content of peat soil is between 230 and 500 %.

ii. Atterberg limit test

Because peat is non-plastic due to the significant incidence of plant remnants, determining the Atterberg limit, or plastic limit PL, of the peat soil was impossible [7]. When dry, non-plastic peat soil has a very low strength and is quite fragile. In some case especially in peat soil, only liquid limit *LL* can be determined. Most of the test cannot find the value of plastic limit test due to peat is to soft and easily to separate. As a result, due to the non-plastic nature of the peat sample, only the liquid limit *LL* was found for the whole research. The Casagrande approach was used to establish the liquid limit *LL*, which was based on BS1377. According to the study liquid limit *LL* of peat soil increases as the quantity of organic material increases [12].

Table 2: Liquid limit test value for untreated and treated peat soil

Type of soil stabilization technique	Liquid limit test $LL\%$	
	Untreated peat soil	Treated peat soil
Electrokinetic	136.107	191.225
Cement lime	184	160
Envirotac	215	-

For the liquid limit test the value for the untreated and treated peat has been stated as table 2. for electrokinetic stabilization technique the liquid limit test was done in the laboratory according to the British standard (BS 1377: Part 2). According to table 2, Prt. Haji Ali's liquid limit was 136.107 percent. The liquid limit was found to be raised when a 50 kg pressure was placed and a voltage gradient of 110 V was provided over a 3 hour operational time. Prt. Haji Ali's liquid limit has been raised to 191.225 percent. There is a 55.15 percent difference between untreated and treated peat soil.

While the Lime Cement stabilization technique the Liquid Limit LL for untreated peat soil at Kampung Tumbuk Dalam Sepang was read at 184%. The liquid limit value was observed decrease to 160 % with the difference about 24%.

And for Envirotac stabilization technique the Liquid Limit LL for untreated peat soil is 215% which is high compared to the other test. For the study that has done by Norazam et. al. in 2017 there is no data for the treated peat soil [5].

iii. Standard proctor compaction test

Table 3: Maximum dry density and optimum moisture content value for untreated and treated peat soil

Type of soil stabilization technique	Untreated peat soil		Treated peat soil	
	Maximum dry density MDD × 10-7 kg/m^3	Optimum Moisture Content OMC %	Maximum dry density MDD × 10-7 kg/m^3	Optimum Moisture Content OMC %
Electrokinetic	6.97	48.812	8.52	127.649
Cement lime	6.1	53	0% 10% 6.1 53 6.1 6.2	0% 10% 6.1 53 6.1 6.2
Envirotac	-	-	4.9	132.47

For electrokinetic stabilization method the Standard Proctor compaction test was done for both samples for untreated and treated peat soil as stated in table 3. The initial results show that maximum dry density (kg/m^3) MDD was observed was 6.97 × 10-7 kg/m^3 and optimum moisture content OMC was 48.812% for Prt. Haji Ali. The sample shows that MDD was increased up to 8.52 × 10-7 kg/m3 while OMC was increased to 127.649%.

For lime cement stabilization method, the standard Proctor 2.5 kg of compaction test based on the BS 1377 was used for the compaction testing. Soil samples were crushed in metal using a 2.5 kg rammer dropped from a height (30 cm). Each layer received twenty-five strikes, with the blows continuing up to three uniform layers. This is due to assess the moisture content, representative samples were taken.

The test was done on the untreated peat soil where the value of maximum dry density *MDD* is 6.1 × 10-7 $kg/m^3$and optimum moisture content *OMC* is 63.5.

The result on treated peat soil for maximum dry density MDD has increase with the increasing percentage of OPC where for the treated peat soil on 0% of OPC was the same with the untreated peat soil which 6.1x10-7kg/m^3. While for 10% OPC the value of treated peat soil was 6.2x10-7kg/m^3. For the 20%of OPC was 6.5x10-7$kg/m^3$and for the 40% of OPC is 6.9x10-7kg/m^3.

While for the result on Optimum Moisture Content *OMC* was slightly different where the result on treated peat soil increasing at 0% and 10% OPC where the value of OMC is increasing from 53% to 63% for 0% OPC and 70% for 10% OPC. And the result dropped for 20% and 40% of OPC where the value dropped to 64% and 62% for the treated peat soil. This might be explained by increasing OPC levels in the soil, which makes the soil less responsive to water content as it approaches maximum dry density. According to the findings, peat soils treated with cement and lime showed identical compaction behaviour [13].

iv. Unconfined compressive strength UCS test

As the quantity of OPC content was raised and the curing durations were extended from 3 to 28 days, the effects of OPC content and curing were clearly visible. The unconfined compressive strength q_u of treated peat soil cured at three days was lower than that of samples cured at 28 days, according to the UCS values. The q_u values for OPC-treated samples that had been cured for three days ranged from 8.4 kPa to 61 kPa. Higher q_u readings of 32.4 kPa to 98.2 kPa, respectively, showed that the treated samples healed after 28 days. As indicated in table 4, the q_u values appeared to improve as the OPC content was increased in the UCS findings for cured at 28 days. The production of cementitious products as a result of pozzolanic reaction has been linked to this behaviour. The discovery of cementitious materials that link soil particles increased the hardness of treated soil, increasing the unconfined compressive strength of peat soil. These are the facts that when the stabilised soils are allowed to cure for longer periods of time, the OPC will gains strength. The relationship between the unconfined compressive strength and the percentage of OPC corresponding to the curing period. It can be observed that with the increasing percentage of stabilizer, the value of compressive strength also increased. It also can be stated that the longer the curing period the higher the value of compressive strength.

Table 4: Unconfined compressive strength value for untreated and treated peat soil for cement lime stabilization

OPC content %	Unconfined co pressive strength q_u kPa	
	3 days	28 days
0 untreated	8.4	8.4
10	17.0	32.4
20	30.0	50.0
40	61.0	98.2

For envirotac stabilization method, The UCS test was carried out on a cured peat soil sample with various stabiliser percentages. The conventional curing procedure of air curing was utilised in this study. The sample is subjected to conventional curing procedures over the course of seven, fourteen, and twenty-one days. According to the results, when the proportion of envirotac in the peat soil sample grows, the strength of the peat soil with envirotac increases, as shown in Table 5. For the 7 days curing period the untreated peat soils the value of UCS increase as the percentage of envirotac also increase the strength from 42.46 kPa to 175.81 kPa on the 15% of envirotac. For the 30% and 45% of envirotac the strength also increased to 241.87 kPa and 422.95 kPa. For the 14 days curing period the percentage of envirotac also increase the strength from 44.84 kPa to 405.53 kPa on the 15% of envirotac. While for the 30% and 45% of envirotac the strength also increased to 537.34 kPa and 560.55 kPa. And for the maximum curing period which 21 day the percentage of envirotac also increase their strength from 46.31 kPa to 501.27 kPa on the 15% of envirotac. While for the 30% and 45% of envirotac the strength also increased to 561.72 kPa and 573.89 kPa. It's because the addicting was bonded to the peat soil sample in a uniform manner. The proportion of envirotac related to the curing duration and the unconfined compressive strength. It can be observed that with the increasing percentage of stabilizer the value of compressive strength also increases. It also can be stated that the longer the curing period the higher the value of compressive strength.

Table 5: Unconfined compressive strength value for untreated and treated peat soil using different percentage of envirotac

Additives	Unconfined compressive strength (kPa)		
	7 days	14 days	21 days
Untreated	42.46	44.84	46.31
15% Envirotac	175.81	405.53	501.27
30% Envirotac	241.87	537.34	561.72
45% Envirotac	422.95	560.55	573.89

3.2 Discussions

From reviewing all the method of soil stabilization technique, all of the test that has done are mostly the same. The physical properties test that has done is by the moisture content. In this test the difference value of untreated and treated peat soil has recorder higher at the method of cement lime stabilization method then followed by the electrokinetic stabilization method. While for the envirotac stabilization method the researcher not done the moisture content test for the treated peat soil. from the result we can conclude that when the method can remove more moisture form the soil this is good for the stabilization of the peat soil. This is because when the peat soil contains more moisture it can easily to settlement and slide. Therefore, by removing the moisture content, the problem can be overcome. In terms of moisture content, the suitable stabilization method that suitable with Parit Nipah peat soil is by the cement lime stabilization method.

From the Atterberg limit test, the test that was done is by the Liquid Limit *LL* test. From the test there are difference in the result whereby for the electrokinetic stabilization method recorded increase in the value of Liquid Limit *LL* form the untreated to the treated peat soil. The liquid limit of peat soil increases as the quantity of organic material increases [13]. This means the value was increase due to the increase amount of organic content. The consequence of the cement lime stabilisation procedure is an increase in the value of the Liquid Limit LL. The hydration of cement caused cementation (pozzolanic reaction) between inter-particle gaps of peat soil, lowering the Liquid Limit LL values. A high liquid limit usually implies a high compressibility as well as a significant potential for shrinkage or swelling.

The other test that has been done is by the Standard Proctor Compaction test. This test was done in order to find the value of Maximum Dry Density MDD and Optimum Moisture Content OPC. The result on untreated peat soil has increase after the curing process. All of the method gives the same increasing result for after and before the curing process.

For the unconfined compressive strength, the result on cement lime stabilization method and envirotac stabilization method was all in the increasing mood. The relationship between the unconfined compressive strength and the percentage of stabilizer corresponding to the curing period. It can be observed that with the increasing percentage of stabilizer the value of compressive strength also increases. It also can be stated that, the longer the curing period the higher the value of compressive strength. On the other hand, when the percentage of stabilizer increase, the strength of the specimen also increases.

4. Conclusion

For the conclusion, the study of properties of peat soil was conducted by referring to various study that has done by the previous researchers in order to achieve the objective of these paper review. There are three method that has been selected in this study that has the same peat soil condition on order to gained the objective which to fine the suitable method to the study area at Parit Nipah Johor. The method of soil stabilization technique that has been selected in this study is the electrokinetic stabilization method and by the chemical stabilization which by the method of cement lime stabilization method and the envirotac stabilization method. All of this method has been selected due to the same type of peat soil condition which hemic type of peat soil.

Based on the study electrokinetic stabilization is one of the suitable stabilizaer and for chemical stabilizer the most suitable stabilizer method that suitable with Parit Nipah Peat soil is by the cement lime stabilization method. All the method behaves in the good manner but electrokinetic stabilization and for chemical stabilization, cement lime stabilization method shows the highest difference in all the test that have done. this is because electrokinetic stabilization method is the different method comared to chemical stabilization which it required to be done in the lab due to the apparatus that only can be done in the lab. Other than that, for chemical stabilizer, cement lime stabilization method is more economical and easier to find the material compared to the others two method. On the other hand, the material for the cement lime stabilization method also more affordable compared to the other two methods. The other advantage of using cement stabilization method is cement has long terms performance record where less cost required in order to do the maintenance process. According to Zuber (2013), OPC is one of the most successfully used soil stabilization. Soil stabilization with cement can helps in improving the soil properties and it was proven by many research that was done. Cement has been used to improve the shear strength of the soil and it also helps in reducing the compressibility and permeability of the soil. For envirotac stabilization method, the material is economical and easy to find but no further study was done by other researchers due to the application of envirotac. This is due to envirotac is still new in this field. Compared with cement lime stabilization method, more study has been done on the peat soil. Therefore, cement lime stabilization method is more suitable for Prt. Nipah peat soil.

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