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Influence of Polymer on the Unconfined Compressive Strength of Peat-Polymer Mixtures

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Abstract

This study investigates the influence of polymer on the unconfined compressive strength of peat-polymer mixtures. Peat soil is known for its low strength and high compressibility, making it challenging for various engineering applications. To improve its mechanical properties, polymers Vinyl Acetate - Acrylic Copolymer (VAAC) were added to peat soil as stabilizing agents. The objective of this research is to assess the effect of polymer content on the unconfined compressive strength of peat-polymer mixtures. Laboratory testing is conducted on samples that cured for 1,3,5 and 7 days and the compressive strength of the peat polymer mixtures were measured using unconfined compression tests. The results demonstrate that the addition of polymers significantly enhances the compressive strength of the peat-polymer mixtures. As the polymer content increases, the compressive strength of the mixtures exhibits a substantial improvement. The findings of this study provide valuable insights into the potential of polymers as effective stabilizing agents for peat soil, offering potential solutions for enhancing the engineering properties and performance of peat-based construction materials.

1. Introduction

Peat is made up of fragmented organic material and is a combination that forms in wetlands under the right climatic and topographic circumstances. Compared to other soil components, peat soils are significantly weaker and more compressible, demanding special considerations for altering the deposits to be suitable for engineering usage and long-term preservation [1]. It comes from plant that has been chemically altered and fossilized. They are soft since they are organic in nature. Peat soils are hence also referred to as organic soils. Because peat soils are organic, they have a low bulk density. Besides that, peat soils are squishy due to the high-water table and the soil's softness, making it difficult to walk on them without sinking. Other than that, due to the need for accessibility from many locations, the construction of infrastructure such as a roadway under peat ground is unavoidable. Because of its softness and high organic content, peat soil is seen as troublesome. To increase the soil's ability to support more weight and lessen the risk of differential settling harming the ground, the soil must be treated. Instead of cutting the peat soil to lessen its presence in the construction area, peat stabilizer is needed to improve its properties in the peat.

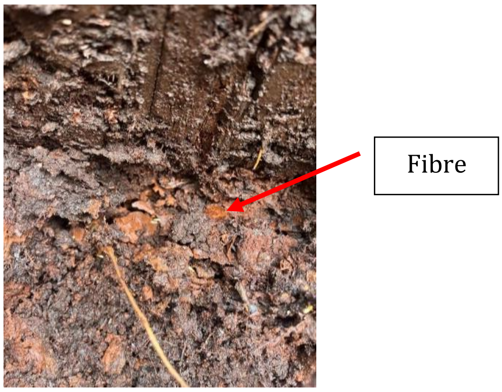
To enhance the peat soil's strength, a polymer will be added. Polymers have unique characteristics because of their structure, which may be changed to suit different requirements. This polymer will be employed because it has the attribute of soil stabilization, which is one that not all polymers have owing to inadequate adhesion to soil particles, and it will be used to determine the strength change for peat stabilization. The low volatile organic compound (VOC) concentration of this polymer means that it has a smaller impact on the environment. Moreover, polymers derived from vinyl acetate have greater viscosities than those derived from other sources, making them more flow resistant.

An unconfined compression test will be performed to look at how this polymer affects the peat. The American Society for Testing and Materials (ASTM) 1995 standard, ASTM D-1633, was used to conduct unconfined compression strength tests on prepared soil samples. These studies were conducted using a loading device. Up until the sample burst, the applied force and the deformation it induced were regularly and continuously recorded.

2. Materials

2.1 Peat

The material used in this study to make the stabilized peat soil consists of disturbed peat samples collected at Parit Nipah, Batu pahat. The excavation process was down below 0.5m the earth surface. Fig. 1 shows peat soil was dark-brown in colour and feels highly spongy when touched, all of which indicates that it has a very high-water retention capacity. It discharges extremely murky, black water that is quite sticky and contains a little bit of peat. The disrupted samples will be stored in a controlled humid chamber provided at UTHM laboratory to preserve their characteristics and moisture content. Since peat soil is made of decomposing wood and roots, this controlled environment is employed to prevent any fungus from growing on the soil's surface. Peat contains a very high amount of water, and its wet density is like that of water [2].



(a) **(b)**

Fig. 1 *Sampling process (a) First picture; (b) Peat and fibre*

2.2 Stabilizer

Stabilization of soil can be classified into two types, traditional and non-traditional stabilizers. Lime, Portland cement, and fly ash are examples of traditional stabilizers. While it might be considered a non-traditional stabilizer for materials such as ionic, polymer, and petroleum resin [3]. The use of vinyl acetate or acrylic-based copolymer is a frequently utilised polymer soil stabilisation approach. Acrylic copolymers are intended to convert soil particles into a solidified medium with certain technical qualities. Vinyl Acetate - Acrylic Copolymer (VAAC) is an innovative soil stabilizer that can both stabilize the soil and prevent dust and erosion. Polyethylene Glycol Octyl Phenoxy ether and Polyethylene Glycol Octyl Phenyl ether make up the VAAC. When applied on peat, it can permeate the soil and coat the soil surface. The stabilizer was added to the peat with ratio 1: 3 (Polymer: water) in samples formation. These polymers are used in civil engineering for a variety of reasons, including soil stabilization, particle enhancement and strengthening, and maintenance. Polymers are typically utilised as soil stabilizer in powder or liquid form. These materials also produce various soil stabilization outcomes [4].

3. Method

The method used in these studies were to determine the influence of the polymer on the unconfined compression strength. All the samples were distributed on a few trays and inserted into drying oven for 24 hours. Then, after 24 hours of drying, all the samples were sieve using 4.75mm sieve to remove all unwanted roots and rocks. Based on the previous studies, proctor test was conducted first to obtain the optimum moisture content (OMC) and maximum dry density (MDD) of the peat soil samples. Both values obtained were used to form all the samples needed. Formed samples then were curing for 1,3,5 and 7 days in a box with room temperature. The air curing technique is used to gradually reduce the moisture content of the stabilised peat soil samples to strengthen them. This technique involved keeping stabilised peat soil samples for UCS and CBR measurements at room temperature of 30±2°C and free from any potential water invasion during the curing process [5]. An unconfined compression test was done to obtain all compressive strength of formed samples.

3.1 Sample Formation

In accordance with the British Standard BS 1377-4-1990, the compaction of peat soil samples involved several steps. First, large materials such as stones and isolated roots were removed from the samples using a 4.75mm sieve. The remaining peat soil was manually mixed with distilled water and polymer mixtures to achieve the optimum moisture content and maximum dry density obtained from the Proctor test. Ten samples were then formed using a compaction machine, ensuring proper compaction of the soil. The samples were filled and tamped in a cylindrical mould with an internal diameter of 38 mm and a height of 78 mm. Each layer was compacted to a density of 57.25 g/m3, resulting in a total of three compacted layers within the mould.

After the compaction process, the samples were cured for specific durations of 1, 3, 5, and 7 days. This curing period allowed the soil to undergo necessary changes and stabilization. The results obtained from the compaction tests were subsequently examined and analyzed. It is important to note that the ratio of the amount of water added in the mixture, known as VAAC (peat soil, water, and polymer mixture), was 1-part VAAC to 3 parts waters (1:3) as shown in Fig. 2. This dilution procedure was implemented to reduce costs and limit the amount of VAAC required for the compaction process. The maximum dry density and the optimal moisture content were highly associated based on the findings of nine soil samples tested using the standard proctor compaction test [6].

In summary, the compaction of peat soil samples involved removing large materials, manually mixing the soil with distilled water and polymer mixtures and compacting the samples using a compaction machine. The samples were then filled and tamped in a cylindrical mould as shown in Fig.3 followed by a curing period of 1, 3, 5, and 7 days. The obtained results were examined, and a specific ratio of water to VAAC was utilized to reduce costs and optimize the compaction process.

Fig. 2 *Polymer mixtures*

Fig. 3 *Compaction process*

3.2 Unconfined Compression Test

Sample in Fig. 4, which had been cured for different durations of 1, 3, 5, and 7 days, were utilized in an unconfined compressive test to determine their unconfined compression strength. Prior to placing the specimen in the testing chamber, it is crucial to ensure that the two plates used are thoroughly cleaned to avoid any potential interference with the test results. When employing a stress-controlled load device, it is recommended to deliver the load continuously at a controlled rate ranging from 0.5 MPa/s to 1.0 MPa/s. This controlled loading rate helps ensure consistent and reliable results. Additionally, it is expected that failure of the specimen occurs within approximately 10 minutes, indicating the test's efficiency. To accurately capture data on stress and deformation during the test, an electronic system meeting the necessary accuracy requirements is employed. With a 1% accuracy level, the maximum load exerted on the specimen is measured in Newtons. This electronic system ensures precise and reliable measurements, contributing to the accuracy of the test results.

The data obtained from the testing machines during the unconfined compressive test, including stress and deformation measurements, is recorded for subsequent analysis. By carefully examining the recorded data and conducting a thorough analysis, valuable insights into the material's behavior and properties can be gleaned. In summary, the unconfined compressive test involving the samples cured for varying durations employs a stress-controlled load device with a controlled loading rate. The cleanliness of the testing plates is ensured, and an electronic system with the necessary accuracy captures data on stress and deformation. This recorded data is then subjected to detailed analysis, enabling a comprehensive understanding of the material's performance and characteristics.

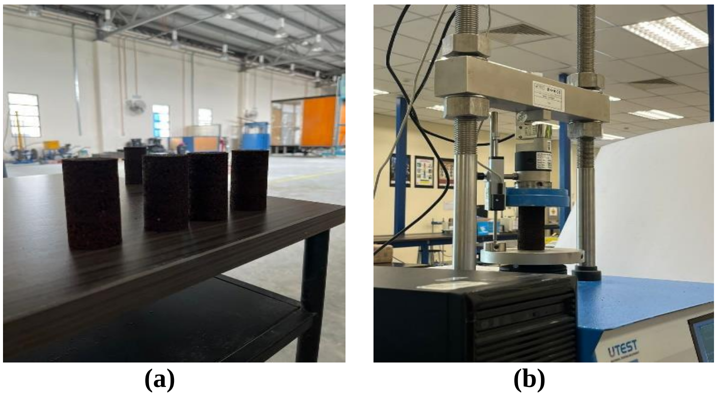


Fig. 4 *UCT (a) Sample for UCT; (b) UCT machine*

4. Results and Discussion

4.1 Standard Proctor Test

Standard Proctor Test Peat soil samples underwent standard Proctor tests, and the outcomes are shown in Figure 5. The original soil sample exhibits an MDD of 0.515 gm/cm3 and an OMC value of 99%. Additionally, compared to the stabilized sample evaluated in this study, this soil sample has the highest dry density and lowest moisture content. This might be explained by the original peat soil's excellent propensity for absorbing and retaining water. According to [7] high water content causes high pore volume, which lowers bulk density and bearing capacity. In summary, this result demonstrates a clear correlation between moisture content and the measured parameters. As the moisture content increases, both the average moisture and wet density tend to increase as well. However, the dry density shows some variations, indicating the complex behavior of the material under different moisture conditions.

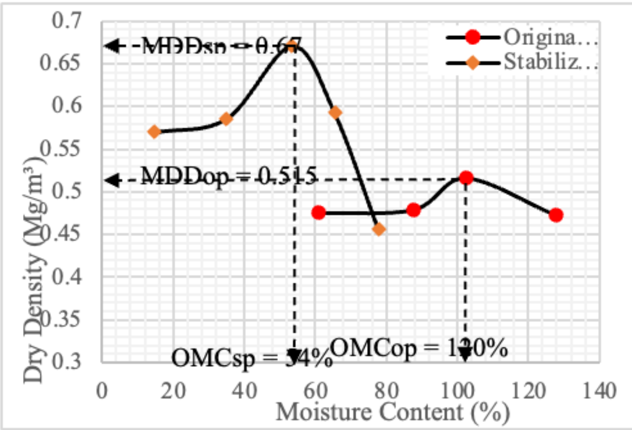


Fig. 5 *Graph for proctor test*

4.2 Effect on Compaction test

The Standard Proctor Test on the peat soil sample is affected by Vinyl Acetate - Acrylic Copolymer (VAAC). From proctor's result, the addition of cement reduces the soil's moisture content, allowing it to hold less water than the initial peat soil sample. Time-dependent describes the chemical response between soils and additions like polymers [8]. With an increase in Vinyl Acetate - Acrylic Copolymer (VAAC), it is found that the soil's maximum dry density increases while the ideal water content decreases. Based on the data provided in the table, which includes measurements of moisture content (%), average moisture (w %), wet density, and dry density (d), the following summary can be made at a moisture content of 5%, the average moisture is measured at 14.78%, the wet density is 0.654, and the dry density is 0.570. When the moisture content increases to 10%, the average moisture also increases to 35.07%. The wet density rises to 0.792, while the dry density increases slightly to 0.586. At a moisture content of 15%, there are two instances. In the first instance, the average moisture is 53.40%, significantly higher than the previous measurements. This increase in moisture content is accompanied by a higher wet density of 1.629 and a higher dry density of 0.671. In the second instance, the moisture content remains at 15%, but the average moisture is higher at 65.47%. The wet density decreases to 0.980, while the dry density remains relatively stable at 0.593. In summary, the data indicates that as the moisture content increases, there is a corresponding increase in average moisture and wet density. However, the relationship between moisture content and dry density is not as straightforward, as it shows variations in response to changes in moisture content. The different measurements highlight the complex behavior of the material and the need to consider multiple factors when analyzing its properties.

4.3 Unconfined Compressive Strength

Based on the obtained data, it is evident that the stabilization process significantly improves the compressive strength of peat compared to its original state. This enhancement can be attributed to the chemical reactions that occur between the stabilizing agents and the peat during the stabilization process. These reactions result in the formation of new compounds or bonds within the peat, leading to increased cohesiveness and decreased susceptibility to deformation under load. The data presented in Fig. 6 shows the unconfined compressive strength values (in kPa) for both stabilized and original peat samples over a period of 1 day, 3 days, 5 days, and 7 days.

For the stabilized peat, the compressive strength steadily increases over time. At the initial 1-day measurement, the compressive strength is recorded at 84 kPa. This value then rises to 126 kPa at 3 days, further increases to 158 kPa at 5 days, and reaches a peak value of 183 kPa at 7 days. This trend demonstrates the progressive improvement in the peat's resistance to deformation and ability to withstand compressive forces as the stabilization reactions continue to take place. In contrast, the compressive strength of the original peat is provided only for the 1-day measurement, where it is recorded at a significantly lower value of 7 kPa. This value serves as a baseline for comparison and highlights the substantial enhancement achieved through the stabilization process. The results of the stabilized peat and original for 1, 3, 5 and 7 days of curing period are shown as in Fig. 7.

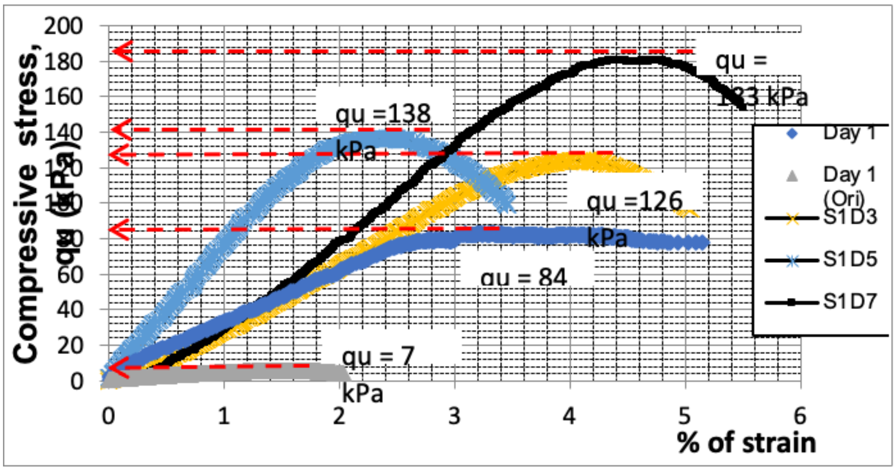


Fig. 6 *The changes of compressive strength*

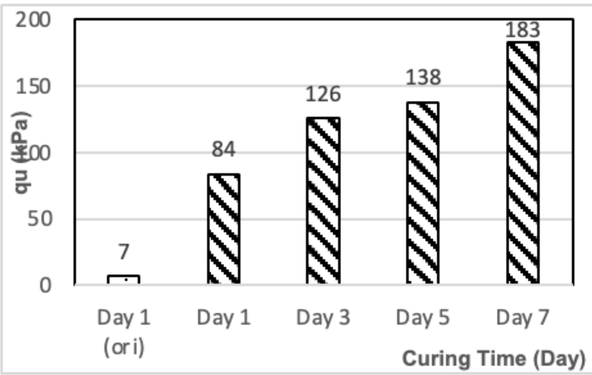


Fig. 7 q_u *at different curing time*

In summary, the data clearly illustrates that the stabilization of peat results in a significant increase in its compressive strength compared to the original peat sample. The progressive strengthening observed over time indicates the ongoing chemical reactions and bond formations between the stabilizing agents and peat. This improvement in compressive strength is crucial for various engineering applications that involve peat soil, as it ensures greater stability and load-bearing capacity in construction projects.

5. Conclusion

As a conclusion, the available information does not provide sufficient data to draw a conclusive statement about the unconfined compressive strength of the peat soil sample. Additional laboratory testing, specifically focused on measuring the soil's strength characteristics, would be necessary to determine its unconfined compressive strength and understand its behavior under compressive forces. The provided information primarily focuses on moisture content, dry density, and the influence of Vinyl Acetate - Acrylic Copolymer (VAAC) on the soil properties, which are important but not directly indicative of the unconfined compressive strength. This study was complete when the objective was achieved.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: Study literature and method: Wan Muhammad Harith Wan Nurdin, Muhammad Shah Zarif Shahrudi and Muhammad Emir Qais Mohd Lukman. Lab test and data: Wan Muhammad Harith Wan Nurdin, Muhammad Shah Zarif Shahrudi and Muhammad Emir Qais Mohd Lukman. Data analysis: Wan Muhammad Harith Wan Nurdin, Muhammad Shah Zarif Shahrudi, Muhammad Emir Qais Mohd Lukman. Siti Nooraiin Mohd Razali. Draft manuscript preparation: Wan Muhammad Harith Wan Nurdin, Muhammad Shah Zarif Shahrudi and Muhammad Emir Qais Mohd Lukman. Finalized the manuscript: Siti Nooraiin Mohd Razali.

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