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Comparison between Unstablized and Stabilized Soil that Affect Shear Strength Characteristics

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Abstract: In civil engineering, clay and peat soils can be classified as problematic soils as they can cause bearing capacity failure such as landslides due to having low shear strength and high-water content. Therefore, a study has been conducted to understand the shear strength characteristics of the original and stabilized soil. Two types of soil were used in this study which are clay and peat. The Vinyl Acetate Acrylic Copolymer (VAAC) was selected as soil stabilizer. Thus, the effect of this VAAC to shear strength can be identified by conducting the direct shear test for the original and stabilized clay and peat. The result shown that when clay and peat are mixed with VAAC, their shear stress rises to 810% and 200% respectively. However, in terms of friction angle, clay combines better with VAAC than peat. In conclusion, this study would understand the shear strength characteristics of clay and peat before and after stabilization with polymers.

Keywords: Peat, Clay, Shear Strength, Direct Shear Test, High Water, Landslides

1. Introduction

Peat is an organic layer of soil surface consisting of high natural moisture content, high compressibility and water holding capacity, low specific gravity, low bearing capacity and medium to low permeability. Peat is also a mixture of fractional organic matter formed in wetlands under suitable climatic and topographic conditions and it is derived from plants that have been chemically altered and fossilized [1]. Peat is usually found in thick layers in confined areas, has low shear strength and high compressive deformation that often results in difficulties when construction work is carried out on deposits. The carrying capacity of peat soil was found to be relatively weak in studies conducted [2] and was apparently influenced by the water level and the presence of wood chips beneath it.

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Clay minerals are known as secondary silicates because they are generated when main rock forming minerals weather. Even in dry weather, summer or winter, this soil will always be moist and chilly. Because the mineral particle gaps are tiny, the texture of this clay is sticky. Clay soil has a variety of mechanisms based on its qualities and behavior, which varies depending on the environment. Swelling, consolidation, shear strength, permeability, and other properties of clay soils can be studied in general. The hydraulic conductivity (permeability) of clay soil occurs because of the interconnecting voids in the soil that enable liquid and gas to move freely [3].

According to previous research, traditional stabilizers commonly used as soil additives to help repair weak soils are lime and cement. This is because lime and cement are the most important inventions in the construction industry. Lime, fly ash and cement are the most common and commonly used conventional stabilizing agents, [4]. However, in this study polymers were used as additives to stabilize peat and clay. Based on previous studies, polymers can bind soil particles together, and stabilize the soil matrix [5]. Therefore, the polymer material chosen is Vinyl Acetate Acrylic Copolymer (VAAC), which is a unique soil stabilizer that can stabilize the soil and control dust and corrosion at the same time. According to a study [6], it can seep into the soil and coat the soil surface when applied on peat. That is, these stabilizers are capable of cementing soil particles and building a durable and waterproof surface.

Therefore, the objective of this study is to understand the shear strength characteristics of the original clay and peat and to identify the changes of shear strength value in clay and peat after stabilized it with polymer.

2. Materials and Methods

Generally, in this research, the main materials used in this study are clay and peat. Clay samples were taken at Pagoh, Johor. Meanwhile, peat samples were taken in Parit Nipah, Batu Pahat, Johor. The type of sample to be used in this study is disturbed soil. For the type of stabilizer, this study was used a non-traditional stabilizer that is a polymer named as Vinyl Acetate Acrylic Copolymer (VAAC). In this study, 70% VAAC is used as an additive in clay and peat to stabilize the shear strength of the soil.

Direct shear tests were conducted in this study to identify the effectiveness of the use of VAAC in peat and clay soils. A curing period of 14 days was recorded. The curing process was conducted in this study to maintain the soil moisture content. Finally, the loads for the direct shear test to be used in this study are 1.75kg, 2.5kg and 3.25kg.

2.1 Materials

The materials to be used in the study are original clay and peat. Density of peat is 1147 kg/m^3[6]. Meanwhile, the density of clay is 1880 kg/m^3 [7]. In this study, clay and peat samples were taken and stored in a closed container. The purpose of storing soil samples in a closed container is to maintain the moisture content of the soil. The Direct Shear Test (DST) was performed in this study. The DST function is to determine the shear strength of the soil to be tested before and after stabilization.

2.2 Method

2.2.1 Sample Preparation

Before the DST is conducted, soil samples were formed into the mold size of 60 x 60 mm. The samples were prepared by compacted the disturbed sample to the nearest original unit weight. The compacted soil then was cured by using the shear mold with the size 60 mm x 60 mm to form the required sample size for DST. **Figure 1** show how to obtain a sample for shear strength test using a mold size 60 x 60mm.

Figure 1: Mold preparations using mold size 60 x 60mm

2.3 Direct Shear Test

2.3.1 Moisture Content

In this DST, the method of measuring the moisture content should be taken into account subtracting the weight of the dry soil from the weight of the wetland, and then dividing by the weight of the dry soil.

$$\%\, moisture\ content\ (MC) = \frac{W2-W3}{W2-W1} \times 100\% \qquad \textbf{Eq. 1}$$

The soil moisture content of each replicate sample was calculated by using the **Eq. 1**.

2.3.2 VAAC in Mixture

Sampling formation is the process of forming a sample before a test is performed. For the formation of this sample, the samples were cured for 14 days tested. However, for the stabilization peat and clay need to mix with diluted VAAC with the right ratio. Based on previous study, The appropriate proportion of VAAC-P was chosen based on the obtained maximum strength of 70% and the amount of water put in VAAC is one VAAC to three waters (1:3).

$$Weight\ of\ \ VAAC\ in\ mixture = \left[\frac{(weight\ of\ soil)}{1+\ (moisture\ content\ of\ original\ soil)}\right] \times 70\% \qquad \textbf{Eq. 2}$$

By using **Eq. 2** the weight of VAAC in mixture can be achieved.

2.3.2 Friction Angle

Due to the varying characteristics that enhance the soil structure, it is shown that peat + Vinyl Acetate–Acrylic Copolymer (PVAAC) and clay + Vinyl Acetate–Acrylic Copolymer (CVAAC) have higher shear stresses than original peat (OP) and original clay (OC). The shear strength of a soil mass is the internal resistance per unit area that a soil mass can offer to withstand failure and sliding along any plane within it. Mohr (1900) highlighted those materials fail due to a critical combination of normal stresses and shear stresses.

$$\tau\ =\ c\ +\ \sigma'\, tan\, \emptyset \qquad \textbf{Eq. 3}$$

By using **Eq. 3**, the friction angle can be achieved.

This analysis was performed to determine the extent to which VAAC workability stabilizes clay and peat samples. In terms of observations during sample preparation, it was found that the polymer mixed with VAAC well while the clay became too wet when mixed with VAAC. Therefore, VAAC clay samples were left for a week before being molded. The end result of the study found that VAAC peat soil has higher shear strength than the original peat soil. In addition, VAAC clay also has higher shear strength than the original clay.

3. Materials and Method

3.1 Moisture content

The moisture content of soil samples needs to be reduced in range 55% to 60%. These steps are required as stated in the previous study, or else it will be too soft to mix with VAAC and cannot be remold [6]. Oven dried method is used by referring to the standard procedure in BS 1377: Part 2: 1990. The samples were taken out every 1 hour to be weighted. until the moisture content is reduced in range 55% to 60%.

Figure 2 show the results of moisture content reduction for every 24 hours for peat and clay. Three sample were used for validation. It clearly seen that, the clay sample required 8 hours to reach the moisture content target and the peat soil took almost 12 hours. It because of the fiber content in peat that have an ability to hold an extra water. Thus, required extra time to reach 55% to 60% of moisture content reduction.

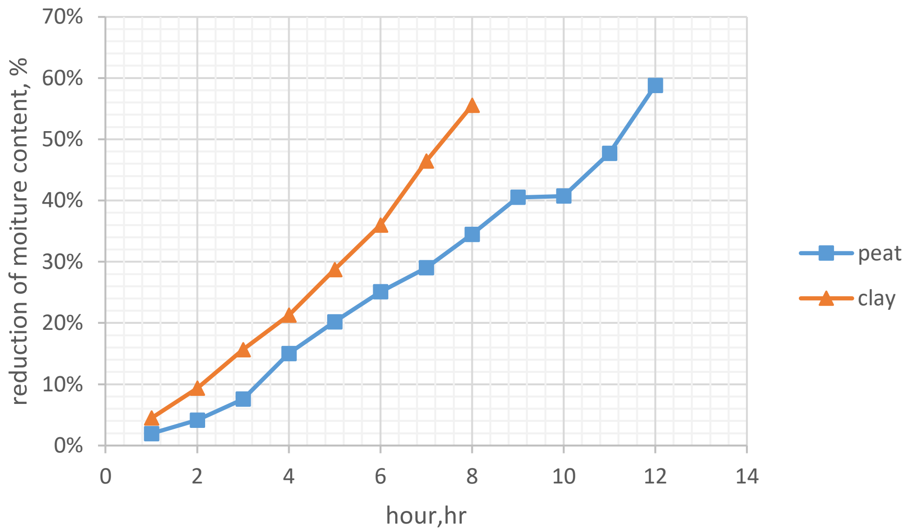

Figure 2: Moisture content reduction for peat and clay

3.2 Frictional angle

Shear strength of a soil mass is the internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it. In physical terms friction angle represents particle interlocking and greater the interlocking between the particles, larger should be the friction angle.

In **Figure 3**, the C and φ for original peat were C = 5.954 kP and φ = 84.8 °. While original clay, the C and φ were C = 4.075 kP and φ = 82.3 ° as shown in **Figure 4**. The value of C and φ for each sample is as shown in **Table 1**. Based on Hanrahan (1952), it concludes that the structure of remolded sample did not represent the original condition of peat soil. Thus, the shear strength of peat was φ is equal to 0. However, in the next study, Hanrahan et al (1967) found an interesting conclusion in their paper where it is opposite with the previous research. It was concluded that the shear strength behavior of peat for remolded and original state is similar and the shear strength peat from this study is c = 5.5 kPa to 6.1 kPa and φ = 36.6° to 43.5°. In this study the value of C is nearest to the value from this researcher but for φ it is quite higher. As known, the property of peat is unique. Thus, the value of C and φ is depends on the properties of peat at different location.

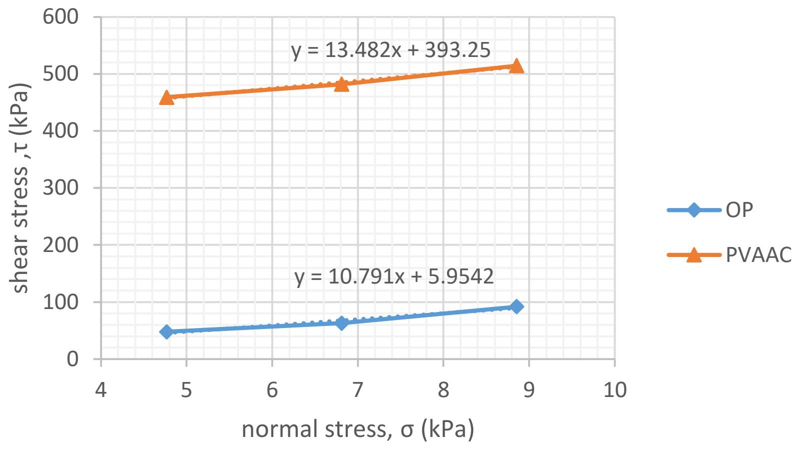

Figure 3: Comparison in peak and residual strength lines obtained by direct shear apparatus on OP and PVAAC

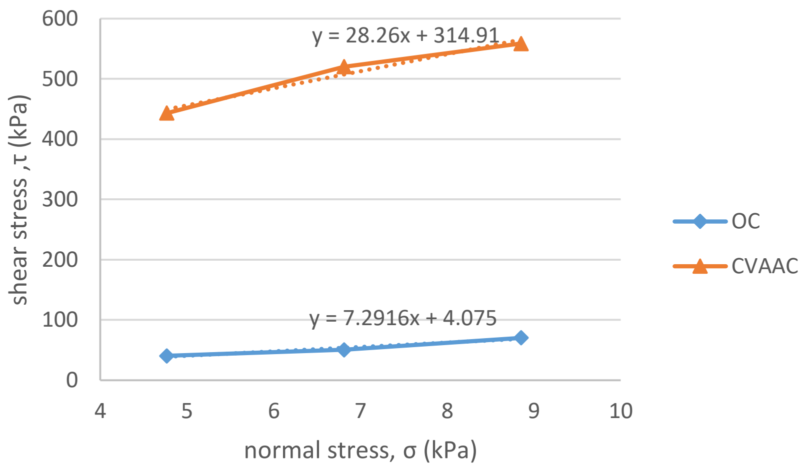

Figure 4: Comparison in peak and residual strength lines obtained by direct shear apparatus on OC and CVAAC

Table 1: Cohesion and frictional angle for each type of samples

Soil type	Cohesion, C	Friction angle, Ø°
OP	5.954	84.8
OC	4.075	82.3
PVAAC	393.25	85.8
CVAAC	314.91	87.9

In the **Table 1,** C value for OP and OC are below 10 kPa which is in very soft soil category. Meanwhile, PVAAC and CVAAC have C value 315 kPa and 393 kPa which categorize as stiff soil. This data proves that VAAC have improve the shear stress of soil.

3.3 Shear strength

The relationship between shear stress and shear strain for the OP, OC, PVAAC and CVAAC generated from the DST. **Figure 5** shown how shear stress increases with shear strain and reaches a maximum before the soil loses its capacity to shear. The peak stress is revealed by the continuous load test.

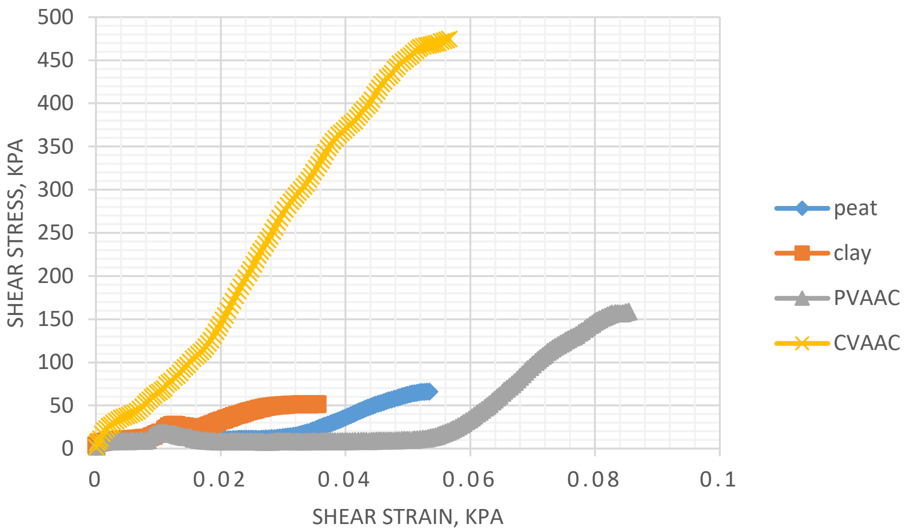

Figure 5: Average stress-strain relationship of OP, OC PVAAC and CVAAC from different normal stress of 4.767 kPa, 6.81 kPa and 8.854 kPa after direct shear test.

Measured using shear strain, a particular deformation's deviation from a rigid deformation is identified. Shear strain is the type of strain that develops when opposing forces are applied parallel to an object's surface. It is an angle shift in a form at some point. When planning building foundations, pavements, or temporary access roads, it allows us to calculate the ground carrying capacity. In addition, soil shear strength tells us how stable retaining walls, slopes, and embankments would be. In figure 5 VAAC has increase peat shear strain to 55% from the original peat and 200% increase of shear stress value. Meanwhile VAAC improved clay to 63% of shear strain and 810% of improvement for shear stress. Form these data, VAAC are really helping to improve the soil structure. From the figure, clay works better with VAAC than peat as it has higher percentage than peat.

4. Conclusion

In conclusion, this study shows that mixing clay and peat with VAAC polymers can help overcome the problem of landslides. This is due to the study's findings, which showed that after clay and peat were mixed using VAAC, their shear strength increased. The result shown that when clay and peat are mixed with VAAC, their shear stress rises to 810% and 200%. However, in terms of friction angle, clay combines better with VAAC than peat. As a result, this study would understand the shear strength characteristics of clay and peat before and after stabilization with polymers.

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