The Effect of Alkali Activator to The Strength of Treated Clay Soil Using Fly Ash Based Geopolymer

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ABSTRACT

The use of ordinary Portland cement (OPC) in soil stabilization work is considered non-environmental friendly due to emission of large amount of carbon dioxide during it production. Therefore, fly ash based geopolymer is used as an alternative for the OPC to stabilize weak soils. The objective of this research is to access the effect of sodium hydroxide (NaOH) molarity as one of the materials used as the alkali activator (AA) to the strength of treated clay using fly ash based geopolymer. This study was done determine the marine clay soil properties and characteristics by conducting particle size distribution, standard proctor compaction, Atterberg limit, specific gravity and pH test. Unconfined Compressive Strength test has been conducted to obtain undrained shear strength of marine clay soil with various molarities of sodium hydroxide added with sodium silicate (Na2SiO3) to form a liquid alkali activator. The result shows that undrained shear strength of the marine clay soil treated with fly ash based geopolymer is comparable to the soil treated using OPC. Higher molarity of sodium hydroxide provided better strength to the fly ash based geopolymer treated soil.

Keywords: Fly ash, geopolymer, soil stabilization, clay.

1. INTRODUCTION

The civil engineering structures like buildings, bridges, highways, tunnels, dams and others are built on or below the ground with certain engineering requirements need to be there before the construction work started. Lack of consideration on weak or soft soils for the building and infrastructure construction is extremely dangerous because of low shear strength and high compressibility [1]. The marine clay is not generally suitable for the engineering construction purpose. Besides, marine clay is defined as soft-sensitive soils that related with high settlement and high instability, poor soil properties, performance uncertainties and low unconfined compressive strength that are not fit for engineering necessities [2]. Due to the concern on the global warming, geopolymer has been explored as an alternative to the OPC binder, where it is widely used in the engineering field to upgrade the usability and quality of the weak soils especially for marine clay soils. Therefore, application of fly ash based geopolymer is used to improve soil properties to solve the problem related weak soil. The benefits of using fly ash geopolymer based are can save cost instead using the OPC and reduce the pollution to the environment [3].

Geopolymer stabilized soil shows a good result especially for the marine clay soil in the requirement of geotechnical in term of dense microstructures, better mechanical properties and volume stability [1]. Besides, the study shows that the soil stabilized with geopolymer based had been improved in compressive strength, low shrinkage and resistance to acid [4].

The mechanical properties of geopolymer stabilized clay soils have been studied with different mixing designation. The mechanical strength of the geopolymer treated soil can be strengthened by increasing the ratio of Na_2SiO_3/NaOH or increasing the concentration of the alkali activator

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[1]. The optimum molarity of the NaOH used is 3M which consider for appropriate geopolymerization. The soil particle is broken down if the molarity of the NaOH is higher than 3M and causes a lower compressive strength [5].

Moreover, the compressive strength of the stabilized soil is affected by curing condition and curing period [1,6]. The compressive strength can be increased with curing at high temperature which is directly cured in the oven at the temperature of 100°C for 1 day. However, the longer of the duration and the higher temperature in curing process did not lead to higher in the compressive strength of sample, as there will be a lot of loss of moisture due to the high exposure of heat to the soils. Furthermore, the longer time of the curing and the higher of temperature make the sample crack and reduce their strength [6].

It is evidence of an improvement of soil properties including the mechanical strength by using geopolymer. However, the outcome is different based on the type of soil and the geopolymer mixture used. In this study the focus will be on the effect of NaOH molarity to the shear strength of soil with different curing temperature.

2. EXPERIMENTAL PROCEDURE

In this study, the physical test conducted are particle size distribution, standard proctor compaction, Atterberg limit, specific gravity, pH test while mechanical test are Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) test. The procedure are referred on the British Standard 1377: 1990. Marine clay soil is collected at the coastal plains of Kuala Perlis. The sample is mixed with different molarities of alkali activator which are 0 M, 3 M, 6 M, 12 M, and 18 M as well as different percentage of fly ash that are 0% and 10%. 5% of OPC was used as a control sample for the laboratory test. Firstly, the physical test was conducted to determine physical properties of marine clay. Then, UCS test is performed after the curing process is take place for the sample at the 25 °C and 40 °C for 7 days also 28 days. The unconfined shear strength of treated marine clay soil with fly ash based geopolymer was compared with the undrained shear strength of treated marine clay soil with Ordinary Portland Cement (OPC).

3. RESULTS AND DISCUSSION

Figure 1 shows the undrained shear strength of treated clay soil using only the AA without fly ash at different NaOH molarity, curing temperature and curing duration in clay soil. The original marine clay soil shows the lowest value of undrained shear strength. The value of the undrained shear strength increased with the present of AA and increasing molarity of NaOH. The curing conditions which varies in term of its duration and temperature also affected the strength of the stabilized soil, where the 28 days of curing at 40 °C is highest among all sample tested. Therefore, 3 M concentration of alkali activator that cured at 40 °C for 28 days is the optimum NaOH molarity for the treatment without fly ash which produces highest undrained shear strength of fly ash based geopolymer among all samples recorded, 765.15 kPa.

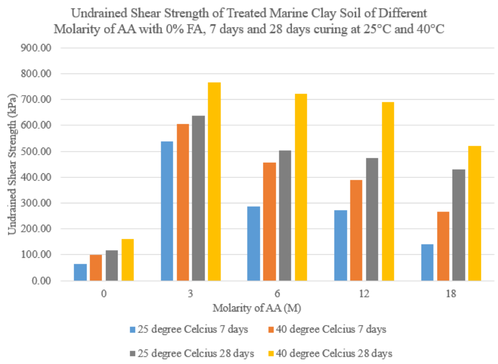

Figure 1. Undrained shear strength of treated marine clay soil by using alkali activator without fly ash.

Figure 2 shows the undrained shear strength of the treated clay soil using 10% fly ash activated with alkali activator under different curing conditions. The original marine clay soil that mixed with 10% FA shows the lowest undrained shear strength value. The value of the undrained shear strength increased by the presence of alkali activator. Longer curing period and higher temperature will improve the strength of the fly ash based geopolymer treated clay. Highest undrained shear strength is recorded by the sample with 6 M concentration of alkali activator that cured at 40 °C for 28 days.

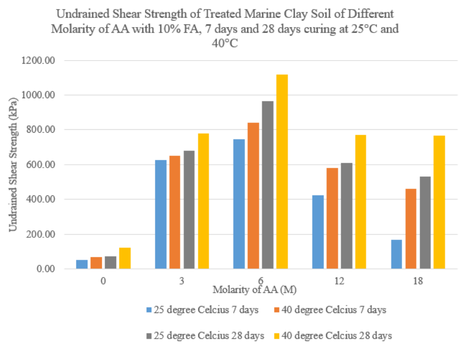

Figure 2. Undrained shear strength of treated marine clay soil by using 10% fly ash based geopolymer.

Figure 3 shows the marine clay soil that mixed with 5% OPC cured at 25 °C for 7 days and 28 days as control sample for this study. The first sample which contain 5% OPC that cured at 25 °C for 7 days, the undrained shear strength recorded is 105.32 kPa, while for sample that cured for 28 days is 106.20 kPa. Comparing the results of OPC stabilized sample with the fly ash based geopolymer and alkali activator treated soil, the performance of the OPC treated sample is lower than both of the other method. Under this conditions, the fly ash based geopolymer perform better and more effective to improve the undrained shear strength of clay soil.

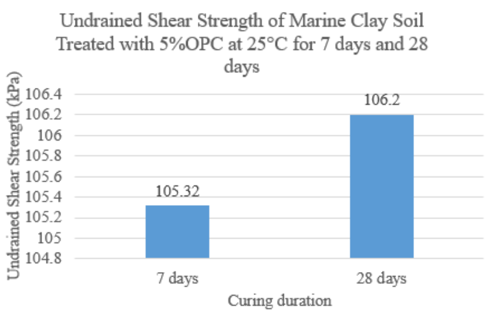

Figure 3. Undrained shear strength of treated marine clay soil using 5% OPC.

4. CONCLUSION

Based on the result, the highest value for the undrained shear strength is 765.15 kPa for sample 3 M (0% FA) while 1118.13 kPa for sample 6 M (10% FA). The strength of both samples is higher than strength of clay soil treated with OPC where the result is 105.32 kPa and106.20 kPa for 7 and 28 days of curing. In general, the presence of the alkali activator increases the shear strength of soil with or without the addition of fly ash. Higher molarity of NaOH will improve the strength with a slight decrement when it reaches the optimum molarity. Therefore, the ash based geopolymer is an excellent alternative to the OPC to increase the undrained strength strength of clay soil.

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