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MODIFIED NATURAL FIBER ON SOIL STABILIZATION WITH LIME AND ALKALINE ACTIVATION TREATED MARINE CLAY

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ABSTRACT: Geotechnical structures and foundations that are constructed on clay soils normally experience serviceability and structural quandaries due to wetting. Traditional and mechanical binder have been widely used for soil stabilization recently in order to improve clay soil. In this study, a comparison was made between lime and alkaline activation treated tropical marine soil reinforced with modified natural fiber. Treatment of soil with lime and alkaline activation show an excessively brittle behavior that influences the stability of the structure. For this purpose, the inclusion of natural biodegradable material which is coir fiber is needed as it enhanced the tensile strength of the soil matrix. The mechanical properties of unconfined compression test were carried out on tropical marine soil stabilized with lime (5%) and alkali activation with class F fly ash as a precursor (60%) with and without fiber inclusions at different curing times. Based on the test results, the inclusion of modified natural fiber in lime and alkaline activation treated tropical marine clay increased the strength of the soil matrix.

Keywords: Tropical marine soil, Modified natural fiber, Lime, Alkaline activation

1. INTRODUCTION

Soft soil is generally recognized as soil with high water content, high compressibility, low permeability, and low shear strength, in which it is mostly found near the coastal area. Problems on dealing with this kind of soft soil usually attract researchers to deal with the soil stabilization. There were many studies conducted in the past concerning the strength enhancement of the soil for future development. Enhancement through the application of chemical agent and additive was widely been used as soil reinforcement or pavement stabilization mechanisms. The treatment use includes new and old techniques, for example, using lime, cement, gypsum, fly ash and ground granulated blast furnace. The utilization of this material attracted most researchers to use it as soil reinforcement due to the possibility to increase the strength of the soil.

Treatment of marine soils with chemical stabilizing agents (e.g. cement, gypsum, lime, and other alkaline admixtures) is one of the widely used methods for ground improvement [1-8]. These stabilizing agents are used to bind the soil particles together through the chemical reactions. Stabilization of clay and lime would increase the optimum moisture content and a decrease in the maximum dry density of the soil [9]. By [1], lime is the most effective chemical agents for treating the soil where it is capable of holding a large amount of water and the cation exchange capacity (C.E.C). It has great contributions in defining clay minerals especially to facilitate water absorption ability. Apart from that, the marine clay soil is known as high plasticity and swelling characteristic, the role of lime and soil formed cementation bonds which is able to help in increase and stiffness of the soils [9-11].

Furthermore, alkaline activation is one of the treatments that has recently been used. Alkaline activation is also known as “geopolymerisation” which is described as a reaction that chemical integrates minerals that consist of silica and aluminum alternately tetrahedrally interlinked by sharing all the oxygen atoms [12]. [13] stated that alkaline activation also is a reaction between silica and alumina usually potassium (K) or sodium (Na) or alkali earth ions like calcium (Ca). Other than that, for the alkaline activated process, waste materials recently have been used as one of the alternatives mixtures for the activated ground improvement such as fly ash, metakaolin, granulate ground blast soil (GGBS), rice husk ash and etc). By [14], usage of waste materials (fly ash) in the construction industry is becoming more frequent as it contributes to the reduction in consumption of cement. However, the treated soils exhibit an excessively brittle performance that affects the stability of structures [15,16]. This is the main weakness of the treated soil. Therefore, a possible solution has been proposed by some researchers [17-19] which is the inclusion of randomly distributed tensile reinforcement elements in soils to effectively increase ductility behavior, reduce the number and width of shrinkage cracks and help to obstruct them [17] and [19].

Therefore, soil reinforcement is one of the preferred alternative methods as it would be able to help in strengthening the soil, lower the water content and compressibility of the soil. By [20], soil reinforcement is defined as a technique to improve the engineering properties of the soil as it develops the parameters such as compressibility, density, hydraulic conductivity and shear strength. This paper aims to compare the lime and alkaline activation for the modified treated tropical marine clay reinforced with modified natural fiber at the different curing time. A number of untreated and treated soil specimen with lime (5%) and alkaline activation with precursor (60%) were subjected to the unconfined compression strength test. The test was conducted to determine the strength of the soil matrix for differences between the treated and untreated soil specimen.

2. MATERIAL AND METHOD

2.1 Materials

2.1.1 Soil specimen

The tropical clay soil that was used in this study were taken from Klang, Selangor within 2m from the ground surface. The basic engineering property tests of the marine clay soil were conducted such as moisture content, particle size analysis, specific gravity and Atterberg limit. The testing was conducted based on the [21]. Table 1 below shows the basic properties of the marine clay soil that been used in this study. According to table 1, the soil can be classified as CH which is clays with high plasticity by [22].

2.1.2 Coir Fiber

Coir fiber that was used in this study was taken from a factory in Batu Pahat Johor. The usage of coir fiber as the soil reinforcement where the material that is known as environmentally friendly, cheap and locally available. [23] highlighted that the coir fibers were used in the study as the materials have the property of elasticity, light, high durability, initial strength and low light resistance.

2.1.3 Additive

Hydrated lime and fly ash class F are the two additives that been used for the clay soil. The reagent (calcium carbonate) was supplied in pellet by Evergreen Engineering, Selangor. The chemical content of the reagent was up to 99%. The fly ash class F (low calcium) was collected from Lafarge Sdn Bhd, Petaling Jaya Selangor. The fly ash was then mixed with the 10 molar potassium hydroxide (KOH) named as the precursor of the alkaline activation process. 10 molar KOH concentration was fixed for the alkaline activation according to the previous findings [24]- [26]. Table 2 shows the chemical and physical properties of the fly ash. Fly ash with low calcium is categorized where the classification of it was based on the total of SiO_2, Al_2O_3 and Fe_2O_3 must be more than 70% and the CaO must be less than 7%.

Table 1: Basic properties of Marine Clay Soil

Parameter	Values
Moisture Content	72%
Specific Gravity	2.59
Soil Classification	Clays with high plasticity with traces of sand
Particle Size Distribution	Clay- 31% Silt – 67% Sand – 2%
Liquid Limit	57-72%
Plastic Limit	32-40%
Plasticity Index	25-37%
Organic Content	6.88%
pH	7.5
XRD	Monmorillionite-illite, Quartz, Mica, Halloysite, Kaolinite

Table 2: Chemical Composition of Fly Ash

Chemical Composition	(%) by Weight
SiO_2	57.471
Al_2O_3	15.365
Fe_2O_3	4.707
CaO	3.317

2.2Method

2.2.1 Sample Preparation

Two main tests were conducted in this study. First, marine clay soil was dried in the oven for 24 hours at 105°C and was grind into powder until it passes through the sieved of 2 mm. 5% of lime of dry unit weight soil were then mixed together with the soil. [1], [27]-[28], stated the usage of the 5% lime was considering practical experience as lime fixation is for gaining the maximum strength, at which considerable increasing of the workability can be obtained. [34] stated that the amount of lime related to the montmorillonite- rich clay content normally does not exceed 8%. Next, for alkaline activation process, fly ash was mixed with the 10 molars of

KOH. KOH was diluted in 1 liter of distilled water to achieve the concentration of the of 10 molars. As the mixture was mixed, the reaction of the KOH was extremely strong and the solution needed to cool to ambient temperature before being used [29]. Table 3 shows the mixture proportion of the soil specimen. There are three types of mixtures which based on the soil (S), clay lime fiber (CLF) and clay with alkaline activator fiber (CFAF). The testing of the natural soil sample was included as it was to provide references to the analysis regarding the mixture of CLF and CFAF.

2.2.2 Proctor Test

Standard Proctor compaction test was conducted to determine the optimum moisture content and the maximum dry density of the soil specimen. The test was conducted based on [30]. The results were set out as the compaction basis for all of the specimen. The dry soil was initially mixed by hand, with the lime and 1% of treated fiber for lime stabilization and for the alkaline activation, the natural soil was mixed with the fly ash (60%) and the treated fiber. Then, the alkaline solution was added through the soil specimen. Both mixtures must be well mixed until a uniform blend is achieved.

Table 3: Mixture Proportion of Various Test Soil specimen.

Croup Series	Test Number	Samples	UCS Test Curing days
C	C	Natural Soil	-
CLF	CL CLF	Clay+ Lime+ Clay+ Lime+ Fiber	7 & 28 7 & 28
CFA	CFA	Clay+ FA(60) + 10 KOH	7 & 28
	CFAF	Clay+ FA(60) + 10 KOH + Fiber	7 & 28

2.2.3 Unconfined Compressive Strength Test

The soil specimens were prepared directly right after the determination of the optimum moisture content based on the standard Proctor compaction test. A cylindrical mold with the diameter of 50mm and height of 100mm were used to prepare soil specimens. Soil specimens for both lime and alkaline activation were prepared the same for this testing. The unconfined compressive strength test (UCS) was conducted according to the [31] in which the test is to gain the strength of the soil specimens. 3 samples were prepared for each test number to make sure the average strength for the specimen is correct. The specimens were then being extruded and immediately being wrapped with the plastic sheet and aluminum foil. This was done to keep the moisture content and humidity of the specimens for curing date. After the certain curing date, the specimens were tested using the Instron 3366 universal testing machine with the 10 kN load cell. The test was subjected to the loading rate of 1mm/min until it failed and the graph of stress-strain curve was obtained from each test. The testing is applied for both test specimens but for the alkaline activation sample the sample should be submerged in water first for 24 hours before the curing period. [32] highlighted the saturation was made with the intention to eliminate the positive effect suction on the specimen and this submerging was an exception for the natural soil, where the loss of structural integrity would happen when submerging the soil specimens. Curing time is a parameter that been used to determine the behavior of the soil specimen in for 7 and 28 days curing time. The behavior of the soil specimen in term of the strength of the soil for the untreated soil treated the soil with lime and fiber and treated the soil with alkaline activator with fiber were determined. A significant strength behavior between these two curing days was observed. Fig. 1 photograph shows the UCS test for the soil specimens.

(a)

(b)

Fig. 1 (a) & (b): Photograph of UCS Test

2.2.4 Microstructural Analysis

The microstructural analysis was performed based on the changes of the soil specimen before and after the stabilization. Soil specimens were examined in the presence of lime and KOH with and without fiber using Hitachi SU8010 which allows elimination of charging effect with low voltage imaging. Before the analysis was done, the specimens were sputter-coated with platinum using Quorum Q150R S Sputter coater to increase the electrical conductivity of the surface and reduce the charging. Fig. 2 shows the photograph of the sputter coater used before the FESEM test was conducted.

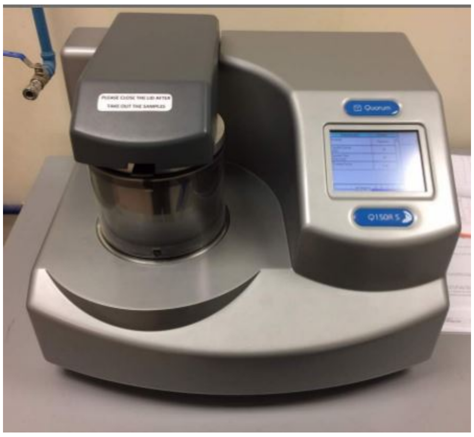


Fig. 2: Sputter coater

3. RESULT & DISCUSSION

3.1 Proctor Test

Fig. 3 shows the dry density versus moisture content between the natural soil and treated soils for both lime and alkaline activation

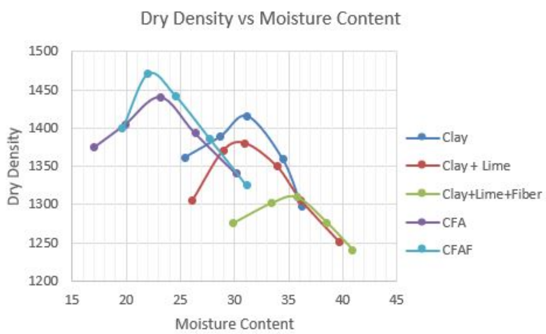


Fig. 3: Dry Density versus Moisture Content of Natural Soil and Treated Soil.

Based on the graph, it can be seen that the moisture content of lime stabilization with fiber increased as the maximum dry density decrease compared to the natural soil. The increment of the moisture content was from 31% to 36% respectively with the maximum dry density was 1410kg/cm3 to 1310 kg/cm3. This might be due to the applicability of the inclusion of fiber to absorb the water. The statement was supported by [33], [1], where the inclusion of the fiber could improve the water absorption. Other than that, the significant maximum dry density occurred between the lime stabilization and natural soil shows that the inclusion of fiber increases the workability and the strength of the soil. By [34] inclusion of fiber and lime reinforced soil is better than natural soil in term of strength properties.

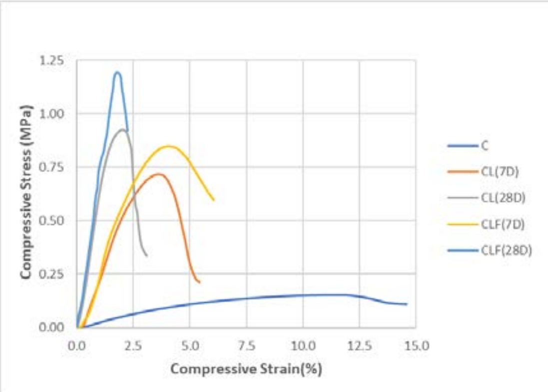
For alkaline activation, the moisture content shown to decrease as the maximum dry density keep increasing. The trend shows the same with [34] was the optimum moisture content is decreased with the increasing maximum dry density. The decreasing moisture content was about 31% to 23% respectively and the dry density is increasing from 1410 kg/cm3 to 1470kg/cm3. The decreasing of moisture content might be due to the higher percentage of fly ash that has been used in the study that mostly retains to absorb the water. This trend was similar to [35] where the addition of treated POFA would reduce the affinity of the soil for water. [36] also stated that the increase of maximum dry density attributed to both specific gravity and particle size of the binder and natural soil.

3.2 Unconfined Compressive Strength

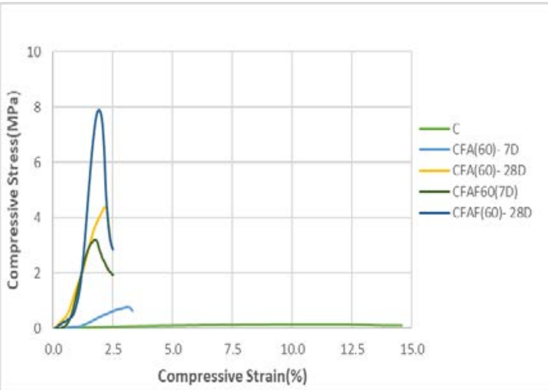
Fig. 4a shows the stress-strain behavior of marine clay soil for untreated soil (Clay), treated soil (CL) and soil with the inclusion of fiber (CLF) after curing date of 7 and 28 days. As it can be seen in the graph, clay soil shows obviously low strength of the soil specimens with only 0.19 MPa compared to the CLF after 28 days. The result shows the increase in the strength of the soil. The maximum compressive strength of the CLF at 7 and 28 curing days were 0.85 and 1.15 MPa respectively compared to the CL for both 7 and 28 days were only 0.93 MPa. This shows that with the inclusion of the fiber in the lime-treated soil increased the strength and stiffness of soil specimens. By [23] inclusion of fiber in lime-treated soil would develop the interfacial force and interlocking strength mixtures as it increased in curing age. The fiber content was also found as the main factor that affects the strength of soil specimens [37].

For alkaline activation soil stabilization, Fig. 4b the result shows that the compressive strength of CFA for 28 days was higher with 4.40 MPa compared to the CFA for 7 days with 0.77 MPa. The different increment of soil strength between both 7 and 28 days shows 3.63 MPa. This shows that the higher strength of soil achieved after 28 curing days. The statement was fully supported by [12], longer curing time at ambient temperature is one of an economically viable way to further increase the strength level and by [32] the curing time and water content of soil have a significant strengthening effect on the treated specimens.

From the Fig. 4a and b, it can be seen that the compressive strength test for both treated soils shows that higher increment of strength occurred in alkaline



(a)



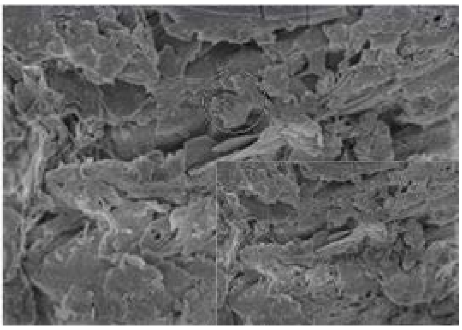
(b)

Fig. 4: (a) Stress-strain graph for lime treated the soil
(b) The stress-strain graph for alkaline activation treated the soil

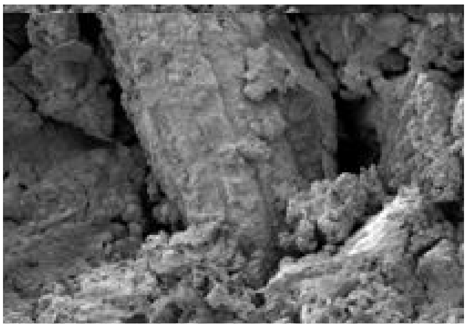
activation compared to lime stabilization. The increase in compressive strength of soil stabilization by using alkaline activator is due to the strong chemical reagent KOH and its high molarity that was used. [38] stated that the increase of compressive strength of the activation samples is related with the high molarity solutions that were used. Supported by [39] high concentration of KOH and NaOH solution increased the speed of chemical dissolution and would develop the higher compressive strength through the early stages of the reaction. From the Fig., it can be concluded that the strength for alkaline activator stabilizer give three times higher compressive strength compared to the lime treated and both with the inclusion of the fiber became beneficial to the soil stabilization.

3.3 Microstructural Analysis

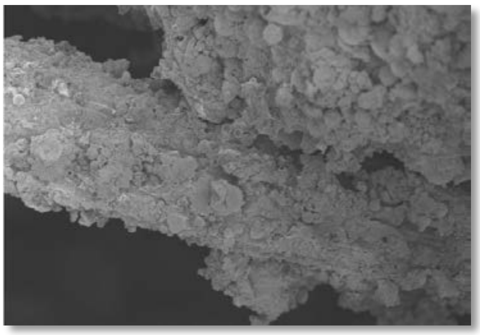
Fig. 5 shows the changes in morphology in natural soil, CLF and CFAF (60% of fly ash/ KOH 10M). In Fig. 5a below, it can be observed that the soil morphology shows that the natural soil is in a condition of small fracture particles where there is a lot of pores between the structure. When the soil was treated with lime or AA without fiber, the clay generally shows an increase interaction between the soil particle compared to without the treatment. Next, Fig.s 5b and c show the morphology of soil treated with lime (CLF) and soil treated with AA (CFAF60).



(a)



(b)



(c)

Fig. 5: FESEM for 28 days (a) Clay, (b) CLF and (c) CFAF

From the Fig., it can be seen the pores in soil have been reduced making the soil to be denser. Furthermore, as the soil was treated with the inclusion of fiber, the fiber binder seems to increase the interfacial bonding as well as strengthen the specimen. By [1] the inclusion of fiber in treated soil would increase the effectiveness of transferring the load from the matrix to fibers

4. CONCLUSIONS

In this study, it can be concluded that the lime-treated and alkaline activation soil stabilization with the inclusion of fiber increased the compressive strength of the soil compared to natural soil. Based on the compressive strength test recorded, the samples of alkaline activation with KOH was about five times higher and stable compared to lime-treated for the soil stabilization. It has also been supported by the microstructural analysis were the samples treated shows the interaction on treated samples with fiber strengthen the soil modification and improvement towards the properties of soil. This statement was supported by [35], were based on SEM and EDS analyzed the treatment of the matrix was observed because of there was a coexistence of cementitious and pozzolanic reaction between the soil and binder, which is responsible for improving the strength of stabilized clayey soil specimens.

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