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Effectiveness of Canlite and Probase Stabilized Laterite Soil

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Abstract – *Besides traditional chemical stabilizers, polymer emulsion that is considered as a non-traditional chemical stabilizer had been introduced recently. Among polymer emulsions, Canlite and Probase have been widely used for soil stabilization. The aim of this paper is to investigate the effectiveness of Laterite soil stabilization treated by Canlite-liquid and Probase-liquid soil stabilizers. A testing program, scheduled to achieve the overall objectives of this study was conducted to determine the basic properties of Laterite soil, establish the relationship between the compaction characteristics (maximum dry density and optimum moisture content) with the amount of polymer emulsion and last but not least to compare the strength of the Canlite-treated and Probase-treated Laterite soil. The effects of both polymer soil stabilizers – Canlite and Probase – were examined. The optimum moisture content of the mixtures was used as a reference to determine the water content for the preparation of all the specimens and later used in the unconfined compressive strength (UCS) test. The laboratory test results showed that the additional amount of Canlite and Probase have improved the physical properties, liquid limit and unconfined compressive strength (UCS) of the Laterite soil. The compressive strength of the treated Laterite was found varied and depends on the type of stabilizers, quantity of additives and curing time. From the UCS tests, it was found that Probase improves the strength of the Laterite more than Canlite.*

Keywords: Laterite Soil, Soil Stabilization, Polymer Emulsion, UCS Test

1.0 INTRODUCTION

Soil is used extensively as construction materials in the building of roads, dams, embankments and airfields. The properties of the material need to be measured and evaluated before being used [1] and some quality control measures must be introduced to ensure the quality of the product. In this sense, it is worth to mention that the strength of a soil varies between different types of soils. Indeed, there are a wide variety of soils in Malaysia; one of the special soils is known as Laterite soil.

Laterite soils are found abundantly in tropical country such as Malaysia. Laterite soil is well known in Asian countries as a building material for more than 1000 years whereby the Angkor Wat temple is an example in the usage of Laterite soil as construction materials. Generally, Laterite soils are regarded as good foundation materials as they are virtually non-

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swelling [2]. However, Laterite soil contains high amount of clay minerals such that its strength and stability could not be guaranteed under loads especially under presence of water [3]. When Laterite soil consists of high plastic clay, the plasticity of soil may cause cracks and damages on building foundations, pavements, highways or any other construction projects. It is therefore important, to understand the behaviour of Laterite soil in determining a proper method of soil stabilization.

Common soil stabilization methods can either by means of mechanical or chemical stabilizations. The former refers to either compaction or the introduction of fibrous and other non-biodegradable reinforcements to the soil while the latter is the method of improving the engineering properties of soil by adding certain chemicals to improve the existing soil. Despite the existing traditional chemical stabilizers, polymer emulsion is considered as a non-traditional chemical stabilizer and had been introduced recently. The function of polymers is to enhance the strength of soils and to efficiently improve the strength of silty-sand soil under wet and dry conditions. Polymer emulsions such as Canlite and Probase that are used on laterite soils have been studied by many researchers [4-9]. In this study, both polymer soil stabilizers, namely, Canlite and Probase are tested onto Laterite soils. Both products are produced in two different forms, specifically liquid and powdered form; however only liquid form is used in this research. Previous studies found that the unconfined compressive strength of Laterite soil was improved significantly with the addition of Canlite and Probase [4-9]. However, there is a gap in the comparison study of the shear strength enhancement between the two polymer soil stabilizers. Thus, this paper comparatively studies the geotechnical properties (plasticity and shear strength), the effect of the amount of polymer emulsion-treated soil on shear strength and the effect of curing time of the polymer emulsion on treated soil between the Canlite-treated soil and Probase-treated soil.

2.0 LABORATORY TESTS AND SAMPLES PREPARATION

In order to determine the strength of the Laterite soil, physical and mechanical properties tests have been carried out. The physical test was done via the Atterberg Limits test for soil classification while the Standard Proctor Compaction (SPC) test and Unconfined Compressive Strength (UCS) test were conducted for the mechanical properties test. The procedures of these tests are in accordance with British Standard 1377, ASTM D4318, ASTM D2166 [10-12].

The Laterite soil used in this research was obtained from a site at the Faculty of Electrical and Electronic, Universiti Teknologi Malaysia Skudai Johor. All samples were remoulded with specified amounts of the polymer emulsion soil stabilizers (Canlite and Probase). The amounts of polymer emulsion that were added to the soil were 2%, 8% and 16%, together with another sample prepared without any polymer emulsions (untreated soil sample), which was used as a control sample. All treated soil samples were cured for 3, 7 and 28 days. All the treated specimens were prepared by referring to the respective maximum dry densities (MDD) and optimum moisture contents (OMC) of the untreated soil. Pre-determined quantities of Probase and Canlite were then measured based on the dry mass of soil samples and then mixed uniformly. The soil specimen was then mixed with water content corresponding to the OMC.

The mixing process was performed within a reasonable time (approximately five to ten minutes) to ensure that the polymer emulsions were not exposed to the air for too long, which

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may cause evaporation. The percentages of polymer emulsions added to the Laterite soil was 2%, 8% and 16%. The specimens were mixed thoroughly and compacted in three layers into a 38mm x 76mm cylindrical mould. The inner surface of the brass mould was layered with a thin transparent sheet to minimize friction. After that, the specimens were extruded from the mould and wrapped with a cling film to preserve the water content, preventing it from carbon dioxide (CO2) exposure. The mass of the specimens was measured and cured in a controlled temperature room at 20ºC with humidity greater than 90% for 3, 7 and 28 days. In the experiment, a single test was performed for each mixture for different curing time. Nevertheless, triplicate samples were first tested to make sure the repeatability and accuracy of testing data as shown in Figure 1. There were three soil specimens prepared for the control samples and were further tested on the UCS test. The results obtained from the three samples were 210kPa, 250kPa and 230kPa, respectively and the average of the three samples were 230kPa.

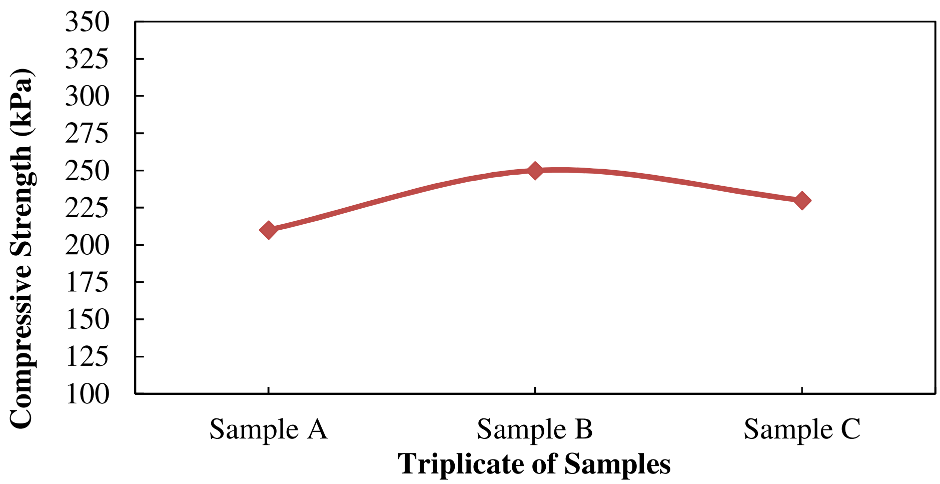

Figure 1: Repeatability data for UCS test of the untreated sample

3.0 RESULTS AND ANALYSIS

Results for laboratory tests such as Atterberg Limits, compaction characteristics and unconfined compressive strength (UCS) were obtained and discussed. Standard proctor compaction test was carried out for the untreated Laterite soil. However, the Atterberg Limits test was carried out for both treated and untreated; for comparison purposes. The UCS test was conducted to all the soil samples with soil stabilizer content at different curing periods of 3, 7 and 28 days.

3.1 Soil Classification

Classification of soil was determined based only on the Atterberg Limits Test. The Atterberg Limits test was carried out to the untreated and treated-Laterite soil based on BS 1377:1990 (Part 2). For the treated-Laterite soil, it was conducted in all three different percentages of both polymer emulsions, in order to classify the actual type of Laterite soil. For the Liquid Limits test, cone penetration tests were carried out to the untreated soil and both Canlite-treated, Probase-treated soil whereby a graph of penetration against moisture content was

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plotted. The results of the Atterberg Limits test (LL, PL and PI) on the samples are shown in Figures 2 and 3. The liquid limit (LL), plastic limit (PL) and plasticity index (PI) of the natural Laterite Soil are 75%, 41% and 33%, respectively. Besides, the addition of varying percentages of stabilizers caused a change in the Atterberg Limits (LL, PL and PI) for all samples.

Figures 2 and Figure 3 show the changes of LL, PL and PI after the addition of Canlite and Probase. According to [13], a liquid limit less than 35% indicates low plasticity, whereas percentages between 35% and 50% indicate intermediate plasticity; between 50% and 70% indicates high plasticity and between 70% and 90% indicates very high plasticity. Based on the result shown in Figure 2 and Figure 3, all samples including treated and untreated, have very high plasticity. Canlite comprises of two working agents denoted as AC 101 (Alkaline Composite Ionize Polymers Volume 101) and SS 299 (Soil Stiffener 299). When the Canlite was added to the Laterite soil, these two agents actually diminish the water membrane surrounding the soil particles, thus substituting the water membrane with its high plasticity and adhesive characteristic [6], [7], [8]. As a result, the soil samples become harder as the percentage of Canlite goes higher. For the Probase, it consists of an agent denoted as TX-85, which is also an ionic type stabilizer and has the same function as the Canlite.

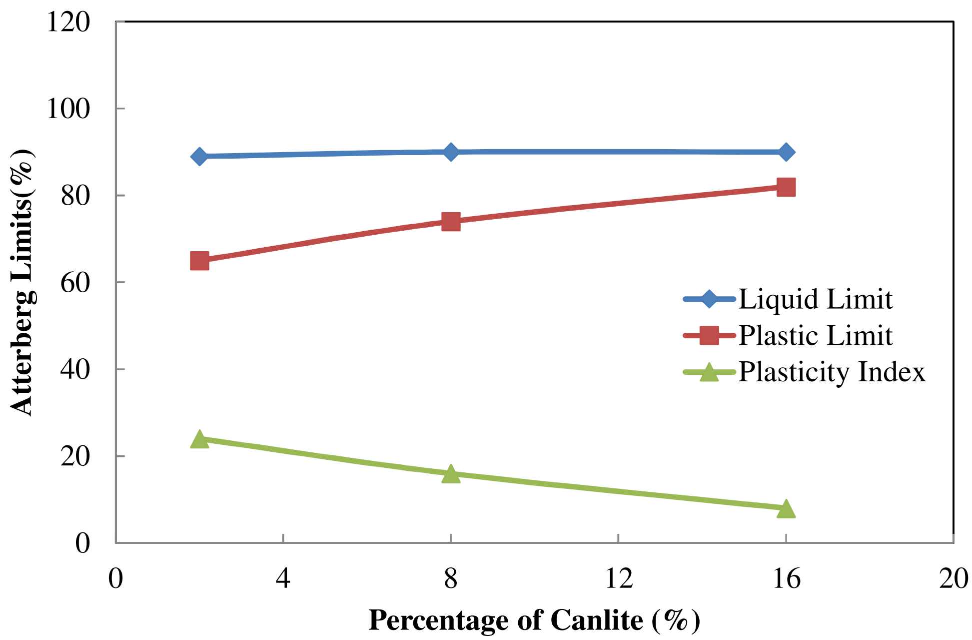

Figure 2: Atterberg limits of Canlite-treated Laterite

By increasing the amount of polymer emulsion soil stabilizers (Canlite and Probase), the LL increases, hence causing an increase in PL while decreasing the PI. LL is the transition between liquid and plastic behaviours. If the value is greater than LL, the soil behaves as a viscous liquid; if the value is lesser than LL, the soil behaves as a viscous plastic solid [12]. A reduction in PI gives an indication that the soil has been stabilized and workability has

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increased as a result of the hydration process [14]. It also enhances the friability of the soil owing to the increase of coagulation and aggregation of the clay mineral particles under the influence of calcium ions [4]. Thus, higher percentage of polymer emulsion may improve coagulation. In other words, increasing polymer emulsion will increase the water holding capacity [4], [7]. However, this explanation is not valid if it exceeds a certain percentage. This is because at a certain percentage, the polymer emulsion soil stabilizer does not play significant roles in the coagulation process, since the clay mineral particles are saturated by cations [16]. This phenomenon can be observed as the soil is treated with 16% of the Probase, the PI becomes higher than the soil treated with 8% of Probase (refer Figure 3).

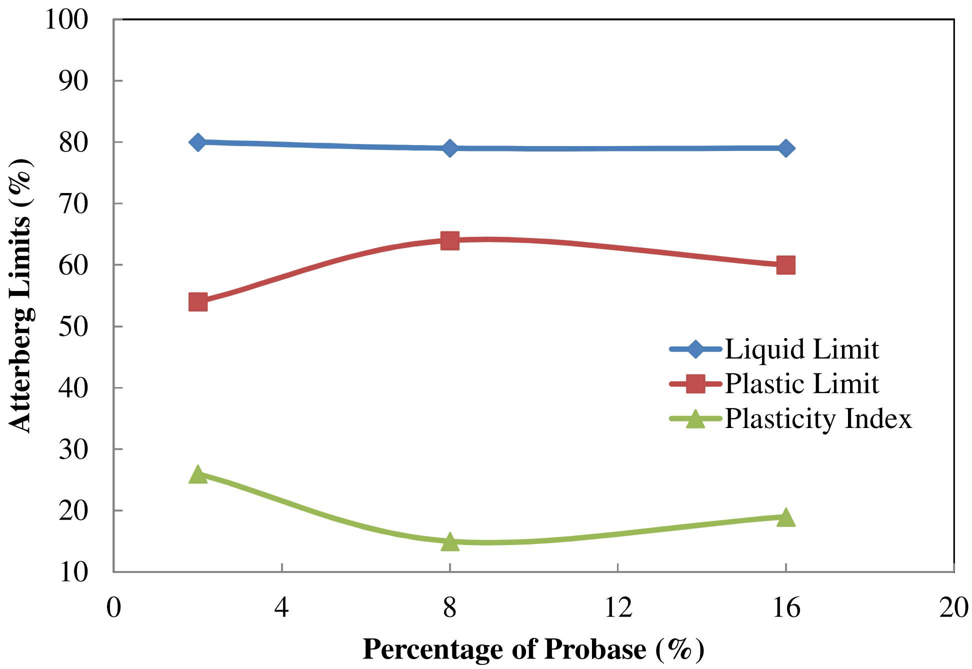

Figure 3: Atterberg limits of Probase-treated Laterite

3.2 Compaction Characteristic

Compaction increases the inter particle bond strength, which is due to the expulsion of air between the individual particles, hence increasing the bearing capacity of the soil. The Standard Proctor Compaction test was used to determine the compaction characteristic of the natural Laterite soil. The purpose of this test was to determine the optimum moisture content (OMC) at which the maximum dry density (MDD) was achieved. Generally, an increase in dry density is an indicator of soil improvement and it occurs due to the rearrangement of both the particle size and the increase in the specific gravity of the soil and stabilizer [17].

When water is added to the Laterite soil during the compaction, it acts as a softening agent on the soil particles, which improves the compressibility of the soil matrix. Based on Figure 4, when the water content is increased the dry density also increases. However, at a certain point, the increase in water content will decrease the dry density; this turning point exhibits an optimum moisture content and maximum dry density.

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The optimum moisture content of the mixtures was then used as a reference to determine the water content for the preparation of all the specimens. These specimens were used in the unconfined compressive strength test (UCS). A compaction graph was then tabulated in Figure 4. Based on Figure 4, OMC and MDD were determined from the plot of dry unit weight versus moisture content. MDD of 13.16 KN/m^3 was achieved, corresponding to the OMC of 34.15%. It is clearly shown that the usage of 34% of water is optimum and suitable for the specimen preparation. It is worth to note that the 34% of water needed in the specimens would not obtain the exact amount of 34% moisture content. The evaporation of water to the atmosphere might occur during mixing, compaction and curing process. For the curing process, the specimens were wrapped with a cling film and cured in a controlled temperature room at 20ºC with humidity greater than 90%. The weight of each specimen was weighted before and after curing to ensure the consistency of density.

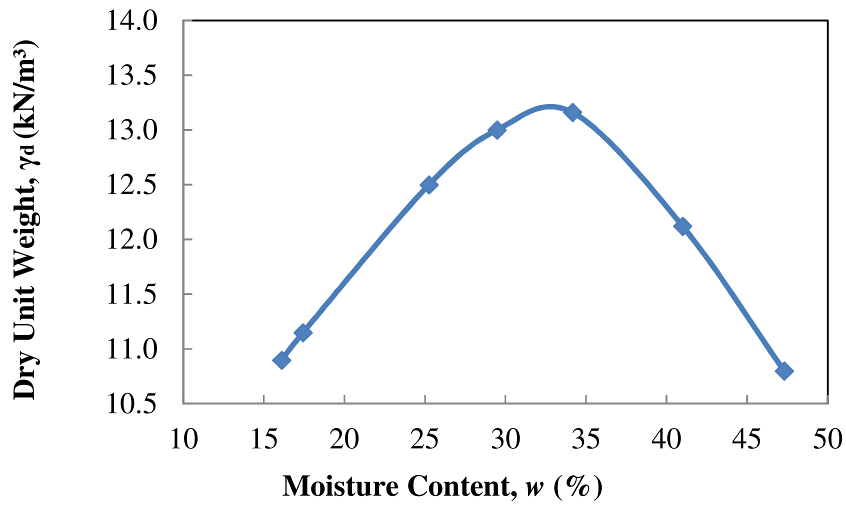

Figure 4: Compaction curve for untreated Laterite soil

3.3 Unconfined Compressive Strength (UCS) Test

The main objective of the UCS test is to determine the compressive strength of the soil samples before and after the polymer stabilization. The result of the UCS test was tabulated in Table 1.

The effect of stabilizer type was evaluated by testing two liquid stabilizers, namely, Canlite and Probase. The former comprise of two working agents denoted as AC 101 (Alkaline Composite Ionize Polymers Volume 101) and SS 299 (Soil Stiffener 299). The latter is a soil stabilizer that is used for stabilizing the soil for roads and is an environmentally safe water-based formula tested by SIRIM Department of Environment Certification and approved by Acute Toxicity Test. Besides, the initial density of each sample was recorded and compared to the density of specimens prior to the UCS test. If the initial mass of the same specimen differs with each other for more than 1%, then the particular specimen will be redone to make sure both samples of the same mixture have similar density. Nevertheless, triplicates of the samples for a particular specimen were also made to ensure consistent and accurate results. After that, only a single test was performed for each mixture.

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In this section, the development in shear strength was analysed by taking into consideration the additive contents and the influence of the curing period. In addition, the comparison between Canlite and Probase was made to identify the most effective stabilizer that improves the Laterite soil for both short (i.e. 7 days) and long term (i.e. 28 days) durations.

Table 1: Summary of UCS test result

	Water Content (%)	Compressive Strength (kPa)			
		0 day	3 days	7 days	28 days
Untreated Sample (US)	34	230	-	-	-
US + 2% Canlite	32	-	280	330	420
US + 8% Canlite	26	-	320	480	600
US + 16% Canlite	18	-	350	500	650
US + 2% Probase	32	-	420	500	630
US + 8% Probase	26	-	680	880	1100
US + 16% Probase	18	-	400	520	640

3.3.1 Effect of Polymer Quantities

Three different percentages of liquid stabilizers were used to evaluate each stabilizer against the natural Laterite soil such as 2%, 8% and 16%. Figure 5 and Figure 6 show the important role of the polymer emulsions in the development of UCS of the polymer treated soil. Figure 5 shows that the value of UCS increases when the amount of Canlite is increased. For example, based on Figure 5, the 3-day UCS increased from 230kPa to 320kPa when 2% Canlite is increased to 8% and further increased to 350kPa with the addition of 16% Canlite; improvement of 190kPa was found at the 28-day UCS when 2% Canlite was added to the soil and continues to increase to 650kPa when Canlite was increased to 16%. A similar initial trend has been observed in Probase-treated soil as shown in Figure 6. However, there is a reduction of strength for soil treated with 16% of Probase. Since the soil used in this research is Laterite soil that contains an amount of clay minerals, the bonding of the fine particle size in Laterite becomes stronger due to the presence of the adsorption mechanism of the polymer emulsion (Canlite and Probase) [19], which increases the value of UCS. The Canlite and Probase are categorized as cationic polymer. Besides that, the molecules of the polymer can easily form an electrostatic bond with clay particles in the Laterite, which cause more cohesion between the soil particles.

In Probase-treated soil, as mentioned earlier, there was an increment of UCS as Probase was increased up to 8%. However, with a further increase in percentage of Probase up to 16%, the value of UCS decreased significantly. [4] A similar occurrence had been reported and may due to the nature of water-based stabilizers. [4], [19], [20] It was also found that adding more than the optimum amount of the liquid stabilizers can increase the moisture content to a

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higher value than the optimum content, whereby this extra moisture content reduces the compressibility of the aggregate and increases the water filled pores inside the soil, thus decreasing the strength of soil. In addition, the size of the polymer molecules in distilled water is highly dependent on ionic concentration. Conformation refers to a polymer molecule that can move freely or stretches out in the solution [19]. If it moves tightly, it will assume a smaller size whereas if it stretches out, it will occupy a larger space of variable shape. By increasing the Probase up to 8%, the polymer molecules are separated from each other and moves freely but after increasing the concentration to 16%, the polymer molecule of Probase began to overlap and segments of the molecules became entangled while their bonding effect diminishes. Thus, the UCS decreases if more than 8% of Probase were added to the soil.

Based on Figures 5 and 6, conclusions can be drawn as the existence of optimum amount of stabilizer will influence the increase in the ultimate UCS value for any polymer emulsion stabilizer treated soil. The optimum amount of Probase was until 8 percent, as shown in Figure 6; it enhanced the strength until 8%, which measures 1100kPa. It also reduced the strength to 640kPa when the quantity increases from 8% to 16%. For the Canlite, the optimum amount is also 8% as the UCS started to become constant after 8%. As discussed earlier, the size of polymer molecules in distilled water is highly dependent on ionic concentration; different polymers have different ionic concentrations. Although no reduction was found in the Canlite-treated samples, the improvement was found to be very little and if the quantity of Canlite was further increased to more than 16%, a reduction will occur.

3.3.2 Effect of Curing Time

The effect of curing time is presented in Figure 7 and Figure 8. All the soil samples were cured for 3, 7 and 28 days. UCS increases as the curing time is increased up to 28 days. In each case, the compressive strength increased with the increase in curing time. For instance, the compressive strength of the 8% Canlite-treated achieved 600kPa at 28 days, which is approximately 3 times greater than the strength of the natural Laterite. Meanwhile, the 8% Probase-treated Laterite after 28-day curing gained a compressive strength of 1100kPa, which is approximately 5 times greater than the untreated Laterite. The Canlite and Probase gained over 100% of strength in 28 days. The highest strength recorded at 28 days was 650kPa and 1100kPa for Laterite treated with Canlite and Probase, respectively.

Principally, longer curing periods improve the reaction process between the soil particles and the liquid stabilizers because the loss of moisture content causes the soil samples to become drier and harder to sustain the load. Moreover, curing of the polymer emulsion that takes place by “breaking” the emulsion subsequent to water loss occurs due to evaporation [19]. Aside from that the breaking of the emulsion can also occur when the individual emulsion droplets that are suspended in the water phase combines and the emulsion particles “wet” the surface of the soil particles before the polymer is deposited on the surface [21]. Hence, the compressive strength of the soil is affected by the amount of polymer deposited on the surface of the soil particles. The more polymers deposited on the surface will increase the percentages of the liquid stabilizers, resulting in more compressive strength.

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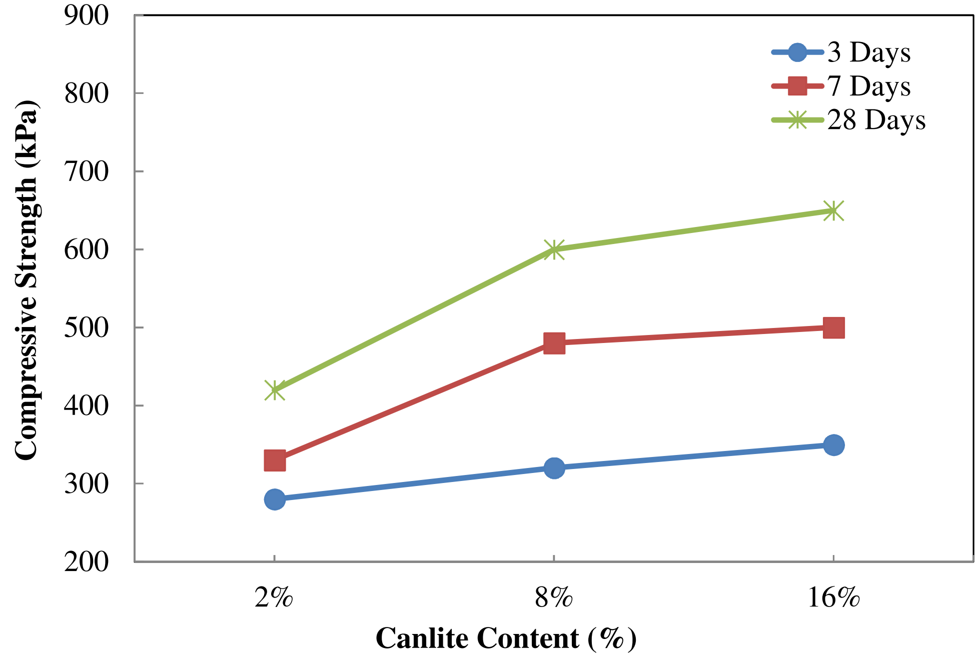

Figure 5: Effect of polymer content on the UCS of the Canlite-treated Laterite

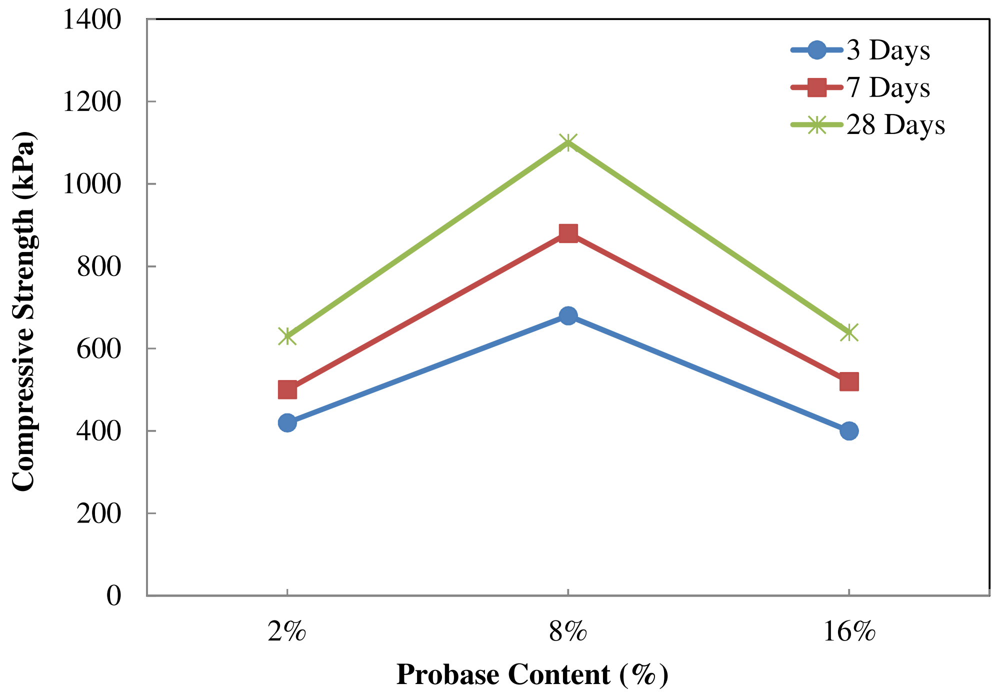

Figure 6: Effect of polymer content on the UCS of the Probase-treated Laterite

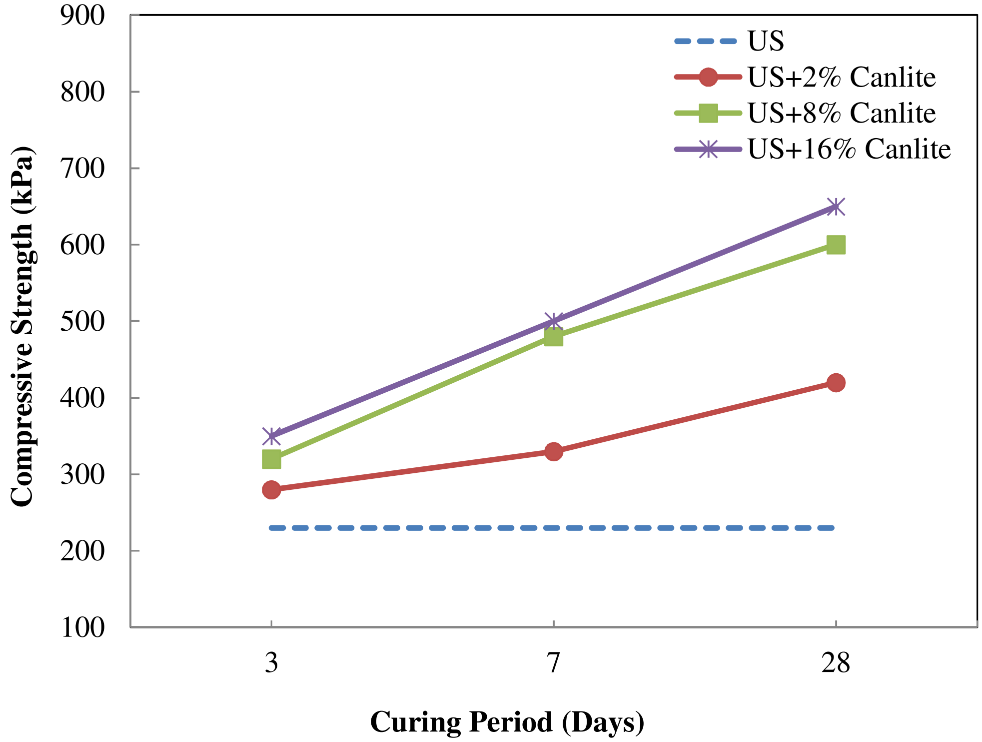

Figure 7: Effect of curing time on Canlite-treated Laterite

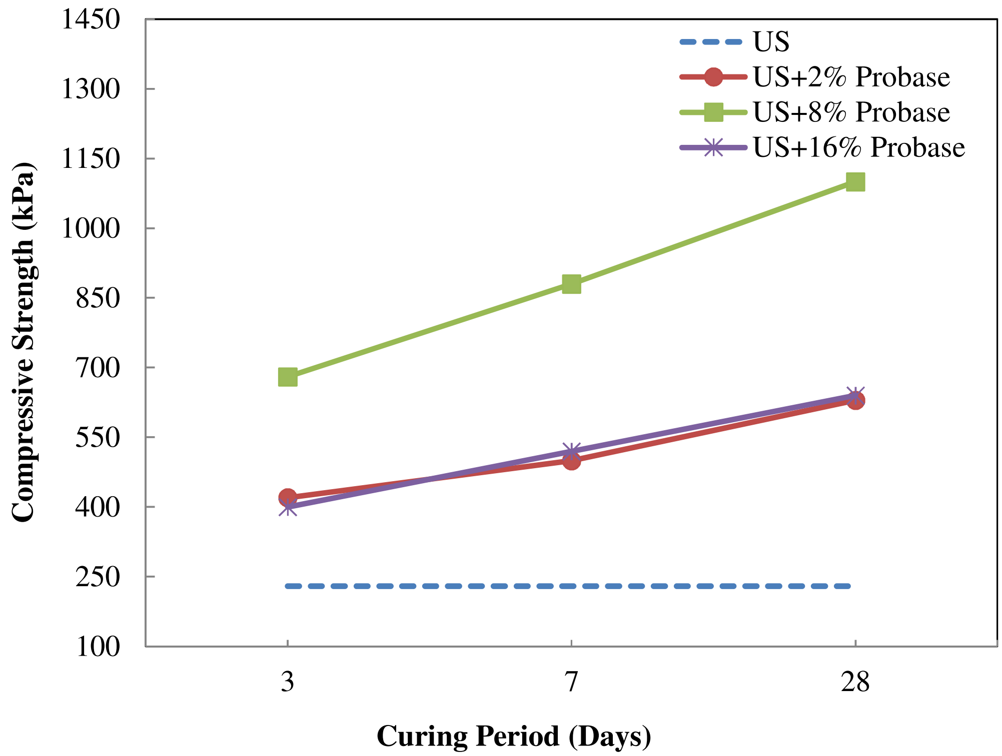

Figure 8: Effect of curing time on Probase-treated Laterite

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3.3.3 Comparison between Canlite and Probase Stabilizer

The comparison between Canlite-treated and Probase-treated Laterite was shown in Figure 9 to Figure 11. It is observed that the UCS of the Probase-treated Laterite shows greater improvement than the Canlite-treated Laterite for all percentages (2%, 8% and 16%). Based on Figure 9, with the addition of 2% of polymer-stabilized Laterite, the Probase improved the natural Laterite approximately three times of the UCS while Canlite only improved twice of the UCS of the untreated soil. For the 8% polymer content as shown in Figure 10, Probase was found to have the greatest UCS, which is 1100kPa, approximately five times more than the UCS of natural Laterite which is only 230kPa. As discussed in section 3.3.1, there is an optimum amount of stabilizer for Probase and Canlite. For Probase, it is 8%, whereby if more than that, the strength of the treated Laterite will decrease while for the Canlite, it showed 8% as the optimum; however, it performed differently from the Probase such that the UCS started to become constant after 8%.

Generally, Canlite and Probase soil stabilizers have the same function of stabilizing poor soil to the desired geotechnical properties such as increased UCS and bearing capacity. However, different polymers have different ionic concentrations such as pH value that can affect its performance on different soils. It is safe to say that certain products are more effective for specific soil types. For the Laterite soil, in which contains an amount of clay minerals, Probase was found to have better effect to the Laterite. Probase caused stronger electrostatic bond formation with the soil particles than that of Canlite and the cohesion between the soil particles were also greater in the Probase-treated soil.

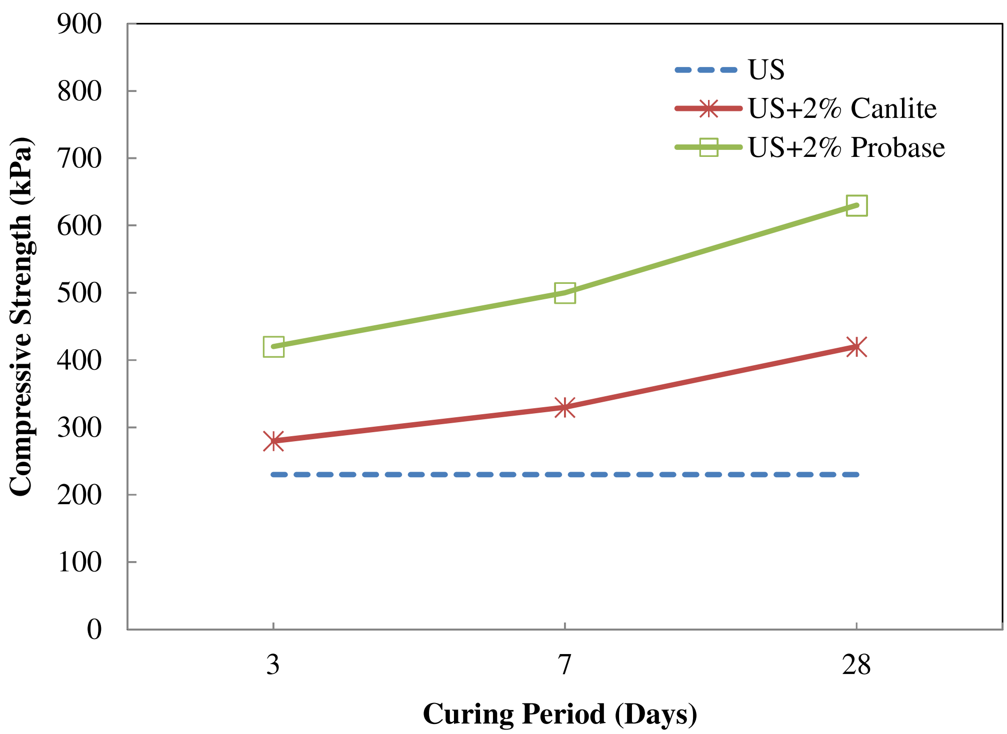

Figure 9: Comparison chart for UCS of 2% polymer-treated Laterite

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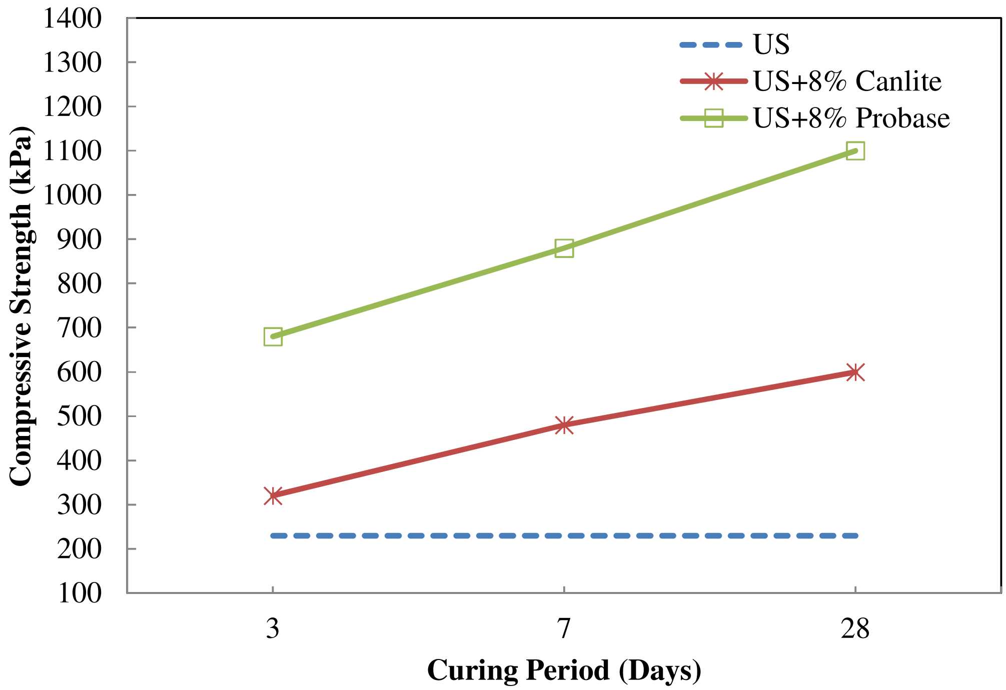

Figure 10: Comparison chart for UCS of 8% polymer-treated Laterite

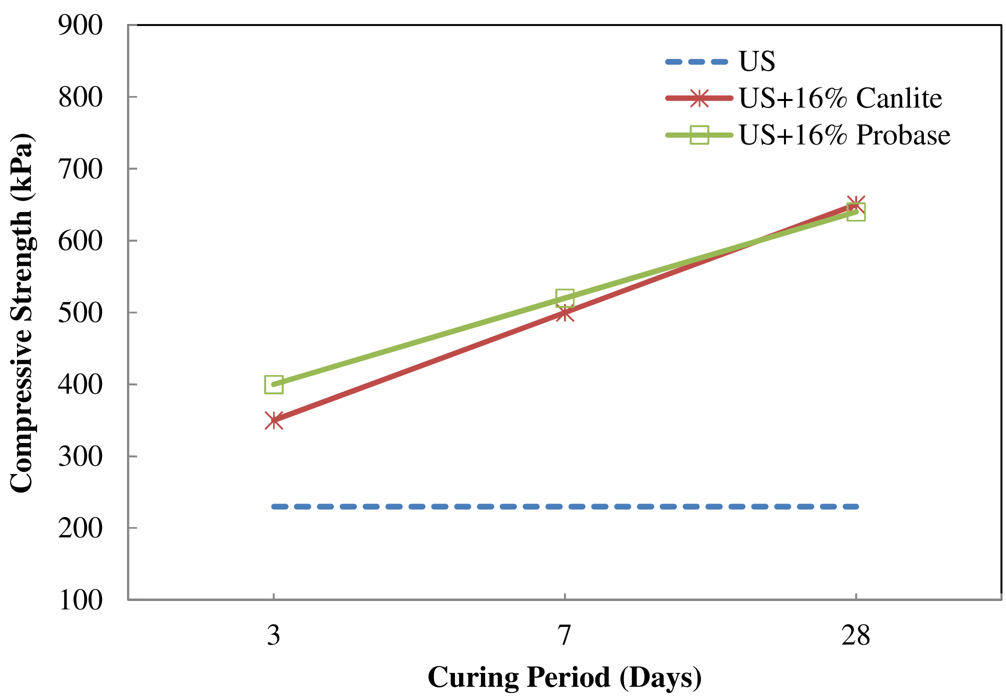

Figure 11: Comparison chart for UCS of 16% polymer-treated Laterite

4.0 CONCLUSSION

The results of the laboratory experiment have drawn several conclusions regarding the stabilization of Laterite soil by using non-traditional stabilizers – Canlite and Probase. The conclusions were based only on the test conditions presented.

1. The effects of both polymer soil stabilizers – Canlite and Probase were examined. The laboratory test results showed that the additional amount of Canlite and Probase has improved the physical properties, liquid limit and unconfined compressive strength of Laterite soil. From the Atterberg Limits tests, an increase in the amount of liquid stabilizers (Canlite and Probase) would decrease the PI. An increase in PL and LL also indicates that the soil is less plastic and more trafficable. A reduction in PI gives an indication that the soil has been stabilized with an increase in workability.

2. From the UCS tests, it was found that Probase improves the strength of the Laterite greater when compared to Canlite. The unconfined compressive strength of the specimens has been increased with the increment of polymer contents; this phenomenon is explained by the increase in the amount of polymer and that the polymer covers all areas of the sample and increases cross-links. There is an optimum additive quantity for the maximum unconfined compressive strength. Based on the laboratory tests, 8% of the liquid stabilizers (both Canlite and Probase) are the optimum amount of stabilizer required for Laterite soil.

3. The unconfined compressive strength improves with the increase of curing time. Canlite-treated Laterite can achieve up to three times greater strength as compared to natural Laterite while Probase-treated Laterite can improve approximately five times greater strength than the untreated Laterite after 28 days.

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