Stabilization of Laterite Soil using GKS Soil Stabilizer

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ABSTRACT

Today, due to the increasing population and also development of construction industry, having sufficient knowledge and information about the various methods of improving the current surface soils for use in various construction projects is an essential issue for a Geotechnical Engineer. The technology for soil improvement is one of the most trustable and practical ways. It is also economically viable to increase the resistance of soil, soil strength, soil permeability, as well as to limit water absorption, control soil erosion, losing water, and soil settlement. A new liquid polymer soil stabilizer, which was developed for use as a means of stabilization treatment of soil known as SS299, was examined in this study. In order to understand the effects of SS299 on the stabilization of Laterite soil, laboratory tests on the unconfined compressive strength and shear strength of untreated and treated soil specimens were performed. The results indicated that SS299 soil stabilizer is able to significantly increase the unconfined compression strength and shear strength of Laterite soil. The unconfined compression strength increased with the duration of curing time, the variation mainly occurring in the first 7 days. Also the result indicated that this stabilizer is worth popularizing for practical projects such as road construction, backfilling, erosion control and for slope stability.

KEYWORDS: Stabilization, Laterite Soil, Curing Time, Direct Shear, UCS.

INTRODUCTION

Today, due to the increasing population and also development of construction industry, having sufficient knowledge and information about the methods of improving the current surface soils for use in various construction projects is an essential issue for a Geotechnical Engineer. The technology for soil improvement is one of the most trustable and practical ways. It is also economically viable to increase the resistance of soil, soil strength, soil permeability, as well as to limit water absorption, control soil erosion, losing water/water seepage and soil settlement Eisazadeh (2010).

Using soil improvement techniques rather than using other methods, such as replacing or adding reinforced soil, either in terms of performance and ease of work and also from an economic aspect and the speed of work, is thus justifiable. Nowadays, engineers in construction industries, particularly in the geotechnical sector, use improving soil technologies in many areas such as in road construction and buildings, retaining structures and the related materials especially in the foundation of buildings and to improve the coastal areas for construction.

Soil stabilization is the process of improving the physical and engineering properties of a soil to obtain some predetermined targets Eisazadeh (2010). It operates in various forms such as mechanical, biological, physical, chemical and electrical. Nowadays, among the different methods of soil improvement such as mechanical, physical, and chemical stabilization, using chemicals for soil stabilization in order to increase soil strength parameters and loading capacity and decreasing the settlement seem to be a more popular choice. This is due to its low cost and convenience, particularly in the geotechnical projects that require a high volume of soil improvement Saeed, K *et al* (2012).

Among the chemical compounds, using the various combinations such as enzymes, liquid polymers, resins, acids, silicates, and lignin derivatives is more common than others. But reviews on previous researches, show that the performed analysis on traditional stabilizers such as lime and cement are more common when compared with the researches that are done on non-traditional stabilizers Liu, J *et al* (2011).

The inorganic types of stabilizing agents have been popularly applied to soil stabilization, such as cement Bell, (1995); Chen and Lin,(2009), lime Mckinley *et al*.(2001); Cai *et al*.(2006), fly ash Dermatas and Meng, (2003), and their mixtures Peter and Little, (2002); Ouhadi and Goodarzi, (2006); Zhu and Liu, (2008). These inorganic stabilizing agents are mainly used in non-ecological soil stabilization, such as foundations, roadbeds, embankments and piles. They improve the engineering properties of soils greatly, such as the strength and stiffness. On the other hand, the organic polymer soil stabilizers as a new stabilizing agent applied in soil ecological stabilization have received recent attention Barry *et al*. (1991); Nwankow, (2001); Liu *et al* (2009). It should be noted that because of the proprietary nature of the commercial stabilization additives, their exact chemical compositions are not disclosed. In this study, a new type of organic polymer soil stabilizers was introduced. In order to understand the effect of SS 299 on soil stabilization of Laterite soil, laboratory tests on unconfined compressive strength and shear strength of untreated and treated soil specimens was performed.

MATERIALS AND TEST METHODS

MATERIALS

The residual laterite soil used in this investigation was a reddish color clayey soil with high amounts of iron oxides commonly found in tropical regions Eisazadeh (2010). This soil was excavated from a hillside (Balai Cerap) located in the skudai campus of Universiti Teknologi

Malaysia (UTM) .The physical properties and particle size distribution of the natural soil are presented in Table 1 and graph 1 respectively.

Table 1: The Physical Properties of Soil

Engineering & Physical Properties (Laterite)	Values
Specific Gravity	2.69
Liquid Limit, LL (%)	75
Plastic Limit, PL (%)	41
Plasticity Index, PI	34
(%)BS Classification	MH
Maximum dry density (Mg/m3)	1.31
Optimum moisture content (%)	34
Unconfined compressive strength (kPa)	270

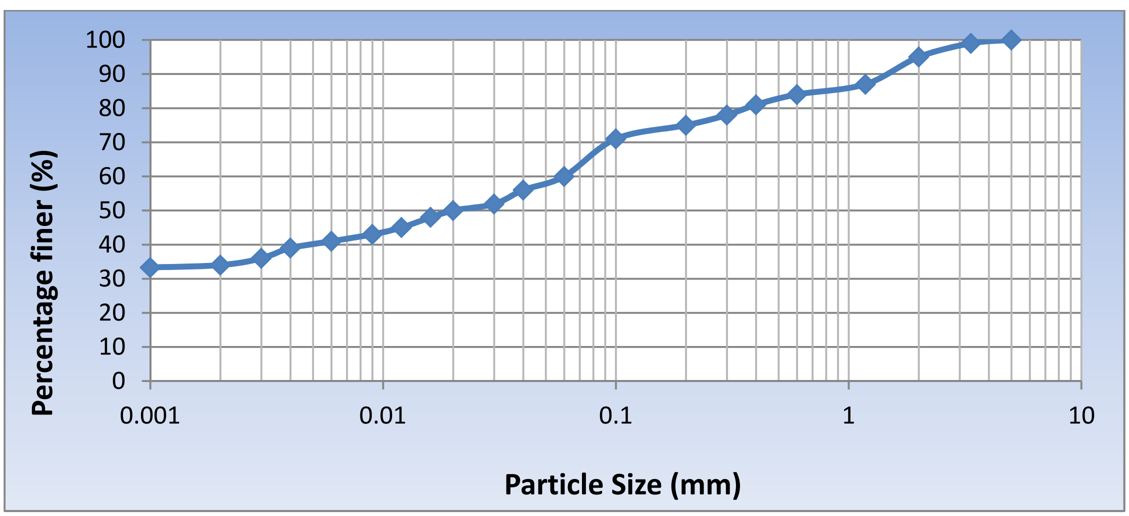

Figure 1: Particle Size Distribution

The liquid polymer used in this study prepared from GKS soil Stabilizer Company, which is a local company in Malaysia with its location in Johor. Figure 2 and 3 shows the soil and liquid polymer respectively which used in this study.

Figure 2: Air- dried Laterite Soil

Figure 3: SS 299 Liquid Soil Stabilizer

TEST METHODS

In order to understand the usefulness of SS299 as a new soil stabilizer for stabilizing the Laterite soils by modifying the properties of soil itself, laboratory tests including unconfined compressive test and direct shear test were performed to evaluate the performance of SS299 on Laterite soil through examining the changes in the unconfined compressive strength (USC) and shear strength. Owing to different test requirements, there are differences in preparation of specimens and test procedures for different tests.

SAMPLE PREPARATION

Previous investigations conducted on the lateritic soil indicated that oven drying significantly changes its plasticity and compaction properties Goswami and Mahanta, (2007).Therefore; all mix designs for this type of soil were prepared from air-dried soil. The air-dried soil was then broken into smaller sizes and sieved through a 2 mm sieve. The sieving was done to ensure that the soil was of uniform grade throughout the experiment Eisazadeh (2010). As is generally recommended for geotechnical testing practice for stabilization of soils contaminated by chemicals, dionized water was used in all aspects of sample preparation. The required amount of water known as optimum water content (OMC) was determined for the natural soil, Therefore, depending on the BS 1377: Part 4: 1990 (clause 3.3.4.1), series of standard proctor compaction tests were performed to determine the optimum moisture contents for Laterite soil.

In this research, a standard and rational step by step protocol was used for preparing various mix designs. First of all, the required amount of water known as Optimum Moisture Content (OMC) was determined for soil. Secondly, the dried soil was directly mixed with the required amount of water and liquid polymer until a uniform mixture was achieved. Finally soils were compacted in 38mm×76mm cylindrical mould with designed optimum water content and maximum dry density as specified in clause 4.1.5 of BS 1924: Part 2: 1990b. The specimen was initially cured for 2 hours inside the mould, and then removed from the mould, put in thin wall PVC tube, wrapped with thin plastic and sealed to the atmosphere with rubber tight lids. The samples were then stored for curing time in a controlled temperature room (27 ± 2_C) until required for testing at each of the curing periods, 3, 7, 14, and 28 days (Figure 3). It should be stressed that to ensure the accuracy of the results, four samples for each soil mix design and the three curing periods were prepared. Beside to that, for more suitability to present the samples, designation scheme was used by using letters in the specimen designation which LP is liquid polymer stabilizer content, LC is Laterite soil, T is treated samples, and UN is untreated samples.

Figure 3: Sample Curing Box

UNCONFINED COMPRESSIVE STRENGTH TEST

Four concentrations 3%, 6%, 9% and 12% of SS299 dilutions (by weight of dry soil) were proposed for stabilization of Laterite soil and the water (0%) as a control. The unconfined compression tests were carried out at the loading rate of 2 mm/min until samples failed. Additionally, unconfined compression test was performed on specimen triplicates and average values were used. The procedures followed to perform these tests were in accordance to the BS 1377: part 7: 1990.

DIRECT SHEAR TEST

One concentration (9%) of SS299 dilutions (by weight of dry soil), as optimum amount of liquid polymer which was found by UCS tests were proposed for stabilization of Laterite soil and the water (0%) as a control. Two-layered compaction was adopted to test specimens with the 60 mm in diameter and 20 mm in height. Specimens were sheared after 3, 7, 14, and 28 days being cured. Strength tests were performed on samples using a standard shear box at a constant rate strain with the speed of 1 mm/min and under the normal pressures of 28, 56, 110 and 220 Kpa until failure or maximum horizontal displacement of 10 mm in order to define the shear strength parameters (c and ψ) And the shear strength parameters were obtained on specimen triplicate and average values were used. The value of displacement was selected based on the capability of the machine utilized for the tests. The procedures followed to perform these tests were in accordance to ASTM 3080 as described by Head (1990b) in addition to the BS 1377: part 7: 1990.

LABORATORY TEST RESULTS AND ANALYSIS

UNCONFINED COMPRESSIVE STRENGTH

The values of unconfined compressive strength of specimens with different SS299 concentration and curing time are presented in figures 4 to 7 respectively. As seen, an increase in SS299 concentration from 3% to 12% induces a gradual improvement in strength for the specimens tested. As shown in figures, the strength of each specimen improved by increasing the curing time and this tendency becomes stronger with increase of SS299 concentration. Compared with the untreated specimens, the treated specimens had greater strength after curing.

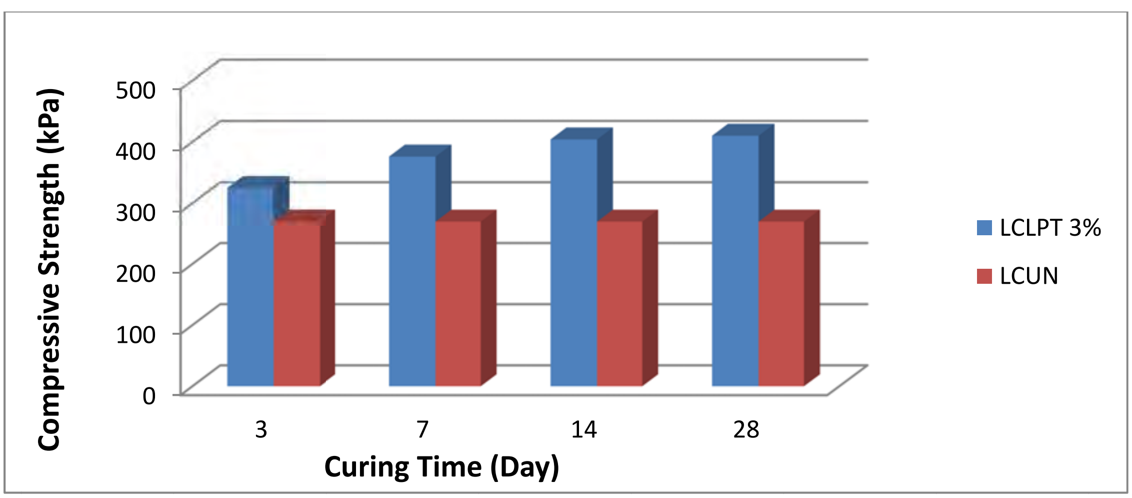

Figure 4: Variation of unconfined compressive strength of samples with curing time

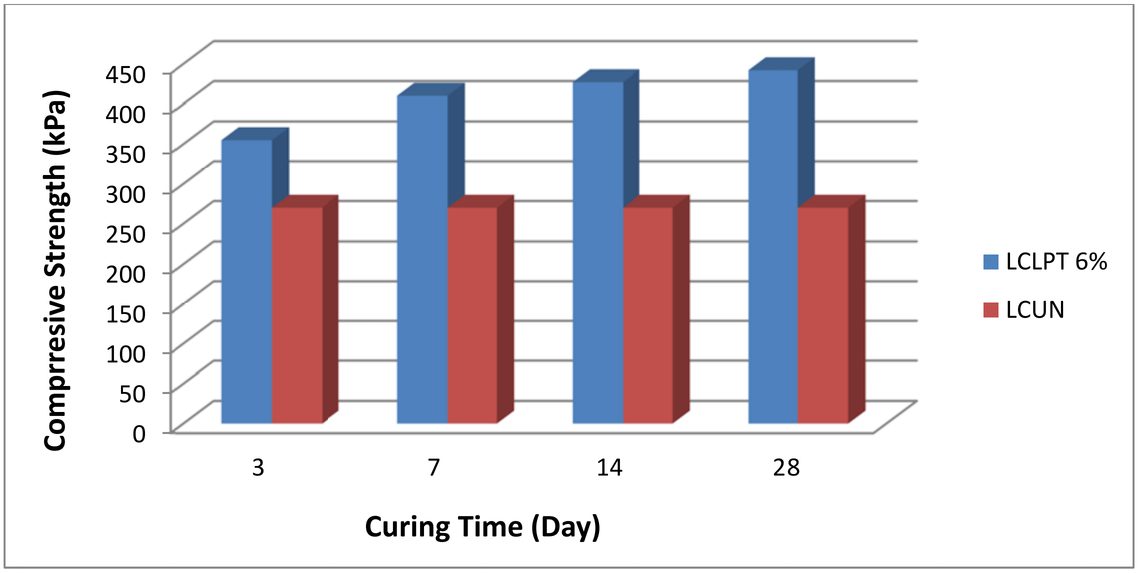

Figure 5: Variation of unconfined compressive strength of samples with curing time

The maximum value of the strength as 605KPa is observed at 12% SS299 concentration with 28 days of curing time, which is more than 2 times that of the untreated specimen. Additionally, figure 8 shows the comparison of unconfined compressive strength for all untreated and treated samples. As seen, the increase in strength of the treated specimens mainly occurs in the first 7 days of curing. With a concentration of 9% as an example, the relative increment of unconfined compressive strength tested after 7 days is 2 times more than the untreated samples.

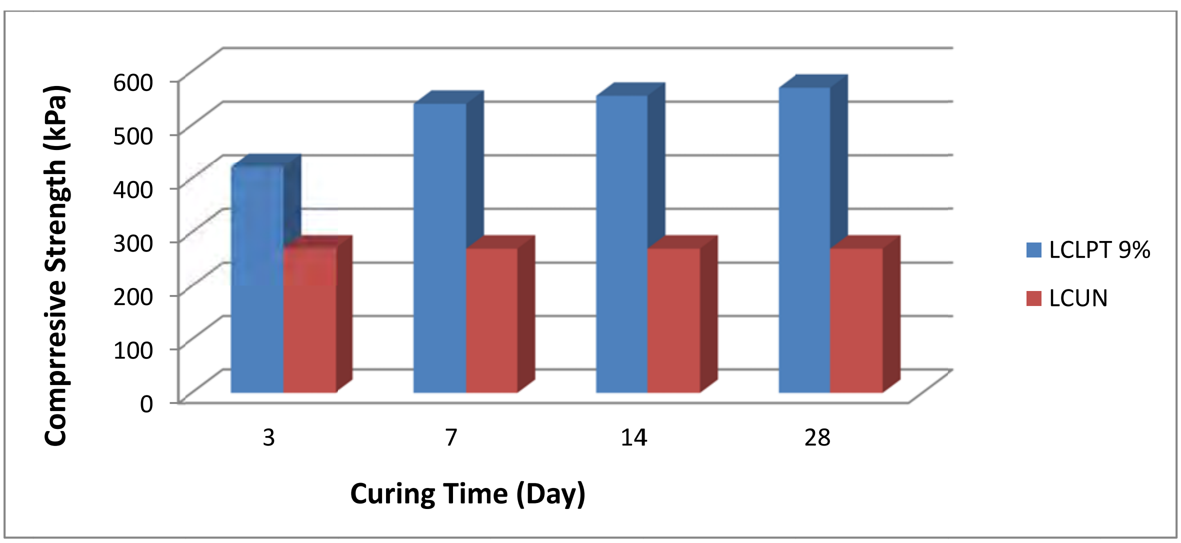

Figure 6: Variation of unconfined compressive strength of samples with curing time

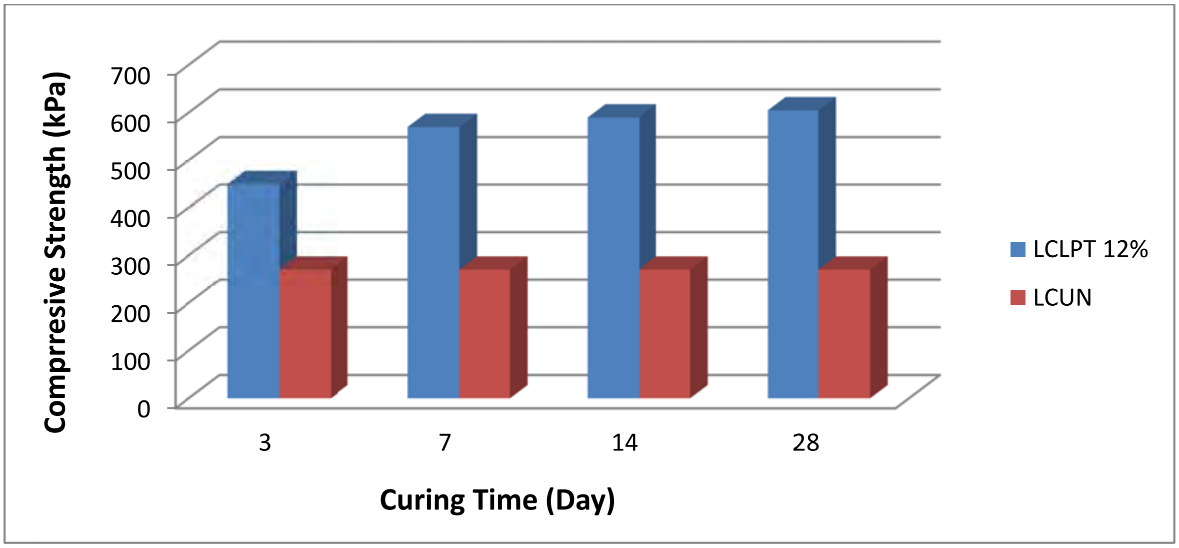

Figure 7: Variation of unconfined compressive strength of samples with curing time

It can be seen from figure 8 that there were specific changes in the treated samples with more than 9% of SS299 in laterite soil and around 90% of increment happened in the first 7 days of curing time. So it seems that the optimum amount of SS299 in Laterite soil is 9% based on the increment and time. So, based on the result of Unconfined Compressive Strength tests, the optimum amount of SS299 was chosen for the Standard Direct Shear Tests.

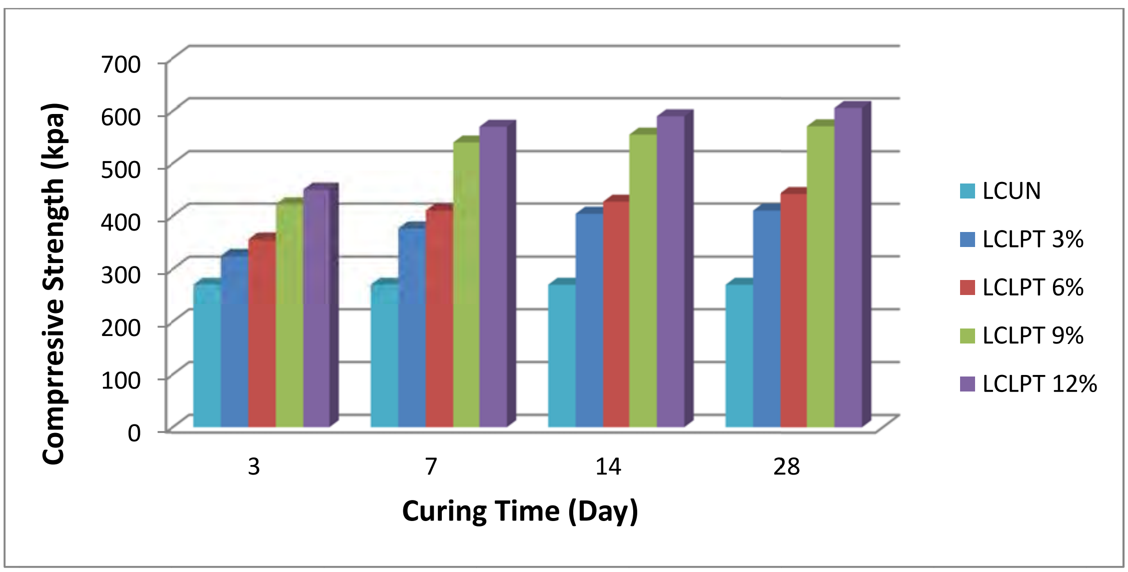

Figure 8: Comparison of unconfined compressive strength of samples with curing time

SHEAR STRENGTH PARAMETERS

Direct shear test were performed to obtain the shear strength of specimens that were treated and cured. The obtained shear strength by means of cohesion and internal friction angles are stated in Table 2. The Cohesion and Internal Friction Angle for the Laterite soil are 38.6KPa and 22.29^0 respectively, which is indicated in figure 9. It is observed that both cohesion and internal friction angle of specimens increased greatly after curing. Additionally, the optimum amount of SS299 has a significant influence on the development of cohesion and internal friction angle.

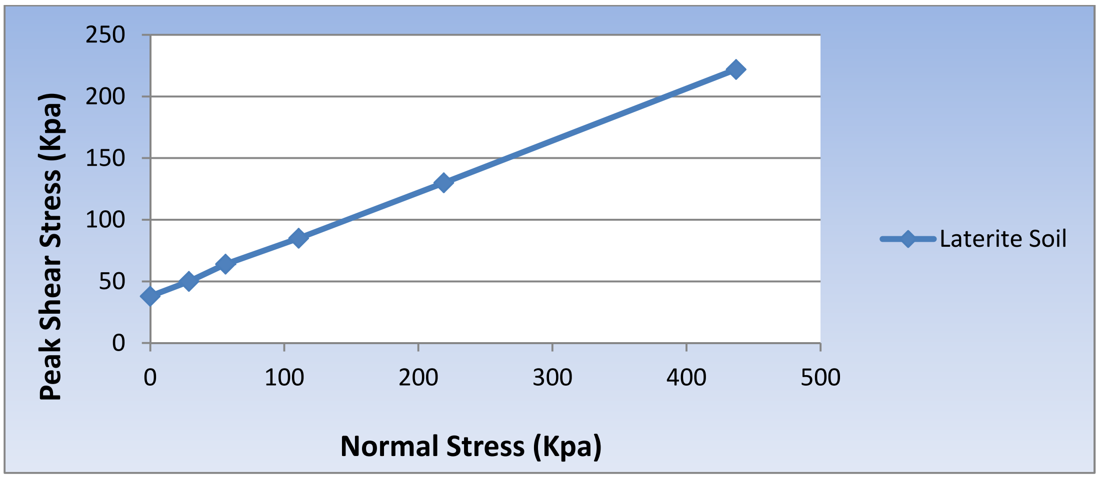

Figure 9: Peak Shear Stress-Normal Stress curve for Laterite Soil

Table 2: Cohesion and angle of internal friction of specimens tested at different curing time, (9%) SS299

Parameter/Day	3 Days	7 Days	14 Days	28 Days
Cohesion (kpa)	44.6	58.3	63.8	66.5
Angle of internal friction (degree)	26.3	32.8	34.4	37.87

The variations of cohesion with 9% of SS299 concentration are shown in figure 10. As shown in figure 10, cohesion improves with the increase of SS299 concentration and the curing time. It can be seen that the cohesion of treated samples increased 1.7 times after 28 days. Further, more than 60% of increment happened after 7 days which shows the fast reaction times between soil and SS299.

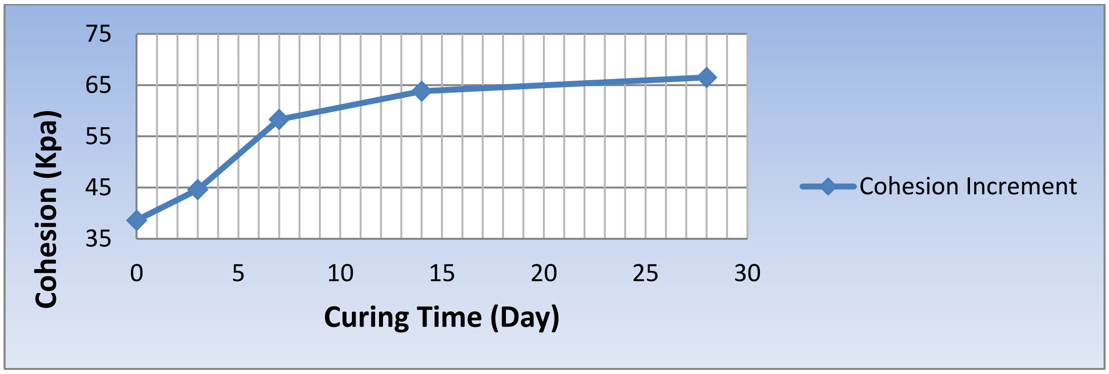

Figure 10: Cohesion Increment of Soil by added 9% of SS299

The internal friction angle of specimens treated with curing time is illustrated in figure 11. It is observed that the internal friction angle of specimens had changed with the increase of SS299 concentration. It can be seen that the internal friction angle increased around 1.7 times after adding 9% of SS299 to the Laterite soil and 28 days for curing. Also, the 70% of increment of friction angle happens after 7 days. Therefore, the clayey soil stabilized by SS299 has higher cohesion and internal friction angle than the untreated soil. In addition, it was found that the untreated and treated specimens show a strain-softening ductile failure in the shear process.

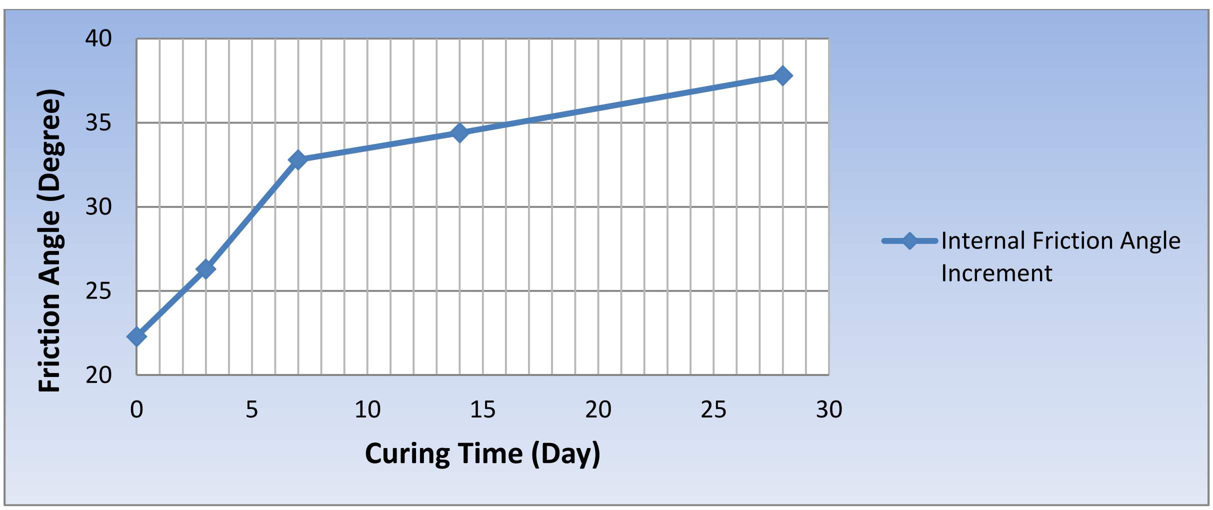

Figure 11: Internal Friction Angle Increment of Soil by added 9% of SS299

CONCLUSIONS

Based on the laboratory tests, the effects of polymer soil stabilizer (SS299) on stabilization treatment of Laterite soil have been examined. It is shown from the laboratory test results that the additional amount of SS299 causes the beneficial changes in the unconfined compressive strength and shear strength of Laterite soil used in this study. It is observed from laboratory testing that the properties of stabilized soil vary and depend on the concentration rate of SS299 and also the curing time.

The unconfined compressive strength improves with the increase of curing time and this increase mainly occurs in the first 7 days. The unconfined compressive strength, cohesion and friction angles also improve with the increase of SS299 concentration and curing conditions. Based on laboratory tests, 9% of SS299 can be said to be the optimum amount of stabilizer required for Laterite soil. The results shows that the SS299 is a suitable stabilizer for some of the practical project generally undertaken such as in increasing the road bearing capacity , increasing the bearing capacity of backfills behind retaining structures and reduce the lateral Earth pressure, and erosion control in the management of slope stability.

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REFERENCES

Ali, F. (2012) Stabilization of Residual Soils Using Liquid Chemical. *Electronic Journal of Geotechnical Engineering, 17*.

Ahmed, A., & Khalid, H. A. (2011) Quantification of the properties of enzyme treated and untreated incinerator bottom ash waste used as road foundation. *International Journal of Pavement Engineering, 12*(03), 253-261.

Liu, J., Shi, B., Jiang, H., Huang, H., Wang, G., & Kamai, T. (2011) Research on the stabilization treatment of clay slope topsoil by organic polymer soil stabilizer. *Engineering Geology, 117*(1), 114-120.

Eisazadeh, A., Kassim, K. A., & Nur, H. (2010) Molecular characteristics of phosphoric acid treated soils. *World Academy of Science, Engineering and Technology, 63*, 1-3.

Eisazadeh, A., Kassim, K. A., & Nur, H. (2010) Characterization of phosphoric acid-and lime-stabilized tropical lateritic clay. *Environmental Earth Sciences*.

Eisazadeh, A., Kassim, K. A., & Hadi, H. (2010) Physicochemical characteristics of phosphoric acid stabilized bentonite. *The Electronic Journal of Geotechnical Engineering, 15* (Bund. C), 327-355.

Zhu, Z., Liu, S. (2008) Utilization of a new soil stabilizer for silt subgrade. Engineering Geology 97, 192–198.

Cai, Y., Shi, B., Ng, C.W.W., Tang, C. (2006) Effect of polypropylene fibre and lime admixture on engineering properties of clayey soil. Engineering Geology 87, 230–240.

Mckinley, J.D., Thomas, H.R., Williams, K.P., Reid, J.M. (2001) Chemical analysis of contaminated soil strengthened by the addition of lime. Engineering Geology 60, 181–192.

Bell, F.G. (1995) Cement stabilization and clay soils, with examples. Environmental and Engineering Geoscience 1 (2), 139–151.