Effect of Rubber Powder and Lime on Slope Failure in Clay Soil

Shakri M.S.

Lecturer, Faculty of Engineering and The Built Environment
SEGi University, Malaysia
e-mail: shakrishariff@segi.edu.my

Kannia M.

Faculty of Engineering and The Built Environment
SEGi University, Malaysia
e-mail: kannia23maniam@gmail.com

ABSTRACT

Construction of engineering structures on weak or soft soil is considered as unsafe. Improvement of load bearing capacity of the soil may be undertaken by a variety of ground improvement techniques. Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the strength of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Stabilization can be used to treat a wide range of sub-grade materials, such as soil from expansive clays to granular materials. This process is accomplished using a wide variety of additives, including lime, fly-ash, crumb rubber powder and Portland cement. Therefore with using rubber powder and lime with clay soil has been researched to find solution and disputes associated. There are two tests had been conducted which are Standard Proctor Test and Standard Test Method for One-Dimensional on the clay soil, 8% and 16% of rubber powder and 4% to 10% of lime. First sample of clay soil, 8% crumb rubber powder and 4% to 10% lime was tested using compaction test shows that highest point achieved was 2.67 g/cm^3 (dry density) (OPM) and for second sample of clay soil, 16% crumb rubber powder and 4% to 10% of lime the highest was obtained 2.81 g/cm^3 (dry density). Comparison for this both sample have been made and its shows there is slight increasing changes on the dry density and more compaction effort when there is more amount of CRB and lime. Additionally, based on Standard Test Method for One-Dimensional on the clay soil, results showed that by increasing percentage of lime, Cc index will be reduced where by using lime 8% and rubber powder in range 8% to 16%, Cc index recorded below 1.5.

KEYWORDS: Rubber Powder; Lime: Slope; Clay

INTRODUCTION

Slope failure occurs when the downward movements of material due to gravity and shear stresses exceeds the shear strength. Therefore, factors that tend to increase the shear stresses or decrease the shear strength increase the chances of failure of a slope. Different processes can lead to reduction in the shear strengths of rock mass and one of the major causes for slope failure in Malaysia is the clay soil. Thus for this study have decided to choose clay soil as the main specimen and improve the strength by adding admixture. The soil have collected at Selayang-Rawang highway, Selangor Malaysia, landslide site at 1m depth as shown in Figure 1.

Stabilization is the process of blending and mixing materials with soil to improve certain properties of the soil. Soft clays generally display extremely low yield stresses, high compressibility, low strength, low permeability and consequently low quality for construction. Thus, soil stabilization like soil-additives mixing can be effectively embraced to improve the strength and deformation characteristics of the soft clays. The potential of using rubber from worn tyres in many civil engineering works has been studied for more than 30 years. Applications where tyres can be used have proven to be effective in protecting the environment and conserving natural resources [6]. Crumb rubber powder used in this study was retrieved from discarded used truck tyres by crushing and removal of the textiles and metal fibres. The crumb rubber powder sizes are between 10 – 40 mesh according to mesh size range in each market category [8]. It was obtained from Continental Tyre PJ Malaysia Sdn Bhd. Lime stabilization is one of the methods of improving the properties of soils especially the cohesive soils. There are many types of lime in available, can be divided into two which are quicklime (calcium oxide) and hydrated lime (calcium hydroxide) which burned from limestone (calcium carbonate). In this research, calcium hydroxide have been used where commonly called slaked lime or hydrated lime with the chemical formula $Ca(OH)_2$ which is fine powder form. Therefore with using both chemical additives substances trying to improve the stabilisation of clay soil. For the solution few studies have been conducted such as sieve analysis on clay soil, moisture content test, specific gravity determination under preliminary properties determination, while compaction test and consolidation test for mechanical properties determination.

Figure 1: Location soil sample collected at Selayang-Rawang highway, Selangor Malaysia,

Figure 2: Sample of clay soil, rubber powder and lime

EXPERIMENTAL PROGRAM
Preliminary Experiments

Scrap tire rubber powder can be obtained from tires through two principal processes are ambient, which is a method in which scrap tire rubber is ground or processed at or above ordinary room temperature and cryogenic, a process that uses liquid nitrogen to freeze the scrap tire rubber until it becomes brittle and then uses a hammer mill to shatter the frozen rubber into smooth particles. For this study, the rubber powder was produced from three used automobile tires by mechanical shredding at ambient temperature. Steel was removed by magnetic separation and one

part of textile fibre was removed by density. Tyre rubber fibres consist of a complex mixture of elastomers, polyisoprene, polybutadiene and styrene-butadiene. Stearic acid (1.2%), zinc oxide (1.9%), extender oil (1.9%) and carbon black (31.0%) are also important components of tyres [4] In Malaysia, for economic reasons, policies for the production of rubber are typically oriented towards benefiting the sizeable rubber industry, which has inadvertently resulted in a considerable problem of waste tires. As a counter-measure, the government is encouraging research on sustainable methods of handling the growing problem of rubber waste through various funds and grants. Stabilization is a process of fundamentally changing the chemical properties of soft soils by adding binders or stabilizers, either in wet or dry conditions, to increase the strength and stiffness of the originally weak soils [7]. Lime in the form of quicklime (calcium oxide – CaO), hydrated lime (calcium hydroxide – Ca(OH)$_2$), or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – CaCO$_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. It is hydrated lime that reacts with clay particles and permanently transforms them into a strong cementitious matrix. Soil stabilization significantly changes the characteristics of a soil to produce long-term permanent strength and stability. The reaction between water and soil with lime and silica and alumina materials of the soil leads to development of cementing material in the soul which and it is done increases soil resistance and stability. This reaction is a function of time, and it is done slowly and over several years such as cement hydration. In other words, first calcium hydrate is dissolved and then resulting OH are combined with Si and Al in clay soil and Hydroxides with Ca ++, silicate and aluminate are produced [5]. The composition of rubber powder and lime have been listed out and summarized in Table 1 and Table 2. While Table 3 shows the configuration that have been designed and decided to be used in this study.

Table 1: Chemical composition on crumb rubber powder (CRB)

Composition	Percentage, %
Rubber	54.0
Carbon Black	29.0
Textile	2.0
Oxidize zinc	1.0
Sulphur	1.0
Additives	13.0

Table 2: Chemical composition on hydrated lime

Composition	Percentage, %
Calcium Hydroxide	88.0
Magnesium Oxide	1.2
Iron Oxide	2.5
Aluminium Oxide	1.0
Silicon Dioxide	3.0

Table 3: Proportion percentage of CRB and lime used for clay soil

Sample 1	Sample 2
Clay soil + CRB (8%) + Lime (4%)	Clay soil + CRB (16%) + Lime (4%)
Clay soil + CRB (8%) + Lime (6%)	Clay soil + CRB (16%) + Lime (6%)
Clay soil + CRB (8%) + Lime (8%)	Clay soil + CRB (16%) + Lime (8%)
Clay soil + CRB (8%) + Lime (10**%**)	Clay soil + CRB (16%) + Lime (10%)

At the early stage of experiment, void ratio and density of the soil solids have been identified. The purpose of this test is to find ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature. By using [3] placed 10 g of a dry soil sample of two different percentage of rubber powder (8% and 16%) and lime (4%,6%,8% and 10%) (Passed through the sieve No. 10) in the pycnometer. The weight of the pycnometer containing the sample, W_{PS} was determined and recorded. Added distilled water to fill about half to three-fourth of the pycnometer and soaked the sample for 10 minutes. Applied a partial vacuum to the contents for 10 minutes, and removed the entrapped air. Stoped the vacuum and carefully removed the vacuum line from pycnometer. Filled the pycnometer with distilled (water to the mark), cleaned the exterior surface of the pycnometer. Obtained the weight of the pycnometer and contents, W_B. Cleaned the pycnometer filled it with distilled water only (to the mark) and determined the weight of the pycnometer and distilled water, W_A. The specific gravity of soil solids is used in calculating the phase relationships of soils, such as void ratio and degree of saturation and also density of the soil solids. This is done by multiplying its specific gravity by the density of water at proper temperature.

Compaction Test

This laboratory test conducted to measure the maximum dry unit weight ($\gamma_{d,max}$) and optimum water content (w_{opt}) of two different percentage sample that were subjected to specific compactive efforts. The results from these tests are also useful for determining the relationship between the compaction water content and the resulting dry unit weight of the sample that were tested. To investigate the influence of different compactive efforts, two different sample was prepared which first sample is clay soil, 8% CRB and (4% to 10%) of lime and second sample is clay soil, 16% of CRB and (4% to 10%) of lime. The intermediate compactive effort that was applied corresponded to that obligatory by the standard Proctor (SP) compaction test [2]. Followed the test procedure, the soil was compacted into a 102 mm (4 in.) diameter mold in three equal layers with each layer receiving 25 blows from a 24.4 N (5.5 lbf.) rammer dropped from a height of 305 mm (12 in.). The total compaction energy that is applied during a standard compaction test is 600 kN-m/m^3. As discussed earlier, tests were conducted on prepared two different samples mixtures having both crumb rubber powder as the clay admixture in the mixture. For each type of clay, soil samples with CRB (8% and 16%) and (9%, 4%, 6%, 8% and 10%) of lime contents were prepared and tested to examine the effect of clay content on the mixtures. However this ratio can be increase or decrease in percentage of use based on type of soil, water ratio, chemical effect depends on the material used and method preparation. Based on the previous study, the use of lime have been decided to have in four different percentage start from 4% to 10% and for CRB

decided to use only two percentage with smaller percentage and bigger percentage. Figure 3 shows preparation of sample for compaction test.

Figure 3: Compaction test preparation   **Figure 4**: Consolidation test preparation

Consolidation Test

This laboratory test was conducted to determine the magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures. From the measured data, the consolidation curve (stress-void ratio relationship) can be plotted. This data is useful in determining the compression index and other consolidation characteristics of soil (Cc and Mv). The soil sample is placed inside a metal ring with a porous stone at the top of the sample and another at the bottom. The samples are 63.5 mm in diameter and 25.4 mm thick. Load on the sample is applied through a lever arm and compression is measured by a micrometre dial gauge. The sample is kept underwater during the test. The load applied was 1 kg, 2 kg, 4 kg and 8 kg consistently. This been repeated conventionally, on the first sample clay soil, 8% CRB and (4% to 10%) of lime and second sample clay soil, 16% of CRB and (4% to 10%) of lime, the load is doubled, thus doubling the pressure on the sample, while measurement of the compression continues. At the end of the test, the dry weight of the test sample is determined. However this ratio can be increase or decrease in percentage of use based on type of soil, water ratio, chemical effect depends on the material used and method preparation [1]. Figure 4 shows preparation of sample for consolidation test.

EXPERIMENTAL RESULTS

Standard Compaction Test

Standard compaction tests were conducted to determine the optimal moisture content and maximum dry density for soil stabilized with different contents of lime and CRB. Figure 5 and figure 6 show standard strength characteristics of the weak clay soil, improved by rubber powder and lime with using various configurations. Figure 5 shows the strength based 8% have reached the optimum results and will increase parallel as the amount of CRB and lime increases. However, in Figure 6 also shows results increasing parallel but with better results, because the maximized amount of CRB does affect the sample, 8% of CRB does not affect much with the

soil. The clay soil mixed with lime and CRB. Clay soil was added in varying proportions of 8% and 16% of rubber powder and 4%, 6%, 8% and 10% of lime. The treatment of the samples with lime and CRB content changed the optimal moisture and maximum dry density values of the samples, and the optimal moisture content increased with increasing lime and CRB content for all the samples. Also the maximum dry density increased with increasing of lime and CRB content. The procedures used in carrying out these tests based on [2].
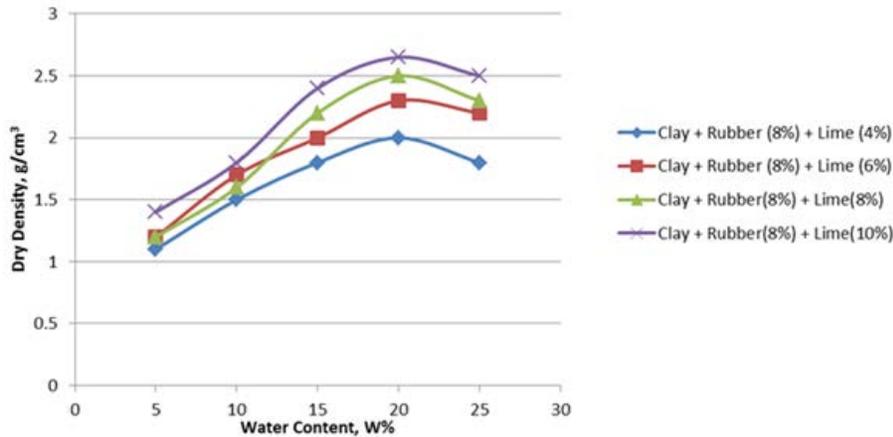
Figure 5: Compaction test result based on 8% CRB with various percentage of lime used
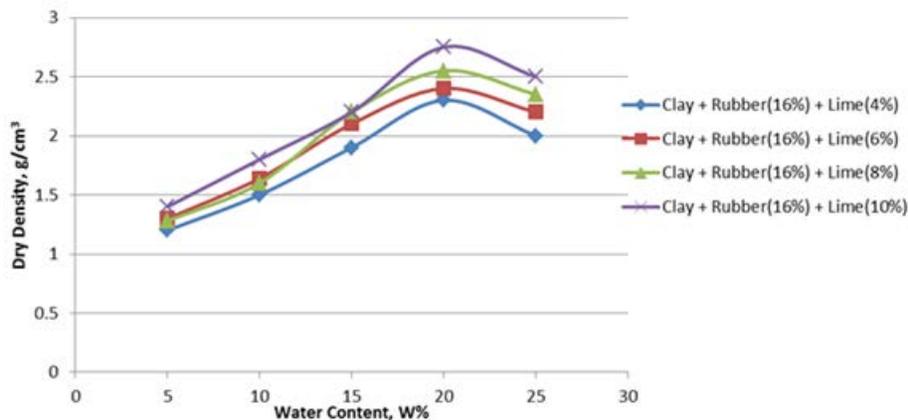

Figure 6: Compaction test result based on 16% CRB with various percentage of lime used

In Figure 7 shows the comparison between both samples, and clearly stated that clay, rubber powder 16% and lime 8% have better strength compare to the one with less amount of rubber powder. It does not collaborate with lime clay soil as expected. The test samples were carefully prepared by maintaining uniformity in density, moisture content and curing time in order to ensure a fair assessment of the effects of the admixture on the geotechnical properties. The testing for stabilized soils was being done by giving a specific period for enhancing the stabilization reaction. It is observed that by increasing lime and rubber powder content, maximum dry density decreases and optimum moisture content increases. Also, when lime is added to soil, instantaneous reaction as cation exchange occurs, and clay particles flocculate together. This process leads to formation of air voids among particles and makes creation of a porous medium

with lower maximum dry density. Furthermore, more water is necessary for filling voids, so optimum moisture content is increased. The maximum dry density and optimum moisture content decreased slightly by addition of rubber powder.
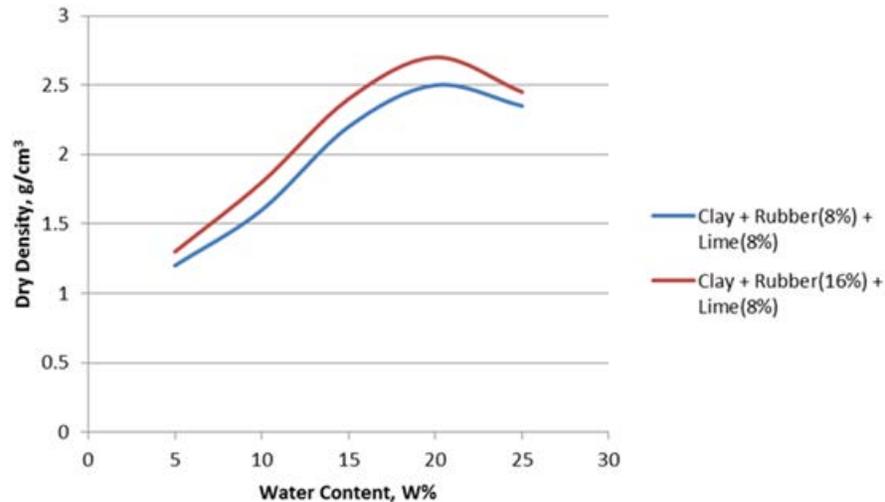

Figure 7: Comparison of 8% and 12% of CRB used

Consolidation Test

Consolidation characteristics of soil based on the rate and amount of consolidation settlement, coefficient of consolidation, settlement and void ratio of the samples were studied in this paper. The amount of settlement is related to the compression index, Cc and coefficient of volume change, Mv. This parameter assumes importance in the preloading technique The test results may be expressed in a number of ways but in this study, two useful compressibility parameters are compression index (Cc) and coefficient of volume compressibility (mv). From the changes in thickness at the end of each load stage the compressibility of the soil observed, and parameters measured such as Compression Index (Cc) and Coefficient of Volume Compressibility (mv). Moreover, the strength of samples was investigated, for evaluating the effect of lime and rubber powder on strength properties of soil. Figure 8 and Figure 9 below contain the graphs that achieved by the void ratio and effective vertical stress in log scale (e–σ'p) for sand, CRB and lime composites with a various amount of percentages as (8% and 16%) of rubber powder and 4%,6%,8% and 10% of lime.
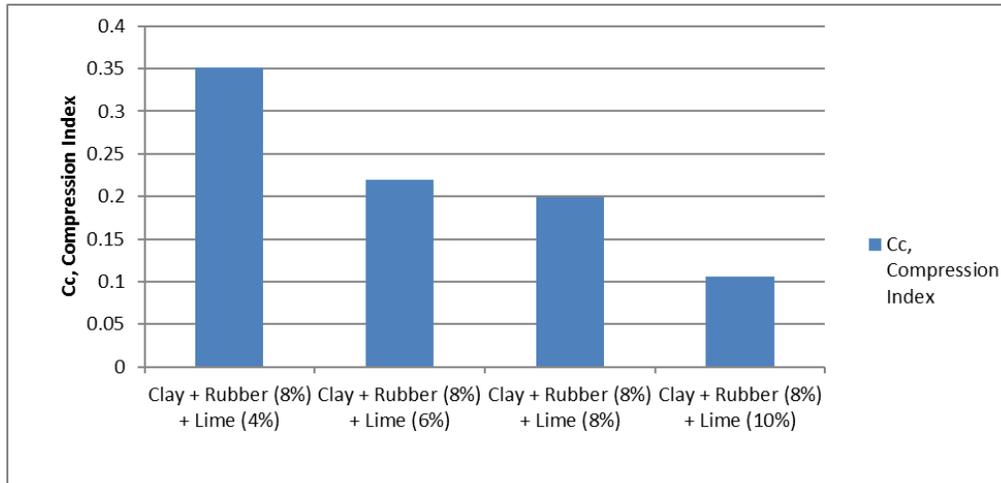
Figure 8: Cc test result based on 8% CRB with various percentage of lime used
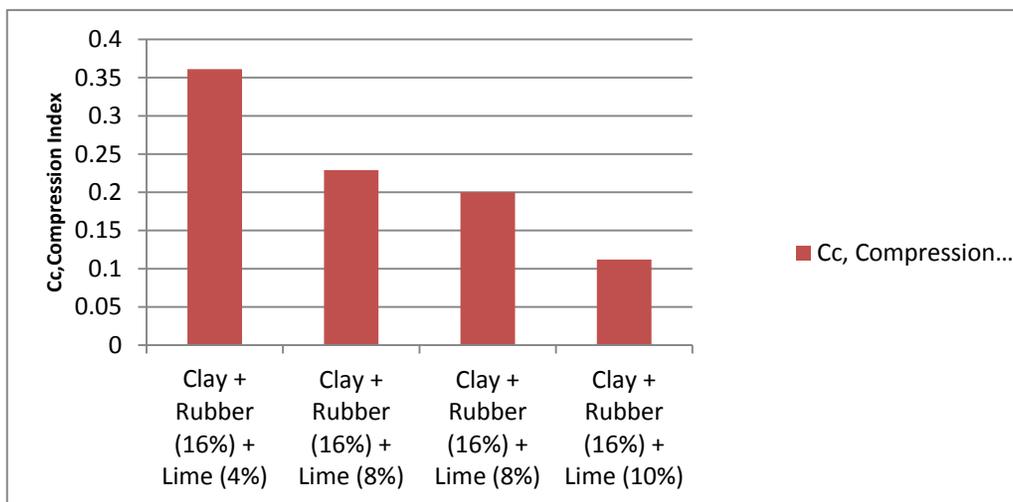

Figure 9: Cc test result based on 16% CRB with various percentage of lime used

Figure 8 and Figure 9 show the compression index Cc of the two different lime-rubber treated clay sample. It is clear from the Figure 8 and 9 shows that the coefficient of consolidation decreases almost linearly with increasing consolidation pressure, however the effect is more significant for samples subjected to vertical consolidation, may be due to the rearrangement of admixture. This finding is in agreement with the theory of consolidation which stated that the coefficient of rate of consolidation decreases with increasing consolidation pressure. However, comparison of Figures 8 and 9 indicates that the decrease is more significant for the sample subjected to vertical drainage some different pattern and the void ratio has some increase in value. This is due to unforeseen error in the procedure during the laboratory works. As shown in the Figure 8, the compressibility reduced in value when the maximized rubber powder and lime mixture was added to the clay. The soil become denser and stiffer, hence the compressibility was decreased. The chemical also acts as a binder that will interlock the rubber powder and lime.
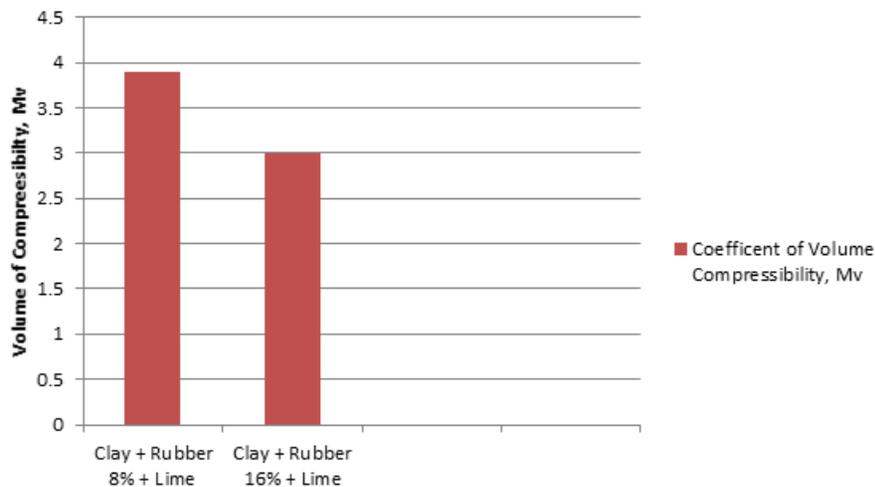
Figure 10: Comparison of average of Coefficient of Volume Compressibility, Mv for 8% and 16% of CRB with various percentage of lime

The volume change may be expressed in terms of void ratio or specimen thickness. This parameter is very useful to estimate the primary consolidation settlement. Figure 10 shows the average results of coefficient of volume compressibility on lime, rubber powder and clay on both samples. It can be noticed that the average coefficient of volume compressibility decreases with increasing the stabilizer content. This could probably be due to pozzolanic reaction taking place within the soil which in turn changes the soil matrix. The free calcium of the lime exchanges with the adsorbed cations of the clay mineral, resulting in reduction in size of the diffused water layer surrounding the clay particles and the maximum number of rubber powder that make increases the sediment.

CONCLUSION

The second phase of the chemical reaction involves pozzolanic reactions within the lime-soil mixture, resulting in strength gain over time. When lime is combined with a clay soil, the pH of the pore water increases. As long as, there is sufficient calcium from the lime to combine with the soluble silica and alumina, the pozzolanic reaction will continue as long as the pH remains high enough to maintain the solubility of the silica and alumina. In addition to pozzolanic reactions, carbon from rubber powder can also lead to long-term strength increases for soils stabilized with lime. This shows that when rubber chips were added to lime and clay, the specimen became stiffer because rubber chips will transform the soil into a semi-granular material just like sandy clay and also acts as a flexible cushion to reduce the settlement of permanent. It proves that in this study, rubber chips acts more like filler or a light-weight semi-granular material for the stabilised soils. Small amount of 8% rubber powder and 10% lime, did not contribute much to stiffness improvement of the soil. However, when adding more rubber powder and lime in excess of 16 % rubber powder and 10% are able to increase the stiffness of the soil compared to specimen without rubber chips. Generally, when maximum amount of rubber powder and lime added to clay soil, a significant improvement in reduced settlement was seen. This study has shown that treatment of soils using lime- rubber can be used effectively in the stabilization of challenging clay soils. In short, this innovative material is able to make use of an industrial waste, economical and environment friendly.

ACKNOWLEDGEMENTS

REFERENCES

1. ASTM D 2435, "Standard Test Method for One-Dimensional Consolidation Properties of Soils"

2. ASTM D 698, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort"

3. ASTM D 854-00, "Standard Test for Specific Gravity of Soil Solids by Water Pycnometer"

4. Amiralian, S. Chegenizadeh, A. and Nikraz.H. (2012), "Laboratory Investigation on the Effect of Fly Ash on the Compressibility of Soil" International Conference on Civil and Architectural applications (ICCAA'2012). 18-19.

5. Bekhiti, M. Trouzine, H. and Asroun, A. (2014), "Properties of Waste Tire Rubber Powder" Engineering, Technology & Applied Science Research.4: 669-672.

6. Hambirao,G.S. and Rakaraddi,P.G. (2014), "Soil Stabilization Using Waste Shredded Rubber Tyre Chips" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).11: 20-27

7. Ho, M, H. and Chan, C, M. (2010), "The Potential of Using Rubberchips as a Soft Clay Stabilizer Enhancing Agent" Modern Applied Science. Universiti Tun Hussein Onn Malaysia. Malaysia.

8. Sellaf, H., Trouzine, H., Hamhami, M. and Asroun, A. (2014), "Geotechnical Properties of Rubber Tires and Sediments Mixtures Engineering", Technology & Applied Science Research.4: 618-624.

9. Edy Tonnizam Mohamad, Nima Latifi, Aminaton Marto, Razieh Moradi, and Seyed Vahid Alavi Nezhad Khalil Abad: "Effects of Relative Density on Shear Strength Characteristics of Sand-Tire Chips Mixture" *Electronic Journal of Geotechnical Engineering*, 2013 (18.D) pp 623-632. Available at ejge.com.

10. Marto, A., Latifi, N., Moradi, R., Oghabi, M., & Zolfeghari, S. (2013) "Shear Properties of Sand – Tire Chips Mixtures" *Electronic Journal of Geotechnical Engineering*, 18(B), 325-334. Available at ejge.com.

11. Akshaya Kumar Sabat and Subasis Pati: "A Review of Literature on Stabilization of Expansive Soil Using Solid Wastes" *Electronic Journal of Geotechnical Engineering*, 18(B), 325-334. Available at ejge.com.

12. Amin Eisazadeh, Khairul Anuar Kassim, and Hadi Nur: "Physicochemical Characteristics of Phosphoric Acid Stabilized Bentonite" *Electronic Journal of Geotechnical Engineering*, 2013 (18.D) pp 623-632. Available at ejge.com.

13. Omid Azadegan, S. Hadi Jafari, and Jie Li: "Compaction Characteristics and Mechanical Properties of Lime/Cement Treated Granular Soils" *Electronic Journal of Geotechnical Engineering*, 2012 (17.P) pp 2275-2284. Available at ejge.com.

14. Amin Chegenizadeh and Hamid Nikraz: "Numerical Shear Test on Reinforced Clayey Sand" *Electronic Journal of Geotechnical Engineering*, 2012 (17.E) pp 577-592. Available at ejge.com.