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STABILIZATION OF MARINE CLAY USING BIOMASS SILICA-RUBBER CHIPS MIXTURE

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Abstract. Marine clay is found widely along the coastal area and had caused expensive solutions in the construction of coastal highways. Hence, soil stabilization was suggested by some consultant to increase the strength of this soil in order to meet the highway construction requirement and also to achieve the specification for the development. Biomass Silica (BS), particularly the SH85 as a non-traditional stabilisation method, has been gaining more interest from the engineers recently. Rubber chips (RC), derived from waste rubber tyres, are considered 'green' element and had been used previously in some geotechnical engineering works. This paper presents the effect of using BS and RC as a mixture (BS-RC mixture), to increase the strength of marine clay for highway construction. Samples of marine clay, obtained from the West Coast Expressway project at Teluk Intan, Perak, were oven dried and grind to fine-grained sized. The marine clay was mixed with 9 % by weight proportion of BS-RC; that were 8%-1% and 7%-2%, respectively. For comparison purposes the result of BS-RC was compared to the result of stabilization by using 9% BS only. Laboratory tests were then carried out to determine the Atterberg limits and compaction characteristics of the untreated and treated marine clay. The Unconfined Compressive Strength (UCS) of the untreated and treated marine clays, compacted at the optimum moisture content was later obtained. The treated marine clay was tested at 0, 3 and 7 days curing periods. The results show that the Plasticity Index of BS-RC treated marine clay was lower than the untreated marine clay. From the UCS test results, it is shown that BS-RC mixtures had significantly improved the strength of marine clay. With the same percentage of 9% BS-RC, the increased of BS from 7% to 8% increased the UCS further to about six times more than untreated marine clay soils in 7 days curing period. The strength gained by using BS-RC at 8%-1% is slightly below the strength by using 9% BS only. From the experimental results, it is shown that BS, in the form of SH85, admixed with rubber chips could significantly improve the strength of marine clay soils.

1. Introduction

Marine clay can be found widely in the ocean bed and onshore as well. This situation differ the properties of marine clay from moist soil and dry soil. Marine clay is microcrystalline in nature and clay minerals like chlorite, kaolinite and illite and non-clay minerals like quartz and feldspar are present in the soil [1]. Malaysian onshore are covered by large areas of marine clay, in particular the currently undergoing West Coast Expressway project is aligned through a few types of soft soils where the major soil type is the marine clay, it is one of the problematic soft soils and should be pre-treated to enhance the usability and serviceability of the constructed highway [2]. Marine clay is characterised by low permeability and has the capability in attenuation of inorganic contaminants [3].

Among the methods used to improve the soft soil is through soil stabilization. It is a process of enhancing the existing material properties to the requirement and specification at the project site [4]. The common method in soft soil improvement process is to remove the soft soil, and replace it with a stronger and good material. However the high cost of replacement incurred alerted highway agencies to explore an alternative methods of highway construction on soft subgrades [5]. One considered economical soft soil stabilization method is chemical stabilized method [5], [6], [7]. Researchers such

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as [8], [9] had studied the use of biomass as a stabilizing chemical in enhancing marine clay properties. While other researcher [10], had studied the combination of chemical and rubber chips in stabilizing the soft soil.

Rubber chips are waste products that could easily be obtained from rubber industry. Figure 1 shows the consumption of rubber in the world. There are numerous researchers [11], [12], [13] showed the possibility of utilization of rubber chips in various different civil engineering application.

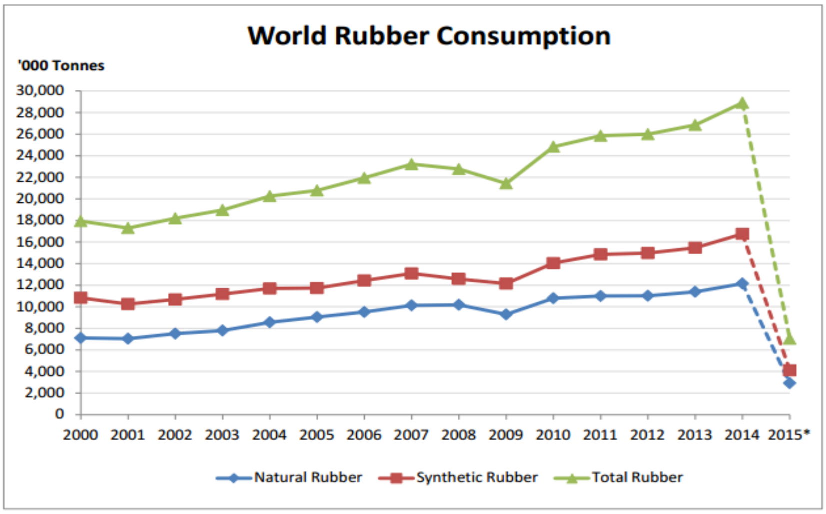

Figure 1. World Rubber Consumption, 2000 – 2015 (Natural Rubber Statistics, 2015) *January – March 2015. Source: International Rubber Study Group, IRSG

While based on the previous research carried out by Latifi *et al.* [14], it was identified that the Biomass Silica chemical additives of SH85 could improve the soil characteristics of marine clay significantly. Hence, it was hypothesized that the combination of chemical-rubber chips mixtures is therefore a more effective soil stabilization agent. Besides to investigate the usability of chemical-rubber chips mixtures as the stabilizing agent in improving the soil characteristics of marine clay from the two engineering perspective of the strength and the compressibility, this paper also aim to compare the results of UCS for treated clay sample using two methods (SH85-RC and SH85 only). In this study, rubber had been cut into small pieces (passing 2 mm sieve size) to produce rubber chips, so that size effects could be prevented [10].

2. Material Selection and Characterization

The marine clay soils used in this study had been sampled and brought from Teluk Intan, Perak, which were taken at 1.2 m to 1.5 m depth. All tests had been carried out at Geotechnical Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia. The results of the soil properties are shown in Table 1.

Table 1. The properties of marine clay of Teluk Intan, Perak

Properties	**[7]**	**This study**
Liquid limit	78%	78%
Plastic limit	46%	47%
Plasticity index	32%	31%
Specific gravity	2.63%	2.5%
Loss of ignition	1.2%	-
USCS classification	OH	MH
Standard Proctor Compaction :		
Maximum dry density, MDD (Mg/m^3)	-	1.21
Optimum moisture content, OMC	-	40%

The BS soil stabilizer added to marine clay is the chemical additives (SH85) in the form of powder, obtained from Probase Soil Stabilizer Sdn. Bhd. While the rubber chips with particle size smaller than 2 mm diameter (cleared of any dust) were obtained from the third party. The treated and untreated marine clay samples were prepared in accordance to the results of compaction test. The proportional of each soil specimen was prepared based on the optimum moisture content (OMC) and the maximum dry density (MDD). In this study the amount of the SH85-RC mixtures was fixed as 9 % (7%+2% and 8%+1%) by weight while the specimens prepared by [7] were mixed with 9% SH85 only.

2.1 Preparation of samples

The cylindrical clay soil samples were prepared in the dimension of 38 mm in diameter and 76 mm in height at moisture content of the optimum moisture content, OMC (obtained from the compaction test) for the Unconfined Compressive Strength (UCS) test.

The UCS test was carried out to determine the UCS of treated and untreated marine clay specimens. The dry marine clay with addition of the additives and the rubber chip was mixed thoroughly using palette knives to form homogeneous soil mixtures. The soil mixtures were then transferred to steel cylindrical mold. Then the mold was compressed in the hydraulic jack to obtain the cylinder specimen shape. After the compaction, the specimen was removed by using steel plunger slowly to avoid the fracturing of the specimen. The specimen was weighted then was placed in the polythene bottle then placed in the container with room temperature 27 ºC. The cylindrical soil specimens were tested at three different curing periods of 0, 3 and 7 days. In UCS tests, the soil mixtures were sheared at a constant strain rate of 1.52 mm/min [15] until the soil developed an obvious shearing plane or excessive soil deformations. The maximum load per unit area was defined as UCS [2]. Figure 2 and Figure 3 show the UCS test equipment and typical specimen of UCS test respectively.

Figure 2 Unconfined Compressive Strength Test Equipment

Figure 3 Unconfined Compressive Strength Typical specimen

3. Results and Discussions

Table 2 summarizes the UCS of the treated and the untreated marine clay at three different curing periods. The shear strength values were determined based on the peak stress of respective specimens. Since the researcher [2] only performed the test up to 7 days, the discussion further will only focus on the values of UCS at 7 days curing period.

Table 2. Summary results of Unconfined Compressive Strength test of the treated and the untreated clay soils at various curing times for two types of stabilization methods.

Soil Description	Unconfined Compressive Strength at various Curing Period (Days)			
	0	7	14	28
Untreated Clay	117 kPa			
Clay + 7%SH85 + 2% RC	314 kPa	498 kPa	-	-
Clay + 8%SH85 + 1% RC	392 kPa	685 kPa	-	-
Clay + 5%SH85	-	386 kPa	781 kPa	468 kPa
Clay + 7%SH85	-	568 kPa	632 kPa	686 kPa
Clay + 9%SH85	-	710 kPa	781 kPa	1216 kPa

Figure 4 shows that the compressive strength of the untreated clay soil is 117 kPa (control data) and the addition of SH85 to the soil has significant influences on the compressive strength of the soil. Moreover, it was clear from figure 4 that the compressive strength of the stabilized soil increases with increasing curing time [7].

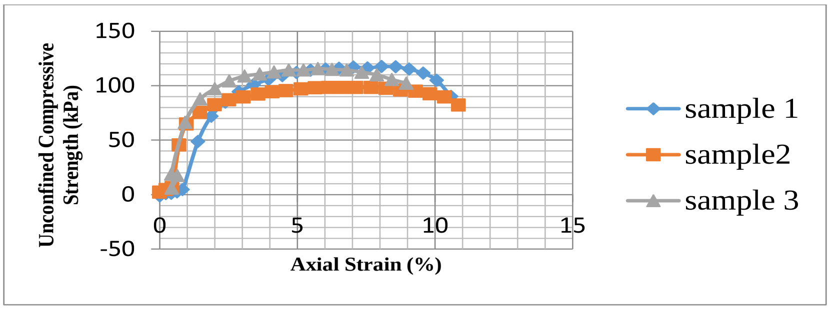

Figure 4. Unconfined Compressive Strength versus Strain for Untreated Clay

3.1 Soil Stabilization using the Combination of SH85 and Rubber chips

The results in Figures 5, 6 show the effect of using different amount of SH85 content (7% and 8%) and RC content (2% and 1%) for the SH85-RC treated samples. Apparently, the SH85-RC treatment significantly enhanced the strength characteristics of the marine clay.

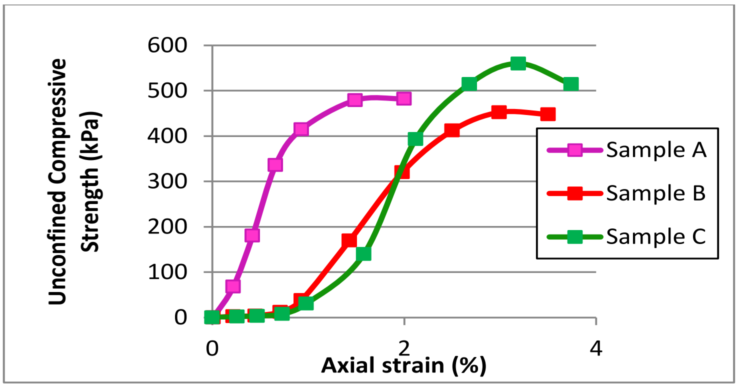

Figure 5. Unconfined Compressive Strength for 7%SH85+2%RC Treated Marine Clay Sample for 7 Days of Curing

Figure 5 show the results of three samples of SH85-RC (7%+2%) mixture. Based on the result, sample C giving the highest strength value of 560 kPa, while samples A and B are 482 kPa and 452 kPa respectively. The average strength of these three samples is 498 kPa.

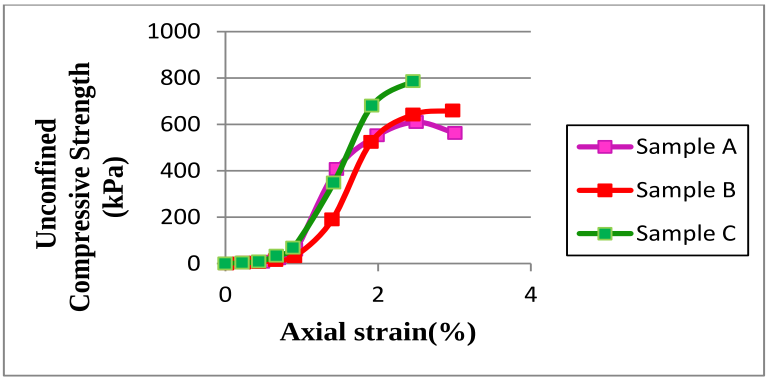

Figure 6. UCS for 8%SH85+1%RC Treated Marine Clay Sample for 7 Days of Curing

Figure 6 show the results of three samples of SH85-RC (8%+1%) mixture. Based on the result, sample C giving the highest strength value of 785 kPa, while samples A and B are 609 kPa and 659 kPa respectively. The average strength of these three samples is 685 kPa.

Based on the results from figures 5 and 6, it can be concluded that the increased of BS from 7% to 8% increased the UCS further to about six times more than untreated marine clay soils in 7 days curing period.

3.2 Soil Stabilization using SH85 only

Figures 7, 8 and 9 show the results of UCS tests of clay soil and stabilized mixture of clay soil with various amount (5%, 7%, and 9%) of SH85 for 7 days. The addition of SH85 significantly enhanced the strength characteristics of the marine clay. For the purpose of this study, only result of 9% SH85 sample will be used for comparison.

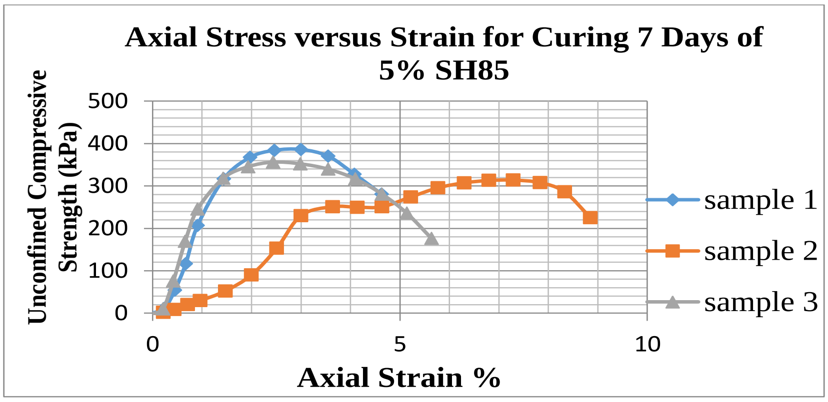

Figure 7. Strength versus Strain for three samples of 5% SH85, sample 1, 2 and 3 at 7 Days

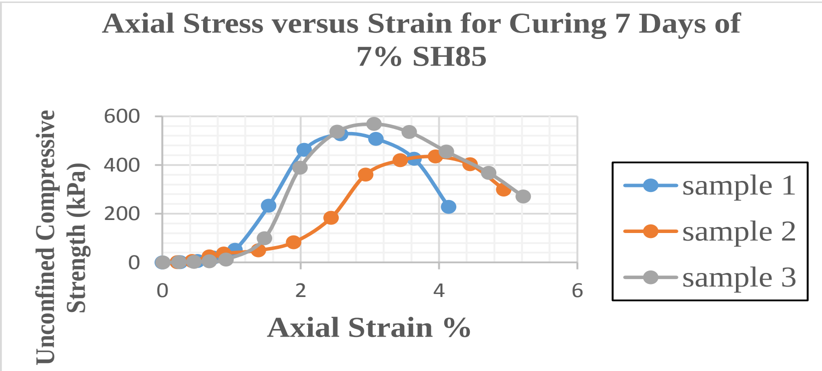

Figure 8. Strength versus Strain for three sample of 7% SH85, Sample 1, 2 and 3 at 7 Days

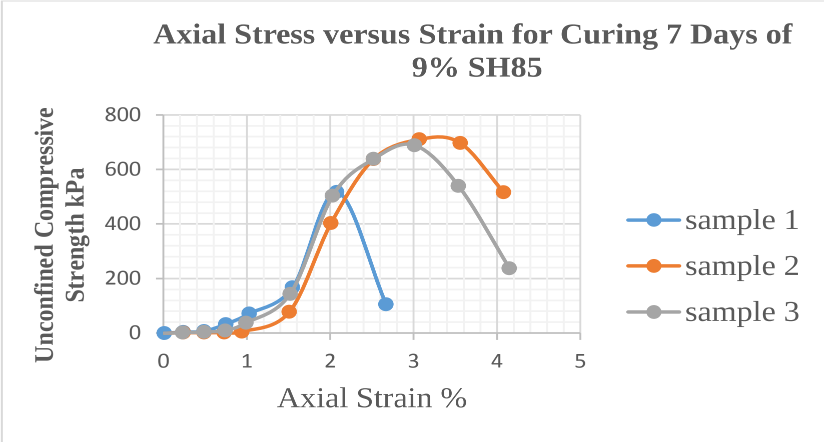

Figure 9. Strength versus Strain for three samples of 9% SH85, sample 1, 2 and 3 at 7 Days

4. Conclusion

This study has demonstrated the benefits of reusing chips of scrap tires to reinforce a cohesive soil. The Biomass Silica (in the form of SH85) and the Biomass Silica-rubber chips (BS-RC) mixture used as stabilizer, affect the strength of the marine clay.

The BS and BS-RC are suitable as improvement methods to be applied in geotechnical engineering works, particularly for marine clay. The unconfined compressive strength value of 8%BS-1%RC and 7%BS-2%RC mixture showed significant differences. It showed that the strength of 8%BS-1%RC was higher compared to 7%BS-2%RC, indicated that the addition of BS increased the strength of marine clay. Hence, the 8%BS-1%RC has been selected as the optimum amount mixture for stabilizing of marine clay soils. Besides that the increment of UCS was affected by curing periods. This is due to the existence of BS in the mixture that act as binders and interlock the rubber chips and the marine clay particles. As the curing time increased the void ratio decreased thus increased the strength of the treated soil.

The addition of rubber chips also influenced the strength of marine clay sample. The intention of using rubber chips was to reduce the construction cost as well as to promote the environmental-friendly method of soil stabilization. Based on this study, it showed that the strength of marine clay sample treated with 8%BS-1%RC increased the UCS to 685kPa while the strength of marine clay sample treated with 9%BS only increased the UCS to 710 kPa at 7 days curing period. The close strength obtained could be used as a conclusion that the Biomass Silica-rubber chips mixture is a promising 'green' method for the improvement of marine clay.

References

[1] S. Basack and R. D. Purkayastha, "Engineering properties of marine clays from the eastern coast of India," vol. 1, no. 6, pp. 109–114, 2009.

[2] A. Marto, N. Aziz, M. R. Jahidin, N. Zurairahetty, M. Yunus, F. Kasim, C. S. Tan, S. Engineering, J. Serdand-kajang, M. H. Authority, and F. Paper, "Jurnal Teknologi," vol. 2, pp. 103–108, 2015.

[3] Z. A. Rahman, W. Z. W. Yaacob, S. a. Rahim, T. Lihan, W. M. R. Idris, and W. N. F. Mohd Sani, "Geotechnical characterisation of marine clay as potential liner material," *Sains Malaysiana*, vol. 42, no. 8, pp. 1081–1089, 2013.

[4] A. Modarres and Y. M. Nosoudy, "Clay stabilization using coal waste and lime — Technical and environmental impacts," *Appl. Clay Sci.*, 2015.
[5] A. Senol, T. B. Edil, M. S. Bin-Shafique, H. a. Acosta, and C. H. Benson, "Soft subgrades' stabilization by using various fly ashes," *Resour. Conserv. Recycl.*, vol. 46, no. 4, pp. 365–376, 2006.
[6] P. G. Nicholson, "Admixture Soil Improvement," *Soil Improv. Gr. Modif. Methods*, pp. 231–288, 2015.
[7] N. Amalina and A. Rahman, "Unconfined Compressive Strength and Microstructure of Clay Soil Stabilized by SH85," Final Year Project Thesis, faculty of Civil Engineering, Universiti Teknologi Malaysia (unpublished).
[8] S. Vichan, R. Rachan, and S. Horpibulsuk, "Strength and microstructure development in Bangkok clay stabilized with calcium carbide residue and biomass ash," *ScienceAsia*, vol. 39, no. 2, pp. 186–193, 2013.
[9] S. Wang, "Cofired biomass fly ashes in mortar: Reduction of Alkali Silica Reaction (ASR) expansion, pore solution chemistry and the effects on compressive strength," *Constr. Build. Mater.*, vol. 82, pp. 123–132, 2015.
[10] A. M. B. Mokhtar, B. C. Chan, and P. Raja, "EFFECT OF USING CEMENT ADMIXED WITH RUBBER CHIPS ON THE," 2007.
[11] D. Tapas and S. Baleshwar, "BENEFITS AND IMPACTS OF SCRAP TYRE USE IN GEOTECHNICAL ENGINEERING," vol. 7, no. 3, pp. 1262–1271, 2013.
[12] R. Ayothiraman, "Improvement of Subgrade Soil With Shredded Waste Tyre Chips," pp. 365–368, 2011.
[13] B. Singh and V. Vinot, "Influence of Waste Tire Chips on Strength Characteristics of Soils," vol. 5, no. 9, pp. 819–827, 2011.
[14] N. Latifi, A. Marto, and A. Eisazadeh, "Structural Characteristics of Laterite Soil Treated by SH85 and TX-85 (Non-Traditional) Stabilizers," *Electron. J. Geotech. Eng.*, vol. 18 H, pp. 1707–1718, 2013.
[15] O. F. Soils, F. O. R. E. Analysis, O. F. Nuclear, and P. Plants, "Laboratory Investigations of Soils and Rocks," no. December, 2003.