Stabilization of Marine Clay by Biomass Silica (non-traditional) stabilizers

Aminaton Marto [1,a], Nor Zurairahetty Mohd Yunus [1,b], Faizal Pakir[1,2,c*], Nima latifi[1,d], Ahmad Hakimi Mat Nor[2,e] and Choy Soon Tan[1,f]

[1]Faculty of Civil Eng., Universiti Teknologi Malaysia (UTM), Malaysia

[2]Faculty of Civil and Env. Eng., Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia

[a]aminaton@utm.my, [b]nzurairahetty@utm.my, [c]faizalpakir812@gmail.com, [d]en_latifi@yahoo.com; [e]ahakimi@uthm.edu.my; [f]cstan8@live.utm.my

Key words: Marine Clay, UCS, Soil Stabilization, Biomass Silica

Abstract. The presence of marine clay in Iskandar Malaysia Region, Nusajaya had caused expensive solutions in the construction of structures and roads. Alternatively, soil treatment is suggested to increase the strength of the unsuitable material to meet the constructions requirement for foundation and also to achieve the specifications for development work. In this study, a series of laboratory test has been conducted to determine the potential of Biomass Silica (BS), one of the commercial brands namely "SH-85" to stabilize marine clay to form the basis of a strong, reliable land for construction of roads and building. Testing program involves obtaining specimens of marine clays from various locations at Iskandar Malaysia Region, followed by laboratory tests to determine the Atterberg limits and Unconfined Compressive Strength (UCS) for treated and untreated of marine clay soils. The proportions of BS added were 3, 6, 9, 12 and 15% and tested at 0, 3, 7 and 28 days curing periods. The results shows that the Plasticity Index (PI) was reduce with increment of BS content. While, an addition of BS content increase in strength treated soils 60 times more than untreated soils, which is gain in early 7 curing days period. This finding indicates the BS is a suitable stabilizer for the marine clay to become strong foundation for construction of road and building.

Introduction

Soil stabilization refers to the procedure in which a special soil, a cementing material, or other chemical material is added to a natural soil to improve one or more of its properties. One may achieve stabilization by mechanically mixing the natural soil and stabilizing material together so as to achieve a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposit and obtaining interaction by letting it permeate through soil voids. Where the soil and stabilizing agent are blended and worked together, the placement process usually includes compaction.

A difficult problem in civil engineering works exists when the sub-grade is found to be clay soil. Soils having high clay content have the tendency to swell and shrink when their moisture content is allowed to change[1,2]. In order to address that problem, many research have been done on the subject of soil stabilization using various additives, the most common methods of soil stabilization of clay soils in pavement work are cement and lime stabilization. The high strengths obtained from cement and lime stabilization may not always be required, however, and there is justification for seeking cheaper additives which may be used to alter the soil properties.

Biomas Silica (BS) is the one non-traditional chemical soil stabilizer, are used in some geotechnical projects in Malaysia. Previous research shows that the chemical composition presents in the BS almost the same as a combination of cement and lime which consists of mainly Calcium oxide (CaO) [3]. Some researcher reported that this stabilizer agent increase strength with curing time while SEM results indicated that this stabilizer agent filled the porous areas inside the soil by forming cementation gel [3,4]. This phenomenon led to a better and stronger aggregate of soil particles and finally formed denser soil.

Experimental Program

The consistency limit tests were carried out in accordance with (BS 1377: Part 2: 1990: 4) to determine the influence of the stabilizer on the Atterberg limits of the treated and untreated soils. The samples was dried, crushed and sieved passing 425 μm (in accordance with BS) and containing various contents of different stabilizer to establish the influence of the stabilizer on the Atterberg limits. Deionizer water was used in all preparation samples to avoid any distraction or contaminated by chemical.

A series of Standard Proctor Compaction tests based on the BS 1377: Part 4: 1990 (clause 3.3.4.1) was conducted to determine the optimum moisture content (OMC) and maximum dry density (MDD) to be used for the preparation of test specimens. All preparation samples were done by controlling the bulk density and moisture content to avoid influences of these variables at the strength of stabilization soil. The samples were prepared by 90% OMC (wet side) and 90% of MDD of natural soils. Dry material of marine clay with addition of BS was thoroughly mixed before slowly adding the pre-calculated amount of water. Intermittent hand mixing with palette knives was necessary to achieve a homogeneous mix. A steel mould fitted with a collar, so as to accommodate all the mixtures, was used to compress the cylinders to the target dry density and moisture content. Before compact the soil in the mould, the inside of the mould was coated with lubricant in order to lessen the chance of fracturing of specimens during removal After compaction in a hydraulic jack, the cylinders were extruded using a steel plunger, cleaned of releasing oil and put in the polythene bottle and placed above water in a closed container in a room where the temperature 27±2°C. The humidity and temperature were maintained by the water. The samples were cured for 0, 3, 7, and 28 days. Three specimens were used for each mix and curing period and the average strength value was determined. After curing, unconfined compression strength (UCS) test was conducted and the water content was also determined. A minimum of three tests were conducted for each combination of the variables.

Materials

The marine clay in this study was dredged from the seabed offshore the southern coast of the Nusajaya Region, Johor Malaysia, where a harbor project is under construction and dumped this soil to the other site. It was dark grey in color and highly disturbed by dredging. The dredged clay collected in oil tanks and transported to the laboratory. Table 1 shows the physical properties of this soil.

Table 1 Physical Properties of Marine Clay soils

Physical Properties	**values**
Liquid Limit, LL (%)	58
Plastic Limit, PL (%)	23
Plastic Index, PI (%)	35
Maximum Dry Density, MDD (kg/m^3)	1600
Optimum Moisture Content, OMC (%)	21
90% optimum moisture content at wet side (%)	28
Unconfined Compressive Strength, UCS (kPa)	23

The Biomass Silica (BS) of stabilizer agent utilized in this study with the commercial name ‘SH-85’ was supplied by Probase Manufacturing Sdn Bhd, a local company in Johor state of Malaysia.

Results and Discussion

Atterberg limits

The results of the Atterberg Limits test (LL, PL and PI) on the samples are shown in Fig. 1. The liquid limit (LL), plastic limit (PL) and plasticity index (PI) of the untreated marine clay are 58%, 23% and 35% respectively. Besides, the addition of varying percentages of stabilizers caused a change in the Atterberg Limits (LL, PL and PI) of all samples. As shown in Fig. 1, LL of the soil decreased significantly while PL increase with addition of BS and the constant after 6% BS content. Liquid limit of the soils was obtained at 58% and decrease to 54% after addition stabilizer at 3%, then decline slowly to 6% BS and then constant at 53% afterward. It was suggested that the significant reduction of liquid limit immediately after the addition of BS is due to the depression of double layer, resulting from the crowding of calcium ion Ca^{2+} concentration on clay surface [5]. The reduction in liquid limit along with the increase in plastic limit produced a considerable reduction in the PI of soils. This result is the same as the finding previous research [6].

A very small quantity of BS is required to bring changes in plasticity. In most cases the effect of stabilizer at plasticity clay is instantly, calcium ions from the stabilizer which causes reduction of plasticity, increase friability of the soil and more easily work. This is because of the increase of coagulation and aggregation of the clay mineral particles under the influence of the calcium ions. The increase of the optimum moisture content is because of the increased void volume of the specific surface area. Moreover, extra additions of stabilizer improved coagulation, which increased the water holding capacity.

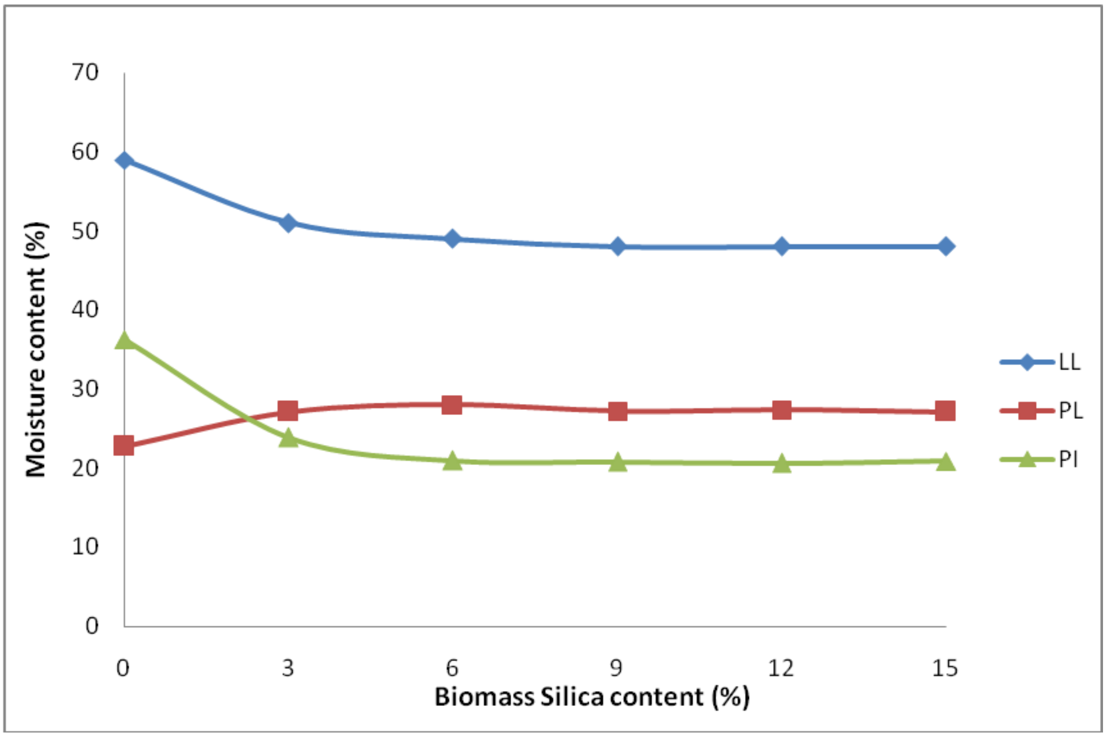

Figure 1: Atterberg limits of marine clay soils after addition of Biomass Silica (BS)

Unconfined Compressive Strength (UCS)

Fig. 2 shows the effect of varies BS content on shear strength of marine clay. The shear strength values were determined based on the peak stress of respective specimens. It can be seen that the increased in BS contents leads to an increase in the unconfined compressive strength (UCS). The strength value increased gradually at BS content of 3% for all specimens at different curing period. Progressives increased in strength were achieved when more than 3% BS added to the soil. In addition, based on Fig. 2 further increased in strength was continued with increasing BS content up to 15% of stabilizer content. For instance the highest strength value obtained by addition of 15% BS on marine clay was 1376 kPa as compared to only 23 kPa achieved on untreated marine clay. Less significant improvement obtained at lower BS content was believed due to insufficient BS content to form significant amounts of cementing products. It was suggested that the ion calcium in BS only sufficient for flocculation and coagulation process. The material stabilized with relatively higher BS levels of 6% and above of BS addition improved the strength after the prolonged curing period. Furthermore, the stabilized material showed superior strength development.

Fig. 3 shows the effect of curing time on BS-treated marine clay at different stabilizer contents. All the soil samples were cured for 3, 7 and 28 days. The shear strength increases significantly during the early stage of modification process and start to be constant after 7 curing days for specimens with addition of less than 6% of BS content. However further increased in strength was achieved with addition higher content of BS (i.e. beyond 9%). For instance, the shear strength of the 12% BS achieved 1150 kPa at 28 days, which was approximately 50 times greater than the strength of the untreated marine clay. Overall, we can see that the strength tremendous increased with addition BS content then increase slightly from 12% to 15% of BS content. It was concluded that the 12% of BS was sufficient for selected marine clay soils.

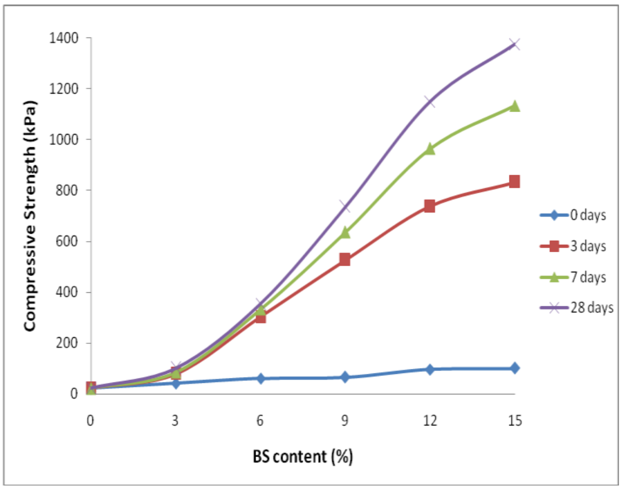

Figure 2: UCS versus BS content

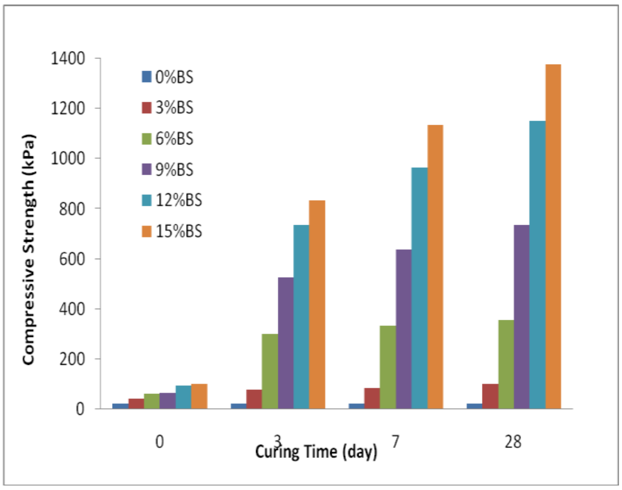

Figure 3: UCS of marine clay with curing time

Conclusion

From the result of this study it can be concluded that the addition of the Biomass Silica on the soil can affect the properties and strength of the soil.

- The liquid limit of the soil decreases while plastic limits increase with an increasing of biomass Silica. As a result, the Plastic Index (PI) reduces with the increment of Biomass Silica (BS) content.
- The liquid limit of the soil decreases while plastic limits increase with an increasing of biomass Silica. As a result, the Plastic Index (PI) reduces with the increment of Biomass Silica (BS) content.

- The addition of Biomass Silica increase strength of soils. The strength gain increase at early 3 days after stabilization and constant increase from 7 to 28 days curing period. The results indicated that the BS is stabilizing agent.
- The results of unconfined compressive strength test showed that 12% of BS was the optimum amount of this stabilization process for marine clay soils.

Acknowledgments

The authors gratefully acknowledged the financial supports by the Universiti Teknologi Malaysia (UTM) under the Potential Academic Staff (Vot 00K65) and also the Ministry of Education (MOE), Malaysia and Universiti Tun Hussein Onn Malaysia (UTHM) through the PhD scholarship. The support of the Construction Research Centre and Construction Research Alliance of UTM is also acknowledged.

References

[1] L. Bjerrum, "Geotechnical Problems involved in Foundations of Structures in the North Sea," *Geotechnique*, vol. 23, no. 3, pp. 319–358, 1973.

[2] A. H. Mat Nor, M. I. H. Mohd Masirin, and M. E. Sanik, "Site Investigation Of Road Drains For Rural Road On Batu Pahat Soft Clay (BPSC)," *IOSR J. Mech. Civ. Eng.*, vol. 11, no. 2, pp. 12–19, 2014.

[3] S. M. Lim, D. C. Wijeyesekera, and H. Bakar, "Critical Overview of Laboratory Assessments used in Soil Road Design," pp. 1–9.

[4] N. Latifi, A. Marto, and A. Eisazadeh, "Structural Characteristics of Laterite Soil Treated by SH-85 and TX-85 (Non- Traditional) Stabilizers," *Electron. J. Geotech. Eng.*, vol. 18, 2013.

[5] A. Kamruzzaman, "Physico-chemical and engineering behavior of cement treated Singapore marine clay," *Ph.D thesis*, no. Civil, 2003.

[6] F. G. Bell, "Lime stabilization of clay minerals and soils," *Eng. Geol.*, vol. 42, no. 4, pp. 223–237, Jul. 1996.