Jurnal
Teknologi

Full Paper

EFFECT OF SODIUM SILICATE AS LIQUID BASED STABILIZER ON SHEAR STRENGTH OF MARINE CLAY

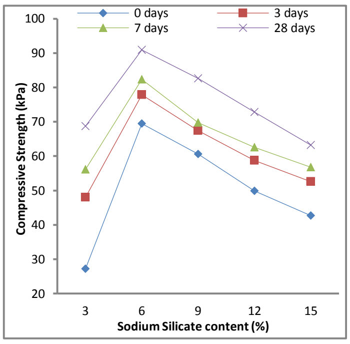
Faizal Pakir[a], Aminaton Marto[b*], Nor Zurairahetty Mohd Yunus[b], Saiful Azhar Ahmad Tajudin[a], Choy Soon Tan[b]

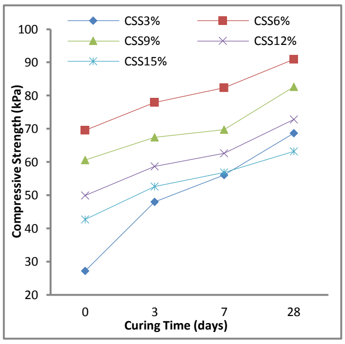
[a]Faculty of Civil and Environmental Eng., Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[b]Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Article history
Received
6 July 2015
Received in revised form
26 July 2015
Accepted
30 July 2015

*Corresponding author
aminaton@utm.my

Graphical abstract





Abstract

Marine clay is one of the problematic soils found in the development project due to the high compressibility and swelling, and low bearing capacity. A new liquid stabilizing agent, with a commercial brand name of "TX-85" had been introduced in the construction industry for improving the strength and reliability of soils for construction of building and road. Therefore, a laboratory study was led to assess the impacts of sodium silicate on the unconfined compression strength (UCS) and plasticity index of marine clay. The results show that the addition of the sodium silicate can reduce the plasticity and slightly increased the UCS of the soils, also the UCS increased with the duration of curing time. It can be concluded that, the stabilization using sodium silicate can be used as an alternative and economic method in the civil engineering projects.

Keywords: Marine clay; stabilization; sodium silicate

Abstrak

Tanah liat marin adalah satu permasalahan dalam projek pembangunan yang disebabkan oleh kebolehmampatan dan pengembangan yang tinggi, dan nilai keupayaan galas yang rendah. Satu ejen penstabilan berasaskan cecair dengan nama komersial iaitu "TX-85" telah diperkenalkan dalam industri pembinaan untuk meningkatkan kekuatan dan keupayaan tanah dalam pembinaan bangunan dan jalan raya. Oleh itu, kajian makmal telah dijalankan untuk menilai kesan sodium silika pada kekuatan mampatan terkurung (UCS) dan indeks keplastikan tanah liat marin. Keputusan menunjukkan bahawa penambahan sodium silika boleh mengurangkan keplastikan dan meningkatkan UCS, juga UCS meningkat dengan tempoh pengawetan masa. Dapat disimpulkan bahawa, penstabilan menggunakan sodium silika boleh digunakan sebagai alternatif dan kaedah ekonomi dalam projek kejuruteraan awam.

Kata kunci: Tanah Liat marin; penstabilan; sodium silika

1.0 INTRODUCTION

Marine clays of low strength and high compressibility are located in many coastal and offshore areas of the world. There are significant challenges to be faced by engineers in the construction project when dealing with marine clay. The marine clay is low strength, high compressibility and greatly influenced by the moisture content. The marine clay will shrink when dry and swell when moisture content increased. The high of movement can cause problematic foundation structure built on it [1]. Conventional method involved a methodology which the presence of marine clay replaces with other suitable soil imposed high cost on the construction project. Alternatively, chemical stabilization was chose to solve this problem.

Chemical stabilization is often used by adding of soil stabilizers or other particle binding energy to increase the engineering and physical properties of the soils. The soil stabilizers can be categorized as traditional stabilizers and nontraditional stabilizers. Traditional stabilizers such as cement lime, fly ash, and bituminous products while nontraditional stabilizers comprises of a variation combination of chemical agents that interact with the soil.

In recent years, the use of non-traditional additive has increased for the purpose of soil stabilization. Concentrated liquid products that do not contain calcium can be used on sulfate rich soils without causing excessive expansion. A variety of suppliers and manufacturers are actively marketing a wide array of these liquid soil stabilizers. Previous research remarks that the liquid soil stabilizers were categorized for three types: ionic, polymer, or enzyme. Liquid chemical stabilizers may work through an assortment of mechanisms, including fragment of clay mineral with expulsion of water from the double layer, interlayer expansion with subsequent moisture entrapment, exchange of inter layer cations, or encapsulation of clay minerals.[2]. The TX-85 is nontraditional stabilizers in liquid form has been used in some geotechnical project in Malaysia. The exact chemical composition not exposed due to the commercial brand of Probase Company. Previous research show that the stabilization using TX-85 increase strength of soil [3][4][5][6].

In this paper, a study was made to recognize the enhancement of marine clay soil stabilized with the sodium silicate. The engineering properties of untreated and treated soil, i.e., unconfined compression strength (UCS) was monitored with curing time.

2.0 EXPERIMENTAL PROGRAMME

2.1 Properties of Soil Samples

This study was conducted on marine clay a soil that is dredged soil from southern coast of the Johor Malaysia. The color of this marine clay soil is dark grey. Figure 1 and Table 1 show the marine clay soils and physical properties of this soil respectively.

Figure 1 Marine clay soils

Table 1 Physical properties of marine clay soils

Physical Properties	Values
Atterberg Limits	
Liquid Limit, LL (%)	58
Plastic Limit, PL (%)	23
Plasticity index, PI (%)	35
Standard Proctor Compaction	
Maximum Dry Density, MDD (kg/m³)	1600
Optimum Moisture Content, OMC (%)	21
Moisture content at 90 % MDD (wet side)(%)	28
Compressive Strength	
Unconfined Compressive Strength, UCS at 90 % MDD (wet side) (kPa)	23

2.2 Properties of Sodium Silicate

The sodium silicate was supplied by Probase soil Stabilizer Company, a local company in Johor state of Malaysia where the 'TX-85' is commercial name of this product. The result of inductively coupled plasma mass spectrometry (ICP-MS) performed on these stabilizer indicated that Na, Al, Si, and Fe were the major elements present. The pH value (12.54) of TX-85 revealed its highly alkaline nature [3].

2.3 Preparation of the Samples

The preparation of the soil sample is very important in this study. A series of Standard Proctor Compaction tests based on the clause 3.3.4.1 of BS 1377: Part 4: 1990 [7] was conducted to determine the optimum moisture content (OMC) and maximum dry density (MDD) to be used for the preparation of unconfined compressive test specimens. After completing this laboratory, the specimens were prepared by 90 % of MDD (wet side) of natural soils. Dry material of marine clay with addition of TX-85 and selected moisture content was thoroughly mixed and placed into a steel mould with size 80 mm in height and 36 mm in diameter. Then the molded specimens were left to cure in the polythene bottle and placed above water in a closed container in a room where the temperature 27±2°C. All specimens of untreated and treated soils containing 3, 6, 9, 12, and 15 % (% by dry weight of soils) sodium silicate were prepared using this method. In order to simplify the presentation of results, a specimen designation scheme was employed. The characters indicated the C for clay, UT for untreated, SS for sodium silicate.

2.4 Curing Time

Curing times of 0, 3, 7 and 28 days were used in this study. A minimum of three samples for each curing time were prepared in order to provide adequate data to validate the results.

2.5 Unconfined Compressive Strength

The unconfined compressive strength (UCS) test has been used on all specimens based on British Standard 1377 part 7:1990 [8] with a constant stress rate at 16 mm/min. Each specimen was compressed until peak load was achieved where the applied load was recorded by a data acquisition system.

The UCS test is to determine the compressive strength of treated and untreated soil using sodium silicate as stabilizer. Triplicate sample were used to get a consistent and accurate result.

2.6 Atterberg Limits

In order to determine the effect of the sodium silicate on the Atterberg Limits of the marine clay, the consistency limit tests were carried out in accordance with British Standard1377 Part 2: 1990 [9]. The samples dried, crushed and sieved passing 425 µm (in accordance with BS) and mixed with different sodium silicate content to establish the effect of the sodium silicate on the Atterberg limits. Deionizer water was used in all samples to avoid any distraction or contaminated by chemicals.

3.0 RESULTS AND DISCUSSION

All the result that had been done in the laboratory was analysed and discussed in this section. The results of the laboratory tests such as Atterberg Limits and unconfined compressive strength (UCS) were obtained and discussed. The Atterberg Limits test was carried out for both treated and untreated for comparison purposes. The UCS test was conducted on all the soil samples with various stabilizer contents for various curing periods at 0, 3, 7 and 28 days.

3.1 Unconfined Compressive Strength (UCS)

The summary result of UCS test for treated and untreated soil with different sodium silicate content and curing time period is shown in Table 2. In general, the compressive strength of soil increases with the addition of sodium silicate in which the strength of treated soils was increased slightly as sodium silicate was added from 3 % to 6 %. On the other hand, the strength of treated soil improved by increasing of the curing time period.

Figure 2 presents the unconfined compressive strength of stabilization marine clay soil with the addition of sodium silicate. Overall, the graph shows that the sodium silicate clearly improved the strength of the natural soil where the UCS increased rapidly with increment of sodium silicate content to 6 %. However, the UCS decreases for the treated samples of more than 6 % of sodium silicate content. For example, for 3 days of curing period, the UCS increased from 48 kPa to 77.9 kPa when 3 % sodium silicate increased to 6 % but the strength decrease to 67.4 kPa with the addition of 9 % sodium silicate and further decreased to 52.6 kPa with the addition of 15 % sodium silicate content. The increments of the proportion of sodium silicate for more than 6 % reduced the compressive strength of soils. This reduction was due to the nature of a water based stabilizers, where the increment of sodium silicate, increased the moisture content of soils. The incremental of moisture content facilitate the water filled pore particles of soils that cause the weakening of soil [4]. It can be concluded that the 6 % of sodium silicate is the optimum stabilizer for the marine clay soils of the study.

Table 2 Summary results of UCS test

Samples	Unconfined Compressive Strength (kPa)			
	0 days	3 days	7 days	28 days
Untreated Soil (UT)	21.3	21.3	21.3	21.3
UT + 3 %SS (CSS3 %)	27.2	48	56.1	68.7
UT + 6 %SS (CSS6 %)	69.5	77.9	82.3	90.9
UT + 9 %SS (CSS9 %)	60.6	67.4	69.7	82.6
UT + 12 %SS (CSS12 %)	49.9	58.7	62.6	72.8
UT + 15 %SS (CSS15 %)	42.7	52.6	56.8	63.2

*UT = Untreated soil, C = Clay, SS = Sodium Silica

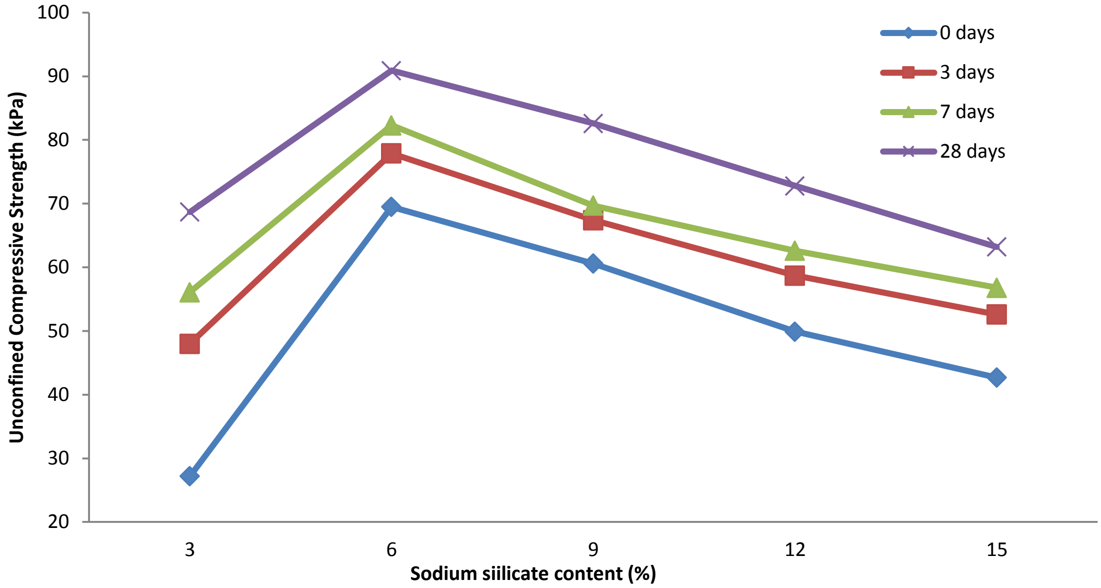


Figure 2 Strength gain for Sodium Silicate treated with various stabilizer contents.

Figure 3 shows the percentage of soil strength increment with different curing periods for 3, 6, 9, 12 and 15 % concentration of sodium silicate. The soil samples were cured for 0, 3, 7 and 28 days. The compressive strength increased with the increasing curing time period. For instance, the compressive strength of the 6 % sodium silicate-treated achieved 69.5 kPa at 0 days period (immediately UCS test after style as prepared), which was approximately 3 times greater than the strength of the untreated soils and increased to 7.9 kPa and 90.9 kPa at 7 and 28day curing time period, respectively. The strength increased during curing can be explained through the new gel form material (cementitious) that formed through soil-stabilizer reactions. Moreover, longer curing periods improved the reaction process between the soil particles and the liquid stabilizers due to the increase in the positive surcharge and the subsequent repulsion of soil particles inside the mixture [3].

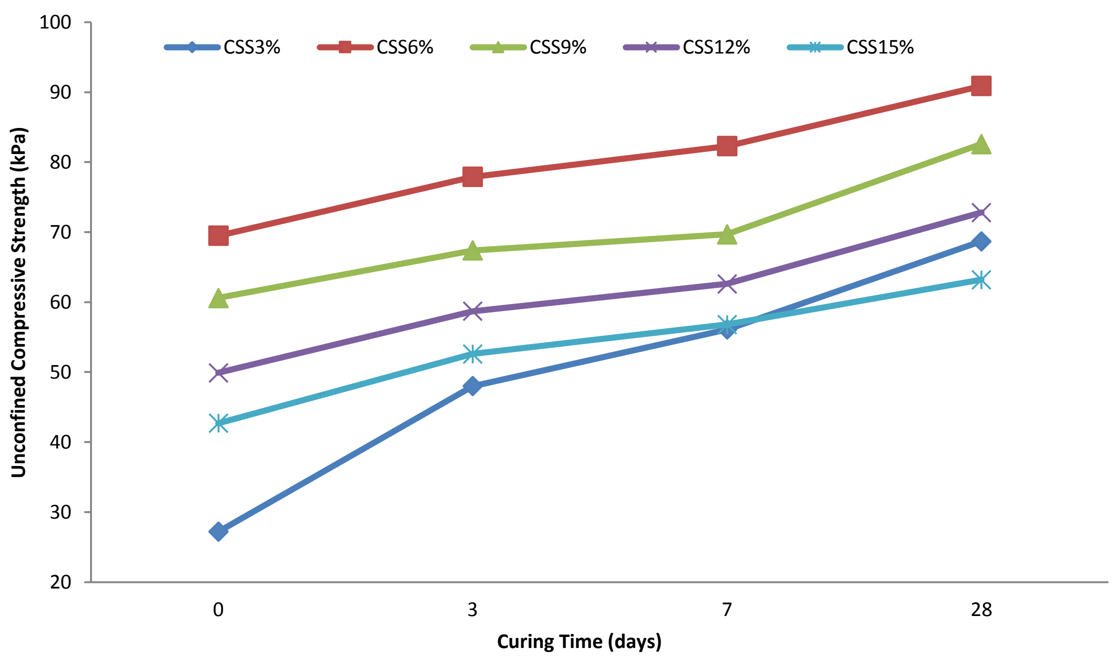


Figure 3 Strength gain for sodium silicate treated with various curing time

3.2 Atterberg Limits

Figure 4 shows the consistency limits values measured for marine clay admixtures with several of TX-85 stabilizer content. The liquid limit (LL), plastic limit (PL) and plasticity index (PI) of the untreated marine clay are 58 %, 23 % and 35 %, respectively. The graphs reveal that the consistency limits of the mixture sample of marine clay were influenced by the addition of TX-85 stabilizer. The LL of soils dropped tremendously with addition of TX-85 to 3 % and slow decreased afterwards while the PL showed a sharp rise with increment of TX-85 and increased slightly from 3 % to 15 % of TX-85 content. As a result, the PI decreased with increment of TX-85 content, indicating that the TX-85 can reduce the thickness of diffusion layer. In addition, the TX-85 is an Ionic type of stabilizer, which provides cation exchange inside the soil and influences the surfaces of soil charge area. The plasticity changes due to the water based nature of the stabilizers. This findings is in line with the results of previous researches [2],[7].

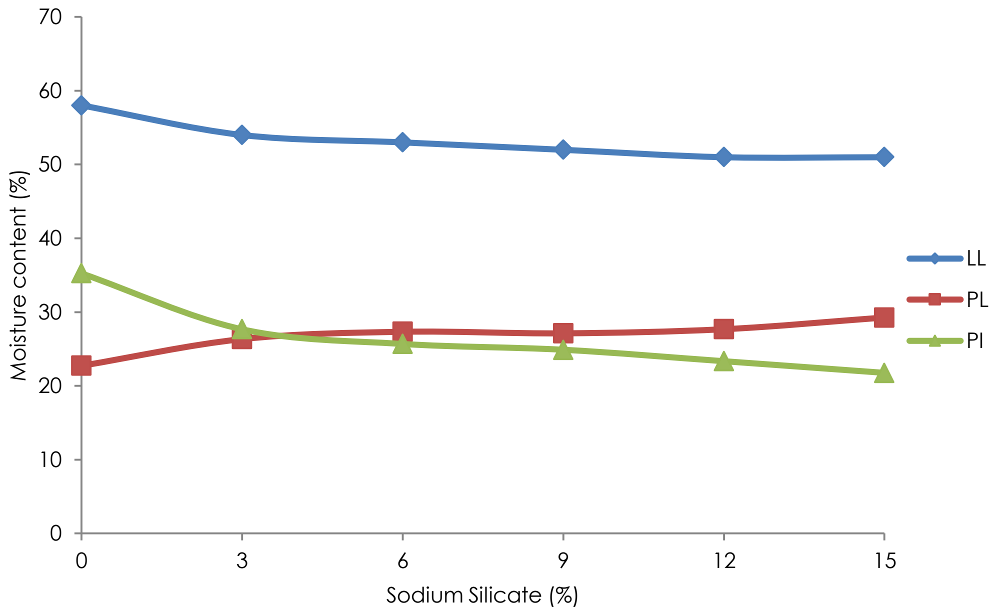


Figure 4 Consistency Limit of treated and untreated soils with variation of TX-85 content

4.0 CONCLUSION

This study was undertaken to investigate the influence of sodium silicate percentage and curing time on the unconfined compressive strength, consistency limits and pH of treated and untreated soils. The conclusions of the study carried out are as follows:

1. The unconfined compressive strength significantly increased with the curing time periods. The unconfined compressive strength of the mixtures rapidly increased at early 0 days and slow increases from 0 to 28 days curing time period.
2. The unconfined compressive strength of the soil specimens has increased with increment of sodium silicate contents. However, the unconfined compressive strength reduces with increment of sodium silicate after 6 %.
3. The results of the unconfined compressive strength test showed that 6 % of TX-85 was the optimum amount of this stabilization process for the selected marine clay.
4. The sodium silicate decreased the liquid limit of the soil and plasticity index reduced with the increment of TX-85.

Acknowledgement

The authors gratefully acknowledged the financial supports from the Universiti Teknologi Malaysia (UTM) under the Research University Grant Tier 2 (Q.J130000.2622.10J71). The Ministry of Higher Education, Malaysia and the Universiti Tun Hussein Onn Malaysia are also acknowledge for the PhD scholarship given to the first author. The support of the Faculty of Civil Engineering, UTM is also acknowledged.

References

[1] Bjerrum, L. 1973. Geotechnical Problems involved in Foundations of Structures in the North Sea. *Geotechnique*. 23(3): 319–358.

[2] Rauch, A. F., Harmon, J. S., Katz, L. E. and Liljestrand, H. M. 2002. Measured Effects of Liquid Soil Stabilizers on

Engineering Properties of Clay. *Transp. Res. Rec. J. Transp. Res. Boar. 1787*: 33–4.

[3] Latifi, N., Eisazadeh, A. and Marto, A. 2013. Strength Behavior and Microstructural Characteristics of Tropical Laterite Soil Treated with Sodium Silicate-Based Liquid Stabilizer. *Environ. Earth Sci.*

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

[5] Marto, A., Latifi, N. and Eisazadeh, A. 2014. Effect of Non-Traditional Additives on Engineering and Microstructural Characteristics of Laterite Soil. *Arab. J. Sci. Eng.* 39(10): 6949–6958.

[6] Fon, C. 2010. Stabilization of Earth Roadbed for Road Building using Probase Soil Stabilizer. *Electron. J. Geotech. Eng*.

[7] British Standard Institution. 1990. British Standard Method of Test for Soils for Civil engineering Purpose: Part 4, Compaction-related tests. London. *BS 1377*. 3.

[8] British Standard Institution. 1990. Soils for civil engineering purposes: Part 7: Shear strength tests (total stress). *London. BS 1377*. 1.

[9] British Standard Institution. 1990. Soils for civil engineering purposes: Part 2 : Classification tests. *London, BS 1377*. 1.

[10] Lu, X. S. and Xiang, W. 2011. Experimental Study on Dynamic Characteristics of Ionic Soil Stabilizer Reinforcing Red Clay. *Adv. Mater. Res.* 374–377: 1391–1395. Oct.