



Determination of Unconfined Compressive Strength and Atterberg Limit of Soft Clay by Stabilizing with Sodium Silicate and Biomass Silica in Batu Pahat

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DOI: <https://doi.org/10.30880/jsue.2021.01.003>

Received 24 August 2021; Accepted 11 October 2021; Available online 16 December 2021

Abstract: Soft clay soils can be considered as problematic soil with the characteristic of high compressibility, low permeability and low shear strength. Construction on soft clay deposit may causes problem such as insufficient bearing capacity, settlement problem and instability on excavation and embankment. Ground improvement methods were used as the aimed of this study is to determine the effect of non-traditional stabilizer on the compressive strength of soft clay soils. Therefore, the objective of this study is to determine effect of compressive strength of untreated and treated soft clay soil with addition of non-traditional stabilizer at different curing periods. The soil properties of soft clay soil such as compaction, Atterberg limits, and unconfined compression strength (UCS) testing methods were used to observe the performance of treated and untreated samples. The test results from the UCS indicated that once Biomass Silica and Sodium Silicate in the form of SH-85 and TX-85 have been added to the clay soil, the strength of the sample will increase with increasing percent of sodium silicate and curing periods.

Keywords: Soft clay, Non-traditional stabilizer, unconfined compressive strength

1. Introduction

Construction is an important support for Malaysia's economic development and is also a key support project of the national economic fixed investment. Engineer must have the ability to make use of a diverse form of soil for use as production purpose. In civil engineering literature, a soil or soil deposit were described as all obviously taking place relatively unconsolidated mineral particles, organic or inorganic, lying over the bedrock that's shaped by weathering of rocks [1]. Ground data inclusive of the soil bearing capacity, soil stress and soil electricity had to be decided to make sure that it turned into appropriate earlier than production start. The soft soil has emerged as a chance to the development industry, specifically in road construction. As we know, soft soil is highly compressible, low shear strength between 25 kPa to 50 kPa and low permeability. Usual construction problems on this deposit are unsatisfactory bearing capacity, more post-production settlement and instability on soil elimination and embankment forming. To counter this problems in geotechnical construction, engineers should have a look at the engineering properties of the soft clay. A form of techniques like displacement, replacement, reinforcement, and stabilization are the strategies practiced for boosting the houses of the susceptible soils [1].

Chemical stabilization techniques are followed to offer the soil strength improvement, general and differential settlements and permeability reduction. Soil stabilization is a cost-effective and environmental approach carried out to accustom the soils' mechanical and chemical traits [2]. There are different sorts of usable admixtures. The chemical response among soils and admixtures boosts the physical and engineering properties. Replacement of soft soil with appropriate soil continues to be notably applied when construction has taken place on soft soil deposit. This method ends in an expensive layout as a massive quantity of appropriate soil is needed to be transported. When there's an addition of admixtures to the soil in the precise quantities, the properties of the soil may be improved. Applying chemical stabilization solutions to stabilize soft clay soil concerns in order to be appropriate for construction purposes. This emphasized on applying stabilizers by one attention and stabilizing the soft clay. Soil stabilization aims at enhancing soil strength and increased resistance to softening with the aid of using water via bonding the soil particles together, waterproofing the particles or mixture of the two [3].

From this study, we will decide the ratio of stabilizer to stabilize clay soil. Adding stabilizer will boost the strength of soil for building purposes. Thus, these study can be used to offer knowledge about the most appropriate chemicals to stabilize soft clay. This report can be used as a manual to pick the optimum powder stabilizer for application, mostly based on soil conditions and preferred strength.

2. Illustrations

Stabilizing agent were widely available on the market and it was developed specifically to stabilize the clay soil with high water content. Stabilizing agent relatively have slow reaction to the ground and will produce lower effect during a short-term period but will give better effect in long term period. Besides, it is very effective and efficient due to the low amount of cost used for the improvement of soil.

This study will be using non-traditional stabilizer which is sodium silicate and biomass silica or commercially called as TX-85 and SH-85 as the stabilizing agent. Probase soil Stabilizer Company, a local company in Johor state of Malaysia are in charge of supplying the sodium silicate. It is an organic combination of Sulphur and acid buffered which is a liquid type of non- traditional stabilizer and typically marketed for stabilization of plantation road soils. The plasticity index when applying this liquid stabilizer can decreased with increment of TX-85 which indicate that TX-85 can reduce the thickness of diffusion layer [4]. Another stabilizing agent used for this study was biomass silica which is in powder form or commercially called as SH-85 Soil Hardener. SH-85 is one of the bio-technological process produced from wastes of biomass silica to form "Artificial Laterite". The product is a cement-like soil and can be used with any type of soil to achieve California Bearing Ratio (CBR) or Unconfined Compressive Strength (UCS) according to the requirement of engineering design.

3. Materials and Methods

The soil sample is a soft soil collected from the Research Centre of Soft Soil (RECESS) Universiti Tun Hussein Onn Malaysia campus in Johor, Malaysia at a depth of 3 meter. Table 1 shows the physical properties of this soil.

Table 1 - Physical properties of soft clay

Physical Properties	Values
Liquid Limit, LL (%)	73
Plastic Limit, PL (%)	29.12
Plastic Index, PI (%)	43.88
Maximum Dry Density, MDD (kg/m ³)	1520
Optimum Moisture Content, OMC (%)	23

The physical characteristics tests were carried out in accordance with (BS 1377: Part 2: 1990: 4). The practice of compressing solid particles closer together, usually by mechanical means, to increase the dry density of the soil is known as a standard proctor compaction test. The amount of water in the soil and the degree of compaction applied influence the dry density that can be attained. The optimal moisture content (OMC) and maximum dry density (MDD) for specimen preparation were determined using a compaction test. To avoid effect of these variables on the strength of stabilized soil, all preparation samples were done with the bulk density and moisture content controlled. The procedure of preparing samples for these tests, which only requires a small amount of soil and one sample, can be repeated numerous times after gradually increasing the amount of water. The Atterberg Limit test was used to classify clay and to explore the impact of moisture content on the behavior of soil, particularly fine-grained soil, after stabilizer addition. The purpose of the consistency limit experiments was to see how the stabilizer affected the Atterberg limits of the treated and untreated soils. To determine the influence of the stabilizer on the Atterberg limits, the samples were dried, crushed, and sieved passing 425 m (in accordance with BS) and having varying quantities of different stabilizers. To obtain an accurate result, two specimens of the same combination were made and averaged. All specimens were treated with varying amounts of TX-85 (liquid) and SH-85 (powder) probase stabilizer for different curing periods (0, 14, and

28 days) [5]. LoadTrac II which is Unconfined Compression Strength Test (UCS) was used to evaluate the shear strength of all samples that had cured. LoadTrac II is defined as the maximum unit axial compressive stress at failure or at 1% strain per minute.

$$q_u = \frac{P}{A} \quad (1)$$

4. Results and Discussion

The result from table shows that the neutral moisture content of Batu Pahat soft clay is 72% and dry unit weight is, γ_d is 8.57kN/(m³) which is rather high for a soil sample at a depth of soil taken of 1 – 1.5 m at the location of RECESS that gives higher moisture content to the soil deposits below the water table. The result of the test is given in **Table 1** below:

Table 1 - Result of moisture content test

Weight	Sample 1	Sample 2	Sample 3
Container (kg)	0.010	0.010	0.010
Wet sample + container (kg)	0.056	0.070	0.066
Wet sample (kg)	0.046	0.060	0.056
Dry sample + container (kg)	0.032	0.040	0.042
Dry sample (kg)	0.024	0.030	0.032
W %	91.67	50	75
W % average	72 %		
Dry unit weight	Sample 1	Sample 2	Sample 3
γ_d	7.68	9.83	8.42
γ_d average	8.57 kg/m ³		

Compaction test is performed to obtain the maximum dry density (MDD) and optimum moisture content (OMC) of a soil by standard proctor compaction test on the graph dry density versus moisture content for sample preparation make specimen unconfined compression strength test (UCS) are shows as **Table 2** and **Fig. 1** shows the graph dry density against moisture content. In determination of atterberg limit, there are two separate test have been carried out are liquid limit(LL) and plastic limit(PL). The difference between the liquid limit and plastic limit is calculated to give plasticity index(PI) of the soft clay. **Table 3 and 4** show the result of atterberg limit test and result liquid limit test. According to BS 1377: Part 7: 1990, the specimen for the unconfined compression strength test is 38mm diameter by 76 mm high. In order to get accurate result, 3 specimen have been prepared for same mixture to get the average data. All specimens at different curing period and different percentages of TX-85(liquid) with SH-85(powder) probase stabilizer such as 0, 14 and 28 days. Each 42 samples have been made according to different percentages which are 5%P, 5%P+1%L, 5%P+2%L, 5%P+3%L, 5%P+4%L, 5%P+5%L and 5%P+6%L. Table 4.6 had shown the result unconfined compression strength test (UCS).

Table 2 - Compaction test for soft clay

Dry density	Mg/m ³	1411.217	1465.766	1503.748	1499.729	1436.288
Moisture content	%	15.577	18.890	21.241	24.946	29.142
Zero air void	%	1850.54	1743.63	1674.98	1577.09	1479.21

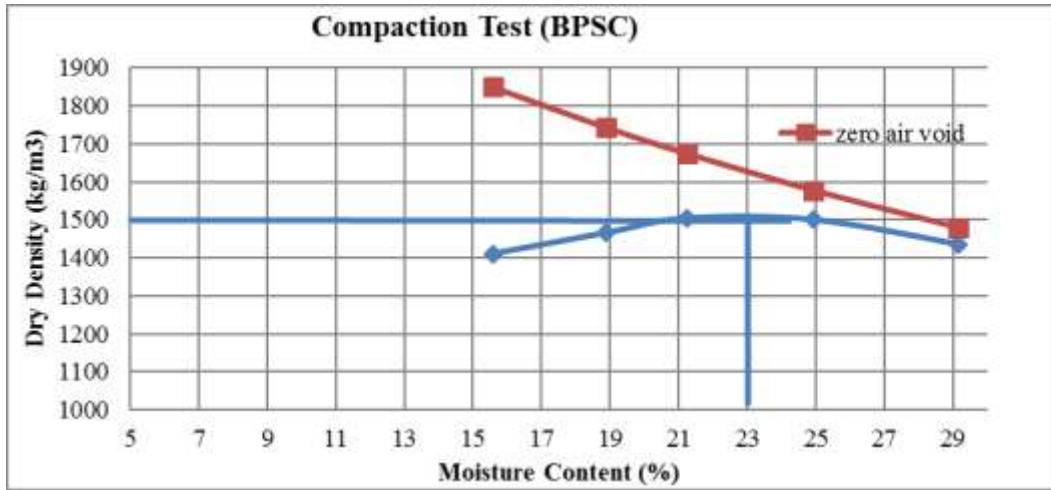


Fig. 1 - Dry density against Moisture Content

Table 3 - Result of Atterberg limit test

Test	Plastic limit, PL (%)	Liquid limit, LL (%)	Plasticity index, PI (%)	Plasticity chart
Results	29.12	73	43.88	Very high plasticity

Table 4 - Results for Unconfined Compression Strength Test (UCS)

0 Day							
SAMPLE	NON	5P+1L	5P+2L	5P+3L	5P+4L	5P+5L	5P+6L
S1	34.48	292.13	263.23	301.56	309.05	288.1	287.78
S2	32.77	294.16	273.15	348.84	303.29	276.66	294.11
AVERAGE	33.625	293.15	268.19	325.20	306.17	282.38	290.95
14 Day							
SAMPLE	NON	5P+1L	5P+2L	5P+3L	5P+4L	5P+5L	5P+6L
S1	34.48	233.49	181.06	221.28	206.51	247.98	266.32
S2	32.77	144.67	231.91	221.24	242.28	265.99	292.25
AVERAGE	33.63	189.08	206.49	221.26	224.40	256.99	279.29
28 Day							
SAMPLE	NON	5P+1L	5P+2L	5P+3L	5P+4L	5P+5L	5P+6L
S1	34.48	269.51	288.44	298.99	274.11	202.76	230.84
S2	32.77	277.10	286.16	314.54	274.88	164.87	247.65
AVERAGE	33.63	273.31	287.30	306.77	274.50	233.82	239.25

Figure 2 shows the combination of three different curing day with different percentage of mixture. The effect of the mixture SH-85 (powder) and TX-85 (liquid) at different percentage affecting the shear strength of the specimens. The shear strength was determined by the peak pressure from the unconfined compressive strength (UCS) test after all of the specimen were cured according to the curing day respectively. It can be seen that the percentage increase in the content of TX-85 leads to increased strength in unconfined compressive strength until the mixture of 5%P+3%L. Most of the result from the test show the peak strength of specimen is 5%P+3%L mixture for 0 day and 28 day curing while the shear strength continue increased up to 5%P+6%L for 14 day curing.

As the result, the optimum content of combination between SH-85 with TX-85 probase stabilizer obtained by addition of 5%P+3%L on soft clay was 325.2 kPa as compared to only 33.63 kPa achieved on soft clay without

stabilizer. Less significant improvement obtained at higher sodium silicate content was believed due to exaggerated sodium silicate content to form a desired strength of the soil sample. It can be seen that after 3% of sodium silicate used in the sample, the strength suddenly decreased. The impact of sodium silicate on the shear strength of clay shows that the unconfined compressive strength of the soil specimens has increased with the increment of sodium silicate however reduce after 4% uses of sodium silicate for 0 and 28 days curing but the shear strength increases for 14 days of curing. The plasticity index also decreased with increment of TX-85 which indicate that TX-85 can reduce the thickness of diffusion layer [4].

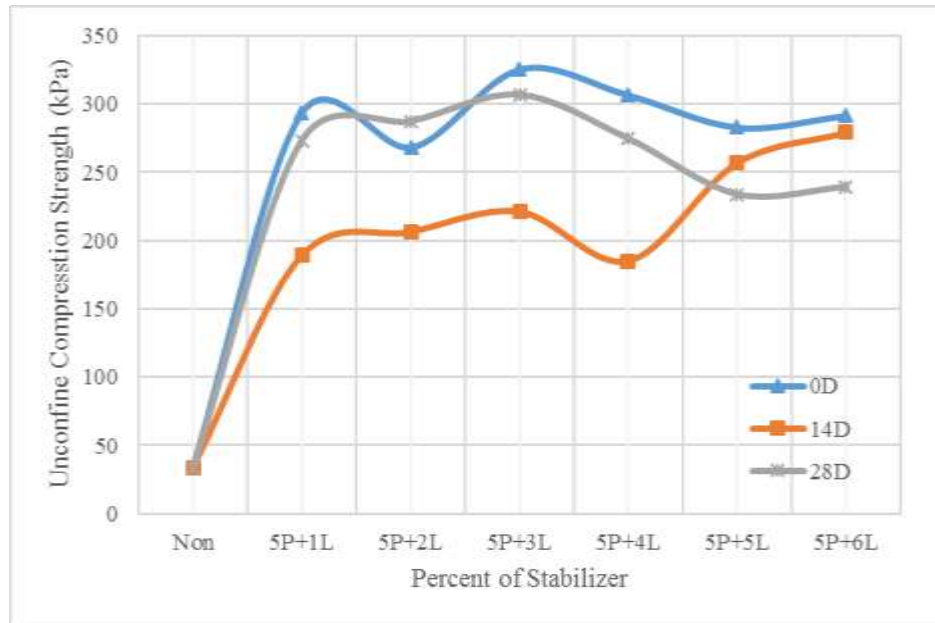


Fig. 2 - UCS versus percent of stabilizer

5. Conclusion

The test results from the Unconfined Compressive Strength Test (UCS) indicated that once Biomass Silica and Sodium Silicate in the form of SH-85 and TX-85 have been added to the clay soil, the strength of the sample will increase with increasing percent of sodium silicate and curing periods. The strength of the clay stabilized with 5P+3L stabilizers is the highest among different percentages of the stabilizer at 0 and 28 days curing. Because of the stabilization process in the sample, there is an immediate increment in rate of strength after addition of the stabilizer. The curing period and the percentages of SH-85 and TX-85 used in the sample have a significant impact on the strength development of the soil.

Acknowledgement

The authors would like to acknowledge the Faculty of Civil Engineering and Built Environment and Centre for Diploma Studies Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor.

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