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The Effect of Sodium Silicate (TX-85) as Liquid Based Stabilizer on Shear Strength of Batu Pahat Soft Clay (BPSC)

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Abstract: Soft clay is one of the most difficult soils found in project development due to its high compressibility and swelling, as well as its restricted bearing capacity. All these problematic issues will directly affect the strength of the soil and cause difficulties for the operation of construction. For the current practices, mechanical stabilization such as compaction and soil replacement were used to increase the clayey soil's strength before starting construction work. However, it is not too practical to be used in terms of the construction time period and high cost. So, to overcome this issue, chemical stabilization was used to increase the soil's compression strength. A new liquid stabilizing chemical with the commercial brand name "TX-85" was utilized into the construction sector to improve the strength and reliability of soils for building and road construction. As a result, a laboratory study was conducted to study the effect of Sodium Silicate towards the unconfined compressive strength of Batu Pahat Soft Clay (BPSC). According to the research that has been conducted, TX-85 was proven can enhance the unconfined compressive strength of BPSC with the optimum proportion of sodium silicate is 9%. Meanwhile, from the conducted compaction test, the value of maximum dry density (MDD) and optimum moisture content (OMC) were 1520 kg/m^3 and 23% respectively. For the Atterberg limit of untreated samples, the obtained values of liquid limit, plastic limit and plasticity index were 73%, 29.12% and 43.88% respectively.

Keywords: Soft Clay, Unconfined compressive strength, Sodium Silicate

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1. Introduction

With the growing population and economy, the demand for the development of infrastructures and roads will be rapidly increased. Due to this issue, most of the main road and building construction in Malaysia are forced to deal with soft soils. It is quite impossible to avoid any project development from being constructed on it because of space and cost limitations. Slope instability, bearing capacity failure, and excessive settlement are the most common soft soil issues, which can arise during or after the construction phase due to the soft soil's low shear strength and high compressibility. This problematic issue will indirectly threaten the construction phases and cause an increment in terms of construction cost and completion time.

Therefore, soil stabilization is necessary to be conducted before starting the construction and development phases. There are two main methods of soil stabilization which are mechanical stabilization and chemical stabilization. Generally, one of the methods will be used to improve the soil quality before starting construction works. However, both mechanical and chemical approaches are occasionally used, and the outcomes vary depending on the role of each additive. Chemical additives affect the geotechnical properties of soil, whereas mechanical additives improve its mechanical properties, such as load-bearing capacity [1]. This research was only focused on chemical stabilization because it is a highly recommended method for the reason that it can provide a shorter duration of the construction period and some other factor that closely depends on the soil condition. For this study, the Sodium Silicate (TX-85) with different proportions in the form of the liquid has been used as the main stabilizer to make soft soil more shear resistant.

The goal of this study is to determine the unconfined compressive strength of Batu Pahat Soft Clay (BPSC) that has been stabilized with a variety of Sodium Silicate (TX-85) proportions. This research has a few objectives which including to examine the soft clay's physical characteristics with the addition of a liquid stabilizer, analyzing the effect on clay's compressive strength with the addition of liquid stabilizer at the different percentage and curing time as well as determining the optimum proportion of sodium silicate as a liquid stabilizer. It was conducted by using the Unconfined Compression Test (UCT) with the soft clay sample collected from RECESS, Malaysia which is located at the UTHM campus. It can be determined by making various percentages of additive (non, 3L, 6L, 9L, 12L, 15L) and different curing times (0 days, 3days, 7days, 14days, and 28days). In addition, this research has been investigated the physical properties of BPSC which covered the Atterberg limit test and compaction test. These two tests were conducted to obtain the value of plastic limit, liquid limit, plasticity index, and most importantly was the value of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) which would be used for sample preparation.

2. Stabilizing agent

In this study, sodium silicate or also known as TX-85 will be used as a stabilizer agent. It is commonly used to stabilize plantation road soils. The sodium silicate for this research investigation was provided by Probase soil Stabilizer Company, a local enterprise in Malaysia's state of Johor and it comes in the form of liquid or solution. TX-85 is a liquid version of unconventional stabilizers that has been employed in various geotechnical projects in Malaysia [2].

In general, sodium silicate is non-traditional chemical stabilizers products which is not calcium based. These stabilizers are usually sold as concentrated liquid diluted with water at the construction site, then either spread on the soil before compaction or pressure injected to treat deeper soil layers. The function of these stabilizers is to improved construction material and enhancing many of the engineering properties of the soil. In addition, it also can reduce swelling and bind particles of soil at the same time fill the void between particle of soil [14].

3. Methodology

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

3.1 Materials

For this research, the soft clay sample was obtained from the research centre for soft soils (RECESS), UTHM at the depth of 3 meter. In order to determine the physical properties of soil, undisturbed sample was used to conduct Unconfined Compressive Strength test (UCS), Atterberg Limit test and compaction test. The soil sample was carefully excavated and properly stored in an airtight container. Table 1 show the physical properties obtained for this type of soil.

Table 1: Physical properties of BPSC

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

3.2 Sample preparation

The physical attributes testing was performed in accordance with the following guidelines: (BS 1377: Part 2: 1990: 4). A standard proctor compaction test is the practice of compressing solid particles closer together, usually by a mechanical device, to enhance the dry density of the soil. The dry density that can be achieved is influenced by the amount of water in the soil and the degree of compaction applied. A compaction test was used to establish the optimal moisture content (OMC) and maximum dry density (MDD) for specimen preparation. All preparation samples were done with the bulk density and moisture content controlled to avoid the effect of these variables on the strength of stabilized soil. After steadily increasing the amount of sodium silicate proportions, the technique of producing samples for these tests, which only requires a little amount of soil and one sample, can be performed multiple times. The untreated samples of Batu Pahat Soft Clay were also tested to the Atterberg Limit test. Three specimens were conducted for each proportion in order to acquire a high accuracy result, and the average of the results was calculated. The specimens were treated with varying amounts of TX-85 for different curing durations (0,3,7,14, and 28 days), and the shear strength of all cured samples was evaluated using the UCS test. Table 2 shows the combination of elements that had been used for this research which covered three components including clay soils, water and sodium silicate.

Table 2: Combination of soft clay, water and stabilizer agent

Proportion of TX-85 (%)	Combination of Elements Used for Each Proportion			Total Moisture Content (%)
	Soft Clay (g)	TX-85 (ml)	Water, 23% (ml)	
0	500	0	115	23
3	500	15	115	26
6	500	30	115	29
9	500	45	115	32
12	500	60	115	35
15	500	75	115	38

4. Results and Discussion

In this part, all of the laboratory results were analyzed and discussed. Laboratory test data such as Atterberg Limits, compaction test, and unconfined compressive strength (UCS) were obtained and reviewed. The Atterberg Limit test and compaction test were performed on untreated soil samples of Batu Pahat Soft Clay (BPSC), while the UCS test was conducted on all soil samples with varied stabilizer percentages for 0,3,7,14, and 28-day curing periods.

4.1 Unconfined Compressive Strength (UCS)

Table 3 and Figure 1 summarizes the results of the UCS test for treated and untreated soil with varying sodium silicate proportions and curing times. The addition of sodium silicate to soil increases its compressive strength in general, with the optimum percentage being 9 %.

Table 3: Summary of the UCS results according to the difference curing days

0 DAY	Unconfined Compressive Strength (kPa)					
	0%	3%	6%	9%	12%	15%
Average	47.42	120.23	138.07	**164.65**	126.50	124.60

3 DAY	Unconfined Compressive Strength (kPa)					
	0%	3%	6%	9%	12%	15%
Average	47.42	67.06	70.12	**127.17**	94.72	71.92

7 DAY	Unconfined Compressive Strength (kPa)					
	0%	3%	6%	9%	12%	15%
Average	56.31	107.98	116.09	**120.70**	72.06	68.46

14 DAY	Unconfined Compressive Strength (kPa)					
	0%	3%	6%	9%	12%	15%
Average	35.69	56.46	63.98	**68.26**	66.32	62.13

28 DAY	Unconfined Compressive Strength (kPa)					
	0%	3%	6%	9%	12%	15%
Average	35.69	61.31	76.95	**77.64**	64.89	65.14

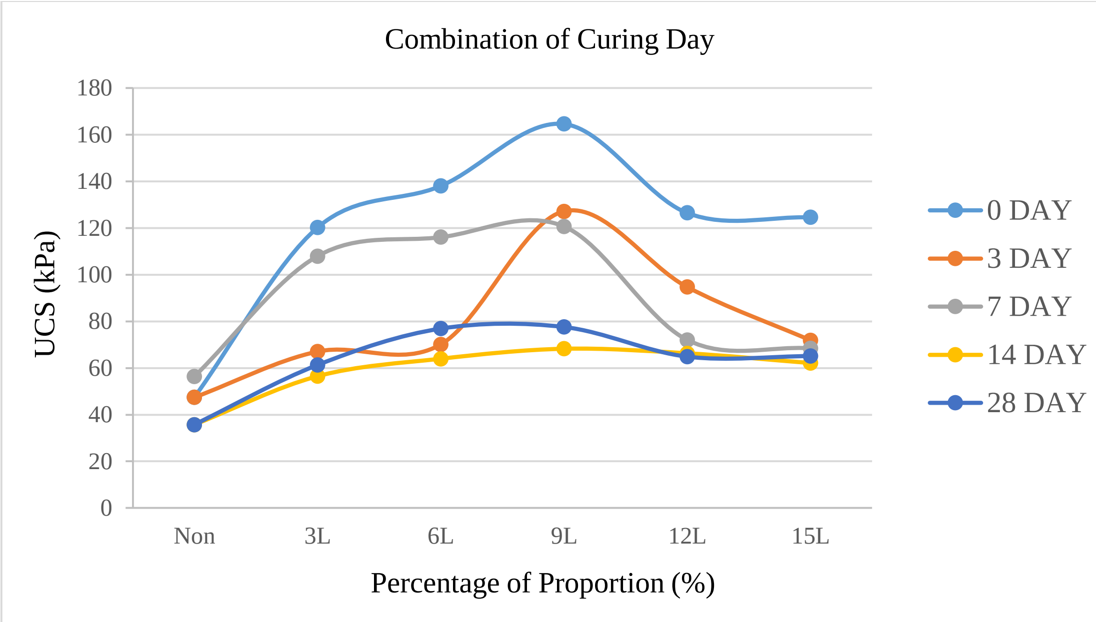

Figure 1: The combination results of UCS for all curing days

From Figure 1, it has been demonstrated that the optimum proportion for the unconfined compressive strength of BPSC stabilized with TX-85 was achieved with the application of 9% proportion. From the graph, it also can be stated that sodium silicate has proven in improving the unconfined compressive strength of soft clay as it increased gradually with additional of stabilizing agent proportion from untreated sample to 9% proportion sample. However, the strength started to drop with the application of 12% and 15% as it has reached their maximum allowable moisture content. In general, sodium silicate is in the form of liquid, thus the pattern of UCS strength will show the increment pattern at the early stages until it reach the optimum strength. After that, it will started to drop gradually with the increasing of moisture content. So, it can be concluded that the pattern of UCS values obtained for this study was accurate.

However, the second objective for this research which was to investigate the impact on compressive strength of BPSC with an additional of liquid stabilizer at the different percentages and curing time could not be achieved. The trend for the effect of moisture content can be seen clearly where the results obtained show that the longer the period of curing day, the lower the values of unconfined compressive strength. It might be happened because of the mistake that had been conducted during the process of curing. The curing process for the samples had been conducted by using water that was put in a storage box along with the soil samples. Water has been used as an alternative method to control the temperature of the samples. Then, aluminium foil was used to wrap the samples as a prevention method to avoid the disturbance of surrounding moisture content towards the soil sample. The same method was conducted by previous researcher and it was successfully proven that by increasing the curing period of samples, the soil's compressive strength had been increased [8]. However, the result was obtained by putting the samples in the bottle before locating them in the storage box that contains water.

In order to overcome this problem, two suggestions have been proposed as a solution to avoid the same issue from being a repetitive problem for the next research that deals with the curing process of soft clay. One of the solutions is by wrapping the samples and puting them in the bottle which is a similar method with the previous researcher and it was successfully proven can increased the compressive strength of soft clay. This is an essential way to minimize the exposure of samples to the surrounding moisture content. Thus, the results that will be obtained will describe the initial moisture content that has been used during the sample preparation.

4.2 Compaction test

Compaction test is performed to obtain the maximum dry density (MDD) and optimum moisture content (OMC) for the BPSC by using standard proctor compaction test. It was conducted for the untreated sample to determine the physical properties of the soft clay. Both values have been used for sample preparation of the UCS test. The obtained values of MDD and OMC for this type of soil are shown in Table 4.

Table 4: The result of OMC and MDD obtained from compaction test

Maximum Dry Density (MDD) ($\mathbf{kg/m^3}$)	1520
Optimum Moisture Content (OMC) (%)	23

The value of MDD and OMC has been used for sample preparation and it has been achieved by using Equation 1 and Equation 2 where ρd is the maximum dry density of untreated BPSC, w is optimum moisture content, ρb for bulk density, *m* for the mass of soil and *v* stand for volume.

$$\rho d = \frac{\rho b}{1 + w} \ (Eq.1)$$

$$\rho b = \frac{m}{v} \ (Eq.2)$$

4.3 Atterberg Limit

For Atterberg Limit, two testings have been conducted which included the test of plastic limit (PL) and liquid limit (LL). This testing was conducted for untreated samples of soft clay. Meanwhile, the plasticity index (PI) can be obtained by finding the difference between the liquid limit and the plastic limit. Table 5 shows the result of Atterberg limit test for BPSC. According to the previous research, the obtained values of liquid limit, plastic limit and plasticity index of BPSC were 72%, 30% and 42% respectively [10]. These values were almost similar with the results obtained in this research.

Table 5: Result of Atterberg limit test for BPSC

Parameters	Values
Plastic Limit, PL (%)	29.12
Liquid Limit, LL (%)	73
Plasticity Index, PI (%)	43.88
Plasticity chart	Very high plasticity

5. Conclusion

The value of maximum dry density (MDD) and optimum moisture content (OMC) for BPSC had been obtained by conducting a compaction test and the results were used for sample preparation. In this study, the obtained value of MDD and OMC were 1520 $\mathrm{kg/m^3}$ and 23% respectively. The value of OMC described that the humidity of BPSC can be classified as moderate. In addition, the optimum proportion for the unconfined compressive strength of BPSC stabilized with TX-85 was achieved with the application of a 9% proportion of liquid stabilizer. This result was obtained by plotting the graph of UCS against the difference percentage of proportion used. From the plotted graph, it also showed that sodium silicate was able to increase the shear strength of soft clay where there was a significant increment between the strength of untreated samples and treated samples. However, the second objective for this research which was to analyze the effect on compressive strength of BPSC with the addition of liquid stabilizer at the different percentages and curing time could not be achieved. It might be happened because of the mistake that had been done during the process of curing. Thus, the curing period has failed to have a considerable impact on the soil's strength development. It also can be summarized that the BPSC was very sensitive with the moisture content and it was directly proportional to their compressive strength. After completion of this research, there are two recommendations can be proposed for the purposes of future research especially in terms of the curing process of the sample. It is including by wrapping the samples and putting them in the bottle to control the level of moisture content and use the proper curing equipment which has temperature monitoring control to control the samples temperature instead of using water.

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