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Compressibility Behaviour of Batu Pahat Soft Clay Treated by Combination between Tx-85 with Sh-85 Probase Stabilizer

Ahmad Hakimi Mat Nor[1]*, Saiful Azhar Ahmad Tajudin[2], Faizal Pakir[2], Ali Abdul-Wahoud Mahmood[3], Muhd Amirul Hafiz Idris[2], Masiri Kaamin[1], Mohd Erwan Sanik[1] and Salman Salim[1]

[1]Department of Civil Engineering, Centre For Diploma Studies, Universiti Tun Hussein Onn Malaysia,
[2]Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia,
[3]Advanced Studies Research Centre, 2365 rue Cardin, Drummondville, Quebec J2C6J6, Canada.

ABSTRACT

Construction on the soft ground area is a great challenge in the field of geotechnical engineering. It gives instability and settlement problems when construction takes place. The characteristics of soft soil are high compressibility, high settlement, low shear strength, and low permeability. This problem can be solved using a stabilisation method of Batu Pahat Soft Clay (BPSC) studied. The research of stabilisation focuses on improving the compressibility of BPSC by combining TX-85 with SH-85 probase stabiliser. This research aims to determine the physical properties and the compressibility behaviour of BPSC when added with different percentage of stabiliser and curing time. The percentage of stabiliser used in this research is 3L+6P, 3L+9P, 3L+12P, and one untreated sample as constant. Then, the sample was cured for 7 and 14 days before going through testing. Two types of tests have been done for this research to get the physical properties: Atterberg limit (plastic limit & liquid limit) and standard proctor test. After that, the consolidation test was performed to investigate the compressibility behaviour of the combination between TX-85 with SH-85 treated BPSC. As a result, the physical properties of BPSC were categorised as highly plastic clay. Meanwhile, the optimum moisture content (OMC) was 23% and the maximum dry density (MDD) was 1520 kg/m3. The compression index and swelling index value of BPSC decreased as combination between TX-85 with SH-85 content increased. Additionally, the preconsolidation pressure increase as the compression index decrease. Thus, this research can improve soil compressibility to support load and decrease the settlement problem that occurs on construction over soft soil.

Keywords: Soft clay, stabilisation, consolidation test, atterberg limit, TX-85(Liquid) and SH-85(powder)

1. INTRODUCTION

In both cities and the countryside, the selection of sites with the best soil is an important engineering decision in the building process. Whether we live in a house, condominium, or apartment, our home is connected to the soil. Different soil types could produce different soil characteristics due to the nature of their pore fluids and the mineralogy of their fabric. Construction on Soft ground areas has more problematic to the construction industry because soft soil characteristics are high compressibility, low shear strength, and low permeability.

A type of clay, called Batu Pahat soft clay (BPSC), is available up to a depth of 40 meters from ground level. Roads in the Batu Pahat district experienced many types of failures such as cracks, large surface deformation and structural deformation of pavement layers and the subgrade. They suggested that to reduce these failures, Batu Pahat soft clay needs to be utilised to reduce imported soil from other places and reduce the possibility of environmental damages. BPSC at Research Centre for Soft Soil (RECESS) has a plasticity index (PI)ranging from 36% to 46%, in which the higher the PI, the greater the potential for problems. Clays, especially those with

Corresponding author: ahakimi@uthm.edu.my

highly plastic, are subject to swell when their moisture content is increased. Moisture control is perhaps the most important single factor in the success of foundations on shrinking and swelling clays. The percentage of clay in soil and clay minerals activity is reflected qualitatively by the plasticity index's value. The larger clay mineral content, and the more active the clay mineral, the greater its potential for swelling, creep, and behaviour changes [1-9].

The applications of stabiliser on soil are used widely in the world to solve the problem of high settlement and weak compressibility of soil. A stabiliser is categorised by traditional and non-traditional generally. Traditional additives include cement, lime, fly ash, and bituminous materials, while non-traditional additives consist of various combinations such as enzymes, liquid polymers, resins, acids, silicates, ions, and lignin derivatives [1]. Chemical stabilisation methods are presented to provide soil strength improvement, mitigation of total and differential settlements, shorter construction period, reduced construction costs, and other characteristics that may impact their utilisation to specific soft ground projects [10-12].

In this study, two types of non-traditional soil additives, known as SH-85 biomass silica or calcium-based powder form and TX-85 as sodium silicate or liquid-based form, were introduced. In order to determine the physical properties and the compressibility behaviour of BPSC treated with different percentages of stabilisers the several geotechnical laboratory tests were performed considering the effect of different of curing time. Laboratory tests, including the Atterberg limit test and compaction test, were conducted to determine the basic physical properties of the treated soil. The compressibility behaviour of BPSC treated with a combination of TX-85 and SH-85 probase stabiliser were discussed using the consolidation test.

2. LITERATURE REVIEW

2.1 Soft Clay

Many engineering problems in the form of slope instability, bearing capacity failure or excessive settlement could occur either during or after the construction phase due to the low shear strength and high compressibility of this soil. Soft soil is typically characterised as soil with low shear strength, highly compressible, and low permeability. The shear strength of soil is reported to be less than 40 kPa and it can be physically moulded by light finger pressure. Generally, construction problems in this deposit are insufficient bearing capacity, excessive post-construction settlement, and instability on excavation and embankment forming. Theoretically, a settlement problem can be defined as a deformation in the soil due to the applied stresses. As a result of the settlement, the geometry of the load-carrying system will be changed, and if the groundwater level is high, a part of the fill material will become buoyancy which will influence the total surcharge loading and the stability of the soil [10].

2.2 TX-85 Liquid Soil Stabiliser

TX-85 liquid soil stabiliser is 100% organic and derived from combined organic sulphur and buffered acids combined as bi-sulphates [13]. TX-85 is one of the various means available for stabilising the soil road if it does not meet sealing requirements and TX-85 also call as sodium silicate. It is an environmentally safe water-based formula tested by the SIRIM Department of Environment Certification and approved for the Acute Toxicity Test. TX-85 is mainly used for stabilising unstable soil to form a stronger road and constructions. It also reduces the plastic index and improves the strength of the soil [2].

2.3 SH-85 powder soil stabiliser

Probase SH-85 Soil Hardener is a bio-technological breakthrough generated from waste biomass silica to form "Artificial Laterite". This soil cement-like product can be used with any type of soil for a road through the formulation of various ratios ranging from 2% to 8%, achieving any California Bearing Ratio (CBR)/Unconfined Compressive Strength (UCS) tests to meet the different standards and requirements of engineering design. Previous research also demonstrated that SH-85 had decreased the compression index and swelling index of marine clay and shows that the chemical composition presents in the biomass silica is almost the same as a combination of cement and lime consisting of mainly calcium oxide (CaO) [14].

2.4 Compressibility behaviour of soil

When a soil mass is subjected to a compressive force, its volume decreases. The property of soil decrease in volume occurs under compressive force is known as the compressibility of soil. According to Craig (1983), consolidation is the gradual reduction in the volume of a fully saturated soil of low permeability due to drainage of some of the pore water, the process continuing until the excess pore water pressure set up by an increase in total stress has completely dissipated [6]. The compression of soil can occur due to compression of solid particles and water in the voids, compression, and expulsion of air or water in the voids. The voids may be filled with air or other gas, water or other liquid, or a combination of these [7]. The compression of saturated soil under a steady static pressure is known as consolidation. It is entirely due to the expulsion of water from the voids. According to Rao and Venkatramaiah (2000), the process of consolidation can be divided into 3 phases.

2.4.1 Initial consolidation

When a load is applied to partially saturated soil, a decrease in volume occurs due to expulsion and air compression in the voids. A small decrease in volume occurs due to the compression of solid particles. The reduction in the soil volume just after applying the load is known as initial consolidation or initial compression. For saturated soils, the initial consolidation is mainly due to the compression of solid particles [8].

2.4.2 Primary consolidation

After initial consolidation, further reduction in volume occurs due to the expulsion of water from the voids. When saturated soil is subjected to pressure, all the applied pressure is taken up by water as an excess pore water pressure. A hydraulic gradient will develop and the water starts flowing out, causing a decrease in volume occurs. This reduction in volume is called the primary consolidation of soil [8].

2.4.3 Secondary consolidation

The volume reduction continues at a very slow rate even after the excess hydrostatic pressure developed by the applied pressure is fully dissipated and the primary consolidation is complete. The additional reduction in the volume is called secondary consolidation [8].

3. METHODOLOGY

In this research, physical property tests were conducted to obtain the property values of BPSC. Soft clay was treated using different percentages of TX-85 and SH-85 (3%L + 6%P, 3%L + 9%P and 3%L + 12%P). Where L is referred to as the liquid stabilizer which is sodium silicate (TX-85) while P is referring to as the Powder stabilizer which is biomass silica (SH-85). The density for every sample was taken as 90% of MDD, estimated as site maximum dry density. Then, a constant mass of the sample was compacted into the ring. After remoulding, the specimen was sealed tightly in a plastic sheet to prevent moisture loss due to surface evaporation before curing at room temperature for 0 day, 7 days, and 14 days. The standard oedometer test is then carried out on a consolidation cell of saturated soil with the dimension of usually 75 mm diameter and 20 mm thick. The vertical compression under each load is observed at suitable intervals, normally until up to 24 hours. The loading applied 25 kPa, 50 kPa, 100 kPa, 200 kPa, 400 kPa, 800 kPa, and the unloading applied was 400 kPa, 200 kPa. Figure 1 shows the methodology flow chart.

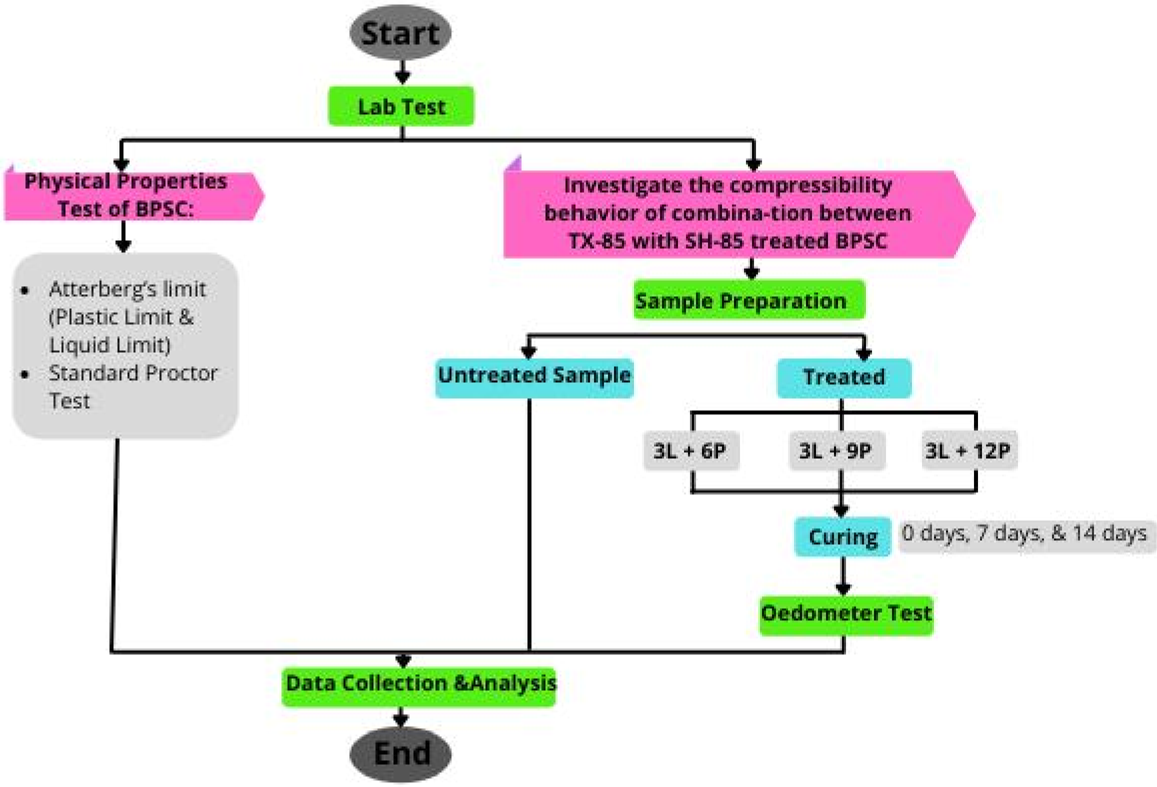

Figure 1. Methodology flow chart.

4. RESULTS AND DISCUSSION

The Atterberg limit was conducted to describe the physical properties of untreated BPSC changes with the water content. The value of the liquid limit obtained is 71.0%. The result obtained was 26.40% for the plastic limit, while the plastic index obtained was 44.60%. Based on the classification of soil according to plasticity, BPSC is classified as a highly plastic clay. Since the plastic index value is more than 17, the BPSC is suitable to be stabilised with TX-85 and SH-85. According to C.Chan et al. (2008), BPSC has a high liquid limit causing it to become soft and sticky until it cannot retain its shape when described as being in the liquid state [11].

Soil compaction is the process of closely packing the soil particles together by mechanical means, thus increasing the soil dry unit weight. Based on the standard proctor procedure, the soil is compacted into a metal mould with equal thickness in three layers. The 2.5 kg mass falling freely through each layer at the height of 300mm with 27 blows applied for each layer. To make sure the final layer is compacted, the surface must lie just above the top mould. The maximum dry density (MDD) was 1520 Kg/m3 and while for optimum moisture content (OMC) was 23%. The maximum dry density and optimum moisture content of Batu Pahat soft clay were in range. Table 1 presents the physical properties of BPSC.

Table 1 Physical Properties of Batu Pahat Soft Clay

Physical Properties	Values
Liquid Limit, LL (%)	71.00
Plastic Limit, PL (%)	26.40
Plastic Index, PI (%)	44.60
Maximum Dry Density, MDD (kg/m3)	1520
Optimum Moisture Content, OMC (%)	23.00

The oedometer test was conducted on both untreated and treated BPSC. The untreated BBPSC specimen was prepared and tested as a control specimen for comparison purposes with the treated specimens. Meanwhile, each duplicate sample was prepared for the combination of TX-85 with SH-85 treated BPSC at different curing periods and SH-85 contents, respectively.

Figures 2, 3, and 4 show the effect of the combination between TX-85 with SH-85 on the untreated compression curves and treated BPSC under different curing time percentages. It shows that the void ratio decrease with the increasing percentage of combination between TX-85 with SH-85, and the void ratio also reduces due to increasing curing time. The reduced patent of void ratio is similar to Nima et al.(2015) [2]. Test results also show that at the low percentage of SH-85 content, minimal cementation effect was observed in the treated BPSC matrix. It seems to suggest that a certain amount of SH-85 was required to complete the interaction between SH-85 and BPSC to form the primary and secondary attractive materials. The increase of apparent pre-consolidation pressure is due to the structure of treated BPSC particles.

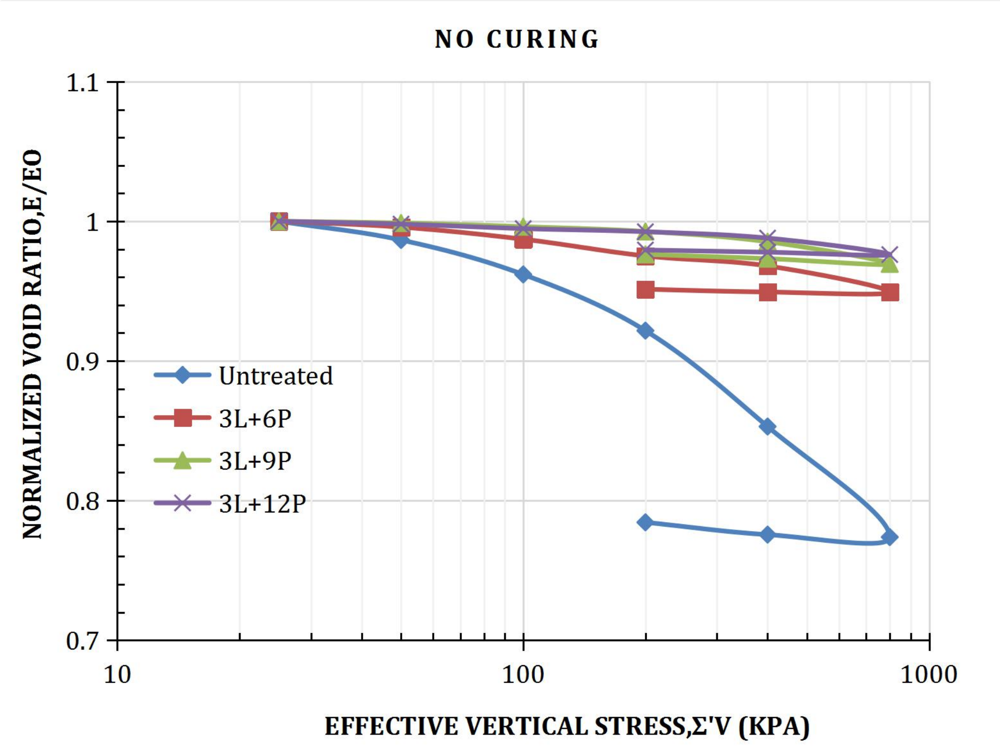

Figure 2. The effect of TX-85 with SH-85 on compression curves of the treated BPSC under 0 days curing.

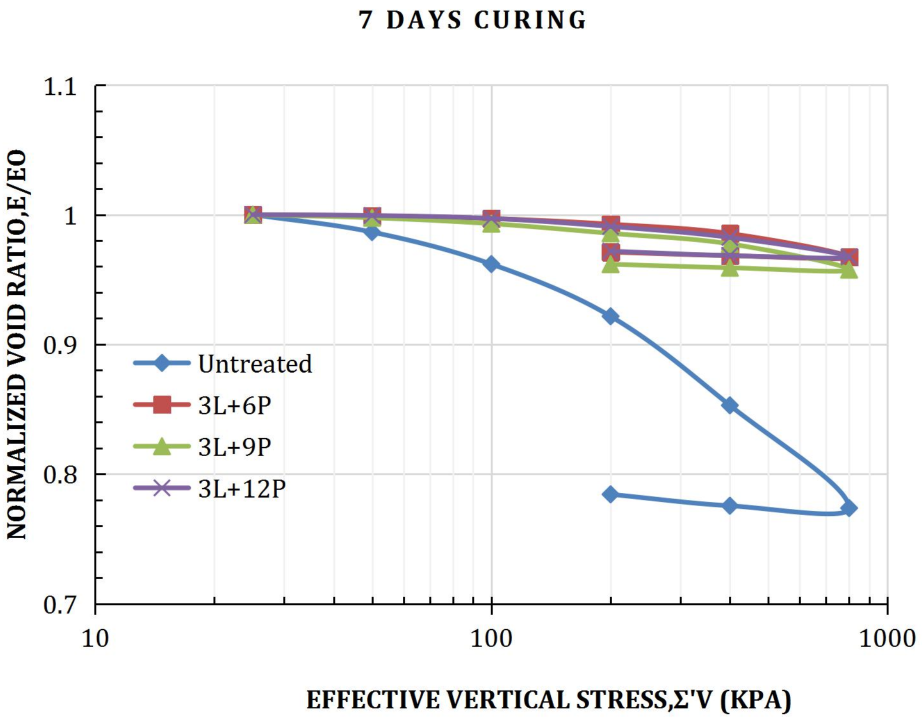

Figure 3. The effect of TX-85 with SH-85 on compression curves of the treated BPSC under 7 days curing.

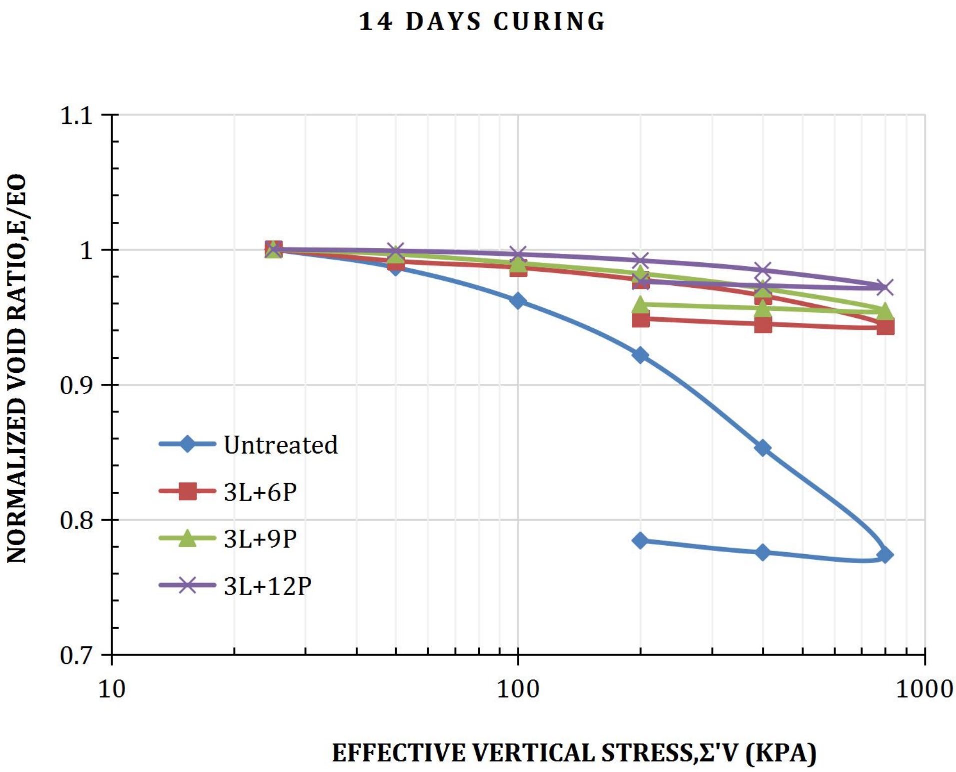

Figure 4. The effect of TX-85 with SH-85 on compression curves of the treated BPSC under 14 days curing.

At consolidation pressure of less than the apparent pre-consolidation pressure (over consolidation), the void ratio of the treated samples reduces with the increase in combination between TX-85 with SH-85 content. Meanwhile, for consolidation pressure beyond the apparent pre-consolidation pressure (under consolidation), the reverse trend is observed. It is also found that the change of void ratio is very small for the pressure range before the apparent pre-consolidation pressure this is because of the soil in over consolidation condition.

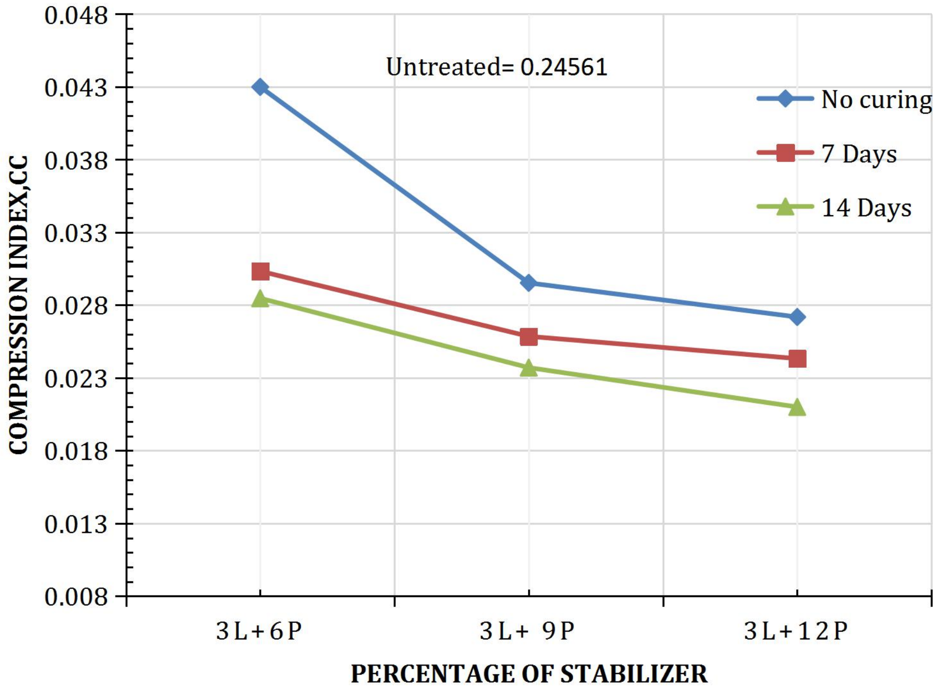

Figure 5. The effect of TX-85 with SH-85 content and curing time on compression index of the treated BPSC.

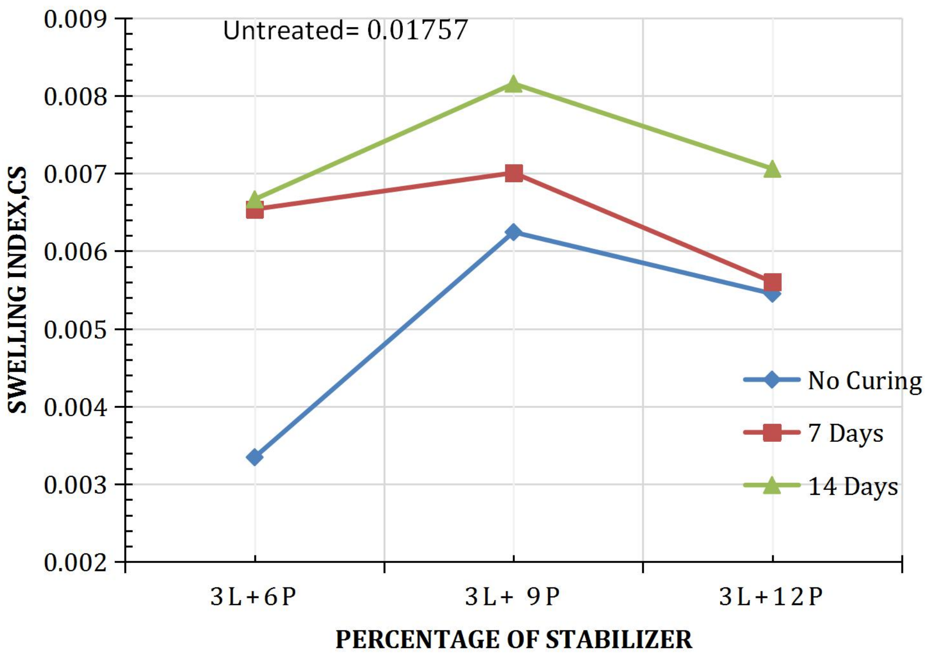

Figure 6. The effect of TX-85 with SH-85 content and curing time on swelling index of the treated BPSC.

The compression index of the treated BPSC is represented as Cc, while Cs represents the swelling index of BPSC treated using the combination of TX-85 with SH-85. It should be noted that the Cc and Cs value of the treated BPSC was calculated from the initial loading of the e-log σ‟ v curve. The Cc value decreased with the increased percentage of combination between TX-85 with SH-85 content. It is also noted that the Cc of the treated BPSC was much lower (Cc treated = 0.02099 until 0.04299) than that of the untreated clay (Cc untreated = 0.24561). This observation is consistent, which showed that the structured soil is more compressible during virgin yielding than the reconstituted soil. Thus, at a higher stress level (beyond the apparent pre-consolidation pressure), the treated samples exhibited normal consolidated behaviour with larger Cc. Figure 5 shows the effect of curing time. Due to the formation of a weak cementation bond at the end of 7 days curing periods, the compression indices were 14% higher than those of 14 days curing periods.

Figure 6 shows the swelling index of the effect on different combinations of SH-85 with TX-85 content and curing time. From the e-log σ‟ v relationships shown in Figures 2, 3, and 4, the swelling characteristics of the treated BPSC in Figure 6 were different from the untreated ones. The swelling index of the treated Batu Pahat soft clay was much 68% lower than the untreated one, and such a relatively rigid type of swelling behaviour is consistent with the heavily over-consolidated natural soil. For treated soft clay, the swelling curve is gradually decreased to the increasing percentage of the combination of TX-85 with SH-85. From Figure 6, the swelling curves of the treated BPSC at different SH-85 contents gradually decreased and affected by the SH-85 content. The swelling index of 14 days curing was higher than the 7 days and 0 days curing against the percentage of SH-85. This indicates that after the progressive destructive, the treated soft clays show significant plastic deformation, which is resisted by the soil fabric only. The treated samples show a very high pre-consolidation pressure for the cases of longer curing periods [3][4][5]. Pre-consolidation pressure is the maximum effective vertical overburden stress that a particular soil sample has sustained in the past. Figures 7, 8, and 9 show the relationship between Pc and Cc with different percentage of SH-85 under different curing period. From the figures, the compression index decrease when the preconsolidation pressure, Pc, increase through the graph. This decrease is due to the soil sustaining high vertical stress from the past, making it to decrease in a compression index.

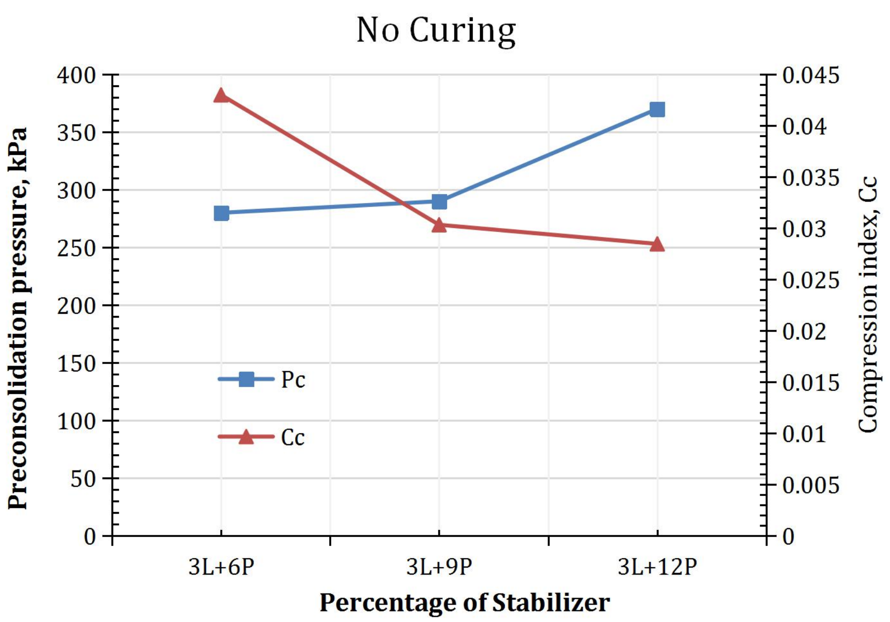

Figure 7. Relationship between Pc and Cc at different percentages of SH-85 under 0 days curing.

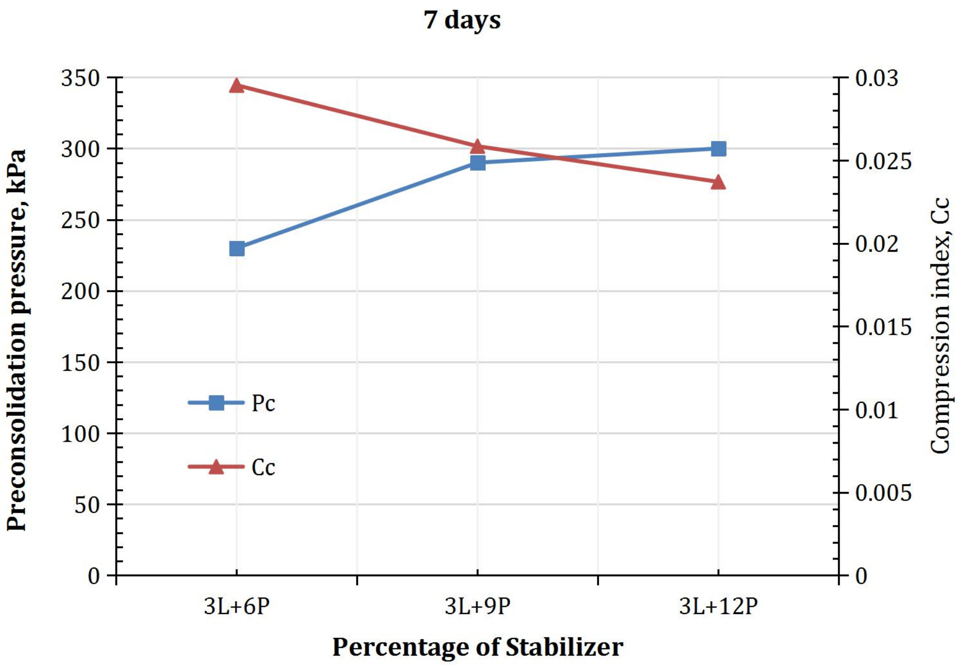

Figure 8. Relationship between Pc and Cc at different percentages of SH-85 under 7 days curing period.

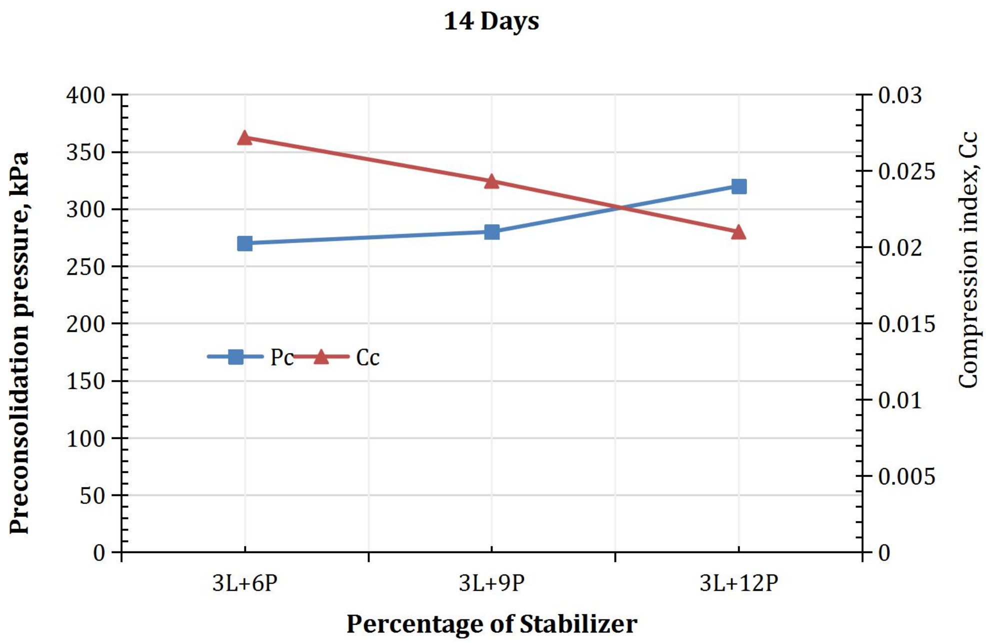

Figure 9. Relationship between Pc and Cc at different percentages of SH-85 under 14 days curing period.

5. CONCLUSION

From the result of this research, the addition of a combination between TX-85 with SH-85 on the Batu Pahat soft clay can affect the properties and strength of BPSC. Significant increase in apparent consolidation pressure and reduction in apparent compression index were observed from the odeometer consolidation test as the combination between TX-85 with SH-85 content and curing time increases. Then, the swelling behaviour of treated clay was very stiff, resulting in a very low swelling index. The void ratio of the sample decreased as the percentage of SH-85 increased from 6%, 9% and 12% of SH-85 content. In addition, the compression index and swelling index value signify the compressibility of soil, and the value of compression index and swelling index decreased as the combination of TX-85 with SH-85 content increased. The compression index decreased when the pre-consolidation pressure, Pc increased because the soil has sustained high vertical stress from the past that makes it decrease in the compression index.

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