Effect of Soft Clay Bearing Capacity on Cement-Lime Stabilization

Haslinda Ab Aziz
Politeknik Sultan Azlan Shah
haslinda8278@gmail.com

Halina Hamid
Universiti Tun Hussien Onn Malaysia
halina1278@hotmail.com

Mazly Mohd Nor
Politeknik Sultan Azlan Shah
mazlymn69@gmail.com

Abstract
Soil stabilization is the process by which a soil physical property is transformed to improve the geotechnical properties of the soil as well as the strength of the soil especially for the construction of subgrade for soft clay. The nature of soil strength is dependent on the characteristics of shear strength, bearing capacity as well as capacity in the strengthening process. Therefore, this study was conducted for the effect of soft clay, bearing capacity on cement-lime stabilization by performing a California Bearing Capacity (CBR) test with curing periods of 4 days, 7 days, 21 days, and 28 days. The study was conducted with a mixing ratio of 3% cement and 4% lime with an addition of 4% cement-lime according to the weight of the soil sample. The test was carried out by laboratory tests and mathematical descriptive. As a result, the CBR value increased by 1.5 to 3.90 to 7 days of curing and increased by 16.82 from the CBR value of 3.0 to 28 days of curing period at a 4% cement-lime mixture ratio. This increase gives a difference of up to 460% of the control sample. Thus, the cement-lime stabilization against soft clay achieves a significant increase in soil bearing capacity.

Keywords: bearing capacity, stabilization, cement-lime

1.0 Introduction

Stabilization in a broad sense incorporates various methods used to modify soil properties to improve its engineering performance (Lim Wijeyesekera, Lim & Bakar, 2014). When construction conditions are unsuitable, there are several options namely finding a new construction site area, redesigning the structure, removing weak soil, and improving soil engineering properties through stabilization (Vitton, 2006). Soil stabilization is usually done for three reasons namely as a construction platform for dry or very wet soils and to facilitate compaction of the top layer, to strengthen weak soils and restrict potential volume changes of highly plastic or compacted soils, and to reduce moisture susceptibility for fine-grained soils. Through stabilization, such as clay, for example, water infiltration rate and moisture content can be reduced as well as can increase the strength of soil parameters.

Once the soil has stabilized, it can indirectly reduce costs and provide consumer safety (Kumar & Thyagaraj, 2020; Mukherjee, 2014).

Various soil stabilization techniques have been applied to the construction. However, there are 2 common techniques, namely mechanical stabilization techniques and chemical stabilization techniques or other alternatives. Most stabilization in construction applies one method or both methods of stabilization. The most widely used method of mechanical stabilization is soil compaction and chemical stabilization is the mixing of materials such as cement, lime, bitumen, and liquid sodium silicate. Chemical stabilization is a necessity in the application of soil stabilization that provides more economic and environmentally friendly (Joshi & Gonnade, 2020).

2.0 Chemical stabilization

Chemical stabilization is used as an alternative to stabilizing materials is to reduce dust while being able to modify soil properties such as increasing strength and reducing water infiltration. According to Amir (2007), among the objectives of chemical stabilization is to change the change of water movement in the soil. There are various types of chemical stabilization such as cement stabilization, bitumen stabilization, and sodium silica stabilization. The choice of chemical stabilization method depends on the type of clay and the plasticity index. This can be referenced through Figure 1 below through a study in Rollings (1996), that has developed a chart and relationship between the types of stabilizing materials compared to the plasticity index values. Through this figure also shows the selection of lime stabilizing material suitable for use on clay with a particle size of more than 75 µm sieve size with a plasticity index value between the range of 10 to 20. While cement stabilization is suitable for use at a plasticity index value less than 10. While if the soil particle size is less transparent sieve size 75 µm and obtains a plasticity index of less than 6%, the use of lime as a stabilizing material is not suitable to be applied. In addition, if the soil particle size is more than 25% beyond the transparent sieve size of 75 µm and obtains a plasticity index of more than 20% the use of cement is not suitable for use.

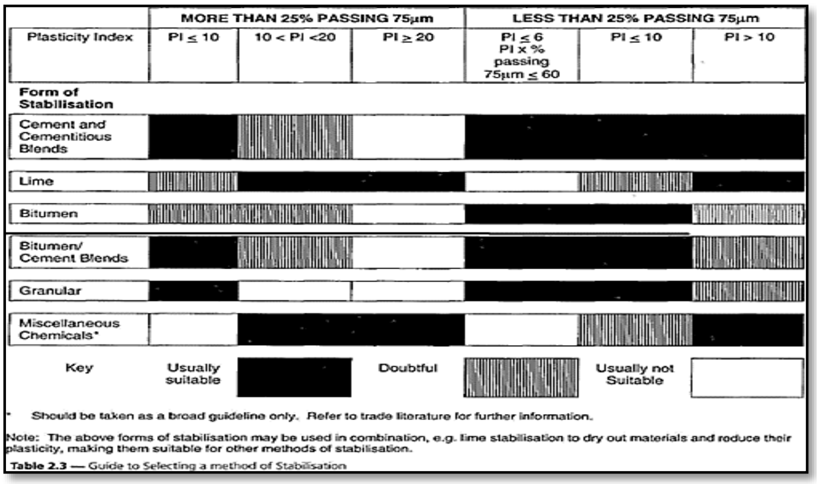

Figure 1: Stabilization method selection guide
Source: Rollings M.P (1996)

3.0 Study methodology

The cement-lime addition percentages of this study were 2%, 4%, 6%, and 8%. The mixing ratio of cement lime additive with a percentage of 4% lime and 3% cement. The addition of 4% lime supported the results of previous studies that showed that the addition of 4% lime can increase the compressive strength of the soil to the maximum. (Farooq, 2011; Ali, 2016). While previous studies also showed the addition of 3% cement showed suitability in the ratio of stabilizer materials (Aref, 2016).

The California Bearing Ratio (CBR) test is one of the most widespread tests to determine strength and bearing capacity of soil. The test was conducted according to BS 1377 Part 9. The soil with different mixture of cement-lime were compacted in modified proctor mold in five layers and optimum moisture obtained from compaction test. CBR test was performed within the laboratory with curing over 4 days, 7 days, 21 days, and 28 days.

The Atterberg Limit and Compaction tests were also performed for the determination of mathematically descriptive relationships with the obtained CBR values. Mathematical descriptive methods used in determining the accuracy of the relationship of CBR value to plasticity index (PI) value, maximum dry density (MDD), and optimum water content (OMC). This method using in Microsoft Excel software.

4.0 Data analysis and discussion

4.1 Analysis of California Bearing Capacity Ratio (CBR) in the laboratory

Figure 2 below shows that the CBR values for the cement-lime stabilizer mixture with percentages of 0%, 2%, 4%, 6%, and 8% on the curing period of 4 days, 7 days, 21 days, and 28 days. This figure, shows that the percentage of 4% mixture has given the highest CBR percentage value which is a sharp increase over the curing period. The value is shown, the CBR value at 4% mixture was 2.69% at 4 days and increased to 16.82% at the 28 day curing period. Meanwhile, for the control sample, the CBR value increased from a 4 day curing period at a CBR value of 0.7 % to a 28 day curing period with a CBR value of 3.0 %.

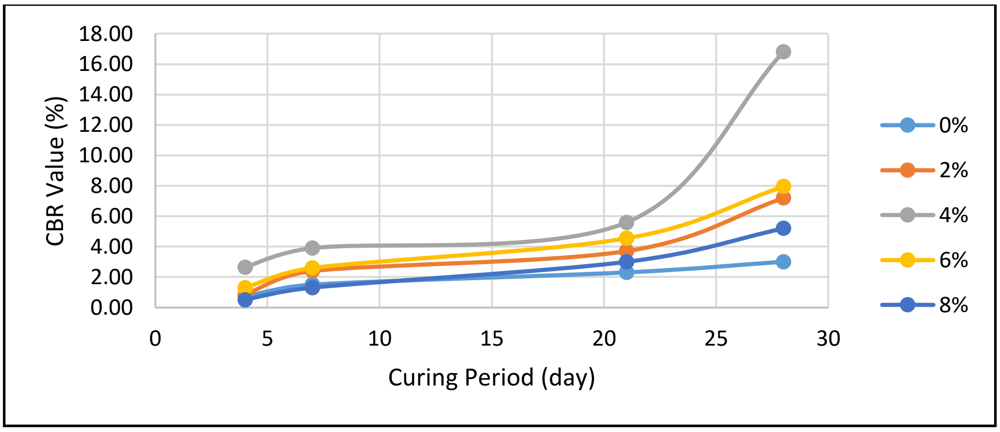

Figure 2: CBR value of cement - lime stabilizer mixture

However, there was a significant difference in the increase in strength rate based on the CBR value between the control sample without stabilizer material with the mixing sample of lime cement stabilizer material. As a result, the addition of lime cement stabilizing material in Batu Pahat Soft Clay soil gives an increase in CBR percentage value. This is shown in Figure 3, with the addition 2 % cement-lime give an increase of 140 % of the CBR value at 28 days curing. The CBR value has increased along with the percentage of cement-lime mixture. However, the maximum CBR value was obtained on a mixture of 4% cement-lime with a CBR value of 460%.

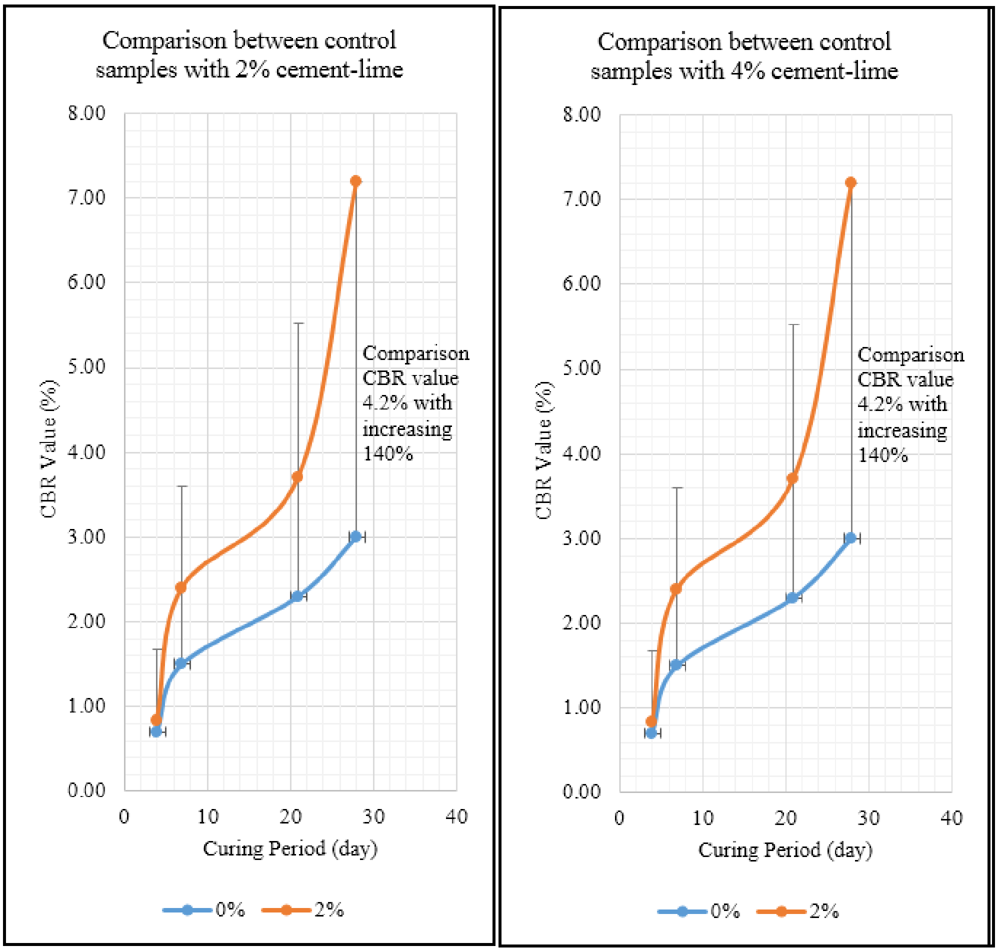

Figure 3: Comparison between control samples with (a) 2% and (b) 4% cement-lime stabilizer material

Meanwhile, the CBR value obtained for 6% of cement lime material gave an increase decrease of 165% and therefore the CBR value for the addition of 8% cement lime by 73% as shown in Figure 4 below. This clearly shows that the maximum CBR value occurs at a percentage mixture of 4% cement-lime and therefore the increase in percentage mixture cement-lime causes a slow decrease in the CBR value. This is supported by researcher Ali (2016) stated that the addition of lime for clay stabilization is not suitable for use when the lime material is more than 9%. This is because the reaction of lime with clay corresponds to a mixture ratio between 3% to 5% of lime in soil stabilization. Therefore, a percentage of 4% of this cement-lime is suitable to be used as a stabilizing material.

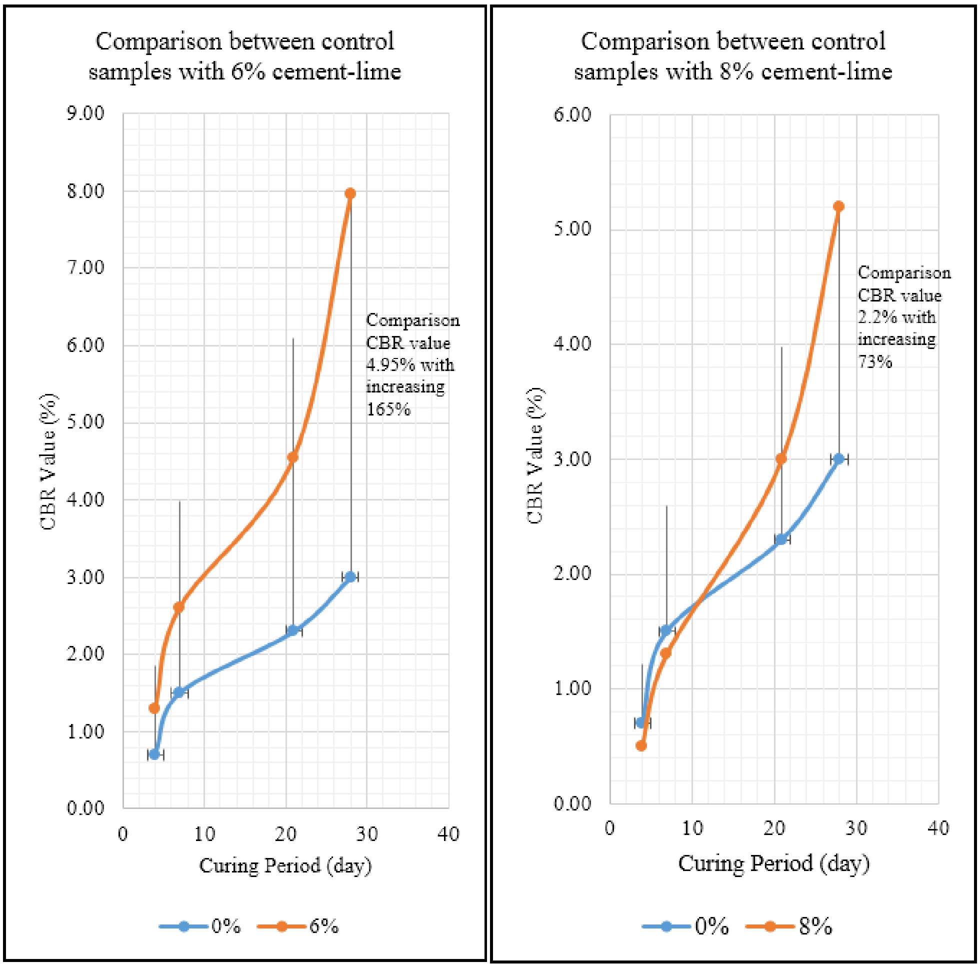

Figure 4: Comparison between control samples with (a) 6% and (b) 8% cement-lime stabilizer

4.2 Analysis of descriptive mathematical methods

Analysis using descriptive mathematical methods used in determining the accuracy of the relationship of CBR value to plasticity index (PI) value, maximum dry density (MDD), and optimum water content (OMC) was also analyzed for soft clay samples with cement-lime stabilizer mixing. A mathematical description of the sets of variables is that the best way of scientific explanation, because in a graphical presentation, prior there is always a component of biasness presentation (Dilip, 2014). To know the association of CBR value with other properties of soil, coefficient of correlation (r) between the CBR value and PI, MDD and OMC are determined. The significance of the correlation ratio has been tested by t-test (Saxena, 1993).

The coefficient of correlation (r) between the values of CBR and PI, MDD, and OMC on this cement-lime stabilizer material is determined based on Figure 5. The figure shows the value of R2 for PI is 0.4539, MDD is 0.2395 and OMC is 0.5935. Based on the value of R2, the coefficient of correlation (r) is obtained.

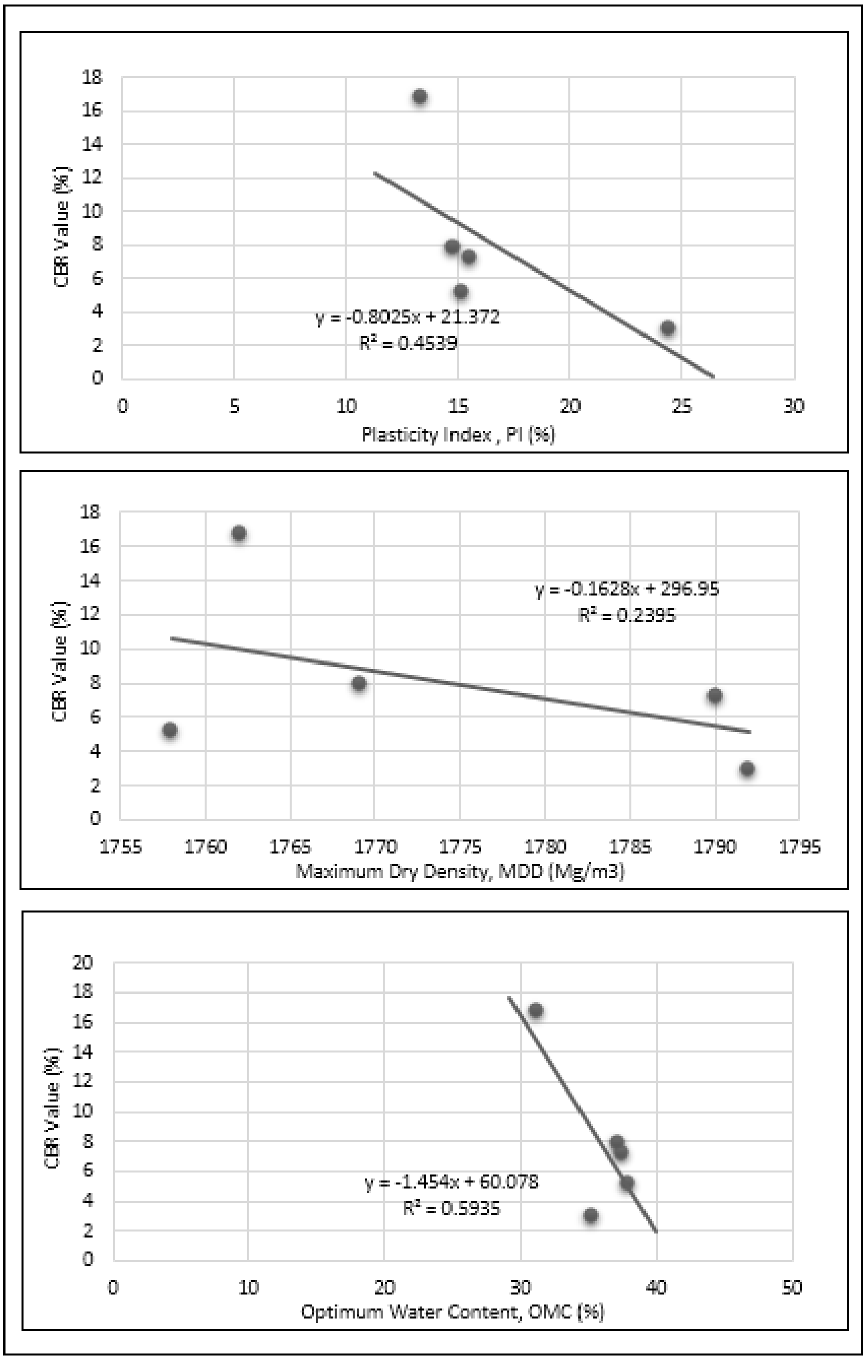

Figure 5: Correlation value coefficients for (a) PI, (b) MDD and (c) OMC with cement-lime stabilizer

Table 1 below shows the correlation value, r for PI is 0.206, the MDD value is 0.0573 and the OMC value is 0.3522. These correlation values conform to the significance level values that have been studied by (Saxena, 1993).

Table 1: Correlation values of PI, MDD, and OMC on the significance level

Soil Characteristics	PI (%)	MDD (mg/m^3)	OMC (%)
Correlation value, r	0.206	0.0573	0.3522
Significance Level	< 5%	< 1%	< 50%

A multiple linear regression model was also developed using a linear function in Microsoft Excel software on soft clay samples of cement-lime stabilizer at a curing period of 28 days. The mathematical relationship is shown in equation (1.0) below.

$$CBR_{(soak)} = -0.880(PI) + 0.0547(MDD) - 1.402(OMC) - 23.564 \quad \text{------} \quad 1.0$$

A comparison of CBR values obtained from tests in the laboratory and those obtained from equation (1.0) for Batu Pahat soft clay samples are shown in Table 2. Based on the table shows the variation between CBR values in the laboratory with mathematical relationships.

Based on Table 2, the difference of CBR values obtained in the laboratory and obtained from the mathematical equations shows a sample of Batu Pahat soft clay stabilized with cement-lime stabilizer. The obtained CBR values obtained slight differences compared to the data calculated using mathematical relations. The maximum difference obtained was 0.4534% while the minimum difference was 0.0116%.

Table 2: Differences of CBR values in the laboratory with mathematical relationships

Sample of Cement-Lime Mixture	CBR (%) from laboratory tests	CBR (%) of the mathematical relationship	variation (%)
0%	3	2.9884	0.0116
2%	7	7.3617	-0.1617
4%	17	16.8716	-0.0516
6%	8	7.4966	0.4534
8%	5	5.4516	-0.2516

Therefore, the CBR value for soft clay stabilized with cement-lime stabilizer material has a significant correlation with plasticity index, maximum dry density as well as optimum soil moisture content.

5.0 Conclusion

In conclusion, cement-lime stabilization at a 4% mixture gave a significant increase in soil bearing capacity on soft clay. In addition, through mathematical methods, the relationship of CBR value with the physical properties of the soil has a high level of significance. There is a slight difference between the CBR values obtained in laboratory tests and computed by using multiple linear regression model involving PI, MDD and OMC.

6.0 Appreciation

The authors would like to thank you for the cooperation in the use of equipment and laboratories at the Sultan Azlan Shah Polytechnic and the Soft Soil Research Centre (RECESS) at the Tun Hussein Onn University in data collection for this study.

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