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SHORT NOTE

EMPIRICAL RELATIONSHIP BETWEEN STRENGTH AND LIQUIDITY INDEX OF CEMENT STABILIZED KAOLIN

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Abstract: This paper presents the correlation between Liquidity Index (LI) and Unconfined Compressive Strength (UCS) of stabilized kaolin for subgrade application. In this study, 9-samples of soil cement were prepared under various of cement and moisture content and cured for 7-days. Ordinary Portland Cement (OPC) of 7% and 13% of soil weight is added to the soil and various of moisture content is used based on the Optimum Moisture Content (OMC) value from the compaction test (0.9, 1.0 and 1.1 from OMC) in order to study the effect of the moisture content on the compaction characteristic and compressive strength. The result from the compaction test shows that the highest and optimum maximum dry density (MDD) was obtained from 7% of cement. The unconfined compressive strength increases as the cement content increases. Based on the LI and UCS relationship, the strength reached a minimum value of subgrade design strength for low volume road (0.8MPa) when the range of the LI is between -0.46 to -0.39 at 7% cement content.

Keywords: *Soil stabilization, kaolin clay soil, Ordinary Portland Cement (OPC), unconfined compressive strength (UCS)*

1.0 Introduction

According to Malaysia's economic agenda which is to optimize the cost and fit for purposes for the low volume road especially in rural area, a design guideline was proposed by Jabatan Kerja Raya (JKR) for low volume roads in May 2012 where the minimum strength for the subgrade is 0.8MPa (JKR Specification for Low Volume Roads, 2012). A part of embankment or natural soil that forms as a foundation of the pavement structure is subgrade. In order to be used as subgrade materials, soils must have acceptable strength and stability to withstand traffic load and the environmental effect. One of the methods to improve the available materials (subgrade) is through stabilisation. The processes of stabilisation is conducted by adding stabilising agents such as cement or lime either to the original or imported soil. The existing amount of water content could contribute to the performance of stabilization work. Ishak *et al.*

(2012) reported that, the in situ water content in the soil strata is keep changing due to environmental effect. Therefore; it is wise to relate the performance of the stabilized soil with the in situ water content.

Although several studies have been made previously to established the performance of stabilized soil with several parameters, however no attempt has been made to study on the relationship between stabilised soil strength and Liquidity Index as shown in Equation 1(Thompson, 1996; Terashi, 1997; Saitoh, 1988; Niina *et al*., 1977, 1981; Terashi *et al*., 1980; Kawasaki *et al*., 1981; Aykut *et al*., 2006; Jack, 1995; Rashid *et al*., 2008; Mekkawy *et al*., 2010)

$$LI = (w-PL)/(LL-PL) \quad (1)$$

where w is in situ water content, PL and LL are plastic and liquid limits of the soil respectively.

Therefore, in this study, a series of laboratory works is conducted to study on the potential relationship between stabilised strength and LI value under 7 days curing period and various of percentage of cement. This relationship is useful as guideline to the road contractor or consultant to construct the subgrade at the minimum cement content, strength and moisture content.

2.0 Materials and Methodology

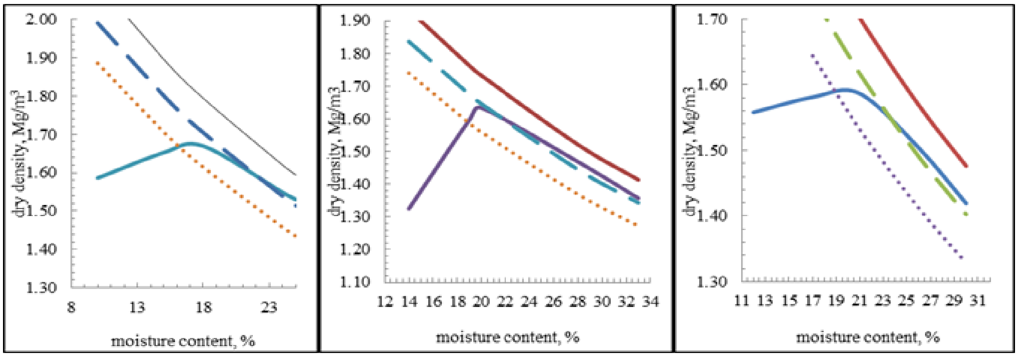
The properties of the kaolin soil based on Atterberg Limit test is 54.0% and 29.1% for Liquid Limit (LL) and Plastic Limit (PL) respectively. Thus, the Plasticity Index (PI) attained is 24.9% which means the soil is in high plasticity. Based on the Unified Soil Classification System, kaolin is classified as well graded fine-grained soil (CH) and group name is sandy elastic clay. Ordinary Portland Cement (OPC) is used as stabilizer agent and mixed with the brown kaolin clay. Samples were prepared at 0%, 7% and 13% cement by the weight of the kaolin. The range of cement is recommended by Walsh-Healey Public Contracts Act (PCA), US Department of Labour (1936) for silt and clayey types of soil.

Soil of 2kg was used for the standard compaction test for each percentage of cement. A cylinder soil cement sample then was prepared in the dimension of 38mm in diameter and 76mm in height for the Unconfined Compressive Strength (UCS) test based on the OMC obtained from the compaction test. In order to study on the relation between LI and soil strength, another two moisture contents value based on 0.9 and 1.1 OMC were included in the experiments. A simple notation is used in this paper to explain the condition of 0.9 and 1.1 OMC value as minimum and maximum water content. In total, 9 samples were prepared and cured for 7days before the UCS test is carried out.

3.0 Experimental Results

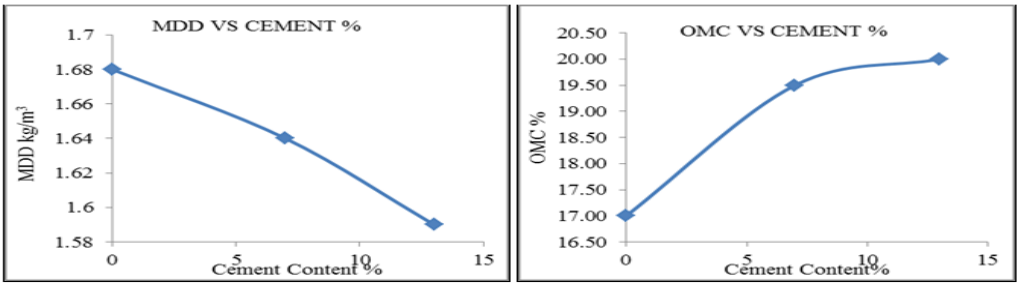
3.1 Compaction Test Result

Figure 1 shows the compaction results for 0%, 7% and 13% cement stabilized soil. The maximum dry density (MDD) and OMC obtained for 0%, 7% and 13% cement are range from 1.59Mg/m^3 to 1.64Mg/m^3 (Figure 1). Meanwhile, the MDD is ranging from 17% to 20% for various cement content. It was found that, the highest value of MDD occurred when the cement content is 0% as shown in Figure 2a and decreased gradually when the cement content is increased. This result has been supported by the OMC results (Figure 2b) where the OMC increased when the cement content is increased. The conclusion is the kaolin soil is absorbing higher water content due to the reaction between a higher cement content with the soil.



(a) (b) (c)

Figure 1: Compaction for percentage of (a) 0%, (b) 7%, and (c) 13% of cement content



(a) (b)

Figure 2: (a) Maximum Dry Density and (b) Optimum Moisture Content versus Percentage of Cement (%)

3.2 Unconfined Compression Strength Test Result

Figure 3 shows the stress-strain curves obtained from UCS test for 7 days curing period under various percentages of cement and moisture content. The strength of kaolin with 0% of cement show that the ultimate condition of moisture content provided a higher strength with 214kPa at 2.4% strain, followed by 189kPa at optimum moisture content with 2.6% strain and 182kPa at minimum moisture content with 2.5% strain.

Meanwhile, Figure 3(b) shows the strength of kaolin with 7% of cement at the ultimate condition value is 1642kPa at OMC with 2.4% strain, followed by 1553kPa at maximum moisture content at 1.3% strain and 1043kPa at minimum moisture content with 1.7% strain. Figure 3(c) shows the strength of kaolin with 13% of cement, with a ultimate value of 2213kPa at OMC with 0.4% strain, followed by 1752kPa at maximum moisture content with 0.018% strain and 1181kPa at minimum moisture content with 0.8% strain.

The strain at failure is generally in the range between 0.4% and 2.6% for all cases of strength. The strength of the samples, cured for 7 days, increased with increase of stabiliser content as shown in Figure 4 and a similar pattern of strength was obtained for the OMC and maximum condition. By adding 7% and 13% of cement content, the strength of the soil increased by 636% and 795% respectively compared to the untreated soil.

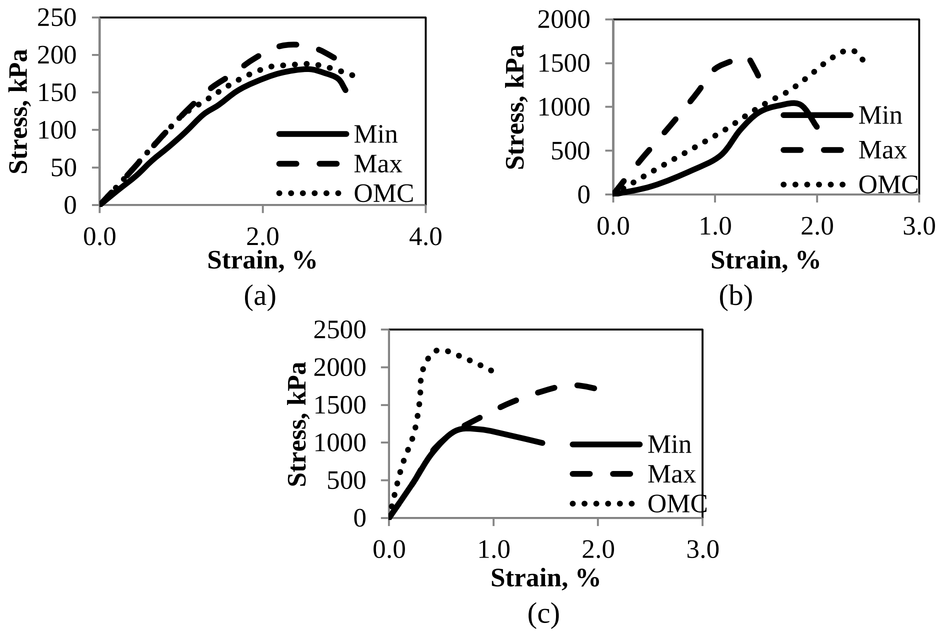


Figure 3: Unconfined Compressive Strength curve for (a) 0%, (b) 7% and (c) 13% cement

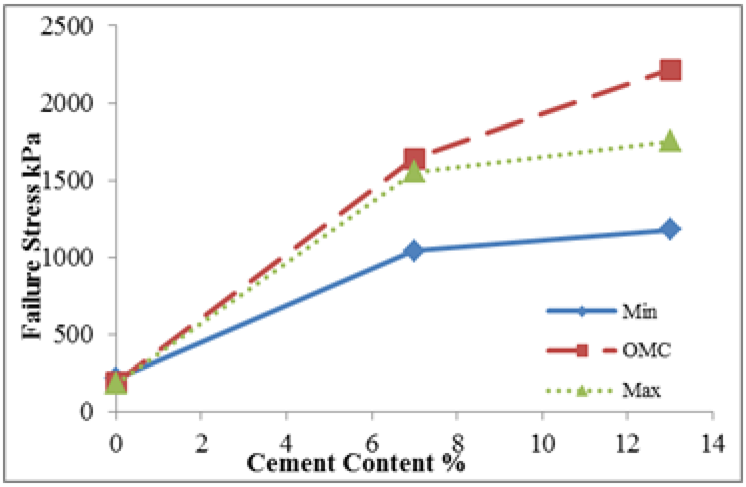


Figure 4: Stress (kPa) versus Percentage of Cement

4.0 Discussion

Figure 5 shows the relation between the Liquidity Index (LI) and ultimate compressive strength for the cement stabilized kaolin. The pattern shows that the ultimate strength obtained when the LI is -0.38 and -0.36 for 7% and 13% cement content respectively. However, the strength reached a minimum value of subgrade design strength for low volume road (0.8MPa) when the range of the LI is -0.46 and -0.39 at 7% cement content. This relationship is useful as guideline to the road contractor or consultant to construct the subgrade at the minimum cement content, strength and moisture content.

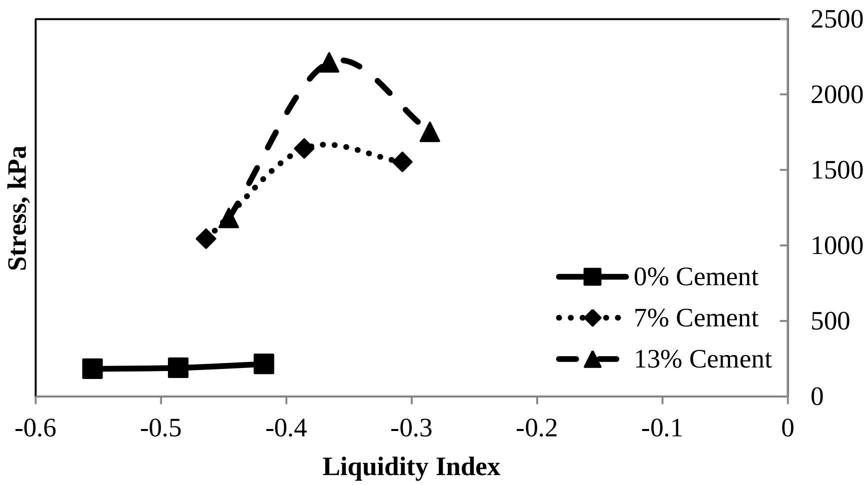


Figure 5: Unconfined Compressive Strength (UCS) versus Liquidity Index (LI)

5.0 Conclusion

Several conclusions could be made from this study as follow:

1. The result from the compaction tests found that the highest and optimum maximum dry density (MDD) was obtained from 7% cement.
2. The UCS increased as the cement content is increased
3. Based on the LI and UCS relationship, the strength reached a minimum value of subgrade design strength for low volume road (0.8MPa) when the range of the LI is -0.46 to -0.39 at 7% cement content.

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