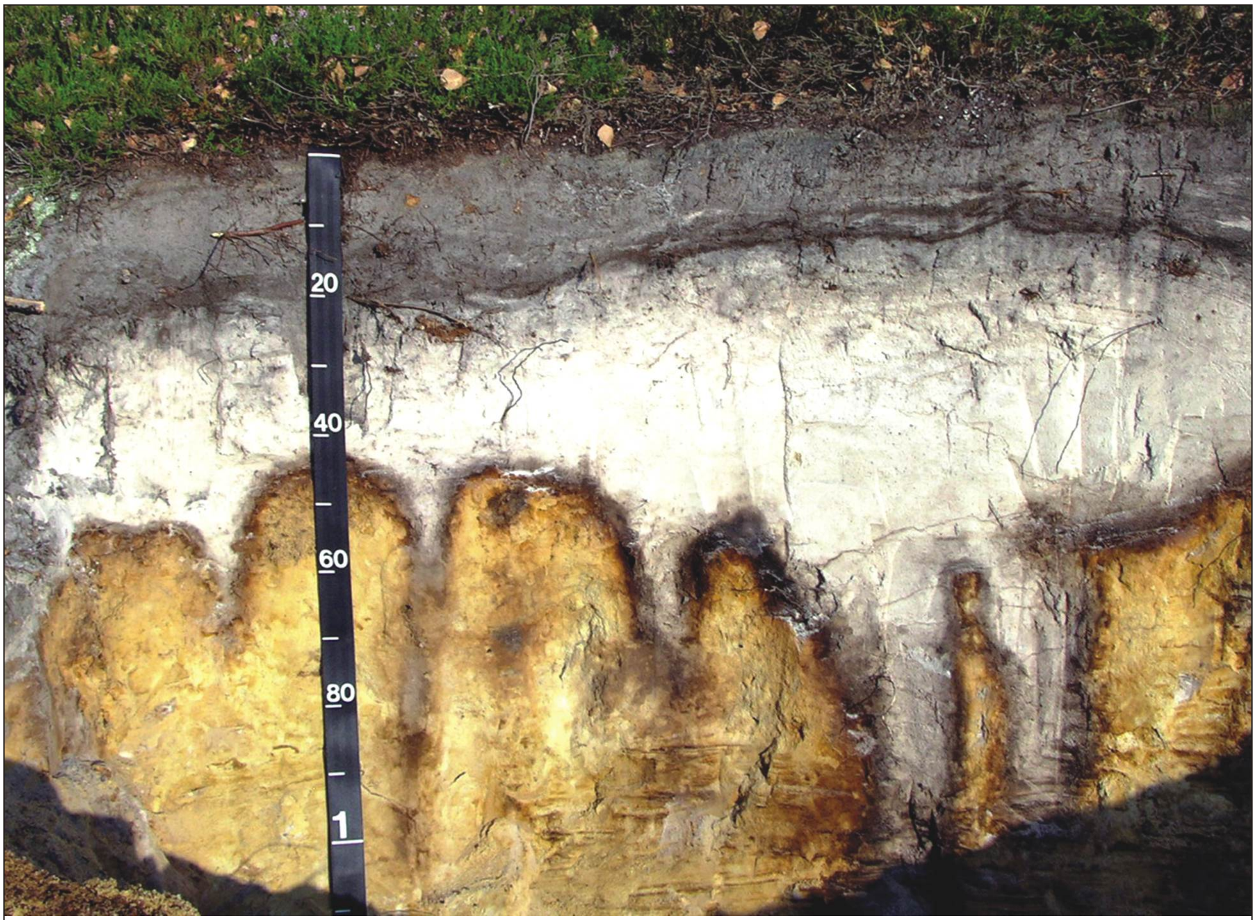

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Relationship between Strength and Liquidity Index of Cement Stabilized Laterite for Subgrade Application

Dyg Nur Intan Afzan Awg Shahminan, Ahmad Safuan A. Rashid, Aliff Ridzuan Bunawan, Haryati Yaacob and Norhazilan Md. Noor
Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310, UTM Johor Bharu, Johor, Malaysia

Corresponding Author: Ahmad Safuan A. Rashid, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310, UTM Johor, Bharu, Johor, Malaysia

ABSTRACT

This study presents the relationship between the strength and Liquidity Index (LI) of laterite under various percentage of cement (0, 7 and 13%) in 7-days curing period. Ordinary Portland Cement (OPC) of 7 and 13% of soil weight is added to the soil and various moisture contents are used based on the Optimum Moisture Content (OMC) value from the compaction test (0.9, 1.0 and 1.1 from OMC). The intention is 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 recorded from 13% cement content. The Unconfined Compressive Strength (UCS) tests are carried out and indicate that the strength increases as the cement content increases. Based on the LI and UCS relationship, the strength has reached a minimum value of subgrade design strength for low volume road (0.8 MPa) when the range of the LI is -0.74 to -0.56 at 13% cement content.

Key words: Laterite, particle size analyses, Atterberg limit, compaction test, unconfined compression test

INTRODUCTION

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, soil must have acceptable strength and stability to withstand traffic load and the environmental effects. There are several factors that affect the strength of the subgrade; types of soils, moisture content during construction, method and effort or modification and changes that may occur over the service life of a pavement.

For a low volume traffic road, the minimum strength of the subgrade material must have Unconfined Compressive Strength (UCS) of at least 0.8 MPa. Subgrade materials that are unsuitable can be replaced with strong materials or improved by using a modification method such as compaction and stabilisation. The process of stabilisation is conducted by adding stabilising agents such as cement or lime to improve the engineering properties of the subgrade (Guyer, 2011). Kitazume (2005) stated that cement binders are the most common stabilising agents that could be used on different type of soil conditions compared to the lime.

Several studies have been made previously to establish a relationship between stabilised strength and several parameter such as curing period, type of stabilisation agent, percentage of cement, pH value, grain size distribution, initial moisture content and temperature (Thompson, 1996; Terashi, 1997; Saitoh, 1988; Niina *et al*., 1977, 1981; Terashi *et al*., 1980;

Kawasaki *et al*., 1981; Wrightman, 1995; Senol *et al*., 2006; Mekkawy *et al*., 2011). However, no attempt has been made to study on the relationship between stabilised soil strength and Liquidity Index (LI) (Eq. 1):

$$LI = (w-PL)/(LL-PL) \tag{1}$$

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

Therefore, this study presents the relationship between soil stabilised strength and LI that is useful as guideline to the road contractor or consultant to construct the subgrade at the minimum cement content, strength and moisture content.

MATERIALS AND METHODS

Materials: Samples of laterite were collected from the hilly area in Universiti Teknologi Malaysia, Johor. Sample was left for one week for air drying before being used for testing. In this research, Ordinary Portland Cement (OPC) is used as a stabilizer agent and the percentages of cements used in this study are 7 and 13% from soil weight according to Walsh-Healey Public Contracts Act (PCA), US Department of Labour (1936).

Preparation of specimens: A 2 kg laterite soil was used to conduct the standard compaction test for each different percentage of cement; 0, 7 and 13%. A cylinder soil cement sample then was prepared in the dimension of 38 mm in diameter and 76 mm in height for the Unconfined Compression Strength (UCS) test based on the Optimum Moisture Content (OMC) obtained from the compaction test. In order to study the relation between Liquidity Index and soil strength, another two moisture contents value based on 0.9 and 1.1 OMC were included in the experiment. A simple notation is used in this study to explain the condition of 0.9 and 1.1 OMC value as minimum and maximum moisture content values. In total, 9 samples were prepared and cured for 7 days prior to UCS test.

RESULTS

Particle size analysis and atterberg limit test results: From dry sieve analysis and wet sieve analysis, laterite as used in this research can be classified as fine-grained soil where the grain size distribution curve shows the cumulative percentage of passing sieve No. 200 (76.2 mm) is more than 50% of tested sample. The properties of the soil obtained from Atterberg Limit test are; Liquid Limit (LL) of 79.6% and Plastic Limit (PL) of 47.8%. Thus, the Plasticity Index (PI) attained is 31.8%. From these values, the type of soil falls in group of sandy fat clay.

Compaction test results: The Maximum Dry Density (MDD) values are gained by plotting the graphs of Dry Density versus Moisture Content as shown in Fig. 1. For 0% of cement content, the OMC is 25.8% and its MDD is 1.51 Mg m^{-3}, for 7% of cement content, the OMC is 25.8% and its MDD is 1.47 Mg m^{-3} and for 13% of cement content, the OMC is 27.2% and its MDD is 1.51 Mg m^{-3}. It was found that, the highest value of MDD was recorded when the cement content is 13% as shown in Fig. 2a. This result has been supported by the OMC results (Fig. 2b) where the OMC increases when the cement content increases. It can be concluded that the laterite soil is absorbing higher water content due to the reaction between a higher cement content with the soil.

Unconfined compression strength test results: Figure 3 shows the stress strain curves obtained from UCS test for 7-days curing period under various percentages of cement and moisture

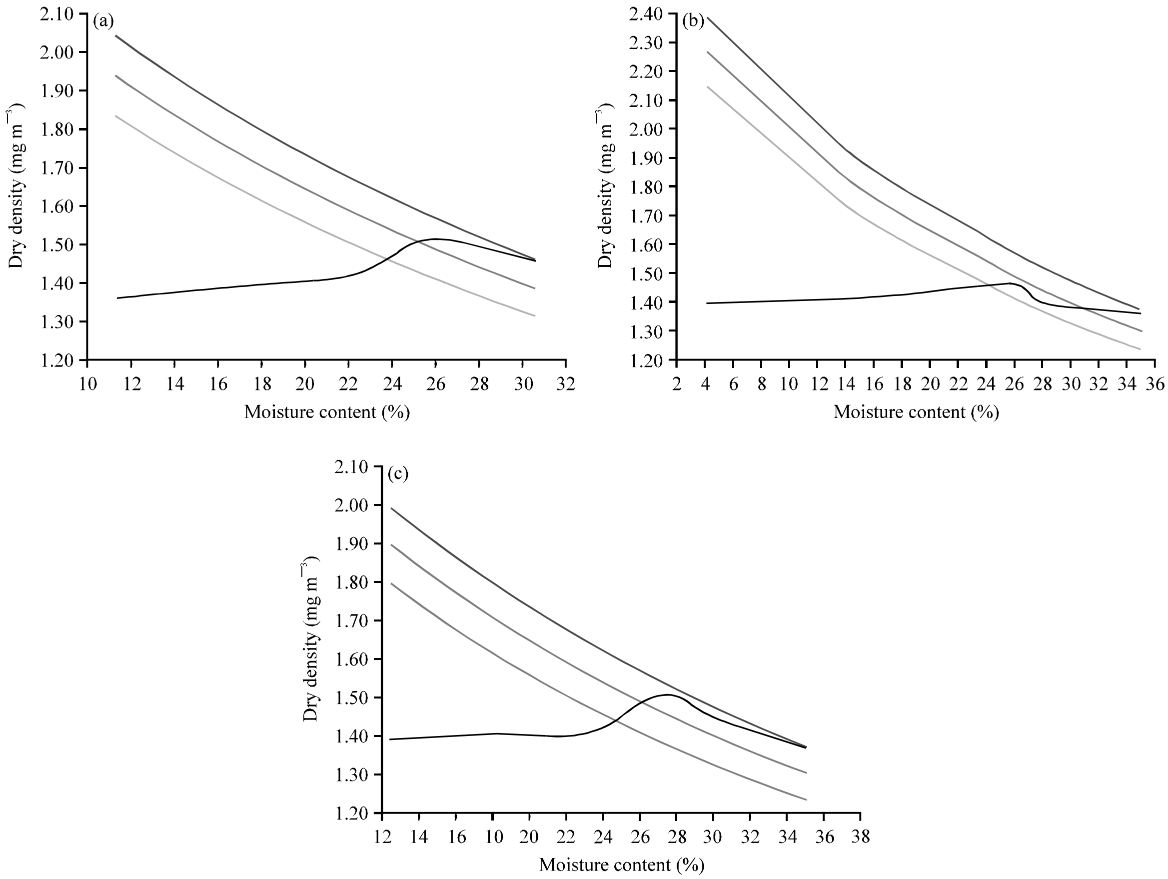

Fig. 1(a-c): Dry density vs. moisture content, (a) 0% of cement, (b) 7% of cement and (c) 13% of cement

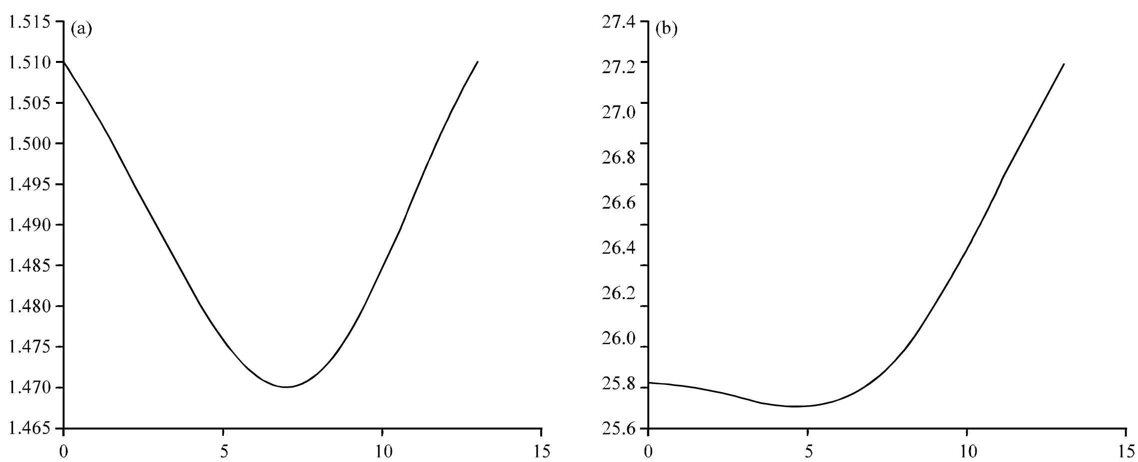

Fig. 2(a-b): Relationship of MDD and OMC with percentage of cement, (a) MDD and (b) OMC

content. From Fig. 3a-c, the strength of laterite with 0% of cement shows that the OMC provided the highest strength with 438 kPa at 0.020% strain, followed by 303 kPa at 1.1 of OMC with 0.013% strain and 221 kPa at 0.9 of OMC with 0.025% strain.

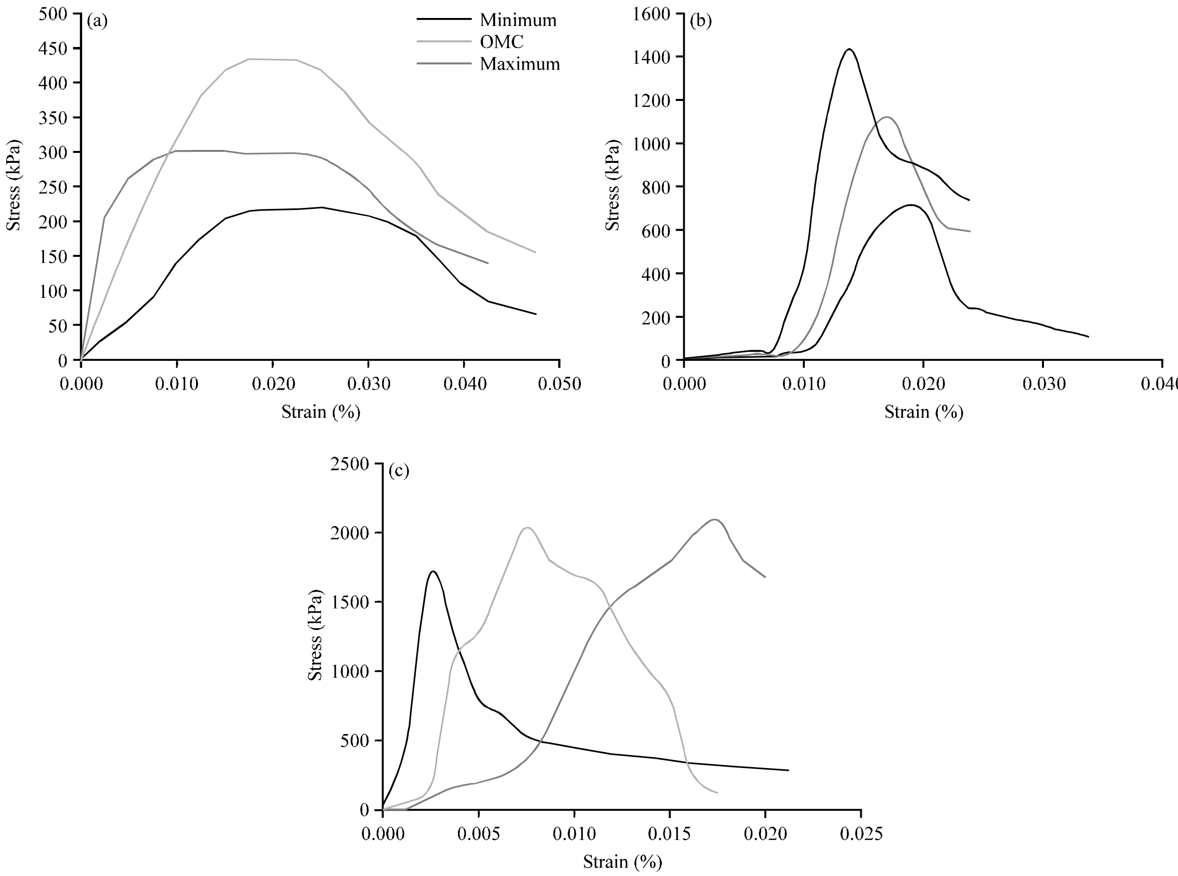

Fig. 3(a-c): Stress vs strain, (a) 0% of cement, (b) 7% of cement and (c) 13% of cement

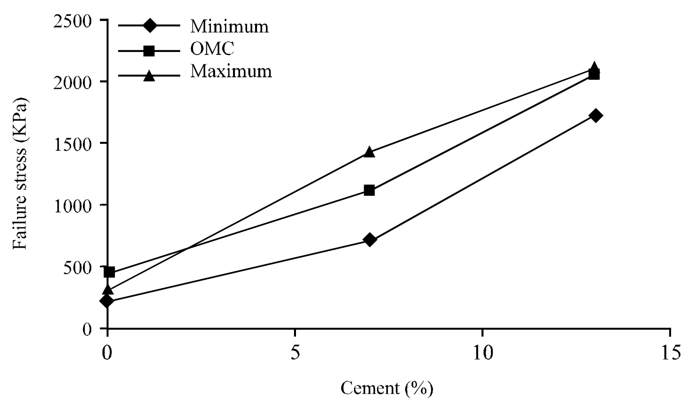

Fig. 4: Failure stress versus percentage of cement

Meanwhile, the highest strength for the treated soil by 7 and 13% cement obtained from the maximum water content condition followed by the OMC and minimum water content. The strain at failure is generally in the range between 0.003 and 0.025% for all cases of strength. It was found that the strength of the samples increases with the increase of stabiliser content as shown in Fig. 4 and a similar pattern of strength was obtained for the OMC and maximum condition. By adding 7 and 13% the strength of soil increases by 249.8 and 546.0%, respectively as compared to untreated soil.

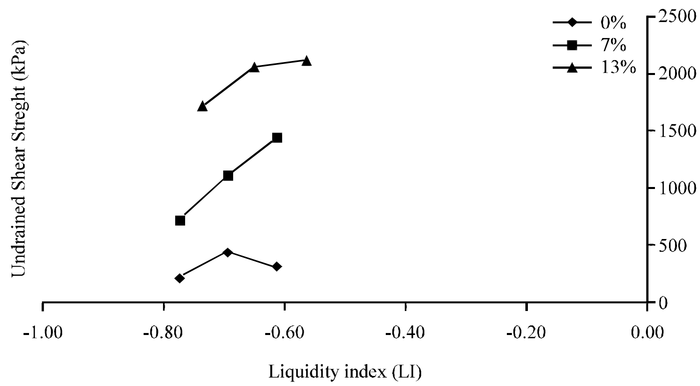

Fig. 5: Undrained shear strength vs. liquidity index

DISCUSSION

According to the results, the relation between the LI and compressive strength for the cement stabilized laterite were plotted in Fig. 5. The pattern shows that the strength increases when the LI increases for stabilized soil. At 0% cement content, the values of undrained shear strength is in between 0.2 to 0.44 MPa with LI ranged from -0.78 to -0.61. Following the addition of 7% cement, the strength increases to range from 0.72 to 1.43 MPa with LI values in range of -0.78 to -0.61. The strength reached a minimum value of subgrade design strength for low volume road (0.8 MPa) when the range of the LI is -0.65 and -0.56 at 7% cement content. This relationship is useful as a guideline to the road contractor or consultant to construct the subgrade at the minimum cement content, strength and moisture content.

CONCLUSION

Several conclusions can be made from this study as follows:

- The result from the compaction test shows that the highest and optimum maximum dry density (MDD) was obtained from 13% cement content
- The unconfined compressive strength increases as the cement content increases
- Based on the LI and UCS relationship, the strength has reached a minimum value of subgrade design strength for low volume road (0.8 MPa) when the range of the LI is -0.74 and -0.56 at 13% cement content

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