International Journal of Engineering & Technology, 8 (1.12) (2019) 47-50

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Some Selected Experimental Study on the Geotechnical Characteristics of Malaysian Laterite Soil Mixed with Sodium Carbonate (Na_2CO_3)

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Abstract

This paper presents the results of an experimental analysis on the geotechnical characteristics of laterite soil found in Malaysia that is polluted with sodium carbonate at varying percentages ranging from 0% to 20%. In demonstrating the effects posed by the chemical reactions on the laterite soil in terms of its geotechnical properties, a selection of experimental tests was designed and conducted of which results indicated shear strength improvement of the soil. Apart from that, the permeability coefficient of the soil mixed with sodium carbonate was also measured using a falling head hydraulic conductivity test which was conducted on three different measurement timeframes namely immediate, one week, and after two weeks. The results indicated that when the percentage of chemical is increased, the permeability of the soil lessened in comparison to its natural properties. Additionally, the Atterberg limits gave out results which clearly indicated that a surplus percentage of sodium carbonate had been used to enhance the liquid and plastic limits in comparison to the limits in pure soil. Consequently, the pH value of the soil was altered from being acidic to being alkaline

Keywords: *Laterite soil; Permeability; Sodium Carbonate; Shear strength; Tropic.*

1. Introduction

The tropics are home to a flourishing amount of lateritic soils which have been widely used in the construction of pavements, embankments, and low-cost houses among others in recent years. There have been instances when the soil's properties failed to adhere to the prerequisite specifications of such construction works; hence, improvement upon the matter is highly called for. Soil stabilization has been identified as one of the ways to increase soil strength i.e. to make it more durable in bearing intense moisture and stress [1]. Soil stabilization entails mixing the parent soil with another type of soil, cement, lime, bituminous products, silicates, numerous other chemicals and materials of natural/synthetic or organic/inorganic origins. Soils with high clay minerals content can be improved in terms of its geotechnical properties via the chemical stabilization method which ultimately produces apt construction materials. This study mainly aims to investigate the changes that occur with respect to the geotechnical properties of laterite soil including its compression, permeability and shear strength when different percentages of Sodium Carbonate (Na_2CO_3) were added to it. The effect of adding soda ash (Na_2CO_3) on laterite soil in terms of its pH level and compaction characteristics was previously disclosed by Shin To Amiri [2]: The soil's pH value altered from 4.87 to 9.82 whilst its compaction characteristics reached their peak with the addition of 10% soda ash per soil weight by 1.33 Mg/ m3 for maximum dry density and 20% for water content. This paper is still in the midst of investigating the effects of mixing laterite soil with sodium carbonate on other geotechnical characteristics of the soil i.e. permeability and shear strength.

2. Previous research

In recent years, many studies have been conducted on the subject of laterite soil stabilization using various methods particularly in countries in Asia and Africa which have this type of soil in abundance [3]. Among the findings of those study are: laterite soil with a high content of clay minerals exhibit decreased soil strength [4] and the most efficient percentage of cement and lime addition to the soil is 2% and 3% respectively [5].
Hydrated oxides of iron and aluminum form a concentration of vastly weathered soils which in turn make up laterite soils [6] that are characterized by hard formations, impermeable textures and often permanent pans when dried [7]. Laterites and lateritic soils refer to a vast assortment of lightly textured, fine-grained, residual soils and nodular gravels as well as cemented soils in red, brown, and yellow [8-9] which are identified based on their degree of hardening: for instance, “ferric” is used to describe iron-rich cemented crusts, “alcrete” or bauxite for aluminum-rich cemented crusts, “calcrete” for calcium carbonate-rich crusts, and “silcrete” for silica-rich cemented crusts. The ratios of silica (SiO_2) to sesquioxides (Fe_2O_3 + Al_2O_3) have also been used to describe these soils: anything between

the ratio of 1.33 and 2.0 suggest that the soil is laterite, whereas anything higher than 2.0 indicate that the soil is non-lateritic [10]. A ratio of less than 1.33 is indicative of laterites.
The addition of leachate to the chemical composition of lateritic soil could pose detrimental effects to concrete foundations in actual constructions. Locally produced lime was found to have varying degrees of stabilizing effects on lateritic soil samples as investigated by Attoh-Okine in 1990 [11], who took into consideration the effect of lime variations on the Atterberg limits, the correlation between moisture–density as well as strength characteristics. The results of the study indicated that the lime treatment had significant and varying stabilizing effects on the Atterberg limits of the soil sample in which soil strength increased when lime was added to the 28-day cured samples. The California Bearing Ratio (CBR) [12] values were observed to have changed accordingly with the change in lime content with a noteworthy reduction in both the soaked and un-soaked samples. The usage of ferric chloride salt to regulate the unwanted fluctuations in volume caused by the highly concentrated alkali contamination on kaolinitic red earth was investigated by Sivapullaiah and Manju in 2006 [13] who had substantially proven that the effects of minute alkali concentrations can be overcome by ferric chloride treatment; however, the treatment was found to be ineffective in overcoming greater and continuous exposures to alkali contamination.
Meanwhile, again Sivapullaiah et al., in 2010 [14] conducted a study on the mineralogical changes and geotechnical properties of a capacious black cotton soil that had been treated with caustic solution. The result indicated that the rectorite properties that exist in the soil are altered when the alkali concentration is increased. Changes in the soil's mineralogy were also observed with the reaction between the soil's minute amount of kaolinitic mineral and the alkali content. Consequently, there is an increase to the soil-specific surface and alterations to the Atterberg limits and free swell volume. These findings were maintained by the characteristics and behavior of the alkali-contaminated samples derived from an alumina extraction plant.
In terms of material preparation, for the purpose of this research, five types of soil-soda ash mixture were formed i.e. with no sodium carbonate (100% local soil), 5% soda ash + 95% laterite soil, 10% soda ash + 90% laterite soil, 15% soda ash + 85% laterite soil, 20% soda ash + 80% laterite soil. The experimental studies on the soil's properties apply to both the local soil and its soda ash combination.

3. Results

There are no methods to identify potentially dispersive soils as provided by the Atterberg limits; however, it is known that when the values of plastic limit, liquid limit and plasticity index are higher, the resistance to dispersion is higher as well. Before a material attains its liquid properties, a certain amount of water needs to enter it first particularly in cases where water attainment is limited. Considering that water intake is time-consuming, this factor should be taken as rather significant, exacerbated by the fact that high plasticity-indexed materials are prone to be clayey leading to low infiltration capacities. Therefore, a certain degree of stability is provided for the material when its high requirement for water is fulfilled. For the purpose of this paper, the Atterberg limits were investigated for the various soda ash-laterite soil mixture percentages in relation to the ASTM D-4318 [15].
Table 1 presents the liquid limit for pure soil that was increased from 69.75 to 80.29 and 20% for soda ash mixture. The soda ash is also shown to have exceeded the laterite soil's plastic limit by about 47%, from 38 to 56 for 0%, and 20% for the soda ash-laterite soil mixture. The liquid and plastic limits alterations affect the plasticity index which is determined by the size of the water content range from which the plastic properties of the soil are exhibited. The results show that the soil had a high plasticity index of 31.75, which was reduced to 24.29 with the addition of the sodium carbonate-laterite mixture and the 20% soda ash to the soil.
In Figure 1, the effect of the various soda ash percentages that are added to the laterite soil on the Atterberg limits trend is presented. There is a nearly parallel upward trend shown by the liquid and plastic limits. Meanwhile, the plasticity index shows a downward trend owing to the laterite soil's high plasticity content when sodium carbonate is added. The plasticity index exhibits its lowest point from where the liquid and plastic limits are exhibiting their highest peak.

Table 1: Atterberg limits according to the various Soda Ash percentages

Mixture (%)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
0% Na_2Co_3	69.75	38	31.75
5% Na_2Co_3	72.58	42	30.58
10% Na_2Co_3	76.8	47	29.8
15% Na_2Co_3	78.3	52	36.3
20% Na_2Co_3	80.29	56	24.29

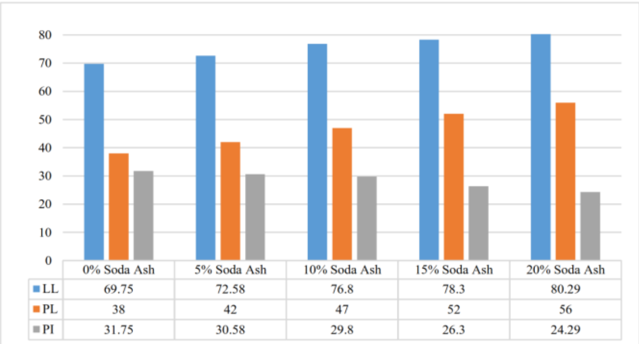

Fig. 1: The effect of the various soda ash percentages on the laterite soil's Atterberg limits. LL = Liquid Limit, PL = Plastic Limit, PI = Plasticity Index.

Cohesion and internal friction angle make up the parameters for shear strength. The correlation is that cohesion increases when the void ratio decreases, while internal friction angle increases with the increase in specific gravity [16]. The laterite soil's mineralogy and chemical composition can also affect the shear strength parameters. Cohesion increases when the kaolinite content increases, while the internal friction angle increases with the increase in sesquioxide contents. High internal friction angles indicate greater interlocking than what is commonly found in soils with such platy minerals content [17]. In addition, water content decreases the shear strength of laterite soils.

Shear strength is determined by water content, the particles' nature, normal effective stress, and dissolved salt composition; however, owing to the 95 percent degree saturation, sheer strength is instead determined by the degree of orientation and friction angle [18].
The test results for the shear strength characteristics of which direct shear test was carried out based on the ASTM D 3080 [19] are shown in Table 2. A direct shear test machine was used to test the shear strengths of five remolded samples of laterite soils found in Malaysia that were added with different sodium carbonate percentages namely 0% soda ash, 5% soda ash, 10% soda ash, 15% soda ash, and 20% soda ash per soil weight. The samples were compressed in a maximum dry density of 1.23 Mg/m3 and a moisture content of 18.27%. Based on the results, the friction angle is shown to have increased by 29.43% i.e. from 16.07º to 20.80º with the addition of 0% to 20% sodium carbonate. A remarkable increase of 84.37% for cohesion was observed i.e. from 28.15 kPa to 51.90 kPa for the 0% and 20% soda ash mixture owing to the soil's high plasticity index.

Table 2: Atterberg limits according to the various Soda Ash percentages

Mixture (%)	Friction angle (φ°)	Cohesion (kPa)
0% Na_2Co_3	16.07	28.15
5% Na_2Co_3	17.99	38.97
10% Na_2Co_3	19.09	46.48
15% Na_2Co_3	20.52	50.83
20% Na_2Co_3	20.8	51.9

Based on Figure 2, there is a clear upward trend for cohesion i.e. from 28.15 kPa to 51.9kPa, marking an improvement of 84.37% from pure laterite soil to 20% soda ash-laterite soil mixture. This indicates that the cohesion in laterite soils can be increased by sodium carbonate. Despite improvements in terms of friction angle, the alteration for shear strength was only 29.43% from pure laterite soil to 20% soda ash-laterite mixture.

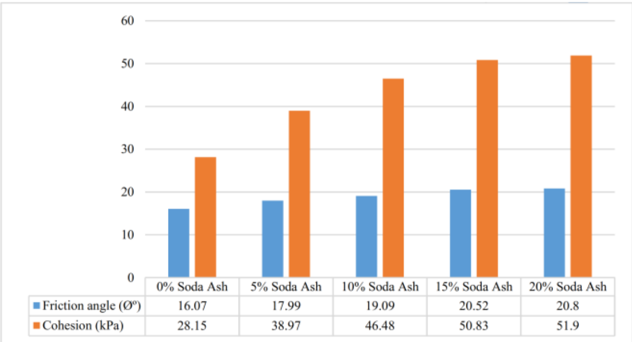

Fig. 2: The effect of various soda ash percentages on the laterite soil's shear strength characteristics

With regards to permeability tests based on the ASTM D-2434 [20] , a coefficient permeability of 8.83E-5 cm/sec was shown for natural laterite soil. Meanwhile, a reduction in alkalinity was shown in the percentages of soils that were treated with soda ash. Figure 3 presents the decreasing permeability coefficient according to the different sodium carbonate percentages and curing times, the latter of which entails an immediate, one week and two weeks' period.

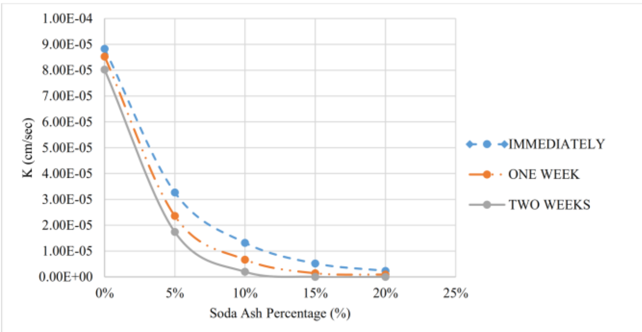

Fig. 3: Decreasing permeability coefficient according to the different sodium carbonate percentages and curing times

4. Conclusion

The investigation of this study revolves around the effects posed by the various sodium carbonate or soda ash percentages i.e. between 0 to 20% on the various geotechnical properties of polluted laterite soils found in Malaysia. This type of soil is typically found in the tropics. To achieve the objective of this study, geotechnical tests such as the Atterberg limits, direct shear and falling head hydraulic conductivity tests were carried out. The findings indicate that an increase in the soda ash percentage would result in an increase in the liquid limit and plastic limit. Findings from the direct shear tests also showed that the addition of soda ash would increase the soil mixes' friction angle and cohesion as compared to pure soil. And lastly, the falling head hydraulic conductivity test results showed that the permeability coefficient decreased with the different sodium ash percentages and curing times. Hydraulic conductivity is reduced probably due to the soil mixes' increased plasticity index.

Acknowledgement

This research was supported by Faculty of Engineering and IT, MAHSA University. We also thank our colleagues who provided insight and expertise that greatly assisted this research.

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