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EVALUATION OF CALIFORNIA BEARING RATIO AND PERMEABILITY OF STABILIZED CLAY SOIL WITH CEMENT KILN DUST

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Abstract

Soil stabilization refers to the process of changing soil physical and chemical properties to improve strength and durability. It has been used for many years to improve the characteristics of the subgrades with problematic soils. Pavements with stabilized base and sub-base layers have been proven to deliver better performance during their service life. Clay is a type of soil with particles of certain minerals giving plastic properties when mixed with water. Soil has an important role in a construction, besides as a building material in a wide variety of civil engineering works. Basic properties of clay are rock-solid in dry and plastic with medium water content. In high water content, clay becomes sticky like (cohesive) and soften. Therefore, clay stabilization is necessary to repair soil's mechanical properties. Cement industry is arguably regarded as the second largest producer of the greenhouse gases that cause global warming phenomenon, which contributes by 5–8% of the worldwide CO_2 *emissions* [redacted] *(Mehta, 2004). The major challenges facing the cement manufacturing industry is the reduction of* CO_2 *emission into the atmosphere during the manufacture of Portland cement. Cement production also results in massive quantities of solid waste material called Cement Kiln Dust (CKD), where the quantity of CKD is estimated by 3–4% of the total produced cement (Najim, Mahmod, & Atea, 2014). In this study laboratory experiment was*

KEYWORDS: *Clay, Cement kiln dust, Liquid limit, plasticity index, California bearing ratio, Permeability*

conducted to evaluate the performance of CKD on clay soil. Presently, disposal of industrial waste products have been a global problem. Their disposal are costly as well as they are harmful to environment. Owing to these problems some researches are being conducted to utilise these waste products in ground construction and modification. To achieve this, a number of mixtures with different CKD contents were used as a stabilizer in improving the properties of clay soil in terms of California Bearing Ratio (CBR) and Permeability test. The Atterberg limits and compaction characteristics were also determined for the Clay soil and stabilized clay. The results indicates that the clay soil used has liquid limitation (LL) value of 32%, plasticity index of 13.4% and CBR value 9.25%. The results further shows that the 15% CKD gives the un-soaked CBR value of 11.33%. .

Introduction

Soil Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soil to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil (Firoozi, Taha, Asghar, & Khan, 2014). The modification of soils to improve their engineering properties has been practiced for many years. Many investigations and research programs have addressed the development of materials evaluation and mixing techniques to determine the best combinations of soils and stabilizing agents (Jose & Rajamane, 2018; Kennedy, Smith, Holmgreen, & Tahmoressi, 2001; Noraida, Sa'don, & Abdul, 2016; Nur Akmal, Ahmad, Norhazilan, & Haryati, 2014). Economics have also played an important role in determining the best procedures and materials. Recently, material and construction economics have made more materials competitive, thus opening the way for more approaches than were previously used. In many parts of countries, engineers must deal with several different types of clay materials varying from extremely expansive to moderately active. Stabilization or modification of these clays is necessary for proper construction. In the past, lime has been used primarily for clay soil stabilization, and cement has been preferred for granular or sandy soils.

Cement Kiln Dust (CKD) is the fine-grained, solid, highly alkaline waste removed from cement kiln exhaust gas by air pollution control devices during cement production. Generally cement kiln dust (CKD) is a fine powered-like by–product of

Portland cement production. They are collected from stacks of high temperature rotary kiln by the federally mandated dust collection systems (e.g. cyclones, electrostatic precipitators and or bag house). Large quantities of cement kiln dust are produce during the manufacture of cement clinker by the dry process. Several factors influence the chemical mineralogical and physical composition (kumar & Singh, 2017).

The main objective of this study was to evaluate the effect of CKD on California Bearing Ratio (CBR) and Permeability of clay soil stabilization.

Material and Methods

Sample collection:

The representative sample of clay soil was collected in Damaturu Metropolitan, Yobe State, Nigeria. The Cement Kiln Dust (CKD) with the chemical composition shown in Table 1 was collected from Ashaka cement industry.

Chemical composition (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	So_3	Tio_2	P_2O_5	Mn_2O_3	LOI
CKD	11	4.48	1.99	44.45	1.02	0.57	0.08	1.25	0.2	0.18	0.14	33.63

Sample preparation

The clay soil samples was air dried and manually grinded to pulverise the big lumps in other to disintegrate particles held up by clay. The CKD was added at varying percentages of 0%, 3%, 7%, 9%, 11% and 15% in accordance with ARS 680 (1996) standard.

Experimental programme

The Atterberg limit tests, California bearing ratio (CKD), Compaction characteristics and permeability were performed on the clay samples at 0%, 3%, 7%, 9%, 11% and 15% with CKD. These tests were conducted in accordance with the British Standards codes BS 1377 - 2 (1990) and BS 1377 - 4 (1990).

Results and Discussions

Atterberg limit

The Atterberg limits tests with different CKD contents were perform to determine the effect of stabilizer contents on the Atterberg limits of the clay soil.

The liquid limit (LL), plastic limit (PL) and plasticity index (PI) of the treated clay soil are shown in Fig. 1. The results indicates that liquid limit of the clay soil-CKD mixture specimens decreased slightly at the addition of 3% CKD and after which liquid limit increased with an increase in CKD content. In other words, CKD caused the maximum decrease in liquid limit (25.05%) at the addition of 3% CKD. Similarly the plastic limit of clay soil-CKD mixture decreased initially (in CKD content equal to 3%) followed by an increase with increasing of CKD content. This reduction in the Atterberg limit at 3% may be attributed to the chemical and cementation effect on structural composition of the soil. However, with further CKD increase after 3%, the liquid limit and plasticity limit increased sharply especially at 15% CKD addition. This is could be attributed to the presence of Ca^{2+}, Si^{2+}, and Al^{3+} cations with increased stabilizer usage they react with soil particles. It was also observed that there is an improvement of plasticity index properties of the stabilized soil for up to 11% CKD addition with a decrease in plasticity index (PI) from 13.4% to 2.7% can be seen. Hence, CKD affects the plasticity index by improving the sensitivity of the soil sample to moisture. This could be due to the cation exchange capacity that occurs when the clay soil is stabilized (Mousavi & Karamvand, 2017). Therefore, the reduction in the plasticity index is due to decrease in the amount of ions in the soil sample and thereby, decrease the amount of ion exchange solution required for the soil stabilization.

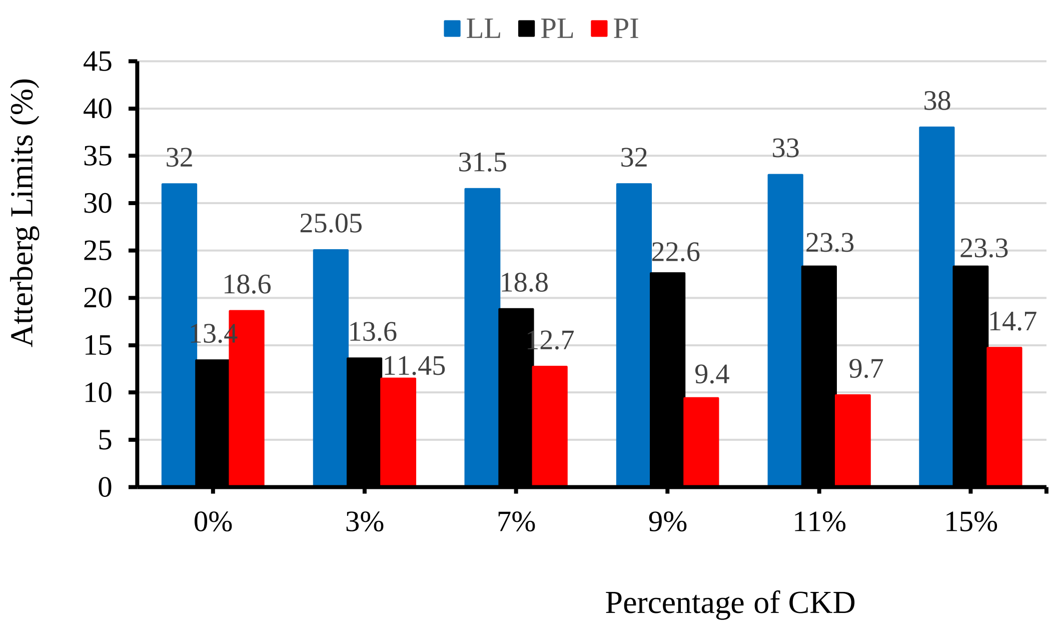

Fig.1: Atterberg Limit results of CKD stabilizer

Compaction tests:

Standard Proctor compaction test was used in order to minimize variations in compaction energy. This allowed for more consistency throughout sample production and, ultimately, more consistent results. The results of compaction tests are given Table 2. It can be seen from the table that the addition of 3% CKD, will have minimum value of optimum moisture content of 9.95% and maximum value of 1.91 g/cm^3 dry density. However this value is higher than maximum dry density of untreated clay soil. Also it can be seen that the more increased in CKD decrease maximum dry density. In other words, maximum dry density will be met at the addition of 3% CKD.

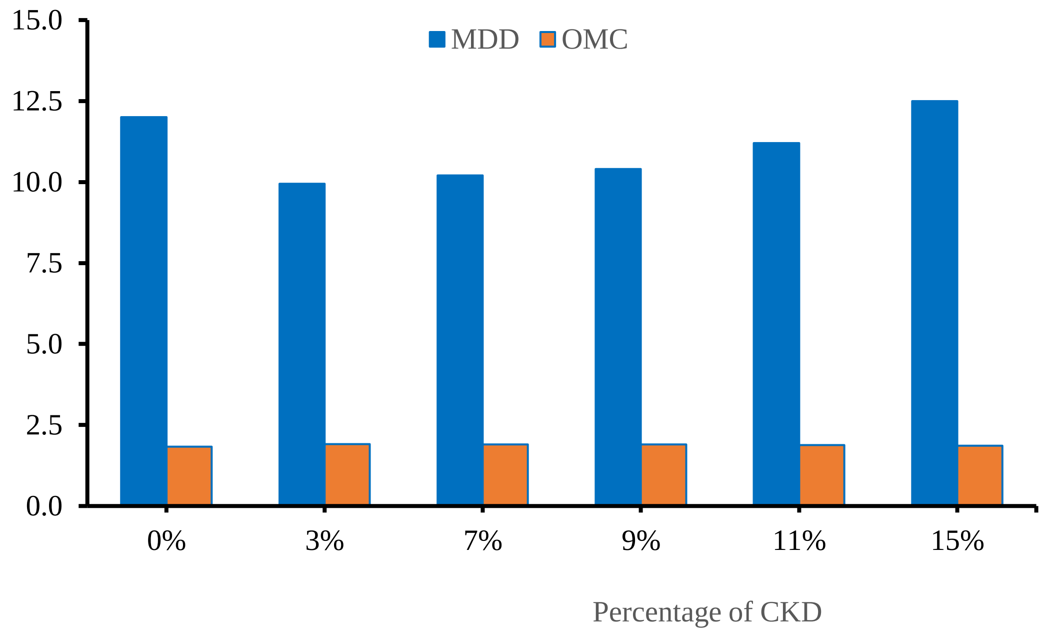

Fig. 2: Results of OMC and MDD at varying percentages of CKD

California bearing ratio (CBR)

Fig. 3 is a result of Soaked and unsoaked CBR value for the test. The result show that there is an increased of CBR with addition of CKD. This increment may be attributed to the chemical and cementation effect on structural composition of the soil. Presence of Ca^{2+}, Si^{2+} and Al^{3+} cations in CKD, it react with water and resulting in the formation of Calcium-Silicate-hydrates (CSH) and Calcium-Aluminate- hydrates (CAH). CSH and CAH are cementation products similar to those formed in Portland cement. Time duration and sufficient water favours these reactions.

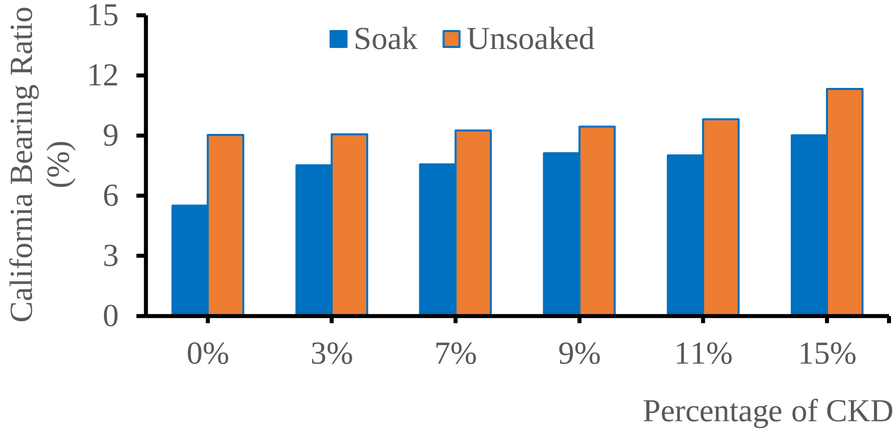

Fig. 3: Results of CBR Test

Permeability Test Result

From Table 2, it can be seen that the Permeability of the Soil Sample have decreased as the percentage of CKD increased. The Coefficient of Permeability at 15 % addition of CKD to the soil is 8.2×10^{-7} cm/sec. As compared to the untreated clay soil (at 0 % CKD), the percentage decrease at 15 % addition of CKD to the clay soil is 87%. This is due to the increase in finer material as percentages of CKD increase in the clay soil-CKD mixture. Permeability decreases because of the growing reaction products and reduction in connected voids.

Table 2: Coefficient of Permeability with varying Percentages of CKD

Percentage of CKD	Coefficient of Permeability (g/cm^3)
0%	6.2×10^{-6}
3%	4.8×10^{-6}
7%	2.8×10^{-6}
9%	8.1×10^{-7}
11%	5.8×10^{-7}
15%	8.2×10^{-7}

CONCLUSION

Based on the results obtained and discussion the following conclusions can be made:

1. The compaction characteristics of soils vary significantly with CKD content. The optimum moisture content increases and maximum dry density decreases with increased CKD content.

2. As compared to untreated clay soil, the percentage increase in OMC at 3% addition of CKD to the soil is 9.5%, and MDD is 1.91%.
3. Liquid limit decreases and Plastic limit of soil increases as the percentage of CKD increases. The Plasticity index of soil reduces with increased CKD content. Hence the soil samples become less plastic and compressible.
4. CBR value for soaked and unsoaked condition increases with increases in percentage of CKD. CBR values of soil are indicator of sub-grade soil strength and are often used for design of flexible pavement. The CBR value of CKD treated clay soil is 9.03% which can be used for the designing of flexible pavement for light and medium traffic
5. Coefficient of permeability i.e., Hydraulic conductivity of soil reduces with increased CKD percentages. Percentage reduction in Permeability of soil is 87%; hence stabilized soil may be used for the impervious core in embankment and, the treated soil could be used as a soil-based barrier layer for containment of hazardous waste.

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