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BLACK COTTON SOIL BEHAVIOUR WITH CEMENT KILN DUST

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ABSTRACT

Cement kiln dust (CKD) is an industrial waste from cement production. The quantities and characteristics of CKD generated depend upon a number of operational factors and characteristics of the inputs to the manufacturing process. Although the relative constituent's concentrations in CKD can vary significantly, ckd has certain physical characteristics that are relatively consistent. When managed on site in a waste pile, ckd can retain these characteristics within the pile while developing an externally weathered crust, due to absorption of moisture and subsequent cementation of dust particles on the surface of the pile .the ability of the ckd to absorb water stems from its chemically dehydrated nature, which results from the thermal treatments it receives in the system. The action of absorbing water releases a significant amount of heat from non-weathered crust phenomenon that can be exploited in beneficial re-use in order to improve the inadequacy of some avoidable extensive clay material for use waste A phenomenon that can be exploited in the stabilization of poor engineering material.

Keywords:-Cement Kiln Dust (CKD), Compaction, Durability, Unconfined compressive Strength (UCS), California Bearing Ratio (CBR)

I. INTRODUCTION

Industrial waste disposal is constantly throwing up challenge in terms of the cost and safe disposal of these wastes that other unexplored waste are being researched upon to determine their suitability as road pavement material. Problematic black cotton soils on the other hand abounds in many parts of the world such that there avoidance becomes impossible in places where the deposits are extensive. Various researchers (Ola, 1983; Balogun, 1991; Osinubi, 1995, 1999; Osinubietal, 2009b, 2010) have attempted to stabilize the Nigerian black cotton soil with different types of stabilizers agents with varying degree of success.

Cement kiln dust (CKD) is an industrial waste from cement production. The quantities and characteristics of CKD generated depend upon a number of operational factors and characteristics of the inputs to the manufacturing process. Although the relative constituent's concentrations in CKD can vary significantly, CKD has certain physical characteristics that are relatively consistent. When managed on site in a waste heap, CKD can retain these qualities inside the pile while developing an externally weathered crust, due to absorption of moisture and subsequent cementation of dust particles on the surface of the pile. The ability of the CKD to absorb waters from its chemically dehydrated nature, which results from the thermal treatments it, receives in the system. The action of absorbing

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water (rehydrating) releases a significant amount of heat from non weathered crust, a phenomenon that can be exploited in the stabilization of poor engineering material.

Expansive soils are also referred to as "black cotton soil" in some parts of the world. They are so named because of their suitability for growing cotton. Black cotton soils have colours ranging from light grey to dark grey and black. Black cotton soils are confined to the semi arid regions of tropical and calm climatic zones and are bounteous where they early evaporation exceeds the precipitation (Chen,1975; Waen and Kirly; 2004) ,Balogun (1991) reported that black cotton soils happen in continuous stretches as superficial deposits and are typical of level terrains with poor drainage. The absence of quartz in the clay mineralogy enhances the formation of fine grained soil material, which is impermeable and water logged. Research work has been carried out on the improvement of geotechnical characteristics of black cotton soil with very little success using bag ash pozzolana (Ijimdiya, 2009). However, no work has been done on the use of CKD treated black cotton soil in waste containment applications. The study was aimed at the evaluation of the suitability of compacted black cotton soil treated with CKD for use in waste containment applications.

Table1: Basic Properties Oxide Composition of the Cement kiln dust

Oxide	CaO	Al2O3	SiO2	Fe2O3	Mn2O3	Na2O	K2O	pH	Gs
Concentration (%)	50.12	4.00	-	2.01	0.002	0.001	1.35	11.7	2.22

II. MATERIALS AND METHODS

2.1. Materials:

Black Cotton Soil: The soil used in this study is light grey in colour and is known as black cotton soil, it was obtained along Borkheda Kota Local Government Area of Rajasthan State using the method of disturbed sampling. Specimens were varied with 0, 5, 10, 15 and 20% of cement kiln dust by dry weight of soil.

Table 2: Properties of natural black cotton soil.

Cement Kiln Dust: The cement kiln dust used was obtained from deposited heaps of the waste at the local cement production industries. The CKD was sieved through Bs sieve No. 200 and was stored in air-tight containers before usage.

2.2: TESTING METHODS

The laboratory tests conducted on the natural soil sample and soil mixtures include: particle size distribution, Atterberg limits, specific gravity, compaction, and unconfined compressive test (UCT).

Index Properties: Laboratory tests were conducted to determine the index properties of the natural soil and cement kiln dust mixtures in accordance with British Standards BS1377 (1990) and BS 1924 (1990) respectively. A summary of the soil index properties is presented in table no.3.

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Table 3: Engineering Properties of CKD Treated Black Cotton Soil

Engineering Properties	**Cement kiln dust (%)**				
	0	**5**	**10**	**15**	**20**
Liquid Limit, %	67.5	65.4	70.6	67.0	62.0
Plastic Limit, %	20.8	20.6	19.4	17.9	14.4
Plasticity Index,%	46.7	45.0	51.2	49.1	47.6.6
Linear Shrinkage, %	15.3	13.3	13.1	14.0	13.5
% Passing BS No. 200 sieve	89.9	83.0	85.0	81.0	83.0
USCS Classification	A-7-6	A-7-6	A-7-6	A-7-6	A-7-6
Specific Gravity	2.36	2.37	2.39	2.38	2.65
Standard Proctor MDD Mg/m3	1.420	1.530	1.580	1.660	1.710
OMC%	24.0	23.2	22.7	18.8	17.6
pH Value	7.2	-	-	-	-
Color	Light Gray				
Dominant Clay mineral	Montmorillonite				

Compaction: The compactive energy level used is the British Standard Light (BSL) and West African Standard (WAS). The tests involving moisture–density relationship, volumetric shrinkage, unconfined compressive strength (UCS), and hydraulic conductivity. Air dried soil samples passing through BS sieve with 4.76 mm aperture mixed with 0%, 5%, 10%, 15% and 20% cement kiln dust by weight of dry soil were used. The British standard light is the effort derived from 2.5 kg rammer falling through 30 cm onto three layers, each receiving 27 uniformly distributed blows; (BS1990) The West African standard compactive effort (WAS), carried out using energies

derived from a rammer of 4.5 kg mass falling through A height of 45 cm in a 1000 cm^3 mould. The soil was compacted in five layers, each layer receiving 10blows.

Unconfined compression testing (UCT): UCT samples were prepared at the optimum moisture contents determined from the compaction curves. The prepared UCT samples were sealed in a plastic bag to cure in the humidity room where the temperature was maintained at 20 ± 2 C for 0, 7 and 14 days before conducting the test. Unconfined compression tests were conducted on a strain-controlled triaxial testing frame at a strain rate of constant without application of the cell pressure (r_3 = zero). The Maximum load was converted to the unconfined compression strength of the sample.

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California bearing ratio: The variation of California bearing ratio (CBR) with CKD content for soil–CKD mixtures is Generally, CBR increased with higher CKD content. There as on for the improvement in the strength from 2% and 3% for the natural soil at IS compactive effort to 15% and 20% CKD treatment for BSL and IS compactive effort respectively. This could be due to the presence of adequate amounts of calcium required for the formation of calcium silicate hydrate (CSH), which is the major compound for strength gain. A CBR value of 180% is recommended by (BS,1990b) which is expected to be attained in the laboratory for cement-stabilized material to be constructed by the mix-in-place method. However, soil–CKD mixtures failed to meet the minimum CBR value of 30% specified by (BS1990b) for materials suitable for use as base course material when determined at MDD and OMC.

III. RESULTS AND DISCUSSION

3.1 Mineralogy and Physical Properties of the Test Materials

Results of the physicochemical tests conducted on the soil sample are presented in Table 1, while the oxide composition of the soil together with that of the CKD is reported in Table 2. The particle size analysis indicates that the soil has sand content of about 18% while the clay and silt content constitute 72%. The average natural moisture content of the soil was found to be 26.05%. Based on these properties, the soil was classified as A-7-6 and CH group under AASHTO (AASHTO, 1986) and the USCS classification systems (ASTM, 1992) respectively and therefore rated as fair to poor sub-grade highway materials.

The particle size distribution curve of the quarry fines (QF) used in the study is presented in while other engineering properties can be summarized as follows: effective size: 2.70 mm, specific gravity: 2.75, uniformity coefficient: 1.37 and coefficient of curvature of 0.9.

3.2 Results of Atterberg limits test on soil mixtures

The addition of CKD changed the Atterberg limits (i.e., liquid limit, plastic limit and plasticity index) of the BC soil – QF composite. The liquid limit (LL) decreased from 85% for the natural BC soil to 72.5% when 10% QF was introduced and decreased further with the addition of CKD. Thus the minimum LL value of 44.62% was recorded upon addition of 20% CKD.

The plastic limit (PL) generally decreased as the CKD con-tent increased, recording 38.09% and 25.5% respectively for 0% and 20% CKD content. The resulting plasticity index (PI) for all soil mixtures was consistently lowered as the CKD content increased. This, in addition to other improved properties ensures good workability on site during field implementation. PI values as low as 12.6% was achieved for 20% CKD which is equivalent to levels achieved with fly ash stabilization.

The liquid limit of the black cotton soils is essentially con-trolled by the thickness of the diffused double layer and the shearing resistance at particle level. The addition of CKD results in the decrease of liquid limit due to the effect of reduction in the diffused double layer thickness as well as due to the effect of dilution of the clay content of the mix.

3.3 Compaction characteristics of stabilized soil mixtures

The results of compaction tests revealed the relationship between dry unit weight and moisture content of each mixture of the BC soil upon stabilization with CKD. The change in composition of the stabilized mixtures reflected in the changes in the maximum dry unit weight and the optimum moisture content. Generally, dry unit weights were lower while the optimum moisture content (OMC) increased after the addition of CKD. For example, while the maximum dry unit weight of the BC soil+10%CKDcomposite was established as 14.9 kN/m^3 at optimum moisture content (OMC) of 32.4%, the maximum dry unit weight of specimens on application of CKD exhibited reduction with a resultant increase in optimum moisture content. The results further showed that maximum dry unit weight of 13.4 kN/m^3 was recorded for the soil mixture containing 20% CKD with a corresponding OMC value of 39.20% which is higher than both the OMC of the natural BC soil (=28.4%) and the average natural moisture content of the BC soil sample used in the study (=26.05%). These variations in compaction characteristics (i.e., maximum dry unit weight and optimum moisture content) of soil mixtures reported similar to the effect of lime and other additives on BC soil.

The decrease in maximum dry unit weight may be attributed to replacement of BC soil/QF particles in a given volume by particles of CKD thereby reducing dry unit weight and increasing the water absorbing ability of the soil mixtures. Beyond these compaction parameters measured immediately after specimen preparation, the post-curing dry unit weight and water content of soil mixtures were measured from curing time increased and can reach the maximum stress at a much smaller strain. It is further observed that the axial strains at failure for + 15% CKD and + 20% CKD mixtures was essentially coincident from 14 days. This suggests the axial strain at failure for the two mixtures.

Visual observations of tested specimens show that the shear failure mode of specimens with higher admixture content cured over longer periods was more of brittle behaviour when com-pared to mixtures tested immediately after preparation or cured over a shorter duration. The effect of curing time on the strength development of soil mixtures was further demonstrated by a variation analysis of the unconfined compressive strength (UCS) at different curing durations represented in. The UCS at each curing time has been normalized by the UCS at 0 day curing. It can be observed that the timeline presents a slow rate of increase in strength between the 7th day and 14th day which is followed by a steeper increase that extends to the 28th day. The seeming delay in strength development at the initial stage of curing probably represents the induction period necessary for pozzolanic reaction between soil particles and the chemical stabilizer in the mixtures resulting in the formation of cementation products.

VI. CONCLUSIONS

In this study, the influence of curing time on the strength properties of black cotton soil stabilized with combined quarry dust and CKD admixture measured in an unconfined compression test was evaluated. Soil mixtures prepared at optimum compaction parameters and compacted with British standard light (BSL) compaction effort were tested after 0, 7 and 14 curing days. Preliminary tests carried out on the soil mixtures showed that the rewash reduction in LL, PI and dry unit weight, irregular trend in the variation of plastic limit and an increase in OMC of soil mixtures.

Results further indicate a general increase in UCS values with increasing CKD content as well as the curing time for soil mixtures. Improvement in UCS values ranged from 1.5 to 5 times higher than those tested immediately after preparation. The study revealed that the stabilized soil mixtures like soils stabilized with other cementitious admixtures have the potential for a time dependent increase in strength and therefore with additional curing time, further strength may develop.

On this subject, further studies considering longer curing times and possibly higher CKD contents are necessary. Data developed in this study are expected to be use full to pavement designers and site engineers in the field implementation of the stabilization scheme such as when to open the stabilized.

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