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EVALUATION OF STRENGTH PROPERTIES OF LATERITIC SOIL STABILIZED WITH CEMENT KILN DUST

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ABSTRACT

The production of sub-standard building materials and increase in cost of construction in Nigeria and other developing countries created the need for findings into locally and readily available materials. This study presents the strength properties of Lapai-Gwarri lateritic soil stabilized with cement kiln dust. The scope includes determination of the physical composition, index properties, compaction and strength characteristics of lateritic soil-cement kiln dust mix. All the test procedures were carried out in accordance with British Standard Institution guide. The soil used was obtained at Lapai-Gwarri area of Minna, using the disturbed sampling technique at a depth of 1.5m and was classified according to AASTHO soil classification. From the results obtained, soil sample encountered is classified as A-7-6 corresponding to CL, it is organic silts and organic silty-clays of very low to medium plasticity, gravelly clays, silty clays and lean clays according to AASHTO and USCS system of soil classification respectively. There was a sharp reduction of plasticity index from 22.20% to 11.09%, with increase in quantity of cement kiln dust, the Compaction characteristics of cement kiln dust soil mixed from 0 and 16% gives the Optimum Moisture Content (OMC) values which decreased from 19.69 - 13.02%. The Maximum Dry Density (MDD) increase in value from 1.50 - 1.79 g/cm³. The Unconfined Compressive Strength test at 7, 14 and 28 days of curing for Cement kiln dust of 0, 4, 8, 12 and 16% obtained average values of 170, 369,511, 461 and 347 (kN/m^2) respectively. The replacement of 8% cement kiln dust to samples of laterite soil significantly improves its compressive strength characteristics and is considered as the Optimum percentage of cement kiln dust present and reduces construction costs.

Keywords: *Cement Kiln Dust;Index Properties; Lateritic Soil; Stabilization; Strength Properties.*

1. INTRODUCTION

In construction, soils encountered mostly during construction are unable to respond to the imposed stresses, which has become a dominant factor responsible for the failure of structures especially in Nigeria (Aigbedion, 2007; Okechukwu *et al.* 2011) identified inadequacy of construction materials and poor attribute of construction are other factors responsible for structural failure. Improving the properties of these soils by the addition of chemical and cementitious additives becomes not only a necessity but an important factor to make them suitable for construction.

In general construction, stable subgrade and base layers are essential for engineering structure, the need to reduce the dilemmas in geotechnical engineering during design and construction in terms of the variable nature of soil and rock properties and other in-situ conditions has become a major challenge because of the issues in reliability of design and construction methods, and problems in the costs and benefits of proposed designs policies. The geotechnical properties like strength and volume stability of the subgrade have significant influence on the overall performance and durability of constructions (William, 2003).

Chemical additives vary from waste products to the manufactured materials which include lime, Portland cement, proprietary chemical stabilizers, class C fly ash, bitumen and recent technology like NANO technology (Parson and Kneebone, 2004).

Soil stabilization is the process of improving the engineering properties of soil and thus making it more suitable. It is also the treatment of soil with modifier to enable their strength and durability to improve such that they become completely suitable for construction beyond their original classification (Hausmann, 1990). Lots of consideration has been given mainly to the problems encountered in the engineering use of laterite soils. This might give the impression that all laterites and lateritic soils give trouble (Christophe, 1949).

Cement kiln dust is a waste product from the manufacturing of cement. The quantities, nature and characteristics of CKD generated depends on the number of operational factors and the characteristics of inputs to the manufacturing process, including the raw fed, fuel used, and the design and operation of the cement kiln. This by-product has desirable properties that make it satisfactory for variety of beneficial use and application including soil improvement (Abeln *et al.* 1993).

The evaluation of possible change in characteristics of lateritic soil when treated with additive such as cement kiln dust can be an important task in the prevention of natural disasters on our road pavements and even buildings. Cement kiln dust provides a cheaper alternative to Portland cement and lime in soil improvement by stabilization. Miller *et al.* (2003) showed that soil improvement by stabilization using CKD is cheaper than lime especially when problematic soils are encountered.

Cement kiln dust is also available in Nigeria and if this is realized, it can find lasting solution to the failure of road and buildings due to weak sub-grade and foundation arising from substandard construction materials. This work lead to improvement without incurring excessive cost in the construction industry.

2. METHODOLOGY

Materials

The soil used was obtained at Lapai-Gwarri area of Minna, using the disturbed sampling technique. Sample was obtained at 1.5m depth and classified according to AASTHO and UCSC soil classification system. Cement Kiln Dust which is a greyish black material is the byproduct of cement and one of the essential materials needed for this work. It was obtained from Obajana Cement Plant Kogi state.

Methods

The soil tests were conducted in Civil Engineering Laboratory, Federal University of Technology, Minna. The material was sieved appropriately and finally stored in an air-tight container pending the time for sample preparations, this is done so it maintains its value. The materials mentioned above were used, the collected soil was air – dried and stored. Laboratory tests were carried out on two different samples (the natural lateritic soil and one treated with Cement Kiln Dust). The treatment with cement kiln dust was done at 4, 8, 12 and 16% dry weight content in accordance to BS 1377 (1990).

2.1 LABORATORY TEST

Index properties of fill materials: Natural moisture content, specific gravities, particle size analysis and Atterberg limits tests were conducted in accordance with tests procedures specified in BS 1377 (1990).

Compaction characteristics: Compaction of the samples was conducted in accordance with the guidelines specified in BS 1377 (1990) to compute the required parameters. The Reduced British Standard Heavy (RBSH) compactive effort was used. The RBSH compaction is the energy resulting from 4.5 kg rammer falling through a height of 30 cm onto three layers, each receiving 25 blows to determine MDD and OMC of the sample according to ASTM D-698 (1992) and ASTM D-1557 (1992).

Unconfined compressive strength (CCS): The test was conducted in accordance with the procedure specified in BS, 1377 (1990), to determine the compressive strength characteristic using the values of OMC obtained during compaction results from Reduced British Standard Heavy compaction method.

2.2 FIGURES AND TABLES

TABLE 1: NATURAL MOISTURE CONTENT

Trial	1	2	3
Can No	M4	PQ4	A21
Weight of can (g)	34.80	38.20	38.20
Weight of can + wet soil (g)	55.30	58.60	54.80
Weight of can + dry soil (g)	51.40	54.70	51.50
Weight of dry soil (g)	16.60	16.65	13.30
Moisture Content (%)	23.50	23.63	24.80
Average Moisture Content (%)		23.97	

TABLE 2: SPECIFIC GRAVITY OF SOIL SAMPLE

Trial	1	2	3
Weight of Cylinder (g)	46.0	46.0	43.6
Weight of Sample + Cylinder (g)	97.4	88.0	87.9
Weight of Sample + Cylinder + Water (g)	170.8	168.1	167.1
Weight of Cylinder + Water (g)	144.9	145.0	142.4
Specific Gravity	2.04	2.21	2.31
Average Specific Gravity		2.2	

TABLE 3: SUMMARY OF INDEX PROPERTIESOF SOIL AND SOIL MIX

CKD(%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
0	**45**	**22.80**	**22.2**
4	**43**	**24.92**	**18.08**
8	**41**	**27.08**	**13.92**
12	**44**	**31.01**	**12.99**
16	**45**	**33.91**	**11.09**

TABLE 4: COMPACTION STRENGTH CHARACTERISTIC OF SOIL SAMPLE AND SOIL MIXTURE

CKD%	Maximum Dry Density (g/cm^3)	Optimum Moisture Content (%)
0	**1.50**	**19.69**
4	**1.71**	**15.95**
8	**1.74**	**15.66**
12	**1.77**	**15.52**
16	**1.79**	**13.02**

TABLE 5: COMPRESSIVE STRENGTH CHARACTERISTICS

CKD (%)	UCS (kN/m^2) 7days Curing	UCS (kN/m^2) 14days Curing	UCS (kN/m^2) 28days Curing	Average (kN/m^2)
0	163	174	174	170
4	314	384	407	369
8	452	500	581	511
12	442	458	484	461
16	336	377	393	367

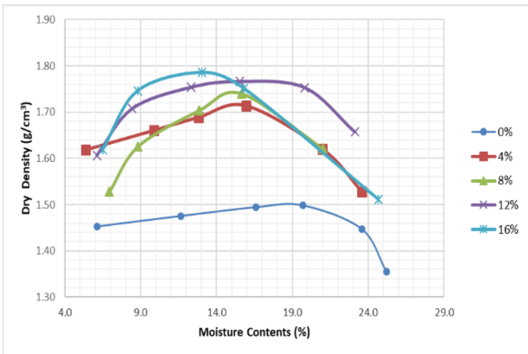


FIGURE 1: COMPACTION GRAPH

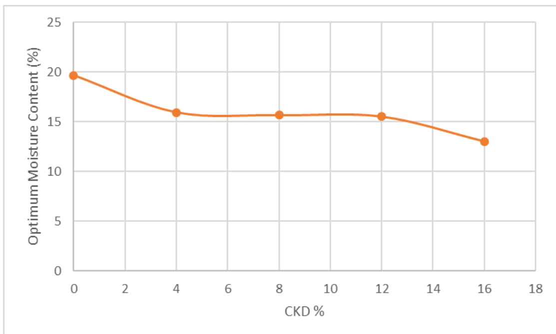
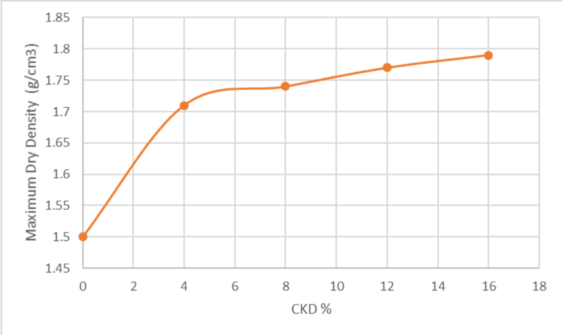


FIGURE 2: RELATIONSHIP BETWEEN OPTIMUM MOISTURE CONTENT AND CKD STABILIZED SOIL



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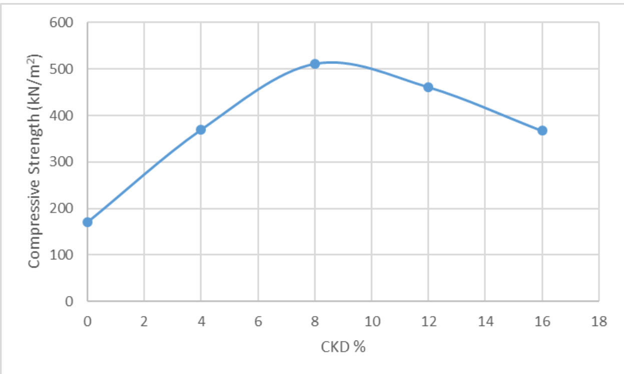

FIGURE 4: RELATIONSHIP BETWEEN COMPRESSIVE STRENGTH AND CKD

3. RESULTS AND DISCUSSION

The natural moisture content of lateritic soil gotten from the laboratory test after taking 3 trials was gotten to be 23.97 % of NMC as shown in Table 1.

The specific gravity of the soil, which was gotten to be 2.2 which is satisfactory for a fine aggregate specific gravity as shown in Table 2.

The liquid limit decreased with the addition of CKD up to 8% and then increased slightly with further increase in the addition of CKD. This initial reduction in the liquid limit according to (Talal and Awad 1998) is accredited to cementitious properties of CKD due to high content of calcium oxide (CaO) which aid flocculation and aggregation of soil particles. The increased in liquid limit beyond 8% CKD content is attributed to the extra water required to turn the soil-CDK mix to fluid. The plastic index increased with the addition of cement kiln dust, this is due to the increase in cementitious property from cement kiln dust. Therefore, the plasticity index reduced with increase in CKD content from 0% to 16%. This may be due to the replacement of the finer soil particles by CKD with consequent reduction in plasticity index (Miller et al;1997). Summary of Index properties of soil and soil mix is shown in Table 3.

The results indicates that between 0% and 16% CKD content, the MDD increased from 1.50mg/m^3 to 1.79 Mg/m^3 respectively while the OMC decreased from 19.69 % to 13.02 %, hence it is safe to say that MDD is inversely proportional to OMC. This is as a result of CKD occupying the void within the soil matrix. The compaction characteristic is shown in Table 4, Figure 1, 2 and 3 shows how the OMC and MDD reacts with the addition of CKD.

The Unconfined Compressive Strength increased from 0% to 8% CKD and decreased gradually from 12% to 16% CKD, the increase in the UCS is attributed to the formation of cementitious compound between CaOH present in the soil and the CKD, the decrease in attributed to the slowing down of the hydration process of Cement. A summary of the compressive strength characteristics is shown Table 5 and the relationship between the cement kiln dust and compressive strength is shown in Figure 4.

4. CONCLUSION

From the Evaluation of Strength Properties of Lateritic Soil Stabilized with Cement Kiln Dust, the following conclusions were drawn:

1. The Lateritic Soil obtained from Lapai-Gwari was classified as A-7-6 and CL an organic silts and

organic clay of very low to medium plasticity according to AASHTO and USCS respectively.

2. Atterberg Limit Test was done at percentage of 0%, 4%, 8%, 12% and 16% of CKD using replacement method. The liquid limit decreased with the addition of CKD up to 8% and then increased slightly with further increase in the addition of CKD, Plastic Limit increased with addition of CKD ranges from 22.80% to 33.91% while Plasticity Index reduced progressively from 22.2 to 11.09.
3. Compaction test was done at percentage of 0%, 4%, 8%, 12% and 16% of CKD using replacement method having Optimum Moisture Content between 13.02% and 19.69, also a Maximum dry density between 1.5g/cm3 and 1.79g/cm3.
4. Unconfined Compressive Strength was done at 0%, 4%, 8%, 12% and 16%, of CKD Compressive Strength increased with increase in CKD from 0% to 8%, then decreased progressively, Compressive Strength ranged between 170 kN/m2 to 511 kN/m2 8% of CKD replacement is gotten to be the Optimum compressive strength because it is more economical.

RECOMMENDATIONS

From the Evaluation carried out on the strength properties of lateritic soil stabilized with Cement Kiln Dust, the following Recommendations were made:

1. Due to practical work on field where heavy weight of soil will be used, more research should be carried out using additional method instead of replacement method in order to ascertain the best percentage of CKD to add in such case.

2. The work can be furthered by implementing other soil parameters such as California Bearing Ration (CBR) and consolidation.

3. Cement kiln dust (CKD) can be used to improve Unconfined Compressive Strength (UCS) of soils. The improvement would make it more suitable and economical to use as stabilizer for sub-base and base course material in highway construction, thereby reducing construction cost.

4. Stabilization of other soil type in Nigeria for improvement with Cement Kiln Dust should be investigated.

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