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INFLUENCE OF COMPACTION DELAY ON SOME CHARACTERISTICS OF LATERITIC SOIL STABILIZED WITH CEMENT KILN DUST

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ABSTRACT:

The influence of compaction delay on some characteristics of cement kiln dust (CKD) – lateritic soil mix prepared using British Standard (BS) and West African Standard (WAS) compactive efforts has been investigated. The results of the investigation showed that there was an insignificant influence of compaction delay on unconfined compressive strength (UCS) and durability of CKD-lateritic soil mix. The california bearing ratio (CBR) of the mix generally decreased with increase in compaction delay.

KEY WORDS: Characteristics of laterite, compaction delay, cement kiln dust, stabilization.

INTRODUCTION:

Soil modification through stabilization with additives such as portland cement, lime, fly ash, bituminous materials and fibres are gaining popularity in recent times. The purpose of modifying soil is to increase strength, reduce deformity, provide volume stability, lower permeability, minimize erodability, enhance durability, and control variability (Baghdadi et al, 1995). In the tropics and subtropics the common material for road bases is lateritic soils, which are reddish, highly weathered and consist of concentrated oxides of iron and aluminium with kaolin as the predominant clay. Because of the high supporting ability of these soils, they are used extensively in road constructions and air field pavements. Although most lateritic soils do not require treatment to give them sufficient strength, some do require some sort of stabilization for use in road construction. It is in this respect that an experimental programme was designed to study the influence of compaction delay on some characteristics of laterite stabilized with cement kiln dust - an industrial waste from cement manufacturing company.

MATERIALS

The CKD used for this work was collected from Ashaka Cement Factory situated in Bajoga Local Government Area of Gombe State of Nigeria. The specific gravity of the dust was found to be 2.55. The dust showed a wide range of particle size ranging from less than 63μm to 600μm in diameter as presented in Table 1.

The soil which was collected from Bauchi environ was reddish in colour and had a specific gravity of 2.44. The particle sizes of the soil are also presented in Table 1. The maximum dry density and the optimum moisture content of the soil was found to be 1.85Mg/m^3 and 15.5% respectively. The soil was classified as A-2-6 according to the American Association of State Highway Officials (AASHTO) Systems.

PREPARATION OF SPECIMENS AND TEST METHODS

Five levels of CKD - 10, 15, 20, 25 and 30% by weight of soil were mixed thoroughly with laterite in a sample tray in the presence of water to obtain a uniform colour. The CKD-laterite mixes were then covered and left to mellow for the required periods before testing using standard procedures. The moisture-density relationship test were performed in accordance with B.S. 1377 ("Method of Testing Soils for Civil Engineering Purposes") and West African Standard, while stabilization tests were performed in accordance with B.S. 1924 ('Methods of Test' 1975) and WAS modified in line with the practice in Nigeria as specified in the General Specification for Bridges and Roadworks (1970). The specimen for unconfined compressive strength (UCS) were wax-cured for 7, 14,

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TABLE 1: SIEVE ANALYSIS OF LATERITIC SOIL AND CKD

SIEVE SIZE (1)	PERCENTAGE OF SOIL PASSING (2)	PERCENTAGE OF CKD PASSING (3)
2.36mm	92.0	100
2.00mm	89.0	100
1.18mm	71.0	100
600μm	43.5	99.50
425μm	31.5	98.75
300μm	24.0	98.25
212μm	17.5	97.25
150μm	13.0	93.75
63μm	7.5	9.95

TABLE 2: COMPACTION CHARACTERISTICS OF CKD-LATERITIC SOIL MIX

CKD	IN ACCORDANCE WITH WAS		IN ACCORDANCE WITH BS	
(%) (1)	MDD (Mg/m^3) (2)	OMC (%) (3)	MDD (Mg/m^3) (4)	OMC (%) (5)
10	1.860	13.5	1.831	13.5
15	1.879	12.4	1.840	12.8
20	1.885	12.3	1.850	12.7
25	1.891	12.3	1.822	13.3
30	1.870	12.5	1.821	14.7

21 and 28 days before testing, while california bearing ratio (CBR) specimens prepared in accordance with B.S. and WAS were wax-cured for 7 and 6 days respectively and immersed in water for 24 hours before testing as required by the Nigerian Specification. The UCS and CBR results reported are averages of two test for each parameter measured.

The durability of CKD-laterite specimens were assessed using the water immersion test procedure and the resistance to loss in strength determined as the ratio of UCS of specimens air-cured for 7 days and subsequently immersed in water for another 7 days to the UCS of specimens air-cured for 14 days.

RESULTS AND DISCUSSION

Compaction

The maximum dry densities (MDD) and the corresponding optimum moisture contents (OMC) for CKD-laterite mixes are shown in Table 1. The results show an initial increase in MDD up to points of 25% and 20% CKD contents respectively for specimens prepared in accordance with West African Standard

TABLE 3: UCS TEST RESULTS FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH WAS (N/MM^2)

ELAPSED TIME (HR)	CURING PERIOD (DAYS) 10% CKD				15% CKD				20% CKD				25% CKD				30% CKD			
	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
1.0	0.73	0.90	1.04	1.16	0.80	0.98	1.10	1.18	0.83	1.11	1.26	1.32	0.88	1.26	1.39	1.64	1.0	1.31	1.56	1.72
2.0	0.72	0.89	1.04	1.15	0.80	0.97	1.10	1.17	0.81	1.10	1.25	1.30	0.88	1.25	1.38	1.63	1.0	1.30	1.55	1.71
3.0	0.71	0.88	1.02	1.14	0.80	0.97	1.09	1.17	0.81	1.10	1.25	1.29	0.87	1.25	1.37	1.62	1.0	1.29	1.54	1.70

TABLE 4: UCS TEST RESULTS FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH BS 1924:1975 (N/mm^2)

ELAPSED TIME (HR)	CURING PERIOD (DAYS) 10% CKD				15% CKD				20% CKD				25% CKD				30% CKD			
	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
1.0	0.49	0.62	0.99	1.07	0.53	0.68	1.05	1.15	0.61	0.92	1.15	1.30	0.66	0.97	1.21	1.34	0.71	1.04	1.27	1.42
2.0	0.48	0.61	0.99	1.07	0.54	0.68	1.05	1.15	0.61	0.92	1.15	1.30	0.66	0.97	1.21	1.34	0.70	1.03	1.27	1.42
3.0	0.48	0.61	0.99	1.07	0.53	0.68	1.04	1.14	0.61	0.91	1.14	[illegible]	0.66	0.96	1.20	1.33	0.69	1.03	1.26	1.41

TABLE 5: CBR TEST RESULTS FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH WAS

ELAPSED TIME (HR)	CKD CONTENT (%)				
	10	15	20	25	30
(1)	(2)	(3)	(4)	(5)	(6)
1.0	53.0	63.4	129.6	116.8	113.8
2.0	25.8	41.5	123.3	107.9	105.7
3.0	25.6	41.3	122.6	107.4	104.5

and British Standards. The increase could be due to the filling of available voids in the mix by the cement kiln dust, which is finer in particle size than laterite soil.

Unconfined Compressive Strength

The results of the UCS test of laterite specimens of size 38mm (diameter) and 76mm (height) remoulded at maximum dry density and optimum moisture content stabilized with 10, 15, 20, 25 and 30% CKD and compacted using WAS and BS compactive efforts are presented in Tables 3 and 4, respectively. As could be observed from the results,

TABLE 6: CBR TEST RESULTS FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH BS (%)

ELAPSED TIME (HR)	CKD CONTENT (%)				
	10	15	20	25	30
(1)	(2)	(3)	(4)	(5)	(6)
1.0	52.5	62.8	128.9	116.4	113.1
2.0	25.0	40.8	122.6	107.7	104.2
3.0	24.9	40.6	121.8	106.6	103.7

TABLE 7: DURABILITY TEST RESULTS FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH WAS

ELAPSED TIME(HR)	10% CKD			15% CKD			20% CKD			25% CKD			30% CKD		
	Pi	Pc	R	Pi	Pc	R	Pi	Pc	R	Pi	Pc	R	Pi	Pc	R
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1.0	0.38	0.90	42	0.45	0.98	46	0.76	1.11	68	0.93	1.26	74	1.10	1.31	84
2.0	0.37	0.89	42	0.43	0.97	44	0.74	1.10	67	0.92	1.25	74	1.08	1.30	83
3.0	0.35	0.88	40	0.42	0.97	43	0.73	1.10	66	0.90	1.25	72	1.04	1.29	81

P_i = UCS of specimens cured dry for seven days and soaked for seven days
P_c = UCS of specimens cured dry for fourteen days
R = Resistance to loss in strength (%)

TABLE 8. DURABILITY TEST RESULTS FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH BS 1924 1975

ELAPSED TIME(HR)	10% CKD			15% CKD			20% CKD			25% CKD			30% CKD		
	Pi	Pc	R	Pi	Pc	R	Pi	Pc	R	Pi	Pc	R	Pi	Pc	R
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1.0	0.20	0.62	32	0.25	0.68	37	0.45	0.92	49	0.63	0.97	65	0.87	1.03	84
2.0	0.19	0.61	31	0.24	0.68	35	0.42	0.92	46	0.63	0.97	65	0.86	1.03	83
3.0	0.19	0.61	31	0.24	0.68	35	0.41	0.91	45	0.61	0.96	64	0.84	1.03	82

the UCS of CKD-soil mix decreased marginally with compaction delay. This was more noticeable for specimens prepared in accordance with WAS. Generally the UCS increased with age, which was indicative of a pozzolanic activity of CKD fines in the mix. The values of all the UCS obtained were lower than the 1.7N/mm^2 seven-day UCS criterion usually adopted for roadworks. However, judging from the criteria for soil-cement mix suggested by Ingles and Metcalf (1973), laterite stabilized with CKD within the percentage levels considered in this work could be used for road subbase and base for light traffic.

California Bearing Ratio

The results of the CBR test which is considered as an indirect measurement of the shear strength of subgrade base courses in pavement design are presented in Tables 5 and 6. There was a steady increase in CBR values up to a point of 20% CKD content, and then followed by a decrease at 25 and 30% CKD content. This was contrary to expectation, since it was anticipated that the CBR would increase continuously with increase in percentage CKD.

Generally the CBR values decreased with increase in compaction delay. The explanation for this observed trend could be that there was a break of bond between particles of soil achieved by initial hydration of CKD because of compaction delay.

Durability and Swell Tests

The results of the durability of CKD-soil mix assessed using water immersion test for the measurement of resistance to loss in strength are presented in Tables 7 and 8. The values obtained in

TABLE 9: SWELL DATA FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH WAS

ELAPSED TIME (HR)	SWELL (mm)				
(1)	10 % CKD (2)	15 % CKD (3)	20 % CKD (4)	25 % CKD (5)	30 % CKD (6)
1.0	0.34	0.21	0.06	0.00	0.00
2.0	1.12	0.84	0.57	0.19	0.08
3.0	0.99	0.22	0.15	0.10	0.02

TABLE 10: SWELL DATA FOR CKD-LATERITIC SOIL MIX PREPARED IN ACCORDANCE WITH BS 1924:1975

ELAPSED TIME (HR)	SWELL (mm)				
(1)	10 % CKD (2)	15 % CKD (3)	20 % CKD (4)	25 % CKD (5)	30 % CKD (6)
1.0	0.54	0.31	0.10	0.02	0.01
2.0	1.28	1.02	0.67	0.24	0.14
3.0	1.10	0.33	0.29	0.13	0.05

this investigation show that the resistance to loss in strength increased with increase in CKD content. At 30% CKD content, the resistance to loss in strength was lesser than 20%. The influence of compaction delay on the resistance to loss in strength of the mix seemed not significant.

The swell data for CKD-soil mix are presented in Tables 9 and 10. The results show that swell decreased with increase in CKD content. The influence of compaction delay on swell of the mix seemed not well established since from the obtained data the trend looks erratic.

CONCLUSIONS

Based on the results of this study it could be concluded that compaction delay has no significant influence on the unconfined compressive strength, durability and swell of CKD-soil mix. The CBR values of the same mix decreased with increase in compaction delay, and this could be attributed to the loosening of coagulated particles caused by the delay in compaction.

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