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MOUND SOIL AS A PAVEMENT MATERIAL

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ABSTRACT

The results of a study on some characteristics of laterite-cement mix containing termite mound soil (50% by weight of laterite) as replacement of laterite are presented in this paper. The study showed that laterite-mound soil mix stabilized with 6% cement could serve as a base course for roads for agricultural trafficking in rural areas where mound soils are abundant. At 6% cement stabilization the unconfined compressive strength (UCS) of 1.57 N/mm^2 and a California bearing ratio (CBR) of 330% were obtained. The durability of the mix at this cement content was also found to be satisfactory with 87.7% resistance to loss in strength, and 1% weight loss and 1.15 % volume change after 12 wet-dry cycle test.

Key Words: Mound soil, Pavement, Road-base, Material

INTRODUCTION

The problem of premature failure of roads in Nigeria has been of great concern to road users. The predominant patterns of failure of Nigerian roads are pitting, rutting or slipping (Ajayi, 1987). Prior to the occurrence of these patterns of failure, the failure of the underlying soil must have occurred, hence the need to modify such soil. In the tropics and subtropics, the common material for road construction is laterite, which is residual in nature. Although there are some laterite soils that do not require treatment to give them sufficient load-bearing capacity, most laterites require some sort of stabilization for use in road construction (Osula, 1989; Osunubi, 1998). The concept of soil modification through stabilization with additives such as lime, fly ash, Portland cement, bituminous materials and fibres are gaining popularity in many parts of the world. It has been established that some soil-cement mix could be improved with increase in quantity of cement. In some instances this is not economical in most developing countries, where the price of cement is high. This informs the need for a quest for an easily obtainable material, which when mixed with laterite will produce a base material that requires lower cement content to satisfy strength and durability criteria. It was in this respect that an experimental programme was designed to study some characteristics of mound soil-laterite mix stabilized with cement.

Termite mound soil is the soil from the habitat or mound of tropical termite. Ecologists have reported that mound are built of earth particles which are cemented together to form a hard brick-like materials that are very resistant to weathering and difficult to chip with a sharp pick. The mound soil used for this study was from habitat of macrotermes bellicosus species of tropical termite. Mound from this species of tropical termite could tower as high as 10m in Southern Guinea Savanna area.

Adepegba (1979) from his study has reported that termites do stabilize a surrounding soil with a brown acidic organic substance secreted by the soldier termites before use for construction of mounds. Analysis showed that the organic substance secreted by the termite was a mixture of acetic acid, 2-amino glucose protein

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(both being hydrolysis products of chittin) and protodeal matter. This substance appeared cementitious. Mound soils have also been reported to be rich in clay and metallic minerals, particularly compounds of potassium, calcium and magnesium relative to the surrounding soils (Omo-Malaka, 1977). This probably explains why mound soil show a high degree of bond and have been used for hard surfacing of tennis lawns in some village schools in Africa.

Location of Soils and Geology of Study Area

The laterite soil used in this study is a reddish-brown soil obtained by method of disturbed sampling at a depth of 2m from the ground surface along Bauchi – Dass road of Bauchi State. The termite mound soil which is yellowish brown in colour was obtained at the outskirt of Bauchi metropolis. A study of the geological and soil maps of Nigeria (D'Hoore, 1964) will show that the soil belong to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks.

PREPARATION OF SAMPLES AND TESTING

The preliminary classification of laterite and mound soils was performed in accordance with BS 1377 ("Methods of Testing", 1975). Prior to testing, the obtained lumps of laterite and mound soil were pulverized using a rubber mallet. Fig 1 shows the grain size distribution curve of the laterite and mound soils. A summary of the soil index properties of the laterite and mound soils are presented in Table 1. The laterite soil is classified as gravelly sands with little fines according to the Unified Classification System (UCS) and as A-2-7 in the American Association of State Highway Officials (AASHTO) system, while the mound soil is classified as well graded sand with little fines according to the USCS and as A-2-4 soil according to the AASHTO system.

Compaction

Compaction in accordance with BS 1377: 1990 was carried out in the laboratory on mound

Table 1 – Properties of Mound Soil and Laterite

Characteristics	Sample	
	Mound Soil	Laterite
(1)	(2)	(3)
Liquid limit (%)	28.76	42.00
Plastic limit (%)	21.77	19.54
Plasticity index (%)	6.99	22.46
Linear shrinkage (%)	7.14	11.79
AASHTO classification	A-2-4	A-2-7
Specific gravity	2.58	2.47
Colour	Yellowish-brown	Reddish-brown

Table 2- Results of Compaction, and Strength Characteristics

Cement Content (%) (1)	MDD (Mg/m^3) (2)	OMC (%) (3)	UCS (N/mm^2) 7 days (4)	UCS (N/mm^2) 14 days (5)	CBR (%) (6)
2	1.764	13.84	0.279	0.270	26.62
4	1.791	14.50	1.210	1.23	134.41
6	1.816	13.16	1.58	2.04	330.00
8	1.779	14.79	1.78	1.86	229.00
Recommended Value	-	-	1.7*		180**

* British Specification for Road and Bridge Works (1970)

** Nigerian General Specification for Bridge and Road works (1970)

Table 3 – Comparison of Laterite-Mound Soil Cement Specimens with Control

Characteristics (1)	Laterite-mound soil cement mixture (X_1) (2)	Control (X_2) (3)	$\frac{(X_1 - X_2)}{X_2} \times 100$ (4)
UCS (N/mm^2)	1.58	1.47	7.48
CBR (%)	330.00	316.00	4.43

soil-laterite mix with 2, 4, 6 and 8% cement with a view to establishing their respective maximum dry densities (MDD), and optimum moisture contents (OMC).

Strength Tests

The mix for the strength specimens were prepared by first mixing laterite and mound soils. To the mix was added the precalculated amount of cement. Mixing at each stage was thoroughly carried out to achieve homogeneity. The required amount of water (determined from moisture density relationship for mound soil-laterite cement mix) was then added and the mixing repeated. The specimens were then compacted after 15 minutes of addition of water. The tests were performed in accordance with BS 1377:1990 modified in line with the practice in Nigeria as specified in the General Specification for Bridges and Road works (1970). Specimens for UCS were cured for 7 and 14 days, whereas CBR specimens were cured for 6 days and immersed in water for 24 hours before testing as required by the Nigerian Specification. Three tests were carried out for each level of cement content.

Durability Tests

The durability assessment of the mound soil-laterite specimens was carried out by the wet-dry test according to ASTM standards and by water immersion test for the measurement of resistance to loss in strength. The resistance to loss in strength was determined as the ratio of the UCS of specimens air-cured for 7 days and later immersed in water for another 7 days to the UCS of specimens air-cured for 14 days.

TEST RESULTS AND DISCUSSION

Compaction characteristics

The results of the variation of the OMC and the MDD with cement content are presented in Table 2. The results show increasing MDD with higher cement content up to 6%. This trend seems to be in order because more voids are filled up by the increased cement fines. Beyond 6% cement, the MDD started to fall, perhaps because the fine grain cement takes up a larger amount of space and thus prevents the interlocking of granular materials. For the OMC, a decreasing trend was observed between 2 and 6% cement content, and then an increase at 8% cement content. The explanation for this trend could be that increasing the cement content resulted in an increased surface area of particles which now required more water to lubricate the entire matrix of soil-cement to enhance compaction, in addition to the water taken up in the hydration process.

Strength Characteristics

The UCS and CBR test results are presented in Table 2. The unconfined compressive strength-cement relationship seems to be orderly at 7 days. At 14 days the UCS increased with cement content up to 6%, and then dropped at 8%. The drop at 8% cement content was contrary to expectation. The UCS values for all except the 8% cement content were

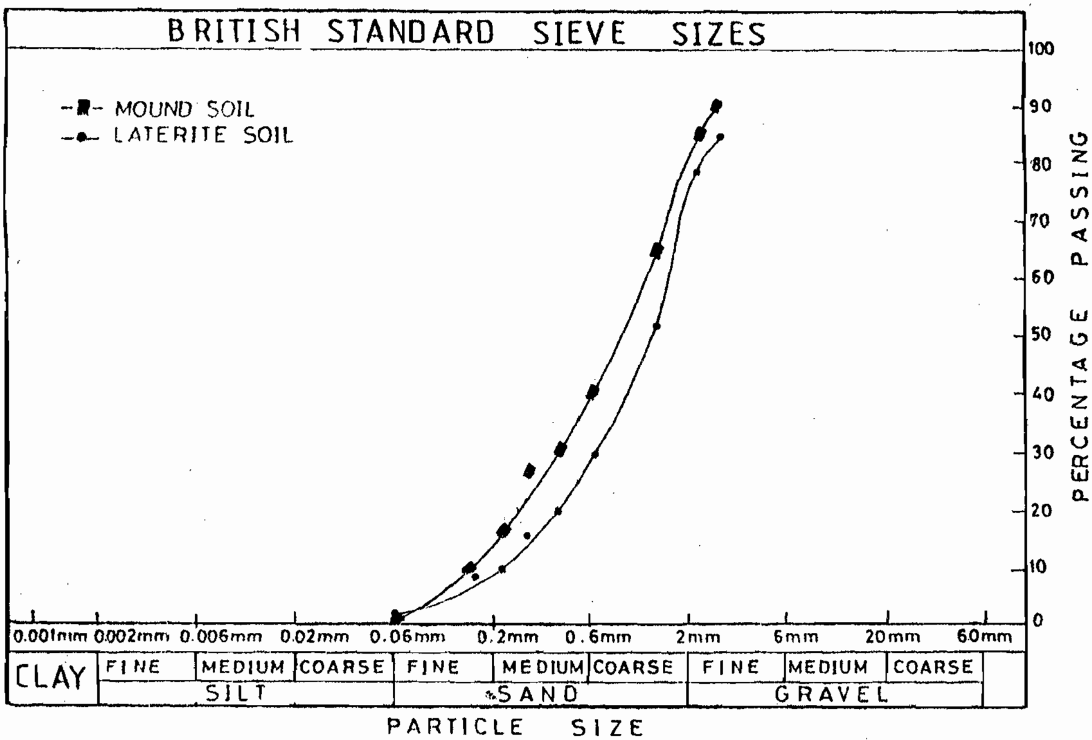

FIG.1 Grains Size Distribution Curves for Laterite and Mound Soil

Table 4 - Results of Durability Characteristics

Cement Content (%) (1)	Resistance to loss in strength (%) (2)	Wetting and drying (%)		Swell (%) (5)
		Weight loss (3)	Volume change (4)	
2	15.90	19.10	0.14	1
4	49.80	6.00	0.45	0
6	87.70	1.00	1.15	0
8	60.20	0.30	1.20	0
Recommended Value	20	7*	2*	2*

* Portland Cement Association (PCA) Specifications

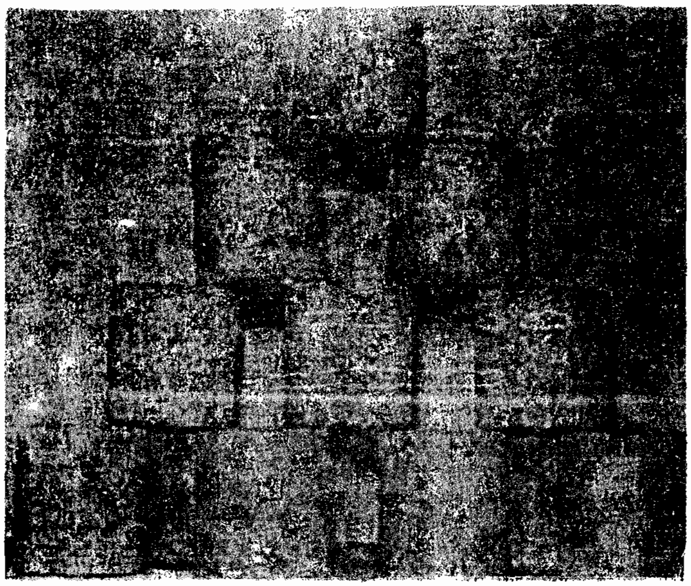

FIG. 2 - Durability Test Specimens

lower than $1.7N/mm^2$ criterion. The CBR values of mound soil-laterite mix treated with cement increased between 2 and 6% cement content, but dropped at 8% cement content. It was expected that the increase would be continuous up to 8% cement. However, the CBR values at 6 and 8% content are above the 180% recommended by the Nigerian General Specification (1970). But considering the 3 to 7% economic cement range recommended by the specification, it could be adjudged that mound soil-laterite mix stabilized with 6% cement met the requirement for road bases.

In soil-cement stabilization, strength is greatly aided by chemical reaction. From the grading curve of mound soil it was evident that the soil contains quite some amount of fines and these fines must have increased the surface area of the mix thereby aiding the secondary reaction between the silica and the alumina of the clay fractions of the mound soil-laterite mix and the free lime product of the primary reaction. It is a known fact that increasing surface area increases the rate of secondary reaction which might be responsible for the continued gain in strength of soil-cement mix. Because mound soil contains compounds of calcium, magnesium and potassium as has been reported in previous work, these compounds made up of reactive elements might also have contributed to the secondary reaction of the mix.

Table 3 shows the comparison of the UCS and CBR of mound soil-laterite mixture stabilized with 6% cement and the control (mix without mound soil stabilized with 6% cement). It is evident that inclusion of mound soil led to 7.48 and 4.43% increase in UCS and CBR values respectively.

Durability Characteristics

The durability test results are presented in Table 4. The results show that the highest value of resistance to loss in strength was recorded for mixture with 6% cement content. From the wet-dry test it was also observed that apart from specimens stabilized with 2% cement, all others met the Portland Cement Association durability requirements. Test specimens after 12 wet-dry cycles are shown in Fig. 2.

CONCLUSIONS

From the results of this study it could be concluded that inclusion of mound soil in a laterite-cement mix positively affected the strength characteristics of the mix, and that judging from the 3 to 7% economic cement range for soil-cement stabilization specified in the Nigerian General Specification and other criteria specified by this standard and other international standards, mound soil-laterite mix stabilized with 6% cement could be used as a base for roads for agricultural trafficking in rural areas where mound soils are abundantly available. Based on the positive outcome of this study and a previous preliminary study by the author on a possible use of mound soil in construction (Udoeyo *et al.*, 2000) a laboratory synthesis of mound soil will be undertaken with a view to producing a substance which could be used as an additive to improve the properties of road subbase.

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REFERENCES

Adepegba, D., 1979. "The Prodigies of Structural Engineering". Lagos University Press, 16 pp.

Ajayi, L. A. ,1987. "Thoughts on Road Failures in Nigeria". The Nigerian Engineer, 22(1): 10-17.

Anago, P. E. and Oni, O., 1991. Moulding Characteristics of Tropical Termite – Mound Sand. The Nigerian Engineer, 26(4): 64-66.

Baghdadi, Z. A.; Fatani, M. N. and Sabban, N. A. 1995. Soil Modification by Cement Kiln Dust. ASCE J. Mater in Civ. Engrg. 7(4): 218-22

D'Hoore, J. L. 1964. Soil Map of Africa, explanatory notes. Commission for Technical Cooperation in Africa (CCTA), Lagos, Nigeria.

General Specification – roads and bridgeworks. Federal Ministry of Works (1970). Federal Government of Nigeria, Lagos, Nigeria.

Methods of Testing Soils for Civil Engineering Purposes. BS 1377 (1975). British Standard Inst., London, England.

Omo-Malaka, S. L. 1977.. A study of the Chemistry and Hydraulic Conductivity of Mould Materials and Soils from Different Habitats of some Nigerian termites. Australian Journal of Soil Research 15:87-90.

Osula, D. O. A. 1989. "Evaluation of Admixture Stabilization fro Problem Laterite". ASCE J. Transp. Engrg. 115 (6): 674-687.

Osinubi, K. J. 1998. Influence of Compactive Efforts and Compaction Delays on Line treated Soil. ASCE J. Transp. Engrg. 12(2): 149-155.

Udoeyo, F. F., Alu, O. C. and Sulaiman, J., 2000. Mound soil as construction material. ASCE J. Mater in Civ. Engrg. 12 (3): 205-221.