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Cement Stabilization of Bama Ridge Soil

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ABSTRACT
This research dwelled on the results of a laboratory investigation into the effect of different compactive efforts on moisture-density relation, durability and strength characteristics of cement-stabilized Bama ridge soil. The Bama ridge is about 10-15cm high and it is approximately 50-100m wide and 350km long. The non-plastic Bama ridge soil stabilized at 7% could be deemed viable as a good base course material for lightly trafficked highway pavement.

INTRODUCTION

The addition of additives such as lime, bitumen or Portland cement to a soil generally tends to improve its physical properties. The additives mentioned have been mostly utilized for the stabilization of sub grade of roads and air fields, though it has also been widely used for parking lots, house foundations as well as lining for canals (Leonards, 1962). Stabilization of soils provides volume stability, reduction in deformity and permeability, enhances durability and minimizes erodability (Baghdadi *et al*., 1995).

Borno State is characterized by heterogeneous soil nature which ranges from the expansive lacustrine deposit of black cotton soil sporadically found in the northern part, to sandstone deposits, laterite and jiglin (a local name for some special hardened pebbles) within Maiduguri and its environs as well as the southern part of the state. Around Maiduguri and Bama towns, there exist several deposits of light brown sand- stones essentially Arkosic Arenite with gradations to feldspathic grey wacke popularly known as the "Bama ridge" (Zarma, 2000). Bama ridge soil trends NW-SE in a some what discontinuous manner from the Cameroun extending through the tip of the Mandara Mountain in Nigeria and unto Bama, Maiduguri and beyond (Thiemeyer, 1992; Zarma, 2000). The extent of the area covered by the Bama ridge soil is depicted in Fig.1.

The idea of cement stabilization seems to be difficult and uneconomical for soils that have

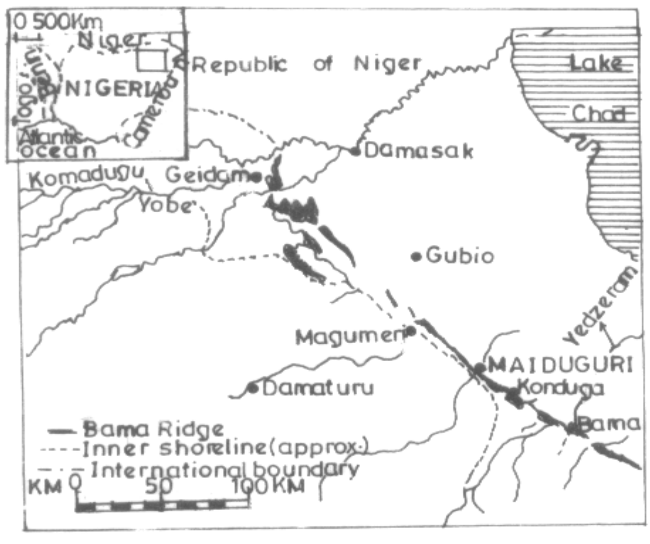

Fig. 1. Area covered by the Bama ridge soil *(Thiemeyer, 1992)*.

liquid limit in excess of 45-50% or plastic limit greater than 20% (Gillot, 1987; Umar, 1998). Lime stabilization significantly improves the strength properties of expansive soils through retardation of swelling and increases the plastic limit (Ashworth, 1966; Kundiri and Kundiri, 2002).

Jha and Sinha (1977) investigated that addition of additives such as lime and cement to soils caused an increase in pH of the moulding water. By and large, cement was given preference as a suitable stabilizer, since most of the failed roads were found to have soil–cement bases (Ogbeide, 1995). On the other hand stabilization could be satisfactorily achieved with bitumen when the soil has not more than 30% passing the 75µm sieve, liquid limits less than 30% and plasticity index less than 18% (O' Flaherty, 1978).

Seemingly, the energy supplied by the compactive effort of a compaction device is used in the reorientation of soil particles, fracture of grains or bond between them (Lambe, 1951).The research reported herein was aimed at investigating the suitability of the Bama ridge soil as a sub grade material as well as identifying the required optimum cement content for the stabilization.

MATERIALS AND METHODS

Sixteen soil samples were collected along the Bama ridge in the proximity of Maiduguri (latitude $11^0$51'N and longitude 13^0 05'E) using the method of disturbed sampling, for the purpose of this research.

The laboratory sample specimens for the compaction were prepared considering moisture content levels of 7, 9, 11, 13 and 15%, while the stabilization was carried out at OMC using cement contents of 3,5,7,9 and 11%. An elapse time of about five minutes was allowed for hydration to take place before starting compaction, after mixing the soil, cement and water. Soil samples compacted immediately following mixing, exhibited changes in compaction characteristics due to the alteration in soil gradation (Osinubi, 1998). The strength of a soil-cement mixture can be evaluated by use of unconfined compression test (Millard, 1993).

The tests involving moisture- density relationships were carried out using air-dried samples. The compactive effort consisting of energy derived from 2.5kg rammer falling through 300mm in three layers each receiving 27 blows of the rammer as British Standard Light (BSL). The British Standard Heavy (BSH) and the West African Standard (WAS) tests were conducted with about 3kg each of the soil sample, using five layers with 27 and 10 blows of the 4.5kg rammer falling through 450mm respectively. The California Bearing Ratio (CBR) test made use of a measurable quantity of 5kg of the soil sample compacted in to five layers with a 4.5kg rammer; each layer given 62 blows at the respective OMC for each compactive effort. The resulting specimen was immersed in water for 24 hours curing period before testing. All sample preparation and experimental procedures were carried out in accordance with the recommendation of the British Standard Institute in BS 1377 (1990) and BS 1924 (1990).

RESULTS AND DISCUSSION

Preliminary tests such as particle size analysis, consistency limits as well as specific gravity were conducted to enable the soil sample to be characterized and classified accordingly. Fig. 2 shows the grain size distribution curve of the soil.

Table 1 revealed that 11.1% of the unstabilized Bama ridge soil passed through B.S. No.200 sieve (75µm), with a liquid limit of 11.8%. It is a non-plastic soil which does not exhibit any volumetric change.

The soil samples were observed to have a sandy texture with a light brown colour and classified as A-3(0) according to the Association of American States Highway and Transportation

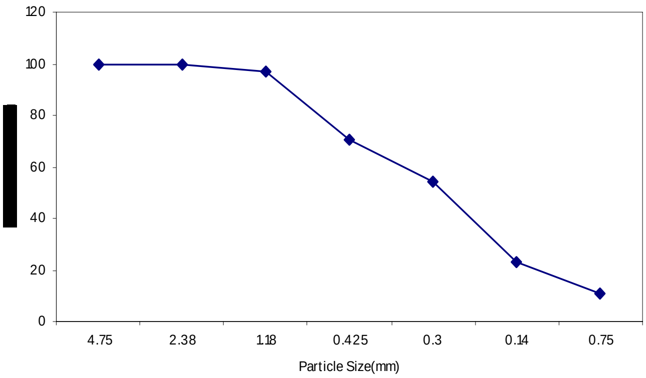

Fig. 2. Particle size distribution for unstabilized Bama ridge soil

Table 1: Index properties of the unstabilized soil

Property	Quantity
Natural moisture content (%)	0.38
Liquid limit (%)	11.8
Plastic limit (%)	00
Plasticity index (%)	NP
Linear shrinkage (%)	00
Specific gravity	2.61
Electrical conductivity (mmHos/cm)	0.12
pH	6.17
Percentage passing BS No. 200 sieve	11.1
Group index	0
AASHTO classification	A-3
USCS classification	CL
Maximum dry densities (Mg/m^3):	
Standard proctor	1.82
British Standard Heavy	1.84
West African Standard	1.83
Optimum moisture content (%):	
Standard proctor	13.9
British Standard Heavy	11.5
West African Standard	12.3
Unconfined compressive strength (kN/m^2)	372
California bearing ratio (%)	24

Officials, AASHTO (1986) classification system and CL (that is, low plasticity soil) in the Unified Soil Classification System, USCS (Punmia, 1981; Craig, 1992; Bowles, 1992).

Since the Bama ridge soil has a non-plastic property, cement stabilization is thus suitable. This agreed with the recommendation of Oglesby and Hicks (1982), for using cement stabilization on soils with plasticity index less than 20%.

The specific gravity of the Bama ridge soil was found to be 2.61, which was close to the range of 2.66 – 2.85 for most soils as stated by Lambe (1951) and Ola (1983). However, Craig (1992) investigated that soils with measurable organic content exhibited specific gravity values as low as 2.0.

Moisture-Density Characteristics

It can be observed from Fig. 3 that an increase of up to 7% cement content was accompanied by a corresponding increase in the Maximum Dry Density (MDD) for the unstabilised Bama ridge soil using all the compactive efforts. The MDD for the unstabilised soil yielded 1.82, 1.84 and 1.83 Mg/m^3 using the British Standard Light (BSL), British Standard Heavy (BSH) and West African Standard Compaction (WASC) respectively. The optimum cement content was observed to be 7% for all the cases. An MDD value of 1.84 Mg/m^3 is an indication of a reasonably stable material for embankment and a good or fairly good sub grade and base course materials (Cheng and Evett, 1981). Inorganic silty clays with a group symbol CL, when compacted are impervious with fair shearing strength, thus having a fairly good workability as a construction material.

Fig. 4 shows that the optimum Moisture Content (OMC) initially decreased and there after increased for the range of cement content using 7-11%. This could be attributed to the introduction of water molecules taken up during the hydration of cement in agreement with Seed (1970).

Strength Characteristics and Durability

With an addition of up to 7% cement content to Bama ridge soil a remarkable improvement was observed which increased the Unconfined Compressive Strength (UCS) from 372 kN/m^2

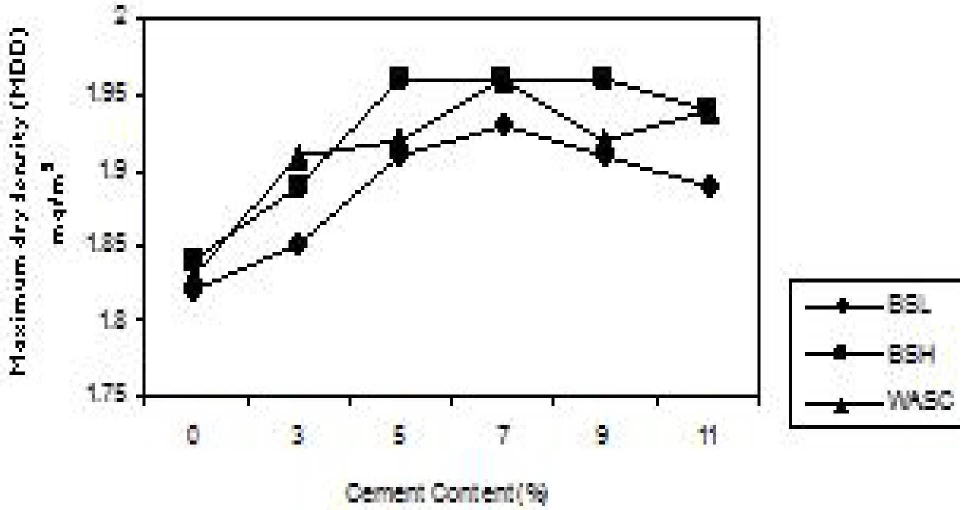

Fig. 3. Variation of MDD with cement content

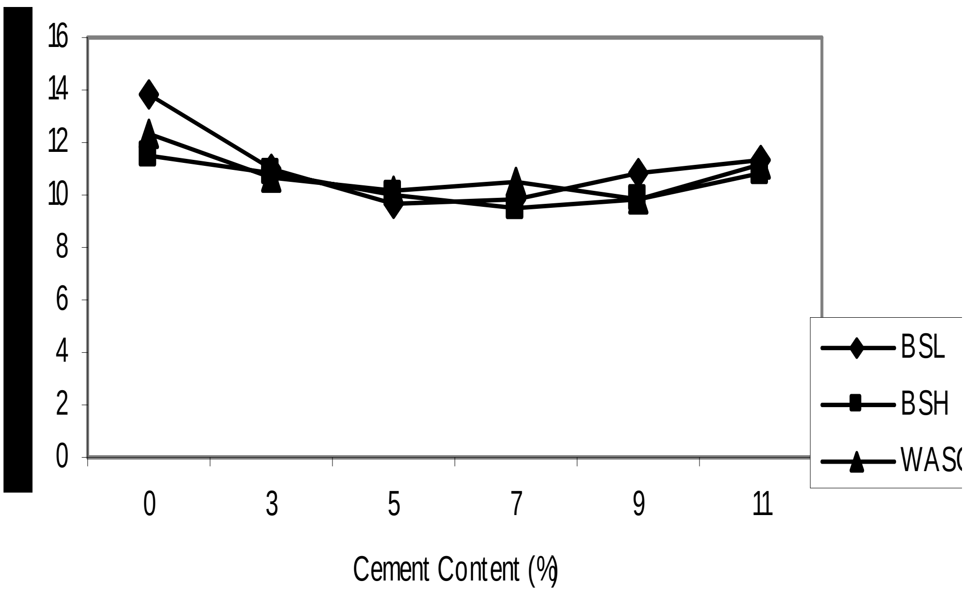

Fig. 4. Variation of OMC with cement content

for the natural or unstabilized soil to 1712 kN/m^2 for 7% cement content waxed cured for 7 days, as shown in Fig. 5.

Fig. 6 showed that the California Bearing Ratio (CBR) values of the Bama ridge soil increased from 24% for natural soil to 56% and above for 7-9% cement-stabilized soil.

This conformed to the findings of Gidigasu and Dogbey (1980), which stated that minimum CBR value of 20-30% is required for sub bases when compacted at OMC.

Consequently, Bama ridge soil stabilized at 7% can be adopted as a good base course for lightly trafficked roads. An assessment of the

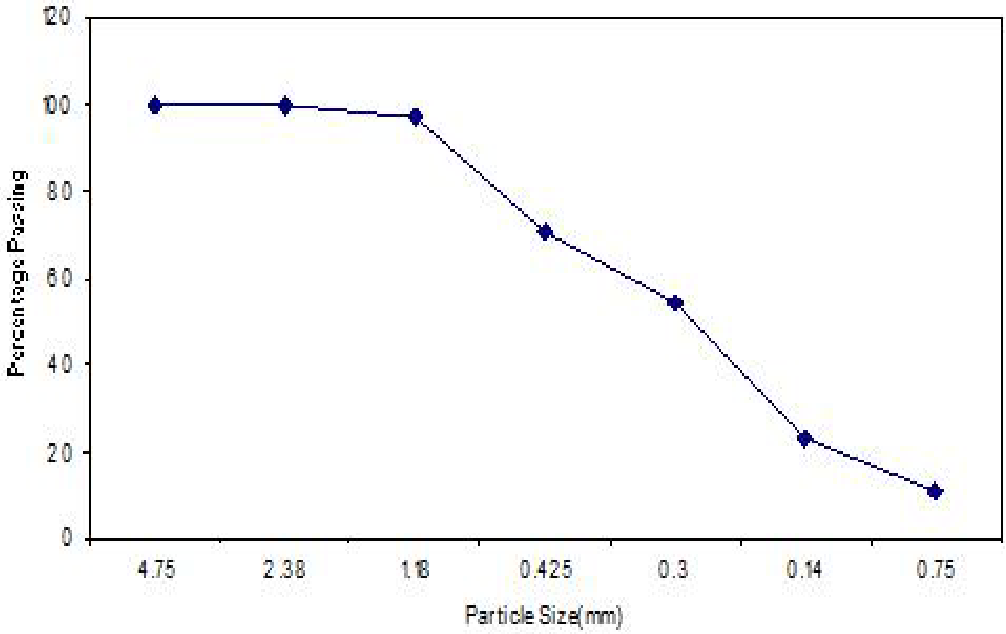

Fig. 5. Variation of UCS with cement content

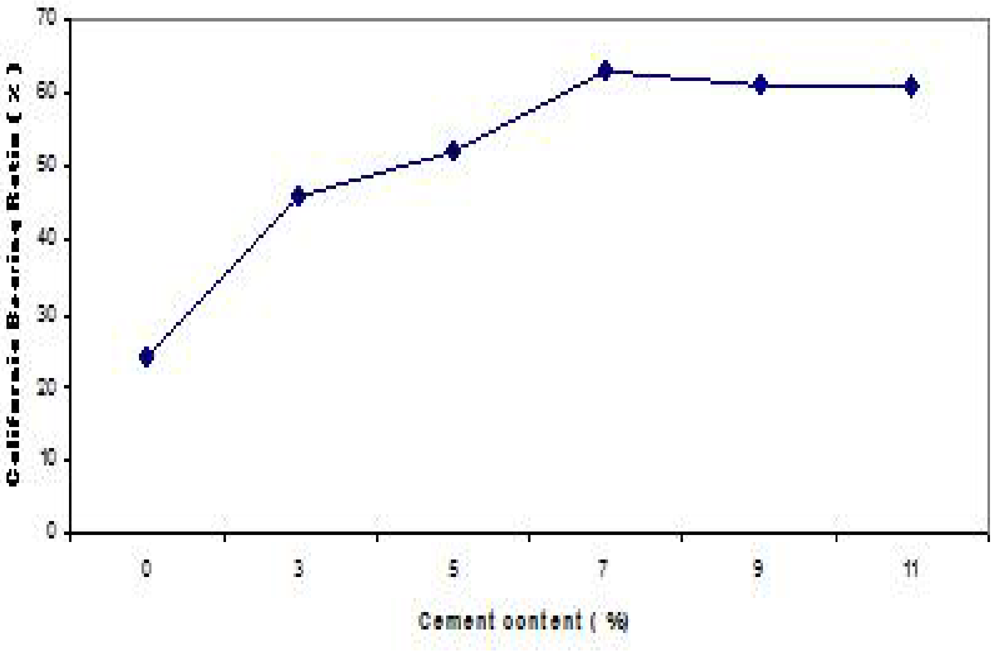

Fig. 6: Variation of CBR with cement content

durability for cement stabilized specimens was conducted by water immersion test using UCS, in which the resistance to loss in strength was measured.

Nevertheless, the results obtained are in concordance with the Nigerian General Specifications (1997), which recommended not greater than 35% passing B.S. No. 200 sieve and CBR value of not less than 10% (48 hours soaked) as suitability criteria for sub grade materials. In the same vein, the values of not less than 30% passing B.S. No. 200 sieve, liquid and plastic limits of less than 30 and 12% respectively as well as a CBR value greater than 30% were recommended by the Nigerian General Specifications (1997) for use as sub base and base course materials.

CONCLUSION

The Bama ridge soil which is a non-plastic soil was classified as A-3(0) which is considerably made up of inorganic silty clays and can be stabilized conveniently using cement on account of its low plasticity index (<20%). Three different compactive efforts, BSL, BSH and WASC were used in order to achieve the aim of this study. The results obtained revealed that the MDD, UCS and CBR values increased with the addition of cement content up to an optimum value of 7%. The stabilized soil could be adopted as a suitable material for lightly trafficked roads.

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REFERENCES

AASHTO 1986. Standard Specifications for Transportation Materials and Methods of sampling and testing, 14th ed. American Assoc. of states Highway and Transportation officials (AASHTO), Washington, D.C.

Ashworth, R. 1966. Highway Engineering. Heinemann Education Books Ltd, London. Pp. 284.

Baghdadi, Z.A., Fatani, M.N. and Sabban, N.A. 1995. “Soil modification by cement kiln dust”. Journal of Materials in Civil Engineering, ASCE, 7(4), 218-222.

Bowles, J.E. 1992. Engineering Properties of Soils and their Measurements, 4th ed. McGraw – Hill International edition, London, Pp. 79-89.

BS 1377(1990). Methods of Testing Soils for Civil Engineering Purposes, British Standard Institute, London.

BS 1924. 1990. Methods of Test for Stabilized Soils, British Standard Institute, London.

Cheng, L. and Evett, J. B. 1981. Soil and Foundation, Prentice Hall, London. Pp. 319.

Craig, R.F. 1992. Soil Mechanics, 5th ed. ELBS with Chapman and Hall, London, pp. 10-22.

Gidigasu, M.D. and Dogbey, J.L.K. 1980. “Geotechnical characterization of laterized decomposed rocks for pavement construction in dry sub-humid environment”. 6th South East Asian Conf. on Soil Engineering, Taipei, 1, 493-506.

Gillot, J.E. 1987. Clay in Engineering Geology, Development in Geotechnical Engineering, Elsevier Science Publishing Co. Inc, New York.

Jha, J. and Sinha, S.K. 1977. Construction and Foundation Engineering, Khanna publishers, Delhi, Pp. 267-937.

Kundiri, A.M. and Kundiri, A.M. 2002. “Influence of lime-stabilization on strength characteristics of expansive soil”. *Research Journal of Science* 8 (1&2), 19-25.

Lambe, W.T. 1951. Soil Testing for Engineers, John Wiley and Sons, Inc, Washington, D.C.

Leonards, G.A. 1962. Foundation Engineering, McGraw-Hill, Inc., London.

Millard, R.S. 1993. “Cement and lime stabilization” Road Building in the Tropics Transportation Research laboratory, State-of-the Art Review, 9, 183-185.

Nigeria General Specifications. 1997. Bridges and Road works. Federal Ministry of Works and Housing, Head quarters, Abuja, Nigeria, Vol. II.

O'Flaherty, C.A. 1978. Highway Engineering. Vol. 2 "Highway" 2nd ed. Edward Arnold, London, Pp. 221-267.

Ogbeide, F.N. 1995. "Optimum compaction specification for some soils in Borno State of Nigeria". Annals of Borno, University of Maiduguri Press, (11 & 12),215-225

Oglesby, C.H. and Hicks, R.G. 1982. Highway Engineering. 4th ed. John Wiley and Sons, Inc. New York.

Ola, S.A. 1983. The Geotechnical properties of the black cotton soils of North eastern Nigeria in: Tropical soils of Nigeria in Engineering practice, A.A. Balkema Rotterdam, Pp. 85-101.

Osinubi, K.J. 1998. "Influence of compactive efforts and compaction delays on lime-treated soil". Journal of Transportation Engineering, ASCE, 124(2), 149-155.

Punmia, B.C. 1981. Soil Mechanics and Foundations. 6th ed. Standard Book House, Delhi, 976pp.

Seed, G.B. 1970. Soil Mechanics and Foundation. John Wiley and Sons, Inc New York, pp. 36-90.

Thiemeyer, H. 1992. A New ^{14}c-Record from the Bama ridge near Konduga, Borno State, Annals of Borno, University of Maiduguri Press, (8&9), 239-242.

Umar, S.G. 1998. "The compaction characteristics of three cement-stabilized soils in former Borno State". Annals of Borno, University of Maiduguri Press, (13&14), 240-248.

Zarma, A.A. 2000. "Petrographic study of the sandstones exposed on the Bama ridge, Maiduguri". Borno Journal of Geology, 2(2), 65-77.