COMPARATIVE RESPONSE OF FOUR PEDOGENIC SOIL MATERIALS TO CEMENT STABILIZATION

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ABSTRACT

A comparative response of four Pedogenic soil materials to cement stabilization was investigated. The studies focused on the compaction characteristics, the unconfined sompressive strength and the California bearing ratio of the samples. The results obtained show that soil materials from Maiduguri responded favorably to cement stabilization compared to soils from Yola. All the values obtained for Maiduguri soils at 2% *cement content met both the conventional UCS values of (3000 kN/m^2 - 6000 kN/m^2) for base course of highly trafficked roads, and the minimum CBR value of 180% as recommended by [I2] to be adequate for cement stabilized soils, while soils from Yola met the conventional UCS values of (1500 kN/m^2-3000 kN/m^2) for base course of lightly trafficked roads not only at 2% cement content but for all the ranges of cement content used (2%-10%),* 4% *cement content was found to be the optimal for Yola soils to achieve the minimum CBR value of 180% set out by [I2]. On stabilizing the soil materials from Maiduguri with* 2% *cement as the optimal content, it can be used as base course for highly trafficked roads, while* 4% *cement was recommended as the optimal cement content and can be used as a-base course for lightly trafficked roads [l1].*

INTRODUCTION

The term pedogenic material applies to laterites, fenicretes, calcretes e.t.c as well as to materials of similar origin, which may have smaller quantities of cementing materials, [1]. According to [2], pedogenic soils are horizons of soils that harden irreversibly on contact with air. In a broader sense, laterite is restricted to a generally reddish colored material formed by the relative accumulation of iron and aluminum oxides formed under tropical conditions by weathering and leaching out more soluble constituents including silica e.t.c. Ferricretes on the other hand are generally restricted to iron-rich materials formed by the accumulation of iron oxide during the cementation and/or replacement of a pre-existing soil by iron oxide deposited by soil water or ground water. While calcrete generally is restricted to whitish colored material formed by the absolute accumulation of (mainly) calcium carbonate during the cementation and/or replacement of pre-existing soil by calcium carbonate deposited from the soil water or ground water. Therefore, by inference, pedogenic soil material is a material, which consists of laterites soils, or soils rich in iron oxides and calcium carbonate deposits.

There are four pedogenic soil materials that have been investigated in this study. Three laterites and one calcrete. The study areas, Yola and Maiduguri are characterized by evaporation exceeding precipitation on annual basis. In such areas leaching is usually inadequate, this makes it difficult for complete removal of calcium carbonate. Laterite that are formed under such conditions with annual rainfall below 1200 mm are called ferruginous laterite (laterite in which iron oxide are dominant). [3]. It is therefore important to note that soil used for road construction in such area is either calcrete or ferruginous laterite based on the above findings.

In developing countries of the tropics, like Nigeria, laterite soil has featured for a long time in the construction of road. Some laterite are suitable for use in their natural state, while other require an additive in order to satisfy the purposes for which they are intended.

Compaction and Strength Characteristics.

The maximum dry density/optimum moisture content (MDD/OMC) of Laterite soils were reported to decrease and increase with corresponding increase in cement content. [4] The same thing was reported except that they included lime in another investigation. [5] Their findings were in agreement with [6, 7, 8, 9], where Optimum Moisture Content (OMC) increased with decrease in maximum dry density (MDD). The initial increase in OMC, which was reported by [10], was due to the increase in surface area of particles caused by addition of cement. Recent works also by [11], reported on the increase of CBR values from 8% for 0% cement content to 100% at 8% cement; this however did not meet the requirements set out by [12], which recommends a CBR value of 180% to be attained for cement stabilized soils which should not exceed 7% cement content for it to be economical. It was further reported that an increase of UCS value from 310 kN/m^2 to 1275 kN/m^2, 1775 *kN/m^2* and 2175 kN/m^2 for specimen wax-cured for 7, 14 and 28 days respectively. Soil samples with 8% did not meet the 7 days conventional of 1720kN/rn^2 recommended by [13] for adequate cement stabilization of base course.

MATERIALS AND METHODS

Location of samples

Four samples were used in this study; two were obtained from two points, which was approximately 50m apart opposite the Maiduguri International Hotel. Maiduguri is located on (latitude 11047.711N and longitude 13013.611E), which is situated on the Quaternary sedimentary Chad formation. While the other two samples were obtained around Yola, one of the samples was along Yola/Fufore and the other along Yola /Mubi road respectively. Yola is located on latitude 90811 N and longitude 1204811 E which is located on Bima sandstone and river alluvium. The two-study areas, Maiduguri and Yola, experiences semi- arid condition and are characterized by the Sudan savannah type of vegetation. It has been reported that an average annual rainfall of 692mm, humidity is usually very low throughout the dry season and the mean annual temperature is 260C, afternoon temperature for Maiduguri may reach 430 C during the hot season.[14]

The annual average temperature for Yola ranges between 170C - 430C while the annual rainfall is about 958.99 mm [15]. The high average temperature of the tropics is advantageous for the stabilization of laterite soil with cement, because strength gains are faster but can also cause problems.

SAMPLE PREPARATION

All the soil samples were collected between 1- 2 m depths corresponding to B-horizon. The classification of soils, the determination of the moisture-density relationship as well as the strength characteristics were performed in accordance with the guidelines of [16] and [17]. British Standard Heavy compaction tests were also carried out on all the samples which were stabilized with 0% - 10 % cement content.

The soil-cement mixture for the specimens were prepared by mixing thoroughly (dry) precalculated amount of soil and stabilizers using a trowel in a sample tray with water to achieve a uniform color. The data for classification of the soils are shown in Table 1, while the properties of the stabilized soils are shown in Tables A1-

A3 in the appendix.

RESULTS AND DISCUSSION

Table 1 Classification data for the soil

Symbol	A_M	B_M	A_Y	B_Y
%Passing 2mm	94.4	99.2	91.7	92.3
%Passing 1mm	88.7	95.4	78.7	65.0
%Passing $425\mu m$	60.79	80.87	36.7	22.0
%Passing $75\mu m$	17.56	24.71	13.0	10.4
%Passing $63\mu m$	4.26	8.24	3.10	2.30
Specific Gravity	2.65	2.56	-	-
Linear Shrinkage %	-	-	9.40	6.00
Liquid Limit %	21.0	22.3	28.5	19.0
Plastic Limit %	14.9	15.4	15.0	11.5
Plasticity Index %	6.1	6.9	13.5	7.5
USCS	SC-SM	SC-SM	SC	SC-SM
AASHTO	A-2-4	A-2-4	A-2-6	A-2-4

DISCUSSION

The effects of stabilization for soil-cement mixes are shown in Figs. 1,2, 3 and 4.

Maximum Dry Density.

Fig. 1 shows the variation of maximum dry density with cement content, the MDD for the two Maiduguri soils increased from 1.86Mg/m^3 and 1.89 Mg/m^3 at 0% cement content to a highest value of 1.95 Mg/m^3 and 1.93 Mg/m^3 at 4 and 6% cement content, respectively and thereafter decrease with increasing Cement contents respectively. For the Yola soils, it increased from 1.96 Mg/m^3 and 1.92 Mg/m^3 at 0% cement content to 2.00 Mg/m^3 and 1.97 Mg/m^3 at 2 and 8% cement content respectively and thereafter decreased with increase in cement content. The increase in MDD may be due to coarse aggregates formed as a result of the excess cement present in the system that plugged the voids to produce denser mixes.

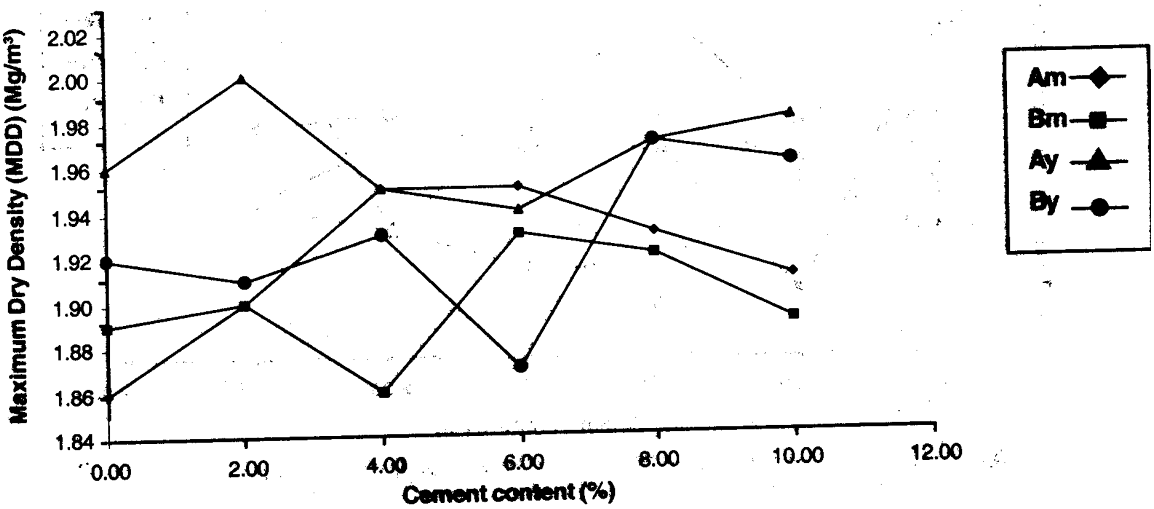

***Fig. 1:** Variation of Maximum Dry Density with Cement content*

Optimum Moisture Content.

Fig. 2 shows the variation of optimum moisture content (OMC). The pattern of the OMC did not conform to the usual trend of increasing OMC/decreasing MDD for cement-treated soil, but rather the pattern of the OMC varied randomly for all the ranges of stabilizer content. The decrease observed in all the cement ranges was abnormal. The abnormality may also be as a result of insufficiency of water in the system, which may lead to self-desiccation and consequently lower hydration as reported by [11]. It was also known that if no water movement to or from cement paste was permitted, the reaction of hydration use up the water until too little is left to saturate the soil surfaces and the relative humidity within the paste decreases.

Strength Characteristics

As stated earlier, high ambient temperatures of the tropics is advantageous for cement stabilization. This makes cement stabilized soil to harden quite rapidly. The effects of cements on the Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) values are presented in Figs. 3 and 4 respectively.

With additions of at least 2% cement to Maiduguri soils, the UCS increased from 72kN/m^2 and 101 kN/m^2 to 3457 kN/m^2 and 3654 kN/m^2 respectively, for specimen-wax cured for 7 days. This result however meets the requirement of 7 day 1720kN/m^2 criterion for adequate cement stabilization of base courses. It also met the minimum conventional UCS values for base course of highly trafficked roads (3000kN/m^2-6000 kN/m^2). Addition of 2% cement to Yola soils, the UCS increased from 51 *kN/m^2* and 47 kN/m^2 to 1600 *kN/m^2* and 1760kN/m^2 for specimen wax-cured for 7 days respectively, sample A from Yola did not meet the 7 day *1720kN/m^2* criterion for adequate cement stabilization of base courses at 2% cement while sample B met the requirement. It is important to note here that acjdition of 2% of cement to Maiduguri soils, met both the minimum conventional UCS values of (3000 kN/m^2 -6000 *kN/m^2)* for base course of highly trafficked roads and the minimum CBR value of 180% set out by [12]. While addition of 2% of cement to Yola soils only met the minimum ventional UCS values of *(1500kN/m2- 3000kN/m2)* for base course of lightly trafficked roads, but could not meet the minimum CBR value of 180% set out by [12], this was metal 4% cement content.

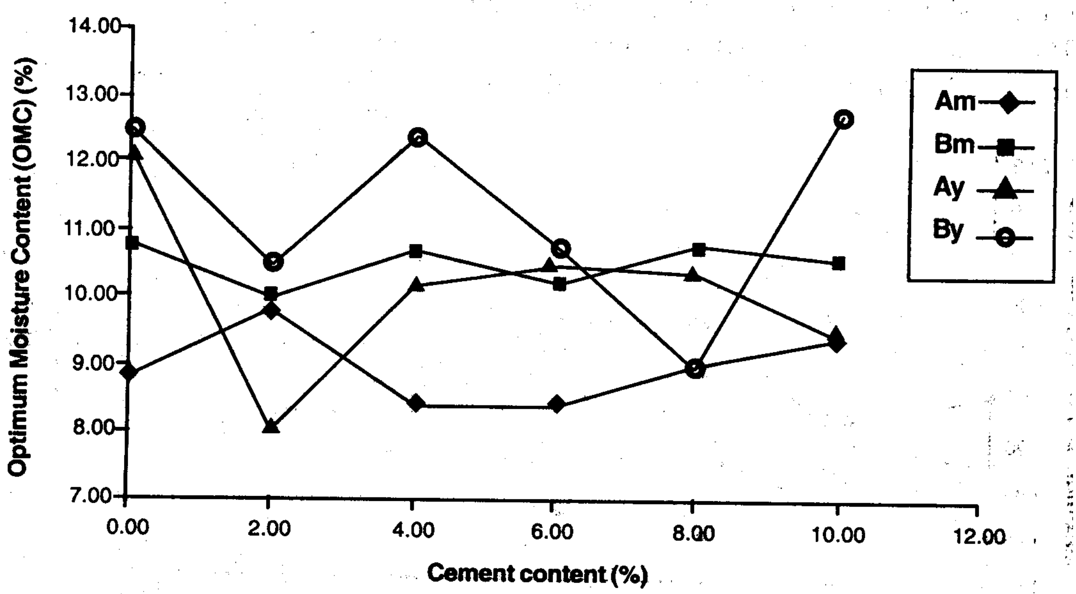

Fig. 2: Variation of Optimum Moisture Content with Cement content.

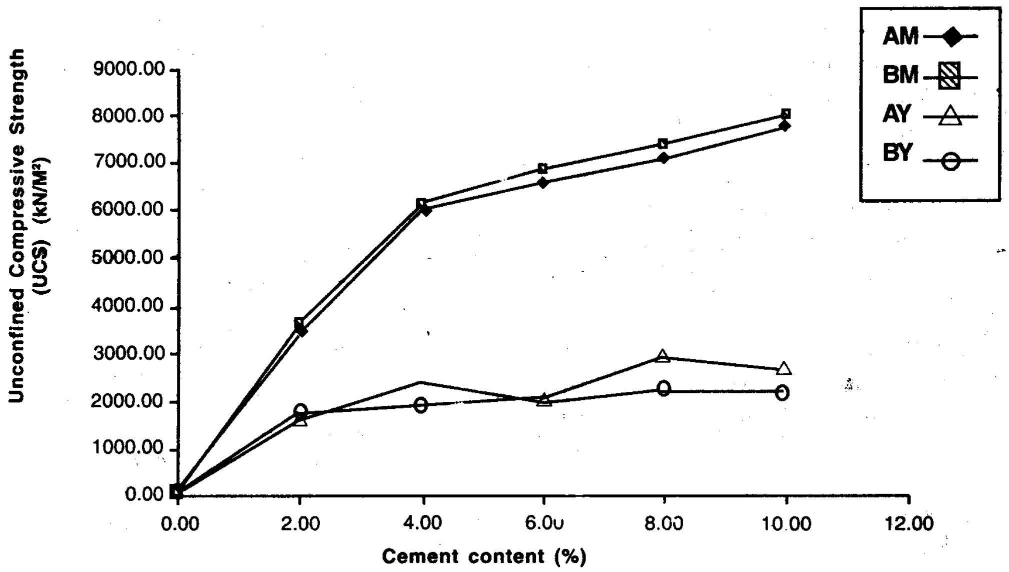

Fig. 3: Variation of Unconfined Compressive Strength with Cement content.

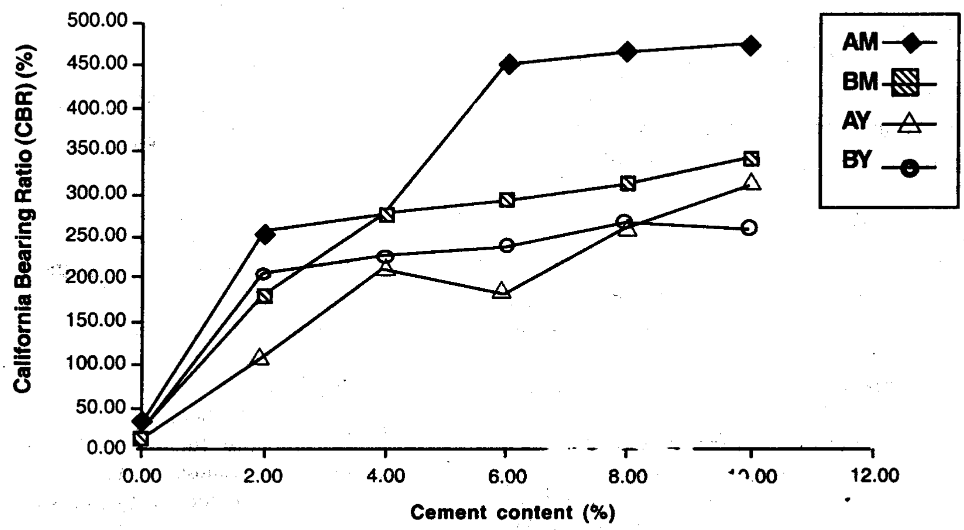

Fig. 4: Variation of California Bearing Ratio with Cement content.

CONCLUSIONS

From the results of the investigation carried out in this study, the following conclusions were made:

1. The results obtained during the study shows that using the conventional 7 day UCS value of *1720kN/m²* criterion for adequate cement stabilization of base courses, only sample A from Yola failed to meet the requirement.
2. The specification set out by [12], which re .omrnencs 180% CBR value to be adequate for stabilized soils was met at 2% and 4% cement for Maiduguri and Yola soils respectively.
3. Comparatively, the results obtained for Maiduguri soils can also confirm earlier [6] findings which recommended a maximum of *3%* cement for, A-2-4 and A-2-6 soils.

RECOMMENDATIONS.

2% and 4% cement are recommerrled as the optimal cement contents for Maiduguri and Yola soils respectively, and the soils can be used as a base course of highly and lightly trafficked roads respectively.

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APPENDIX

Table 1A. Compaction Characteristics of the Natural and Stabilized soils.

% Of Cement	A_M		B_M		A_Y		B_Y	
	MDD	OMC	MDD	OMC	MDD	OMC	MDD	OMC
0	1.86	10.2	1.89	8.8	1.96	l2.1	1.92	12.5
2	1.90	10.0	1.90	9.8	2.00	10.0	1.91 -	10.5
4	1.95	10.7	1.86	10.4	1.95	10.3	1.93	12.4
6	1.95	1.02	1.93	l0.4	1.94	i0.5	1.87	10.8
8	1.93	10.8	1.92	9.6	1.97	10.4	1.97	9.0
10	1.91	10.6	1.89	9.4	1.96	9.4	1.96	12.8

Table 2A. Unconfined Compressive Strength of the Natural and Stabilized soils. (kN/m^2)

% Of Cement	A_M	B_M	A_Y	B_Y
0	72.48	101.00	51.20	46.70
2	3457.04	3654.00	1600.00	1760.00
4	6029.81	6126.54	2400.00	1920.00
6	6594.28	6845.22	2000.00	2000.00
8	7090.00	7334.03	2920.00	2240.00
10	7776.58	7997.85	2640.00	2200.00

Table 3A. California Bearing Ratio of the Natural and Stabilized soils. (%)

% of Cement	A_M	B_M	A_Y	B_Y
0	28	15	13	12
2	255	182	108	144
4	274	274	212	226
6	453	291	182	236
8 -	469	310	258	264
10	475	339	310	258

Legend: A_M = sample A from Maiduguri, B_M = sample B from Maiduguri, A_Y = sample A from Yola, and B_Y = sample B from Yola respectively.