STABILIZATION OF PROBLEMATIC BLACK COTTON SOIL FOR THE CONSTRUCTION OF ENGINEERING STRUCTURES USING ADMIXTURES (A REVIEW)

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Abstract

Black Cotton soil is a problematic soil as it is expansive in nature. The swelling and shrinking properties in Black Cotton soil is imparted due to the presence of the mineral component montmorillonite. It is predominately Black Cotton, black in colour with a smooth texture. Construction over this particular soil is always security challenging due to its low strength and less drainage property. The soil is always a threat to the strength and stability of pavements and highways. This research was an investigation in to the effect of River sand and cement as an admixtures on the properties of Black Cotton soil in order to attain an economically stabilizable state with various percentages of an admixtures (cement river sand). The percentage of cement used were 2%, 4%, 6%, 8% and 10% and that of river sand was 10, 20, 30, 40 and 50 respectively. Details procedure of tests conducted both preliminary and main tests ran were analyzed. Preliminary results indicated that the Black Cotton soil is classified as an A – 7 – 5 soil whose properties are such that, they are not economically stabilize or useable in their natural states for pavement works. details results presented shows that with increase in cement content OMC, grain size and plastic limit increases while the liquid limit, MDD, plasticity index and linear shrinkage decreases. Increase in cement percentage significantly improves the Black Cotton soil properties in terms of its potential use as sub-grade, embankment dam, tunnel, foundation design etc.

Keywords: *stabilization, Compaction, Modification, Road Pavement and Sub-grade.*

INTRODUCTION

Soils have been defined in various ways depending upon professional perspective. Two most important professional that have direct encounter with soil scientist and soil engineers or Civil Engineers. To the soils scientists, soil is any materials that nourishes and supports plant growth, and to the Civil Engineers, soil is any material that supports buildings and roads including other Civil Engineering structures such as foundations, dams, funnels, canals e.t.c.

In his practice, the Civil Engineer has many reasons and important encounters with soil. He uses soil for foundation to support structures and embankment, as a construction materials, nearly every Civil Engineering structure buildings, bridges, highways, tunnels, walls, towers, canal or dams must be founded on the surface of the earth.

Black Cotton soil is among the soils on which those structures mentioned above can be constructed and it is the main soil in focus in this project.

In areas covered by Black Cotton soils, the constructions and performance of roads have been found by several researchers such Ola (1978) to possess a major problems. The reason being that in Black Cotton soils, the predominant Black Cotton mineral in the Black Cotton fraction is montmorillonite. This causes the soil to pose a high volume change with fluctuation in moisture content severe cracking when dry and high swelling potential with low bearing value when wet. Thus the alternative name "expansive Black Cotton". A Black Cotton soil is a soil which contains some Black Cotton mineral as well as other mineral constituents, have plasticity and is cohesive. Black Cotton soils have Black Cotton contents as high as 60% the Black Cotton mineral being predominantly montmorillonite, Black Cotton mineral could be kaolinite group, illite group or montmorillonite group. Kaolinite group is made from large states of alternating single tetra hedral sheets of aluminum. They are very stable with strong structure and which absorbs little water, they have low swell and shrinkage characteristics and respond to water content variation in that, it does sell appreciably on wetting conversely it does not shrink much or crack on drying. Illite group consists of a serious of aluminum sand – wiched between two tetrahedral sheets of silicon. In the octahedral sheets, some of the aluminum is replace by ion and magnesium and in the tetrahedral sheets, there is partial replacement of silicon by aluminum, this is because their cation exchange capacity is high when compared to Kaolinite group. Illite group tends to absorb more water than Kaolinite group and have high swelling and shrinkage characteristics.

Black Cotton soils are characterized by a very heavy texture owing to the montmorillonite, when wet the soils are very sticky when they are extremely hard. They crack broadly on drying. The soil has a striking dark colour which is due to high calcium humus compound. Black Cotton soils do not normally form under high rainfall and forest vegetation, because the calcium could be reached out of the profile and the Black Cotton mineral could be converted at least in part to kaolinite, under these conditions so giving a rather different soil over the same parent rock Ann (1974) Black Cotton soil when use in the construction of many engineering structure such as highway, embankment, earth dam, road pavement (base course and sub-bases) often require to be stabilized and hence compacted to improve the properties of the soil. Compaction has a direct influence on the shear strength of soils by increasing the value of their shearing resistance and cohesion.

To solve this problem, the cost and possibility of importing suitable materials is normally compared with the cost of improving the proportion and strength of the soil. The former process will increase the initial investment on the road, by way of increasing costs of borrowing and hauling large volume of suitable materials involved. The later process which is the one generally used involves soil modification and stabilization. Soil modification is the improvement of the physical properties (plasticity characteristics and frictional characteristics), while soil stabilization is the improvement of the strength. Because a high percentage of cement would be required to achieve stabilization (Ibrahim, 1979). Cement is the most successful additives use for the stabilization of Black Cotton soil (Ola, 1983). River sand, though the most successful additives is still not economical nor meet with the required strength. Thus, the suggestion by Ola of a mixture of River sand and cement and this is known as admixture stabilization. It involves modification with sand before stabilization with cement.

The research exercise is therefore designed to determine the potentials of using sand to modify cay soil with the aim of determining its suitability and stability.

Civil engineering is concerned with the identification and determination of the stability and structure it is expected to withstands. Most of the problems of increasing the strength and stability of natural soils in order to improve on its load bearing properties with a view for determining the life expectancy of projects such as road base and sub-base, dams, rails and allied constructions are faced by the highway design(s) parts of civil engineering.

Generally, the strength of the sub-grade determines the thickness or the type of pavement layer which the engineer will specify to transmit traffic loading to the sampling and analysis combined with a good soil classification and this is termed as soil stabilization. This is the process whereby unsuitable soil are improved in order to meet the requirement of stability and strength for the use in highway construction.

The choice of stabilization methods depends on the property of the soil, determined through the basic laboratory tests, availability of stabilizers, traffic conditions as well as the overall economy.

The Highway Research Board (1943) has set limits for soils that can be economically stabilized with cement. For soils to be economically stabilizable with cement, the Highway Research Board (1943) has set limits of 50% passing B.S No. 200 sieve, 40% liquid and 18% plasticity index. As direct use for road materials, the Nigerian General Specification of Bridges and Road Works (1970) specify the limits to be met as follows: for base materials 55.89% liquid limit, 25.89% plasticity index, A – 2 – 6 as AASHTO classification and 43.28% passing B.S No. 200 sieve, for sub-base materials, the liquid limit, plasticity index and AASHTO classification are the same as that for base material with the exception that the percentage passing the B – S No. 200 sieve is 43.28%. Black Cotton soil are shaly sediments or lagoonal Black Cottons and olivine basaltic rocks. The absent of quartz leads to the formation of fine – grained mostly Black Cotton size, plastic soil which is highly inflammable and easily becomes waterlogged (Ola, 1978). The swelling characteristics of Black Cotton requires to be predicted in order to be able to make rational design of foundations of constructed facility.

Black cotton soil has long been known to be very problematic for construction: it is not considered suitable either for the building of houses or the construction of roads. This has led to many investigations into ways of improving the subgrade by ways of stabilizing it and as such improving the engineering properties of the soil. Black cotton soil has been blamed for the failure of the some of the buildings situated in the Adamawa state of Nigeria, where the cracking of the walls up to the foundation can be due to differential settlement arising from the shrink-swell behavior of the soil.

The Lake Chad Basin is an extensive quarterly lacustrine deposit of black Black Cotton soils. Laboratory investigations show that this soil consists of abundant proportions of montmorillonite and generally poses a major problem for Civil Engineering construction due to high volume changes.

Alternative soils or aggregates suitable for base construction are very difficult to obtain in these localities and hence soil stabilization is of great economic importance to the construction industry. Methods of stabilizing this soil include lime stabilization, cement stabilization, mechanical stabilization, or heat treatment. This paper is primarily concerned with sand stabilization because of the presence of large deposits of dune sands at these locations. The result indicates that sand stabilization shows promise for improving the value of black cotton Black Cottons in pavement construction and is the most economical of all the applicable methods. However the method is recommended only for improving the subgrade and as a sub-base.

Road construction over tropical Black Cotton soil generally poses a major problems due to the ability of the soil to swell and shrink considerably with changes in moisture content which consequently lead to low bearing values when wet and severe cracking when dry. Also, geotechnical and index properties of these materials indicates a classification that connotes inadequacy for use as a sub-grade materials.

The construction of earth roads to meet the present and future requirements of the rural areas have become the greatest challenging task for the transportation engineers in Nigeria. This is of course due to the important roles such roads played toward the socio-economic development of the rural areas in particular and the nation in general, and the position it stands in the boosting of the nation agricultural productions.

Contrarily, the existing rural earth road system in Nigeria is inadequate to meet up with the development programme and requirements as such, they mostly serve as a fairly weather roads due to a variety of reasons among others the nature of the existing or construction soils, the determination of which has not been given much emphasis and or neglected in a majority of instances, a time due to lack of insufficiency of funds.

The problem continually facing an engineer is that dealing with procedures and techniques of improving unsuitable soils by stabilization. In many instances, soils that are unsatisfactory in their natural state can be altered by admixtures by adding some aggregates or by proper compaction and thus made suitable for sub-grade construction.

The purpose of stabilization is to improve the desirable characteristics or conditions of soils, aggregates mixtures to degree where they can be successfully used as a component part o foundation or pavement structures. The engineer must always try to use local and lower cost materials to best advantages.

With my lifelong hope and wish that the project will be of greater significant and help to the body concern in effecting any improvement work on the existing road.

AIMS AND OBJECTIVES

- To evaluate the influence of stabilizer (cement) on the index properties of the mixtures.

- To examine the effect of varying cement sand contents on black cotton soils.
- To evaluate the influence of the stabilizer on the compaction characteristics of the mixture using three (3) compacting energies.
- To analyze or evaluate the influence of stabilizer on California bearing ration (C.B.R.) behaviour of the mixtures using B.S light and B.S heavy.

METHODOLOGY

Black cotton soil were obtained and crushed. The sample was served through 42.5mm sieve size for the purpose of carrying out the atherberg limit. The sample was stabilized with 10%, 20%, 30%, 40% and 50% with varying cement percentage of 2%, 4%, 6%, 8% and 10%.

Moisture content was determined by using oven dry method, specific gravity, free swell test, compaction (B.S light, heavy and west African standard by weighing about 3000g (3kg) of black cotton soil which was crushed to a powdered form in a mortar and then using varying percentage of water content at an increment of 5% to 30% of 150ml with the aid of a cylinder in added for every compaction.

Energy of compaction =

$$\frac{No.of\ blows\ x\ no.of\ layers\ x\ weight\ of\ rammer\ x\ height\ of\ fall\ x\ 9.81}{Volume\ of\ mould\ (cm^3)}$$

Also, California bearing ratio (CBR) was obtained by measuring about 5000g(5kg) of black cotton soil and mixed at optimum moisture content. The soil was placed in CGR mould with cotton attached to the mould top. The test results of load against penetration to produce a penetration of 2.5mm and 5.0mm were determined and express as percentage of standard loads of 13.24KN and 19.96KN respectively. The penetration of the plunger is measured by a dial gauge at a penetration of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5 and 7.0mm

CBR for 2.5mm $=\frac{Applied\ load}{13.24}$ X 100

CBR for 5.0mm = $=\frac{Applied\ load}{19.96}$X 100

CEMENT STABILIZATION

Stabilizing Black Cotton soil with Portland cement alone is not suitable, because the presence of montmorillonite retards hydration. According to Ola (1983) the increased in strength is due to the development of cementations linkage between these hydration products and soil particles. The lime released during hydration of cement may react with any pozolonic material for instance Black Cotton present in the soil.

According to TRRL (1974) the effect of moisture content on the quality of soil cement mix largely arises from its influence on compaction for good compaction it is necessary to bring the materials to the maximum dry density (MDD) for a given effort.

Cement when added to the soil helps in improving the strength and durability. The usual application is to pavement construction where soil cement is substituted for aggregate base. Other successful uses includes shape protection for dams and levees and impermeable hiring for canal and reservoir. The projects describes a study on the effect of cement admixtures on the index and engineering properties (compaction and unconfined strength) of tropical black Black Cottons(s) soils. The amount of cement added to the black soil sample as percentage of the dry soil mass were in the range 2% - 10%. The results obtaining shows that the addition of the cement admixture could improve the engineering properties of tropical black Black Cottons. Cement is used as soil stabilizing agent especially for road construction such as sub base, airport runways and earth dams (Van Impe 1989, Little 1995). It is also used for the construction of low cost houses especially in the third region.

Problematic Black Cotton soils exhibit high compressibility, high swelling potentials, reduced strength, low permeability and durability and consequently are low quality material for construction and present difficulties in construction (Pinto et al, 2003). In such circumstances, engineering properties of problematic soils can be enhanced by the addition of cement thereby producing an improved construction material. The cement soil mixing has been used for many diverse application soil – cement is thoroughly compacted mixture of pulverized soil and cement with the appropriate amount of water.

In stabilization of soil with cement between 5 – 15% by weight of cement added to the soil to produce a material soil cement which is a stronger and more durable than untreated soil having the appearance of very dense soil, its colour is practically of the soil used in construction, it is hard with limited resistance to abrasion because of the characteristics listed earlier above.

The ways in which soil cement may be used in road construction depends on the soil type, site condition and amount of traffic anticipated. It is also the mixture of pulverized soil measure amount of Portland cement and water compacted to high density is used primarily as a base course for roads, street shoulders. It can also be used as sub base for rigid and flexible pavement where the road is subjected to high volume of traffic.

WAYS OF IMPROVING THE CHARACTERITICS OF BLACK COTTON SOIL

- Improving the properties of Black Cotton soil through Aluminum cars.
- Stabilization of Black Cotton soil by sawdust ash and lime.
- Lime reaction stabilization
- Through heat treatment.
- Stabilization of Black Cotton soil with River sand and cement.

STABILIZATION OF BLACK COTTON SOIL WITH RIVER SAND AND CEMENT

The Lake Chad Basin is an extensive quarterly lacustrine deposit of black Black Cotton soils. Laboratory investigations show that this soil consists of abundant proportions of montmorillonite and generally poses a major problem for Civil Engineering construction due to high volume changes.

Alternative soils or aggregates suitable for base construction are very difficult to obtain in these localities and hence soil stabilization is of great economic importance to the construction industry. Methods of stabilizing this soil include lime stabilization, cement stabilization, mechanical stabilization, or heat treatment. This paper is primarily concerned with sand stabilization because of the presence of large deposits of dune sands at these locations. The result indicates that sand stabilization shows promise for improving the value of black cotton Black Cottons in pavement construction and is the most economical of all the applicable methods. However the method is recommended only for improving the subgrade and as a sub-base.

RESULTS AND DISCUSSIONS

Table 1 indicates the vividly preliminary tests results of Black Cotton before adding various percentages of admixtures.

PROPERTIES OF BLACK COTTON BEFORE MODIFICATION

CHARACTERISTICS	*DESCRIPTION*
Passing No. 200 sieve (%)	43.28
Liquid Limits (%)	55.89

Plastic Limit (%)	30.00
Plasticity Index (%)	25.89
Linear Shrinkage (%)	10.71
Natural Moisture Content (%)	8.06
Specific Gravity (%)	2.57
AASHTO Classification	A – 7 – 5

TABLE 2: PRELIMINARY RESULTS OF BLACK COTTON SOIL AND RIVER SAND

SAMPLE	*PH*	*E.C (ms/cm)*	*FREE SWELL (%)*	*S.G*
Black Cotton Soil	6.6	0.06	46.8	2.57
River Sand	6.0	0.04	4.0	2.63

The PH and E.C values are analyzed in the above table indicating that the soil are somehow acidic in nature.

TABLE 3: SHOWING SPECIFIC GRAVITY AND FREE SWELL OF RIVER SAND / BLACK COTTON

SAMPLE CONTENT (%)	***SPECIFIC GRAVITY***	***FREE SWELL (%)***
0/0/100	2.57	46.8
0/10/90	2.57	46.0
0/20/80	2.52	44.0
0/30/70	2.54	41.0
0/40/60	2.58	35.0
0/50/50	2.61	20.0

As River sand percentage is added to the Black Cotton, specific gravity reduces to some extent and later towards the end, increased. Similarity, as the percentage was added to Black Cotton, free swells decreases drastically to the end. Indicating that the Black Cotton soil characteristics of been cracks when dry is becoming normal to the point of being used for road pavement.

TABLE 4: SHOWING RESULTS OF ATTERBERG LIMITS FOR RIVER SAND – BLACK COTTON SOIL

SAMPLE CONTENTS (%)	*L.L (%)*	*PL (%)*	*PI (%)*	*L.S (%)*
0/0/100	55.89	30.00	25.89	10.71

0/10/90	51.0	33.50	17.50	18.10
0/20/80	48.90	36.00	12.90	15.20
0/30/70	45.89	37.50	8.39	13.37
0/40/60	43.50	39.50	4.00	10.00
0/50/50	43.04	40.80	2.24	8.61

As river sand is added to the Black Cotton soil, the liquid limit, plasticity index and linear shrinkage, while plastic limit increases. Gradual decrease in plasticity index tends to lower values at higher River sand contents. This indicates that when any admixture is added to Black Cotton, it brings down the bad behavioural characteristics that made it not good for engineering construction. E.g road pavements. Using Nigeria General specification for bridges and road works, the soil is adjusted unsuitable for direct use as base-course or sub-based materials and stabilization with cement.

TABLE 5: COMPACTION CHARACTERISTICS SHOWING VARIATIONS OF MDD AND OMC WITH VARIOUS PERCENTAGES OF ZERO ADMIXTURES

		PERCENTAGE OF CEMENT CONTENT
COMPACTION METHOD	PARAMETER MDD (KN/m3) OMC %	O % / 100
B.S Light	MDD	13.50
	OMC	24.60
B.S Heavy	MDD	17.4
	OMC	27.4
W.A.S.C (Nigeria	MDD	14.0
	OMC	28.0

The results of the compaction carried out are shown above and the variation of the optimum moisture content (OMC) and maximum dry density (MDD) with varying river sand and cement.

Black Cotton – Cement Mixtures

The OMC increases with increasing cement content. The MDD decreases with increasing cement. The decrease in MDD is because of Flocculated and agglomerated Black Cotton particles caused by iron exchange reaction occupying larger spaces leading to increasing MDD.

TABLE 6: SHOWING COMPACTION CHARACTERISTICS OF RIVER SAND-BLACK COTTON SOIL MIXTURE

COMPACTION METHOD	*PARAMETER MDD (KN/m3) OMC (%)*	*0/10/90*	*0/20/80*	*0/30/70*	*0/40/60*	*0/50/50*
B.S Light	MDD	10.0	14.3	15.6	15.8	20.1
	OMC	26.0	16.7	12.6	20.0	18.9
B.S Heavy	MDD	12.4	16.0	21.6	19.8	20.8
	OMC	28.0	20.0	15.8	25.0	19.4
W.A.S.C Nigeria	MDD	11.5	15.0	18.2	18.0	20.6
	OMC	22.0	19.7	15.0	23.5	16.0

TABLE 7: COMPACTION CHARACTERISTICS TABLE SHOWING VARIATION OF MDD AND OMC WITH VARIOUS PERCENTAGE OF CEMENT IN BLACK COTTON SOIL

		PERCENTAGE OF RIVER SAND CONTENT WITH BLACK COTTON SOIL				
COMPACTION METHOD	**PARAMETER**	**2/0/100**	**4/0/100**	**6/0/100**	**8/0/100**	**10/0/100**
B.S Light	MDD (KN/m^3)	13.9	15.4	15.38	17.9	18.0
	OMC (%)	18.5	6.2	7.8	3.9	5.4
B.S Heavy	MDD (KN/m^3)	18.5	6.2	7.8	3.9	5.4
	OMC (%)	15.5	7.3	8.5	4.5	5.37
W.A.S.C Nig	MDD (KN/m^3)	15.5	16.3	17.2	18.8	18.2
	OMC (%)	6.0	6.3	8.9	4.8	5.6

TABLE 8: COMPACTION CHARACTERITICS TABLE SHOWING VARIOUS MDD AND OMC WITH VARIOUS PERCENTAGE OF CEMENT – SAND-BLACK COTTON SOIL

		PERCENTAGE OF RIVER SAND CONTENT WITH BLACK COTTON SOIL				
COMPACTION METHOD	PARAMETER	2/10/90	2/20/80	2/30/70	2/40/60	2/50/50
B.S Light	MDD (KN/m^3)	19.2	19.7	20.0	20.3	20.1
	OMC (%)	13.5	10.2	16.1	13.1	15.2
B.S Heavy	MDD (KN/m^3)	20.6	20.7	20.7	20.8	20.8
	OMC (%)	10.0	11.0	11.2	11.0	12.1
W.A.S.C Nig	MDD (KN/m^3)	20.1	20.0	20.1	20.5	20.4
	OMC (%)	10.5	10.0	13.0	14.0	14.0

TABLE 9

		PERCENTAGE OF RIVER SAND CONTENT WITH BLACK COTTON SOIL				
COMPACTION METHOD	PARAMETER	4/10/90	4/20/80	4/30/70	4/40/60	4/50/50
B.S Light	MDD (KN/m^3)	20.4	20.1	20.3	20.1	19.7
	OMC (%)	13.0	12.2	15.2	14.5	17.0
B.S Heavy	MDD (KN/m^3)	21.4	21.0	21.5	21.2	21.0
	OMC (%)	12.0	12.2	14.5	15.1	13.1
W.A.S.C Nig	MDD (KN/m^3)	20.0	20.6	21.0	20.0	20.7
	OMC (%)	13.8	12.5	13.0	15.0	16.5

TABLE 10

		PERCENTAGE OF RIVER SAND CONTENT WITH BLACK COTTON SOIL				
COMPACTION METHOD	PARAMETER	6/10/90	6/20/80	6/30/70	6/40/60	6/50/50
B.S Light	MDD (KN/m^3)	19.6	19.5	20.0	19.3	19.1
	OMC (%)	13.4	11.5	7.5	8.1	9.7

B.S Heavy	MDD (KN/m^3)	20.7	20.6	20.6	20.1	20.3
	OMC (%)	10.5	11.6	10.4	12.2	9.8
W.A.S.C Nig	MDD (KN/m^3)	20.2	20.1	20.1	19.8	19.5
	OMC (%)	13.5	11.5	10.5	13.0	10.0

TABLE 11

		PERCENTAGE OF RIVER SAND CONTENT WITH BLACK COTTON SOIL				
COMPACTION METHOD	PARAMETER	8/10/90	8/20/80	8/30/70	8/40/60	8/50/50
B.S Light	MDD (KN/m^3)	19.3	19.9	20.0	19.7	19.7
	OMC (%)	12.8	11.6	12.5	12.1	11.5
B.S Heavy	MDD (KN/m^3)	21.0	21.3	20.5	21.6	20.8
	OMC (%)	13.0	12.0	11.1	11.5	10.1
W.A.S.C Nig	MDD (KN/m^3)	19.8	20.8	20.1	20.6	20.0
	OMC (%)	13.2	11.0	11.2	11.5	10.2

TABLE 12

		PERCENTAGE OF RIVER SAND CONTENT WITH BLACK COTTON SOIL				
COMPACTION METHOD	PARAMETER	10/10/90	10/20/80	10/30/70	10/40/60	10/50/50
B.S Light	MDD (KN/m^3)	20.3	20.2	20.2	19.9	20.2
	OMC (%)	12.8	12.0	12.4	13.1	12.5
B.S Heavy	MDD (KN/m^3)	20.9	21.0	21.3	21.4	12.2
	OMC (%)	13.0	13.1	15.1	15.2	13.0
W.A.S.C Nig	MDD (KN/m^3)	20.7	20.6	21.0	20.8	20.7

OMC (%)	13.2	11.8	12.2	11.0	13.2

TABLE 13: CBR RESULTS OF RIVER SAND / CEMENT / BLACK COTTON SOIL

	B.S HEAVY			*B.S LIGHT*	
CEMENT RIVER SAND (%)	PEN (MM)	TOP (KN)	BOTTON (KN)	TOP (KN)	BOTTOM (KN)
0/0/100	2.5	12	25	10	16
	5.0	19	28	14	20
0/10/90	2.5	17	32	12	27
	5.0	30	47	21	30
0/20/80	2.5	22	35	14	33
	5.0	37	54	25	37
0/30/70	2.5	24	38	17	39
	5.0	40	35	30	40
0/40/60	2.5	27	42	21	33
	5.0	43	62	33	41
0/50/50	2.5	28	47	34	43
	5.0	45	60	29	40
2/0/100	2.5	31	48	29	46
	5.0	48	52	35	49
4/0/100	2.5	33	46	19	42
	5.0	51	58	43	51
6/0/100	2.5	34	37	30	34
	5.0	56	61	51	57
8/0/100	2.5	35	42	33	38
	5.0	32	57	44	49
10/0/100	2.5	36	44	32	37
	5.0	57	59	53	51
2/10/90	2.5	13	32	11	29
	5.0	21	35	18	32
2/20/80	2.5	15	39	14	37
	5.0	25	42	23	39
2/30/70	2.5	17	48	15	45
	5.0	35	54	31	50

2/40/60	2.5	26	56	24	53
	5.0	44	58	40	51
2/50/50	2.5	33	59	29	55
	5.0	47	62	43	57
4/20/80	2.5	37	42	35	38
	5.0	51	54	48	51
4/30/70	2.5	38	44	36	41
	5.0	52	55	50	53
4/40/60	2.5	40	48	33	45
	5.0	53	56	51	55
4/50/50	2.5	42	49	40	47
	5.0	55	58	52	56
6/10/90	2.5	44	47	43	47
	5.0	53	58	50	58
6/20/80	2.5	45	47	31	38
	5.0	56	62	25	35
6/30/70	2.5	48	50	33	42
	5.0	57	59	36	48
6/40/60	2.5	48	51	45	49
	5.0	59	61	52	56
6/50/50	2.5	50	52	47	50
	5.0	53	55	49	52
8/10/90	2.5	51	53	48	50
	5.0	55	58	52	56
8/20/80	2.5	45	51	43	47
	5.0	52	60	50	58
8/30/70	2.5	47	52	44	49
	5.0	54	59	51	57
8/40/60	2.5	43	48	39	45
	5.0	56	61	54	58
8/50/50	2.5	45	49	42	47
	5.0	58	62	56	52
10/10/90	2.5	44	60	19	36
	5.0	49	53	32	38
10/20/80	2.5	46	59	23	46
	5.0	51	55	34	37

10/30/70	2.5	47	53	24	48
	5.0	53	60	37	44
10/40/60	2.5	43	51	40	46
	5.0	54	62	39	47
10/50/50	2.5	45	54	42	49
	5.0	57	46	49	59

CALIFORNIA BEARING RATIO (C.B.R)

From the analysis of CBR, it was found that the value of CBR soil increased with percentage of cement and compaction energy. The B.S heavy gave the maximum value of CBR at 10% of cement and B.S light gave the lowest value of 2% of cement.

CONCLUSION

Based on the tests and research carried out, the Black Cotton soil is identified to be as A- 7 – 5 based on AASHTO classification system. The optimum moisture content increases and maximum dry density decrease with increasing cement content. This shows that increasing OMC decreases MDD for river sand and decreasing OMC increase MDD for cement content.

The Black Cotton cement gradually reduces with increasing river sand and cement content which resulted in reduction of plasticity (texture). River sand and cement content performances on the characteristics of Black Cotton soil showed little appreciation values. Therefore, Nigeria General specification for bridges and road works for pavement indicates that they are not suitable to modify the Black Cotton soil for road construction.

Highway Research Board indicates that percentage passing No.200 sieve criteria for assessing variation of cement stabilization the soil in adjudged unsuitable and uneconomical to modify with river sand and other admixtures.

The maximum dry density generally increased with increase in cement content for both stabilized and unstabilized soil mixtures.

Therefore, the MDD of the Black Cotton – cement mixtures at various cement contents were observed to increased with increase in three compaction energies (B.S Light, heavy and W.A.S.C Nigeria).

RECOMMENDATION

Although, enormous problems were encountered in proper analysis of tests results of the and mixtures (river sand , Black Cotton soils), further investigation need to be carried out.

The River sand should be blended with Black Cotton contents for full compaction in order to ascertain the variability of porosity and strength properties of the Black Cotton soil.
Also, Black Cotton soil should be modified with hydrated lime to reduce its swelling properties when used for road construction work.

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