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Ordinary Portland Cement Stabilization of Engineering Soil using Coconut Shell and Husk Ash as Admixture

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Abstract: *For many developing countries, failure of roads has been a worrisome situation and this more common in south-eastern Nigeria. Over time, the basic preliminary phase of civil engineering project like proper soil investigation is ignored leaving completed civil engineering project at the mercy of the effects of such negligence. In most cases, weak engineering soil is used to foundations without proper studies and investigation to determine the geotechnical engineering properties of a material in use. One of the contributing factors of the use of poor or weak engineering soil is the high cost of stabilizing or binding agents used for construction eg cement, quick lime, etc. The present research was carried out to provide cheaper, safer and better materials to improve engineering soil for civil engineering works. The stabilization of laterite for improved engineering properties was investigated, and the geotechnical, chemical, and phase analytic method was used to characterize both the raw and treated laterite. Coconut Shell- Husk Ash (CSHA) was used as admixture for the stabilization in varying percentage at a constant percentage of Ordinary Portland Cement (OPC). The engineering soil used for this investigation was collected from Amizi, Olokoro in Umuahia South LGA, Abia State, Nigeria and preliminary tests carried out on the sample show that it is too brittle and thus not suitable as sub-base materials. The result of the sieve analysis and Atterberg limits tests graded the soil as Reddish Sandy Silt soil with a little high plasticity and it falls in the A-2-7 AASHTO classification system. It failed some of the standard requirement specified by the Ministry of Works and Housing in Nigeria. For instance, for the standard required 80% CBR, the sample had a value of 28% which is relatively low. The CBR test shows that the addition of cement at 5% by mass improves the soil, and further addition of varying percentages of CSHA in the order; 2%, 4%, 6%, 8% and 10% increased it relatively and it reached its peak of 82% at 8%CSHA and 5%OPC which is which is considerably satisfactory. The triaxial test result showed an improvement from Cu=23 KN/m2 and Ǿ=200 at its natural state to Cu=25 KN/m2 and Ǿ=290 thereby making the soil satisfactory for sub-base material in road pavement construction.*

Keywords: *Stabilization, engineering soil, coconut shell and husk ash, admixture, ordinary Portland cement.*

1. INTRODUCTION

Soil stabilization refers to the process of modifying the physical properties of soil to improve its engineering characteristic strength, durability, handling index and other engineering properties necessary for its technological applications in various fields of civil engineering works. Typically, this is important for road construction and other concerns related to the building and maintenance of vertical and horizontal infrastructures. Stabilized soil has a vastly improved weight bearing capacity, and will also be significantly more resistant to being damaged by vertical or lateral load, friction, water, frost or inclement conditions. Site feasibility study for geotechnical project is of far most beneficial before a project can take off. Site survey usually takes place before the design process begins in order to understand the characteristics of sub-soil upon which the decision on location of the project can be made. The following geotechnical design criteria have to be considered during site selection; (i) Design load and function of the structure, (ii) Type of foundation to be used and (iii) Bearing capacity of soil (sub-soil). It has been observed that in Nigeria, road construction is mostly done using lateritic soils as base and sub-base materials without proper checks on the suitability of these materials for pavement construction. If the surface material accumulates small surface water due to poor drainages, the water penetrates to the base and sub-base courses, thereby initiating failure of the pavement. The water percolates the base and sub-base materials and dissolves them thereby causing big damage to the road pavement. The base/sub-base dilapidates because of high percentage of clay soil content, or as a result improper or inadequate stabilization methods. This depicts the need for special additives in our road pavement material stabilization to ensure improvement in the engineering properties of the soil such as volume stability, strength and stress-strain properties, permeability, and durability. Generally, it can simply be stated that soil stabilization refers to the procedure in which a special soil (weak engineering soil), a cementing material (binder), or other chemical or non-chemical materials (admixtures) are added to a natural soil, or a technique (mechanical) used on a natural soil to improve one or more of its engineering properties and usage. One may achieve stabilization by physically mixing the natural soil and stabilizing materials together so as to achieve a homogenous mixture or by adding stabilizing material to an undisturbed soil deposits and obtaining interaction by letting it permeate through soil voids [1]. It is, at times, necessary to treat or modify these soils to provide a stable sub-grade i.e. borrowed or in-situ or a working platform for the construction of the pavement. The primary objective of this research work was to recycle materials from the agricultural waste coconut shell and husk into useable engineering material as an admixture to stabilize poor lateritic soil from Olokoro, Umuahia, Nigeria so as to improve the characteristic strength, durability and volume stability for civil engineering construction works. Previous researches have shown that lots of chemical materials (cementing and non-cementing) eg ordinary Portland cement, hydrated lime, fly ash, pozzolan, kaolin, chalk, bitumen, crude oil, geosynthetics, metallic chlorides etc and mechanical methods have been used to stabilize weak engineering soils with their attendant high cost [1; 2; 3; 4; 5; 6; 7; 8]. It has equally been shown by a previous research that successful stabilization depends on the proper selection of binders and amount of binder's added [9]. At the same time, previous researchers have carried researches on the use of non-cementing additives or admixtures from waste materials burnt to ash, pulverized and characterized for use e.g. quarry dust, baggasse ash, egg shell ash, palm kernel ash, palm bunch ash, snail shell ash, saw dust ash, vehicle tyre ash, coconut shell ash etc in the stabilization of weak engineering soil and also the binary combination of the above materials with a binder e.g. cement [10; 11; 12; 13]

2. MATERIALS AND METHOD

The lateritic soil sample used for this research investigation was collected from Amizi Olokoro in Umuahia South LGA, Abia State, Nigeria that lies on latitude 05o28'36.900''North and longitude 07o32'23.170'' East from a depth of 2.0meters [14]. The sample was collected in solid state and reddish brown in colour. The soil obtained from this location was air dried in trays for six days after which the soil was crumbled. The dried soil was pulverized using a rubber covered pestle in the tray and sieve characterization with Orderly arranged British Standard Sieves to [15]**;** 4.36mm, 2.36mm, 1.18mm, 600µm, 425µm, 300µm, 212µm, 150µm, 75µm; Lid and receiver; Balance readable and accurate to 0.1g, drying oven, sieve brush and the mechanical shaker was carried out on the sample and it was classified as A-2-7 soil according to AASHTO classification system [16]. The rubber cover was to enable the breaking up of the soil aggregates without crushing the individual particles. Distilled water was used for altering the moisture content of the sample and other test were carried out. The compaction test was carried out on the natural sample soil to determine the maximum dry density (MDD) and optimum moisture content (OMC) by Proctors test on BIS mould. The apparatus according to [17; 18; 19; 20] are as follows; standard compaction equipment conforming to IS standards, a mould of 100mm diameter and 127.3mm height, IS sieve (4.25mm), balance (capacity = 200mg and sensitivity of 0.01mg), oven (100–110), crucibles, jars (graduated), mixing pan, spatula, scoop etc. the soil was compacted in three layers by the rammer of mass 2.6kg, fall height of 31cm and an evenly distributed blows of 25 on each layer. In much the same way the Atterberg limit test was carried out to determine the liquid limit, plastic limit and the plasticity index with the following apparatus, soil sample passing 4.25mm, large glass plate, balance with accuracy of 0.01gm, oven to dry sample at temperature of 105‰ and 110‰, evaporating dishes, desiccators etc. it is important to note that soil used for this laboratory examination is not oven dried prior to testing [9]. The CBR test was also carried out with the lab CBR equipment that meets the essential requirements [15]. The binder used for the research work was Ibeto Ordinary Portland Cement which conforms to BS 12 [20; 21]. With the addition of unconfined triaxial test, the above round of test were also carried out with stabilized sample with cement and coconut shell and husk ash gotten from dumpsites and market places in Amaoba-Oboro in Ikuano L.G.A of Abia state, Nigeria and sun-dried for a period of two weeks to ensure total dehydration for easy burning. Coconut shell and husk ash (CSHA) was added to the studied soil sample in varying percentages; 2%, 4%, 6%, 8% and 10% by weight of the sample [22; 23; 24]. The effects of the coconut shell and husk ash and the stabilizing agent on the sample were thereafter determined and tabulated.

3. RESULTS AND DISCUSSION

The Na and K contents were analysed by flame emission spectrometry. All other elements, including Si, AI, Fe, Mg, Mn, and Ti were determined by atomic absorption spectrometry. The following results were obtained.

Table 1: *Chemical properties of CSHA*

S/N	COMPOUNDS	COCONUT SHELL HUSK ASH
1	SiO2	30.20
2	AI2O3	3.52
3	Fe2O3	3.61
4	P2O5	2.47
5	CaO	4.99
6	TiO2	1.03
7	MgO	21.36
8	Na2O	1.97
9	K2O	0.98
10	MnO	0.96
11	Ignition loss 110-5500C	19.67
12	Total	92.27

After the sieve analysis, more than 50% of the total soil mass passed the no 200 sieve, and it is graded as Reddish Sandy Silt soil with a little high plasticity and it falls in the A-2-7 AASHTO classification system.

Table 2: *Sieve Analysis of Studied Sample*

Sieve size (mm)	Weight of soil retained	% of soil retained	% of soil passing
4.75	-	-	100
2.00	70	14	86
1.18	150	30	56
0.600	56.67	11.33	44.67
0.425	60	12	32.67
0.300	46.66	9.33	23.34
0.150	53.33	10.67	12.67
0.075	40	8	4.67
Reciever	23.33	4.67	-

The specific gravity is within the range of 2.6 - 2.7which falls within the specified value by for natural aggregates [23].

Table 3: *Specific Gravity test*

Test no.	**1**	**2**
Mass of density bottle*(m1)*	39	39
Mass of density bottle + soil*(m2)*	63	62
Mass of density bottle + soil + water*(m3)*	155	154.5
Mass of density bottle + water filled to brim*(m4)*	140	140
Specific gravity, *Gs =(m2-m1)/(m4-m1)-(m3-m2)*	2.667	2.706

Specific gravity, Gs = 2.64

From the result of the Atterberg limits as shown in Table 4, the addition of coconut shell-husk ash (CSHA) has lower increment effect on the liquid limit of the soil compared to the increased Plastic Limit and consequently a reduced Plasticity Index. At 5% OPC, the Liquid limit increased between 38.4% and 45.4%, Plastic Limit increased between 25% and 33.3%, while the Plasticity Index is between 10.3% and 13.4% at varying proportions of CSHA. The Federal Ministry of Works and Housing for road works recommend Liquid Limit of 50% maximum and Plasticity Index of 10% maximum for sub-base and base materials [23].

Table 4: *Atterberg Limits result of CSHA and 5%OPC on studied sample*

CSHA	0%	2%	4%	6%	8%	10%
LL	38.4	40.7	44.4	40.7	42.3	40.0
PL	25	29.7	33.3	29.6	32	29
PI	13.4	11.0	11.1	11.1	10.3	10.4

The results on the effect of the varying proportions of CSHA are a shown in Table 5. It is observed that the maximum dry density MDD had increased from 1.64mg/m3 at control experiment to 1.84mg/m3 and 1.88mg/m3 at 2% and 4% CSHA respectively and decreased to 1.86mg/m3 at 6% and 8% CSHA and finally to 1.854mg/m3 at 10% CSHA. While the OMC had decreased from 14.25% at control experiment to 10.19%, 7.60%, 7.24% and 6.98% at 2%, 4%, 6%, and 8% CSHA respectively but increased to 8.78 at 10% CSHA.

Table 5: *Compaction test result of CSHA and 5%OPC on studied sample*

% of CSHA	0	2	4	6	8	10
MDD (mg/m3)	1.64	1.84	1.88	1.86	1.86	1.854
OMC (%)	14.25	10.19	7.60	7.24	6.98	8.78

From Table 6 and Fig.1, the California Bearing Capacity (CBR) for the natural soil was determined as 28, which is a very poor value for road pavement works. With an increase in the percentage of 2% CSHA, the CBR increased to 43 and 51 at further increase of CSHA at 6%.The maximum CBR value of 82 was recorded at 8% CSHA and 5% OPC as specified by the Nigerian General specification [23]

Table 6: *CBR test result of CSHA and 5% OPC on studied sample*

% of CSHA	0	2	4	6	8	10
Vol. of mould	2315	2315	2315	2315	2315	2315
Wt. of mould + sample	10688	10713	10701	10669	10614	10776
Wt. of mould	6354	6354	6354	6354	6354	6354
Wt. of sample	3820	4241	4313	4330	4286	4260

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Bulk density	1.872	1.883	1.878	1.877	1.840	1.910
	40	65	75	95	105	90
	65	105	120	145	215	150
	95	145	195	210	300	240
	135=28	210=43	250=51	300=61	395=82	290=60
	170	240	295	335	425	320
	185	290	320	370	450	340
	225	325	355	410	490	365
	255=35	345=47	390=53	460=63	530=73	400=55

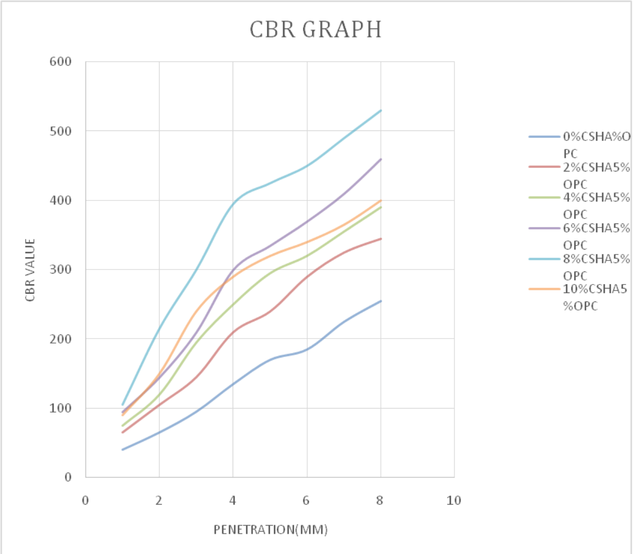

Fig 1: *CBR test graph of the effect of CSHA and OPC on studied sample*

From Table 7 ; results of the triaxial compression tests, it was obvious that there was an increase in the cohesive strength and increase in the angle of internal friction, not until it got to 25KN/m2 at 8% CSHA and+5%OPC.

A normal clay soil has a friction angle of around 30°, which was recorded in the addition of 8%CSHA+5%OPC, having a cohesion value of 25KN/m2and an angle of internal friction of 29o. In this case, however, the water has not had time to drain, making the test undrained. This clearly shows that, when the soil is stabilized with 8%CSHA+5%OPC, it will have a good inter-particle cohesion, and a better angle of friction, making it very plastic and fit for sub-grade works in road construction.

Table 7: *Triaxial test result of CSHA and 5% OPC on studied sample*

CSHA (%)	2	4	6	8	10
C_u (KN/m2)	14	14	17	25	19
Θ (°)	22	26	26	29	29
Compressive Strength (KN/m2)	292	340	345	476	470

4. CONCLUSION

From the foregoing investigation and results, it can be concluded that;

1. The use of Ordinary Portland Cement (OPC) in stabilization of soil can reduce the Liquid Limit, Plastic Limit, and Plasticity Index, and the addition of coconut shell and husk ash increases the Plastic Limit, but reduces the Plasticity Index of the lateritic soil at constant 5% OPC stabilization. The CBR of the soil also increased continuously with the addition of coconut shell husk ash.

2. The result also shows that maximum dry density of soil increased from 0% CSHA to 8% CSHA but reduced at 10%, in effect 8% addition of CSHA is the effective optimum value at 5% OPC stabilization, because minimum OMC was also recorded at this value. Based on this result, it is very clear that CSHA and OPC increased the California bearing ratio and can therefore be used to improve soils with low CBR values and can also be used for stabilize soils with Liquid Limits less than 50%.

3. From the Triaxial test, 8%CSHA+5%OPC recorded a good friction angle of 29° at cohesion value of 25KN/m2 and from the test result it is observed that when the soil is stabilized with 8%CSHA+5%OPC, it will have a good inter-particle cohesion, and a better angle of friction, making it very plastic and fit for sub-grade works in road construction.

4. In view of the high cost of construction materials, it is recommended that agricultural waste materials like coconut shell-husk ash for instance, be used as stabilizing agents to improve engineering soils sub-base quality so as to build a long lasting pavement for sustainable road performance with less cost and easy accessibility.

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