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IMPROVEMENT OF GEOTECHNICAL PROPERTIES OF LATERITIC SOIL USING WALNUT SHELL ASH

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Abstract: This study assesses the improvement of geotechnical properties of lateritic soil stabilized using walnut shell ash. Three natural soil samples A, B and C were collected from different locations in Akure and subjected to the preliminary tests for purposes of classification and identification. Engineering property tests such as California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and Compaction tests were performed on the three natural soil samples and thereafter the soil samples were treated with walnut shell Ash (WSA) at varying proportions of 2, 4, 6, 8 and 10% by weight of soil. The results showed that the addition of WSA improved the strength of the three soil samples. The unsoaked CBR values of the three samples increased to 15.85% at 8% WSA, 28.45% at 8% WSA and for sample C, it increased to 26.90% WSA by weight of soil at 6%. The Unconfined Compressive Strength (UCS) of samples A, B and C increased from 148.70 to 320.76 kN/m^2, 153.42 to 381.28 kN/m^2 both at 8% WSA and from 185.23 kN/m^2 to 490.67 kN/m^2 at 6% WSA respectively. It can therefore be concluded that WSA can effectively stabilize poor lateritic soil.
Keywords: Geotechnical properties; lateritic soil; stabilization; strength; walnut shell ash

INTRODUCTION

Laterites, according to Ola [1], has been defined as the products of tropical weathering with red, reddish brown and dark brown with or without nodules or concreting and generally (but not exclusively) found below hardened ferruginous crust or hard pan. Lateritic soils are generally construction materials and are mostly used in construction. In this tropical part of the world, lateritic soil are used as a road making material and they form the subgrade of most tropical roads, they are used as subbase and bases for low cost roads and these carry low to medium traffic [2].

Ogunribido [3], affirms that lateritic soil is generally used for road construction in Nigeria. Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil consists of high plastic clay, the plasticity of the soil may cause cracks and damage on the pavement, road ways, building foundation or any other civil engineering construction projects, hence, the need for soil improvement by way of stabilization or modification or both. Soil modification is the addition of a modifier (cement, lime etc.) to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification [4]. According to Joel and Edeh, [5], modification refers to soil improvement that occurs in the short term during and after mixing (within hours). It is aimed at reducing plasticity of the soil to the desired level, short term strength gain, soil modification may or may not lead to strength increase but results in alteration of soil properties to enhance workability as evidenced in textural changes that accompany consistency improvements.

According to Amu et al. [6], soil stabilization may be defined as any process by which a soil material is improved and made more stable. Soil stabilization is the treatment of natural soil to improve its engineering properties. The ability to blend naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very important.

Ogunribido [3], opined that the over dependent on the utilization of industrially manufactured soil improving additives (cement, lime etc.) have kept the cost of construction of stabilized road financially high, thereby making the provision of good roads for citizens of third world countries like Nigeria, quite difficult especially in the rural areas that are mostly agriculturally dependent. The cheap locally available materials can be classified as either agricultural or industrial wastes.

Walnuts

Walnuts are rounded, single-seeded stone fruits of the walnut tree commonly used for meat after ripening. Following full ripening, the removal of the husk reveals the wrinkly walnut shell, which is usually commercially found in two segments (three-segment shells can also be formed). During the ripening process, the husk will become brittle and the shell hard. The shell encloses the kernel or meat, which is usually made up of two halves separated by a partition. The seed kernels-commonly available as shelled walnuts are enclosed in a brown seed coat which contains anti-oxidants. The anti-oxidants protect the oil-rich seed from atmospheric oxygen, thereby preventing rancidity [7].

The worldwide production of walnut has been increasing rapidly in recent years with the largest increase coming from Asia. The world produced a total of 2.55 million metric tonnes of walnut in 2010. The average worldwide walnut yield was about 3 metric tonnes per hectare in 2010.

Among the major producers, Eastern Europe has the highest yield. According to the Omics International [8], the most productive farms in 2010 were in Romania, with yields above 23 metric tonnes per hectare. Walnut shells are versatile soft abrasive media with unique physical and chemical properties. These properties make them ideal for a variety of applications, such as walnut shell blasting, tumbling, cleaning, polishing, filtration, non-skid flooring as well as soaps and cosmetics. Walnut shell blasting, wheel blast or air blast equipment is used to drive walnut shell media to remove paints and coatings from buildings, cars, boats, furniture etc. [9].

Location and Geology of the Study

According to Ogunribido [3], Akure, the study area lies Longitude 70 18' N and 70 16' North of equator and between Latitude 50 11.5' E of Green Winch meridian. The study area occurred within the pre-cambrian crystalline rocks of the basement complex of Southwestern of Nigeria. The predominant rock types in the study area are, charnockites, granite gneiss and migmatitic rocks. In some places in the study area, these rocks have undergone deep weathering.

AIM OF STUDY

This study examines the improvement of geotechnical properties of lateritic soil using with the additive-walnut shell ash.

MATERIALS AND METHODS

Materials

- Three soil samples A, B and C were collected at three different locations in Akure, Nigeria at a depth not less than 1.2 meters from the ground surface. The soil samples were air-dried for two weeks at the Geotechnical Laboratory of the Federal University of Technology, Akure before analysis were carried out on them.
- Walnut shells were collected from stores and outlets of traders that sell walnuts. The walnuts shells were sun-dried for one week to remove moisture from it and were thereafter subjected to uncontrollable combustion using open air burning. The burnt ash was collected and sieved through 200 microns sieve.
- Potable water was gotten from the running taps in the laboratory.

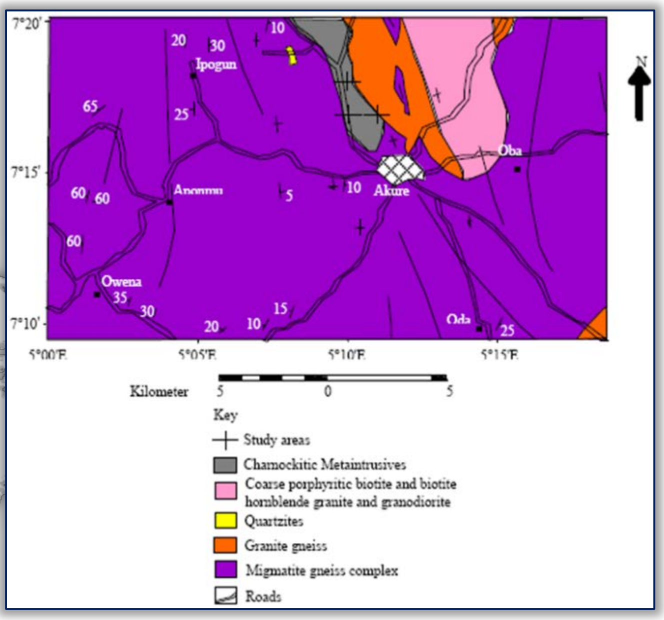

Figure 1: Study Area-Akure, Nigeria. Source: [10]

Methods

The preliminary tests such as natural moisture content, specific gravity, particle size analysis and Atterberg limits for purpose of detecting the index properties of the three natural soil samples were carried out. This, was followed by the engineering tests carried out on the mixtures of each of the three natural soil sample with walnut shell ash at proportions of 2, 4, 6, 8 and 10% by weight of soil respectively. These tests include the Atterberg limits, compaction, California bearing ratio and unconfined compressive strength tests.

RESULTS AND DISCUSSIONS

The results of the chemical analysis, the presence of some oxides which are found in the ordinary Portland cement were also found in the walnut shell ash, such as CaO, which is capable of reacting with the fine particles of soil to enhance stabilization by forming silicates and aluminates of calcium.

SiO_2 required to form dicalcium and tricalcium silicate, also, for improving of strength of the soil. Fe_2O_3 imparts into chemical reaction with calcium and aluminium to form tricalcium aluminoferrite. Al_2O_3 imparts quick setting properties to cementitious materials [12]. While the P_2O_5 has the potential to act as a binding agent to cement particles of soil together, thus increasing its stability [13].

Table 1: Chemical composition of Walnut Shell Ash (WSA), Source: [11]

Elemental Oxides	Weight Composition (%)
SO_3	2.20
P_2O_5	6.20
SiO_2	9.90
Fe_2O_3	1.50
Al_2O_3	2.40
CaO	16.60
MgO	13.40
Na_2O	1.00
K_2O	32.90
TiO_2	0.10

Table 2: Chemical composition of Ordinary Portland Cement, Source: [5]

Elemental Oxides	Weight Composition (%)
CaO	64.0
MgO	1.94
Al_2O_3	5.75
Fe_2O_3	2.50
SiO_2	20.40
MnO	-
TiO_2	-
K_2O	0.61
Na_2O	0.40
SO_3	2.73
LOI	1.20

Table 3: Summary of the preliminary tests results of the three soil samples

Property	Sample A	Sample B	Sample C
Percentage passing BS No 200 Sieve	45.00	42.00	46.00
Natural Moisture Content (%)	19.70	17.50	22.80
Specific gravity	2.72	2.78	2.69
Liquid Limit (%)	56.20	54.20	45.10
Plastic Limit (%)	20.10	22.80	24.10
Plasticity Index (%)	36.10	31.40	21.00
AASHTO Classification	A-7-6	A-7-6	A-7-6

The results from the preliminary tests are presented in table 3, the three soil samples are classified to be A-7-6. According to Garber and Joel [14], for a soil sample to be classified into the A-7 group; it must have a minimum Liquid Limit value of 41%, a minimum Plasticity Index value of 11% and the percentage of materials passing No 200 Sieve must be of minimum value of 36%. Furthermore, the plasticity index of Sample A (36.10) > (LL) 56.20 - 30=26.20. Plasticity Index of Sample B (31.40) > (LL) 54.20 – 30= 24.20. Plasticity Index of Sample C (21.00) > (LL) 45.10 – 30= 15.10. Therefore the three soil samples all belong to the A-7-6 groups.

The results of the Atterberg limits test Liquid limits (LL), Plastic Limits (PL) and Plasticity Index (PI) on the soil samples are shown in table 4. If a soil sample has Liquid Limits value which is less than 35%, it indicates low plasticity. If it is between 35% and 50%, it indicates intermediate plasticity. If it is between 50% and 70%, it indicates that the soil has high plasticity. If it is between 70% and 90%, the soil has very high plasticity and if it is greater than 90%, it is of extremely high plasticity [5].

Table 4: Atterberg limit tests results

Soil Sample	Walnut Shell Ash (%)	LL (%)	PL (%)	PI (%)
A	0	56.20	20.10	36.10
	2	55.20	20.80	34.20
	4	53.90	21.50	32.40
	6	52.50	22.20	30.30
	8	51.40	23.10	28.30
	10	50.40	23.80	26.60
B	0	54.20	22.80	31.40
	2	52.90	23.30	29.60
	4	51.60	23.70	27.90
	6	50.40	24.30	26.10
	8	49.30	24.90	24.40
	10	48.10	25.40	22.70
C	0	45.10	24.10	21.00
	2	43.80	25.00	18.80
	4	43.10	26.10	17.00
	6	42.30	27.60	14.70
	8	41.60	28.60	13.00
	10	40.80	29.10	11.70

Based on the foregoing, soil samples A and B have high plasticity, while sample C has intermediate plasticity. The addition of Walnut Shell Ash (WSA) in proportions of 2, 4, 6, 8 and 10% by weight of soil reduced the plasticity indices of the three soil samples. The reduction in plasticity indices indicates soil improvement [2].

The general decrease in LL at all the soil-WSA combination is attributed to the fact that the WSA reaction forms compounds possessing cementitious properties such as Calcium silicate with soil particles [15].

Table 5: Summary of the Unsoaked CBR and Unconfined Compressive Strength (UCS) results

Soil Sample	Walnut Shell Ash (%)	Unsoaked CBR (%)	UCS (kN/m^2)
A	0	6.50	148.70
	2	10.20	220.85
	4	11.65	265.16
	6	12.82	300.45
	8	15.85	320.76
	10	11.90	265.33
B	0	7.90	153.42
	2	16.85	193.42
	4	18.90	270.87
	6	24.62	292.33
	8	28.45	381.28
	10	27.82	284.49
C	0	18.80	185.23
	2	19.90	240.74
	4	23.20	390.92
	6	26.90	490.67
	8	13.85	462.40
	10	16.22	392.58

Table 5 shows results of Unsoaked California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) following the addition of Walnut Shell Ash (WSA) in proportions of 2, 4, 6, 8 and 10% to each of the three natural soil samples. Variations of the UCS with increase in WSA from 0% to 8% for Sample A, 0% to 8% for Sample B and 0% to 6% for Sample C, after which it dropped in each case. The subsequent increase in UCS is attributed to the formation of cementitious compounds between the CaOH present in the soil and WSA and the pozzolans present in the WSA. This decrease in the UCS values after the addition of 8%, 8% and 6% of WSA to Samples A, B and C respectively may be due to the excess WSA introduced to the soil [15]. The explanation for the observed trends in CBR in each of the three soil samples is also applicable in the case of the Unconfined Compressive Strength. Unsoaked CBR values for Samples A, B and C, at optimum contents were 8%, 8% and 6% respectively with corresponding values of 15.85%, 28.45% and 26.90%.

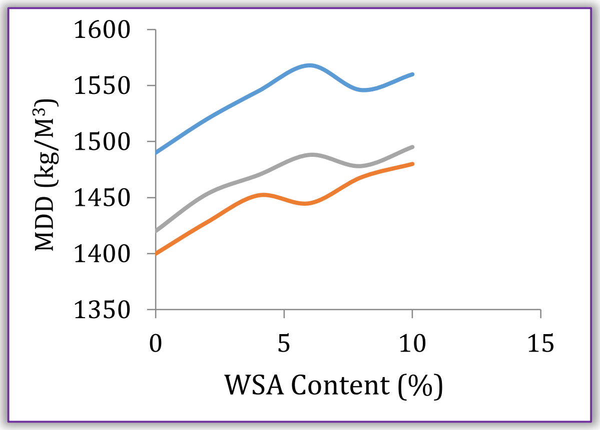

Figure 2: Effects of WSA on the Maximum Dry Density of the samples

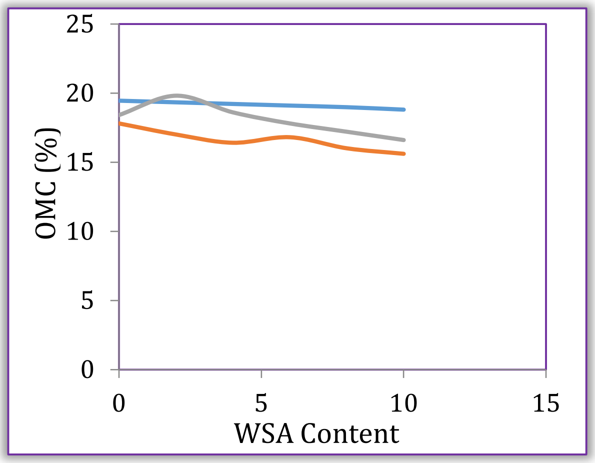

Figure 3: Effects of WSA on the Optimum Moisture Content of the samples

Figure 2 shows gradual increase in values of Maximum Dry Density (MDD) for soil samples A, B and C. Soil sample A has its MDD values increased from 1490 Kg/m^3 at 0% WSA to 1560 Kg/m^3 at 10% WSA. Sample B, as well witnessed gradual increase in values of MDD from 1400 Kg/m^3 at 0% WSA to 1480 Kg/m^3 and for soil sample C, the MDD value at 0% WSA was 1420 Kg/m^3 which increased to 1495 Kg/m^3 at 10% WSA by weight of soil. Figure 3, shows a general reduction in values of Optimum Moisture Content (OMC) with the gradual addition of Walnut Shell Ash (WSA) for the three soil samples. In soil sample A, values of OMC decreased from 19.46% at 0% WSA to 18.80% at 10% WSA. OMC reduced from 17.80% at 0% WSA to 15.60% at 10% WSA in soil sample B. In soil sample C, the OMC reduced from 18.40% at 0% to 16.60% at 10% WSA by weight of soil. According to Lambe and Whiteman [16], the lower the optimum moisture content (OMC), the better its workability and that increase in dry density is an indicator of improvement.

CONCLUSIONS

The procedure for the various tests were carried out in accordance with that stipulated in BS 1377 [17] and British Standards (BS) 1924 [18].

The three soil samples were classified into the A-7-6, A-7-6 and A-7-6 subgroups using AASHTO classification system, under the general system, the three samples all fall within Silt-Clay materials.

Walnut Shell Ash improved the soil samples by reducing their plasticity indices drastically, which are indicators of soil improvement.

Results show that the strength properties of the three natural soil samples improved upon the addition of Walnut Shell Ash. The unsoaked CBR values of the three soil samples at 8, 8 and 6% WSA for samples A, B and C respectively were 15.85%, 28.45% and 26.90% a marked improvement from their values at natural states. The UCS values also increased as well.

The study therefore concluded that Walnut Shell Ash (WSA) can effectively stabilize poor lateritic soil.

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