INDEX AND COMPACTION CHARACTERISTICS OF LATERITIC SOIL TREATED WITH AN OPTIMAL CONTENT OF RICE HUSK ASH MIXED WITH QUARRY DUST AND CEMENT.

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Abstract
The effect of cement and quarry dust (QD) on the index and compaction properties of lateritic soil treated with 10% Rice husk ash (RHA) obtained from Offa Kwara State Nigeria was studied. The index properties of the soil and that of the soil treated with 10% RHA mixed with cement and quarry dust in the proportions of 2%, 4%, 6%, 8% and 10%, 20%, 30%, 40% respectively were determined. Subsequently, specimens of soil samples treated with 10%RHA were prepared and compacted using the British standard light energy level by combining cement in proportions of 0%, 2%, 4%, 6%, and 8% mixed with quarry dust in proportion of 0%, 10%, 20%, 30%, 40%. From the results obtained, the sample was classified as sandy clay (SC) according to the Unified soil classification system (USCS) and A-6 according to the AASHTO classification system. The Plastic and liquid limits of the treated sample increased with the addition of cement but decreased as the QD content was increased. The specific gravity increased on the addition of cement and QD but started decreasing when the cement content exceeded 4%. The maximum dry density increased throughout the experiment in the presence of the stabilisers used and it attained a peak value of 1915 Kg/m3 from an initial value of 1780Kg/m3. The results obtained from this experiment recommends an optimal mix proportions of 40%QD + 10%RHA + 4% Cement and 20%QD + 10%RHA + 6% cement when using the admixtures on an A-6 lateritic soil for construction purposes.

Keywords: *Quarry dust, Rice husk ash, maximum dry density, cement, Index properties.*

Introduction

Environmental pollution is one of the greatest challenges been faced by the recent population outburst and urbanisation in Nigeria. Quarry dust, a by-product from crushing sites and rice husk also a by-product from rice processing mills have been found to constitute great nuisance to the immediate environment where they are produced and also surrounding communities where they are disposed. These by-

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products are non bio-degradable and therefore they will continue to cause disturbances wherever they are deposited so the need for recycling or re-use arose. Several authors have made promising attempts on these by products under study where each of these additives were either studied individually with soil samples or they were combined with different additives like lime, fly ash, sharp sand etc. Muntohar, A.S (2002) did an Investigation on utilization of ashes produced from rice husks burnt in Yogyakarta, Indonesia. He varied the RHA content using 7.5%, 10% and 12.5% with lime content of 2%, 4%, 6% and 10% (by dry weight of soil). Remolded samples were tested at OMC and MDD they showed a decrease in swelling potential of expansive soils and improvement in strength and bearing power under soil-lime-RHA mixtures. Similarly, Basha et al (2004) carried out a study on stabilization of residual soil using cement and rice husk ash. They evaluated the properties of soil such as compaction, strength and X-ray diffraction. Their results showed that both cement and RHA reduces the plasticity of soils. Also, In terms of compressibility, addition of rice husk ash and cement decreases MDD and increases OMC. Hence, From the view point of plasticity, compaction, strength characteristics and economy addition of 6-8% cement and 10-15% RHA was recommended. Other studies done by Okafor et al (2009), Aparna Roy (2014), Ali Rahman et al (2014), Ashango and Patra (2016) all showed that a combination of either RHA/Quarry dust/Cement and soils have a positive influence on the engineering properties of the soil. In addition, their researches suggested that 10% RHA should be the optimum content that should be added to soils when the aim is to improve the geotechnical properties of the soil . However, at the point of carrying out this research, there is currently no study on RHA + Cement + Quarry dust soil mixtures of soils in Kwara state, Nigeria. The aim of this work is to assess the effect of cement and quarry dust on the index and compaction characteristics of lateritic soils treated with an optimal content of RHA and the specific objectives are to assess effects of theses additives on the index properties of the soil (plastic limits, liquid limits and Specific gravity) and to determine the possible reduction in percentage of cement as a result of the presence of optimum rice husk ash content and the quarry dust stabilisers.

Materials used for the Study

The following materials were used for this study;

(i) Water: distilled water was collected and used for all laboratory testing.

(ii) (ii) Soils: A disturbed lateritic soil sample obtained from Atari area in Offa, Kwara state, Nigeria (8.132^{o}N and 4.712^{o}E) was collected from a depth of 900mm The sample of lateritic soil was prepared as required by BS1377-1;1990 method.

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(iii) Quarry dust; Crushed granite fines was obtained from crusher sites in Kwara state, Nigeria.

(iv) Rice husk ash; Rice husk was obtained from Achalla rice mill, Achalla Anambra state. It was burnt under controlled temperature of 700 degrees centigrade in a furnace. The ash obtained thereafter was sent to centre of energy and research development for its characterisation. The chemical composition of the RHA is given in table 1 below,

Table 1. Showing the chemical composition of RHA

OXIDES (%)	RHA (Tested, 2019)
SiO_2	86.13
Al_2O_3	0.54
Fe_2O_3	0.67
CaO	0.59
MgO	0.48
Na_2O_3	0.18
K_2O	2.91
LOI	6.11
Specific gravity	2.13

Research methodology

A thorough study on literature was done to determine the optimal content of RHA proposed by previous researchers who have used RHA as a stabiliser in their study. It was observed that in all the literatures reviewed that used RHA as a stabiliser for soil improvement, an optimum content of 10% RHA was recommended, though in a few cases 10% - 15% have been suggested. Hence, an optimal mix of 10% RHA was adopted for this study. Subsequently, a disturbed lateritic soil sample containing high percentages of fines were collected from Offa, Kwara state. The natural moisture content was taken before the sample was air dried for 5 days and this was followed by the particle size analysis. Further tests on its index properties like the liquid limits, plastic limits, specific gravity and compaction were carried out on the sample and that treated with 10% RHA.

Specimen of soil samples were prepared by combining cement in proportions of 0% to 8% mixed with quarry dust in proportion of 0% to 40% by weight of lateritic soil treated with 10% RHA and was compacted using standard proctor energy level to determine its compaction characteristics (Optimum moisture content and Maximum

dry density) as shown in figure 2 and table 5. The laboratory values obtained was plotted graphically using Microsoft excel.

Results and discussions

Laboratory investigations on the natural soil sample

Preliminary tests conducted to determine the natural properties of the soil revealed that the soil has relatively low natural moisture content. The natural moisture content was 15.9% and this could be attributed to the period of its collection (in December, during the dry season) and depth measured from the surface level at which the sample was taken from (900mm deep). The index and compaction properties are summarized below.

Table 2 Showing the Index and Compaction properties of natural soil

PROPERTIES	SAMPLE
Natural moisture content (%)	15.9%
Liquid limit (%)	34.4%
Plastic limit (%)	19.21%
Plasticity index (%)	15.19%
Percentage passing through No 200 sieve	19.2%
AASHTO Classification	A-6
USCS Classification system	SC
MDD BSL (Kg/m^3)	1780
OMC BSL (%)	24.2

The soil sample is classified as sandy clay (SC) according to unified soil classification system (USCS) because of the percentage of fines passing through the sieve no. 200 is greater than 12% and over 50% passed sieve no.4 (Punmia et al, 2005). Also, it is classified as A-6 while using the American association of state highway and transport official (AASHTO). According to the Federal Ministry of Works and Housing (1997) specification (Bello and Adegoke, 2010), only the samples that have percentage passing on No 200 BS sieve less than 35% is suitable for sub base and base materials in pavement construction. Therefore, it can be affirmed that the soil sample under study with percentage passing of 19.2% in BS sieve No 200 satisfy this criterion and therefore is sufficient to be used as sub base and base materials.

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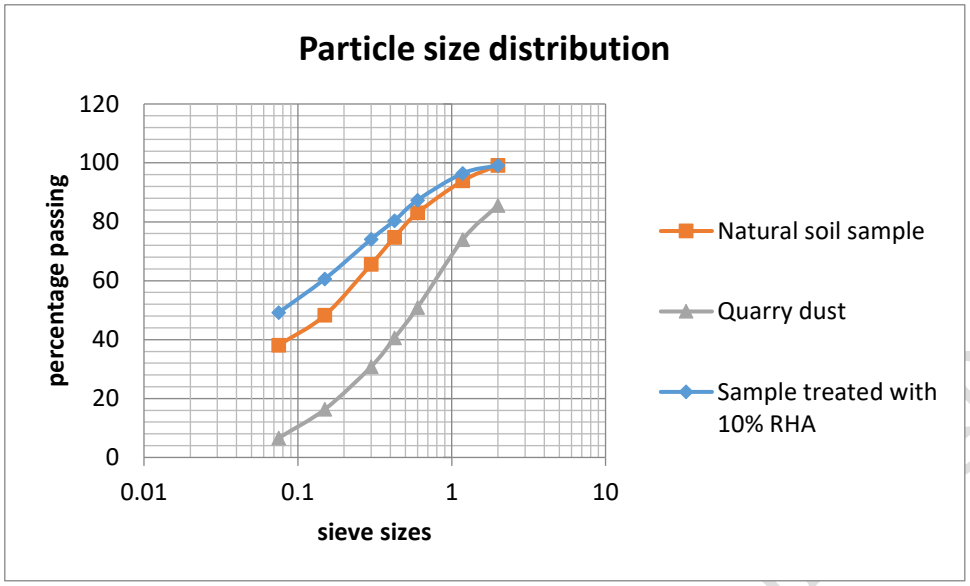


Figure 1: The particle size distribution of the soil sample, Quarry dust and RHA

Specific Gravity

The specific gravity is the ratio of the mass of soil solids to the mass of an equal volume of water. It is an important index property that has direct relationship with the soil mineralogy and it gives great insight about the weathering history of the parent rock. From the study conducted by Roy and Bhalla (2017), they showed that increase in specific gravity can lead to increase in the shear strength parameters, California bearing ratio (CBR) and the strength of subgrade materials used in road construction. The specific gravity in this experiment was carried out in accordance with BS 1377. The values of the specific gravity for the natural soil sample and that of the RHA+QD+Cement soil mixtures are shown in table 3 below.



Figure 2: Apparatus for Specific Gravity Determination *(pictures taken during the cause of the experiment at the soil mechanics laboratory, Federal polytechnic, Offa, Kwara State, Nigeria.)*

Table 3: Result for specific gravity test

Specific gravity test	0%	10%RHA + 2% Cement	10% RHA +4% Cement	10% RHA + 6% Cement	10% RHA + 8% Cement
0% QD	2.43	2.63	2.45	2.17	2.05
10% QD	2.52	2.58	2.61	2.45	2.24
20% QD	2.61	2.65	2.67	2.61	2.55
30% QD	2.67	2.71	2.69	2.67	2.35
40% QD	2.66	2.68	2.61	2.48	2.17

From Table 3, it was observed that the specific gravity of the natural soil (control sample) is 2.43 and the addition of 10% RHA + 10% QD +2% cement increased this value to 2.58. Overall, the addition of Quarry dust and cement on the soil treated with 10% RHA increased the specific gravity but when the cement content was in the range of 4% to 6%, the values of the specific gravity started to fall. Further addition of the cement at 8% mix adversely affected the specific gravity of the sample as the results gotten showed that the specific gravity was lower than that of the untreated natural soil sample. According to the conclusions reached in the study done by Roy (2016), the observation here indicates that the stabilizers will increase the shear strength parameters (cohesion) when added but will affect the soil negatively when the cement content is added in excess of 4%. The specific gravity was calculated using;

$$Specific Gravity(Gs)\ of\ soil = \frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)}$$ (ASTM D, 2014)

Atterberg's limits

The results from the atterbergs limit test for soil mixtures prepared as discussed in the methodology are presented in table 4 below.

Table 4: Result for atterberg's limit test

	Atterberg's limit	0%	10%RHA + 2% Cement	10% RHA +4% Cement	10% RHA+ 6% Cement	10%RHA+ 8% Cement
0% QD	LL	34.4	34.0	31.55	30.1	29.5
	PL	23.65	21.25	22.56	20.26	19.2
	PI	10.75	12.75	8.99	9.84	10.3

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10% QD	LL	31.53	30.45	29.55	30.55	28.24
	PL	21.55	20.55	19.25	18.55	18.15
	PI	9.98	9.9	10.3	12	10.09
20% QD	LL	29.56	27.45	26.55	27.8	25.11
	PL	18.25	17.45	18.45	17.55	16.45
	PI	11.31	10	8.1	10.25	8.66
30% QD	LL	26.45	29.45	31.54	30.12	31.2
	PL	15.85	18.26	21.56	18.35	20.56
	PI	10.6	11.19	9.94	11.77	10.64
40% QD	LL	23.13	26.22	29.61	27.48	25.17
	PL	12.55	15.45	18.55	16.55	15.25
	PI	10.58	10.77	11.06	10.93	9.92

From the results in table 4 obtained in the experiment, it was observed that the liquid and the plastic limits of the RHA treated soil sample decreased. Overall, The addition of quarry dust and cement reduced the atterberg limit properties of the soil sample. The reduction in the liquid and plastic limit is attributed to the coarse nature of the quarry dust and this effect was felt most when the quarry dust content was added in excesses of 30% and 40% (Mbamalu, C.f et al, 2020). Similarly, the fine particles in the RHA replaced some of the fines in the soil and this adversely affected the liquid and plastic limit.

Compaction characteristics

The table and figure below shows the compaction characteristics of the soil sample treated with 10% RHA mixed with Cement and Quarry dust using the mix proportion in the matrix shown in table 5.

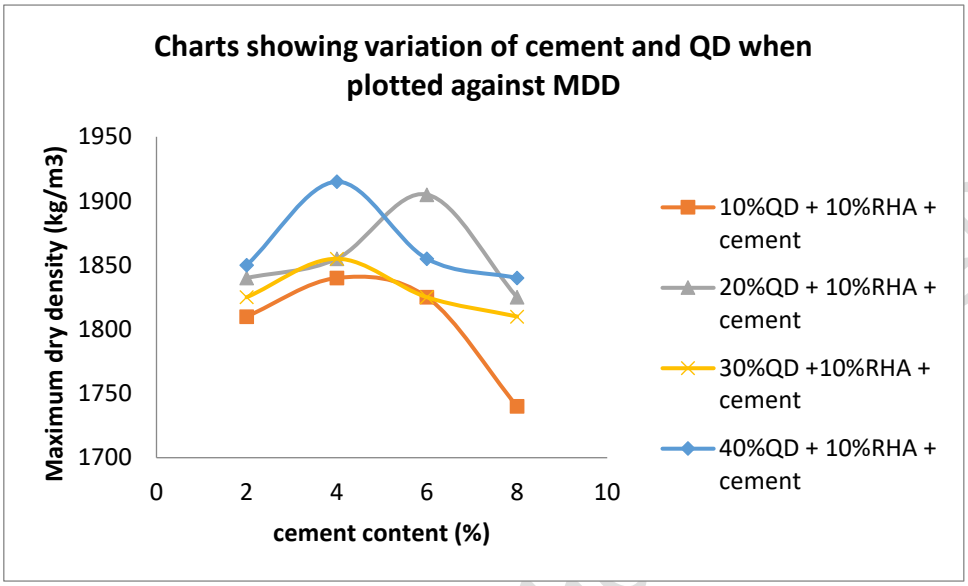
Optimum moisture content and maximum dry density

Table 5: Optimum moisture content

	2% Cement	4% Cement	6% Cement	8% Cement
10% QD	19.1	13.07	9.6	24.2
20% QD	13.1	13.4	15.2	18.00
30% QD	13.5	7.8	13.0	13.5
40% QD	13.8	12.8	10.8	11.0

The table above is a matrix showing the variations in the optimum moisture content of the rice husk ash treated quarry dust-cement soil mixtures. By visual observation, it could be seen that the optimum moisture content was increasing as the cement content increased and decreased as the quarry dust increased.

The maximum dry density was observed to increase as the cement content increased and started declining on the addition of cement in excess. The MDD also increased as the quarry dust percentage was increased. The optimal mix proportion was determined graphically as shown in fig 3 below.



The values plotted in figure 3 show that the additives mixed in various proportions as shown in table 4 all increased the MDD of the natural soil sample (see table 2) except for 10%QD + 10%RHA + 8% cement which had a negative effect on the MDD when compared with the MDD of the natural soil sample. Therefore, from the results obtained in this experiment, a blend of QD and cement mixed in the proportions tried above can be used to improve the compaction characteristics of soil samples treated with 10%RHA but in cases of soil stabilisation for optimal performance, the proportions of 40%QD + 10%RHA + 4% Cement and 20%QD + 10%RHA + 6% cement gave the most satisfactory mix with associated cost savings in cement because they produced an MDD of 1915kg/m3 and 1905Kg/m3 with a corresponding OMC of 12.8% and 15.2% respectively.

Conclusion and recommendations

The index and compaction properties of lateritic soil around Atari area of Offa local government, Kwara state using Quarry-dust, cement and RHA as admixtures have been investigated in this study and the following conclusions were reached;

I. The sample is classified as sandy clay (SC) according to the USCS and A-6 according to the AASHTO classification system and this was done based on the results gotten from its particle size distribution and sieve analysis.

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II. The atterberg limits of the treated sample generally decreased in the presence of the additives.

III. The specific gravity of the cement-QD soil mixtures treated with 10%RHA, which is an indication of the strength properties of the soil increased on the addition of cement and QD but started decreasing when the cement content was in the range of 4% - 6%. This is an indication that the additives have a positive impact on the compaction and strength properties of the soil but shouldn't be added in excess of 6% cement content for soil stabilisation purposes.

IV. Graphical analysis shows that the geotechnical properties of the soil are sensitive to variation of the admixtures used in this study.

V. The results obtained from this experiment recommends an optimal mix proportions of 40%QD + 10%RHA + 4% Cement and 20%QD + 10%RHA + 6% cement when using the admixture for soil stabilisation.

VI. Also, if the objective is to control environmental pollution by finding a way to safely re-use or dispose these industrial and agricultural bye products, the additives can be added in any of the mix proportions shown in figure 3 except 10%QD + 10%RHA + 8% cement.

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