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Un-Confined Compressive Strength (UCS) of Lateritic Soil Stabilized with Rice Husk Ash (RHA) and Calcium Carbide Waste (CCW)

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Abstract – This work is aimed at studying the unconfined compressive strength of lateritic sand stabilized with the mixture of rice husk ash (RHA) and calcium carbide waste (CCW) in order to determine the optimum quantity of the stabilizers in percentage by weight of laterite. This research work was based on the laboratory test. The laterite samples was excavated from pits located within and samples extracted from the sample pits was stored in bags then spread out to dry on a platform. The already burnt rice husk ash and the calcium carbide waste was ground into a powder pozzolana, sieved and stored in polythene bags to prevent moisture and contamination from other materials. The Unconfined Compressive Strength (UCS) of the stabilized soil with a decrease in the weight of the calcium carbide waste at a constant weight of the rice husk ash (i.e. 60g). In the case of 60g RHA and 74g CCW, the values of the Unconfined Compressive Strength increased from 181.12kN/m2 for the natural soil to 183.61kN/m2 at 10.60% RHA and 13.07% CCW by dry weight of soil, Thereafter, the UCS drops to 192.20kN/m2 at 9.82% RHA and 3.11% CCW by dry weight of soil after which the optimum mix proportion has reached. It concluded that the rice husk ash can be classified as a pozzolanic material because the percentage sum of its SiO2, Al2O3 and Fe2O3 components exceeds the minimum requirement of 70% as specified by the ASTM C 618-78 for pozzolans. The study then recommend that when RHA and CCW are to be combined to stabilize lateritic soil, the percentage replacement of the binders by weight of the dry soil should not be more than 60:40 proportions that is 22.50% RHA and 14.48% CCW and the moisture content of the mix should depend on proportion of the CCW.

Keywords: Calcium Carbide Waste, Lateritic Soil, Pozzolans, Rice Husk Ash, Un-Confined Compressive Strength.

1. Introduction

Housing for citizens is one of the major challenges facing humankind in the 21st century. Although studies have shown that the problem of housing is universal, it is, however, more critical in less developed countries (LDCS) including Nigeria. The challenge of housing is not particularly acute to the rural dwellers, it also affects the urban areas in many less developed countries, where expansion of the urban population due to the high population growth rate and a massive rural-urban drift have compounded the housing situation.

In recent years, the potential for laterite earth as a valuable and desirable construction material is being rediscovered. When referring to earth, soil, laterite or mud in building construction, both terms mean the same material, they are materials excavated from the sub-soil layers of the ground kneaded together for walling or other building construction purposes. Methods derived from the traditional techniques are being developed to improve the quality of earth construction and broaden the potential for the application. Earth is primarily used for the construction of building non-load bearing wall and can also be used for other construction like roofs.

According to Aliyu and Yaradua (2012), laterite has been the most important of all building materials used in the history of building construction. Middendort (2001) recorded cases of the use of mud and clay, which dated back to Mesopotamia around 800. BC. Adam and Agib (2001) stated that more than two billion people live in buildings constructed of laterite and clay products mostly in Asia and Africa.

Because of these limitations in the use of laterite in construction activities, recent research efforts have been geared towards improving its engineering properties for low-cost house. One way by which improvement of laterite for earth building construction can be achieved, is through soil stabilization.

Garber and Hoel (2000) describe soil stabilization as the treatment of natural soil to improve its engineering properties. In general, soil stabilization is the process of creating or improving certain desired properties in a soil material so as to render it stable useful for a specific purpose. Since the inception of this process of stabilization, most soil materials, which have been thought not useful, have found application in many areas of both civil and building construction

A number of researches have been made on utilization of locally- available waste materials to stabilize laterite earth for construction purposes. Examples of such recent researches include the use of bagasse ash, rice husk ash, locust bean pod ash, sugarcane straw ash mixed to stabilize laterite as undertaken by Osinubi and Stephen (2005, 2006, 2007); Osinubi and Mustapha (2008); Ochepo (2008), Osinubi and Eberemu (2006);Adam and Jimoh (2011); Ogunribido (2012). The search for local additives to supplement cement in most applications is paramount, because cement is very expensive to obtain.

Notable alternatives are some natural additives such as locust bean pod ash, cow dung, earthworm hill, sugarcane straw ash and rice husk ash. All these can be seen locally in most parts of Nigeria and can be used as stabilizing agents to laterite. The use of these additives depends on the expertise of the local earth builders and availability of the additives in a given locality. In this study, laterite earth will be stabilized using rice hush ash (RHA) and calcium carbide waste (CBW) to serve as stabilizers to laterite in order to improve its engineering properties against water penetration, which lead to the exhibition of cracks on walls. Water penetration in to the building walls is the rate at which water enters into the structure and also leads to the rate at which cracks develop in building. The faster water penetrates into the walls of the structure, the more likely for the building to collapse. That is why stabilization is necessary in earth mud especially in constructing of walls in building.

This study will be focusing on the finding of the effects of selected additives (i.e., RHA and CCW) when mixed with laterite in preventing its shrinkage and swelling properties. This work aimed at studying the unconfined compressive strength of lateritic sand stabilized with the mixture of rice husk ash and calcium carbide waste in order to determine the optimum quantity of the stabilizers in percentage by weight of laterite so as to effectively reduce the cost of building production.

2. Methodology

This work was based on the laboratory test that will be carried out on lateritic soil, which was stabilized with the mixture of rice husk ash (RHA) and calcium carbide waste (CCW) at different replacement levels. The laterite samples was excavated from pits located within and samples extracted from the sample pits was stored in bags then spread out to dry on a platform. The already burnt rice husk ash and the calcium carbide waste was ground into a powder pozzolana, sieved and stored in polythene bags to prevent moisture and contamination from other materials. The specimens were mould and the unconfined compressive force at which each of the specimen was crushed and the average stress was calculated.

The base line for the proportioning of the rice husk ash and the calcium carbide waste was established in accordance with the chemistry analysis of the two materials that is the chemical reaction between these two materials as shown below:

$$Ca(OH)_2 + SiO_2 + H_2O = CaSiO_3 + 2H_2O$$

Hence, by calculating the grams/moles of $Ca(OH)_2$ and SiO_2 that produced calcium silicate hydrate ($CaSiO_3$ + $2H_2O$) as the end product which correspond to that of the ordinary Portland cement end product, recalled the molar mass of (**Ca=40, Si=28, O=16 and H=1).**

[40(16 x 1)2] + [28(16 x 2)] + [1 x 2(16)] = Calcium Silicate Hydrate (**CSH**)

74g/m of **Ca $(OH)_2$** + 60g/m of **SiO_2** + 18g/m of **H_2O** gives **CSH.**

Therefore, these proportions were employed as the baseline for the mixture of both materials. Then, the weight of RHA was increased from 60g at a constant weight of CCW (i.e. 74g) likewise the weight of the CCW was decreased from 74g at a constant weight of RHA (i.e. 60g) until the optimum mix proportion of the mixture of both materials reached.

3. Data Collection, Analysis and Presentation

Table 1: Determination of the Optimum Mix Proportion of the RHA and CCW in Laterite Stabilization by varying the Weight of RHA at constant weight of CCW in Compaction and Unconfined Compressive Strengths

Wt of soil (g)	**Wt of Stabilizers (g)**		**Cohesion, c (kN/m²)**	**Internal Friction Angle(φ)**	**Normal Stress (σ_1- σ_2) kN/m²**	**Shear Stress $\tau = c + (\sigma_1 - \sigma_2) \tan\varphi$ (kN/m²)**	**% wt of stabilizers in soil**		**MDD (kg/m³)**	**OMC (%)**
	RHA	**CCW**					**RHA**	**CCW**		
700	0	0	98.90	22.50	198.50	181.12	0	0	2160	17.25
566	60	74	102.45	21.20	210.34	183.61	10.6	13.07	1990	17.35
561	65	74	103.65	21.50	215.50	188.54	11.59	13.19	1880	17.50
556	70	74	108.35	21.80	220.50	196.54	12.59	13.31	1850	17.72
551	75	74	109.30	21.70	224.20	198.52	13.61	13.43	1840	17.90
546	80	74	109.37	21.80	223.50	198.76	14.65	13.55	1830	18.05
541	85	74	110.10	21.95	224.35	200.29	15.71	13.68	1815	18.15
536	90	74	110.25	22.10	226.10	202.06	16.79	13.81	1805	18.25
531	95	74	110.25	22.15	226.30	202.37	17.89	13.94	1800	18.35
526	100	74	110.89	22.60	236.50	209.34	19.01	14.07	1790	19.30
521	105	74	111.00	22.65	238.10	210.36	20.15	14.20	1785	20.12
516	110	74	112.35	23.25	245.23	217.71	21.32	14.34	1750	20.35
511	115	74	113.10	23.45	250.12	221.60	22.50	14.48	1600	21.45
506	120	74	110.14	18.50	248.45	193.63	23.72	14.62	1900	21.10
501	125	74	105.10	17.50	217.35	173.63	24.95	14.77	1950	20.35

Source: Experimental result 2017

Table 2: Determination of the Optimum Mix Proportion of the RHA and CCW in Laterite Stabilization at constant weight of the RHA and varying the CCW in Compaction and Unconfined Compressive Strengths (UCS)

Wt of soil (g)	**Wt of Stabilizers (g)**		**Cohesion, c (kN/m^2)**	**Internal Friction Angle(φ)**	**Normal Stress (σ_1- σ_2) kN/m^2**	**Shear Stress $\tau = c + (\sigma_1 - \sigma_2)\tan\varphi$ (kN/m^2)**	**% wt of stabilizers in soil**		**MDD (kg/m^3)**	**OMC (%)**
	RHA	**CCW**					**RHA**	**CCW**		
700	0	0	98.90	22.50	198.50	181.12	0	0	2160	17.25
566	60	74	102.45	21.20	210.34	183.61	10.60	13.07	2050	17.50
571	60	69	103.64	21.05	218.50	197.09	10.51	12.08	1990	17.55
576	60	64	108.30	21.69	223.20	207.08	10.42	11.11	1900	17.60
581	60	59	109.35	21.75	224.25	219.82	10.33	10.15	1880	17.65
586	60	54	109.40	21.80	224.85	227.33	10.24	9.22	1845	17.75
591	60	49	109.45	22.00	225.12	235.42	10.15	8.29	1825	18.05
596	60	44	109.52	22.12	226.05	248.40	10.07	7.38	1810	18.10
601	60	39	110.15	22.15	226.14	256.21	9.98	6.49	1805	18.15
606	60	34	110.30	22.65	246.25	267.06	9.90	5.61	1792	18.27
611	60	29	110.35	22.72	248.10	278.23	9.82	4.75	1787	18.28
616	60	24	125.15	21.25	256.25	287.80	9.74	3.90	1752	19.00
621	60	19	123.28	19.50	222.25	201.98	9.66	3.06	1850	18.06
626	60	14	120.25	18.50	215.20	192.20	9.58	2.24	1925	17.22

Source: Experimental result 2017

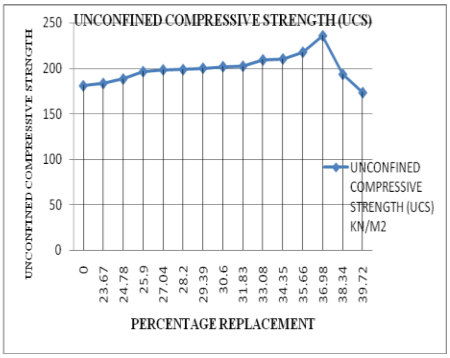

Figure 1: Unconfined Compressive Strength (UCS) at changing weight of RHA at constant weight of CCW

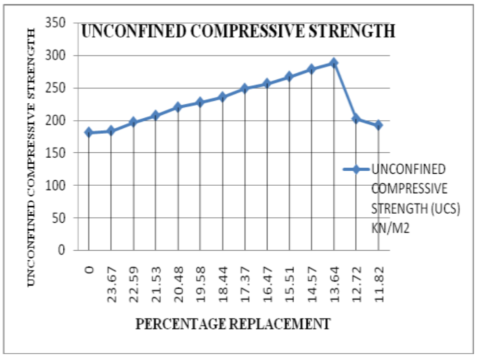

Figure 2: Unconfined Compressive Strength (UCS) at changing weight of CCW at constant weight of RHA

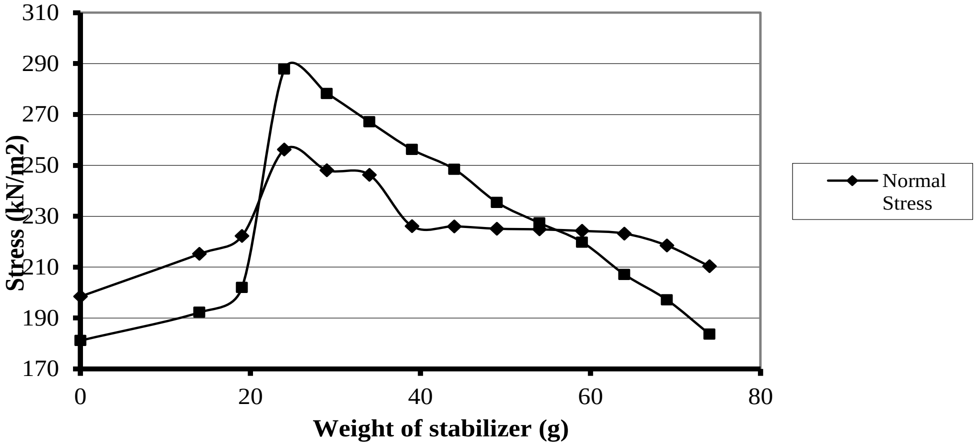

Figure 3: Comparison of Normal stress and Shear stress at changing weight of RHA and constant weight of CCW

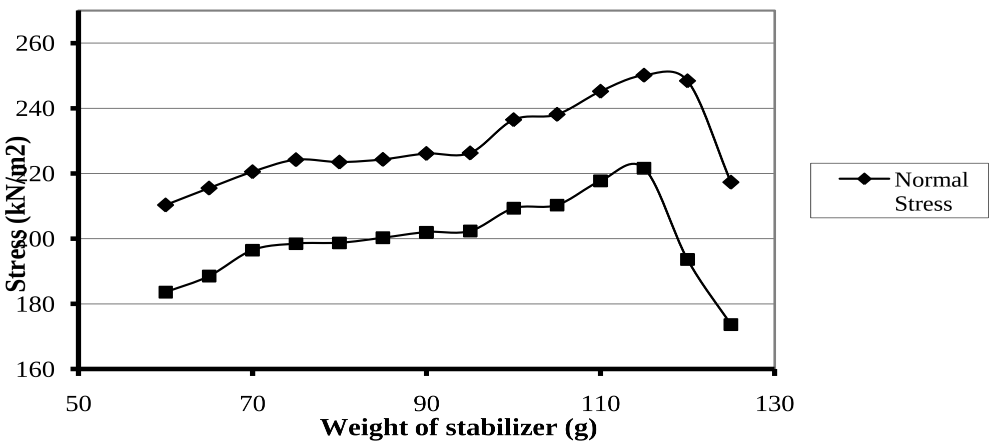

Figure 4: Comparison of Normal stress and Shear stress at changing weight of CCW and constant weight of RHA

Table 1 and Table 2 above show the Unconfined Compressive Strength of the soil stabilized with rice husk ash and calcium carbide waste using 60g rice husk ash and 74g calcium carbide waste as a basis mix proportion established in the chemistry analysis of the two samples.

Figure 1 shows the Unconfined Compressive Strength (UCS) of the stabilized soil with an increase in the weight of the rice husk ash at a constant weight of the calcium carbide waste (i.e 74g). In the case of 60g rice husk ash (RHA) and 74g calcium carbide waste (CCW), the values of the Unconfined Compressive Strength (UCS) increased from 181.12kN/m^2 for the natural soil to 183.61kN/m^2 at 10.60% rice husk ash (RHA) and 13.07% calcium carbide waste (CCW) by dry weight of soil, the Unconfined Compressive Strength (UCS) continue increasing at an increased in the weight of rice husk ash (RHA) up to 115g to 74g of calcium carbide waste (CCW) in which the strength happened to be 221.60 kN/m^2 at 22.50% rice husk ash (RHA) and 14.48% calcium carbide waste (CCW) by dry weight of soil. Thereafter, the Unconfined Compressive Strength (UCS) drops to 193.63 kN/m^2 at 23.72% rice husk ash (RHA) and 14.62% calcium carbide waste (CCW) by dry weight of soil after which the optimum mix proportion has reached. Therefore, the optimum replacement level here is 115g rice husk ash (RHA) and 74g calcium carbide waste (CCW) which is approximately 60:40 in percentage mix proportion of the mixture of the rice husk ash (RHA) and calcium carbide waste (CCW).

Figure 2 shows the Unconfined Compressive Strength (UCS) of the stabilized soil with a decrease in the weight of the calcium carbide waste at a constant weight of the rice husk ash (i.e. 60g). In the case of 60g rice husk ash (RHA) and 74g calcium carbide waste (CCW), the values of the Unconfined Compressive Strength (UCS) increased from 181.12kN/m^2 for the natural soil to 183.61kN/m^2 at 10.60% rice husk ash (RHA) and 13.07% calcium carbide waste (CCW) by dry weight of soil, the Unconfined Compressive Strength (UCS) continue increasing at a decrease in the weight of calcium carbide waste (CCW) down to 24g at a constant rice hush ash (i.e 60g) in which the strength happened to be 224.80 kN/m^2 at 9.90% rice husk ash (RHA) and 3.96% calcium carbide waste (CCW) by dry weight of soil. Thereafter, the Unconfined Compressive Strength (UCS) drops to 192.20kN/m^2 at 9.82% rice husk ash (RHA) and 3.11% calcium carbide waste (CCW) by dry weight of soil after which the optimum mix proportion has reached.

Therefore, the optimum replacement level here is 60g rice husk ash (RHA) and 24g calcium carbide waste (CCW) which is approximately 70:30 in percentage mix proportion of the mixture of the rice husk ash (RHA) and calcium carbide waste (CCW).

4. Conclusion

In view of the results and inferences, the following conclusions can be drawn from the results of the various tests performed:

i. Based on the chemical test, the rice husk ash can be classified as a pozzolanic material because the percentage sum of its SiO_2, Al_2O_3 and Fe_2O_3 components (85.57%) exceeds the minimum requirement of 70% as specified by the ASTM C 618-78 requirement of 70% minimum for pozzolanas.

ii. The optimum mix proportion of a mixture of the rice husk ash (RHA) and calcium carbide waste (CCW) when increasing the weight of the rice husk ash at constant weight of the calcium carbide waste is 115g RHA to 74g CCW, which is approximately 60:40 in percentage mix proportion of the mixture of the RHA and CCW respectively.

iii. The optimum mix proportion of a mixture of the rice husk ash (RHA) and calcium carbide waste (CCW) when decreasing the weight of calcium carbide waste (CCW) at constant weight of the rice husk ash (RHA) is 24g CCW to 60g RHA, which is approximately **70:30** in percentage mix proportion of the mixture of the RHA and CCW respectively.

iv. There are more trials of the laboratory test when increasing the weight of rice husk ash (RHA) at constant calcium carbide waste (CCW) compare to when the weight of the rice husk ash (RHA) was kept constant at a decrease in the weight of calcium carbide waste (CCW).

v. The unconfined compressive strength (UCS) achieved at optimum mix proportion of 70:30 is higher than the one achieved at 60:40 optimum mix proportion.

vi. The percentage replacement of the binders by weight of the dry soil at 70:30 optimum mix proportions is 9.90% RHA and 3.96% CCW.

vii. The percentage replacement of the binders by weight of the dry soil at 60:40 optimum mix proportions is 22.50% RHA and 14.48% CCW.

5. Recommendations

Following the observation from the results, the following are there by recommended for effective use of rice husk ash (RHA) and calcium carbide waste (CCW):

i) When RHA and CCW are to be combined to stabilize lateritic soil, the percentage replacement of the binders by weight of the dry soil should not be more than 60:40 optimum mix proportions that is 22.50% RHA and 14.48% CCW by weight of dry soil.

ii) To have good compressive strength of lateritic soil stabilized with RHA and CCW, the ratio should not be more than 60:40 content is recommended

iii) Further research on the durability characteristics of lateritic soil stabilized with rice husk ash and calcium carbide waste should also be explored to further provide database on its durability characteristics.

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