EFFECT OF DIFFERENT COMPACTION ENERGIES ON THE STRENGTH CHARACTERISTICS OF LATERITE SOIL TREATED WITH ACTIVATED RICE HUSK ASH

Tijjani Kabir*[1]; Umar Saeed Yusuf[1], Adamu Umar Chinade[1], Aminu Shehu Yakubu[2]

[1]Department of Civil Engineering, Abubakar Tafawa Balewa University, Bauchi. Bauchi State
[2]Bauchi State Ministry of Education.

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ABSTRACT: *Compacted laterite soils have been used in a variety of geotechnical structures as engineered barriers, such as in landfill liners and hydraulic containment structures. In this study, laterite soil with addition of activated rice husk ash at varying percentages (5, 10, 15 and 20%) by weight of laterite and at mouldling water content relative to the OMC was compacted three (3) compaction energy (BSL, WAS, BSH) and tested for Unconfined Compressive Strength (UCS). Preliminary tests including Atterberg limit were carried out earlier to classify the soil using standard methods. Results from the tests showed that 10 % of activated rice husk ash with laterite mixture compacted using WAS and BSH achieve adequate unconfined compressive strength (UCS) values. However, with BSL compaction energy, adequate unconfined compressive strength (UCS) values was achieved with 15 % activated rice husk ash with the range of moulding water content. Therefore thus study recommended that lateritic soil with 10 % activated rice husk ash compacted using WAS or BSH or 15 % activated rice husk ash compacted using BSL is adequate for geotechnical engineering purposes. Multiple linear regression analysis of the results using Minitab version 8.1 indicated that the results are statistically significant with coefficient of determination (R^2) values of 0.68, 0.89 and 0.83 for BSL, WAS and BSH compaction energies respectively.*

KEYWORDS: Activated Rice Husk Ash, Atterberg Limit, Compaction Energies, Unconfined Compressive Strength (UCS),

Introduction

Lateritic soils are one of important soils and are widespread in tropical areas and subtropical climates. They are the most highly weathered soils in the classification system. Laterites are soil types rich in iron and aluminum that are formed in tropical areas. Most laterites are rusty-red because of the presence of iron oxides. They develop by intensive and long lasting weathering of the underlying parent rock.

Rice husk ash (RHA) is an agricultural waste byproduct, and its disposal presents a major challenge by waste managers. RHA from parboiling plants exerts critical environmental threat; thus, approaches for its reduction are urgently needed. RHA material is considered a real super pozzolan due to its richness in silica, the content of which is approximately 85–90%

Waste products of society are those that the generator find more profitable to discard than to utilize. They include agricultural, household, human and industrial wastes. There are also low, intermediate and high-level radioactive or nuclear wastes.

Although wastes are not intrinsically valueless as some of them have value in some other location; the bulk of wastes usually constitute a disposal problem. Some wastes can be recycled. Wastes that are generated undergo chemical reactions with various elements in the environment to produce various compounds and gases, which are capable of polluting the environment. These compounds mix with the various elements of the environment such as rain, dew, etc., to form liquid called leachate, whose chemical composition varies widely depending on the waste material involved. Rice husk is an abundant biomass; a by-product from the production of rice. It is a waste material in rice producing countries with little or no commercial interest. It is a major source of fuel in most rice mills; being burnt to generate energy. The resulting ash generated is a waste causing pollution and disposal problems. Rice milling generates the product known as husk which surrounds the paddy grain. During the milling of paddy, about 78 % is received as rice, broken rice and bran. The remaining 22 % is received as husk. This husk is used in the rice mills to generate steam used in the parboiling process. The husk contains about 75 % organic volatile matter, leaving 25 % to be converted into ash during the firing process. Rice husk ash contains around 85 – 90 % amorphoussilica. So for every 1000 kg of paddy milled, about 220 kg (22 %) of husk is produced and when the husk is burnt in the boilers, about 55 kg of RHA is generated. In some urban and rural areas of Nigeria, local milling is done by women; they mainly use firewood as heat source and as such 100 % of the rice husk from the mill is a waste. Protection of our environment from pollutants emanating from wastes generated by man-made activities and disposal systems in less developed countries is now a matter of growing concern; because of the detrimental effects on the environment, especially on soil and groundwater which ultimately affects the health of the populace.

Handling and transportation of rice husk is problematic due to its low density. Rice husk ash is a great environment threat causing damage to land and surrounding area where it is dumped. Therefore, commercial use of rice husk and its ash is the alternative solution to disposal problem.

Objective of the Paper

This paper is aimed at determining the **e**ffect of compaction energies on strength characteristics of laterite soil treated with activated rice husk ash for soil improvement and stabilization. By activating the ash with alkaline substance such as sodium hydroxide (NaOH) it help to increase the activities of the ash.

Literature Review

Rice husk ash is an agricultural waste material that require disposal. It contains about 20 % ash which can be retrieved as amorphous, usually reactive silica use as filler, catalyst support and absorbent. It possesses pathogen characteristic similar to lime in chemical composition these reducing the overall environmental impact stabilization process.

Solid Waste consist of materials, which are classified according to their physical and chemical properties as garbage, rubbish, trash, junks and ashes (Umar et al., 2021, Frempong and Yanful*.,* 2008). The feasibility, environmental suitability and performance of the beneficial reuse of industrial and agricultural waste material are increasingly being investigated by researchers. Some of these materials include plastics, glass, scrap tires, fly ash, cement kiln dust etc.

Furthermore, Studies have been carried on the use of compacted lateritic soil in various geotechnical engineering fields such as in soil stabilization, liners and cover in waste containment application (Liman, 2009; Osinubi and Nwaiwu, 2005; Osinubi and Eberemu, 2006; Osinubi and Eberemu, 2009; Osinubi and Amadi, 2009; Osinubi and Amadi, 2010; Amadi and Eberemu, 2013). Lime had been used to stabilize the hydraulic conductivity of clay against chemical attack by organic solutions (Broderick and Daniel, 1990).

Amu and Faluyi, (2005), carried out an investigation to study the influence of RHA on Atterberg limits, strength, compaction characteristics, and swell and consolidation properties of laterite. The finding from their research indicated that the plasticity properties of laterite were significantly modified upon the addition of RHA and lime.

Large cracks can occur in wet compacted clays used as soil barrier when allowed to dry. Researchers reported that compacted clay in landfill covers undergo seasonal changes in water content even at great depth due to seasonal variation in precipitations and evapotranspiration. Field studies have shown that desiccation can induce large cracks, and this can induce lead to an increase in hydraulic conductivity of the barrier material thus making it to exceed the regulatory minimum value. A maximum volumetric shrinkage stain of is required for a material to be suitable for the construction of a liners".

Alkaline Activators

The most used alkaline activators are mixture of sodium or potassium hydroxide ($NaOH_2$ KOH) with sodium water glass or potassium water glass (nS_1 O_2 Na_2O) (Iqbal *et al.*, 2015). Katz studied alkali activated slags reporting an increase in mechanical strength when the concentration of the activator increases. According to Hameed *et al*., 2007, the alkaline activator plays a crucial role in the polymerization reaction, behaving more swiftly when the soluble silica is present. Criado and Susan *(*2017*)* also confined that water glass favours the polymerization process leading to a reaction product with more silica and more mechanical strength.

Fernando *et al.* (2007) developed patented binders and obtained from the alkali- activation of matakaolin, that the new binder is generated by an adjustment of the process used by the Romans and Egyptians. The alkali-activation of alumino-silicate material is a complex chemical process evolving dissolution of raw materials, transportation or orientation and poly-condensation of the reaction product. Investigation about alkali-activated binders has deserved increased attention by the research community mainly due to its environmental performance and superior durability over ordinary Portland cement.

MATERIALS AND METHODS

Materials:

The materials used in this study are:

Soil

The soil sample was obtained from Dungulbe village in Bauchi town (latitude 10° l8'N and longitude 11° 24'E) in Bauchi local government area of Bauchi state. The sample was collected using the method of disturbed sampling at a depth between 1.0m to l.5m from three different test pits. The material was collected in polythene bags and transported to the Soil Mechanics Laboratory of Abubakar Tafawa Balewa University, Bauchi. Preliminary analysis of the samples was conducted and the soil classified in accordance with the American Association of State Highway and Transportation Officials (AASHTO, 1986) and the Unified Soil Classification System (USCS) in ASTM D2487 – 11 respectively. The tests were conducted in accordance with BS 1377 (1990) and the stabilization tests were conducted in accordance with BS 1924 (1990).

Rice Husk Ash

The rice husk used was obtained from local rice millers, burned and ashed at a temperature of about 700^oC in accordance with the methods used by Alhassan and Mustapha, (2007). The resultant oxide composition of the ash is expected to conform with earlier findings such as that presented by Alhassan and Mustapha, (2007).

Water

The water used was portable drinking Water known as pure water in the absence of distilled water.

Sodium Hydroxide

Sodium hydroxide (NaOH) is an alkaline-base material which was added to the mixture to activate the rice husk ash.

Methodology

Tests on the natural soil were conducted in accordance with BS 1377 (l990), as described in their procedures below. These tests include;

- Classification tests
- Compaction (BSL, WAS and BSH)
- Unconfined compressive strength (UCS)

RESULTS AND DISCUSSIONS

Classification of the Soil

The physical properties of the soil showed that the soil is light brown in colour with specific gravity of 2.43; percentage passing 200mm sieve size was 84.4% and free swell was 27% and sand content was found to be 15.6%, thus making the soil sandy clay. The Atterberg limit test results also showed that the untreated soil has liquid limit (W_l) of 31.7%; plastic limit (W_p) of 17.6% and plasticity index (I_p) of 14.1% with linear shrinkage value of 15%.

Also the sieve analysis and Atterberg limit (W_l&I_p) test results indicated that the soil was classified as A – 6 (11) according to AASHTO M 145-2012 classification system; and a clayey soil of low plasticity (CL) according to ASTM D 2487, 2011 classification system.

Chemical properties of the soil

X – Ray Florescence result of the ARHA and the soil are shown in table 2 and 3 respectively. The result on table 3 showed that the prevalent oxide composition of the soil are; Silicon oxide (SiO_2) 61.04 %, Ferrite oxide (Fe_2O_3) 27.02 % Potassium oxide (K_2O) 6.44 % and Tin oxide (Ti_2O_3) 2.28 % with other traces of Aluminium Oxides (Al_2O_3) 1.21 %, and Calcium Oxide (CaO) 0.5

Table 1: Physical Properties of the Soil

Soil Properties	Value
Natural moisture content w, (%)	5.8
Specific gravity (G)	2.43
% Passing sieve No. 200	84.4
Sand (0.075mm – 4.75mm) %	15.6
USCS	CL
AASHTO Classification	A-6 (11)
Group index (GI)	11
Liquid limit (%)	31.7
Plastic limit (%)	17.6
Plasticity index (%)	14.1
Linear shrinkage (%)	15
Free swell index (%)	27
Color	Light brown
Maximum dry density BSL (Mg/m^3)	1.52
Maximum dry density WAS (Mg/m^3)	1.59
Maximum dry density BSH (Mg/m^3)	1.64
Optimum moisture content BSL (%)	20.2
Optimum moisture content WAS (%)	19.2
Optimum moisture content BSH (%)	15.5

Table 2: Oxide Composition of the Soil and ARHA

Oxide	Concentration (%)	
	Soil	ARHA
SiO2	61.04	67.3
Fe2O3	27.02	0.95
Al2O3	1.21	4.96
CaO	0.5	1.58
MgO	0.01	0.53

K2O	6.44	
TiO3	2.28	
P2O5	0.54	
SO3	0.08	
ZeO2	0.43	
Eu2O3	0.22	
PbO	0.09	
Na2O	0.01	
Cr2O3	0.01	
V2O5	0.01	
MnO	0.02	
CuO	0.02	
ZnO	0.01	
LOI		20

Unconfined Compressive Strength Results

The average result of unconfined compressive strength (UCS) for ARHA treated lateritic soil compacted at the energy levels of BSL, WAS and BSH, at moulding water content relative to the OMC and cured for 7 days, 14 days, and 28 days are summarized in Tables 3a – 3c

Table 3a: Strength (UCS) for ARHA treated lateritic soil (BSL Compaction Energy)

Compaction Energy	Curing Days	Activated Rice Husk Ash (%)	Unconfined Compressive Strength (kN/m²) Moulding Water Content Relative OMC (%)		
			-2	0	2
BSL	7	0	174	168	157
		5	187	176	165
		10	217	212	208
		15	243	221	223
		20	312	235	248
	14	0	185	176	179
		5	199	187	194
		10	305	293	265
		15	321	317	297
		20	358	328	319
	28	0	196	187	191
		5	211	201	189
		10	426	265	310
		15	225	318	206
		20	210	341	183

Table 3b: Strength (UCS) for ARHA Treated Lateritic Soil (WAS Compaction Energy)

Compaction Energy	Curing Days	Activated Rice Husk Ash (%)	Unconfined Compressive Strength (kN/m²) Moulding Water Content Relative OMC (%)		
			-2	0	2
	7	0	212	202	199
		5	286	264	228
		10	338	302	241
		15	367	343	267

WAS		20	386	375	278
	14	0	238	224	219
		5	274	245	231
		10	290	284	278
		15	343	321	302
		20	400	346	321
	28	0	286	264	242
		5	340	321	296
		10	416	395	347
		15	432	421	389
		20	457	442	411

Table 3c: Strength (UCS) for ARHA Treated Lateritic Soil (BSH Compaction Energy)

Compaction Energy	Curing Days	Activated Rice Husk Ash (%)	Unconfined Compressive Strength (kN/m^2) Moulding Water Content Relative OMC (%)		
			-2	0	2
BSH	7	0	356	321	301
		5	375	342	322
		10	389	364	346
		15	421	385	364
		20	454	396	378
	14	0	245	332	211
		5	268	354	231
		10	289	368	243
		15	314	390	358
		20	334	421	386
	28	0	342	321	303
		5	385	364	345
		10	453	432	402
		15	490	484	452
		20	522	499	487

The unconfined compressive strength of the treated soil with ARHA

The UCS values were observed to increases in all the three compaction energies. Therefore, the variation in the UCS values are of increasing order with increase in the curing ages and an increase in activated rice husk ash content in the soil samples. However, with increase in moulding water content from – 2 to +2 % relative to OMC, the UCS values decreased. This may be due to the pozzolanic effect of the ARHA. The treated soil with up to 10 % ARHA content showed an adequate improvement in the UCS values as compared to the untreated soil samples. a liner material should have minimum shear strength of 200kN/m^2. Thus, the UCS values obtained when the soil sample was treated with activated rice husk ash up to 10 % and compacted using BSL, WAS and BSH energies, at OMC (with -2 and +2 moulding water content), have meet the minimum requirement for compacted soil used as liner. The decrease of the UCS values when the soil sample is treated with 15 – 20 % activated rice husk ash at moulding water content could be as a result of insufficient water content required for complete hydration process(Chinade et al., 2017, Kundiri, 2002).

Increase in curing age of the treated samples showed an increase in the UCS values when the soil was treated with ARHA and compacted using BSL, WAS and BSH energy levels. For BSL compaction energy, with up to 15 % of activated rice husk ash, the UCS value increase from 212 kN/m^2 to 307 kN/m^2. The same trend was observed for WAS and BSH compaction energies where it increased from 302 kN/m^2 to 395k N/m^2 and from 364 kN/m^2 to 432 kN/m^2 respectively from 7days to 28days.

Conclusions

Relevant engineering properties of lateritic soil necessarily needed as suitable for construction were investigated.

The silica sesquioxide molar ratio as determined from the XRF indicates that the soil is non – lateritic soil.

For all the Compactive efforts, there is an increase in the MDD values with corresponding decrease in OMC when the soil is treated with up to 10 % ARHA. However at 15 – 20 % the MDD values declined.

The unconfined compressive strength of the soil sample increases with increase in activated rice husk ash content and with increase moulding water content for all the Compactive efforts used.

Samples with up to 10 % activated rice husk ash content, compacted using WAS and BSH energies and cured for 7 days and above attained values more than the minimum USC requirement.

Activated rice husk ash is found to be effective and economical agro-waste admixture that can be used to improve the strength of lateritic soil for various geotechnical applications. Hence Minimum compaction energy of BSL with 15 % activated rice husk ash is to be used as material for geotechnical application.

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