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STABILIZATION OF SUB-BASE LATERITIC SOIL WITH RICE HUSK ASH: A CASE STUDY OF OGUGU-ADUPI ROAD, KOGI STATE, NIGERIA.

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ABSTRACT The common conventional additives for road construction today are Cement, Lime and Bitumen which are very expensive to purchase. Lateritic soil however needs to be treated to upgrade its strength and durability in order to meet the standard Engineering requirements. The aim of this work is to stabilize a road of 13km using Rice Husk Ash (RHA). Nine clayey lateritic soil samples were collected from the proposed road at three different chainages to a depth of 1.5 – 2m. They were sundried and sieved to remove the particles and thereafter manually mixed in a tray with water until a homogenous color was achieved. The procedure for the various test were in accordance to ASTM D 2487-2000. The tests conducted were Atterberg limit test, AASHTO, USCS, Compaction test, UCS and CBR. The soil samples were subjected to soil classification and geotechnical tests in their natural state. The rice husk was collected from a rice milling industry close to the proposed road and was burnt at a controlled temperature and then sieved through 0.425mm sieve to obtain the fine ashes. The clayey soil was mixed thoroughly with 2%, 4%, 6%, 8% and 10% of RHA in percentage by dry weight of soil sample. The maximum dry density (MDD), optimum moisture content (OMC), California Bearing Ratio (CBR) and unconfined compressive strength (UCS) of samples with RHA were determined. It was discovered that the mixture of the RHA with clayey soil improved the engineering properties of the soil because of the reductions in specific gravity (SG) and (MDD). The CBR value increased from 6.95 to 14.42 at 6% while the UCS also increased from 50.2 to 130.3 at 6%, therefore, the optimum value for stabilization using RHA is 6%. The research showed that RHA will stabilized the sub base of Ogugu- Adupi road.
Keywords: Maximum Dry Density, Rice Husk Ash, Clay Soil, Optimum Moisture Content,

INTRODUCTION

Agricultural wastes are readily available in large quantity in Kogi State since the state is an agricultural dependent. People farm throughout the year because of the large body of water (River Niger and Benue) available. The waste material posed serious hazard on the environment and means of disposal is a challenge to the State. Stabilization of soil was described by Ogundipe (2013) as the process of homogenization and mixing materials with a soil to upgrade certain properties of the soil. It's a process where by an unsuitable soil for construction is modified, improved and stable for construction beyond its original state. The method which can either be blending the soil to obtain a desired graduation or mixing the available additives which may change the graduation, texture or plasticity or act as cementation binder of the soil. Stabilization of soil is being used for different kinds of engineering works but mostly they are used for road construction and pavement for the increase of strength and optimum durability of soil materials. The materials used for road projects are as significant as other engineering Design factors (Kanyi, 2017; Osinubi et al, 2017), (Oriola and George, 2017) Lateritic soils are very important in road construction. Lateritic soils contribute to the general economy of the tropical and sub-tropical regions where they are in surplus because soil are often used in Civil engineering works as construction materials for roads, houses, landfill for foundations, embankment dams etc. Its better and cheaper to improve the available soil material to achieve desirable objective than to go far away burrow pit for a replacement (Kanyi, 2017; Osinubi et al. 2017; Oriola and George, 2010) There is also stabilization of soil with non-conventional eco-friendly agricultural waste material such as Rice husk ash, palm front ash, saw dust ash corncob ash, coconut pond ash etc. The expensive methods and cost of highway construction necessitate the need for their efficient control. Although several stabilization methods of stabilizing the soil are available but soil stabilization using agricultural waste has more potentials. (Mohammed Ali Rohgozar et al, 2017).

Stabilization is a chemical treatment of soil in order to improve their strength and durability in such a way to make them suitable for road construction as against their natural state. Soil modification and stabilization increases the strength, bearing capacity and durability of soil (Kanyi, 2017). Soil stabilization has three purposes which are; strength improvement, air pollution control and soil water sealing. (Amu and Adetuberu, 2010). The use of non-traditional additive reduces the construction cost instead of cement and lime which for time immemorial being in used for soil stabilization (Ali FH et al, 1992 and Basha EA et al, 2005). Lateritic soil is described by Ola S.A (1983), as a product of weathering or breaking down of rocks with red or reddish brown and dark brown color which are generally found below earth crust or hard surface, from investigation most lateritic soil in their natural state exhibit low bearing capacity and low strength due to the presence of high content of clay. In case where the lateritic soil possess high content of clay material then the bearing capacity and the stability cannot be assured when subjected to loading especially in the presence of moisture. These materials can be locally improvised at a low cost within our environment. According to Bello et al., (2015).Local materials can be classified as agricultural or industrial waste. This Study is aimed at stabilization of Ogugu-Adupi road, Kogi state using non- traditional additive with the objective of discovering the usefulness of Agricultural waste such as RHA in road construction. Also, to discover experimentally the effect of RHA on the geotechnical properties such as Atterberg limit, Compaction characteristics, California Bearing ratio (CBR) and Unconfined compressive strength (UCS) of the soil. It has been proven by the researchers that Rice husk Ash is durable and good for soil stabilization. Those Agricultural wastes play important roles in the improvement of the engineering properties of a weak/poor sub-grade soil. Determining the Asphaltic pavement thickness depend on the result of the soaked CBR value obtained during the laboratory test. The Clayey soil collected from Ogugu-Adupi proposed road was used for the research work. The presence of high content of clay in the natural state of clayey soil brings about low bearing capacity and poor strength. The Plasticity in the clay can cause cracks and damages to the engineering works therefore it's very important to change its geotechnical characteristic of soil strength and durability of the sub grade for road construction.

MATERIALS AND METHODOLOGY

Materials

Clayey soil

Disturbed soil sample utilized for this research was obtained from Ogugu in Olamaboro local government. The soil samples were obtained from three different chainages along the proposed road for construction. Sample from a depth of 1.5m-2.0m and a method of disturb sampling was used for the research work in order to determine the general properties of the soil which are the most important control standard test in accordance to ASTM D 2487- 2000. The clayey soil in their natural state possess high content of plasticity material which causes low bearing capacity and stability when subjected to loading in the presence of moisture. Presence of plasticity in the clay causes cracks and damages to civil engineering structures such as pavement, building foundation, road ways, and many other construction projects. However, under certain circumstances, not all the desired parameters could be investigated because of many factors involved. Amu and Adetuberu (2010).In this work, two controls were established. Soil sample without additive and soil sample with increasing addition of the RHA ashes. All tests were conducted in Civil Engineering department at Federal Polytechnic Ado-Ekiti in accordance with the standard procedure.

Rice Husk Ash (RHA)

In Lokoja, Kogi state Rice is cultivated in large quantity in both dry and wet season because of the large body of water (River Niger & Benue).Rice husk is waste product gotten from rice milling which is not good for animal feed and causes environmental hazards to the dumped area. The waste obtained from the rice mill is about 10 tones, rice husk are being generated yearly in the world according to Fattah et, al., (2013).The Rice husk used for this research work was processed waste material incinerated and monitored under a regulated temperature of 700^0c and atmosphere. The Rice husk ash contained 85% to 90% amorphous silica, which is determined to be pozzolanic properties was achieved. Experimentally, it was proven that the chemical analysis indicates SiO2 (93%) as the principal material constituent and others. According to ASTMC 618, Silica can be used as a pozzolanic material and has the potentials to be used for soil stabilization agent. Apart from silica, it possess other compounds such as Aluminum oxides, calcium oxides, magnesium oxides. The ashes from the burnt Rice husk was passed through 0.425mm sieve and used for the laboratory work. Table 1. Physical and chemical properties of RHA.

METHODOLOGY

Methods of Testing

The procedure for various tests was carried out in accordance to ASTM D 2487-2000. Clayey soil sample on getting to the laboratory was tested to determine its natural moisture content. The soil samples was then spread on the floor to facilitate easy air drying. The soil samples were pulverized, broken down and was subjected to classification and Engineering strength test in their natural air – dried state. First, was to determine the distribution of particle size, Atterberg limits, Compaction, CBR and UCS. Later, test was conducted on the soil sample and the additive in percentage by weight. All tests were carried out at Federal polytechnic Ado-Ekiti, Civil Engineering Department.

Preparation of Soil Mixtures

Preliminary investigation for the natural soil on specific gravity, moisture content, Atterberg limit and particle size analysis were conducted to determine the classification and identification properties. The soil-additive RHA, Mixtures were prepared by taking the percentage by dry weight of clayey soil and additive (2% 4% 6% 8% 10%) of RHA in to a tray for thorough manual mixing to achieve a uniform color at least 5 minutes before adding water to the dry mixture. The soil and additive mixing continues until a homogenous color was achieved. The samples will be taking for test to determine the Engineering properties such as California bearing ratio, compaction and undrained compressive strength. The procedure was carried out in accordance to ASTM D 2487-2000.

Compaction Test

Compaction proctor test was conducted on mixture of soil sample at different percentage of **(2%, 4%, 6%, 8%, 10%), of RHA** accordance to ASTM D1557-2000. The size of the mould 1000ml (capacity with a diameter of 100mm internal and of 127.3mm height was used. The soil and additive was manually blended in a dry tray and thereafter, water was added and a homogenous mixed was achieved for the test. The compaction test was conducted to investigate the maximum dry density (MDD) and optimum moisture content (OMC).

Unconfined Compressive Strength (UCS)

In accordance to ASTM D 2166-2000 the unconfined compressive strength test which is the commonest and flexible method was conducted for evaluating the strength of stabilized soil. Cylindrical specimens test of diameter 38mm with a height of 76mm was compacted into a metallic mould by kneading system at MDD and OMC of the corresponding standard or modified proctor compaction test. 7 days was set aside for curing of the samples immediately after the soil and additives RHA were thoroughly mixed and compacted for 1 hour then the water mixed samples were enveloped in polyvinyl film materials and store under wet condition for proper curing. All the specimen were tested with a tri axial load to check failure. The Static compaction with split mould was used to prepare samples for OMC and MDD.

California Bearing Ratio (CBR) Test

In accordance to ASTM D 1883-2000, the CBR tests were conducted. CBR is one of the most effective and common test in determining strength of a stabilized soil. A 6kg of soil sample and the additive mixed thoroughly for over 5mins. The sample was compacted with a 4.5kg mechanical hammer into the CBR mould separately. The compacted specimen are in three layers with 56 blows for each layer. An inner diameter of 150mm and 175mm height is the size of mould for placing CBR sample. The samples were kept for curing in wet sand for 7 days before undergoing a testing. The Soaked CBR test was also performed after the CBR value was obtained through penetration of 2.5mm and 5mm as a percentage of the standard force. The soak CBR value shows the highest value obtained if the soil is fully saturated. All the test procedures were followed in accordance to standard.

Atterberg Limit

In accordance to ASTM D 4318-2000 the liquid limit and plastic limit investigation was conducted on the samples in their natural state and those mixed with RHA additive with different percentages such as (0%, 4%, 6%, 8%, 10 %). A soil sample which passes through sieve 0.425mm are kept dried then the addition of water to form paste. The 1cm thick layer was graduated up in a cup, then grooved in the soil which is in the cup and the handle was made to rotate at the rate of 2 blows per sec. Water content was enough to cover the groove for 13mm length at 25 blows to give a liquid limit. This test was done by liquid limit apparatus designed by A. Casagrande.

RESULTS AND DISCUSSION

Results of Preliminary investigation

Table 1 Chemical composition of Rice Husk Ash

Constituent	Percentage (%)
SiO_2	81.2
Al_2O_3	6.01
Fe_2O_3	0.08
CaO	0.75
MgO	0.91
SO_3	0.42
Na_2O	0.13
K_2O	2.56
P_2O_3	6.1

From the Table 1 above, Rice husk ash possess a high percentage content of silica and aluminate, this indicate that Rice husk ash is a pozzolana material. As shown above, RHA possessed high percentage of SiO_2 (81.2%), Al_2O_3 (6.01%), Fe_2O_3 (0.08%) to make a total of 87.29%. According to ASTM C618-2003 states that the total pozzolanic material to be substituted for reinforcement or stabilization of road construction should be up to 70%. Therefore RHA is suitable for road construction.

Table 2 Geotechnical Properties of the Natural Clayey Soil

Characteristics	Description
Natural moisture content (%)	22.27
Percent Passing B.S sieve no 200	77
Liquid limit (%)	49.0
Plastic limit (%)	17.2
Plasticity index (%)	14.8
Group Index	22.27
AASHTO classification	A-7-6
MDD(mg/m3)	23.65
OMC (%)	9.7
UCS(KN/M2)	50.2
CBR (%)	
Unsoaked	6.95
Soaked	3.72
Specific gravity	2.7
Color	Grey whitish

Soil Identification

Before the additives were added to the natural soil, test was conducted and results were displayed as above in Table 2. The properties of the soil are classified as A-7-6 in the AASHTO (1986) Classification system. This is an indication that the soil falls below the recommended standard for road construction works therefore, it requires stabilization. . According to Garba and Hoel (2009).A minimum liquid limit value of 41% is required for a soil to be classified into A-7 group. Also the Plasticity index must be greater than 11%, the percentage passing of soil through BS no 200 sieve must be greater than 35%, all these conditions were met by the soil sample. The sub-group classification of A-7-6 required to must satisfy the following requirement. P.L > L.L-30. Therefore, 24.8 > 49.0 -30 = 19. This is an indication that the soil falls below the recommended standard for road construction works therefore, the soil must be stabilized.

Results

Consistency Limit

Atterberg Limit

Table 3 Liquid Limit and Plastic Limit of Clay Soil with RHA

Added Additive (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Specific Gravity
0	49.0	27.2	24.8	2.7
2	48.0	29.1	22.1	2.67
4	43.6	30.8	20.7	2.65
6	40.5	36.3	19.5	2.60
8	35.0	38.1	20.6	2.53
10	32.1	41.8	22.6	2.45

The table 3 displayed the influence of Liquid limit behavior on different percentage of RHA. The liquid limit decreases with increase or addition of RHA. It decreases from 49.0% to 32.1%. General decrease in Liquid limit shows decrease in compressibility and shrink swelling properties of the soil. This is of high and great importance for sub grade soil. The clay mineral in the soil determines the character of the liquid limit either increase or decrease value. The general reduction in liquid limit with increase in RHA is characterized to the fact that RHA reaction forms compounds which exhibit Cementous properties such as calcium silicate cement with the natural soil properties (Figure 1)

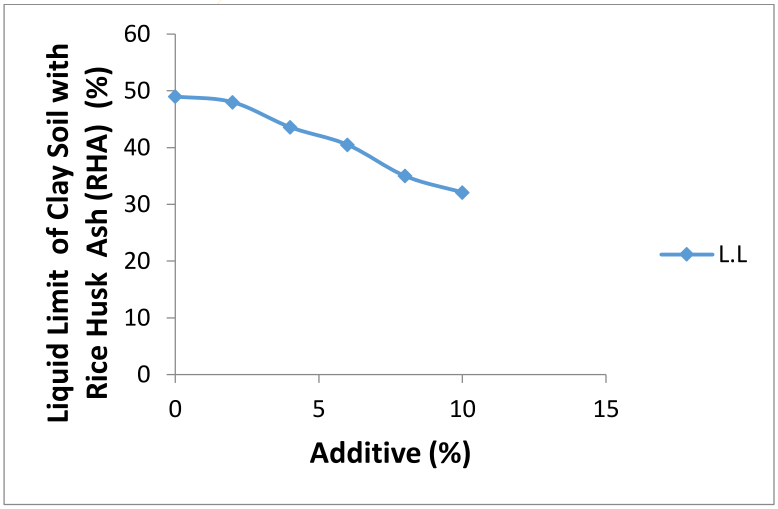

Figure 1Liquid Limit of Clay Soil with Rice Husk Ash (RHA) Additive (%)

Muntohar and Hantoro (2000) confirmed this findings. There are changes in plastic limit with the addition of RHA as shown on the Table 3General decrease in plastic limit with increase in RHA content which is as a result of cationic exchange reaction. The result agrees with Muntohar and Hantoro (2000) findings that plastic limit decrease with increase in RHA. According to the specification of Federal ministry of Works and Housing, the approved maximum liquid limit of 40% materials for subgrade. The average liquid limit of the natural clayey soil sample is greater than 40% therefore, the soil needs to be stabilized for road construction.

The plasticity index of the sample decreases from 24.8% to 22.6% with the increase of the RHA is an indication of soil improvement because some water to be absorbed by the clay minerals are expelled (Figure 2). From the table 3, the specific gravities of natural clayey soil reduces from 2.7% to 2.45% with the addition of RHA which shows that it enhances the soil property for different practices in geotechnics.

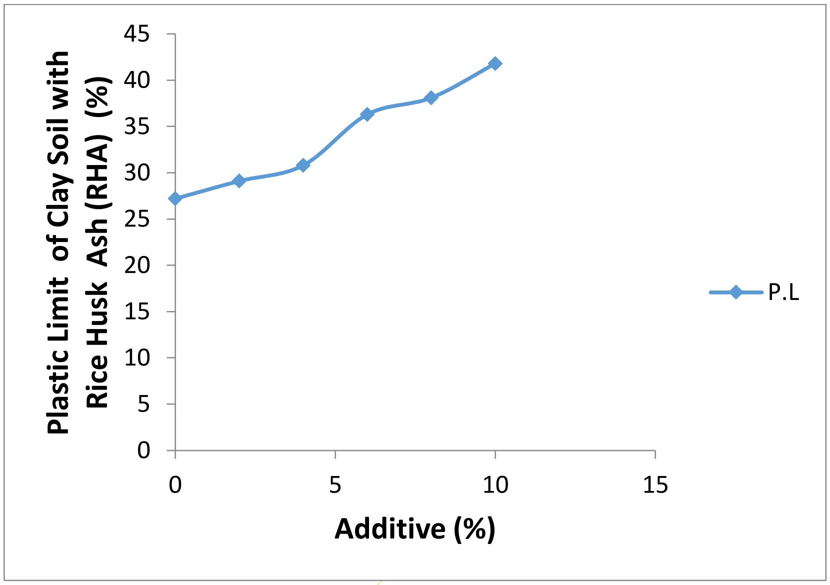

Figure 2Plastic Limit of Clay Soil with Rice Husk Ash (RHA) Additive (%)

Compaction Test Results

Table 4 Optimum Moisture Content, Maximum Dry Density, CBR, and UCS of Clay Soil with RHA Additive

Added RHA (%)	MDD g/cm3	OMC (%)	CBR (%)	UCS
0	23.65	9.7	6.95	50.2
2	22.45	10.3	10.95	50.8
4	21.70	11.0	12.95	56.7
6	18.60	11.2	14.42	130.3
8	16.0	16.1	1.81	60.8
10	14.6	17.60	1.20	58.10

Table 4 shows the MDD and OMC of clayey soil with RHA. The test carried out displayed great increase in Optimum moisture content with increase in RHA content while there was reduction in the maximum dry density. The replacement of some percentages of clay soil with RHA in the mixture lead to the decrease in maximum dry density which has a relatively low specific gravity compare to natural soil which is 2.70 (Figure 3).

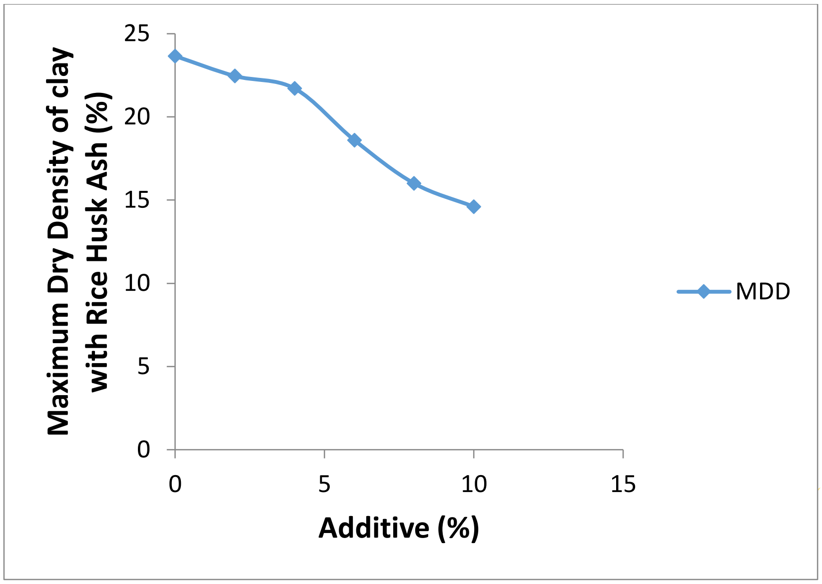

Figure 3 Maximum Dry Density of Clay Soil with Rice Husk Ash (RHA) Additive (%)

The decrease can also be considered as the fillers of RHA in the soil voids. The optimum moisture content OMC increases as there is increase in RHA content as shown in Figure 4.

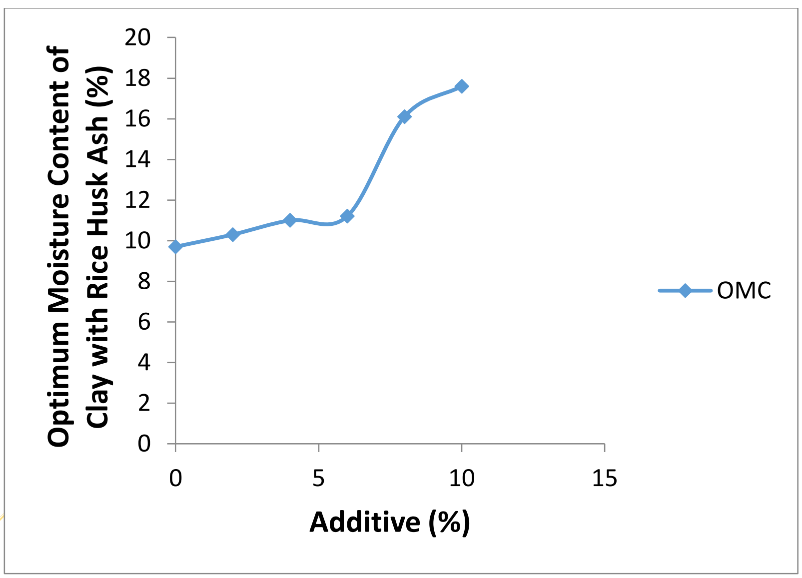

Figure 4 Optimum Moisture Content of Clay Soil with Rice Husk Ash (RHA) Additive (%)

This increase in OMC can cause decrease in the quantity of free silt and clay fraction which is part of the forming of coarse materials with wider surface area. It also indicates that surplus water is required for effective compaction of the mixtures (see Figure 4).

As shown in figure 5, the California Bearing Ratio **(**CBR) of the clay soil with RHA additives was increasing up to 6% addition of RHA in the soil. This greatly increased the stabilization capacity and bearing strength of the clay soil to resist any internal shear stress during loading. On the contrary, the CBR of the clayed soil with RHA started decreasing after 6% of RHA content until 10% of additive content is reached. The shows that, the stabilization of clay soil with RHA should not exceed maximum of 6% of RHA additive to prevent decrease in its strength.

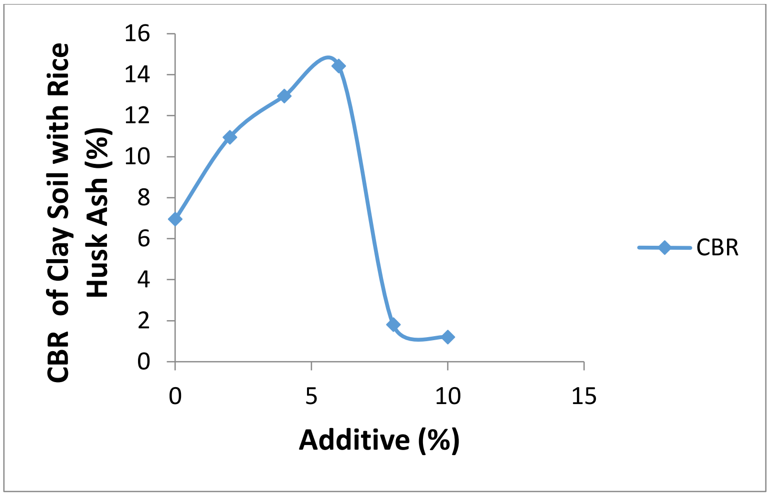

Figure 5 California Bearing Ratio of Clay Soil with Rice Husk Ash (RHA) Additive (%)

Unconfined Compressive Strength

It was observed from the table 4 and figure 6 that there is increase in percentage value of UCS with the increase in RHA content. UCS value increase from 50.8% to 130.3% and suddenly dropped at 8% RHA. The decrease might be as a result of reduction in the content of silt and clay in the soil which stop the rate of cohesion of the samples. The initial increment of UCS value between 2% - 6% RHA can be described as the formation of cementitious compound between the CaOH available in the soil and the pozzolanic effect on the mixtures. The change in value of UCS at 8% is as a result of excess RHA present that will form weak bonds among the soil and the cementitious compound.

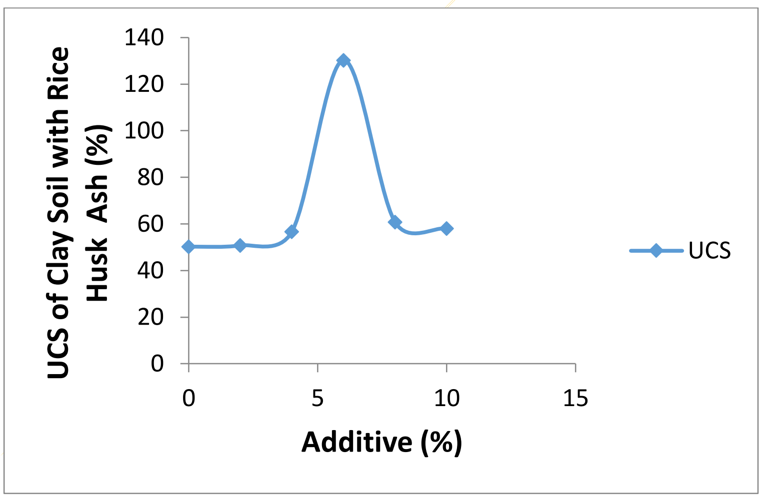

Figure 6 Unconfined Compressive Strength of Clay Soil with Rice Husk Ash (RHA) Additive (%)

The initial increment of UCS value between 2% -6% RHA can be described as the formation of cementitious compound between the CaOH available in the soil and the pozzolanic effect on the mixtures. The change in value of UCS at 8% is as a result of excess RHA present that will form weak bonds among the soil and the cementitious compound.

Contribution to Knowledge

With these experimental results, the sub-base clay soil of Ogugu Adupi road can be stabilize for standard transportation with little amount of money using rice husk Ash generated in the environment. This will be a good data for the next road contractors and engineers that might work on the road in future.

CONCLUSIONS

The challenge of disposing agricultural waste can be handled by using RHA as stabilizing agent to improve the geotechnical properties of the soil. From the research, CBR attained the highest value of 14.2 at 6% while UCS also achieved it optimal value of 130.3 at 6%. Therefore, the optimum value for the stabilization with RHA is 6%

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CONFLICT OF INTEREST

Authors have no Conflict of Interest

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