STABILIZATION OF A-6 LATERITIC SOIL USING RICE HUSK ASH AND PROMOTER

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ABSTRACT

Lateritic soil sample classified as A-6, taken from a borrow pit at Birgin Gwari, Minna, was stabilized with 0 to 6% Rice Husk Ash (RHA), at 2% variations. Each of the soil-RHA mixture was admixed with 0 to 2% promoter (calcium chloride and sodium hydroxide), at 0.5% variations. Unconfined Compressive Strength (UCS) test samples of the soil-RHA-promoter mixtures were prepared at Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), cured for 1, 7, 14, 28 and 60 days, before testing. The results indicated marginal increase in UCS with increase in curing period, but no defined trend in the UCS values was observed as curing period increases constant promoter content. The results also indicated that, at constant percentage content of promoter, increase in percentage of RHA has more pronounced effect on the strength (UCS) of the stabilized soil than curing age. The UCS values peak at 6% RHA/0.0% promoter and 28 days curing period.

Keywords: *Lateritic soils, Rice husk ash, Promoter, Maximum dry density, Optimum moisture content, Unconfined compressive strength.*

1 INTRODUCTION

Soil improvement could either be by modification or stabilization, or both. Soil modification is the addition of a modifier (cement, lime, etc.) to a soil 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 (Alhassan 2008).

Lateritic soils are generally used for road construction in Nigeria. Some of these soils in their natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains a large amount of clay materials its stability and strength cannot be guaranteed under load in presence of moisture (Alhassan, 2008). When lateritic soil consists of high plastic clay, the plasticity of the soil may result to cracks and damage on pavement, roadways, building foundations or any civil engineering construction projects. Improvement in strength and durability of lateritic soil in recent times has become imperative; this has geared researchers towards using stabilizing materials that can be sourced locally at a very low cost (Bello *et al*., 2015). Where in most cases sourcing for alternative soil may prove economically unwise, to improve the soil by way of stabilizing it to meet the desired objective becomes a viable option (Mustapha 2005, Osinubi, 1999). These local materials can be classified as either agricultural or industrial wastes *Amu et al.* (2011a). The ability to blend the naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very essential (Amu *et al*., 2011b; Amu and Adetuberu, 2010; Bello *et al*., 2014).

Over the years, cement and lime have been the two major materials used for modifying or stabilizing soils. The price of these materials has rapidly increased due to the sharp increase in the cost of energy and high demand. This has therefore, prevented third world countries Nigeria from providing good road for its citizen particularly rural dwellers. Amu *et al*., (2011b), Bello *et al*. (2014) and Sear (2005) showed that Portland cement, by nature of its chemistry, produces large quantities of CO_2 for every ton of its final product which contributes to the melting of the ozone layer covering the earth surface. Therefore, replacing cement in soil stabilization with agricultural waste material, like Rice Hush Ash (RHA) and little promoter for stabilization of soils will reduce the overall environmental impact of the stabilization process.

Rice husk is an agricultural residue gotten from paddy rice. World rice production (2016) indicated that the global rice production by 2015/2016 season was 472.09 million tons, while for 2016/2017, it was estimated to be 483.26 million tons, representing an increase of 11.17 million tons (2.37%) rise in the production. This translate to about 157.2 and 160.9 million tons of rice husk for 2015/2016 and 2016/2017 respectively, with corresponding increase of 2.37% over these two seasons (Alhassan and Alhaji, 2017). According to Oyetola and Abdullahi (2006), about 2.0 million tons of rice is produced annually in Nigeria. Rice production in Nigeria for 2016/2017 season was projected by Wailes and Chavez (2012) to stand at 3.120 million metric tons.

Partially burnt husk from the milling plants when used as a fuel, also contributes to pollution and efforts are being made to overcome this environmental issue by utilizing it as a supplementary cementing material (Chandrasekhar *et al*, 2006). The chemical composition of rice husk is found to vary from one sample to another due to the differences paddy type, production year, climate and geographical conditions. Chandrasekhar, *et al*. (2003) and Zhang, *et al*. (1996) stated that burning rice husk under controlled temperature below 800°C can produce ash with silica, mainly in amorphous form. Nair *et al.,* (2008) reported an investigation on the pozzolanic activity of RHA by using various techniques in order to verify the effect of incineration temperature and burning duration. They stated that the samples burnt at 500 or 700 °C and for more than 12 hours produced ashes with high reactivity with no significant amount of crystalline material. The short burning durations (15 – 360 minutes), resulted in high carbon content for the produced RHA, even with high incinerating temperatures of 500 to 700 °C. A state-of-the-art report on RHA was published by Mehta (1992), which contains a review of physical and chemical properties of RHA, the effect of incineration conditions on the pozzolanic characteristics and a summary of the research findings from several countries on the use of the ash as a supplementary cementing pozzolanic material. Alhassan and Alhaji (2017), in a view, chronicled utilisation of RHA for improvement of deficient ioils in Nigeria. Use of RHA and promoter in soil stabilization is relatively a new area.

Promoters are chemical waste that increase available surface area of stabilization against crystal growth and lead to improvement of mechanical strength. In other to improve the strength, durability and engineering properties of soil-cement, small quantities of promoter have been used. Addition of 1.0 and 4.0% by weight of hydroxides and various salts, greatly increase compressive strength (Lambe *et al*., (1979).. O'Flaherty (1988) noted that most promoters and agricultural wastes possess pozzolanic properties that have cementitious tendencies on exposure to moisture. Robert (1993) defined pozzolanas are siliceous and aluminous material which themselves possess little or no cementitious value but, will, in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature, to form compounds possessing cementitious properties. Sodium silicate has often been used as a pozzolana for replacement of RHA. However, sodium silicate is expensive and difficult to handle, which is why a cheap and easy to handle promoter (calcium chloride and sodium hydroxide) sorted and used in this research as replacement for RHA.

2 MATERIALS AND METHODOLOGY

2.1 Materials

The materials used in this research are A-6 lateritic soil, rice husk ash, promoter (calcium chloride and sodium hydroxide) and distilled water

2.1.2 Lateritic soil

The disturbed lateritic soil sample used for this study was collected from borrow pit at Birgin Gwari, a suburb of Minna town in Niger State, Nigeria. Before the soil samples were taken, the top soil was removed to depth of 0.5 to 1m. The sample was collected, sealed in plastic bags and placed in sacks to avoid loss of moisture during transportation. The soil sample was then air dried in Civil Engineering laboratory, Federal University of Technology, Minna. Before commencing laboratory tests of the soil sample, it was pulverized and sieved through BS No. 4 sieve (4.76mm).

2.1.3 Rice husk ash

The Rice Husk Ash (RHA) used for this study was obtained after burning rice husk collected from a local rice milling plant in Minna. The raw husk of parboiled rice was burnt for 2 days in open place without controlling the temperature (mass burning/ashing). The ash was then transported to laboratory and sieved through sieve 75µm and then stored in air-tight polythene bags to avoid any form of hydration.

2.1.4 Promoter

The promoter used for this study is calcium chloride and sodium hydroxide, which was obtained from chemical and agro products sellers in Ibadan, Oyo state, Nigeria. The promoter was obtained in a solid form and converted to 1.0 molar concentration of calcium chloride and 1.5 molar concentration of sodium hydroxide.

$$Ca\,Cl + NaOH \text{-----} Ca(OH)2 + NaCl \quad (1)$$

2.1.5 Distilled Water

The water used for this research was distilled water. This was obtained in a chemical equipment shop in Bosso, Minna. Distilled water is of great importance in the stabilization process involving promoter, because presence of impurities in water can affect the cementitious process and reduce the compressive strength and durability of the stabilized soil.

2.2 Methodology

Laboratory test were carried out to determine the index properties of the natural soil, which include moisture content, specific gravity, sieve analysis, Atterberg limit, compaction characteristics. These tests were conducted accordance with BS 1377 (1990). XRF and XRD tests were also carried out to determine the chemical and mineralogical properties of the lateritic soil and RHA.

The natural lateritic soil was then thoroughly mixed with RHA, varied from 0 to 6% at 2% variations. Each of the soil-RHA mixture was then admixed with 0, 0.5, 1.0, 1.5 and 2% promoter. Compaction test was carried on the natural and the soil-RHA-promoter mixtures in accordance with BS 1377 (1990) and BS 1924 (1990) respectively. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), obtained from the compaction tests, carried out at British Standard Light (BSL) energy level, were then used to mould cylindrical samples that were eventually used for Unconfined Compressive Strength (UCS) test. Molded samples for UCS tests were properly sealed and cured for 1, 7, 14, 28 and,60 days before testing in with BS 1377 (1990) and BS 1924 (1990) respectively for unstabilized and stabilized samples respectively.

3 RESULTS AND DISCUSSION

3.1 Index Properties of the natural soil

Results of index properties tests conducted on the natural lateritic soil are presented on Table I, while Figure 1 shows XRF of the soil. From Table I, the soil is an A--6 and CL (clay of low plasticity) according to AASHTO and Unified Soil Classification System (USCS) respectively. It falls below the standards recommended for most geotechnical construction works and would therefore require stabilization (AASHTO, 1986; Alhassan and Alhaji, 2007).

TABLE I: INDEX PROPERTIES OF THE NATURAL LATERITIC SOIL

Property	Quantity
Percentage Passing BS sieve No 200 (%)	57.5
Natural Moisture Content (%)	5.1
Liquid Limit (%)	39.36
Plastic Limit (%)	24.42
Plasticity index (%)	14.94
OMC (%)	12.30
MDD (Mg/m^3)	2.1634
Specific Gravity	2.6
AASHTO Classification	A-6
Unified Soil Classification System	CL
Unconfined Compressive Strength (kN/m^2)	146.9
Colour	Reddish Brown

TABLE II: CHEMICAL COMPOSITION OF THE RHA

Constituent	Composition%
SiO_2	67.3
Al_2O_3	4.9
Fe_2O_3	0.95
Ca	1.36
MgO	1.80
Loss in lgnition (LOI)	17.78

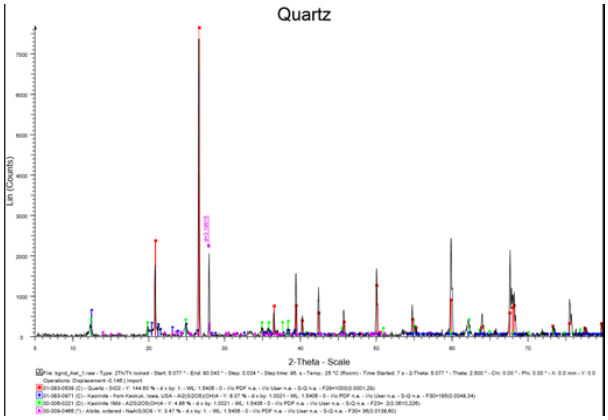

FIGURE 1: XRF OF THE LATERITIC SOIL.

3.2 Effect of Treatment with RHA and promoter

3.2.1 Unconfined Compressive Strength

Unconfined compressive strength (UCS) is the most common and adaptable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil (Singh and Singh, 2008). Variation of UCS with increase in RHA from 0 to 6% and promoter from 0 to 2% at British Standard Light energy level and after 1, 7, 14, 28 and 60 days curing period are presented in Figures 2 to 6.

The Variation of UCS with promoter at various percentage of RHA for 1 day curing period is shown in Figure 2. From the figure, it is observed that, at constant percentage content of RHA, UCS gradually reduces as percentage of the promoter increase. The figure also shows that as the percentage content of RHA increases, UCS increases. The UCS reduce from 146.9 to 43.2 kN/m^2 at 1.5 % promoter and increase from the natural value of 146.9 kN/m^2 to peak value of 268.5 kN/m^2 at 0.5% promoter/6% RHA. This subsequent increase in the UCS value is attributed to the formation of cementitious compounds between the CaOH, present in the promoter and RHA and the pozzolans present in the RHA. The decrease in UCS values, after 1.5% promoter may be attributed to the excess promoter introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed.

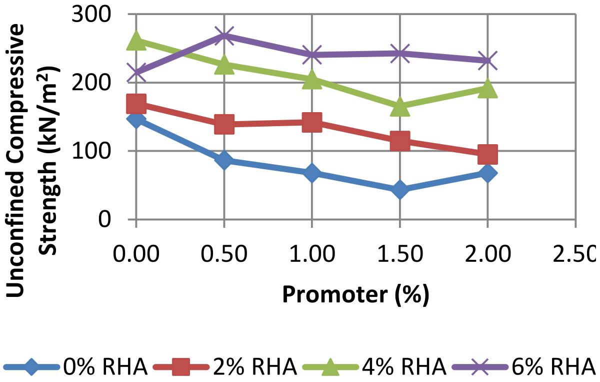

FIGURE 2: VARIATION OF UCS WITH PROMOTER AT VARIOUS PERCENTAGE OF RHA FOR 1 DAY CURING PERIOD.

Variations of UCS with promoter at various percentage of RHA for 7 days curing period are shown in Figure 3. From this figure, it is also observed that UCS gradually values decreased as percentage content of the promoter increases, while increase in UCS values are observed as percentage of RHA increased. UCS reduced from 117.2 to 47.5 kN/m^2 at 1.5 % promoter/0% RHA. Increase in UCS values is observed for the natural soil from 117.2 kN/m^2 to peak value of 300 kN/m^2 at 0.5% promoter/6% RHA. This trend in the variation of UCS values is attributed the reason advanced in the case of 1 day curing period.

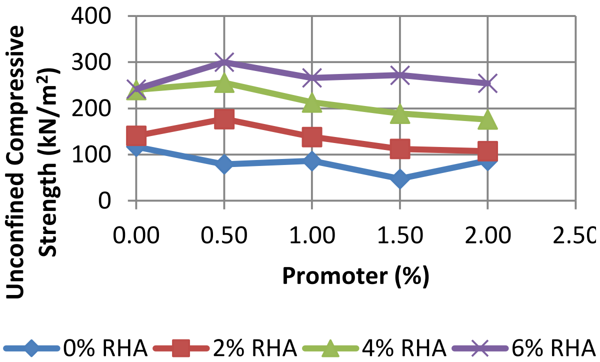

Figure 3: Variation of UCS with promoter at various percentage of RHA for 7days curing period.

Figure 4 presents variation of UCS with promoter at various percentage of RHA for 14 days curing period. Similar trend in variation of UCS values is also observed for the 14 days curing period. UCS reduced from 166.7 to 40.1 kN/m^2 at 1.5 % promoter/2%RHA. For the natural soil, it increased from 166.7.2 kN/m^2 to peak value of 288.9 kN/m^2 at 0.5% promoter/6% RHA. The trend in the variation of UCS values for this curing period is attributed the reason advanced for the case of 7 days curing period.

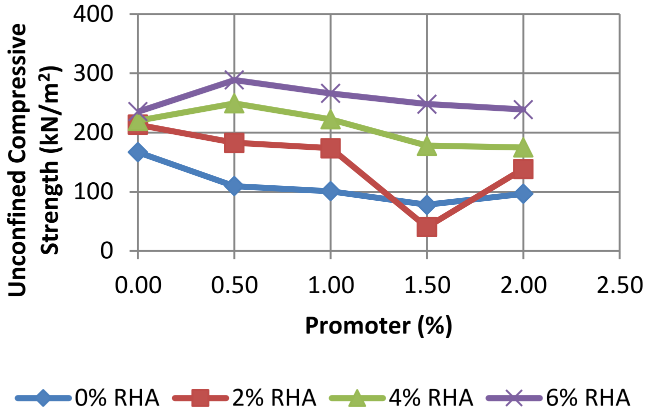

FIGURE 4: VARIATION OF UCS WITH PROMOTER AT VARIOUS PERCENTAGE OF RHA FOR 14 DAYS CURING PERIOD.

Figure 5 presents variation of UCS with promoter at various percentage of RHA for 28 days curing period. From the figure, it is also observed that UCS gradually reduced as percentage of the promoter increased, and increases with increase in percentage of RHA. UCS value reduced from 118.5 to 43.2 kN/m^2 at 2 % promoter/0%. It increase from 118.5 kN/m^2 at 0.5% promoter/0%RHA to peak value of 336.4 kN/m^2 at 0% promoter and 6% RHA. The maximum UCS value recorded was 293 and 295kN/m2 at 6 and 8% RHA contents respectively, after 28 days curing period.

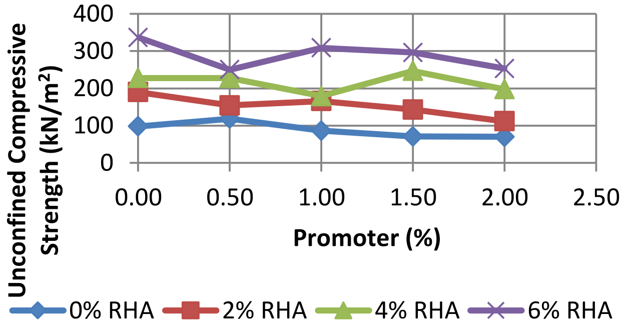

FIGURE 5: VARIATION OF UCS WITH PROMOTER AT VARIOUS PERCENTAGE OF RHA FOR 28 DAYS CURING PERIOD.

Figure 6 presents variation of UCS with promoter at various percentage of RHA for 60 days curing period. From the figure, it is observed that UCS reduces with increase in percentage of promoter. UCS reduces from 132.7 to 74.1 kN/m^2 at 2 % promoter/0%. It increased from 132.7 kN/m^2 at 0.5%promoter/0%RHA to peak value of 268.5 kN/m^2 at 0.5%promoter and 6% RHA. From the figure, as percentage content of RHA increases, the UCS of the stabilized soil increased. This increase in the UCS is attributed to the formation of cementitious compounds between the CaOH present in the promoter and RHA and the pozzolans present in the RHA. The observed decrease in UCS values, after 1.5% promoter may be due to the excess promoter introduced to the soil, which resulted to the formation of weak bonds between the soil and the cementitious compounds, formed. This is in conformity with reason advanced by Alhassan (2008) and Alabi1 *et al*. (2015).

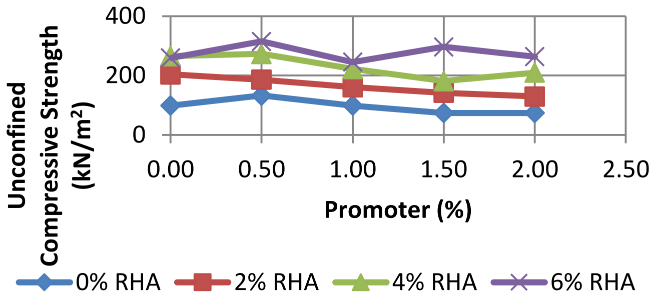

FIGURE 6: VARIATION OF UCS WITH PROMOTER AT VARIOUS PERCENTAGE OF RHA FOR 60DAYS CURING PERIOD.

3.2.2 Effect of curing age on UCS of the stabilized soil

Variation of UCS of the stabilized soil with curing period and at constant content of promoter are presented on Figures 7 to 10 for 0, 2, 4 and 6% RHA content respectively.

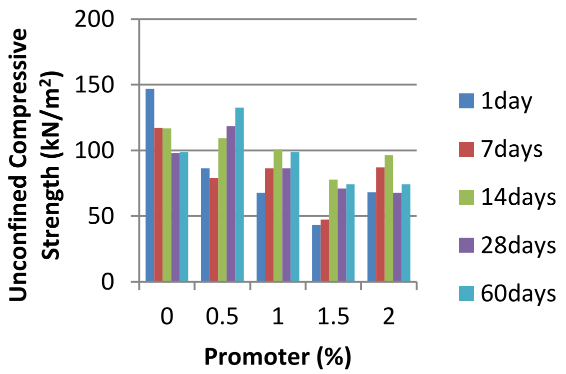

FIGURE 7: VARIATION OF UCS WITH PERCENTAGE OF PROMOTER AND CURING DAYS AT 0% RHA.

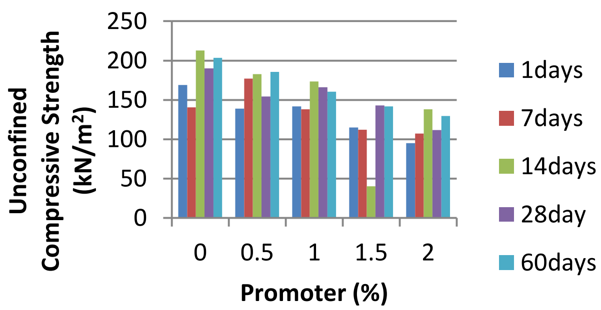

FIGURE 8: VARIATION OF UCS WITH PERCENTAGE OF PROMOTER AND CURING DAYS AT 2% RHA.

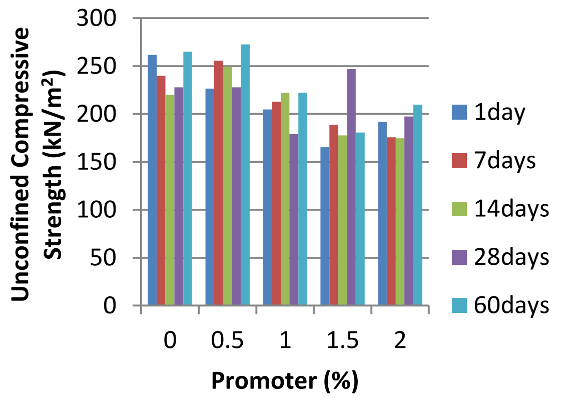

FIGURE 9: VARIATION OF UCS WITH PERCENTAGE OF PROMOTER AND CURING DAYS AT 4% RHA.

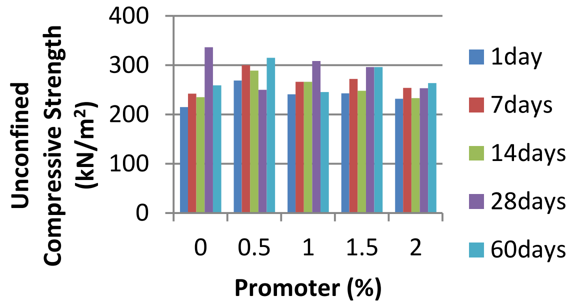

FIGURE 10: VARIATION OF UCS WITH PERCENTAGE OF PROMOTER AND CURING DAYS AT 6% RHA.

Observation of Figures 7 to 10 showed that, although, there is a marginal increase in UCS with increase in curing period, no defined trend in the UCS values was observed as curing period increases at constant content of promoter. The figures showed that increase in percentage of RHA has more pronounced effect on the strength (UCS) of the stabilized soil than curing age, at constant percentage of promoter.

4 CONCLUSION

From the results of this study, the following conclusions are drawn:

The lateritic soil used for the study was identified to be an A--6 and CL (clay of low plasticity) according to AASHTO and Unified Soil Classification System (USCS) respectively.

There was marginal increase in UCS with increase in curing period, but no defined trend in the UCS values was observed as curing period increases at constant content of promoter.

At constant percentage content of promoter, increase in percentage of RHA has more pronounced effect on the strength (UCS) of the stabilized soil than curing age. The UCS values peak at 6% RHA/0.0% promoter and 28 days curing period.

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