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# Utilization of Traditional Building Materials (Rice Husk Ash) in the Production of Sustainable Economic Building Materials

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## ABSTRACT

*This paper tends to evaluate the variations in compressive strength developed between ordinary and improved compressed earth brick earth stabilized with rice husk ash (RHA) at different percentage of RHA additions ranging from 0.0%, 2.5%, 5.0%, 7.5%, 10.0% and 12.5% by weight of dry soil at various curing periods of 14, 21 and 28days respectively. The Clay soil sample collected from Bambami village of Batagarawa Local government of Katsina state Nigeria, while the Rice Husk were obtained from Dandume local government of the same state. the results revealed that, a compressed earth brick (CEB) when stabilized with a rice husk ash is comparable with other bricks in every respect and can perform well in modern construction work and demonstrates the properties and shows its good effect when compared with conventional bricks especially in terms of strength and durability at 10.50% and 12.50% curing period of 28days with compressive strength of 3.98N/mm2, 3.80N/mm2 respectively, while the ordinary un-stabilized compressed bricks with 0.00%(control group) recorded with 1.00N/mm2 as the highest compressive strength value obtained at curing period of 21dyas among the other control samples. Whoever, other parameter measured indicates that, increase in optimum moisture content (OMC) and decrease in maximum dry density (MDD) with increase in percentage addition of RHA. There was also improvement in CBR and Ultimate bearing capacity with increase in addition of RHA content. The result also indicates the maximum dosage of RHA is between 10% to 12.5%. the study therefore, concluded that rice husk ash can be used as an alternative soil stabilization agent for improving the properties of soft clay soil in making compressive earth brick suitable for load bearing walls of not more than two stories in areas where the rice husk is available.*

**Keywords:** *strength, brick, earth, stabilization, compressed, rice husk ash.*

## INTRODUCTION

Building with earth is one of those ancient technologies which still remain alive in the place untouched by industrialization. Innovation, however, has evolved low strength sun dried adobe into burnt clay brick with more strength gained. Mounted interest in searching sustainable green building material has created compressed earth stabilized brick which attract people for its low carbon emission especially in the production stage.

(Riza, Fetra Venny 2011). Rice husk ash (RHA) is a pozzolanic material that could be potentially used in soil stabilization, though it is moderately produced and readily available. When rice husk is burnt under controlled temperature, ash is produced and about 17%-25% of rice husk's weight remains ash. (Mohammed Y. Fattah 2013). The combustion of agricultural residues volatizes the organic matters and a silica-rich ash is produced. Of all the agricultural wastes, rice husk yields the largest quantity of ash with about 93 per cent silica which gives it puzzolanic properties. When burned in ordinary way rice husks produce a crystalline silica ash. However, if burned under suitable conditions, a highly reactive black non-crystalline silica residue having puzzolanic properties is produced.

Temperature and duration of combustion are of utmost importance for good quality rice husk ash. The right temperature is 700°C for 2-3 hours. Thus, a controlled combustion of rice husk in electricity generation plants produces amorphous or non-crystalline silica with about 85-90 per cent cellular particles. These particles are highly micro porous and possess a very high specific surface (5 × 105 to 10 × 105 cm2/g). Rice husk ash when mixed with soil (20 per cent), instead of lime sludge, produces excellent Binding properties.

This binder when used as 30 per cent in mixture with Portland cement gives the properties of Portland puzzolana cement. (S.K Duggal 2008).

## INVESTIGATIONS

The impact of rice husk ash (RHA) has been investigated on a soft clay soil on the natural moisture content, compaction test, C.B.R, Shear and compressive strength tests at various percentages of RHA additives.

## MATERIALS AND PROCEDURE

Clay soils used were obtained from Bambami village of Batagarawa local government of Katsina, Nigeria. The soil was taken to the geology and soil mechanic laboratory of civil engineering Department Hassan Usman Katsina Polytechnic, where by the Natural moisture content, Specific gravity, Atterberg limit, Compaction test, Sieve analysis, C.B.R, Shear box and compressive tests was performed on the clay using various percentage of RHA and using 0% of addition as a control.

A compaction and C.B.R test was conducted on the mixed soil using heavy compaction in accordance with the procedure of BS 1377: Part 4: 1990. Also Atterberg limit test, Specific gravity, Shear box and compressive strength tests was performed at various percentage of the RHA addition of the soil bulk density in accordance with the procedure of BS 1377; Part 4: 1990.

At the end of the investigation, ultimate bearing capacity and maximum compressive strength at different percentage addition of RHA was determined.

The Rice husk used was also obtained from Dandume local government area of Katsina state, Nigeria. The husk was burnt to a temperature of 500$^0$C for converting the husk into ash. The ash was then taken to the block making and concreting laboratory of Building Technology Department of the Hassan Usman Katsina Polytechnic for the block making. Fifty-four (54) number of bricks were casted for this purposes by using manual compress brick making machine, whereby nine (9) blocks was casted for each sample for the curing period of 14, 21 and 28days respectively.

Three (3) blocks from each sample was crushed for compressive strength test and the results showing the variations in the compressive strength at different curing age is in table 8 and figure 3.

**Table1.** *Physical properties of Rice Husk*

| S/No. | Parameter measured | volume |
|---|---|---|
| 1 | Moisture content | 8-9% |
| 2 | Bulk density | 96-160.00 kg/m$^3$ |
| 3 | hardness | 5-6 Mohr's scale |

**Source:** *Kumar, A. et al, properties and industrial applications of rice husk: a review of international journal of emerging technology and advanced engineering vol.2 (2012)*

**Table2.** *Chemical analysis of Rice Husk Ash (RHA)*

| S/No. | Constituents | Composition (%) |
|---|---|---|
| 1 | $SiO_2$ | 67.3 |
| 2 | $Al_2O_3$ | 4.9 |
| 3 | $Fe_2O_3$ | 0.95 |
| 4 | CaO | 1.36 |
| 5 | MgO | 1.81 |
| 6 | LOI | 17.78 |

**Source:** *Auj.T and Alhassan, Potential of RHA for Soil Stabilization 11(4): 246-250 (April, 2008)*

**Table3.** *Properties of Clay Soil before Stabilization*

| S/No. | Paramount measured | Values obtained |
|---|---|---|
| 1 | Liquid Limit | 23% |
| 2 | Plastic Limit | 12% |
| 3 | Plasticity Index | 12% |
| 4 | Optimum Moisture Content (OMC) | 12.50% |
| 5 | Max. Dry Density (MDD) | 1850Kg/m3 |
| 6 | Unified Soil Classification System | CL |
| 7 | Natural Moisture Content | 22% |
| 8 | Specific Gravity | 2.69 |
| 9 | Soil Bearing Capacity | 49KN/m3 |
| 10 | California Bearing Ratio (CBR) | 15.0% |

**Table4.** *Optimum Moisture Content at various percentage addition of RHA*

| S/No. | RHA addition | Optimum moisture content (%) |
|---|---|---|
| 1 | 0.0% | 12 |
| 2 | 2.5% | 13 |
| 3 | 5.5% | 13.4 |
| 4 | 7.5% | 14 |
| 5 | 10.5 | 14.5 |
| 6 | 12.5% | 13.5 |

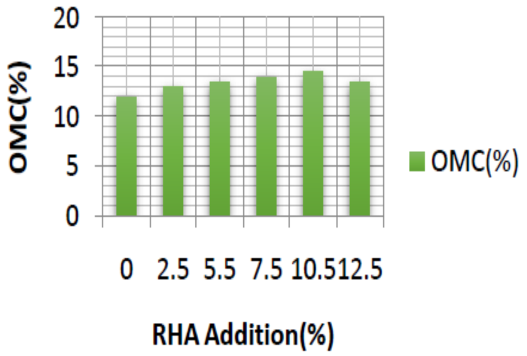



**Figure1.** *Optimum Moisture Content (%)*

**Table5.** *Maximum dry density at various percentage addition of RHA*

| S/No. | RHA addition | Maximum dry density(MDD) kg/m$^3$ |
|---|---|---|
| 1 | 0.0% | 1850 |
| 2 | 2.5% | 1820 |
| 3 | 5.0% | 1820 |
| 4 | 7.5% | 1800 |
| 5 | 10.5 | 1650 |
| 6 | 12.5% | 1600 |

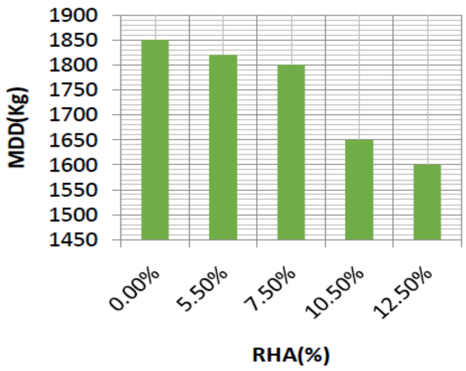



**Figure2**

**Table6.** *California bearing ratio at different percentage of RHA*

| S/No. | RHA addition | CBR % |
|---|---|---|
| 1 | 0.0% | 24.9 |
| 2 | 2.5% | 26.5 |
| 3 | 5.0% | 28.4 |
| 4 | 7.5% | 29 |
| 5 | 10.5 | 24.3 |
| 6 | 12.5% | 23.2 |

**Table7.** *Consistency limit at various percentage addition of RHA*

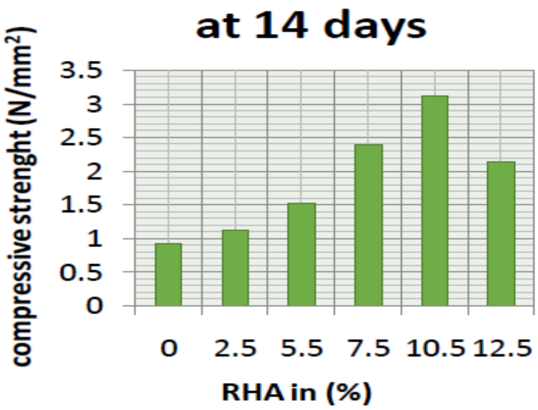
| S/No. | RHA addition | Liquid limit (%) | Plastic limit (%) | PI % |
|---|---|---|---|---|
| 1 | 0.0% | 24 | 12 | 12 |
| 2 | 2.5% | 23 | 12 | 11 |
| 3 | 5.0% | 20 | 11 | 9 |
| 4 | 7.5% | 18 | 11 | 7 |
| 5 | 10.5 | 17 | 10 | 7 |
| 6 | 12.5% | 17 | 12 | 5 |

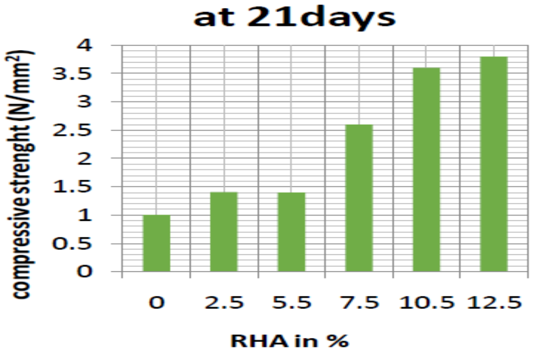
**Table8.** *Direct shear test result and Ultimate bearing capacity at various percentages RHA addition*

| S/No. | C | ø | BC KN/m2 | BC KN/M$^2$ |
|---|---|---|---|---|
| 1 | 0.0% | 2.5 | 11 | 49 |
| 2 | 2.5% | 0.5 | 17 | 142 |
| 3 | 5.0% | 0.5 | 18 | 149 |
| 4 | 7.5% | 0.5 | 19 | 167 |
| 5 | 10.5 | 0.5 | 22 | 233 |
| 6 | 12.5% | 0.5 | 22 | 235 |

**Table9.** *Compressive Strength Test in (N/mm2)*

| S/No. | RHA addition (%) | Age (days) | Compressive strength N/mm2 |
|---|---|---|---|
| 1 | 0.00 | @ 14 days | 0.91 |
| | 2.50 | | 1.12 |
| | 5.50 | | 1.51 |
| | 7.50 | | 2.40 |
| | 10.50 | | 3.11 |
| | 12.50 | | 2.14 |
| 2 | 0.00 | @ 21days | 1.00 |
| | 2.50 | | 1.41 |
| | 5.50 | | 1.40 |
| | 7.50 | | 2.60 |
| | 10.50 | | 3.60 |
| | 12.50 | | 3.80 |
| 3 | 0.00 | @ 28days | 0.74 |
| | 2.50 | | 1.33 |
| | 5.50 | | 1.14 |
| | 7.50 | | 2.16 |
| | 10.50 | | 3.89 |
| | 12.50 | | 3.80 |



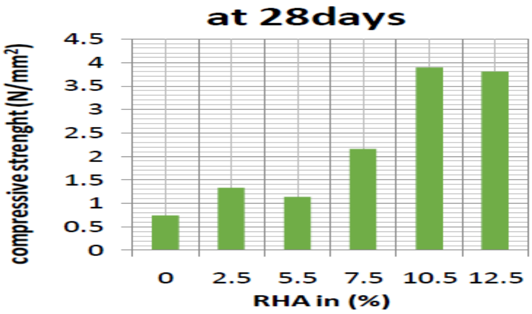



**Figure 3, 4 & 5.** *Compressive strength at different curing age in N/mm$^2$*

## RESULTS AND DISCUSSIONS

**Table1:** presents the findings of the physical properties of the Rice Husk Ash (RHA). The table indicates that the moisture content of RHA was 8-9%, bulk density value of 96-160 and the hardness of 5-6 Mohr's scale (Kumar, A., Mohanta, K. Kumar D. 2012).

**Table2:** the study also shows that, the combine percent composition of silica, $Al_2O_3$ and $Fe_2O_3$ is more than 70%. This shows that, it is a good pozzolana that could help to mobilize the CaOH in the soil for the formation of cementations compounds (Oyotola and Abdullahi).

**Table3:** shows the engineering properties of the clay soil used. Based on the test conducted, the engineering properties of the soil obtained show that, the soil belongs to CL base on Unified Soil Classification System (ASTM D2487).Although the test was conducted during very dry season, but natural moisture content at a depth of 1.5m was found to be 22%. The water Content of soft clay in Malaysia is generally high about 60 to 80%. The un-drained Shear strength is generally low from 7 to 12kpa. The undesirable properties include low strength, high plasticity, poor workability, difficult compaction and high swell potential (Broms, 1990)

**Table4:** presents the results of Optimum Moisture Content (OMC) at various percentage addition of RHA. The result was also presented graphically in Fig.1 which show that, increase in OMC with the increase in percentage addition of RHA up to 10%, it decreases at 12.5%. However, increase in OMC was due to the addition of RHA, which decreased the quantity of free silt and clay fraction and coarse materials with larger surface area were formed (these processes need water to take place) Auj.T. and Alhassan (2008).

**Table5:** Presents the results of obtained from Maximum Dry Density (MDD) test at various percentage addition of RHA. The result was also presented in Fig. 2 which is also indicating that, decrease in the MDD can be attributed to coating of the soil by the RHA which result to large particles with larger voids and hence less density (Osula, 1991)

**Table6:** shows the C.B.R Value at various percentage addition of RHA from 0% to 12.5% respectively. From the table, it can be observed that the C.B.R. Value from 0 to 7.5% increases with the increase in percentage of RHA addition from 24.9% to 29.0%, and then it suddenly decreases to 24.3 and 23.2 at 10% and 12.5% respectively. The decrease in C.B.R. after 7.5% may be due to the excess of RHA which was not mobilized in the reaction.

**Table7:** Also shows the relationship between Liquid limit, Plastic limit and Plasticity which also indicates that the liquid limit decreases from 24% to 17% with increase in percentage addition of RHA from 0 to 12.5%, the decrease can be considered to be as a result of replacement of the soil fines by RHA. According to (Okafor et al, 2003) It can be seen that, plastic limit remains constant. The result further indicates that, plasticity index decreases from 12.0% to 5.0% with increase in percentage addition of RHA from 0 to 12.5%. This trend may be attributed to the replacement of the finer particles by the RHA with consequent reduction in the clay content and plasticity index.

**Table8:** shows the result of direct shear test, the result is also presented in figure 3 above. From the result it can be seen that there is an increase in angle of internal friction with the increase in percentage addition of RHA from 0% to 12.5% that is $18^0$ to $22^0$, while cohesion was initially changed from 2.5% to 0.5% at 0 to 2.5% then it remains constant as 0.5% up to 12.5%. The ultimate bearing capacity was found to be increasing with an increase in percentage addition of RHA from 49 to 233KN/m$^2$. The increase in strength is due to high percentage of siliceous material which indicates that RHA can be an excellent material for soil stabilization.

**Table9:** Show that, the highest compressive strength obtained was 3.98N/mm$^2$ at curing period of 28days with RHA additions of 10.50%. On the other hand, 0.74 N/mm$^2$ was obtained at the same curing period of 28days with addition of 0.00% (control sample). And

this indicates that, the brick stabilized with 10.50% RHA at age of 28days can performs better than conventional brick with 81.41% of compressive strength. According to (Martirena *et al*. 1998) all the blocks produced except those in the control group at all the curing age and that of 2.5% at 14 days can be used for load bearing walls of one or two store buildings for having the compressive strength of 1.4 N/mm$^2$ and 2.8N/mm$^2$ respectively.

## Conclusion

At the end of the study it was found that, on addition of RHA the compaction characteristics of soft clay soil is improved and the optimum moisture content(OMC) increases with increase in percentage of RHA. While Maximum dry density (MDD) decreases with increase in percentage addition of RHA. The study also shows that, there is slight improvement of C.B.R value with increase in percentage addition up to 10%. Others parameters found to be improved are the consistency limit as well as Ultimate bearing capacity of the clay soil with rice husk ash mixture. Therefore, RHA was found to be suitable as stabilizing agent for soft soil improvement, and the maximum dosage is between 10% and 12.5% at curing period of 28days.

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