# AN EVALUATION OF COMPRESSIVE STRENGTH OF CONCRETE MADE WITH RICE HUSK ASH OBTAINED BY OPEN AIR BURNING

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## ABSTRACT
*Pozzolanic materials have long demonstrated their effectiveness in producing high performance concrete. Artificial pozzolanas such as rice husk ash have gained acceptance as supplementary cementing materials in many parts of the world. This work evaluates the Compressive strength of rice husk ash (RHA) as a partial replacement for ordinary Portland cement (OPC) in concrete. A total of 90 cubes of 150mm dimensions were cast with cement replacement level by RHA ranging from 0 to 40%, while a control mix of 28-day target strength of 25N/mm$^2$ was adopted. The cubes were cured in water and tested for compressive strength at 7, 14, 21 and 28 days. Stripping of the concrete cubes from the mould was carefully done after 24 hours of the concrete setting under air. The results with graph plotted show the trend of strength development of the samples. The results show that the density and compressive strength of concrete decreased with increase in rice husk ash content. The 28-day, density and compressive strength dropped from 2485kg/m$^3$ to 2122kg/m$^3$ (i.e.14.61% loss) and from 27.21N/mm$^2$ to 19.00 (i.e.30.17% loss) respectively for 0-40% variation of RHA content. The 10% RHA sample was found to show a promise of attaining similar strength as the control mix at a later curing age having progressed to about 90% (i.e. 24.07N/mm$^2$—89%) of the design Strength by the 28-day.*

**Key words:** Admixture, Cement, Concrete strength, Compressive, Pozzolanic properties, Rice husk ash,

## INTRODUCTION
There has been an alarming rate of increase in the price of building materials in the recent past, this has necessitated government, private and individuals to go in research for locally sourced materials to supplement (replace-fully or partially) the conventional materials. It is in this regard that the researcher intends to carry out this study with a view to partially replace cement in concrete with rice husk ash which is locally available. The whole concept of this idea is to ensure that an average working class citizen of Nigeria will be able to own a house. Concrete is a composite material which consists essentially of a binding medium, within which are embedded particles or fragments of a relative inert filler in Portland cement. Concrete, the binder is a mixture of Portland cement, possibly additional cementitious materials such as fly ash and water; the filler may be any of a wide variety of natural or Artificial, fine and coarse aggregates; and in some instances, an admixture (Moxie, 2001).Concrete is presently one of the most popular materials used in building construction and Other civil engineering works. When reinforced with steel, it has a higher capacity for Carrying loads. Concrete being a heterogeneous material, the quality of the constituents and the proportions in which they are mixed, determine its strength and other properties.

A vast majority of the cement used in construction work is the Portland cement. Portland cement is manufactured by mixing naturally occurring substances containing calcium carbonate with substances containing alumina, silica and iron oxide (ECO-CARE, 2005).

ASTM C 618-05 defined pozzolana as siliceous or siliceous and aluminous materials which in themselves have little or no cementitious properties but in finely divided form and in the presence of moisture, they react with calcium hydroxide which is liberated during the hydration of Portland cement at ordinary temperatures to form compounds possessing cementitious properties. They include pumice, tuffa, volcanic ash, diatomaceous earth, calcined clay, shales, and pulverized-fuel ash (PFA) or fly ash. By - product mineral admixtures such as fly ash, rice husk ash, and ground granulated blast furnace slag are attracting much attention as materials that not only contribute to improvement of concrete performance (for example, high strength, high durability, and reduction of heat of hydration) but are also indispensable to the reduction of energy and carbondioxide generated in the production of cement (Nagataki, 1994). ASTM C 618-05 specified that any pozzolana that will be used as a cement blender in concrete requires a minimum of 70% for silica, alumina and ferric oxide, and a maximum $SO_3$ content of 5%. Neville (1995) described rice husk ash as a pozzolana.

Rice Husk is the outer covering of the rice grain consisting of two interlocking, It is usually produced as a waste while processing rice through a process called threshing (Ikpong, 1993), threshing could be manual or mechanical. Rice Husk Ash (RHA) is obtained after burning rice husk in an electric furnace, which allow for accurate monitoring of the burning temperature. The burning temperature will be maintained within the range of 650-700$^0$C as this is the thermal level that produces highly reactive amorphous ash (Ikpong 1993), The colour is dependent on the carbon content of the ash.

Rice husk ash is a finely fragmented or divided particle of agricultural waste product measuring less than 11/2 [about 1/9mm] in diameter, it is obtained from removal of rice grain from shell called husk (Neville and Brooks, 2002, Varghese 2006). Several institutions have investigated the properties of RHA and found out that it contains higher proportion of silica and there has been some commercial exploitation of its pozzolanic reaction with lime. Rice Husk Ash is also described as a fine pozzolanic material, which itself is poorly cementious but can form a cementitious compound in the presence of lime and water, the pozzolanic value of RHA depends on the burning conditions. Controlled incineration of the husk to about 700$^0$C yield amorphous RHA which is highly pozzolanic (Okpala 1987).

Matawal (2005) revealed that RHA obtained from burning rice husk between temperatures of 1500$^0$C-1560$^0$C could be use in partial replacement of cement as an active addition, the ash melt to a non pozzolanic material greater than 100mm and less than 2mm. The chemical composition has been analyzed to contain $SiO_2$ (90%) $Al_2O_3$ (1.5%), $Fe_2O_3$ (0.5%), C (0.75%) remaining 3% or more is a mixture of CaO, MgO, $K_2O$ and NaO. Okpalla (1987) showed that at 40% partial replacement of cement, Rice Husk Ash (RHA) produced a concrete with the same strength as plain Ordinary Portland Cement (OPC) concrete. Mbachu and Kolawole (1998) examined the influence of coarse aggregate on the drying shrinkage and elastic moduli of concrete with OPC partially replaced with RHA. Results showed that OPC/RHA concrete cast with quarry granite as coarse aggregate exhibited the least drying shrinkage over time and also gave the highest values of elastic moduli when compared with river gravel. On high performance concrete incorporating Rice husk ash as a supplementary cementing material, Zhang and Malhotra, (1996) reported that rice husk ash concrete had excellent resistance to chloride ion penetration and higher compressive strengths at various ages up to 730 days compared with that of the control concrete. Mahmud, Majuar, Zain and Hamid

(2005) reported that with 10 % replacement of cement with Rice husk ash, high workability rice husk ash concrete mixtures in the range of 200-250 mm slump and having 28 days strengths of 80 MN/m2 can be produced. They concluded that Rice husk ash is just as good as Condensed silica fume in producing strength concrete of Grade 80 and can also be produced at a much lower cost the condensed silica fume, The main objective of this study is to investigate the suitability of Rice Husk Ash (RHA) produced by open burning as partial replacement for cement in concrete.

## MATERIALS AND METHODS

The materials used in the tests were Rice Husk Ash, ordinary Portland cement (Dangote Brand), Sand, Granite (19mm coarse aggregate) and Water. The tools used were moulds (150 mm x 150 mm size), shovels, hand trowels and head pans. The Rice Husk was obtained from a milling farm, in Gidan Kwano village in Minna, Niger State. The ash was obtained by burning the Rice Husk on an iron sheet in the open air under normal temperature, during the burning the husk was not tampered with to avoid the formation of crystalline ash which is less reactive to lime (Smith, 1987). The idea of burning them in a furnace was dropped because it will be time-consuming and uneconomical for most people especially those in the rural areas. The burnt ash was passed through a BS sieve (75 microns). The portion passing through the sieve would have the required degree of fineness of 0.063mm and below while the residue was thrown away (Mbachu and Kolawole, 1998). The batching of the concrete materials was done by volume. The mix proportion used for this work was 1:2:4. The proportions of cement to ash in the concrete were 100:0% as control, 90:10%, 80:20%, 70:30% and 60:40% respectively. The fine aggregate used was sand. The sand used was river sand, free from deleterious substances obtained from Bosso area of Minna; the coarse aggregate used was granite obtained from Tri-Acta quarry in Minna with maximum size 19mm (3/4in) specified. The concrete materials cement, aggregates and ash were mixed by hand with a water/cement ratio of 0.55 by weight. The materials were mixed together thoroughly by stirring to form a Uniform mass. The moulds were cleaned with engine oil to prevent the development of bond between the mould and the concrete and permit easy stripping. The freshly mixed concrete was scooped into the mould. Each mould was filled in three layers with the concrete; each layer was rammed 25 times with a tamping rod. Then the concrete cubes in the moulds were left in the open air for 24 hours. For each of the cement: ash proportions, three cubes of concrete were cast. Therefore, a total of 90 cubes were produced for testing. Stripping of the concrete cubes from the mould was carefully done after 24 hours of the concrete setting under air. Curing of the concrete cubes was done by complete immersion in a clean curing tank measuring 1.5 m x 1.5m filled with tap water only for periods of 7, 14, 21 and 28 days respectively. Chemical analysis of RHA was carried out at National Metallurgical Development Centre, Jos. The X-ray Analyzer together with Atomic Absorption Spectrophotometer (AAS) were employed for the analysis except for Sulphur Oxide, Sodium and Potassium Oxide where the Flame Analyzer was used, gravimetric method was employed in the determination of the Carbonate and Hydrogen Carbonate. For compacted bulk density, the container is filled in three stages, each third of the volume being tamped 25 times with a 16 mm diameter round-nosed rod. The overflow is removed. The net mass of the aggregate in the container divide by its volume represents the density. Before crushing, the cubes were brought out of the water and kept for about 10 minutes for most of the water to drip off. They were then weighed on a weighing balance and then taken to the crushing machine in accordance with BS 1881: Part 116 (1983). The cubes experienced cracks due to failure in their strength as a result of the load applied by the crushing machine.

## RESULTS AND DISCUSSIONS

The results contained in Table 1 shows that RHA contains some of the elements (oxides) found in both pozzolana and ordinary Portland cement. When compared with the composition of ordinary Portland cement, the percentage of CaO in ordinary Portland cement was far higher than that of the Rice Husk Ash. These compounds are known to have cement properties that would be beneficiary to the concrete. However, the total percentage of Iron Oxide, Silicon Oxide and Aluminum Oxide is a little above the minimum of 70% specified for pozzolanas (ASTM 618, 2005).

**Table 1:** Chemical content of RHA and OPC used for the research

| Oxide | RHA | |
|---|---|---|
| $Fe_2O_3$ | 0.95 | |
| $SiO_2$ | 67.30 | |
| $Al_2O_3$ | 4.90 | |
| CaO | 1.36 | |
| MgO | 1.81 | |
| $Na_2O$ | | |
| $K_2O$ | | |
| $P_2O_5$ | | |
| $TiO_2$ | | |
| $SO_3$ | 0.75 | |
| L.O.I* | 17.78 | - |
| **% of Essential Oxides ($Fe_2O_3$+$SiO_2$+$Al_2O_3$)*** | 73.15 | |

**Sources:** National Metallurgical Development Centre Jos .

*Where: RHA= Rice Husk Ash, OPC = Ordinary Portland Cement*

From the results shown in Table 2, it can be seen that for the control (0% ash content) and for each cement:ash combination, the compressive strength increases as the age of the concrete increases. This is due to hydration of cement. The control had the highest rate of early strength development. FAO, (1986) reported that cement blended with pozzolanas would produce 65 to 95 % strength of OPC concrete in 28 days. Further, they reported that their strength normally improves with age since pozzolanas react more slowly than cement due to different composition and at one year about the same strength is obtained. This behaviour was confirmed by Sideris and Sarva, (2001) and Sengul Tasdemir and Tasdemir (2005) was similar to the pattern of this study. In their study, Sideris and Sarva, (2001) reported that the replacement of ordinary Portland cement by a pozzolanic material usually has beneficial effects on cement's durability at ages up to 1.5 years. The above account for the low strength values recorded with the addition of ash in the mixture. At age 28 days, the respective compressive strengths were 27.21MN/m$^2$, 24.07MN/m$^2$, 22.06MN/m$^2$, 20.37MN/m$^2$, and 19.00MN/m$^2$. The results show that for the same age, the compressive strength decreases as the proportion of ash increases. This is because the ash possesses little cementing properties compared to a Portland cement.

According to BS 8110 (1985), a grade 25 concrete of 1:2:4 mix design without any blending of the cement should have acquired strength of 13.5 N/mm$^2$ within the first seven (7) days of wet curing and 25 N/mm$^2$ within 28 days. , The 10% RHA sample was found to show a promise of attaining similar strength as the control mix at a later curing age having progressed to about 90% (i.e. 24.07N/mm$^2$—89%) of the design Strength by the 28-day,see Table 3. Based on the above and the result obtained from this work, OPC/RHA ratio of 70/10 would be suitable for concrete. From the results in Figure 1, it can be seen that for the control (0% ash content) and for each cement: ash ratio, the density decreases with age of curing. This is expected because as the concrete hardens it uses up water in hydration, and the products of hydration occupy less space than the original water and cement (Neville, 1995). Also the results show that for the same age, the bulk density decreases as the proportion of ash increases. This is expected because ordinary Portland cement has a higher specific gravity than ash.

**Table 2: Means Compressive Strength Corresponding To Hydration Period And Percentage of Rice Husk Ash (RHA).**

| RHA Content (%) | 0 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|
| | | STRENGTH | (N/mm$^2$) | | |
| Age (days) | | | | | |
| **7** | 18.30 | 16.75 | 15.03 | 14.72 | 12.88 |
| **14** | 22.93 | 22.03 | 17.09 | 16.04 | 13.67 |
| **21** | 24.99 | 22.98 | 18.98 | 17.22 | 16.01 |
| **28** | 27.21 | 24.07 | 22.06 | 20.37 | 19.00 |

**Table 3: Compressive Strength as Percentage of 28-Day Strength of Rice Husk Ash (RHA).**

| RHA Content (%) | 0 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|
| | | STRENGTH | (N/mm$^2$) | | |
| Age (days) | | | | | |
| **7** | 67.25 | 61.56 | 55.24 | 54.10 | 47.34 |
| **14** | 84.27 | 80.96 | 62.81 | 58.95 | 50.24 |
| **21** | 91.84 | 84.45 | 69.75 | 63.29 | 58.84 |
| **28** | 100.00 | 88.46 | 81.07 | 74.86 | 74.86 |

**Source: Author's work, 2011.**

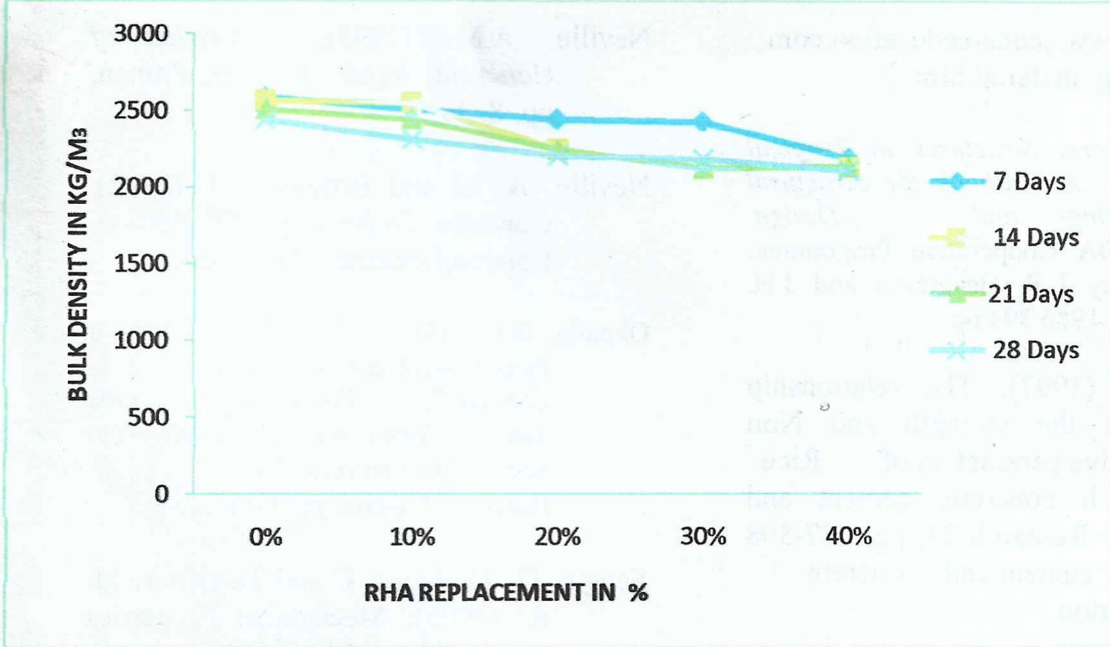


**Fig. 1: Density Of Rha Concrete**

## CONCLUSION

The result of the research work presented demonstrate that although the RHA/OPC concrete only had compressive strength values ranging between 74.86 to 100% of the 28-day strength (for 40% to 10% RHA), the 10% RHA sample was found to show a promise of attaining similar strength as the control mix at a later curing age having progressed to about 90% (i.e. 24.07N/mm$^2$—89%) of the design Strength by the 28-day. The introduction of rice husk ash (RHA) presents a good tendency of pozzolanic activity, while research studies towards boosting the property of the rice husk ash sample from the study area will be a welcome development in continuing the search for alternatives. The RHA/OPC concrete can at the moment be adopted for construction of masonry walls and simple foundations. Further studies should be concentrated on boosting the total **$Al_2O$ + $Fe_2O_3$** content of the RHA sample from Gidan Kwano village where a large quantity of rice husk is being produced which is littering the environment and could be used as supplements to cementitious material. The RHA/OPC concrete sample can be investigated for longer hydration periods such as 56, 90, and 120 days to ascertain its pozzolanic tendencies.

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