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Pozzolanic Characterization of Rice-Husk-Ash from Two Varieties of Rice in Gombe: A Strategy for Achieving Low Cost Housing

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Abstract:- Rice husk ash is a promising pozzolanic material for partial replacement of ordinary Portland cement (OPC) in lightweight concrete construction. With the spate of increasing cost of building materials on daily basis, especially cement, resulting in very high cost of housing, RHA has been found to be an alternative sustainable material that will lead to decrease in cost of mass housing delivery.The objective of the study is to characterize the pozzolanic properties of twoidentified RHA varieties (Jamila and Fadama II) in Gombe, the study area, with a view to determiningthe mechanical properties of lightweight concrete strength at different replacement levels of ordinary Portland cement with the identified RHA varieties. Standard cubes (100mm x 100mm x 100mm) and prisms (100mm x 100m x 500mm) were produced in laboratory. In all204specimens of M15 grade mix were produced, cured in curing tank, and tested by crushing. The strength of the concrete at various replacement of cement viz: 15%, 20%, 25%, and 30% with Rice Husk Ash were compared with controlled mix of same grade M15. The compressive and the flexural strength at 7, 14, 21 and 28 days were determined,and the results at respective days of curing was encouraging. The optimum replacement of rice husk ash with OPC was found to be 20% for Jamila and 30% for Fadama II. The resultscan be used for lightweight construction in low cost housing in the study area.

Keywords:- *Rice husk ash, Optimum replacement level, Low cost Housing.*

I. INTRODUCTION

One of the major problems facing effective delivery of a large number of affordable housing projects in Nigeria over the years has been the incessant increase in price of building materials (Stone, 1993; Arayela, 2003; Ezeigwe, 2015; Okafor, 2016; Ezema, Opoko, &Oluwatayo, 2017; Igwe, Okeke, Onruwah, Nwafor&Umeh, 2017; and Segun, 2019). This has led to the development of much cheaper local building materials, mostly from waste, to enhance the construction of low-cost houses. Achuenu (1999) had earlier noted that substructures, walls and finishes contribute significantly to the total cost of building. It means therefore that any effort at reducing the cost of these elements will subsequently bring down the total cost of a building. Cement has been identified as the most expensive component of concrete, sandcrete blocks and mortar (Bustani, Kunya, Mua'azu, Mohammed and Owoyale 2002) and is the basic building material whose involvement in a successful building, from substructure through walling and concrete works to finishes has been identified as very vital which cannot be compromised (Job, 1998; Arayela 2002; and Duggal, 2012). The most available local material that can reduce the cost of building by reducing the consumption of expensive cement in concrete is rice husk ash (RHA). Studies have established that RHA could be used to replace the Ordinary Portland Cement (OPC) content in concrete (Achuenu, 2005; Oyekan and Kamiyo, 2007; Oyekan and Kamiyo, 2011; Chik, Jaya, Abu-Bakar and Johari, 2011 &Jalam, Jalam, and Ali, 2016), in sandcrete blocks (Oyetola and Abdullahi, 2009; Allen, 2010 &Jalam, 2016) and in plaster and bonding mortar (Oyetola and Abdullahi, 2009 &Jalam, 2016).

II. LITERATURE REVIEW

According to Jalam, Jalam, Sale and Job (2016), an overall cost saving of 24% could be achieved in building construction at optimum replacement level of OPC with RHA of 20% where ever OPC is to be used. The 20% reduction in building materials cost will go a long way in making shelter affordable. However, various optimum replacement level of OPC with RHA were reported by different researchers. For instance, Oyetola and Abdullahi (2009) and Allen (2010)reported that optimum replacement level of OPC with RHA is 20%; Achuenu and Achuenu (2010) and Duggal (2012) reported that RHA can optimally replace OPC at 30%; Hassam and Hilmi (2010) reported 10%; Pornkasem J. *et al* (2018) reported 20%; Khan *et al* (2014) reported 30% while Jenea*et al* (2015) reported 15%.A study conducted by Akeke*et al* (2016) also shows that the elemental chemical composition of natural pozzolan varies based on their locations. The results of Akeke's findings have established that there is variability in the chemical composition of RHA based on location and this will affects its efficacy or pozzolanic activity when used to partially replace cement. Utilisation of rice husk ash (RHA) by exploiting its inherent pozzolanic properties is an effective way to solve the environmental and disposal problem of rice husk (Jalam, 2019).A pozzolanic material or pozzolan is defined as materials that contain active silica (SiO_2) and is not cementitious in itself, but will, in a finely divided form combine chemically with lime in the presence of water at ordinary temperatures to form a strong cementing material **(**ASTM C 618; Okoya Barrack Omondi, 2013 and Duggal, 2008).

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For RHA to be used as pozzolana in cement and concrete, it should satisfy requirements for chemical composition of pozzolans; the combined proportion of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) in the ash should not be less than 70% as per ASTM C618 (Omondi, 2013; Nguyen Van Tuan, 2011). Silica is the compound that has been found to be responsible for the strength in concrete (Fapohunda *et al*, 2017). This has established RHA as having the ability to contribute to the strength development process if used in concrete production. However, the varying percentage of SiO_2 from as low as 73.60% to as high as 97.53% suggests that the reactivity of these RHAs may also vary. Therefore, for an optimum cost reduction to be achieved in utilising RHA in replacing OPC, there is the need to know the optimum replacement levels of the RHA obtained from the varieties of rice grown within a locality.

III. MATERIALS AND EXPERIMENTAL METHODS

The major material for this research is the rice husk, sourced from rice milling industries in Gombe town from two different varieties of rice (Jamilaand Fadama II), the most common varieties grown in large quantities in the state.The two rice hush (RH) samples differ in appearance due to machine and methods of milling, which subsequently affected RHA and the results Figures 1 & 2. The weight of the husk were measured before it was subjected to burning in kiln at a controlled temperature of 700ºC to obtain the desired rice husk ash. After burning, it was allowed to cool and the weight of the ash measured.

The following laboratory experimental analysis were conducted on the two specimens to determine both physical and chemical properties of the varieties viz: X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Scanning electron microscopy (SEM), Compressive strength test of concrete cubes and Flexural strength test of concrete beam.

Fadama II Jamila

Fig. 1: Rice Husk after milling

Fig. 2: Rice husk ash after incineration

A. XRF and XRD analysis

The **XRF** was performed using RigakuMiniflex 600 machine to determine the chemical composition (oxide content such as CaO, SiO_2, $Al_2O_3Fe_2O_3$ etc.) of the RHA varieties while the **XRD** analysis was to determine the silica structure (amorphous and crystallo-graphic) of RHA. X-ray diffraction (XRD) analysis was performed using XRD machine. The diffraction pattern was analysis based on the Bragg's diffraction law ($n\lambda=2d\sin\theta$).

B. Scanning Electron Microscopy (SEM)

The morphology of the RHA samples was obtained using PhenonProX scanning electron microscope machine. The samples were mounted on the specimen stub using double - sided conductive tapesand placed inside the SEM to analysis and the working distance was 12mm.Thepowerful analytical techniquewas performed to analyze the sample specimens at high magnifications, and to produce high-resolution images.SEM relies on the detection of high-energy electrons emitted from the surface of samples after being exposed to a highly focused beam of electrons from an electron gun. This beam of electrons is focused to a small spot on the sample surface, using the SEM objective lens.

IV. CONCRETE WORK

A. Materials and methods

The major materials required for the concrete work are ordinary Portland cement OPC, Rice husk ash sourced from milling industry and incinerated in a kiln at controlled temperature,river sand as fine aggregate, coarse aggregatewith nominal sizes of 20mm sourced from nearby quarry site and water sourced from a nearby borehole.

B. Control Beams and cubes

M15 grade concrete (1:2:4) beams and cubes of sizes (100 x 100 x 500)mm and (100 x 100)mm were produced for flexural and compressive strength test respectively. Twelve (12) number each of the specimens were produced for test at 7, 14, 21 and 28 days of curing immersed in curing tank. Three specimens were tested at each intervals, and the average strength was calculated and the results recorded.

C. Treatment Beams and cubes

Using the same M15 grade of concrete, beams and cubes of same sizes above were produced with cement partially replaced with the RHA at 15%, 20%, 25% and 30%for both flexural and compressive test at 7, 14, 21 and 28 days of curing in curing tank. A total 192 beams and cubes for each varietywere produced for the laboratory test.Three specimens were tested by crushing at intervalsof curing, and the average strength was calculated and the results recorded.

V. RESULTS AND DISCUSSION

Chemical properties of the varieties(XRF)

S/No	Elemental oxides	Percentage composition of varieties (%)	
		Fadama II	Jamila
1	SiO_2	78.16	73.30
2	Al_2O_3	0.77	1.93
3	Fe_2O_3	0.27	1.55
4	CaO	1.07	2.62
5	SO_3	0.48	2.41
6	Na_2O	16.77	0.00
7	K_2O	1.17	5.72
8	P_2O_5	0.43	10.86
9	Cl	0.55	0.76

Table 1: Oxide composition of the two varieties

Table1 shows the elemental chemical composition of the two varieties of rice husk ash used for this study. The combined proportion of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) in the ash in each case is more than the minimum 70% require as per ASTM C618 for RHA to be used as pozzolanas in cement and concrete (Bakar B.H, 2010 andJenea et al, 2015) This shows that RHA varieties as having the ability to contribute to the strength development process if used in concrete production. The silica percentage shows significant difference with Fadama II having 78.16%, and Jamila having 73.30%

RHA Sample	Position (°2θ)	Height (Counts)
Fadama II	24.1036	30.05
	21.0959	52.95
Jamila	26.8787	91.50
	23.0243	30.25

Chemical properties of the varieties XRD

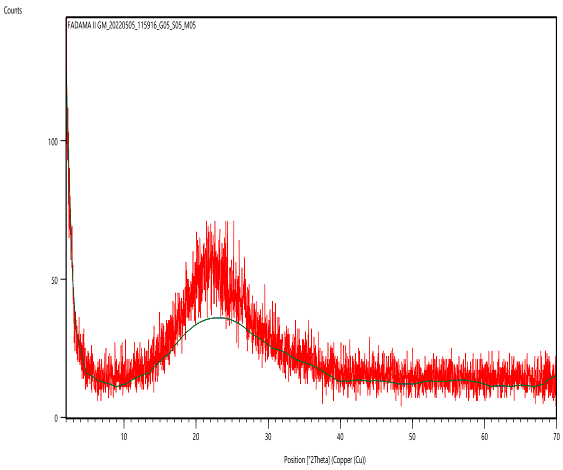


Fig. 1: X-Ray Diffraction of Fadama II variety

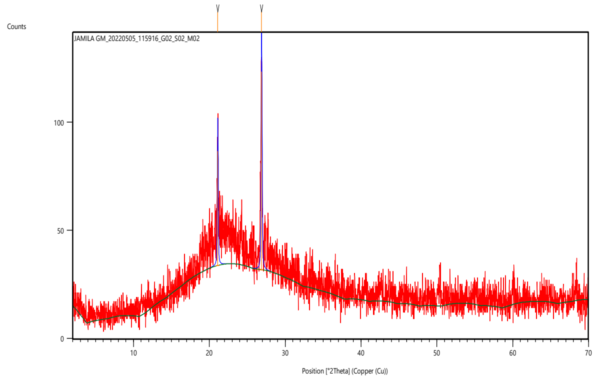


Fig. 2: X-Ray Diffraction of Jamila variety

A. *X-Ray diffraction*

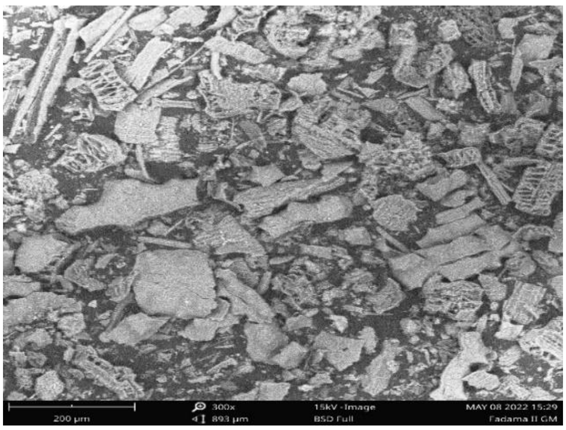
The crystalline phases produced two sharp peaks in the diffractogram in one variety (Jamila) and amorphous phases produced a single broad peak in both Jamila and Fadama II. Since the area under the broad peak of the graphs is significantly greater than the area under the crystalline peaks, from inspection,we can tell that the identified RHA samples are primarily amorphous.

The XRD of the two RHA varieties shown in ***Figures 1and 2*** indicates that the structure of silica present are of amorphous material having a diffused peak of counts at respective 2θ positions indicated in the ***table2*** *below*

Table 2: Diffraction peaks of RHA varieties

B. *Scanning Electron Microscopy (SEM)*

The morphologies of RHA were captured by SEM, as illustrated in thefigures1 & 2 below. Inspection of these figures reveals that the RHA was irregular in shape similar to previous research (Srinivasreddy A.B et al 2013). These irregular shaped particles could significantly affect the properties of the finished product. The finer, angularand irregular particles of RHA along with some porous structures create a higher water demand than Portland cement, indicating that the silica is a highly porous material with a large internal surface area.



(a) Accelerating voltage = 15.0kv, Display image = 300x

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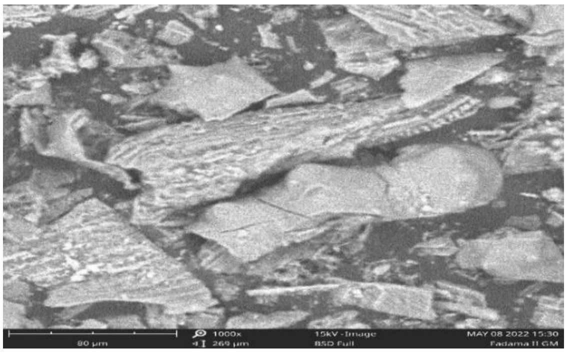
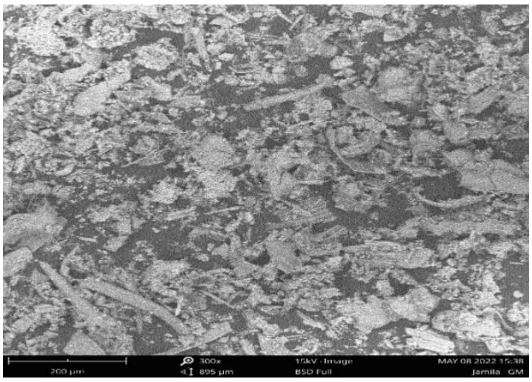
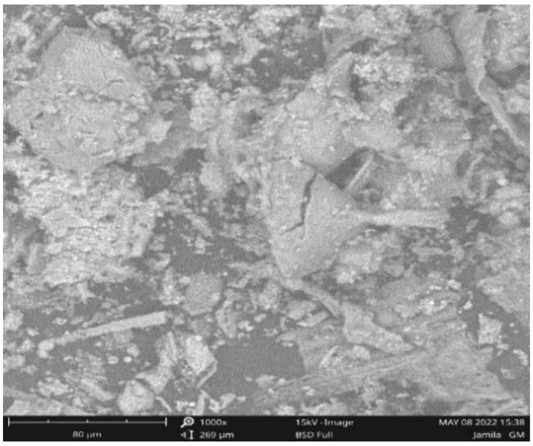


(b) Accelerating voltage = 15.0kv, Display image =1000x
Fig. 3: A and B Fadama II



(a) Accelerating voltage = 15.0kv, Display image = 300x



(b) Accelerating voltage = 15.0kv, Display image = 1000x
Fig. 4: A and B Jamila

VI. ONCRETE WORK RESULTS

% of RHA	Days of curing			
	7	**14**	**21**	**28**
0%	10.59	13.42	13.93	16.10
15%	12.50	13.37	14.50	15.50
20%	12.50	13.57	14.60	16.67
25%	11.83	12.87	14.43	15.83
30%	9.50	11.67	14.13	15.33

Table 3: Compressive strength (Fadama II)

% of RHA	Days of curing			
	7	**14**	**21**	**28**
0%	10.59	13.42	13.93	16.10
15%	9.67	13.37	13.90	15.27
20%	9.43	12.87	13.30	15.13
25%	7.23	9.33	11.67	13.33
30%	7.37	10.37	11.57	13.03

Table 5: Compressive strength (Jamila)

% of RHA	Days of curing			
	7	**14**	**21**	**28**
0%	2.97	3.21	3.60	3.92
15%	2.27	2.35	3.07	3.40
20%	2.80	3.00	3.13	3.33
25%	2.12	2.47	2.73	3.24
30%	2.29	2.60	2.87	3.21

Table 4: Flexural strength (Fadama II)

% of RHA	Days of curing			
	7	**14**	**21**	**28**
0%	2.97	3.21	3.60	3.92
15%	1.64	2.47	2.56	3.20
20%	1.77	2.28	2.87	3.55
25%	1.21	2.46	2.67	2.83
30%	1.40	2.11	2.40	2.86

Table 6: Flexural strength (Jamila)

Tables 3-6: show the results of the compressive and flexural strength at various replacement levels. The optimum replacements for Fadama II was found to be 30% while Jamila attained 20% as highlighted. The results of the flexural strength also falls between 10% - 30% of the value of compressive strength in N/mm^2, which is in agreement with (Neville, 2000 and Balteh M, 2016.)

VII. CONCLUSION

Rice husk ash, which is an agricultural waste, can be converted into valuable product through incineration under controlled temperature, which can further be analyze in laboratory to determine its silica contentfor used in partial replacement of binder in construction. The RHA used in this study is similar to Class F pozzolan i.e(SiO_2 + Al_2O_3 + Fe_2O_3 $\geq$ 70%), and exists in an amorphous form that contained certain amounts of crystalline silica as quartz phase.

The percentage of silica content varies from 76.37 to 80.28 with the change of variety. The difference can be attributed to the condition under which the paddy was grown such as climate, soil, use of fertilizer and the rice varieties as postulated.

The results of strength development of concrete specimens at respective days of curing is in conformity with standard i.e 65% at 7days, 90% at 14days and 99% at 28 days. The compressive and the flexural strength at 7, 14, 21 and 28 days of curing as determined, shows the optimum replacement of rice husk ash with OPC to be 20% for Jamila and30% for Fadama II.An evidenced-base optimum replacement level of OPC with RHAhas been established and tied to variety and location. This will allow for an

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informed use of a particular RHA for an optimum performance and cost saving thereby leading to the reduction in the overall cost of construction particularly in low cost housing delivery in the study area.

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