EFFECTS OF COMBINING RICE HUSK ASH AND CEMENT KILN DUST ON THE COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT
The need to seek for viable alternative construction material to traditional ones has been on the rise because of environmental concern and the fast depletion of natural resources that are considered as traditional raw material for concrete production. Researchers have revealed that agricultural and industrial related wastes and by-products are viable replacement materials, especially for cement in concrete. These wastes and by-products have in the past been explored individually and not in combination. Thus, the purpose of this research was to further investigate if combining two of these wastes as replacement of cement will lead to enhanced or acceptable properties. Cement Kiln Dust (CKD) and Rice Husk Ash (RHA) which have both shown prospects when used individually but which appears to complement each other in terms of oxide composition were adopted for investigation. The percentage level of cement replacement adopted were 0%, 10%, 20%, 30%, 40% and 50%. The replacement percentage by weight was divided equally between the RHA and CKD for each concrete mix. Workability was measured in the fresh concrete by the Slump test and 100mm x 100mm x 100mm cube specimens were tested for compressive strength at 7, 14 and 28days using a concrete mix ratio of 0.55/1:1½:3. Results showed that workability still reduced with increase with increase in percentage of replacement with an acceptable value of 15mm for 30% replacement, if mechanical vibrator is to be employed. Compressive strengths of 29 N/mm2 and 28N/mm2 were obtained at 10% and 20% of replacement of cement respectively. While the maximum strength of the specimen with 0% replacement was 26N/mm2. Although the increase in strength can be considered nominal but the volume in reduction of cement required for a large volume concrete can be significant. This leads to economy of material and enhances the alternative usage of agricultural and industrial wastes. Compressive strength values of 29 N/mm2 and 28N/mm2 for the 10% and 20% cement replacement also satisfied the provisions for minimum structural grade concrete of 25N/mm2.

KEY WORDS: *Rice husk ash, Cement kiln dust, replacement, workability, compressive strength.*

I. INTRODUCTION

Out of the three most important construction materials in the world, Soil, Steel, and Concrete, Concrete is the most widely used, especially in developing countries of the world [11], This is because of the properties of concrete such as ease of production, satisfactory performance in strength, as it can be easily reinforced as appropriate, ability to be moulded into a variety of shapes and high durability, when properly constructed [8,10]. However, concrete consumes a lot of raw and industrial materials and its major cementitous material, cement is not environmental friendly. It is well known that production of cement consumes high energy, depletes natural resources and emits large amount of greenhouse gases (mostly CO_2) it has been reported that the production of one ton of cement consumes about 4GJ of energy and requires about 1.7 tons of raw materials (Limestone and Shale) which leads to environmental degradation and pollution problems [9]. With increasing concentration on environmental protection, energy conservation with minimal impact on economy and non-renewable material conservation, researchers all over the world have been motivated to source for alternatives materials to the traditional raw materials for concrete or the reduction of the use of these raw materials by partial replacement. Agricultural and industrial wastes have become viable sources of materials for the replacement of constituents of normal concrete [2]. For cement, over the years many industrial wastes such as

Pulverized Fly Ash (PFA), Blast Furnace Slag (BFS) Silica Fume (SF), Cement Kiln Dust (CKD), Metakaolin (MK) and ashes produced from various agricultural wastes such as palm oil waste, Rice Husk (RHA), Wood (WA) Maize Husk (MHA), millet husk (MHA), Groundnut Shell (GSA) Acha husk (AHA), periwinkle shell (PSA) and others have been tried as pozzalana or secondary cementitious materials They have been shown to provide environmentally safe, more durable, low heat and low cost concrete construction [1,3,6,7,12] have shown the outstanding technical benefit of incorporating cement replacement materials (RHA) in which it significantly improves the durability properties of concrete. These properties are difficult to achieve by the use of pure Portland cement alone. Extensive studies have been carried out and have indicated that the RHA can be beneficially utilized [7,12]. These supplementary cementing materials play an important role when added to Portland cement because they usually alter the pore structure of concrete to reduce its permeability, thus increasing its resistance to water penetration and water related deterioration such as reinforcement corrosion, sulphate and acid attack. However, the use of these cement replacement materials have been limited to not more than 20-30% maximum replacement of cement and are sometimes attended with other side effects. For instance, workability is known to reduce with increase in proportion of replacement for most cement replacement materials [3,13**]**. A general observation shows that the limitation as to the maximum replacement percentage may be due to the use of only one replacement material. It has been observed that most of these materials often have high concentration of only one or two major or important oxides (CaO, SiO_2, Al_2O_3, Fe_2O_3) of cement and not in the appropriate distribution. Based on this fact it was therefore decided that two materials which appear to complement each other in these oxide composition should be explored. Therefore, Cement Kiln Dust and Rice Husk Ash were chosen as two materials that could be explored. Cement Kiln Dust is a by-product of the Cement manufacturing industry, while Rice Husk Ash is an agricultural waste from rice milling industries. These wastes have been shown to have pozzolanic properties [3,13]. While CKD has a high Calcium Oxide (CaO) content, Rice Husk Ash has a high Silica (SiO_2) content, both CaO and SiO_2 are essential chemicals in the hydration of cement and production of cementitious materials for binding of aggregates in concrete. Rice husk wastes are from rice milling which are in abundance in all parts of Nigeria. The residues constitute environmental problems and its effective disposal is of importance to the rice millers [12]. Furthermore, in Nigeria, the boom in construction in a rapidly developing country has resulted in huge demand for cement, the demand which cement manufacturers have been trying to meet through increased capacity of existing factories or construction of new ones. Thus the production of cement production waste such as cement kiln dust is expected to increase rapidly. Therefore, the cement industry will be concerned as to its safe disposal or usage especially for the leftover that cannot be recycled into production.

This study therefore focused on how cement in concrete may be replaced by these two materials in combination with a view to increasing the percentage of replacement and reducing some of the other side effect like reduced workability.

II. MATERIALS AND METHODS

2.1 Fine and Coarse Aggregates

The fine aggregate (sand) was obtained from naturally occurring clean sand from River Kaduna, in Kawo area, located within latitude 10° 30´ N and longitude 7° 27´E. The properties tests were performed in accordance with the relevant British Standards (BS 812 part 2, 1995, BS 812 part 101, 1990 and BS 812 part 103, 1989). The particle size distribution conducted on the fine aggregate shows it to fall within Zone 2 of BS 882 part 2 (1973) with a specific gravity of 2.65. Coarse aggregate was 20mm maximum size machine crushed granite chipping obtained from local suppliers in Kawo area of Kaduna. It was air dried and sieving was used to remove particle sizes less than 4.75mm. The specific gravity of the coarse aggregate was found to be 2.58.

2.2 Cement

Dangote 42.5 grade cement was used in the study; sealed bags were obtained from local dealers in Mando area of Kaduna. The physical as well as the chemical properties tests were carried out in accordance with Nigerian Industrial Standards, NIS 11(1974), NIS 445(2003), NIS 446(2003) and NIS 447(2003). Where Nigerian standards were not available, British and European Standards such as BS

4550 (1978), BS 12 (1991) and EN 196-1: 1995 were adopted. Tests results showed that the cement met with all standards to be classified as Ordinary Portland Cement (OPC), the oxide composition is as presented in Table 1.

2.3 Rice Husk Ash (RHA)

Rice husk ash used for this research was sourced from a local mill in Ida village in Kagarko LGA, Kaduna state. The husks were collected in jute bags. The burning, grinding and the determination of the oxide composition were carried out. The samples after burning and grinding were sieved using sieve No 200 (75µm). A sample of the ash which was black in colour is shown in Plate I, while the oxide composition is presented in Table 1 as well.

Plate I : Sieved Rice Hush Ash (RHA)

2.4 Cement Kiln Dust (CKD)

The CKD used was obtained from freshly deposited heaps of the waste at the Ashaka Cement production plant, located in Nafada LGA in Gombe State. The sample is shown in Plate II shows that the CKD is off white to cream in colour and the oxide composition is presented is also presented in Table 1.

Plate II: Sample of Cement Kiln Dust

The oxide composition of the three cementitious materials has been presented pictorially in Figure 1 while this composition is compared with typical or standard OPC in Table 1.

2.5 Water

Water is an important constituent of concrete as it contributes to the chemical reaction with cement to form strength giving cement paste. Therefore, the quantity and the quality of water used need to be assessed. Usually water required for concrete mixing must not contain any unwanted organic and inorganic materials in excessive magnitude. The water used was suitable for consumption (odourless, tasteless and colourless) and was obtained from Nigerian Defence Academy Water supply network. The Academy receives its water from the public service of the Kaduna State Water Board.

Table 1: Oxide Composition of Dangote Cement, Rice Husk Ash (RHA) and Cement Kiln Dust (CKD)

OXIDE	Dangote Cement (OPC) (%)	RHA (%)	CKD (%)	Standard OPC (%)
SiO_2	21.55	83.93	9.36	17-25
Al_2O_3	5.28	2.1	5.9	3-8
P_2O_5	-	0.84	<0.01	-
SO_3	1.50	0.43	-	2.0-3.5
K_2O	-	0.84	0.02	-
Na_2O	-	3.44	<1	-
CaO	64.45	1.34	40.77	60-67
TiO_2	-	0.23	0.16	-
MnO	-	0.35	0.15	-
Fe_2O_3	3.95	0.66	2.53	0.5-0.6
MgO	1.85	2.14	1.33	0.5-4.0
V_2O_5	-	0.027	0.01	-
Cr_2O_5	-	0.01	0.027	-
LOI	1.44	3.27	39.74	0.3-1.2

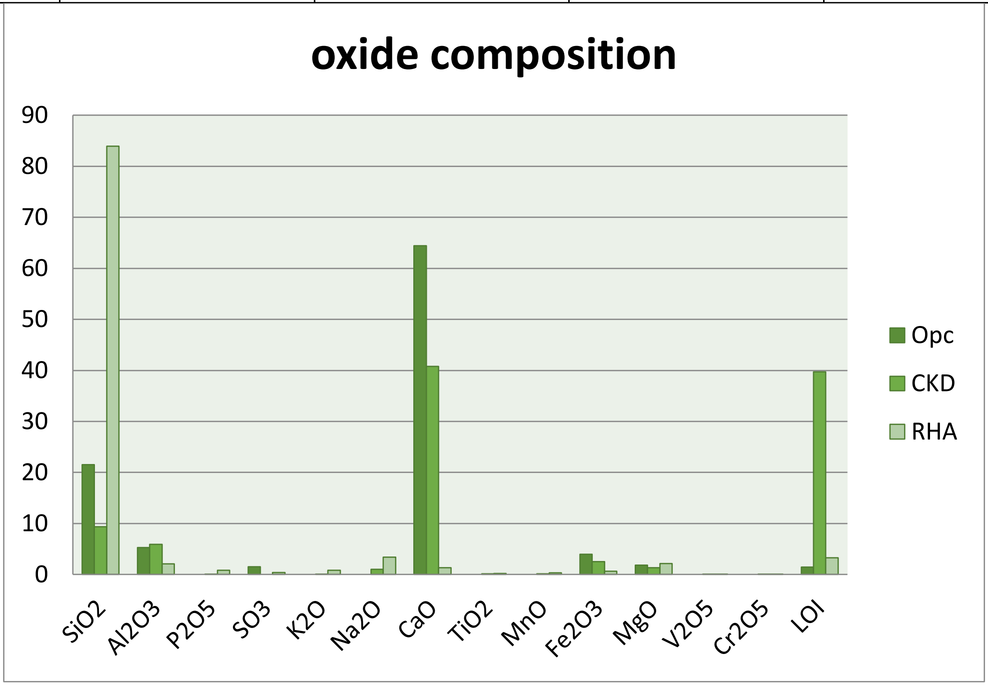

Figure 1 : Comparison of the Oxide Compositions of OPC, RHA and CKD

2.6 Concrete Test Procedure

a)Mixes and Casting Procedure: It is generally known that in Nigeria, the most popular structural concrete grade is 25N/mm^2 measured on standard cube samples. Therefore and based on experience, a prescribed mix, 0.55/1:1$^1/_2$:3 was adopted. This was chosen to achieve this grade of concrete. Cement replacement was done from 0% to 50% at steps of 10% and the replacement proportion was divided equally between the two replacement materials as shown in Table 2. Mixing was done on an impermeable surface in the laboratory until a consistent mix was achieved. 100mm cube samples were thereafter cast according to the provisions of BS 1881 Part 108 (1983) and curing was in water for 7days, 14days and 28days strengths.

b) Tests: The Slump test was adopted as a measure of workability and was carried out according to BS 1881 Part 108 (1983) provisions. At the appropriate time the cubes were removed from water and tested in the ELE 3000kN Compression machine in the Civil Engineering laboratories of the Nigerian Defence

Academy. The compressive machine is configured to crush cubes in accordance with BS 1881 Part 116 (1983) standard.

Table 2: Cement Blending Proportions

Mix ID	Proportion of Cementitious materials (%)			TOTAL (%)
	Cement	CKD	RHA	
A	100	0	0	100
B	90	5	5	100
C	80	10	10	100
D	70	15	15	100
E	60	20	20	100
F	50	25	25	100

III. RESULTS AND DISCUSSION

3.1 Oxide Composition of Cement Blends

As may be observed from Table 1, the oxide composition of RHA shows that it contains 83.93% silica which is an important ingredient as it imparts strength to the cement due to the formation of Dicalcium and Tricalcium Silicates. Although, the presence of excess silicate strengthens the cement, but at the same time it prolong the setting time [**14**]. The lime content of RHA is relatively very low at 1.34%, this result is consistent with previous observations [2]. On the other hand the Lime content of CKD is moderate at 44.77% but the Silica is very low at 9.36%. The two materials are expected to complement each other. The oxide composition of the cement produced by the combination of these materials at the proportion specified in Table 2 is presented in Table 3.

Table 3: Proportion of Major Oxides of Cement in Different Mixes Compared with that of OPC

Oxide	Mix A (%)	Mix B (%)	Mix C (%)	Mix D (%)	Mix E (%)	Mix F (%)	Std OPC (%)
CaO	64.5	60.2	55.8	51.5	47.1	42.8	61-65
SiO_2	21.6	24.1	26.6	29.1	31.6	34.1	17-25
Al_2O_3	5.3	5.2	5.0	4.9	4.8	4.7	3-8
Fe_2O_3	4.0	3.7	3.5	3.2	3.0	2.8	0.5-0.6

Table 3 was prepared on the assumption that the oxides in Cement will act as similar oxides in Cement. As may be observed, none of the blended cement met the standard for the OPC for the critical oxide for strength, CaO, the best being Mix B with 10% replacement. However, it was assumed that this may not be too critical since pozollanic activities in concrete is attributable to two actions; pozollanas either act as fillers or react with CaOH produced by the hydration of cement to produce more cementitious material in the matrix.

3.2 Workability.

As has been generally observed in previous works, slump of concrete mixes decreased with increase in replacement of cement. The results of Slumps for various mixes are as presented in Table 4 and the general trend is presented in Figure 2. This observed trend may be attributed to the fact that the density of the RHA is lower than that of Cement and CKD and the particle size finer. Therefore, the volume of RHA is higher than that of the replaced cement leading to higher water requirement for wetting and mixing RHA proportion when compared to that of similar weight of Cement. In order to increase the workability, it may be required that the percentage of RHA in the replacement proportion be made less than that of the CKD. This in itself may increase the CaO content of the cement blend and drive it nearer to that of the standard OPC.

Table 4: Slump Test Result of Mixes

Mix ID	Total Percentage Replacement (%)	Slump(mm)	Type of Slump
Mix A	0	110	Shear slump
Mix B	10	80	True slump
Mix C	20	40	True slump
Mix D	30	15	True slump
Mix E	40	0	No slump
Mix F	50	0	No slump

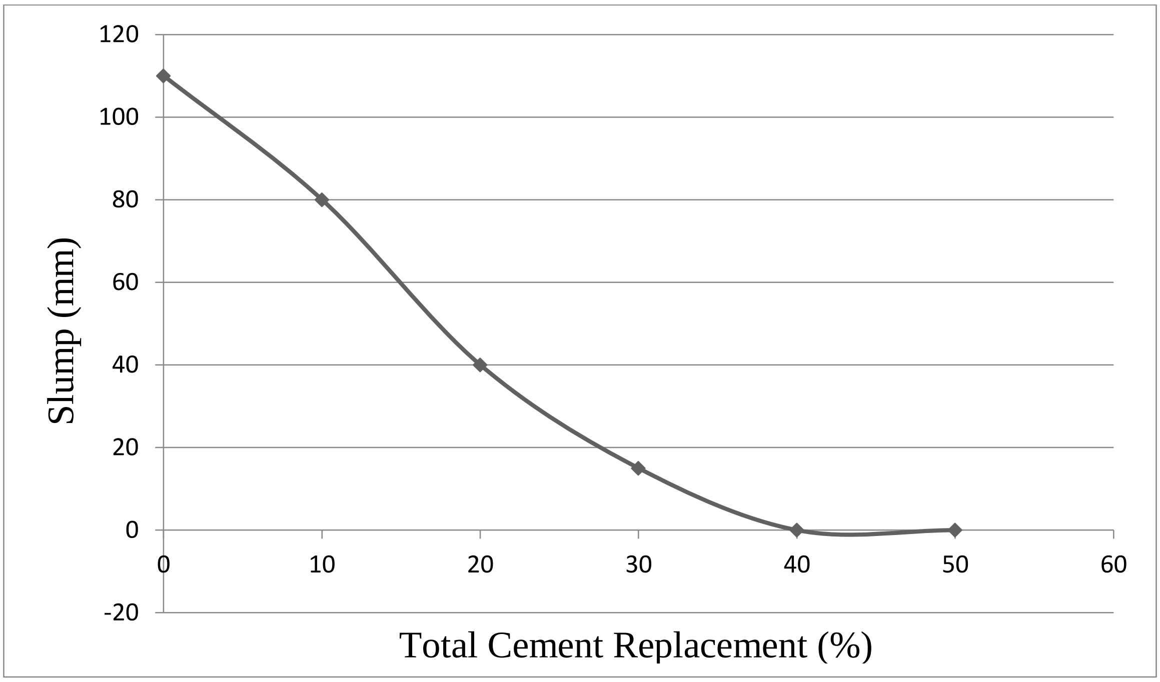

Figure 2: Workability (Slump) of Concrete Mixes Made with Different Cement Blends

3.3 Compressive Strength Test

The results of the Compressive strength test have been plotted in Figure 3. It shows increasing strength with age for all the blends, however there was a curious drop in the rate of strength growth between 7 days and 14days for all the blends except the 10% replacement blend. Since this also affected the 0% replacement concrete, it may be due to a systemic problem and may not be attributable to cement replacement. The general trend is that compressive strength steadily decreases with increase in the percentage of replacement of cement in the concrete. However, the target value of 25N/mm^2 was achieved at replacement value not higher than 20% (26N/mm^2 at 0%, 29N/mm^2 at 10% and 28N/mm^2 at 20%). Note that there may have been an undervaluing of the 0% figure as the strength at 7 days was higher than those for 10% and 20% replacements. From the trend of the result, it appears possible to achieve a higher replacement level say up to 30%, if the blending formulation is revised with a higher proportion of CKD in the replacement portion. For example, a combination of either 20% CKD and 10% RHA or 25% CKD and 5% RHA could be explored. This may result in improved workability and also increase in strength at 30% replacement.

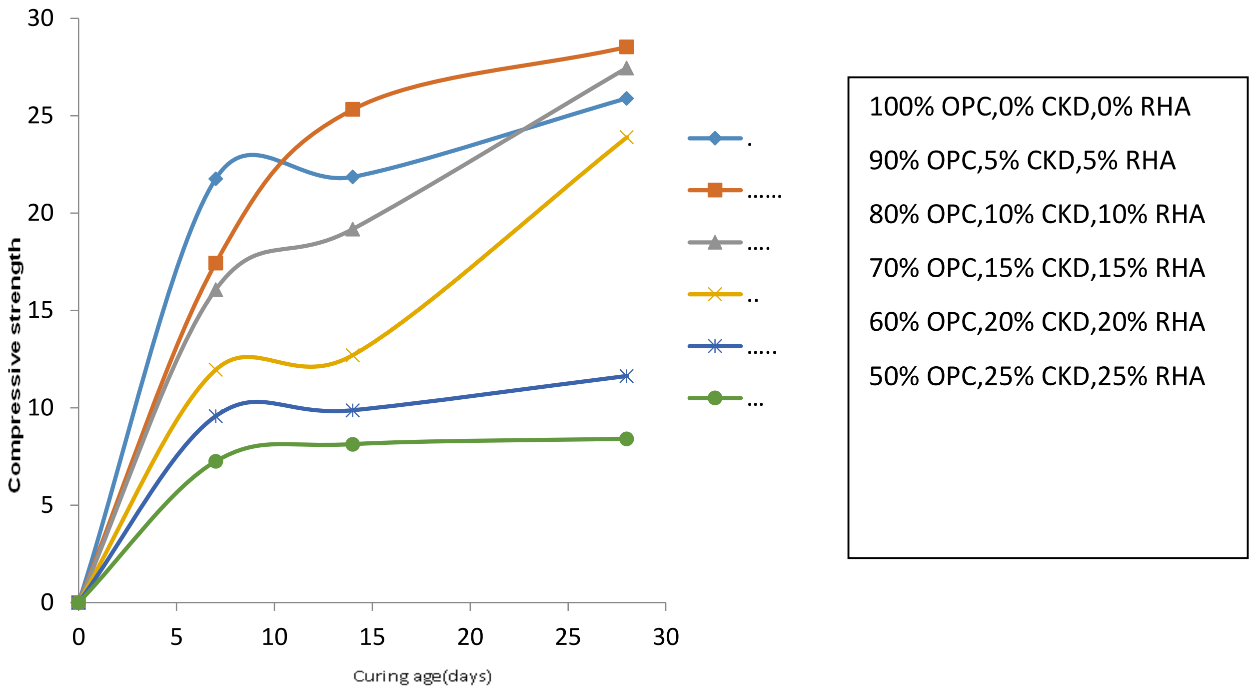

Figure 3: Relationship Between Age and Concrete Compressive Strength for Different Percentages of Cement Replacement with Combined CKD and RHA

IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The following conclusion can be drawn:

a) Workability of concrete decreased with increase in cement replacement with the CKD + RHA blend. An acceptable limit for workability is at 30% replacement especially when a mechanical vibrator is to be employed.

b) The target grade of 25N/mm^2 was achieved at replacement of not more than 20% (26N/mm^2 at 0%, 29N/mm^2 at 10% and 28N/mm^2 at 20%). At 30%, the compressive strength obtained was about 23N/mm2 which was just short of target but above 30% replacement, the grade obtained fell well short of target (**11.5**N/mm^2 at 40% and **7.5**N/mm^2 at 50%). A higher replacement value has not been achieved with these materials and formulation method.

4.2. Recommendations

a) To achieve a better workability and possibly higher replacement, it may be necessary to explore other blending formulation, especially one which has a higher percentage of CKD in the replacement portion.

b) If this higher percentage is achieved, then further work can be done on tensile strength, flexural strength and durability.

c) Since CKD is still a by-product of cement production, other industrial and agricultural wastes or materials with high CaO content can be explored in combination with RHA as cement replacement material.

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