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COMBINED EFFECT OF RICE HUSK ASH AND CEMENT KILN DUST AS CEMENT REPLACEMENT MATERIALS IN CONCRETE

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ABSTRACT

This study is aimed at evaluating the suitability of using ash sourced from rice husk and dust from cement kiln (RHA/CKD) as a partial replacement of conventional cement (ordinary Portland cement) in concrete with 1:2:4 and 0.55 as a mix ratio and water cement ratio respectively.. The ash was obtained by uncontrolled burning process; the ash was cooled, grounded, and passed through a 75 microns BS sieve. The result of X-ray fluorescence (XRF) test carried out on rice husk ash RHA and Cement Kiln Dust CKD indicates that the RHA has higher content of silicon oxide when compared with CKD, while CKD has higher content of calcium oxide compared with RHA. Cement was replaced with 0 %, 10 %, 20 %, 30 %, 40 % and 50 % of combined RHA/CKD and 100 mm cube Concrete cubes were cast and cured in water for 7, 14, and 28 days. The result of workability showed that as the RHA/CKD content increased the workability (slump) decreased, but setting times, consistency and soundness of RHA/CKD-cement paste increased with RHA/CKD content increase; also, the compressive strength of RHA/CKD based concrete increases with age, and with RHA/CKD content up to 20 % cement replacement at 28 days, then gradually decreases. It was concluded that the optimum blend of RHA/CKD as cement replacement in concrete should not be more 20 % replacement.

Keywords: Rice husk ash (RHA), Cement kiln dust (CKD), workability, compressive strength and pozzolana

INTRODUCTION

The constant increase in the need to find a beneficial use of wastes from industries and agricultural products in order to ensure that the environment is protected, energy is conserved have pushed researchers to look for substitutes of cement as a binder in the construction industries with little effect on the economy. Such materials gave safe, stable, more durable and low cost civil engineering constructions (Afolayan *et al.,* 2015). In the world today, the quest to achieve maximum economy, efficiency and safety in sustainable engineering constructions with the use of wastes is becoming the world focus and a subject of major interest.

Dust from Cement Kiln and Ash from Rice Husk were chosen as materials that could be used for the experiment. Dust from Cement Kiln is an unwanted material obtained in Cement production process while Rice Husk is an agricultural by-product (waste). Research carried out by researchers revealed that wastes (by-products) have good pozzolanic properties. With CKD having a high Calcium Oxide (CaO) content (about 40.63 %) and the Ash from Rice Husk having a high Silica oxide (SiO_2) content (70.93 %) and as always known, both CaO and SiO_2 are necessary oxides in cement hydration and production of calcium-silica- hydrates (CSH) for binding of concrete aggregates. Cement Kiln Dust acts as an additive in the production of concrete whether other pozollanas are added or not. El-Mohsen and Mostafa, (2015) stated that not more than 5 % CKD replacement would not affect the strength properties of concrete. Also Zainab, (2013) opined that using CKD as an additive up to 20 % will result to an improved compressive strength.

Mujedu *et al.,* (2014) conducted out a study on the use of Corn Cob Ash and Saw Dust Ash as Cement Replacement in Concrete Works. The results showed that the combination of CCA and SDA is good as a pozzolan having a sum of SiO_2, Al_2O_3 and Fe_2O_3 up to 76.67 %. The slump value was found to step-down because the content of CCA and SDA contents steps-up, indicating that concrete becomes stiffer with ash content increase. The strength in compression of the concrete was found to increase as the curing period increased and then decreased as the ash content increased. it has been observed that the compressive strength of concrete was lower at early stages, but improved significantly up to 56 days.

Obilade, (2014) carries out a study on Ternary Blended in Cement Concrete with some content of Rice Husk Ash and Saw Dust Ash**.** The results showed an increased Compacting factor with RHA percentage, relatively to the SDA percentage in the blends. The same increase was also observed on the compressive strength of RHA and SDA in the blends. An

Optimum Strength of the mixes considered was 70 % OPC at 25 % RHA and 5 % SDA with a value of 15.08 N/mm^2. It is recommended that OPC-RHA-SDA-concrete should be adopted as lightweight concrete civil works.

MATERIALS AND METHODS

Materials

The materials sourced and used are:

Cement

The cement used for this study was ordinary Portland cement (OPC) with grade 42.5. It's a finely powdered, grayish binding material.

Fine Aggregate

Fine aggregate was sourced from Samaru campus of Ahmadu Bello University, Zaria. It was conformed to BS 882 (1992) requirement.

Coarse Aggregate.

Coarse aggregates having nominal maximum sizes of 19-20 mm used was sourced from a local commercial quarry within Zaria, with average of 2.63 and 1460 kg/m^3 as specific gravity and bulk density respectively.

Water

Potable water from concrete materials laboratory Civil Engineering Department Laboratory of Ahmadu Bello University, Zaria

Rice Husk Ash

The rice husks were obtained from a mill at Kontagora Local Government, Niger state. It was air dried and then burnt in a drum, the ash was ball milled after cooling for four hours at Chemical Engineering Department, A.B.U Zaria. The ash was sieved through sieve No 200 (75 μm) to obtain an ash with particle size similar to that of OPC.

Cement Kiln Dust

The CKD used was sourced from deposited heaps of CKD waste at the Sokoto Cement Company of Northern Nigeria production plant, located along Kalambaina Road Sokoto in Sokoto State, Nigeria. The CKD was sieved through BS, No 200 (75 μm) and stored in an air tight container to prevent it from absorbing moisture from the environment.

Oxide composition: X-ray Fluorescence (XRF) test was conducted at the Chemical Engineering Laboratory A.B.U Zaria, so as to know the oxide composition of the ash.

Methods

A grade 20 concrete was designed using the absolute volume method, Table1 presents the proportion of concrete constituent materials used.

Table 1: Proportions of concrete constituent materials

% Replacement proportion	Blended (RHA/CKD)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Rice husk Ash (g)	Cement kiln (g)
0	(0 % + 0 %)	5.70	6.90	13.80	0	0
10	(2 % + 8 %)	5.13	6.90	13.80	11.40	45.60
20	(4 % + 16%)	4.56	6.90	13.80	228	912
30	(6 % + 24 %)	2.40	6.90	13.80	342	1368
40	(8 % + 32 %)	2.10	6.90	13.80	456	1824
50	(10 % + 40 %)	1.80	6.90	13.80	570	2280

Standard Consistency Test

The standard consistency test on cement paste was carried out in accordance with BS EN 197-1:2009 standard. The penetration of the plunger to 5 to 7 mm above the soffit of the paste mould indicates normal consistency.

Initial and Final Setting Times Test

The test was conducted to evaluate the initial setting time and final setting time of cement paste in accordance with BS EN 196 part 3:1995. The time (min) when the plunger penetrates 5-7 mm above the mould soffit was considered as the initial setting time and the final setting time (min) was when the annular of the needle doesn't make an impression on the paste.

Slump Test

The ease at which the fresh concrete flows was assessed using the slump or workability test in accordance with BS EN 12350-2:2009 standard.

Soundness

This soundness of cement paste was measured in accordance to BS EN 196-3: 1995

The Compressive Strength Test

The resistance of the concrete to crushing when the cement was replaced by the blend of RHA-CKD was conducted in accordance with BS EN 12390, Part 3. It was conducted at Civil Engineering Department, A.B.U Zaria. Three samples par specimen were crushed (compressive strength test) each after curing in water for 7, 14 and 28 days using a 2000 kN load capacity Compression Machine at a fixed rate of 15 kN/s and the average of the results was taken as a representative result.

RESULTS AND DISCUSSION

Chemical Composition of RHA and CKD

Table 2 shows the oxide composition (%) of RHA and CKD, the oxides are an indication of the possibility of RHA and CKD to have pozzolanic properties.

Table 2: Result of chemical composition of RHA and CKD

S/No.	Oxides	RHA (%)	CKD(%)
1	Na_2O	0.121	0.5
2	MgO	1.881	1.36
3	Al_2O_3	13.13	5.9
4	SiO_2	70.19	9.36
5	P_2O_5	1.75	0.06
6	SO_3	0.669	0.2
7	K_2O	0.885	0.02
8	CaO	4.356	40.63
9	TiO_2	0.045	0.16
10	Cr_2O_3	0.002	0.027
11	Mn_2O_3	0.065	0.15
12	Fe_2O_3	0.304	2.53
13	LOI	13.26	30.20

The results of chemical composition of RHA and CKD show that, RHA has a very high percentage of Silica oxide followed by CKD which also has another high percentage of Calcium oxide. This agrees with Afolayan *et al.,* (2015), who stated that "CKD has a high Calcium Oxide (CaO) content while Rice Husk Ash has a high Silica (SiO_2) content, and both CaO and SiO_2 are essential compounds in the hydration of cement'' this finding is also in par with (El-Moshen and Mostafa, 2015),

Slump Test

Figure 1 shows the relationship between a slump and percentage addition of RHA/CKD content in 0%, 10 %, 20 %, 30 %, 40 % and 50 % respectively. The results indicate that the slump of the fresh concrete mix decreases as the percentage of RHA/CKD content step-up. The decrease may be as a result of the high loss on ignition of RHA and CKD which makes the RHA and CKD absorb water and hence decreased workability, or due to increase water demand as a result of the high specific surface area of RHA and CKD (Wazumtu and Ogork, 2015**).** This agrees with (Sumadi and Lee, 2008) and with the finding by Oriola *et al.*, (2015) that decreasing the percentage replacement of RHA will lead to low water demand in the mix and that will give a more workable concrete. The spaces between the cement particles will be occupied by the RHA and CKD particles which increases the mix stability and results to an increased cohesiveness (reduced workability). The water absorbing characteristics of RHA increase the demand of water with the increasing amount of RHA in the mixture.

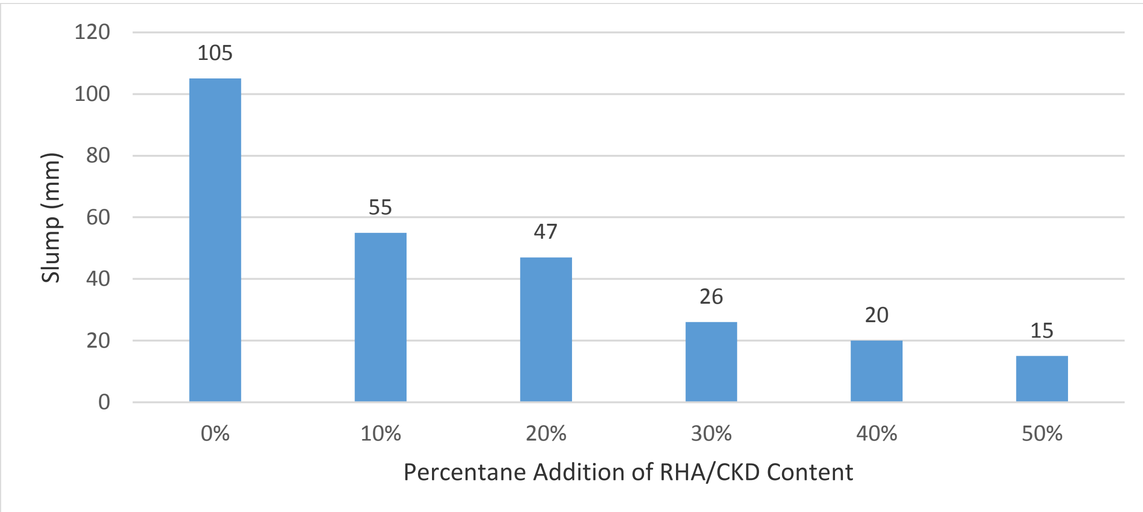

Figure.1: Slump values against RHA/CKD replacements

Consistency

The addition of RHA/CKD content to cement paste escalated the normal consistency of cement paste as shown in Figure 2. The trend indicated that additional water is demanded for the particles to wet as the surface area of the particle is ballooned according to Marthong, 2012. Large quantity of water is needed to wet, extra quantity of RHA/CKD added to the mix to produce RHA/CKD-cement solid mixture and this may probably contributed to step-up in cement-RHA/CKD paste consistency, this correlates with Ettu *et al.*, (2013) explanation on OPC-Sawdust ash cement composites.

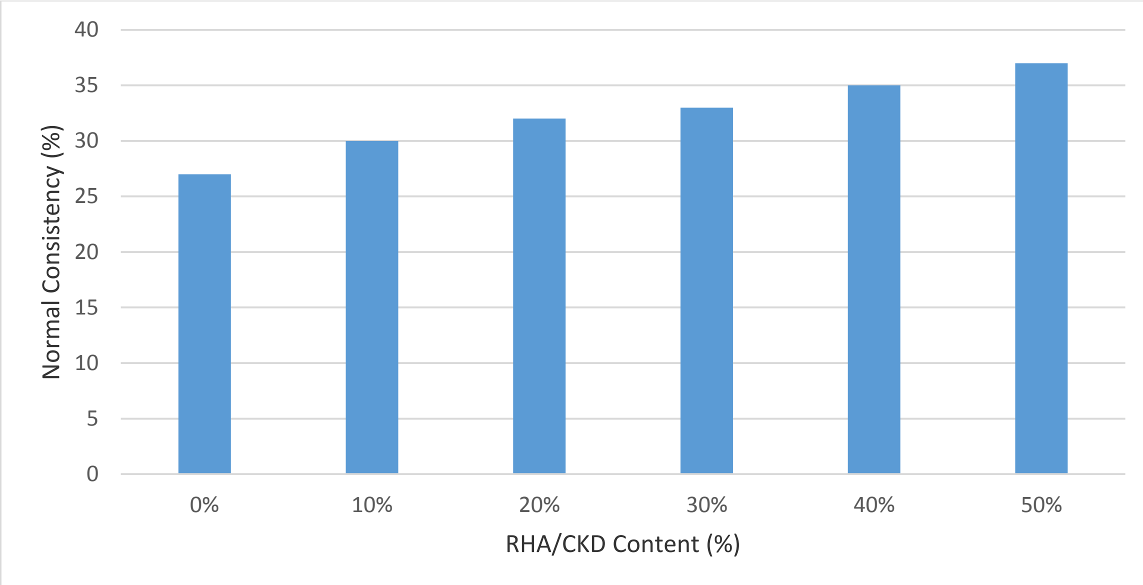

Fig. 2: Normal Consistency of RHA/CKD-Cement Paste

Setting Times

The results of setting times presented in Fig. 3 unveiled that the result of setting times of RHA/CKD-cement paste increased with increment of RHA/CKD content. This trend may be as a result of the potassium oxide (K_2O) presents in RHA/CKD that obstructs the total compounding of lime and induces setting anomalies effect on setting (Stocchi, 1990). It may be as a result of the formation of magnesium silicate ($MgSiO_3$) in the cement paste which was cognised to be a retarder thereby creating a time lag in the setting time of cement (Wazumtu and Ogork, 2015**)**.

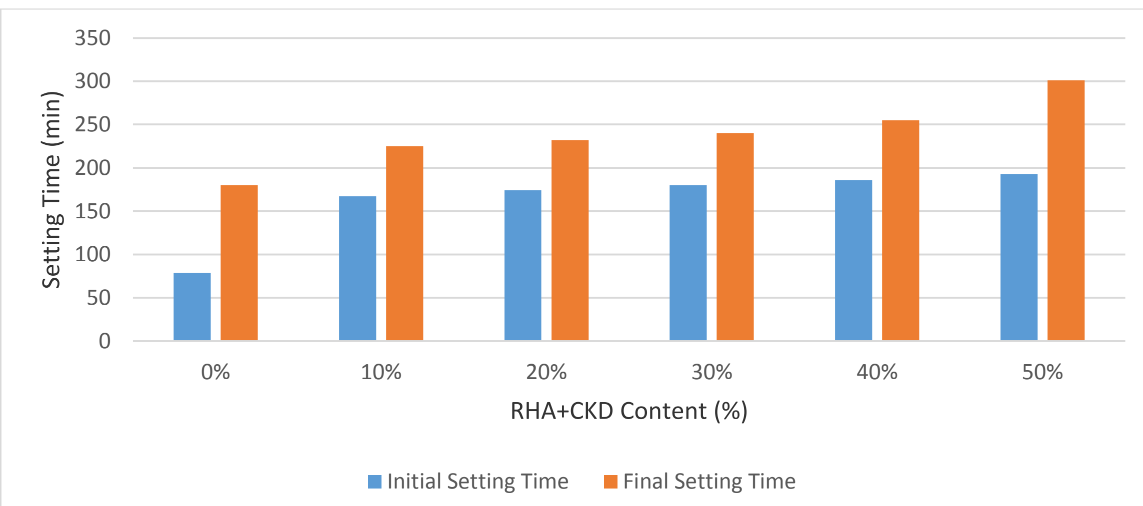

Fig. 3: Setting Times of RHA/CKD-Cement Paste

Soundness of cement

From Figure 4, it can be observed that the soundness of cement increases as the RHA/CKD content increase, and the values of soundness obtained at each replacement levels fall within the range of the acceptable limit specified by BS EN 196-3 (1995). Which stated that cement is only sound if it soundness value falls within the range of 0-10 mm and unsound above 10 mm.

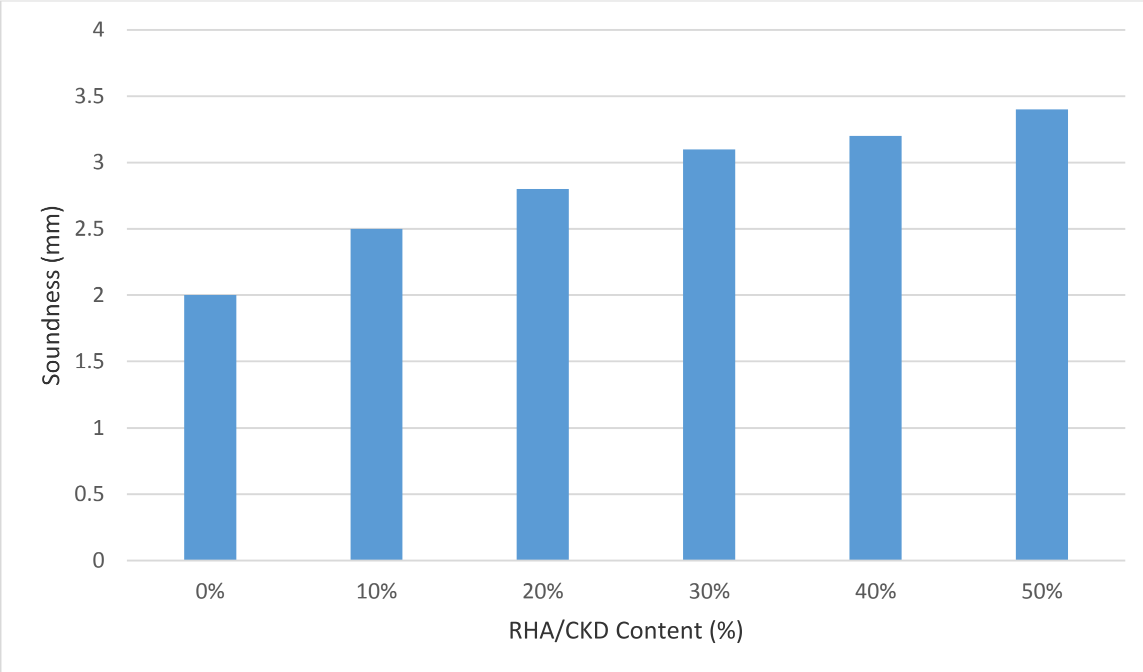

Fig. 4: Soundness of RHA/CKD-Cement Paste

Compressive Strength

The results of compressive strength test of RHA/CKD-concrete revealed that the strength of concrete cubes increased as the curing age, the compressive strength value became stepped-up with 20 % addition of RHA/CKD at 28 days. A further increase beyond the 20 % RHA/CKD content shows a step-down in the strength of the concrete as can be seen in Figure 5. The increase in the strength of concrete with an increment of curing age is probably on account of hydration of cement and RHA/CKD, whilst the step-up in compressive strength as the RHA/CKD content increased equal to 20 % perhaps owing to the establishment of extra calcium silicate hydrates from the pozzolanic reaction of RHA/CKD with the cement oxide and a pozzolanic reaction of the major chemical components of the RHA and CKD pozzolana that are situated within the pores of the concrete. While the step-down in the strength of concrete with the addition of RHA/CKD beyond 20 % perhaps due to saturation of the cement blend with oxides of K_2O and MgO in RHA/CKD, which created composites that might subdue the strength of concrete, constituting calcium silicate hydrates from hydration of cement, this is in agreement with Wazumtu and Ogork, (2015) reported on assessment of groundnut shell ash (GSA) as Admixture in Cement Paste and Concrete. So, based on the result presented in Figure 5, it was resolved that the optimum percentage of RHA/CKD to be used should not exceed 20 % replacement.

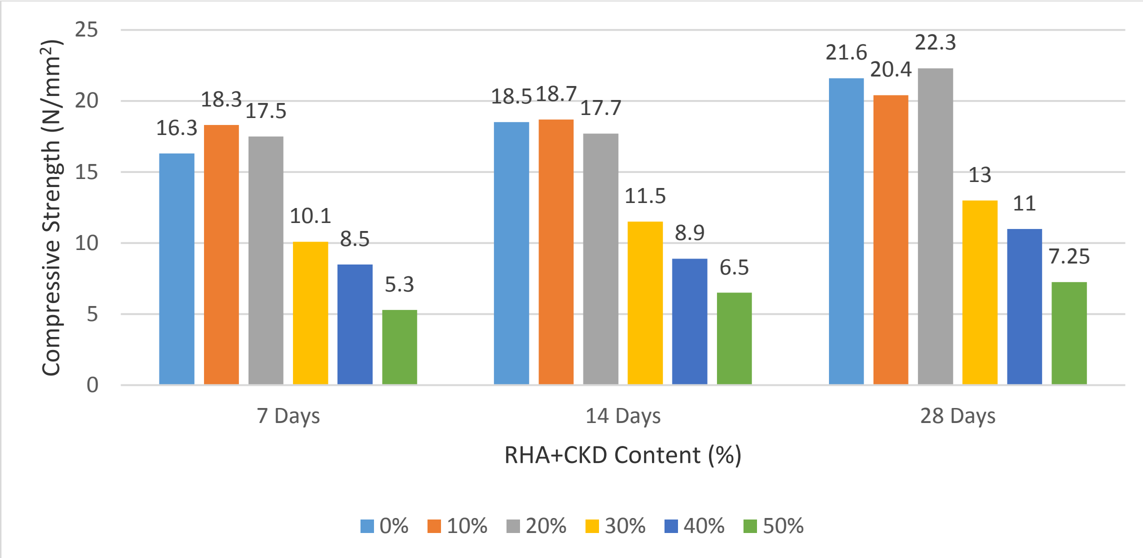

Fig. 5: Compressive Strength of RHA/CKD-Concrete

CONCLUSIONS

CKD has lesser (17.25 %) sum of Fe_2O_3, SiO_2 and Al_2O_3 compared with RHA (83.63 %), while the CaO content of CKD (40.63 %) was higher than that of RHA (4.4 %,). The combined effect of the high content of CaO in CKD and high sum of Fe_2O_3, SiO_2 and Al_2O_3 in RHA produces more Calcium Silica Hydrates (CSH) bonds which contributes to increased compressive strength equal to 20 %, it was discovered that inclusion of RHA/CKD as cement replacement reduces the workability (slump) of concrete but steps-up the setting time. The strength of concrete was detected to increase with age of curing and with cement replaced by a combination of RHA/CKD up to 20 % and then decelerate. This means that the optimum blend of RHA/CKD as cement substitute in concrete should not be more 20 % for best compressive strength values.

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