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Studies on the Effect of Rice Husk Ash as Cement Admixture

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ABSTRACT: Compressive strength tests were carried out on six mortar cubes with cement replaced by rice husk ash (RHA) at five levels (0, 10, 20, 30, 40 and 50%). After the curing age of 3, 7, 14 and 28 days. The compressive strengths of the cubes at 10% replacement were 12.60, 14.20, 22.10, 28.50 and 36.30 N/mm^2 respectively and increased with age of curing but decreased with increase in RHA content for all mixes. The chemical analysis of the rice husk ash revealed high amount of silica (68.12%), alumina (1.01%) and oxides such as calcium oxide (1.01%) and iron oxide (0.78%) responsible for strength, soundness and setting of the concrete. It also contained high amount of magnesia (1.31%) which is responsible for the unsoundness. This result, therefore, indicated that RHA can be used as cement substitute at 10% and 20% replacement and 14 and 28 day curing age.

KEYWORD: Compressive Strength, Setting Time, Soundness, Curing

INTRODUCTION

Cement is a material with cohesive and adhesive properties when mixed with water, which makes it capable of bonding material fragments into a compact whole (Neville, 1996). Cements are classified as calcium silicate and calcium aluminate cement. Calcium silicate cement is further classified into Portland and Slag, while calcium aluminate is classified into High alumina and Pozzolona cement (Jackson and Dhir, 1991).

Rice husk has recently been recognized as pozzolona. A pozzolona is a siliceous/ aluminous material which in itself has little or no cementitious value, but which will in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide liberated during the hydration of Portland cement to produce stable, insoluble cementitious compound which contributes to its strength and impermeability (Sima, 1974). Rice husk ash is one of the promising pozzolanic materials that can be blended with Portland cement for the production of durable concrete and at the same time it is a value added product. Addition of rice husk ash to Portland cement does not only improve the early strength of concrete, but also forms a calcium silicate hydrate (CSH) gel around the cement particles which is highly dense and less porous, and may increase the strength of concrete against cracking (Saraswathy and Ha-Won, 2007).

Many countries have the problem of shortage of conventional cementing materials. Recently there are considerable efforts worldwide of utilizing indigenous and waste, materials in concrete. One of such materials is the rice husk which under controlled burning, and if sufficiently ground, the ash that is produced can be used as a cement replacement material in concrete (Anwar *et al*, 2000).

Rice husks are used as building materials; lightweight concrete briquettes have been made from partly burnt husks. Insulating blocks have also been made with cement and husk ash that resists very high temperatures (Grith, 1974).

MATERIALS AND METHOD

Sampling

The rice husk used for this work was obtained from Arkilla, Wamako Local Government, Sokoto State. The sample was allowed to dry under the sun for three days. The dried husk was ashed in a muffle furnace for two hours at 1100^{o}C to obtain a finely divided ash, which is then sieved and kept ready for analysis (Rice Husk Ash, 2009).

Production of the Block Samples

In the preparation of mortar cubes, 555g of standard sand, 185g of cement sample and a certain volume of distilled water were mixed thoroughly. Similarly, cement, rice husk ash (RHA) and sand, with percentage of cement replaced by RHA were mixed together, until a homogeneous mixture was obtained (Table 1). The measured quantity of water was then sprayed on to the mixture. The mixture was further mixed until a paste of the required workability was obtained (Oyetola and Abdullahi, 2004).

Curing

The mortar cubes were kept inside the humid chamber for 24 hours. The cubes (92.5g) were submerged in the curing chamber for 3, 7, 14 and 28 days. The cubes were then crushed on their respective days and the compressive strength determined (CCNN, 1984).

Physical Tests

Various physical tests were carried out; including compressive strength test, setting time and soundness expansion using standard procedures as reported by Vazirani and Chandola (1984).

Compressive Strength Test

The compressive strength of the block samples was determined in accordance with the standard procedure for pre-cast concrete blocks. The weights of the block samples were always taken before the compressive strength test was conducted. Three sample blocks were crushed each at 1, 3, 7, 14, and 28 days after casting at different replacement levels using the compressive testing machine according to CCNN (1984).

Chemical Analysis of RHA and Cement

Chemical Analysis of RHA and Cement was carried out using CCNN (1984) procedures.

RESULTS AND DISCUSSION

Compressive Strength

Table 1: Mixtures Used for the Compressive Strength, Setting Time and Soundness Tests.

Experiment	Cement (g)	RHA (g)	Sand (g)	Water / Binder Ratio
1.	185	0	555	0.56
2	166.5	18.5	555	058
3	148	37	555	0.60
4.	129.5	55.5	555	0.62
5.	111	74	555	0.64
6	92.5	92.5	555	0.61

RHA = Rice Husk Ash

Concrete is a structural material which consists of Portland cement, aggregate (sand and rock), and water. It is believed that the compressive strength of concrete is influenced by the curing conditions, specimen preparation, age at testing, mode of testing, and mode of failure of the specimen (Neville and Brooks, 1987).

The main and the most important mineral content of Portland cement are the calcium silicates, C_3S and C_{2S}. These silicates hydrate as follows:

$$2C_3S + 6H \longrightarrow C_3S_2H_3 + 3CH$$

$$2\,C_2S + 4H \longrightarrow C_3S_2H_3 + CH$$

$$2C_3S + 2\,C_2S + 10H \longrightarrow 2\,C_3S_2H_3 + 4CH$$

In the presence of RHA that contains 68% SiO_2, the SiO_2 will combine wit the released $Ca(OH)_2$.

$$2\,SiO_2 + 3\,CH \longrightarrow C_3S_2H_3$$

This means that the $Ca(OH)_2$ is being depleted from the system. It is very essential that the hydrated cement should have a pH of 13±1 otherwise the hydrated silicates and aluminates will be destabilized thereby causing the weakening of the cement structure which explains the reduction of the compressive strength with the increase in concentration of RHA

When water is added to cement, the hydration starts topically. In the presence of RHA there is competition for the added water between the SiO_2 and other cement material. Since the SiO_2 is finer it absorbs the water first before the commencement of the hydration of the other cement materials. This, therefore, explains the retardation effect of the RHA on the setting time (Birnin-Yauri, 2009).

The results of the compressive strength tests are shown in Table 2. The compressive strength tests carried out on six mortar cubes showed that the strength of the blocks for all mix increases with age at curing and decreases as the RHA content increases. The best compressive strength result was obtained with the percentages of cement replaced by 10% rice husk ash (RHA) and it decreased appreciably as the percentage of RHA increased. However the strength showed impressive increase with ageing, with highest compressive strength encountered in the 28 days;

which may be due to retention of water with the structural frame of the mixture thereby allowing better hydration.

Table 2: The Compressive Strength Tests Parameter

Amount of Cement (%)	Amount of RHA(%)	Design Strength (N/mm^2)				
		1 Day	3 Days	7 Days	14 Days	28 Days
100	0	16.00	25.70	28.00	32..30	41.00
90	10	12.60	14.20	22..10	28.50	36.30
80	20	6.70	10.40	18.6 0	24.30	30.20
70	30	4.20	8.60	16.3 0	22.40	24.00
60	40	2.00	6.20	14.4 0	18.20	20.30
50	50	0.90	4.10	9.20	11.50	14.00

The Setting Time

Table 3 show the initial and final setting times of the entire cubes were considered using cement and different percentages of rice husk (RHA). The initial and final setting times increases with increase in rice husk ash content. The reaction between cement and water is exothermic. The liberation of heat and evaporation of moisture causes the stiffening of the paste and slower heat-induced evaporation of water from the cement/RHA paste due to its lower cement content (Ikpong 1993), and therefore an accelerated increase in the initial setting time of the mixture was observed. Thus, an increase in the setting time was noticeable from 136 minutes (at 10% RHA) to 154 minutes (at 20% RHA) and the setting time continued to increase until the last proportion as the percentages of rice husk ash increased to 50% (281 minutes). Similarly, the final setting time also increase as the percentages of RHA increases thereby retarding the hydration process. This result is in consonant with the work of Dashan and Kamang (1999) and that of Oyetola and Abdullahi (2004).

Table 3: Initial and Final Setting Times of Cement Pastes

Cement (%)	RHA (%)	Initial Setting Time (Mins)	Final Setting Time (Mins)
100	0	122	183
90	10	136	227
80	20	154	255
70	30	165	275
60	40	213	350
50	50	281	402

Table 4: Chemical Analysis of RHA and Cement (Weight %).

Constituents	RHA	Cement
SiO_2	68.12	23.43
CaO	1.01	64.40
Al_2O_3	1.06	4.84
Fe_2O_3	0.78	4.08
MgO	1.31	1.34
K_2O	21.23	0.29
SO_3^-	0.137	2.79
LOI	18.25	5.68
Free Lime	-	1.50

LIO = Loss on Ignition

Chemical Analysis of RHA and Cement

The silica content is one of the most important constituents of cement. The silica content of the RHA was found to be 68.12% (Table 4), which indicated higher silica content than in cement. This value is closer to the required value of 70% minimum for pozzolanas (ASTM, 1978) and is slightly higher than the value (67.30%) reported by Oyetola and Abdullahi (2004).

Alumina content on the other hand was higher in cement than in the RHA sample. Higher alumina in cement in form of C_3A will led to widespread construction problems, due to its faster hardening properties (Hewlett, 1998). However the alumina content in the RHA falls within the Nigerian Industrial Standard and ASTM specifications (ASTM, 1979). This value is lower than the value reported in the work of Oyetola and Abdullahi (2004).

Calcium oxide is responsible for the formation of C_3S ($3CaO.SiO_2$) in cement and all other clinker minerals, responsible for the strength in the late or early part of the concrete (Taylor, 1990). The percentage calcium oxide in rice husk was 1.01% much lower than that in cement (64.40%).
Similarly, low magnesia content was obtained in both the RHA falling within the same range (1.31-13.5%) than that of cement. High magnesia content is not required in cement because it causes unsoundness (Taylor, 1990).
On the other hand, the percentage iron III oxide in RHA (0.78%) is much lower than that of cement (4.08%). The Iron oxide may be from laterite associated with the geological formation. Cement containing higher amount of iron(III) oxide, is responsible for imparting colour on cement product (Lea, 1970). The percentage of iron (III) oxide is slightly lower than that reported by Oyetola and Abdullahi (2004).
Potassium oxides are the main alkalis associated with cement. There was high percentage of potassium oxide in the RHA than in cement. Higher alkali in cement is undesirable as it causes damage to kiln and attack reinforced concrete as reported by Taylor (1990). It also results into alkalisilicates reaction.
High sulphate content in cement could be from gypsum which is one of the raw materials in cement (Singh, 2000) and is to use control the setting time. Nevillle (1986) opined that cement products with high amount of sulphate are acid resistance while Taylor (1990) believed that small amount of SO_3^- present in cement prevent the formation of C_3S.
The loss on ignition obtained (18.25%) is higher than the expected 12% maximum for pozzolanas. A high loss on ignition is indicative of prehydration and carbonation, which may be caused by improper and prolonged storage or adulteration during transport or transfer (PCA, 1988).
Free lime content is the excess uncombined lime in cement. Higher amount of free lime is undesirable as it is the main cause of unsoundness in hydrated cement, thus, responsible for cracking of concrete; a value of 1.0 or above indicate that balite will be present at equilibrium at a clinkering temperature and thus liable to persist in the products while value less 1.0 has an effect which is are easier burnability, low cement strength and low heat consumption (Taylor, 1990). The free lime content was found absent in the RHA.

CONCLUSION

The following conclusions are drawn.

i. The chemical analysis done on rice husk ash indicated high amount of silica for rice husk ash (68.12%) which is a very good value for workability.
ii. The increase in setting time of paste having rice husk ash showed low level of hydration for rice husk ash concrete which result from reaction between cement and water, which liberate calcium hydroxide ($Ca(OH)_2$).
iii. Rice husk ash which contains high amount of silica, as in cement, is important as a minor cement substitute, if there is addition of other raw materials containing slightly higher calcium oxide and alumina.

Recommendations

The following recommendations are drawn.

1. Use of other admixtures be incorporated with rice husk ash , in order to retard the hydration of water be studied
2. Other raw materials containing slightly higher calcium oxide and alumina could be used to improve the used of RHA as cement replacement.

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