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Effect of Rice Husk Ash (RHA) as Partial Replacement of Cement on Concrete Properties

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Abstract: Cement is widely noted to be most expensive constituents of concrete. The entire construction industry is in search of a suitable and effective the waste product that would considerably minimize the use of cements and ultimately reduces the construction cost. Rice husk ash (RHA) which has the pozzolanic properties is a way forward. The possibility of using RHA as a construction material need to be investigates. Three grades of ordinary Portland cement (OPC) namely; 33, 43 and 53 as classified by Bureau of Indian Standard (BIS) are commonly used in construction industry. A comparative study on effects of concrete properties when OPC of varying grades was partially replaced by RHA is discussed in this paper. Percentage replacement of OPC with RHA was 5, 10, 15 and 20% respectively. The compressive strength, water absorption, shrinkage and durability of concrete were mainly studied. The study suggests that up to 20% replacement of OPC with RHA has the potential to be used as partial cement replacement, having good compressive strength.

Keywords: Rice Husk Ash, ordinary Portland cement (OPC), partial replacement.

1. INTRODUCTION

Traditionally, rice husk has been considered a waste material and has generally been disposed of by dumping or burning, although some has been used as a low-grade fuel. Nevertheless, RHA has been successfully used as a pozzolana in commercial production in a number of countries including India. RHA use in the civil construction field may be a viable solution to its disposal as waste on the environment. Interest in RHA utilization by the construction industry is not new. The process was investigated by Mehta [1977], who observed that it was possible to obtain ashes rich in silica (in crystalline or glassy state) depending on the combustion conditions. In the glassy silica case, highly pozzolanic ashes would be obtained, which would be adequate for partial substitution of Portland cement. Pozzolanic definition by ASTM C618 [1978] is a siliceous or siliceous and aluminous material which, in itself, possesses little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.

RHA produced after burning of Rice husks (RH) has high reactivity and pozzolanic property. Chemical compositions of RHA are affected due to burning process and temperature. Silica content in the ash increases with higher the burning temperature. As per study by Hwang and Wu [1989] RHA produced by burning rice husk between 600 and 700°C temperatures for 2 hours, contains 90-95% SiO2, 1-3% K2O and < 5% un burnt carbon. Under controlled burning condition in industrial furnace, conducted by Mehta [1992], RHA contains silica in amorphous and highly cellular form, with 50-1000 m2/g surface area. So use of RHA with cement improves workability and stability, reduces heat evolution, thermal cracking and plastic shrinkage. This increases strength development, impermeability and durability by strengthening transition zone, modifying the pore-structure, blocking the large voids in the hydrated cement paste through pozzolanic reaction. RHA minimizes alkali-aggregate reaction, reduces expansion, refines pore structure and hinders diffusion of alkali ions to the surface of aggregate by micro porous structure. These properties are difficult to achieve by the use of pure Portland cement alone.

Recent study on the use of RHA as a construction material has been reported by Jayasankar et al. [2010], Nargale et al. [2012] and Sandesh et al. [2012], where the amount of replacement varies from 0 to 20% without varying the grade of ordinary Portland cement (OPC). The strength gained in concrete when OPC was partially replaced by a material processing pozzolanic property also depends upon the grades of OPC [Marthong, 2002]. Different grades of OPC are available depending on the respective country codal classification. Bureau of Indian Standard (BIS) normally classify three grades of OPC namely: 33, 43 and 53, which are commonly used in construction industry. Indian Standard code of practice for plain and reinforced concrete [IS 456, 2000], recommends use of RHA in concrete but does not specify quantities. The possibility of using RHA as part replacement of OPC need to be investigate for confident used of these materials. The review of literature however, could not find any comparative study on the effect of concrete properties when cement of varying grades were partially replace by RHA are addressed together. Thus, in the present work a holistic approach was adopted to investigate the possibility of using RHA as a construction material. The contributions to strength gain, improvement in durability, water absorption and shrinkage are the main parameter of study.

2. MATERIALS AND METHODS

Materials

A. Cement

Ordinary Portland cement (OPC) was used in which the composition and properties is in compliance with the Nigerian standard organization defined standard of cement for concrete production.

B. Fine Aggregate

Fine aggregate was purchased which satisfied the required properties of fine aggregate required for experimental work and the sand conforms to zone III as per the specifications of IS 383: 1970.

C. Coarse Aggregate:

Crushed granite of 20 mm maximum size has been used as coarse aggregate. The sieve analysis of combined aggregates confirms to the specifications of IS 383: 1970 for graded aggregates.

D. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked in to very carefully. Mixing water should not contain undesirable organic substances or inorganic constituents in excessive proportions.

E. Rice Husk Ash (RHA).

After collection, the Rice Husk is burnt under guided or enclosed place to limit the amount of ash that will be blown off. The ash is ground to the required level of fineness and sieved through 600 µm sieve in order to remove any impurity and larger size particles.

Methods

A. Batching and mixing of materials

Batching of materials was done by weight. The percentage replacements of Ordinary Portland cement (OPC) by Rice Husk Ash (RHA) were 0%, 5%, 10%, 15% and 20%. The 0% replacement was to serve as control for other samples.

B. Concrete Mix Design

The concrete used in this research work was made using Binder, Sand and Gravel. The concrete mix proportion was 1:2:4 by weight.

C. Casting of samples

Cubic specimens of concrete with size 150 x 150 x 150 mm were cast for determination of all measurements. Six mixes were prepared using different percentages of 0, 5, 10, 15 and 20 RHA. The concrete was mixed, placed and compacted in three layers. The samples were demoulded after 24 hours and kept in a curing tank for 7, 14 and 28 days as required. The Compacting Factor apparatus was also used to determine the compacting factor values of the fresh concrete in accordance with BS 1881: Part 103 (1983).

D. **Testing of samples**

Testing is done as per following IS code. The testing done for compressive strength of cubes were measured 7,14, 28,56 and 90 days as per IS : 516 – 1959 ,the testing done for flexural strength of beam were measured 28 days as per IS : 5816 - 1999 and the testing done for split tensile strength of cylinder were measured 28 days as per IS : 516 – 1959.

3. RESULTS AND DISCUSSIONS

A. Results of compacting factor test on fresh concrete sample

The results obtained from the compacting factor test on fresh concrete samples are given in the Table 1. The table indicates that the compacting factor values reduce as the RHA content increases. The compacting factor values reduced from 0.91 to 0.89 as the percentage RHA replacement increased from 0% to 20%. These results indicate that the concrete becomes less workable (stiff) as the RHA percentage increases meaning that more water is required to make the mixes more workable. The high demand for water as the RHA content increases is due to increased amount of silica in the mixture. This is typical of pozzolan cement concrete as the silica-lime reaction requires more water in addition to water required during hydration of cement (Bui et al. 2005).

Table no. 1: compacting factor values of RHA concrete

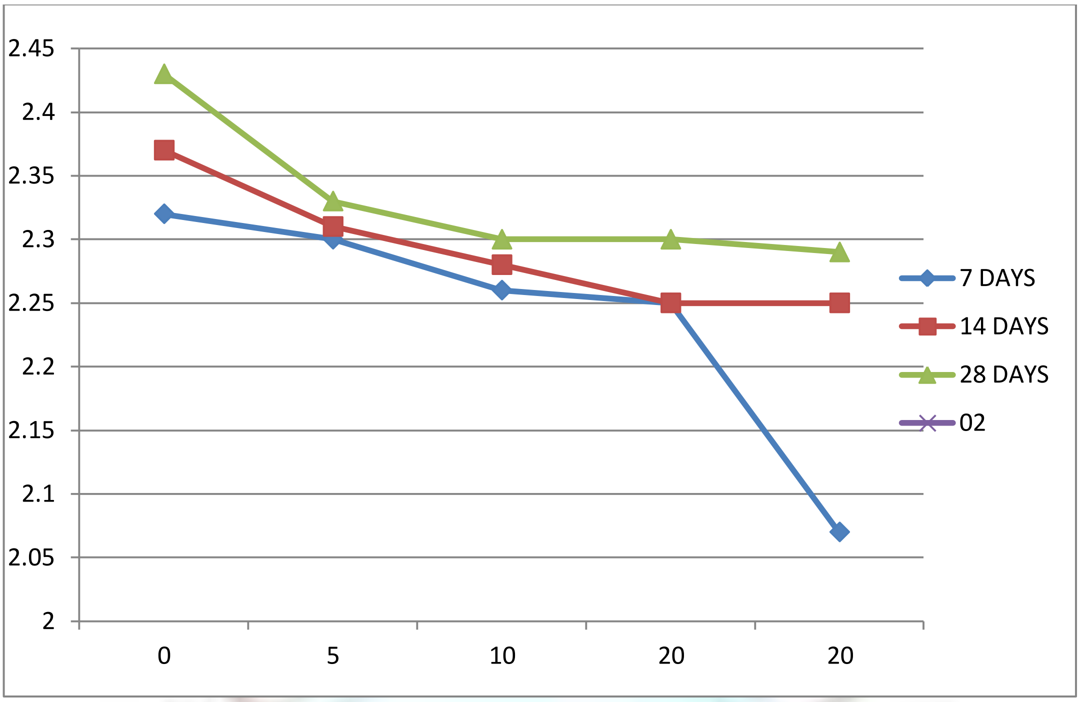
Percentage replacement of RHA (%)	Compacting Factor values
0	0.91
5	0.91
10	0.90
15	0.90
20	0.89

B. **Bulk Densities of Concrete Cube**

The Bulk Densities of the Concrete Cubes cast at various days of curing are shown in Table 2 and Figure 1

Table no. 2. Bulk Densities of Concrete Cubes with various percentages of RHA

Rice Husk Ash Replacement	Bulk Density (g/cm3)		
(%)	7 days	14 days	28 days
0	2.32	2.37	2.43
5	2.30	2.31	2.33
10	2.26	2.28	2.30
15	2.25	2.25	2.30
20	2.07	2.25	2.29



X- AXIS Rice Husk Ash Replacement (%)
Y- AXIS Bulk Density(g/cubic cm)

Fig. 1: Effect of RHA content on Bulk Density of Concrete at different curing age

C. Workability

The slump and compacting factors test decreased upon the inclusion of RHA as partial replacement of OPC. Thus, it can be inferred that to attain the required workability, mixes containing RHA will required higher water content than the corresponding conventional mixes. The workability (slump) of concrete for 33, 43 and 53 grades OPC varies from 24, 20 and 15 mm for concrete containing 40% RHA respectively. The higher value of slump is obtained for concrete with cement of 33 grades and least for 53 grades cement. This behaviour was as expected because higher the grade of cement the more fine it is. Finer cement requires more water to wet the surface particles.

D. Compressive Strength

The variation of cubes strength at different ages of 7, 28, 56 and 90 days with different grades of OPC and various percentages of RHA contents. The compressive strength of concrete in all grades of OPC at early age is significantly higher than that of concrete produced with RHA. It was also observed that compressive strength continued to increase with age but decreased with RHA contents in all grades of OPC. The strength reduction was found to be lower for higher grade OPC. Comparison on the attaining of strength at 28 days it was observed RHA with 43 and 53 grades OPC attained about 60% of strength as compared to normal concrete, while RHA with 33 grades OPC could attain only 50% of its strength. This comparison shows that RHA 43 and 53 OPC with medium workability concrete compared favorably with OPC concrete in term of early strength development. In long term strength gain (at 90 days), RHA 43 and 53 grades OPC attained about 75% strength as compared to concrete with 0% RHA replacement, while RHA 33 grades OPC the strength gain was about 55% only. The comparison clearly shows that strength of RHA concrete slightly increase with age in all three grades of OPCs. Thus it indicate that replacement by RHA for 43 and 53 ;8grades OPC is seems to be better in term of ultimate strength gain than that of 33 grades OPC. The same behavior was also observed by Marthong [2002] when OPC of various grades were partially replaced by class-F fly ash. However, the optimum strength of RHA concrete was observed to be 10% replacement in all the three grades of OPCs.

E. Shrinkage

The consistency of RHA cementitious paste decreased as compared to OPC cement paste. This shows reduction in water demand and should reduced shrinkage. However, in the present study it has been observed that the shrinkage of specimens with 40% RHA content measured at the age of 90 days found to be same as that of pure concrete at each proportion. Hence, it may be concluded that influence of RHA on shrinkage is negligible.

F. Water absorption

The variation in water absorption with RHA contents. The water absorption was calculated on the basis of initial soaked cube and then oven dried. The test results depict that water absorption up to 20% replacement decreased with the inclusion of RHA in all grades OPC as compared to pure cement and there after start increasing. The water absorption of 53 grade OPC concrete with RHA content is least than the other two and being maximum for 33 grades OPC concrete. This behaviour may be due to the fact that, 53 grade cement is finer and 33 grade OPC being coarser particles. Thus, permeability of paste with coarser cement particle is higher. The water absorption of RHA concrete also varies with age of concrete. The results also depict that water absorption too decreased with age. With age the water absorption decreased because gel gradually fills the original water filled spaces.

G. Durability

The variation in compressive strength with RHA content for 28 days exposed in sulphate solution and tap-water. It is observed that for each grades of cement the strength of ordinary cube and that partially replaced by RHA immersed in sulphate solution have less compressive strength than the corresponding referral cubes immersed in tap-water. Strength decreases as RHA contents increased. The decreased in cube strength exposed in sulphate solution over that exposed in tap-water are about 9% for ordinary cubes and that of 40% RHA content are about 10% for all grades of OPC. Thus, inclusion of RHA as partial replacement of cement seems that it does improve the durability when exposed to sulphate environment. Comparing all the three grades of OPC, the strength loss seem to be betters for 53 grade OPC as compared to the other two grades.

4. CONCLUDING REMARKS

From the methods and discussion work carried out and the analysis of the results following conclusions seem to be valid for possible use of RHA as partial replacement of cement.

1. Important oxides content was 67.58% by weight of RHA. This shows that RHA has a significant physical and chemical property that encourages its uses as a pozzolanas.
2. In all grades of OPC, setting times increased upon the addition of RHA but are in the range recommended for pure cement.
3. Workability decreased upon the inclusion of RHA. Thus, mixes containing RHA will required higher water content than the corresponding conventional mixes.
4. Test results indicate that RHA concrete can attain the same order of strength as conventional concrete at longer curing periods. However, the early strength development was observed to be about 50-60% of their 28 days strength. Compressive strength of concrete increases with grade of cement. The rate of strength gain by RHA-33 grades OPC is lower as compared to 43 and 53 grades. However, study suggested the use of RHA as partial replacement of cement up to a maximum of 10% by volume in all grades of cement.
5. Shrinkage of RHA concrete is similar to the pure cement concrete in all grades of OPC.
6. Water absorption of RHA concrete up to 20% replacement decreased with the increased in grades of OPC.
7. Inclusion of RHA as partial replacement of cement slightly improves the durability when exposed to sulphate environment. However, RHA with 53 grades OPC seems to be better.
8. From the study conducted, it was clearly shown that RHA is a pozzolanic material that has the potential to be used as partial cement replacement material and can contribute to the sustainability of the construction material.

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