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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 0, 10, 20, 30 and 40% 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 performance and durability.

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% SiO_2, 1-3% K_2O 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 m^2/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.

3. Experimental program

3.1 Processing of RHA and concrete ingredients

The rice husk collected from local mill in Meghalaya, India was burnt in a furnace to produce RHA. After burning it was cooled inside the furnace for about 24 hours. The burnt ashes were taken out for grinding using a Los Angeles machine. Fig. 1 shows the products obtained after the operations. The final product of RHA was graded in accordance with BS-812 [1967]. Chemical properties of RHA and their comparison with OPC are presented in Table 1.

Coarse aggregate from crushed basalt rock was use. River sand was used as fine aggregate. Material used have been tested as per relevant codal provision [IS 2386 (I, III), 1963]. Various grades of OPC classified by BIS namely: 33, 43 and 53 conforming to standard codal provision [IS 269-1989, IS 8112-1989 and IS 12269-1987] were used. The cement by RHA are 0, 10, 20, 30 and 40% per each grades. Table 2 illustrates the detail of various percentages chosen. The mix was designed for target cube strength of 30 MPa at 28 days with water-cement ratio of 0.38. A simple method of mix proportioning using RHA (i.e. RHA as part replacement of cement by weight) has been adopted.

Fig.1 Product after each process

3.2 Casting, Curing and Testing of specimens

Eighteen cubes of sizes 150x150x150 mm were cast per variety of sample per each grades of cement for strength test and water absorption test. Cube strength was examined at different age's i.e. 7, 28, 56 and 90 days. However, water absorption test were examined at 56 and 90 days. For water absorption, the cubes were kept moist for the above test age in tap water and then heated for 24 hours at 110 ºC in an oven.

Two un-reinforced beams of sizes 150 x150x1000 mm per each grade of cement were cast to measure the shrinkage. Shrinkage test of beam after 28 days of curing were done by measuring the change in length of the specimen at 7 days interval.

Six mortar cubes of 50x50x50 mm were cast per variety of the sample and per each grades of cement for durability test (sulphate resistance). The resistance to sulphate attack were evaluated by immersion of well-cured specimens after 28 days of curing in a standard sodium sulphate solution (Na_2SO_4) having concentration of 16 gm/l [Buenfeld and Newman, 1984]. An enhanced sulphate salt concentration as high as eight times that of average salt concentration of sea water was considered. The specimens were alternately wetting and drying at 7 days intervals and then determining the strength loss as a result of sulphate exposure for 28 days.

Table 1: Physical and Chemical Properties of RHA and OPC

Elements	SDA % by weight	OPC % by weight
Specific gravity	2.53	3.14 (**33**), 3.15 (**43**), 3.20 (**53**)
Moisture contents (% by weight)	2.15	0.343
Loss on ignition (g/cm^3)	3.67	1.05
SiO_2	75.0	20.70
AL_2O_3	1.29	5.75
Fe_2O_3	0.78	2.50
CaO	3.3	64.00
MgO	0.22	1.00
MnO	0.2	0.05
Na_2O	0.4	0.20
K_2O	1.50	0.60
P_2O_5	0.59	0.15
Total SiO_2 +Fe_2O_3 +AL_2O_3	77.58	28.95

Table 2 Details of proportions of cement and fly ash

Symbols	% of cement	% of RHA
C100	100	0
F10	90	10
F20	80	20
F30	70	30
F40	60	40

4. Results and discussion

Various parameters which significantly affect the properties of concrete (plastic and harden state) with the inclusion of RHA are discussed below.

4.1 Effect of RHA on cementitious properties

The physical and chemical properties of SDA used in this study are shown in Table 1. It is seen that the RHA proportion of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3) when combined together was 77.58%, which slightly less than that specified by ASTM C 618[1978] for pozzolana.

The main physical properties of RHA that influence the activity in gaining strength is its fineness. RHA required having equal or finer than OPC for its good cementing efficiency. The fineness of the 33, 43 and 53 cement grades OPC in this investigation are found to be 9, 8 and 6% residue on 90 micron sieve size respectively. Fineness of RHA is found to be 5%. This shows that RHA is of finer size as comparable to cement particles. Thus, it is expected to have appreciable influence on the strength development on concrete.

Fig. 2 shows the variation of setting time [initial setting time (IST) and final setting time (FST)], where it increased with increasing RHA content. This behavior may be due to the low rate of hydration in the paste containing RHA. 33 grades OPC takes longer time (both initial and final) as compared the other two grades. This same trend was also observed by Marthong [2002] when OPC of various grades were partially replaced by class-F fly ash. The soundness as shown in Fig. 3 slightly increased upon the inclusion of RHA. Soundness of 33 grades OPC was found to be slightly lower as compared to the other two grades of OPC. The obtained values of setting time and soundness was however, within the recommended range for all grades of OPC paste [IS 269-1989, IS 8112-1989 and IS 12269-1987].

Fig. 4 shows the variation of normal consistency for different grades of OPC using different percentage RHA. The plot indicates that the water requirement for the paste increases approximately linearly for all grades of OPC. The normal consistency of 43 and 53 grades cement are higher by 9 and 12% as compared to that of 33 grade cement. Further, the cement of 53 grades is finer as compared to 33 grades OPC; hence more water is required for wetting the particles, as the total surface area of the particle is increases.

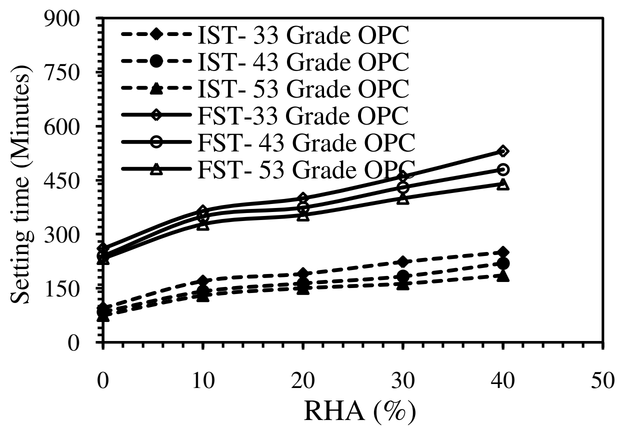

Fig. 2 Variation of setting times with RHA content

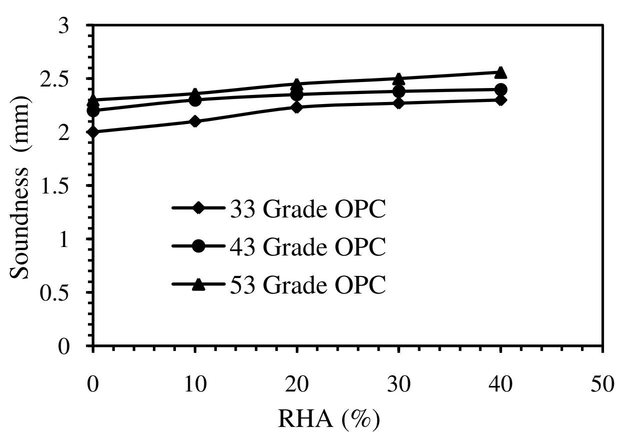

Fig. 3 Variation of soundness with RHA content

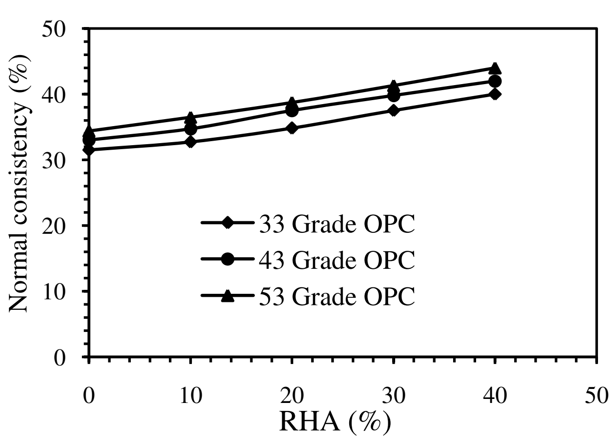

Fig. 4 Variation of consistency with RHA content

4.2 Effect of RHA on concrete properties

4.2.1 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.

4.2.2 Compressive strength

Fig. 5 to 7 presents 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 grades 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

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observed to be 10% replacement in all the three grades of OPCs.

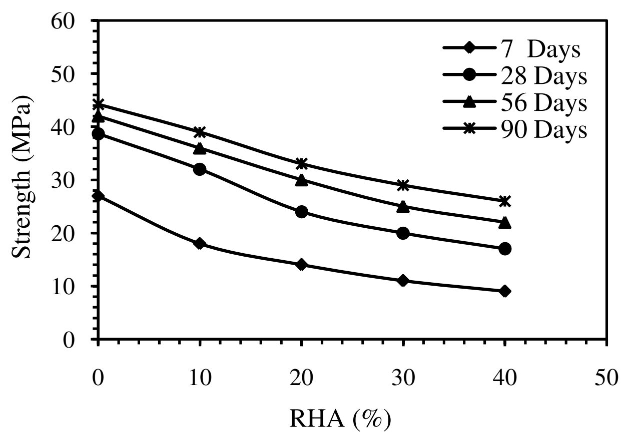

Fig. 5 Variation of compressive strength of 33 grade OPC

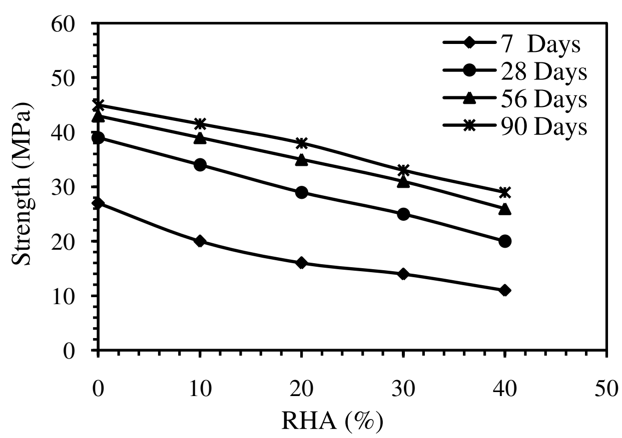

Fig. 6 Variation of compressive strength of 43 grade OPC

4.2.3 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.

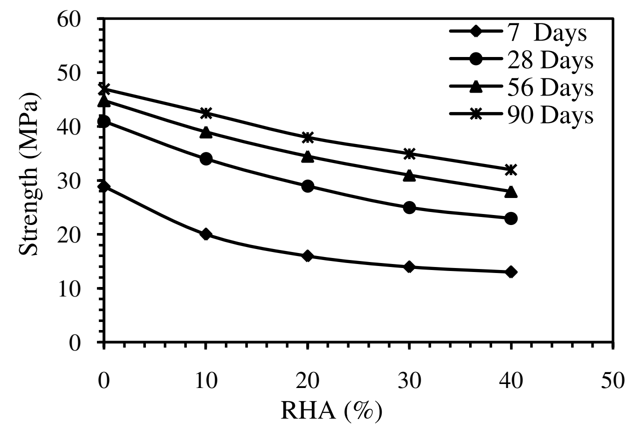

Fig. 7 Variation of compressive strength of 53 grade OPC

4.2.4 Water absorption

Fig. 8 shows 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.

4.2.5 Durability

Fig. 9 shows 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.

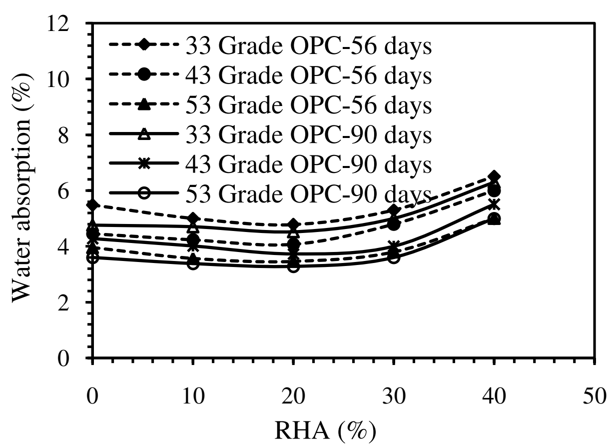

Fig. 8 Variation of water absorption with RHA content

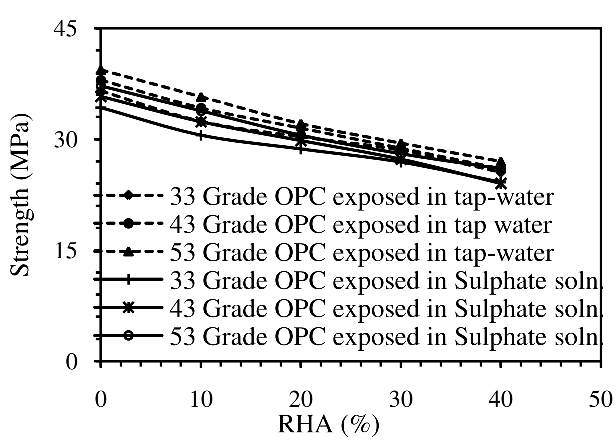

Fig. 9 Variation of compressive strength under different environment

5. Concluding remarks

From the experimental 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 77.58% 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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