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The Influence of RHA on the Mechanical Properties of Mortar Heated Up To High Temperature

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***Abstract*—**The performance of mortar subjected to high temperature and cooled in normal ambient temperature was examined in the laboratory to comply with the situation of burning & cooling of a structure. Four series of cubical (5 X 5 X 5 cm) mortar specimens were made from OPC, and partial replacement (10, 15, 20, 25 & 30%) of OPC by Rice Husk Ash (RHA) produced in the uncontrolled environment. These specimens were heated in electric furnace to 200, 300, 400, 500 and 700^{0}C. The specimens were kept in normal room temperature for cooling. They were then tested for mechanical properties and the results shows that particular 20% RHA mixed mortar shows better fire performance.

***Keywords*—**Fire performance, Rice Husk

I. Introduction

FIRE is one of the most serious risks and shows big problem in structures. Firing of structure can be happen at any time in any building. Though there are many methods and ways to control fire, it is evident that the structural element is heated until full control of fire. But still structural elements need a certain period to fully cool down if its leave in normal ambient temperature. Sometimes inside elements requires long duration for cooling. However most of the structural materials experiencing firing to high temperature are weakened which is not visibly understood. But the building can not be abandon yet and it is again used. Hence the performance of structural elements under fire recently becomes more and more important.

There is an increasing number of research works in this field are being done. Some parts of Eurocodes deal with fire safety of concrete structures [1]-[3]. A very important part of the fire on concrete is degradation of mechanical properties of concrete. This problem has been studied since the 1950's [4]-[6]. In the present study the performance of mortar subjected to high temperature and cooled in normal ambient temperature was examined in the laboratory to comply the situation of burning & cooling of a structure.

Cement mortar and coarse aggregate is the main composition in concrete and the mortars are more vulnerable under high temperature. In this work traditional cement mortar made from OPC and modified cement mortar from OPC and Rice Husk Ash (RHA) was used. Rice Husk is an agricultural by product material and generally used as feed for cattle, poultry etc. And a large amount of rice husk is used as fuel to produce steam in rice mill. The burning process of rice husk is in uncontrolled manner. After burning a huge amount of rice husk ash is produced and dumped it as waste**.**

The use of RHA in mortar and concrete as partial replacement of cement has been extensively investigated in recent years. Large number of research on the changes in different properties of mortar has been carried out. Alireza Naji Givi et al. [7] in their review accumulated the advantages of using RHA in concrete. Inclusion of RHA as partial replacement of cement enhances the tensile & compressive strength of concrete and also its durability.

Sarshar [8] has examined the degradation of compressive strength of cement paste specimens produced from Ordinary Portland Cement (OPC). The specimens are cylindrical in shape and height to diameter ratio is 1(one). All the tested specimens' diameter is 63 mm and heated up to 300 or 520^0 C and then cooled in different ways.

Sarshar [8] stated that specimens cooled with water shows much greater strength reduction than in those cooled slowly. To improve the fire performance of concrete a number of research studies indicates that the addition of silica fume in concrete showed inferior performance as compared to pure Ordinary Portland Concrete especially at elevated temperature [9]. The addition of fly ash (FA) or ground granulated blast furnace slag (GBBS) with OPC instead of silica fume enhances the fire resistance of concrete [8]. But the performance of mortar or concrete for RHA inclusion in case of firing is not reported yet.

II. Experimental Works

A. Materials

The objective of the experimental program was to examine the influence of RHA on the strength properties of cement mortar. The materials used were ordinary Portland cement (OPC) complying with ASTM Type I, ASTM graded sand used as fine aggregates and RHA obtained from wild open combustion process where the maximum temperature was reached at 428^{0}C. The chemical composition of RHA is shown

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in Table 1.

The mix proportion of cement mortar is 1: 2.75 by weight of material for all samples. Controlled sample is of zero RHA designated with A0. Other samples were mixed in different proportions of RHA with OPC cement i.e. OPC cement was partially replaced by RHA. Detail mixtures of mortar with sample ID is shown in Table 2.

TABLE 1 CHEMICAL COMPOSITION OF RICE HUSK ASH

Constituent	% Composition
Fe_2O_3	1.38
SiO_2	90.2
Al_2O_3	0.85
CaO	1.18
MgO	1.21
L.O.I	3.95

TABLE II PERCENT MIXING OF OPC & RHA

Mix ID	OPC %	RHA %
A0	100	--
A10	90	10
A15	85	15
A20	80	20
A25	75	25
A30	70	30

B. Sample Preparation & Testing

After mixing cubical specimen of 5X5X5 cm. size were prepared for individual % RHA. For each % RHA samples were prepared for each range of firing tests. Hence total number of samples including control specimen is 18 for individual % RHA. Before demoulding all samples were kept in a moist place for 24 hours. Next samples were left for curing in a water tank at 22 ± 2^0 C temperature for 90 days. Before starting the firing tests all samples were preconditioned. It was done by two steps. First keeping those in open air for 12 hours and then heating the sample at 100^0C for 12 hours. After heating samples were taking off from oven and cool down in open air for 12 hours.

Afterwards the specimens were taken for firing tests in an electric muffle furnace as shown in Fig. 1 & Fig. 2. The size of furnace 30X30X30 cm. and its heating capacity was 1200^0C. The heating rate is shown in Table 3 and Fig. 3. Five series of firing tests were done. These heating ranges are 200^0, 300^0, 400^0, 500^0 & 700^0 C respectively. Firing of samples in each temperature was maintained for 30 minutes.

Compressive strength test of samples was done after cooling of specimen in normal room temperature. The ambient temperature at the time of cooling & testing was 32^0 C.

Fig. 1: Muffle furnace

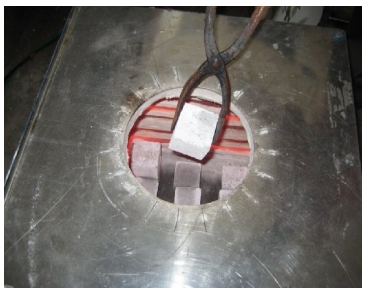

Fig. 2: Heating of sample in muffle furnace

TABLE III SPECIMEN HEATING RATE

Time (sec)	Temperature (^{0}C)
0	24
75	160
140	270
195	365
237	440
296	550
360	650
380	675
405	700

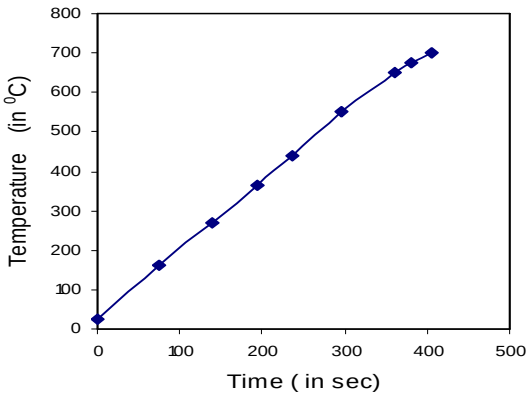

Fig 3: Time-Temperature Curve

III. Result and Discussion

All samples were tested in universal testing machine for its strength properties. Before that the weight loss of each specimen were measured. It was found that the % weight loss is increased with increasing amount of %RHA. Fig. 4 shows the variation of percent weight loss with respect to temperature for different percent of RHA replacement. The entire graphs show same nature of curvature. A maximum of 22.2% weight loss was observed which for 30% RHA replacement. First 10-15% weight loss is due to preconditioning of samples and this change the graphs sharply. Then the graphs maintain a linear and gradual slope for all %RHA replacement. It is important to noted that there is 4-6% of weight loss occur for temperature range from 200-700^{0}C for A10-A30 type sample. On the other hand this was 9% for samples without RHA.

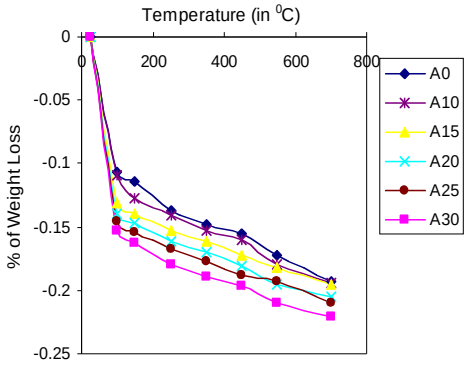

Fig 4: Temperature VS % Weight loss

The strength for different samples A0 to A30 at ambient temperature of 32^{0}C are shown the table 4. Inclusions of RHA by 20% strengthen the mortar specimen by 10% as that for the control specimens "A0" as shown in Fig. 5. And the further increment in RHA lower the mortar compressive strength. But the trends for the curve of other specimens (A10-A30) do not match with that of control specimens heated at higher temperature.

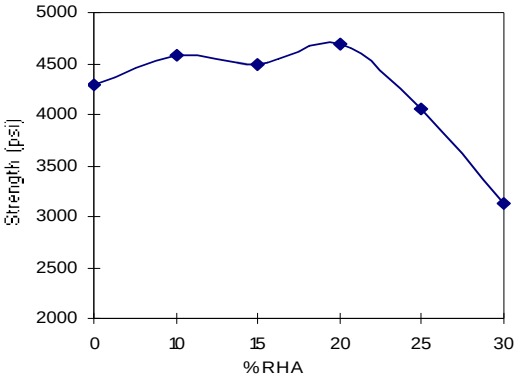

Fig 5 : % RHA Vs Strength

The strength of A0 sample for different range of temperature was tested and plotted in the graph shown in Fig.6. The Compressive strength of mortar increased up to a maximum of 140% when it was heated to up to 300^{0}C. Finally the strength was reduced to 65% when firing at 700^{0}C. So heating of OPC mortar at elevated temperature higher than 300^{0}C can lead to significant amount of deterioration.

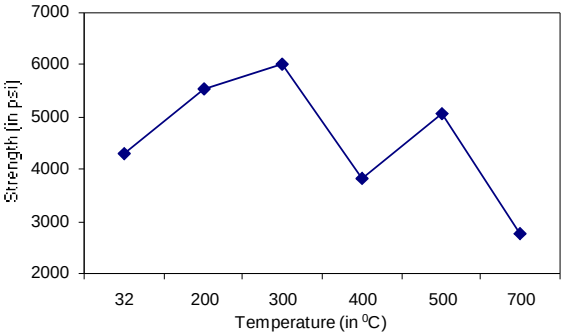

Fig. 6:Temperature Vs Strength for A0 Specimen

Table 4 shows the compressive strength of mortar before and after firing at different temperature & %RHA. The maximum strength is found at temperate of 300^{0}C for A15 sample. The strength of all samples increased with the increasing temperature up to 300^{0}C and reduced thereafter. The comparative graph for strength in different temperature & %RHA is shown in Fig.7. It is found that samples for A10 A15 & A20 show same nature of strength increasing pattern. A15 sample shows highest percentage increase in strength while heating up to 300^{0}C, shown in Table 5. On the other hand A10 sample can withstand and hold its original strength up to 500^{0}C but its loss 38% strength after firing at 700^{0}C. But the minimum amount of strength loss (28%) is found for A30 sample.

TABLE IV TEMPERATURE & STRENGTH (IN PSI) FOR DIFFERENT % RHA

Sample ID	Temperature (in ^{0}C)					
	32	200	300	400	500	700
A0	4282	5550	6013	3825	5063	2775
A10	4590	5325	6363	5350	4688	2863
A15	4500	4775	6875	5650	3900	2825
A20	4700	5050	5813	5400	4575	3013
A25	4063	5013	4513	5163	3413	2763
A30	3125	4688	4938	3563	3675	2254

TABLE V CHANGE IN STRENGTH (IN %) W.R.T. CONTROL SPECIMEN OF 32^0C FOR FIRING AT ELEVATED TEMPERATURE

Sample ID	Temperature (in ^{0}C)				
	200	300	400	500	700
A0	130	140	89	118	65
A10	116	139	117	102	62
A15	106	153	126	87	63
A20	107	124	115	97	64
A25	123	111	127	84	68
A30	150	158	114	118	72

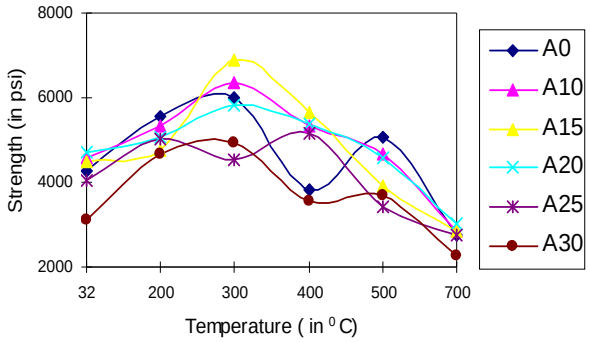

Fig 7 :Temperature Vs Strength Curve

IV. CONCLUSION

From the study it would be concluded that addition of RHA as cement replacing material is quite satisfactory. At higher temperature the performance of mortar incorporating rice husk ash perform better behaviors than OPC mortar. It was observed that at 20% replacement level of OPC by RHA is accepted under elevated temperature.

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