Yash Ashmoh Binder from Rice Husk Ash

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ABSTRACT

Rice husk is one of the most important biomass fuel and renewable source of energy to generate power. It is burnt in Atmospheric Fluidized Bed Combustion (AFBC) water tube boiler furnace at 700-800°C. After combustion Rice Husk Ash (RHA) generated at this temperature gives rise to amorphous ash. The ash content of husk is about 20% and silica content (as silicon dioxide) in RHA is 92-93%. Rice husk ash is highly porous, light weight with very high external surface area and thus is very useful pozzolonic material. Rice husk ash type varies considerably according to burning techniques. The RHA used for this study for making mortar to replace partially or completely pozzolona Portland cement (PPC) is of amorphous ash collected after combustion temperature 700-800°c from boiler electrostatic precipitator (ESP) outlet. The different mix proportion of RHA, lime and PPC in the ratio of 50:40:10, 55:35:10, 60:30:10 and 65:25:10 respectively ground in ball mill for 8.0 hours and screened to 100 mesh sizes. After grinding from each mix which is termed as Yash Ashmoh mortar in the ratio of Yash Ashmoh: Sand was made to prepare standard cubes of 10cm x 10cm x 10cm dimensions and were allowed to dry and subsequently cured in water for7 and 28 days. Yash Ashmoh with above mentioned mix proportions gave 97.5, 122.5, 140.0 and 155.0 kg/cm^2 average compressive strength after 7 days and 105.0, 130, 145.0 and 165.0 kg/cm^2 after 28 days curing. The maximum compressive strength was obtained with the mix proportion of 65:25:10. The compressive strength of Yash Ashmoh was compared with standard PPC mortar. The results revealed that Yash Ashmoh can be used in a big way for non structural purposes replacing up to 90% PPC. Yash Ashmoh binder is being used by the mill to produce flower pots, interlocking bricks, curved stones, drain trench covers etc. Further studies are in progress to develop the cement which can be used in concrete mix for high strength and making the concrete durable to chemical attack and water proofing compounds. RHA is truly called as carbon neutral green product.

Introduction:

India is one of the leading paddy rice (*Oryza sativa*) growing country in the world after China. It is a primary source of food for billion people. During growth, rice plants absorb silica from the soil and accumulate it into their structures. It is this silica, concentrated by burning at high temperatures removing other elements which makes it so valuable. In Yash Papers we purchase Rice husk from neighboring three divisions of U.P. i.e. Faizabad, Gorakhpur and Allahabad. As the mill is situated in rice growing belt it has a little or absolutely no problem in getting the Rice husk in plenty for using as a fuel in cogeneration of 6 MW power. The calorific value varies with paddy variety, moisture and bran content but the typical value for husk with 8-10% moisture content and zero bran is 15 MJ/kg. The rice husk contains about 20% ash which is higher than the ash content of most of other biomass fuels. In the rice husk ash (RHA) the silica content is 92-95%. The silica presents in RHA is highly porous, light weight with very high external surface area. It has a pozzolanic, insulating as well as absorbent property hence making it very useful to many industrial applications.

In practice, the type of RHA varies considerably according to the burning techniques. The silica in the RHA undergoes structural transformations depending upon combustion conditions in the boiler furnace. At 600-800°C combustion temperature amorphous silica is formed and at temperature greater than this crystalline ash is formed. It is worthwhile to mention that amorphous silica is most suitable for producing RHA cement and binder in RHA, lime and cement mortar. The loss on ignition of RHA due to carbon content is about 5-10%. Thus RHA is carbon neutral green product and it can be used in variety of applications(1) like :

- Green concrete i.e. as mortar in concrete, cement mixture as partial and complete substitution of Pozzolana Portland cement (PPC)
- Calcium ferrite bonded porous silica refractory and sodium silicate bonded porous silica refractory.
- Low cost building blocks
- Ceramic glaze
- Insulators
- roofing shingles
- Oil spill absorbent
- Silica fumes or micro silica used in admixture in high strength concrete.
- Silicon chips for using in semiconductor manufacture after purifying amorphous RHA to get 99.9% purity at a high cost.
- Production of sodium silicate and sodium silicate film.
- As a free running agent for fire extinguishing powder.
- An abrasive filler for tooth paste. (1)

The most promising industrial application of RHA is to produce binder to partially replace the expensive Pozzolana Portland cement (PPC) and with this idea we have undertaken this study. If succeed in commercial exploitation of RHA then we shall kill two birds with one arrow. On the one hand we will solve our dumping problem of RHA and shall get value addition from RHA secondly shall get many environmental benefits of substituting Portland cement with RHA.

Experimental

Materials and methods

The rice husk is purchased from various sources in and around Faizabad through contractors and local farmers. The annual consumption of rice husk is about 84500 tonnes. This husk is burnt in Atmospheric Fluidized Bed Combustion (AFBC) Water Tube Boiler to generate 6 MW power to meet total requirement of electrical power of the mill. The furnace temperature is maintained around 700-800°C. The RHA generated is around 18-20% of the total husk fired in the boiler. The annual RHA generation by the mill is about 17000 tonnes. The RHA used in this study was obtained from the boiler Electro Static Precipitator (ESP) outlet.

The chemical analysis of rice husks taken from various literature sources (2, 3) is given as under in Table 1.

Table 1
Chemical analysis of rice husk

S.No.	Property	
1	Bulk density kg/m^3	96-160
2	Length of husk (mm)	2.5-5.0
3	Ash, (%)	22.24
4	Carbon, (%)	35.77
5	Hydrogen, (%)	5.06
6	Oxygen, (%)	36.59
7	Nitrogen, (%)	0.32
8	Sulphur, (%)	0.082
9	Moisture, (%)	8.05

The chemical composition and properties of RHA have been studied by Cook (4) and is reproduced in table 2 as under:

The RHA collected from boiler ESP outlet is taken for laboratory test with different mix proportion of RHA, lime and Pozzolana Portland cement (PPC) in the ratio 50:40:10, 55:35:10, 60:30:10 and 65:25:10. These ratios are based on the total dry weight of the required sample. In the study we have only varied the proportion of RHA and lime and kept the proportion of PPC constant. The each mix proportion is grinded separately in a ball mill having 1.5 m long and 1.5 m diameter mild steel drum driven by 25 HP electrical motor fabricated by mill engineer at site. After filling 80 kg with the mixture in required proportion in the ball mill, the cylindrical balls in shapes having 15 mm length and 20 mm diameter was charged in the drum such that total weight of cylindrical balls weighs 500 kg. The cover of the ball was closed and allowed to run for 8.0 hours to grind the mix to 100 mesh particle size (150µm). In this way all the different mix was grinded separately (5). The each ground mixture is taken out from the ball mill. Thus the grinded mixture is named Yash Ashmoh and used as mortar. Standard cubes of 10cm x 10cm x 10 cm dimensions were made by using mortar of Yash Ashmoh: sand in the 1:3 ratios with requisite amount of water. The cubes are dried in a ambient atmosphere for 24.0 hours. The dried standard cubes were marked property for its further testing. The compressive strengths were determined of each blend of cubes using compressive strength tester of J.S.R. make. To compare the strength of Yash Ashmoh with standard cubes of 10cm x 10cm x 10 cm dimensions were also made using pozzolana Portland cement and sand mortar in the 1:3 ratio using sufficient amount of water. The initial and final setting time of the mortar was also measured by vicat apparatus.

Table 2
Chemical composition & physical properties of RHA

S.No.	Property	
1	Silicon dioxide (SiO_2),%	92.995
2	Other oxides, (%)	3.818
3	Loss of ignition, (%)	2.932
4	Specific gravity	2.36

Results and discussion

The composition of Yash Ashmoh (5) as obtained after blending and grinding with lime and PPC along with the composition of PPC for comparison is given in Table 3.

Table 3
Composition of PPC and Yash Ashmoh (wt, %)

S.No.	Constituent	Chemical Formula	PPC	Yash Ashmoh*
1	Silica	SiO_2	19.0—25.0	60.0—62.0
2	Lime	CaO	62.0—66.0	24.0—26.0
3	Alumina	Al_2O_3	4.0—8.0	2.0
4	Iron oxide	Fe_2O_3	2.0—5.0	1.0
5	Magnesium oxide	MgO	0.5—4.0	<2.0
6	Alkali oxides	Na_2O, K_2O	0.5—1.3	<1.5
7	Sulphuric an hydride	SO_3	1.0—3.0	—
8	Carbon	C	—	<4.0
9	Water	H_2O	—	6.0—7.0

* Computed on the basis of 92% silica in RHA and 90% CaO in quick lime.

It is well known that compound composition of PPC is highly complex and it could be seen from the data given Tables 3 that it is quite different from that of Yash Ashmoh.

The PPC has about 40-55% $3CaOSiO_2$, 20-25% $2CaOSiO_2$, 7-11% $4CaOAl_2O_3Fe_2O_3$ plus $2CaOFe_2O_3$, 7-15% $3CaOAl_2O_3$ and 0.5-2% CaO.

Where as Yash Ashmoh is a very finely ground intimate mechanical mixture of RHA which is mostly silica, hydrated lime (mostly CaO) and an additive ie. PPC. (5)

The results of the comparative strength of different cubes made by blending RHA, lime and PPC in varied proportion

Table 4
Compressive strength of different cubes from mortar of Yash Ashmoh

S.No.	Ratio of mix	Compressive Strength (kg/cm^2) Average			
	RHA:Lime:PPC	After 7 th days	Compressive strength % less than mix PPC:sand standard	After 28 days	Compressive strength % less than PPC:sand Standard
1	PPC:sand 1:3 (standard for comparison)	230.0	—	250.0	—
2	50:40:10	97.5	57.6 %	105.0	58.0%
3	55:35:10	122.5	46.7%	130.0	48.0%
4	60:30:10	140.0	39.1%	145.0	42.0%
5	65:25:10	155.0	32.6%	165.0	34.0%

keeping the proportion of PPC in the blend constant at 10% is given in Table 4.The compressive strength of the cubes made from only PPC and sand is also given in Table 4 for comparison. It may be noted that initial setting time between 60-90 min. and final setting time 5 to 7 hr. was recorded. These values are well within the specification for PPC initial settling time 30-45 min. and final setting time 10 hr.

It could be seen from the data given in Table 4 that when in the mix proportion of RHA and lime was 50:40:10 the compressive strength of the cubes after curing for 7 days and 28 days was 97.5 and 105.0 and when mix % of RHA:Lime: PPC were 55:35:10 and 60:30:10 the compressive strength were 122.5,140.0 and 130.0,145.0 kg/cm^2 after 7 days and 28 days of curing respectively. The maximum compressive strength of the cubes made from the mortar of the mix proportion RHA:Lime:PPC 65:25:10 was obtained and it is 155.0 kg/cm^2 165.0 kg/cm^2 after 7 th days and 28 days of curing. The comparision of compressive strength with PPC: sand mortar with different mix proportion of RHA: lime: PPC is shown in the figure 1.

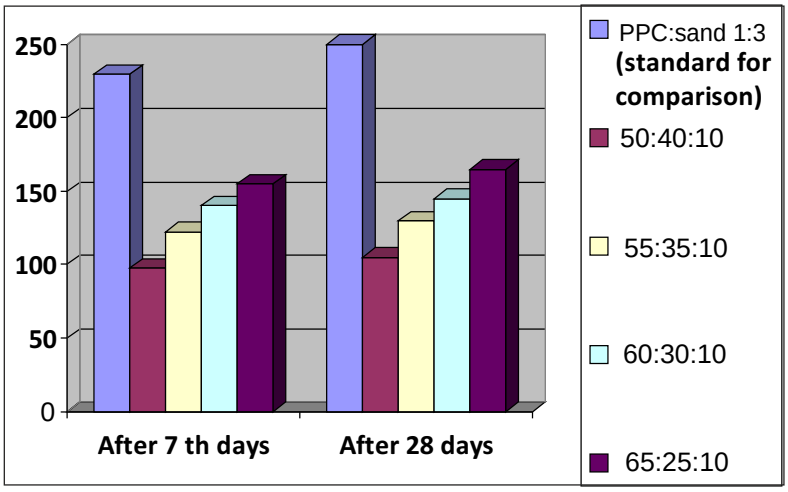

Figure 1
Comparison of compressive strength of cubes made from different mix mortar with standard PPC mortar

The compressive strength of the cubes made from PPC: sand mortar as recorded was 230 kg/cm^2 and 250 kg/cm^2 after 7 days and 28 days of curing in water. The data recorded in Table 4 revealed that maximum compressive strength which could be obtained by preparing the mortar from the mix of RHA, lime and PPC in the percentage of 65:25:10 respectively gave maximum compressive strength which is 34.0% less than the strength obtained from mortar of PPC:sand in ratio of 1:3. It is indicated by the data that Compressive strength obtained by the Yash Ashmoh is quite satisfactory for being used in non structural purposes replacing up to 90% PPC, in preparation of curved stones, flower pots, drain trench covers, interlocking bricks, etc.

In Yash Papers Limited we have already made above mentioned items and are being used in our mill site.

Further studies are in progress to develop the yash ashmoh which can be used in concrete mix for high strength and making the concrete durable to chemical attack, abrasion, reinforcement, corrosion and water proofing compound i.e. water resistance (impermeability).

Thus in short we can say that RHA has a great potential to replace PPC as a building material and may be truly called as carbon neutral green product. It is hoped that RHA will soon become solution from present day problem of disposal as land filling.

Conclusion

1. Yash Ashmoh is a slow setting binder as compared to PPC.
2. Yash Ashmoh can be used in big way for non structural purposes replacing up to 90% PPC.
3. It can be used in the preparation of curved stones, flower pots; drain trench covers, interlocking bricks, etc.

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