

Mechanical Properties of Rice Husk Ash (RHA) - High strength Concrete

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Abstract: - High strength and high performance concrete are being widely used all over the world. Most of the applications of high strength concrete have been found in high rise buildings, long span bridges etc. The potential of rice husk ash as a cement replacement material is well established. Earlier researches showed an improvement in mechanical properties of high strength concrete with finely ground RHA as a partial cement replacement material. A review of literature urges the need for optimizing the replacement level of cement with RHA for improved mechanical properties at optimum water binder ratio. This paper discusses the mechanical properties of RHA- High strength concrete at optimized conditions.

Keywords: - Rice husk ash, high strength concrete, pozzolanic activity

I. INTRODUCTION

cent of the rice paddy is husk, giving an annual total production of 120 million ton. It is estimated that 1,000kg of rice grain produce 200kg of rice husk; after rice husk is burnt, about 20 percent of the rice husk or 40 Kg would become RHA. Rice husk ash (RHA) is a general term describing all types of ash produced from burning rice husks. In practice, the type of ash obtained varies considerably according to the burning technique. At 550°C – 800°C amorphous ash is formed and at temperatures greater than this, crystalline ash is formed. This study is conducted to investigate the optimum replacement level of rice husk ash (RHA) to cement in high strength concrete. The research involved partial replacement of cement by RHA and thereby making concrete more affordable to the common man and also to find a solution to the disposal problems created by rice husk.

II. MATERIALS AND METHODS

The ingredients used for the study were the same as those used for conventional concrete except the usage of mineral and chemical admixture. For this study Ordinary Portland cement of 53 grade with specific gravity 2.93 was used. River sand passing through 4.75mm sieve with fineness modulus of 2.89 and specific gravity 2.49 which falls under grading zone II was used as fine aggregate. The coarse aggregate used was crushed granite with a maximum nominal size of less than 20mm, bulk density of 1400 kg/m³ and specific gravity 2.85.

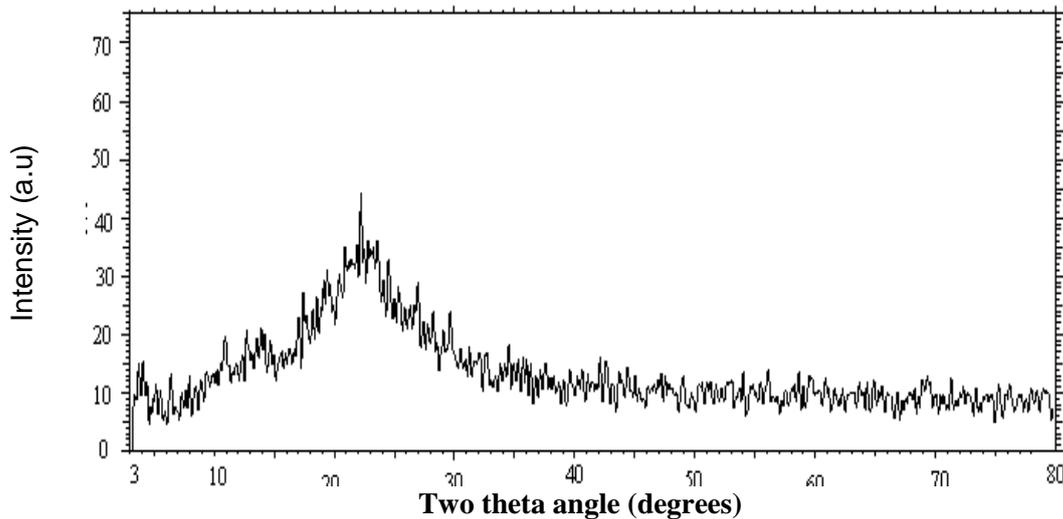
Mineral admixture

The addition of RHA to cement has been found to enhance cement properties: The addition of RHA speeds up setting time, although the water requirement is greater than for OPC. RHA cement has improved compressive strength due to its higher percentage of silica. RHA cement has improved resistance to acid attack compared to OPC, thought to be due to the silica present in the RHA which combines with the calcium hydroxide and reduces the amount susceptible to acid attack. More recent studies have shown RHA has uses in the manufacture of concrete for the marine environment. Replacing 10percent Portland cement with RHA can improve resistance to chloride penetration. RHA can also replace silica fume in high strength concrete. Silica fume or micro silica is the most commonly used mineral admixture in high strength concrete. The major characteristics of RHA are its high water demand and coarseness compared with condensed silica fume. To solve these problems RHA needs to be ground finely into particles of 8-10 μm and a super plasticizer added to

reduce water requirement.

Preparation of Rice Husk Ash

Rice husk was collected from a rice mill at Perumbavoor, in Kerala state, India. The rice husk was burnt in an annular kiln for obtaining amorphous silica under controlled burning as described in Nair et al [1]. The broad band near 22 degrees of the 2-theta scale of the XRD spectrum of the RHA sample (Fig 1) shows that the ash obtained is of amorphous nature.



Specific gravity

Specific gravity of RHA is determined by using a standard Le-Chatelier's flask and kerosene. The specific gravity of the sample is 2.04.

Surface area

The surface area of the RHA sample was determined at SUD-CHEMIE with Micromeritics Gemini V2.00 instrument. The BET Surface Area of the sample: 38.3986 m²/g.

Super plasticizer

The super plasticizer used is Conplast-SP-430, manufactured by FOSROC, India. Conplast SP430 is based on Sulphonated Naphthalene Polymers and is supplied as a brown liquid instantly dispersible in water. It gives water reductions up to 25percent without loss of workability to produce high quality concrete of reduced permeability.

III. EXPERIMENTAL PROGRAM

The program consists of casting and testing a total of 114 specimens. The specimens of standard cubes (150mm x150mm x150mm), standard cylinders of (150mm diameter x 300mm height) and standard prisms of (100mm x100mm x500mm) were cast with and without RHA. Earlier researches have shown that the replacement of cement with 30percent RHA resulted in reduction of strength. Hence specimens were cast with M60 grade concrete with different replacement levels of cement varying as 0percent, 5percent, 15percent and 25percent with RHA at varying water -binder ratio (w/b). The w/b used is 0.35, 0.4 and 0.45. The optimum percentage replacement of RHA is arrived by analyzing the cube compressive strength test results. The other properties of the optimized mix are then studied in detail. The details of mix proportions are given in Table 1.

Table 1. Details of mix proportions

Mix	w/b	Quantity in kg/m ³ of concrete						
		Cement	RHA	Water	FA	CA		SP (l)
						12mm	20mm	
CA0	0.35	500	0	174	396.	539.	809.	4.0
LA10	0.35	428	50	174	396.	539.	809.	4.4
LA15	0.35	392	75	174	396.	539.	809.	4.4
LA20	0.35	356	100	174	396.	539.	809.	8.0
LA25	0.35	320	125	174	396.	539.	809.	9.0
MA0	0.4	500	0	200	396.	539.	809.	1.7
MA10	0.4	392	50	200	396.	539.	809.	2.7
MA15	0.4	356	75	200	396.	539.	809.	4.0
MA20	0.4	320	100	200	396.	539.	809.	4.4
MA25	0.4	392	125	200	396.	539.	809.	6.1
HA0	0.45	500	0	225	396.	539.	809.	3.0
HA10	0.45	392	50	225	396.	539.	809.	4.0
HA15	0.45	356	75	225	396.	539.	809.	4.0
HA20	0.45	320	100	225	396.	539.	809.	4.4
HA25	0.45	392	125	225	396.	539.	809.	6.1

IV. RESULTS AND DISCUSSION

Optimum level of RHA content

The 7th and 28th day cube compressive strength of the concrete mixes prepared by varying the w/b and the percentage replacement of cement with RHA were compared (Fig.2) to find out the optimum content of RHA. From the results obtained, it is observed that for a particular w/b the compressive strength of concrete increased as the replacement levels up to 25 percent. Also, the compressive strength increased when the w/b is increased from 0.35 to 0.4. This is attributable to the amorphous nature of RHA. The maximum compressive strength is obtained when the w/b is 0.4 and the replacement of cement with RHA is 25 percent. This mix is taken as the optimized mix.

Mechanical Properties

The results of the various tests that were conducted to study the mechanical properties are discussed in the subsequent sections. The results obtained with the optimum mix are compared against that of the control mix.

Compressive strength (Cube)

The study includes 7th, 28th and 90th day cube compressive strength of the concrete mixes prepared by varying the w/b and the percentage replacement of cement with RHA. From the results obtained, it is observed that for a particular w/b the compressive strength of concrete increased as the replacement levels up to 25 percent. Beyond that the compressive strength reduces. Also, the compressive strength increased when the w/b is increased from 0.35 to 0.4. This is attributable to the amorphous nature of RHA. But compressive strength decreases when it is further increased to 0.45. The maximum compressive strength is obtained when the w/b is 0.4 and the replacement of cement with RHA is 25 percent. This mix is taken as the optimized mix. The 28 day compressive strength showed an increase of 5 percent while the 90 day compressive strength showed an increase of 6 percent. This shows the strength development due to the pozzolanic action of the RHA at later ages. The comparison of compressive strengths (cube) is given in Fig.3.

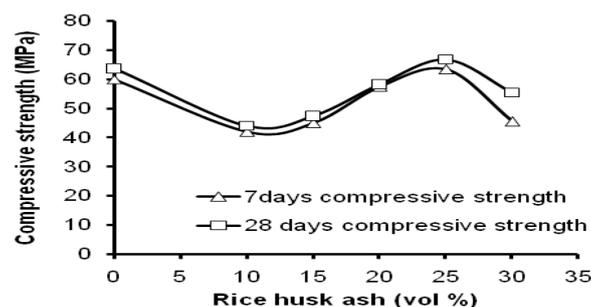


Fig 2 Compressive strength v/s percent replacement curve (w/b = 0.4)

Compressive strength (Cylinder)

The cylinder compressive strength of concrete prepared using the optimized mix is found to be greater than that of the control mix. It was also noticed that the 28th day compressive strength of the optimized mix showed an increase of about 13percent than that of the control mix. The increase in compressive strength is attributed to the pozzolanic property and filling ability of RHA which have finer particle size when compared with cement. The studies conducted by Barbhuiya, et al. [1], Giaccio et al., [2] and Salas et al., [3] also have produced similar results. The comparison of compressive strengths (cylinder) is given in Fig.4.

Flexural strength

The results show that the Flexural strength at 28 days increased with the replacement of 25percent cement with RHA. This is due to the higher specific area of the RHA which accelerated the pozzolanic reaction. Another possible reason may be the presence of higher CaO content in the RHA. The results of the present investigation indicate that the percentage of RHA contributing to the mechanical properties is more significant than that of control concrete. The research conducted by Barbhuiya, et al. [2], Giaccio et al., [3], Bhikshma et al., [5], Habeeb et al., [6] and Salas et al., [4] also revealed that the flexural strength increased with the addition of RHA to concrete. The comparison of results of flexural strength test conducted on 28 days on samples of control concrete and the optimum mix is given in table 5. The comparison of Flexural strength of mixes is given in Fig 6.

Splitting tensile strength

From the results obtained it is noted that the splitting tensile strength slightly reduces. Bhikshma et al., [5] has reported that the splitting tensile strength increased as the replacement level increased up to 12percent and beyond that the splitting tensile strength decreases. Here it is to be noted that the replacement level of MA25 mix is 25 percent. This may be the reason for the reduction in splitting tensile strength.

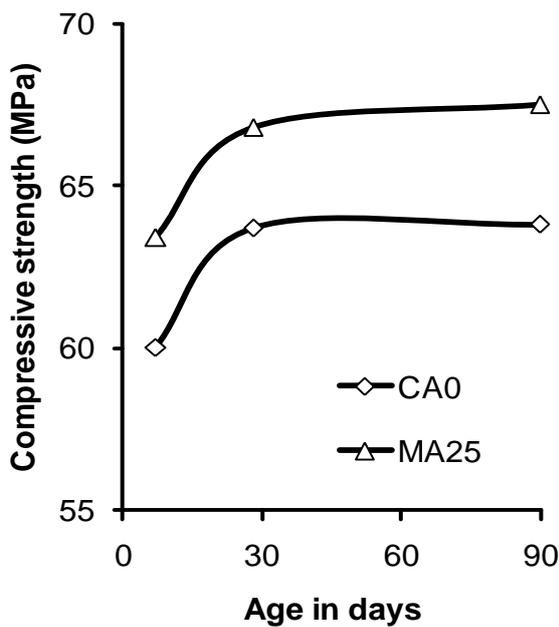


Fig 3.Comparison of Compressive strengths(Cube)

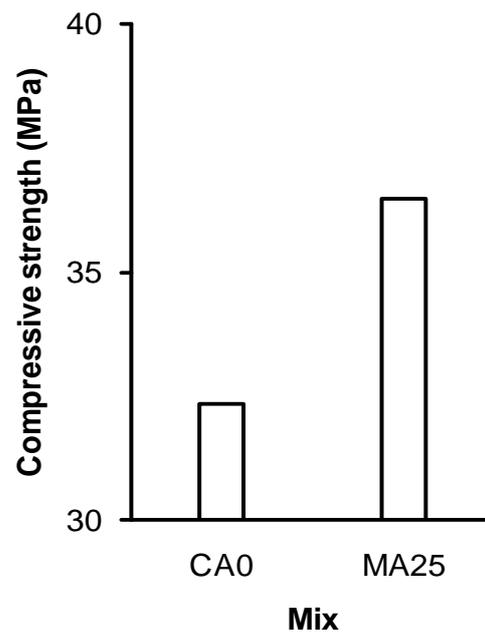


Fig 4.Comparison of Compressive strengths(cylinder)

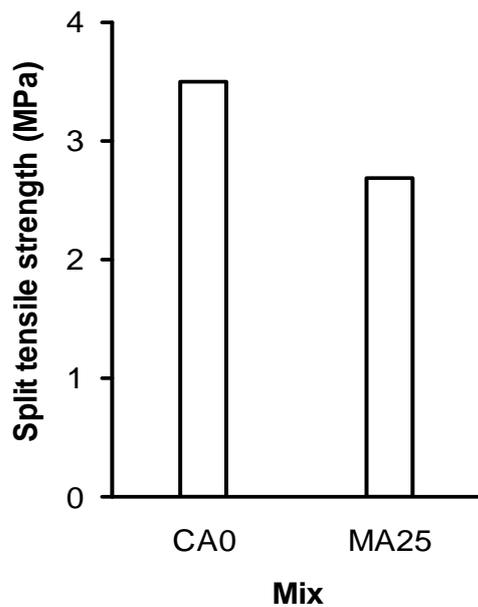


Fig 5. Comparison of Flexural strength

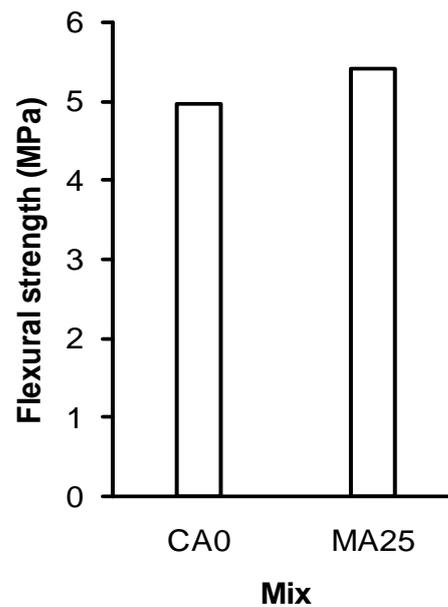


Fig 6. Comparison of Split tensile strengths

Bond strength

The results of bond strength studies indicate that the bond strength increases with the replacement of 25 percent cement with RHA. This may be due to the better packing ability of the finer particles of RHA at the interface between the reinforcement and the cement paste. It also reduces the porosity as the pores in the cement paste are filled by the finer particles of the RHA. The inclusion of RHA reduces the bleed water and thus prevents it from getting blocked in between the reinforcement and the cement paste

Modulus of Elasticity

The study shows that the Modulus of Elasticity slightly reduces with the replacement of cement with 25 percent of RHA. Sata, et al., [7] and Habeeb et al., [6] reported that the modulus of elasticity increased with the increase in compressive strength. Ahmadi et al., [8] noticed a decrease in the modulus of elasticity when the replacement of cement by RHA increases. The contradiction in the results obtained may be due to the difference in the fineness of the RHA samples. The reduction in the modulus of elasticity is attributable to the inclusion of more compressible material (amorphous silica) into the concrete which increases the strain

Density

The replacement of cement with RHA results in reduction of density of concrete. This is due to the fact that the specific density of the RHA is much lower than that of cement. The optimum mix with 25 percent replacement showed 5.5 percent reduction in density when compared with the control concrete.

Fresh Properties -Workability

All mixes after mixing were immediately tested to determine slump. It is observed that the dosage of super plasticizer increased with the increase of RHA content. This can be attributed to the porosity of the RHA sample. As the percentage replacement of RHA increases, the quantity of the RHA in the mix increases which in turn necessitates the excessive use of super plasticizer content to achieve the same degree of lubrication as that of control concrete.

V. CONCLUSION

From this experimental study it is inferred that the incorporation of RHA in concretes results in improved compressive strength and flexural strength. A slight increase in bond strength was also reported. RHA- High strength concrete showed a reduction in density compared with conventional concrete. Hence this study promotes the use of RHA in high strength concrete as a sustainable cement replacement material.

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