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Experimental Study on Rice Husk Ash in Concrete by Partial Replacement

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Abstract: This paper describes the experimental study on strength characteristics of M40 grade concrete in which cement is partially replaced by rice husk ash. Rice Husk Ash (RHA) is one of these waste products which are generated as a by-product of rice paddy milling industries. In this study, the strength related properties such as compressive strength, splitting tensile strength, flexural strength were calculated in which concrete specimens produced with 0%, 10%, 12.5% and 15% of the RHA as the cement replacement percentages. Specimens were tested at the ages of 7 and 28 days. Finally, concluded that the RHA replacement level of 12.5% in M40 grade concrete showed higher when compared to other replacement levels.
Keywords: Rice husk ash, Compressive strength, Split tensile strength, Flexural strength.

Introduction:

Concrete is one of the crucial materials for infrastructure development due to its versatile application, globally its usage is second to water. For last few decades, there are many concerns raised for the continuous increase of cement use because of the reasons that the production of cement causes large amount of carbon dioxide (CO_2) emission and it also consume significant amount of natural rock and minerals that may lead to deplete at one point of time. Manufacture of one tonne of Portland cement (PC) generates about one ton of CO_2 to the atmosphere which constitutes 5% global CO_2 emission. To build sustainable environment, it is necessary to control the emission of CO_2. Due to increase in the cost of conventional building materials and environmental hazard, the designers and developers are looking for 'alternative materials' to reduce the use of cement in civil engineering constructions. For this objective, the researchers are trying to use various waste products in concrete technology.

Rice Husk Ash (RHA) is one of these waste products which are generated as a by-product of rice paddy milling industries. For rice growing countries like India, rice husks have attracted more attention due to environmental pollution and an increasing interest in conservation of energy and resources. The concrete industry offers an ideal method to integrate and utilize a number of waste materials, which are socially acceptable, easily available, and economically within the buying powers of an ordinary man. Presence of such materials in cement concrete not only reduces the carbon dioxide Emission, but also imparts significant improvement in workability and durability. Considerable efforts are being taken worldwide to utilize locally available natural waste and by-product materials in making concrete, such as Rice Husk Ash as supplementary cementing materials to improve concrete properties (durability, strength, etc.). The effect of using RHA as a partial replacement for cement has been investigated in this research. RHA is a carbon neutral green product. Lots of ways are being thought of for disposing them by making commercial use of this RHA. Rice husk ash is a very fine pozzolanic material. The utilization of rice husk ash as a pozzolanic material in cement and concrete provides several advantages, such as improved strength and durability properties, reduced materials costs due to cement savings, and environmental benefits related to the disposal of waste materials and to reduce the carbon dioxide emissions. The chemical composition of Rice Husk is found to vary from one sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions.

Rice husk ash is obtained by burning rice husk in a controlled manner without causing environmental pollution. When it is properly brunt it has high SiO_2 content and can be used as a concrete admixture. Rice husk ash exhibits high pozzolanic characteristics and contributes to high strength and high impermeability of concrete. Rice husk ash essentially consists of amorphous or non-crystalline silica with about 85- 90% cellular particle, 5% carbon and 2% K_2O. Each tonne of paddy produces about 40 kg of RHA. There is a good potential to make use of RHA as a valuable pozzolanic material to give almost the same properties as that of micro silica.

Alireza Naji Givi, et al (2010) reported that the effects of using Rice Husk Ash (RHA) as a partial cement replacement material in mortar mixes. This work is based on an experimental study of mortar made with Ordinary Portland Cement (OPC) and 10%, 15%, 20%, 25% and 30% of OPC replaced by RHA. The RHA used was obtained from uncontrolled auto combustion of rice husk, in a chamber, without control of temperature and burning time. The mechanical properties investigated were the compressive strength, and also the porosity of mortar was tested. The obtained results show that the strength and porosity of mortar incorporating RHA were better, up to 20% of cement replacement level. Habeebh (2009) reported that the investigation on the behaviour of concrete produced from ordinary Portland cement with RHA. The properties of fresh concrete and the effect of replacing 5%, 10%, 15%, and 20% of cement with RHA on the compressive strength were investigated. Incorporation of RHA in concrete resulted in increased water demand, for the hardened properties, RHA concrete gave excellent improvement in strength for 10% replacement, and up to 20% of cement could be valuably replaced with RHA without adversely affecting the strength. Maurice E. Ephrain, (2012) reported that this paper present the results of investigation on the use of rice husk ash as a partial substitute for cement in construction. The results shows that at 5% partial replacement of cement with rice husk ash can be used for structural concrete and at 15% replacement or more it can be used for non - structural construction works or light weight concrete construction. The cost analysis shows substantial amount of savings for the country.

Materials Used:

Cement: The Ordinary Portland Cement of 53 Grade conforming to IS 12269 – 1987 was used in this study. The specific gravity, initial and final setting of OPC 53 grade were 3.08, 28 and 320 minutes respectively.

Fine Aggregate: Locally available river sand conforming to grading zone II of IS 383 –1970. Sand passing through IS 4.75mm Sieve will be used with the specific gravity of 2.65. The sieve analysis of fine aggregate is shown in Table 1

Table 1. Sieve Analysis of River Sand

Sieve size	% passing
4.75mm	98
2.36mm	96
1.18mm	78
600µm	51
300 µm	26
150 µm	7

Coarse Aggregate: Locally available blue metal was used. Crushed granite stones of size passing through 20mm sieve and retained on 4.75 mm sieve as per IS: 383-1970 was used for experimental purpose. The sieve analysis of natural coarse aggregate is shown in Table 2.

Table 2. Sieve Analysis of Natural Coarse Aggregate

Sieve Size (mm)	% Passing
25	100
20	100
16	100
12.5	100
10	33
6.3	3
4.75	0

Water:

Casting and curing of specimens were done with the potable water that is available in the college premises.

Rice husk ash:

RHA, produced after burning of Rice husks (RH) has high reactivity and pozzolanic property. 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 physical and chemical properties of RHA are shown in Table 3 and Table 4.

Table 3. Physical Properties of Rice Husk Ash

Physical properties	**Value**
Specific gravity	2.19
Fineness passing through 45µm sieve in (%)	99.5
Colour	Grey

Table 4. Chemical Properties of Rice Husk Ash

Chemical properties	**Value**
Silicon dioxide(SiO_2)	88.32
Silicon dioxide(SiO_2)	0.46
Ferric oxide(Fe_2O_3)	0.67
Calcium oxide(CaO)	0.51
Magnesium oxide(MgO)	0.44
Sodium oxide(Na_2O_3)	0.12
Potassium oxide(K_2O)	2.91

Mix Proportions:

In this study, control specimen (MCS) was designed as per IS 10262-2009 to achieve M40 grade of concrete with w/c ratio of 0.4. Concrete were produced with 0, 10, 12.5 and 15% of the RHA as cement replacement levels. There are four different mix proportions were prepared these proportions were shown in Table 5.

Table 5. Concrete Mix Proportions

Mix	MCS	MR10	MR12.5	MR15
Cement (kg/m^3)	492.5	443.25	430.94	418.63
FA (kg/m^3)	755	755	755	755
CA (kg/m^3)	968	968	968	968
Water (lit/m^3)	197	197	197	197
RHA (%)	0%	10%	12.5%	15%

Casting and Testing of Specimens:

All the ingredients were first mixed in dry condition in the concrete mixer. The concrete mix proportion is already shown in table. The calculated amount of water added to the dry mix and mixed thoroughly to get uniform mix. Before casting machine oil was smeared on the inner surface of the mould and the concrete was poured in to the mould. After24 hours of casting, the specimens were demoulded and cured for 28 days using water tank. After the curing period was over, the specimens were white washed and kept ready for testing. For each mix, six cube specimens, three cylinder specimens and three beam specimens of size 100 x 150 x 1000 mm. Cube and specimens were tested on 7 days and 28 days.

Results and Discussion:

Strength Characteristics - Compressive Strength:

The cube compressive strength results at various ages such as 7, 28 days for different replacement levels such as 0%, 10%, 12.5% and 15% of cement with Rice husk ash are expressed in Table 6. The development of Compressive Strength with ages for the above different mixes was plotted in the form of graph as shown in Fig 1.From the test results it was observed that the maximum compressive strength is obtained for mix with 12.5% RHA was observed that the maximum compressive strength at the water-binder ratio of 0.40. The compressive strength development is due to the pozzolanic reaction of RHA. The rapid rate of strength development is due to the fact that for lower water-binder ratio, the cement particles are held at closer interval than for higher water-binder ratios. Also due to the action of silica fume on calcium hydroxide, more gel is formed. These two factors enhance the formation of a continuous system of gel, which provides better development of strength at early ages since, silica fume starts react with calcium hydroxide and produces C-S-H gel immediately.

Table 6. Compressive Strength Results

Mix	RHA (%)	7 days strength (N/mm^2)	28 days strength (N/mm^2)
MCS	0%	28.22	40.12
MR10	10%	30	40.22
MR12.5	12.5%	37.5	42.65
MR15	15%	29.42	42.08

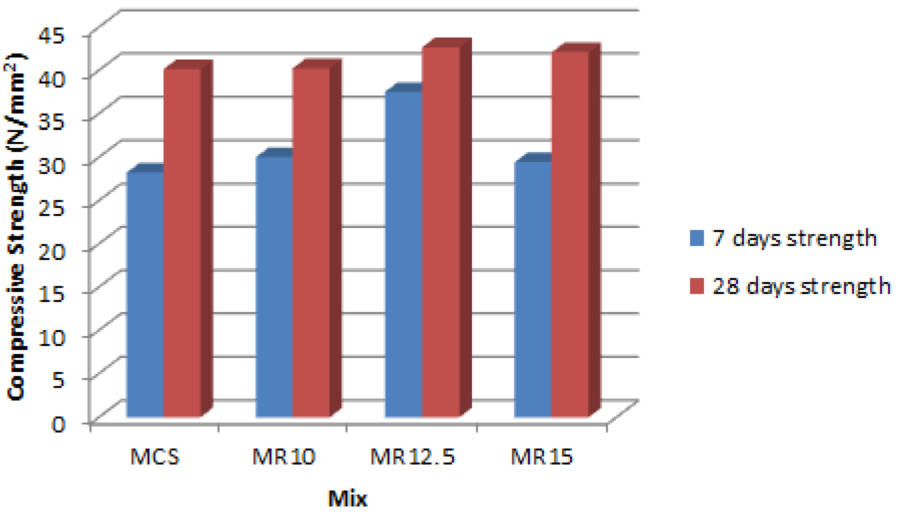

Figure 1. Comparison of Compressive Strength Results for various mixes

Split Tensile Strength

The split tensile strength results of mixes at the age of 7 and 28 days for different replacement levels such as 10%, 12.5%, and 15% of cement with Rice husk ash are presented in Tables 7. The development of Split tensile strength with ages for the above different mixes was plotted in the form of graph as shown in figure 2. From the test results it was observed that the maximum split tensile strength is obtained for mix with 12.5% RHA. In the replacement of RHA the mix with 12.5% RHA was observed that the maximum split tensile strength at the water-binder ratio of 0.40.

Table 7. Split Tensile Strength Results

Mix	RHA (%)	7 days strength	28 days strength
MCS	0%	1.055	2.044
MR10	10%	1.15	2.204
MR12.5	12.5%	2.91	3.255
MR15	15%	2.266	2.4

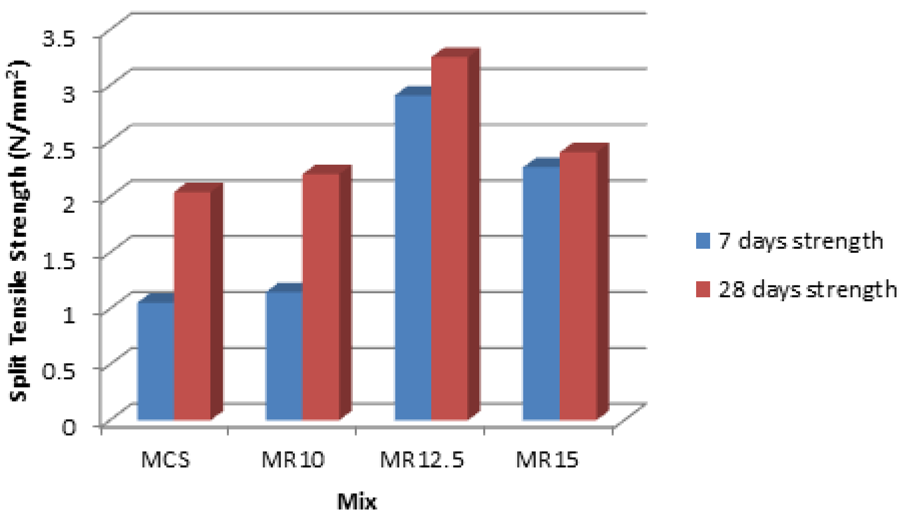

Figure 2. Comparison of Split Tensile Strength Results for various mixes

Flexural Strength

The size of beam used was 100 x 150 x 1000 mm. To start with trial specimens having a span of 1000 mm were tested under two-point loading. The effective span was 800 mm. Hence the point load was applied at one third point from the end supports. The reinforcement used were high yield strength deformed (HYSD) bars 2 No's of 10mm diameter in the tension zone and 2 no's of 8mm diameter in compression zone and one specimens for each parameter. The shear reinforcement is designed in such a way that, the shear capacity of the specimen is higher than the flexural strength. This is done to ensure flexural failure. For shear span 2 legged 6mm diameter stirrups at 110 mm centre to centre is provided.

Figure 3. Test setup of the Beam

Figure 4. Deflected Profile of the Beam

Table 7. Flexural Strength Results

Mix	RHA (%)	Ultimate Load(N/mm^2)	Deflection in (mm)	Flexural Strength N/mm^2)
MCS	0%	48.4	5.52	21.51
MR10	10%	57.2	7.85	25.42
MR12.5	12.5%	57.2	5.15	25.42
MR15	15%	52.8	8.05	23.47

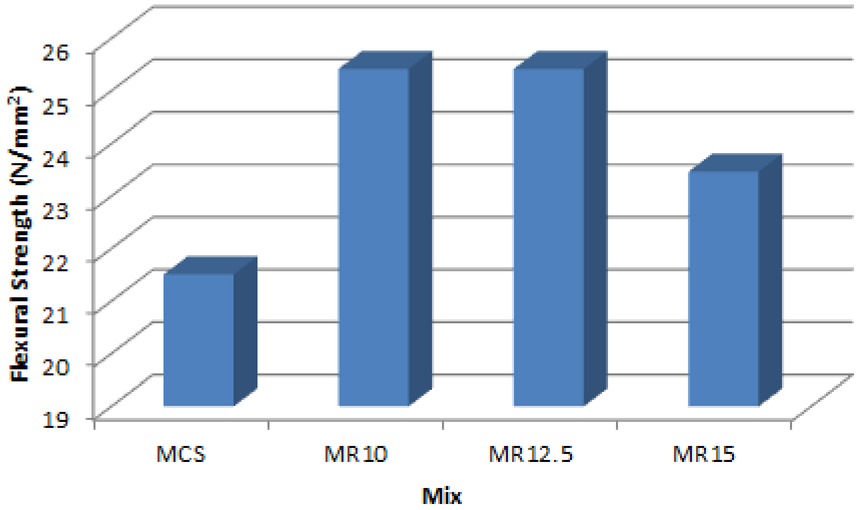

Figure 5 Comparison of Flexural Strength Results for various mixes

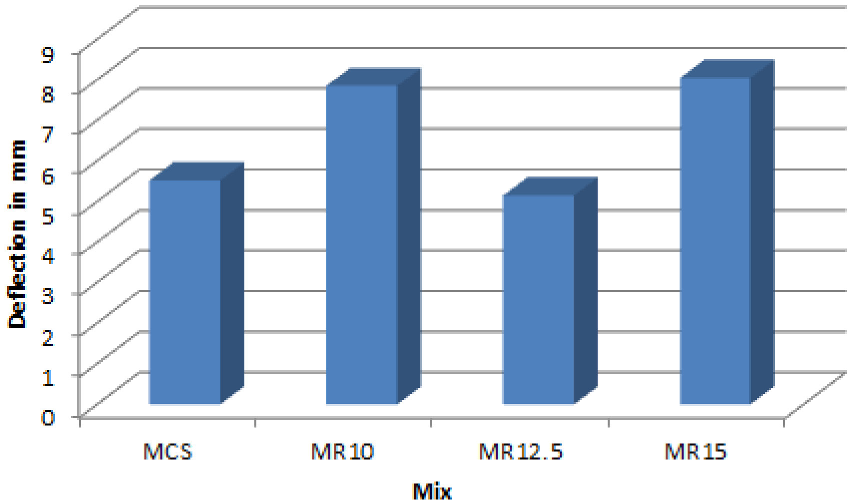

Figure 6. Comparison of Deflection for various mixes

Conclusion

Experimental Investigations on Strength Characteristics

Based on the experimental investigations carried out on the strength characteristics of mixes the following conclusions are arrived at:

- At the ages of 7 and 28days the compressive strength of mixes containing Rice husk ash was more than that of mixes without Rice husk ash. This indicates that addition of Rice husk ash as partial replacement to cement causes an increase in strength. Thus Rice husk ash acts as pozzolanic material, hence the compressive strength of concrete increases as the percentage of Rice husk ash increases.

- At the age of 28days the compressive strength of mix 12.5%RHA shows the highest strength when compared to other replacement levels of RHA with Cement. This indicates that the optimum percentage of replacement of Rice husk ash with cement is 12.5 percent.

- In the replacement levels of Rice husk ash with cement, the optimum replacement of Rice husk ash with cement for M40 grade of concrete was found to be 12.5% for achieving maximum split tensile strength at the age of 28 days.

- At the age of 28days the flexural strength of mix 12.5% RHA shows the highest strength when compared to other replacement levels of Rice husk ash with cement. The ultimate load and first crack load for the above mix shows the highest value and this indicates that the optimum percentage of replacement of Rice husk ash with cement is 12.5 percent.

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