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Properties of Partially Replaced Cement Concrete with Rice Husk Ash

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Abstract*: This study investigates the progressions in mechanical properties of concrete by substitution of cement by Rice Husk Ash (RHA) in conjunction with superplasticizers. Rice husk is a by-product of the rice milling process, with inexact generation of 200 kg for every one ton of rice. Diffusion of Rice Husk Ash in the concrete matrix enhance the properties of the concrete. This investigation has been done to determine the strength parameters of concrete with various extents of cement supplemented by Rice Husk Ash. M20 grade concrete (Designed as per Indian standards) was tried with substitutions by weight of the cement amount by 2.5%, 5%, 7.5%, 10% and 15%. Various strength Test results reveal enhancement of strength at 5% substitution of cement by rice husk with compressive strength and flexural strength having an increment of 9.78% and 25.09% respectively as compared to the control mix. Pulse velocity test of the modified concrete at 5% replacement of cement by rice husk ash confirms it as a "good" dense Concrete matrix.

Keywords: Rice husk ash (RHA), Cement replacement, superplasticizers, workability, Compressive strength, Flexural strength, split tensile strength, Pulse velocity.

I. INTRODUCTION

Due to the wide use of concrete, the cost of building materials is increasing enormously in some parts of the world also in developing country like India. This rising cost can however be reduced by use of alternative building materials that are locally available and cheap. Some industrial and agricultural waste products may be used as a replacement of conventional building material. There are different wastes available in large quantities that have similar binding properties as that of cement. Rice husk ash is one of the suitable substitutions of cement. Rice husk is a byproduct of agricultural waste generated in rice mills. During milling of paddy 80% weight found out as rice and remaining 20% weight received as husk. This husk is used as fuel in industries to generate steams and other purposes. This husk contains about 75 % organic fickle matter and the remaining 25 % of the weight of this husk is converted into ash during the firing process, this ash is known as rice husk ash (RHA).

From the 20th century, there had been an increase in the economic consumption of mineral admixtures for the replacement of cement in construction industries. The use of by-products also reduces the pollution and proved as an environment friendly method of disposal of large quantities of waste materials that would otherwise pollute land, air and water. Typically, RHA contains 80 – 90% of amorphous silica 1-2 % Potassium oxide (K_2O) and remaining being sunburn carbon. Related studies have been carried out to investigate impact of Rice husk ash as partial replacement which has depicted that RHA is suitable for replacement of cement in making of concrete. As per a study, Rice husk ash can be added to cement concrete as partial replacement of cement up to 10% without any significant reduction in any of the property of concrete (Bhushan et. al., 2017).

The use of RHA in concrete has following positive impact:

- Increased compressive and flexural strengths (Zhang et al.,1996; Ismaila 1996; Rodriguez 2005).
- Reduced permeability (Zhang et al., 1996; Ganesan et al.,2007).
- Increased resistance to chemical attack & Reduced potential for efflorescence due to reduced calcium hydracids (Chindaprasirt et. al., 2007).
- Increased durability (Coutinho 2002).
- Reduced effects of alkali-silica reactivity (ASR) (Nicole et al., 2000).
- Reduced shrinkage due to particle packing, making concrete denser (Habeeb et al., 2009).
- Enhanced workability of concrete (Coutinho 2002; Habeeb et al., 2009; Mahmud et al., 2004).
- Reduced heat gain through the walls of buildings (Lertsatitthanakorn et al., 2009).
- Reduced amount of super plasticizer (Sata et al., 2007).

Additionally, RHA blended concrete can decrease the total porosity of concrete and modifies the pore structure of the cement, mortar, and concrete, and significantly reduce the permeability which allows the influence of harmful ions leading to the deterioration of the concrete matrix. RHA blended concrete can improve the compressive strength as well as the tensile and flexural strength of concrete (Alireza Naji Givi et. al. 2010).

In the present study, Ordinary Portland cement (Grade 43) was replaced by rice husk ash at different percentage such as 2.5, 5, 7.5, 10% & 15% of weight of the cement to find out the optimum percentage of rice husk ash in concrete mix with the help of strength parameters like compressive strength, split tensile strength, flexural strength and ultrasonic pulse velocity. The mechanical property tests of materials have been carried for fine aggregates, coarse aggregates and cement in the laboratory followed by designing of M20 grade concrete as per Indian standards. Super plasticizers (Polymer based, 1% by weight) has been also used in the concrete mix for increasing the workability at adopted water/cement ratio of 0.45.

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II. OBJECTIVES OF THE STUDY

- To improve the engineering properties of Concrete like Compressive Strength, Tensile Strength and Flexural Strength.
- To make Concrete cost-effective by reducing the amount of Cement.
- To optimize the use of waste product like Rice Husk Ash (RHA) in preparation of Concrete

III. METHODOLGY

The specification of materials and the testing methodology adopted for experimental program is described as below:

A. Materials

The ordinary Portland cement of 43grade manufactured by the ULTRATECH Cement Company was used in the study, which is in accordance with IS:8112-1989, having design strength for 28 days being a minimum of 43 MPa or 430 kg/cm^2.The sand obtained from river beds or quarry is used as fine aggregate. Fine aggregates complying with gradation of zone-IV as per IS 383:2016 was used in the present study. The coarse aggregate having nominal size of 20mm in accordance to IS 383:2016 has been used in this experimental study. Rice husk ash (RHA), rich in silica content, is produced from rice husk by using proper combustion technique and can used as alternative for cement as it exhibits high reactivity and pozzolanic property. RHA is generally an agricultural by-product of incinerating husk under controlled temperature of below 800 °C. The process yields about 25% ash compositing 80% to 95% amorphous silica & about 5% alumina, depicting it as a highly pozzolanic material. Super plasticizer used was of type: Asian Bond; Colour: Brown Liquid; Specific Gravity @30^0 C: 1.110 +0.01; Chloride content: Nil; pH: 6; Chemical Base: modified Polycarboxylic Ether.

B. Mixture Proportions

The design mix proportions for M20 grade concrete obtained as per ratio 0.45:1: 1.87: 2.91, designed in accordance with IS: 10262-2009 with a fixed amount of superplasticizer i.e., 1% by weight of binder, for various partial replacements percentages of cement content is given below in following table:

Table- I Mix Proportions

Cement Replacement By RHA %	Cement kg/m^3	Fine Aggregates kg/m^3	Coarse Aggregates kg/m^3	Water kg/m^3	RHA kg/m^3	Super plasticizer kg/m^3
0%	394	734.46	1146.35	177.3	0	0
2.5%	384.15	734.46	1146.35	177.3	9.85	1.773
5%	374.3	734.46	1146.35	177.3	19.7	1.773
7.5%	364.45	734.46	1146.35	177.3	29.55	1.773
10%	354.6	734.46	1146.35	177.3	39.4	1.773
15%	334.9	734.46	1146.35	177.3	59.1	1.773

C. Investigatory Tests

To investigate the mechanical behavior of the concrete mixes produced as per the abovementioned proportions, following investigatory tests were performed:

- Workability test (slump cone test) as per IS: 1199 – 1959
- Compressive strength test as per IS: 516 – 1959
- Split tensile strength test as per IS: 516 – 1959
- Flexural strength test as per IS: 516 – 1959
- Ultrasonic pulse velocity (Non- destructive) as per IS: 13311 (Part 1) – 1992.

Workability Test: The slump cone test is carried out in this study as per procedures mentioned in IS: 1199 – 1959.

Compressive Strength Test: In accordance with IS: 516 – 1959, to determine the compressive ability of hardened concrete, the cubes of size 150mm X 150mm X 150mm were casted and cured for 7days and 28days.Then the compression strength of the cured specimens was determined at 7days and 28days. Compression testing machine was used for testing the compressive strength of concrete. At the time of testing the cube is taken out of water and is surface dried and then tested keeping the smooth faces in upper and lower part. In this study, for all mixes, i.e., for 0 to 15 % replacement of cement by Rice husk ash compressive strength is determined.

Fig. 1.Concrete cube under compression.

Split Tensile strength test: In accordance with IS: 516 – 1959, Split Tensile strength of concrete was tested on cylindrical specimens having 300mm length and 150 mm diameter at different percentage of Rice husk ash content in concrete. The tensile strength of modified concrete has been tested on specimens cured for 7 and 28 days. After 7 days of curing, test has been conducted to check the gain in initial strength of concrete & after 28 days of curing test gives the data of final strength of concrete. Compression testing machine is used for testing the Split Tensile strength test on concrete along. At the time of testing the cylinders are taken out of water and dried and then tested. For calculating the split tensile strength (F_t) following relationship is followed:

$$F_t = \frac{2P}{\pi DL}$$

F_t = Split tensile strength of the concrete

P = Compressive load at failure

D = Diameter of the cylinder

L = length of the cylinder

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Flexural Strength test: In accordance with IS: 516 – 1959 the flexural strength of concrete was tested on beams of dimensions 100mmX100mmX500mm. Six beams were casted, three beams each for 7 Days & 28 days of curing period, for various percentage replacements of cement by rice husk ash and tested in UTM by applying two-point loads. These point loads acted at equidistance from centre of beams.

Fig.2 Concrete Beam under Two-point Flexural Load

Ultrasonic Pulse Velocity Test: An ultrasonic pulse velocity test is a nondestructive test conducted to check the quality of the concrete matrix. In this test, the strength and quality of concrete is determined by measuring the speed of an ultrasonic pulse passing through the concrete. The test consists of passing ultrasonic wave through the core of the concrete to be tested and measuring the time taken by pulse to get through the matrix. Higher the velocities through the concrete matrix better will be the quality and homogeneity, while slower velocities indicate concrete may hold many cracks or voids.

$$\text{Pulse velocity} = \frac{\text{Width of the structure/specimen}}{\text{Time taken by pulse wave to pass through it}}$$

The Quality defining criteria for concrete is dependent on the velocity of ultrasonic pulse passing through it. Based on IS: 13311 (Part 1) – 1992 the range of the velocity and the defined quality corresponding to the specific range is as under:

Table- II UPV Quality Grading Criteria

S No.	Pulse Velocity by Cross Probing (km/sec)	Concrete Quality Grading
1.	>4.5	Excellent
2.	3.5 to 4.5	Good
3.	3 to 3.5	Medium
4.	<3	Doubtful

IV. RESULTS & DISCUSSION

The results obtained after execution of the investigatory tests are discussed as under:

A. Slump Cone Test: The results of the slump cone test are presented in the Fig.3. It can be seen from the figure below; Slump value was obtained in the decreasing trend with increase in amount of RHA in the concrete.

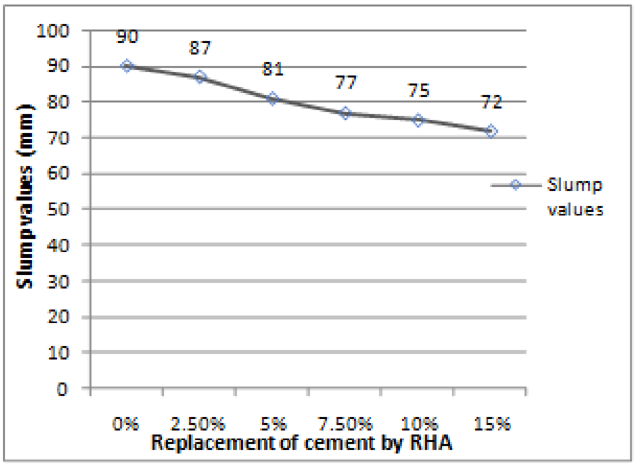

Fig.3 Slump Cone Test Results

B. Compressive Strength Test: The obtained results of the compressive strength tests on concrete cubes of different mixes are shown in Fig. 4: On replacing the cement by RHA, the compressive strength test result shows an increment in compressive strength of the concrete up to 5% replacement of cement by RHA & on further replacement i.e., at 7.5%, 10% & 15%, the compressive strength of the concrete degraded.

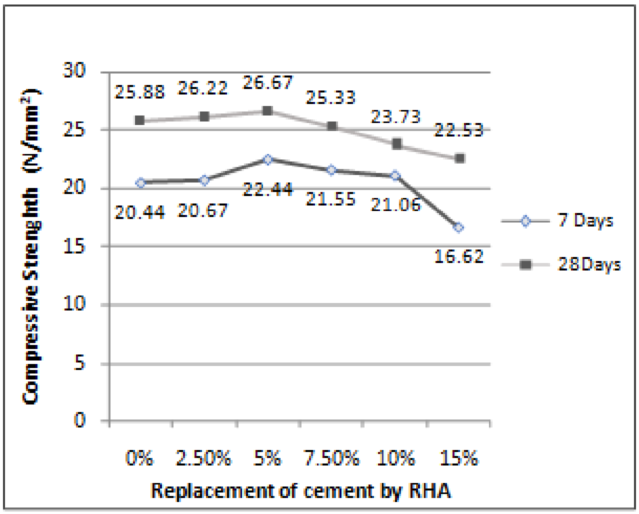

Fig.4 Compressive Strength Test Result

C. Split Tensile Strength Test: As per the explained test procedure for determining split tensile strength of the proposed mixes of the concrete, following results as shown in Fig. 5 were obtained.

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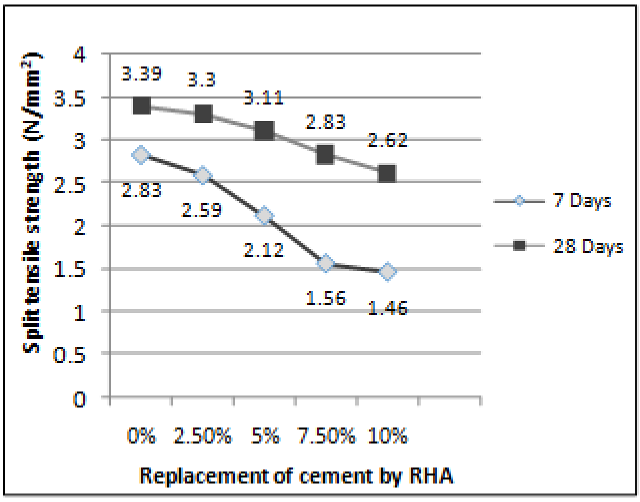

Fig.5 Spilt Tensile Strength Results

D. Flexural Strength Test: Testing of beams as shown in Fig. 6, as per the arrangements and loading condition prescribed in IS 516; 1959 for flexural strength test gives the following outcomes. The results show that with increase in replacement percentage of cement by RHA there is significant increase in the flexural strength of the concrete up to 5% replacement, thereafter on further replacement the flexural strength of the concrete decreased

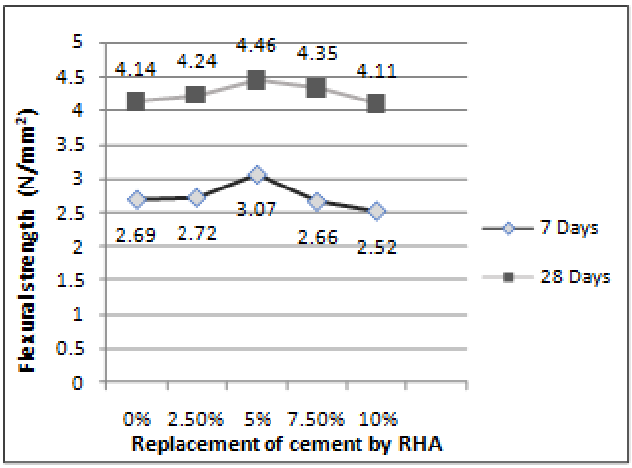

Fig.6 Felxural Strength Results

E. UPV Test: As per IS: 13311 (Part 1) – 1992, ultrasonic pulse velocity test was conducted as presented in Table 3 & Fig. 7. An average value of the pulse velocity for 3 specimens for each type of mix is depicted in the following results:

Table- III UPV Test Results

S No.	Percentage Replacement of Cement by RHA	Pulse Velocity by Cross Probing (km/sec) at 7 days	Concrete Quality Grading at 7 days	Pulse Velocity by Cross Probing (km/sec) at 28 days	Concrete Quality Grading at 28 days
1	0%	3.62	Good	3.64	Good
2	2.5%	3.71	Good	3.72	Good
3	5%	3.82	Good	3.84	Good
4	7.5%	3.62	Good	3.52	Good
5	10%	3.55	Good	3.47	Medium

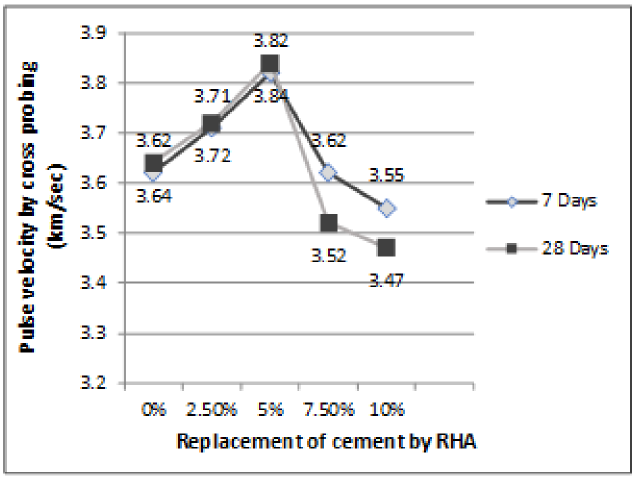

Fig.7 UPV Test Results

Results obtained on the basis of direct transmission of pulse through the concrete reflected that quality of concrete when checked after 7 days of curing was good for all the different mixes & at 28 days curing the quality was good for 0%,2.5%,5% & 7.5% whereas for 10% replaced concrete it was graded as of medium quality

V. CONCLUSION

From the investigations carried out in this research, following conclusions were drawn out: -

1. The workability of the modified concrete reduced with the increment in amount of RHA as partial replacement of cement. A decrement of 10% in slump value as compared to control mix of the concrete, was obtained at 5% replacement of the cement.
2. The compressive strength of concrete was found to be maximum for 5% replacement by RHA. An increment of 9.78% & 3% was obtained in compressive strength after 7 days & 28 days of curing respectively at 5% replacement of cement.
3. The split tensile strength was found to be continuously reducing. The reduction in tensile strength at 5% replacement of cement was about 25.79% & 8.25% after 7 days & 28 days of curing.
4. Flexural strength increased till 5% replacement of cement and thereafter it decreased. An increment in flexural strength at 5% replacement of cement was about 14.12% & 7.72% after 7 days & 28 days of curing respectively.
5. Pulse Velocity was found to be enhancing up to 5% replacement of cement and on further replacement it got reduced. At 5% concrete was at good condition and pulse velocity increased by 5.49% & 5.52%, as compared to control concrete after 7 days of & 28 days of curing respectively.

On the account of the test results obtained above, the Rice husk ash diffused concrete at 5% replacement of cement, is thus found to be better & efficient. The enhancement of the strengths obtained is possibly due to the higher fineness of RHA, which may increase the reaction of RHA particles with $Ca(OH)_2$ to give more calcium silicate hydrate (C-S-H) gel.

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Although the workability of the modified concrete was found degrading since RHA are fibrous particles with high specific surface area leading to high water demand, thus diffusion of suitable quantity & type of admixtures can resolve this workability degradation.

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