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A N I N T E R N A T I O N A L J O U R N A L

Mechanical Behavior of Concrete Modified by Replacement of Cement by Rice Husk Ash

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ABSTRACT

Construction industry is in need of lump sum quantities of materials which has increased both their demand and price. The use of large quantities of cement leads to increasing CO_2 emission and as a consequence, the greenhouse effect. Consumption of wastes and byproducts from various sources in the manufacture of concrete has gained a great deal of importance in present days. Various researches are currently being conducted concerning the use of such products in concrete. RHA is a carbon neutral green product. Lots of ways are being thought of for disposing them by making commercial use of this. Rice husk ash is a good super-pozzolan which can be used to make special concrete mixes. The rice husk ash has been taken for this present study due to its easy availability and effective pozzolonic properties that are expected to improve the mechanical strength properties of concrete. Concrete specimens were made for evaluation of Compressive, Split Tensile, Flexural strength and Stress-Strain Behavior of concrete. The tests were conducted at the age of 7 and 28 days. Generally all mixes containing RHA achieved better properties than the conventional mix without RHA. By the experimental investigation the recommendation is given for using optimum percentage of RHA in concrete.

Key words: *husk ash; strain; compressive; split tensile; flexural.*

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INTRODUCTION

Concrete is the largest building material used by the construction industry. Concrete is basically made of both fine and coarse aggregates, binding by cement. Each one of these constituents of concrete hasn't a positive environmental impact and gives rise to different sustainability issues. The recent concrete construction practice is unsustainable even not only it consumes enormous quantities of stones, sand and water, but also one billion tons of cement a year, which is not an environment friendly material. For manufacturing of cement large amount of energy is needed and also 8 % of carbon dioxide is released to the atmosphere during cement production. In fact, many byproducts and solid wastes can be used in concrete mixes as admixtures or aggregates or cement by partial or full replacement, depending on their physical and chemical characterization, if adequately treated. Thus cement is replaced by partial amount of RHA as a mineral admixture. Several materials are used to manufacture good quality concrete. It is important to know the properties of cement, aggregate, and water, as they impart strength and durability to concrete of all the materials that influence the behavior of concrete, cement is the most important constituent, because it is used to bind the sand and aggregate together and it resists atmospheric action. Durability problems arise during the service life of a concrete structure. This actually is a result of improper design, execution or specification at the time of tendering for the work. There is no material which is 100% resistant to chemical action and deterioration due to physical action such as abrasion or impact. However under normal conditions, good quality of concrete has a long life.

MATERIALS USED

Cement

Cement is the most important ingredient in concrete. Ordinary Portland Cement (OPC) of 43 Grade confirming to IS: 12269 – 1987 is used for the entire investigation. The specific gravity of Ordinary Portland cement is 3.15.

Fine Aggregate

Depending upon the particle size distribution, locally available river sand confirming to Zone II of Table 4 of IS 383– 1970 was used in the casting process. The specific gravity of the sand is found to be 2.65. Fine aggregate used should be properly graded to give minimum void ratio and should be free from deleterious materials like clay, silt content and chloride contamination etc.

Coarse Aggregate

The coarse aggregate is the strongest and the least porous component of concrete. It is also a chemically stable material. The blue granite stone was used as a coarse aggregate for this work. The nominal size of the aggregate is 20mm. The specific gravity of the coarse aggregate is found to be 2.78. By restricting the maximum size of aggregate and also by creating the transition zone stronger by usage of mineral admixtures such as rice husk ash, the cement concrete becomes more homogenous and there is a marked enhancement in the strength properties as well as durability characteristics of concrete.

Water

Water is a crucial and important ingredient of the concrete as it actively participates in the chemical reaction with cement and results in hardening of the concrete. The water used in this study was potable water. The potable water used was confirming to the requirements of IS 456-2000.

Rice Husk Ash (RHA)
Rice husk ash is obtained by burning of the rice husk obtained from rice mills. Calcium hydroxide accounts for up to 25% of the hydrated cement and calcium hydroxide does not contribute to the concrete's strength or durability. Like other pozzolans, RHA reacts with the calcium hydroxide (lime) by-products produced during cement hydration to produce additional cementing compound, which is responsible for holding the concrete together. It is very fine, highly reactive and gives fresh concrete a creamy and non sticky texture that makes finishing easier. RHA improves the compressive strength of concrete, makes finishing easier, reduces efflorescence and also mitigates alkali, silica reaction.

Fig 1. Rice Husk Ash

It is a pozzolan material consisting of alumina and silica. So it can be used in the concrete to replacement of Ordinary Portland Cement. The chemical composition of RHA includes Sand or Silica, Calcium Oxide (CaO), Magnesium Oxide (MgO), Iron Oxide (Fe_2O_3), Aluminium oxide (Al_2O_3), Sodium Oxide (Na_2O) and Potassium Oxide. Their percentage varies at different temperatures. The physical properties of RHA are given in Table 1.

Table 1 Physical Properties of RHA

Color	Grey
Appearance	Powder form
Specific Gravity	2.14
Normal Consistency	30%

Replacement of cement by RHA
The advantage of replacing some of the cement with RHA rather than addition of RHA to the mix is that any existing color formulas or mix designs won't change, or slightly change. This is because the dosage of pigments and super plasticizers are added based on the cement content in the concrete. It is ok to simply add RHA to an existing mix, but it is important to realize that the total equivalent cement content will increase. This will affect not only the addition pigment and admixture dosages but also the water to cement ratio, a critical factor in mix design. RHA is compatible with most of the concrete admixtures, such as super plasticizers, retarders, accelerators, etc. The results demonstrate that 15% replacement of cement with RHA is effective. The addition of more than 20% RHA has a detrimental effect on strength and efflorescence.

EXPERIMENTATION

Concrete Mix Proportions

The M30 mixes were designated in accordance with IS 10262 – 1982. Based on the results, the proportions M30 was considered. Concrete mix with w/c ratio of 0.45 was prepared. The details of mix proportions are given in Table 2 for 1m^3 of concrete.

Table 2 Materials required for 1m^3 of Concrete (kg/m^3)

Grade	Cement	FA	CA	Water
M30	438	686.24	1126	197

In this work, the percentage replacement of RHA was 10%, 20% and 30% of the total weight of cement.

Casting of Specimen

The experimental investigation was carried out by casting cubes; cylinder and prism for both the conventional concrete mix and RHA replaced concrete. The mixing procedures are as follows: Initially Cement, Sand and RHA were taken in the required quantities and were mixed dry and kept separately. Then, coarse aggregate and the prepared dry mix were kept in three layers and approximate amount of water was sprinkled on each layer and mixed thoroughly. Mixing procedure was extremely tedious to the formation of lumps. Concrete was thoroughly mixed and compacted. The cubes of size 150 mm x 150 mm x 150 mm were cast for testing the compressive strength of concrete and cylinders of diameter 150 mm and height 300 mm were cast for the split tensile strength. For flexural strength test, prisms of size 500 mm x 100 mm x 100 mm were cast. Samples for different percentages of concrete were casted. The number of specimens cast for the present study is listed in Table 3.

Table 3 Details of Test Specimens

Type of specimen	No. of specimens	Size of specimens
Cube	20	150 mm x 150 mm x 150 mm
Cylinder	20	150 mm diameter and 300 mm height
Prism	20	500 mm x 100 mm x 100 mm

Curing of Specimens

The specimens were remolded 24 hours after casting and the specimens were kept inside a water tub containing potable water and allowed for curing. They were taken out from the curing tank after 7 days and 28 days and were dried for 1 day in shadow before testing. The specimens were tested in saturated condition after wiping out the surface moisture from the specimen.

TEST RESULTS AND DISCUSSION

Compressive Strength

The cubes of size 150 mm x 150 mm x 150 mm were employed for testing the compressive strength of concrete. All the cubes of Conventional Concrete and RHA replaced Concrete were tested in a HEICO Compression Testing Machine with references of IS: 516 – 1959 at an age of 7 days and 28 days. The test results of the Compressive Strength were given in graphically in Fig.2

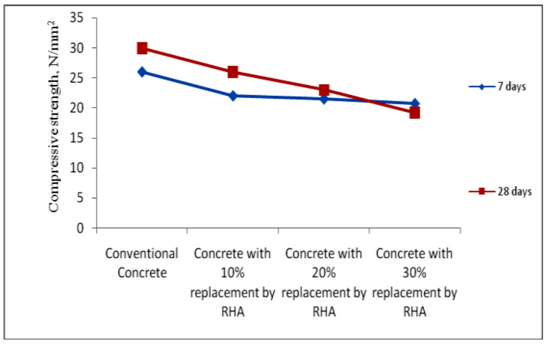

Fig. 2 Compressive Strength at 7 days and 28 days

Split Tensile Strength

The tensile strength characteristics of concrete are of considerable importance and split tensile test is a simple and reliable method for measuring the tensile strength of concrete. Splitting tensile tests were carried out on cylindrical specimens of diameter 150 mm and height 300 mm at an age of 7 days and 28 days using HEICO Compression Testing Machine of capacity 400 tonnes confirming to IS: 5816 – 1970. The test results were given in Fig.3.

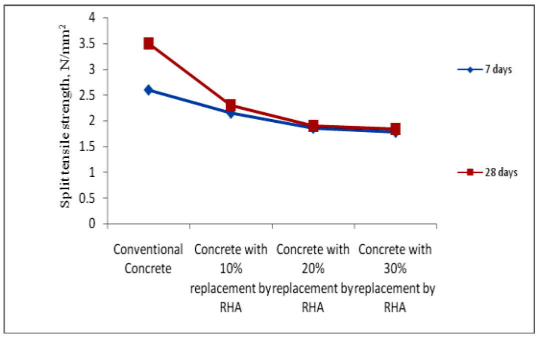

Fig.3 Split Tensile Strength at 7 days and 28 days

Flexural Strength

The flexural strength tests were carried out in Universal Testing Machine by Two Point loading method with the guidelines given by IS: 516 – 1959. The specimens were of size 500 mm x 100 mm x 100mm. The variation of flexural strength is presented graphically in Fig.4.

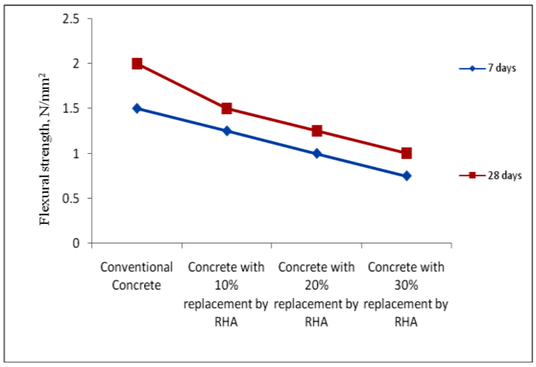

Fig.4 Flexural Strength at 7 days and 28 days

Stress – Strain Behavior of Concrete

The stress strain values for 10%, 20%, 30% replacement by RHA were given in Table 4, Table 5 and Table 6 respectively. The stress strain curves of concrete with

10%, 20% and 30% replacement by RHA were shown in Fig.5, Fig.6 and Fig.7 respectively.

Table 4 Stress Strain Values for 10% Replacement of RHA

Load (N)	Area (mm^2)	Deflection (mm)	Stress (N/mm^2)	Strain
0	17663	0	0	0
10000	17663	0	0.566	0
20000	17663	0	1.132	0
30000	17663	0	1.698	0
40000	17663	0	2.264	0
50000	17663	0.012	2.830	8E-05
60000	17663	0.026	3.397	0.0002
70000	17663	0.034	3.963	0.0002
80000	17663	0.044	4.529	0.0003
90000	17663	0.056	5.095	0.0004
100000	17663	0.072	5.661	0.0005
110000	17663	0.08	6.227	0.0005
120000	17663	0.094	6.79	0.0006
130000	17663	0.11	7.360	0.0007
140000	17663	0.156	7.926	0.001
150000	17663	0.218	8.492	0.0015

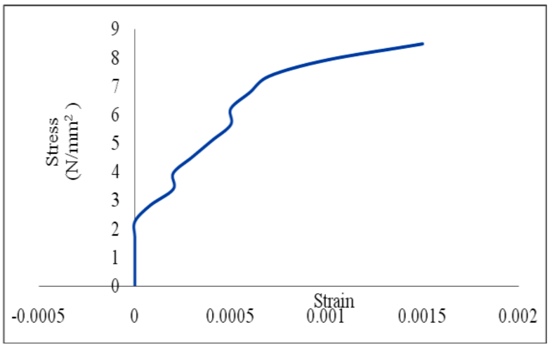

Fig.5 Stress Strain curve for 10% replacement by RHA

Table 5 Stress Strain Values for 20% Replacement of RHA

Load (N)	Area (m^2)	Deflection (mm)	Stress (N/mm^2)	Strain
0	17663	0	0	0
10000	17663	0	0.566	0
20000	17663	0	1.132	0
30000	17663	0	1.698	0
40000	17663	0	2.264	0
50000	17663	0.01	2.830	0.0001
60000	17663	0.03	3.397	0.0002
70000	17663	0.03	3.963	0.0003
80000	17663	0.05	4.529	0.0003
90000	17663	0.06	5.095	0.0005

100000	17663	0.08	5.661	0.0006
110000	17663	0.1	6.227	0.0007
120000	17663	0.12	6.794	0.0008
130000	17663	0.15	7.360	0.001
140000	17663	0.2	7.926	0.0013
150000	17663	0.27	8.492	0.0018

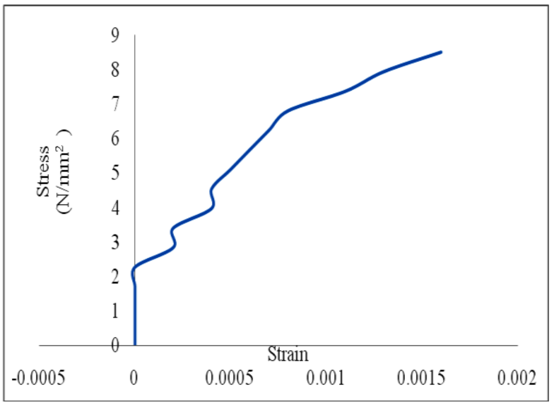

Fig.6 Stress – Strain curve for 20% replacement by RHA

Table 6 Stress Strain Values for 30% Replacement of RHA

Load (N)	Area (mm^2)	Deflection (mm)	Stress (N/mm^2)	Strain
0	17663	0	0	0
10000	17663	0	0.566	0
20000	17663	0	1.132	0
30000	17663	0	1.698	0
40000	17663	0	2.264	0
50000	17663	0.02	2.830	0.0002
60000	17663	0.03	3.397	0.0002
70000	17663	0.05	3.963	0.0004
80000	17663	0.06	4.529	0.0004
90000	17663	0.07	5.095	0.0005
100000	17663	0.08	5.661	0.0006
110000	17663	0.09	6.227	0.0007
120000	17663	0.12	6.794	0.0008
130000	17663	0.16	7.360	0.0011
140000	17663	0.19	7.926	0.0013
150000	17663	0.24	8.492	0.0016

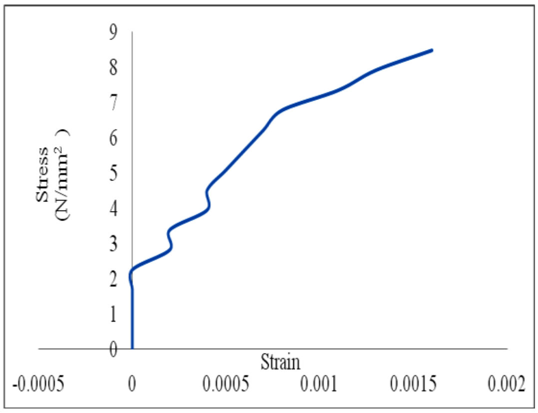

Fig.7 Stress – Strain curve for 30% replacement by RHA

Micro Structural Behavior of Rice Husk Ash

The micro structure of cement replaced by Rice husk ash was observed and the micro structural behavior was reported. The composition of chemical elements were also observed and discussed. The scanning electron microscope (SEM) analysis and EDAX analysis were carried out on powder samples prepared from burning of rice husk. The results obtained in SEM and EDAX analysis were shown in Fig.8 and Fig.9 and were discussed in the following section.

Table 7 Result of Weight Percentage of Elements

Element	Weight Percentage
	RHA
O	55.86
Mg	1.57
Si	35.37
P	3.53
K	2.42
Ca	1.26
Total	100.00

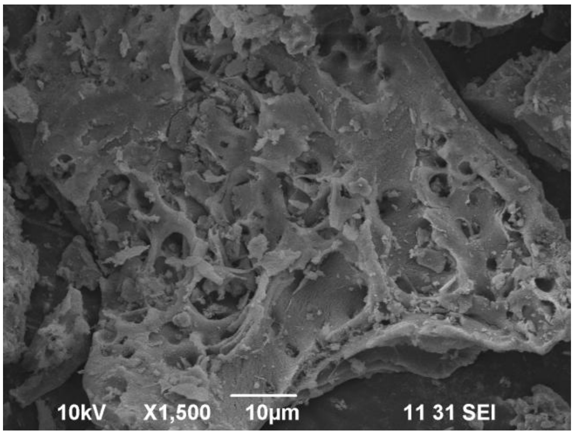

Fig.8 SEM image of Rice husk ash

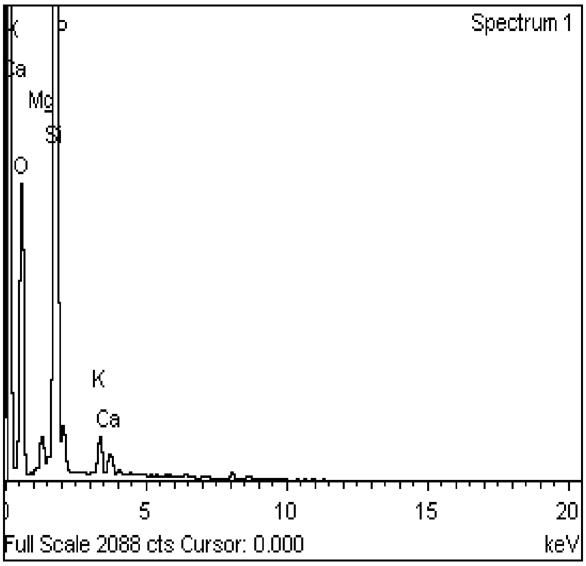

Fig.9 EDAX Spectrum of Rice husk ash

In Fig.8 shows the micrograph of rice husk ash, it consists of fine particles, which appears to have agglomerated large group of particles. The extent of coverage is substantial but not enough materials formed to create a continuous film on the surface of the particle. Some region shows the traces of no hydration products and absence of deposition of hydration products. This shows that due to abundance of hydration products the appearance has changed from small isolated particles to tangled web of flake like crystals. The hydration products consist of a mixture of phases as it's typical for Portland cement. The shows that the SEM analysis of Rice husk ash particle has been covered in a continuous pattern of very small particles were identified. The EDAX graphs were shown in Fig.9 and the weight percentage of elements are shown in Table 7. This result shows that Mg content increases in rice husk ash and also the graphs shows that the Silica content increases at the maximum level.

CONCLUSIONS

Experimental investigations were carried out for concrete mixes with 10%, 20% and 30% replacement of cement by RHA to find the mechanical properties of concrete with w/c ratio 0.45.The test results show clearly that concrete with RHA shows significant effects on the mechanical properties of concrete. Out of all the mixes considered, Concrete with 10% and 20% replacement of cement by RHA was found to be optimum. From the basic study to utilize RHA as cement replacement, the following conclusions are arrived.

1. The flexural strength value is more for 20% replacement of RHA.
2. From the examination on RHA used for cement replacement it can be inferred that the normal consistency of cement defer according to the percentage of RHA.
3. RHA incorporated cement, it can be inferred that RHA acts as retarder & increases the initial setting time of the cement.
4. It is noticed from the analysis of the compressive strength results that as the replacement percentage of RHA increases, the compressive strength decreases due to low pozzolanic property of RHA.
5. The Scanning Electron Microscopy images show that the Rice husk ash is creating a very denser formation.

6. From the EDAX analysis it was concluded that the content of Silica is the maximum level and also a small variation in Ca content. So Rice husk ash is a good pozzolans material to replace by cement at certain percentage.

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