Experimental Investigation on Partial Replacement of Rice Husk Ash as Cement and Coconut Shell as Coarse Aggregate for the Production of Light Weight Concrete

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Abstract— *The present study reports the mechanical and durability properties of concrete using rice husk ash as cement and coconut shell as coarse aggregate replacement. Rice husk ash is used because of its fineness and size it can be effectively used as a replacement of cement and coconut shell can be grouped in a light aggregate and the concrete obtained using coconut shell meets the requirement of concrete. In this study, there are seven different mixes. Coconut shell was replaced at different replacement levels (0%, 5%, 10%, 15%, 20% and 25%) and Rice husk ash was kept constant (10%) and a conventional concrete mix. Mechanical and durability properties were studied. From the results it is conclude that this concrete shows good results in mechanical properties and the advantages being many, including efficient utilization of waste rice husk ash and coconut shell, reduction in natural source depletion etc, the use of coconut shell in concrete seems to be a feasible option. Such study will help to arrive at final decision regarding quantity of coconut shell for replacing conventional aggregates in concrete production.*

Keywords— Conventional concrete, CS-RHA concrete, Rice husk ash, Coconut shell, Density, Mechanical properties, Durability properties.

1. INTRODUCTION

Infrastructure growth across the world formed demand for construction resources. Concrete is the leading civil engineering building material. Concrete manufacturing includes consumption of components like cement, aggregates, water and admixture(s). Among all the constituents, aggregates form the leading part; it inhabits 70%-80% of concrete. CO_2 emissions have increased due to the production of cement and inadequate disposal of RHA indications to air pollution and the embankment difficulty. To lessen these problems, RHA was castoff as additive of cement in the production of concrete.

Rice husk is some of the agricultural wastes; the outward layer of rice kernel is acquired by refining of paddy. Roughly 200 kg of husk can be gained from a tonne of paddy, founding about one fifth of the over-all rice formed. Hence, RHA can be stated as a supplementary cementitious material (SCM) by using restricted additional of cement for concrete making. Thus, the adding is a favorable key to moderate the environmental effects.

Among the coconut producers in the world, India stands in third place. Large volume of waste caused from coconut. The unwanted coconut shell (CS) might be recycled as partial replacement as conventional coarse aggregate. It could help to create economical concrete and at the similar time disposal problem can be reduced. The CS can be grouped in a light aggregate. The concrete obtained with a CS as a coarse aggregate meets the minimum requirements of the concrete. The 28-day air drying densities of CS concrete are fewer than 2000 kg/m^3 and fall within the lightweight structural concrete series.

2. EXPERIMENTAL DETAILS

2.1 Materials

i. Cement

In current studies, Zuari cement of 53 grade having a specific gravity of 3.16 compliant to Indian standard, IS 12269: 2013 was used.

Table 1: Properties of Cement

Sl no.	properties	Test results
1	Normal consistency	28%
2	Initial setting time	110 min
3	Final setting time	315 min
4	Specific gravity	3.16
5	Fineness modulus	2.5

ii. Rice Husk Ash

RHA acquired from the scorching of Rice husk. RHA used in this experiment was obtained from Shrisha Rice Mill, Tumakuru, karnataka, India.

Table 2: Properties of RHA

Sl. No.	Properties	Test results
1	Appearance	Very fine powder
2	Color	Black
3	Specific gravity	2.21
4	Normal consistency	38%
5	Initial setting time	56 min
6	Final setting time	260 min

iii. Fine Aggregates

M-sand is used as fine aggregate in this study. Fine aggregate was procured which fulfilled the assets of fine aggregate requisite for experimental exertion and the M-sand adapts to zone II as per the specifications of IS 383:2016.

Table 3: Properties of Fine Aggregates

Sl No.	Properties	Test results
1	Specific gravity	2.68
2	Fineness modulus	2.785
3	Bulk density	1656 kg/m^3
4	Water absorption	2%
5	Gradation	Zone II

iv. Coarse Aggregates

Crushed stones with a maximum size of 20 mm were used as coarse aggregates. Sieve analysis of collective aggregates approves to the provisions of IS 2386 part 1: 1997 for graded aggregates.

Table 4: Properties of Coarse Aggregate

Sl No.	properties	Test results
1	Specific gravity	2.68
2	Water absorption	0.2%
3	Bulk density	1520 kg/m^3
4	Impact value	26.6%
5	Crushing value	27.6%

v. Coconut Shell

Waste coconut shells were collected. The collection of particle dimensions of the CS was kept in the middle of 5 to 20 mm for practice in concrete. The surface texture of the CS was fairly even on concave and uneven on convex faces.

Table 5: Properties of Coconut Shell

Sl No.	Properties	Test results
1	Specific gravity	1.37
2	Water absorption	8.05%
3	Bulk density	630 kg/m^3
4	Impact strength	12.3%

vi. Water

Water preferred in casting and for curative, shall adapt to IS 456. Usage of sea water is proscribed. Water should be in good condition. Water should be free from trash, organic matters and excessive chemicals or minerals.

2.2 Compressive Strength of Mortar

This test is to find the optimum value of RHA to use for the partial replacement as cement. RHA is replaced in percentage namely 5%, 10%, 15% and 20%. Mortar mixtures with different percentages of RHA indicated by notations R5, R10, R15 and R20 respectively. Volume batching is adopted. Procedure is same as for cubes.

Size of the moulds = 75mm×75mm×75mm.

Table 6: RHA Mortar Proportions

Constituents	g			
	R5	R10	R15	R20
Cement	190	180	170	160
RHA	7	14	21	28
Sand	600	600	600	600
Water	87.67	87.34	87	86.68

2.3 Preparation of concrete mistures

Here, volume batching of materials is adopted. Concrete mix was prepared for different percentage of coconut shell and keeping RHA percentage as constant. Concrete mixing device functioned as tiling drum type mixer of ability 200 kg was used for uniform concrete mixing.

Firstly, designed volume of cement, RHA and M-sand were thoroughly dry mixed in blender so that uniform mix is obtained. Calculated amount of CS for that particular mix is added together with coarse aggregates into the mixer. Afterwards, half of calculated water is added to the blender and permitted for uniform mingling. Immediately, remaining water is added for thorough mixing. All these process should be done in less than 5 min.

2.4 Workability

The workability of concrete can be distinct as the easiness with which concrete can be mixed, handled, placed and compacted. In this experimental study, slump cone test is adopted to find concrete workability, because the procedure is simple and it is easy to conduct.

2.5 Specimen casting and curing

The moulds were cleaned and oiled before the pouring concrete. Moulds are kept on the vibrating machine and immediately after mixing, fresh concrete is emptied into the moulds in 3 strata and each stratum are vibrated separately for about 3-5 sec.

150mm cubes, 150mm X 300mm cylinders, 100mm X 100mm X 500mm prisms and 100mm X 50mm cylinders were casted, for each concrete mixture.

After de-moulding of specimen, they are subjected to water curing for 28 days at 27±1 ˚C.

3. TESTS

a. Mechanical Properties

i. Compressive Strength

Compressive strength of the specimens was determined using a CTM machine of 2000kN capacity. The compression strength was measured at the ages of 7, 14and 28 days.

Specimens were tested on CTM to obtain the failure load of the specimens. The rate loading was 1.2mm/min. The average of three identical specimens, compressive strength is taken as compressive strength of specimen.

The compressive strength was calculated as failure load divided by cross sectional area of specimen.

Compressive strength = (Failure load in N)/Cross sectional area in mm^2

ii. Split Tensile Strength

Split tensile strength of the specimens was determined using a CTM machine with 2000kN capacity. The split tensile strength was measured at the age of 7 and 28 days.

The loading on the specimen was done as per IS 5816-1999

Split tensile strength was calculated by using the formula

$F = (2P) / (\pi DL)$

Where,

F = Split tensile strength (N/mm^2)

P = Failure load in N

D = diameter of the specimen in mm

L = length of the specimen in mm

iii. Flexural Strength Test

Flexural strength of the specimens was determined using a flexure testing machine. The flexural strength was measured at the age of 7 and 28 days.

The loading on the specimen was done as per IS5816-1999.

Flexural strength was calculated by using formula

$F_b = (3pl) / (bd^2)$

Where,

F_b = Modulus of rupture (Mpa)

P = Corrected load indicated in N

l = length of specimen in mm

b = width of beam at point of fracture in mm

d = depth of beam at point of fracture in mm

b. Durability Properties

i. Water Absorption

The water absorption characteristics of concrete are important in knowing durability properties. The test was executed to determine the amount of water absorbed by the concrete when it is replaced with coconut shell in different variants.

The dimension of test sample is 50mm in dia and 100mm in height cylinders were prepared.

The test is done as per IS 2185 (part 1):2005.

ii. Rapid Chloride Ion Penetration

The rapid chloride permeability test (RCPT) developed by Whiting (1981) and later adopted as ASTM C1202 test and AASHTO T277. This examination is a quick estimation of electrical conductance of concrete with respect to its resistance against chloride ion penetration.

This test as per ASTM C1202: 1997.

Table 7: Mix Proportion of Concrete Mixtures

Materials	**Mass (kg/m³)**						
	CC	**RHA$_{10}$**	**CS5**	**CS10**	**CS15**	**CS20**	**CS25**
Cement	394	354.37	354.37	354.37	354.37	354.37	354.37
Rice husk ash	0	27.63	27.63	27.63	27.63	27.63	27.63
Fine aggregate	726.81	726.81	726.81	726.81	726.81	726.81	726.81
Coarse aggregate	1090.24	1090.24	1035.71	981.2	926.69	872.18	817.67
Coconut shell	0	0	27.05	54.10	81.15	108.20	135.25
Water	197	197	197	197	197	197	197
W/C	0.5	0.5	0.5	0.5	0.5	0.5	0.5

4. RESULTS AND DISCUSSIONS

a. Workability of Concrete

Here slump cone is used to measure the workability. Normal concrete account for the high slump compared to CS-RHA concrete. Normal concrete and CS-RHA concrete offers shear slump in the range of 75 to 100 mm. The degree of workability is medium.

b. Compressive Strength of Mortar

Compressive strength of mortar is tested to check the optimum value to replace it with cement. From the result it's clear that 10% replacement gives much more values which are compared with other percentage replacements. 10% RHA replacement is directly involved in increase in strength of coconut shell concrete.

In this study, 10% replacement of RHA is adopted.

Table 8: Compressive Strength of Mortar for 7 Days

Mortar type	No. of specimens	Avg. breaking load (kN)	Compressive strength (N/mm^2)
R5	3	92.42	16.42
R10	3	114.25	20.30
R15	3	88.31	15.69
R20	3	74.80	13.30

c. Mechanical Properties

i. Compressive Strength of Cubes

The compressive strength results of CS-RHA concrete were compared with the CC.

Table 8: Mechanical Properties of Concrete

MECHANICAL PROPERTIES	AGE (DAYS)	CONSTITUENTS						
		CC	RHA_{10}	CS5	CS10	CS15	CS20	CS25
Compressive strength (Mpa)	7	21.53	25.62	23.59	21.26	18.95	17.18	14.48
	14	24.60	29.74	27.76	24.68	21.46	19.68	15.98
	28	30.76	35.18	33.70	30.23	27.08	24.86	22.48
Split tensile strength (Mpa)	7	1.60	2.18	2.04	1.89	1.68	1.51	1.46
	28	1.95	2.53	2.30	2.14	2.01	1.84	1.71
Flexural strength (Mpa)	7	2.87	2.96	3.02	3.11	2.91	2.98	2.93
	28	3.13	3.28	3.34	3.51	3.26	3.33	3.28

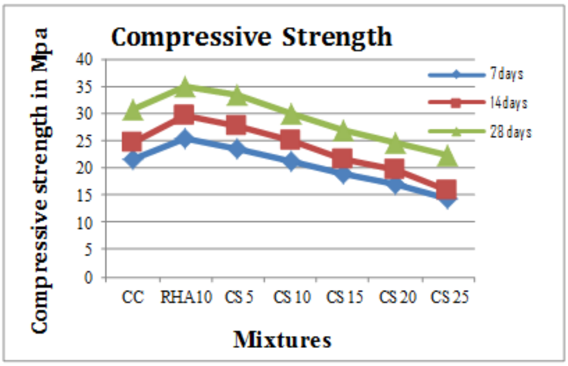

Chart 1: Compressive Strength of Concrete

Table 8, shows that the compressive strength of concrete mixtures in series. There will be increase in strength of concrete at 10% replacement of RHA, then compressive strength of CS-RHA concrete decreases gradually as the amount of coconut shell increases. 15% replacement is considered as economical percentage.

ii. Split Tensile Strength

From the result, it is observed that that the splitting strength of CS-RHA concrete is higher when compared to conventional concrete. Then this strength is keeps on decreasing as the percentage mix increases. At 15% replacement of CS, the strength is nearly equal to the conventional concrete strength when tested at the age of 7 and 28 days cured period.

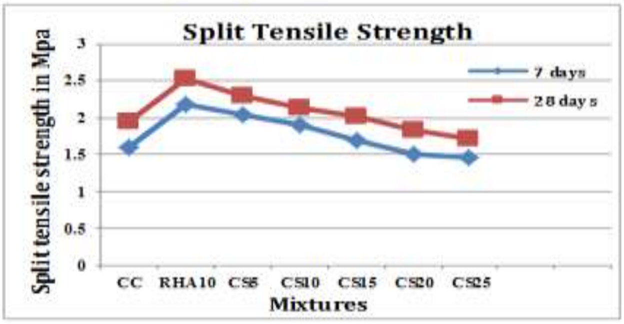

Chart 2: Split Tensile Strength of Concrete

iii. Flexural strength test

The results of the test show that there will be an increase in flexural strength as the proportion of CS upsurges in the concrete at 7 and 28 days. While conventional concrete shows less result than the CS-RHA mixtures. CS15 can be taken as optimum value because at that mix there will be approximately 12% increase in strength can be seen.

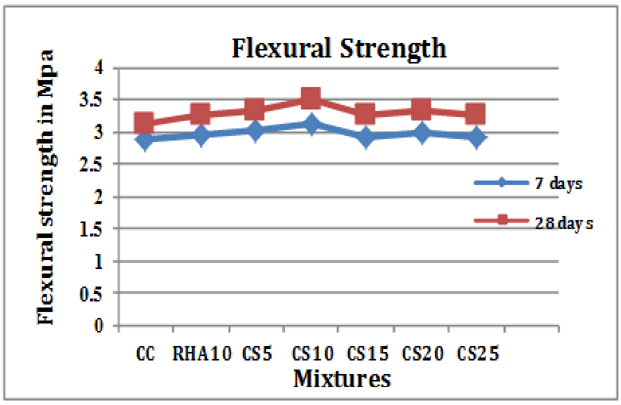

Chart 3: Flexural Strength of Concrete

d. Durability Properties

i. Water Absorption

The water absorption increases with increase in the percentage replacement of CS can be seen. Here, the study shows that CS25 mix shows 27% increase in water absorption compared to conventional concrete. This is due to the use of RHA and CS, basically these materials absorbs more water. Hence involvement of these materials leads to gradually increase in water absorption in the concrete.

Table 9: Water Absorption

Sl. no	Type of concrete	Water absorption in %
1	CC	2.751
2	RHA10	2.675
3	CS5	2.933
4	CS10	3.091
5	CS15	3.233
6	CS20	3.376
7	CS25	3.664

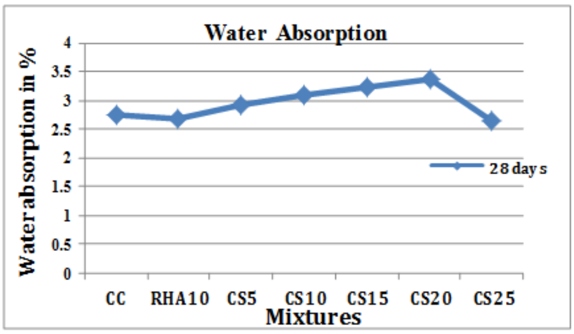

Chart 4: Water Absorption of Concrete

ii. Rapid Chloride Ion Penetration

Chloride ions permeability of concrete mixture is estimated by RCPT. The sample is of 100mm dia X 50mm height cylinder, cured and tested at the age of 28 days. Existence of chloride ion is the main aspect for corrosion. In common, ions are transferred from contaminant constituents or outside sources as sea water into the concrete.

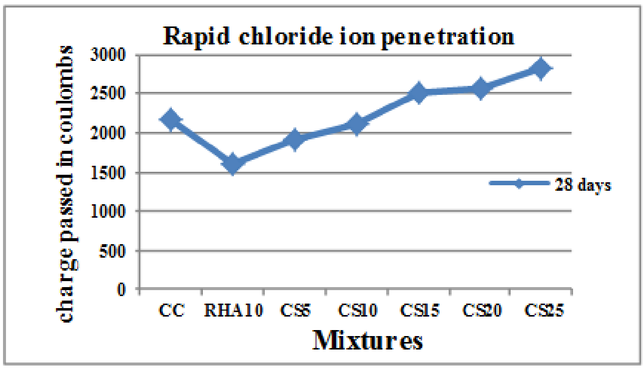

Chart 5: RCPT

Table 10: RCPT

Concrete type	Total charge passed in coulombs	Chloride penetration rate
CC	2172	Moderate
RHA_{10}	1601	Low
CS5	1911	Low
CS10	2121	Moderate
CS15	2517	Moderate
CS20	2560	Moderate
CS25	2836	Moderate

Table 8: Density of Concrete

Concrete type	De-mould density (kg/m^3)
CC	2508
RHA_{10}	2478
CS5	2410
CS10	2364
CS15	2295
CS20	2233
CS25	2182

5. CONCLUSION

This investigational study intended to discover the possibility and feasibility of partial addition of coarse aggregate by waste CS and cement by RHA for concrete production.

The following conclusions can be written, based on the results of this survey:-

- This concrete can be used as partially light weight concrete by considering the decrease in density when percentage of coconut shell increases. In this study we can see that there is 10 to 13% decrease in density when 25% replacement done.
- Increase of 13% compressive strength can be seen initially at 28 days of curing and then the strength goes on decreasing.
- Split tensile strength also increases initially about 23% and then gradually strength will decrease.
- This concrete accounts for about 6% increase of flexural strength for 20% replacement of CS at 28 days of curing.
- Replacement of RHA and CS results in enhance of water permeability of about 27% and 24% increase in chloride permeability for 25% replacement when it is compared with normal concrete.

In this study, the chloride ion penetration is higher than the conventional concrete. When compared CC with CS25, it shows that approximately 23% increase is seen in CS25 mix. Though it is rated as moderate penetration, not much higher absorption is taken place. Moderate value of water absorption is 25% replacement of CS. Beyond 25%, the water absorption will more. By this we can conclude that up to 25% replacement there will moderate rate of permeability of chloride ions.

e. Effect of CS-RHA on Concrete Density

Concrete cubes were casted for conventional concrete and with dissimilar percentage variation were evaluated just before testing them for compressive strength. Concrete density is determined to examine the influence of replacement. The result shows that with upsurge in proportion of CS, density decreases. This is due to the materials use. Here, density of RHA is less than cement and density of CS is less than coarse aggregate. These materials directly contribute the decrease in density of concrete.

Hence this CS-RHA concrete is used as partially light weight concrete.

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