Experimental Research on Mechanical Properties of Concrete by Partial Replacement of Ordinary Portland Cement with Rice Husk Ash

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Abstract - *Rice husk ash (RHA) has high reactivity and pozzolanic properties and it is made by burning rice husk (RH). The method of burning and the temperature affect the chemical composition of rice husk ash. The amount of silica in the ash increases as the burning temperature increases. It can be used in concrete as a partial replacement for cement. This paper presents a study on the mechanical properties of concrete by partially replacing cement with rice husk ash while maintaining the quality and strength of concrete. Cement was replaced with rice husk ash by weight at 0%, 5%, 10%, 15%, 20% and 25%. The slump was tested for fresh concrete. The Compressive, split tensile, and flexural strengths were tested on hardened concrete after curing in water for 7, 14, and 28 days.*

***Key Words*: Rice Husk Ash, Ordinary Portland Cement, Compressive Strength, Split Tensile Strength, Flexural Strength, Workability, Concrete, Replacement.**

1.INTRODUCTION

The most widely used human-made civil engineering material on the planet is concrete. It is a hardening construction material made up of cement, fine aggregate, and coarse aggregates combined with water. Cement manufacture releases a large amount of greenhouse gases into the atmosphere, which contributes to global warming and the cost of cement is very high. So, we need to reduce cement production and find some economical alternatives which will cost less than cement. There are many pozzolanic materials (ground-granulated blast-furnace slag, fly ash, rice husk ash, and silica fume) available in our country. Rice husk ash is a local ingredient that has been shown to be extremely pozzolanic, which can be used as a partial replacement for OPC in concrete. Rice husk ash is an agricultural waste product to substitute a percentage of cement would not only reduce the cost of concrete construction in this country but would also provide a means of disposing of this ash. In addition, cement production can be reduced. Rice husk ash is a very cheap material. It is very easy to get. It has high reactivity and pozzolanic property and it is created by burning rice husk. The burning procedure and temperature have an impact on the chemical composition of rice husk ash. Silica concentration in the ash increases with higher the burning temperature. Rice husk ash greatly reduces the danger of alkali-silica reaction damage, gives more resistance to chloride infiltration, and provides greater resistance to sulphate and other chemical attacks. Concrete made with rice husk ash continues to gain strength and improved durability properties. The rice husk ash powder is shown in figure 1.0.

Figure 1.0: Rice Husk Ash Powder

1.1 Objective: To study the mechanical properties of concrete by partially replacing cement with rice husk ash.

1.2 Methodology: The research methodology used in the experimental work is shown in figure 2.0.

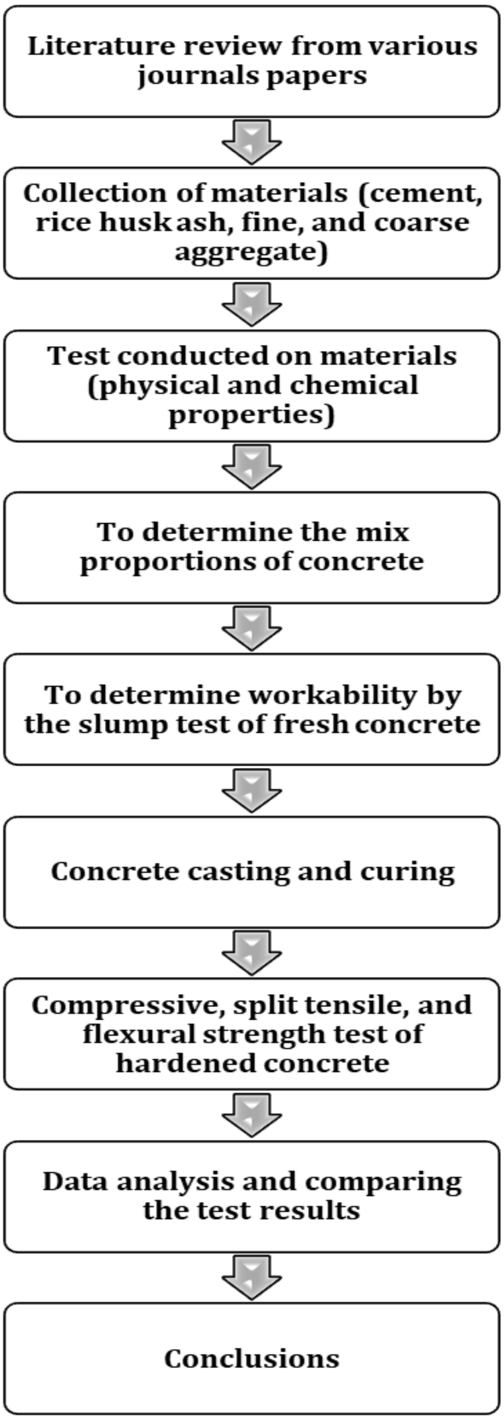

Figure 2.0: Flowchart Diagram of Planning of Work.

2. MATERIAL USED

2.1 Cement: Ordinary portland cement, 53 Grade conforming to IS 12269:2013 was used. The physical properties of ordinary portland cement are given in table 1.0. The chemical properties of rice husk ash are obtained from X-ray analysis are shown in table 2.0.

Table 1.0: Physical Properties of Ordinary Portland Cement

Properties	Value
Specific Gravity	3.15
Consistency (%)	32 %
Initial Setting Time	55 min
Final Setting Time	420 min
Soundness	1.9 mm
Fineness	1.5 %

Table 2.0: Chemical Properties of Ordinary Portland Cement

Properties	Value
Silica (SiO_2)	19.28%
Alumina (Al_2O_3)	6.68%
Iron Oxide (Fe_2O_3)	2.02%
Lime (CaO)	64.75%
Magnesia (MgO)	1.62%
Sulphur Trioxide (SO_3)	1.83%
Sodium Oxide (Na_2O)	0.12%
Potassium Oxide (K_2O)	0.80%
Loss on Ignition (LOI)	2.90%

2.2 Fine Aggregate: Fine aggregates are the particles that pass through 4.75 mm sieve and retain on 0.075 mm sieve. As a fine aggregate, good quality river sand conforming to grading zone II of IS 383:1970 was used. The physical properties of fine aggregates investigated are listed in table 3.0 below.

Table 3.0: Physical Properties of Fine Aggregate

Properties	Value
Particle Shape	Round
Size	4.75 mm Down
Fineness Modulus	2.53
Specific Gravity	2.67
Apparent Specific Gravity	2.71
Water Absorption	0.81%
Surface Moisture	Nil

2.3 Coarse Aggregate: Coarse aggregates are the particles that retain on 4.75 mm sieve. Locally available crushed stones conforming to IS 383:1970 were used. The physical properties of coarse aggregates investigated are listed in table 4 .0 below.

Table 4.0: Physical Properties of Coarse Aggregate

Properties	Value
Particle Shape	Angular
Size	20 mm
Fineness Modulus	6.85
Specific Gravity	2.70
Apparent Specific Gravity	2.75
Water Absorption	0.62%
Surface Moisture	Nil

2.4 Water: Water is an important ingredient of concrete because it takes an important role in the chemical reaction between cement and water. The quantity and quality of water must be carefully monitored because it contributes to the formation of the strength-giving cement gel. The experimental study was conducted utilizing drinking water, as specified by IS 456:2000.

2.5 Rice Husk Ask: The rice husk ash for this experiment was obtained locally. IS 456:2000 recommends the use of rice husk ash in concrete but does not define how much should be used. The physical and chemical properties of rice husk ash are mentioned in tables 5.0 and 6.0.

Table 5.0: Physical Properties of Rice Husk Ash

Properties	Value
Specific Gravity	2.3
Color	Grey
Shape	Irregular
Mineralogy	Non-Crystalline
Particle Size	< 45 Micron
Appearance	Very Fine
Odor	Odorless

Table 6.0: Chemical Properties of Rice Husk Ash

Properties	Value
Silica (SiO_2)	93.15%
Alumina (Al_2O_3)	2.30%
Iron Oxide (Fe_2O_3)	0.57%
Lime (CaO)	0.46%
Magnesia (MgO)	0.36%
Sulphur Trioxide (SO_3)	0.22%
Sodium Oxide (Na_2O)	0.10%
Potassium Oxide (K_2O)	0.66%
Loss on Ignition (LOI)	2.18%

3. EXPERIMENTAL PROGRAMMES

3.1 Design Mix: In the research study, the M40 grade of concrete was designed as per IS: 10262-2019. Following obtaining the proportions of control concrete, the trial mix was determined to be 1:1.24:2.24 for a water-cement ratio of 0.40. The proportion for different ingredients of the mix without rice husk ash are shown in table 7.0. Rice husk ash was used to partially replace ordinary Portland cement on a weight basis. The proportion for different ingredients of the mix with rice husk ash are shown in table 8.0 to 12.0.

Table 7.0: Mix Specification for 1 m³ Control Concrete

Cement (kg/m³)	FA (kg/m³)	CA (kg/m³)	Water (kg/m³)
492	612	1101	197
1	1.24	2.24	0.40

Table 8.0: Mix Specification for 1 m³ Rice Husk Ash Concrete (5 %)

Cement (kg/m³)	RHA (kg/m³)	FA (kg/m³)	CA (kg/m³)	Water (kg/m³)
467.4	24.6	612	1101	197
0.95	0.5	1.24	2.24	0.40

Table 9.0: Mix Specification for 1 m³ Rice Husk Ash Concrete (10 %)

Cement (kg/m³)	RHA (kg/m³)	FA (kg/m³)	CA (kg/m³)	Water (kg/m³)
442.8	49.2	612	1101	197
0.90	0.10	1.24	2.24	0.40

Table 10.0: Mix Specification for 1 m³ Rice Husk Ash Concrete (15 %)

Cement (kg/m³)	RHA (kg/m³)	FA (kg/m³)	CA (kg/m³)	Water (kg/m³)
418.2	73.8	612	1101	197
0.85	0.15	1.24	2.24	0.40

Table 11.0: Mix Specification for 1 m³ Rice Husk Ash Concrete (20%)

Cement (kg/m³)	RHA (kg/m³)	FA (kg/m³)	CA (kg/m³)	Water (kg/m³)
393.6	98.4	612	1101	197
0.80	0.20	1.24	2.24	0.40

Table 12.0: Mix Specification for 1 m³ Rice Husk Ash Concrete (25 %)

Cement (kg/m³)	RHA (kg/m³)	FA (kg/m³)	CA (kg/m³)	Water (kg/m³)
369	123	612	1101	197
0.75	0.25	1.24	2.24	0.40

3.2 Test Procedure: For concrete casting, cube molds of size 150 mm × 150 mm × 150 mm, cylinder molds of size 150 mm diameter and 300 mm length, and beam molds of size 100 mm × 100 mm × 500 mm were used. The slump cone apparatus was also used to determine the slump value of fresh concrete. Before the concrete was poured into the molds, the cast iron molds were cleaned and mineral oil was applied to all surfaces. Six mixtures were prepared using different percentages of 0, 5, 10, 15, 20, and 25 rice husk ash. The concrete components were mixed well until uniform consistency is achieved. This mixing process was done by hand machine as shown in figure 3.0. All specimens were properly compacted by tamping rod. For 24 hours, the caste specimens were kept at room temperature as shown in figure 4.0. The concrete cubes, cylinders, and beams were de-molded and placed in the curing tank until the day of testing as shown in figure 5.0. After 7, 14, and 28 days of curing the concrete cubes were tested for compressive strength, concrete cylinders were tested for split tensile strength, and concrete beams were tested for flexural strength. All the concrete specimens were tested in a universal testing machine (UTM) as shown in figure 6.0.

Figure 3.0: Process of Hand Mixing of Concrete

Figure 4.0: Casting of Concrete specimens

Figure 5.0: Concrete Specimens in Curing Tank

Figure 6.0: Universal Testing Machine (UTM) with a Test Specimen

4. RESULTS AND DISCUSSION

4.1. Slump Test: The objective of a concrete slump test is to measure the consistency or workability of a concrete mix**.** The slump test results are reported in table 13.0 for various mix proportions.

Table 13.0: Workability of Control and Rice Husk Ash Concrete

Type of Concrete	Slump Value (mm)
0%	75
5% RHA	65
10% RHA	50
15% RHA	45
20% RHA	35
25% RHA	25

The table indicates that the value of the slump decreases as the rice husk ash content increases. In this experiment, the workability of rice husk ash concrete is less than control concrete because more water is needed to make the mixture more workable if the rice husk ash percentage in the mixture increases. As the amount of rice husk ash increases, the amount of silica in the mixture increases, and consequently the demand for water increases. The silica-lime reaction requires more water in addition to the water required during the hydration of the cement. The results of the slump test are shown in graphical form in figure 7.0.

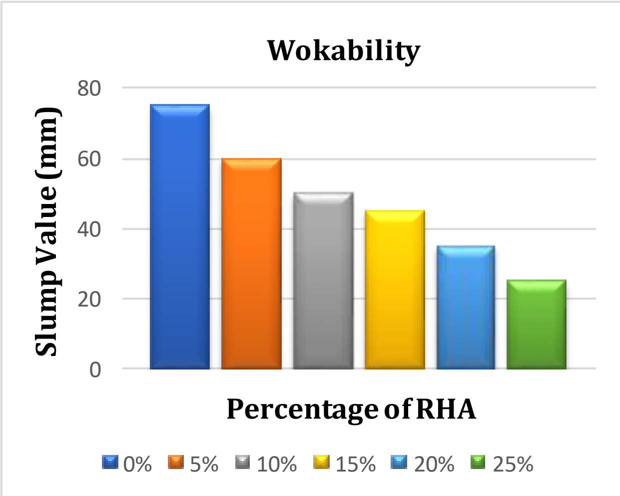

Figure 7.0: Graphical Representation of Slump Test Results

4.2. Compressive Strength Test: After 7, 14, and 28 days of curing, the compressive strength was determined. The compressive strength of concrete cubes was tested based on IS 516:1959. The compressive strength (in N/mm^2) results are shown in table 14.0. The results of the compressive test are shown in graphical form in figure 8.0.

Table 14.0: Compressive Strength Test Results (N/mm^2)

Type of Concrete	7 Days	14 Days	28 Days
0%	33.25	40.92	46.35
5% RHA	32.77	39.11	47.32
10% RHA	30.11	37.02	45.20
15% RHA	28.53	36.91	43.71
20% RHA	27.12	36.10	41.82
25% RHA	20.62	26.98	36.10

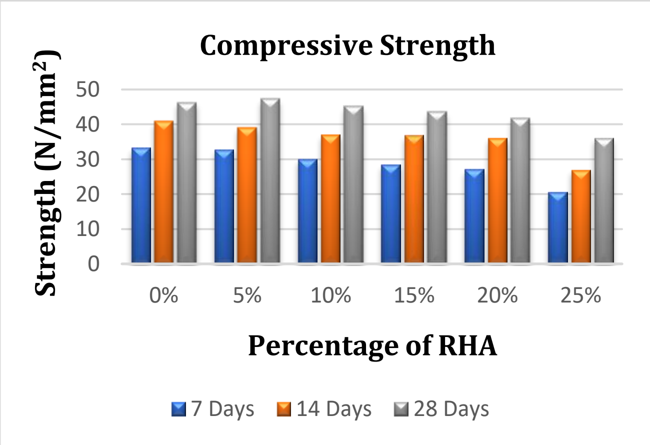

Figure 8.0: Graphical Representation of Compressive Strength Test Results

4.3. Split Tensile Strength: After 7, 14, and 28 days of curing, the split tensile strength was determined. The split tensile strength of concrete cylinders was tested based on IS 516:1959. The split tensile strength (in N/mm²) results are shown in table 15.0. The results of the split tensile strength test are shown in graphical form in figure 9.0.

Table 15.0: Split Tensile Strength Test Results (N/mm²)

Type of Concrete	7 Days	14 Days	28 Days
0%	3.40	4.10	4.69
5% RHA	3.34	3.93	4.76
10% RHA	3.13	3.78	4.63
15% RHA	2.96	3.71	4.41
20% RHA	2.72	3.63	4.23
25% RHA	2.16	2.80	3.72

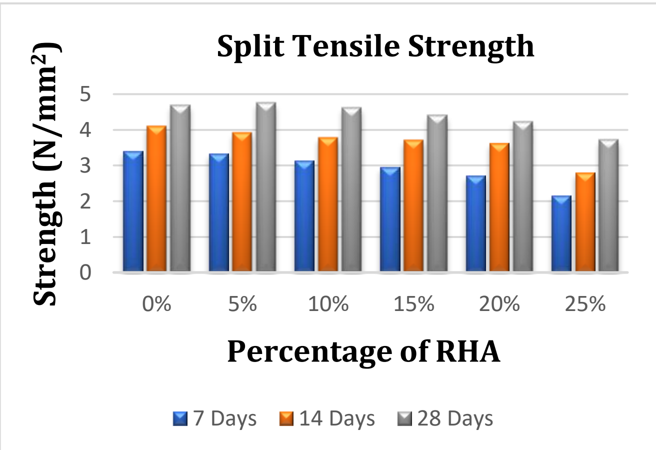

Figure 9.0: Graphical Representation of Split Tensile Strength Test Results

4.4 Flexural Strength: After 7, 14, and 28 days of curing, the flexural strength was determined. The flexural strength of concrete prisms was tested based on IS 516:1959. The flexural strength (in N/mm²) results are shown in table 16.0. The results of the flexural strength test are shown in graphical form in figure 10.0.

Table 16.0: Flexural Strength Test Results (N/mm²)

Type of Concrete	7 Days	14 Days	28 Days
0% RHA	3.70	4.58	5.17
5% RHA	3.63	4.42	5.28
10% RHA	3.32	4.29	4.99
15% RHA	3.15	4.16	4.83
20% RHA	2.98	4.11	4.66
25% RHA	2.43	2.98	3.98

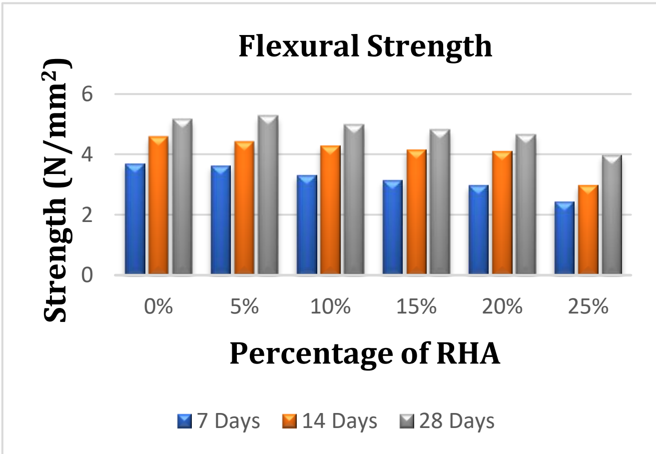

Figure 10.0: Graphical Representation of Flexure Strength Test Results

5. CONCLUSIONS

This experimental study arrived at the following conclusions –

1. The workability of concrete decreases as the replacement level of rice husk ash rises.
2. At 5% rice husk ash replacement, the concrete has reached its maximum compressive strength.
3. At 5% rice husk ash replacement, the concrete has reached its maximum split tensile strength.

4. At 5% rice husk ash replacement, the concrete has reached its maximum flexural strength.

5. The compressive, split tensile and, flexural strength of rice husk ash concrete mix are higher than that of conventional concrete mix.

6. It has been demonstrated, for lowering construction costs can be used rice husk ash as a partial replacement of ordinary Portland cement.

6. FUTURE SCOPE:

1. Other levels of rice husk ash replacement can be investigated.

2. The durability properties of concrete can be investigated using rice husk ash in concrete.

3. Combination of rice husk ash with different other waste materials can be executed.

4. By increasing the curing time of this study up to 90 days, changes in strength properties need to be investigated.

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