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Performance of Rice Husk Ash (RHA) as Partial Replacement of Cement in Concrete

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Abstract: The increasing demand for sustainable construction materials has led to the exploration of agricultural waste as a viable alternative in concrete production. Rice Husk Ash (RHA), a by-product obtained from the controlled burning of rice husk, is rich in amorphous silica and exhibits significant pozzolanic properties. This study investigates the performance of RHA as a partial replacement of cement in conventional concrete.

Concrete mixes were prepared by replacing cement with RHA at proportions of 0%, 5%, 10%, and 15% by weight. The workability of fresh concrete was evaluated using slump tests, compaction factor test, while mechanical properties were assessed through compressive and split tensile strength tests at different curing periods. Durability characteristics such as water absorption were also studied, along with a cost analysis of the mixes.

The results indicate that RHA significantly influences both fresh and hardened properties of concrete. An optimum replacement level was observed where strength and durability improved, while increasing the replacement levels resulted in reduced performance. The study concludes that RHA can be effectively utilized as a sustainable and cost-efficient supplementary cementitious material in concrete.

Keywords: Rice Husk Ash, Concrete, Compressive Strength, Split Tensile Strength, Workability, Durability, Sustainable Construction, Cost Analysis.

I. INTRODUCTION

Concrete is one of the most widely used construction materials in the world due to its strength, durability, and versatility. However, the production of cement, which is a key ingredient of concrete, is associated with high energy consumption and significant carbon dioxide emissions. This has led to increasing interest in the development of sustainable and eco-friendly construction materials.

In recent years, the utilization of industrial and agricultural waste materials as partial replacement of cement has gained considerable attention. Among these materials, Rice Husk Ash (RHA), an agricultural by-product obtained from the controlled burning of rice husk, has emerged as a promising supplementary cementitious material. RHA contains a high percentage of amorphous silica, which contributes to its pozzolanic properties and enhances the performance of concrete.

The use of RHA in concrete not only helps in reducing the environmental impact caused by cement production but also provides an effective solution for the disposal of agricultural waste. Additionally, it has the potential to improve certain mechanical and durability properties of concrete when used in appropriate proportions.

Despite its advantages, the performance of RHA-based concrete depends on several factors such as the quality of ash, fineness, replacement level, and curing conditions. Therefore, it is essential to evaluate its effect on different properties of concrete in a systematic manner.

The present study aims to investigate the performance of Rice Husk Ash as a partial replacement of cement in concrete. The evaluation is carried out in terms of workability, compressive strength, split tensile strength, durability, and cost analysis to determine its suitability as a sustainable construction material.

II. MATERIALS

Ordinary Portland cement, potable water, rice husk ash and aggregates were used in this experimentation. Rice husk ash and ordinary Portland cement that comply with the Indian standards are utilized as cementitious materials. Natural sand with a specific gravity of 2.58 and crushed limestone coarse aggregates with a nominal size of 16 mm with specific gravity of 2.66 were used to make the concrete samples. Sand and gravel may be used to create concrete, as evidenced by the grain size, fineness modulus of 3.1, shock resistance of 34% and sand equivalent value of 95%.

III. EXPERIMENTAL PROGRAMME

The experimental programme was designed to study the effect of partial replacement of cement with Rice Husk Ash (RHA) on the properties of M20 grade concrete. The study includes preparation of concrete mixes, casting of specimens, curing, and testing of hardened concrete.

A. Mix Design

The mix design for M20 grade concrete was carried out as per IS 10262 guidelines. Cement was partially replaced with RHA in different proportions to evaluate its effect on strength.

Table 3.1.1: Mix Proportions Used for Different Mixes:

Mix	% RHA	%Cement	W/C
Control Mix	0	100	0.5
Mix 1	5	95	0.5
Mix 2	10	90	0.5
Mix 3	15	85	0.5

Water-cement ratio was kept constant for all mixes.

B. Batching and Mixing

Batching of materials was done by weight to ensure accuracy. Required quantities of cement, fine aggregate, coarse aggregate, and RHA were measured and mixed thoroughly in dry condition. Water was then added gradually and mixing was continued until a uniform mix was obtained.

C. Casting of Specimens

Concrete was placed in standard cube moulds of size **150 mm × 150 mm × 150 mm**. The moulds were filled in three layers, and each layer was compacted properly using a tamping rod to remove air voids.

After casting, the top surface was leveled and finished smoothly. The specimens were kept undisturbed for 24 hours at room temperature.

D. Curing of Specimens

After 24 hours, the specimens were taken out from mould and shifted to a curing tank containing clean water. Curing was carried out for **7 days and 28 days** to evaluate development of strength.

E. Testing of Specimens

(a) Compressive Strength Test

Compressive strength test was conducted on concrete cubes using a Compression Testing Machine (CTM) as per IS 516 guidelines. The load was applied gradually until failure, and the maximum load was recorded.

Compressive strength was calculated using the formula:

$$f_c = \frac{P}{A}$$

Where:

- f_c= Compressive strength (N/mm²)
- P = Load at failure (N)
- A = Cross-sectional area (mm²)

(b) Workability Test

Slump test was conducted to determine the workability of fresh concrete. The slump cone was filled with concrete in layers and tamped properly. The vertical settlement (slump) in mm was measured after removing the cone.

In addition to this, compaction factor test was also performed to assess the workability of concrete more accurately, especially for low workability mixes. In this test, concrete was allowed to fall through upper and lower hoppers into a cylinder, and the weights of partially compacted and fully compacted concrete were measured.

The compaction factor was calculated using the formula:

$$\text{Compaction Factor} = \frac{\text{Weight of partially compacted concrete } (W_1)}{\text{Weight of fully compacted concrete } (W_2)}$$

(c) Split Tensile Strength Test

Split tensile strength test was conducted on concrete cylinders using a Compression Testing Machine (CTM) as per IS 5816 guidelines. The load was applied gradually along the diameter of the specimen until failure, and the maximum load was recorded. Split tensile strength was calculated using the formula:

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

Where:
P = Applied load (N)
D = Diameter of cylinder (mm)
L = Length of cylinder (mm)

F. Number of Specimens

For each mix proportion, at least **3 specimens** were cast and tested for each curing period (7 days and 28 days) to ensure accuracy of results.

All tests were conducted as per relevant IS codes, and observations were recorded carefully for analysis.

IV. RESULTS AND DISCUSSION

The results obtained from the experimental study are presented and discussed in this chapter. The effect of partial replacement of cement with Rice Husk Ash (RHA) on workability and compressive strength of concrete has been analyzed.

A. Workability of Concrete

The workability of fresh concrete was determined using the slump test. The slump values for different mix proportions are given below.

Table 4.1.1: Slump Values for Different Mixes

Mix Type	RHA (%)	Slump (mm)	Compaction Factor
Control Mix	0%	70	0.89
Mix 1	5%	62	0.87
Mix 2	10%	45	0.81
Mix 3	15%	30	0.76

Discussion:

- It was observed that the both slump value and compaction factor **decrease with an increase in RHA content**, indicating a reduction in workability of concrete.
- The control mix (0% RHA) shows the **highest slump and compaction factor**, confirming better flow ability and ease of compaction.
- The decrease in values due to the higher surface area and porous nature of RHA which absorbs more water.
- The reduction in workability is acceptable up to an optimum level (around 10–15% RHA), beyond which **additional water or admixtures may be required**.

B. Compressive Strength of Concrete

The compressive strength test was conducted at 7 days and 28 days curing periods. The results are presented below.

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Table 4.2.1: Compressive Strength at 7 Days and 28 Days.

Mix Type	RHA (%)	Strength (N/mm²) 7 days	Strength (N/mm²) 28 days
Control Mix	0%	13.5	20.2
Mix 1	5%	14.5	20.5
Mix 2	10%	15.0	21.0
Mix 3	15%	12.5	19.5

Discussion:

- Compressive strength increases with addition of RHA up to optimum level (generally 5–10%).
- Maximum strength is usually observed at 10 % replacement .
- Beyond optimum percentage, strength decreases due to reduction in cement content.
- RHA improves later age strength due to pozzolanic reaction.

C. Split Tensile Strength of Concrete

The Split Tensile Strength test was conducted at 7 days and 28 days curing periods. The results are presented below.

Table 4.3.1: Split Tensile Strength at 7 Days and 28 Days.

Mix Type	RHA (%)	Strength (N/mm²) 7 days	Strength (N/mm²) 28 days
Control Mix	0%	1.6	2.28
Mix 1	5%	1.7	2.30
Mix 2	10%	1.9	2.5
Mix 3	15%	1.5	2.1

Discussion:

- Split tensile Strength increases with addition of RHA up to 10%.
- Maximum strength is usually observed at 10% RHA replacement with cement.
- Beyond 10% percentage, strength decreases due to reduction in cement content.
- RHA improves later age strength due to pozzolanic reaction.

V. DURABILITY ANALYSIS (RESULTS AND DISCUSSION)

Durability of concrete mixes was evaluated to assess their resistance against environmental conditions such as water absorption and permeability. Tests were conducted as per relevant IS guidelines. The specimens were cured and then tested for water absorption and durability performance. Lower water absorption indicates better durability of concrete.

Water absorption was calculated using the formula:

Water Absorption (%) = $\frac{W_2 - W_1}{W_1} \times 100$

Where:

W_1 = Dry weight of specimen (g)

W_2 = Wet weight of specimen (g)

Mix Type	RHA (%)	Dry Weight (g) W1	Wet Weight (g) W2	Water Absorption (%)
M0	0%	8500	8670	2.00
M1	5%	8480	8630	1.77
M2	10%	8450	8580	1.54
M3	15%	8420	8570	1.78

VI. COST ANALYSIS (RESULTS AND DISCUSSION)

Cost analysis was carried out to evaluate the economic feasibility of using Rice Husk Ash (RHA) as partial replacement of cement. The cost of materials for conventional concrete and RHA concrete mixes was calculated based on market rates.

Total cost was calculated using the formula:

Total Cost = $\sum(Quality\ of\ Material\ \times Unit\ Cost)$

The percentage cost reduction was calculated as:

$$\text{Cost Reduction (\%)} = \frac{C_c - C_r}{C_c} \times 100$$

Where:

C_c = Cost of conventional concrete

C_r = Cost of RHA concrete

Mix ID	RHA (%)	Cement (kg/m³)	RHA (kg/m³)	Cost of Cement (₹)	Cost of RHA (₹)	Total Cost (₹/m³)
M0	0%	400	0	2400	0	4500
M1	5%	380	20	2280	100	4400
M2	10%	360	40	2160	200	4300
M3	15%	340	60	2040	300	4250

VII. OVERALL DISCUSSION

- Workability decreases with increase in RHA content.
- Compressive strength and spilt tensile strength increases up to an optimum i.e. upto 10%, replacement level and then decreases.
- RHA acts as a pozzolanic material and enhances long-term strength.
- Use of RHA also helps in reducing cement consumption and environmental impact.

The results indicate that partial replacement of cement with RHA is feasible and beneficial up to a certain limit.

VIII. CONCLUSION

Based on the experimental investigation on partial replacement of cement with Rice Husk Ash (RHA) in M20 grade concrete, the following conclusions are drawn:

A. *Conclusions*

1) The workability of concrete decreases with increase in percentage of RHA due to its porous nature and higher water absorption capacity.
2) Compressive strength and spilt tensile strength of concrete increases with the addition of RHA up to an optimum level and decreases beyond that limit.
3) The optimum percentage of RHA replacement is generally found to be "between**5% to 10%"** for achieving maximum strength.
4) Early age strength (7 days) is comparatively lower due to slower pozzolanic reaction of RHA.
5) At later stages (28 days), strength improves due to pozzolanic activity between RHA and calcium hydroxide.
6) Partial replacement of cement with RHA reduces the overall cement consumption, making the concrete more economical and durable.
7) Use of RHA helps in reducing environmental pollution and promotes sustainable construction practices.

Thus, it can be concluded that Rice Husk Ash is a suitable and sustainable material for partial replacement of cement in concrete.

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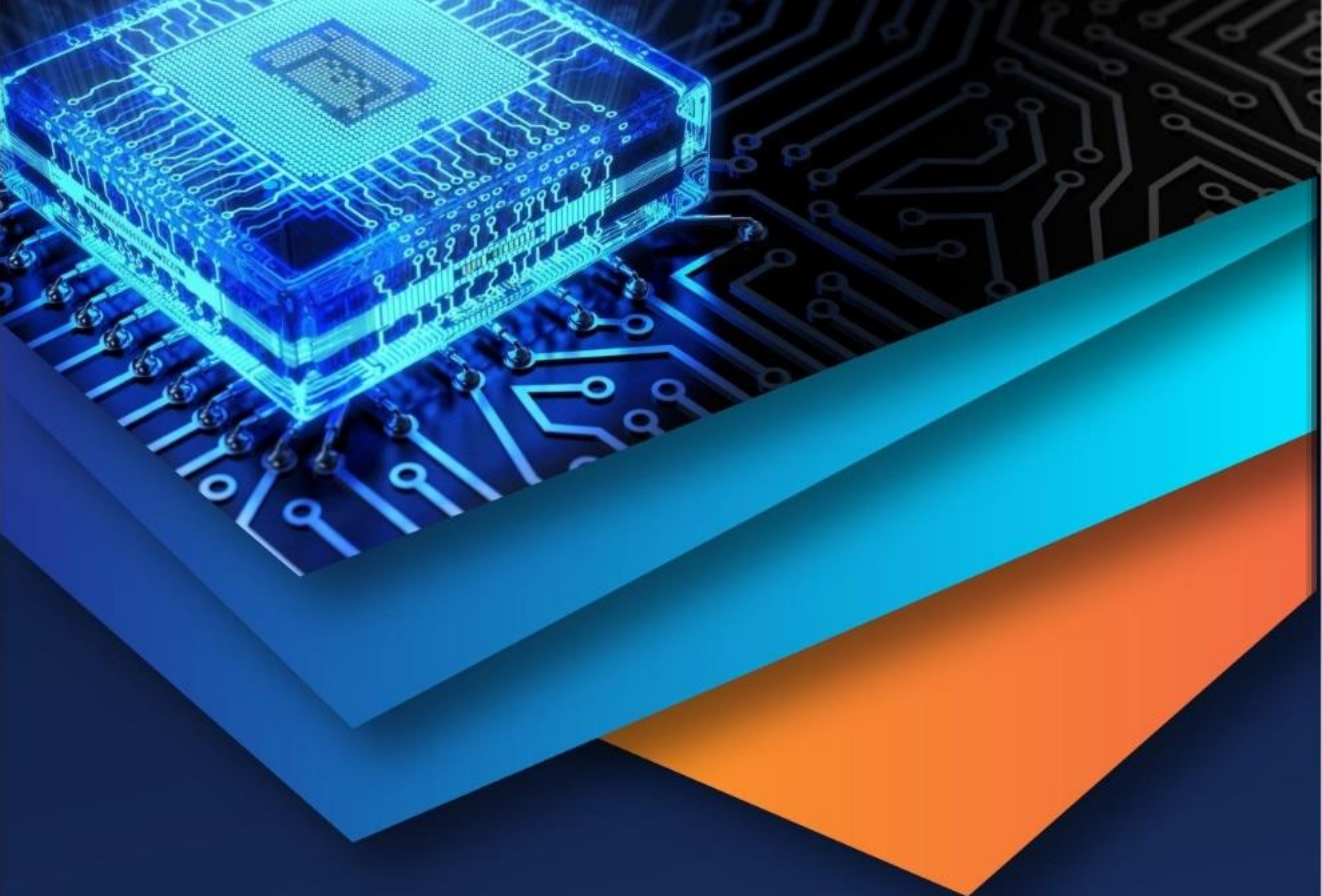

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