



EXPERIMENTAL INVESTIGATION ON THE USE OF RICE HUSK ASH IN M20 GREEN CONCRETE

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Abstract:

The construction sector depends heavily on Ordinary Portland Cement (OPC), whose manufacture is energy intensive and associated with substantial carbon dioxide emissions. Agricultural residues can provide supplementary cementitious materials while reducing waste-disposal problems. This study experimentally investigates Rice Husk Ash (RHA) as a partial replacement for OPC in M20 grade green concrete. Four mixes containing 0%, 5%, 10%, and 15% RHA were prepared under the experimental programme. Workability was assessed using the slump test, while compressive strength was evaluated at 7, 14, and 28 days and split tensile strength at 28 days. The reported slump values decreased from 82 mm for the control mix to 61 mm at 15% RHA. The 28-day compressive strength increased from 24.10 MPa for the control to 26.20 MPa at 10% RHA, followed by a reduction to 23.90 MPa at 15%. Similarly, 28-day split tensile strength increased from 2.92 MPa to 3.13 MPa at 10% RHA and then decreased to 2.86 MPa. On the basis of the combined workability and strength results, the 10% RHA mix provided the best overall performance in the reported experimental programme. The study indicates that appropriately processed RHA can be used as a supplementary cementitious material in M20 concrete while supporting agricultural-waste utilization and reduced cement consumption.

Keywords: Rice Husk Ash; Green Concrete; M20 Concrete; Sustainable Construction; Cement Replacement; Compressive Strength; Split Tensile Strength; Slump; Agricultural Waste

1. INTRODUCTION

1.1 Background

Concrete is one of the most widely used construction materials because of its strength, versatility, durability and economic advantages. Its extensive use has increased the demand for cement, while cement manufacture creates an important environmental burden through energy consumption and carbon dioxide emissions. Sustainable concrete research therefore increasingly considers supplementary cementitious materials obtained from industrial and agricultural residues.

Rice Husk Ash is produced by controlled burning of rice husk and is characterized in the dissertation as a fine, silica-rich material with pozzolanic activity. Reactive silica can participate in secondary reactions with calcium hydroxide released during cement hydration, contributing to additional calcium silicate hydrate gel. The fine particles can also provide a filler effect and influence the packing of the cementitious matrix.

Rice husk is generated in large quantities in rice-producing regions. When the residue is not effectively utilized, open burning or disposal can create environmental problems. Using RHA in concrete provides a route for converting an agricultural by-product into a useful construction material while partially reducing the quantity of Portland cement.

1.2 Problem Statement

The performance of RHA concrete is dependent on the replacement percentage, ash fineness, silica characteristics, water demand, curing conditions and mix proportions. Increasing RHA content can reduce workability because the ash is fine and porous, whereas moderate replacement may improve strength through filler and pozzolanic effects. Consequently, an experimental assessment is required to identify a suitable replacement level for normal-strength M20 concrete.

1.3 Objectives

Prepare M20 concrete with 0%, 5%, 10% and 15% RHA replacement by weight of cement.

Characterize the constituent materials used in the experimental programme.

Evaluate fresh-concrete workability through the slump test.

Measure compressive strength at 7, 14 and 28 days.

Measure 28-day split tensile strength.

Compare the control and RHA mixes and identify the replacement level giving the best combined performance.

2.LITERATURE REVIEW

The dissertation reviews research on RHA concrete from 2012 to 2026. The reviewed work generally reports that RHA can contribute to sustainable concrete because of its silica content, pozzolanic behaviour and ability to reduce cement consumption. The literature also indicates that the response is strongly dependent on material processing and replacement level.

2.1 Previous Research

Çaglar (2026) investigated data-driven and multi-objective approaches for sustainable RHA concrete and reported the potential for optimizing strength and environmental performance.

Çaglar et al. (2025) reviewed RHA in structural concrete and highlighted the importance of fineness, silica content and burning temperature; approximately 10–15% replacement was frequently associated with favorable performance.

Ubayi et al. (2024) reviewed RHA as a partial cement replacement and reported that moderate replacement can improve strength and durability, while excessive replacement may reduce performance.

Ramesh et al. (2023) studied M20 concrete with 0–20% RHA and reported increasing strength up to an optimum level followed by reduction at higher replacement.

Patel et al. (2022) reported improved 28-day strength at 10% RHA and associated the improvement with particle packing and pozzolanic effects.

Das et al. (2020) investigated M20 concrete with 0–15% RHA and reported reduced workability but improved 28-day strength at moderate replacement.

Sharma et al. (2019) observed decreasing slump with increasing RHA and reported strength improvement up to approximately 10–15% before reduction.

Van Tuan et al. (2018) summarized the influence of RHA on strength, durability and sustainability and identified moderate replacement as a commonly favorable range.

Habeeb and Mahmud (2017) reviewed RHA concrete and emphasized the role of amorphous silica, fineness and processing in strength and durability development.

Ganesan, Rajagopal and Thangavel (2008) investigated RHA blended cement and the optimum replacement level for strength and permeability properties.

2.2 Research Gap

The reviewed literature does not establish one universal optimum RHA percentage for every concrete grade and material source. Differences in ash production, fineness, replacement percentage and mix design produce different outcomes. The present work therefore focuses specifically on M20 concrete and compares 0%, 5%, 10% and 15% RHA under the reported laboratory conditions, using workability, compressive strength and split tensile strength as the main performance indicators.

3. MATERIALS AND EXPERIMENTAL METHODOLOGY

3.1 Materials

Material	Reported properties / specification
OPC	43 Grade; IS 8112:2013; specific gravity 3.15; bulk density 1440 kg/m ³
Rice Husk Ash	Fine powder; specific gravity 2.15; silica-rich; highly reactive pozzolanic material
Fine aggregate	Natural river sand; Zone II; IS 383:2016; specific gravity 2.65; absorption 1.0%
Coarse aggregate	Crushed stone; 20 mm and 10 mm; specific gravity 2.70; absorption 0.5%
Water	Potable water; clear; approximately pH 7; used for mixing and curing

3.2 Mix Proportion

The M20 mix was reported as a nominal proportion of 1:1.5:3 for cement, fine aggregate and coarse aggregate, with a water-cement ratio of 0.45. RHA replaced cement at 0%, 5%, 10% and 15% by weight while the total binder content was maintained constant.

Mix	RHA (%)	Cement (kg)	RHA (kg)	Fine agg. (kg)	Coarse agg. (kg)	Water (L)
M0	0	67.32	0.0	132.04	252.45	30.29
M5	5	63.95	3.37	132.04	252.45	34.83
M10	10	60.59	6.73	132.04	252.45	34.83
M15	15	57.22	10.1	132.04	252.45	34.83

3.3 Experimental Programme

A total of 36 concrete cubes of $150 \times 150 \times 150$ mm and 12 cylinders of 150×300 mm were reported. Cubes were tested at 7, 14 and 28 days, while cylinders were tested at 28 days. Fresh concrete was subjected to the slump test immediately after mixing. Specimens were cast in steel moulds, compacted, demoulded after approximately 24 hours and water cured until the specified testing ages.

3.4 Standards

The reported procedures followed IS 10262:2019 for mix proportioning, IS 1199:2018 for slump testing, IS 516 (Part 1/Sec 1):2021 for compressive strength, and IS 5816:1999 for split tensile strength.

4. TESTING PROCEDURES

4.1 Slump Test

The slump test was used to determine the consistency and workability of fresh concrete. The cone was cleaned and placed on a level surface. Concrete was filled in three layers, each compacted with 25 blows of a standard tamping rod. The cone was lifted vertically and the vertical subsidence was measured. The dissertation reports that the fine and porous nature of RHA increases water demand and therefore tends to reduce slump as RHA content increases.

4.2 Compressive Strength

For compressive strength, 150 mm cube specimens were removed from water curing at 7, 14 and 28 days. The specimens were cleaned and placed centrally in a calibrated compression testing machine. Load was applied continuously until failure, and the maximum load was used to calculate compressive strength as load divided by the loaded area of $22,500 \text{ mm}^2$. Three specimens were tested for each mix and age, with the average value used for analysis.

4.3 Split Tensile Strength

The split tensile test was conducted on 150 mm diameter $\times$ 300 mm long cylinders after 28 days of water curing. Cylinders were positioned horizontally between compression platens with packing strips for load distribution. Load was applied continuously until a vertical splitting crack developed. Three cylinders were tested for each mix and the average split tensile strength was reported.

4.4 Experimental Variables

Parameter	Value
Concrete grade	M20
Binder	OPC 43 Grade + RHA
RHA replacement	0%, 5%, 10%, 15%
Nominal proportion	1 : 1.5 : 3
Water-cement ratio	0.45
Cube size	$150 \times 150 \times 150$ mm
Cylinder size	150×300 mm
Curing	Water curing
Compressive testing ages	7, 14, 28 days

Split tensile testing age	28 days
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5.RESULTS: WORKABILITY AND COMPRESSIVE STRENGTH

5.1 Slump Test Results

Mix	RHA (%)	Slump (mm)
M0	0	82
M5	5	76
M10	10	69
M15	15	61

The slump decreased progressively from 82 mm for M0 to 76 mm, 69 mm and 61 mm for M5, M10 and M15, respectively. Thus, the addition of RHA reduced fresh-concrete workability under the reported mix conditions. The trend is consistent with the reported porous and fine nature of RHA, which increases water demand.

5.2 Compressive Strength Results

Mix	RHA (%)	7 d (MPa)	14 d (MPa)	28 d (MPa)
M0	0	16.2	20.8	24.1
M5	5	16.8	21.6	25.3
M10	10	17.5	22.4	26.2
M15	15	16.1	20.7	23.9

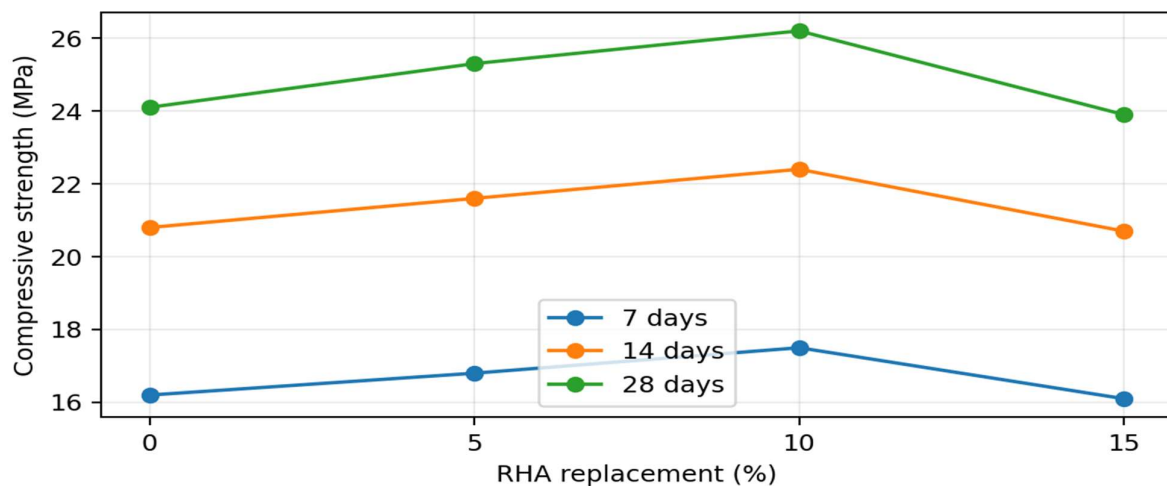


Figure 1. Compressive strength development at different RHA replacement levels.

6.COMPRESSIVE STRENGTH DISCUSSION

6.1 Seven-Day Strength

At 7 days, compressive strength increased from 16.20 MPa for M0 to 16.80 MPa for M5 and 17.50 MPa for M10. At 15% RHA, the value decreased to 16.10 MPa. The reported explanation is that moderate RHA benefits from filler action and early pozzolanic activity, while the higher replacement level reduces the amount of cement available for primary hydration.

6.2 Fourteen-Day Strength

At 14 days, the control mix reached 20.80 MPa, while M5, M10 and M15 reached 21.60, 22.40 and 20.70 MPa, respectively. Continued hydration and pozzolanic reaction increased the strength of all mixes compared with their 7-day values. M10 remained the highest-strength mix.

6.3 Twenty-Eight-Day Strength

At 28 days, M0 achieved 24.10 MPa, M5 achieved 25.30 MPa, M10 achieved 26.20 MPa and M15 achieved 23.90 MPa. M10 therefore exceeded the control strength by 2.10 MPa, corresponding to an increase of approximately 8.7% relative to M0. M5 also exceeded the control by approximately 5.0%, while M15 was approximately 0.8% below the control.

Mix	28-day strength (MPa)	Change vs M0
M0	24.1	Reference
M5	25.3	+5.0%
M10	26.2	+8.7%
M15	23.9	-0.8%

6.4 Interpretation

The observed rise up to 10% RHA is attributed in the dissertation to the combined filler effect, improved particle packing and pozzolanic reaction producing additional C–S–H gel. At 15%, the reduction in cement content and increased water demand appear to outweigh these benefits under the tested conditions. The results therefore identify 10% as the most favorable replacement level within the four investigated mixes.

7.SPLIT TENSILE STRENGTH AND COMPARATIVE DISCUSSION

7.1 Split Tensile Strength

Mix	RHA (%)	Failure load (kN)	28-day split tensile strength (MPa)
M0	0	220	2.92
M5	5	228	3.02
M10	10	236	3.13
M15	15	216	2.86

The 28-day split tensile strength followed the same general pattern as compressive strength. M10 recorded the highest value of 3.13 MPa, compared with 2.92 MPa for the control mix. This represents an increase of approximately 7.2%. M5 increased to 3.02 MPa, while M15 decreased to 2.86 MPa.

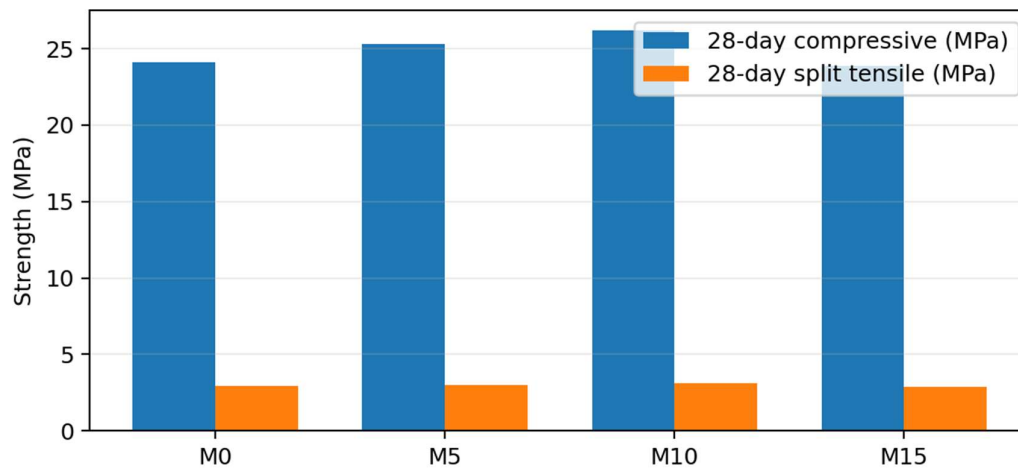


Figure 2. Comparison of 28-day compressive and split tensile strength.

7.2 Overall Trend

Both strength indicators improved from 0% to 10% RHA and decreased at 15%. The similar trends suggest that the replacement level that supported compressive strength also supported tensile performance. The reported mechanisms include additional C–S–H formation, filler action, improved particle packing, reduced internal voids and improved paste–aggregate bonding.

7.3 Workability–Strength Balance

Increasing RHA improved strength only up to the moderate replacement range while continuously reducing slump. Therefore, the selection of a replacement level cannot be based on strength alone. Under the present experimental conditions, 10% RHA provided the strongest combined performance, while still retaining a reported slump of 69 mm.

8.SUSTAINABILITY, CONCLUSIONS AND FUTURE SCOPE

8.1 Sustainability Significance

The use of RHA as a partial cement replacement has two connected sustainability implications. First, it reduces the quantity of OPC required for a given concrete mixture. Second, it provides a beneficial use for an agricultural residue that otherwise may require disposal or uncontrolled burning. The experimental findings demonstrate that these sustainability benefits can be pursued while maintaining or improving the measured mechanical properties at a moderate RHA replacement level.

8.2 Conclusions

RHA was successfully incorporated into M20 concrete at 5%, 10% and 15% replacement levels under the reported laboratory conditions.

Slump decreased continuously from 82 mm at 0% RHA to 61 mm at 15% RHA, confirming the influence of RHA on fresh-concrete water demand.

Compressive strength increased with curing age for all mixes.

The highest compressive strengths at 7, 14 and 28 days were recorded for the 10% RHA mix: 17.50, 22.40 and 26.20 MPa, respectively.

The 10% RHA mix achieved the highest 28-day split tensile strength of 3.13 MPa.

At 15% RHA, both compressive and split tensile strengths declined relative to the 10% mix.

Considering workability, compressive strength and split tensile strength together, 10% RHA was the most favorable replacement level among the mixes investigated.

The results support the use of suitably processed RHA as a supplementary cementitious material for sustainable M20 concrete.

8.3 Limitations and Future Scope

The reported experimental programme focuses on workability, compressive strength and split tensile strength. Future investigations can extend the study to flexural strength, water absorption, permeability, chloride and sulphate resistance, microstructural characterization, durability under aggressive exposure, long-term performance, and life-cycle or carbon-emission assessment. Larger-scale trials and optimization of RHA processing conditions can also help evaluate field applicability.

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