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Incorporation of RHA (Rice Husk Ash) and WPSA (Waste Paper Sludge Ash) as Partial Substitution of Cement in M20 Concrete

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***Abstract:** The increasing consumption of cement in concrete construction creates both economic and environmental concerns, encouraging the use of waste-derived supplementary cementitious materials. This paper study investigates the use of RHA and WPSA as partial replacement for the cement in M20 grade concrete. The concrete specimens were produced by incorporating RHA, WPSA, and their combined blend in place of a portion of the cement at selected dosage levels. The fresh-state behaviour of each mix was assessed using slump and compaction factor measurements. After curing for 7 to 28 days, the hardened specimens were tested to determine their compressive and split tensile strengths. The experimental observations indicated a progressive decline in concrete workability as the proportion of ash-based materials increased. WPSA produced the most favourable strength response at 2% replacement, achieving a twenty-eight-day compressive strength of 31.26 N/mm² compared with 30.93 N/mm² for the control mix. The study demonstrates that these types of waste items have potential as partial cement replacements while also providing a useful route for waste utilization and decreasing in cement consumption.*
***Keywords:** RHA, WPSA, M20 Concrete, Cement Replacement, Compressive Strength, Sustainable Concrete*

I. INTRODUCTION

Concrete has become a fundamental material in modern infrastructure, serving as a primary component in the construction of buildings, bridges, roads, dams, and other civil engineering structures, and cement is its principal binding component. The growing requirement for concrete has increased the demand for cement and, consequently, the consumption of natural resources and energy associated with its production. The search for different materials has now become super important for creating economical and environmentally responsible concrete. Agricultural and industrial residues that possess suitable pozzolanic or cementitious characteristics can provide an alternative route for reducing cement consumption while simultaneously addressing waste-disposal problems.

RHA is obtained by firing rice husk, an agricultural residue generated during rice processing. The ash contains a significant amount of silica, and its suitability as a Cement-replacing additive depends strongly on the form of silica and the conditions under which the husk is burned. Properly produced RHA can participate in pozzolanic reactions and may influence the strength, permeability and durability characteristics of concrete. Earlier investigations reported that RHA can be incorporated into materials at suitable replacement levels, although increasing its proportion may have serious affect workability because of the clear and porous nature of ash [1–4].

WPSA is obtained from the thermal treatment of residual sludge generated by the paper industry. Paper recycling produces sludge containing fibres and mineral fillers, creating a disposal challenge for paper mills. When suitably processed, the resulting ash can exhibit cementitious and pozzolanic characteristics. Previous studies have investigated paper-industry residues as half differential for cement and reported that controlled replacement levels can produce material with right mechanical features while reducing waste-disposal requirements [5–8].

The combined utilization of agricultural and industrial waste materials provides an opportunity to address two waste streams through a single construction application. In accordance to decreasing the quantity of cement required, the application of RHA and WPSA can decrease the weight of waste directed towards disposal. Lastly, the paper has also shown that the performance of these materials depends on their replacement percentage, particle characteristics, processing conditions and interaction with the other constituents of concrete [3,6,9].

The present experimental study therefore examines M20 concrete incorporating RHA, WPSA and a combined RHA+WPSA mixture as half for cement. The investigation focuses on fresh concrete's working ability, its strength and also the tensile strength related to split technology and also material cost. The experimental programme was designed to identify replacement levels that can provide satisfactory performance while improving the usage of waste materials.

II. MATERIALS & METHODS

A. Materials

These mixtures consisted of Portland Cement also known as (OPC) 53 grade, clean mixtures, coarse mixtures as well, water, Rice Husk Ash and Waste Paper Sludge Ash. The cement used in the investigation conformed to IS 12269:1987 and had a pre-defined gravity of 3.10. The coarse aggregate was crushed, angular aggregate with a nominal maximum size of 20 mm. Its reported specific gravity was 2.62 and water absorption was 0.89%. The fine aggregate had a particular gravity of 2.63 and a clear modulus of 2.83. The aggregate characteristics were checked with reference to the relevant Indian Standard requirements [10–13].

RHA was made from rice husk obtained from a local source in Himachal Pradesh. The husk was washed, dried and subsequently burned to obtain ash. The final reading regarding the material was passed through a 90-m sieve. The RHA was reported as a light-grey fine powder with a particular gravity of 2.21.

WPSA was received from waste sludge collected from a paper-manufacturing source at Baddi, Himachal Pradesh. The sludge was burned to produce ash and then processed for use in the concrete mixes. The WPSA was reported as a dark-grey fine powder passing through a 90-micron sieve, along a particular gravity of 2.09.

TABLE I
PHYSICAL FEATURES OF MATERIALS

Material	Property	Value
Cement	Type	OPC 53 grade
Cement	Specific gravity	3.10
Fine aggregate	Specific gravity	2.63
Fine aggregate	Fineness modulus	2.83
Coarse aggregate	Nominal size	20 mm
Coarse aggregate	Specific gravity	2.62
Coarse aggregate	Water absorption	0.89%
RHA	Particle size	Passing 90 µm sieve
RHA	Specific gravity	2.21
WPSA	Particle size	Passing 90 µm sieve
WPSA	Specific gravity	2.09

B. Concrete Mix Design

This mix was designed for an M20 grade using the mix-design procedure specified in IS 10262. A maximum aggregate size of 20 mm, mild exposure condition and a target workability of approximately 75 mm were considered. The adopted water-cement ratio was 0.50. The calculated target mean compressive strength was 27.59 N/mm².

For the control mixture, the quantities per cubic metre were approximately 186 kg of water, 372 kg of cement, 562 kg of fine aggregate and 1217 kg of coarse aggregate. The corresponding basic proportion was approximately 0.50:1:1.50:3.247 for the water, cement, and also fine mixture and coarse aggregate.

Cement was substituted with RHA and WPSA individually at 2%, 4%, 6% and 8%. Additionally, the mixtures were made by substituting cement alongside an equal combination of RHA and WPSA, with the total replacement maintained at 2%, 4%, 6% and 8%.

TABLE II

Proportions needed for investigation table 2. Mixed proportions taken for study and investigation

Mix	Replacement	Water (kg/m³)	Cement (kg/m³)	Fine Aggreigate (kg/m³)	Coarse Aggregate (kg/m³)	RHA (kg/m³)	WPSA (kg/m³)
Control	0%	186	372.0	562	1217	–	–
RHA	2%	186	353.4	562	1217	18.6	–
RHA	4%	186	334.8	562	1217	37.2	–
RHA	6%	186	316.2	562	1217	55.8	–
RHA	8%	186	297.6	562	1217	74.4	–
WPSA	2%	186	353.4	562	1217	–	18.6
WPSA	4%	186	334.8	562	1217	–	37.2
WPSA	6%	186	316.2	562	1217	–	55.8
WPSA	8%	186	297.6	562	1217	–	74.4
RHA+WPSA	2%	186	353.4	562	1217	9.3	9.3
RHA+WPSA	4%	186	334.8	562	1217	18.6	18.6
RHA+WPSA	6%	186	316.2	562	1217	27.9	27.9
RHA+WPSA	8%	186	297.6	562	1217	37.2	37.2

C. Specimen Preparation and Curing

The required quantities of cement, aggregates, RHA and WPSA were weighed before mixing. The ingredients were mixed manually on a non-absorptive platform. The constituents were first mixed, then by the addition of all of the required water. The left water was then mixed gradually to get a uniform concrete mixture.

For each mix, cube and cylindrical type of specimens were prepared for strength evaluation. The cube specimens measured 150 mm × 150 mm × 150 mm and were used for compressive strength testing. Cylindrical samples were used for split tensile strength evaluation. The samples were compacted manually in layers using a tamping bar.

After demoulding, the samples that were placed in a curing tank. Experiments were done after curing periods of 7 and twenty-eight-days.

D. Testing Programme

The concrete was examined using slump and compaction factor tests. The slump test was used to determine the change in workability resulting from the amalgamation of RHA and WPSA. The concrete that got hardened was tested for cumulative strength and tensile power after 7 and twenty-eight-days of curing.

The testing programme followed the relevant Indian Standard procedures identified in the project, including IS 383, IS 10262, IS 1199, IS 2386, IS 4031 and IS 456.

III. RESULTS AND DISCUSSION

A. Fresh Concrete Properties

The control concrete produced a slump of 90 mm. Addition of RHA, WPSA and the combined RHA+WPSA material reduced the slump as the replacement level increased. For RHA, the slump decreased from 65 mm at 2% replacement to 20 mm at 8% replacement. WPSA produced a slump of 60 mm at 2% and 20 mm at 8%. The combined mixture showed a more pronounced reduction, with slump values decreasing from 30 mm at 2% replacement to 7 mm at 8%.

The reduction in slump indicates that increasing the quantity of the ash materials makes the concrete mixture less workable. This trend is particularly important when higher replacement levels are considered because additional attention to water demand or chemical admixtures may be required in practical applications.

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TABLE III
SLUMP TEST RESULTS

Mix	Replacement	Slump (mm)
Control	0%	90
RHA	2%	65
RHA	4%	55
RHA	6%	25
RHA	8%	20
WPSA	2%	60
WPSA	4%	55
WPSA	6%	50
WPSA	8%	20
RHA+WPSA	2%	30
RHA+WPSA	4%	20
RHA+WPSA	6%	15
RHA+WPSA	8%	7

The compaction factor showed a similar trend. The control concrete had a compaction factor of 0.93. For RHA mixes, the value declined from 0.90 at 2% replacement to 0.82 at 8%. WPSA mixes decreased from 0.92 to 0.81, while the combined RHA+WPSA mixes decreased from 0.84 to 0.78.

TABLE IV
COMPACTION FACTOR RESULTS

Mix	2%	4%	6%	8%
RHA	0.90	0.87	0.83	0.82
WPSA	0.92	0.90	0.85	0.81
RHA+WPSA	0.84	0.83	0.80	0.78

B. Compressive Strength

The control M20 concrete achieved compressive strengths of 20.40 N/mm² at 7 days and 30.93 N/mm² at 28 days. The increase between the two curing ages confirms continued strength development with curing.

For RHA concrete, the 28-day compressive strength was 29.26 N/mm² at 2% replacement and 28.85 N/mm² at 4%. The values decreased to 24.74 N/mm² and 21.48 N/mm² at 6% and 8%, respectively. Thus, within the tested RHA range, the lower replacement levels provided the closest strength to the control concrete.

WPSA produced the most favourable compressive-strength response among the investigated individual replacement materials. The 2% WPSA mixture achieved 24.07 N/mm² at 7 days and 31.26 N/mm² at twenty-eight-days. The 28-day outcomes were slightly greater than the 30.93 N/mm² obtained for the control concrete. At 4%, 6% and 8% WPSA, the 28-day compressive strengths decreased to 27.59, 25.10 and 23.04 N/mm², respectively.

The combined RHA+WPSA mixtures produced 28-day compressive strengths of 28.89, 27.66, 24.52 and 18.82 N/mm² for 2%, 4%, 6% and 8% total replacement, respectively. The outcomes indicates that the combined replacement was feasible at lower percentages, while larger substitute levels responded in a considerable reduction in strength.

TABLE V
COMPRESSIVE STRENGTH RESULTS

Mix	Replacement	7-day strength (N/mm²)	28-day strength (N/mm²)
Control	0%	20.40	30.93
RHA	2%	19.67	29.26
RHA	4%	19.63	28.85

Mix	Replacement	7-day strength (N/mm²)	28-day strength (N/mm²)
RHA	6%	18.66	24.74
RHA	8%	15.22	21.48
WPSA	2%	24.07	31.26
WPSA	4%	22.30	27.59
WPSA	6%	19.67	25.10
WPSA	8%	16.89	23.04
RHA+WPSA	2%	19.84	28.89
RHA+WPSA	4%	18.82	27.66
RHA+WPSA	6%	18.60	24.52
RHA+WPSA	8%	16.03	18.82

C. Split Tensile Power

The control concrete recorded split tensile of 1.94 N/mm² and 2.71 N/mm² at 7 & 28 days, accordingly.

RHA at 2% replacement increased the 28-day split-tensile strength to 2.94 N/mm², compared with 2.71 N/mm² for the control. At 4% replacement, the strength remained almost equal to the control value at 2.72 N/mm². Further increases in RHA content reduced the tensile strength. The WPSA mixtures showed the strongest tensile response at 2% replacement. The corresponding 7-day and 28-day strengths were 2.34 N/mm² and 3.11 N/mm². At 4% replacement, the 28-day value was 2.92 N/mm². The values declined with further replacement, reaching 2.02 N/mm² at 8%.

For the combined RHA+WPSA mixtures, the 2% replacement level produced a 28-day split tensile strength of 2.95 N/mm². At 4%, the value was 2.81 N/mm², while the 6% and 8% mixtures recorded 2.64 and 2.24 N/mm², respectively.

TABLE VI
SPLIT-TENSILE STRENGTH AND RESULTS

Mix Types	Replacement	7-day strength (N/mm²)	28-day strength (N/mm²)
Control	0%	1.94	2.71
RHA	2%	2.03	2.94
RHA	4%	1.99	2.72
RHA	6%	1.89	2.34
RHA	8%	1.34	1.97
WPSA	2%	2.34	3.11
WPSA	4%	2.10	2.92
WPSA	6%	1.82	2.78
WPSA	8%	1.69	2.02
RHA+WPSA	2%	1.96	2.95
RHA+WPSA	4%	1.86	2.81
RHA+WPSA	6%	1.71	2.64
RHA+WPSA	8%	1.65	2.24

D. Cost Analysis

The material-cost tests were done using the rates reported in the testing study. Cement was considered at ₹9.00/kg, sand at ₹1.40/kg and coarse aggregate at ₹1.45/kg, while RHA and WPSA were assigned zero material cost because they were treated as waste-derived materials.

The calculated material cost of the concrete was ₹5,840.60 per m³. The cost lowered when a portion of cement was changed by RHA or WPSA. For example, the reported cost for 2% RHA replacement was ₹5,673.20 per m³, while the 2% WPSA mix had the same reported total. The combined RHA+WPSA mixture at 4% replacement had a reported material cost of ₹5,505.80 per m³, and the 8% combined replacement reduced the reported cost to ₹5,338.40 per m³.

The cost results indicate that replacing a portion of cement with waste-derived materials can provide an economic advantage, particularly when the changed materials are available at negligible material cost.

TABLE VII
REPRESENTATIVE MATERIAL-COST COMPARISON

Concrete mix	Reported material cost (₹/m³)
Control concrete	5840.60
2% RHA	5673.20
2% WPSA	5673.20
4% RHA+WPSA	5505.80
8% RHA+WPSA	5338.40

IV. CONCLUSION

The experimental investigation confirms that RHA and WPSA can be incorporated into M20 concrete as certain substitutes for cement, although the performance depends strongly on the replacement percentage.

Conclusions of the study are as follows:

1) Incorporation of RHA, WPSA and the combined RHA+WPSA material resulted in a progressive reduction in concrete workability as the replacement percentage increased.
2) The control concrete achieved a twenty-eight-day compressive strength of 30.93 N/mm² and a split tensile strength of 2.71 N/mm².
3) The 2% WPSA mixture produced the highest compressive strength among the investigated mixes, reaching 31.26 N/mm² at 28 days, slightly above the control value.
4) RHA replacement at 2% and 4% maintained 28-day compressive strength relatively close to the control concrete. Higher RHA replacement levels caused a more noticeable reduction in strength.
5) The 2% RHA mixture produced a 28-day split tensile strength of 2.94 N/mm², while the 2% WPSA mixture achieved 3.11 N/mm². The combined 2% RHA+WPSA mixture achieved 2.95 N/mm².
6) Increasing the said part of WPSA beyond the lower replacement levels gave outcomes in a gradual reduction in both compres sive and tensile powers.
7) The combined RHA+WPSA material be used as a partial cement replacement, although higher replacement levels produced a greater reduction in strength within the tested range.
8) The cost assessment indicates that the application of RHA and WPSA can reduce the material cost because these waste-derived materials were considered to have negligible material cost.
9) The study demonstrates a practical approach for utilizing agricultural and paper-industry residues while reducing the quantity of cement required in concrete.

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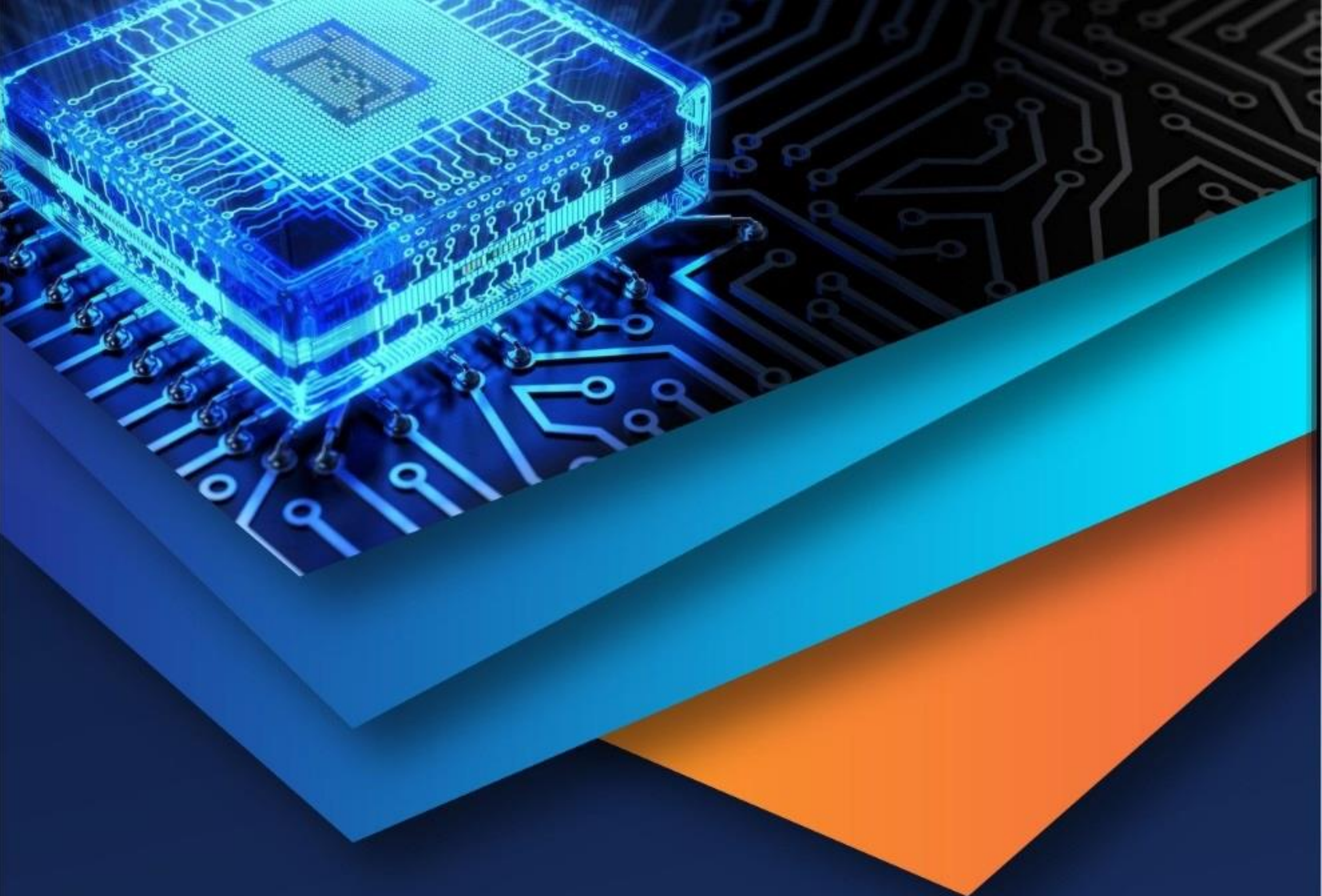

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