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Experimental Investigation on the Effect of Rice Husk Ash and Waste Paper Sludge Ash as Cement Substitutes in M20 Concrete

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ABSTRACT

In the modern era of rapid industrialization and urbanization, concrete and cement mortar remain indispensable materials in construction, driven by the rising demand for housing and infrastructure. However, this growth has created major environmental challenges due to excessive use of natural resources and the large volume of industrial waste generated. If not managed properly, these wastes pose disposal issues and ecological risks. As a result, researchers are actively exploring sustainable alternatives that not only reduce dependence on cement but also improve the mechanical and durability characteristics of concrete. One of the most critical concerns in cement production is carbon dioxide (CO_2) emission. Nearly one ton of CO_2 is released for every ton of cement manufactured, contributing significantly to climate change and environmental degradation. To address this, industrial byproducts are being investigated as partial cement replacements, which reduce CO_2 emissions, conserve natural resources, and encourage circular economy practices. This research focuses on the use of Rice Husk Ash (RHA) and Waste Paper Sludge Ash (WPSA) as supplementary cementitious materials. Both byproducts possess pozzolanic properties that enhance the binding and strength characteristics of concrete. In this study, RHA and WPSA were incorporated at 2%, 4%, 8%, and 10% replacement levels by weight of cement. A total of 78 specimens, including cubes and cylinders, were prepared, cured, and tested for compressive, flexural, tensile, and consistency properties.

Results showed that moderate replacement levels enhanced concrete performance, offering dual benefits of waste utilization and improved strength. Thus, incorporating RHA and WPSA represents a sustainable, eco-friendly approach to green construction.

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KEYWORDS: *Rice Husk Ash, Waste Paper Sludge Ash, Sustainability, Compressive Strength, Green Construction.*

1. INTRODUCTION

1.1. Background of Concrete and Cement Usage

Concrete is the most extensively used construction material worldwide due to its strength, durability, and adaptability. Cement, being the key binding component of concrete, plays a vital role in infrastructure development. However, the large-scale production of cement has emerged as a significant environmental concern because of its high energy consumption and the release of carbon dioxide (CO_2), which directly contributes to global warming and climate change.

1.2. Need for Sustainable Alternatives

The construction industry faces dual challenges meeting the increasing demand for concrete while minimizing its ecological footprint. One promising solution is the use of supplementary cementitious materials derived from industrial and agricultural waste. This practice not only reduces the environmental impact of cement production but also provides a sustainable method of waste disposal, thereby supporting the principles of green construction and circular economy.

1.3. Role of Rice Husk Ash (RHA) and Waste Paper Sludge Ash (WPSA)

Rice Husk Ash (RHA), an agricultural byproduct from rice milling, is rich in amorphous silica, which imparts pozzolanic properties when used in concrete. Similarly, Waste Paper Sludge Ash (WPSA), produced from paper manufacturing processes, contains reactive compounds that can enhance the binding characteristics of cement. Both materials have been identified as potential substitutes for cement, capable of improving the mechanical strength and durability of concrete while reducing the overall consumption of natural resources.

1.4. Objective of the Study

- To analyze the performance of concrete prepared with different proportions of Rice Husk Ash (RHA), Waste Paper Sludge Ash (WPSA), and their combined use (RHA + WPSA) in terms of strength and workability.
- To evaluate the feasibility of replacing a portion of cement with unprocessed RHA and WPSA in order to reduce cement consumption.
- To assess the potential of these supplementary cementing materials for promoting sustainability by lowering environmental pollution and supporting green construction practices

1.5. Research Gap

The safe disposal of agricultural and industrial by-products, particularly rice husk and paper sludge, remains a pressing challenge. A large proportion of rice husk and straw is still disposed of through open-field burning, causing severe air pollution and greenhouse gas emissions, while paper sludge from the pulp industry is largely dumped in landfills, leading to soil and groundwater contamination. Although both **Rice Husk Ash (RHA)** and **Waste Paper Sludge Ash (WPSA)** exhibit pozzolanic properties, their potential as supplementary cementitious materials has not been fully explored. Limited studies exist on their combined utilization in concrete, especially in structural-grade mixes like **M20 concrete**, and little attention has been given to long-term durability and sustainability aspects.

1.6. Need and Significance of the Study

The construction industry is a major consumer of natural resources and a significant source of CO_2 emissions through cement production. Replacing cement with RHA and WPSA offers multiple benefits:

1. **Sustainability:** Reduces cement consumption, conserves resources, and lowers carbon footprint.
2. **Waste Management:** Provides an eco-friendly solution for agricultural and industrial waste disposal.
3. **Cost Reduction:** Lowers the overall cost of concrete production by using locally available by-products.
4. **Improved Performance:** Pozzolanic reactions enhance compressive strength, durability, and resistance to cracking.
5. **Green Construction:** Aligns with global sustainability goals and supports healthier ecosystems.

1.7. Scope of the Study

This research investigates the partial replacement of cement with RHA and WPSA in **M20 grade concrete**, focusing on cost-effectiveness, strength development, and environmental benefits. The study emphasizes practical applicability by using easily adoptable methods in conventional construction. It also explores optimum replacement levels for achieving desired mechanical properties while reducing cement usage, contributing to green and sustainable construction practices.

2. RESEARCH METHODOLOGY

2.1. Ordinary Portland cement (OPC)

Ordinary Portland Cement of 53 Grade (Ambuja brand) was employed throughout the experimental work. The physical properties of the cement were determined through standard laboratory tests, and the results were found to be in compliance with the specifications outlined in IS: 12269–1987. These properties are presented in Table 4.1.

Table 2.1: Properties of OPC 53 Grades

Sr. No.	Characteristics	Values Obtained Experimentally	Values Specified By IS 12269:1987
1.	Specific Gravity	3.11	3.10-3.15
2.	Standard Consistency	32%	30-35
3.	Initial Setting Time	116 minutes	30min(minimum)
4.	Final Setting Time	284 minutes	600min(maximum)
5.	Compressive Strength(N/mm^2) 7 days 28 days	 38.50 N/mm^2 52.32 N/mm^2	 37 N/mm^2 53 N/mm^2

2.2. Aggregates
Aggregates form the major portion of a concrete mix and play a vital role in imparting dimensional stability and strength to the material. They constitute nearly 75% of the total volume of concrete, making their properties highly significant in determining the overall performance of the mix.

2.2.1. Fine Aggregates
The fine aggregates used in this study were locally sourced natural sand. Testing was carried out in accordance with the specifications laid down in IS: 383–1970. The results of the tests conducted on the fine aggregates are presented in Table 4.2(A) and Table 4.2(B). The sand was classified under Grading Zone III.

Table 2.2 (A): Sieve Analysis of Fine Aggregate

Weight of sample taken =1000 gm					
Sr. No	IS-Sieve (mm)	Mass Retained (gm)	Cumulative mass Retained	Cumulative %age mass Retained	Cumulative %mass passing through
1	4.73	1	1	0.11	99.90
2	2.35	23	22	2.31	97.70
3	1.17	78	100.0	10.01	90.0
5	600μ	154	252	25.30	74.70
6	300μ	263	516	51.71	48.30
7	151 μ	426	943	94.20	5.80
8	Below150μ	59	1000.00	100.00	0
	Total			**Σ283.64**	

FM of fine aggregate = 283.66/100=2.8364

Table 2.2 (B): Physical Properties of fine aggregates

Characteristics	Value
Specific gravity	2.62
Bulk density	5%
Fineness modulus	2.82

2.2.2. Coarse Aggregates
The coarse aggregates used in this investigation were locally available and had a maximum size of 20 mm. All necessary tests were conducted in accordance with the guidelines specified in IS: 383–1970. The results obtained from these tests are presented in Table 4.3(A) and Table 4.3(B).

Table 2.3 (A): Sieve Analysis of Coarse Aggregate (20 mm)

Weight of sample taken =2000 gm					
Sr. No	IS-Sieve (mm)	Mass Retained (gm)	Cumulative mass retained	Cumulative %age mass Retained	Cumulative % mass passing through
1	40.00	0	0	0	100
2	20.0	145	144	7.250	92.751
3	10.	1829	1973	98.70	1.30
5	4.740	124	1997	99.90	0.10
6	2.361	0	1999	99.90	0.10
7	1.180	0	1997	99.90	0.10
8	600μ	0	1997	99.90	0.10
9	300μ	0	1997	99.90	0.10
10	150 μ	0	1999	99.90	0.10
11	Below150μ	2	2000.0	100	0
	Total			**Σ805.350**	

FM of Coarse aggregate = 805.350/100=8.05350

Table 2.3 (B): Properties of Coarse Aggregates

Characteristics	Value
Type	Crushed
Colour	Grey
Shape	Angular
Nominal Size	20 mm
Specific Gravity	2.62
Total Water Absorption	0.89
Fineness Modulus	8.05

2.3. Rice Husk Ash (RHA)

For this study, rice husk was procured from a local mill in Kashmir, India. The collected husk was first thoroughly washed with potable water to remove impurities and then sun-dried. Subsequently, it was subjected to open burning in the atmosphere to obtain rice husk ash (RHA).

Table 2.4: Physical properties of Rice Husk Ash

Appearance	Fine powder
Particle Size	Sieved through 90 micron sieve
Specific gravity	2.21
Color	Light grey

2.4. Waste Paper Sludge Ash (WPSA)

The waste paper sludge used in this study was collected from Kashmir Paper Limited. The sludge was subjected to open burning in order to convert it into ash, which was subsequently utilized for experimental work.

Table 2.5: physical properties of the waste paper sludge ash (WPSA)

Appearance	Fine powder
Particle Size	Sieved through 90 micron sieve
Color	Dark grey
Specific gravity	2.09

2.5. Mix Design

The concrete mix design was done by using IS 10262 for M-20 grade of concrete.

Design stipulations for proportioning

➢ Grade designation	➢ M20
➢ Type of cement grade	➢ OPC 53 grade confirming to IS12269:1987
➢ Maximum nominal size of aggregates	➢ 20 mm
➢ Minimum cement content kg/m^3	➢ 320 kg/m^3
➢ Maximum water cement ratio	➢ 0.55
➢ Workability	➢ 75 mm (slump)
➢ Exposure condition	➢ Mild
➢ Degree of supervision	➢ Good
➢ Type of aggregate	➢ Crushed angular aggregate
➢ Maximum cement content	➢ 450 kg/m^3
➢ Chemical admixture	➢ Not

Test Data for Materials

Cement used	OPC 53 grade confirming to IS 12269:1987
Specific gravity of cement	3.10
Specific gravity of	
Coarse aggregate	2.88
Fine aggregate	2.63
Sieve analysis Coarse aggregate Fine aggregate	Coarse aggregate : Conforming to Table 2 of IS: 383 Fine aggregate : Conforming to Zone III of IS: 383

Target Strength for Mix Proportioning

The target average compressive strength at 28 days is calculated using the formula:

$$f'_{ck} = f_{ck} + 1.65s$$

Where:
- f'_{ck} = Target average compressive strength at 28 days
- f_{ck} = Characteristic compressive strength at 28 days
- s = Standard deviation

From Table 1, the standard deviation is taken as s = 4.6 N/mm²s

$$f'_{ck} = 20 + (1.65\times4.6) = 27.590\ N/mm^2$$

Thus, the target mean strength for the mix design is 27.590 N/mm².

Selection of Water-Cement Ratio

According to Table 5 of IS: 456–2000, for mild exposure conditions, the maximum permissible water–cement ratio is 0.55. Based on practical considerations and previous experimental experience, a water–cement ratio of 0.50 was adopted for this study. Since 0.50<0.550.50 < 0.550.50<0.55, the selected value satisfies the codal requirements.

Selection of water and sand content From Table 4 of IS 10262:1982

Maximum Size of Aggregate(mm)	Water Content including Surface Water, Per Cubic Meter of Concrete(kg)	Sand as percent of Total Aggregate by Absolute volume
20	186	35

Adjustments from Table 6 of IS 10262:1982

Change in condition	Percent adjustment required	
	Water Content	Sand in total Aggregate
Increase or decrease in water- cement ratio that is 0.05	0	-2
Increase or decrease in value of compacting by 0.10	0	0
For Sand	0	-1.5

Sand Content by Absolute Volume

The required sand content, expressed as a percentage of the total aggregate by absolute volume, is calculated as:

$$35-3.5=31.5\%$$

Therefore, the percentage of coarse aggregate becomes:

$$100-31.5=68.5\%$$

Cement Content Calculation
- Adopted water–cement ratio = **0.50**
- Cement content = 186/0.50=372 kg/m³

As per IS: 456 (Table 5), the minimum cement content required for *mild exposure conditions* is 300 kg/m³. Since the calculated value (372 kg/m³) is higher than the minimum requirement, it is considered satisfactory.

Determination of Coarse and Fine Aggregate Contents

According to IS: 10262–1982 (Table 3), for a maximum aggregate size of 20 mm, the amount of entrapped air in wet concrete is approximately 2%.

Hence, the absolute volume of fresh concrete is:

V=Gross Volume (1 m³) − Entrapped Air (0.02 m³) = 0.98 m³

Table 2.6: The mixture proportions used in laboratory for Experimentation are shown in table

Mix	%	w/c ratio	Water (Kg/m³)	Cement (Kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (Kg/m³)	RHA (Kg/m³)	WPSA (Kg/m³)
Control	-	0.500	186.0	372. 0	562.0	1217.0	-	-
Rice Husk Ash	2	0.500	186.0	353.40	562.0	1217.0	18.61	-
	4	0.500	186.0	334.81	562.0	1217.0	37.22	-
	6	0.500	186.0	316.21	562.0	1217.0	55.80	-
	8	0.500	186.0	297.62	562.0	1217.0	74.40	-
Waste Paper Sludge Ash	2	0.500	186.0	353.41	562.0	1217.0	-	18.61
	4	0.500	186.0	334.81	562.0	1217.0	-	37.21
	6	0.500	186.0	316.20	562.0	1217.0	-	55.82
	8	0.500	186 0	297.60	562.0	1217.0	-	74.40

Mixture of RHA and WPSA	2	0.500	186.0	353.41	562.0	1217.0	9.30	9.31
	4	0.500	186.0	334.82	562.0	1217.0	18.61	18.60
	6	0.500	186.0	316.21	562.0	1217.0	27.90	27.90
	8	0.500	186.0	297.60	562.0	1217.0	37.21	37.20

2.6. Casting

Prior to casting, all moulds were thoroughly cleaned, oiled, and properly tightened to prevent leakage during compaction. The required quantities of coarse aggregates, fine aggregates, cement, and supplementary materials (RHA and WPSA) were weighed accurately before mixing.

The concrete was prepared by hand mixing on a non-absorbing platform. Initially, the dry materials were mixed uniformly. A depression was then formed at the center of the dry mix, into which about 70–80% of the mixing water was added. The materials were thoroughly mixed, and the remaining water was gradually sprinkled to achieve a uniform consistency.

For each mix, 12 specimens were prepared: six cubes of size 150 × 150 × 150 mm for compressive strength testing at 7 and 28 days, and six cylinders for splitting tensile strength at the same ages. The casting was carried out with cement partially replaced by rice husk ash (RHA) and waste paper sludge ash (WPSA) at varying replacement levels of 5%, 10%, 15%, and 20%.

In total, 156 specimens were cast, comprising 78 cubes and 78 cylinders.

(A) Oiling of Cubes &Cylinder (B) Dry mixing (C) Filling of Moulds

Fig. 2.1: Casting

2.7. Compaction

The compaction of fresh concrete was carried out manually using a tamping bar. The moulds were filled in four equal layers, each approximately one-quarter of the mould's height. Every layer was compacted by applying 25 strokes of the rounded end of the tamping bar, ensuring uniform distribution across the entire surface area of the mould. After proper compaction, the top surface of the concrete was leveled and finished smoothly using a metal trowel.

Fig. 2.2: Compaction

2.8. Curing of Concrete

Curing is an essential process in concrete technology, aimed at maintaining sufficient moisture and favorable temperature conditions for continued hydration of cement. It not only prevents premature drying but also reduces the risk of contraction stresses, which may develop when concrete is exposed to hot atmospheres or drying winds at an early age, before attaining adequate strength.

Concrete is generally cured by water, although curing compounds and wet coverings are also used in practice. Proper curing enhances the strength, durability, impermeability, and resistance of concrete to abrasion and frost action. Common methods include water spraying, ponding, or covering the surface with wet hessian cloth.

Curing is typically initiated as soon as the concrete has hardened sufficiently, and for ordinary concrete, a curing period of at least 14 days is recommended under normal conditions. However, IS codes specify that the period should not be less than 10 days, as the rate of hydration reduces with decreasing ambient temperature.

In the present study, curing was carried out by immersing the test specimens in water tanks immediately after demoulding. The specimens were cured for 7 and 28 days and subsequently removed from water at the time of testing.

Fig. 2.3: Curing Tank

3. RESULTS AND DISCUSSION

3.1. Fresh Concrete

3.1.1. Slump Test

The slump value of all the mixture are represented in Table 5.1

Table 3.1: Slump Tests Results

Mix	Percentage	Slump Value
Control	0%	91mm
RHA	2o%	64mm
	6.0%	56mm
	8.0%	24mm
	10.0%	21mm
WPSA	2.0%	61mm
	4.0%	56mm
	6.0%	51mm
	8.0%	21mm
Mix (RHA+WPSA)	2.0%	31mm
	4.0%	21mm
	6.0%	16mm
	8.0%	7mm

3.1.2. Slump Test

The variation of slump values with different percentages of replacement is illustrated in Table 5.1. It was observed that the slump value decreased progressively with an increase in the replacement level of cement by rice husk ash (RHA), waste paper sludge ash (WPSA), and their combined proportions (RHA + WPSA). This reduction in slump indicates a decrease in the workability of concrete at higher replacement levels.

3.1.3. Compaction Factor Test

The compaction factor values corresponding to all mix proportions are presented in Table 5.2. These values further support the observations from the slump test, showing a reduction in workability as the percentage replacement of cement with RHA, WPSA, and their combination increased.

Table 3.2: Compaction Factor Results

Mix	Percentage	Compaction Factor
CONTROL	0%	0.930
RHA	2%	0.900
	4%	0.870
	6%	0.830
	8%	0.820
WPSA	2%	0.920
	4%	0.900
	6%	0.850
	8%	0.810
MIX (RHA+WPSA)	2%	0.840
	4%	0.830
	6%	0.800
	8%	0.780

The compaction factor value for the control mix was found to be 0.930. With the partial replacement of cement by rice husk ash (RHA), the compaction factor decreased gradually from 0.920 at 5% replacement to 0.820 at 20% replacement. Similarly, in the case of waste paper sludge ash (WPSA), the compaction factor reduced from 0.920 to 0.81 over the same replacement range. For the combined mix (RHA + WPSA), the values declined from 0.840 to 0.780, indicating a more pronounced reduction in workability compared to individual replacements.

3.2. Hardened Concrete

3.2.1. Effect of Age on Compressive Strength

The 28-day compressive strength of the M20 grade control concrete was obtained as 30.930 N/mm². The compressive strength results of all mixes are summarized in Table 5.3 and are also represented graphically, where the compressive strength is plotted against different percentages of cement replacement.

Table 3.3: Compressive Strength of Control concrete in N/mm^2

Grade of concrete	7Days	28Days
M20	20.40	30.930

The strength achieved at different ages namely, 7 and 28 for Control concrete.

It is evident that with an increase in curing age, the strength of control concrete also improves. The rate of strength development is more pronounced up to 28 days, after which the gain continues but at a comparatively slower pace.

3.2.2. Effect of Age on Split Tensile Strength of Control Concrete

The 28-day split tensile strength of M20 grade control concrete was found to be 2.710 N/mm². The experimental results are summarized in Table 5.4 and represented graphically, where the split tensile strength is plotted against different percentages of cement replacement.

Table 3.4: Split Tensile Strength of Control concrete in N/mm^2

Grade of concrete	7Days	28Days
M20	1.940	2.710

3.2.3. Effect on Compressive Strength of Concrete Containing Various Percentages of RHA

The compressive strength results of concrete mixes incorporating rice husk ash (RHA) as a partial replacement of cement are presented in Table 5.5 and illustrated graphically. The strength development is compared with that of control concrete at different curing ages. The results clearly show the influence of varying replacement levels (5%, 10%, 15%, and 20% RHA) on the compressive strength behavior of concrete.

Table 3.5: Compressive Strength of RHA Concrete

Mix	Percentage of Cement Replacement	Cube Compressive Strength (N/mm^2)	
		7 days	28 Days
CONTROL	0%	20.40	30.930
RHA	2%	19.670	29.260
	4%	19.630	28.850
	6%	18.660	24.740
	8%	15.220	21.480

Table 3.6: Split Tensile Strength of RHA Concrete

Mix	Percentage of Cement Replacement	Split Tensile Strength (N/mm^2)	
		7 days	28 Days
M20	0%	1.940	2.710
RHA	2%	2.030	2.940
	4%	1.990	2.720
	6%	1.890	2.340
	8%	1.340	1.970

Split Tensile Strength of RHA Concrete at 28 Days

As presented in Table 5.6, the split tensile strength for 2% replacement with RHA is higher than that of the control mix. Although the strength decreases with further increase in RHA content, up to 4% replacement it still remains greater than the split tensile strength of the control mix.

3.2.4. Effect on Compressive Strength of Concrete Containing Various Percentages of WPSA

Table 3.7: Compressive Strength of WPSA Concrete

Mix	Percentage of Cement Replacement	Cube Compressive Strength (N/mm^2)	
		7 days	28 Days
CONTROL	0%	20.40	30.930
WPSA	2%	24.070	31.260
	4%	22.30	27.590
	6%	19.670	25.10
	8%	16.890	23.040

Compressive Strength of WPSA Concrete at 28 Days

According to the results in Table 5.7, the compressive strength at 7 days for 2% and 4% replacement of cement with WPSA is higher than that of the control mix. However, with further increases in the percentage of replacement, the compressive strength gradually decreases. At 28 days, the compressive strength for 2% replacement is recorded as 31.260 N/mm², which is higher than the control mix strength of 30.930 N/mm². For 4% replacement, the compressive strength remains close to that of the control mix, while higher replacement levels lead to a reduction in strength.

3.2.5. Effect on Split Tensile Strength of Concrete Containing Various Percentages of WPSA

Table 3.8: Split Tensile Strength of WPSA Concrete

Mix	Percentage of Cement Replacement	Split Tensile Strength (N/mm^2)	
		7 days	28 Days
M20	0%	1.940	2.710
WPSA	2%	2.340	3.110
	4%	2.10	2.920
	6%	1.820	2.780
	8%	1.690	2.020

3.8 (B): Split Tensile Strength of WPSA Concrete at 28 Days

From the results presented in Table 5.8, the split tensile strength at both 7 and 28 days for 2% and 4% replacement with WPSA is higher than that of the control mix. At 6% replacement, the split tensile strength is nearly equal to the control mix, while further increases in cement replacement lead to a reduction in strength.

3.2.6. Effect of Compressive Strength of Concrete containing various percentages of Mix (RHA+ WPSA)

Table 3.9: Compressive Strength of Mix (RHA+ WPSA) Concrete

Mix	Percentage of Cement Replacement	Cube Compressive Strength (N/mm^2)	
		7 days	28 Days
CONTROL	0%	20.40	30.930
MIX (RHA+WPSA)	2%	19.840	28.890
	4%	18.820	27.660
	6%	18.60	24.520
	8%	16.030	18.820

3.9 (B): Compressive Strength of Mix (RHA+WPSA) at 28 Days

The results in Table 5.9 show that a 10% replacement of cement with the Mix (RHA + WPSA) yields a compressive strength nearly equivalent to that of the control mix. However, with further increases in the percentage of replacement, the compressive strength gradually declines.

3.2.7. Effect of Split Tensile Strength of Concrete containing various percentages of Mix (RHA+ WPSA)

Table 3.10: Split Tensile Strength of Mix (RHA+ WPSA) Concrete

Mix	Percentage of Cement Replacement	Splitting Tensile Strength (N/mm^2)	
		7 days	28 Days
M20	0%	1.940	2.710
MIX (RHA+WPSA)	2%	1.960	2.950
	4%	1.860	2.810
	6%	1.710	2.640
	8%	1.650	2.240

The data in Table 5.10 indicates that when 2% of cement is replaced with the combined mix of RHA and WPSA, the split tensile strength surpasses that of the control concrete. At a 4% replacement level, the tensile strength remains almost comparable to the control mix. Beyond this, with 6% and 8% replacement, a steady decline in split tensile strength is observed.

3.3. Cost Analysis

Cost of Material

Cost of Cement per kg =₹ 9.00
Cost of Sand per kg =₹ 1.40
Cost of Coarse Aggregate per kg =₹ 1.45
Cost of RHA per kg =₹ 0.00
Cost of WPSA per kg =₹ 0.00

(All the rates are excluding the miscellaneous charges)

Table 3.11: Cost of Material for Normal Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	372.0	9.000	3348.000
Rice Husk Ash(RHA)	0	0.000	0.000
Waste Paper Sludge Ash (WPSA)	0	0.000	0.000
Sand	550	1.400	770.000
Coarse Aggregate	1188	1.450	1722.60
Total Cost			**5840.60**

Table 3.12: Cost of Material for 2%RHA Partially Replaced Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	353.40	9.000	3180.60
Rice Husk Ash(RHA)	18.60	0.000	0.000
Waste Paper Sludge Ash (WPSA)	0	0.000	0.000
Sand	550. 0	1.400	770.000
Coarse Aggregate	1188. 0	1.450	1722.60
Total Cost			**5673.20**

Table 3.13: Cost of Material for 4%RHA Partially Replaced Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	334.80	9. 000	3013.20
Rice Husk Ash(RHA)	37.20	0.000	0.000
Waste Paper Sludge Ash (WPSA)	000	0.000	0.000
Sand	550.0	1.400	7700
Coarse Aggregate	1188. 0	1.450	171.1
Total Cost			**4804.300**

Table 3.14: Cost of Material for 6%RHA Partially Replaced Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	316.20	9.000	2845.80
Rice Husk Ash(RHA)	55.80	0.000	0.000
Waste Paper Sludge Ash (WPSA)	0	0.000	0.000
Sand	550.0	1.400	770.0
Coarse Aggregate	1188	1.450	1722.60
Total Cost			**5338.40**

Table 3.15: Cost of Material for 8%RHA Partially Replaced Concrete'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	297.60	9.00.0	2678.40
Rice Husk Ash(RHA)	74.40	0.000	0.000
Waste Paper Sludge Ash (WPSA)	0	0.000	0.000
Sand	550.0	1.400	770.0
Coarse Aggregate	1188.0	1.450	1722.60
Total Cost			**5171.0**

Table 3.16: Cost of Material for 2%WPSA Partially Replaced Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	353.40	9.000	3180.60
Rice Husk Ash(RHA)	0	0.000	0.000
Waste Paper Sludge Ash (WPSA)	18.60	0.000	0.000
Sand	550.0	1.400	7700
Coarse Aggregate	1188.0	1.450	1722.60
Total Cost			**5673.20**

Table 3.17: Cost of Material for 4%WPSA Partially Replaced Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	334.80	9.000	3013.20
Rice Husk Ash(RHA)	0	0.000	0.000
Waste Paper Sludge Ash (WPSA)	37.20	0.000	0.000
Sand	550. 0	1.400	770. 0
Coarse Aggregate	1188. 0	1.450	1722.60
Total Cost			**5505.80**

Table 3.18: Cost of Material for 6%WPSA Partially Replaced Concrete 'm^3'

Description	Quantity(Kg/m^3)	Cost(₹ per Kg)	Cost of material(₹)
Cement	316.20	9.000	2845.80
Rice Husk Ash(RHA)	0	0.000	0.000
Waste Paper Sludge Ash (WPSA)	55.80	0.000	0.000
Sand	550. 0	1.400	770. 0
Coarse Aggregate	1188. 0	1.450	1722.60
Total Cost			**5338.40**

Table 3.19: Cost of Material for 8%WPSA Partially Replaced Concrete 'm³'

Description	Quantity(Kg/m³)	Cost(₹ per Kg)	Cost of material(₹)
Cement	297.60	9.0	2083.20
Rice Husk Ash(RHA)	0	0.0	0.0
Waste Paper Sludge Ash (WPSA)	74.40	0.0	0.0
Sand	550. 0	1.4	797.5
Coarse Aggregate	1188. 0	1.450	1663.2
Total Cost			**4543.9**

Table 3.20: Cost of Material for 2%MIX (RHA+WPSA) Partially Replaced Concrete 'm³'

Description	Quantity(Kg/m³)	Cost(₹ per Kg)	Cost of material(₹)
Cement	353.40	9.0	3180.60
Rice Husk Ash(RHA)	9.30	0.0	0.0
Waste Paper Sludge Ash (WPSA)	9.30	0.0	0.0
Sand	550	1.4	770. 0
Coarse Aggregate	1188	1.450	1722.60
Total Cost			**5673.20**

Table 3.21: Cost of Material for 4% MIX (RHA+WPSA) Partially Replaced Concrete 'm³'

Description	Quantity(Kg/m³)	Cost(₹ per Kg)	Cost of material(₹)
Cement	334.80	9.0	3013.20
Rice Husk Ash(RHA)	18.60	0.0	0.0
Waste Paper Sludge Ash (WPSA)	18.60	0.0	0.0
Sand	550	1.4	770. 0
Coarse Aggregate	1188	1.450	1722.60
Total Cost			**5505.80**

Table 3.22: Cost of Material for 8% MIX (RHA+WPSA) Partially Replaced Concrete 'm³'

Description	Quantity(Kg/m³)	Cost(₹ per Kg)	Cost of material(₹)
Cement	316.20	9.0	2845.80
Rice Husk Ash(RHA)	27.90	0.0	0.0
Waste Paper Sludge Ash (WPSA)	27.90	0.0	0.0
Sand	550	1.4	770
Coarse Aggregate	1188	1.45	1722.60
Total Cost			**5338.40**

Table 3.23: Cost of Material for 10% MIX (RHA+WPSA) Partially Replaced Concrete 'm³'

Description	Quantity(Kg/m³)	Cost(₹ per Kg)	Cost of material(₹)
Cement	297.60	9.0	2678.40
Rice Husk Ash(RHA)	37.20	0.0	0.0
Waste Paper Sludge Ash (WPSA)	37.20	0.0	0.0
Sand	550	1.4	770
Coarse Aggregate	1188	1.45	1722.60
Total Cost			**5171. 0**

Cost Reduction for 1 m³ Concrete by:

2% replacement of cement = ₹ 130.200
4% replacement of cement = ₹ 260.400
8% replacement of cement = ₹ 390.600
10% replacement of cement = ₹ 520.800

4. CONCLUSIONS

This study evaluated the feasibility of partially replacing cement with Rice Husk Ash (RHA), Waste Paper Sludge Ash (WPSA), and their combination in M20 grade concrete.

Key Findings

- Compressive and split tensile strengths improved at moderate replacement levels, with **up to 10% RHA** and **4–8% WPSA** showing better performance than the control mix.

- The combined mix (RHA + WPSA) showed potential, though optimum proportions require further refinement.
- Early strength development was lower but improved significantly with curing age.
- Workability decreased with higher replacement levels.
- The use of RHA and WPSA is economical and sustainable, offering an effective solution for waste utilization while reducing reliance on cement.

Future Scope

Further research is needed on:

- Durability aspects (permeability, chloride resistance, sulphate attack, and corrosion).
- Performance in reinforced concrete elements under flexure, shear, and torsion.
- Microstructural studies to analyze pozzolanic activity.
- Long-term durability under varied environmental conditions.
- Optimization of RHA and WPSA properties through controlled processing.

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