Experimental Investigation on Fly Ash and Rice Husk Ash as Partial Cement Replacement Materials in Concrete

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***Abstract*—The increasing need for sustainable construction materials has led to the utilization of industrial and agricultural wastes in concrete. Fly Ash (FA) and Rice Husk Ash (RHA) are widely available by products with good pozzolanic properties. This experimental investigation focuses on the use of fly ash and rice husk ash as partial replacement materials for cement in concrete. Concrete mixes were prepared by replacing cement with varying percentages of FA and RHA, both individually and in combination. The study aims to reduce cement consumption while improving the environmental sustainability of concrete. Tests were conducted to evaluate workability, compressive strength, split tensile strength, and durability properties of concrete. Specimens were tested at different curing ages to assess strength development. Results showed that fly ash improves workability and long-term strength, while rice husk ash enhances strength and durability due to its high silica content. An optimum replacement level was identified that provided better performance than conventional concrete. The study concludes that FA and RHA can be effectively used to produce economical, durable, and eco-friendly concrete.**

***Index Terms*—Fly Ash, Rice Husk Ash, Sustainable Concrete, Cement, Replacement, Workability, Durability, Compressive Strength.**

I. INTRODUCTION

Concrete is a mixture of cement, sand, aggregates, and water, and it is one of the most widely used construction materials in the world. Its popularity comes from its versatility, strength, and ability to be molded into different shapes for various engineering and architectural applications. This study focuses on the use of fly ash and rice husk ash as partial replacements in concrete, especially for M30 grade mixes. These materials are industrial and agricultural wastes that can improve concrete properties while reducing environmental impact.

Since cement production releases a large amount of CO_2, using alternative materials like fly ash and rice husk ash helps reduce pollution and supports sustainable construction. Rice husk ash, obtained by burning rice husk at 550°C to 700°C, has a fine microstructure that enhances the strength and durability of concrete.

1.1 Concrete

Concrete is a construction material made from cement, fine aggregate, coarse aggregate, and water. It is widely used due to its durability and versatility. Concrete has high compressive strength but low tensile strength, which is improved using reinforcement or fibers. Admixtures are added to enhance its properties.

A. Types of Concrete

Common types include Normal Strength, Plain, Reinforced, Prestressed, Precast, Lightweight, High-Density, Air-Entrained, Ready-Mix, Polymer, High-Strength, and High-Performance Concrete.

Advantages of Concrete

- Resistant to fire, water, and high temperatures
- Materials are easily available
- Free from natural defects
- Can be made economical with desired strength

1.2 Cement

Cement is a binding material that hardens and holds other materials together. Portland Pozzolana Cement (PPC) is used in masonry, plastering, and waterproofing. It produces less heat, reduces cracks, and resists chemicals better than Ordinary Portland Cement (OPC). It contains pozzolana, gypsum, and clinker, and its grade depends on 28-day compressive strength.

1.3 Aggregates

Aggregates form 70–80% of concrete and provide strength while reducing shrinkage.

A. Fine Aggregate:

Particles passing 4.75 mm sieve (sand, crushed sand). They fill voids between coarse aggregates, improve density, and influence concrete strength. Grading zones (I–IV) are based on particle size distribution.

B. Coarse Aggregate:

Particles retained on 4.75 mm sieve (gravel, stones). Larger size reduces cement and water demand. Shape affects strength angular aggregates give better bonding but lower workability. Common sizes: 20 mm (high strength) and 40 mm (normal concrete).

1.4 Fly Ash

Fly Ash is a fine powder by-product from coal-fired thermal power plants. It is a pozzolanic material that reacts with lime and water to form cement-like compounds, improving concrete strength and workability. It is classified as Class F (low calcium) and Class C (high calcium).

A. Properties: Fine spherical particles (mostly <45 μm), high fineness, and specific gravity ranging from 1.3 to 4.8.

B. Reaction: Fly ash reacts slowly with calcium hydroxide to form C-S-H gel, enhancing long-term strength and durability.

C. Uses: Used in concrete, road construction, soil stabilization, embankments, and precast products.

1.5 Rice Husk Ash

A. Rice Husk Ash (RHA) is a by-product of burning rice husks and is rich in silica, making it a useful pozzolanic material. It improves concrete strength, durability, and chemical resistance while reducing cement usage.

B. RHA is fine, lightweight (specific gravity ~2.25), and eco-friendly. It is used in construction, soil improvement, and industries. Proper burning and storage are important to maintain its quality.

II. LITERATURE REVIEW

Sand et al. (2019) found that replacing cement with rice husk ash up to 10% increases compressive and tensile strength, but strength decreases beyond 10%. The maximum strength at 10% replacement was 4.4 MPa (compressive) and 0.53 MPa (tensile).

He et al. (2019) found that adding 0.4% wood fibre improves AAC block strength, while rubber powder

(0.5–1%) shows little effect. The best performance is achieved with 1% rubber powder and 0.4% wood fibre.
Sukmana et al. (2019) studied the use of phosphogypsum in NAAC using the Taguchi method. The optimal mix—34% Portland cement, 35% phosphogypsum, and 10% quicklime—achieved a compressive strength of 20.93 kg/cm² with a density of 806 kg/m³.
Kunchariyakun et al. (2018) studied AAC blocks by replacing sand with rice husk ash and bagasse ash. They found that increasing autoclaving temperature (140°C–180°C) and time (4–12 hours) improves strength and microstructure. However, at 180°C, further increase in time does not significantly improve strength due to maximum dissolution of silica ions.
Karolina R. and Muhammad F. (2017) found that using fly ash and bottom ash in NAAC reduces cement and sand usage. Adding 30% fly ash improved properties, giving the highest compressive strength (12.687 MPa), tensile strength (1.540 MPa), and lowest water absorption (2.76%), compared to normal NAAC.
Wahane A. (2017) concluded that AAC blocks are lighter (about 80% less weight) than red bricks, making them more earthquake-resistant, reducing dead load, and easier to use in construction.
Shuisky A. et al. (2017) studied sodium sulphate in NAAC and found that 1.23% sodium sulphate with 20% cut-off material provides the best structural properties.
Shrivastva and Tiwari (2017) studied aerated concrete blocks with varying aluminium content (0–0.16%). They found that increasing aluminium reduces density, while 0.04% and 0.08% aluminium gave compressive strengths of 4.48 N/mm² and 3.75 N/mm², higher than third-class bricks.another study showed that adding mineral additives like wollastonite and diopside to NAAC improves properties. Using 5% diopside achieved 3.3 MPa compressive strength, 0.131 W/m·°C thermal conductivity, and 580 kg/m³ density, while also reducing energy consumption.
Narattha et al. (2015) studied partial replacement of cement with fly ash and silica fume in NAAC. They found that silica fume improves compressive strength and thermal conductivity more than fly ash, and various hydration phases like calcium silicate hydrate and ettringite were present in all mixes.

III. MATERIALS USED AND THEIR PROPERTIES

3.1 Cement

OPC 53 grade cement is widely used due to its high compressive strength of 53 MPa achieved after 28 days of curing. It has low permeability, which helps reduce moisture, chemical penetration, and pollutants, thereby ensuring durability and long-term strength of structures.

A. Compressive Strength of Cement:
Compressive strength is the ability of cement or concrete to withstand loads without cracking. It is an important property that indicates the quality and durability of concrete. For general construction, compressive strength typically ranges from 15 MPa to 30 MPa. In this test, a cement–sand mortar (1:3 ratio) is prepared, moulded, cured, and tested in a compression testing machine at different ages (7, 14, and 28 days). The observed result shows that for a load of 140 kN and area of 0.005 m², the compressive strength is 28 N/mm², indicating good quality cement suitable for construction.

B. Specific Gravity of Cement:
Specific gravity of cement is the ratio of the weight of cement to the weight of an equal volume of water. It affects mix design and is usually around 3.15. The test is conducted using a density bottle.

$$\text{Specific gravity of cement} = (W2 - W1) / \{(W2 - W1) \times (W3 - W4)\}$$

$$\text{Specific gravity of cement} = (W2 - W1) / \{(W2 - W1) \times (W3 - W4) \times (w4 - w1) / (w5 - w1)$$

From the observations (W1=34 g, W2=48 g, W3=85.5 g, W4=76 g, W5=85 g), the specific gravity is 3.1, which is close to the standard value.
This indicates good quality cement, and the small variation may be due to moisture or minor experimental errors. Hence, the cement is suitable for construction.

3.2 Fine Aggregate

River sand (Zone IV) from a nearby source is used as fine aggregate after removing impurities. Fine aggregate consists of particles passing through a 4.75 mm sieve.

A. Fineness Modulus of Fine Aggregate:
Fine aggregate consists of particles passing through a 4.75 mm sieve. The fineness modulus is determined by sieve analysis using standard sieves and indicates the particle size distribution of sand.
From the test results, the fineness modulus is 2.8, which shows that the sand has suitable grading and is good for construction purposes.

B. Specific Gravity of Fine Aggregate:
Specific gravity of fine aggregate is the ratio of its weight to the weight of an equal volume of water, determined using a pycnometer.
From the observations (W1=510 g, W2=882 g, W3=1723 g, W4=1498 g), the specific gravity is 2.53, which lies within the standard range (2.5–2.7).
This indicates that the sand is of good quality and suitable for construction.

3.3 Coarse Aggregate
Fineness Modulus of Coarse Aggregate:
Coarse aggregate consists of particles retained on a 4.75 mm sieve. The fineness modulus is determined by sieve analysis and indicates the grading of the aggregate. From the test results, the fineness modulus is 2.6, which shows that the aggregate is well-graded, neither too coarse nor too fine. Hence, the coarse aggregate is suitable for concrete work.

3.4 Tests on Concrete
Workability of Concrete by Slump Cone Test
The slump cone test is used to determine the workability and consistency of fresh concrete. It indicates the fluidity and ease of handling of concrete.

In this test, concrete is filled in layers, tamped, and the mould is lifted to measure the slump. Different slump types include true slump, shear slump, and collapse slump. The observed slump value is 100 mm, which indicates medium workability, suitable for most construction works.

IV. MIX DESIGN

4.1 Design of M30 Grade High Strength Concrete:
The mix design is carried out for M30 grade concrete using OPC 53 cement, 20 mm aggregate, and Zone IV sand under severe exposure conditions. Based on IS codes, the target strength is 38.25 N/mm² and the selected water-cement ratio is 0.4.

A. Required data:

- Grade Designation – M30
- Type of Cement & Grade of Cement – Opc 53
- Maximum Nominal Size of Aggregate – 20mm
- Exposure Condition – Severe (Is – 456, Table 3)
- Minimum Cement Content – 320 Kg/M3
- Workability in Terms of Slump – 100mm (Is – 456, Table 5)
- Transportation Time – 30 Min
- Standard Deviation - 5 N/Mm2
- Method of Placing – Pumping
- Type of Coarse Aggregate – Crushed Angular Aggregate
- Maximum Cement Content – 450 Kg/M3
- Water Cement Ratio – 0.45 (Is – 456: Table – 5)
- Fine Aggregate – Zone - 4
- Test Data of Material:
- Specific Gravity of Cement = 3.1
- Specific Gravity of Fine Aggregate = 2.53
- Specific Gravity of Coarse Aggregate = 3
- Specific Gravity of Water = 1

B. Steps involved in mix design:

1. Target Strength
2. Water Cement Ratio
3. Water Content
4. Calculation of Cement Content
5. Aggregate Proportion B/W Coarse Aggregate & Fine Aggregate
6. Mix Calculation

1. Target strength:
$F'CK = fck + 1.65s = 30 + 1.65(5) = 38.25\ N/mm^2$

2.Water Cement Ratio:
Exposure – Severe
W/C Ratio = 0.45 – 0.05 = 0.4
Water Cement Ratio = 0.4

3. Water Content:

IS – 10262, table – 4, p.no.5
20mm aggregate – 186 kg
100mm slump
For every 25mm – add 3% (IS – 10262)
1866% of 186 = 197 kg

4. Calculation Of Cement:

Water Cement Ratio = Water Content/Cement Content
Cement Content = Water Content / Water Cement Ratio = 492.5 kg/m^3

5. Aggregate Proportion B/W C.A & F.A:

IS – 10262, table – 5, p.no.6
ZONE – 4 – 0.66 FOR (W/C – 0.5)
Every 0.05 decrease increase 0.01
0.66 + 0.02 = 0.68
For pumpable concrete C.A can be reduced up to 10%
Vol. of coarse aggregate = 0.68 – (10% of 0.68) = 0.68 – 0.0 = 0.612
Vol. of fine aggregate = 1- 0.612 = 0.388

6. Mix calculation:

Vol. Of Concrete – 1m3
Vol. of cement – (mass/ sp. gravity) (1/1000) = 492.5 /3.1 (1/1000) = 0.158
Vol. of water = (Mass/sp. gravity) (1/1000) = (197/1) (1/1000) = 0.197
Mass of coarse aggregate = 1175.04
Mass of fine aggregate = 628.24

Summary:
Cement – 492.5 kg/m3
Water - 197
Fine Aggregate – 628.24 kg/m3
Coarse Aggregate – 1175.04 kg/m3
Water cement ratio – 0.4
The ratio comes to be 1:1.27:2.38 for M30 grade concrete

4.2 Casting of Test Specimens:
The experimental program involves casting and testing M30 concrete specimens with and without fly ash and rice husk ash. A total of 10 cube specimens were prepared with different proportions of cement replacement using fly ash and rice husk ash. Manual mixing was used, where cement and fine aggregate were first mixed, followed by the addition of coarse aggregate to obtain a uniform mix. These variations help study the effect of partial replacement on the properties of concrete.

4.3 Mix of Concrete:
Manual mixing is used in this experiment. Cement and fine aggregate are first mixed thoroughly, followed by the addition of coarse aggregate to obtain a uniform mix. After proper mixing, the concrete is placed into moulds and compacted to prepare specimens for testing.

4.4 Casting Specimens
For casting, standard cast iron moulds of size 150 × 150 × 150 mm are used. The moulds are cleaned and oiled before placing the concrete. The mixed concrete is filled in layers and properly compacted. After casting, specimens are kept undisturbed for 24 hours in the laboratory. Then they are removed from the moulds and cured in clean water to achieve the required strength.

4.5 Curing of Specimens
After casting, the specimens are kept undisturbed in moist air at room temperature for 24 hours. They are then removed from the moulds and submerged in clean water in a curing tank. The water is changed every 5 days, and specimens are cured for 7 and 28 days to achieve proper strength.

Testing Of Cube Specimens

The cube specimens cured as explained above are tested as per standard procedure after removal from curing tank and allowed to dry under shade.

- The cube specimens are tested for:
- Compressive strength in 7 days
- Compressive strength in 28 days

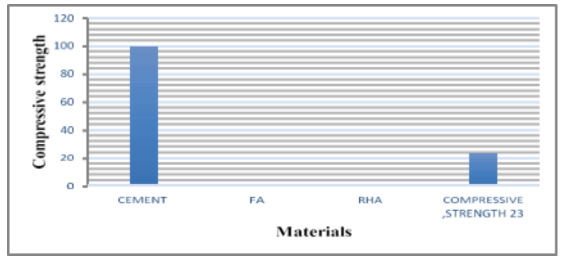
V. RESULTS AND DISCUSSIONS

Cubes are casted with M30grade concrete. Up to fifty percent of cement is replaced by a combination of Fly Ash and rice husk ash in different proportions and fibers are added to the combinations in different percentages. as shown in. The cubes are test dafter 7, 28 days. An experimental study is to be conducted to find out the compressive strength and at 7days and 28 days. In concrete the partial replacement of cement by Fly ash and rice husk ash.

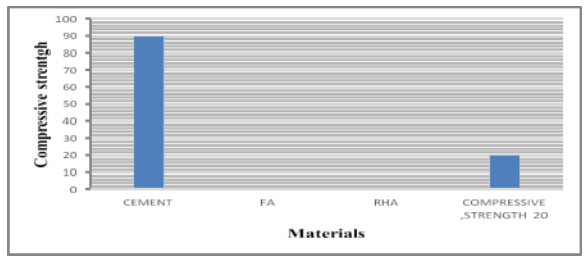
Table 1: Mixing Proportions and its compressive strength load

S. No	Cement (%)	Fly Ash (%)	Rice Husk Ash (%)	Age (Days)	Strength N/mm²
1	100	0	0	7	23
2	90	10	0	7	20
3	100	0	0	28	36
4	90	10	0	28	34
5	90	0	10	28	32
6	90	5	5	28	33
7	80	10	10	28	30
8	70	15	15	28	27
9	60	20	20	28	24
10	50	25	25	28	20

The following graphs represents % of cement, % of fly ash, % of fibers in the mix design with compressive strength values (7days)

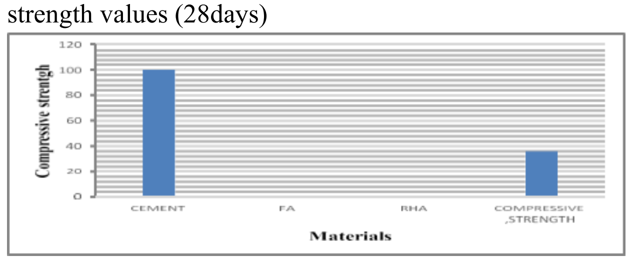


Graph 1: 100% cement – Strength 23 N/mm²

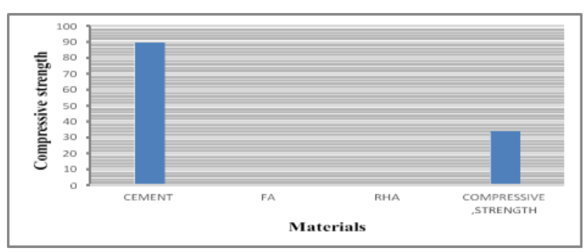


Graph 2: 90% cement, 10% fly ash, and 0% rice husk ash– Strength 20 N/mm²

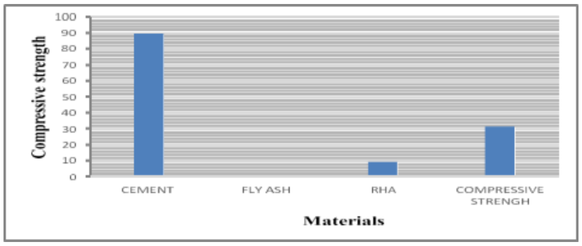
The following graphs represents % of cement, % of fly ash, % of fibers in the mix design with compressive strength values (28days)



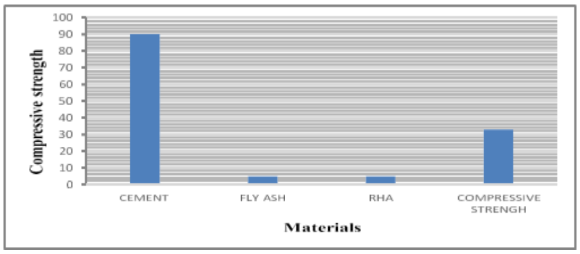
Graph 3: 100% cement, 0% fly ash, and 0% rice husk ash, Strength 36 N/mm²



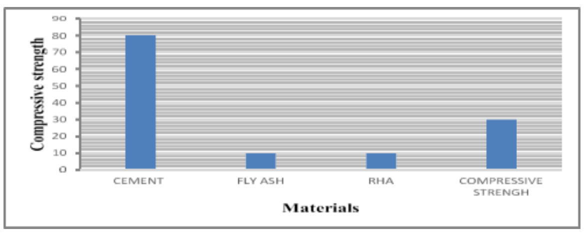
Graph 4: 90% cement, 10% fly ash, and 0% rice husk ash – Strength 34 N/mm²



Graph 5: 90% cement, 0% fly ash, and 10% rice husk ash – Strength 32 N/mm²



Graph 6: 90% cement, 5% fly ash, and 5% rice husk ash- Strength 33N/mm²



Graph 7: 80% cement, 10% fly ash, and 10% rice husk ash- Strength 30N/mm²

VI. CONCLUSION

Based on the Obtained Result by Conducting Various Test in Laboratory Investigation
The Following Conclusion We Drawn
The experimental study shows that the compressive strength of concrete varies with the percentage replacement of cement by fly ash (FA) and rice husk ash (RHA).
The conventional mix with 100% cement achieved 23 N/mm² at 7 days and 36 N/mm² at 28 days, which is the maximum strength among all mixes.
Partial replacement with 10% fly ash resulted in slightly lower early strength (20 N/mm² at 7 days) and 34 N/mm² at 28 days, indicating that fly ash provides good strength development, especially at later ages.
When rice husk ash is used alone (10%), the strength further reduced to 32 N/mm² at 28 days, showing that RHA alone decreases strength compared to normal concrete.

The combined use of 5% fly ash + 5% RHA gave 33 N/mm² at 28 days, which is better than RHA alone and close to fly ash mix, indicating a balanced performance.

As the total replacement percentage increases beyond 20%, the compressive strength decreases significantly:

- 30 N/mm² (10% FA + 10% RHA)
- 27 N/mm² (15% FA + 15% RHA)
- 24 N/mm² (20% FA + 20% RHA)
- 20 N/mm² (25% FA + 25% RHA)

VII. APPPENDIX

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