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Investigation of the Strength & Impact on Green Concrete with Industrial Waste By-Products

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Abstract
Cement is a crucial construction material, widely used for creating strong and durable buildings and infrastructure. However, one of the primary environmental issues associated with its production is the high energy demand. Globally, cement manufacturing results in approximately 1.6 billion tons of production annually, contributing around 7% of total carbon dioxide emissions released into the atmosphere. In developing nations like India, alternative materials such as Fly Ash, Brick Dust, and Rice Husk Ash—which are naturally rich in silica—can serve as supplementary cementitious materials. These can partially replace Portland cement in concrete mixtures without compromising compressive strength.
This research focuses on incorporating Fly Ash sourced from the Reliance power plant in Rosa, Uttar Pradesh, along with Rice Husk Ash and Brick Dust from the Lucknow Division, into concrete at replacement levels of 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% by mass. It was concluded that a 40% substitution using these materials is feasible for practical construction applications. Additionally, it was observed that using Rice Husk Ash and Brick Dust in concrete results in a 7% cost reduction compared to Fly Ash concrete, particularly in construction projects in the Jaipur division.
Keywords:*Strength,Health,ConstructionIndustry,SafetyManagement,Analysis, Fly Ash, Brick Dust, Rice Husk, Supplementary cementitious material, Compressive Strength.*

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I. Introduction

Concrete is the most widely used construction material globally, composed of cement, water, and aggregates. Its environmental impact is significant, primarily due to the high energy consumption and carbon dioxide emissions during cement production. Cement manufacturing contributes to about 7% of global CO_2 emissions, mainly through fossil fuel use and the calcination process. Although 90% of concrete is made up of inert materials like sand and gravel, the small proportion of cement is the main source of emissions.

To reduce this environmental impact, studies have focused on replacing cement with supplementary cementitious materials like Fly Ash, Rice Husk Ash, and Brick Dust. Fly Ash, a by-product of coal-fired power plants, is abundant in India due to the heavy reliance on coal for electricity. It has excellent pozzolanic properties and can replace up to 30–50% of cement in concrete, improving its durability and reducing cement consumption. High Volume Fly Ash Concrete (HVFA), developed in the 1980s, is one such solution offering enhanced performance and sustainability.

Fly Ash, Rice Husk Ash (RHA), and Brick Dust (BD) are industrial and agricultural by-products with potential for use as supplementary cementitious materials in concrete. Fly Ash is collected from thermal power plants and has long been recognized for its pozzolanic properties, capable of replacing a significant portion of cement in concrete. Rice Husk Ash, produced from burning rice husks—a by-product of rice milling—also exhibits strong pozzolanic behavior when burned under controlled temperatures (500–700°C) and finely ground. It contributes to improved mechanical properties and reduced chloride diffusion in concrete. Similarly, Brick Dust, derived from brick kilns and demolition waste, contains silica and alumina, making it suitable for pozzolanic reactions with lime.

The disposal of these materials poses environmental challenges, but their use in concrete can reduce cement demand, lower CO_2 emissions, and promote sustainable construction. Specifically, in the Lucknow division of India—where rice and brick production is high—these materials are abundant and underutilized.

Studies and experiments confirm that controlled combustion of rice husk and recycling of brick kiln waste into construction materials present a viable solution for both waste management and eco-friendly concrete production.

Research Objective

The objective of this research is to find the scope for the use of Brick Dust and Rice Husk Ash in Lucknow division to reduce the amount of cement in concrete for the construction work in Lucknow. This is done via material testing of concretes with various percentage of replacement of cement by Fly Ash from Reliance power plant in Rosa Shahjahanpur, Uttar Pradesh and Rice Husk Ash and Brick Dust collected from Lucknow division, Uttar Pradesh.

In present time fly ash is used in concrete as replacement of cement in a percentage for construction work. Fly ash used in the experiment was bought form Reliance power plant in Rosa, Uttar Pradesh. As there is no power plant near by Lucknow which produces good quality Fly Ash, so construction companies use to buy fly ash which cost around Rs1 per kg. Maximum cost includes transportation cost.Soitisnecessarytofindoutotherwastematerialwhichiseasilyavailable in Lucknow division sothiscostcanbereduced and the problem of disposing industrial waste material is minimized.

As we know that Lucknow is the highest producer of rice in Utter Pradeshand there is a large number of brick manufacturing companies in Lucknow so Rice Husk Ash and Brick Dust is generated as a waste in a large quantity which is also a threat to environment sothis research is doneforfindingthepossibilityofusing Rice HuskAshandBrickDustasareplacementforapercentageofcementratherthan Fly Ash.

II. Literature Review

Numerous studies have explored the incorporation of Fly Ash (FA) as a supplementary cementitious material to enhance the durability, sustainability, and cost-effectiveness of concrete. High Volume Fly Ash Concrete (HVFA) has gained global attention, particularly in fly ash-rich countries, for reducing Portland cement usage while maintaining or improving concrete performance.

Pioneering research by Pitt (1976) and Cook (1977) demonstrated that Rice Husk Ash (RHA), when burned under controlled conditions, exhibits high lime reactivity suitable for use in cement. Similarly, Brick Dust (BD), rich in silica and alumina, has shown pozzolanic behavior, though limited research exists on its use as a cement replacement.

Studies by Alvin Harison (2014) and Dr. S.L. Patil (2012) examined the mechanical behavior of concrete with varying percentages of fly ash replacement, showing optimal strength retention up to 30%. A. Camoes (2003) and A. Bilodeau (2001) further validated the potential of HVFA in producing high-performance, durable concrete with compressive strengths up to 60 MPa, supporting environmental sustainability.

Crouch (2007) and T.P. Agrawal (2012) emphasized that HVFA mixtures enhance durability, lower permeability, and reduce environmental impact. Despite slightly longer setting times and variable strength at early ages, long-term benefits are significant. Upadhyaya (2014) and Mukherjee (2012) noted that fly ash content up to 30% yields consistent performance, although higher percentages may lead to reduced compressive strength and quality degradation.

Globally, the use of Coal Combustion Products (CCPs) like fly ash is encouraged by regulatory support and standardization, as discussed by Craig Heidrich (2013). These insights underline the importance of fly ash, RHA, and BD as viable and sustainable alternatives for cement in concrete, supporting ecological and structural goals in modern construction.

Objective of this study

- Investigation of the strength & impact on green concrete with industrial waste by-products
- To evaluate the mechanical properties (compressive, tensile, and flexural strength) of green concrete made using industrial waste by-products such as fly ash, rice husk ash, GGBS, and brick dust.
- To assess the environmental benefits of replacing traditional cement and aggregates with sustainable industrial by-products in concrete.
- To analyze the durability and performance of green concrete under various environmental conditions.
- To compare the behavior and strength of green concrete with conventional concrete mixes.
- To determine the optimum percentage replacement of cement or aggregates with industrial waste that provides maximum strength without compromising structural performance.
- To contribute to sustainable construction practices by minimizing CO_2 emissions and promoting the reuse of industrial waste materials.

Material Required for Investigation

- Concrete is made by adjusting the proportions of core materials—cement, water, and aggregates—based on the specific structural requirements, strength, and durability needs. The study used Ordinary Portland Cement (OPC) 43 grade (Jaypee) conforming to IS:8112-1989, with tests such as setting time and compressive strength conducted to assess its quality.
- Water, a critical component, facilitates the hydration process, forming a cement gel that binds the mix. Water-cement ratios used were 0.46 for M20, 0.42 for M25, and 0.38 for M30 grades. The water quality significantly affects concrete strength and durability.
- Aggregates, both fine (river and crushed sand) and coarse (basalt rock), conforming to IS:383-1970 standards, form the bulk of concrete. Recycled and manufactured aggregates, including slag and bottom ash, are also considered for sustainable alternatives. Proper grading and cleanliness of aggregates are essential for achieving desired concrete properties.

Chemical admixtures

Chemical admixtures are additives used in small quantities (typically <5% of cement mass) to enhance specific properties of concrete. Common types include:

- Accelerators (e.g., $CaCl_2$, NaCl) that speed up setting but may cause reinforcement corrosion.
- Retarders (e.g., sugars, citric acid) delay setting for better handling in large pours.
- Air entrainers improve freeze-thaw durability by introducing microscopic air bubbles, though at the cost of reduced strength.
- Plasticizers/Superplasticizers (e.g., lignosulfonate, polycarboxylates) enhance workability or reduce water content, improving strength and durability.

In this study, Glenium Sky 8630, a high-performance polycarboxylic ether-based superplasticizer, was used to improve concrete properties.

III. Methodology

This research aims to evaluate the mechanical performance and environmental benefits of green concrete by partially replacing traditional cement with various industrial waste by-products. The methodology involves material selection, mix design formulation, sample preparation, testing, and analysis.

Materials Used

- **Cement:** Ordinary Portland Cement (OPC 43 Grade) conforming to IS: 8112-1989.
- **Fine Aggregate:** Clean, graded river sand conforming to IS: 383-1970.
- **Coarse Aggregate:** Crushed basalt stones (20 mm nominal size).
- **Water:** Potable water free from impurities, used for mixing and curing.
- **Admixtures:** Superplasticizer (e.g., Glenium Sky 8630) for enhanced workability.

Industrial Waste By-products:

- **Fly Ash** (from thermal power plants)
- **Rice Husk Ash (RHA)** (from parboiled rice mills)
- **Brick Dust (BD)** (from demolished or unused bricks)
- **GGBS** (Ground Granulated Blast Furnace Slag, if applicable)

Mix Design

Concrete mixes will be designed for M20 and M25 grades as per IS 10262:2019. The mix variations include:

- Control mix (0% replacement)
- 10%, 20%, 30%, and 40% cement replacement (by weight) with Fly Ash, RHA, and BD in separate and combined proportions

Factors to Be Considered for Mix Design

The design of concrete mix will be based on the following factors:

Table: Grades of Concrete ((IS456,2000) clause 6.1)

Grade Designation	Specified Characteristic Compressive Grade Designation Strength in N/Mm2 at 28 Days Curing

M 10	10
M 15	15
M 20	20
M 25	25
M 30	30
M 35	35
M 40	40
M 45	45
M 50	50
M 55	55
M 60	60

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Sample Preparation

- Batching and mixing will be done using a concrete mixer.
- Cubes (150 mm × 150 mm × 150 mm) will be cast for compressive strength tests.
- Cylinders (150 mm × 300 mm) for split tensile strength.
- Beams (100 mm × 100 mm × 500 mm) for flexural strength.

Curing Process

All specimens will be cured in water for 7, 14, and 28 days. A standard curing tank will be maintained at 27 ± 2°C.

Testing Procedures

- **Compressive Strength Test** (IS: 516-1959)
- **Split Tensile Strength Test** (IS: 5816-1999)
- **Flexural Strength Test** (IS: 516-1959)
- **Workability Test** using Slump Cone (IS: 1199-1959)
- **Water Absorption Test** to evaluate porosity and durability

Target Mean Strength

Considering the inherent variability of concrete strength during production it is necessaryto design the mixtohaveatargetmean strength which is greater than characteristic strength by a suitable margin.

ft =fck+1.65x S

where,

ft = Target mean strength

fck=Characteristic strength.

Assumed Standard Deviation (S)

(IS10262,Concretemix proportioning, 2009) clauses 3.2.1.2, A-3 and B-3)

Grade OfConcrete	M10	M15	M20	M25	M30	M35	M40	M50
Standard Deviation(N/mm2)	3.5	3.5	4.0	4.0	5.0	5.0	5.0	5.0

Procedure

1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fckand the level of quality control.

ft =fck+1.65 S

where S is the standard deviation obtainedfrom the table of approximatecontent given after the design mix.

2. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water-cement ratio. The water cement ratio so chosenis checked against thelimitingwatercement ratio fortherequirements of durability given in Table and adopt the lower of the two values.
3. Estimate the amount of entrapped air for maximum nominal size of theaggregate from the table.
4. Select the water cement, for the required workability and the maximum size of aggregates (for aggregates

in saturated surface dry condition)

5. Determine the percentage of fine aggregates intotal aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate, the values are given in table.
7. Calculate the cement content from the water cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps F and G above, calculate the content of coarse and fine aggregate per unit volume of concrete from the following relations: -

$$V = |W + \frac{C}{S_C} + \frac{1}{P}\frac{f_a}{S_{fa}}| \times \frac{1}{1000}$$

$$V = |W + \frac{C}{S_C} + \frac{1}{1-P}\frac{C_a}{C_{ca}}| \times \frac{1}{100}$$

where V =Absolute volume of concrete

=Gross volume(1 m^3)minus the volume of entrapped air

S_c=Specific gravityofcement

W = Mass of water per metre cube of concrete, in kg C=Massofcementpermetrecubeofconcrete,inkg
p = Ratio of fine aggregate to total aggregate by absolute
volumef_a,C_a=Totalmassesofcoarseandfineaggregates,percubicmetre of concrete respectively, in kg
S_{fa},S_{ca}=Specificgravitiesofsaturatedsurfacedryfineandcoarse aggregates respectively.

i. Determinethe concretemixproportionsforthefirsttrialmix.

ii. Prepare the concrete using the calculated proportions and cast three cubes of 150mm size and test them wet after 28-days moist curing and check for the strength.

iii. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived. (IS10262, Concrete Mix Design, 2009)

IV. Result and Analysis

This thesis deals with the presentation of test results, and discussions onCompressive strength and development of Control concrete,Fly ash concrete, Rice Husk Ash concrete and Brick Dust concrete at curing period of 28 days. The present investigation is based on the IS method for Control concrete. For Fly Ash concrete, Rice Husk Ash concrete and Brick Dust concrete, replacement method is considered. Mix proportions have been obtained for M20, M25 and M30 grade concrete from the mix design. By conducting design mixes, an optimized proportion for the mix is obtained for M20, M25 and M30 grade control concrete. Compressive strength behaviour of Fly ash concrete, Rice Husk Ash concrete and Brick Dust concrete designed by the replacement method are studied, wherethe effect of age and percentage replacement of cement with Fly Ash, Rice Husk Ash and Brick Dust on Compressive strength is studied in comparison with that of M20, M25 and M30 grade Control concrete.

Mix proportioning of Control concrete:

Accordingto IS method of mix design, the proportions of Control concrete werefirst obtained; trial mixes were carried out to determine the strength at 7, 28, 90 and 180 days, and the results obtained are shown in figure, where in the compressive strength obtained for M20, M25 and M30 grade design mixes are represented against age.The compressive strength at different ages of M20, M25 and M30 grade concrete under design mix are dissipated through graph. The final mix proportions arrived atis shown in tables. Comparison of compressive strength at 7,28, 90 and 180 days of design mix are shown.

Compressive Strength:

Most concrete structures are designed assuming that concrete processes sufficient compressive strength but not the tensile strength. The compressive strength is the main criteria for the purpose of structural design. To study the strength development ofFly Ash concrete, Rice Husk Ash concrete and Brick Dust concrete in comparison to Control concrete, compressive strength tests were conducted at the ages of 7, 28, 90 and 180 days.

Table: Effect of Fly Ashon Compressive Strength of M20Grade Concrete

Compressivestrengthof cubes,W/C= 0.46				
	CompressiveStrength(MPa) (Ultimatecompressiveload) /22.5			
	7 Day	**28 Day**	**90 day**	**180 day**
0 % FA	37.9	45.2	48.6	50.4
5 % FA	38.3	45.7	49.3	51.1
10 %FA	37.6	44.9	48.2	50.6
15 %FA	33.3	41.7	44.6	46.2
20 %FA	31.2	40.6	43.2	44.9
25 %FA	28.8	37.2	39.9	41.2
30 %FA	25.6	33.1	35.3	38
35 %FA	23.2	30.9	32.6	34.2
40 %FA	19.9	28.8	30.7	32.3

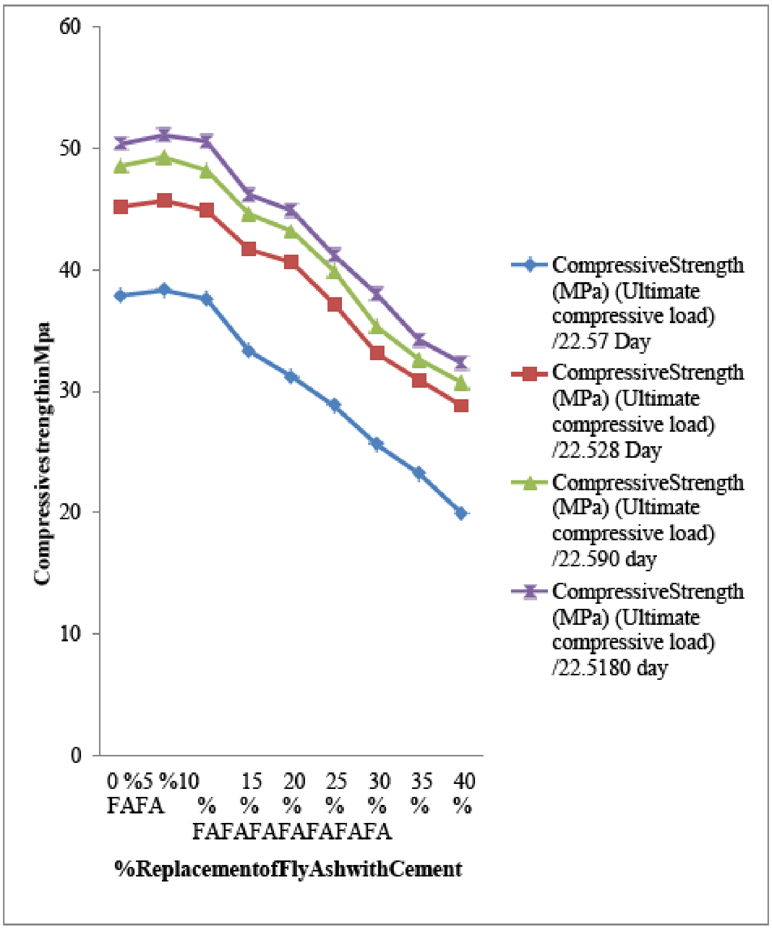

Fig: ChangeincompressivestrengthofM20gradeofconcreteindifferent ages replacing cement with Fly Ash

V. Conclusion

The results show that it is possible to achieve desired strength in concrete by replacing cement upto 40% by Fly Ash, Brick Dust and Rice Husk Ash. The conclusion is as follows:

- Fly Ash and Brick Dust concrete shows more strength as compare to Rice Husk Ash concrete.
- Rice Husk Ash makes concrete light in weight as compared to Fly Ash and Brick Dust concrete. So it will be helpful in reducing dead load of the construction.
- Brick Dust makes concrete heavier so it will be helpful in using it in foundation work and making earthen dams etc. where heavy weight is essential for the structure.
- There is 33-40% reduction in cost of concrete by using these industrial wastes (FA, RHA and BD).
- There is 7% reduction in the cost of concrete when using Rice Husk Ash and Brick Dust in Lucknow Region as compared to Fly Ash concrete.
- FutureScope
- More field test can be conducted od using appropriate technology to grind Rice Husk Ash and Brick Dust to make concrete.
- The variation in Rice Husk Ash combustion process currently employed can be investigated to determine the best source of Rice Husk Ash for the use in concrete.
- Effectondifferentcuringperiodson concrete.
- Effect on the strength of concrete by using different water cement ratio forthe design mix concrete.
- For use ofBrick Dust Concrete and Rice Husk Ash Concrete as a structural material, it is necessary to investigate the behavior of reinforced Brick Dust Concrete and Rice Husk Ash concrete under flexure, shear, torsion and compression.
- The logistics of implementing the use of Fly Ash, Rice Husk Ash and Brick Dust concrete in developing country construction should also be investigated to ensure that this low cost construction material is helping the people who need it most.

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