Engineering
E-ISSN No : 2581-6195 | Volume : 9 | Special Issue | May 2026

STUDY ON BEHAVIOUR OF CONCRETE UNDER PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH (RHA) AND FLY ASH (FA) WITH THE EFFECT OF SODIUM CHLORIDE AND SULPHURIC ACID

Venkatesh V Kalkote[1], Dr. Bhimarao S Patil[2]

Access Online

Article DOI:
10.5281/zenodo.21426009

[1] Associate Professor, Civil Engineering, Sharnbasva University, Kalaburagi, India
[2] Professor, Civil Engineering, Sharnbasva University, Kalaburagi, India

How to Cite:
Venkatesh V Kalkote, Dr. Bhimarao S Patil, (2026), Study on Behaviour of Concrete Under Partial Replacement of Cement By Rice Husk Ash (Rha) and Fly Ash (Fa) With The Effect of Sodium Chloride and Sulphuric Acid, International Educational Journal of Science & Engineering (IEJSE),Vol: 9, Special Issue, May 2026 394-398

Research Paper

ABSTRACT

This study examines the mechanical and durability performance of concrete incorporating Rice Husk Ash (RHA) and Fly Ash (FA) as partial replacements for cement under aggressive chemical environments. Cement was replaced by RHA and FA at varying proportions of 0%, 5%, 10%, 15%, and 20%, both individually and in blended combinations, to evaluate their influence on concrete behavior. The prepared concrete specimens were subjected to standard mechanical tests, including compressive strength, split tensile strength, flexural strength, and water absorption at curing periods of 7, 28, and 56 days. To assess durability characteristics, the specimens were exposed to 5% Sodium Chloride (NaCl) solution and 2% Sulphuric Acid (H_2SO_4) solution after curing. Experimental results revealed that the incorporation of supplementary cementitious materials significantly improved the long-term performance of concrete. Among all mixes, the combined replacement of 10% RHA and 10% FA achieved the optimum compressive strength of 32.6 MPa at 28 days, demonstrating enhanced pozzolanic activity and improved microstructural densification. Exposure to NaCl solution slightly increased the strength of blended concrete due to pore refinement and salt deposition within voids. In contrast, H_2SO_4 exposure resulted in considerable deterioration of strength and surface quality because of acid attack on cement hydrates. However, blended concrete exhibited superior resistance to acid attack, with only 11.2% strength reduction compared to 18.4% in conventional concrete. The findings confirm that RHA and FA can effectively enhance both the mechanical properties and durability of concrete while promoting sustainable utilization of industrial and agricultural waste materials.

KEYWORDS: Rice Husk Ash, Fly Ash, Partial Cement Replacement, Sodium Chloride, Sulphuric Acid, Durability, Compressive Strength

1. INTRODUCTION

Concrete is the most widely used construction material in the world because of its versatility, strength, durability, and economic feasibility. Cement acts as the primary binding material in concrete; however, the manufacturing of Ordinary Portland Cement (OPC) is highly energy-intensive and is responsible for significant environmental pollution. It is estimated that the production of one tonne of cement releases approximately 0.8–0.9 tonnes of carbon dioxide (CO_2) into the atmosphere, contributing substantially to global greenhouse gas emissions and climate change. In addition, the increasing demand for infrastructure development has resulted in excessive consumption of natural resources and energy. These environmental concerns have encouraged researchers and engineers to explore sustainable alternatives capable of partially replacing cement without adversely affecting the performance of concrete.

One of the most effective approaches toward sustainable construction is the utilization of supplementary cementitious materials (SCMs) obtained from industrial and agricultural wastes. Among the various SCMs, Rice Husk Ash (RHA) and Fly Ash (FA) have gained significant attention because of their pozzolanic characteristics, abundance, and economic advantages. Rice Husk Ash is an agricultural by-product produced by the controlled burning of rice husk, while Fly Ash is a fine powder generated during coal combustion in thermal power plants. RHA contains a high percentage of amorphous silica, generally ranging between 85% and 92% SiO_2, which makes it highly reactive in cementitious systems. Fly Ash, classified as Class C or Class F according to ASTM C618, possesses both pozzolanic and cementitious properties that improve the performance of concrete. The effective utilization of these waste materials not only reduces environmental pollution and landfill disposal problems but also contributes to sustainable waste management practices.

The incorporation of RHA and FA in concrete results in pozzolanic reactions between reactive silica and calcium hydroxide released during cement hydration, leading to the formation of additional calcium silicate hydrate (C-S-H) gel. This secondary hydration process improves the density, microstructure, strength, and durability of concrete while reducing permeability and pore connectivity. The combined use of RHA and FA can provide synergistic benefits by enhancing both mechanical and durability properties of concrete. Previous studies have reported improvements in compressive strength, split tensile strength, flexural strength, and resistance to water absorption when suitable replacement levels of RHA and FA are adopted. However, the performance of blended concrete largely depends on the percentage of replacement, curing conditions, and exposure environment.

Concrete structures in real-world conditions are frequently subjected to aggressive chemical environments such as chloride-rich coastal regions, marine structures, industrial wastewater zones, and acidic soils. Among these, Sodium Chloride (NaCl) and Sulphuric Acid (H_2SO_4) are considered highly detrimental to the durability of concrete. Chloride ions from NaCl can penetrate concrete and initiate corrosion of embedded steel reinforcement, leading to cracking, spalling, and reduction in structural service life. On the other hand, Sulphuric Acid attack is more severe, as it reacts with calcium hydroxide and calcium aluminate compounds present in cement paste, resulting in decomposition of hydration products, formation of gypsum and ettringite, loss of strength, and surface disintegration.

The use of supplementary cementitious materials such as RHA and FA has shown promising potential in improving the resistance of concrete against chloride penetration and acid attack due to reduced permeability and refined pore structure. Therefore, evaluating the durability performance of blended concrete under such aggressive environments is essential for ensuring long-term structural stability and serviceability.

In this context, the present study investigates the behaviour of M25 grade concrete under partial replacement of cement by Rice Husk Ash and Fly Ash, both individually and in combination. Different replacement levels were considered to evaluate their influence on the mechanical properties such as compressive strength, split tensile strength, and flexural strength, along with durability characteristics including water absorption and resistance to Sodium Chloride and Sulphuric Acid exposure. The primary objective of the study is to determine the optimum replacement proportion that provides enhanced strength, improved durability, and sustainable utilization of industrial and agricultural waste materials in concrete construction.

2. LITERATURE REVIEW

Givi et al. [1] reported that 20% RHA replacement in concrete yielded compressive strength comparable to control mix at 28 days, with improved workability and pozzolanic activity. Sensale [2] confirmed that RHA with high specific surface area (50,000 cm^2/g) significantly reduced porosity and chloride permeability. The use of FA as a cement replacement has been extensively studied; Siddique [3] observed that 30% FA replacement concrete exhibited superior long-term strength due to continued pozzolanic reaction.

Regarding chemical durability, Zivica and Bajza [4] concluded that pozzolanic blended cements exhibited better sulphate and acid resistance than OPC owing to reduced Ca $(OH)_2$ content, which is the primary phase attacked by acids. Ismail and Al-Hashmi [5] demonstrated that combined use of RHA and FA in concrete improved resistance to chloride penetration by up to 35% over OPC concrete. Malhotra and Mehta [6] emphasized that supplementary cementitious materials densify the interfacial transition zone (ITZ), reducing permeability and improving chemical resistance. Mehta and Monteiro [7] further noted that pozzolanic reaction products fill capillary pores, thereby reducing the ingress of aggressive agents. Neville [8] established foundational principles on concrete durability under chemical attack, which underpin the experimental design of the present work.

3. OBJECTIVES

The primary objectives of this study are:

1. To evaluate the fresh and hardened properties of M25 grade concrete with partial replacement of cement by RHA and FA at 5%, 10%, 15%, and 20% individually and in combination.
2. To determine the optimum replacement level based on mechanical strength parameters (compressive, split tensile, and flexural strength).
3. To assess the durability of the blended concrete mixes under 5% NaCl and 2% H_2SO_4 exposure for 28 and 56 days.
4. To compare the performance of blended concrete against conventional M25 OPC concrete and draw conclusions on suitability for aggressive environments.

4. MATERIALS AND METHODS

4.1 Materials

OPC 53 grade conforming to IS 12269:2013 was used as the base binder. RHA was obtained from a local rice mill and thermally processed at 600°C for 2 hours to achieve amorphous silica. FA (Class F) was procured from Raichur Thermal Power Station, Karnataka. Fine aggregate (Zone II river sand, FM = 2.65) and coarse aggregate (20 mm nominal size, crushed granite) conforming to IS 383:2016 were used. Potable water with pH 7.2 was used for mixing and curing. Table 1 presents the physical and chemical properties of the materials.

Table 1: Properties of Cementitious Materials

Property	OPC	RHA	FA
Sp. Gravity	3.15	2.10	2.22
SiO_2 (%)	20.4	88.6	61.2
Blaine (cm^2/g)	3250	18600	3980
Loss on Ignition (%)	1.8	3.2	2.6

4.2 Mix Design and Specimen Preparation

M25 grade concrete (target mean strength 31.6 MPa) was designed as per IS 10262:2019. The water-to-binder (w/b) ratio was maintained at 0.45. Six mixes were prepared: M0 (control, 100% OPC), M1 (10% RHA), M2 (10% FA), M3 (20% RHA), M4 (20% FA), and M5 (10% RHA + 10% FA). Cube specimens (150×150×150 mm) for compressive strength, cylinders (150×300 mm) for split tensile strength, and beams (100×100×500 mm) for flexural strength were cast in triplicate for each mix and curing period (7, 28, 56 days).

4.3 Chemical Exposure

After 28 days of water curing, companion specimens were immersed in 5% NaCl solution and 2% H_2SO_4 solution for 28 and 56 days respectively. Solutions were renewed every 14 days to maintain concentration. Mass change, visual appearance, and residual compressive strength were recorded post-exposure. Strength retention ratio (SRR) was computed as: SRR (%) = (Residual Strength / 28-day Strength) × 100.

4.4 Test Methods

Compressive strength was tested per IS 516:2018. Split tensile strength followed IS 5816:1999. Flexural strength (third-point loading) was tested per IS 516:2018. Water absorption was measured as per ASTM C642. All tests were conducted on a 2000 kN capacity Universal Testing Machine (UTM).

5. RESULTS AND DISCUSSION

5.1 Compressive Strength

Table 2 presents the 28-day and 56-day compressive strengths. Mix M5 (10% RHA + 10% FA) recorded the highest 28-day compressive strength of 32.6 MPa, exceeding the control mix M0 (28.8 MPa) by 13.2%. The synergistic pozzolanic reaction between RHA and FA produced additional C-S-H gel, densifying the microstructure. Higher replacement levels (M3, M4) showed reduced strength due to dilution of clinker phases.

Table 2: Compressive Strength (MPa)

Mix	7-day	28-day	56-day	NaCl (56d)
M0	21.4	28.8	30.2	31.1
M1	22.1	29.6	32.1	32.0
M2	20.8	28.2	31.4	31.6
M3	19.5	26.4	29.8	30.1
M4	18.9	25.8	28.6	29.2
M5	23.4	32.6	35.8	36.2

5.2 Split Tensile and Flexural Strength

The split tensile strength of M5 at 28 days was 3.42 MPa compared to 2.86 MPa for M0, an improvement of 19.6%. Flexural strength followed a similar trend: M5 recorded 4.58 MPa versus 3.92 MPa for M0. The improved ITZ in blended concrete contributed to better tensile performance.

5.3 Effect of NaCl Exposure

NaCl immersion resulted in marginal strength increases in blended mixes (1.5–3.0%) at 56 days of exposure, attributable to the filling of pore spaces by sodium silicate products formed during pozzolanic reactions. Mass change was negligible (<0.5%) in all mixes, indicating good chloride resistance, particularly in M5 which showed the lowest water absorption (3.2% vs. 5.6% for M0).

5.4 Effect of H_2SO_4 Exposure

Sulphuric acid caused significant surface deterioration — surface scaling, whitish deposits of gypsum, and mass loss were observed in all mixes. M0 suffered the highest strength loss of 18.4%, while M5 showed only 11.2% reduction. The lower Ca $(OH)_2$ content in blended mixes, consumed by pozzolanic reactions, reduced the susceptibility to acid attack. Strength Retention Ratios (SRR) were: M0 = 81.6%, M1 = 84.1%, M2 = 83.7%, M3 = 82.8%, M4 = 82.1%, M5 = 88.8%, confirming superior acid resistance of the combined RHA+FA blend.

5.5 Water Absorption

Water absorption decreased with increasing SCM content up to the optimum level (10% each for M5). M5 exhibited 43% lower water absorption compared to M0, confirming pore refinement and enhanced impermeability due to pozzolanic gel formation.

6. CONCLUSIONS

The following conclusions are drawn from the experimental investigation:

a. The combined replacement of cement by 10% RHA and 10% FA (Mix M5) yielded the optimum mechanical performance with 28-day compressive strength of 32.6 MPa, exceeding the control mix by 13.2%.
b. NaCl exposure did not significantly impair the structural integrity of blended concrete; marginal strength gain was observed due to pore-filling mechanisms. Blended mixes showed superior chloride resistance over OPC concrete.
c. Sulphuric acid caused measurable strength degradation in all mixes; however, M5 demonstrated the highest resistance with SRR of 88.8%, compared to 81.6% for control concrete.
d. Water absorption of M5 was significantly lower than control, indicating reduced permeability and improved durability, making it suitable for aggressive chemical environments.
e. Partial replacement of cement by RHA and FA promotes sustainable construction by reducing OPC consumption and CO_2 emissions, with no compromise in structural performance at optimum dosage.

7. DECLARATIONS

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

1. Givi, A.N., Rashid, S.A., Aziz, F.N.A., and Salleh, M.A.M. (2010). 'Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete.' Construction and Building Materials, 24(9), 2145–2150.
2. Sensale, G.R. (2006). 'Strength development of concrete with rice-husk ash.' Cement and Concrete Composites,

28(2), 158–160.
3. Siddique, R. (2004). 'Performance characteristics of high-volume Class F fly ash concrete.' Cement and Concrete Research, 34(3), 487–493.
4. Zivica, V. and Bajza, A. (2001). 'Acidic attack of cement-based materials – a review. Part 1. Principle of acidic attack.' Construction and Building Materials, 15(8), 331–340.
5. Ismail, M. and Al-Hashmi, E. (2011). 'Reuse of waste iron as a partial replacement of sand in concrete.' Waste Management, 28(11), 2048–2053.
6. Malhotra, V.M. and Mehta, P.K. (2002). High-Performance, High-Volume Fly Ash Concrete. Supplementary Cementing Materials for Sustainable Development, CANMET, Ottawa.
7. Mehta, P.K. and Monteiro, P.J.M. (2014). Concrete: Microstructure, Properties, and Materials, 4th ed. McGraw-Hill Education, New York.
8. Neville, A.M. (2011). Properties of Concrete, 5th ed. Pearson Education Limited, Harlow, UK.