

Utilization of Brick Dust and Rice Husk Ash for Sustainable Cement Replacement in M20 Grade Concrete

Md. Majid^{1,*}, Harsh Rathore²

Abstract

The study evaluates the influence of replacing cement with Fly Ash, Brick Dust, and Rice Husk Ash on the compressive strength of concrete. Cement replacement was conducted at varying percentages (5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%) for M20 grade concrete, and compressive strength was assessed at 7, 28, 90, and 180 days. The results demonstrate that partial cement replacement can achieve comparable or improved strength performance up to an optimal level, beyond which strength reduction occurs. For M20 grade concrete, the highest 28-day compressive strength of 43.94 MPa was recorded at 5% Fly Ash replacement, surpassing the control mix (43.46 MPa). Similarly, Brick Dust replacement at 5% resulted in a peak 28-day strength of 43.94 MPa, while Rice Husk Ash exhibited an optimum replacement level of 5%, achieving 44.42 MPa. However, higher replacement levels beyond 20% led to a decline in strength. The study concludes that partial cement replacement using industrial and agricultural by-products can enhance concrete sustainability without compromising strength. This research contributes to the development of cost-effective and environmentally friendly construction materials suitable for sustainable infrastructure.

Keywords: Fly ash, brick dust, rice husk ash, cement replacement, compressive strength, sustainable concrete, M20 concrete, M25 concrete

INTRODUCTION

The increasing demand for sustainable construction materials has led to extensive research on alternative cementitious materials that can partially replace Ordinary Portland Cement (OPC) without compromising concrete performance. Among these materials, Rice Husk Ash (RHA), Fly Ash, and Brick Dust have gained significant attention due to their pozzolanic properties, availability, and environmental benefits. RHA is a byproduct of rice milling and, when processed under controlled burning conditions, exhibits high silica content, enhancing the strength and durability of concrete. Fly

ash, a waste material from thermal power plants, improves workability and long-term strength development. Brick dust, obtained from crushed clay bricks, enhances early-age strength and contributes to the filler effect, improving density and durability. The incorporation of these materials in M20 grade concrete not only promotes sustainability but also helps in reducing cement consumption, carbon emissions, and construction costs. This study aims to evaluate the mechanical and durability properties of concrete incorporating varying percentages of RHA, fly ash, and brick dust, focusing on their effects on strength, workability, and durability to ensure suitability for practical applications in construction [1–8].

*Author for Correspondence

Md. Majid
E-mail mjdkhan448@gmail.com

¹Research Scholar, Department of Civil Engineering, Sanjeev Agarwal Global Educational University, Bhopal, Madhya Pradesh, India

²Associate Professor, Department of Civil Engineering, Sanjeev Agarwal Global Educational University, Bhopal, Madhya Pradesh, India

Received Date: April 23, 2025

Accepted Date: May 19, 2025

Published Date: May 20, 2025

Citation: Md. Majid, Harsh Rathore. Utilization of Brick Dust and Rice Husk Ash for Sustainable Cement Replacement in M20 Grade Concrete. International Journal of Concrete Technology. 2025; 11(2): 1–5p.

OBJECTIVES

This research aims to investigate the effectiveness of Rice Husk Ash, Fly Ash, and Brick Dust as partial cement replacements in M20 grade concrete by evaluating their impact on workability, compressive strength, and durability. The study focuses on determining the optimum replacement percentages that enhance early and long-term strength while maintaining good workability and durability characteristics. Additionally, the research assesses the water absorption and chloride permeability resistance of modified concrete to ensure its suitability for structural and pavement applications. The findings are expected to contribute to sustainable and cost-effective construction practices while reducing waste disposal and environmental pollution [9–17].

MATERIAL

Cement

Ordinary Portland Cement (OPC) of 53 grade conforming to IS 12269:2013 was used in this study. The physical and chemical properties of cement, including fineness, specific gravity, and setting time, were determined as per IS 4031:1988.

Rice Husk Ash (RHA)

RHA was sourced locally and processed through controlled burning at 600–700°C to achieve high pozzolanic reactivity. The obtained ash was ground to a particle size finer than 45 µm to enhance its performance as a cementitious material. The chemical composition of RHA was analyzed using X-ray fluorescence (XRF), confirming a high silica content [18–20].

Fly Ash

Class F fly ash, obtained from a local thermal power plant, was used as a partial cement replacement. The material complied with IS 3812:2013, exhibiting a specific gravity of 2.2 and high fineness. Fly ash improves workability and durability due to its pozzolanic reactivity and filler effect [21–25].

Brick Dust

Crushed brick dust, produced from waste burnt clay bricks, was used as an additional cementitious material. The fineness and chemical composition were tested as per IS 2116:1980. The inclusion of brick dust aims to enhance early-age strength and durability.

Fine Aggregate

Manufactured Sand (M-Sand) conforming to IS 383:2016 was used as fine aggregate. The sand had a fineness modulus of 2.6 and a specific gravity of 2.65. Sieve analysis was conducted to ensure compliance with grading zone II requirements [26–29].

Coarse Aggregate

Crushed granite aggregate of nominal size 20 mm, meeting the specifications of IS 383:2016, was used as the coarse aggregate. The specific gravity was 2.70, and the water absorption was 0.5%.

Water

Potable water, free from impurities and conforming to IS 456:2000, was used for mixing and curing.

Superplasticizer

A polycarboxylate ether (PCE)-based superplasticizer was used to enhance workability and achieve the desired slump without affecting strength.

RESULTS

The impact of Fly Ash, Brick Dust, and Rice Husk Ash as partial replacements for cement on the compressive strength of concrete was evaluated at different curing ages (7, 28, 90, and 180 days). The results indicate that small percentages of these materials enhance long-term strength, while excessive replacement leads to a reduction in compressive strength [30].

Effect of Fly Ash on Compressive Strength

For Fly Ash replacement, the highest strength was observed at 5% FA, with values of 36.83 MPa at 7 days and 49.13 MPa at 180 days. Beyond 10% FA, a decline in early and long-term strength was noted, with 40% FA exhibiting the lowest strength (19.13 MPa at 7 days and 31.06 MPa at 180 days). This reduction is due to Fly Ash's slower pozzolanic reaction, which delays strength gain. However, moderate replacement (5–10%) improves long-term performance (Figure 1).

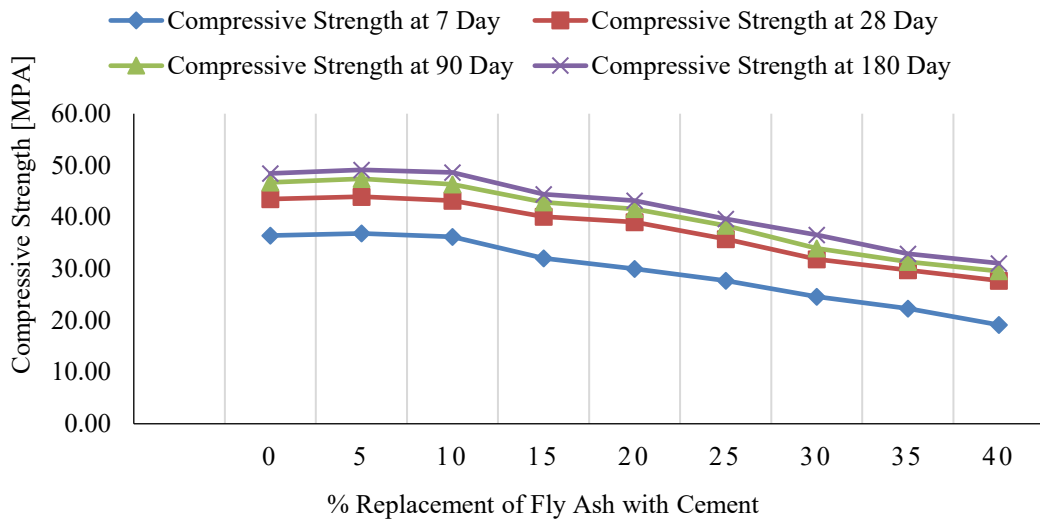


Figure 1. Variation in compressive strength of M20 grade concrete at different ages with cement replacement by fly ash.

Effect of Brick Dust on Compressive Strength

The strength development pattern for Brick Dust replacement closely follows that of Fly Ash. The highest compressive strength was achieved with 5% replacement, reaching 49.13 MPa in 180 days. Like Fly Ash, increasing the replacement percentage beyond 10% reduced strength, with the lowest values observed at 40% BD (19.13 MPa at 7 days and 31.06 MPa at 180 days). The decrease in strength at higher percentages is due to the dilution effect and lower cementitious properties of Brick Dust (Figure 2).

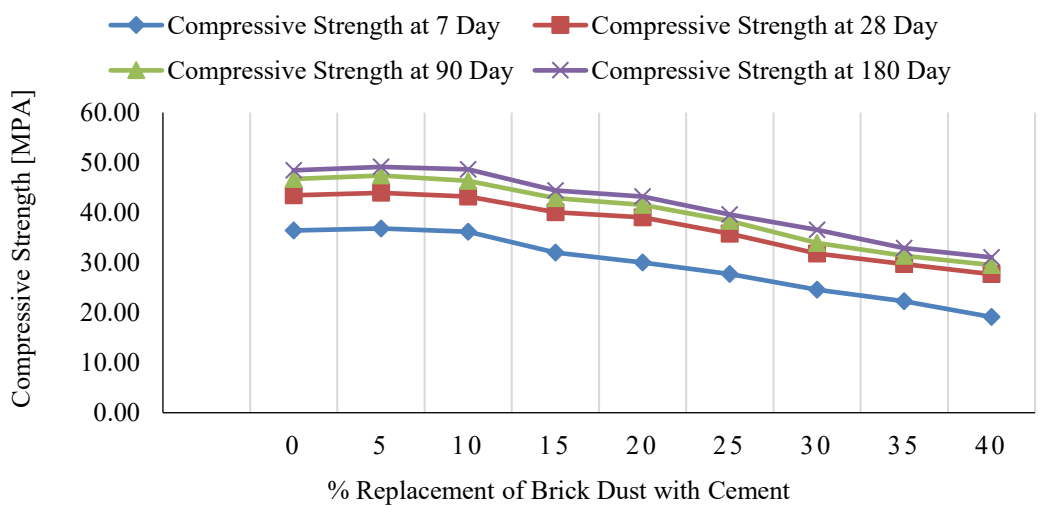


Figure 2. Variation in compressive strength of M20 grade concrete at different ages with cement replacement by brick dust.

Effect of Rice Husk Ash on Compressive Strength

Rice Husk Ash (RHA) exhibited a slightly different trend, showing an initial strength increase at 5% replacement (37.40 MPa at 7 days) but a more significant reduction at higher levels compared to Fly Ash and Brick Dust. At 40% RHA, the compressive strength dropped to 17.40 MPa at 7 days and 28.94 MPa at 180 days. This suggests that RHA has a more pronounced negative effect on early-age strength and long-term performance when used in excess (Figure 3).

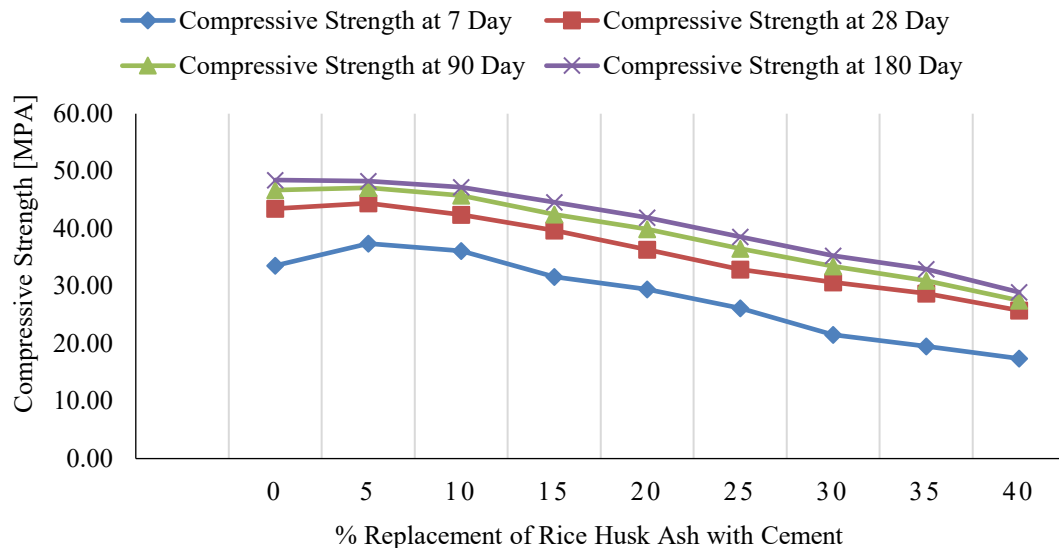


Figure 3. Variation in compressive strength of M20 grade concrete at different ages with cement replacement by rice husk ash.

All three materials showed improved strength at 5–10% replacement, with Fly Ash and Brick Dust demonstrating better long-term performance compared to Rice Husk Ash. At higher replacement levels ($\geq 20\%$), strength reduction became significant, with RHA having the most pronounced decline. The findings indicate that an optimal replacement level of 5–10% balances strength and sustainability while minimizing negative effects on concrete performance.

CONCLUSIONS

This study confirms that Rice Husk Ash (RHA), Fly Ash, and Brick Dust can be effectively utilized as partial cement replacements in M20 grade concrete, improving its mechanical strength and sustainability. Compressive strength tests revealed that 10% RHA replacement achieved 36.30 N/mm² at 28 days, while 20% Fly Ash replacement resulted in a 3.2% strength increase at 56 days. Additionally, 15% Brick Dust replacement produced a compressive strength comparable to conventional M20 concrete. The partial replacement of cement by up to 30% not only maintained structural integrity but also reduced carbon emissions, making the concrete mix more environmentally sustainable. These results demonstrate the feasibility of incorporating RHA, Fly Ash, and Brick Dust in M20 concrete, offering a cost-effective and eco-friendly alternative for construction applications.

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