

Replacement of Cement by Waste Glass Powder and Sand by Waste Crushed Glass in Fly Ash Cement Brick

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Abstract— In accordance with Indian Standard IS 16720, this study examines the use of crushed waste glass in place of sand in fly ash cement bricks and waste glass powder as a partial alternative for cement. The study evaluates how these alterations affect important mechanical characteristics as density, water absorption, and compressive strength. Three replacement scenarios were evaluated: varying levels of cement replacement (0% to 40%), sand replacement (0% to 40%), and a combination of both in optimal proportions. The bricks, produced in standard dimensions (230 × 110 × 75 mm), were manufactured using OPC 53-grade cement with a class 15 classification. Experimental analyses identified the most effective replacement ratios, demonstrating that a well-balanced combination enhances compressive strength while maintaining water absorption within permissible limits.

Keywords— Waste Glass Powder, Waste Crushed Glass, Fly Ash Cement Brick, Sustainable Construction, Mechanical Properties.

I. INTRODUCTION

Extensive study on alternative materials made from industrial waste has resulted from the construction industry's growing emphasis on sustainability. Glass is one such waste material that contributes greatly to environmental pollution and is not biodegradable. One practical way to lessen the environmental impact of waste glass is to recycle it into building materials.

This study explores the possibility of using waste crushed glass (WCG) as a partial replacement for sand in fly ash cement bricks and waste glass powder (WGP) as a partial substitute for cement. The study intends to assess the changed bricks' mechanical qualities, such as durability, water absorption, and compressive strength, by using these waste materials.

The integration of WGP and WCG in brick production offers multiple benefits, including reduced cement consumption, minimized landfill waste, and enhanced resource efficiency. Furthermore, repurposing glass waste in construction materials aligns with the principles of the circular economy, supporting environmentally sustainable practices in the building sector. By assessing the feasibility of these modified bricks, this study contributes to the advancement of sustainable construction methods and promotes the responsible utilization of industrial byproducts in building materials.

II. METHODOLOGY

I. Materials Used

The study utilized high-quality construction materials to ensure accurate experimental outcomes. Ordinary Portland Cement (OPC) 53 grade was used as the primary binding material, while river sand served as the fine aggregate. Class F fly ash was incorporated to enhance durability and sustainability. Furthermore, waste glass powder (WGP) was gathered, cleaned, and ground into a fine powder before being utilized as a partial cement substitute. In a similar vein, waste crushed glass (WCG) was gathered and turned into fine aggregate to partially replace sand.

II. Mix Proportions

Three distinct sets of mix proportions were designed to analyze the effect of WGP and WCG on brick properties:

Set 1: WGP was substituted for some of the cement in 5% increments, ranging from 0% to 40%.

Set 2: Sand was partially replaced with WCG in 5% increments between 0% and 40%.

Set 3: Strength analysis was used to identify the optimal WGP and WCG combinations.

III. Brick Casting and Curing

Bricks measuring 230 × 110 × 75 mm were cast using the prepared mix proportions. To guarantee adequate hydration and strength development, the freshly molded bricks were then cured for 28 days. The casting and curing processes adhered strictly to the specifications of Class 15 fly ash bricks, in compliance with IS 16720 standards.

IV. Testing Procedures

The following tests were carried out to assess the bricks' performance:

(A) Compressive Strength Test:

The compressive strength test for bricks, conducted as per IS 3495:1992, assesses their load-bearing capacity. The test begins with selecting at least five bricks, making sure they are free of flaws or cracks. These bricks are then oven-dried at 105°C to 115°C for 24 hours and cooled to room temperature. To achieve uniform load distribution, a thin layer of cement paste is applied to the top and bottom surfaces and allowed to set for 24 hours. Each brick is then placed centrally between the plates of a compression testing machine, ensuring proper alignment. A gradually increasing load is applied at a rate of 14 N/mm² per minute until the brick fails, and the maximum load at failure is recorded. The compressive strength is determined using the formula $\text{Compressive Strength} = P / A$, where P is the maximum load (N) and A is the loaded surface area (mm²). The results are compared with the minimum strength requirement specified in IS 3495:1992, typically 3.5 N/mm² for common bricks. This test helps evaluate the structural suitability of bricks for construction applications.

(B) Water Absorption Test:

The water absorption test, conducted as per IS 3495:1992, evaluates the porosity and durability of bricks. Five dry bricks are selected, weighed, and recorded as W1 (dry weight) before being completely submerged in room-temperature water for a full day. After soaking, the bricks are removed, wiped to remove excess water, and immediately weighed to determine W2 (wet weight). The water absorption percentage is then calculated using the formula $(W2 - W1) / W1 \times 100$. Water absorption should not be more than 20% for regular bricks and 15% for premium bricks, under IS 3495:1992 norms. Bricks' strength and long-term performance in building may be compromised by increased water absorption, so this test aids in determining how durable they are.

(C) Density Measurement:

The density measurement test determines the mass-to-volume ratio of bricks, which influences their structural integrity and load-bearing capacity. The test involves selecting a dry brick, measuring its dimensions (length, width, and height) using a vernier caliper or a measuring scale, and calculating its volume (V) in cubic centimeters. The brick is then weighed to obtain its mass (M) in grams, and the density is computed using the formula: $\text{Density} = M / V$ (g/cm³). While lesser density could imply more porosity, which could have an impact on durability, higher density denotes superior compactness and strength. By ensuring that bricks fulfill the necessary requirements for strength and stability, this test aids in determining whether they are suitable for construction applications.

By providing crucial information regarding the feasibility of utilizing surplus glass materials in brick manufacture, these studies advanced sustainable building practices.

III. RESULTS AND DISCUSSION

I. Results for Cement Replacement by Waste Glass Powder

The results indicate that as the waste glass powder (WGP) replacement percentage increases, there is a noticeable impact on compressive strength, water absorption, and density of the bricks. The compressive strength increases from 15.2 MPa at 0% WGP to a peak of 18.0 MPa at 20% replacement, after which it slightly declines, reaching 15.5 MPa at 40% WGP. This suggests that up to 20% WGP enhances strength, but excessive replacement weakens the structure. Water absorption decreases consistently from 12.5% at 0% WGP to 10.0% at 40%, indicating improved compactness and lower porosity. The density of bricks also increases from 1900 kg/m³ at 0% to 2000 kg/m³ at 40%, showing that WGP contributes to denser and potentially more durable bricks. According to these results, replacing WGP increases strength and decreases porosity up to an ideal level of 20%, after which additional replacement may have a detrimental effect on mechanical qualities.

WGP Replacement (%)	Compressive Strength (MPa)	Water Absorption (%)	Density (kg/m ³)
0	15.2	12.5	1900
5	15.8	12.2	1915
10	16.5	11.9	1930
15	17.3	11.4	1945
20	18	11	1960
25	17.6	10.8	1975
30	16.9	10.5	1985
35	16.2	10.2	1990
40	15.5	10	2000

II. Results for Sand Replacement by Waste Crushed Glass

The findings show that increasing the replacement of waste crushed glass (WCG) has a substantial impact on the bricks' density, water absorption, and compressive strength. At 0% WCG, the compressive strength is 15.2 MPa; at 20% replacement, it peaks at 18.2 MPa, after which it gradually declines to 15.6 MPa at 40% WCG. This implies that WCG increases strength up to a certain point, after which more addition could make the bricks weaker. Water absorption decreases consistently, from 12.5% at 0% WCG to 9.5% at 40%, indicating improved density and reduced porosity. The density of the bricks increases from 1900 kg/m³ at 0% to 2005 kg/m³ at 40%, demonstrating that WCG contributes to the compactness and weight of the bricks. According to these results, adding WCG up to 20% improves strength and durability, however replacing too much could lower compressive strength while increasing density and water resistance.

WCG Replacement (%)	Compressive Strength (MPa)	Water Absorption (%)	Density (kg/m ³)
0	15.2	12.5	1900
5	15.9	12	1910
10	16.7	11.6	1925
15	17.5	11.2	1940
20	18.2	10.8	1955
25	17.8	10.4	1970
30	17	10	1985
35	16.3	9.7	1995
40	15.6	9.5	2005

III. Results for Combined Cement and Sand Replacement

The results indicate that the combined replacement of waste glass powder (WGP) and waste crushed glass (WCG) influences the compressive strength, water absorption, and density of the bricks. The compressive strength increases from 16.8 MPa at 10% WGP and 10% WCG to a peak of 18.3 MPa at 20% replacement of both materials, after which it declines to 15.9 MPa at 40% replacement. This suggests that a 20% replacement level provides the optimal strength, beyond which further substitution may weaken the bricks. Water absorption decreases consistently, from 11.8% at 10% replacement to 9.2% at 40%, indicating improved compactness and reduced porosity. Additionally, density increases from 1925 kg/m³ at 10% replacement to 2000 kg/m³ at 40%, suggesting that higher replacement levels result in denser bricks. According to these results, adding WGP and WCG up to 20% improves strength and durability; higher replacements increase density and water resistance but may marginally lower compressive strength.

WGP (%)	WCG (%)	Compressive Strength (MPa)	Water Absorption (%)	Density (kg/m ³)
10	10	16.8	11.8	1925
20	20	18.3	10.6	1950
30	30	17.1	9.9	1980
40	40	15.9	9.2	2000

From the results, it is observed that 20% replacement of both cement and sand provides the highest compressive strength and acceptable water absorption.

IV. CONCLUSION

The study concludes that replacing cement with waste glass powder and sand with waste crushed glass in fly ash cement bricks enhances the strength and sustainability of bricks. The optimal replacement level is 20% for both cement and sand. Further studies can be conducted to assess long-term durability and environmental impact.

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