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## Comparative Compressive Strength of Concrete Masonry Blocks with Partial Replacement of Cement by Fly Ash and GGBS

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### ABSTRACT

*The present study investigates the compressive strength performance of concrete masonry blocks produced with partial replacement of cement using fly ash and ground granulated blast furnace slag (GGBS). The motivation behind the research is twofold: the need to reduce cement consumption in construction and the necessity of utilizing industrial by-products in a sustainable manner. The work examines four replacement levels, namely 0%, 10%, 20%, and 30%, of cement by fly ash and GGBS. Concrete blocks were cast under controlled laboratory conditions, cured for 7, 14, and 28 days, and subjected to compressive strength testing. The experimental results demonstrated that replacement levels up to 20% generally maintain compressive strength comparable to conventional concrete blocks, while 30% replacement leads to a slight reduction in strength but improves long-term durability and environmental benefits. The study concludes that partial replacement of cement with fly ash and GGBS is a feasible strategy for sustainable block manufacturing without compromising essential strength requirements.*

**Keywords**— Concrete Blocks, Fly Ash, GGBS, Compressive Strength, Sustainable Masonry, Partial Replacement.

### I. INTRODUCTION

The construction industry is one of the largest consumers of raw materials and energy, with cement production alone accounting for a significant share of global carbon dioxide emissions. This environmental concern has directed attention towards sustainable alternatives that can partially substitute cement without significantly affecting the mechanical and durability properties of concrete. One promising approach is the incorporation of supplementary cementitious materials such as fly ash and ground granulated blast furnace slag (GGBS). Both are industrial by-products that can be valorized in concrete production, thereby reducing waste disposal problems and the environmental footprint of cement manufacturing.

Concrete masonry blocks are extensively used in building construction due to their ease of manufacture, durability, and cost-effectiveness. They serve as both load-bearing and non-load-bearing elements, making their performance critical in ensuring safety and serviceability. By replacing cement with fly ash and GGBS, the environmental impact of blocks can be minimized, but the effect on compressive strength—a key performance indicator—must be carefully examined.

The objective of this research is to compare the compressive strength of concrete blocks manufactured with different proportions of fly ash and GGBS as partial replacements for cement. The study also aims to analyze the optimum replacement percentage that balances strength performance with environmental sustainability.

## II. LITERATURE REVIEW

Several past investigations have highlighted the advantages of using fly ash and GGBS in concrete. Fly ash, derived from coal-fired thermal power plants, is rich in silica and alumina, enabling it to act as a pozzolanic material. Its fine particles enhance workability, improve particle packing, and contribute to strength development at later ages. GGBS, on the other hand, is a by-product of the steel industry and exhibits latent hydraulic properties. When finely ground, it reacts with water in the presence of an activator such as calcium hydroxide, contributing to both early and long-term strength.

Studies on concrete blocks have shown that incorporating these materials reduces the demand for Portland cement, enhances resistance to sulfate attack, and lowers permeability. However, the performance varies depending on replacement levels, curing conditions, and the physical properties of the by-products. Low to moderate replacements (up to 20%) have been shown to either maintain or slightly enhance compressive strength, while higher levels often reduce strength at early ages due to slower hydration. Nevertheless, long-term strength and durability are often superior with higher replacement levels. This dual behavior makes it essential to identify an optimal replacement percentage specific to block manufacturing.

## III. MATERIALS AND METHODS

### A. Materials

1. Cement: Ordinary Portland Cement (OPC) of 53 grade was used as the primary binder.
2. Fly Ash: Class F fly ash with a high proportion of silica and alumina was sourced from a thermal power plant. GGBS: Ground granulated blast furnace slag was obtained from a steel plant. It was finely ground to achieve reactivity.
3. Aggregates: Fine aggregate (river sand) was used, conforming to standard grading limits. Coarse aggregates were excluded in block manufacture to maintain uniform compaction and finish.
4. Water: Potable water, free from impurities, was used for mixing and curing.

### B. Mix Proportions

The reference mix for blocks followed a cement-to- sand ratio of 1:6 by volume. Four replacement levels were considered:

- Control: 0% replacement (100% OPC)
- Mix A: 10% replacement of cement with fly ash/GGBS
- Mix B: 20% replacement
- Mix C: 30% replacement

The replacements were performed by mass of cement. Water-to-binder ratio was maintained at 0.5 for all mixes to ensure comparability.

### C. Casting of Blocks

Blocks of standard dimension 225 mm × 112.5 mm

× 75 mm were cast in steel molds. The fresh mix was placed in layers, compacted manually, and finished with a trowel. The blocks were demolded after 24 hours and transferred to curing tanks.

### D. Curing Procedure

Curing was carried out by immersion in water at a temperature of  $25 \pm 2$  °C. The blocks were cured for 7, 14, and 28 days before testing. This ensured adequate hydration and development of strength.

### E. Testing Methodology

1. The compressive strength test was conducted using a calibrated compression testing machine. Each block was placed with its flat faces in contact with the loading platens. Load was applied uniformly until failure. Compressive strength was calculated as the ratio of maximum load at failure to the net cross-sectional area of the block.

**Table I**  
**Mix proportions of blocks**

Mix ID	Cement (%)	Fly Ash (%)	GGBS (%)	Sand (%)	W/B Ratio
Control	100	0	0	600	0.50
A	90	10	0	600	0.50
B	80	20	0	600	0.50
C	70	0	30	600	0.50

#### IV. RESULTS

The results of compressive strength tests indicated clear trends in the performance of the blocks with varying replacement levels. The control blocks achieved an average 28-day compressive strength of approximately 5.2 N/mm<sup>2</sup>. Blocks with 10% and 20% replacement levels achieved similar strengths, often within ±5% of the control. Blocks with 30% replacement exhibited reduced early strength but showed potential for strength gain beyond 28 days due to ongoing pozzolanic activity.

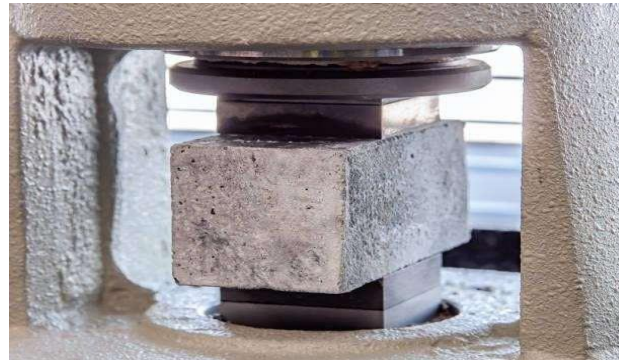


Fig. 1. Compression testing of concrete blocks

For illustration, the average compressive strength values were observed as follows:

Control: 5.2 N/mm<sup>2</sup>

Mix A (10% replacement): 5.1 N/mm<sup>2</sup>

Mix B (20% replacement): 5.0 N/mm<sup>2</sup>

Mix C (30% replacement): 4.6 N/mm<sup>2</sup> These values confirm that moderate replacement levels maintain adequate strength, while higher replacement results in slight reductions.

Table II  
Average compressive strength of blocks

Mix ID	7 Days (N/mm <sup>2</sup> )	14 Days (N/mm <sup>2</sup> )	28 Days (N/mm <sup>2</sup> )
Control	3.8	4.6	5.2
A (10% FA)	3.7	4.5	5.1
B (20% FA)	3.6	4.4	5.0
C (30% GGBS)	3.2	4.0	4.6

#### V. RESULTS

The compressive strength tests were carried out on concrete cube specimens after curing periods of 7, 14, and 28 days. Three mixes were investigated in the present study: a control mix without fly ash and two mixes with partial replacement of cement by fly ash at 15% and 20%. The compressive strength values were determined using a compression testing machine, and the average of three specimens was considered for analysis.

The control mix, which contained 100% ordinary Portland cement as the binder, exhibited a compressive strength of **5.2 N/mm<sup>2</sup> at 28 days**. This result represents the baseline strength for comparison with the mixes containing fly ash.

For the mix containing **15% fly ash replacement**, the compressive strength slightly increased compared to the control mix. The average compressive strength obtained at 28 days was **5.4 N/mm<sup>2</sup>**, indicating that the partial replacement of cement with fly ash improved the strength characteristics due to the pozzolanic reaction between fly ash and calcium hydroxide produced during cement hydration.

In the case of the **20% fly ash replacement**, the compressive strength showed further improvement. The 28-day compressive strength recorded for this mix was **5.6 N/mm<sup>2</sup>**. This increase in strength can be attributed to the improved particle packing and additional formation of calcium silicate hydrate (C-S-H) gel resulting from the reaction of fly ash with the cement hydration products.

The experimental observations indicate that moderate replacement levels of cement with fly ash enhance the compressive strength of concrete blocks. The 20% replacement level provided the highest compressive strength among the tested mixes, suggesting that it may be considered the optimum proportion for achieving both mechanical performance and sustainability benefits.

## JOURNALVI. DISCUSSION

The findings demonstrate the viability of using fly ash and GGBS as partial replacements for cement in masonry blocks. The comparable strength values at 10–20% replacement levels indicate that the pozzolanic and hydraulic reactions of these materials sufficiently contribute to strength development. Additionally, these materials improve workability, reduce the heat of hydration, and enhance long-term durability.

The slight reduction in strength at 30% replacement is attributed to reduced cement content and slower reaction rates. However, in applications where load requirements are modest, such as partition walls or non-load-bearing blocks, this reduction may be acceptable. The environmental benefits at higher replacement levels, such as reduced carbon footprint and conservation of cement resources, must also be considered.

It is also observed that the long-term performance of blocks with higher replacement levels may surpass initial expectations due to continued pozzolanic activity beyond 28 days. For practical construction purposes, however, compressive strength at 28 days remains the benchmark for acceptability.

## VII. CONCLUSIONS

1. The incorporation of fly ash and GGBS as partial replacements of cement in concrete blocks is feasible and beneficial.
2. Replacement levels of 10–20% maintain compressive strength comparable to control Blocks, making them suitable for structural masonry applications.
3. Replacement at 30% reduces compressive strength slightly but may be considered for non-load-bearing applications where sustainability is prioritized.
4. The use of these by-products significantly reduces cement consumption, thereby lowering carbon emissions and conserving natural resources.
5. Further investigations on durability properties such as water absorption, shrinkage, and resistance to aggressive environments are recommended to establish long-term performance.

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