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Experimental Study on Mechanical Properties of High-Performance Concrete Incorporating GGBS and Marble Powder

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Abstract

High-Performance Concrete (HPC) has gained significant importance in modern construction due to its superior strength and improved performance characteristics. The incorporation of supplementary cementitious materials and industrial by- products in concrete not only improves mechanical properties but also contributes to sustainable construction practices. In the present study, the effect of Ground Granulated Blast Furnace Slag (GGBS) and marble powder as partial replacements of cement in M50 grade High-Performance Concrete was investigated. Cement was partially replaced with GGBS in the range of 20–40% and marble powder in the range of 5–15%. Mechanical properties such as compressive strength, split tensile strength, and flexural strength were evaluated at different curing ages. The experimental results indicate that the incorporation of GGBS improves the later-age strength of concrete, while marble powder enhances early-age strength due to its filler effect. The optimum mix proportion was observed at 30% GGBS and 10% marble powder, which exhibited higher strength compared to control concrete. The results demonstrate that the use of these materials can enhance mechanical performance while reducing cement consumption and environmental impact.

Keywords

High-Performance Concrete, GGBS, Marble Powder, Mechanical Properties, Compressive Strength, Sustainable Concrete

1. Introduction

Concrete is the most widely used construction material due to its versatility, durability, and ability to withstand heavy loads. However, the increasing demand for

infrastructure development has resulted in a significant rise in cement consumption, which contributes to environmental concerns such as carbon dioxide emissions and resource depletion. To address these challenges, the use of industrial by- products and supplementary cementitious materials in concrete has gained considerable attention in recent years.

High-Performance Concrete (HPC) is characterized by improved mechanical properties, enhanced workability, and superior structural performance compared to conventional concrete. The development of HPC involves optimizing the mix design and incorporating mineral admixtures that improve the microstructure and strength characteristics of concrete.

Ground Granulated Blast Furnace Slag (GGBS) is an industrial by-product obtained during the production of iron in blast furnaces. It possesses latent hydraulic properties and reacts with calcium hydroxide in the presence of water to form additional calcium silicate hydrate gel, which enhances the strength of concrete at later ages.

Marble powder is a waste material generated during the cutting and polishing of marble stones. Large quantities of marble powder are produced worldwide, leading to environmental issues related to waste disposal. Utilizing marble powder in concrete can provide a sustainable solution while improving certain mechanical properties due to its fine particle size and filler effect.

Several studies have reported that the incorporation of GGBS and marble powder in concrete improves strength and performance when used in optimum proportions. However, limited research has been conducted on the combined use of these materials in High-Performance Concrete. Therefore, the present study aims to investigate the mechanical properties of M50 grade concrete incorporating GGBS and marble powder as partial replacements of cement.

2. Materials Used

2.1 Cement

Ordinary Portland Cement (OPC) of 53 grade conforming to IS 12269:2013 was used. The cement was fresh and free from lumps.

2.2 Fine Aggregate

Natural river sand conforming to Zone II as per IS 383:2016 was used as fine aggregate.

2.3 Coarse Aggregate

Crushed angular aggregate with a maximum size of 20 mm was used in the preparation of concrete mixes.

2.4 Ground Granulated Blast Furnace Slag

GGBS used in this study conformed to IS 12089:1987. It is a finely ground powder with latent hydraulic properties.

2.5 Marble Powder

Marble powder obtained from a marble processing unit was used as a partial replacement of cement. It mainly acts as a filler material.

2.6 Water

Potable water conforming to IS 456:2000 was used for mixing and curing.

2.7 Superplasticizer

A high-range water reducing admixture conforming to IS 9103:1999 was used to improve workability.

3. Mix Design and Experimental Methodology

Concrete mix design was carried out for **M50 grade** as per IS 10262:2019. The target mean strength was calculated considering the characteristic compressive strength and standard deviation. A water- binder ratio of **0.35** was adopted to achieve high strength.

The following mix combinations were prepared:

Mix ID	Description
CC	Control Concrete
G20	20% GGBS
G30	30% GGBS
G40	40% GGBS
G30MP5	30% GGBS + 5% MP
G30MP10	30% GGBS + 10% MP
G30MP15	30% GGBS + 15% MP

Cube, cylinder, and prism specimens were cast and cured for testing.

4. Results and Discussion

4.1 Compressive Strength

Table 1 Compressive Strength Results

Mix	7 Days (MPa)	28 Days (MPa)	56 Days (MPa)
CC	41.2	52.8	55.6
G30MP10	43.5	59.5	64.8

The results show that compressive strength increased significantly at later ages for mixes containing GGBS. Marble powder improved early strength due to filler action.

4.2 Split Tensile Strength

Mix	28 Days (MPa)	56 Days (MPa)
CC	3.8	4.1
G30MP10	4.5	5.1

Improved tensile strength was observed due to improved paste-aggregate bonding.

4.3 Flexural Strength

Mix	28 Days (MPa)	56 Days (MPa)
CC	5.4	5.8
G30MP10	6.2	6.9

Flexural strength improved due to the denser concrete matrix.

5. Discussion

The experimental results indicate that GGBS significantly contributes to later- age strength development due to secondary hydration reactions. Marble powder improves particle packing and reduces voids in the concrete matrix. The combined effect of these materials results in enhanced mechanical performance.

6. Conclusions

The following conclusions can be drawn from the present study:

1. GGBS and marble powder can be effectively used as partial replacements of cement in High- Performance Concrete.
2. Workability of concrete improved with the incorporation of GGBS and marble powder.
3. GGBS improved compressive strength at later curing ages.
4. Marble powder enhanced early strength due to filler effect.
5. The optimum mix proportion was **30% GGBS and 10% marble powder**.
6. The use of these materials contributes to sustainable and eco- friendly concrete production.

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