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Partial Replacement of Cement by GGBS along with the Nylon Fibrein Fibre Reinforced Concrete

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Abstract: *The increasing demand for sustainable and durable construction materials has led to significant interest in using industrial by-products and fibre reinforcement in concrete. This project focuses on the partial replacement of cement by Ground Granulated Blast Furnace Slag (GGBS) along with the addition of nylon fibres in fibre-reinforced concrete (FRC) to improve its mechanical and durability properties.*

In this study, cement is partially replaced with GGBS at varying percentages (10%, 20%, and 30%) while maintaining a constant water–cement ratio. Nylon fibres are incorporated in different proportions by weight of concrete to enhance tensile strength and crack resistance. The concrete mixes are tested for compressive strength, split tensile strength, and flexural strength at various curing periods (7, 14, and 28 days).

Keywords: *GGBS*

I. INTRODUCTION

Fibre Reinforced Concrete (FRC) is a composite material consisting of concrete reinforced with discrete, randomly distributed fibres. The primary role of the fibres is to bridge across the cracks that develop in the concrete, thereby providing post-cracking ductility and improving toughness. While various fibres (e.g., glass, synthetic, natural) are used, steel fibres are most common for structural applications requiring significant enhancement in tensile and flexural strength.

This project aims to explore the combined effect of GGBS (Ground Granulated Blast Furnace Slag) and nylon fibres on the mechanical and durability characteristics of fibre-reinforced concrete. The study focuses on identifying the optimal percentage of cement replacement with GGBS and the suitable dosage of nylon fibres to achieve improved performance in concrete.

II. OBJECTIVES

- To study the effect of partial replacement of cement with GGBS on the mechanical properties of concrete such as compressive strength, tensile strength, and flexural strength.
- To evaluate the performance of nylon fibre in improving the tensile and crack resistance characteristics of concrete.
- To determine the optimum percentage of GGBS replacement and nylon fibre content that yields the best combination of strength and workability.
- To compare the mechanical properties of modified concrete (with GGBS and nylon fibre) with those of conventional concrete..

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III. METHODOLOGY

- Understanding the Problem & Research Void
- Literature Review & Determination of Research Approach
- Procurement of Materials & Preliminary Material Testing
- Design of Trial Mix Proportions
- Casting of Specimens
- Curing of Specimens
- Testing of Hardeded Concrete
- Analysis of Results & Determination of Optimum Mix
- Interpretation & Conclusion

IV.MATERIALS

Cement

Cement is the primary binding material used in concrete, commonly in the form of Ordinary Portland Cement (OPC). It reacts with water to form a hard matrix that binds aggregates together and provides strength.

GGBS

GGBS stands for Ground Granulated Blast Furnace Slag — a by-product of iron manufacturing used to make concrete stronger, more durable, and more environmentally friendly more environmentally friendly.

Nylon Fibre

Nylon fibers are synthetic fibers made from polyamides, known for their strength, elasticity, and resistance to wear and moisture.

Coarse aggregate

Coarse aggregate consists of crushed stones retained on 4.75 mm sieve. It provides strength and bulk to concrete.

Supperplasticizer

Superplasticizers are chemical admixtures that improve workability without increasing water content, enabling high-performance concrete.

V. MIX DESIGN

At present, there are several scientific methods available for proportioning the materials to achieve the desired strength of concrete. However, it is difficult to select a single best method, as most methods require trial adjustments at the final stage. The main objective of mix design is to achieve the required strength and durability while minimizing the cement content as much as possible without compromising performance.

The grade of concrete adopted for this project is M30, and all comparisons are made with the conventional M30 mix. The mix design calculations were carried out as per IS 10262:2019. In this study, cement is partially replaced with Nylon fibres are added to improve the mechanical properties of concrete.

Tests are conducted by maintaining a constant target strength of 30 MPa (N/mm²) for all mixes. The properties of concrete vary based on the percentage of GGBS and Nylon Fibre Added

Control Mix

M1: 0% replacement.
M2: 15% GGBS+ 0.5% Nylon Fibre.
M3: 20% GGBS + 1% Nylon Fibre
M4: 15% GGBS + 1.5% Nylon Fibre

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The performance of concrete is evaluated based on compressive strength, tensile strength, flexural strength, workability, and durability. The study helps in identifying the optimum mix for better strength and sustainability.

VI. FRESH CONCRETE PROPERTIES

SLUMP CONE TEST

Fresh concrete properties were evaluated using the slump cone test and compaction factor test to determine the workability of fibre reinforced concrete containing GGBS and Nylon Fibre. The slump test was conducted to measure the consistency of fresh concrete. Workability refers to the ease with which concrete can be mixed, placed, compacted, and finished without segregation or bleeding. In this study, the addition of steel fibres reduced the slump value due to increased internal resistance, while fly ash improved workability because of its spherical particle shape. The slump value obtained indicates the suitability of the mix for different construction applications.

COMPACTION FACTOR TEST

The compaction factor test was performed to assess the workability of concrete mixes with low consistency. This test is more precise and sensitive compared to the slump test, especially for fibre reinforced concrete. The compaction factor is defined as the ratio of the weight of partially compacted concrete to that of fully compacted concrete. The presence of Nylon reduces workability, making compaction more difficult, which is effectively captured in this test. The results help in identifying variations in workability among different mixes and in selecting the optimum mix for better performance and durability.

VII. HARDENED CONCRETE PROPERTIES

COMPRESSIVE STRENGTH TEST

The compressive strength test was conducted to evaluate the strength characteristics of concrete containing fly ash, silica fume, and steel fibres. Concrete was mixed in required proportions, placed into cube moulds, and compacted properly to eliminate voids. After 24 hours, the specimens were demoulded and cured in water for 7 and 28 days. The specimens were then tested using a compression testing machine (CTM), where load was applied gradually until failure occurred. The compressive strength was calculated by dividing the ultimate load by the cross-sectional area of the specimen. The failure pattern observed was typically of hourglass type due to lateral restraint provided by the testing machine, and the results indicate the improvement in strength due to the presence of mineral admixtures and Nylon fibres.

SPLIT TENSILE STRENGTH TEST

The split tensile strength test was performed to determine the tensile behaviour of concrete, which is generally weak in tension. Cylindrical specimens were cast, cured, and tested after 28 days by applying a diametrical compressive load along the length of the specimen. This induces tensile stresses perpendicular to the applied load, causing the specimen to fail in tension. The splitting tensile strength was calculated using the standard formula based on maximum load and specimen dimensions. The inclusion of steel fibres enhances the tensile strength by bridging cracks and delaying failure, while GGBS contributr to improved bonding and microstructure. The test results help in understanding the ductility and crack resistance of fibre reinforced concrete.

VIII. RESULT

SLUMP CONE TEST

Mix	Slump Value (mm)	Workability
M1 (Control)	85	Medium
M2	95	Medium-High
M3	80	Medium

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M4	70	Low

COMPACTION FACTOR TEST

Mix	Compaction Factor	Workability
M1 (Control)	0.90	Medium
M2	0.92	Medium-High
M3	0.88	Medium
M4	0.85	Low

HARDENED CONCRETE PROPERTIES

The hardened concrete properties of fibre reinforced concrete containing GGBS and Nylon FIbre were evaluated through compressive strength and split tensile strength tests. These tests were carried out to determine the mechanical performance and strength characteristics of the developed concrete mixes. The results were compared with the conventional M30 grade concrete to assess the improvement in properties due to the addition of mineral admixtures and Nylon fibres

COMPRESSIVE STRENGTH TEST

The compressive strength test was conducted on cube specimens after 7 and 28 days of curing using a Compression Testing Machine (CTM). As per Bureau of Indian Standards guidelines (IS 456:2000 and IS 516:1959), the compressive strength of M30 grade concrete should not be less than 30 N/mm².

SPLIT TENSILE STRENGTH TEST

The split tensile strength test was carried out on cylindrical specimens after 28 days of curing. According to IS 456:2000 and IS 5816:1999, the split tensile strength of concrete should be approximately 1/10 of the characteristic compressive strength (fck). The inclusion of steel fibres enhances tensile strength and crack resistance, while fly ash and silica fume improve the overall strength and durability of concrete.

IX. CONCLUSION

The use GGBS as partial replacement of cement, along with the inclusion of Nylon fibres, contributes to the development of sustainable and high-performance concrete. This approach helps in reducing cement consumption, thereby lowering environmental impact and promoting greener construction practices. Based on the experimental investigation carried out in this study, the following conclusions are drawn:

The properties of all materials used, including cement, GGBS and Nylon were found to be satisfactory as per relevant standards.

The use GGBS as partial replacement of cement, along with the inclusion of Nylon fibres,, resulted in an improvement in compressive strength and split tensile strength compared to conventional concrete.

The optimum mix proportion was observed at 15% GGBS+ 1.5% Nylon l Fibres, which showed better overall performance.

The maximum compressive strength and split tensile strength were achieved at 28 days for the optimum mix, indicating enhanced mechanical properties due to the combined effect of pozzolanic materials and fibre reinforcement.

The addition of steel fibres significantly improved crack resistance, ductility, and tensile behaviour of concrete.

Based on the results, it is concluded that the developed fibre reinforced concrete with mineral admixtures can be effectively used in structural applications, providing improved strength, durability, and sustainability compared to conventional concrete.

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