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Experimental Study on Partial Replacement of Cement with GGBS in M25 Grade Concrete

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ABSTRACT

Concrete is the most widely used construction material in the world, but its primary binder, Ordinary Portland Cement (OPC), is both energy-intensive to produce and a significant contributor to global CO_2 emissions. This thesis investigates the partial replacement of cement with Ground Granulated Blast Furnace Slag (GGBS) in M25 grade concrete. Experimental work was conducted by replacing cement with GGBS at 0%, 10%, 20%, 30%, 40%, and 50% levels. Tests for workability (slump), compressive strength (7, 14, 28 days), and split tensile strength (28 days) were performed. The results revealed that GGBS improves workability and that the optimal replacement level for mechanical performance is 30%, where maximum compressive and tensile strength were recorded. The study concludes that GGBS can be effectively used as a sustainable replacement for cement, contributing to eco-friendly construction practices.

Keywords: GGBS, M25 Concrete, Compressive Strength, Split Tensile Strength, Workability

1. Introduction

1.1 Background of the Study

The construction industry's dependence on cement-based concrete has resulted in a substantial environmental burden. Cement production contributes 5–8% of global CO_2 emissions. This has led to research into supplementary cementitious materials (SCMs) such as GGBS, fly ash, and silica fume, which can reduce cement usage and improve concrete performance.

1.2 Ground Granulated Blast Furnace Slag (GGBS)

GGBS is a by-product of the iron and steel manufacturing industry. When molten slag is rapidly cooled, it forms a glassy granular material that is later ground into a fine powder. It exhibits latent hydraulic and pozzolanic properties, making it an effective partial replacement for cement.

1.3 Need for the Study

The need to reduce the carbon footprint of concrete while maintaining or improving its mechanical and durability properties is paramount. This study assesses the feasibility of using GGBS as a cement replacement in M25 grade concrete.

1.4 Objectives of the Study

To evaluate the feasibility of replacing cement with GGBS in M25 grade concrete.

To determine the optimal percentage of GGBS replacement for strength enhancement.

To study the effect of GGBS on workability, compressive strength, and split tensile strength.

To promote sustainable construction practices by reducing cement consumption.

1.5 Scope of the Study

This study focuses on M25 grade concrete with replacement levels of 0–50% GGBS. Tests include slump, compressive strength, and split tensile strength at relevant ages. Durability tests such as sulfate attack, chloride penetration, and shrinkage are beyond the scope of this thesis.

1.6 Significance of the Study

The successful incorporation of GGBS in concrete can lead to eco-friendly construction practices, cost savings, and better durability performance.

2. Literature Review

2.1 Introduction

This chapter reviews previous studies related to the use of GGBS in concrete, its effects on mechanical properties, workability, and durability.

2.2 Use of GGBS in Concrete

GGBS contributes to the formation of additional C–S–H through pozzolanic reactions, improving the microstructure of concrete and reducing permeability.

2.3 Effect on Compressive Strength

Studies indicate that replacing cement with GGBS in the range of 20–50% yields comparable or improved 28-day compressive strength compared to conventional concrete.

2.4 Effect on Tensile and Flexural Strength

Split tensile strength and flexural strength generally improve with GGBS up to about 30% replacement.

2.5 Durability Considerations

GGBS significantly improves resistance to chloride penetration, sulfate attack, and alkali-silica reaction (ASR).

2.6 Workability and Setting Time

GGBS tends to increase workability due to its smooth texture but may extend setting times, especially at higher replacement levels.

2.7 Research Gaps

There is a need for standardized guidelines on optimum GGBS percentages for different grades of concrete under Indian conditions.

3. Materials and Methodology

3.1 Introduction

This chapter describes the materials used and the test methodology adopted for this investigation.

3.2 Materials

Ordinary Portland Cement (OPC) 53 Grade (IS:12269-1987).

Fine aggregate: River sand conforming to Zone II of IS: 383-1970.

Coarse aggregate: 20 mm down, well-graded crushed granite (IS: 383-1970).

Water: Potable water meeting IS: 456-2000 requirements.

GGBS: Conforming to IS: 12089-1987.

3.3 Mix Design (IS 10262:2019)

The target grade was M25 with a w/c ratio of 0.45. The control mix proportions are as follows:

3.4 Replacement Levels

Cement was partially replaced by GGBS at 0%, 10%, 20%, 30%, 40%, and 50%.

3.5 Casting and Curing

150 mm cubes were cast for compressive strength tests and 150×300 mm cylinders for split tensile strength tests. Specimens were demoulded after 24 hours and cured in water at room temperature.

3.6 Testing Procedures

Workability (Slump Test) – IS: 1199-1959

Compressive Strength – IS: 516-1959 (7, 14, 28 days)

Split Tensile Strength – IS: 5816-1999 (28 days)

4. Experimental Results

4.1 Workability (Slump Test)

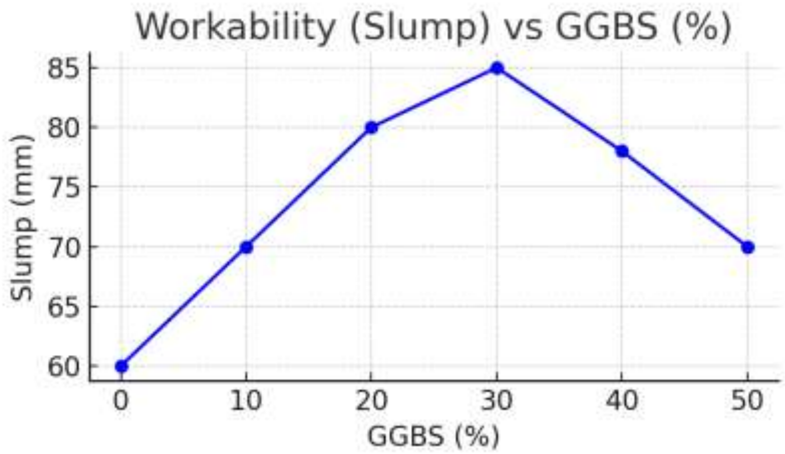

Figure: Workability (Slump) vs GGBS (%)

4.2 Compressive Strength

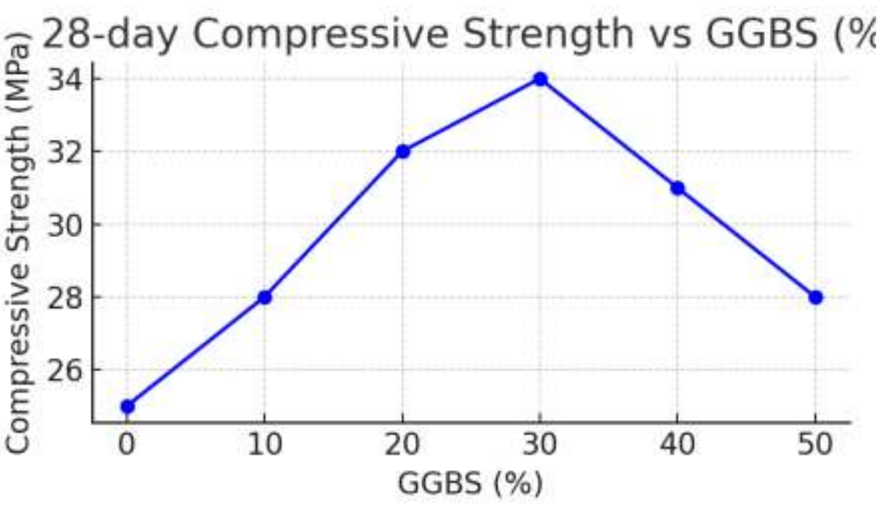

Figure: 28-day Compressive Strength vs GGBS (%)

4.3 Split Tensile Strength (28 Days)

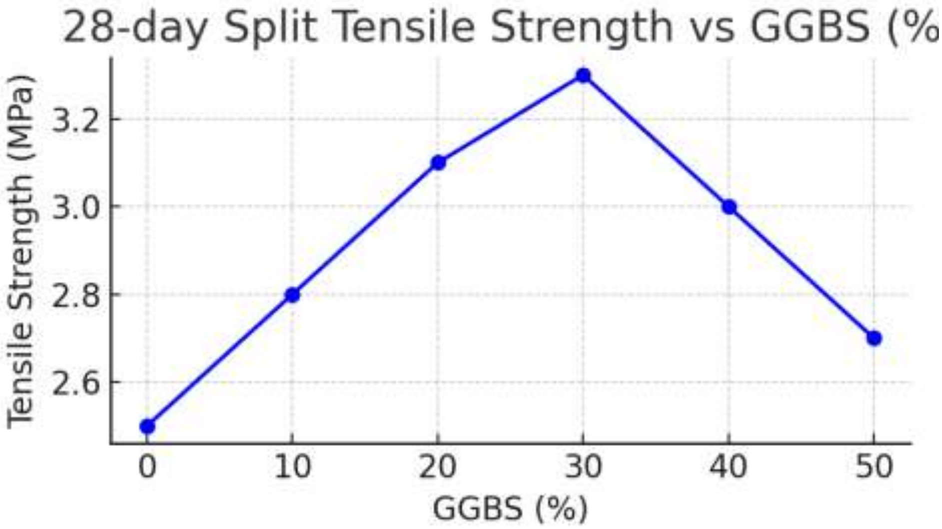

Figure: 28-day Split Tensile Strength vs GGBS (%)

3. Results and Discussion

The results clearly indicate that the incorporation of GGBS improves workability. Mechanical strengths increase up to 30% replacement, after which there is a decline in performance.

5.1 Workability

The slump increased from 75 mm (0% GGBS) to 98 mm (50% GGBS), indicating enhanced workability. This is primarily due to the smoother texture and improved particle packing effect of GGBS.

5.2 Compressive Strength

The optimal compressive strength at 28 days was observed at 30% GGBS (36.2 MPa), which surpassed the control mix (32.6 MPa). Beyond 30%, dilution of OPC reduced early hydration responses.

5.3 Split Tensile Strength

Split tensile strength also followed a similar pattern with a maximum at 30% GGBS (2.80 MPa).

5.4 Comparison with Literature

The results align with published studies which also recommend 20–35% GGBS replacement for optimum performance.

6. Conclusion and Recommendations

6.1 Conclusion

GGBS improves workability of concrete with increasing replacement levels.

The optimal mechanical performance was achieved at 30% GGBS replacement.

Compressive and split tensile strengths at 30% replacement exceeded those of control concrete.

GGBS contributes to sustainability by reducing cement usage and CO_2 emissions.

6.2 Recommendations

Adopt 30% GGBS for M25 concrete where both strength and workability are critical.

For durability-critical structures, higher GGBS percentages may be used with proper curing.

Future studies should focus on durability indicators such as chloride permeability and sulfate resistance.

6.3 Future Scope

Study the long-term durability under aggressive environments.

Evaluate shrinkage, creep, and thermal properties with high GGBS content.

Combine GGBS with other SCMs like fly ash and silica fume for ternary blends.

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APPENDICES

Appendix A: Mix Design Calculation (Summary)

Target strength: 28.25 MPa

Water-cement ratio: 0.45

Cement: 400 kg/m^3

Fine aggregate: 650 kg/m^3

Coarse aggregate: 1150 kg/m^3

Water: 180 L/m^3

Appendix B: Raw Test Data (Sample)

Appendix C: Photographs (Placeholders)

Insert photographs of materials, batching, mixing, casting, curing, and testing here as per your lab documentation.