Optimization of GGBS Content for Sustainable Concrete Application: Experimental Findings

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Abstract

The construction industry significantly impacts the environment due to the high carbon footprint of cement production. Ground Granulated Blast Furnace Slag (GGBS) is a sustainable alternative that partially replaces cement in concrete. This study investigates the effects of high GGBS replacement levels (75%, 80%, and 85%) on concrete's mechanical properties. Results indicate that high GGBS replacement hinders strength development, failing to achieve target strength within 56 days. The findings highlight the need for optimized GGBS levels to balance sustainability with structural integrity. Future research should focus on determining optimal replacement percentages and extending curing durations.

Introduction

The construction industry is a major contributor to CO2 emissions, with cement production being a primary factor. Cement manufacturing releases large amounts of carbon dioxide, exacerbating climate change. As global efforts toward sustainability increase, finding alternatives to conventional cement is crucial.

GGBS, a byproduct of the iron and steel industry, offers a sustainable solution by partially replacing cement in concrete. It helps reduce CO2 emissions while enhancing durability and long-term performance. Incorporating GGBS into construction aligns with environmental sustainability goals, making it a promising alternative for greener infrastructure.

This study examines the impact of different GGBS proportions on concrete strength and workability, contributing to the optimization of mix designs that balance sustainability with performance.

Design/Other information

Concrete Mix Design:

- The M40 grade mix design followed IS 10262:2009 standards.
- The optimal mix design was determined to achieve desired workability and strength.
- Proportions were adjusted to assess the impact of GGBS on the water-to-binder ratio.

Testing Methods:

- **Slump Test:** Conducted to evaluate workability.
- **Compressive Strength Test:** Cubes were tested at various curing periods (7, 28, and 56 days).
- **Microstructural Analysis:** Examined to assess hydration and porosity changes.

GGBS Sourcing:

- The GGBS used in this study was obtained from JSW Steel, Bengaluru.
- Chemical and physical properties were analyzed to ensure quality consistency.

Environmental Impact:

- GGBS reduces cement demand, lowering CO_2 emissions significantly.
- Using GGBS in concrete enhances sustainability by utilizing industrial byproducts.
- Optimizing GGBS content can contribute to reducing construction-related pollution.

Set up

Materials Used:

- **Cement:** Ordinary Portland Cement (OPC) 53 grade
- **Coarse Aggregate:** 20mm and 12mm well-graded aggregates
- **Fine Aggregate:** M-sand, Grade II
- **Water:** Locally available potable water
- **GGBS:** Sourced from JSW Steel, Bengaluru

Mix Design:

- Concrete mix formulated for M40 grade as per IS 10262:2009
- Three replacement levels tested: 75%, 80%, and 85% GGBS
- Workability measured through slump tests

Results

- **Strength Development:**
  - High GGBS levels (75%-85%) delayed strength gain beyond 56 days.
  - Early-age strength was significantly lower compared to conventional concrete.
  - 85% GGBS exhibited the highest retardation in strength development.
  - This suggests that while GGBS has cementitious properties, its strength gain is more gradual, requiring longer curing times to reach desired structural performance.
  - The slow strength development can be attributed to the lower calcium silicate hydrate formation, which plays a critical role in concrete strength.
- **Water-to-Binder Ratio Impact:**
  - Increased GGBS content altered water-to-cementitious ratio, affecting hydration.
  - Higher ratios disrupted strength gain, requiring extended curing periods.
  - The increased replacement of cement with GGBS influences workability but may also lead to higher initial porosity, which contributes to the lower early-age strength.
  - Although GGBS-based concrete has a smoother texture and better flowability, its mechanical properties need to be carefully optimized for load-bearing structures.
- **Microstructural Observations:**
  - Fineness and chemical composition of GGBS influenced strength performance.
  - Microscopic analysis indicated that higher GGBS levels led to incomplete hydration of cementitious materials, explaining the lower early-age strength results.
  - The presence of unreacted GGBS particles within the matrix suggests the need for further optimization of water-to-binder ratios to enhance long-term performance.

Conclusions

- GGBS replacement above 75% negatively impacts concrete strength within standard curing times.
- Optimal replacement levels must balance sustainability with mechanical performance.
- Future studies should explore lower GGBS percentages and prolonged curing for improved performance.
- The study underscores the need for optimizing mix designs to enhance durability while reducing environmental impact.

References

1. Ganesh Babu K, Sree Rama Kumar V. Efficiency of GGBS in concrete. Cem Concr Res 2000; 30: 1031–1036.
2. Oner A, Akyuz S. An experimental study on optimum usage of GGBS for compressive strength of concrete. Cem Concr Compos 2007; 29: 505–514.
3. Dinakar P, Sethy KP, Sahoo UC. Design of self-compacting concrete with ground granulated blast furnace slag. Mater Des 2013; 43: 161–169.
4. Kumar VRP, Gunasekaran K, Shyamala T. Characterization study on coconut shell concrete with partial replacement of cement by GGBS. J Build Eng 2019; 26: 100830.
5. Al-Otaibi S. Durability of concrete incorporating GGBS activated by water-glass. Constr Build Mater 2008; 22: 2059–2067.
6. Tavasoli S, Nili M, Serpoosh B. Effect of GGBS on the frost resistance of self-consolidating concrete. Constr Build Mater 2018; 165: 717–722.

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