Experimental Investigation on Partial Replacement of Cement With GGBFS

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Abstract— ***The utilization of supplementary cementitious materials (SCMs) such as Ground Granulated Blast Furnace Slag (GGBFS) in concrete construction offers promising opportunities to enhance sustainability and performance while mitigating the environmental impact of Portland cement production. However, the widespread adoption of GGBFS faces challenges stemming from variability in properties, lack of standardized guidelines, and limited understanding of its performance in diverse concrete applications. This research addresses these challenges through a comprehensive experimental investigation aimed at systematically evaluating the influence of GGBFS on various properties of concrete. Mechanical properties, durability performance, and microstructural characteristics of GGBFS-blended concrete are rigorously assessed through laboratory-scale testing and analysis. The findings provide valuable insights into the feasibility and effectiveness of using GGBFS in concrete mixtures, offering evidence-based guidance for engineers and practitioners. By promoting the sustainable utilization of GGBFS, this research contributes to advancing environmental stewardship and fostering resilience in infrastructure systems.***

Keyword – (GGBFS),Ordinary portland cement (OPC), Compressive Strength, Durability, Indian standards.

1.INTRODUCTION

The production of portland cement, a cornerstone material in concrete construction, has long been recognized as a significant contributor to environmental degradation. Its manufacturing process involves high energy consumption and substantial CO2 emissions, making it a notable contributor to greenhousegas emissions globally. As the world increasingly grapples with pressing concerns about sustainability and environmental stewardship, there's a heightened urgency to mitigate the environmental footprint associated with concrete production.

In response to these challenges, researchers and industry stakeholders are actively exploring alternativematerials and technologies that offer more sustainable solutions. Supplementary cementitious materials (SCMs) like Ground Granulated Blast Furnace Slag (GGBFS) have emerged as promising candidates for enhancing the sustainability of concrete.

GGBFS is a by-product generated during the iron-making process in blast furnaces. When molten slagis rapidly quenched with water, it solidifies into a granular material. This slag is then finely ground to produce GGBFS, which possesses both hydraulic properties and pozzolanic activity. When incorporated into concrete mixtures, GGBFS can impart numerous beneficial properties.

Firstly, GGBFS improves the workability of concrete, enhancing its ease of placement and consolidation. This attribute is particularly valuable in large-scale construction projects where efficient concrete placement is crucial. Moreover, GGBFS enhances the durability of concrete structures by reducing permeability,
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improving resistance to chemical attack, and mitigating the risk of alkali-silica reaction (ASR).

Furthermore, GGBFS contributes to the long-term performance of concrete by promoting the formationof denser and more durable hydration products. This leads to enhanced mechanical properties, such as compressive strength, and increased resistance to various forms of deterioration over the service life ofthe structure.

One of the most significant environmental benefits of using GGBFS is its ability to reduce the overall cement content in concrete mixtures. Since cement production is a major source of CO2 emissions in the construction industry, any reduction in cement consumption directly translates to a decrease in carbon footprint. By partially replacing Portland cement with GGBFS, concrete producers can significantly lower the embodied carbon of their products, contributing to overall sustainability goals.

2.LITERATURE REVIEW

Sreejith Haridas and Shaji M Jamal, (2017)

Studied that the GGBS increases the workability of concrete, as compared to control mix. The optimum replacement percentage of cement with GGBS is found to be 40%.Compressive strength of mix with optimum percentage of GGBS shows 3.53% higherstrength than control mix in 28 days. Use of M60 mix in which cement is replaced with 40% GGBS can reduce the consumption, thus reducing production of cement and emission of carbon dioxide to atmosphere.

Salasah Alto bat et. al (2015)

Studied the restrained shrinkage cracking and relaxation behaviour of self – compacting concrete (SCC) with various proportion of GGBS. The effects of GGBS proportion on degree of restraints and curing regime are studied. The result shows that GGBS improves the cracking resistance and relaxation behaviour of SCC relative to normal concrete mix. Curing condition and degree of restraint play a significant role on the cracking and relaxation behaviour of SCC and revealed that GGBS can replacement cement up to 70% and 50% for low and high degree of restraint respectively under moist curing condition.

Sonali K. Gadpalliwaret al.,(2014)

The workability of concrete had been found to be decrease with increase of quarry sand in concrete. The workability of concrete had been found to be decrease with increase of RHA but the GGBS increases the workability of concrete.Compressive strength increases with increase of percent of quarry sand up to certain limit. Concrete acquires maximum increase in compressive strength at 60% quarry sand replaced by natural sand for M40 grade of concrete.

T. Vijayagowri, P. Sravana, P. Srinivasa Rao (2014)

'Studies on strength behaviour of high volumes of slag in concrete Investigated the effects on compressive strength, split tensile strength and flexural strength of concrete at 28, 90, 180 and 360 days by partial replacement of cement with GGBFS on. He used 50% GGBFS as replacement material of cement an also used various water/binder ratios are 0.55, 0.50, 0.45, 0.40, 0.36, 0.32, 0.30 and 0.27. He observed that the strength gain by replacement of slag is inversely proportional to the water/ binder ratio and slag concrete gains appreciable amount of strength at later ages (90 days onwards). He found out that the strength of high volume of slag concrete is more at later ages because rate of hydration of slag with Ca(OH)2 and water is slow. He concluded that on replacement of cement by 50% GGBFS helps to reduce the cement content of concrete, thereby reducing the cost of concrete and also protecting the environment from pollution.

Reshma Rughooputh and Jaylina Rana (2014)

'Partial replacement of cement by ground granulated blast furnace slag in con- crete'Studied the effects on various properties of concrete including compressive strength, tensile strength, splitting strength, flexure strength, modulus of elasticity, drying shrinkage and initial surface absorption by partial replacement of OPC by GGBFS on. The tests were conducted with replacement ranging from 30 % to 50% at 7and 28 days. It was found that compressive strength is lower at the early age but increase after the later age time. Flexural strength of test specimens increased by 22% and 24%, tensile strength increased by 12% and 17% for 30% and 50% replacement respectively. Drying shrinkage increased by 3% and 4%.

Static modulus of elasticity increases by 5% and 13%. Based on the results the optimum mix was the one with 50% GGBFS.

Sabeer Alavi, I. Bhaskar, R. Venkata Subramani (2013)

'Strength and durability characteristics of GGBFS based SSC 'Studied the effects of partial replacement of cement with 10 - 50% of GGBFS and found that 30% GGBFS replace- ment is good as beyond that the compressive strength starts decreasing. He also concluded that the split tensile strength and flexural strength conducted at 7 and 28 days increases with increase in GGBFS content. It was also found that the workability increases with the increase in percentage of GGBFS.

Yogendra O. Patil, Prof P.N. Patil, Dr, Arun Kumar Dwivedi (2013)

'GGBS as partial replacement of OPC in cement concrete 'Researched on the effects on compressive strength and flexural strength of concrete when cement is partially replaced with various percentages of GGBS. The tests were conducted with replacement ranging from 10 % to 40 % at 7, 28 and 90 days. It was observed that the strength of concrete is inversely propor- tional to the percentage of replacement of cement with GGBS. The result shows the marginal reduction of 4 – 6 % in compressive and flexural strength for 90 days curing with replacement of OPC by GGBS up to 20% and beyond that of more that 15%. He concluded that, the cost of concrete reduces at the current market rate by 14% by 20% replacement of OPC with GGBS.

H. J. Brown et. al (2010)

Conducted several studies with fly ash replacing cement at levels of 10-40% by volume. He concluded that for each 10% of ash substituted for cement, the compacting factor or workability changed to the same order as it would by increasing the water content of the mix by 3-4%. When fly ash was substituted for sand or total aggregate, workability increased to reach a maximum value at about 8% ash by volume of aggregate. Further substitution caused rapid decrease in workability

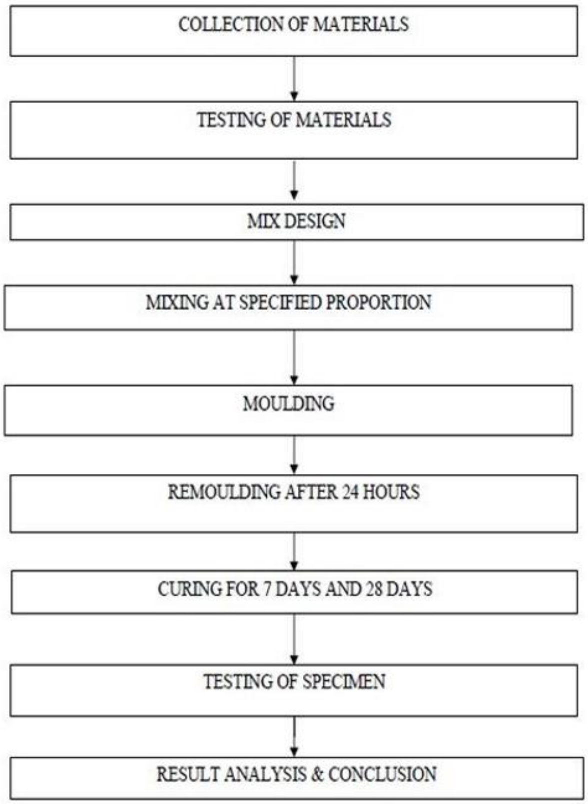
Mohammed Shariq, Janaka prasad, A.K. Ahuja (2008)

'Strength development of cement mortar and concrete incorporating GGBFS'Studied the effect of curing procedure on the cement mortar and concrete incorporating ground gran- ulated blast furnace slag compressive strength development. The compressive strength devel- opment of cement mortar is calculated by the 20, 40 and 60 percent replacement of GGBFS for different types of sand. Similarly the strength development of concrete is investigated with 20, 40 and 60 percent replacement of GGBFS on two grades of concrete. Tests results show that the incorporating 20% and 40% GGBFS is highly significant to increase the compressive strength of mortar after 28 days and 150 days, respectively.

G. G. Carette et. al (1984)

Studied the effect of Canadian fly ashes on the compressive strength of concrete mixes. Cement was replaced with 20% fly ash in all the mixes. Compressive strength was measured up to the age of 365 days. It was seen that compressive strength continued to increase with age, indicating pozzolanic action of fly ashes

3.METHODOLOGY



Step 1- Collection of Materials:

This initial step involves gathering all the necessary materials to create the concrete mix and specimensfor testing. These would typically include:

Ground Granulated Blast Furnace Slag
Fine Aggregate
Cement

Coarse Aggregate
Water

Step 2 - Mix Design:

In this phase, the researcher determines the specific quantities of each ingredient to be used in the concrete mix. This will influence the final properties of the concrete, including its strength. The researcher will likely experiment with different mix ratios to find the optimal combination for incorporating waste plastic bottles while achieving the desired strength.

Step 3- Mixing at Specified Proportion:

Once the mix design is finalized, the concrete ingredients are combined according to the predetermined proportions. This might involve using a mechanical mixer to ensure a homogenous mixture.

Step 4 -Molding:

The prepared concrete mix is then poured into molds. These molds will determine the shape of the concrete specimens that will be subsequently tested for strength.

Step 5 - Remolding After 24 Hours:

After 24 hours, the concrete specimens are removed from the initial molds.

Step 7 -Curing for 7 Days and 28 Days:

Curing is a vital process that allows the concrete to gain strength. During curing, the molded concrete specimens are placed in a controlled environment with specific temperature and humidity conditions. The flowchart specifies curing periods of 7 days and 28 days.

Step 8 - Testing of Specimens:

After the curing period, the concrete specimens undergo testing to determine their mechanical properties, such as compressive strength and flexural strength. This data is used to assess the effectiveness of the mix design in incorporating waste plastic bottles for strength optimization.

Step 9 - Result Analysis & Conclusion:

Finally, the researcher analyzes the data collected from the tests performed on the concrete specimens. This analysis helps determine the optimal mix design for using waste plastic bottles to achieve the desired strength in fiber-reinforced concrete.

4.EXPERIMENTAL WORK

A. MATERIAL USED

1. Ground Granulated Blast Furnace Slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) is a byproduct of steel manufacturing, produced by quenching molten iron slag with water or steam. It's finely ground and exhibits cementitious properties when activated with alkalis or lime in concrete. GGBFS is commonly used to replace a portion of Portland cement in concrete mixes, enhancing workability, durability, and strength while reducing environmental impact. In experiments, GGBFS is studied for its effects on concrete properties like compressive strength and durability, determining optimal replacement percentages for desired outcomes. Its functions include increasing cementitious content, reducing heat of hydration, improving workability, reducing permeability, offering environmental benefits, enhancing sulfate resistance, and boosting long-term strength.

In our project, Ground Granulated Blast Furnace Slag (GGBFS) is being used as a partial replacement for cement in concrete mixes. This means that a portion of the cement in the concrete mix is being replaced with GGBFS. The percentage of replacement can vary depending on the desired properties of the concrete.

2.Cement

Cement plays a pivotal role in construction, acting as the primary binding agent in concrete and mortar production. To ensure its reliability and performance, various tests are conducted according to established standards such as IS 4031 in India. These tests assess key properties like particle size (fineness), setting times, consistency, and color, providing insights into cement's suitability for different applications.

Ground Granulated Blast Furnace Slag (GGBFS) is emerging as a promising cementitious material, often used in conjunction with Ordinary Portland Cement (OPC) or Portland Pozzolana Cement (PPC). These materials, conforming to specific grade standards like IS-269 and IS 1489, are utilized for casting concrete samples in experimental investigations. OPC 43 Grade of Cement (confirming IS-269) and PPC 43 Grade of Cement (confirming IS 1489-Part2) is used for casting of Normal Concrete samples and GGBFS Concrete samples

3.Coarse Aggregate

Coarse Aggregates are inert materials mixed with a binding agent to make concrete. In pervious concrete, they determine porosity, strength, and permeability. Common types include crushed stone, gravel, expanded shale/clay, and porous ceramic aggregates. Qualities of aggregates include chemical inertness, hardness, toughness, strength, purity, and workability. Tests include specific gravity, water absorption, moisture content, sieve analysis, impact value, and abrasion value. 20 mm to 40mm aggregate was used in this project for both Normal and GGBFS Concrete. Coarse aggregate sieve analysis was determined according to ASTM C 136.

4.Fine Aggregate

Fine Aggregate is a granular material made of rock and mineral particles, typically silica or calcium carbonate. It's finer than gravel and coarser than silt, forming a significant part of soils with over 85% sand-sized particles. Testing methods for fine aggregate (sand) include sieve analysis to determine particle size distribution, specific gravity measurement using a pycnometer, water absorption assessment by soaking.

samples, and moisture content determination through drying and weighing.

5.Water

Water plays a crucial role in concrete manufacturing by chemically reacting with cement and facilitating the workability of the mixture. Its quality impacts concrete strength, with excessive mixing water often leading to poor-quality concrete. Water used in experiments adheres to IS: 456-2000 standards, ensuring cleanliness and freedom from harmful substances like oils, acids, alkalis, salts, sugars, and organic materials. Potable water is typically suitable for concrete mixing, with a pH value not less than 6 recommended.

B. MIX DESIGN

Mix design is defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. Generally we are using M20 and M25 grade of concrete for better result Mix design of M20 and M25 grade concrete as per Indian standard codebook: Normally we used wic ratio falls under 0.4 to 0.6 as per IS Code 10262 for nominal mix M25 (1:1:2) and M20 (1:1.5:3) The Mix design is done as per IS 10262:2009

Mixing of GGBFS

We had prepared M20 and M25 grade concrete by the partial replacement of Cement with Ground Granulated Blast Furnace Slag The prepared grade concrete of M20 and M25 mix had replaced cement with GGBFS by 15%, 20% and 25% to check the compressive strength of the concrete

Mix design is a process of selecting suitable ingredients for concrete and determining their proportions which would produce economical concrete. The proportioning of the ingredients of concrete is an important segment of concrete technology as it ensures quality and economy. For obtaining the concrete of desired performance characteristics, the component materials should be selected likewise. Then by considering these components, appropriate mix design is prepared.

Water-cement ratio 0.47 used in this research. The details of mixes are shown below

Casting of Specimen

Specimens for compressive strength and split tensile strength were cast using mix proportions from a specified table. Materials like cement, Ground Granulated Blast Furnace Slag, fine aggregates, and coarse aggregates were dry mixed for uniformity. 50% of the total water was added initially and mixed for 3-4 minutes, followed by addition of 40% of water. Remaining 10% of water was sprinkled and mixed thoroughly. Oiled molds were filled with the mix and placed on a vibrating table for proper mixing. Specimens were then cured in open air for 24 hours after casting.

Curing

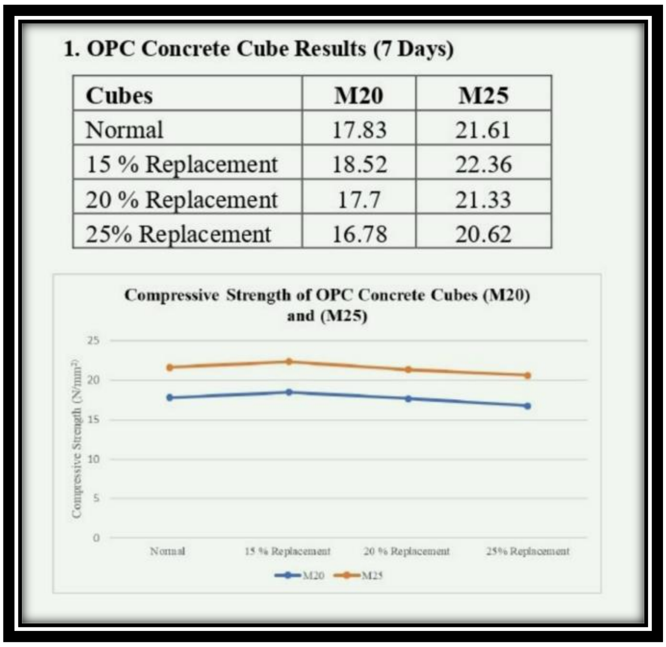
In investigating the use of Ground Granulated Blast Furnace Slag (GGBFS) in concrete, curing is crucial for achieving required strength and durability. Moisture retention is key for proper hydration, with methods like wet burlap or curing compounds used. Temperature control ensures optimal strength development.

Curing duration may vary, and quality control involves monitoring conditions and concrete samples. Testing post-curing assesses properties like compressive strength to evaluate GGBFS effectiveness as a cementitious material. Overall, curing is tailored to optimize concrete performance and assess GGBFS benefits.

Testing of Specimen

After casting, specimens undergo curing for a predetermined time. When testing compressive strength of GGBFS concrete cubes, specimens are demolded after 24 hours and placed in a curing tank. Upon testing, specimens are removed from the tank and allowed to surface dry for 10-15 minutes. Testing is conducted using a Compression Testing Machine (CTM) at a load rate of 5 kN/sec as per IS: 516-1959 standards. The maximum load sustained just before failure is recorded to evaluate compressive strength.

5. Results



1. OPC Concrete Cube Results (7 Days)

Cubes	M20	M25
Normal	17.83	21.61
15 % Replacement	18.52	22.36
20 % Replacement	17.7	21.33
25% Replacement	16.78	20.62

6.CONCLUSION

The experimental exploration of Ground Granulated Blast Furnace Slag (GGBFS) as a supplementary material in concrete has yielded insightful outcomes. Within the studied range, replacing cement with GGBFS up to 15% has shown a marginal increase in compressive strength, attributed to the pozzolanic reaction fostering densification of the concrete matrix. However, beyond this threshold, at 20% and 25% replacement levels, the improvement in strength diminishes, signaling an optimal balance between benefits and dilution effects. Additionally, GGBFS contributes significantly to the durability of concrete by mitigating permeability and enhancing resistance against chemical aggressions such as sulfate and alkali-silica reactions, thereby potentially prolonging the lifespan of concrete structures, especially in adverse environmental conditions. Furthermore, embracing GGBFS as a substitute for conventional cement aligns with sustainable construction practices, as it reduces the environmental footprint by curtailing the energy-intensive and carbon dioxide-emitting processes associated with traditional cement production. This integration of GGBFS underscores a promising avenue for enhancing both the performance and sustainability of concrete infrastructure

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IS Codes Referred

1. IS 269: Specification for Ordinary Portland Cement

2. IS 1489 (Part 1): Specification for Portland Pozzolana Cement

3. IS 383: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete

4. IS 2386 (Part 1): Methods of Test for Aggregates for Concrete (Particle Size and Shape)

5. IS 10262: Guidelines for Concrete Mix Proportioning

6. IS 456: Code of Practice for Plain and Reinforced Concrete

7. IS 516: Methods of Tests for Strength of Concrete

8. IS 456: Code of Practice for Plain and Reinforced Concrete