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Behavior of Self Compacting Concrete by Partial Replacement of Fine Aggregate with Ground Granulated Blast Furnace Slag

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Abstract: This study investigates the behaviour of SCC with partial replacement of fine aggregate using Ground Granulated Blast Furnace Slag (GGBS). GGBS is a by-product obtained during the manufacturing of iron in blast furnaces and is widely used as a supplementary material in concrete. The main objective of this research is to evaluate the influence of GGBS on the fresh and hardened properties of SCC. In this study, fine aggregate is partially replaced with GGBS at different percentages such as20%, 25% and 30%. The fresh properties of SCC are evaluated using tests like slump flow, V-funnel, and L-box tests to determine workability, filling ability, and passing ability. The hardened properties are analysed through compressive strength, split tensile strength, and flexural strength tests after curing periods of 7, 14, and 28 days. The experimental results indicate that the incorporation of GGBS improves the work ability and cohesiveness of SCC while maintaining adequate strength. An optimum replacement level is observed where the mechanical properties of concrete show significant improvement. The use of GGBS also contributes to environmental sustainability by reducing the consumption of natural sand and utilizing industrial waste. Overall, the study concludes that partial replacement of fine aggregate with GGBS in SCC is a viable and eco-friendly approach that enhances the performance and durability of concrete.
Keywords: Ground granulated blast furnace slag, super plasticizer

I. INTRODUCTION

Concrete is one of the most widely used construction materials in the world due to its strength, durability, and versatility. Conventional concrete requires mechanical vibration during placement to achieve proper compaction. However, in structures with congested reinforcement or complex formwork, proper compaction becomes difficult and may lead to defects such as honeycombing, segregation, and reduced durability. To overcome these issues, Self-Compacting Concrete (SCC) was developed. Self-Compacting Concrete is a highly flow able concrete that can spread into place, fill the formwork, and encapsulate reinforcement without the need for mechanical vibration. SCC improves construction efficiency, reduces labor requirements, enhances surface finish, and ensures better structural performance. The development of SCC requires careful selection of materials and mix proportions to achieve adequate filling ability, passing ability, and resistance to segregation. In recent years, the use of industrial by-products in concrete has gained significant attention due to environmental concerns and the need for sustainable construction materials. One such material is Ground Granulated Blast Furnace Slag (GGBS), a by-product obtained during the manufacture of iron in blast furnaces. GGBS possesses cementitious and pozzolanic properties that improve the strength, durability, and workability of concrete. Its use also reduces the consumption of natural resources and lowers carbon emissions associated with cement production. This project focuses on studying the behaviour of Self-Compacting Concrete when fine aggregate is partially replaced with GGBS.

The study aims to evaluate the effects of different replacement percentages on the fresh and hardened properties of SCC, including workability, compressive strength, and durability. The results of this investigation will help determine the suitability of GGBS as a sustainable material in the production of Self- Compacting Concrete.

II. MATERIALPROPERTIES

A. Fine Aggregate

The fine aggregates used for this work were natural river sand and GBFS. Natural sand Confirms to grading zone II and GBFS confirms to grading zone III as per IS: 383 (1970). The physical properties of sand such as sieve analysis, specific gravity, bulk density, etc., were determined as per IS: 2386 (1963). replacement of fine aggregate by GGBS. Observed that 7 days, 14 days and 28 days compressive strength. The results of compressive, splittensile strength test have indicated that the strength of concrete

Table1: Physical properties of fine aggregate

S.No	Name of test	Observed value
1.	Specific gravity	2.3
2.	Bulking of sand	11.1%
3.	Seive analysis	2.6

B. Sieve Analysis

Sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution of a granular material. With careful selection of the gradation, it is possible to achieve high bulk density, high physical stability and low permeability. The sieve analysis of fine aggregates determined as per IS: 383 (1970).

C. GGBS

Ground Granulated Blast Furnace Slag which is a by- product of iron manufacturing industry is an accepted mineral admixture for use in concrete. This granulated material when further ground to less than 45micron is called Ground Granulated Blast Furnace Slag (GGBS).

Table 2: Physical properties of GGBS

S.No	Property	Value
1	Normal consistency	30%
2	Initial & Final setting time	55min & 9hr
3	Specific gravity	2.98
4	Fineness of cement by seive	8%

The reduction involved in the setting and hardening of concrete generates significant heat and can produce large temperature rises, particularly in thick section pours. This can result in thermal cracking. Replacing Portland cement with GGBS reduces the temperature rise and helps to avoid early age thermal cracking. The greater the percentage of GGBS, the lower will be the rate at which heat is developed and the smaller the maximum temperature rise.

D. Chemical Composition of GGBS

Silicate and aluminate impurities from the ore and coke are combined in the blast furnace slag with a flux which lowers the viscosity. In the case of pig iron manufacturing the flux consider mostly of a mixing of limestone and for sterilite or in some cases dolomite.

Table3: Chemical composition of GGBS

S.No	Components	Percentage
1	Calcium Oxide	34 to 43%
2	Silicon Dioxide	27 to 38%
3	Aluminium Oxide	7 to 12%
4	Magnesium Oxide	7 to 15%
5	Iron	0.2 to 1.6%

E. Coarse Aggregate

Material are large to be retained on 4.7mm sieve size(say 5mm for convenience) are called coarse aggregate. A maximum size of 10mm is usually selected as coarse aggregates up tp20mm.

Table 4: Physical properties of Coarse aggregate

S.No	Name of test	value
1	Specific gravity	2.88
2	Seive analysis	2.30
3	Crushing test	12.2%

F. Water

Portable tap water available in the laboratory with pH value of 7.0 and conforming to the requirements of IS456-2000 is used for making concrete and curing the specimen as well. Water is an important ingredient of concrete as it actively participates in chemical reaction with cement.

III. METHODOLOGY

In our project SCC with partial replacement of fine aggregate using GGBS with below mix design for 20%,25%, and 30%replacement.

A. 20 % Replacement of Fine aggregate with GGBS:

Materials	Ratio
Cement	1
Fine aggregate	1.50
GGBS	0.38
Coarse aggregate	2
Water	0.40

Mix Ratio= 1:1.50:0.38:2

B. 25% Replacement of Fine aggregate with GGBS:

Materials	Ratio
Cement	1
Fine aggregate	1.41
GGBS	0.47
Coarse aggregate	2

Mix Ratio = 1:1.41:0.47:2

C. 30 % Replacement of Fine aggregate with GGBS:

Materials	Ratio
Cement	1
Fine aggregate	1.31
GGBS	0.56
Coarse aggregate	2

Mix Ratio =1:1.31:0.56:2

IV. RESULTS

A. Compressive Strength (Cube- 150×150×150mm)

GGBS Replacement	7Days (Mpa)	14 Days (Mpa)	28 Days (Mpa)
20%	25.8	31.6	36.4
25%	27.1	33.4	38.2
30%	24.9	30.5	34.7

25 % gives the maximum compressive strength

B. Split tensile strength(Cylinder150×300mm)

GGBS replacement	7Days (Mpa)	14 Days(Mpa)	28 Days(Mpa)
20%	2.30	2.85	3.40
25%	2.45	3.05	3.65
30%	2.20	2.75	3.20

25% gives the high tensile strength

C. Flexural Strength (Prism100×100×500mm)

GGBS replacement	7 Days	14 Days	28 Days
20%	3.8	4.6	5.4
25%	4.1	4.9	5.9
30%	3.6	4.3	5.1

Flexural strength also high in 25% replacement

D. Final Comparison

Replacement	Compressive strength	Splittensile strength	Flexural strength
20%	36.4Mpa	3.40Mpa	5.4Mpa
25%	38.2Mpa	3.65Mpa	5.9Mpa
30%	34.7Mpa	3.20Mpa	5.1Mpa

IV.CONCLUSION

This project investigated the behavior of Self-Compacting Concrete (SCC) with partial replacement of fine aggregate by Ground Granulated Blast Furnace Slag (GGBS) at replacement levels of 20%, 25%, and 30%. Based on the experimental results of compressive strength, split tensile strength, and flexural strength, the following conclusions can be drawn:

- The incorporation of GGBS as a partial replacement for fine aggregate improved the mechanical properties and overall performance of SCC.
- The compressive strength increased with the increase of GGBS content up to 25% replacement, after which a slight reduction was observed at 30% replacement.
- The maximum compressive strength of 38.2 MPa was obtained at 25% GGBS replacement, which was higher than the other mixes.

- The split tensile strength and flexural strength also followed a similar trend, showing improvement up to 25% replacement and a slight decrease at 30%.
- The optimum replacement level of GGBS was found to be around 25%, which provided better strength characteristics compared to other percentages.
- The use of GGBS in SCC also contributes to **s**ustainable construction, as it utilizes industrial by-products and reduces the consumption of natural sand.
- Therefore, GGBS can be effectively used as a partial replacement for fine aggregate in SCC, improving strength properties while promoting environmentally friendly construction practices.

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