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# Effect of Addition of Ground Granulated Blast Furnace Slag on Concrete

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**ABSTRACT:** This paper presents the results of an experimental investigation carried out to evaluate the performance characteristics of concrete. Ground granulated blast furnace slag (GGBFS), a by-product of the steel manufacturing industry, being used as an effective partial cement replacement material, has already been proven to improve several performance characteristics of concrete. This can enhance concrete applications in pavement, wall panel and slab by improving workability in the plastic state, and increasing strengths and reducing permeability in the hardened state. With careful attention to detail during the concrete mixture can be produced with GGBFS and replacement of ordinary Portland cement. From the test results of the above investigation, it can be concluded that the compressive strengths of all percentage slag concretes are almost equal at 7-day with their values around 21% higher than that of Ordinary Portland Cement (OPC) concrete. At 28-days, whereas 45% and 50% GGBFS concretes result in 32% and 36% higher strength respectively, compressive strength of 55% ground granulated blast furnace slag concrete is only around 10% more than that of OPC concrete.

**KEYWORDS:** GGBFS, OPC, admixture, Compressive strength.

## I. INTRODUCTION

GGBFS promises to be a sustainable and cost-effective material that will not only improve the compressive strength and durability of the concrete but also considerably reduce the carbon production. GGBFS is usually used as mineral additives in Portland cement production in India. GGBFS is more difficult to grind than clinker, specific surface area of GGBFS in cement is under 300 m<sup>2</sup>/g. GGBFS was in use as a main supplementary cementing material from many years. It possesses both cementitious and pozzolanic properties. Pozzolanic concretes are used extensively throughout the world; the oil, gas, nuclear and power industries are among the major users. The applications of such concretes are increasing day by day due to their superior structural performance, environmental friendliness, and energy-conserving implications. Although the concrete in such structures is always provided with adequate insulation, nevertheless, it is difficult to inspect the insulation and there is always a possibility of its deterioration. By using reclaimed and recyclable industrial by-products such as fly ash and ground, granulated blast-furnace (GGBF) slag, cement and concrete industry can play an important role in supporting India to reduce the total greenhouse gas emission.

During the past few decades, there has been a growing awareness and concern of the increasing concentrations of greenhouse gases in the atmosphere, which have adverse effects upon our climate. The production of every tonne of portland cement contributes about one tonne of CO<sub>2</sub> into the atmosphere. It is, therefore, imperative that supplementary cementing materials such as fly ash or GGBF slag be substituted for portland cement to reduce CO<sub>2</sub> emissions. The use of these materials in concrete not only helps to reduce the greenhouse gas emissions but results in environmentally-friendly concrete that has excellent long-term strength and durability characteristics, and is often more economical than normal portland cement concrete.

This paper investigates the results of study on the effect of GGBFS on the strength of concrete. In the concrete mixtures, the replacement levels of cement were chosen at 45% 50% and 55% GGBS, which are the common levels used in practice.

## II. RELATED WORK

The contributions of the mineral admixtures to performance improvement of the recycled aggregate concrete are higher than that to the natural aggregate concrete presented by Shi-congKou[1]. V. Sata et al [2] studied the effects of W/B ratios on pozzolanic reaction of by-product biomass ashes, namely rice husk–bark ash (RHBA) and palm oil fuel ash (POFA). To make environment-friendly concrete is the development of high strength-high-volume fly ash concrete which is synthesized from materials of geological origin or by-product materials such as fly ash which is rich in silicon and aluminum by G. Kate and S.Thakare[3]. The effect of level of cement replacement with fly ash as a supplementary cementitious material for development of the compressive strength of hardened concrete was investigated with different fly ash quantities. The strength of concrete after a given curing period decreases with increase in fly ash content. However the increase in strength continues for a long period for concrete with high volume of fly ash introduced by Gunavant Kate and PraneshMurnal[4]. The change in the structural behavior of beams & columns with Glass Fiber Reinforced Polymers circular bars of different thickness studied by C B Nayak et al [5]. The research work studied by CB Nayak [6] the effect of AFRP on a steel beam with five types of strengthening and without strengthening pattern. Also, the compressive and flexural behaviour of structure considering with strengthening and without strengthening. A good work on use of pharmaceutical industrial waste water for compressive strength studies is also reported[7].

## III. METHODOLOGY

Selection of the type of cement will depend on the overall requirements for the concrete. The content higher than 10% of calcium may cause problems of poor workability retention. The OPC (43 grade) was partially replaced by different amount of GGBFS and was used to describe concrete performance. Ordinary Portland Cement (OPC) meets the requirements conforming to IS: 12269. In the present investigation the parameters were used as a locally available crushed stone fine aggregate and crushed stone coarse aggregate of sizes 20 mm and 12.5 mm. Careful attention is to be given to aggregate size, shape, surface texture, mineralogy, and cleanness. For each source of aggregate and concrete strength level there is an optimum-size aggregate that will yield the most compressive strength per unit of cement. Supplementary cementitious material replacement of 45, 50, 55% cement materials by different amount of GGBFS. Regular potable water was used as mixing water to all mixtures. The following physical properties of materials are given in table 1.

**Table 1: Material properties**

SN	Material	Specific gravity
1	20 mm Aggregate	2.96
2	10 mm aggregate	2.95
3	Fine aggregate	2.94
4	GGBFS	2.98
5	Cement	3.15

## IV. EXPERIMENTAL RESULTS

To investigate the influence of binder composition all mixtures used in this study maintained a different aggregate volume that was composed of unequal proportions of fine aggregate. Five GGBFS based concrete mixtures were made. Various concrete mixes are prepared by replacing Ordinary Portland Cement (OPC) 43-Grade and ground granulated blast furnace slag (GGBFS) at a 45%, 50% and 55% by weight of cement. The concrete mixture CM-1, CM-2, CM-3 was made with the blended cement incorporating of GGBFS with 45%, 50%, 55% respectively with water to cement ratio 0.50 and mixture CM-4, CM-5 were made with replacing cement by GGBFS 50%, 55% respectively with water to cement ratio 0.44. For this purpose, different concrete mixes are obtained mixing blast furnace slag and silica fume with 43-Grade Ordinary Portland Cement (OPC). The proportions of the concrete mixtures are summarized in Table 2. GGBFS is processed from granulated slag, a cementitious material that consists of same constituents, which are also present in cement. It has more than 90% glass content or calcium aluminosilicates. The physical and chemical characteristics of GGBFS satisfy the requirement per IS: 12089-1987 for GGBFS. For achieving good workability, high performance water-reducing admixture used. It is intended for applications where retardation and long workability retention are required. The test specimens prepared were concrete cubes with size of 150 mm for compressive strength



tests. The specimens were cast in accordance with IS 456-2000. The cube specimens of 150 mm size are cast in steel moulds in three layers and compacted on a vibrating table. A total of forty-five cubes are prepared. The specimens are kept in the moulds for 24 hours, after which they are de-moulded and placed in a water curing tank for 28 days. The specimens are then air dried for 3, 7 and 28 days and tested under compression to failure.

**Table 2: Concrete mix proportions per cubic meter**

SN	Concrete Mix	Cement (kg)	GGBFS (kg)	Fine aggregate (kg)	Coarse Aggregate (kg)	Admixture (kg)	w/c ratio
1	CM-1	135	165	937	1100	3.00	0.5
2	CM- 2	150	150	940	1154	3.00	0.5
3	CM-3	165	135	942	1107	3.00	0.5
4	CM- 4	170	170	959	1039	3.4	0.44
5	CM- 5	153	187	956	1036	3.4	0.44

**V. RESULTS AND DISCUSSION**

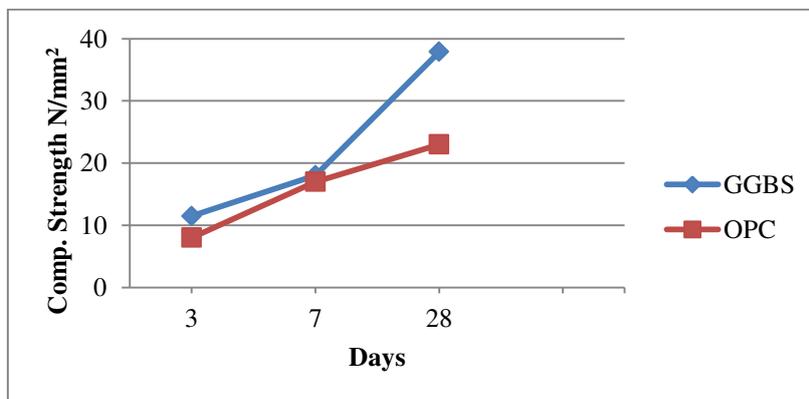
After studying the behaviour of concrete specimen under varying conditions in the present investigation, following results obtained:

**A) Compressive Strength of GGBFS Concrete**

As in the case of ground granulated blast furnace slag (GGBFS) concrete also gives better result in comparison to ordinary concrete. It is observed that the compressive strength of ordinary and 55% GGBFS concrete is maximum at 7-day after which it decreases, whereas in 45% and 50% GGBFS concrete, strength increases. Compressive strengths of all percentage slag concretes are almost equal at 7-day with their values around 21% higher than that of ordinary concrete. At 28-days whereas 45% and 50% GGBFS concretes result in 32% and 36% higher strength respectively, compressive strength of 55% ground granulated blast furnace slag concrete is only around 10% more than that of plain concrete.

**B) Comparison of Strength of Ordinary Concrete**

Compares performance of 10% pozzolanic concrete with ordinary concrete. Comparison for 20% replacement of cement by pozzolanic material by weight. It is observed that whereas both types of pozzolanic concrete show better compressive strength than ordinary concrete, silica fume concrete shows better results than slag concrete. The compressive strength of concretes made with 45, 50, 55% GGBS were higher than that of corresponding control concrete mixtures, the contributions of GGBS to the long-term compressive strength at 28 days. The figure 1 to 5 shows the performance of concrete with various mixture by replacing GGBFS.



**Fig. 1: Mix 1 -45% Replacement of OPC with W/C ratio 0.5**

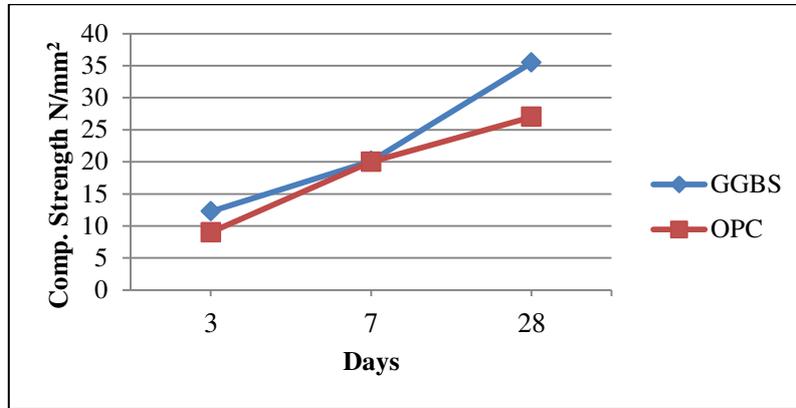


Fig. 2. Mix 2 - 50% Replacement of OPC with W/C ratio 0.5

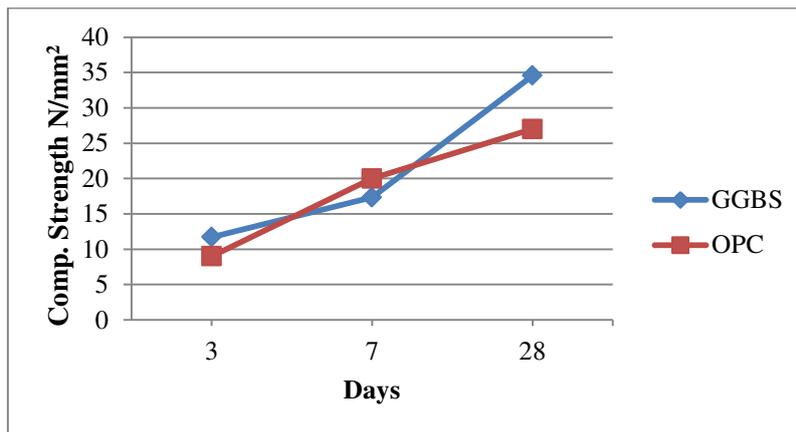


Fig.3. Mix 3 - 55 % Replacement of OPC with free W/C ratio 0.5

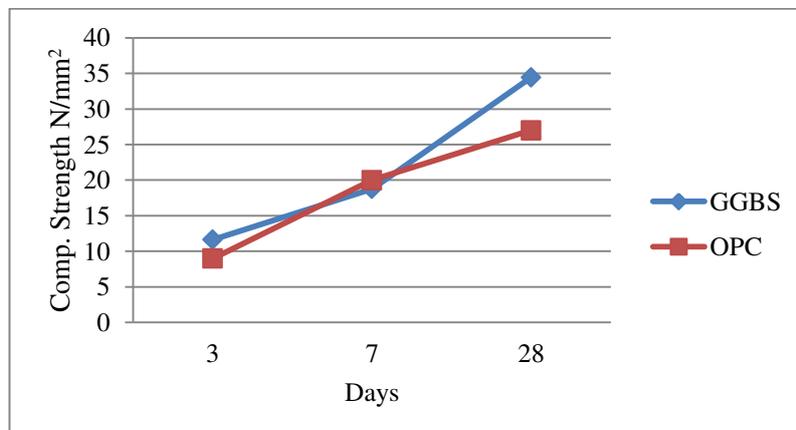


Fig.4. Mix 4- 50% Replacement of OPC with W/C ratio 0.44

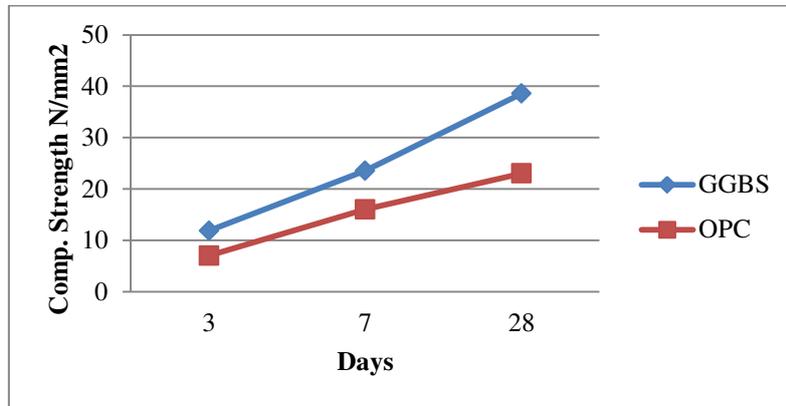


Fig.5. Mix 5 - 55% Replacement of OPC with W/C ratio 0.44

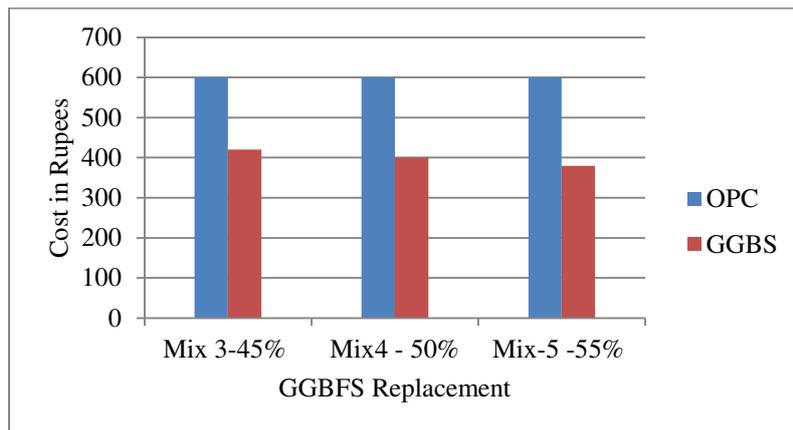


Fig. 6. Cost comparison between OPC and GGBS

### VI. CONCLUSION

The following conclusions are drawn from the results of this investigation.

1. Compressive strengths of all percentage slag concretes are almost equal at 7-day with their values around 21% higher than that of OPC concrete.
2. At 28-days, whereas 45% and 50% GGBFS concretes result in 32% and 36% higher strength respectively, compressive strength of 55% ground granulated blast furnace slag concrete is only around 10% more than that of OPC concrete. In comparison to OPC, GGBFS is economical concrete.
3. Ground granulated blast furnace slag-based concretes can safely be used for construction of structural elements which are expected to be subjected to higher temperature during their service life. Whereas pozzolanic concrete show better compressive strength than OPC concrete.
4. For the such concrete practically applicable in pavement construction, readily when crushed steel slag is used as a portion of the aggregate. If the unit cost of steel slag modified mixes is the same as conventional dense graded mixes, overall project costs may increase because of the decrease in coverage by the heavier steel slag mix.



5. When Portland cement and water are mixed, a chemical reaction called hydration initiates, resulting in the creation of calcium-silicate-hydrate (CSH) and calcium hydroxide (CH). CSH is a gel that is responsible for strength development in Portland cement pastes. CH is a byproduct of the hydration process that does not significantly contribute to strength development in normal portland cement mixtures.
6. The contributions of the mineral admixtures i.e., GGBFS shows performance improvement in concrete.

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