An Experimental Investigation to Study the Effect of Use of Chemical and Mineral Admixtures on Properties of Concrete

Nikit Arun Maske[1] Prof. Swapnil R. Satone[2]
[1]P.G. Student [2]Professor
[1,2]Department of Structural Engineering
[1,2]KDK College of Engineering, Nagpur, Maharashtra, India

Abstract— The utilization of supplementary cementitious materials is well accepted because of the several improvements possible in the concrete composites and due to the overall economy. The present paper is an effort to quantify the 28-day cementitious efficiency of ground granulated blast furnace slag (GGBS) in concrete at the various replacement levels with the help of literature review found and experimental investigation studied.
Key words: Ground-Granulated Blast-Furnace Slag (GGBS or GGBFS), Supplementary Cementations Material, Efficiency of Concrete Base

I. Introduction

Concrete is one of the important construction material used in the world in all engineering works including the infrastructure development at all stages. It has been used in construction sector for a long time and proved that, it is a cheap material and its constituents are widely available in nature. Due to wide spread usage and fast infrastructure development in all over the world, there is shortage of natural materials. The quality of concrete is determined by its mechanical properties as well as its ability to resist the deterioration. It's a great opportunity for the concrete industry that they can save natural materials by replacing natural materials with Ground granulated blast furnace slag (GGBS). Ground Granulated Blast Furnace Slag has been constantly in use as cementitious replacement for sustainable infrastructure.

A. Admixtures

There are two types of admixture -

1) Mineral admixtures
2) Chemical admixtures

B. Mineral Admixtures

1) Need of GGBS as a Mineral Admixture

Ground-granulated blast-furnace slag (GGBS or GGBFS) is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500ºC to 1600ºC. The molten slag has a composition of 30% to 40% silicon dioxide (SiO_2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water- quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires little additional energy compared with the energy required for the production of Portland cement. The replacement of Portland cement with GGBS will lead to a significant reduction of carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material. It can be used to replace as much as 80% of the Portland cement when used in concrete. GGBS concrete has better water impermeability.

C. Here Are Some Benefits for GGBS

Sustainability - It has been reported that the manufacture of one tonne of Portland cement would require approximately 1.5 tons of mineral extractions together with 5000 MJ of energy, and would generate 0.95 tonne of CO_2 equivalent. As GGBS is a by-product of iron manufacturing industry, it is reported that the production of one tonne of GGBS would generate only about 0.07 tonne of CO_2 equivalent and consume only about 1300 MJ of energy.

Colour - Ground granulated blast furnace slag is off-white in colour. This whiter colour is also seen in concrete made with GGBS, especially at replacements greater than 50%. The more aesthetically pleasing appearance of GGBS concrete can help soften the visual impact of large structures such as bridges and retaining walls. For coloured concrete, the pigment requirements are often reduced with GGBS and the colours are brighter.

Setting Times - The setting time of concrete is influenced by many factors, in particular temperature and water/cement ratio. With GGBS, the setting time will be slightly extended, perhaps by about 30 minutes. The effect will be more pronounced at high levels of GGBS and/or low temperatures. An extended setting time is advantageous in that the concrete will remain workable for longer periods, therefore resulting in less joints. This is particularly useful in warm weather.

D. Chemical Admixture

Chemical Admixtures are the ingredients in concrete other than Portland cement, water, and aggregate that are added to the mix immediately before or during mixing. Producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations.

II. Scope and Objectives

- To enhance the property of concrete.
- To minimize the use of conventional material by using mineral admixtures and chemical admixtures.

III. Experimental Investigation

A. Material Used

1) Cement

Ordinary Portland cement (53 Grade) is used. Cement is a fine, grey powder. It is mixed with water and materials such as sand & aggregate to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The ordinary Portland cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous material clay predominates and in calcareous materials calcium carbonate predominates.

The physical properties of the cement tested according to Indian standards procedure confirms to the requirements of IS 10262- 2009 and the physical properties are given in table –

Sr.No	Properties	Result Obtained	Standard Values
1	Standard Consistency	33%	-
2	Initial Setting Time (minutes)	32	Not be less than 30 minutes
3	Final Setting Time(minutes)	330	Not be greater than 600 minutes
4	Soundness(mm)	5	<10
5	fineness	9.0%	<10%
6	Specific gravity	3.15	-

Table 1: Physical properties of cement

2) *Fine Aggregates*

The sand used for the experimental program of sieve analysis. The sand was first sieved through 4.75mm to remove any particles greater than 4.75 mm and then was washed to remove the dust. The sand confirming to zone II as per IS 383:1970 was used for making references concrete. Properties used in the experimental work are tabulated in table-

Sr. No.	Properties	Result Obtained
1	Type	Natural
2	Specific Gravity	2.67
3	Bulkage	8.5%
4	Fineness Modulus	2.48
5	Surface Texture	Smooth
6	Particle Shape	Rounded

Table 2: Physical properties of fine aggregates

3) *Coarse Aggregate*

All types of aggregate are suitable. The normal maximum size is generally 10-20mm. consistency of grading of vital importance. Coarse aggregate confirming to IS 383:1970.

Regarding the characteristics of different types of aggregates, crushed aggregates tend to improve the strength because of the interlocking of the angular particles, whilst rounded aggregates improve the flow because of lower internal friction

Sr No	Properties	Result Obtained
1	Type	Natural
2	Specific Gravity	2.67
3	Surface Texture	Rough
4	Particle Shape	Angular

Table 3: Physical Properties of Coarse Aggregates (20 mm)

4) *GGBS (Ground Granulated Blast Furnace Slag)*

Sr. No.	Properties	Result Obtained
1	Specific Gravity	2.87
2	Fineness (retained on 90 micron sieve)	0
3	Fineness (retained on 45 micron sieve)	0.8
4	Initial time (min)	160
5	Soundness (mm)	1

Table 4: Physical properties of GGBS

Binder	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O
GGBS	39.18	10.18	2.02	32.82	8.47	-	1.14	0.30

Table 5: Chemical properties of GGBS

B. *Mix Proportion and Mix Details*

In this investigation, M30 mix concrete is considered to perform the test by-weight basis by replacing 30% and 50% of cement by GGBS.

Adopted Mix Proportion is: (1: 1.74: 3.04: 0.40)

C. *Test Specimens and Test Procedure*

150 mm concrete cubes and cylinders of 150 mm diameter and 300 mm length were used as test specimens to determine the compressive strength of concrete and split tensile strength of concrete for both cases (i.e., normal concrete and GGBS concrete). The ingredients of concrete were thoroughly mixed till uniform consistency was achieved. The cubes and cylinders were properly compacted. All the concrete cubes and cylinders were de-moulded within 24 hours after casting. The de-moulded test specimens were properly cured in water available in the laboratory at an age of 7, 14 and 28 days. Compression test was conducted on a compression testing machine available in the laboratory as per IS 516-1959. The load was applied uniformly until the failure of the specimen. The split tensile strength was conducted as per IS 5816-1976. The specimen was placed horizontally between the loading surfaces of the compression testing machine and the load was applied without shock until the failure of the specimen. The concrete beams of size (150mm x 150mm x 700mm) were tested as per IS 516-1959 for flexural strength. The load was applied through two similar rollers mounted at one third points of the supporting span. The load was applied without shock until the failure occurs.

D. *Observations*

Notations

A: Conventional Mix (Control Mix)

A_1: 30% replacement of GGBS with Cement

A_2: 50% replacement of GGBS with Cemen

Type Of Concrete Mix Proportion	Cement %	Ggbs %	Sand %	Aggregates %
A	100	0	100	100
A_1	70	30	100	100
A_2	50	50	100	100

Table 6:

1) Slump Test

Slump values of various proportions of GGBS replacing cement in M30 grade concrete-

Type Of Concrete	Slump Value (mm)
A	68
A_1	72
A_2	76

Table 7:

2) Compressive Test on Cube as per IS 516-1959: (Size: 150x150x150) mm

The compressive strength of concrete was determined at the age of 7 days and 28 days as presented in Table 4 and Table 5. The specimens were cast and tested as per IS: 516-1959.

Type Of Concrete Mix Proportion	7 Days N/Mm^2	14 Days N/Mm^2	28 Days N/Mm^2
A	23.86	29.2	36.51
A_1	22.56	30.12	38.1
A_2	18.98	28.78	33.65

Table 8:

3) Split Tensile Test: AS Per IS: 5816 – 1999

Type Of Concrete Mix Proportion	7 Days N/Mm^2	14 Days N/Mm^2	28 Days N/Mm^2
A	4.12	4.63	4.95
A_1	4.10	4.51	4.98
A_2	3.96	4.34	4.60

Table 9:

4) Flexure Strength Test: As Per IS: 516-1959

Type Of Concrete Mix Proportion	7 Days N/Mm^2	14 Days N/Mm^2	28 Days N/Mm^2
A	4.97	5.07	5.23
A_1	4.85	5.06	5.31
A_2	4.6	4.87	5.02

Table 10:

E. Discussion

Ground granulated blast furnace slag is off-white in colour and substantially lighter than Portland cement. This whiter colour is also seen in concrete made with GGBS, especially at addition rates of 50% and above.

The slag has a composition of 30% to 40% CaO and approximately 30% to 40% silicon dioxide (SiO_2), which is close to the chemical composition of Portland cement. GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically 40% to 50% is used in most instances. For on the ground concrete structures with higher early-age strength requirement, the replacement ratio would usually be 20 to 30%.

The reaction between GGBS, Portland cement and water are complex. When Portland cement reacts with water, the insoluble hydration products (mainly calcium silica hydrates) form close to the cement particle. The more soluble product of hydration (Calcium hydroxide) migrates through the pore solution and precipitates as discrete crystals, surrounded by large pores. When GGBS particles are also present, both the GGBS and Portland cement hydrate to form calcium silicate hydrates. Additionally, the GGBS react with the excess of calcium hydroxide to form a finely dispersed gel, which fills the larger pores. The result is a hardened cement paste, which contains far fewer calcium hydroxide crystals and therefore has fewer large capillary pores. The reduction in free calcium hydroxide makes concrete chemically more stable, and the finer pore structure limits the ability of aggressive chemicals to diffuse through the concrete.

It is observed that the early age strength values of GGBS concrete mixtures are lower than the control mixtures. As the curing period is extended, the strength values of the GGBS concrete mixtures increase more than the control mixtures. Since the pozzolanic reaction is slow and depends on the calcium hydroxide availability, the strength gain takes longer time for the GGBS concrete. The chemical reaction of the Portland cement is expressed as follows:

Cement (C_3S, C_2S)+H_2O(H) → CSH-gel + $Ca(OH)_2$(CH)

$Ca(OH)_2$(CH) + SiO_2(S) + H_2O(H) →CSH-gel

As it can be seen from the above reactions, calcium hydroxide is produced by the hydration of Portland cement and consumed by the pozzolanic reaction. The pozzolanic reaction can only takes place after the Portland cement hydration starts. It can be seen that the mixture with the highest GGBS addition presents the highest compressive strength increase from the seventh day to curing period. This shows that as the GGBS content is increased, the strength gain increases in time.

The optimum percentage level of 30% GGBS replacement to the weight of the cement is taken with the M30 mix ratio of 1: 1.74: 3.04: 0.40 which gave better results when compared to the control mix. The compressive strength of 38.1 N/mm2 is achieved in the mix due to the presence of GGBS which exhibits more filler effect. The presence of GGBS in concrete results in denser micro-structure of the concrete matrix which enhances the durability properties. GGBS has a high value percentage of strength- enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement. Slump values achieved are nearly the same for control concrete and GGBS concrete. Medium workability was achieved with the given 0.40 w/c ratio, which gives an increase in compressive strength. Split tensile strength of 4.98 N/mm2 and flexural strength of 5.31 N/mm2 are achieved by 30% replacement of cement.

IV. CONCLUDING REMARKS

Based on the experimental investigation, the following conclusions can be drawn:

1) From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period.
2) It is observed that GGBS-based concretes have achieved an increase in strength for 30% replacement of cement at the age of 28 days. Increasing strength is due to filler effect of GGBS.
3) The degree of workability of concrete was normal with the addition of GGBS up to 50% replacement level for M30 grade concrete.

REFERENCES

[1] Mohamed, N.G., Abdesselam Z., Samia, H. (2012) Investigating the Local Granulated Blast Furnace Slag, J. Civil Engng - Scientific Research, 10–15.
[2] Deepa, A.S. (2012) Comparative mechanical properties of different ternary blended concrete. Indian J. Research, 1(10), 65– 69.
[3] Oner, S. Akyuz (2007), GGBS For Compressive Strength Of Concrete, Cement & Concrete Composites 29, Science Direct, Page No. 505–514
[4] Rafat Siddique, Rachid Bennacer (2012), Use Of Iron And Steel Industry By-Product (GGBS) In Cement Paste And Mortar, Science Direct, Conservation and Recycling 69 Page No. 29– 3
[5] Nileena M S; Praveen Mathew (October 2014), Effect Of GGBS And GBS On The Properties Of Self Compacting Concrete, IJIRAE, ISSN: 2349-2163, Volume 1 Issue 9
[6] S. Arivalagan(2014), Sustainable studies on concrete with GGBS as a replacement material in cement, Jordan Journal of Civil Engineering, Volume 8, No. 3
[7] Moslih Amer Salih, Nima Farzadnia, Abang Abdullah Abang Ali, Ramazan Demirboga(2015), Development of high strength alkali activated binder using palm oil fuel ash and GGBS at ambient temperature, Construction and Building Materials 93, Elsevier, Page No. 289–300
[8] Concrete Technology by M. S. Shetty Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. IS 383-1970 Bureau of Indian Standards, New Delhi.
[9] Code of Practice for Plain and Reinforced Concrete. IS 456-2000, Bureau of Indian Standards, New Delhi.
[10] Methods of Sampling and Analysis of Concrete. IS 1199-1959, Bureau of Indian Standards, New Delhi.
[11] IS 10262: 2009, "Guidelines for Concrete Mix Design Proportioning", Bureau of Indian Standards, New Delhi.
[12] IS 2386: 1963, "Methods of test for Aggregates for Concrete", Part I & III, Bureau of Indian Standards, New Delhi.
[13] IS 516:1959, "Methods of Tests for Strength of Concrete", Bureau of Indian Standards, New Delhi.

