

# **An Experimental Study of Properties of Concrete with Ground Granulated Blast Furnace Slag as Supplementary Cementitious Material and Quarry Dust as Fine Aggregate**

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**ABSTRACT:**Portland cement as an ingredient in concrete, which is one of the widely used construction materials, especially in developing countries. The current cement production rate of the world is approximately 1.2 billion tonnes per year and carbon dioxide emitted during this production is an important issue for the construction industry to participate in sustainable development. In recent years the use of GGBS concrete is well recognised. Combining GGBS and OPC at mixer is treated as equivalent to factory made PSC. Concrete with different properties can be made by varying the proportions of GGBS. GGBS is a non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The use of GGBS in concrete increases the strength and durability of concrete. Resistance to chemical attack may be enhanced by using GGBS in concrete. In the present investigation an attempt is made to study the effect of variation of cement replacement by GGBS and quarry dust as fine aggregate on the strength and workability properties of concrete. The compressive strength development of GGBS modified concrete mixes are reported on 3, 7, 28, 56, and 90 day.

**KEYWORDS:** Admixture, Aggregate, Concrete, Ground Granulated Blast Furnace Slag, Quarry Dust

## **I. INTRODUCTION**

Blast furnace slag cements are in use for a reasonably long period due to the overall economy in their production as well as their improved performance characteristics in aggressive environments. GGBS is a by-product from the blast furnaces used to make iron. The two products produced from the blast furnace are – molten iron and molten slag. The molten slag comprises mostly silicates and alumina from the original iron ore combined with some oxides from the limestone. GGBS is a fine glassy material (Fig. 1.1). When it is ground it has usually white colour. It imparts a lighter, brighter colour to concrete. Its specific gravity is less than that of cement, but has more fineness. It can be used as a direct replacement for ordinary cement on one-to-one basis by weight. Replacement rates for GGBS vary from 30% to 85%

Quarry dust is a waste obtained during quarrying process. It has very recently gained good attention to be used as an effective filler material instead of fine aggregate. In the present study, the hardened and durable properties of concrete using quarry dust were investigated. Also, the use of quarry dust as the fine aggregate decreases the cost of concrete production in terms of the complete replacement for natural river sand.

## **II. LITERATURE REVIEW**

Worldwide research is in pace on studying the effect of addition of GGBFS in concrete. Large volume of literature is available in this field and a few of them relevant to the current study are summarized here. In most circumstances, experience in Ireland and the UK has shown that using 50% GGBS has no impact on the normal programme for striking vertical or horizontal formwork (**Jain and Pal, 1998**). Where the proportion of GGBFS is restricted to levels up

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Vol. 6, Issue 11, November 2017

to 50 % the striking times are not increased sufficiently to affect the construction programme, under normal conditions. Results (Rajamane et al, 2003) show that for massive or medium - sized concrete construction, the use of 70% GGBFS does not present a practical limitation to the striking time.

Creemers (2008) reported an overview of results of research into the durability characteristics of blends of GGBS with CEM I and CEM II/A cements. The test results show that the substitution of up to 50% to 70% GGBS for CEM II/A significantly reduces the chloride diffusion coefficient in concrete compared to the CEM II/A cements alone. The diffusion coefficient with the blends of GGBS and CEM II/A are similar to those measured in concretes made with CEM III/B cements. The presence of GGBS in concrete does increase the depth of carbonation as measured under laboratory conditions. However the test data demonstrates that this is still low relative to the concrete cover required by I.S. EN 206-1 to protect against carbonation induced corrosion. This is in agreement with long-term carbonation studies in Germany (Wierig, 1984) that have shown carbonation depths of concretes with up to 75% GGBS to be low in relation to concrete cover.

## III. MATERIALS AND METHODS

### III.1 MATERIAL PROPERTIES

Different tests were conducted for each material as specified by relevant IS codes. Different tests were conducted for each material as specified by relevant IS codes

#### III.1.1 Cement

Laboratory tests were conducted on cement to determine the physical properties such as standard consistency, initial setting time, final setting time and specific gravity.

Table 1. Physical properties of cement

Grade	53 grade
manufacturer	Chettinad cements
Specific gravity	3.168
Fineness	2
Standard consistency(percentage)	31.5
Initial setting time(minutes)	185

#### III.1.2 Coarse aggregate

Is 6461-1971 part 1 defines coarse aggregate as that which is retained on 4.75 mm IS sieve and contains only so much fine material as in permitted by the specification. Crushed stone aggregate of size 10mm and specific gravity 2.762 was used as coarse aggregate.

Table 2. Properties of Coarse Aggregate

Specific gravity	2.762
Fineness modulus	6.87

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Vol. 6, Issue 11, November 2017

Sieve size	Weight retained (gm)	% weight retained	Cumulative % weight retained	% passing
20 mm	49	1.63	1.63	98.37
10 mm	2530	84.33	85.96	14.04
4.75	401	13.37	99.33	0.067
pan	20	0.67	100	0.00

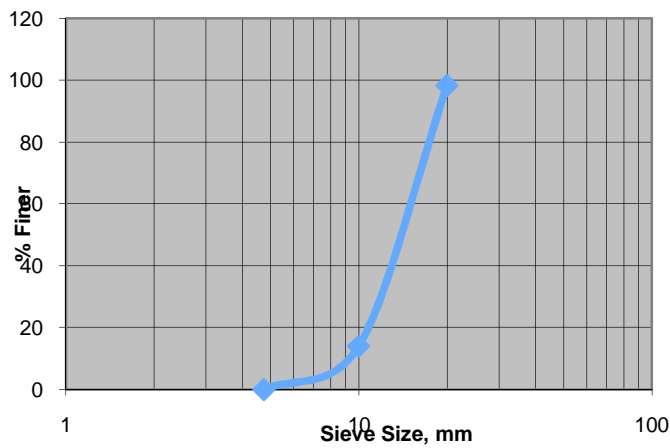


Fig. 1 Particle Size Distribution of Coarse Aggregate

### III.1.3 Fine aggregate (Quarry dust)

Quarry dust is a waste obtained during quarrying process. It is an effective filler material instead of fine aggregate. Also the use of quarry dust decreases the cost of concrete production in terms of the complete replacement for natural river sand. The sieve analysis result is presented in **Table 3**

Table 3 Sieve Analysis Data of Quarry Dust

Sieve size	Weight retained(gm)	% weight retained	Cum.% wt retained	% passing
4.75 mm	4	0.4	0.4	99.6
2.36 mm	19	1.9	2.3	97.7
1.18 mm	277	27.7	30	70
600 $\mu$	203	20.3	50.3	49.7
300 $\mu$	180	18	68.3	31.7
150 $\mu$	187	18.7	87	13
75 $\mu$	61	6.1	93.1	6.9
pan	69	6.9	100	0

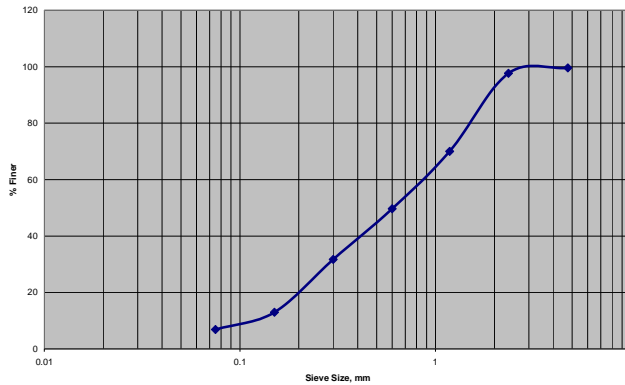
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Vol. 6, Issue 11, November 2017

FIG 2 PARTICLE SIZE DISTRIBUTION OF QUARRY DUST



### III.1.4 Ground granulated blast furnace slag

Ground granulated blast furnace slag (GGBS) is a mineral admixture commonly used in concrete as it improves durability and reduce porosity. It improves the interface with the aggregate. GGBS is a by-product in the manufacture of pig iron and the amount of iron and slag obtained are of the same order. The slag is a mixture of lime, silica and alumina, the same oxides that make up Portland cement but not in the same proportion.

To investigate the particle size distribution of GGBS, hydrometer analysis was conducted and the data is presented in **Table 3.5**. A particle size distribution curve is also presented in **Fig.3.3**.

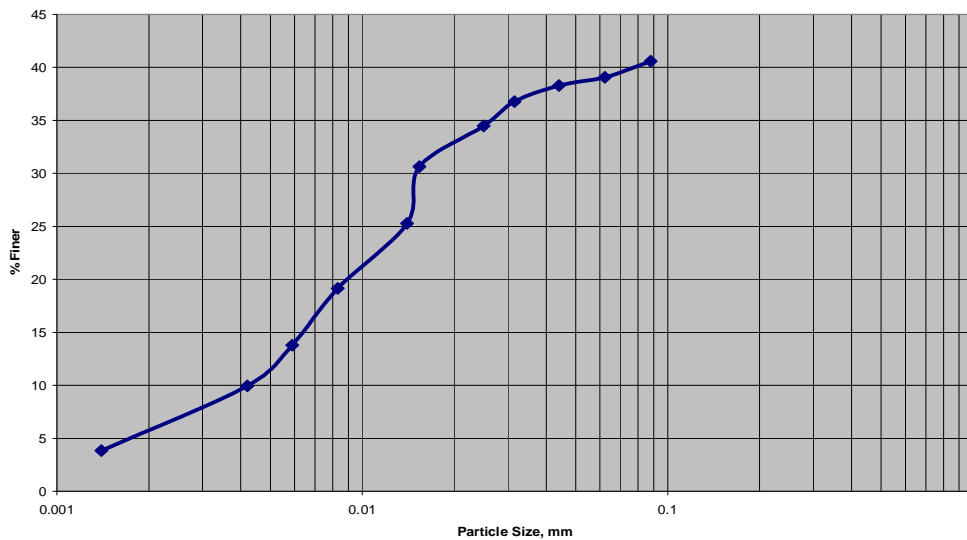


Fig. 3 Particle Size Distribution Curve of GGBS

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Time,t(min)	Observed reading, $R_h$	Corrected reading,R	Effective depth, $H_e$ (cm)	Particle diameter,D(mm)	Percentage fine,N
¼	15.75	13.25	14.9	0.0880	40.595
½	15.25	12.75	14.95	0.0623	39.064
1	15	12.5	15	0.0441	38.298
2	14.5	12	15.25	0.0315	36.765
4	13.75	11.25	15.6	0.0250	34.468
8	12.5	10	14.55	0.0154	30.638
15	10.75	8.25	15.10	0.0140	25.277
30	8.75	6.25	15.75	0.0083	19.149
60	7	4.5	16.4	0.0059	13.787
112	5.75	3.25	16.8	0.0042	9.957
1200	3.75	1.25	17.55	0.0014	3.829

Table 4. Hydrometer Analysis of GGBS

### III.1.5 Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement, since it helps to form the strength giving cement gel the quantity and quality of water is required to be looked in to very carefully.

### III.2 TESTS PLANNED

To investigate the performance of concrete incorporating GGBS as the mineral admixture in concrete made of quarry dust as fine aggregate, following tests are planned.

1. Workability tests-slump cone and compacting factor test
2. Compressive strength of concrete cubes
3. Flexural strength of concrete beam
4. Split tensile strength of concrete cylinder

#### III.2.1 Workability test

Though workability is a very important property of concrete, it is quite difficult to define and measure. A concrete is said to be workable if it can be easily mixed, handled transported, placed in position and compacted.

##### *Slump Cone Test*

Slump test is the most commonly used method of measuring consistency of concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

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Vol. 6, Issue 11, November 2017

### Compacting Factor Test

This test is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration.

### III. 2.2 Compression Test on Cubes

Compression test is the most common test conducted on hardened concrete partly because it is an easy test to perform and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimens of the size 10x10x10 cm size, after moist curing it for 3, 7, 28, 56 and 90 days. The test is done by loading the cube in compression in a compression testing machine at a standard rate of 315 kN/minute.

### III.2.3 Flexural strength of beams

Tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Direct measurement of tensile strength of concrete is difficult. Beam tests are found to be dependable to measure flexural strength property of concrete.

$$\text{Flexural strength of the specimen } F_d = Pl/bd^2$$

Where b is the width in mm

d is the depth in mm

l is the length in mm

P is the maximum load in N

### III.2.4. Split Tensile Strength

This test is also referred to as Brazilian test. This test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of the compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter.

$$\text{Split tensile strength} = 2P / 3.14DL$$

Where P is the compressive load on the cylinder

L is the length of the cylinder

D is the diameter of the cylinder

## IV.RESULTS AND DISCUSSIONS

### IV.1 FRESH CONCRETE PROPERTIES

#### IV.1.1 Workability tests

Slump test was conducted on the fresh concrete prepared for all the mixes and the slump values obtained are shown in **Table 4.1**.The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump.

Table 5. Workability – Slump of Concrete Mixes

Mix	Slump (mm)
Control Mix	53
Mix 1 (25% GGBS)	28
Mix 2 (50% GGBS)	10
Mix 3 (75%GGBS)	0

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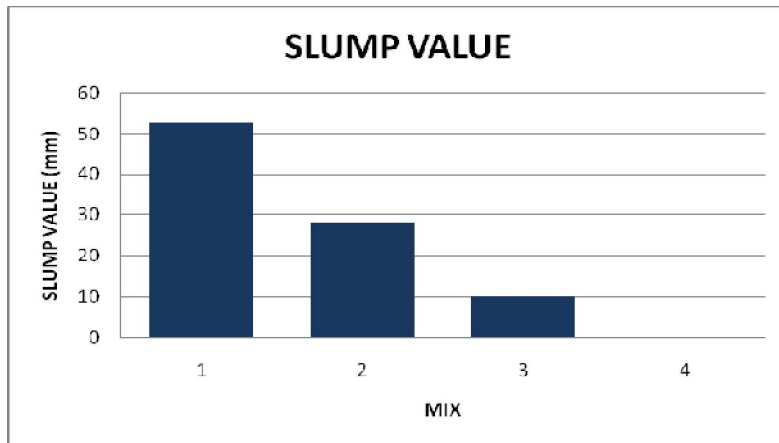


Fig. 4. Slump for Different Mixes

Table 6 Workability –Compacting Factor of Concrete Mixes

Mix designation	Compacting factor
Control mix	0.927
Mix 1 (25% GGBS)	0.909
Mix 2 (50% GGBS)	0.902
Mix 3 (75% GGBS)	0.901

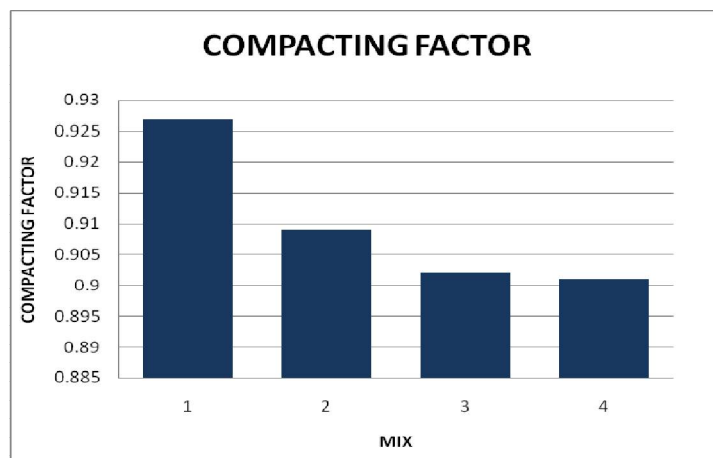


Fig. 5. Compacting Factor for Different Mixes

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Vol. 6, Issue 11, November 2017

## IV.2 HARDENED CONCRETE PROPERTIES

Cube strength, flexural strength and split tensile strength were conducted for all the mixes. The cube strength and flexural strength are determined at 3, 7, 28, 56 and 90 days of casting. Split tensile strength of concrete cylinders was determined at 56 and 90 days of casting.

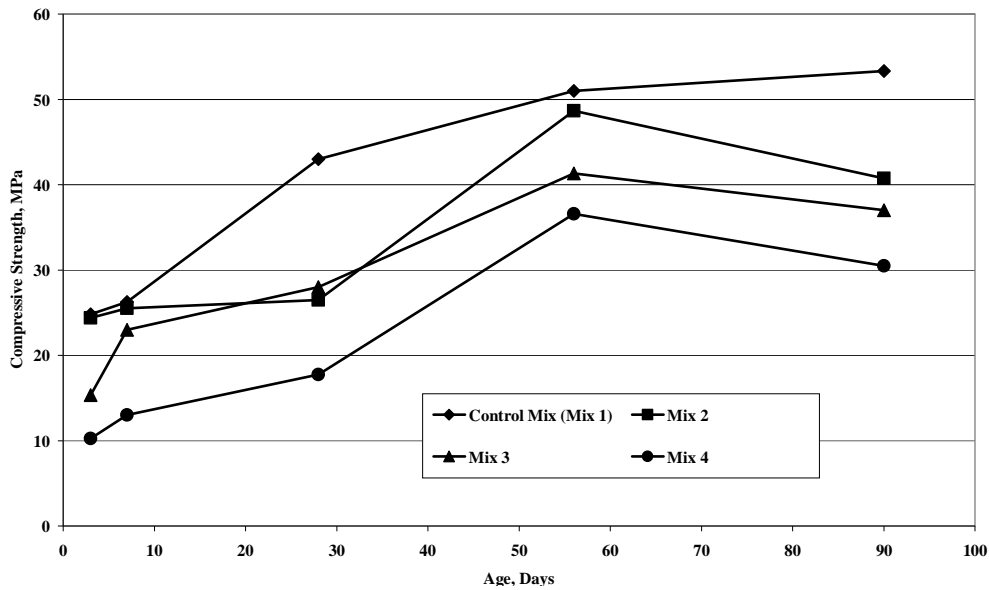


Fig.6 Variation of Compressive Strength with Age.

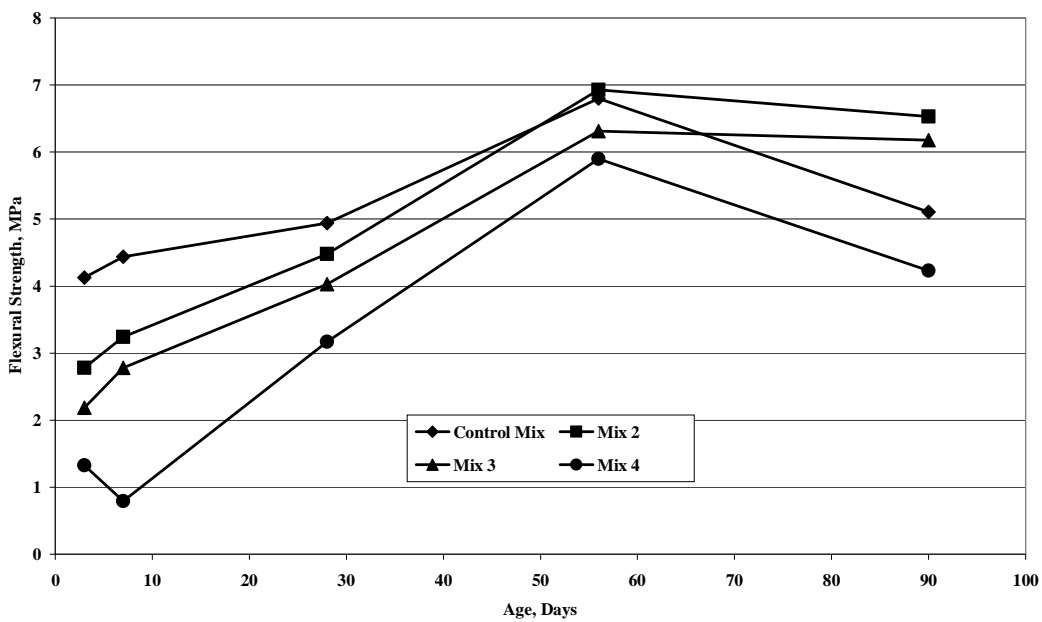


Fig.4 Variation of Flexural Strength with Age.



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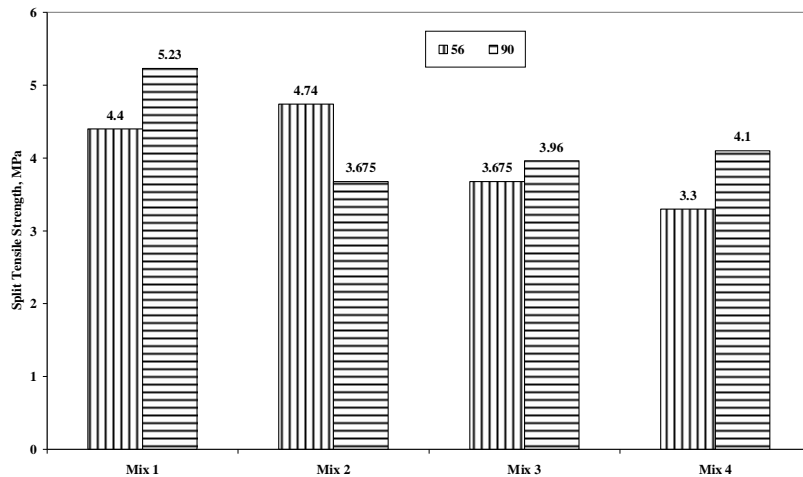


Fig. 8 Split Tensile Strength at 56 and 90 Days

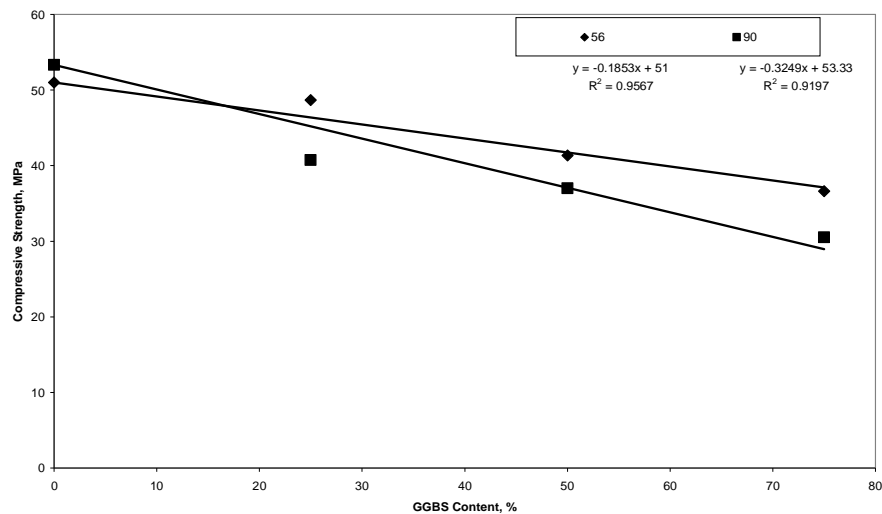


Fig. 9 Variation of Compressive Strength at 56 and 90days

## V. CONCLUSIONS

From the light of limited observations and the associated discussions presented in the previous chapter following conclusions are drawn:

- The behaviour of concrete containing Ground Granulated Blast Furnace Slag (GGBS) as a supplementary cementitious material (partial replacement to cement) is studied.
- The addition of GGBS as a cement replacement material, reduces the workability of concrete, both slump and compacting factor. This is probably due to the finer particle size of GGBS. The reduction in the value of slump and compacting factor can be expressed as a function (a second degree polynomial) of the percentage of GGBS in the mix.
- The addition of GGBS in concrete necessitates the use of plasticizers or superplasticisers to get a reasonably workable mix.

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Vol. 6, Issue 11, November 2017

- The compressive strength development of GGBS admixed concrete are slower than their control mix at early age of hydration (up to 28days of age).
- Extended moist curing beyond 28days, the strength development is faster for GGBS mixes. However, curing beyond 56days leads to the leaching of  $\text{Ca}(\text{OH})_2$ , and loss in compressive strength.
- The rate of flexural strength development is more in case of GGBS admixed concrete mixes.
- The loss in flexural strength after 56days curing is predominant for Control mix and mix containing 75% GGBS.
- The later age compressive strength progressively reduces with the increase in GGBS dosage in the mix. There exists a reasonably good correlation of compressive strength and the GGBS dosage.

## Suggestions for Future Work

- The study can be extended to assess the durability performance of concrete containing GGBS.

The strength parameters of GGBS mixes modified with super-pozzolanic materials such as silica fume, rice-husk ash or metakaolin can be investigated.

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