International Journal on Emerging Technologies **6**(2): 72-79(2015)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Utilization of Ground Granulated Blast Furnace Slag to Improve Properties of Concrete

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(Received 30 June, 2015 Accepted 08 August 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The Ground granulated Blast furnace slag (GGBFS) is a waste of industrial materials; it is relatively more recent pozzolanic material that has received considerable attention in both research and application. Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other industrial branches. The present paper is an effort to quantify the effect on properties of ground granulated blast furnace slag (GGBFS) at various replacement levels and evaluate its efficiencies in concrete. From the result from this study the Slump values of various mix proportions of GGBFS concretes increased when replacement of GGBFS with cement increase 10-40%.The Compressive strength decreases with increase in percentage (%) of GGBFS at the age of 7 and 28 days as compared to control mix but it increases with increase in the percentage of GGBFS at the age of 56 days. Flexural strength of concrete mix decrease with increase in percentage (%) of GGBFS at the age of 7 and 28 days as compared to mix but it was nearly equal with increase in the percentage of GGBFS at the age of 56 days. The Spilt tensile strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 days and 28 days as compared to control mix due to slower rate of reaction. The Spilt tensile strength of the mix with 20%, 30% cement replacement better performed than control mix at 56 days. The results obtained from the study shows that the percentage (%) of GGBFS (10-40%) in concrete increased the Sulfate and Chloride resistance.

Keywords: GGBFS, Compressive strength, Flexural strength, Sulphate, Chloride resistance

I. INTRODUCTION

Creating quality concrete in the present climate does not depend slowly on achieving a high Strength property. Improving the durability of the concrete to sustain a longer life span and producing a greener concrete are becoming one of the main criteria in obtaining quality concrete.

By using industrial by-products such as Ground Granulated Blast-furnace Slag (GGBFS) as mineral admixture partially replacing Ordinary Portland Cement (OPC) in the concrete, the amount of greenhouse gas produced in making the concrete and the energy required to produce the concrete are reduced. It has been well documented that GGBFS is a very good mineral admixture to be used in improving the properties of the concrete due to its positive effects on its sustainable development and the environment. In blending GGBFS with OPC, a concrete paste with improved fluidity and reduced bleeding can be achieved. It is well documented that with the addition of GGBFS, the early strength of the concrete is affected. However as the concrete curing age increases, the strength of the concrete improves. The properties of GGBFS aid the concrete in resisting chloride induced corrosion and the blended concrete will have a reduced pore connection which helps in preventing chloride penetration. In this work, the effect of GGBFS replacement on the properties of GGBFS concrete is studied. Five mixes with water/cementitious (w/c) ratio and different amount of cementitious materials were studied. The amount of GGBFS replacement was set at 10-40%. Slump test, Compressive strength, flexural strength, Spilt tensile strength and Sulphate and Chloride resistance test were performed to study the effect of GGBFS on the properties of the concrete.

The GGBFS replacement resulted in higher early strength, lower permeability, and better durability against chloride penetration compared to OPC concrete.

II. MATERIALS AND METHODS

A. Ground Granulated Blast furnace Slag (GGBFS)

Blast furnace slag 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 1500°C to 1600°C.

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 (GGBFS).

Table 1: Chemical properties of GGBFS.

S.NO.	Constituents	Proportion
1	Cao	33-35 %
2	Al_2O_3	16-18 %
3	Fe_2O_3	1.9-2.1 %
4	SO_3	0.5-0.9 %
5	MgO	8-10 %
6	SiO_2	32-34 %

Table 2: Physical Properties of GGBFS.

S.NO.	Characteristics	Value
1	Bulk Density	650-750 kg/m^3
2	Surface Area	11750 cm^2/gm
3	Particle shape	Irregular
4	Particle Size,d10	< 2µ
5	d50	<5µ
6	d90	<9µ

B. Material Used

The work in this paper presents the investigation on the behaviour of concrete produced from blending of cement with the combination of Ground Granulated Blast Furnace Slag. The physical and chemical properties of GGBFS were first investigated. The M-25 Mix proportioning is designed as per guidelines, according to the Indian Standard Recommended Method IS 10262- 2009. Cubes and beams mould were used for casting. Proportions of concrete as determine were 1:1.56:2.9 with a water cement ratio of 0.45 by weight.

The other concrete mixtures were made by replacing cement with 10%, 20%, 30% and 40% GGBF slag. The effect of GGBFS on concrete properties was studied by means of the fresh properties of concrete and the mechanical properties i.e. Slump test, Compressive strength, split tensile strength, flexural strength, and Sulphate and chloride resistance test. The materials used in experimental investigation include:-

Cement: Ordinary Portland cement (OPC) satisfying the requirements of IS: 4031 is used. The specific gravity of cement was found to be 3.21 & Normal consistency is 36%.

Fine Aggregates: The sand used for the experimental programme was locally procured. The sand was first sieved through 4.75 mm sieve and remaining particles removed from sieve and then washed to remove the dust. The fine aggregate were tested as per Indian Standard Specification IS: 383-1970.

Coarse Aggregate: A good quality of coarse aggregate having the maximum size of 10 mm and 20 mm were used in the present work whose specific gravity was to be 2.70 and 2.82. The shape of the aggregate was not flaky. The 10 mm aggregates were first sieved through 10 mm sieve and then through 4.75 mm sieve and 20 mm aggregate were first sieved through 20 mm sieve. The aggregates were tested per Indian standard Specifications IS: 383-1970.

Water: The water to be used for casting should be free from organic matter. Tap water in the laboratory was used for mixing the ingredients of concrete and curing of the specimens.

Ground Granulated Blast Furnace Slag (GGBFS): Blast furnace slag used in this work is ground granulated blast furnace slag (GGBFS). Ground granulated blast furnace slag (GGBFS) was obtained from JSW Ispat Steel Ltd. Granulated slag is an admixture that can be used as a cement replacement material according IS 456: 2000.

III. EXPERIMENT

M25 grade is prepared by hand mixing (IS: 10262-2009). The Portland cement was partially replaced by GGBFS. Five mixes M-0, M-1, M-2, M-3 and M-4 are prepared by combination of Portland cement & GGBFS i.e. 0%, 10%, 20%, and 30% and 40% respectively. For each mix 3 samples casted, Cubes of 150 mm dimension were tested for the determination of compressive strength and beam of 500×100×100 dimension were tested for the determination of flexural strength and to determine the Splitting tensile strength Cylinders of size 150mm x 300 mm were used to prepare the GGBFS concrete and slump cone apparatus is used to determine the workability of mix at 7, 28 and 56 days as per Indian standard Specifications IS: 516-1956.

IV. RESULTS AND DISCUSSION

Following Tables shows the experimental results of the test samples made from partial replacement of cement using GGBFS. In the Table 3 the result of Slump values of various mix proportions of GGBFS concretes increased when replacement of GGBFS with cement increase 10-40%. Slump value Control mix concrete has obtain less value than the 40% replacement GGBFS. Test result of Compressive strength(Table 4) of the mix lower with 10%, 20%, 30%, 40% GGBFS replacing with cement as compared to control mix at 7 days and 28 days due to slower rate of reaction. The compressive strength of the mix with 10%, 20%, 30% cement replacement increased at 56 days whereas the mix 40% cement replacement showed a decrease in strength at 56 days as compared to control mix. The result shown in Table 5 the result of Flexural strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 & 28 days due to slower rate of reaction. The flexural strength of the mix with 10%, 20%, 30% cement replacement increased after at 56 days where as the mix 40% cement replaced showed a decrease in strength by at 56 days as compared to control mix. It is shown in Table 6 the result of Spilt tensile strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 days and 28 days due to slower rate of reaction. The Spilt tensile strength of the mix with 20%, 30% cement replacement better performed than control mix at 56 days where as the mix 40% cement replaced showed a decrease in strength by at 56 days as compared to control mix. The result shown in Table 7 shown the compressive strength in sulphate solution of the mix with 0%, 10%, 20%, 30%, and 40% cement replacement was found to be decreased. Thus from these results it is clear that as the any percentage of GGBFS in concrete increased the Sulfate resistance. In Table 8 the result of compressive strength in chloride solution of the mix with 0%, 10%, 20%, 30% and 40% cement replacement 7 days and 28 days strength was found to be decreased as compared to control mix. The variation in the result was found in the case of testing at 56 days.

Table 3: Test result (Slump test (C.m) of M25 grade concrete with various percentages of GGBFS.

Sr. No.	Type of concrete	Slump value
1	control concrete	29 cm
2	10% GGBFS	30 cm
3	20% GGBFS	32 cm
4	30% GGBFS	35 cm
5	40% GGBFS	40 cm

Table 4: Test result (Compressive strength (MPa) of M25 grade concrete with various percentages of GGBFS.

Sr. No.	GGBFS content,%	Design mix	Compressive Strength (MPa)		
			7 days	28 days	56 days
1	0	M-0	17.8	23.7	24.9
2	10	M-1	17.1	22.8	25.3
3	20	M-2	16.8	22.2	26.8
4	30	M-3	15.8	21.9	28.7
5	40	M-4	14.8	21.4	26.2

Table 5: Test result (Flexural strength (MPa) of M25 grade concrete with various percentages of GGBFS.

Sr. No.	GGBFS content,%	Design mix	Flexural strength (MPa)		
			7 days	28 days	56 days
1	0	M-0	14.6	19.2	19.9
2	10	M-1	14.3	18.9	20.7
3	20	M-2	13.8	18.6	22.4
4	30	M-3	12.5	17.4	23.5
5	40	M-4	11.9	16.7	21.4

Table 6: Test result (Spilt tensile strength (N/mm^2) of M25 grade concrete with various percentages of GGBFS.

Sr. No.	GGBFS content,%	Designation of mix	Spilt tensile strength (N/mm^2)		
			7 days	28 days	56 days
1	0	M-0	3.9	4.1	4.23
2	10	M-1	3.86	4.07	4.2
3	20	M-2	3.81	4.04	4.22
4	30	M-3	3.72	3.98	4.25
5	40	M-4	3.66	3.94	4.18

Table 7: Test result (Compressive strength in sulfate solution (MPa) of M25 grade concrete with various percentages of GGBFS.

Sr. No.	GGBFS content,%	Design mix	Compressive strength (MPa) in sulphate solution		
			7 days	28 days	56 days
1	0	M-0	17.8	23.9	24.7
2	10	M-1	17.1	22.8	25.0
3	20	M-2	16.7	22.1	26.8
4	30	M-3	16.3	21.8	28.7
5	40	M-4	14.6	21.3	25.7

Table 8: Test result (Compressive strength in Chloride solution (MPa) of M25 grade concrete with various percentages of GGBFS.

Sr. No.	GGBFS content,%	Design mix	Compressive strength (MPa) in Chloride solution		
			7 days	28 days	56 days
1	0	M-0	18.4	24.2	24.6
2	10	M-1	17.0	23.5	24.9
3	20	M-2	16.3	22.1	26.8
4	30	M-3	16.2	21.7	28.4
5	40	M-4	14.6	21.3	25.8

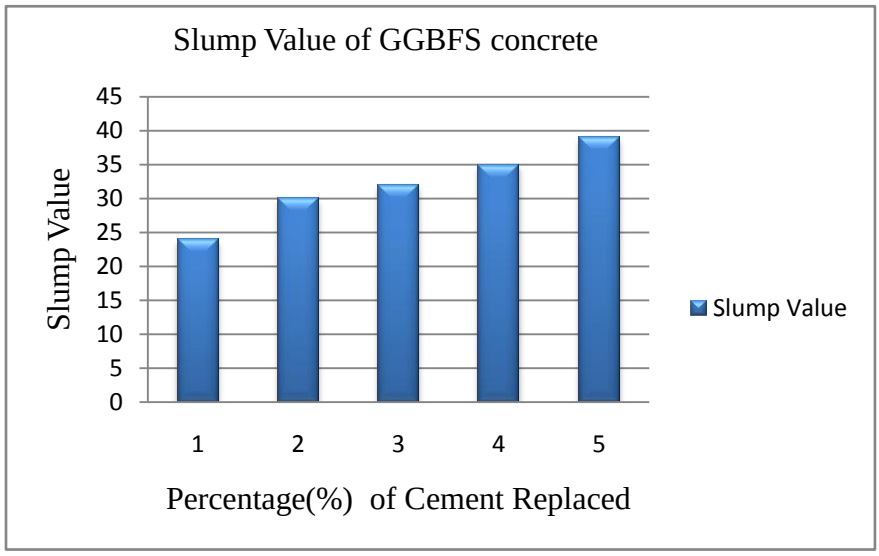

Fig. 1. Test result (Slump test(c.m) of M25 grade concrete with various percentages of GGBFS.

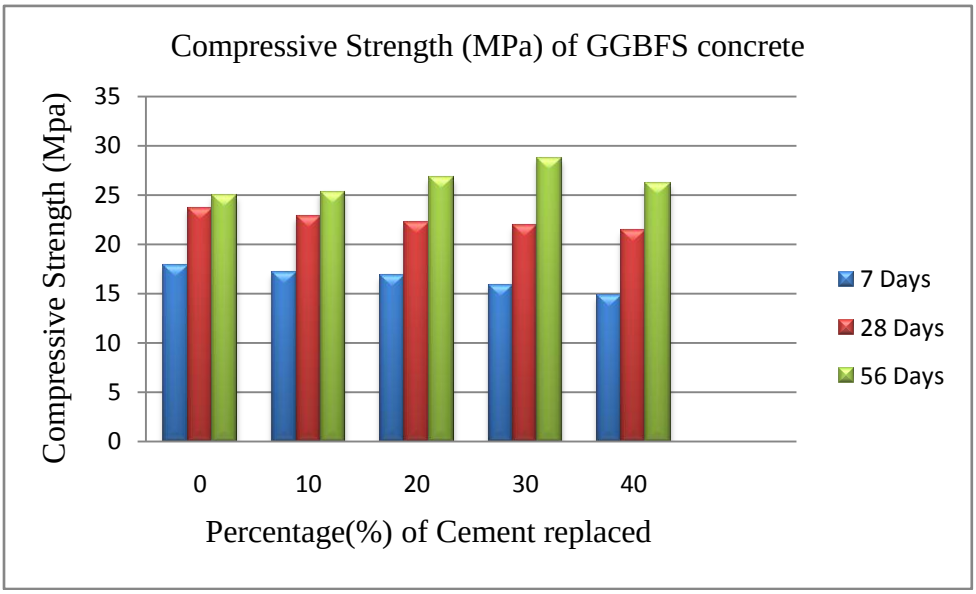

Fig. 2. Test result (Compressive strength (MPa) of M25 grade concrete with various percentages of GGBFS.

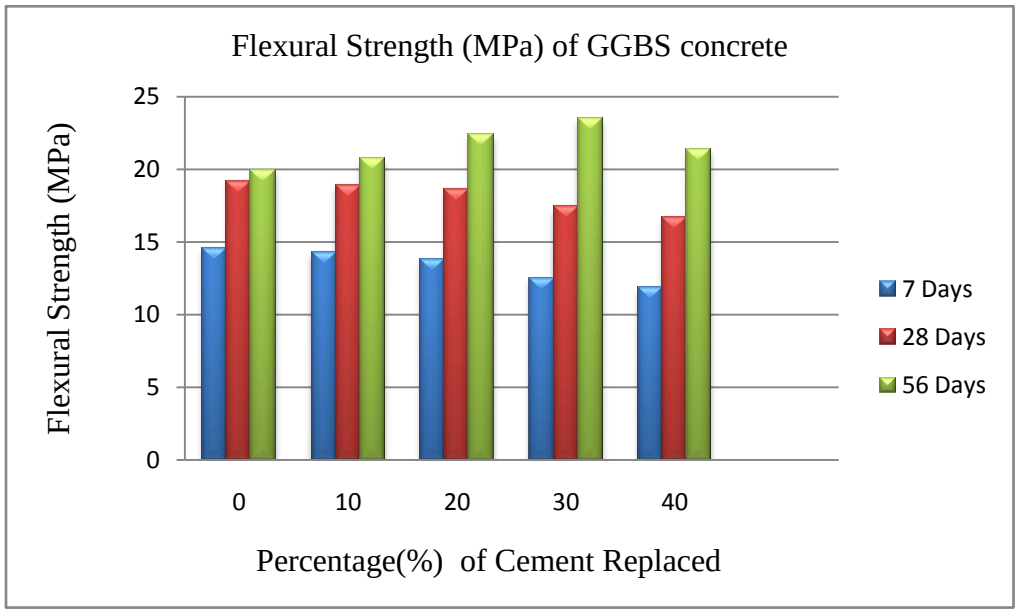

Fig. 3. Test result (Flexural strength (MPa) of M25 grade concrete with various percentages of GGBFS.

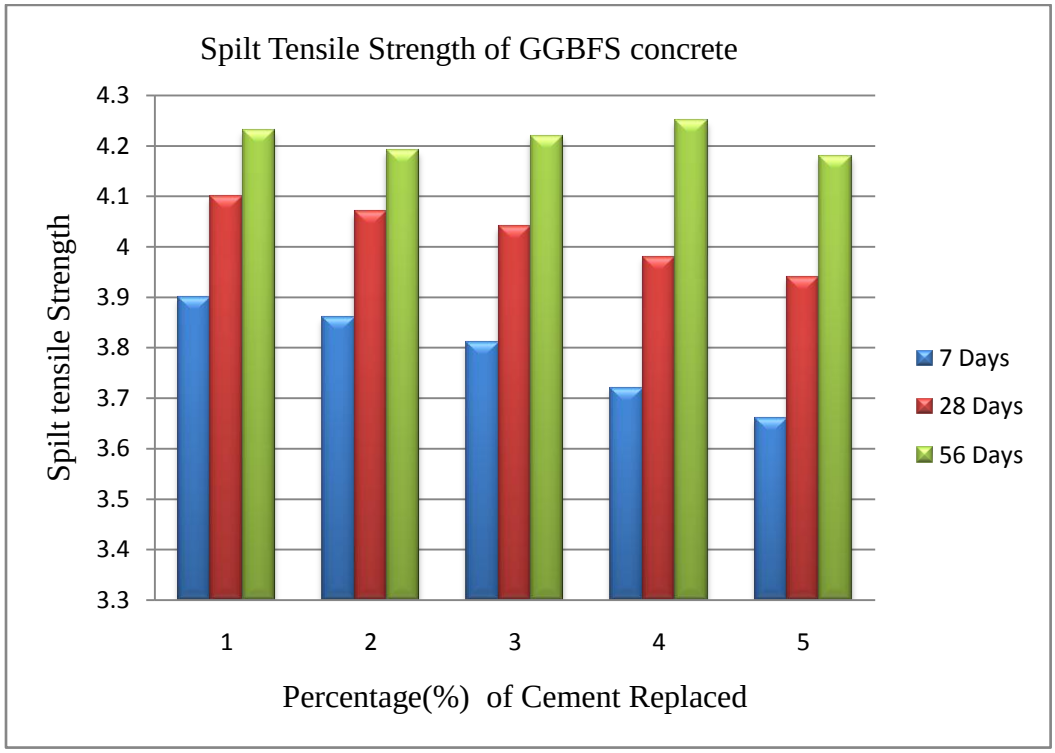

Fig. 4. Test result (Spilt tensile strength (N/mm^2) of M25 grade concrete with various percentages of GGBFS.

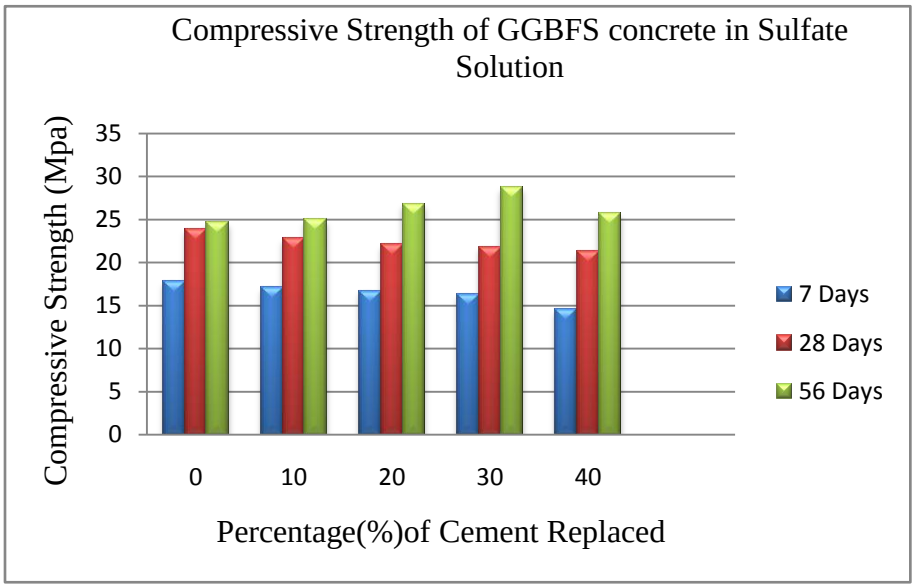

Fig. 5. Test result (Compressive strength in sulfate solution (MPa) of M25 grade concrete with various percentages of GGBS.

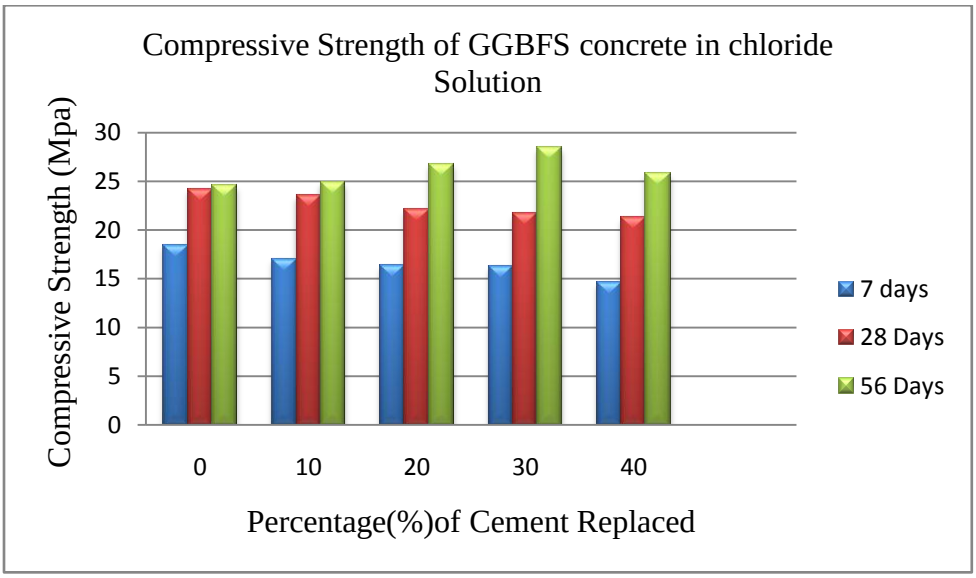

Fig. 6. Test result (Compressive strength in Chloride solution (MPa) of M25 grade concrete with various percentages of GGBFS.

CONCLUSIONS

-The Slump values of various mix proportions of GGBFS concretes increased when replacement of GGBFS with cement increase 10-40%. Slump value. Control mix concrete has obtain less value than the 40% replacement.

-The GGBFS concrete obtained compressive strength in the range of 17.8 to 14.8 MPa at 7 days on replacement with GGBFS of 10 to 40% respectively, while it achieved strength of 23.7 to 21.4 MPa at age of 28 days.

At the age of 56 days, the strength achieved is 24.9 to 26.2 MPa. Compressive strength decreases with increase in percentage (%) of GGBFS at the age of 7 and 28 days but it increase with increase in the percentage of GGBFS at the age of 56 days.

-The GGBFS concrete obtained flexural strength in the range of 14.6 to 11.9 at 7 days as replacement with GGBFS of 10 to 40% respectively while it achieved strength of 19.2 to 16.7 MPa at age of 28 days. At the age of 56 days, the strength achieved is 19.9 to 21.4 MPa. Flexural strength decrease with increase in percentage (%) of GGBFS at the age of 7 and 28 days but it was nearly equal with increase in the percentage of GGBFS at the age of 56 days.

-The Spilt tensile strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 days and 28 days due to slower rate of reaction. The Spilt tensile strength of the mix with 20%, 30% cement replacement better performed than control mix at 56 days where as the mix 40% cement replaced showed a decrease in strength by at 56 days as compared to control mix.

-From the result the percentage (%) of GGBFS (10-40%) in concrete increased the Sulfate resistance increased.

-It is shown from the result the chloride resistance of concrete specimens in which cement was replaced by GGBFS were found to be better performed than the specimens without GGBFS.

-The compressive strength of the specimen with GGBFS (10-30%) cement replacement increase at 56 days where as the mix 40% cement replaced showed a decrease in strength as compared to control mix.

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