"Study on Durability Properties of High Strength Concrete Containing Ground Granulated Blast Furnace Slag against Sulphate Attack"

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Abstract—The use of cementitious materials becomes popular due to several benefits in concrete mix. For present workthebyproduct from steel manufacturing industry known as GGBFS (Ground Granulated Blast Furnace Slag)is used. GGBFScontain nearly same chemical constituents like cement with varying percentage. Advantage of this varying percentage is for improving different properties like resistance to chemical attack, workability, compressive strength and cost.of concrete by replacing it with cement.

This paper presents the effect of sulphuric acid on compressive strength of High Strength Concrete (HSC) and change in pH of curing solution. The concrete mix sample were cast with water to cementitious material (w/cm) ratio 0.28; using 0% and 20% GGBFS with ordinary portland cement. The specimens were cured for 28 days in water and sulphuric acid solution at different concentrations. The pH of acidic solution and water was maintained as 2.5, 3.5, 4.5, 5.5 and 7.4 respectively. The results show that, as sulphuric acid concentration increases, reduction in compressive strength increases.

Keywords: *High Strength Concrete, Ground Granulated Blast Furnace Slag,sulphuric acid.*

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I. INTRODUCTION

Concrete is the most widely used construction material due to its significant compressive strength and low cost. The concrete mainly divided into three types: ordinary concrete, standard concrete and high strength concrete (the concrete having strength 60MPa and above up to 80MPa [1]. Now a days High Strength Concrete (HSC) is used to reduce cross-section and there by self weight of the building. The other benefit of using HSC is that ultimate deformation decreases with the increasing strength. The requirement of high cement content in HSC is being produced using supplementary cementitious materials like fly ash, Ground granulated blast furnace slag, silica fume, metakaolin and rice husk-ash and make concrete durable [2-4].

Due to rapidly growing steel industries, there is a big challange of disposal of waste material, produced during manufacturing of steel called ground granulated blast furnace slag (GGBFS). A study has been carried out to observe the effect of GGBFS as a partial replacement to cement. It acts as a pozzolan which results in denser and impermeable concrete structure as the pore space filled with C-S-H rather than in Portland cement [5-6]. The presence of GGBFS in the concrete improves the workability and the mobility of the concrete mix. This is due to surface characteristics of the GGBFS which are smooth and absorb little water during mixing. Concrete containing GGBFS have long term strength development due to very slow initial hydration of GGBFS. The progressive release of alkalis by the GGBFS, together with the formation of calcium hydroxide by Portland cement, results in continuing reaction of GGBFS over a long period. [7]. Sulfuric acid is a very aggressive acid whichreacts with the free lime $Ca(OH)_2$, in cement paste forminggypsum ($CaSO_4$, $2H_2O$). The reaction between gypsum and calcium aluminate hydrate (C_3A) has lead to the formation of ettringite ($3CaO.Al_2O_3.3CaSO_4.32H_2O$) with an increase in volume of the concrete and the reacted surface becomes soft and white. Hence, concrete structures losses its mechanical strength [6-7]

II. MATERIALS AND METHODS

2.1 Cement:-

Ordinary Portland Cement (OPC) 53 grade conforming to IS: [12269-1987] has been used.

2.2 Ground Granulated Blast Furnace Slag:-

produced by JWS Cement, Pune are used. The GGBFS consists essentially of silicates and aluminosilicatesof calcium. It confirms to Indian standard code, IS [12089-1987].

The physical and chemical properties of cement and GGBFS are mentioned in Table 1 and Table 2

2.3 Aggregate:-

Locally available Godavari river sand was used as a fine aggregate of size passing through the sieve 4.75 mm. The crushed aggregate of size passing through the 12.5 mm sieve conforming to the requirements of IS: [383-1970] was used. The fineness modulus for coarse and fine aggregates are 6.31 and 3.49, also the specific gravity of coarse and fine aggregates are 2.83 and 2.49 respectively.

2.4 Water:-

Potable water was used for mixing and curing of concrete specimens.

2.5Superplasticizer

Conplast SP 430 of FORSOC chemicals (India) Pvt. Ltd, Bangalore, confirming to IS [9103-1999] was used as superplasticing admixture based on sulphonatednapththalene polymers having specific gravity as 1.22-1.225 at 30^0C

Table 1 Physical properties of Cement and GGBFS

Item	Fineness (m^2/kg)	Specific gravity
OPC	380	3.13
GGBFS	426	2.97

Table 2Chemical properties of Cement and GGBFS

Item	C_aO	SiO_2	Al_2SO_3	Fe_2O_3	M_gO	SO_3	K_2O	Na_2O
OPC	63.76	20.69	4.72	3.06	2.08	2.92	0.61	0.26
GGBFS	37.34	37.73	14.42	1.11	8.71	….	….	….

2.6 Experimentalprogramme

High strength concrete is designed with help of the guidelines given by the British Department of Environment (DOE) method for compressive strength nearly equal to 80 MPa by using GGBFS as replacement to cement. To achieve target compressive strength the concrete cubes of 150 x 150 x 150 mm size were cast for 0% (control mix) and 20% GGBFS at water to cementations material ratio (w/cm) 0.28.The dosage of superplasticizer used as 1.8% for respective replacement of GGBFS. In all 30 concrete cubes were cast and tested.

2.7 Curing:-

After 24 hours the concrete cube specimens of various concrete mixtures were demoulded. The acid attack test on concrete cube was conducted by immersing the cubes in the acidic solution and water for 28 days. Sulphuric acid with pH of 2.5, 3.5, 4.5, 5.5 and 7.4 was maintained in separate tank including water, in which the concrete cubes were stored. After completion of immersion period, the concrete cubes were taken out and kept for one hour before going to test.

2.8 Testing:-

When the cubes were completely dried, tested for compressive strength when compared with control concrete specimen.The resistance of concrete to acid attack was found by the % reduction in compressive strength. The compressive strength of concrete specimens after exposure to sulphuric acid solutions was examined at the end of the 28-days and compared with compressive strength of cubes cured in water to determine the relationship between the reduction in compressive strength of the specimens.

III. RESULTS AND DISCUSSION

3.1 Compressive Strength:-

The Percentage loss in compressive strength for 0.28 w/cm ratios is shown in the following In figure No.1 the pH concentration is indicated on X-axis and percentage strength loss is on Y-axis. From the figures, it is seen that as the pH concentration increases; strength loss increases. The maximum strength loss was found at 2.5 pH concentrations as it increases from 5.5 pH. This effects may caused due to the attack of sulpHatewith the hydration products of tri-calcium aluminate(C_3A) which in later term, reacts with hydration products of tetra-calcium ferritealuminateand calcium hydroxide ($Ca(OH)_2$) to form expansive crystalline products (gypsum, monosulfate or ettringite). Expansion resulting from ettringite formation generally develops tensile stresses in the concrete. When these stresses become greater than the concrete's tensile capacity, concrete begins to crack. These cracks allow easy ingress for more sulfates and the deterioration accelerates. In order to decrease expansion, the water content of concrete should decreases which ultimately increases the resistance of the concrete to the sulfate solution. All mortar samples cured in the sulfuricacid solutions showed a higher percentage loss in compressive strength than those ofthe controlled mix.

Table 3% reduction in compressive strength at w/cm 0.28

GGBFS %	pH of acidic water			
	5.5	**4.5**	**3.5**	**2.5**
0%	11.27%	12.82%	13.22%	14.09%
20%	12.74%	14.77%	16.02%	18.18%

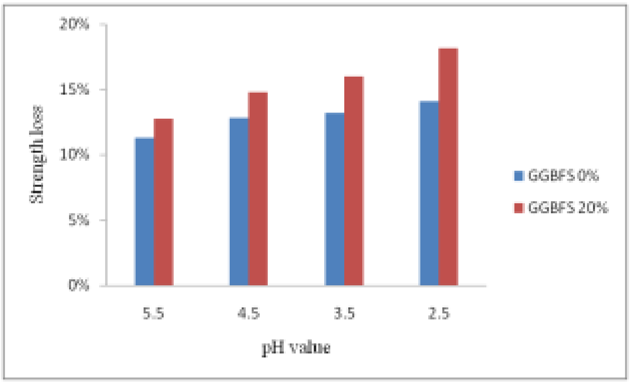

Fig.1 Percentage reduction in compressive strength at w/cm 0.28

3.2 Change in pH:-

The changes in pH value of the sulfuric acid solution during the attack were observed for different pH value. Fig.2 shows the curing period on X-axis and pH concentration on Y-axis. The pH of the solution decreases for all concrete specimens rapidly. After 28 days the pH value increases to 8.8, 11.9, 11.8, 11.7 and 9.8 from 7.4, 5.5, 4.5, 3.5 and 2.5 respectively. Decomposition of the concrete samples with time results in increase in pH value of solution. This may be due to the sulfuric acid solutions that were partially neutralized by the alkalis of the cement and by reaction with consumption which came from the clinker, mineral admixtures and aggregates. Therefore, after immersing the samples in the sulfuric acid solutions, the values of pH increased rapidly with time upto third day, after that the rate of increase in pH became slow till constant pH value were obtained. Finally the pH of acidic solutions changed to the pH of alkaline solutions.

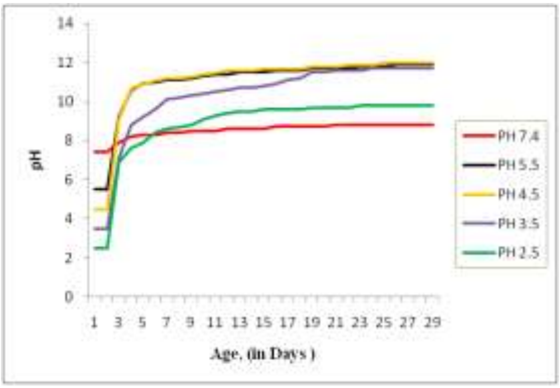

Fig. 2 pH value at 28 days

IV. CONCLUSIONS

1. In high strength concrete as water/cement ratio adopted is low, superplasticizers are necessary to maintain required workability. As the percentage of mineral admixtures is increased in the mix, the percentage of super plasticizer should also be increased, for thorough mixing and for obtaining the desired strength.
2. There is drastic change in pH value of both the curing solutions upto third day and after that, the rate of reduction in pH value becomes slowly till a constant pH value is obtained.
3. The maximum percentage reduction in compressive strength at 0.28 w/cm ratio.is18.18% at replacement of 20% GGBFS when cured in H_2SO_4 solution at pH 2.5 than control concrete.

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