Durability Studies on High Strength Concrete

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***Abstract*—High strength concrete (HSC) is very useful for recent construction technology; the major problem of HSC is the insufficient ductility. To investigate the ductility of HSC, the entire stress-strain curve, especially in the descending branch, shall be recorded. The aim of this study is to investigate the durability of High strength concrete for different replacement levels of mineral admixtures by alternate wetting and drying phenomenon which includes; acid attack, sulphate resistance and marine Environment and also to determine the compressive strength of concrete as GGBFS partial replacement for cement. Concrete mix is designed for M80 Grade of concrete using modified ACI method. Maximum Compressive Strength of 96.4MPa and 91.6 MPa at 28days were found for the HSC specimens at a partial replacement of cement with 30% of GGBFS in normal water curing and accelerated curing tank respectively. The specimens immersed in marine solution were found to have less weight loss when compared to acids and sulphate solution.**

***Index Terms*— High strength concrete, M80 Grade, Compressive strength, Durability**

I. Introduction

HIGH Strength Concrete (HSC) is a special concrete that possesses required uniformity, which cannot be achieved easily by conventional practices. However, special performance can be achieved using low water/binder ratio and the addition of chemical and mineral admixtures. However, these requirements may vary the cement content in concrete. The importance of HSC to structural engineering is unquestionable. However, HSC is a relatively new material. Some results of researches on conventional concrete are not entirely applicable. The validity of those results for high performance concrete should be investigated. Even though high strength concrete is very useful for recent construction technology, the major problem of HSC is the insufficient ductility. To investigate the ductility of HSC, the entire stress-strain curve, especially in the descending branch, shall be recorded. More understandings of the ductility of HSC can help structural engineers to evaluate the degree of increasing the ductility of HSC and make the using of HSC safer. Hui-sheng [1] found that compressive strength significantly affected by water- binder ratios up to 60% replacement of cement by fly ash. Hosam et al [2] investigated the seawater resistance of concrete by adding different admixtures like GGBFS, silica fume. The results shows that cement-silica fume combination has more resist seawater attack. Gaurav et al. (2015) found that optimum percentage of GBFS to be used is from 40% to 50% for normal conditions with respect to strength and economy and 50% to 60% for marine water conditions. Eguchi et al [4] results shows that concrete with GGBS exhibited high resistance to ingression of chloride ions. Upon 80% or above replacement of GGBS, compressive strength was greatly decreased. Wei-Hao Lee et al. [5] found that geo-polymer concrete has good chloride resistance as the time of curing increases. Ban and Kang [6] found that concrete capillary penetration resistance increases by replacement of cement by GGBS. Due to insufficient Ca(OH)2, GGBS produce high amount of secondary C-S-H and C-A-S-H bonds that reduced both macro and micro pores in concrete. Therefore, an optimum performance was observed in tests of porosity, permeability, water absorption and capillary absorption. Xie et al [7] Geo-polymer concrete developed with high amount of GGBS exhibited lower mass loss and retained higher residual compressive strength even after the sulfate exposure during acid tests. The sulfate resistance increases considerably with the increase of GGBS content. Gedam [8] found that use of supplementary cementations materials in high-performance concrete showed excellent performance in durability. Mallikarjuna Rao and Kireety [9] exposed geopolymer mortar produced with 100% GGBS to nitric and sulfuric acid solutions. Severe degradation of strength and mass was observed in both solutions. However, losses were more in sulphuric acid compared to that of nitric acid. Chakraborty et al [10] developed concrete with GGBS produces a cohesive mix due to finer particle size of GGBS and therefore reduces the permeability. Hence it is durable and stronger.

The objective of present study is to investigate the durability of HSC for different replacement levels of mineral admixtures by alternate wetting and drying phenomenon which includes; acid attack, sulphate resistance and marine Environment and also to determine the Compressive strength of HPC concrete as a partial replacement of cement with mineral admixture (GGBFS) for 28 days.

II. LITERATURE STUDIES

The materials were used for the study are: cement (OPC 53), fine aggregate, coarse aggregate, mineral admixtures (GGBFS), chemical admixtures (GLENIUM B233) and acids (HCL, H2SO4, Ammonium Sulphate and Marine solution).

The mix design is being done for M80 Grade of concrete using

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Modified ACI method (Aitkin Method). In the mix 30%, 60% and 70% cement was replaced by Ground Granulated Blast Furnace Slag, keeping water/binder ratio same and the mixes named as GGBFS-30%, GGBFS-60% and GGBFS-70% shown in Table I. The methodology is used for this study is shown in Fig. 1.

Table I: Mix design details of GGBFS

Components	Replacement levels of GGBFS		
	GGBFS-30%	GGBFS-60%	GGBFS-70%
Water (lit.)	150.79	150.79	150.79
Cement (kg)	392	224	168
GGBFS (kg)	168	336	392
Coarse Aggregate (kg)	1075	1075	1075
Fine Aggregate (kg)	710.2	710.2	710.2
Super plasticizer (lit.)	5.503	5.503	5.503

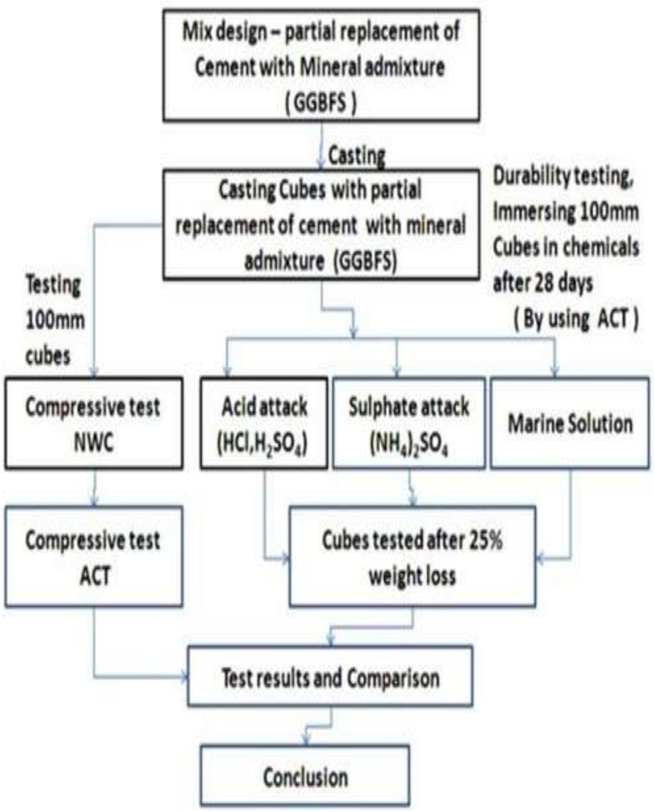

Fig. 1: Study methodology

III. Results and Analysis

Experimental studies were done to determine the mechanical properties (Compressive Strength) and durability properties of High Strength Concrete using GGBFS mineral admixture. The durability study includes acid attack, sulphate attack and marine environment. The 100 mm cube samples were used for compression test of concrete. Four specimens were cast for each test. For the 28th day compressive strength was found by testing. The average of 3 results for each test was taken. The HSC compressive strength compared with cured concrete was given in Fig. 2.

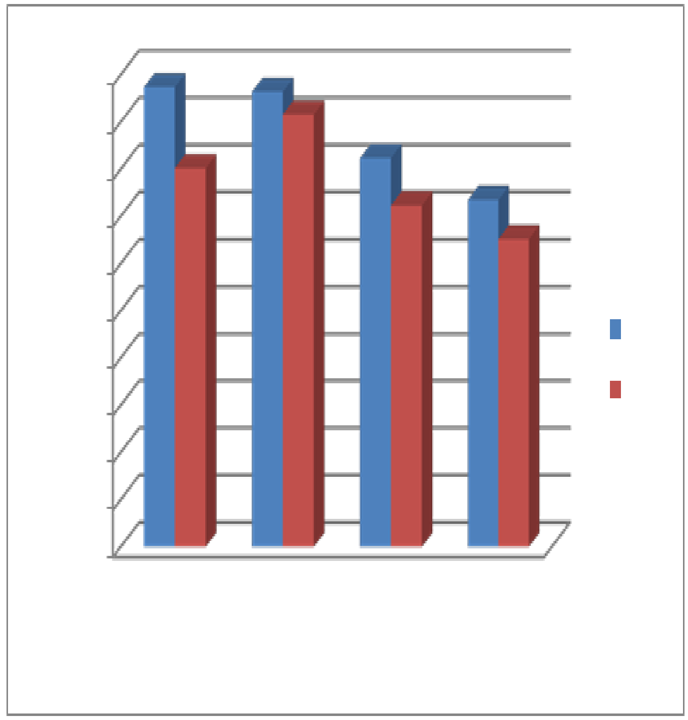

Fig. 2. Comparison of Compressive strength of HSC with Cured Concrete.

In order to evaluate and compare the durability of HSC, the tests were conducted on concrete specimens at different replacement levels of GGBFS are Acid attack, Sulphate attack and Marine environment. For durability studies the cubes were cured in accelerated curing tank (ACT) is used. For acid resistance test 100 x 100 x 100mm cubes were used. Acid resistance test have been carried out for GGBFS concretes at different replacement level. The specimens were immersed in two different acid solutions, sulphuric acid (1% H2SO4) and hydrochloric acid (1% HCl). The specimens were subjected to alternate wetting and drying at every 15 days interval. The weight loss of HPC after 1-30, 30-60, 60-90, 90-120 and 120-150 days of immersion (5 cycles) were observed, which 3 represents the weight loss up to 1-30, 30-60, 60-90, 90-120 and 120-150 days of immersion (5 cycles) of GGBFS concrete with 0%, 30%, 60% and 70% replacement level in 1% HCl solution. Test values shows that there is no significant weight loss and weight loss is only 1.26% after 150 days of immersion. 1 % HCl solution is, in general found to be less corrosive than 1% H2SO4 solution. Figure 3 shows the variation of weight loss GGBFS concrete for 1-30, 30-60, 60-90, 90-120 and 120-150 days. GGBFS concrete with 30% replacement level shows maximum weight loss up to 150 days and 0%, 60% and 70% replacement level shows relatively lower value. Figure 4 shows the acid attack on concrete specimen with hydrochloric acid, brown colour indicate the reaction of chlorides on the surface of the concrete.

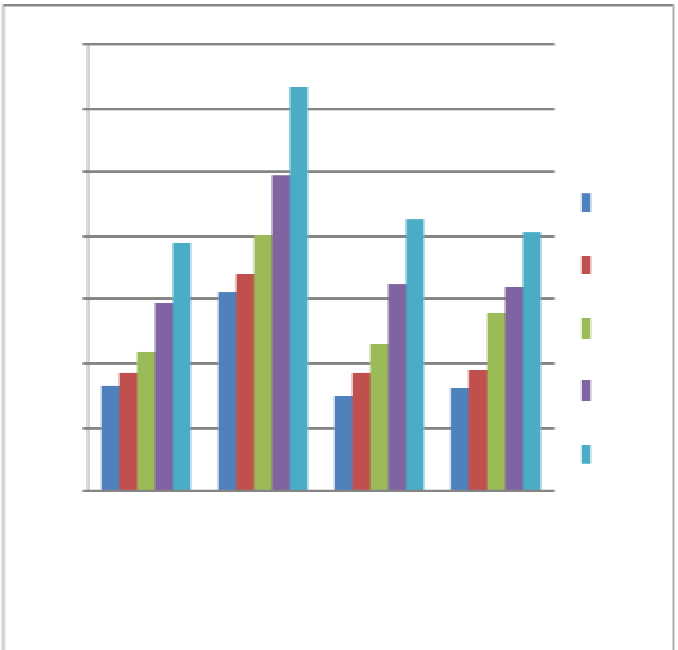

Fig. 3. Variation in Weight Loss after Immersion in HCl.

Fig. 4. Concrete exposed to 1% Hydrochloric Acid.

It represents the weight loss up to 1-30, 30-60, 60-90, 90-120 and 120-150 days of immersion (5 cycles) of GGBFS concrete with 0%, 30%, 60% and 70% replacement level in 1% H_2SO_4 solution. Test values shows that there was no significant weight loss, maximum of 2.04% after 150 days of immersion. 1 % H_2SO_4 solution was, in general found to be more corrosive than 1% HCl solution. Figure 5 shows the variation of weight loss GGBFS concrete for 1-30, 30-60, 60-90, 90-120 and 120-150 days. GGBFS concrete with 60% replacement level shows maximum weight loss up to 150 days and 0%, 30%, 70% replacement level shows relatively lower value. Figure 6 shows the acid attack on concrete specimen with sulphuric acid.

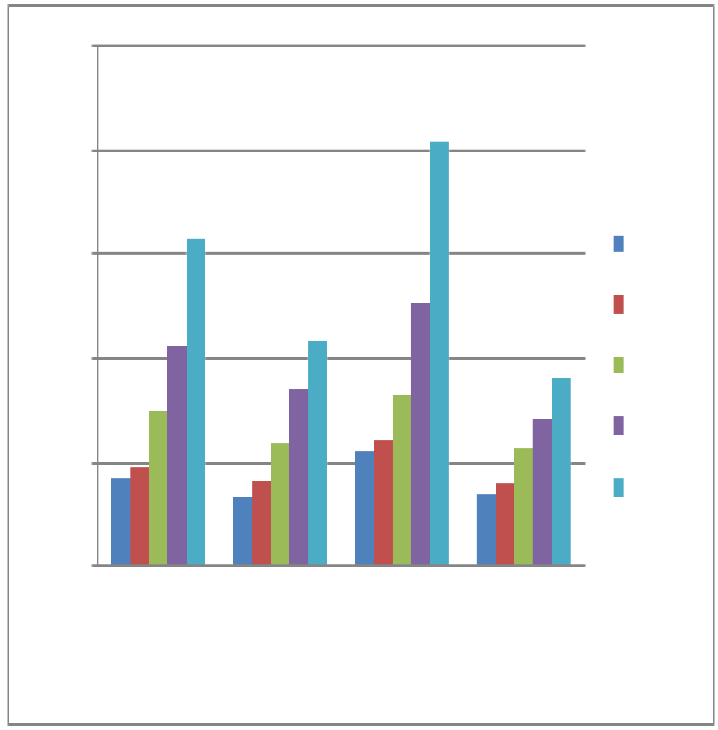

Fig. 5. Variation in Weight Loss after Immersion in H2SO4.

Fig. 6. Concrete exposed to 1% Sulphuric Acid.

It represents the weight loss up to 1-30, 30-60, 60-90, 90-120 and 120-150 days (5 cycles) immersion of GGBFS concrete with 0%, 30%, 60% and 70 % replacement level in 5% $(NH_4)_2SO_4$ solution. It shows the variation of weight loss GGBFS concrete for 1-30, 30-60, 60-90, 90-120 and 120-150 days. GGBFS concrete with 60% replacement level shows higher weight loss as compared to 0%, 30%, and 70% up to 150 days immersion. Figure 7 shows the sulphate attack on concrete specimen, white crystal structures found in the concrete surface.

Fig. 7. Concrete exposed to 5% Ammonium sulphate solution.

It represents the weight loss up to 1-30, 30-60, 60-90, 90-120 and 120-150 days (5 cycles) immersion of GGBFS concrete with 0%, 30%, 60% and 70 % replacement level in marine solution. Figure 8 shows the variation of weight loss of GGBFS concrete for 1-30, 30-60, 60-90, 90-120 and 120-150 days (5 Cycles). GGBFS concrete with 60% replacement level shows slightly higher weight of loss when compare to other two three mixes up to 150 days of immersion. Figure 9 shows the marine solution attack on concrete specimen.

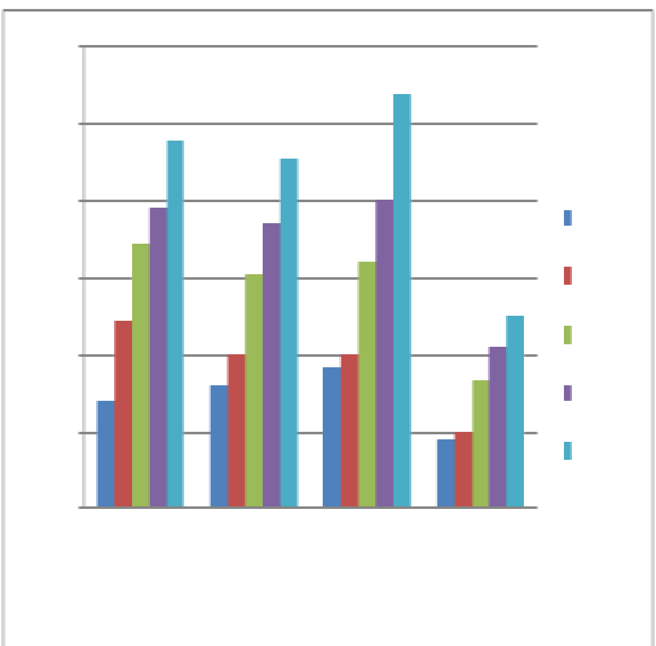

Fig. 7. Variation in Weight Loss after Immersion in Marine water.

IV. Conclusion and Recommendations

The study was carried out to determine the mechanical properties and durability properties of High Strength concrete. Mechanical properties like Compressive Strength, Durability properties like acid attack, sulphate attack and marine environment were done. Based on the experimental work done, the following conclusions are drawn;

- Maximum Compressive Strength of 96.4MPa at 28days is found for the HSC specimens at a partial replacement of cement with 30% of GGBFS in Normal Water Curing.

- Maximum Compressive Strength of 91.6MPa at 28days is found for the HSC specimens at a partial replacement of cement with 30% of GGBFS in Accelerated Curing Tank.

- In hydrochloric acid, 30% of GGBFS replaced with cement concrete shows more weight loss when compared to 0%, 60%, and 70% of GGBFS replaced with cement.

- In sulphuric acid, 60% of GGBFS replaced with cement concrete shows more weight loss when compared to 0%, 30%, and 70% of GGBFS replaced with cement.

- The Weight loss of HPC concrete was found to be more in ammonium sulphate solution (NH4)2SO4 when compared to acid solutions (HCl, H2SO4). In sulphate solution, 60% of GGBFS replaced with cement concrete shows more weight loss when compared to 0%,30%, and 70% of replacement.

- The specimens immersed in marine solution were found to have less weight loss when compared to acids and sulphate solution.

- In marine water, 60% of GGBFS replaced with cement concrete shows more weight loss when compared to 0%, 30%, and 70% of GGBFS concretes.

Fig. 7. Concrete exposed to Marine water.

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