BEHAVIOUR OF M 25 GRADE CONVENTIONAL CONCRETE AND FLY ASH BLENDED CONCRETE IN ACIDIC ENVIRONMENT

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ABSTRACT

Concrete is highly susceptible to acid attack because of its alkaline nature and it is a serious issue due to speed of damage of concrete structures worldwide. The acid attack on the concrete structures is increasing due to growing activities in both urban and industrial areas over the past 30-40 years.

The present investigation is mainly aim to study the variation in compressive strength and mass of M 25 grade Conventional Concrete (CC) and Fly Ash blended Concrete (FC_20, FC_30) mixes after 30 and 60 days of immersion in acid after 28 days of initial curing. Concrete mixes were subjected to two acid attacks i.e.., 3% Hydrochloric Acid (HCl) and 3% Sulphuric Acid (H2SO4).

KEYWORDS: M 25 Grade concrete, HCl, H2SO4, Compressive Strength and mass.

1. INTRODUCTION

Various industries produce numerous solid waste materials. The disposal of these solid waste materials is an environment hazard for the surrounding living beings. Now a day's increasing environmental concerns and sustainable issues, the utilization of solid waste materials is the need of the hour. The productive use of solid waste materials is the best way to alleviate the problems associated with their disposal. The construction industry has enormous potential for the use of solid waste materials as construction material. Based upon their properties, the solid waste materials can either be used as supplementary cementitious materials or as replacement of fine/coarse aggregate in concrete or mortars. Based on the research reports some solid waste materials such as fly ash, silica fume, grounded blast furnace slag etc have been put in use in manufacturing of either cement or concrete.

The rate of hydration in fly ash is generally very slow. As a result, the strength gain is very slow, but continues with time over the years. The pozzolanic property of fly ashes is taken advantage of while replacing cement partially with fly ash in cement concrete. Partial replacement of cement in concrete with fly ash leads to several advantages.

Fly ash is finely divided waste by product obtained from the combustion of pulverized coal in suspension fired furnaces of thermal power plants. It is collected by electrical or mechanical precipitators including cyclone precipitators or bag houses. It is generally finer than cement and consists of mostly spherical glassy particles of complex chemical as well as mineralogical composition.

2. LITERATURE REVIEW

This chapter discusses the research work carried out on concrete using industrial wastes materials and various acids. This chapter gives a comprehensive review of the work carried out by various researchers in the field of reusing the industrial wastes materials in concrete.

Emmanuel K. Attiogbe and Sami H. Rizkalla concluded that increase in sulphur content of test specimens, as measured with an SEM equipped with an energy-dispersive x-ray analyzer, is a good indicator of the extent of damage in concrete due to exposure to sulphuric acid. Photomicrographs, as well as the variation in sulphur concentration with distance from the acid-exposed

Surface of test specimens, clearly show that deterioration of concrete due to sulphuric acid attack starts at the surface and progresses inwards. The increase in thickness (expansion) of small specimens (with large surface area-to-volume ratios) may be a more consistent measure than the weight loss of larger specimens when comparing the effects of different sulphuric acid concentrations on concrete. The relationship between degree of concrete deterioration and depth of penetration of sulphuric acid could be represented by the variation in sulphur concentration.

Salim Barbhuiya and Davin Kumala concluded that in sulphuric acid environment, the compressive strength loss was minimum for a concrete mix in which cement was replaced with 30% fly ash and 10% ultra-fine fly ash. The mass loss was less in this mix compared to the mix without fly ash. However, mass loss was also less in mixes containing higher amount of fly ash. The SEM image of concrete mix with 30% fly ash and 10% ultra-fine fly ash cured in water for 28 days showed denser microstructure characterized by less amounts of calcium hydride crystals. The SEM images of concrete mix containing 30% fly ash and 10% ultra-fine fly ash exposed to sulphuric acid for 28 days showed that the surface is highly porous. A noticeable amount of C-S-H gel appears to have been decomposed into finer particles.

B. Madhusudhan Reddy, H. Sudarsana Rao and M.P George concluded that both initial and final setting times of fly ash based (BC) and silica flume blended cement (SFBC) got retarded with an increase in hydrochloric acid concentration in deionized water. Continuous decrease in compressive strength BC and SFBC specimens prepared with HCl acid solution is observed as the acid concentration increases till the maximum concentration tested.

3. EXPERIMENTAL PROGRAMME

3.1 Materials

Constituent materials used to make concrete can have a significant influence on the properties of the concrete. The following sections discuss constituent materials used for manufacturing of both conventional concrete (CC) and Fly Ash (FC) based concrete. Chemical and physical properties of the constituent materials are presented in this section.

3.1.1 Cement

Ordinary Portland Cement 53 grade was used corresponding to IS 12269 (1987). The physical properties of the cement as obtained by the manufacturer are presented in the Table 3.1.

Table 3.1 Physical Properties of Cement

Physical properties	**Test result**
Specific gravity	3.15
Fineness (m^2/Kg)	311.5
Normal consistency	30%
Initial setting time (min)	90
Final setting time (min)	220
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	0.8 0.01
Compressive strength (MPa) 3 days 7 days 28 days	25 39 57

3.1.2 Fly Ash

The physical properties of the Fly Ash as obtained by the manufacturer are presented in the Table 3.2.

Table 3.2 Physical properties of Fly Ash

Material	Specific gravity	Fineness (m^2/kg)	Water absorption (%)
Fly Ash	2.12	360	40-60

3.1.3 Coarse aggregate

Crushed granite stones of size 20 mm used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm per IS 2386 (Part III, 1963) are 2.6 and 0.3% respectively. The bulk density, impact strength and crushing strength values of 20 mm aggregate are 1580 kg/m3, 17.9% and 22.8% respectively.

3.1.4 Fine aggregate

Natural river sand is used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) are 2.6 and 1% respectively. Fineness modulus of sand is 2.26.

3.1.5 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided.

3.2 Test Methods

This section describes the test methods that are used for testing the hardened properties of concrete.

3.2.1 Compressive strength test

Compressive strength test was conducted on the cubical specimens for all the mixes at different curing periods as per IS 516 (1991) shown in fig 3.1. Three cubical specimens of size 150 mm x 150 mm were cast and tested for each age and each mix. The compressive strength (f'c) of the specimen was calculated by dividing the maximum load applied to the specimen by the cross-sectional area of the specimen.

Fig.3.1 compressive strength of cubes

3.2.2 Pulse Velocity

The test involves determination of pulse velocity through concrete as per procedure give in ASTM C 597-02. Battery operated Portable Ultrasonic Non-destructive Digital Indicating Tester was used to measure the pulse velocity through concrete. Pulses of longitudinal stress waves are generated by an electro acoustical transducer held in contact with one face of concrete and are received by another transducer held in contact with other face of concrete specimen. The time (T) taken by pulse to pass through specimen of length (L) is known as transit time. The pulse velocity (V) is calculated by dividing the length of specimen (L) by transit time (T). Average value of three specimens was considered as the pulse velocity of concrete mix. The apparatus set for the test is shown in Fig 3.2 and values of pulse velocity for grading concrete as per BIS 13311-92 (Part-I) are given in Table 3.3.

Table 3.3 Concrete quality grading as per BIS 13311-92 (Part-I)

Pulse velocity (m/s)	Concrete quality grading
Above 4500	Excellent
3500 – 4500	Good
3000 - 3500	Medium
Less than 3000	Doubtful

Fig.3.2 Ultrasonic Pulse Velocity test of cubes

3.2.3 Acid Resistance

Resistance of concrete specimens against external acid attack was evaluated as per ASTM C 267-01. The specimens were identified using plastic numbers fixed with the help of adhesive. Each specimen of concrete was weighed on completion of initial water curing period of 28 days. Then the specimens were immersed in 3% sulphuric acid solution and 3% hydrochloric acid. During this test the changes in the following properties of specimens were determined after 30 and 60 days of immersion the specimens in 3% sulphuric acid solution and 3% hydrochloric acid. The Figs. 3.3 and 3.4 show the deterioration of specimens after 30 and 60 days of immersion in sulphuric acid solution and hydrochloric acid respectively.

- Weight of specimen
- Appearance of specimen
- Compressive strength

Fig.3.3 Cubes after acidic attack (H_2SO_4)

Mix Type	**Compressive strength(MPa)**				
	Normal curing period(28 days)	**Acidic immersion period(days)**			
		30		**60**	
		HCl	**H_2SO_4**	**HCl**	**H_2SO_4**
CC	33.06	31.12	30.08	28.78	25.11
FC_20	31.14	28.29	27.67	25.45	22.43
FC_30	32.82	30.60	29.68	28.56	24.91

Fig. 3.6 Cubes after acidic attack (HCl)

3.3 Mix Design

Table 3.4 Mix Proportions of CC, FC_20 and FC_30

Mix Type	**Cement Kg/m^3**	**Fly Ash Kg/m^3**	**Water l/m^3**	**20mm kg/m^3**	**Sand kg/m^3**
CC	384	0	202	1139	636
FC_20	342	54	202	1139	636
FC_30	269	80	202	1139	636

This section describes the proportions of M 25 grade conventional concrete mix proportions as per IS 10262 (2009) and IS 456 (2000) shown in Table 3.4.

4. RESULTS AND DISCUSSIONS

4.1 Introduction

In this Chapter, the test results are presented and discussed. The test results cover the performance of Conventional Concrete (CC) and Fly Ash blended Concrete (FC_20), (FC_30) in acid environment. The hardened properties of CC and FC viz. compressive strength, weight, ultrasonic pulse velocity (UPV) and rebound hammer test were determined before and after acid attack at different curing periods.

4.2 Variations in Compressive Strength

The variations in compressive strength values after acid attack are represented in below. Table 4.1 shows the compressive strength of CC, FC_20 and FC_30 (Cement replaced with 20% and 30 % of Fly Ash in CC).

Table 4.1 compressive strength of concrete mixes

The variations in percentage loss of compressive strength values after acid attack are represented in table 4.2.

Table 4.2 percentage loss of compressive strength of concrete mixes

Mix Type	**Loss of compressive strength (%)**			
	Acidic immersion period (days)			
	30		**60**	
	HCl	**H_2SO_4**	**HCl**	**H_2SO_4**
CC	5.87	9.01	12.95	24.05
FC_20	9.15	11.14	18.27	27.97
FC_30	6.76	9.57	12.98	24.10

From the Tables 4.1 and 4.2, it is seen that the compressive strength of all concrete mixes have been decreased with the increase in the immersing period in each acid environment. The percentage loss of compressive strength is higher in FC_20 when compared to CC at all acid immersion periods. But it is noted that in FC_30 reduced this percentage loss when compared to FC_20. It may be due to the high pozzolanic action of fly ash which densifies the pore structure of the mix that leads to the enhancement of micro level and macro level properties. As it can be seen from the results, the percentage loss of compressive strength is marginally similar in both the CC and FC_30 concrete mixes. The percentage loss of compressive strength is observed to be more in H_2SO_4 than HCl.

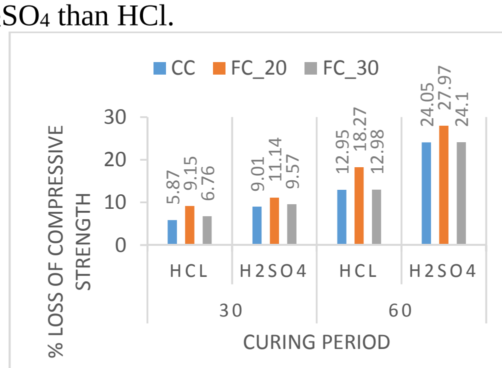

Fig. 4.1 percentage loss of compressive strength of concrete mixes

4.3 Variations in Mass

The variations in mass after acid attack are represented below. Table 4.3 shows the mass of CC, FC_20 and FC_30 (Cement replaced with 20% and 30 % of Fly Ash in CC).

Table 4.3 Mass of concrete mixes

Mix Type	Mass(kg) Acidic immersion period (days)			
	30		60	
CC	8.51	8.49	8.38	8.36
FC_20	8.23	8.15	8.11	8.01
FC_30	8.42	8.41	8.32	8.29

The variations in percentage loss of mass values after acid attack are represented. Table 4.4 shows the mass.

Table 4.4 percentage loss of mass of concrete mixes

Mix Type	Loss of mass (%) Acidic immersion period (days)			
	30		60	
	HCl	H2SO4	HCl	H2SO4
CC	3.29	3.52	4.77	5.00
FC_20	5.07	5.99	6.46	7.61
FC_30	3.66	3.78	4.80	5.15

From the Tables 4.3 and 4.4, it is seen that the mass of all concrete mixes have been decreased with the increase in the immersing period in each acid environment. The percentage loss of mass is higher in FC_20 when compared to CC at all acid immersion periods. But it is noted that the incorporation of FA in FC_30 reduced this percentage loss when compared to FC_20. It may be due to the pozzolanic action of fly ash which defines the pore structure of the mix that leads to the enhancement of micro level and macro level properties. As it can be seen from the results, the percentage loss of mass is marginally similar in both the CC and FC_30 concrete mixes. The percentage loss of mass is observed to be more in H_2SO_4 than HCl.

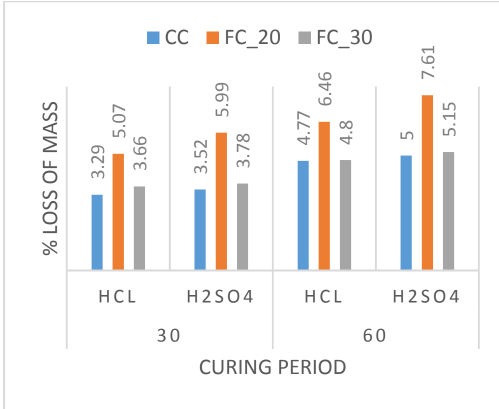

Fig. 4.2 percentage loss of mass of concrete mixes

5. CONCLUSION

This chapter summarizes the overall conclusions drawn from the investigation of concrete using fly ash (cement replaced with fly ash).

The following conclusions have been drawn from the present investigation.

1) The loss of compressive strength and mass values are more in FC_20 when compared to CC at all immersion periods due to more deterioration of aggregates.

2) It is noted that the increase of FA in FC_30 reduced the percentage loss when compared to FC_20. It may be due to the high pozzolanic action of fly ash which densifies the pore structure of the mix that leads to the enhancement of micro level and macro level properties. This pozzolanic action compensates the deterioration caused by aggregates.

3) It is seen that the percentage loss of compressive strength and mass of all concrete mixes have been decreased with the increase in the immersing period in each acid environment.

4) The loss of compressive strength and mass value of all concrete mixes is more in H_2SO_4 when compared to HCl immersion.

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