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'ACID RESSISTIVE CONCRETE'

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ABSTRACT

The present day world is witnessing the construction of very challenging and aesthetic structures. The investigation examines the progressive deterioration of concrete mixtures which contains various combinations of fly ash based GFRC mixes exposed to chloride solution and sulphate. The acid attack tests have been conducted for measuring the durability of GFRC. Cubes of 150X150X150 mm have been cast, cured (28 days in water) and then kept immersed in 5% conc. solutions of HCl for 10 days and then tested for recording the residual compressive strengths of GFRC produced with the fly ash mineral admixtures and then the results have been analysed and useful conclusions have been drawn. The irregular Fibres distributed randomly fill the crack in the composite. Fibres impart energy absorption, toughness and impact resistance properties to fibre reinforced concrete. In the present experimental investigation the glass fibres has been used to study the effect on compressive & flexural strength on M20 grades of concrete.

Keywords: *GFRC, A/B ratio, W/B ratio, Fly Ash.*

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1. INRODUCTION

Conventional concrete in India is often produced with four components namely,

1) Cement
2) Water, together they act as binder.
3) The crushed or uncrushed stone.
4) Natural Sand or stone dust.

Fly ash is the finely divided mineral residue which results from the combustion of ground or powdered coal in electric generating plant (ASTM C 618). Fly ash consists of inorganic material present in the coal that has been fused while coal combustion. It effects the many properties of concrete in both states i.e. fresh and hardened state. Glass fibres are the most versatile industrial materials. They are produced from raw materials, which are available in virtually unlimited supply. The glass fibres are derived by compositions which contains silica. The bulk properties such as resistance to chemical attack, stability, hardness, transparency, and inertness, as well as desirable fibre properties such as strength, flexibility, and stiffness which glass fibers exhibits. Glass Fibre Reinforced Concrete (GFRC) produced when these glass fibres are added to concrete. The environmental problems of power plants and decreases electric costs can be reduced by utilizing the waste materials in cement and concrete industry. Utilization also reduces the amount of solid waste, conserves existing natural resources and greenhouse gas emissions associated with Portland clinker production.

1.1 What causes damage to concrete?

In the case of domestic waste water, the organic substances released during the biological cleaning phase are changed into biomass as carbon dioxide (CO_2) and hydrogen sulphide (H_2S) are separated. H_2S is also a rather non-aggressive gas with regard to concrete, but is highly poisonous and the cause for bad smell that was mention earlier. The odour threshold is as low as 0.1ppm, from 1 to 10 ppm odour is perceived as unpleasant. If a concentration of 0.1 vol. % is reached, cramps and unconsciousness occur, only a few minutes exposure to such a mixture can potentially be life threatening.

1.2 Bacterial acid corrosion:

Similar to the corrosion of sulphate rich soils, the formation of gypsum in concrete through the 'Bacterial Acid' pathway causes the concrete to soften, ultimately leading to roof collapse.

(Equation 2)

$$H_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 + H_2O$$

(Equation 3)

$$CaSO_4 + H_2O \longleftrightarrow CaSO_4 \_ 2H_2O$$

Fig 1.1: Photograph of bridge pier corroded by acid water.

1.3Affected area:

- Bridge piers
- Sewage treatment plant tank
- Water treatment tank walls
- Industrial areas
- Dams etc.

2. LITERATURE REVIEW

Following are the papers submitted on various concrete mixes as follows:

Hassan et al. [2000] (1) presented the influence of two mineral admixtures, fly ash and silica fume on the properties of super-plasticized high-performance concrete. The results indicated that usage of the mineral admixtures improved the properties of high performance concrete. Fly ash based GFRHPC mixes resisted acid attack in a better way as compared to conventional M20 concrete at all ages of exposure to HCl, Mg SO_4 and H_2SO_4.

Bentz [2000] (2) Developed a three-dimensional micro structural model for fibre reinforced concrete and applied it to examine the spalling phenomena of high-performance concrete and suggested that 20 mm fibres showed superior performance when compared to that of 10 mm fibres. It is observed that the residual compressive strength of all GFRHPC mixes are considerably higher than that of M20 grade reference mix at all ages of acid exposure for all the three acids tried in this investigation.

Tixier and Mobasher [2003] (3) Modelled the damage in cement-based materials which is subjected to external sulphate attack. They reported that the parameters like internal porosity and w/b ratio are important in controlling the external sulphate attack. Maximum loss of compressive strength has occurred at 90 days of acid immersion. This is true for all the acids tried in the present investigation.

Wang and Li [2007] (4) presented the mechanical performance of engineered cementitious composites incorporats high volume fly ash. With respective of these results, it is proposed to study the effect of fly ash as a partial replacement to cement on the durability of Glass Fibre Reinforced High Performance Concrete.

3. METHODOLOGY

The main aim of this experimentation is to study the effect of partial replacement of concrete by glass fibre on the properties of concrete, when it is subjected to hydrochloric acid attack. To study this effect the following parameters were considered in this experimentation:

- Aggregate-binder ratio (A/B ratio): 2.0
- Water-binder ratio (W/B ratio): 0.5
- Percentage replacement of cement by Fly ash: 10

Table No 3.1: Properties of cement

Sr. No.	Characteristics	Value obtained	Standard Value
1.	Normal consistency (%)	33%	26%-33%
2.	Initial setting time (min.)	30	Not less than 30
3.	Final setting time (min)	600	Not less than 600
4.	Fineness (%)	8%	<10
5.	Soundness (mm)	5.4	Less than 10mm

3.4 Casting of test cubes

To evaluate the resistance of fly ash based Glass fibre reinforced concretes to acid attack, a GFRC mix would be tried for Fly Ash mineral admixture with varying percentage of glass fibre with weight of concrete One plain concrete mix of M20 grade has also been cast and tested in the laboratory as reference mix. As there is no standard method for proportioning GFRC mixes, weight batching method has been used for arriving at the mix proportion in this work.

All the materials were taken by weight as per the mix proportions and mixed thoroughly to obtain a uniform mix. The various parameters studied are given below.

i. **Aggregate-Binder Ratio (A/B Ratio): 2.0**
ii. **Water-Binder ratio (W/B ratio): 0.5**
iii. **Percentage replacement of cement by fly ash: 10**
iv. **Fibre Volume percentage: 0, 1.0, & 2.0**

For acid attack, for each percentage of glass fibre 6 concrete cubes of size 150x150x150 mm will be cast. Out of these, 3 cubes would be tested for 28 days compressive strength and remaining 3 concrete cubes were tested for residual compressive strength after 10 days of acid immersion. The test program will consist of finding out residual compressive strength test due to immersion in 5 % concentration of acid. The moulds would be removed after 24 hours and the specimens will be kept in a clear water tank by immersing in a clear water. After curing the specimens in clear water tank for a period of 28 days, the specimens would be removed outside of the water tank and allowed to dry under shade. Also 9 cubes would be cast for each mix for durability studies. After water curing, the 3 cubes would keep in 5% concentration acid solution for 10 days acid curing.

3.5 Design for M20 Grade as per IS 10262-1982

(a) Design Stipulations

1. Fck at 28 days = 20 mpa
2. Maximum size of aggregate = 20 mm angular
3. Degree of workability = 0.9 compacting factor
4. Degree of quality control= Good
5. Type of exposure = mild

(b) Test data for materials

1. Sp. gravity of cement = 3.15 (OPC 53 Ultratech)
2. sp. gravity of coarse aggregate = 2.64
3. sp gravity of fine aggregates = 2.61
4. Water absorption
    i.coarse aggregates = 0.5 %
    ii.fine aggregates =1.0 %

5. Free surface moisture
   i.coarse aggregates = nil
   ii.fine aggregates = 2.0 %

(c) Target mean strength of concrete

$f_{ck} = f'_{ck} + 1.65*S$ (Standard deviation (S) = 4)

$f_{ck} = 20 + 1.65*4$

$f_{ck} = 26.6$

(d) Selection of water / cement ratio

For f_{ck}= 26.6 Mpa , w/c = 0.5

(e) Selection of water and sand content.

For 20 mm maximum size aggregate , sand conforming to grading zone II , water content per m^3 of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume = 35%.

Require sand content as percentage of total aggregate by absolute volume.

=35 - 3.5

= 31.5%

Required water content

= 186 + 5.58

= 191.58litre / m^3

(f) Determination of cement content.

W/C ratio = 0.5

Water = 191.58 litre

Cement = (191.58/0.5) = 383 kg/ m^3

This cement is adequate for mild exposure condition.

(g) Determination of coarse aggregate & fine aggregate contents.

For specified maximum size of coarse aggregate of 20 mm, the amount of entrapped air in wet concrete is 2%.

Fine aggregate,

$V = [(w) + (c / S_c) + (f_a) / ((p) \times (S_{fa}))] \times 1/100$

$0.98 = [191.60 + 383/3.15 + (f_a)/(0.315 \times 2.60)] \times 1/100$

$f_a = 546\ kg/m^3$

Coarse aggregate,

$C_a = (1-p) / (p) \times (f_a) \times (S_{ca}) / (S_{fa})$

$= (1-0.315) / 0.315 \times 546 \times 2.6 / 2.6$

$C_a = 1188\ kg/m^3$

Water content = 191.6 lit / m^3

Cement aggregate = 383 kg / m^3

Fine aggregate = 546 kg/ m^3

Coarse aggregate = 1188 kg /m^3

The mix proportion becomes:

Table No 3.9: Mix proportion

Material	Cement	F.A	C.A.	Water
Density	383 kg/m^3	546kg/m^3.	1188 kg/m^3	191.6kg/m^3
Proportion	1.0	1.425	3.10	0.50

I. Actual quantities per bag of cement

The mix is **0.50: 1.0: 1.425: 3.10**.

II. For 50 kg of cement

Cement = 50 kg

Sand = 71 kg

Coarse aggregate = 155 kg

Water:

For W/C ratio of 0.50, quantity = 25 litre of water
Extra quantity of water to be added for absorption, in case of coarse aggregate by 0.50% of mass.
Quantity of water to be deducted for moisture present in sand, at 2% by mass = 1.42 litres.

A. Actual quantity of water required to be added

= 25.0 + 0.77 -1.42
= 24.35 litres

B. Actual quantity of sand required after

= 71.0 + 1.42 allowing for mass of free moisture
= 72.42 kg

C. Actual quantity of coarse aggregate required

Fraction I = 93 – 0.46 = 92.54 kg
Fraction II = 62 – 0.31 = 61.69 kg

Therefore, the actual quantity of different constituent's required for 1 bag mix is

Water = 24.35 kg
Cement = 50.0 kg
Sand = 72.42 kg
CA Fraction I = 92.54 kg
Fraction II = 61.69 kg

Mould :
Materials: Material proportioning are taken according to ratio **0.50: 1.0: 1.425: 3.10**.
Material for one cube,

1. Aggregate = 4.15kg.
2. Sand =1.91 kg.
3. Cement =1.38 kg.
4. Water = 0.68 kg.
5. Glass fibre = 81.2 gms.

Machine Mixing
The concrete is mixed in 'laboratory tilting drum mixer'. The material are poured in the mixer in following manner :

1. Aggregates
2. Sand
3. Cement
4. Water
5. Glass fibre

Filling and compaction of mould:

The concrete is poured in cube in three layers. Each layer is tamped 25 time by 'tamping rod'. By hand compacting, the standard tamping rod is used and the strokes of rod are distributed in uniform manner over the c/s of mould for cubical specimen. Where voids are left by tamping rod the sides of mould are tamped to closed the voids.
Curing: The test specimens are stored in place free from vibration. After this the specimen are marked and removed from mould and unless required for test within 24 hours, immediately submerged in clean fresh water and kept there until taken out just prior to test. The specimens are not to be allowed to become dry at any time until they have been tested.

Acid immersion:
The marked cubes are immersed in 5% conc. HCl acid for 10 days.
Compression testing:

After 28 days the testing cube are removed from water and leave it to dry for 4-5 hrs before testing. Also the cubes that are immersed in acid are live for drying-5 hrs and then tested for compression testing.

4. Results

Compressive strength

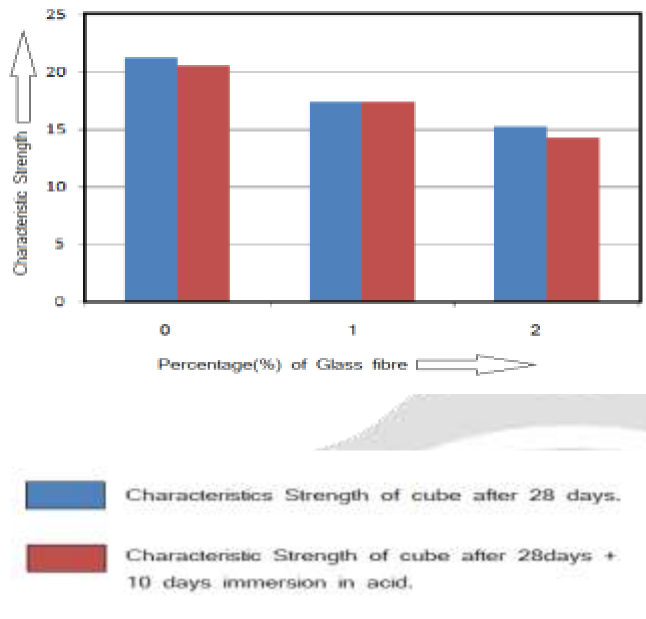
Compression test is the most common test conducted on hardens concrete, partly because it is an easy test to perform and partly because most of the desirable characteristic properties of concrete are related to its compressive strength qualitatively. In this test, the values of compressive strength for different replacement levels of glass fibre contents (0%,1%, & 2%)at the end of different curing period (28 days) are given in table. These values are plotted in figure and which show the variation of compressive strength cement replacement at different curing ages respectively.

Table No.4.1: Result Compressive Strength Comparison

Glass fibre % Replacement	**Compressive strength of concrete blocks (Mpa) 28 days**				**Compressive strength of concrete blocks after 28+ 10 days acid curing**			
	1	2	3	Average	1	2	3	Average
0%	20.18	19.72	24	21.3	19.23	19.15	23.4	20.59
1%	17.60	17.20	17.42	17.41	17.11	17.90	17.13	17.38
2%	15.55	15.24	15	15.26	14.2	14.5	14.15	14.28

Fig4.1: Photograph of compression testing of a cube.

Fig4.2: Photograph of compression testing machine.



5. CONCLUSION

According to the Table No. 4.1,

1) For plain concrete cube (.i.e. 0% of glass fibre), the compressive strength is on an avg. 21.3N/mm^2 for M-20 grade of concrete. After immersing the cube in acid, the avg. compressive strength of cube is 20.59N/mm^2.
2) For GFRC cubes with 1% & 2% respectively has the avg. compressive strength of 17.41N/mm^2 & 15.26N/mm^2.
3) After cubes are immersed in acid for 10 days, the cubes with 1% & 2% of glass fibres respectively has the compressive strength of 17.38N/mm^2 & 14.28N/mm^2. Thus it shows that when compared, cubes with 1% of glass fibre shows better results then that of 0% & 2% .
4) As the percentage of glass fibre by weight of concrete goes on increasing, the volume of concrete decreases and voids are filled by glass fibre which reduces the compressive strength.
5) In Concrete without glass fibre exposed to acid attack undergoes erosion due to penetration of acidic content through small hair cracks present on surface.
6) Glass fibre is water absorbent. So it should be immersed in water for 5-10 minutes before mixing in concrete, so that it should not influence the water -cement ratio.
7) As the percentage of glass fibre increases, the density of concrete decreases.
8) Glass fibre shall be used in between 0 to 1 % (percent) to obtain better results under acid attack for long duration.
9) While designing the concrete, glass fibre property should be considered.

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