Experimental Investigation on Effect of Strength of Concrete by using Alkali Resistance Cem-Fill type Glass Fibers

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Abstract: ***Plain concrete is poor in tensile strength but strong in compressive strength, and also possess a limited ductility property and low resistance to crack. In order to improve tensile strength, response to climate effect and as well as to be ductile member and play a significant role and show resistance to crack and punching shear. Hence, fibres are to be added in certain percentage in the mix of concrete to improve and impart the strain properties and as well as crack resistance, ductility property, flexural strength and toughness. Mainly the investigation studies and research have been done for the fibers which has been devoted to steel fibers. As the steel fibers are not showing resistance to corrosion especially when they exposed to environment. So, in the recent times, glass fibers have been introduced and is available, which are free from corrosion problem associated with steel fibers. Glass fiber reinforced concrete is more effective in resisting bending and punching shear. Fiber reinforced concrete is used for the construction of airport pavements to improve the properties of strength, toughness and as well as long term durabilities. The present research studies are made on various properties of glass fiber reinforced concrete by using AR-Glass cem-fill type fibers in concrete in various percentages (0.33% , 0.67% and 1%). the present paper investigated on glass fibers reinforced concrete to study on the grade M50 strength properties like compressive strength, split tensile strength, flexural strength and durability properties like Acid and Sulphate attack on both ordinary and Glass Fiber Concrete at stipulated ages (7days,28days & 56days). using alkali resistance AR cem-fill type glass fiber in the study. The present thesis would give much more beneficiary to the field of concrete technology towards development of concretes possessing very much enhanced and special durable properties. Based on the study, valuable advice will be given for concrete structures.***

Keywords: M50 grade concrete, Glass fiber, PC based superplasticizer, strength properties

1. Introduction

Glass fiber is a mixture of cement, fine aggregate, coarse aggregate, water, chemical admixtures and alkali resistant glass fibres.

Glass fibre Reinforced Concrete or GRC (sometimes called Glass fibre Reinforced Cement and Glass Fiber Reinforced Concrete or GFRC), and known around the world by various names such as Composite Cement Verre or CCV, Fiber Beton, Fiber Takviyeli Beton and Glasfaserbeton or GFB.

Glass fibre Reinforced Concrete (GRC) is a material which today is making a significant contribution to the economics, to the technology and to the aesthetics of the construction industry worldwide.

This environmentally friendly composite, with its low consumption of energy and natural raw materials, is being formed into a great variety of products and has won firm friends amongst designers, architects, engineers and end users for its flexible ability to meet performance, appearance and cost parameters.

Since its introduction in 1969, GRC has matured and today's designer has available to him, depending upon his performance requirements, a range of matrix modifiers such as acrylic polymers, rapid set cements and additives to improve the long term stability of the material. Extensive independent test and performance data are available on all aspects of matrix formulation.

The Alkali Resistant glass fiber is generally used at the 2-5% level in the manufacture of factory finished prefabricated products either by the spray process or using traditional concrete casting methods. GRC's high strength enables products with thin sections to be manufactured. These products are considerably lighter in weight than their counterparts made from normal concretes. Advantages, in addition to the inherent durability of GRC, are that the products are easy to handle and fast to install. Furthermore, GRC units can be manufactured with dense smooth surfaces that minimise resistance to water flow.

Product weight is a critical health and safety issue in many countries. Limits on the weights that individual workers can carry often mean that the heavier traditional concrete alternatives are not acceptable. GRC products can be designed to be as little as one-fifth of the weight of a comparable precast concrete product. A 100-kg concrete product requires mechanical lifting; a 20-kg GRC product is a one-man lift.

2. Literature Review

Glass fiber Reinforced Concrete or GFRC is concrete containing of dispersed glass fibers and play a significant role in the concrete members which is responsible for controlling of tensile cracks, improvement of strength properties, long term durability, toughness and as well as strain capacity which all these properties is the consequence of prevention the cracks and leads the engineers to use in bridges, tunnels, highway and as well as in airfield pavement.

Rengaswamy et al. (1996) studied the effect of water cement ratio on the strength performance of glass fiber reinforced concrete (GFRC). The various strengths considered for performance evaluation were compressive strength, flexural strength, split tensile strength, and briquette tensile strength of GFRC. Addition of glass fibers in concrete showed a significant enhancement in strength properties. In the present work, the effect of alkali-resistant glass fibers on the properties of wet concrete and on various strengths of structural concrete are investigated and the results obtained experimentally are presented.

Bantia et al (1997) studied the performance of E-glass and AR-Glass fiber reinforced composites with the cementitious matrices. The results were compared with those of ordinary Portland cement composites. It was shown that by adjusting the composition of the matrix, there is a potential for developing highly durable fiber – cement composites, even with E – glass, which is probably the most sensitive to corrosion of the man – made high strength fibers.

Chawla and Tekwari (2012) outlines the experimental investigation conducted on the use of glass fibers with structural concrete. CEM-FILL anti crack high dispersion, alkali resistance glass fiber of diameter 14 micron, having an aspect ratio 857 was employed in percentages varying from 0.33 to 1 percent by weight in concrete and properties of this FRC, like compressive strength, flexural strength toughness, modulus of elasticity, were studied.

Deshmukh et.al. (2012) has studied in his paper 'Effect of Glass Fibers on Ordinary Portland cement Concrete 'that the glass fiber of 0 %, 0.03%, 0.06% and 0.1 % by volume fraction of concrete were used and the results have shown improvement in mechanical and durability properties with the addition of glass fibers. It is observed that compression, flexural and split tensile increased with increase in percentage of glass fiber.

Chandramouli et al (2010) had conducted experimental investigation to study the effect of using the alkali resistance glass fibers on compressive, split tensile and flexural strength on M20, M30, M40 and M50 grades of concrete. The mechanical properties of glass fiber reinforced polyester polymer concrete were evaluated. The author observed that the modulus of rupture of polymer concrete containing 20 per cent polyester resin and about 79 per cent fine silica aggregate is about 20 MPa. The addition of about 1.5 per cent chopped glass fibers (by weight) to the material increases the modulus of rupture by about 20 per cent and the fracture toughness by about 55 per cent.

Tassew and Lubell (2014) experimentally studied on the mechanical properties of Glass fiber reinforced ceramic concrete. The experiment proceeded with the addition of Glass fibers of various size compositions in various volume fractions ranging from 0% to 2% with the concrete. The experiment was conducted over the cubes, cylinders and prisms to find the Compressive, Tensile & Flexural strength of the specimens with various glass fiber mixes. The obtained results suggested that the Compressive strength increased with increase in glass fiber volume fraction while the fibers had negligible effect on modulus of elasticity & the direct shear strength of concrete was also noticed to increase with the increase in the glass fiber volume not more than 0.5%.

Homam et al (2004) observed that reduction of both water absorption and chlorine ion permeability in the specimen showed that natural pozzolana is not only suitable for high performance concrete but also results in better properties than the control concrete. Permeability of concrete allows aggressive chemicals such as chlorides and sulphates to penetrate through concrete causing damage. In fact, chloride diffusion and sulphate attack are the main reasons for concrete deterioration. The ability of concrete to resist chemical attack is characterized by permeability and diffusivity which are considered as "durability indicators.

3. Materials allocated for investigations

Materials were used for producing GFRC has been tested based on the Indian standard code. And the relevant used materials were cement, coarse aggregate, fine aggregate, AR cem-fill type glass fiber & PC Base superplasticizer.

3.1 Cement

Ordinary Portland cement of grade 53 has been used. The Cement has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications are 12269-1987.The specific gravity was 3.14 and fineness was 3200cm2/gm. The standard consistency and initial setting of OPC tested 30% and 30 minutes respectively results are shown in Table 1.

3.2 Coarse Aggregate

Machine Crushed angular granite metal of 20 mm size from a local source was used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc., The coarse aggregate is also tested for its various properties .The specific gravity, and fineness modulus are found to be 2.64 and 8.3 respectively the obtained results shown in table 2.

3.3 Fine Aggregate

The locally available river sand was used as fine aggregate in the present investigation. And is tested for different properties, such as specific gravity, fineness modulus, bulk density etc. Sieve analysis is carried out and results are shown in Table 2.

3.4 Glass Fiber

The glass fibers are of Cem-FIL Anti-Crack HD with Modulus of Elasticity 72 GPA, Filament diameter 14 microns, Specific Gravity 2.68, length 12mm and having the aspect ratio of 857.1. For kilo gram, the number of fibers are 212 million as shown in Table 3.

3.5 PC based Superplasticizer

The new generation of this kind of admixtures is represented by polycarboxylate ether-based superplasticizers (PCEs). With a relatively low dosage (0.15–0.4% by cement weight) they allow a water reduction up to 40%, due to their chemical structure which enables good particle dispersion as shown in Table 4.

3.6 Water

According to IS: 456 -2000, the water used for mixing and curing of concrete was free from deleterious materials. Therefore potable water was used in the present study.

Table 1: Physical properties of OPC Cement

S.No	Porperty	Result	Req as per IS codes
1	Consistency	30%	
2	Specific gravity	3.14	
3	Initial setting time	30min	Not less than 30min
4	Final setting time	340min	Not more than 600min
5	Soundness	2mm	Not more than 10mm
6	Fineness	3.5%	Less than 10%
7	Compressive strength	7days 38.5	
		28days 54	

Table 2: Physical properties of F.A & C.A

S.No	Property	Test result	
		F.A(ZoneII)	C.A
1	Specific gravity	2.6	2.64
2	Fineness modulus	3.62	8.3

Table 3: Physical properties of Glass Fiber

Property	Recommended
Specific gravity	2.68
Modulus of elasticity(Gpa)	72
Tensile strength (Mpa)	1700
Length (mm)	12
Aspect ratio	875.1

Table 4: Physical and mechanical property of Admixture

Appearance	Yelow-brown liquid
% Solid residue	Approx. 38%
PH	5.3-5.4
Specific Gravity : Kg/l	Approx 1.09

4. Experimental Investigation

In the present experimental investigation, properties like compressive strength, split tensile strength, flexural strength, chloride attack and sulphate attack tests are carried out on both ordinary and glass fiber concrete. Mixes, have been studied. And the tests have been conducted for concrete of grade M50. And the program involved the various process such as mix proportion, casting, curing & testing which are mentioned in the below sections.

4.1 Test specimens

Test specimens used in the investigation are cube 150x150mm, cylinder with 150mm diameter & 300mm length and beam with cross section of 150x150mm and with length of 700mm.

4.2 Design Mix

As per IS: 10262-2009 The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The mix design for concrete has been done based on the IS: 10262-2009 and according to the calculation obtained the mix proportion for M50 as 1:1.53:2.76:0.33:0.004 and shown in the below Table 5.

Table 5: Mix Proportion of M50

Grade of Concrete GF %	Cement	F.A	C.A	W/C	Admixture
M50-0%	1	1.53	2.76	0.33	0.004
M50-0.33	1	1.53	2.76	0.33	0.004
M50-0.67	1	1.53	2.76	0.33	0.004
M50-1	1	1.53	2.76	0.33	0.004

4.3 Mixing of Concrete

The mixing process is carried out in an electrically operated concrete mixer and has a of capacity 60 lts. The materials are arranged in uniform layers, one after the other in the order of coarse aggregate, fine aggregate and cementitious material. Dry mixing is done to obtain a uniform color. Wet mixing is done until a mixture of uniform color and consistency are achieved which is then ready for casting. Before casting the specimens, workability of the mixes was found.

Figure 1: Slump test

4.4 Casting of Concrete

The cast iron moulds are cleaned of dust particles and applied with mineral oil on all sides before concrete is poured in the moulds. The moulds are placed on a level platform. The well mixed green concrete is filled, allowed to flow and settle itself in the moulds. Excess concrete was removed with trowel and top surface is finished level and smooth.

4.5 Curing of Concrete

The specimens are left in the moulds undisturbed at room Temperature for about 24 hours after casting. The specimens are then removed from the moulds and immediately transferred to the curing pond containing clean and fresh water. The curing water is renewed at every 5 days.

4.6 Testing of specimens

A time schedule for testing of specimens is maintained to ensure their proper testing on the due date and time. The cast specimens are tested as per standard testing procedures, immediately after they are removed from curing pond and wiped off the surface water, as per IS 516-1959. The test results are tabulated carefully for compressive, split tensile & flexural strength test.

4.6.1 Compressive strength test

The test specimens are tested in accordance with IS 5161959. The testing takes place in a hydraulically operated digital compression testing machine of 2000 KN capacity. The machine has the facility to control the rate of loading with a control valve. The machine has been calibrated to the required standards. The plates are cleaned, oil level is checked and kept ready in all respects for testing. Compressive Strength (fcu) = P/A Where, P is the applied compressive force and A is the cross sectional area of cube (150x150).

Figure 2: CTM Machine

4.6.2 Split tensile strength test

The test is carried out by placing a cylindrical specimen (150 mm in diameter and 300 mm long) horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. Applying the load, along the generatrix, the vertical diameter of the cylinder is subjected to a vertical compressive stress and as well horizontal stress of 2P/∏ LD. It is observed that cylinder did split into two halves. Split Tensile Strength = 2P/∏ Where P is the Maximum compressive load in the cylinder is the length of cylinder D is its diameter.

4.6.3 Flexural strength test

The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from center to Centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm Centre to Centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.fcr = PL/bd^2

Figure 3: UTM Machine

5. Discussion on the Test Results

5.1 Effect of % of Glass Fiber on Workability of concrete

The result shows that workability of the concrete is solely affected by addition of fibers in the mixes. The slump value for M 50 grade of concrete was observed to be 85 mm. With the addition of fibers the value of slump reduces and is reported between 50 to 70 mm. a bit harsh mixes are obtained as the percentages of fibers are increased shown in fig 4.

5.2 Effect of glass fiber on bleeding of concrete

Based on the experimental studies it found that increase in the percentage of glass fiber gives reduction in bleeding. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks occurring where there is some restraint to settlement.

5.3 Effect of % of glass fiber on compressive strength of concrete

During experimental studies it obtained that the strength values were found optimum at 0.33 % of the glass fiber by weight of concrete when compared to those of ordinary concrete and glass fiber of 0.67 % and 1 %. And the consequence of the optimum result was due to required workability and easily compaction of glass fiber concrete and it is necessary to be mentioned that more percentage of glass fiber gives less workability for the same water-cement ratio which is the consequence of porosity. Table 5 gives the compressive strength of ordinary concrete and glass fiber which are varies from 37 N/mm2, 53.8 N/mm2 & 58.4 N/mm2 for 7, 28 & 56 days respectively. And for 0.33% of glass fiber the compressive strength are 42 N/mm2, 61.7 N/mm2 & 67.4 N/mm2 for 7, 28 & 56days respectively and for 0.67 % of glass fiber the compressive strength are 39 N/mm2 , 58.6 N/mm2 & 64 N/mm2 for 7,28 & 56 days and finally for 1% of glass fiber the compressive strength by using CTM machine note down as 38.1 N/mm2 ,57 N/mm2 & 63.2 N/mm2 for the ages of 7,28 & 56 days respectively which all these values for above mentioned proportions are given in the Fig 5 & Table-6.

5.4 Effect of % of glass fiber on split tensile strength of concrete

Table -7 illustrated us that the split tensile strength of ordinary concrete & glass fiber reinforced concrete for the age of 7, 28 & 56days which are given in the Fig 6.

5.5 Effect of % of glass fiber on Flexural strength of concrete

Table -8 gives the flexural strength of ordinary concrete & glass fiber reinforced concrete for the age of 7, 28 & 56days which are given in the Fig 7.

5.6 Variation of % of compressive strength, split tensile strength and flexural strength of the glass fiber concrete mixes compared with ordinary concrete mixes

Table -9 gives the optimum compressive, split tensile & flexural strength gained with 0.33% of the glass fiber in the mix by weight of concrete which is the max strength compared to those of 0.67% and 1% of GFRC and the variation for compressive strength is 13 to 15.5% for the split tensile strength is 12 to 17.5% increased and also for the flexural strength the increased in strength compared to those of 0.67% & 1% as noted from 16 to 19% as shown in the Fig 8.0

5.7 Durability study of ordinary and glass fiber concrete mix

Durability of concrete can be defined as its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration. So, for the durability purport experimental study carried out on chloride and sulphate attack shown in fig 9.0 & 10.0 & table 10 & 11.

Table 6: Compressive strength of ordinary and glass fiber reinforced concrete.

Grade with glass fiber %	Age (Days)	Compressive Strength (N/mm^2)
M 50 GF-0.00	7	37
	28	53.8
	56	58.4
M 50 GF-0.33	7	42
	28	61.7
	56	67.4
M 50 GF-0.67	7	39
	28	58.6
	56	64.7
M 50 GF-1.00	7	38.1
	28	57
	56	63.2

Table 7: Split tensile strength of ordinary and glass fiber reinforced concrete

Grade with glass fiber %	Age (Days)	Compressive Strength (N/mm^2)
M 50 GF-0.00	7	3.65
	28	5.31
	56	5.7
M 50 GF-0.33	7	4.1
	28	6.2
	56	6.7
M 50 GF-0.67	7	3.86
	28	5.73
	56	6.4
M 50 GF-1.00	7	3.7
	28	5.6
	56	6.3

Table 8: Flexural strength of ordinary and glass fiber reinforced concrete

Grade with glass fiber %	Age (Days)	Compressive Strength (N/mm^2)
M 50 GF-0.00	7	3.72
	28	5.43
	56	5.79
M 50 GF-0.33	7	4.3
	28	6.37
	56	6.9
M 50 GF-0.67	7	4.1
	28	5.9
	56	6.63
M 50 GF-1.00	7	3.91
	28	5.87
	56	6.47

Table 9: Percentage variation

Grade with glass fiber %	Age (Days)	Compressive Strength (%)	Split tensile strength (%)	Flexural strength (%)
M 50 GF-0.33	7	13	12	16
	28	15	17	17.5
	56	15.5	17.5	19

Table 10: gives the weight loss percentage of ordinary concrete & Glass fiber reinforced concrete for grade of M50 in 5 % HCL solution shown in fig 11.

Grade of Concrete	% of Glass fiber	Loss of weight by % after immersion in (HCL)		
		7days	28days	56days
M50	0.00	1.2	2.45	4.35
M50	0.33	1.18	2.42	4.21
M50	0.67	1.12	2.38	4.15
M50	1.00	1.1	2.32	4.08

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Table 11: Gives the weight loss percentage of ordinary concrete & Glass fiber reinforced concrete for grade of M50 in 5 % H_2SO_4 solution shown in fig 12.

Grade of Concrete	% of Glass fiber	Loss of weight by % after immersion in (HCL)		
		7days	28days	56days
M50	0.00	8.56	12	22.5
M50	0.33	8.4	11.7	22.1
M50	0.67	8.1	11.5	22.3
M50	1.00	7.93	11.2	21.8

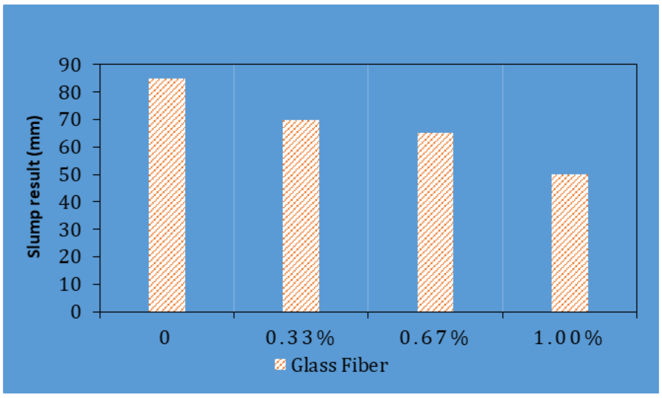

Figure 4: Effect of % of glass fiber on workability

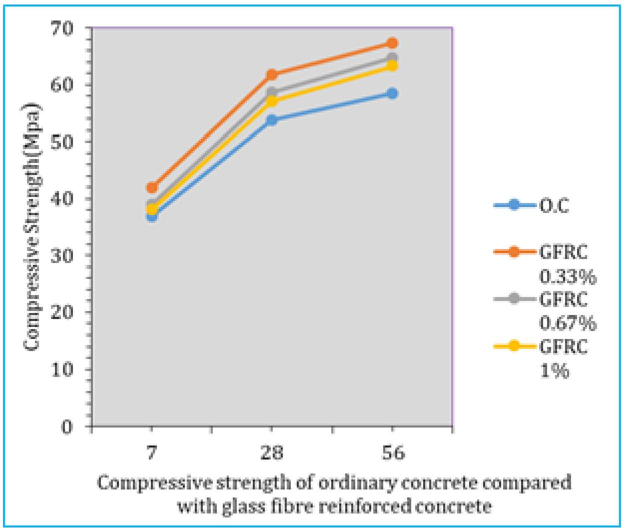

Figure 5: Effect of % of glass fiber on Compressive strength

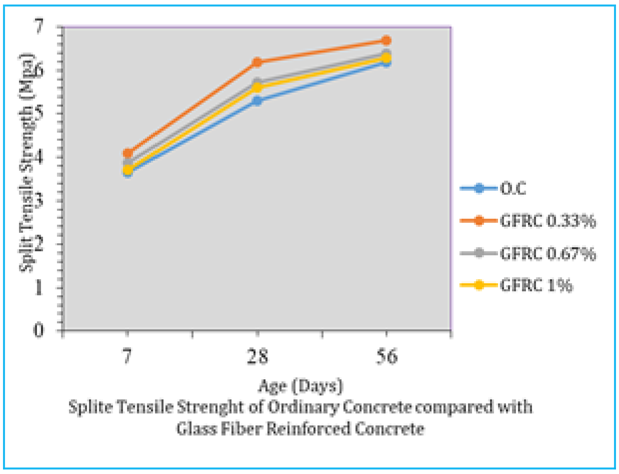

Figure 6: Effect of % of glass fiber on Split tensile strength

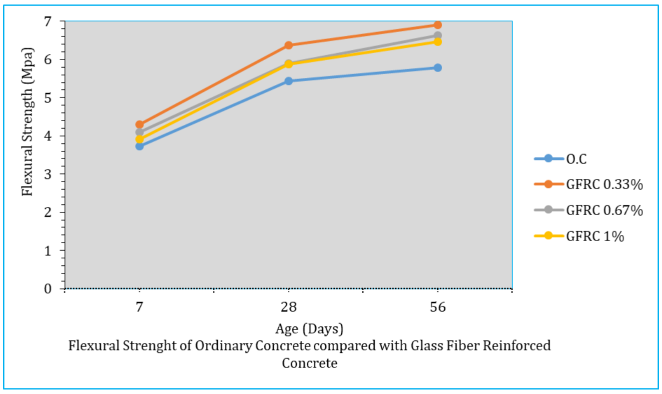

Figure 7: Effect of % of glass fiber on Flexural strength

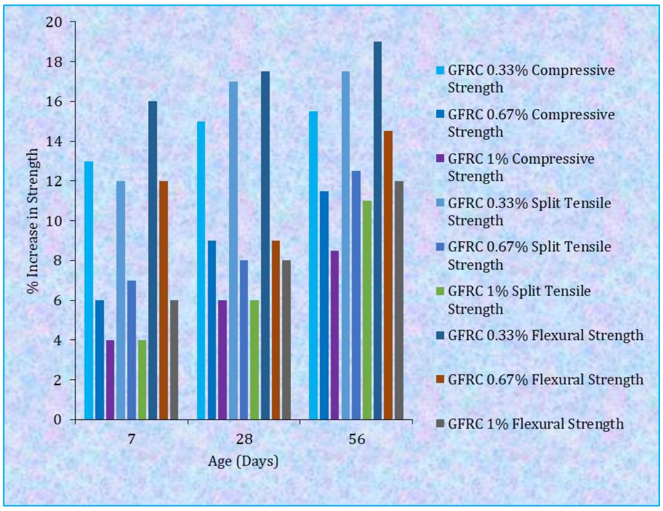

Figure 8: Percentage in variation of all three type strength

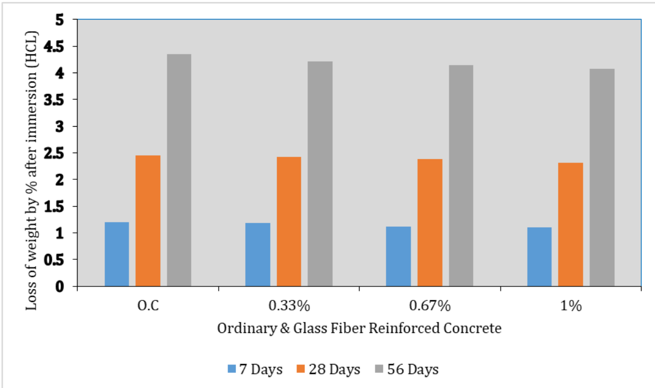

Figure 9: Loss of weight by 5% solution of H_2SO_4

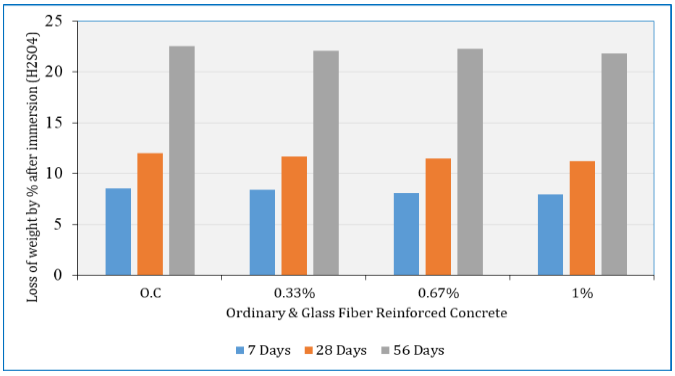

Figure 10: Loss of weight by 5% solution of HCL

6. Conclusion

In the present thesis the following conclusions are drawn from the experimental investigation.

1) Decrease in bleeding is consider by addition of glass fibers in concrete mixes.
2) Lower percentages of glass fibers up to 0.3% do not affect the workability of concrete.
3) If the percentage of glass fiber highest than 1%.So, it is necessary to consider the superplasticizer otherwise it will affect the workability of A reduction in bleeding is observed by addition of glass fibers in the glass fiber concrete mixes; concrete.
4) The percentage increase of compressive strength at the age of 7days varies from 4% to 13% from 0.33% to 1% of glass fibers & from 6% to 15% at the age of 28 days for 0.33% to 1% of glass fibers. And for 56days the percentage of compressive strength is varies from 8.5% to 15.5% for 0.33% to 1% of glass fibers.
5) The percentage increase of split tensile strength at the age of 7days varies from 4% to 12% from 0.33% to 1% of glass fibers & from 6% to 17% at the age of 28 days for 0.33% to 1% of glass fibers. And for 56days the percentage of compressive strength is varies from 11% to 17.5% for 0.33% to 1% of glass fibers.
6) The percentage increase of flexural strength at the age of 7days varies from 6% to 16% from 0.33% to 1% of glass fibers & from 8% to 17.5% at the age of 28 days for 0.33% to 1% of glass fibers. And for 56days the percentage of compressive strength is varies from 12% to 19% for 0.33% to 1% of glass fibers.
7) The compressive strength, split tensile strength and flexural strength of GFRC is found to be maximum at 0.3% percentage of fiber at the age of 56 days compare to those of ordinary concrete, 0.67% & 1% of glass fiber.
8) The variation in compressive strength of glass fiber concrete mixes are observed to be 15 to 20% when compared with ordinary concrete mixes.
9) The weight loss percentage of ordinary concrete & Glass fiber reinforced concrete for grade of M50 in 5 % HCL solution varies from 1.2 to 4.35% and the compressive strength decrease from 3.5 to 7% at the ages varies from 7 to 56 days.
10) The weight loss percentage of ordinary & glass fiber reinforced concrete for grade of M50 in 5% solution of H2SO4 varies from 7.93 to 22.5 % and the compressive strength varies from 4.5 to 12% respectively.

7. Future Scope

1) The future investigation will be done for the below temperature effect on glass fiber reinforced concrete.
2) Glass fiber for High strength concrete of grade M60 & M80 in order to study long term durability.
3) Using fly ash by partial replacement of cement and investigate the strength and durability properties and as well as strength characteristic of glass fiber reinforced concrete.

References

[1] Rengaswamy, N. S., Parthiban, G. T., Saraswathy, B. and Balakrishnan, K. (1996). Effect of w/c Ratio on the Performance of Glass Fiber Reinforced Concrete, ICI Bulletin, 54, 15–17.
[2] N. Banthia (2003),"Crack Growth Resistance of Hybrid Fiber Composites", Cem. Con. Comp., Volume 25, Issue 1, Pp. 3-9, 2003.
[3] Chawla K. a d Tekwani B. "Studies of glass fiber reinforced concrete composites" International Journal of Structural and Civil Engineering Research vol. 2, No. 3 pp 176-182 (2013).
[4] Deshmukh S.H. , Bhusari J. P , Zende A. M. (2012), "Effect of Glass Fibres on Ordinary Portland cement Concrete" IOSR, Journal Of Engineering, June 2012, Vol. 2(6) pp: 1308-1312.
[5] Chandramouli, K. Srinivasa Rao P. Pannirselvam N., Seshadri Sekhar T. And Sravana P. (2010) "Strength Properties of Glass Fiber Concrete" Asian Research Publishing Network VOL.5, NO. 4, APRIL 2010.
[6] Tassew S.T. and Lubell A.S. (2014), "Mechanical properties of Glass fibre reinforced ceramic concrete" Construction and Building Materials, Vol. 51, pp. 215-224.
[7] IS 10262-2009 Indian standard CONCRETE MIX PROPORTIONS – Guideline.
[8] IS 516-1959 Methods of test for strength of concrete, Bureau of Indian standards, New Delhi.
[9] IS 4031 Indian Standard method of physical tests for hydraulic cement.

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