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Mechanical Properties of Glass Fiber Reinforced Concrete

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Abstract: **GFRC has advantage of being light weight and thereby reducing the overall cost of construction there by bringing economy in construction. GFRC is concrete that uses glass fibres for reinforcement instead of steel. It is typically cast in a thin section of around ½" to ¾". Since the fibres cannot rust like steel, there is no need for a protective concrete cover thickness to prevent rusting. With the thin, hollow construction of GFRC products, they can weigh a fraction of weight of traditional precast concrete. This paper has compressive, flexural and tensile behaviour of the glass fiber reinforced concrete and aims to contribute to the classification and specification of glass fiber reinforced concrete (GFRC) and to deal with the question if structural glass fiber reinforced concrete as a special kind of glass fiber reinforced concrete is suited for use in load-bearing members. Despite excellent material properties, the use of glass fibers in a concrete matrix is carried out so far only in non-structural elements or as a modification for the prevention of shrinkage cracks. The aim of research is the use of alkali-resistant macro glass fibers as concrete reinforcement in structural elements as an alternative. In the future, structural glass fiber reinforced concrete shall provide a simple and visually appealing alternative to conventional steel bar or steel fiber reinforced concrete. The glass fibers can also be used in combination with conventional reinforcing bars or mat reinforcements. Initial investigations have announced some potential.**

Keywords: **Glass Fiber Reinforced Concrete (GFRC), reducing the overall cost of construction.**

I. INTRODUCTION

With the development of alkali resistant glass fiber (by trade name 'CEM-FIL) by the U.K. Building Research Establishment and Pilkington glass, U.K. a wide ranging applications of fibrous concrete is being made in many areas of building construction. Glass reinforced cement consists of 4 to 4.5 per cent by volume of glass fiber mixed into cement or cement sand mortar. This glass reinforced cement mortar is used for fabricating concrete products having a section of 3 to 12 mm in thickness. Methods of manufacture vary and include spraying, casting, and spinning, extruding and pressing. Each technique imparts different characteristics to the end product. Spray deposition constitutes a very appropriate and by far the most developed method of processing. In the simplest form of spray processing, simultaneous sprays of cement or cement sand mortar slurry and chopped glass fiber are deposited from a dual spray gun into, or onto a suitable mould. Mortar slurry is fed to the spray gun from a metering pump unit and is atomised by compressed air. Glass fiber is fed to a chopper and feeder unit that is mounted on the same gun assembly.

II. LITERATURE REVIEW

A literature review is carried out on the glass fiber reinforced concrete. A number of literatures are available on the strength aspects of the glass fiber concrete. This section presents a brief report on the literatures reviewed as part of this project.

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."

Chandramouli et al (2010) have observed that the percentage increase of compressive strength of various grades of glass fiber concrete mixes compared with 28 days compressive strength is observed from 20 to 25%.The percentage increase of flexural and split tensile strength of various grades of glass fiber concrete mixes compared with 28 days is observed from 15 to 20%.

Srinivasa Rao et al (2012) have observed that the durability of concrete from the aspect of resistance to acid attack on concrete increases by adding AR-glass fibers in concrete. It was observed that there was no effect of sulphates on concrete. Chloride permeability of glass fiber reinforced concrete shows less permeability of chlorides into concrete when compared with ordinary concrete.

III. METHODOLOGY

A. Experimental Program:

Summarized information about materials used in the present study and their characteristics are presented herein.

- **Cement:** Portland Pozzolana cement conforming to IS 1498-1991 was adopted in this work. The chemical composition and physical properties are given in Table 1.
- **Coarse aggregate:** Machine crushed angular granite metal passing through 20 mm sieve and retained on 10 mm sieve has been used. It is free from impurities such as dust, clay particles and organic matter. The coarse aggregate used conforms of IS 383-1970.
- **Fine aggregates**: Locally available river sand was used. The sand was dried before used to avoid problem of bulking. The sand is tested according to IS 2386-1963. The sand used conformed to zone – II as per IS 383-1970 classifications.
- Water: Locally available potable water with p^H value of 7.65 was used in the present work and it conforms to IS: 3025-1986.
- **Glass fibers:** Anti-Crack HD is an engineered alkali-resistant (AR) glass fiber designed to reduce plastic shrinkage cracking in concrete and mortars.

Table 1 Glass fiber properties

1	Material	Alkali Resistant Glass
2	Design	Monofilament Fiber
3	Diameter	14 microns
4	Specific Gravity	2.68
5	Colour	clear / white
6	Moisture Content	< 0.6% (ISO 3344)*
7	Modulus of elasticity	72 GPa or 10,000 KSI
8	Tensile Strength	1,700 MPa

Table 2 Chemical composition and physical properties of Portland pozzolana cement

S. No	Description	Portland Pozzolana cement
1	**Chemical composition**	
	Lime	54.44%
	Soluble Silica	17.48%
	Alumina	5.40%
	Iron Oxide	4.00%
	Magnesia	0.76%
	Sulphur calculated as SO_3	1.54%
	Loss on Ignition	2.06%
	Insoluble Residue	13.64%
	Chloride	0.0176%
2	Fineness (Specific Surface)	374 m^2/kg
3	**Compressive strength**	
	3 days	31.1 N/mm^2
	7 days	40.8 N/mm^2
	28 days	58.8 N/mm^2
4	**Setting Times**	
	Initial	160 minutes
	Final	220 minutes

5	**Soundness** a. Expansion after boiling for 3 hours in Lechatelier Method. b. Expansion of Autoclave test	 0.50 mm 0.010%

Mix proportions adopted in to work for M30 grade concrete are 1 : 1.70 : 3.06 with a water cement ratio equal to 0.45

Batching, casting, vibrating and curing of test specimen:

The details of batching, casting, vibrating and curing are summarised herein.A tilting type rotary drum mixer was used. All the ingredients were placed in the mixture and water was added during rotation. Then glass fibre was mixed with the ingredients and mixing was continued. All the test specimens were casted in removable standard (cast iron) moulds conforming to IS: 10086-1982 and vibrated on a standard vibrating table conforming to IS:7246-1974. The test specimens are demoulded after a lapse of 24 h from the commencement of casting and submerged under water till the time of testing.

B. Testing of specimen:

Compressive strength:

The real dimensions of the specimen were taken into consideration in calculation. Tests for compressive strength were carried out according to IS: 516-1959. Specimens stored in water were taken out from the water after the specified period of curing and air dried. The cubes were placed in the compressive testing machine in such a manner that a load was applied to the opposite side of cube. The load was applied without shock and was increased continuously at rate of approximately 140 kg/cm^2/min until the resistance of the specimen to increasing load breaks down and no greatest load is sustained. The maximum load applied to the specimen is then recorded. The compressive strength of the specimen is calculated by dividing the maximum load applied on the specimen during the test by the cross sectional area. Specimens are cast for different ages of 1, 3, 7, 28 and 56 days.

Fig. 1 Testing of specimen in compression testing machine

Split tensile strength:

The real dimensions of the specimen were taken into consideration in calculation. Tests for split tensile strength were carried out according to IS: 5816-1999. Specimens stored in water were taken out from the water after the specified period of curing and air dried. Apply the load without shock and increase it continuously at the rate to produce a split tensile stress of approximately 1.4 to 2.1 N/mm^2/min, until no greater load can be sustained. Record the maximum load applied to specimen. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. . The split tensile strength of the specimen is calculated by the code IS 5816- 1999. Specimens are cast for different ages of 1, 3, 7, 28 and 56 days.

Fig. 2 Testing of specimen for split tensile strength

Flexural strength:

The real dimensions of the specimen were taken into consideration in calculation. Tests for flexural strength were carried out according to IS: 516-1959. Specimens stored in water were taken out from the water after the specified period of curing and air dried. The specimen shall be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two line spaced 20·0 or 13·3 cm apart. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without shock and increasing continuously at a rate of loading of 400 kg/cm^2/ min for the 15·0 cm specimen and at a rate of 180 kg/cm^2/min for the 10 cm specimens, The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted. The flexural strength of the specimen is calculated by the code IS 516- 1959. Specimens are cast for different ages of 1, 3, 7, 28 and 56 days.

Fig. 3 Testing of specimen for flexural strength

IV. RESULTS AND DISCUSSIONS

A. COMPRESSIVE STRENGTH:

Tables 3, 4, 5 and 6 present compressive strength of glass fiber reinforced concrete at various ages (1, 3, 7, 28 and 56 days) with various percentages (0%, 5%, 6% and 7%) of glass fiber by weight of cement.

Table 3 Conventional concrete (0 % glass fiber)

S.No.	Age (days)	Compressive Strength (N/mm^2)
1	1	10.73
2	3	16.83
3	7	21.60
4	28	39.00
5	56	43.87

Table 4 Concrete with 5% glass fiber (by weight of cement)

S.No.	Age(days)	Compressivestrength (N/mm^2)
1	1	12.87
2	3	17.00
3	7	21.53
4	28	47.27
5	56	54.40

Table 5 Concrete with 6% glass fiber (by weight of cement)

S. No	Age(days)	Compressive strength (N/mm^2)
1	1	12.87
2	3	18.50
3	7	21.53
4	28	48.00
5	56	54.80

Table 6 Concrete with 7% glass fiber (by weight of cement)

S.No	Age(days)	Compressivestrength (N/mm^2)
1	1	12.60
2	3	18.83
3	7	23.73
4	28	48.40
5	56	55.20

Figures 4 and 5 present the variation of compressive strength of glass fiber reinforced concrete with age (1, 3, 7, 28 and 56 days) for various percentages (0%, 5%, 6% and 7%) of glass fiber by weight of cement. Figure 13 presents the variation of compressive strength with various percentages (0%, 5%, 6% and 7%) of glass fiber by weight of cement.

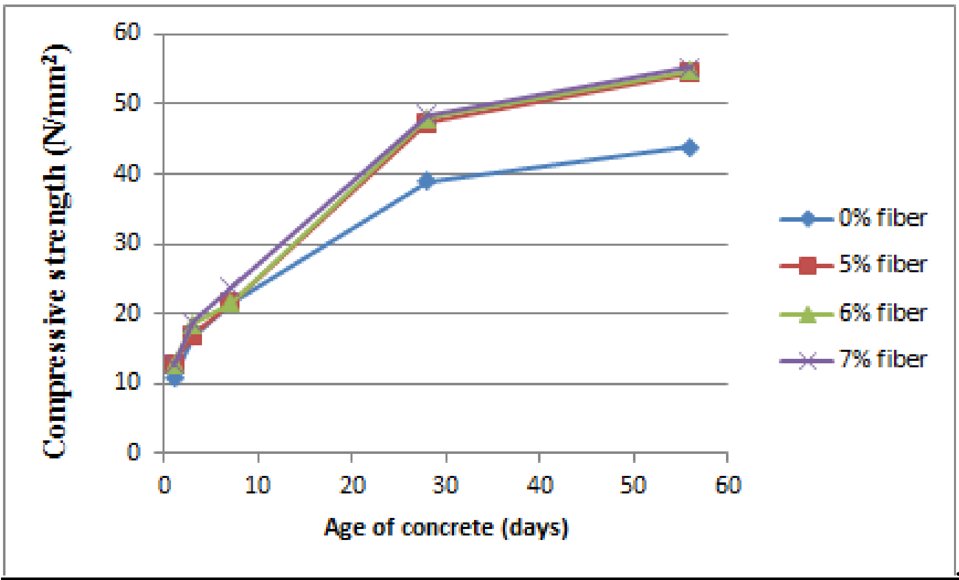

Fig. 4 Variation of compressive strength with age of concrete

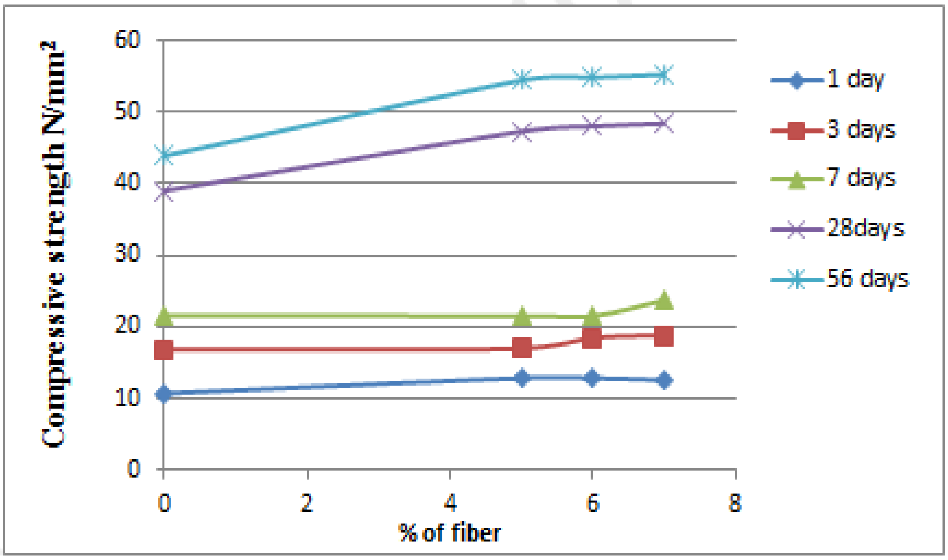

Fig. 5 Variation of compressive strength with % of fiber

From Tables 3, 4, 5 and 6 and Figures 4 and 5, it is observed that concrete at all the ages (1, 3, 7, 28 and 56 days) experienced an increase of compressive strength when glass fibers of different percentages (5, 6 and 7%) were added. There is very minor increase in the compressive strength at all ages (1, 3, 7, 28 and 56 days) for different trials of 5%, 6% and 7% of glass fiber. It is further observed that out of three trials of 5%, 6% and 7% of glass fiber, addition of 7% of glass fiber resulted in maximum increase of compressive strength. Glass fiber reinforced concrete with 5% glass fiber by cement weight exhibited about 17.5% more strength compared to conventional concrete. Glass fiber reinforced concrete with 6% glass fiber by cement weight exhibited about 18.75% more strength compared to conventional concrete. Glass fiber reinforced concrete with 7% glass fiber by cement weight exhibited about 19.5% more strength compared to conventional concrete

Table 7 Increase in compressive strength as % of compressive strength of conventional concrete

S.No	% of fiber	Increase in compressive strength as % of compressive strength of conventional concrete
1	5	17.49
2	6	18.75
3	7	19.42

B. SPLIT TENSILE STRENGTH:

Tables 8, 9, 10 and 11 present split tensile strength of glass fiber reinforced concrete at various ages (1, 3, 7, 28 and 56 days) with various percentages (0%, 5%, 6% and 7%) by weight of cement.

Table 8 Conventional concrete (0 % glass fiber)

S.No	Age (days)	Split tensile Strength(N/mm^2)
1	1	1.62
2	3	2.04
3	7	2.86
4	28	3.77
5	56	4.37

Table 9 Concrete with 5% glass fiber (by weight of cement)

S.No	Age (days)	Split tensile strength (N/mm^2)
1	1	1.90
2	3	2.80
3	7	3.34
4	28	4.50
5	56	5.16

Table 10 Concrete with 6% glass fiber (by weight of cement)

S.No	Age (days)	Split tensile strength (N/mm^2)
1	1	1.94
2	3	2.78
3	7	3.67
4	28	4.59
5	56	5.27

Table 11 Concrete with 7% glass fiber (by weight of cement)

S.No	Age (days)	Split tensile strength (N/mm^2)
1	1	1.83
2	3	2.40
3	7	3.26
4	28	4.33.
5	56	5.04

Figures 6 and 7 present the variation of split tensile strength of glass fiber reinforced concrete at various ages (1, 3, 7, 28 and 56 days) with various percentages (0%, 5%, 6% and 7%) of glass fiber by weight of cement.

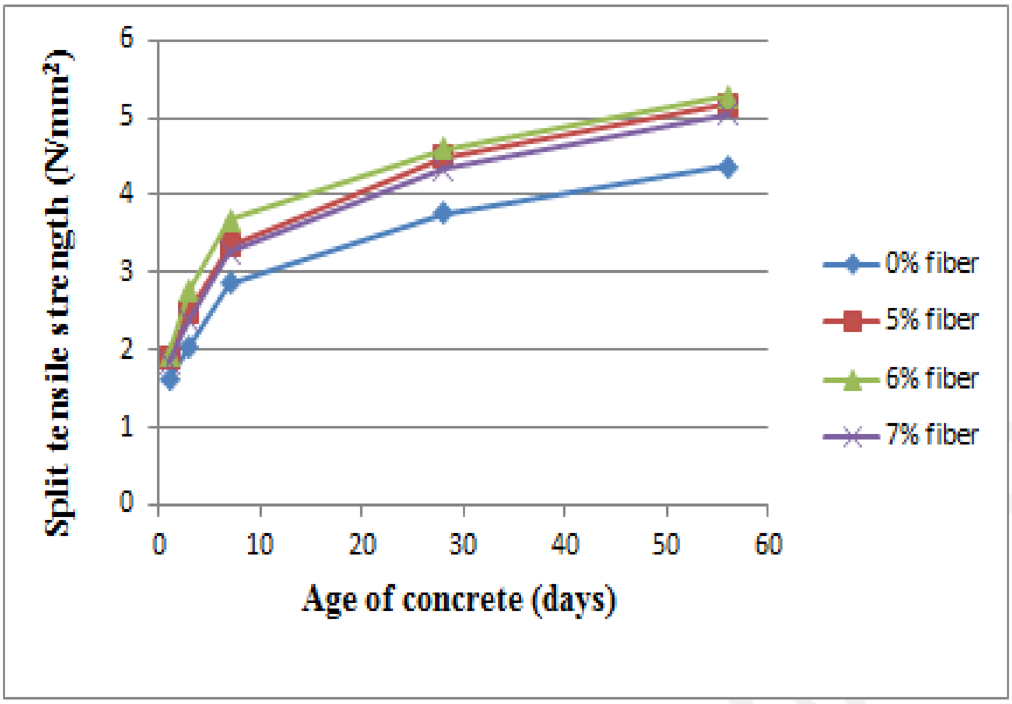

Fig. 6 Variation of split tensile strength with age of concrete

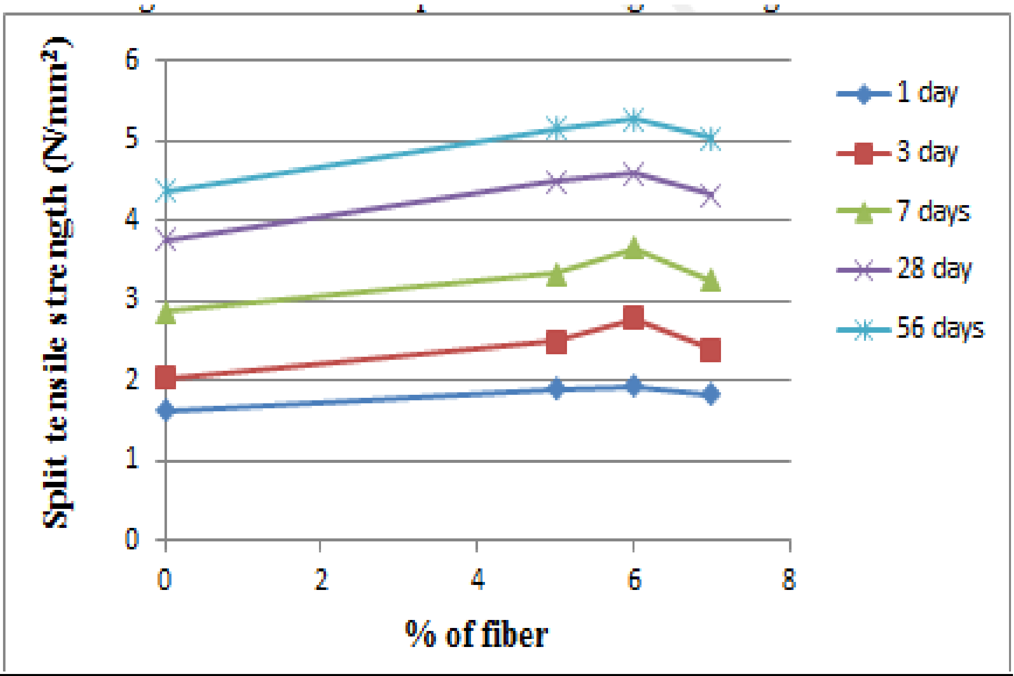

Fig. 7 Variation of split tensile strength with % of fiber

From Tables 8, 9, 10 and 11 and Figures 6 and 7 it is observed that, concrete at all the ages (1, 3, 7, 28 and 56 days) experienced an increase of split tensile strength when glass fibers (5 and 6%) were added by percentage weight of cement. But concrete at all the ages (1, 3, 7, 28 and 56 days) suffered a decrease of split tensile strength when glass fibers of percentage 7% weight of cement. It is further observed that out of three trials of 5%, 6% and 7% of glass fiber addition of 6% of glass fiber resulted in maximum increase of split tensile strength. Glass fiber reinforced concrete with 5% glass fiber by cement weight exhibited about 16% more strength compared to conventional concrete. Glass fiber reinforced concrete with 6% glass fiber by cement weight exhibited about 18% more strength compared to conventional concrete. Glass fiber reinforced concrete with 7% glass fiber by cement weight exhibited about 13% more strength compared to conventional concrete.

Table 12 Increase in split tensile strength as % of split tensile strength of conventional concrete

S.No	% of fiber	Increase in split tensile strength as % of split tensile strength of conventional concrete
1	5	16.22
2	6	17.86
3	7	12.93

C. FLEXURAL STRENGTH:

Tables13, 14, 15 and 16 present flexural strength of glass fiber reinforced concrete at various ages (1, 3, 7, 28 and 56 days) with various percentages (0%, 5%, 6% and 7%) of fiber by weight of cement.

Table 13 Conventional concrete (0 % glass fiber)

S.No	Age (days)	Flexural strength (N/mm^2)
1	1	2.48
2	3	4.37
3	7	4.68
4	28	6.61
5	56	7.57

Table 14 Concrete with 5% glass fiber (by weight of cement)

S.No	Age (days)	Flexural strength (N/mm^2)
1	1	3.03
2	3	5.27
3	7	5.81
4	28	8.07
5	56	8.76

Table 15 Concrete with 6% glass fiber (by weight of cement)

S.No	Age (days)	Flexural strength (N/mm^2)
1	1	3.46
2	3	5.46
3	7	6.18
4	28	8.47
5	56	9.51

Table 16 Concrete with 7% glass fiber (by weight of cement)

S.No	Age (days)	Flexural strength (N/mm^2)
1	1	3.17
2	3	5.2
3	7	5.57
4	28	7.97.
5	56	9.04

Figures 8 and 9 present the variation of flexural strength of glass fiber reinforced concrete at various ages (1, 3, 7, 28 and 56 days) with various percentages (0%, 5%, 6% and 7%) of glass fiber by weight of cement.

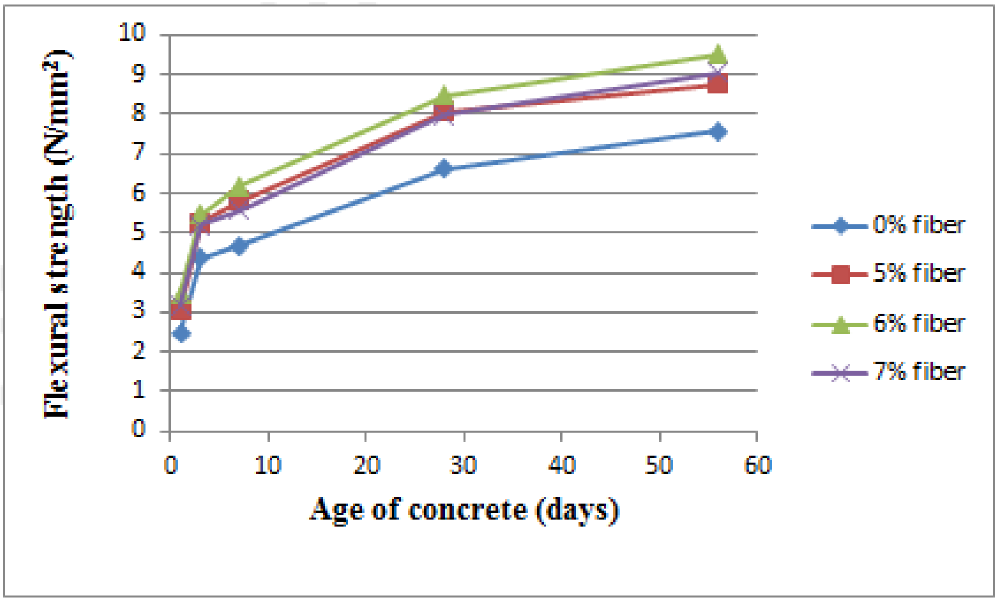

Fig. 8 Variation of flexural strength with age of concrete

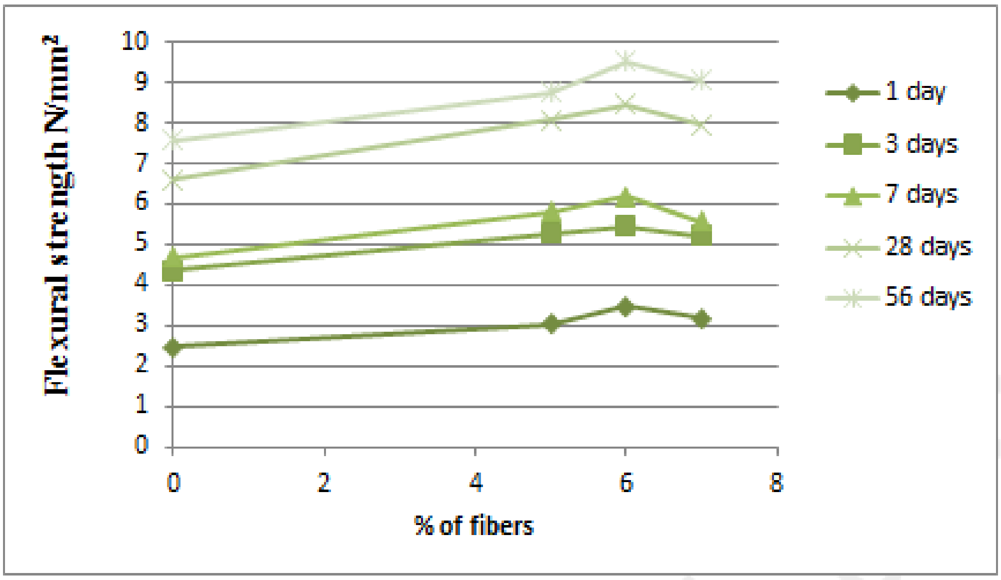

Fig. 9 Variation of flexural strength with % of fiber

From Tables 13, 14 15, and 16 and Figures 8 and 9, it is observed that concrete at all the ages (1, 3, 7, 28 and 56 days) experienced an increase of flexural strength for 5 and 6% of glass fibers (by weight of cement) addition. But concrete at all the ages (1, 3, 7, 28 and 56 days) suffered a decrease of flexural strength for 7% glass fibre (by weight of cement) addition. It is further observed that out of three trials of 5, 6 and 7% of glass fibre addition, 6% of glass fibre addition resulted in maximum increase of flexural strength. Glass fiber reinforced concrete with 5% glass fiber by cement weight exhibited about 18% more strength compared to conventional concrete. Glass fiber reinforced concrete with 6% glass fiber by cement weight exhibited about 22% more strength compared to conventional concrete. Glass fiber reinforced concrete with 7% glass fiber by cement weight exhibited about 17% more strength compared to conventional concrete

Table 17 Increase in flexural strength as % of flexural strength of conventional concrete

S.No	% of fiber	Increase in split tensile strength as % of flexural strength of conventional concrete
1	5	18.09
2	6	21.95
3	7	17.06

V. CONCLUSIONS

From experimental investigation carried out on glass fiber reinforced concrete at various ages (1, 3, 7, 28 and 56 days) and at various percentages (5, 6 and 7%) glass fiber by weight of cement. The following points were concluded:

- It is observed that out of three trials of 5%, 6% and 7% of glass fiber, addition of 7% of glass fiber resulted in the maximum increase of compressive strength. However, there is not much change in the compressive strength with change of glass fiber percentage.
- It is observed that out of three trials of 5%, 6% and 7% of glass fiber, addition of 6% of glass fiber resulted in the maximum increase of split tensile strength.
- It is observed that out of three trials 5%, 6% and 7% of glass fiber, addition of 6% of glass fiber resulted in the maximum increase of flexural strength.
- It is observed that three trials that is 5%, 6% and 7% of glass fiber, the split tensile strength of the glass fiber reinforced concrete is about 9% to 10% against conventional concrete is 8% to 12%.
- It is observed that three trials that is 5%, 6% and 7% of glass fiber, the flexural strength of the glass fiber reinforced concrete is more against the theoretical value of 0.7 $\sqrt{f_{ck}}$ of conventional concrete
- Overall it is observed that addition of 6% of glass fiber resulted in the maximum increase of strength properties of concrete.

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