Effect of Strength in Grade Concrete with Partial Replacement of Glass Fiber

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Abstract— The present study has been taken up for evaluating the different grades of concrete. Emphasis has been given to the compressive strength, flexural strength, split test and workability properties of glass fiber concrete beams. This paper presents the results of an experimental investigation carried out on ten re concrete beams, 150 mm 150 mm 700mm in size. The beams were tested under two point loading. 90 cubes 150 mm 150 mm and 10 cylinder of 150 mm dia &300 mm length with different dosages of glass fiber (0%, 0.5%, 1.0%, 1.5%&2.0%) The study parameters include first crack load and ultimate load. And load was at 5.2 KN/s in 2000 KN compressive testing machine.

Key words: Glass Fiber, Grade Concrete

I. Introduction

Concrete is currently the most widely used building material. Although many structures are built of concrete, there are still some limitations related to the use of conventional concrete, such a slow tensile strength and almost no ductility. Concrete, as a material of construction, has been accepted for a long time. It is popularly believed that concrete structures are designed for a maintenance free operating life of over fifty years. However, the experience in the past shows that there have been a number of cases of severe damages or even failures in some of them, even within a short span. A brief review of the parameters influencing the deterioration of concrete structures in marine environment shows that it is a complex phenomenon that involves an understanding of several different aspects. These can be broadly classified into two major sections, environmental parameters and material parameters, with the material parameters including both that are relevant to the concrete and steel. It is the concrete characteristics that influence the time to initiation of corrosion initially and later the cracking of concrete due to corrosion of steel is of importance. The reinforcements generally in a passive state up to initiation of corrosion and after initiation it is influenced by the environment in concrete up to cracking and later by the environment itself. The relationships between these have a lot of bearing on the performance of structures In the last few years many researchers. Have begun to realize that strain localization also occurs for concrete specimens loaded in compression; however, the compressive failure mechanism is more complex than the tensile failure mechanism. In addition, the formation of micro-cracks in compressive failure is distributed in a wider region than in tensile failure. For the compression-loaded concrete specimens, there are no observable cracks unlike tension-loaded specimen. This is because concrete has nearly tenfold greater strength in compression than in tension. However, stress is definitely concentrated at the crack tip region and micro-cracks form in the loaded direction

If you aren't yet familiar with glass fiber reinforced concrete (GFRC) you should be. GFRC is a specialized form of concrete with many applications. It can be effectively used to create façade wall panels, fireplace surrounds, vanity tops and concrete countertops due to its unique properties and tensile strength. One of the best ways to truly understand the benefits of GFRC is to take a deeper look into this unique compound. GFRC is similar to chopped fiberglass (the kind used to form boat hulls and other complex three-dimensional shapes), although much weaker. It's made by combining a mixture of fine sand, cement, polymer (usually an acrylic polymer), water, other admixtures and alkali-resistant (AR) glass fibers. Many mix designs are available online, but you'll find that all share similarities in the ingredients and proportions used.

Some of the many benefits of GFRC include:

- Ability to Construct Lightweight Panels– Although the relative density is similar to concrete, GFRC panels can be much thinner than traditional concrete panels, making them lighter.
- High Compressive, Flexural and Tensile Strength– The high dose of glass fibers leads to high tensile strength while the high polymer content makes the concrete flexible and resistant to cracking. Proper reinforcing using scrim will further increase the strength of objects and is critical in projects where visible cracks are not tolerable.

A. The Fibers in GFRC- How They Work

The glass fibers used in GFRC help give this unique compound its strength. Alkali resistant fibers act as the principle tensile load carrying member while the polymer and concrete matrix binds the fibers together and helps transfer loads from one fiber to another. Without fibers GFRC would not possess its strength and would be more prone to breakage and cracking.

Understanding the complex fiber network in GFRC is a topic in and of itself. Stay tuned, I'll post a more in-depth article on GFRC fibers next week.

1) Casting GFRC

Commercial GFRC commonly uses two different methods for casting GFRC: spray up and premix. Let's take a quick look at both as well as a more cost effective hybrid method.

2) Spray-Up

The application process for Spray-up GFRC is very similar to Concrete in that the fluid concrete mixture is sprayed into the forms. The process uses a specialized spray gun to apply the fluid concrete mixture and to cut and spray long glass fibers from a continuous spool at the same time. Spray-up creates very strong GFRC due to the high fiber load and long fiber length, but purchasing the equipment can be very expensive.

3) Premix

Premix mixes shorter fibers into the fluid concrete mixture which is then poured into molds or sprayed. Spray guns for premix don't need a fiber chopper, but they can still be very costly. Premix also tends to possess less strength than spray-up since the fibers and shorter and placed more randomly throughout the mix.

One final option for creating GFRC is using a hybrid method that uses an inexpensive hopper gun to apply the face coat and a handpicked or poured backer mix. A thin face (without fibers) is sprayed into the molds and the backer mix is then packed in by hand or poured in much like ordinary concrete. This is an affordable way to get started, but it is critical to carefully create both the face mix and backer mix to ensure similar consistency and makeup. This is the method that most concrete countertop makers use.

Just like regular concrete, GFRC can accommodate a variety of artistic embellishments including acid staining, dying, integral pigmentation, decorative aggregates, veining and more. It can also be etched, polished, sandblasted and stenciled. If you can imagine it, you can do it, making GFRC a great option for creating concrete countertops and especially three-dimensional concrete elements.

II. Objectives of the Study

To study the Flexural behavior of glass fiber reinforced concrete members.

III. Glass Fiber

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm. The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used verities of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR-glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

Name	Value	Unit
Type	E-Glass fiber	-
Young's modulus	73000	MPa
Tensile strength	1900-2600	MPa
Elongation	0-3.2	%
Density	2600	Kg/m^3
Length	25	Mn

Table 1: Physical properties of E- glass fiber

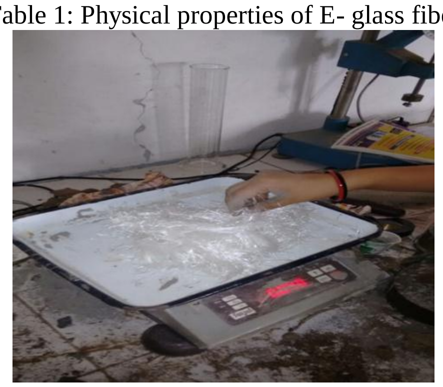


Fig. 1: Glass Fiber

A. *Cement:*

Cement acts as a binding agent for materials. Cement as applied in Civil Engineering Industry is produced by claiming at high temperature. It is admixture of calcareous, siliceous, aluminous substances and crushing the clinkers to a fine powder. Cement is the most expensive materials in concrete and it is available in different forms. When cement is mixed with water, a chemical reaction takes place as a result of which the cement paste sets and hardens to a stone mass. Depending upon the chemical compositions, setting and hardening properties, cement can be broadly divided into following categories.

1) *Portland Pozzolana Cement (MYCEM CEMENT)*

The cement used in this experimental investigation is Portland pozzolana cement. Storage of cement requires extra special care to preserve its quality and fitness for use. To prevent its deterioration, wind, rain etc.

Physical properties of Mycem PPC cement		
Initial setting time	Minutes	90
Final setting time	Minutes	190
Compressive strength		
3 days	MPa	27
7 days	MPa	35
28 days	MPa	51
Specific Gravity		
Mycem PPC Cement		3.15
Drying Shrinkage		
Drying shrinkage	%	0.030
Declared % of fly ash in PPC		
Fly ash % in PPC	%	34.88%

Table 2: Test on Cement

B. *Standard Consistency and Initial Setting Time*

Standard consistency of cement is defined as that water content at which the needle of the apparatus fails to penetrate the specimen by 5mm from bottom of the mould.

C. *Specific Gravity Test for Cement*

Specific gravity test	Weight(kg)	cement(weight in kg)
Weight of pycnometer	W1=0.644kg	0.644
Weight of pycnometer+cement	W2=0.844kg	0.844
Weight of pycnometer+cement + kerosene	W3=1.321kg	1.321
Weight of pycnometer+ kerosene	W4=1.144kg	1.141
Specific gravity W2-W1/(W2-W1)-(W3-W4)0.79		3.15

Table 3: Specific Gravity Test

D. *Fine Aggregates:*

The material we have used as fine aggregate in this project is ROBO SAND. Robo sand is an ideal substitute to river sand. It is manufactured just the way nature has done for millions of years. Robo sand is created by a rock-hit – rock crushing technique using state of the art plant and machinery with world class technology. Created from specific natural rock, it is crushed by a three stage configuration consisting of a Jaw crusher followed by a Cone crusher and finally a Vertical Shaft Impact or (VSI) to obtain sand that is consistent in its cubical particle shapes and gradation. Robo sand is the environmental friendly solution that serves as a perfect substitute for the fast depleting and excessively mined river sand. Robo sand 0–4.75 mm is suitable for all concrete preparations and is used across all segments such as independent houses, builders RMC Plants, Concrete Batching Plants and Infrastructure Concrete works.

Fig. 2: fine & coarse aggregate

E. Specific Gravity Test for Coarse and Fine Aggregate:

Specific gravity test	weight	20mm coarse aggregate (weight in kg)	10mm coarse aggregate (weight in kg)	Sand (weight in kg)
Weight of Pycnometer	W1=0.644kg	0.644	0.644	0.644
Weight of pycnometer+aggregate	W2=0.844kg	0.848	0.848	0.844
Weight of pycnometer+aggregate+ water	W3	1.632	1.632	1.624
Weight of pycnometer+ water	W4	1.502	1.502	1.502
Specific gravity W2-W1/(W2-W1)-(W3-W4)		2.88	2.88	2.60

Table 4: Specific Gravity Test

Sample =24 hrs & wire basket used in specific gravity test

F. Water:

Water to be used in the concrete work should have following properties:

– It should be free from injurious amount of soils
– It should be free from injurious amount of acids, alkalis or other organic or inorganic impurities.
– It should be free from iron, vegetable matter or any other type of substances, which are likely to have adverse effect on concrete or reinforcement.
– It should be fit for drinking purposes.

The function of water in concrete

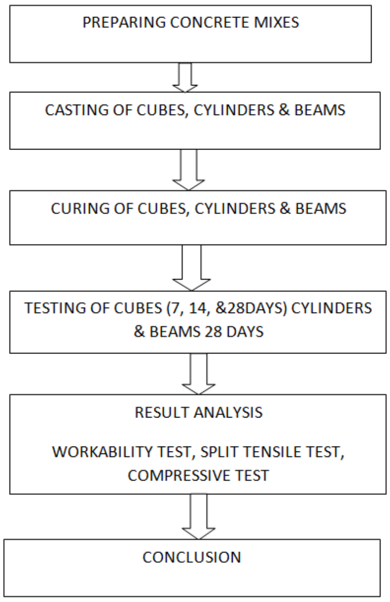
– It acts as lubricant
– It acts as a chemically with cement to form the binding paste for coarse aggregate and reinforcement It enables the concrete mix to flow into formwork.

G. Admixtures

Fig. 3: Admixtures

IV. EXPERIMENTAL SETUP

In order to achieve the stated objectives, this study was carried out in few stages. On the initial stage, all the materials and equipments needed must be gathered or checked for availability. Then, the concrete mixes according to the predefined proportions. Concrete samples were tested through concrete tests such as cube test. Finally, the results obtained were analyzed to draw out conclusion



A. Experimental Program

1) Mix Proportion

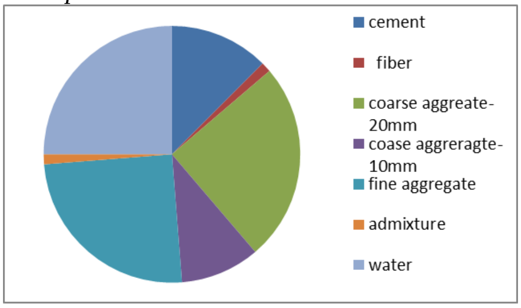


Fig. 4: Mix Proportion

2) Mix Proportion

Mix Calculation	M-25(%in volume)	M-30(%in volume)
Mass of cement	10	12
Mass OF water	13.8	16
Mass of admixture	0.134	0.16
Mass of coarse aggregate-20mm	33.7	32.04
Mass of coarse aggregate-10mm	13.56	12.50
Mass of fine aggregate	28.8	27.3
Total	99.98	100

Table 5: Mix Proportion

In order to study the interaction of Steel fibers scrubber (chip formed) & glass fiber with concrete under compression, flexure, split tension 162 cubes, 18 beams and 18cylinders were casted respectively. The experimental program was divided into 18 groups. Each group consists of 9 cubes, one cylinders and one beams, of 15x15x15cm, 15(dia) x30cm and 15x15x70cm respectively, For concrete grade of grade M 25& M 30 with different dosages of steel fiber scrubber & glass fiber (0%,0.5%,1.0%,1.5%,2.0%)

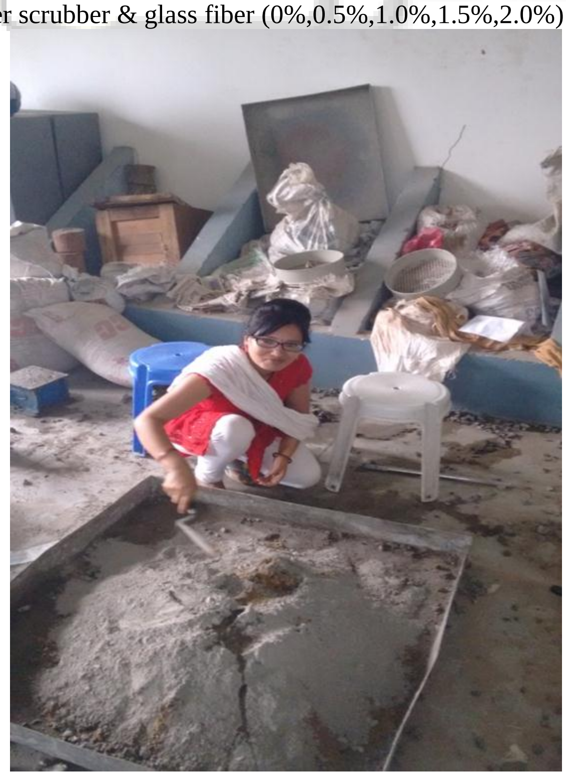


Fig. 5: Dry mixing of concrete

B. Casting of Specimens:

For casting the cubes, beam specimens, standard cast iron metal moulds of size150x150 cubes, 150x150x70 mm beam moulds are used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before the concrete is poured into the moulds. Thoroughly mixed concrete is filled into the mould in three layers of equal heights followed by tamping. Then the mould is placed on the table vibrator for a small period. Excess concrete is removed with trowel and top surface is finished to smooth level.

Fig. 6: casting of cubes, beams & cylinder

C. Curing:

Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature. More elaborately curing is defined as process of maintaining satisfactory moisture content and favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to sufficient degree to meet the requirement at service. After casting the molded specimens are stored in the laboratory and at a room temperature for 24 hours from the time at addition of water to dry ingredients. After this period the specimens are removed from the moulds immediately submerged in clean and fresh water. The specimens are cured for 28days in the present work.

Fig. 7: casting of cubes

D. Cube Compression Test

This test was conducted as per IS 516-1959. The cubes of standard size150x150x150 mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of compression testing machine, of capacity 2000 KN without eccentricity and a uniform rate of loading of 5.2 KN/s was applied till the first crack in the cube. The maximum load was noted and the compressive strength was calculated.

Fig. 8: Compressive Testing Machine

The results are tabulated in Table 5.1Cube compressive strength in MPa = P/AWhere,
P= cube compression load
A= area of the cube on which load is applied (150 x 150= 22500 mm^2)

E. Flexural Test

SFRC beams of size 150x150x700mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 600mm apart, with a bearing of 50mm from each support. The load shall be applied on the beam from two rollers which are placed above the beam with a spacing of 200 mm. The load is applied at a uniform rate such that the extreme fibers stress increases at 0.7N/mm^2 /min i.e., the rate of loading shall be 5.2 KN/s. The load is increased till the specimen fails. The maximum value of the load applied is noted down. The appearance of the fracture faces of concrete and any unique features are noted.

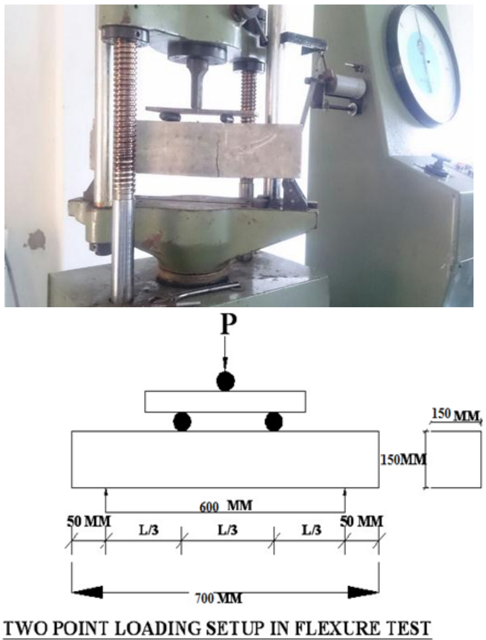


Fig. 9: Flexural testing two points load

The modulus of rupture is calculated using the formula.
$\sigma_s = Pl/bd^2$, where,
P = load in N applied to the specimen
l = length in mm of the span on which the specimen is supported (600)
b = measured width in mm of the specimen
d = measured depth in mm of the specimen at point of failure

F. Split Tensile Test

SFRC cylinders of size 15cm (dia) x 30cm (height) are casted. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a horizontal stress of $2P/\pi LD$.

Fig. 10: split test cylinder

Where, P is the compressive load on the cylinder
L is the length of the cylinder
D is diameter of the cylinder.

The main advantage of this method is that the same type of specimen and the same testing machine as used for the compression test can be employed for this test. This is why this test is gaining popularity. The splitting test is simple toper form and gives more uniform results than the other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, than the modulus of rupture. Splitting strength gives about 5 to 10%higher value than the direct tensile strength.

V. RESULT

% of glass fiber	**Compressive strength in MPa**			**Average compressive strength in MPa**		
	After 7 days	After 14 days	After 28 days	7 days	14 days	28 days
0%	18.82	25.90	28.8	18.72	25.9	28.8
	18.72	25.90	28.90			
	18.62	25.90	28.70			
0.5%	18.92	26.30	29.20	18.92	26.1	29.1

	18.82	26.00	29.00			
	19.02	26.00	29.10			
1.0%	19.1	26.20	29.50	19.1	26.2	29.4
	19.2	26.40	29.50			
	19.0	26.20	29.20			
1.5%	19.4	26.70	29.90	19.4	26.7	29.8
	19.5	26.80	29.70			
	19.3	26.60	29.80			
2.0%	19.2	26.30	29.50	19.2	26.3	29.4
	19.3	26.40	29.50			
	19.1	26.20	29.20			

Table 6: Result of cube (Grade M-25) compressive strength in MPa

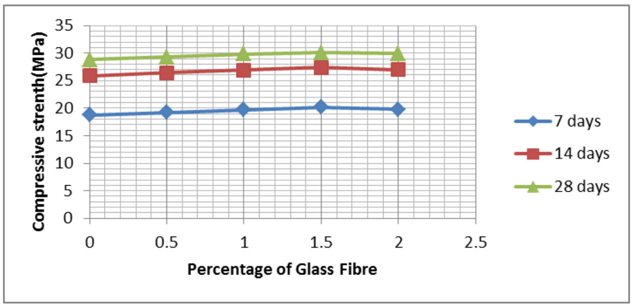


Fig. 11: variation in compressive strength according to % of glass fiber (Grade M-25)

Result of compressive strength for M-25 grade of concrete on cube specimen with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber mixes are shown in table & graph below. Table-5.2 gives the compressive strength values of M-25grade concrete and glass fiber concrete mixes and their values are observed to be varied from 18.72 to 28.88 N/mm^2 with 0% glass fiber, 18.92 to 29.10 N/mm^2 with 0.5% 19.1 to 29.40 N/mm^2 with 1.0%; 19.4 to 29.8 N/mm^2 with 1.5%, & 19.20 to 29.4 N/mm2 with 2.0% of glass fiber. With addition of glass fiber compressive strength gradually increases up to 1.5% & again gradually downfall with 2.0% of glass fiber.

% of glass fiber	Compressive strength in MPa			Average compressive strength in MPa		
	After 7 days	After 14 days	After 28 days	7 days	14 days	28 days
0%	21.00	29.20	32.60	21.00	29.1	32.3
	21.00	29.00	32.10			
	21.00	29.10	32.20			
0.5%	21.30	29.40	32.60	21.3	29.4	32.6
	21.40	29.50	32.50			
	21.20	29.30	32.70			
1.0%	21.80	30.70	34.10	21.8	30.6	34
	21.90	30.50	33.90			
	22.70	30.60	34.00			
1.5%	22.40	31.00	34.55	22.4	31	34.45
	22.50	29.90	34.65			
	22.30	31.10	34.15			
2.0%	21.165	30.70	34.20	22.165	30.7	34.1
	21.175	30.80	34.10			
	21.755	30.60	34.00			

Table 7: Result of cube (Grade M-30) compressive strength in MPa

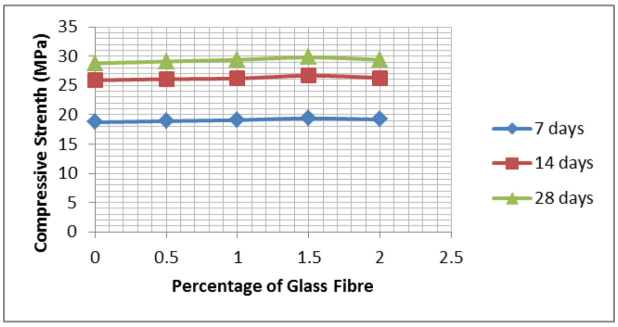


Fig. 12: variation in compressive strength according to % of glass fiber (Grade M-30)

Result of compressive strength for M-30 grade of concrete on cube specimen with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber mixes are shown in table & graph below. Table-5.4 shows the compressive strength values of M-30 grade concrete and glass fiber concrete mixes and their values are observed to be varied from 21.00 to 32.30 N/mm^2 with 0% glass fiber, 21.30 to 32.6 N/mm^2 with 0.5% 21.8 to 34.00 N/mm^2 with 1.0%; 22.40 to 34.45 N/mm^2 with 1.5%, & 22.165 to 34.10 N/mm2 with 2.0% of steel fiber. With addition of glass fiber compressive strength gradually increases up to 1.5% & again gradually downfall with 2.0% of glass fiber.

% of glass fiber	Flexural strength	
	Specimen code	After 28 days
0%		3.7
0.5%	G1	4.1
1.0%	G2	4.5
1.5%	G3	4.9
2.0%	G4	5.4

Table 8: Result of beam (Grade M-25) FLEXURAL strength in MPa

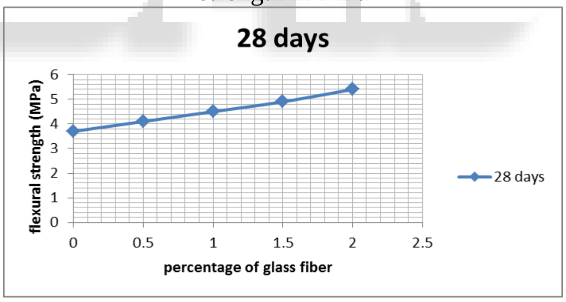


Fig. 13: variation in flexural strength according to % of glass fiber (Grade M-25)

Result of flexural strength for M-25 grade of concrete on beam specimen with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber mixes are shown in table & graph below. Table-5.6 shows the flexural strength values of M-25grade concrete and glass fiber concrete mixes and their values are observed to be varied from 3.7 N/mm^2 to 5.54 N/mm^2 from 0% up to 2.0% addition of steel fiber chip and this value increasing gradually up to 2.0 % of addition glass fiber chip.

% of glass fiber	Flexural strength	
	Specimen code	After 28 days
0%		4.9
0.5%	G5	5.2
1.0%	G6	5.4
1.5%	G7	5.6
2.0%	G8	5.9

Table 9: Result of beam (Grade M-30) FLEXURAL strength in MPa

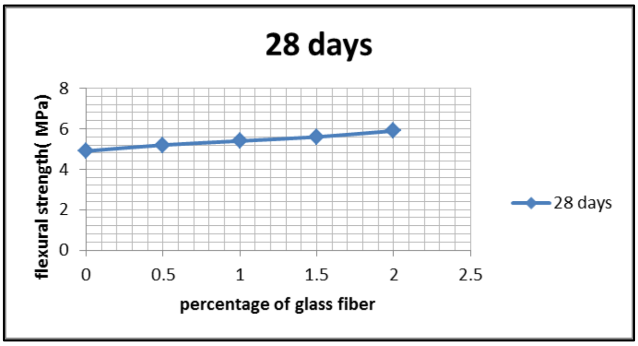


Fig. 14: variation in flexural strength according to % of glass fiber (Grade M-30)

Result of flexural strength for M-30 grade of concrete on beam specimen with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber mixes are shown in table & graph below. Table-5.8 shows the flexural strength values of M-30 grade concrete and glass fiber concrete mixes and their values are observed to be varied from 4.9N/mm^2 to 5.9 N/mm^2 from 0% up to 2.0% addition of glass fiber and this value increasing gradually up to 2.0 % of addition glass fiber.

% of glass fiber	**Split tensile strength(N/mm^2)**	
	Specimen code	After 28 Days
0%	S1	2.4
0.5%	S2	2.9
1.0%	S3	3.3
1.5%	S4	3.7
2.0%	S5	4.1

Table 10: Result of beam (Grade M-25) split tensile strength in MPa

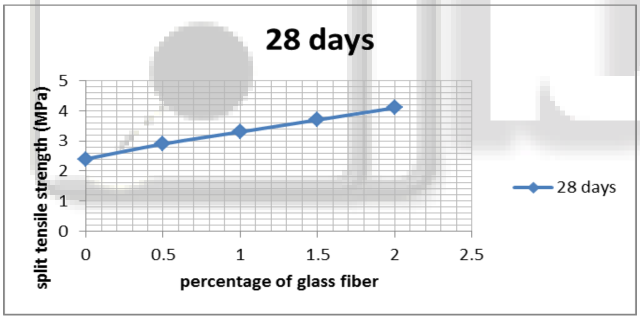


Fig. 15: variation in split tensile strength according to % of glass fiber (Grade M-25)

Result of split tensile strength for M-25 grade of concrete on cylinder specimen with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber chip mixes are shown in table & graph below. Table-5.10. shows the split strength values of M-25grade concrete and steel fiber chip concrete mixes and their values are observed to be varied from 2.4 N/mm^2 to 4.1 N/mm^2 from 0% up to 2.0% addition of steel fiber chip and this value increasing gradually up to 2.0 % of addition steel fiber chip.

% of glass fiber	**Split tensile strength(N/mm^2)**	
	Specimen code	After 28 Days
0%	S1	3.2
0.5%	S2	3.4
1.0%	S3	3.6
1.5%	S4	3.8
2.0%	S5	4.5

Table 11: Result of beam (Grade M-30) split tensile strength in MPa

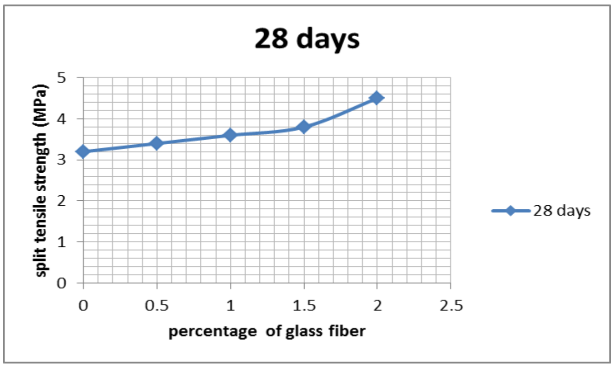


Fig. 16: variation in split tensile strength according to % of glass fiber (Grade M-30)

Result of split tensile strength for M-30 grade of concrete on cylinder specimen with 0%, 0.5%, 1.0%, 1.50%, 2.0% steel fiber chip mixes are shown in table & graph below. Table-5.12 shows the split strength values of M-30 grade concrete and glass fiber chip concrete mixes and their values are observed to be varied from 3.2 N/mm^2 to 4.5 N/mm^2 from 0% up to 2.0% addition of glass fiber and this value increasing gradually up to 2.0 % of addition glass fiber.

% of glass fiber	Slump in mm
0%	80
0.5%	70
1.0%	63
1.5%	55
2.0%	48

Table 12: slump test (Grade M -25) in mm

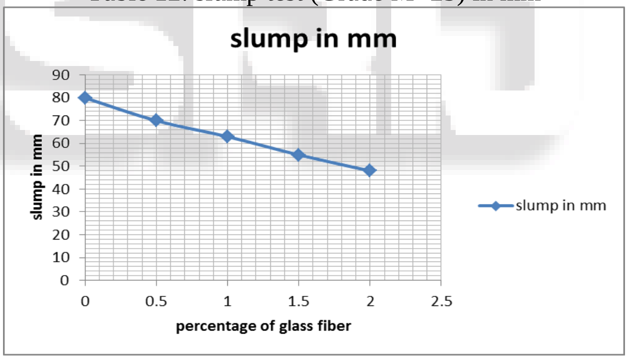


Fig. 17: slump value according to % of glass fiber (Grade M-25)

Result of slump test value for M-25 grade of concrete mix with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber c mixes along with admixture used replaced by 1 % of weight of cement are shown in table & graph below. Table-5.14 shows the slump values of M-25 grade concrete and glass fiber concrete mixes and their values are observed to be varied from 80mm with 0% ,70 mm with 0.5%63 mm with 1.0% ,55 with 1.5% & 48 mm with2.0% of glass fiber mixes it is found from graph with addition of fiber workability reduces respectively

% of glass fiber	Slump in mm
0%	85
0.5%	78
1.0%	71
1.5%	62
2.0%	55

Table 13: slump test (Grade M -30) in mm

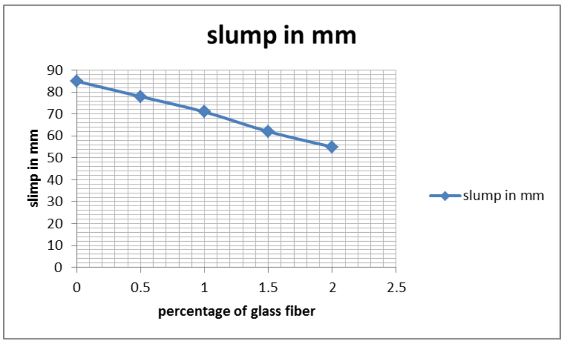


Fig. 18: slump value according to % of glass fiber (Grade M-30)

Result of slump test value for M-30 grade of concrete mix with 0%, 0.5%, 1.0%, 1.50%, 2.0% glass fiber mixes along with admixture used replaced by 1 % of weight of cement are shown in table & graph below. Table-5.16 shows the slump values of M-30 grade concrete and glass fiber concrete mixes and their values are observed to be varied from 85 mm with 0% ,78 mm with 0.5%71 mm with 1.0% ,62 with 1.5% & 55 mm with2.0% of glass fiber mixes it is found from graph with addition of fiber workability reduces respectively

Based on the experimental investigation the following conclusion is given within the limitation of the test result.

1) Addition of steel fiber and glass fiber resulted in significant improvement on the strength properties of concrete (M-25 and M-30) grade
2) Compared to plane concrete the fiber addition resulted in better strengthening (compressive, tensile and flexural) properties of concrete.
3) The reinforcing efficiency of fiber addition was dependent on the optimum dosages level of steel and glass fiber up to 1% to 1.5% of fibers since increased fiber addition resulted in loss workability.
4) The maximum increase in compressive strength was observed of concrete grade M-25 &M-30 respectively at 1.5% of steel and glass fiber.
5) Compressive strength was decrease of both concrete grade in case of 2% steel fiber and glass fiber.
6) Tensile strength is continuously increased with increasing the percentage of steel and glass fiber and maximum tensile strength was achieved in the case of 2% steel and glass fiber for both grade of concrete M-25 &M-30.

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