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A Study on Mechanical Properties and Stress Strain Behaviour of Glass Fiber Reinforced Concrete (GFRC)

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Abstract— Concrete is a weak building material in tension. Inherently, micro cracks will be present in concrete. The formation of micro cracks normally due to shrinkage of concrete. Moreover, concrete suffers from low tensile strength, limited ductility and little resistance to cracking. In order to improve these properties, an attempt has been made to study the effect of addition of glass fibers in ordinary Portland cement concrete. In the present experimental investigation glass fibers in different percentage 0 to 0.09% has been studied for the effect on mechanical properties, stress-strain behavior and formation of cracks. The results have shown improvement in mechanical and ductility properties with the addition of glass fibers.

Keywords – 53 Grade Ordinary Portland Cement, Coarse aggregate, Fine aggregate, Water, Glass fibers.

1. INTRODUCTION

Concrete is a weak building material in tension. Moreover, concrete suffers from low tensile strength, limited ductility and little resistance to cracking. The concrete without any fibres will develop cracks due to plastic shrinkage, drying shrinkage and other reasons of changes in volume of concrete. The development of these micro cracks causes elastic deformation of concrete. Plain concrete is a brittle material and having the values of modulus of rupture and strain capacity is low.

Concrete is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional reinforcement and to some extent by the inclusion of a sufficient volume of fibers. The use of fibers also alters the behavior of the fiber-matrix composite after it has cracked, thereby improving its toughness. The major factors affecting the fiber reinforced concrete are: water cement ratio, volume fraction of fibers, diameter and length of fibers.

Glass Fiber Reinforced Concrete (GFRC) is a type of fiber reinforced concrete. Glass fiber reinforced concrete (GFRC) consists of high strength glass fiber embedded in a cementitious matrix. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the components acting alone.

2. LITERATURE REVIEW

Chandramouli K, Srinivasa Rao P: In their research experimental investigation the alkali resistance glass fibres has been used to study the effect on compressive, split tensile and flexural strength on M20, M30, M40 and M50 grades of concrete. In this research the Test specimens consisting of 150×150×150 mm cubes, 150×300 mm cylinders and 100×100×500 mm beams were casted using different grade of concrete mixers and tested as per IS: 516 and 1199 [1].
They have concluded that…

- A reduction in bleeding is observed by addition of glass fibres in the glass fibre concrete mixes.
- A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks.
- The percentage increase of compressive strength of various grades of glass fibre 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 fibre concrete mixes compared with 28 days is observed from 15 to 20%.

Jayeshkumar Pitroda, Dr. L. B. Zala and Dr F. S. Umrigar: The use of hypo sludge in concrete formulations as a supplementary cementatious material was tested as an alternative to traditional concrete. The cement has been replaced by hypo sludge accordingly in the range of 0%, 10%, 20%, 30% & 40% by weight for M-25 and M-40 mix. Concrete mixtures were produced, tested and compared in terms of compressive & flexural strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties for up to 28 & 56 days [2].

Based on limited experimental investigation concerning the compressive & flexural strength of concrete, the following observations are made regarding the resistance of partially replaced hypo sludge with 0.56% glass fibre [3]:

[1] Compressive strength reduces when replacement of hypo sludge percentage increases when compare to traditional concrete.
[2] From this test, replacement of cement with this paper industries waste material provides maximum compressive strength at 10% replacement but it is lesser than traditional concrete.
[3] Use of hypo sludge in concrete can save the paper industries waste disposal costs and **produce a 'greener' concrete for construction.**
[4] A better measure by a innovative supplementary cementitious Construction Material is formed through this research [4].

3. EXPERIMENTAL PROGRAM

The experimental program was designed to study the compressive strength and stress strain behavior of M20 grade (6mm length of glass fiber), M20 grade (12mm length of glass fiber), M40grade (6mm length of glass fiber), M40 grade (12mm length of glass fiber) with and without addition of glass fibers.

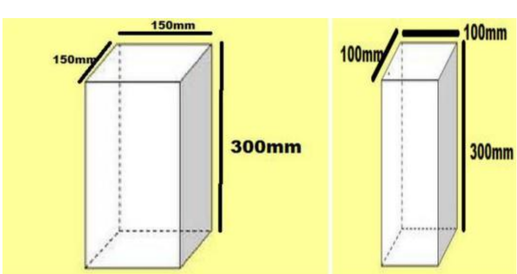


Fig. 1. Prism outer and inner dimensions

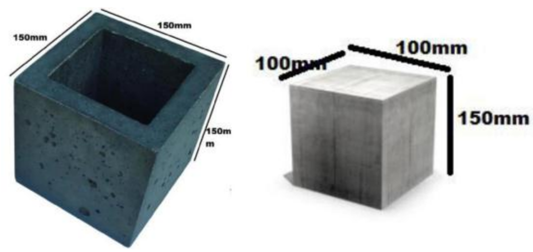


Fig. 2. Cube outer and inner dimensions

The program consisted of casting and testing a total number of ninety six specimens. In this 48 prisms with dimensions of 300mmx150mmx150mm (inner core 300mmx100mmx100mm and outer shell 300mmx150mmx150mm) and 48 cubes of 150x150x150mm (inner core of size 150mmx100mmx100mm and outer shell 150mmx150mmx150mm) size. Of these 48 prisms, 24 prisms (various percentages of glass fibers 0%, 0.03%, 0.06% and 0.09%) are meant for M20 grade of concrete with 6mm length of fibers used and 24 prisms (various percentages of glass fibers 0%, 0.03%, 0.06% and 0.09%) meant for M20 grade of concrete with 12mm length fibers used [5,6].

In remaining 48 specimens, 24 cubes (various percentages of glass fibers 0%, 0.03%, 0.06% and 0.09%) with M40 grade 6mm length of fiber and 24 cubes (various percentages of glass fibers 0%, 0.03%, 0.06% and 0.09%) with M40 grade with 12mm length of fibers used[7] .

3.1 MATERIALS USED:

- 53 Grade Ordinary Portland cement.
- Fine Aggregate.
- Coarse Aggregate
- Water.
- Glass Fibers 6mm
- Glass Fibers 12mm

(i) Cement:

Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS 12269. The cement was obtained from a single consignment and of the same grade and same source. Latter procuring the cement was stored properly. The specific gravity, standard consistency, initial setting time, and final setting time are respectively 3.11, 33%, 35min, and 215min.

(ii) Fine Aggregate:

S. No	Tade name	Cem-FIL anti-crack high dispersion glass fibers
1.	Number of fibers	212million/kg
2.	Aspect ratio for 6mm and 12mm respectively	428.57, 857.1
3.	Specific surface area	$105m^2/kg$
4.	Typical addition rate	0.6 to $1.0kg/m^3$ of concrete
5.	Tensile strength	1700MPa
6.	Modulus of elasticity	73GPa
7.	Corrosion resistance	Excellent
8.	Specific gravity	2.6
9.	Density	$26kN/m^3$
10.	Filament diameter	14µ

Table1.: DETAILS OF SPECIMENS CAST

The Fine aggregate conforming to Zone-2 according to IS 383 was used. The fine aggregate used was obtained from a nearby river source. The bulk density, specific gravity, and fineness modulus of the sand used were 1.41g/cc, 2.68, and 2.90.The sand obtained was sieved as per IS sieves (i.e. 2.36, 1.18, 0.6, 0.3, and 0.15mm). Sand retained on each sieve was filled in different bags and stacked separately for use.

(iii) Coarse Aggregate:

Crushed granite was used as Coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm nominal size. 20mm well graded aggregate according to IS 383 is used in this investigation. The bulk density, specific gravity and fineness modulus of the coarse aggregate used were 1.46g/cc, 2.78 and 7.1. The coarse aggregate procured from quarry was sieved through the sieves of sizes 20mm, 16mm, 12.5mm, 10mm and 4.75mm respectively. The material retained on each sieve was filled in bags and stacked separately.

(iv) Water:

Potable water was used in the experimental work for both mixing and curing.

(v, vi) Glass fibers:

Glass Fibers 6mm & 12mm is details is shown below table.

Fig. 3. Glass fiber with 6mm length

Fig. 4. Glass fiber with 12mm length

4. MIX DESIGN AND METHODOLOGY

Two grades M20, and M40 mix were designed and Glass fiber were added 0%, 0.03%, 0.06%, 0.09% of volume of concrete. The proportions arrived for different grades of concrete

4.1 Mixing:

The amount of water in the mixture played an important role on the behavior of fresh concrete. When the mixing time was long, mixtures with high water content bleed and segregation of aggregates and the paste occurred. This phenomenon was usually followed by low compressive strength of hardened concrete.

4.2 Casting

The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there are small gaps they were filled with plaster of Paris. The moulds then oiled and kept ready for casting. The entire casting was done in two stages one each corresponding to M20 and M40 grades. A pan mixer of having 100kg capacity was used for mixing concrete. Glass fibers were added after the thorough mixing of dry ingredients. Water was added subsequently.

At the end of casting the top surface was made plane using trowel and a hacksaw blade to ensure a top uniform surface. In this experimental program inner core (without glass fiber) i.e.150X100X100mm are prepared initially, then After 10 hrs of casting the moulds were de-molded. These removed cubes are again inserted into the 150X150X150mm cube and remolded the outer shell with glass fiber reinforced concrete.

4.3 Curing

After the completion of casting (inner and outer core) all the specimens were kept to maintain the ambient conditions viz. temperature of 27±2 C and 90% relative humidity for 24hours. The specimens were removed from the mould and submerged in clean fresh water until just prior to testing. The temperature of water in which the cubes were submerged was maintained at 27± 2 C. The specimens were cured for 28 days.

4.4 Testing

At the end of the required number of days of curing 28 days the specimens were taken out from the curing tank, allowed to dry properly and kept ready for testing. The specimens were tested under 2000KN capacity TOTM for ultimate loads for each grade and type and testing procedure has been as explained in experimental Investigation.

Fig. 5. Testing of prisms with 0.002 least count dial gauge

Fig. 6. Trial test of the prism with 0.01 least count dial gauge

4.4.1 Digital Dial Guage

i. Dial Test Indiactor measures displacement at an angle of a lever perpendicular to the axis of the indicator
ii. Digital Display easy to read

iii. Stable Microprocessor for accurate readings
iv. Buttons : On/Off, Zero, MM
v. With data output port
vi. With Backlug (Optional)
vii. Battery: SR44/LR44
viii. Auto Power Off

ix. Least count 0.002

FIG. 7. Digital Display easy to read

5. EXPERIMENTAL INVESTIGATION

5.1 Compressive Strength:

The cube specimens were tested on compression testing machine of capacity 2000 KN. .The bearing surface of the machine was wiped off clean and any loose other sand or other material removed from the surface of the specimen .Top and bottom surface of specimens finished smooth with plaster of Paris.

The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on the specimen was recorded. The testing of a cube specimen is shown below.

Fig. 8. Details of cube testing under TOTM

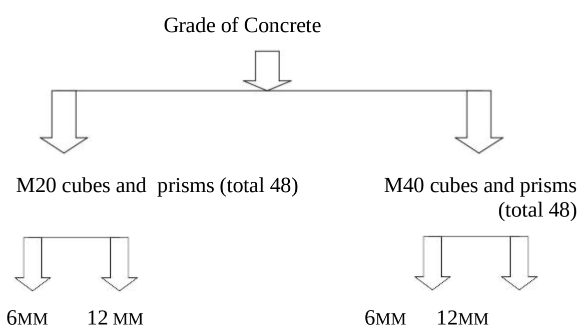
5.2 Testing Procedure:

The specimens cast were arranged in the TOTM of 2000 KN capacity. The axis of the specimen was carefully aligned at the center of the loading frame. The specimen is subjected to gradual increase of load and deformations are recorded at regular intervals.

The test was continued after reaching peak load also. Then the load started decreasing, the deformations are recorded in post peak region also. The specimens continued to resist the load at peak and after reaching breaking point, the load has fallen suddenly.

6. RESULTS AND DISCUSSIONS

The experimental investigations are conducted on M20 and M40 grades without fiber, with glass fiber and the stress-strain behavior have been analyzed. In the present work, to study the compressive strength and stress-strain behaviour of various parameters like the effect of fiber, fiber lengths and grades of concrete are considered and the results of the tested specimens are presented in this chapter



Compressive strength of Different Cubes and percentage of Fiber

***Table 2.:** Compressive strength of M20 grade of concrete (6mm)*

Percentage of Fiber (%)	Specimen Number	Compressive strength (N/mm^2)	Average of 3 Cubes
0	1	28.47	28.412
	2	28.47	
	3	28.28	
0.03	1	34.21	31.378
	2	38.84	
	3	28.08	
0.06	1	36.38	36.322
	2	36.19	
	3	36.38	
0.09	1	37.57	37.837
	2	38.16	
	3	37.77	

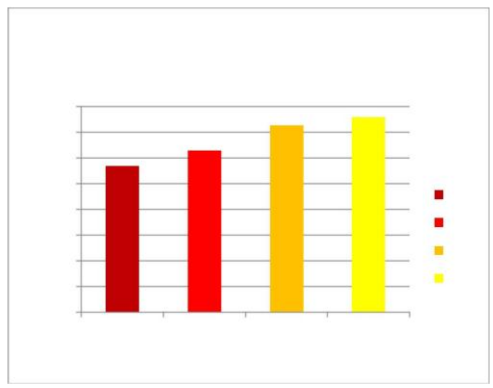


Fig. 9. Compressive strength of M20 grade of concrete (6mm)

***Table 3**: Compressive strength of M20 grade of concrete (12mm)*

Percentage of Fiber (%)	Specimen Number	Compressive strength (N/mm^2)	Average of 3 Cubes
0	1	29.269	29.729
	2	29.660	
	3	30.258	
0.03	1	33.818	32.682
	2	32.213	
	3	32.015	
0.06	1	35.20	35.88
	2	36.02	
	3	36.42	
0.09	1	38.001	36.930
	2	36.20	
	3	36.590	

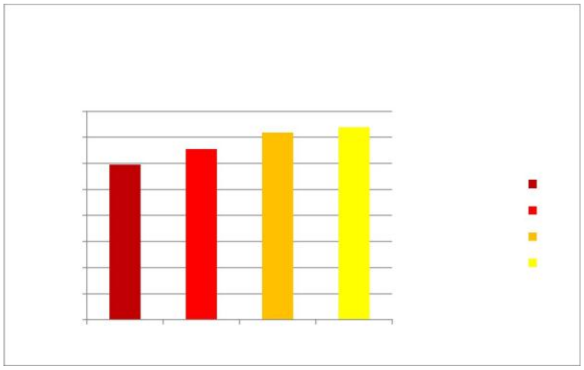


Fig. 10. Compressive strength of M20 grade of concrete (12mm)

Table 4*: Compressive strength of M40 grade of concrete (6mm)*

Percentage of Fiber (%)	Specimen Number	Compressive strength (N/mm^2)	Average of 3 Cubes
0	1	47.82	47.76
	2	47.50	
	3	47.98	
0.03	1	51.35	52.95
	2	53.76	
	3	53.75	
10.06	1	53.35	53.59
	2	53.49	
	3	53.93	
0.09	1	56.139	56.742
	2	56.097	
	3	57.990	

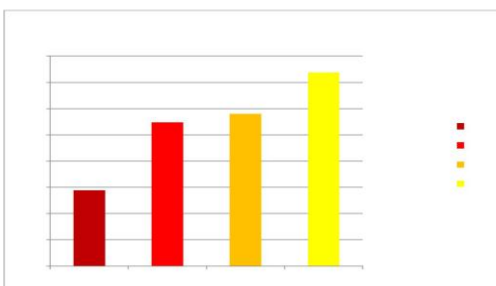


Fig. 11. Compressive strength of M40 grade of concrete (6mm)

Table 5*: Compressive strength of M40 grade of concrete (12mm)*

Percentage of Fiber (%)	Specimen Number	Compressive strength (N/mm^2)	Average of 3 Cubes
0	1	47.463	47.59
	2	47.663	
	3	47.661	
0.03	1	50.430	50.825
	2	51.023	
	3	51.023	
0.06	1	51.617	52.47
	2	53.001	
	3	52.803	
0.09	1	56.36	55.70
	2	55.37	
	3	55.37	

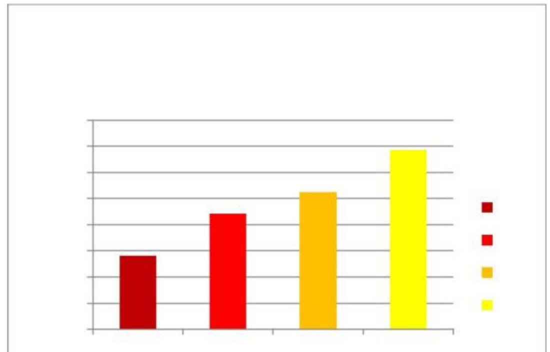


Fig. 12. Compressive strength of M40 grade of concrete (12mm)

Table 6*: Cube Compressive strength for M20 and M40 with variation in fiber length and % of fiber*

S. No	Grade of concrete	Length of fiber (mm)	Compressive strength with 0% Fiber	Compressive strength with 0.03% Fiber	Compressive strength with 0.06% Fiber	Compressive strength with 0.09% Fiber
1	M20	6	28.41	31.38	36.32	37.84
		12	29.73	32.68	35.88	36.93
2	M40	6	47.76	52.95	53.59	56.74
		12	47.59	50.83	52.47	55.7

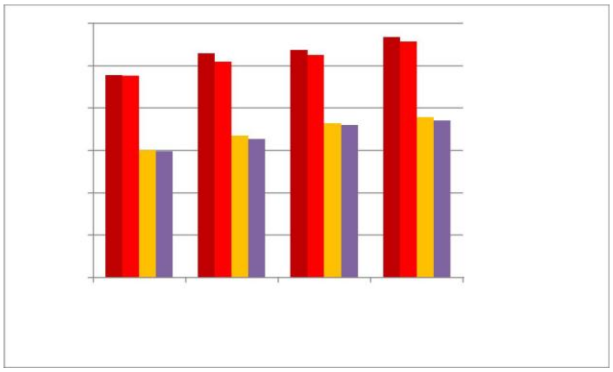


Fig. 13. Cube Compressive strength for M20 and M40 with variation in fiber length and % of fiber

***Table 7**: Effect of glass fiber on prisms strength and crack growth at peak load Details of prisms tested (M20 and M40)*

S. No	Grade of concrete	Length of fiber (mm)	% of Fiber	Prism Strength N/mm^2	Strain at peak load	No.of Prisms
1	M 20	6	0	23.731	0.196	3
			0.03	25.116	0.181	3
			0.06	27.09	0.163	3
			0.09	27.89	0.125	3
2	M 20	12	0	23.731	0.196	3
			0.03	27.687	0.183	3
			0.06	27.885	0.137	3
			0.09	30.653	0.121	3
3	M 40	6	0	41.53	0.354	3
			0.03	45.48	0.31	3
			0.06	49.04	0.222	3
			0.09	51.61	0.183	3
4	M 20	12	0	41.53	0.354	3
			0.03	45.09	0.283	3
			0.06	47.85	0.201	3
			0.09	50.43	0.173	3

7. CONCLUSIONS

The present work consists of testing prisms and cubes understand the development of compressive strength, stress-strain behavior of concrete with different percentages of fiber contents. Based on this work the following conclusions can be drawn.

1. Compressive strength of concrete increased with the increase in percentage of glass fibers

1. Of the three fiber contents, i.e., 0.03%, 0.06% and 0.09%, Specimen with 0.09% gave higher increase in strength than the other two.
2. It is noted that improvement in strength and strain of GFRC specimen beyond ultimate strength increased with increase in fiber content.

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