A COMPARATIVE AND EXPERIMENTAL STUDY OF VARIOUS MIX DESIGN CONCRETE USING STEEL AND GLASS FIBRE

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ABSTRACT

Concrete is the most common materials used in the construction industies. In the past few years, many and modification has been done to produce concrete which has the desired characteristics. There is always a search for concrete with higher strength and durability. Plain concrete has good compressive strength but has low tensile strength, low ductility and low fire resistance .This research paper aim to study characteristics and comparison of the mechanical properties of steel and glass fiber reinforce concrete with conventional concrete. In order to achieve and verify that 1%,2%,3% fiber percentage by the volume of cement are used in this study with three different concrete mixes M20, M25, and M30. 28days compressive strength, spilt tensile strength, flexural strength, tests have been performed in the hardened state. In this project the behavior of cube, cylinder & beam structures strengthen by using FRC is experimentally tested. The fiber used are steel and glass fibers in various volume fraction the main reason for adding steel fiber to concrete matrix is to improve the post cracking response of the concrete i.e. to improve its energy absorption capacity and apparent ductility and to provide a crack resistance and crack control and addition of glass fiber for bridging the micro-cracks are suggested as the reason for the enhancement in flexural fiber.

Keyword : - *Concrete, Ductility, FRC, Strength, micro-crack, Fibres*

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1. INTRODUCTION

Concrete is considered a brittle material, primarily because of its low tensile strain capacity and poor fracture toughness. Reinforcement of concrete with short randomly distributed fibres can address some of the concerns related to concrete brittleness and poor resistance to crack growth. Fibers, used as reinforcement, can be effective in arresting cracks at both micro and macro-levels. At the micro-level, fibers inhibit the initiation and growth of cracks, and after the micro-cracks converts into macro-cracks, fibers provide mechanisms that abate their unstable propagation, provide effective bridging, and impart sources of strength gain, toughness and ductility. Concrete can be modified to perform in a more ductile form by the addition of randomly distributed discrete fibres in the concrete matrix.

Concrete possess very low tensile strength. Cracks propagate with application of load, leads to brittle fracture of concrete. Micro cracks are formed in concrete during hardening stage. The new technology of using fibres made the invention of fibre reinforced concrete to overcome these problems associated with cement based materials such as low tensile strength, poor fracture toughness and brittleness of cementitious composites. Inherent micro cracks and weak in tension are the shortcomings of conventional concrete thus recent years have witnessed the extensive use of fibres like glass, steel, carbon and poly-propylene etc. In order to meet the challenges of the rapidly growing civil engineering industry. Addition of such fibres increases fire resistance, impact, compressive, erosion, split tensile and flexural strength, durability, serviceability of concrete, fatigue, fracture and shrinkage characteristics, cavitations and reduces formation and propagation of micro cracks. Aim of this work is to present the information accumulated from various researches and to highlight the benefit out of using fibres [1]. In conventional concrete now a days different types of fibres are used and they are broadly divided into three types. The basic types of fibres and their sub-types are discussed below,

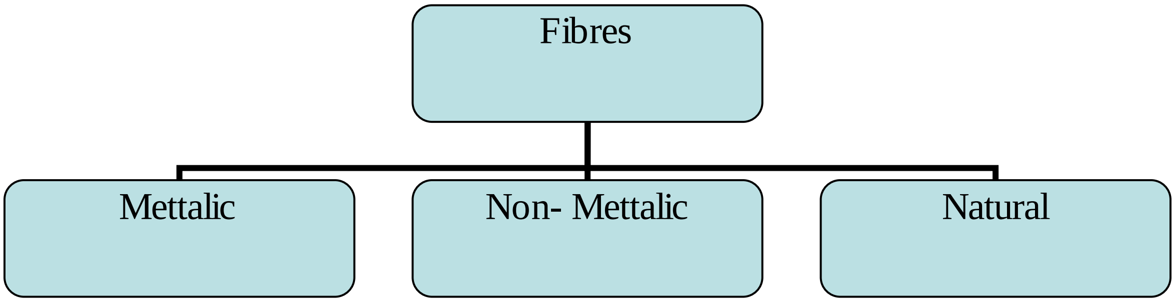


Fig -1: Types of Fibres

The principle reason for incorporating fibres into a cement matrix is to increase the toughness and tensile strength and improve the cracking deformation characteristics of the resultant composite. For FRC to be a viable construction material, it must be able to compete economically with existing reinforcing system. Fibres are generaaly used in concrete to control cracking , to reduce the permeability of concrete, to reduce bleeding of water, to produce greater impact, abrasion resistance in concrete. Generally fibres do not increase the flexural strength of concrete. The amount of fibres added to the concrete mix is expressed as a percentage of total volume of the composite (concrete and fibres), termed as volume fraction (Vf). Vf typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). fibres which are used with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio[2]. In this research paper Steel Fibers and Glass Fibers are used as Fiber reinforcement to concrete and compare with conventional concrete. Objective of this paper is to add the Steel fibers (crimped) and Glass fiber to the concrete and to study the strength properties of concrete with the variation in fiber content. i.e., to study the strength properties of concrete (M20, M25, M30 Grade) for fiber content of 1% 2% and 3%at 28 days. The strength properties being studied in this paper are as follows:

1. Compressive strength
2. Split tensile Strength
3. Flexural strength
4. Impact Resistance

These properties are then compared to the plain cement concrete.

2. MATERIALS USED & IT'S PROPERTIES

1. Cement

43-grade OPC is used throughout the experimental work and The cement used has been tested for various proportions as per IS: 4031-1988. Cement is tested in laboratory and results are as shown in Table-1.

2. Fine Aggregate

Locally available sand, from Pravara River, is used as fine aggregate, it confirms to zone II of IS 383-1983 and, other necessary properties are given in Table-2.

3. Coarse Aggregate

Locally available crushed stone aggregates with size 5mm to 12.5 mm and of maximum size 12.5 mm are used. The test results are given in Table-3.

4. Water

Water confirming to the requirements of IS-456: 2000 is suitable for making concrete. In the present work, available tap water is used for concreting.

Table -1: Cement Properties

Sr. No.	Description of Test	Results
1	Fineness of cement (residue on IS sieve No. 9)	3 %
2	Specific gravity	3.15
3	Standard consistency of cement	29 %
4	Setting time of cement a) Initial setting time b) Final setting time	 100 minute 293 minute
5	Soundness test of cement (With Le-Chatelier's mould)	1.7 mm
6	Compressive strength of cement: a) 3 days b) 7 days	 34.59 N/mm^2 56.08 N/mm^2

Table -2: Physical Properties Of Fine Aggregate (Sand)

Sr. No.	Property	Results
1	Particle Shape, Size	Round, 4.75mm down
2	Fineness Modulus	3.17
3	Silt content	2%
4	Specific Gravity	2.63
5	Bulk density	1793 Kg/m^3
6	Surface moisture	Nil

Table -3: Physical Properties Of Coarse Aggregate

Sr. No	Property	Results
1	Particle Shape, Size	Angular, 20mm,10mm down
2	Fineness Modulus of 20mm aggregates	7.4
3	Specific Gravity	2.74
4	Water absorption	1.02%
5	Bulk density of 20mm aggregates	1603 Kg/ mm^3
6	Surface moisture	Nil

5. Crimped Type Steel Fiber (CR 50/30)

Crimped type steel fibers conforming to ASTM A 820 type-I are used for experimental work. CR 50/30 is high tensile steel cold drawn wire with crimped types, glued in bundles & specially engineered for use in concrete. Dosages used: 1%,2%,3% at the constant by weight of cement. Fibers are made available from Kasturi Composite Pvt. Ltd.; Amravati (Maharashtra). Physical Properties of Fibers are given in Table-4.

Table -4: Physical Properties Of Steel Fibre

Sr. No.	Property	Values
1	Diameter	0.6 mm
2	Length of fiber	30 mm
3	Appearance	Bright in clean wire
4	Average aspect ratio	50
5	Deformation	Continuously deformed circular segment
6	Tensile strength	1025 Mpa
7	Modulus of Elasticity	200 GPa
8	Specific Gravity	7.5

6. Glass Fiber

The glass fibers used are of Cem-FIL Anti-Crack HD with modulus of elasticity 72 GPA, Filament diameter 14 microns, specific gravity 2.68, length 12 mm. Dosages used: 1%,2%and 3% at the constant by weight of cement (Properties as obtained through the manufacturer are shown on Table-5).

Table -5: Physical Properties Of Glass Fibre

Sr. No.	Property	Values
1	Fibre	AR Glass
2	Specific Gravity	2.68
3	Elastic Modulus (Gpa)	72
4	Tensile Strength (Mpa)	1700
5	Diameter (micron)	14
6	Length(mm)	12
7	Number of fibre (million/Kg)	235

3. METHODOLOGY

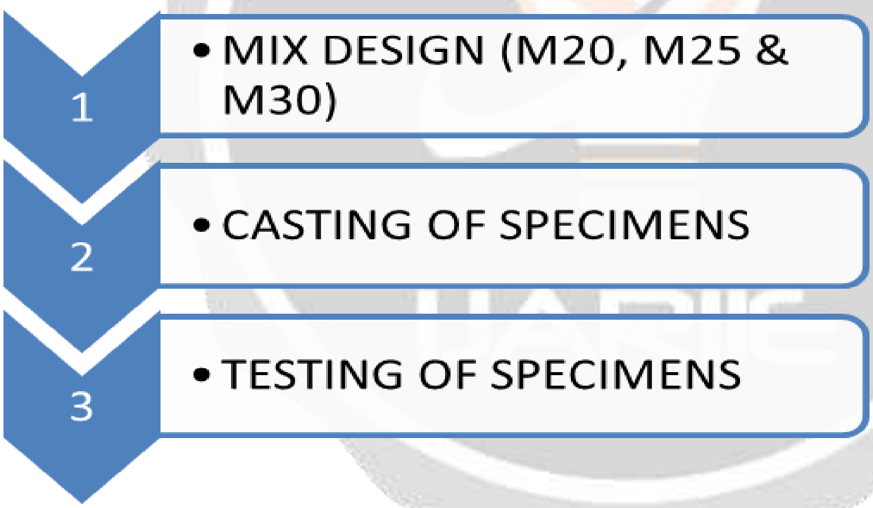


Fig -2: Methodology

3.1 Mix Design

There are various methods of mix design. In the present work, Indian Standard method (IS: 10262 - 2009) is used for Concrete mix design of grade M20, M25, M30.

3.2 Casting of Specimens

1. Cube moulds of 150 x 150 x 150 mm are used for casting the specimens for compressive strength.
2. Cylindrical moulds of 150 mm diameter and 300 mm long are used for casting the specimens for split tensile strength test.
3. Rectangular moulds of 150 x 200 x 1800 mm are used for casting the specimens for flexure test.

The table below shows the details of casting of cube, cylinder and beam specimen for each w/c ratio.

Table -6: Details Of Specimen Casted

Concrete Grade	% Steel Fiber	% Glass Fiber	Number Of Specimen		
			Cube	Cylinder	Beam
M20	0	0	9	3	3
M20	1	1	9	3	3
M20	2	2	9	3	3
M20	3	3	9	3	3
M25	0	0	9	3	3
M25	1	1	9	3	3
M25	2	2	9	3	3
M25	3	3	9	3	3
M30	0	0	9	3	3
M30	1	1	9	3	3
M30	2	2	9	3	3
M30	3	3	9	3	3

3.3 Curing Of Specimens

After 24 hours specimens were opened and they were kept in gunny bags and then water sprinkled over this specimens for a curing of required period. All these specimens were properly grouped according to their coding so that removal of the specimen from their place for testing work could be conveniently done in a proper sequence. The elements were left undisturbed for a whole period of curing.

3.4 Testing Of Specimens

- **Testing of Cube Specimens for Compressive Strength:**
  For the compression test, the cubes are placed in machine in such a manner that the load is applied on the Faces perpendicular to the direction of cast. In Compression testing machine, the top surface of machine is fixed and load is applied on the bottom surface of specimen. The rate of loading is gradual and failure (crushing) load is noted. Also the failure pattern is observed precisely.

- **Testing of Cylinder Specimens for Split Tensile Strength:**
  For determining split tensile strength, cylinder specimens are placed between the two plates of Compression Testing Machine. Plywood strips of 3 mm thick, 25 mm wide and 300 mm long, are placed between the plates and surface of the concrete specimens. The load is applied at a uniform rate till the specimen failed by a fracture along vertical diameter. The split tensile strength is calculated from the formula,

  $t = 2P/\pi DL$

  Where, P =load at failure

  D = diameter of specimen

L = length of specimen

- **Testing of Beam Specimens for Flexure:**

In flexure test, the beam specimen is placed in the machine in such a manner that the load is applied to the upper most surface as cast in the mould. All beams are tested under two-point loading in Universal Testing Machine of 100-tonne capacity. The load is increased until the specimen failed and the failure load is recorded. The flexural strength is calculated from the formula

$f_b = PL / bd^2$

Where, P = the applied load at failure,

d = depth of specimen,

b = breadth of specimen

L = Length of specimen

4. RESULT & DISCUSSION

The results obtained by carrying out the tests on the cubes, cylinders and beams made with mix proportions decided earlier are as stated in tabular form as below,

Table -7: Comparative Statement Of Compressive Strength

Sr. No.	Grade Sample	Water cement ratio	% of Steel fiber	% of Glass Fiber	Compressive strength, Mpa	
					7days	28 days
1	M20	0.45	0	0	18.67	28.29
2	M20	0.45	1	1	17.12	31.48
3	M20	0.45	2	2	18.33	33.21
4	M20	0.45	3	3	18.05	30.11
5	M25	0.40	0	0	21.32	32.14
6	M25	0.40	1	1	22.39	34.27
Sr. No.	Grade Sample	Water cement ratio	% of Steel fiber	% of Glass Fiber	Compressive strength, Mpa	
					7days	28 days
7	M25	0.40	2	2	29.35	41.40
8	M25	0.40	3	3	30.05	40.60
9	M30	0.35	0	0	24.76	37.52

10	M30	0.35	1	1	25.23	38.05
11	M30	0.35	2	2	27.90	42.28
12	M30	0.35	3	3	26.49	40.14

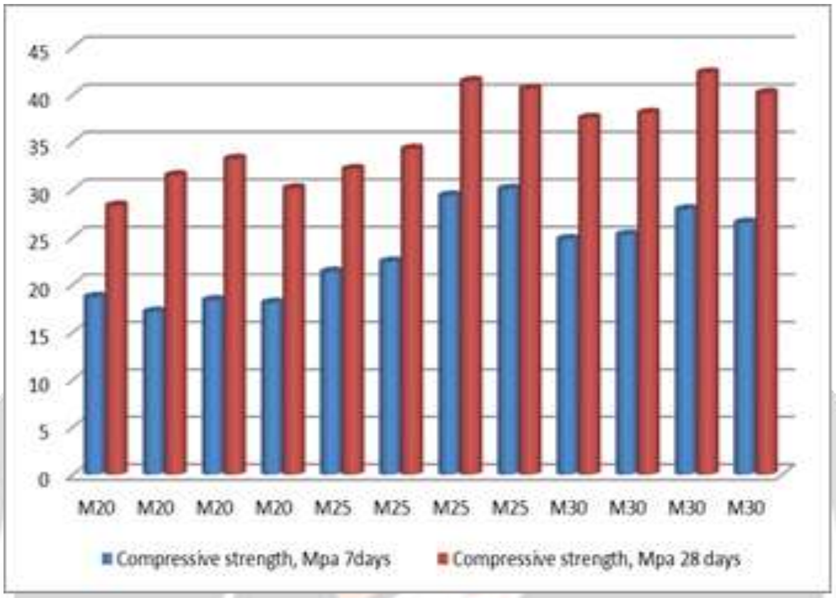


Chart -1: Comparative Statement Of Compressive Strength

Table -8: Comparative Statement Of Split Tensile Strength

Sr. No.	Grade Sample	Water cement ratio	% of Steel fiber	% of Glass Fiber	Splitting strength, Mpa
					28 days
1	M20	0.45	0	0	2.30
2	M20	0.45	1	1	3.93

3	M20	0.45	2	2	4.62
4	M20	0.45	3	3	4.13
5	M25	0.40	0	0	3.440
6	M25	0.40	1	1	4.52
7	M25	0.40	2	2	6.055
8	M25	0.40	3	3	5.21
9	M30	0.35	0	0	4.80
10	M30	0.35	1	1	5.27
11	M30	0.35	2	2	5.80
12	M30	0.35	3	3	5.66

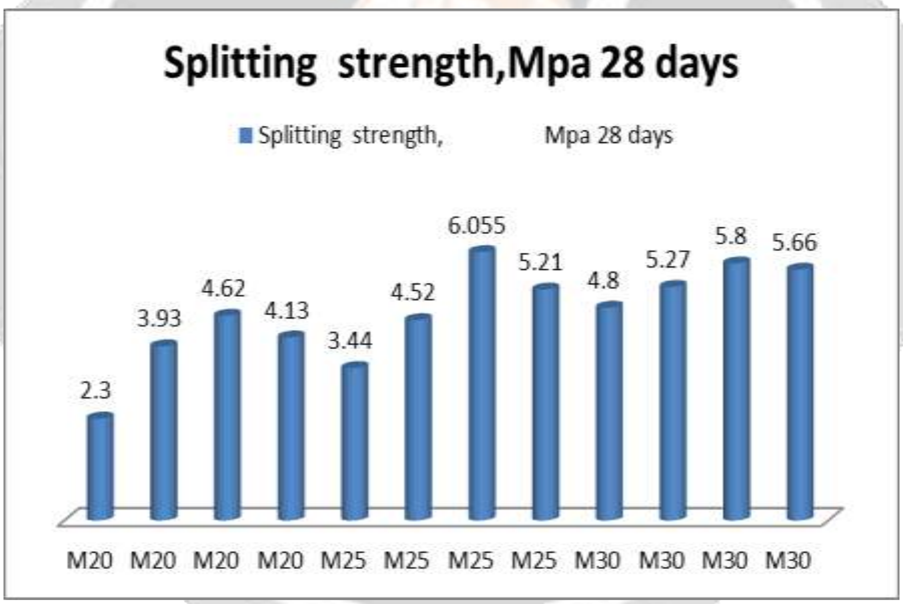


Chart -2: Comparative Statement Of Split Tensile Strength

Table -9: Comparative Statement Of Flexural Strength

Sr. No.	Grade Sample	Water Cement Ratio	% of Steel Fiber	% of Glass Fiber	Flexure Strength N/mm^2
					28 days
1	M20	0.45	0	0	6.74
2	M20	0.45	1	1	8.19
3	M20	0.45	2	2	9.84
4	M20	0.45	3	3	8.70

5	M25	0.40	0	0	7.23
6	M25	0.40	1	1	8.49
7	M25	0.40	2	2	9.86
8	M25	0.40	3	3	9.14
9	M30	0.35	0	0	7.51
10	M30	0.35	1	1	8.71
11	M30	0.35	2	2	9.93
12	M30	0.35	3	3	9.72

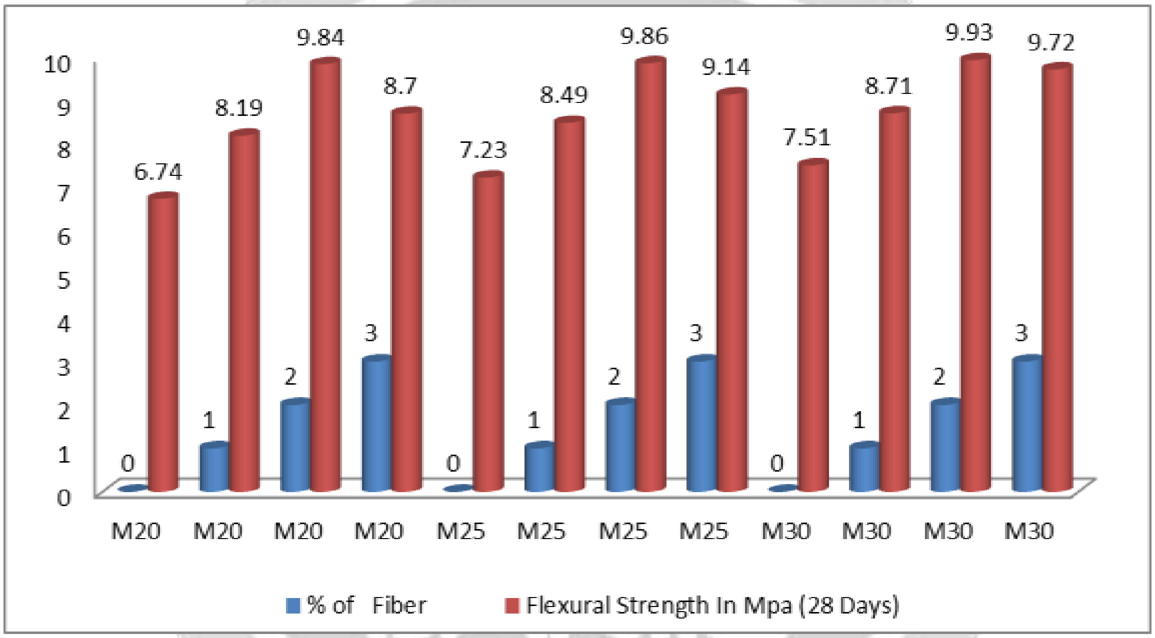
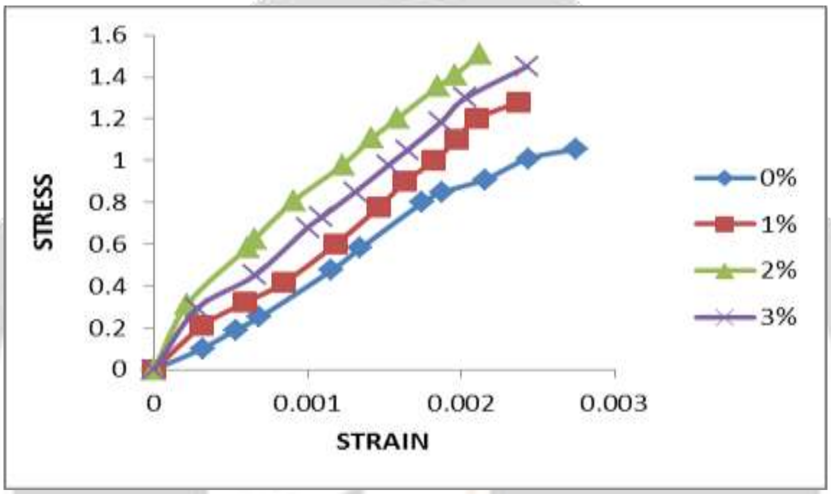


Chart -3: Comparative Statement Of Flexural Strength

Table 10: Comparative Statement Of Stress Strain Curve Of M20 Grade Of Concrete

0%		1%		2%		3%	
Strain	Stress N/mm²	Strain	Stress N/mm²	Strain	Stress N/mm²	Strain	Stress N/mm²
0	0	0	0	0	0	0	0
0.0003	0.101	0.0003	0.209	0.00022	0.314	0.0003	0.29
0.0005	0.19	0.0006	0.321	0.00061	0.585	0.0007	0.45
0.0007	0.25	0.0008	0.415	0.00066	0.625	0.001	0.68
0.0012	0.475	0.0012	0.6	0.00091	0.808	0.0011	0.73

0.0013	0.58	0.0015	0.78	0.00123	0.98	0.0013	0.85
0.0018	0.8	0.0016	0.9	0.00142	1.108	0.0015	0.98
0.0019	0.85	0.0018	1	0.00159	1.205	0.0017	1.05
0.0022	0.91	0.002	1.1	0.00185	1.356	0.0019	1.19
0.0024	1.01	0.0021	1.2	0.00196	1.41	0.002	1.3
0.0028	1.055	0.0024	1.28	0.00212	1.51	0.0024	1.45

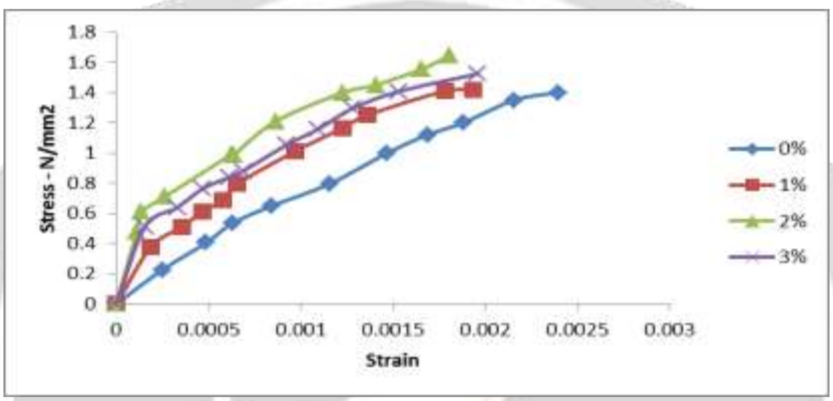


Graph.1 Stress Strain Curve Of M20 Grade Of Concrete

Table 11: Comparative Statement Of Stress Strain Curve Of M25Grade Of Concrete

0%		1%		2%		3%	
Strain	Stress N/mm^2	Strain N/mm^2	Stress N/mm^2	Strain	Stress N/mm^2	Strain	Stress N/mm^2
0	0	0	0	0	0	0	0
0.0003	0.225	0.0002	0.375	0.0001	0.48	0.00016	0.512
0.0005	0.405	0.0004	0.51	0.0001	0.61	0.00033	0.639
0.0006	0.535	0.0005	0.612	0.0003	0.71	0.00047	0.763

0.0008	0.65	0.0006	0.69	0.0006	0.99	0.00061	0.84
0.0012	0.795	0.0007	0.795	0.0006	0.99	0.00069	0.88
0.0015	0.999	0.001	1.01	0.0009	1.21	0.00093	1.055
0.0017	1.12	0.0012	1.164	0.0012	1.4	0.00109	1.157
0.0019	1.2	0.0014	1.251	0.0014	1.45	0.00128	1.295
0.0022	1.35	0.0018	1.41	0.0017	1.56	0.00153	1.407
0.0024	1.4	0.0019	1.416	0.0018	1.64	0.00196	1.525

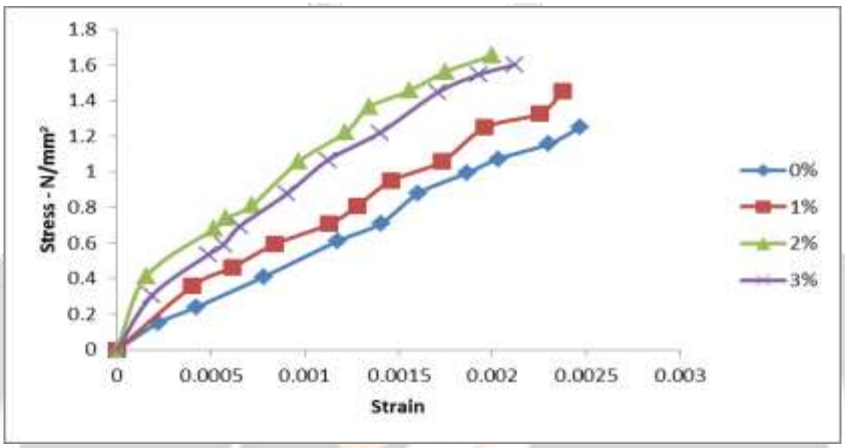


Graph.2 Stress Strain Curve Of M25 Grade Of Concrete

Table 12: Comparative Statement Of Stress Strain Curve Of M 30 Grade Of Concrete

0%		1%		2%		3%	
Strain	Stress N/mm^2	Strain	Stress N/mm^2	Strain	Stress N/mm^2	Strain	Stress N/mm^2
0	0	0	0	0	0	0	0
0.0002	0.15	0.0004	0.357	0.0002	0.41	0.00019	0.305
0.0004	0.24	0.0006	0.463	0.0005	0.68	0.00049	0.535
0.0008	0.41	0.0008	0.593	0.0006	0.74	0.00057	0.59
0.0012	0.61	0.0011	0.707	0.0007	0.81	0.00066	0.695

0.0014	0.71	0.0013	0.809	0.001	1.06	0.00091	0.877
0.0016	0.88	0.0015	0.949	0.0012	1.22	0.00113	1.067
0.0019	0.993	0.0017	1.059	0.0013	1.36	0.0014	1.22
0.002	1.073	0.002	1.249	0.0016	1.46	0.00171	1.447
0.0023	1.157	0.0023	1.328	0.0018	1.56	0.00193	1.547
0.0025	1.251	0.0024	1.452	0.002	1.66	0.00212	1.602



Graph.3 Stress Strain Curve Of M 30 Grade Of Concrete

5. CONCLUSION

- From above discussion it is conclude that, all mechanical properties viz. compressive strength, flexure strength, splitting strength, shear strength are improved by addition of fibers irrespective of fiber type and w/c ratio.
- All strength likes compressive strength, flexure strength and splitting strength are improved with increasing w/c ratio. There is marginal improvement in flexure and shear strength of concrete with change in w/c ratio.
- The resistance of RC and plain concrete dose shows pronounced effect on shear and flexure strength. But the addition of fibers in both type i.e. with or without reinforcement shows improvement in the shear and flexure strength.
- The percentage increase of compressive strength of various grades of concrete mixes with glass and steel fibers 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 concrete mixes compared with 28 days is observed from 15 to 20%.
- In general, the significant improvement in various strengths is observed with the inclusion of glass and steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.
- Satisfactory workability was maintained with increasing volume fraction of fibers by using different w/c ratio.

- The width of cracks is found to be less in SFRC & GFRC than that in plain cement concrete beam.

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