USE OF DUAL FIBRES FOR IMPROVED STRENGTH AND DUCTILITY CHARACTERISTICS OF FIBRE REINFORCED CONCRETE (FRC)

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ABSTRACT

It is found that the addition of glass fiber in certain percentage to steel fiber is resulting in optimum strengths in tension and flexure. The study of deflections has indicated that the presence of fibers not only has increased the flexural strength but also the deflections are controlled. The ultimate deflections recorded with various percentages are more compared to the reference specimens. The specimens with the fibers have more reserved strength even after the first crack showing the ductile behavior where as specimens without fiber have undergone a brittle failure at the instant of crack formation. The studies showed mixed fibers provide better properties in controlling cracks and higher strengths than reference specimen without fiber. In the present experimental investigation, glass and steel fibers were mixed by volume percentage in different proportions of 0-100, 25-75, 50-50, 75-25 and 100-0 in each of the total fiber percentages of 0.5, 0.75, 1.0 and 1.5 to prepare mixed fiber reinforced concrete (MFRC). Standard cylinder and beam specimens (prisms) were cast in M25 concrete, cured and tested for split tensile and flexural strengths. The percentages by volume of glass and steel fibers were varied as mentioned above. The influence of mixed fiber is discussed.

Keywords: Monofilament, Alkali Resistant, Strength, Deflection, Cracking, Ductility.

I. INTRODUCTION

Experimental studies have shown that fibers improve the mechanical properties of concrete such as flexural strength, compressive strength, tensile strength, creep behavior, impact resistance and toughness. Moreover, the addition of fibers makes the concrete more homogeneous, isotropic and a more ductile material (5, 6, and7). The use of fibers in concrete leads to minimization of cracks. Majumdar et al[10]. have studied the influence of glass fiber on cement matrix and have come out with encouraging results. The addition of steel fibers significantly improves strength properties like impact strength, toughness, tensile strength, flexural strength, fatigue strength and reduces spalling (1, 2, 3, 4 and 5). The glass fiber provides higher resistance to propagation and occurrences of early cracks sustaining higher stresses.

The present studies are aimed at investigating the mechanical properties of dual mild steel and Cem-Fil AR HD fibrous concrete for different total fiber percentages with five varying mixing proportions in each total fiber percent. The study is expected to provide an optimized mixed fiber reinforced concrete for structural application.

II. EXPERIMENTAL INVESTIGATION

The details of materials used in the present experimental investigation are as follows.

2.1 Materials

2.1.1 Cement

OPC of 53 grade having specific gravity of 3.15.

2.1.2 Coarse Aggregate

Machine crushed well graded angular granite aggregate of nominal size 20 mm from local source are used. The specific gravity is 2.84. It is free from impurities such as dust, clay and organic matter.

2.1.3 Fine Aggregate

River sand locally available is used. The specific gravity is 2.47.

2.1.4 Glass Fiber

Cem – Fil HD glass fiberis used. The properties are shown in Table. 1

Table 1. Properties of Glass Fiber Cem – Fil ARC14 306 HD

Fibers	Density	Elastic modulus	Tensile strength	Diameter	Length	No. of fibers
	t/m^3	GPa	MPa	micron	mm	million/kg
AR-Glass	2.6	73	1700	14	12	212

2.1.5 Steel Fiber

Monofilament Steel fiber of 1 mm diameter with aspect ratio of 55 is used.

2.1.6 Water

Locally available potable water is used.

2.2 Concrete Mix

The M25 grade of concrete and quantities used per cubic meter are shown in Table 2. The water cement ratio has been fixed depending upon the compaction factor test, with the workability at medium level.

Table 2. Materials Required for 1cu.m. of Concrete

Grade	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water cement ratio
M-25	400	640	1200	0.5

2.3 Mixing – Casting – Testing

As per I.S. specifications, the concrete is carefully mixed by uniformly sprinkling dual fiber in a pan mixer. The mix was cast in moulds. For each percentage of fiber sufficient number of cubes, cylinders and flexural beams were cast as per I.S. specifications for testing at the curing age of 28days. The tests were conducted for compression, split tension and flexure on the specimens using standard procedures.

III. RESULTS AND DISCUSSIONS

3.1 Workability

The water Cement ratio taken is 0.5. Higher percentages of fiber beyond 0.5 percentage and up to 1.5 percentages require super plasticizer. At higher percentages of fiber balling has occurred and mix was not in a workable condition with a W/C ratio of 0.5. The replacement of Steel fiber with Glass fiber by 0, 25, 50 and 100 percentages from total fiber content of 0.5, 0.75, 1.0 and 1.5 by volume, the workability was affected marginally.

3.2 Compressive Strength

From Table 3, it is observed that with increase in fiber percentage, the compressive strength also increases with age. At the age of 28days with 1.5 percent fiber the compressive strength is 46.21 percent in excess over the strength of reference mix. As the percentage replacement of steel fiber by glass fiber is increased, the compressive strength decreases, but on the overall it is more than that of control concrete as can be seen from the Table 3**.**The variations are shown by bar charts in Fig.1.

3.3 Flexural Strength

From Fig.1, it is observed that with increase in fiber percentage, the flexural strength also increases with age. At the age of 28 days with 1.5 percentage fiber the flexural strength is 77.7 percent in excess over the strength of reference mix. The variation of flexural strength at 28 days with various percentages of glass fiber of 0, 25, 50, 100 percentages by volume used as replacement for steel fiber in total fiber content of 0, 0.5, 0.75, 1.0 and 1.5 percentages were studied and results are presented in Fig.1. It is observed that as the percentage of total fiber content is increased, the flexural strength also increases and it is seen as maximum at mixed fiber proportion of 25 – 75 percentage in all the total fiber percentages. As the percentage replacement of steel fiber by glass fiber is increased and steel fiber percentage is decreased, the flexural strength goes on decreasing in all the total fiber percentages. The ultimate flexural strength variation of MFRC against the total fibre percentage is plotted for various combinations as shown in Fig.2.

3.4 Ductility Characteristics

Beam specimens of M25 Mix with various percentages of fibers have been tested for flexural strength under two point loading as per the standard specifications. The flexural specimens tested have exhibited ductility characteristics.At the failure load a diagonal crack has appeared in between the loading points and the specimens have not failed suddenly. The failure is not brittle and is entirely different from that of plain concrete, where failure is brittle. The ductility characteristics exhibited by the specimens are due to the introduction of fiber in the mix. At the age of 28 days with 1.5 percentage fiber the deflection is 205.26 percent in excess over the deflection of reference mix. The results of deflection are shown in Table 5. Considering the MFRC with 25 percent glass and 75 percent steel fibres, the balling effect is observed to be reduced thus softening the effect of failure and thus contributing to increased ductility. The load deflection variations noted on MFRC specimens are shown in Fig.3.

Table.3 Compressive Strength of Mixed Fiber Reinforced Concrete Cube at 28 days

S. No.	Total fiber (%)	Dual Fiber (%)		Ultimate Load (P_u) in KN	Compressive strength (f_u) in N/mm^2	Increase in compressive strength (%)
		Glass	Steel			
1	0.0	0.0	0.0	457.2	45.72	-------
2	0.5	0	100	599.0	59.90	31.01
3	0.5	25	75	580.2	58.02	26.90
4	0.5	50	50	557.3	55.73	21.89
5	0.5	75	25	532.5	53.25	16.47
6	0.5	100	0	519.7	51.97	13.67
7	0.75	0	100	617.8	61.78	35.13
8	0.75	25	75	604.2	60.42	32.15
9	0.75	50	50	583.6	58.36	27.65
10	0.75	75	25	542.5	54.25	18.66
11	0.75	100	0	530.1	53.01	15.94
12	1.0	0	100	639.8	63.98	39.94
13	1.0	25	75	621.4	62.14	35.91
14	1.0	50	50	603.0	60.03	31.89
15	1.0	75	25	587.7	58.77	28.54
16	1.0	100	0	564.9	56.49	23.56
17	1.5	0	100	668.5	66.85	46.21
18	1.5	25	75	642.2	64.22	40.46
19	1.5	50	50	634.6	63.46	38.80
20	1.5	75	25	604.3	60.43	32.17
21	1.5	100	0	598.5	59.85	30.90

Table.4 Ultimate load and deflection values of mixed fiber Reinforced concrete standard prisms.

S.No	Total fiber (%)	Mixed fiber(%)		Average load (KN)	Average deflection (mm)	Flexural strength(N/mm2)
		Glass	Steel			
1	0	0	0	11.58	0.76	4.63
2	0.5	0	100	16.58	1.65	6.63
3	0.5	25	75	16.71	1.58	6.47
4	0.5	50	50	14.83	1.33	5.93
5	0.5	75	25	14.50	1.21	5.80
6	0.5	100	0	13.92	1.16	5.57
7	0.75	0	100	17.25	1.82	6.90
8	0.75	25	75	17.42	1.73	6.97
9	0.75	50	50	16.00	1.57	6.40
10	0.75	75	25	14.92	1.48	5.97
11	0.75	100	0	14.17	1.24	5.67
12	1.0	0	100	18.58	2.16	7.43
13	1.0	25	75	18.75	1.94	7.50
14	1.0	50	50	16.92	1.89	6.77
15	1.0	75	25	16.08	1.75	6.43
16	1.0	100	0	14.75	1.32	5.90
17	1.5	0	100	19.92	2.32	7.97
18	1.5	25	75	20.58	1.98	8.23
19	1.5	50	50	19.25	1.91	7.70
20	1.5	75	25	18.42	1.87	7.37
21	1.5	100	0	15.75	1.40	6.30

Table.5 Comparison of Deflection and Percentage change of MFRC

S. No.	Total fiber (%)	Mixed Fiber (%)		Deflection at first crack load (δ) in	Deflection at ultimate load (δ_u) in mm	Increase in ultimate deflection w.r.t. first crack load	Increase in ultimate deflection w.r.t. control
		Glass	Steel				
1	0.5	0	100	0.85	1.65	94	117.10
2	0.5	25	75	0.79	1.58	101.28	107.89
3	0.5	50	50	0.65	1.33	104.61	75
4	0.5	75	25	0.58	1.21	108.62	59.21
5	0.5	100	0	1.07	1.16	8.41	52.63
6	0.75	0	100	0.73	1.82	149.32	139.47
7	0.75	25	75	0.62	1.73	179.03	127.63
8	0.75	50	50	0.54	1.57	190.74	106.58

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9	0.75	75	25	0.49	1.48	202.05	94.74
10	0.75	100	0	1.11	1.24	11.71	63.16
11	1.0	0	100	0.59	2.16	266.10	184.21
12	1.0	25	75	0.52	1.94	273.07	155.26
13	1.0	50	50	0.40	1.89	372.50	148.68
14	1.0	75	25	0.28	1.75	525	130.26
15	1.0	100	0	1.18	1.32	11.86	73.68
16	1.5	0	100	0.47	2.32	393.62	205.26
17	1.5	25	75	0.36	1.98	450	160.53
18	1.5	50	50	0.22	1.91	768.19	151.32
19	1.5	75	25	0.14	1.87	1235.71	146.05
20	1.5	100	0	1.50	1.70	13.33	123.68

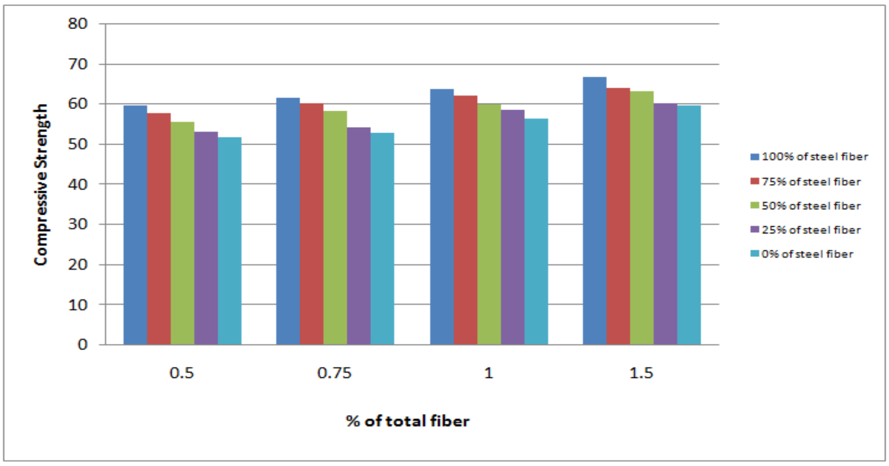

Fig 1: Variation of Compressive strength for various percentages and for various proportions of steel fibre

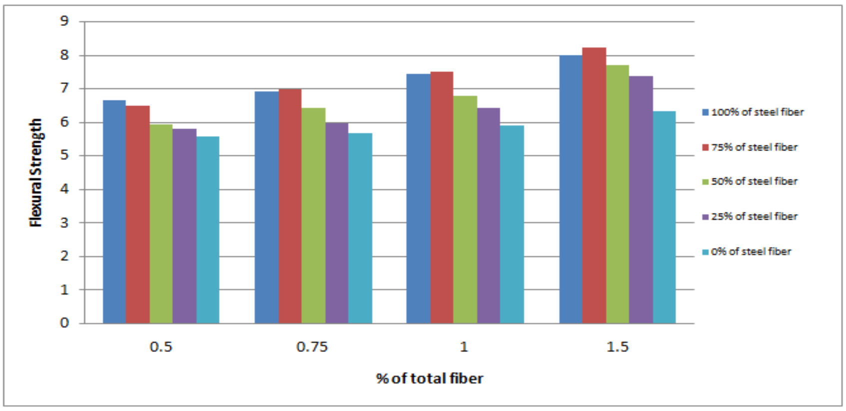

Fig 2: Variation of Flexural strength for various percentages and for various proportions of steel fibre

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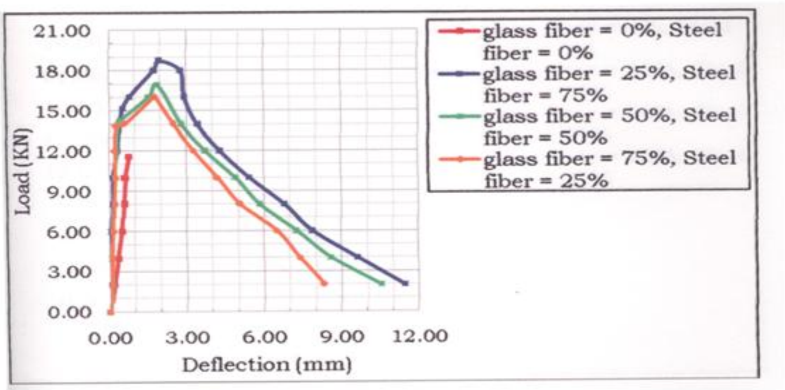

Fig 3: Load deflection curves of MFRC standard prisms at various mixed fibres percentages in total fibre percentage of 1.0

3.5 Cracking Characteristics

Observation of specimens during Split tensile strength test shows a single crack occurring at failure along diameter of cross section without any appearance of longitudinal crack. It is observed that failure has taken place gradually with the formation of cracks. In the case of plain concrete specimens the failure is sudden and brittle. Hence it is established that the presence of fibers in the matrix has contributed towards arresting sudden crack formation. The presence of glass fibres has contributed in preventing the formations of micro cracks.

VI. CONCLUSIONS

Based on the present experimental investigation conducted and the analysis of test results, the following conclusions are drawn.

1. For the M25 mix with a water cement ratio of 0.5, the workability of concrete is only marginally affected even with a total fiber content of 1.0 percent by volume. Higher percentages of dual fibers from 1.0 percentage affect the workability of concrete, and may require the use of super plasticizers to maintain the workability. Steel fiber of 1 mm diameter and length of 55 mm having an aspect ratio of 55 can be satisfactorily mixed along with glass fiber having high aspect ratio to increase the strength and other characteristics.
2. The compressive strength of dual fiber concrete is found to be maximum at 1.5 percentage of fiber. With this percentage there is an increase of 46.21 percent for M25 grade mix at 28 days.
3. The Flexure strength of dual fiber concrete is also found to be maximum at 1.5 percent of fiber, and there is an increase of 77.75 percent for M25 grade mix at 28 days.
4. The compressive strength of dual fiber concrete is maximum at 100 percent total fiber content of steel at 28 days compared to plain concrete. There is substantial increase in the compressive strength for mixed fiber combination when compared to plain concrete. As the percentage of steel fiber is reduced and glass fiber is increased, the compressive strength is getting reduced compared to that of 100 percent steel fiber in the matrix.
5. The flexural strength of dual fiber concrete is found to be maximum at 75 percent total steel fiber content in the mixed fiber proportion at 28 days compared to plain concrete in all the total fiber percentages. As the

percentage of steel fiber is reduced and glass fiber is increased, the flexural strength is getting reduced compared to that of mixed fiber percent of 25 – 75 in the matrix.

6. The ductility characteristics have improved with the addition of mixed (glass and steel) fibers. The failure is gradual compared to that of brittle failure of plain concrete.
7. Cracks can be controlled by introducing glass fibers. Cracks have occurred and propagated gradually till the final failure. This phenomenon is true with all the percentages of glass fiber. Glass fiber also helps in controlling the shrinkage cracks.
8. Compared to metallic fibers like steel, alkali resistant glass fiber gives corrosion free concrete. By judiciously combining Glass fiber with Steel fiber, optimum FRC possessing required strength and other properties can be produced.

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