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FLEXURAL BEHAVIOUR OF MIXED FIBRE (STEEL AND GLASS) REINFORCED CONCRETE BEAMS (PROTO TYPE)

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ABSTRACT

Fibres are added to Concrete to improve its strength properties particularly in tension and flexure. Metallic fibres like steel have been extensively tried by the researches in various investigations conducted on steel fibre reinforced concrete (SFRC). It has been well established that small percentage of discrete steel fibres added to concrete matrix improves the all-round strength properties of concrete including the prevention of shrinkage cracks. Inorganic fibres like glass contribute towards arresting of micro-cracks in addition to improving the ductility of the concrete composite though the strength contribution is less. In the present experimental investigation, mixed fibres (steel and glass) are employed in the preparation of Mixed Fibre Reinforced Concrete (MFRC). Proto-type beams of size 75mmX150mm with a length of 1200mm were with various overall percentages of mixed fibre reinforcement. Out of the fibre percentage, ,the proportion between steel and glass is varied. The beams were also provided with conventional reinforcement. The beams were tested for flexure and the variation of deflections under increasing loads, formation of cracks etc., are observed. Based on this, important conclusions are drawn on the flexural behaviour of mixed fibre reinforced concrete beams (MRFC beams).

Keywords:* *Mixed fibre, Aspect ratio, Conventional reinforcement, flexure , deflection , ductility.

I. INTRODUCTION

1.1. Concrete Admixtures

As an important construction material being used vastly at present, continuous research is being carried out to improve the various properties of concrete to put it to all-round use .Various types of mineral admixtures like fly-ash, condensed silica fume or micro silica, metakaoline GGBS (Ground Granulated Blast furnace Slag) etc., are being used as part replacement of Ordinary Portland Cement (OPC) in concrete making. The mineral admixtures help concrete in better workability, strength and durability besides economy .Various metallic fibres like steel and inorganic fibres like asbestos, glass etc., are being tried to improve the strength of concrete particularly in tension, flexure, impact etc., besides many other structural benefits. Chemical admixtures like super-plasticizers are being employed to maintain the workability of concrete at lower water-cement ratios.

1.2. Details of Present Study

In the present experimental investigation, mixed fibre reinforcement is tried to prepare mixed fibre reinforced concrete (MRFC) .Metallic fibre like steel and inorganic fibre like glass are mixed in various proportions in a given total fibre percentage. The reference concrete mix is M25. Proto-type beams are cast with various combinations of mixed fibre in addition to the conventional reinforcement. After testing the beams for load-deflection behavior, it is aimed at some important conclusions on the behavior of the beams and the influence of mixed fibre.

1.3. Brief Review

Various authors have tried to use metallic and non-metallic fibres in concrete and studied the mechanical properties (8, 9). The ACI code (2, 3 and 4) has formulated the guide lines for using steel fibres in Fibre reinforced concrete (FRC).

II. EXPERIMENTAL INVESTIGATION

The following are the details of the experimental investigation conducted on mixed fibre reinforced concrete beams.

2.1 Materials of Concrete

- **Cement:** Ordinary Portland cement of 53 Grade from Ultra Tech conforming to specifications.

2.1.2. Fine Aggregate

- River sand locally available is used as fine aggregate conforming to specifications.

2.1.3. Coarse Aggregate

Machine crushed well graded angular granite aggregate of nominal size from local source is used.

2.1.4. Water

Potable water locally available is used for mixing and curing the concrete.

2.2 Fibers Used

2.2.1. Glass Fiber and Steel Fiber

Fibers of alkali resistant glass with an aspect ratio of 857:1 and steel fiber with an aspect ratio of 55 are used conforming to ASTM C 1666M [13] and ASTM A 820M [14]. The details are given in table 1

Table1. Properties of Fibers (Glass and Steel)

Fiber	Type	Density kg/m^3	Elastic modulus GPA	Tensile strength MPA	Dia.	Length mm	No. of fiber
AR-Glass	Cem- FIL ARC 14 306 HD	2600	73	1700	14 micron	12	212 million /kg
Steel	Steel wire	7850	210	250	1mm	55	Mono filament

2.2.2. Super Plasticizers

SP430 (CONPLAST) of M/S Fosrock chemicals (India) was employed to maintain the workability of the mix wherever needed.

2.3 Concrete Mix Details

The details of the M25 Concrete mix used are given in table 2 as arrived at as per I.S: 10262 [17, 18].

Table 2. Materials Required for 1 Cubic Meter of Concrete

Grade	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water cement ratio
M25	425	682	1277.76	0.5

2.4 Mixed Fibre Combinations

On the overall 6 total percentages of mixed fibre like 0.0, 0.50, 0.75, 1.00, 1.25 and 1.5 were employed.In the mixed fibre. The steel fibre is replaced by glass fibre at 0, 25, 50, 75 and 100 percentages. In total, 20 combinations of mixed fibre were tried in addition to the reference concrete beams without any fibre.

2.5 Details of the beams

The dimensional details of the test beams are as follows

- Size of the beam = 75mm x150mm x1200 mm
- Area of section = 75mm x150mm =11250mm2
- Limiting percentage steel = 1.2 x (11250 /100) = 135 mm2
- 2 No's, 8 mm diameter bars as tension reinforcement and 8 mm diameter bars for shear stirrups at a uniform spacing of 100 mm c/c , with two hanger bars of 8mm diameter were used for the fabrication of the beam. Fig 1 illustrates the set up of the reinforcement cage.

2.6 Workability of Mix

The workability of the MRFC mixes was maintained medium by adding a small dosage of super-plasticizers whenever required.

2.7 Casting and Curing Of Beams

Reinforced concrete beams of sizes 75mm x 150 mm x 1200 mm were cast with varying percentages of mixed fibres. Replacement of glass fibres at 0, 25, 50, 75 and 100 percentages with steel fiber in overall fiber percentages of 0.0 , 0.50 , 0.75, 1.00, 1.25 and 1.50 was carried out. After 24 hrs of air drying in the moulds, the demoulded specimens are placed in the curing tank filled with fresh potable water. At the age of 28 days of curing the beams were taken out and readied for testing. Standard procedures were used for Casting and Curing. Photographs of the reinforcement cage and casting of the beam are shown in figs 1 and 2.

2.8 Testing of prototype beams

Each beam was tested in the loading frame under two point loading using the hydraulic jack, and proving ring attachment. Deflections were measured at various load increments. First crack load, Ultimate load, Crack formation, variation of deflection etc., were noted.

Fig.1. Mould and Reinforcement Cage for Casting MRFC Prototype beams.

Fig.2. Casting of Reinforced Prototype Beam with MRFC

III. DISCUSSION

3.1 Presentation of Results

The load deflection observations of various test beams are noted. Typical values are shown in Table 3 and 4. The load-deflection curves plotted for two typical combinations of mixed fibres are shown in Fig 3 and 4.

3.2 Workability of MRFC mixes

The workability values of the MRFC mixes were obtained by conducting compaction factor test. Medium workability was maintained in between 0.88 to 0.94 of compacting factor. The maximum of 3 percent super plasticizer was added in the mix with 1.5 percent overall fiber proportion. It is observed that at higher percentages of mixed fibers greater than 1.0, the workability is decreasing. The mix is becoming harsh giving lesser workability requiring superplasticizer.

3.3 Use of conventional Reinforcement in MRFC

The beam specimens cast in the present investigation are of size 75mm x 150 mm x 1200 mm (Fig.1). When somewhat longer spans are used , the beams require certain amount of conventional reinforcement also even when MRFC is being used. Beams cast only with MRFC over longer lengths do not exhibit a strong flexural behavior. Hence, nominal reinforcement has been provided for the beams and the MRFC is poured into the forms and casting has been completed.

Mixed fibres used in the concrete matrix improve the tensile strength as well as flexural strength of the beams. But at the same time , conventional steel reinforcement is also required to supplement the flexural strength. The present study is conducted to find the additional contribution of mixed fibers in flexural strength for beams with conventional reinforcement. Hence it can be stated that when beams of longer spans are being cast with MRFC, certain amount of conventional steel is also required to achieve the optimum flexural strength.

3.4 First Crack load and Ultimate load

In the different total fiber percentages, it is observed that as the percentage of steel fiber is increased in the mix, the first crack load and the ultimate load of the beams are getting increased. For beams with no fiber, the first crack and the ultimate loads are 37.5 and 48.5 KN respectively. With total fiber percent of 1.0 and with 100 percent steel fiber, maximum load of 63.75 KN at first crack and 72.50 KN at ultimate load are obtained. For other total fiber percentages up to 1.0, the respective values are in between.With 100 percent glass fibre in the same overall 1.0 percent there is an increase of 23.19 percent in ultimate load. Considering other percentages above 1.0 percent , it can be seen that the first crack as well as the ultimate loads are gradually falling down. With a maximum overall percentage of 1.5 percent, the reduction in the first crack load is 4 KN and the reduction in the ultimate load is 6 KN respectively when compared to 1 percent overall fibre. The reduction in ultimate load might have occurred because of balling of fibres and subsequent formation of voids in concrete. Even with 50 percent glass and 50 percent steel fibers the increase in the first crack load and the ultimate loads are 13.75 KN and 8.25 KN respectively. Even though 100 percent steel fibre in an overall fibre percentage of 1.0 is giving the maximum increase. It can be said that the presence of glass fibre in various proportions has shown considerable increases in the first crack load and the ultimate load. By mixing glass fibre and steel fibre there are other advantages also.

3.5 Balling effect with higher percentage of Mixed Fibres in MRFC

When components of MRFC are cast, there is an optimum percentage of fibre to be used in concrete to obtain optimum strength properties. In present investigation, a total fibre of 1.0 percent is found to be optimum for MRFC beams. When percentage of total fibre used has exceeded. 1.0 percent, it is found that the load carrying capacity of the beams is getting reduced. It is a common phenomenon that when, higher percentages of steel fibres are employed, at random orientation, fibres get twisted with each other without spreading in the mix causing balling effect. Due to this effect, the voids are formed inside the concrete due to lack of proper mixing and compaction and the load carrying capacity is reduced. Hence, when higher percentages of fibres are employed in MRFC mixes, proper care should be taken for uniform dispersion of fibre in the concrete mix.

3.6 Variation of Deflections

It is observed that the values of deflections recorded at the ultimate load are gradually increasing from overall 0 percent to 1 percent fibres employed in the beams (Tables 3 and 4 and fig 3 and 4).The ultimate deflection with 0 percent fibre is 4.30 mm where as the ultimate deflection with overall 1.0 percent fibre with various mixed percentages of glass fibre and steel fibre varies from 9.45 mm in the specimens with 100 percent steel fibre to a maximum of 13.55 mm in the specimens with 100 percent glass fibre. There is an increase in deflection of 215.11 percent in specimens with 100 percent glass fibre and 119.76 percent in specimens having 100 percent steel fibre. With the presence of glass fibre has increased the deflection capacity of the beams. With this, it can also be mentioned that the moment rotations characteristics of beams is improved with the presence of glass fibres.

3.7 Ductility Characteristics

It is seen from the load-deflection observations that the ultimate deflection capacity of the beams has been tremendously increased with the introduction of the fibres. Hence it can be stated that the presence of fibres has increased the deflection capacity making the beams more ductile up to an optimum of total fibre of 1.0 percent. In the ultimate load ranges, the beams have become more ductile with the presence of fibres.

3.8 Cracking Characteristics

While testing the various MRFC beams, it is observed that the cracks are getting formed gradually in the fibrous beams. In the case of beams without fibre, the formation of cracks and spreading of cracks has occurred within a short period. In the case of fibrous beams, the cracks have gradually developed. The cracks are almost vertical and they are formed in the middle third portion of the beam indicating flexural failure. On the whole, the cracking behavior of the MRFC beams is uniform and gradual and there was no sudden failure. Hence it can be finally stated that use of Mixed fibres in concrete impart more tensile strength and more flexural strength in addition to other beneficial properties.When more steel fibre percentage is employed in any overall mixed fibre percentage, it is observed that a number of micro cracks have occurred in concrete in additions to the main cracks. With increase in the glass fibre content in overall mixed fibre percentage, it is observed that most of the micro cracks are eliminated. This is an advantage obtained with the presence of glass fibre along with steel fibre.

Table 3 Load Deflection Values of Mixed Fiber Reinforced Concrete Prototype Beam (M_{33})

S.no	Proving ring reading	Load in (KN)	Deflection in mm	Remarks
1	0	0	0	Total fiber = 1.0%
2	20	6.25	0.31	Glass fiber = 25%
3	40	12.5	0.51	Steel fiber = 75%

4	60	18.25	0.69	
5	80	26.25	0.84	
6	100	31.25	1.18	
7	120	37.5	1.57	
8	140	44.75	2.04	
9	160	50	2.75	
10	175	55	3.75	First crack load
11	180	56.25	4.07	
12	200	63.75	5.18	
13	220	69	9.75	Ultimate load
14	210	66.5	10.83	
15	200	63.75	13.03	

Table 4 Load Deflection Values of Mixed Fiber Reinforced Concrete Prototype Beam (M_{25})

S.no	Proving ring reading	Load in (KN)	Deflection in mm	Remarks
1	0	0	0	Total fiber = 1.0%
2	20	6.25	0.37	Glass fiber = 50%
3	40	12.5	0.73	Steel fiber = 50%
4	60	18.25	1.19	
5	80	26.25	1.54	
6	100	31.25	2.18	
7	120	37.5	2.83	
8	140	44.75	3.47	
9	160	50	4.03	
10	170	54	4.25	
11	180	56.25	6.2	
12	210	66.5	10.08	Ultimate load
13	180	56.25	13.32	
14	160	50	14.43	
15	150	48.5	15.61	

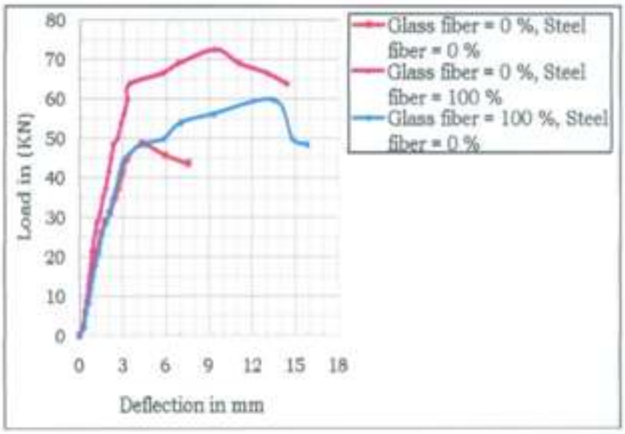

Fig. 3 Load Deflection Curves of MFRC Prototype Beam with 1.0 percent total fiber

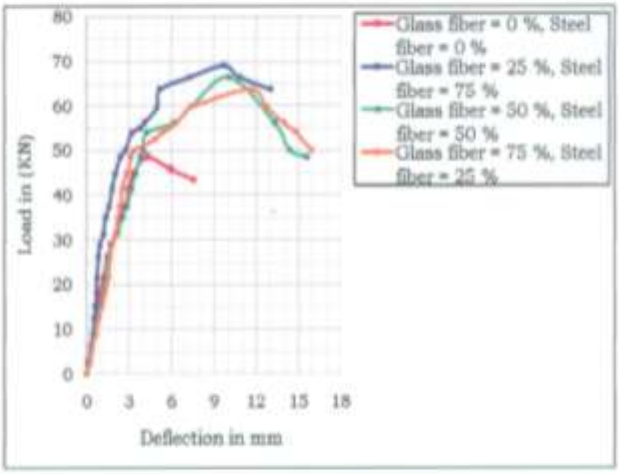

Fig. 4 Load Deflection Curves of MFRC Prototype Beam with 1.0 percent total fiber

IV. CONCLUSION

Based on the experimental investigation the following conclusions are drawn.

- When beams of larger spans are being cast with MFRC, certain amount of conventional steel is also required to achieve the optimum flexural strength.

- Maximum deflection has occurred at an optimum percentage of 1% fibres. With increase in the fibre content beyond 1.0% the ultimate load and deflections are also getting reduced.
- There is an increase of nearly 49.48% with overall 1% of fibre with 100% steel fibre in ultimate load compared to 0%. With 100% glass fibre in the same overall percent there is an increase of nearly 23.19%. However the flexural behavior is smooth.
- The presence of mixed fibres increases the deflection capacity, making the beams more ductile up to an optimum of 1% fibres. In the ultimate load ranges the beams have become more ductile with the presence of fibres. Glass fibre is contributing towards smoother behavior, better ductility and arresting of minor cracks.
- MFRC gives an optimum concrete composite suitable for practical structural component.

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REFERENCES

[1] ACI 544.1R-96, (Reapproved 2009) 'Report on fiber reinforced concrete'. American Concrete Institute.

[2] ACI 544.2R-89 (Reapproved 2009) 'Measurement of properties of fiber reinforced concrete'. American Concrete Institute.

[3] ACI 544.3R-08, 'Guide for specifying proportioning and production of fiber reinforced concrete'. American Concrete Institute.

[4] ACI 544.4R-88, 'Design Considerations for Steel Fiber Reinforced Concrete'. American Concrete Institute.

[5] ACI 549.3R-09, 'Report on Glass Fiber Reinforced Concrete Premix'. American Concrete Institute.

[6] A. Ravichandran, K. Suguna, P.N. Ragunath, 'Mechanical Properties of High-Strength Concrete with Hybrid Fibre Reinforcement'. International Journal of Applied Engineering Research, Volume 3, Number 6, 2008, PP. 829-836.

[7] A. Sivakumar, Manu Santhanam, 'Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres'. Cement & Concrete Composites, 29, 2007, PP. 603–608.

[8] I.S. 456-2000, 'Code of practice of plain and reinforced concrete'. BIS.

[9] I.S. 9103-1999, 'Specification for admixtures for concrete'. BIS

[10] I.S. 10262-2009, 'Recommended guidelines for concrete mix design'. BIS.

[11] ASTM C 469M-10, 'Standard test method for state module of elasticity and poisson ratio of concrete in compression'. ASTM International.

[12] ASTM C 1240-05, 'Standard Specification for Silica Fume used in Cementitious Mixtures'. ASTM International.

[13] ASTM C 1666M-08, 'Standard Specification for Alkali Resistant (AR) Glass Fiber for GFRC and Fiber Reinforced Concrete and Cement'. ASTM International.