Improving the Flexural Performance of Concrete Beams Using 2D Steel Fibres

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Abstract – *Concrete is the most widely used structural material in the world with an annual production of over seven billion tons. The reason for its extensive use is that it provides good workability and high strength. But the ordinary cement concrete has many disadvantages like very low tensile strength, limited ductility, little resistance to cracking and presence of internal micro cracks leading to its brittle failure. Under such circumstances, the need of developing concrete with high ductility, strength and energy absorption capacity has revealed its importance. The invention of Fibre Reinforced Concrete has solved the issues related to the poor performance of ordinary cement concrete. Fibre Reinforced Concrete (FRC) contains fibrous material which increases its structural integrity. A fibre is a small discrete reinforcing material produced from steel, plastic, glass, carbon and natural materials in various size and shapes. Among these different forms of FRCs, Steel Fibre Reinforced Concerte (SFRC) is the commonly used one. This study deals with the flexural performance of concrete beams of grade M30 reinforced with hooked end steel fibres by conducting three point loading test. The steel fibre content was varied by 0.25%, 0.50%, 0.75% and 1.0% by weight of cement. The results showed that the flexural strength of concrete beams was increased with increasing fibre reinforcement.*

***Key Words*: Fibre Reinforced Concrete, Hooked end steel fibres, Steel Fibre Reinforced Concrete beam, Three point loading test, Flexural strength**

1. INTRODUCTION

Steel fibres have been used to enhance the properties of ordinary cement concrete for many years [6]. Steel Fibre Reinforced Concrete (SFRC) is defined as concrete made with hydraulic cement containing fine and coarse aggregate and discontinuous discrete fibre [8]. A numerical parameter describing a fibre is its aspect ratio which is calculated by dividing fibre length by an equivalent fibre diameter (l/d) [7]. The typical aspect ratio for the fibre ranges from 30 to 150 [3]. The different types of steel fibres used in SFRC includes straight, hooked, paddled, deformed, crimped and irregular steel fibres [10]. In SFRC, the steel fibres are randomly dispersed and distributed throughout the member. The steel fibres assist in controlling the propagation of micro cracks present in the mortar aggregate interface by bridging across the cracks formed after the application of load on the member. Thus the steel fibres present in the concrete prevent the widening of micro cracks into major cracks. SFRC is being increasingly used to improve the tensile, flexural, impact and fatigue strength [8]. Since the modulus of elasticity of the steel fibre is higher than that of the matrix, they help to carry the load by increasing the tensile strength of the material [7]. Also, the steel fibre reinforcement has nearly similar thermal coefficiency as that of concrete and has ductile properties, therefore can absorb energy well [1]. This study aims at determining the flexural performance of concrete beams of grade M30 reinforced with various percentages of hooked end steel fibres by conducting three point loading test in the Universal Testing Machine.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials

The cement used for the entire experiment was Ordinary Portland Cement of grade 53 conforming to IS 12269:1987. The coarse aggregates conform to IS 2386:1963 and were of crushed angular type passing through 20 mm sieve and retaining on 4.75 mm sieve. The fine aggregate used was M sand conforming to zone I of IS 383:1970. The trade name of the 2D steel fibre used in this study is Novocon 1050 (Fig -1). It is a cold drawn wire fibre, deformed with hooked ends to provide optimum anchorage within the concrete mix. Novocon 1050 steel fibres conforms to ASTM A 820/A 820M – 04 (type I cold drawn wire). The properties of 2D steel fibres are given in table -1.

Table -1: 2D steel fibre properties

Fibre diameter	1 mm
Fibre length	50
Aspect ratio	50
Tensile strength	1050 MPa

Fig -1: 2D steel fibres with hooked ends

2.2 Concrete Mix Details

The grade of concrete chosen for the study was M30. The mix design for M30 was done according to the recommendations mentioned in IS 456:2000 and IS 10262:2009. The materials were tested for various properties required for the mix design. After various trials, the mix proportion was arrived at 1:1.784:3.09. Admixture of type GLENIUM SKY 8433 produced by BASF Incorporation was added to increase the workability of concrete and to minimize the amount of water-to-cement ratio, for obtaining a desired slump range of 75 mm–125 mm as per IS 456:2000, Cl. 7.1. The proportioning for the mix is given in the Table -2.

Table -2: M30 grade concrete mix details

Mix	Cement	Fine aggregate	Coarse aggregate	w/c ratio	Admixture
M30	1	1.784	3.09	0.38	0.3%

2.3 Preparation of Test Specimen

The study consisted of an experimental investigation on the flexural performance of Plain Cement Concrete (PCC) beams reinforced with hooked end steel fibres. The dimensions of M30 grade beams reinforced with steel fibres were 500 mm × 100 mm × 100 mm. The steel fibre reinforced beams were cast at four different fibre percentages of 0.25%, 0.50%, 0.75% and 1.0% by weight of cement. Then the specimens were cured for 28 days. At the end of curing, the beam specimens were tested in the UTM under the three point loading arrangement for determining the ultimate load and the corresponding deflection.

Table -3: Details of beam specimens for flexural test

Mix	Specimen designation	% steel fibre added by weight of cement
M30	M30 control	0%
M30	M302D0.25	0.25%
M30	M302D0.5	0.50%
M30	M302D0.75	0.75%
M30	M302D1	1.0%

2.3 Three Point Bending Test

The beam flexural tests under three point loading were performed in a universal testing machine with 1000 kN capacity. The test set up used for the study is shown in the Fig -2.

Fig -2: Experimental set up

In the three point loading, maximum fibre stress will come below the point of loading where the bending is maximum. The load was applied at midpoint of the beam specimen, increased at a uniform rate till the ultimate failure .The specimens were arranged with simply supported conditions with an effective span of 300 mm. Deflection of the beam was measured using a dial gauge of least count 0.01mm at centre of the specimen. The three point loading arrangement for the beams is shown in the Fig -3.

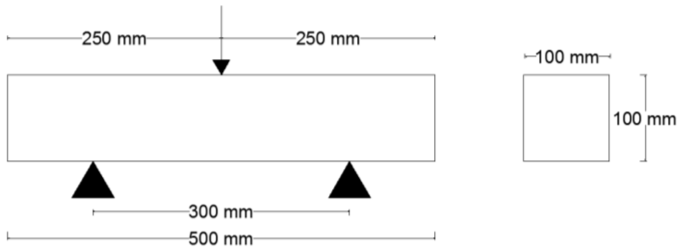

Fig -3: Three point loading arrangement

3. RESULTS AND DISCUSSION

The results obtained from the three point bending tests conducted on concrete beam specimens of grade M30 reinforced with steel fibres are tabulated in the Table-3. The variations are plotted in the Chart -1.

3.1 Ultimate Load for Steel Fibre Reinforced Concrete Beams

Table -4: Ultimate load for the steel fibre reinforced concrete beams

Specimen designation	Steel fibre content	Ultimate load (kN)	% increase in the ultimate load in comparison with control beam
M30 control	0%	11.2	-
M302D0.25	0.25%	12.4	10.71
M302D0.5	0.50%	13.0	16.07
M302D0.75	0.75%	14.2	26.78
M302D1	1.0%	12	7.14

The ultimate loads obtained for all the fibre reinforcement percentages of the steel fibre reinforced concrete beams were greater than the control beam of grade M30 (Table -4). This may be due to the fact that the steel fibers will effectively hold the micro cracks in concrete mass. However, it was found that the ultimate load tend to increase up to an optimum fibre reinforcement percentage after which the ultimate load decreased. This is similar to the 'over-reinforced' behaviour associated with RC design where too much reinforcement leads to a reduction in strength [2].

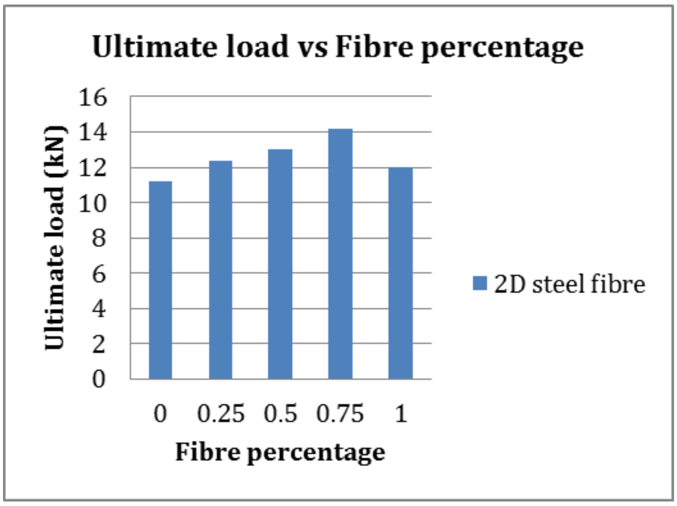

Chart -1: Ultimate load for 2D steel fibre reinforced concrete beams

The optimum steel fibre reinforcement percentage was obtained as 0.75% by weight of cement. An increase of 26.78% in the ultimate load was found for the beam reinforced with 0.75% of steel fibre in comparison with the M30 grade control beam. To get the maximum benefit it is recommended to use 0.75% steel fibers. More percentage of steel fibers may lead to the workability problem and makes concrete more porous because of the presence of air cavities [9].

3.2 Crack Patterns for Steel Fibre Reinforced Concrete Beams

The crack patterns obtained for the M30 grade control beam and the beams reinforced with both 2D steel fibres are shown below. All the crack patterns were flexural crack patterns. Maximum crack width was found in the beam having the minimum steel fibre content. With the increase in fibre reinforcement, the crack width was found to be decreased. This can be imparted to the improved tensile strength of the beam with the addition of the steel fibres.

Fig -4: Flexural failure of M302D0.25

Fig -5: Flexural failure of M302D0.5

Fig -6: Flexural failure of M302D0.75

Fig -7: Flexural failure of M302D1

4. CONCLUSION

Following conclusions are drawn based on the results obtained from experiment.

i. The ultimate loads for all the steel fibre reinforced beams were greater than the M30 grade control beam.
ii. The ultimate load was found to be increasing with the increase in the steel fibre reinforcement up to an optimum value.
iii. The optimum value of ultimate load was obtained at 0.75% steel fibre content for concrete beams reinforced with steel fibres.
iv. In comparison with the control beam, the ultimate load was found to be increased by 26.78% for the steel fibre reinforced beam at the optimum fibre reinforcement.
v. After the optimum fibre content, the ultimate load decreased which can be attributed to the 'over-reinforced' behaviour associated with RC design where too much reinforcement leads to a reduction in strength.

REFERENCES

[1] Alan Richardson and Marcus Heather, "Improving the Performance of Concrete Using 3D Fibres", Structures and Buildings, Vol. 167, Issue SB9, 2013, pp. 101 – 109.

[2] Ali A. Abbas, Sharifah M. Syed Mohsin, Demetrios M. Cotsovos and Ana M. Ruiz-Teran, "Shear behaviour of steel-fibre reinforced concrete simply supported beams", Elsevier, Construction and Building Materials, Vol. 43, 2013, pp. 544–558.

[3] Amit Rai and Dr. Joshi Y. P., "Applications and Properties of Fibre Reinforced Concrete", International Journal of Engineering Research and Applications, Vol. 4, Issue 5, 2014, pp. 123-131.

[4] A. M. Shende, A. M. Pande and M. Gulfam Pathan, "Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade", International Refereed Journal of Engineering and Science (IRJES), Vol. 01, Issue 1, 2012, pp. 43-48.

[5] HaiLong Zhang and ChangChun Pei, "The Study on Mechanical Properties of Cement Mortar With Different Types of Steel Fibers", International Conference on Mechatronics, Electronic, Industrial and Control Engineering, 2015, pp. 164-167.

[6] Halit Cenan Mertol, Eray Baran and Hussain Jibril Bello, "Flexural Behavior of Lightly and Heavily Reinforced Steel Fiber Concrete Beams", Elsevier, Construction and Building Materials, Vol. 98, 2015, pp. 185–193.

[7] K. Srinivasa Rao, Rakesh kumar S. and Laxmi Narayana A., "Comparison of Performance of Standard Concrete and Fibre Reinforced Standard Concrete Exposed to Elevated Temperatures", American Journal of Engineering Research (AJER) Vol. 02, Issue 3, 2013, pp. 20-26.

[8] Milind V. Mohod, "Performance of Steel Fiber Reinforced Concrete", International Journal of Engineering and Science, Vol. 01, Issue 12, 2012, pp. 01-04.

[9] S. A. Mahadik, S. K. Kamane, A. C. Lande, "Effect of Steel Fibers on Compressive and Flexural Strength of Concrete", International Journal of Advanced Structures and Geotechnical Engineering, Vol. 03, No. 04, October 2014, pp. 388-392.

[10] Sreeja M. D., "Behaviour of Steel Fibre Reinforced Concrete Beam under Cyclic Loading", IOSR Journal of Mechanical and Civil Engineering, Vol. 06, Issue 3, 2013, pp. 01-04.