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Characteristic Properties of Steel Fibre Reinforced Concrete with Varying Percentages of Fibre

KEYWORDS: steel fibres, microcracks, compressive strength, tensile strength, flexural strength.

Dr Deepa A Sinha

Ph. D. Structural Engg, Associate Professor, Structural Engineering Dept, BVM Engineering College, Vallabh Vidyanagar, Anand, Gujarat, India.PIN-388120.

ABSTRACT *In this work the strength characteristics of steel fibre reinforced concrete with varying percentages of fibres is found and hence arrived at optimum percentage of steel fibres. M30 grade concrete as per IS: 10262-2009 was designed which yielded a proportion of 1:1.86: 2.41 with a w/c ratio of 0.45. The steel fibres were added at the rate of 0.5%, 0.75%, 1.0%, 1.25%, 1.50%, 1.75%, and 2.0% by volume fraction. Based on the compressive strength and tensile strength it is concluded that the optimum percentage of steel fibre to be added in the concrete mix is 1% by volume fraction.*

Introduction

Plain concrete has two major deficiencies; a low tensile strength and a low strain at fracture. The tensile strength of concrete is very low because plain concrete normally contains numerous microcracks. It is the rapid propagation of these microcracks under applied stress that is responsible for the low tensile strength of the material. These deficiencies have lead to considerable research aimed at developing new approaches to modifying the brittle properties of concrete. Current research has developed a new concept to increase the concrete ductility and its energy absorption capacity, as well as to improve overall durability. This new generation technology utilizes discrete steel or synthetic fibres from 19 to 64mm in length. The fibres are randomly dispersed throughout the concrete matrix providing for better distribution of both internal and external stresses by using a three dimensional reinforcing network. [1,2]

General requirements for the fibres used as temperature/ moisture, shrinkage reinforcement include: high tensile strength, high bond strength (typically mechanical) and ease to incorporation into the matrix to ensure optimum distribution. The primary role of the fibres in hardened concrete at low volume is to modify the cracking mechanism. By modifying the cracking mechanism, the macro-cracking becomes microcracking. The cracks are smaller in width; thus reducing the permeability of concrete and the ultimate cracking strain of the concrete is enhanced. Unreinforced concrete will separate at a crack, reducing the load carrying ability to zero across the crack. The fibres are capable of carrying a load across the crack, if all of the characteristics listed above are met by the fibres. Fibres reinforced concrete specimens, unlike plain concrete specimens which fail at the point of ultimate flexural strength or the first crack, do not fail immediately after the initiation of the first crack. After first crack, the load is transferred from the concrete matrix to the fibres.

Although every type of fibre has been tried out in cement and concrete, not all of them can be effectively and economically used. Each type of fibre has its own characteristic properties and limitations. Currently steel, glass, polymeric and carbon fibres are commonly used and natural fibres, such as bamboo, jute, asbestos cotton etc are of limited use. These various available fibres are classified into metallic fibres and non-metallic fibres. [2,3]

Materials and Methodology

In this paper, the main objective of this study is to find out the strength characteristics of steel fibre reinforced concrete with varying percentages of fibres and hence to arrive at optimum percentage of steel fibres. In the experimentation53 grade OPC was used in the experimentation. Coarse aggregates of 12mm and down size having a specific gravity of 2.74 and locally available sand with a specific gravity of 2.67 and falling in Zone-II were used. Steel fibers of 30 mm length and 0.7 thicknesses with corrugated shape which gave an aspect ratio of 42 were used. The mix design was carried out for M30 grade concrete as per IS: 10262-2009(4) which yielded a proportion of 1:1.86: 2.41 with a w/c ratio of 0.45. The dosage of super plasticizer used was 0.78% (by weight of cement). The steel fibres were added at the rate of 0.5%, 0.75%, 1.0%, 1.25%, 1.50%, 1.75%, and 2.0% by volume fraction. The cement, sand and coarse aggregates were weighed according to the proportion of 1:1.86: 2.41 and dry mixed. The required amount of water was added to this dry mix and intimately mixed. The calculated quantity of superplasticizer was now added and mixed thoroughly. After this, different percentage of steel fibers (0.5% upto 2%) by volume was added to the mix and the entire concrete was agitated thoroughly to get a homogeneous mix. Then the mix was placed layer by layer in the moulds to cast the specimens. The specimens were prepared both by hand compaction as well by imparting vibrations through vibrating table. The specimens were finished smooth and kept under wet gunny bags for 24 hours after which they were cured for 7 days and 28 days by immersing them in water. Compressive strength and tensile strength is found on 150 x 150 x 150 mm standard cubes and 150 x 300 mm standard cylinders as per IS: 516-1969 (6) and the flexural strength test is carried out on 100x100x500 mm standard beams as per IS 9399:1979(5) Specification for apparatus for flexural testing of concrete".

Experimental results

Overall results of compressive strength

Following table 1 gives the overall results of compressive strength of concrete with different percentage of steel fibres. Also it gives the percentage increase or decrease of compressive strength w.r.t. reference mix. The variation of the compressive strength is depicted in the form of graph as shown in fig. 1

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Table no. 1 Overall result of compressive strength

Percentage of steel fibres added	7 days strength		28 days strength	
	Average compressive strength (MPa)	Percentage increase or decrease of compresssive strength w.r.t. ref. mix	Average compressive strength (MPa)	Percentage increase or decrease of compresssive strength w.r.t. ref. mix
0%	25.63		40.30	
0.50%	26.52	3	40.80	1
0.75%	27.70	8	41.50	3
1.00%	28.44	11	42.49	5
1.25%	26.93	5	41.85	4
1.50%	26.52	3	40.61	1
1.75%	26.40	3	39.11	-3
2.00%	26.09	2	38.07	-6

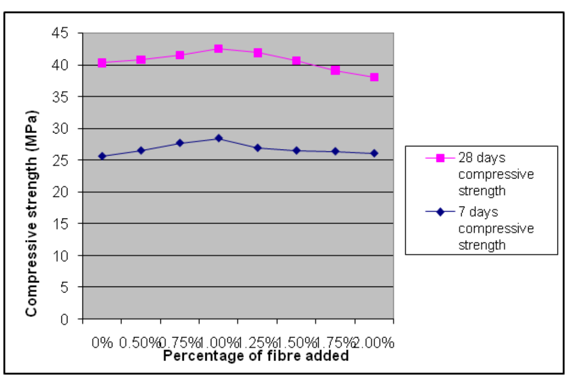

Figure 1 Variation of compressive strength

Overall results of tensile strength :
Following table 2 gives the overall results of tensile strength of concrete with different percentage of steel fibres. Also it gives the percentage increase or decrease of tensile strength w.r.t. reference mix. The variation of the tensile strength is depicted in the form of graph as shown in fig. 2

Table 2 Overall result of tensile strength

Percentage of steel fibres added	7 days strength		28 days strength	
	Average tensile strength (MPa)	Percentage increase or decrease of tensile strength w.r.t. ref. mix	Average tensile strength (MPa)	Percentage increase or decrease of tensile strength w.r.t. ref. mix
0%	2.50	-	3.54	-
0.50%	2.83	13	3.82	8
0.75%	3.11	24	4.10	16
1.00%	3.54	42	4.67	32
1.25%	3.44	38	4.39	24
1.50%	3.26	30	4.10	16
1.75%	3.11	24	3.96	12
2.00%	2.97	19	3.68	4

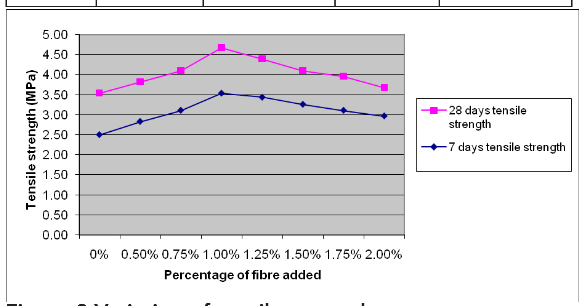

Figure 2 Variation of tensile strength

Overall results of flexural strength :
Following table 3 gives the overall results of flexural strength of concrete with different percentage of steel fibres. Also it gives the percentage increase or decrease of flexural strength w.r.t. reference mix. The variation of the flexural strength is depicted in the form of graph as shown in fig. 3

Table 3 Overall results of flexural strength

Percentage of steel fibres added	7 days strength		28 days strength	
	Average flexural strength (MPa)	Percentage increase or decrease of flex-ural strength w.r.t. ref. mix	Average flexural strength (MPa)	Percentage increase or decrease of flex-ural strength w.r.t. ref. mix
0%	3.94	-	4.31	-
0.50%	4.06	3	4.74	10
0.75%	4.09	4	5.01	16
1.00%	4.13	5	5.23	21
1.25%	5.20	32	5.76	34
1.50%	5.35	36	6.10	42
1.75%	5.65	43	6.50	51
2.00%	5.69	44	6.91	60

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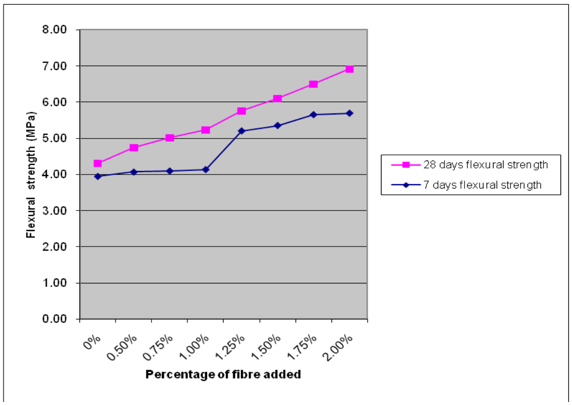

Fig.3 Variation of flexural strength

Observations and discussions

Fig. 1 shows variation of compressive strength after 7 days and 28 days of curing. It is found that with the increase in fibre content up to 1%, the strength is increasing i.e. compressive strength is found to be higher at 1% fibre content and with further increase in fibre content the strength is decreasing. It is found that 1% addition of steel fibres result in 11% and 6% increase in 7 days and 28 days compressive strength respectively. Higher percentage addition of fibres substantially decreases the compressive strength as can be seen from table 1.

This may be due to the fact that the addition of higher percentage of steel fibres may lead to congestion of fibres causing balling effect and improper bonding with concrete.

Similar trends are observed for tensile strength. It is found that 1% addition of steel fibres result in 42% and 32% increase in 7 days and 28 days tensile strength respectively as seen from table 2. Higher percentage addition of fibres substantially decreases the tensile strength as can be seen from figure 2.

This may be due to the fact that the presence of steel fibres delays the development of fine cracks and their prorogation. Also the presence of fibres reduces the widening of cracks, thus resulting in improvement in the load carrying capacity of the composite. However there is a limit up to which the fibre content can due to the balling effect and improper bonding with concrete.

Thus it can be concluded that addition of 1% steel fibres results in higher tensile strength and use of more than 1% steel fibres will bring down the tensile strength.

It is found that the flexural strength goes on increasing as the percentage of steel fibres in it increases. When 2% steel fibres are added the flexural strength is found to increase by 44% and 60% for 7 days curing and 28 days curing periods as seen from table 3.

This is due to the fact that as the amount of fibre in the composite increases it greatly helps in curbing the formation, propogation and widening of cracks more effectively thus resulting in increase of flexural strength. The ductile behavior of the beam was observed due to the effective bridging action of fibers across the cracks.

Thus it is seen that with 1% fibre addition the compressive and the tensile strength increases, but as the fibre is further increased the compressive and the tensile strength decreases, whereas the flexural strength keeps increasing upto 2% fibre addition.

Conclusions:

Following conclusions may be drawn based on the observations.

- Addition of 1% steel fibres result in higher compressive strength and use of more than 1% steel fibres will bring down the compressive strength.
- Addition of 1% steel fibres result in higher tensile strength and use of more than 1% steel fibres will bring down the tensile strength.
- Flexural strength is found to increase as the percentage of steel fibres in it increases.
- Based on the compressive strength and tensile strength it can be concluded that the optimum percentage of steel fibre to be added in the concrete mix is 1% by volume fraction.

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