International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-5,May 2016
ISSN: 2395-3470
www.ijseas.com

An Experimental Approach to Investigate Effect of Steel Fibers on Tensile and Flexural Strength of Flyash Concrete

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Abstract

Plain concrete possesses very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in concrete and its poor tensile strength is due to propagation of such micro cracks. Fibres when added in certain percentage in the concrete improve the strain properties well as crack resistance, ductility, as flexure strength and toughness. The present paper outlines the experimental investigation to study the effects of replacement of cement (by fly ash) of steel fibre. Beams and cylinders of size (500 x100x100) mm and (D=150mm, L=300mm) respectively were casted. Cement is replaced with three percentages (20%, 30%, 40%) of fly ash. NOVOCON® URW1050 STEEL FIBRE of diameter 1mm, having an aspect ratio 50 and length 50mm was employed in percentages, varying from 1.0% to 2.0% by weight of concrete and the properties of this SFRC (Steel fiber reinforced concrete) like flexure strength and tensile strength were studied. The result of this study confirmed that the addition of steel fiber & fly ash improved the flexural & tensile strength of concrete.

Keywords: *Concrete, Steel fibre, Fy ash, Flexural & Tensile strength, Steel fiber Reinforced Concrete(SFRC)*

1. Introduction

Concrete is a composite material composed of coarse aggregate bonded together with cement which hardens over time. Concrete is very strong in compression but weak in tension. Concrete is relatively brittle material when subjected to normal stress and impact loads. The tensile strength of concrete is less due to widening of micro-cracks existing in concrete subjected to tensile stress. Due to presence of steel fibre, the micro- cracks are arrested. The introduction of steel fibres is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength. Fly ash is fine powder waste material produced from many thermal power plants. The disposal of fly ash is one of the major issues for environmentalists as dumping fly ash as a waste material may cause severe environmental problem. Therefore, the utilization of fly ash as a low cost mineral admixture in concrete instead of dumping it can have great beneficial effects. It can be used particularly in mass concrete applications where main emphasis is to control thermal expansion due to heat of hydration of cement paste and it also helps in reducing thermal and shrinkage cracking of concrete at early ages. Steel Fiber Fly Ash concrete (SFFAC) is mixtures of cement concrete containing short discrete, uniformly dispersed and randomly oriented suitable fibrous material which increases its structural integrity. The amount of steel fiber added to concrete mix is measured as percentage of the total weight of composites. The composite matrix that is obtained by combining Cement, Fly ash, Aggregates and Steel fiber is known as “Fly Ash Steel Fiber Concrete”. The fiber in the cement fly ash based matrix acts as crack arresters, which restrict the growth of micro cracks and prevent these from enlarging under load.

2. Experimental Details

The experimental programme consisted of casting and testing of 40 beam specimens [100x100x500mm] with 9 different types of concrete mixes by varying percentage of steel fibres and fly ash and 20 cylinder specimens [150x300mm] with 9 different types of concrete mixes by varying percentage of steel fibres and fly ash. The specimens have been tested for flexural strength and tensile strength respectively.

2.1 Material Used

Cement, fine aggregates, coarse aggregates, steel fibres and water used throughout the investigation, had some of the following properties:

Table 1: Mix Design for M25 Grade Concrete

Target Mean Strength	**31.60 Mpa**
Cement Content	395.00 Kg/m^3
Fine Aggregate Content	636.65 Kg/m^3
Coarse Aggregate Content	1182.35 Kg/m^3
Water Content	184.00 Kg/m^3
Water Cement Ratio (w/c ratio)	0.47

Table 2: Mix Design For M30 Grade Concrete

Target Mean Strength	**38.25 Mpa**
Cement Content	413.30 Kg/m^3
Fine Aggregate Content	630.00 Kg/m^3
Coarse Aggregate Content	1170.00 Kg/m^3
Water Content	186.00 Kg/m^3
Water Cement Ratio (w/c ratio)	0.45

3. Mixing, Casting and Curing

3.1 Mixing

The concrete mixture has been prepared by hand mixing. After weighting cement, fly ash, fine aggregate and coarse aggregate, these have been mixed dry to get uniform color. In this mixture, the required quantities of fibre in percentage have been added. Fibres have been mixed up by sprinkling them with the hand while mixing in such manner that fibres are distributed uniformly throughout. Then the water has been added carefully without loss of water during mixing.

3.2 Casting

The moulds have been filled concrete with 0%, 1.0%, 1.5% and 2.0% fibres & Fly Ash at (0%, 20%, 30% & 40%) by weight of cement. For compacting fibre reinforced concrete table vibrator is the most suitable as it gives the advantages of fibres acquiring a tendency to align them in a plane perpendicular to the direction of vibration. So, by using table vibrator, the vibration has been given to the beams and cylindrical moulds. The top surface of the specimen have been finished and leveled.

4. Concrete Tests

4.1 Fresh Concrete Test

The test which is carried out to determine the workability of concrete is Slump test. It is performed on Fresh Concrete. Workability is carried out by Slump Test as per IS. 1199-1959 on Fiber Reinforced Concrete. The test results have been tabulated in Table (3), which includes the quantity of the material for the mixture, the value of Slump Test for **(**M25 Grade for 20% Fly Ash with 1% Steel Fiber**)** & **(**M30 Grade for 20% Fly Ash with 1% Steel Fiber**)**.

Table 3: Workability of Steel Fiber Reinforced Fly Ash Concrete

Grade of Conc	M25	M30
Mix Type (F.A %) & (S.F %)	20% &1%	20% &1%
W/C Ratio	0.47	0.45
Slump Value (mm)	34	41

5. Hardened Concrete Tests

5.1 Flexural Strength of Beam

The flexural strength of beam with various types of fiber reinforced concrete has been measured by flexural test as per IS: 516-1959. The flexural strength for steel fiber reinforced concrete has been summarized in Table 4 & 5. Graphs are plotted between Steel fiber percentages vs. Flexural strength as shown in figs. 4.1, 4.2, 4.3, 4.4, 4.5, 4.6.

Fig: 1 Testing of Flexural Strength of Beam (Specimen before test)

Fig: 2 Testing of Flexural Strength of Beam (Specimen after test)

Table 4: Flexural Strength of M25 Grade SFRC in N/mm^2 at 7 & 28 days curing period

Days	Control Mix	20% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
7	12.42	12.75	13.02	14.34
28	15.52	**16.33**	16.06	16.20

Table 5: Flexural Strength of M25 Grade SFRC in N/mm^2 at 7 & 28 days curing period

Days	Control Mix	30% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
7	12.42	14.44	14.78	15.05
28	15.52	16.40	16.26	**16.53**

Table 6: Flexural Strength of M25 Grade SFRC in N/mm^2 at 7 & 28 days curing period with 40 % replacement by Flyash

Days	Control Mix	40% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
7	12.42	14.04	14.24	14.37
28	15.52	**15.93**	15.79	16.13

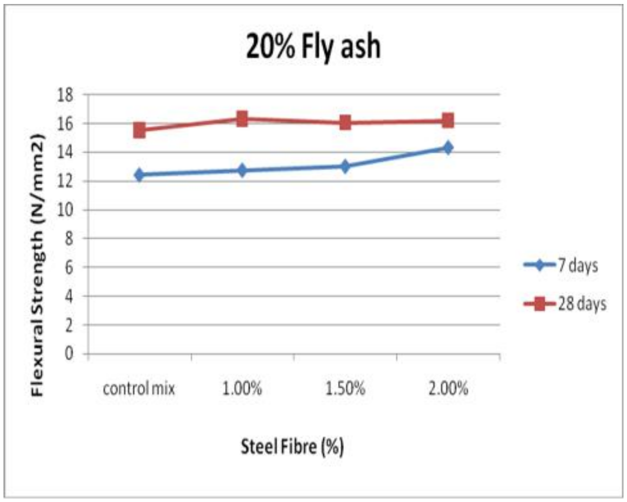

Figure 3: Flexural Strength of SFRC(20% Flyash) & Control Mix

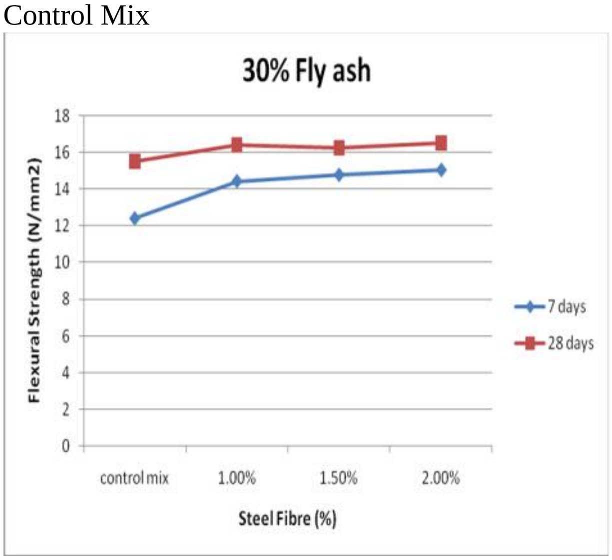

Figure 4: Flexural Strength of SFRC(30% Flyash) & Control Mix.

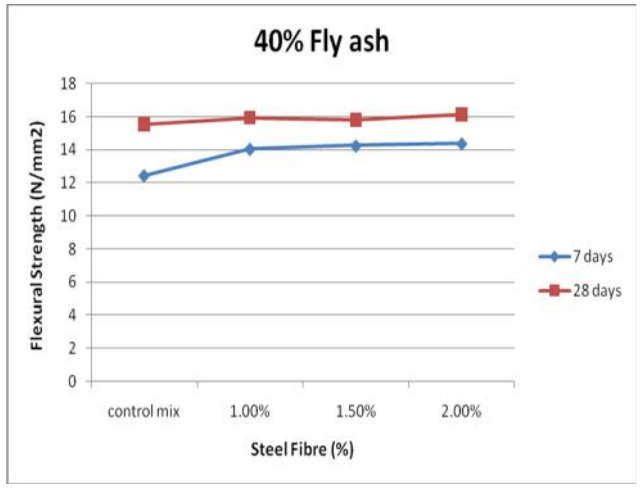

Figure 5: Flexural Strength of SFRC (40% Flyash) & Control Mix

Table 7: Flexural Strength (N/mm^2) of M30 Concrete & SFRC at 7 & 28 days curing period with 20 % replacement by Flyash

Days	Control Mix	20% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
7	14.17	14.37	14.04	14.47
28	16.20	16.47	16.77	**16.94**

Table 8: Flexural Strength (N/mm^2) of M30 Grade SFRC at 7 & 28 days curing period with 30 % replacement by Flyash

Days	Control Mix	30% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
7	14.17	14.19	14.24	14.44
28	16.20	16.87	17.34	**17.48**

International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-5,May 2016
ISSN: 2395-3470
www.ijseas.com

Table 9: Flexural Strength (N/mm^2) of M30 Grade SFRC with 40% Flyash after 7 & 28 days of curing.

Days	Control Mix	40% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
7	14.17	14.61	13.97	14.10
28	16.20	15.99	**16.44**	15.66

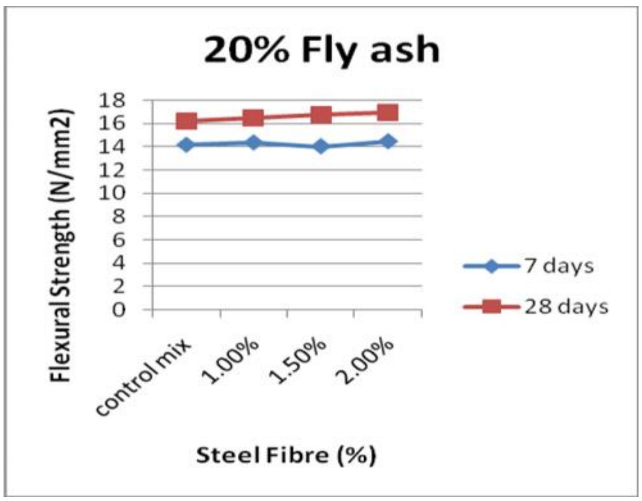

Figure 6: Flexural Strength of SFRC at 20% replacement by Flyash

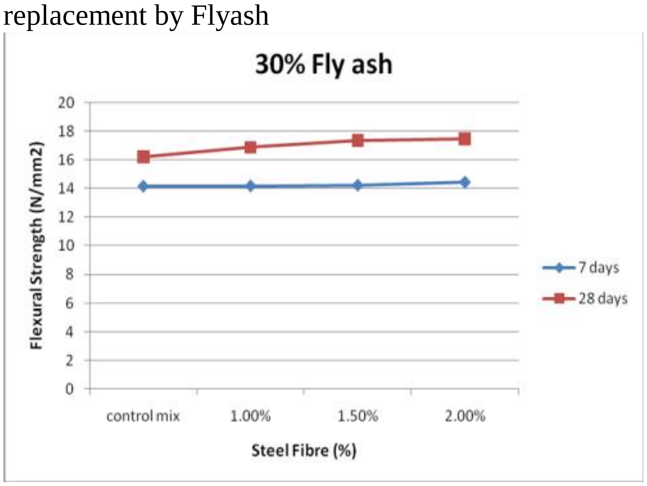

Figure 7: Flexural Strength of SFRC at 30% replacement by Flyash

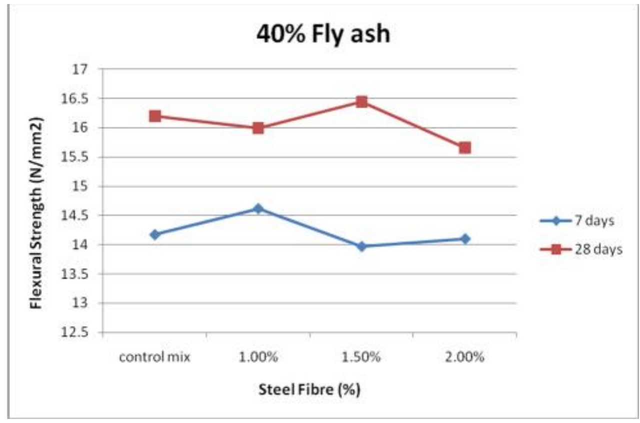

Figure 8: Flexural Strength of SFRC at 40% replacement by Flyash.

4.3 Split Tensile Strength

The tensile strength of cylinder specimen for various types of Steel fiber reinforced concrete has been measured by Split Tensile test as per IS: 516-1959. The tensile strength for steel fiber reinforced concrete has been summarized in Table 7 & 8.

Fig 8: Specimen before Split Tensile Strength Test

Table 10: Split Tensile Strength (N/mm^2) M25

Days	Control Mix N/mm^2	20% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
28	2.69	**3.11**	2.54	2.28

Table 11: Tensile Strength (N/mm^2) of with replacement of cement by 30% Flyash.M25

Days	Control Mix (N/mm^2)	30% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
28	2.69	2.73	2.32	2.49

Table 12: Tensile Strength (N/mm^2) of M25 & SFRC with replacement of cement by 30% Flyash.

Days	Control Mix N/mm^2	40% fly ash		
		1% steel fiber	1.5% steel fiber	2% steel fiber
28	2.69	1.91	2.36	2.03

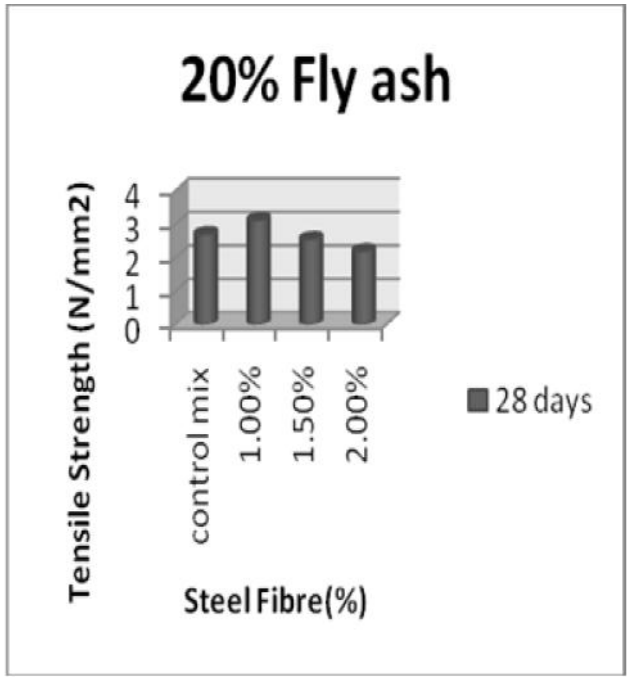

Fig 9: Tensile Strength of SFRC with 20% Flyash.

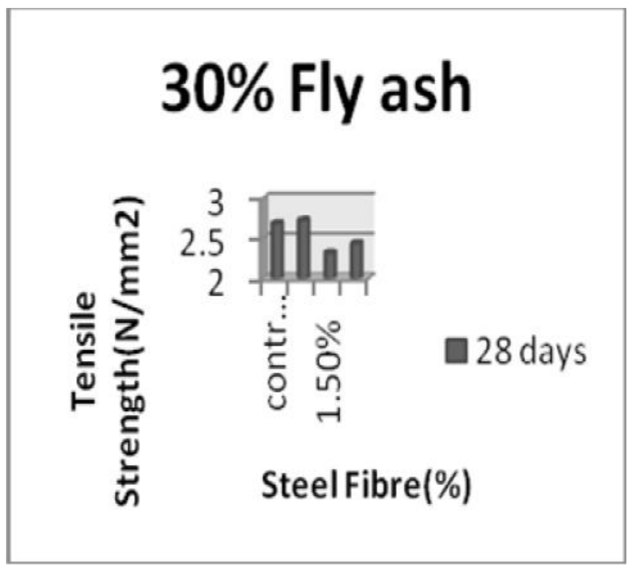

Fig 9: Tensile Strength of SFRC with 30% Flyash.

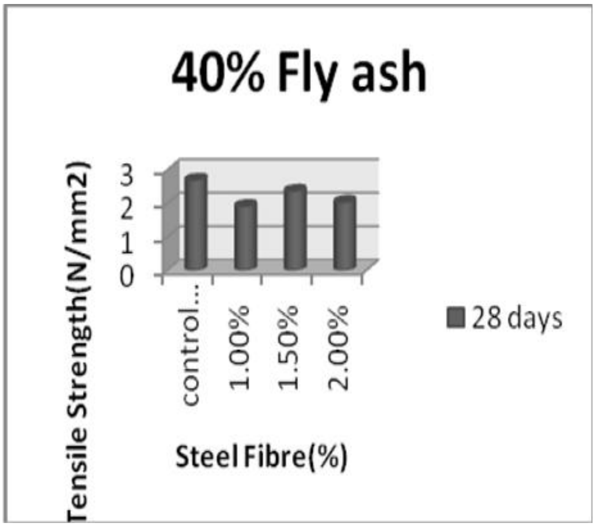

Fig 10: Tensile Strength of SFRC with 40% Flyash.

Table 13: Tensile Strength (N/mm^2) of M30 & SFRC with 40% Flyash after 7 & 28 days of curing

Mix Proportion	Steel fibers	28days Tensile strength(N/mm^2)
Control Mix		2.84
20% fly ash	1%	**2.97**
	1.5%	2.88
	2.0%	2.61
30% fly ash	1%	3.08
	1.5%	**3.19**
	2.0%	2.57
40% fly ash	1%	2.83
	1.5%	**3.48**
	2.0%	2.23

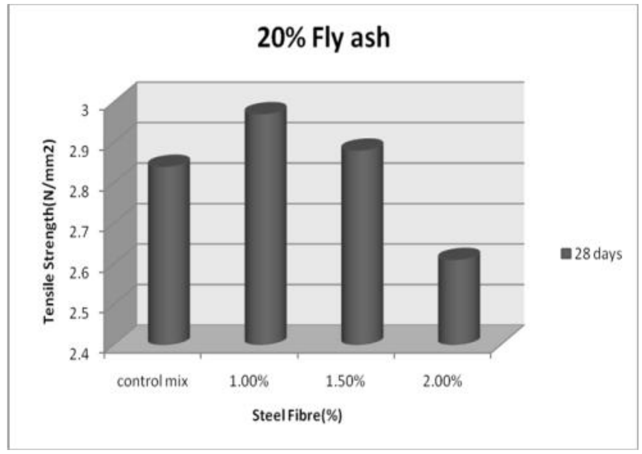

Fig 11: Tensile Strength of SFRC with 20% Flyash

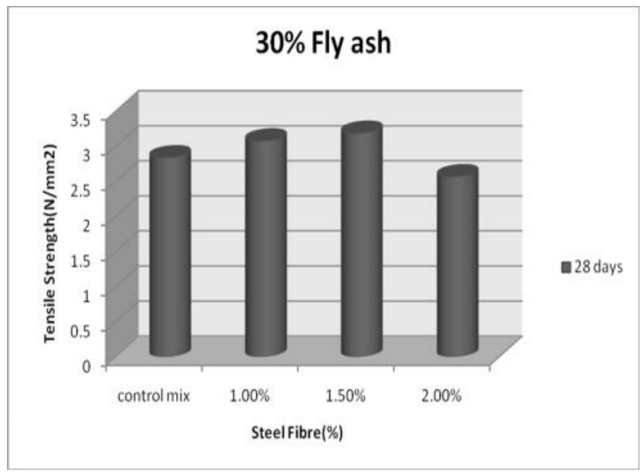

Fig 12: Tensile Strength of SFRC with 30% Flyash

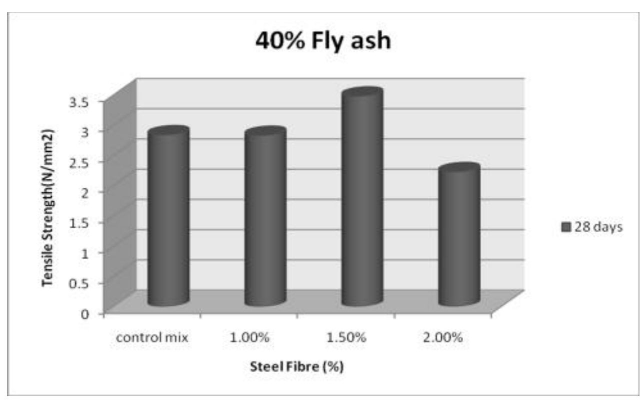

Fig 12: Tensile Strength of SFRC with 40% Flyash

6. Conclusions

1. The optimum flexural strength obtained is 16.42 N/mm^2 with addition of 2% steel fibers and 30% replacement of cement by flyash.(M25)
2. For M30, optimum flexural strength obtained is 17.48 N/mm^2 with addition of 2% steel fibers and 30% replacement of cement by flyash
3. With the addition of 2% S.F & replacement of cement by 30% Fly ash, the gain in flexural strength is 7.90%.
4. The split tensile strength of control mix of M30 Grade at 28 days is 2.84N/mm^2.
5. With the addition of 1% S.F & replacement of cement by 20% Fly ash, the gain in tensile strength is 4.57%.
6. The split tensile strength of control mix of M25 Grade at 28 days is 2.69N/mm^2.
7. The optimum split tensile strength obtained is 3.48N/mm^2 at 40 % replacement of cement and 1.5% addition of steel fibers.

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