



BEHAVIOR OF STEEL FIBER REINFORCED CONCRETE BEAM USING FLY ASH

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ABSTRACT

This paper focuses on investigating the flexural behaviour of Fly ash reinforced concrete beams with steel fibers 40% of cement was replaced with fly ash. Experimental investigation included testing of three reinforced fly ash concrete beams with steel fibers and three beams without steel fibers. Compressive strength of fly ash concrete with steel fibers were also found out. Data presented include load-deflection characteristics, cracking behavior, ductility and strain characteristics of reinforced fly ash concrete beams with steel fibers. There was 34.6% increase in load carrying capacity with the addition of fibers in the beam.

Key words: Reinforced fly ash concrete beams, steel fibers, compressive strength, ductility.

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1. INTRODUCTION

The ability of concrete reinforced with steel fiber to resist cracks and its propagation is a very desirable property. Fiber composites displays increased tensile strength, both at first crack and at ultimate by virtue of the fibers holding together the matrix. Thus the ductile nature of fiber composite beams would increase its energy absorption characteristics and its ability to withstand dynamic and shock loads.

1.2. Past Study

Kavade and Warudkar (2017) concluded that Steel fiber reinforced concrete could be used to improve static and dynamic tensile strength, energy absorbing capacity and better fatigue. **Ramkripal Singh et al (2016)** found that the optimum flexural strength is obtained for M25 and M30 concrete with addition of 2% steel fibers and 30% replacement of cement

by fly ash. **Hussain and Arfath (2015)** observed that the load carrying capacity of fly ash concrete beams with steel fibers was more than the coconut fibers.

Chandu and Supriya (2015) found that modulus of rupture of steel fiber reinforced concrete was more as compared to polypropylene fiber reinforced concrete. Incorporation of steel fibers and silica fume showed superior crack and strength behavior (**Harle and Tantarale (2014)**). **Shweta and Kavilkar (2014)** found that addition of binding wire as a steel fiber to concrete, led to a decrease in compressive strength but increased flexural and tensile strength. (**Sama et al.**). **Madheswaran and Singh et al (2014)** found that the slump of silica fume concrete with steel fiber decreased with increase in silica fume and steel fiber. **Rai and Joshi (2014)** reported increased ductility and load carrying capacity with marked decrease in final cracking in concrete reinforced with fibres.

Challoob and Srivastava (2013) concluded that concrete mixtures with the addition of steel fibers showed significant increase in their bond strength. Improvement in bond strength for all concrete mixtures had been observed as the percentages of fibers volume fraction increased. **Alani and Aboutalebi (2013)** concluded that the compressive strength and tensile strength of concrete are almost same for both synthetic and steel fibers, where as steel fibers showed more ductility. **Khadake and Konapure (2012)** found that the stiffness of concrete increased with the addition of steel fibers and fly ash **Vairagade and Kene et al (2012)** concluded that with low volume fraction of fiber result nearly minor effect on compressive strength of fiber reinforced concrete. **Vairagade and Kene (2012)** reviewed steel fiber concrete had good absorb energy during deformation (swami et al.). Here, an attempt is made to study the flexural behavior of fly ash concrete beams reinforced with steel fibers.

2. EXPERIMENTAL PROGRAM

2.1. Preliminary Tests

The preliminary tests were carried out on the materials and the data obtained was used to design the M25 concrete mix based on the Indian Standard Code-10262(2009). Table1. gives the details of the concrete mix. Ordinary Portland cement of 53 Grade is used in this research. 40% cement was replaced with class F fly ash. Steel fibers (Hooked end) of volume fraction 0.5%, 1%, 1.5%, and 2% were mixed with concrete along with 0.6% of super plasticizer (CONXL PCE- DM09). Fe 415 grade steel was used for the stirrups and longitudinal bars.

Table 1 Mix Ratios

Grade of Concrete	M25	M25	M25	M25
Fly ash Replacement %	0	0	40	40
Water- Cement ratio	0.49	0.49	0.49	0.49
Cement (kg/m ³)	331	331	198.6	198.6
Fly ash (kg/m ³)	0	0	132.4	132.4
Fine Aggregate (kg/ m ³)	769.01	769.01	752.39	752.39
Coarse Aggregate (kg/ m ³)	1201.764	1201.764	1175.78	1175.78
Super plasticizer (l/ m ³)	1.98	1.98	1.98	1.98
Water (kg/ m ³)	162.19	162.19	162.19	162.19
Mix proportion	1:2:32:3.63	1:2:32:3.63	1:2.27:3.55	1:2.27:3.55

2.2. Experimental Investigation

2.2.1. Concrete Cubes and Prisms

A total of 105 cube specimens of size 150mm X 150mm X 150mm were cast and tested for its compressive strength. Nine specimens were control concrete (CC) and thirty six cubes were cast with steel fibers (CCS). Twelve cubes were cast with fly ash concrete (FC) and 48 specimens with fly ash and steel fibers(FCS).CC and CCS categories of specimens were tested at 7,14 and 28 days. FC and FCS series of specimens were tested at 7,14,28 and 56 days. The volume fraction of steel fibers used in the specimens were 0.5%, 1%, 1.5% and 2%.The compressive strength of cube test was done in Universal Testing Machine of 100T capacity as per IS 516:1959.

Flexural strength was determined by testing concrete prism of size 100mm X 100mm X 500mm as per IS 516:1959 with center point loading. Forty five specimens were cast, out of which three were control concrete (CC) and 12 specimens were with steel fibers (CCS). Nine prisms were cast with fly ash concrete (FC) and 24 specimens with fly ash and steel fibers (FCS).



Figure 1 Casted and tested specimens

2.2.2. Reinforced Concrete Beam

The test specimens were designed and detailed as per IS 456:2000. The beam cast had a cross section 150mm X 250mm spanning a length of 2500mm. Beams were cast using M25 grade concrete and Fe 415 steel is used for longitudinal reinforcement and stirrups. Six specimens were cast to study the behavior of Reinforced Concrete beams with steel fibers and fly ash under flexural loading. The details of test specimens are shown in Table 2. A volume fraction of 2% of steel fiber is added in the concrete beams and 40% fly ash is replaced with cement. 2 nos. of 12mm diameter and one 16mm dia. bars at bottom and 2 nos. of 10mm dia. bars were used as longitudinal reinforcement. 8mm dia. bars at 120mm c/c spacing were used as Stirrups.The reinforcement details are shown in figure2.

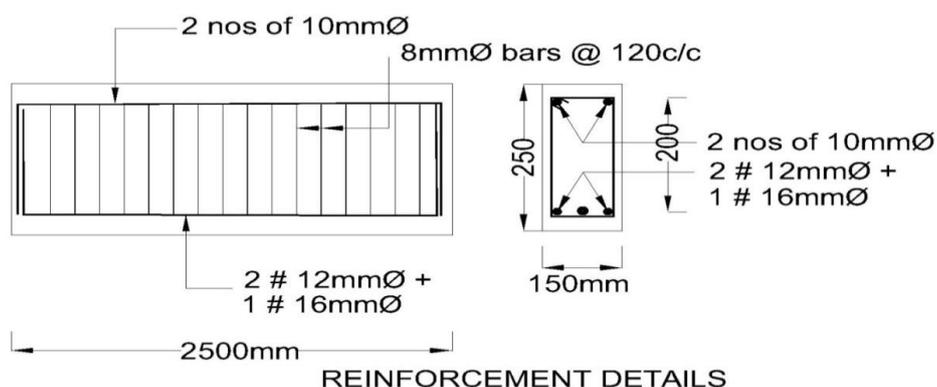


Figure 2 Reinforcement detail of beam specimen

Table 2 Details of test specimens

Sl.no	Specification	% of fly ash	% of steel fibers	No. of days
1	RC 0%-0%-28	0	0	28
2	RCS 0%-2%-28	0	2	28
3	RFC 40%-0%-28	40	0	28
4	RFCS 40%-2%-28	40	2	28
5	RFC 40%-0%-56	40	0	56
6	RFCS 40%-2%-56	40	2	56

RC and RCS denotes the RC beam without Steel fibers and with Steel fibers respectively.

RFC represents Reinforced Fly ash Concrete beams without Steel fibers and RFCS denotes Reinforced Fly ash concrete beams with 2% Steel fibers.

2.3. Test Set-up for Beams

The test set up consists of a vertical loading frame of 40T capacity. All the specimens were tested for flexural strength under two point loading in the vertical loading frame. The effective span of the beam was 2.3 m. Uniform rate of loading were applied at one-third distance from the supports at a uniform rate till the ultimate failure of the specimens. The deflections at midspan were measured and under the loading using Linear Voltage Displacement Transducers (LVDTs) as shown in Figure 3. Three strain gauges were fixed at the top, above and below the Neutral axis respectively. A computer captured readings from a data logger connected with strain gauges and LVDTs at every load intervals until failure of the specimens. The experimental set-up is shown in Figure.4

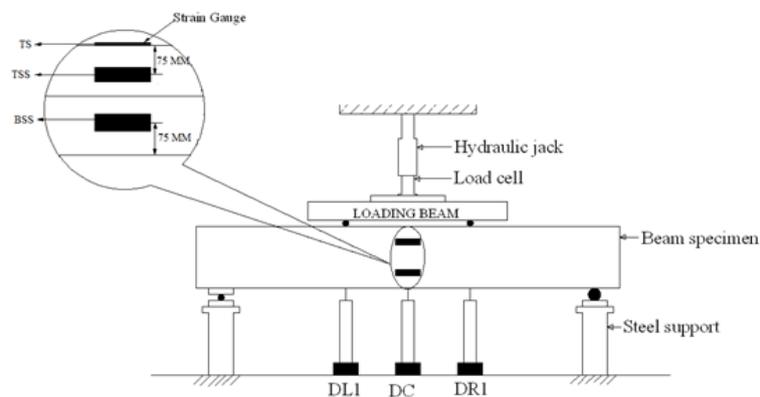
**Figure 3** Position of Strain gauges and LVDTs



Figure 4 Experimental set-up for the test specimens

3. TEST RESULTS AND DISCUSSION

3.1. Compressive Strength

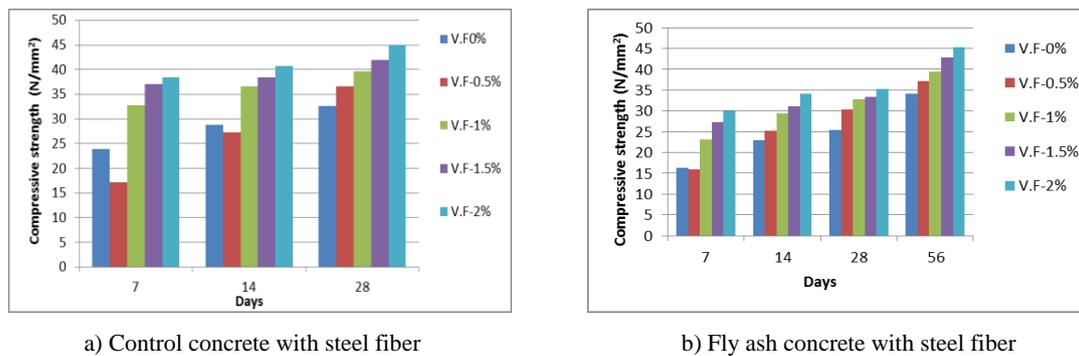


Figure 5 Compressive strength of specimens

The compressive strength of concrete cubes with and without fly ash with the addition of steel fibers is shown in Figure 5(a) and (b) respectively. From the test results, it is observed that 2% volume fraction of steel fibers gives maximum compressive strength for all test specimens. The compressive strength of concrete cube with 2% steel fiber increases by 38.30% with respect to the control concrete without steel fiber; When tested at 28 days. It is observed that the compressive strength of fly ash concrete with 2% steel fiber is increased by 33% with respect to control concrete when tested at 56 days.

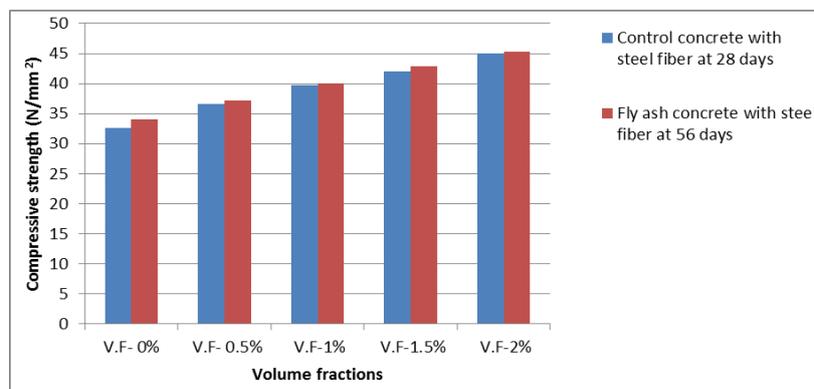


Figure 6 Comparison of compressive strength specimens

3.2. Flexural Strength

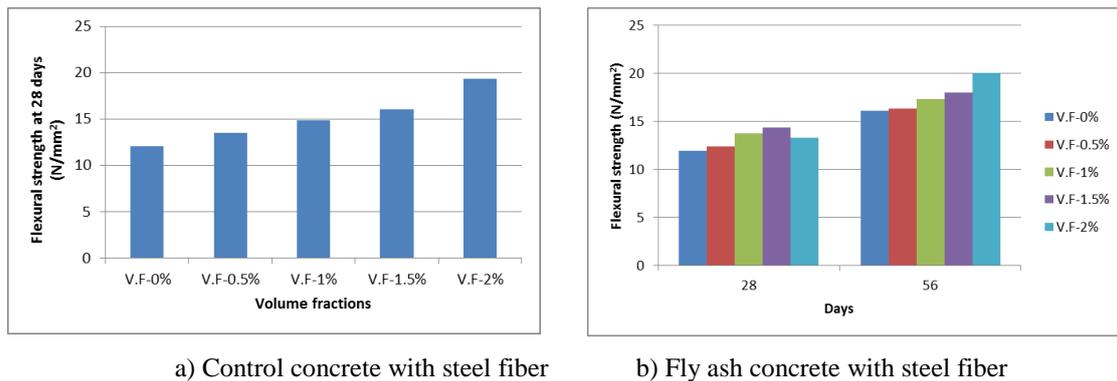


Figure 7 Flexural strength of specimens

The flexural strength of concrete prism without fly ash is increased by 60.98% with the addition of 2% steel fibers at 28 days when compared with the control concrete without steel fibers. The flexural strength of control concrete with fly ash is increased by 22.98 % with the addition of 2% steel fibers when tested at 28th day of control specimen of fly ash concrete. The test results are shown in the figure 7(a) and 7(b).

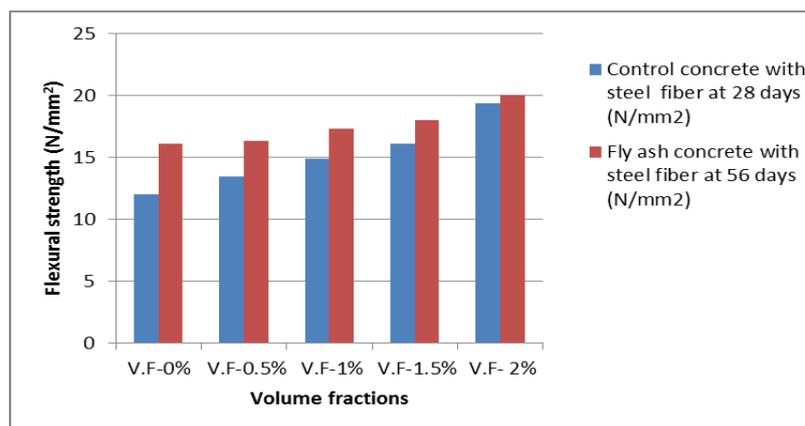


Figure 8 Comparison of Flexural strength specimens

The flexural strength of fly ash concrete with 2% steel fibers at 56 days is found to be increasing by 64.72% when compared with the conventional concrete without fly ash tested at 28 days. It is also observed that the flexural strength is maximum for FCS specimen with 2% steel fibers when tested at 56 days.

3.3. Crack Pattern

The crack pattern of the test specimens are shown in figure 9.

Behavior of Steel Fiber Reinforced Concrete Beam Using Fly Ash

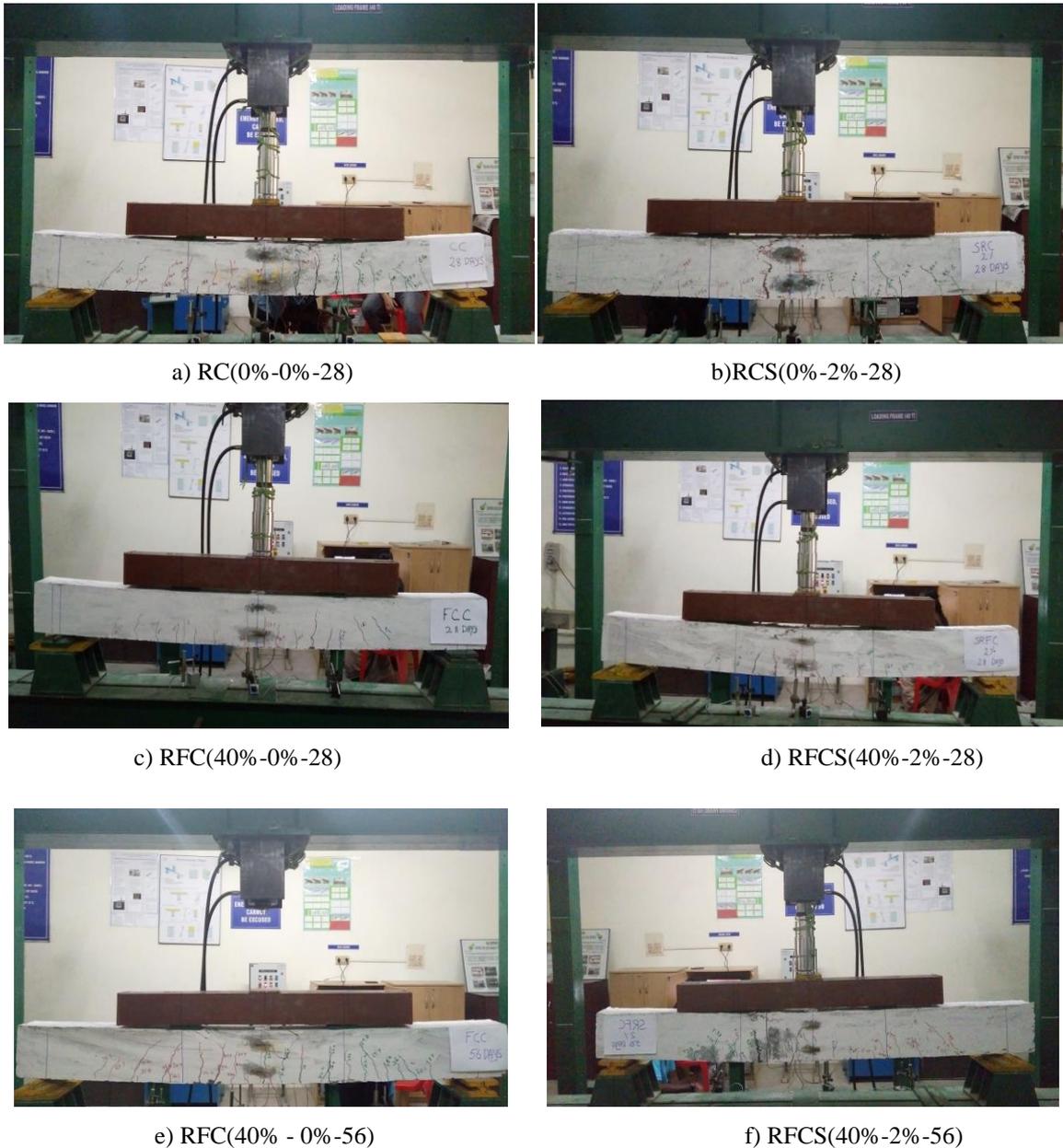
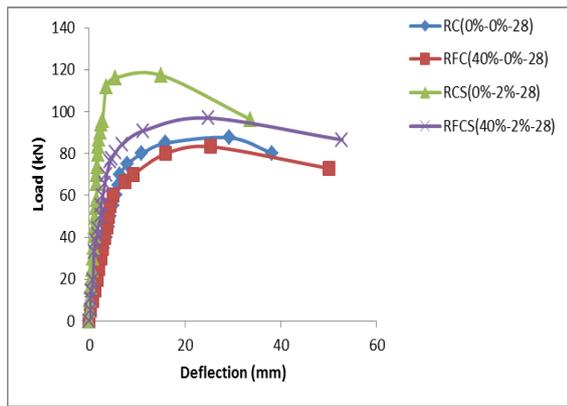


Figure 9 Failure pattern of the beam specimens

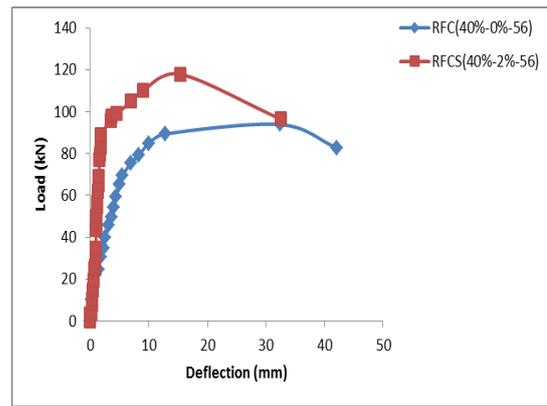
It is observed that all test specimen failed in flexure due to the flexural cracks developed at the centre of the beam.

3.4. Load-Deflection Curves

The ultimate load carrying capacity of the specimens RC(0%-0%-28), RCS(0%-2%-28), RFC(40%-0%-28), RFCS (40%-2%-28) are 87.6kN, 117.4kN, 83.3kN and 97kN with a deflection of 29.3mm, 16mm, 25.3mm and 24.8mm respectively when tested at 28th day. The ultimate load carrying capacity of the specimens RFC(40%-0%-56) and RFCS(40%-2%-56) are 93.9kN and 117.9.4kN with a deflection of 32.4mm and 15.4mm respectively when failed at 56th day.



a) Beam specimens at 28 Days

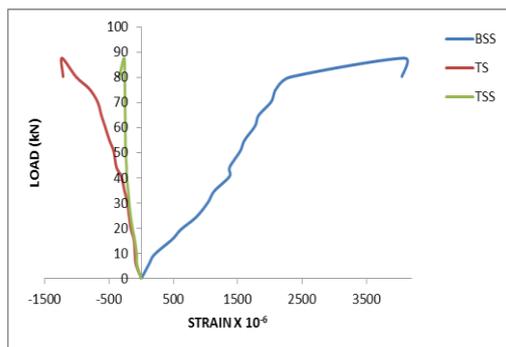


b) Beam specimens at 56 days

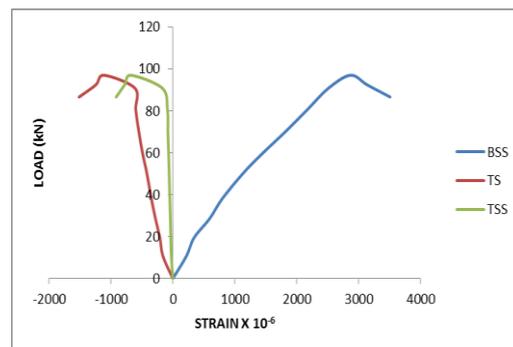
Figure 10 Load versus deflection curves of the test specimens

3.5. Load-Strain Behaviour

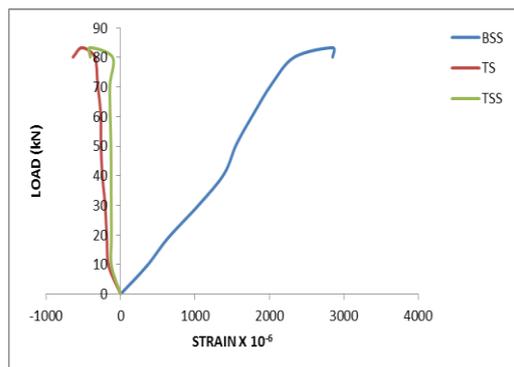
The strain at the top surface of the beam RC(0%-2%-28) is 1232×10^{-6} which is 90% higher than RC(0%-0%-28). For the beam with the reinforced fly ash concrete beam having 2% steel fibers shows an increase in strain of 95% with respect to fly ash concrete beam without steel fibers.



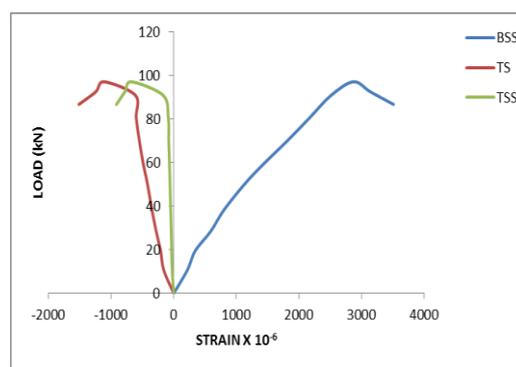
(a) RC(0%-0%-28)



(b) RCS(0%-2%-28)



(c) RFC (40%-0%-28)



(d) RFCS (40%-2%-28)

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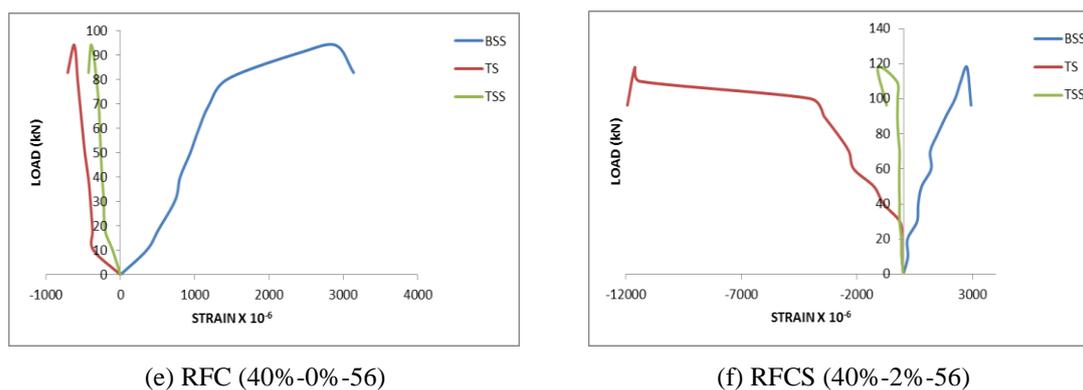


Figure 11 Load-Strain Curves of the tested specimens

3.6. Ductility

Ductility is the ability of a structure to undergo deformation without losing its load carrying capacity. The ductility factor was calculated for all the tested specimens from load-deflection curves shown in Figure 10. It is the ratio of ultimate deflection to yield deflection. Yield deflection was taken as the deflection corresponds to 80% of the ultimate load. It is observed from Table 4, that the specimen with 40% Fly ash and 2% Steel fiber has the highest ductility.

Table 4 Ductility in different beam specimens

Sl.no	Beam Specimens	Yield displacement (mm)	Ultimate displacement (mm)	Ductility factor
1	RC(0%-0%-28)	8.1	29.3	3.62
2	RFC (40%-0%-28)	9.5	24.3	2.5
3	RCS(0%-2%-28)	3.5	15	4.3
4	RFCS(40%-2%-28)	6.7	24.8	3.7
5	RFC(40%-0%-56)	8.5	32.4	3.81
6	RFCS (40%-2%-56)	3.4	15.4	4.5

4. CONCLUSIONS

- In Control concrete with steel fiber (CCS), maximum increase in compressive strength is 38.25% for 2% of steel fiber at 28 days. The addition of steel fibers from 0% to 2% volume fraction increases the compressive strength and flexural strength with 40% replacement of cement by fly ash at 28 days.
- Fly ash concrete with steel fiber (FCS) showed the maximum increase in compressive strength of upto 33.1% for 2% volume fraction of fiber at 56 days as compared to Fly ash concrete(FC).
- FCS specimens at 56 days of compressive strength increase 0.61% than the 28 days of CCS 2%.
- Flexural strength of FCS specimen at 56th day increase 2.32% than the CCS 2% of 28th day.
- Addition of steel fibers to conventional concrete as well as fly ash cement concrete increase load carrying capacity of beam.
- Ductility was improved when the 40% of fly ash and steel fibers were added in beam specimens.

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