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Shear and flexural behaviour of prestressed and non-prestressed plain and SFRC concrete beams

Sudhir P. Patil *, **Keshav K. Sangle**

Structural Engineering Department, Veermata Jijabai Technological Institute (VJTI), Matunga, Mumbai, India

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KEYWORDS

Prestressed;
Non-prestressed;
Steel fibre reinforced concrete beam;
Fly ash;
Shear strength;
Flexural strength

Abstract The present study aims at improving the shear and flexural strength of the concrete by the addition of steel fibres. Also the study investigates the effect of prestressing on the shear and flexural strength of concrete. In this research work, 20% of fly ash (class-C) is added as a replacement of binder to its weight and 1.5% steel fibres by weight of concrete. Based on the experimental results, it can be seen that the load carrying capacity of steel fibre increased by 30–50% than the plain beam for non-prestressed. And load carrying capacity is increased approximately by 30–90% than the plain prestressed concrete beam. The use of steel fibres in a concrete mix was found to increase the crack resistance of the beams. Crack width was not more than 6 mm and 3 mm in case of the non-prestressed and prestressed steel fibre reinforced concrete beams respectively. Hence, based on experimental results it can be concluded that prestressed steel fibre reinforced concrete beams help to improve the shear strength, flexural strength, and crack resistance.

1. Introduction

Reinforced concrete is a composite material which consists of steel as reinforcement. Concrete has relatively low tensile strength and ductility. The reinforcement has higher tensile strength and ductility. Reinforcing helps to resist the tensile stresses in the particular region of concrete where unacceptable cracking may occur. To improve the load carrying capacity of the reinforced concrete pre-stressing can be done.

Pre-stressing of concrete improves the load bearing strength of the concrete. During service, the reinforcing steel is subjected to tensile forces. So, it is placed in tension before the concrete is poured around it. The tension on the reinforcing steel is released once the concrete gets hardened, hence, a built-in compressive force on the concrete. This helps to take up more stress and reduces compressive force on the concrete. As the concrete will be under compression, it is less subjected to failure or cracking.

The effect of steel fibres on the shear strength of lightweight concrete beams without web reinforcement was investigated by Kang et al. (2011). They tested 12 beams under four-point loads, including six steel fibre-reinforced lightweight concrete beams and three normal weight steel fibre-reinforced concrete (SFRC) beams. Finally, a shear strength equation for SFRLC beams without web reinforcement has been proposed based on the review. Yang and Kang (2011) proposed a simple approach

* Corresponding author.
E-mail address: sudhir_pp@yahoo.com (S.P. Patil).
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to predict the stress at ultimate and the corresponding incremental stress in unbonded tendons of simply supported post-tensioned beams. To evaluate the total elongation of the unbonded tendon between two anchorages, an equivalent strain distribution factor is established from the distribution of concrete strains at the tendon level along the beam length. Kang et al. (2012) studied the shear–flexure coupling behaviour of steel fibre-reinforced concrete (SFRC) beams. They used the obtained test results to validate the nonlinear modelling techniques developed for considering shear–flexure coupling effects in SFRC beams. The shear capacity of concrete beams reinforced with fibre reinforced polymers was investigated. Steel stirrups were used as shear reinforcement in all beams. Based on this investigation, a simplified expression for the shear capacity of FRP reinforced concrete members was introduced (Wegian and Abdalla, 2005). The flexural fatigue of self-compacting fibre-reinforced concrete was studied. The two-million cycle fatigue strength of SCFRC has been found to be higher than that of normally vibrated fibre-reinforced concrete (Goel et al., 2012). It was found that the first-crack strength and the whole post-cracking behaviour were mainly influenced by the amount of fibres (Antonio et al., 2012). The addition of fibres delayed the initiation of flexural cracks and decreased the crack width (Yang et al., 2012). Steel fibres improve the concrete quality and the post-crack performance and reduce the brittle behaviour of normal concrete and high strength concrete (Ding et al., 2012). An equation for predicting the shear strength of steel fibre reinforced concrete (SFRC) beams has been developed based on the existing experimental results. A large database containing 222 shear strength tests of SFRC beams without stirrups was divided into six different groups based on their span-depth ratio, concrete compressive strength and steel fibre shapes (hooked, crimped and plain). The proposed equations were obtained by performing both linear and non-linear regression analyses on each database (Emma et al., 2011). On the other hand, in an attempt to delay the onset of shear cracking and to reduce the crack width, experimental studies have been conducted on reinforced concrete (RC) columns, which have been laterally pre-stressed by high-strength shear reinforcement (Watanabe et al., 2004). The results of these flexure–shear tests have indicated that transverse pre-stressing increases the shear capacity at the first diagonal cracking (shear crack strength) and remarkably decreases the width of shear cracks, especially their residual openings.

Based on the literature review, it can be seen that steel fibre reinforced concrete and pre-stressed concrete have attracted the researchers the most due to the improved mechanical properties. It can also be seen in the literature that the combination of fly ash, steel fibre reinforcement and pre-stressed concrete is not explored to its full extent. The present study aims at improving the shear and flexural strength of concrete by the addition of steel fibres and pre-stressing of concrete. The concrete beams were cast using steel fibre reinforced with fly ash of M40 grade concrete. This work includes experimental determination of shear strength and flexural strength of plain concrete beam with and without pre-stressing; steel fibre reinforced concrete beam with and without pre-stressing.

2. Materials and methodology

For the present study M40 grade of concrete was used which is designed as per the IS code. The mix proportion obtained was 1:1.30:2.37 with W/C ratio of 0.4. And water reducing admixture (Flowcon-PC 163 JK) of 1% by weight of cement was used. Table 1 shows the concrete mix proportion for plain and steel fibre reinforced concrete.

A total of 36 beam samples were cast with each having cross-section of 140 mm × 140 mm with 1500 mm length. Plain concrete beam specimens consist of 20% fly ash by weight of cement. Steel fibre reinforced concrete specimens consist of 20% fly ash by weight of cement and 1.5% steel fibres by volume of concrete. Steel fibres used in the study have tensile strength of 1050 MPa, aspect ratio (length of fibre to its diameter) of 80, length of fibres of 60 mm and diameter = 0.75 mm. For the present study it was decided to consider percentage fibres as 1.5%, considering workability and to avoid balling of fibres to suit the available facilities in the laboratory.

Dramix type of fibres was selected for use in the present study based on literature review, as it mixes properly,

Table 1 Concrete mix proportion.

Sr. No.	Mix proportion per cubic metre
Mix-1 (plain concrete)	Cement: 412.8 kg/cu.m, (IS: 12269-1976, IS: 2720-part-3, IS: 4031-1968, IS: 12269-1976, IS: 12269-1976). 43 grade, specific gravity of cement = 3.15 (IS: 2720-part-3) Batch type: concrete mixing (IS: 4634:1968) was carried out Coarse aggregate: 1223.89 kg/cu.m. (IS: 2386-part-4, IS 283-1970) Fine aggregate (river sand): 673.5 kg/cu.m (IS 2386-(part-I)-1963) Water: 206.4 kg/cu.m (IS: 456-2000). Water/cement (W/C) ratio was 0.40 < 0.6 (IS 456-2000) Fly ash: 103.2 kg/cu.m class-C (IS 3812 part I-2003) Water reducing Admixture: 5.16 kg/cu.m
Mix-2 (steel fibre reinforced concrete)	Cement: 412.8 kg/cu.m, (IS: 12269-1976, IS: 2720-part-3, IS: 4031-1968, IS: 12269-1976, IS: 12269-1976). 43 grade, specific gravity of cement = 3.15 (IS: 2720-part-3) Batch type: concrete mixing (IS: 4634:1968) was carried out Coarse aggregate: 1223.89 kg/cu.m. (IS: 2386-part-4, IS 283-1970) Fine aggregate (river sand): 673.5 kg/cu.m (IS 2386-(part-I)-1963) Water: 206.4 kg/cu.m (IS: 456-2000). Water/cement (W/C) ratio was 0.40 < 0.6 (IS 456-2000) Fly ash: 103.2 kg/cu.m class-C (IS 3812 part I-2003) Water reducing Admixture: 5.16 kg/cu.m Steel fibres: 39.37 kg/cu.m. Dramix type-Bekaert company (ISO-9001 certified)

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thoroughly in the matrix. Even in the literature review the strength parameter achieved by concrete matrix was also better when Dramix type of steel fibres was used. Balling or curling of fibres was found least when compared with other types of steel fibres. The fibres were relatively stiff and glued into bundles. The glue dissolved in the water during mixing, thus dispersing the fibres in the mix as shown in Fig. 1.

The concrete mix was prepared in a single lift and consolidated using tamping rods. After setting, the beam specimens were covered with wet gunny bags. The burlap was kept for 3 days. At the end of the third day, the forms were stripped and the beam specimens were kept for curing up to 28 days.

Prestressing of plain and steel fibre reinforced concrete is done as per Fig. 2. Two prestressing strands having a diameter of 4 mm each was used in the present study. The average eccentricity maintained was 30 mm. All the prestressing specimens were designed to have the same prestressing force Pu = 27156.74 N and amount of prestressed steel (25.13 mm^2). The prestressing strands were tensioned using a single strand hydraulic jack a day prior to casting. The strand force was calculated by the elongated length of the tensioned strand as well as by a pressure transducer installed on the hydraulic jack. The tensioned strands were locked on steel abutments using barrels (male and female cone) in the prestressing yard. After three days of casting beam specimens, a gradual tension transfer procedure to concrete was used to cut the prestressed strands by a mechanical cutter simultaneously.

Fig. 3a shows the single point loading setup where a simply supported beam was applied with a concentrated load at mid span of the beam. For double point test simply supported beam with two concentrated loads applied at span/3 distance from the supports was used as shown in Fig. 3b.

Load was applied using hydraulic jack up to the failure of specimen and the crack patterns were observed. At each load increment, cracks were inspected and marked and the beam specimens were photographed.

3. Results and discussion

The casted beam specimens were subjected under single/double shear and flexural loading. Tables 2 and 3 show the details of experiments carried out on plain and SFRC concrete for non-pre-stressed and pre-stressed beam specimens.

Table 4 shows the strength of plain and SFRC concrete beam specimens used in non-pre-stressed and pre-stressed. In the subsequent section the following terminologies are used:

PL-S-1 = Plain concrete beam specimen-1 for single point load.
PL-S-2 = Plain concrete beam specimen-2 for single point load.
PL-S-3 = Plain concrete beam specimen-3 for single point load.
PL-D-1 = Plain concrete beam specimen-1 for double point load.
PL-D-2 = Plain concrete beam specimen-2 for double point load.
PL-D-3 = Plain concrete beam specimen-3 for double point load.

Plain concrete experimental results for single point load and double point load are shown in Figs. 4 and 5 respectively.

Plain concrete beam specimens tested under single point loading conditions were having almost a linear graph for load versus deflection curve shown in Fig. 4. Specimen-PL-S-2 was having less load carrying capacity. The shear strength of specimen PL-S-3 was more than the remaining two specimens. The average load carrying capacity for central point load was 5.35 kN. There were abrupt brittle failures of all specimens at the centre with average deflection of 0.97 mm.

Plain concrete beam specimens tested under double point loading conditions were having a slightly nonlinear graph for load versus deflection curve shown in Fig. 5. Specimen-PL-D-2 was having more load carrying capacity. The shear strength of Specimen PL-D-1 was less than the remaining two specimens and the average load carrying capacity for two point load was 7.95 kN. There were abrupt brittle failures of all specimens near the centre of beam specimens with average deflection of 1.14 mm.

SFRC beam specimens under single point loading conditions were having almost the same load carrying capacity as shown in Fig. 6. The average load carrying capacity for central

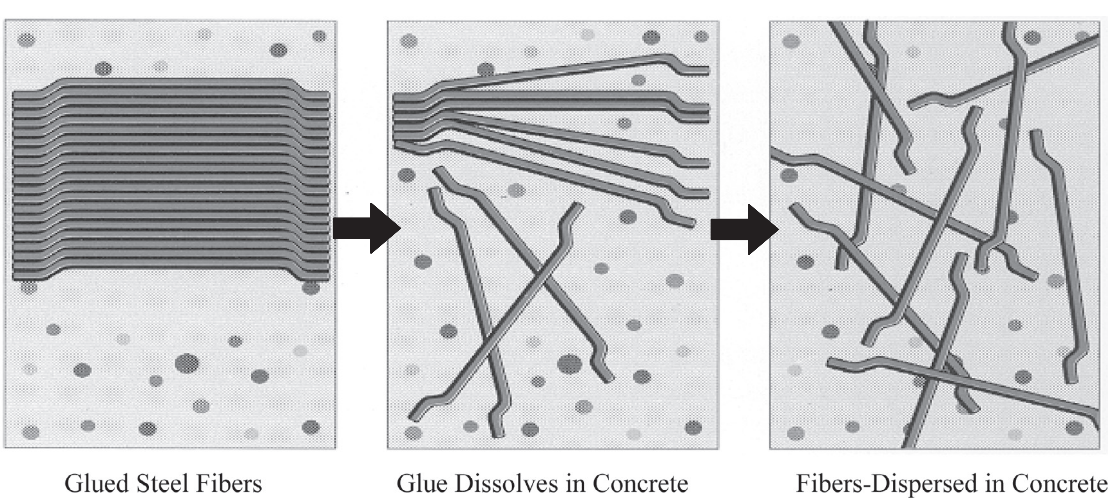

Figure 1 Dispersion of steel fibre in concrete (Bekaert-Dramix®).

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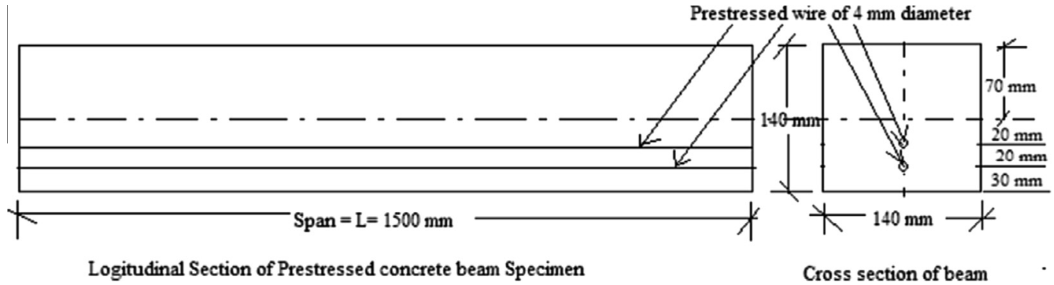

Figure 2 Prestressed concrete beam specimen.

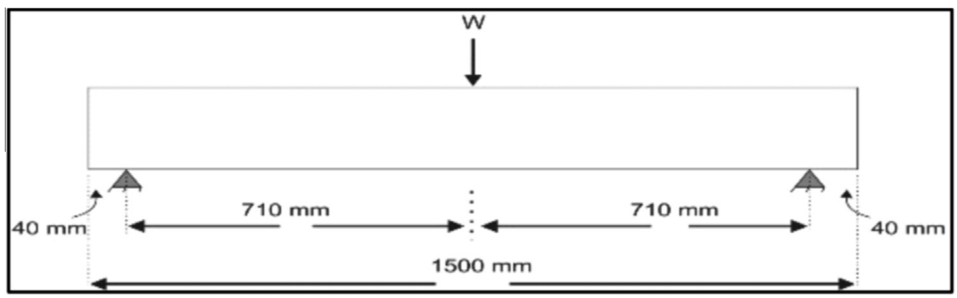

Figure 3a Single point loading setup.

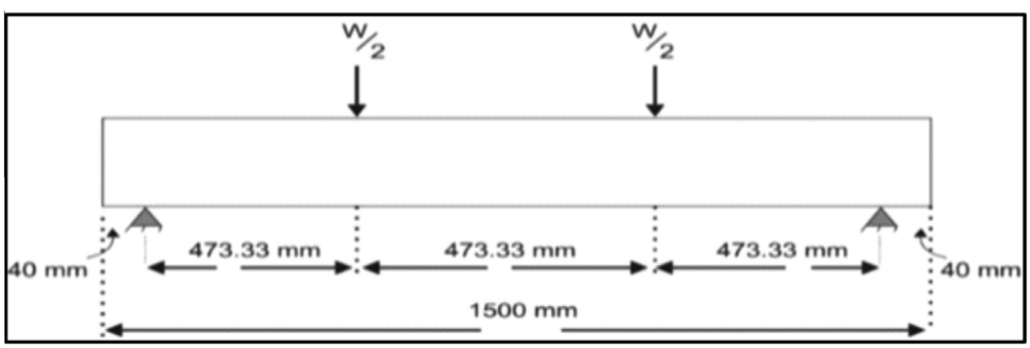

Figure 3b Double point loading setup.

Table 2 Details of non-prestressed beam specimens.

Beam specimen series	No. of beam specimens	Specimen denoted	% Fly ash	% of steel fibre	Specimen type	Point loads adopted for testing
Series-1	3	PL-S-1,2,3	20	0	Plain concrete	Single
Series-2	3	PL-D-1,2,3	20	0	Plain concrete	Double
Series-3	3	SF-S-1,2,3	20	1.5	Steel fibre concrete	Single
Series-4	3	SF-D-1,2,3	20	1.5	Steel fibre concrete	Double

point load was 6.87 kN. There were ductile failures of all specimens near the centre of the beam specimen by experimental observations with average deflection of 1.95 mm.

Fig. 7 shows the load versus deflection curve for SFRC beam specimens under double point loading conditions. All specimens were having approximately the same load carrying capacity. The specimen SF-D-2 was having a slightly less load carrying capacity than the remaining two specimens. The average load carrying capacity for all beam specimens for one third point load was 10.20 kN. Specimen SF-D-2 was having failure below the load near the left side support. There were ductile failures of all beam specimens near the centre of the beam specimen having an average deflection of 2.43 mm.

Fig. 8 shows load versus deflection curve for plain prestressed concrete beam specimens under single point loading. Specimen-PL-P-S-3 was having slightly more load carrying capacity than specimens PL-P-S-1 and PL-P-S-2 and the average load carrying capacity of all the specimens was 9.24 kN. The average vertical deflection for all specimens was 1.70 mm.

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Table 3 Details of prestressed beam specimens.

Beam Specimen series	No. of beam specimens	Specimen denoted	% Fly ash	% of steel fibre	Specimen type	Point loads adopted for testing
Series-1	3	PL-P-S-1,2,3	20	0	Plain concrete	Single
Series-2	3	PL-P-D-1,2,3	20	0	Plain concrete	Double
Series-3	9	SF-P-S-1,2,3	20	1.5	Steel fibre concrete	Single
Series-4	9	SF-P-D-1,2,3	20	1.5	Steel fibre concrete	Double

Table 4 Strength of concrete used in non-prestressed and prestressed plain and SFRC concrete beam specimens.

Beam specimen series	Compressive strength F_{ck} in MPa	Split tensile strength in MPa	Analytical split tensile strength 0.7 $\sqrt{F_{ck}}$ in MPa
Series-1–2	42.35	4.03	4.55
Series-3–4	45.72	5.26	4.73

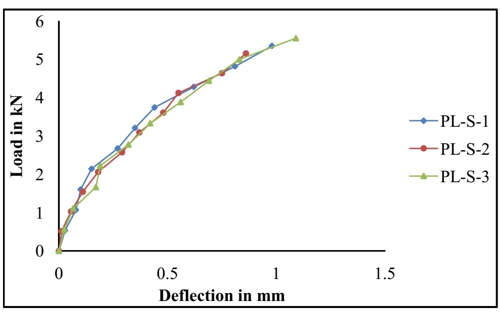

Figure 4 Plain concrete beam specimens under single point loading.

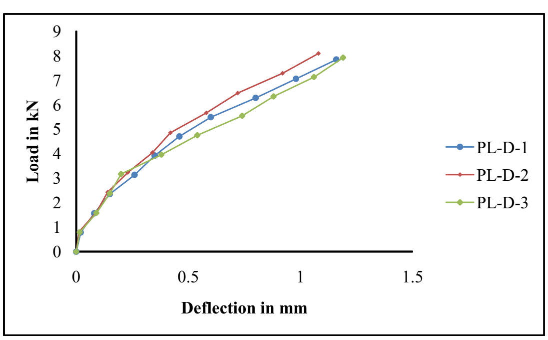

Figure 5 Plain concrete beam specimens under double point loading.

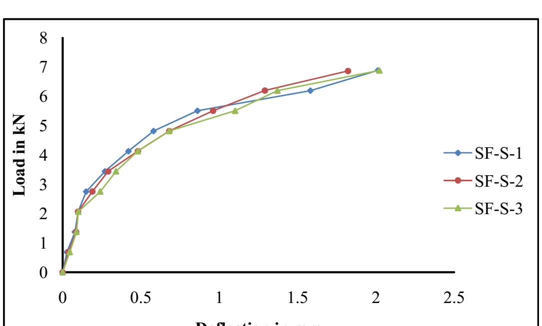

Figure 6 SFRC beam specimens under single point loading.

Fig. 9 shows load versus deflection curve for plain pre-stressed concrete beam specimens under double point loading. All specimens shown in Fig. 9 were having approximately the same load carrying capacity and the average load carrying capacity was 13.57 kN, which was slightly more than the analytical strength of 13.13 kN. Specimen PL-P-D-2 was having less deflection than another two specimens and the average

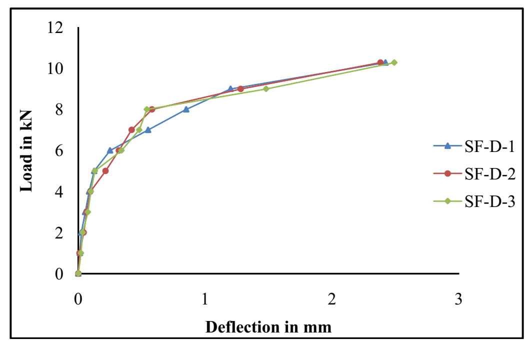

Figure 7 SFRC beam specimens under double point loading.

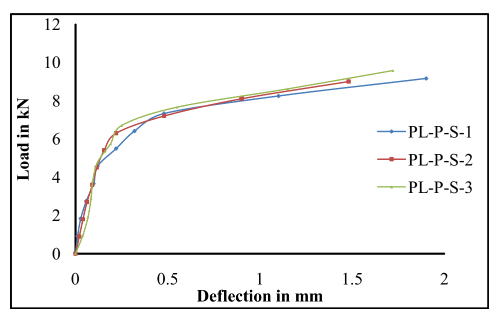

Figure 8 Plain pre-stressed concrete beam specimens under single point loading.

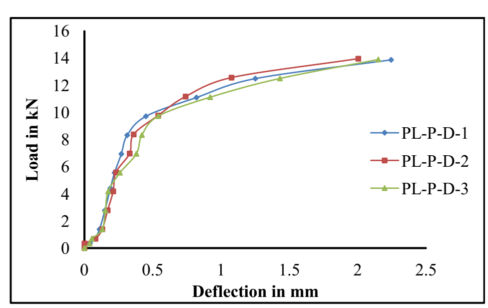

Figure 9 Plain pre-stressed concrete beam specimens under double point loading.

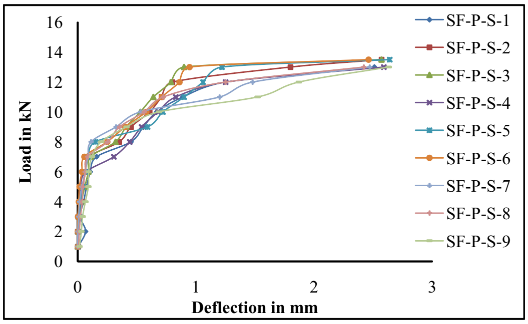

Figure 10 SFRC pre-stressed concrete beam specimens under single point loading.

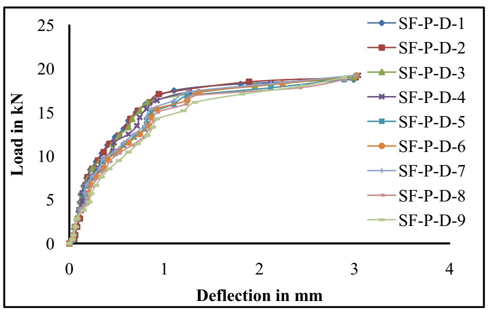

Figure 11 SFRC prestressed concrete beam specimens under double point loading.

deflection of all specimens of plain pre-stressed concrete with double point loads was 2.132 mm.

Fig. 10 shows load versus deflection curve for SFRC pre-stressed concrete beam specimens under single point loading. All nine specimens were having approximately the same load carrying capacity. The average load carrying capacity of all specimens was 13.22 kN. Specimen SF-P-S-8 was having less deflection i.e. 2.42 mm and SF-P-S-5 was having maximum deflection i.e. 2.64 mm. The average deflection of all specimens was 2.54 mm.

Fig. 11 shows load versus deflection curve for SFRC pre-stressed concrete beam specimens under double point loading. All nine specimens were having a variation in load carrying capacities. The average load carrying capacity of all specimens was 19 KN, and it was more than the analytical load carrying capacity of 13.46 kN. The average deflection of all specimens was 2.98 mm.

4. Non-prestressed concrete beam specimens

Based on the above figures a comparison of plain with steel fibre reinforced concrete beams shows an increase in the load carrying capacity of steel fibre reinforced concrete by approximately 30–50% than the plain beam. From the above figures, it can be clearly seen that the load carrying capacity of the SFRC concrete beam beyond the elastic limit was more than that of the plain concrete beams. Thus, as the plastic capacity of the beam was considerable with the use of steel fibres, the increased ductility was justified. The use of steel fibres in a concrete mix was found to increase the crack resistance of the beams. This was due to the fact that the presence of fibres throughout the cross section of the beam and especially, at the surface entraps the cracks developed at the surface and prevents the further propagation of the crack through the depth of the beam. It was observed that the development of the first crack for the fibre reinforced concrete beam was at higher loads than the plain concrete beam. It was also noted that deflection was satisfactory. Crack width was not more than 6 mm in case of any of the fibre reinforced beams. Flexural as well as shear strength of concrete increased due to the presence of fibres. In case of plain beam specimen cracks developed at an early stage. Load carrying capacity of the beam ended after the development of cracks. Flexural strength of the beam increases as the distance between loading point and support decreases. In case of double point loading flexural strength was observed to be greater than single point loading. Failure in case of a single point load was flexure type failure in the initial stages and shear–flexure failure at a later stage of loading. While in the case of the two point load testing programme diagonal cracks were developed below loads concluding shear failure. Table 5 shows the shear strength, flexural strength and deflection of non-pre-stressed concrete beam.

5. Prestressed concrete beam specimens

Load carrying capacity is increased approximately by 30–90% than the plain prestressed concrete beam. The steel fibres in concrete also add to the ductility of beam elements and help in improving the energy absorption characteristic of beams. Shear and flexural strength of concrete is increased for a steel fibre reinforced prestressed concrete beam specimen.

It was observed that the development of the first crack for a fibre reinforced prestressed concrete beam was at higher loads than the plain prestressed concrete beam. It was also noted that deflection was satisfactory. Crack width was not more than 3 mm in case of any of the beam specimens.

In case of double point loading flexural strength was observed to be greater than single point loading. Failure in case of single point load was flexure type failure in the initial stages and shear–flexure failure at a later stage of loading. While in case of the two point load testing programme diagonal cracks were developed below loads concluding shear failure. Table 6 shows the summarised results for prestressed concrete beam shear and flexural strength.

Table 5 Summarised experimental results for non-pre-stressed concrete beam.

	Shear strength (kN)		Flexure strength (MPa)		Deflections in mm	
	Single point	Double point	Single point	Double point	Single point	Double point
Plain concrete	2.675	3.975	4.10	4.25	0.97	1.14
SFRC	3.435	5.1	5.35	5.48	1.95	2.43

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Table 6 Summarised experimental results for pre-stressed concrete beam.

	Shear strength (kN)		Flexure strength (MPa)		Deflections in mm	
	Single point	Double point	Single point	double point	Single point	Double point
Plain concrete	4.62	6.785	7.28	7.32	1.7	2.27
SFRC	6.61	9.5	10.55	10.28	2.54	2.98

Thus from Tables 5 and 6 it is clear that prestressing and steel fibre reinforcing in concrete helps to improve the shear and flexural strength of the concrete. Analytically the strength of pre-stressed concrete beam was calculated as per the following.

Grade of concrete – M40.
Modulus of elasticity – $5000\sqrt{f_{ck}} = 31622.78\ \text{N/mm}^2$.
Span $l = 1500$ mm.
Characteristic strength of concrete $f_{ck} = 40\ \text{N/mm}^2$.
Characteristic strength of high tensile wire $f_{up} = 1861.58\ \text{N/mm}^2$.
Modulus of elasticity ES = $200{,}000\ \text{N/mm}^2$.
Characteristic strength of High tensile wire $f_{pe} = 1080.00\ \text{N/mm}^2$.
At initial stage.

Initial stage consists of the effect of prestressing force developed in wire due to initial stresses–strains and self-weight of the beam without the consideration of any imposed load or live loads.

Prestressing force in wire due to effective prestress Pp

$$Pp = Ap \cdot f_{pe} \tag{1}$$
$$Pp = 12.566 \times 1080$$
$$Pp = 13517.28\ \text{N}$$

Moment of inertia of cross section I (See Fig. 12)

$$I = \frac{b \cdot d^3}{12} \tag{2}$$
$$I = \frac{140 \cdot 140^3}{12}$$
$$I = 32013333.33\ \text{mm}^4$$

Section modulus Z

$$Z = \frac{I}{y} \tag{3}$$
$$Z = \frac{32013333.33}{70}$$
$$Z = 457333.33\ \text{mm}^3$$

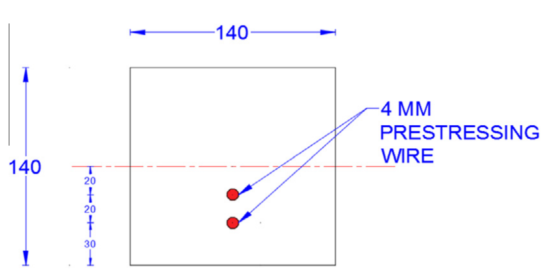

Figure 12 Cross section of prestressed concrete beam.

Self-weight of beam per unit length w

$$w = 0.14 \times 0.14 \times 1 \times 24$$
$$w = 0.4704\ \text{kN/m}$$
$$w = 0.4704\ \text{N/mm}$$

Bending moment

Bending moment due to prestressing force in wire M_p

$$M_p = Pp \cdot (e_1 + e_2) \tag{4}$$
$$M_p = 13517.28(20 + 40)$$
$$M_p = 811036.80\ \text{Nmm}$$

Bending moment due self weight of beam M_S

$$M_s = \frac{w \cdot l^2}{8} \tag{5}$$
$$M_s = \frac{0.4704 \times 1500^2}{8}$$
$$M_s = 132300.00\ \text{Nmm}$$

Stresses in the section

Direct stress due to prestressing force in wire σ_d

$$\sigma_d = -\frac{N \cdot Pp}{Ac} \tag{6}$$
$$\sigma_d = -\frac{2 \times 13517.28}{140 \times 140}$$
$$\sigma_d = -1.3793\ \text{N/mm}^2$$

Bending stress due to prestressing force in wire σ_p

$$\sigma_p = \pm\frac{M_p}{Z} \tag{7}$$
$$\sigma_p = \pm\frac{811036.8}{457333.33}$$
$$\sigma_p = \pm 1.7734\ \text{N/mm}^2$$

Bending stress due to self-weight of beam σ_S

$$\sigma_s = \pm\frac{M_s}{Z} \tag{8}$$
$$\sigma_s = \pm\frac{132300}{457333.33}$$
$$\sigma_s = \pm 0.2893\ \text{N/mm}^2$$

Stresses in extreme fibres of section

Stress at top σ_{top}

$$\sigma_{top} = -\sigma_d - \sigma_s + \sigma_p \tag{9}$$
$$\sigma_{top} = -1.3793 - 0.2893 + 1.7734$$
$$\sigma_{top} = 0.1048\ \text{N/mm}^2$$

Stress at bottom σ_{bot}

$$\sigma_{bot} = -\sigma_d + \sigma_s - \sigma_p \tag{10}$$
$$\sigma_{bot} = -1.3793 + 0.2893 - 1.7734$$
$$\sigma_{bot} = -2.8634\ \text{N/mm}^2$$

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Figure 14 Crack in SFRC.

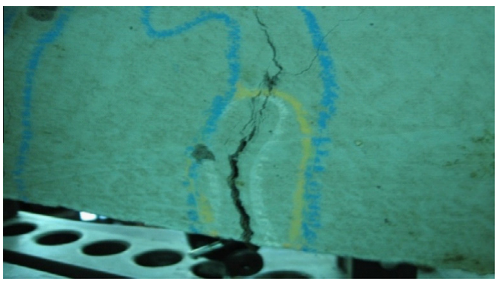

Figure 13 Crack in plain concrete.

Deflection in beam

Upward deflection due to prestressing force in wire y_p

$$y_p = \frac{P_p \cdot (e_1 + e_2) \cdot l^2}{8.Ec.I} \tag{11}$$

$$y_p = \frac{13517.28 \times (20 + 40) \times 1500^2}{8 \times 31622.78 \times 32013333.33}$$

$$y_p = 0.2253 \text{ mm} \uparrow$$

Downward deflection due to self-weight y_s

$$y_s = \frac{5 \cdot w \cdot l^4}{384 \cdot Ec \cdot I} \tag{12}$$

$$y_s = \frac{5 \times 0.4704 \times 1500^4}{384 \times 31622.78 \times 32013333.33}$$

$$y_s = 0.0306 \text{ mm} \uparrow$$

Net deflection y_{net}

$$y_{net} = y_p - y_s \tag{13}$$

$$y_{net} = 0.2253 - 0.0306$$

$$y_{net} = 0.1950 \text{ mm} \uparrow$$

Load required to cause zero deflection

$$y = y_s - y_p + y_L \tag{14}$$

$$0 = -0.1950 + \frac{W \times 1500^3}{48 \times 31622.78 \times 32013333.33}$$

$$W = 2803.15 \text{ N}$$

The use of steel fibres in concrete mix was found to increase the crack resistance of the beams as shown in Figs. 13 and 14. This was due to the fact that the presence of fibres throughout the cross section of the beam and especially at the surface entraps the cracks developed at the surface and prevents further propagation of the crack through the depth of the beam.

6. Conclusions

Based on the experimental results of plain concrete and steel fibre reinforced concrete beams subjected to single point and double point loadings the following conclusions can be drawn:

1. Load carrying capacity of steel fibre reinforced concrete beam specimens were more than the plain concrete beam specimens by approximately 30–50%. And load carrying capacity is increased approximately by 30–90% than the plain pre-stressed concrete beam.
2. The use of steel fibres in a concrete mix was found to increase the crack resistance of the beams.
3. Plain concrete beam specimens showed abrupt brittle failure and SFRC beam specimens showed ductile failure.
4. Pre-stressed steel fibre reinforced concrete beams helps to improve the shear strength, flexural strength, and crack resistance and provides maximum mechanical strength.

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