VOL. 14, NO. 4, FEBRUARY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FLEXURAL BEHAVIOUR OF PRESTRESSED COMPOSITES BEAMS

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ABSTRACT

In this research work a hybrid prestressed composite beam with embedded I-section is designed and is been tested and compared with prestressed concrete beam and composite beam with embedded I-section under flexural strength in a high grade concrete of M35. Concrete which is generally a low tensile capacity material due to which cracks are formed on the surface of the higher grade concrete due to many conditions like heavy loading, dry shrinkage etc. In order to avoid this cracking steel reinforcement are introduced in the beams and thereby increasing the tensile capacity. In general, longer span sections induce larger bending moment thereby increasing the beam depth which becomes inconvenience to the user. Hence, a section with much lesser depth will be possible by introducing prestress to the concrete. In some critical cases a section depth will be restricted due to some local case to case basis. In those cases a concrete section with embedded steel section or a concrete section with embedded steel section with prestress may be of great help in reducing the depth of the section. Hence, an attempt has been made to study the concrete section with embedded steel section with and without prestressing and compared with conventional prestressed concrete beam. The results show that the energy absorption capacity of the section is increased by 152.5% by using embedded steel section in concrete and 227.7% by using embedded steel section with prestressing in concrete when compared to conventional prestressed concrete beam.

Keywords: pre-stress, steel I-section, composite beams, energy absorption capacity.

1. INTRODUCTION

Concrete is the most generally utilized material in construction industry, however for high rise buildings, the ordinary concrete prompts greater individuals in the structure, which is uneconomical and space consuming. So for high rise building, composite components are prescribed like pre-stress concrete, sandwich structures and composite structures.

Although the idea of pre-stressing was around for hundreds of years but modern pre-stressed concrete structures was officially introduced by Freyssinet to the public in 1936 [1-3], following that worlds first pre-stressed concrete bridge was constructed in United States i.e. Walnut Lane Memorial Bridge which was designed by Gustave Magnel in 1950[4]. The design and specification code for pre-stress was introduced in between 1950s and 1960s [5-7]. After years of development, nowadays pre-stressed concrete structure is one of the most important topics in the structural engineering, Pre-stress technique has enabled the concrete structure to compete successfully within the areas that was previously dominated by steel structures, like bridges with long span, tall buildings.

The major disadvantage of the conventional concrete is formation of crack which is formed in the tensioned zone of the concrete, and the main advantage of the pre-stressed concrete is non-appearance of crack under nominal service load and in this manner better strength and durability can be accomplished. The differences inside the conduct of prestressed beam in terms of the conventional beam seem because of high yielding moment and bending strength of prestressed beam [8].There are two types of pre-stress i.e. bonded and unbounded pre-stress beam in which bonded has more initial stiffness, more ductility as compared to un-bonded tendons [9], tendons consist of high strength [10] but there are many losses while doing pre-stress like loss due to pre-stress force loss and elastic shortening, but pre-stress force loss will be occurred in case of higher transfer length, and elastic shortening occurs under larger eccentricity usually in larger cross-section [11], but in this case both the losses can be neglected as the cross section is small and transfer length is also less.

In the past, many attempts have been made to enhance the strength of RC beams by bonding steel fibers, adding reinforcement, providing external steel plates to the beam to obtain enhanced flexure. The composite beam theory was developed for sandwich structure, and for T girders [12-13] but it is known that I-section of steel has higher tensile strength, in which the shear force is resisted by web of the I-section, while the bending moment is resisted by flanges of the I-section experienced by the beam. According to the theory of beam, the I-shaped section is efficient form which can carry both bending and shears by the web itself. But it is weak in torsion, due to which hollow structural sections is preferred, so using I-section as embedded in concrete results a very efficient hybrid concrete beam. So an attempt has been made in this work to study the flexural strength of precast hybrid composites beams in a high strength concrete of grade M35.

In this research work three types of beam are been used which are as follows:

a) Pre-stressed concrete beam.

b) Composite beam with embedded I-section.

c) Pre-stressed composite beam with embedded I-section.

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The discussed above the details of prestress concrete beam used in this research work is shown in Figure-1.

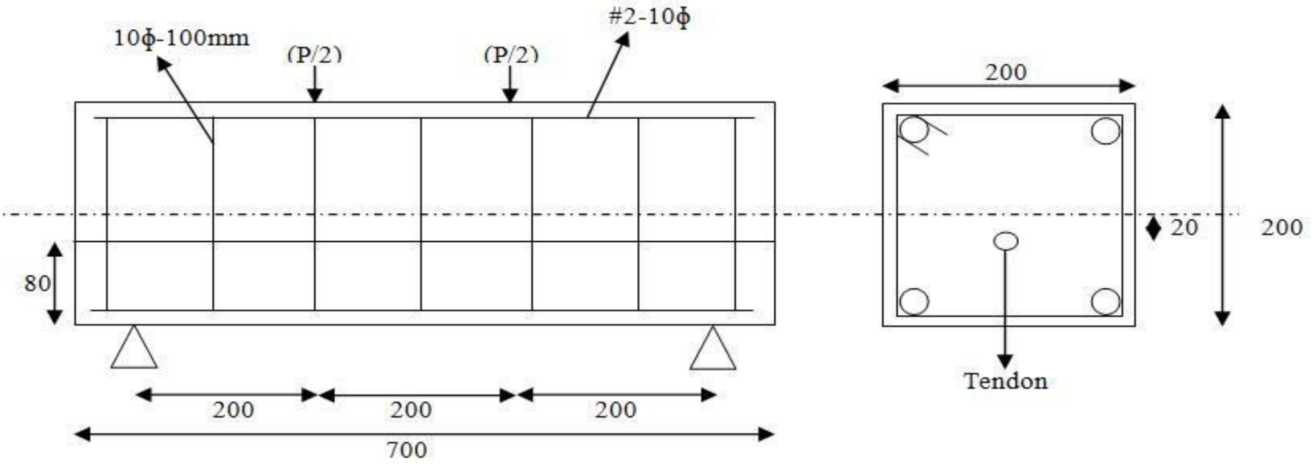

Figure-1. Concrete sections and cable profile of pre-stressed beams.

A. Composite beam with embedded I-section

The theory of composites was basically invented for composite structures like sandwich structure, composite steel concrete girders. Generally concrete is strong in compression and susceptible in tension, for overcoming this, typically reinforcement is furnished to increase its tensile strength.

However in this study a hybrid composite beam is introduced wherein embedded i-section is delivered inside the concrete which may also give better tensile strength to the concrete which may additionally withstand higher load with small beam size due which the dead load of the beam can be reduced hence the total height and self-weight of the building can be reduced. The beam details are shown in Figure-2.

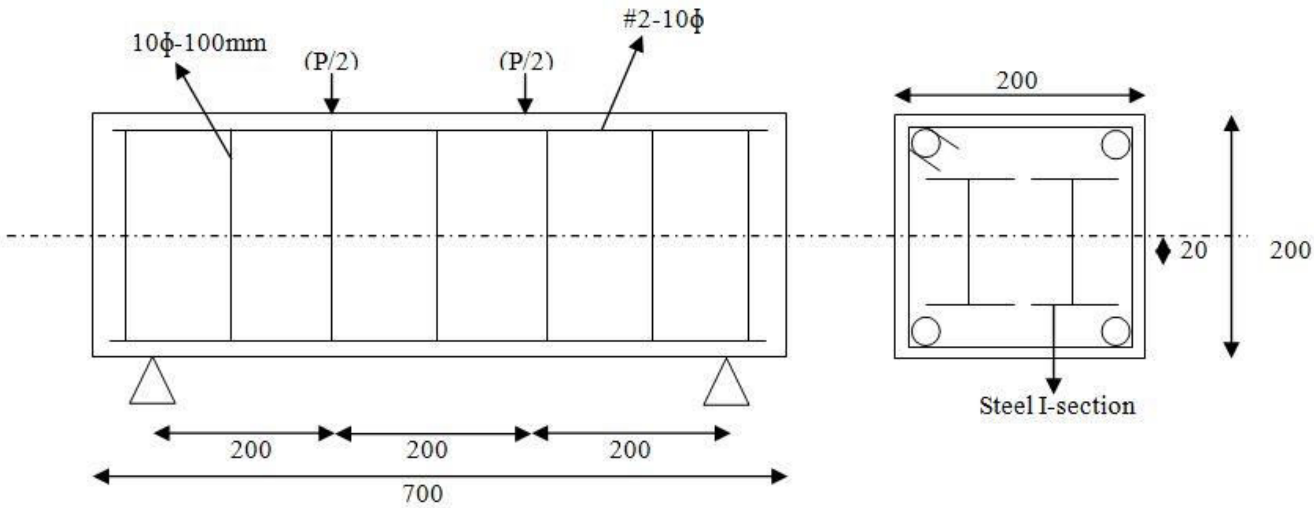

Figure-2. Composite beam with embedded steel I-section.

B. Hybrid pretensioned composite beam with embedded I-section

In this study a new hybrid beam is added that's made up with the aid of combining each pretension concrete with embedded steel i-section as shown in Figure-3 in which the shear force is resisted by web of the i-section, while the bending moment experienced by beam is resisted by flanges, in the concrete which in result will be a stronger in flexural and durable as compare to ordinary conventional beams. It could be utilized in heavy loaded structures and as pre-stressed concrete is used, the construction speed may also be increase which in result reduces the total cost of the construction.

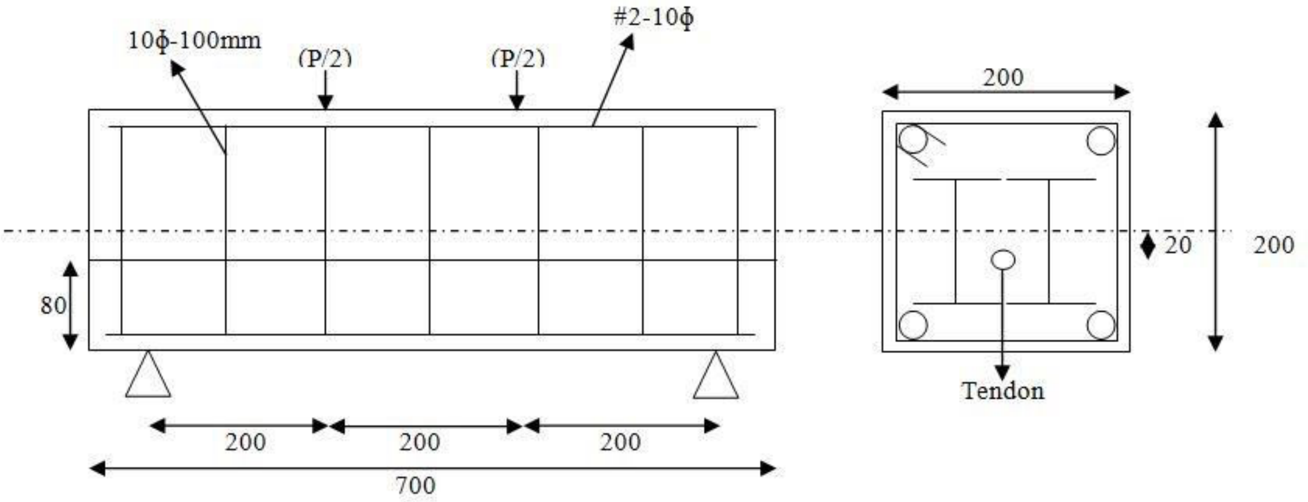

Figure-3. Pre-stress composite beam with embedded steel I-section.

2. OBJECTIVES

The aim of this research work is to design a mix design for M35 grade of concrete which is used to study and compare the flexural behavior of three composite beams i.e. pre-stressed concrete, composite beam with embedded I-section and prestressed composite beam with embedded I-section.

3. EXPERIMENTAL INVESTIGATIONS

An experimental program has been designed to investigate the mechanical properties and flexural behaviour of prestressed composite beams.

3.1 Materials used

Ordinary Portland cement is available in 33, 43 and 53 grades. For the present comparative investigation, OPC 53 grade confirming to IS 12269-1987 was used. Cement should be dry, powdery and free of lumps. Specific gravity test was conducted in line with IS code 4031-1988 in result the specific gravity was 3.15. In this research work, coarse aggregate of size 10 - 12 mm has been used and the specific gravity of the aggregate is determined to be 2.70 and Natural river fine aggregate is used in this investigation having specific gravity of 2.65. Water is a very important part of concrete production because it reacts with the cement and bonds all components together. The admixture used in this research is poly carboxylic ether which is a high range water reducing admixture with a solid content of 50% is used for this project. The water binder ratio will affect the properties like strength, durability, water tightness and other related properties of cement concrete.

3.1.1 Steel I-section

Steel is one of the most important building materials in construction industry. It can be used in many ways for different purposes. Different steel members are manufactured based on their usage. Different types of steel section are manufactured in industries like angle section, channel section, I- section. In this project ISMB 100 is used in which shear force is resists by web, while most of the bending moment is resisted by flanges. The details of I-section are shown in the Table-1.

Table-1. Sectional properties of beam.

Type	Weight	Sectional area	Depth of beam	Thickness of web	width of flange	I_{xx}	I_{yy}
	kg/m	cm^2	mm	mm	mm	mm^4	mm^4
ISMB 100	9	11.4	100	4.2	50	183	12.9

3.2 Mix design

The mix design utilized in this study relies on IS code 10262-2009 and volumetric technique Considering a standardized compressive strength of 35MPa, which incorporates 370 kg/m^3 cement, 949 kg/m^3coarse aggregate, 1008.5 kg/m^3 fine aggregate, 148 litre/m^3 water, and 2.96 litre/m^3super plasticizer with water to cement ratio of 0.45.

Specimens were cast like cube, cylinder using mix ratio of M35 conventional concrete. The procedure for the preparation of concrete is as follows:

(i) Coarse aggregate and sand were poured into the hand fed drum mixer. It was allowed to dry mix for at least 1 minute after which measured cement was poured into the dry mix.

(ii) After 1 minute of dry mixing, water was added along with super plasticizer into the drum mixer and it was mixed for approximately 2 minutes. After the mix was prepared it was filled into moulds and vibrated to remove any voids and trapped air from the moulds.

3.3 Mechanical properties

Tests were conducted to ascertain the mechanical properties like compressive strength and split tensile strength. Casting of cubes which were of 100 mm × 100 mm × 100 mm size was prepared and the compressive strength test was conducted as per IS 516:1959. To determine compressive strength, the specimens were kept under the compressive testing machine and load was applied until it failed to bear the load. Similarly, cylinders were cast with dimensions of 100 mm diameter and 200 mm height to determine the split tensile strength as per ASTM C496.

Table-2. Compressive strength and split tensile strength results.

S. No	**Compressive strength** (N/mm^2)		**Split tensile strength**(N/mm^2)	
	7 days	**28 days**	**7 days**	**28 days**
1.	25.3	39.6	1.4	2.8
2.	27.4	42.9	1.7	2.92
3.	26.3	41.8	1.6	3.01

3.4 Experimental program for composite beams

Three set of beams for each type of beam was cast are subjected to a flexural test (two-point loading). The dimension of the beam cross-sectionally taken as 200 x 200 x 700 mm holding a constant area of transverse and longitudinal reinforcement the spacing for stirrups is kept as 100mm for beam specimens. The reinforcement details of the beam specimen are shown below in Table-3.

Table-3. Details of reinforcement bars.

S. No	**Longitudinal reinforcement**		**Transverse reinforcement**	
	Top bar(mm)	**Bottom bar**(mm)	**Size**(mm)	**Spacing** (mm)
B-1	2-10ϕ	2-10ϕ	8- ϕ	100
B-2	2-10ϕ	2-10ϕ	8- ϕ	100
B-3	2-10ϕ	2-10ϕ	8- ϕ	100

The procedure for the preparation of pre-stress beam is as follows:

a) Three moulds were kept in the pre-stress bed and pre-stressing cable was inserted in it as shown in figure 1.
b) Pre-stressing force of 30 kN was applied in the pre-stressing cable.
c) Concrete was poured in it and proper vibration was provided using vibrator needle.
d) De-moulding was done after 7 days of curing and was kept for curing.

The procedure for the preparation of composite beam with embedded I-section beam is as follows:

i. Two I-sections was inserted in the reinforcement and kept in the mould as shown in Figure-2.
ii. Concrete was poured and needle vibrator was used to remove voids and trapped air from the moulds.
iii. De-moulded after 24hrs and kept for curing.

The procedure for the preparation of composite beam with embedded I-section beam is as follows:

a) Two I-sections was inserted in the reinforcement and kept in the mould.
b) Moulds were kept in the pre-stress bedand pre-stressing cable was inserted in it.
c) Pre-stressing force of 30kN was applied in the pre-stressing cable as shown in figure 3.
d) Concrete was poured in it and proper vibration was provided using vibrator needle.
e) De-moulding was done after 7 days of curing and was kept for 28days curing.

3.4.1 Testing

The beams are placed on a universal testing machine which has an end condition of simply supported, which has a capacity of 3000 kN at max. After that, the centering of the beam must be checked from the center at the top of the frame to the center of the beam. Then a two-point load is placed on the beam and a hydraulic pump is used to increase the pressure of load on the beam and load is stopped when the beam has failed in its ultimate load as shown in Figure 5, 6 & 7.

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A. Testing setup | B. Beam failure

Figure-4. Testing of the pre-stress beam under two-point loading progress.

Figure-5. Testing of the composite beam with embedded I-section under two-point loading.

Figure-6. Testing of the pre-stressed composite beam with embedded I-section under two-point loading.

4. RESULTS AND DISCUSSIONS

Three types of beam specimens are cast and each type have three samples for average values as mentioned above and tested for flexure test of (two-point loading). These beams are divided into (B-1, B-2, and B-3). Specimen B-1 is a pre-stress beam, B-2 is composite beam with embedded I-section and B-3 is pre-stress composite beam with embedded I-section.

The ultimate load achieved by the beam B-1 was 171 kN with the deflection of 1.74mm. In (B-2) Ultimate load achieved by the beam was 421 kN with the deflection of 2.1mm. In beam (B-3), Ultimate load achieved by the beam was 453 kN with the deflection of 2.3mm. The comparison of load Deflection curve between B-1, B-2 & B-3 is shown in the Figure-8.

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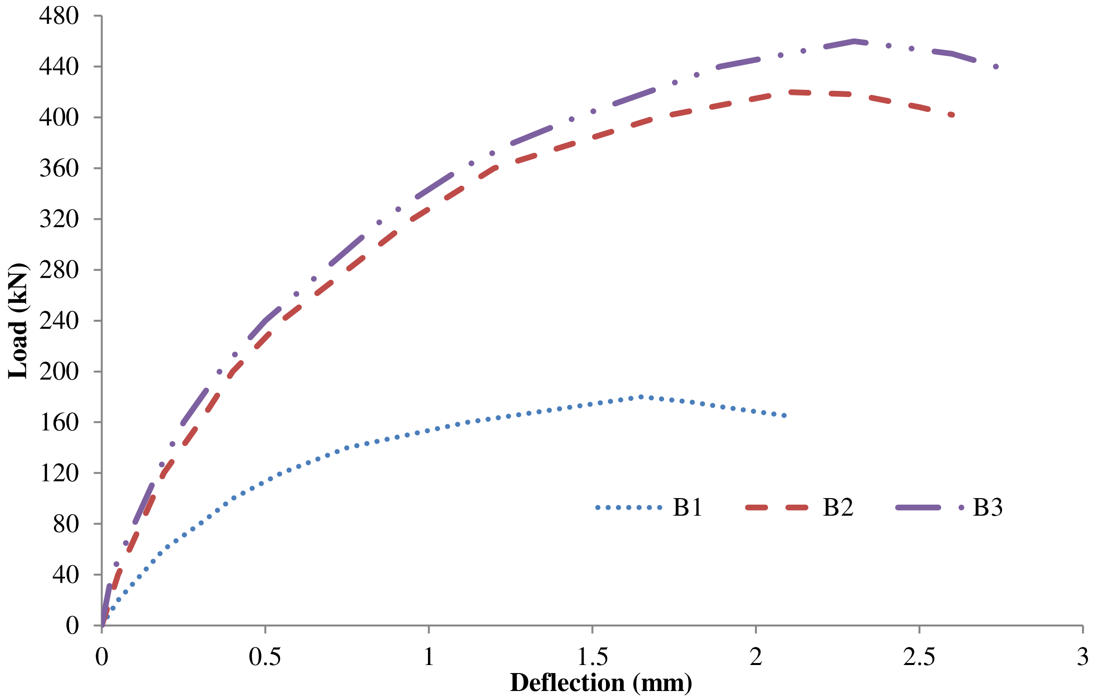

Figure-7. Comparison of load- deflection curve between all three beams.

In Table-4, Beam properties like ultimate load, maximum deflection, and is given for B-1, B-2 and B-3 beams.

Table-4. Energy absorption capacity of beams.

Beam designation	**Span**	**Ultimate load** (kN)	**Percentage increase**	**Maximum deflection** (mm)	**Energy absorption capacity** (kN-mm)	**Percentage Increase**
B-1	600	171	-	1.74	516.45	-
B-2	600	421	146	2.1	1304.1	152.51
B-3	600	453	164.91	2.3	1692.5	227.71

The results show that the ultimate load of B-3 has increased by 152.51 % in compare to B-1 in spite of having same cross-section and eventually energy absorption capacity of the prestress composite beam with embedded I-section is high as compare to B-1 by 227.71%.

As per Cezary Graczykowski's experimental test was conducted for pre-stressed beam in which it was concluded that pre-stress concrete beam has a strong potential for increasing mechanical properties like strength, higher stiffness, and mass reduction[18] and further Hu Shaowei has conducted a bending capacity test for pre-stress composite beams and concluded that there are number of advantages of pre-stress composite beams over nominal composite beams, the flexural capacity was increased in pre-stressed composite beams. As a result of bending test it was observed that pre-stressed composite beam has achieved a maximum bending of 441kNm [19].

5. CONCLUSIONS

Concrete mixture of grade M35 was designed and compressive strength and split tensile test was conducted to find the mechanical properties of the concrete. In this experimental work the behavior of different composite beams under flexural condition is been observed, the formation of crack is observed. The conclusions of this study are enumerated below:

a) The Compressive strength of concrete achieved was 41.43 N/mm^2

b) The split tensile strength achieved for the concrete was 2.91 N/mm^2

c) The ultimate load for pre-stress beam was 178kN with a deflection of 1.65mm.

d) The ultimate load for composite beam with embedded I-section was 420 kN with a deflection of 2.1mm.

e) The ultimate load for pre-stress composite beam with embedded I-section was 455 kN with a deflection of 2.3mm.

f) On the basis of this experimental work, it can be stated that the pre-stressed composite beam with embedded I-section can resist more load as compare to other two beams as the B-3 beam has 146% more load bearing capacity then B-1 and approx. 165% more than B-1 beams under same cross section for all three beams.

g) The Energy absorption capacity of B-3 beam is also increased by 227.71% in compare to B-1 and B-2 beam Energy absorption capacity is also increased by 152.71% in compare to B-1.

In this experiment, the pre-stressing force of 30kN was given in the tendons, further if the pre-stressing force is increased then the beam can resist more loads and deflection in the beam can also be reduced as the upward force is been increased.

On the basis of the experimental work it is observed that the crack is been formed from the support ends to the point load only which is caused due to shear failure due to heavy load, so shear has to be taken care in the support ends in this type of composite beams.

ACKNOWLEDGEMENT

The authors admiringly acknowledged that the work is completed under the support of SRM institute of Science and Technology by providing the materials required for completing the project and FOSROC chemicals for providing material support.

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