

# Properties of Polypropylene Fiber Reinforced Concrete and Structural Behaviour of Beam

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**ABSTRACT:** Concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction, the brittle behaviour of the material remains a larger handicap for the seismic and other applications where flexible behaviour is essentially required. Polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. Polypropylene is one of the cheapest and abundantly available polymers. Chemical inertness makes the polypropylene fibers resistant to most chemicals. Its melting point is high ranges between 159 °C - 179 °C. So that it can withstand a working temperature of 100 °C for short periods without detriment to fiber properties. In the present research work the mix design of grade M25 was calculated to prepare the concrete specimens for the different proportion of polypropylene fiber such as 0 kg/m<sup>3</sup>, 3 kg/m<sup>3</sup>, 4 kg/m<sup>3</sup> and 5 kg/m<sup>3</sup> (i.e. 0%, 0.12%, 0.16% and 0.2%). For each grade of concrete, cube specimen was cast, cured and tested at 7 & 28 days to assess the compressive strength of the concrete. Cylinder and prism were cast cured and tested for each grade of concrete for 28 days maturity to assess the split tensile strength and flexural strength of the concrete. Behaviour of structural member (RCC beam) has also been studied in the present research work with different proportion of polypropylene fiber. Finally the results of specimens of various percentages of fibers in concrete have been compared and the result of the project is explained.

**KEYWORDS:** Polypropylene fiber-reinforced concrete (PFRC), Compressive strength, Split tensile strength, Flexural strength and RCC beam.

## I. INTRODUCTION

The capability of durable structure to resist weathering action, chemical attack, abrasion and other degradation processes during its service life with the minimal maintenance is equally important as the capacity of a structure to resist the loads applied on it. Although concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction, the brittle behaviour of the material remains a larger handicap for the seismic and other applications where flexible behaviour is essentially required. Recently, however the development of PFRC has provided a technical basis for improving these deficiencies. PP fibers affects the various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact, crack prevention and chloride penetration.

## II. RELATED WORK

O Kayali et al., [1] in this paper, the effect of polypropylene and steel fibers on high strength lightweight aggregate concrete is investigated. Sintered fly ash aggregates were used in the lightweight concrete; the fines were partially replaced by fly ash. The research results show that addition of steel fibers appreciably increased the ductility of light weight aggregate concrete but did not significantly affect the value of compressive strength. The value of the indirect

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tensile strength and that of the modulus of rupture of lightweight high-strength concrete could be approximately doubled with the use of steel fiber reinforcement at 1.7% by volume of the concrete. Addition of polypropylene fibers at 0.56% by volume of concrete resulted in a 90% increase in the value of the indirect tensile strength. The value of the modulus of rupture increased by about 20% as a result of this reinforcement. This type of fibers, however, did not significantly affect the value of the compressive strength or the modulus of elasticity.

M. Alhozaimy et al., [2] gives an overview of a comprehensive set of experimental data were generated regarding the effects of collated fibrillated polypropylene fibers at relatively low volume fractions (below 0.3%) on the compressive, flexural and impact properties of concrete materials with different binder compositions. Author concluded that polypropylene fibers have no statistically significant effects on the compressive strength and toughness of conventional concrete at the volume fractions used in this investigation. The presence of silica fume, however, increased the average compressive strength by 17% and 23% of plain and fibrous concretes. On the average, the addition of 0.1%, 0.2% and 0.3% volume fraction of fibers increase the flexural toughness by 44%, 271% and 387%, respectively. Silica fume increases the flexural toughness by 48% and 79% in the case of plain and fibrous concretes, respectively.

Machine Hsiea et al., [3] gives an overview of the mechanical properties of polypropylene hybrid fiber-reinforced concrete. Author concluded that comparing with the strengths of pure concrete, the compressive strength of polypropylene hybrid fiber-reinforced concrete increased by 14.60–17.31%; the splitting tensile strength did by 8.88–13.35%; modulus of rupture did by 8.99–24.60%.

Pu Wang et al., [4] this paper studied experimentally the synergic mechanical properties of hybrid fiber reinforced concrete (HFRC) with different kinds and percent of steel fibers and polypropylene fiber, to find out the higher performance of mechanical properties of hybrid fiber reinforced concrete mixtures. Author concluded that the steel fiber can improve the splitting tensile and bending strength of the concrete obviously. The hybrid fiber concrete improves more. Compared with plain concrete, hybrid fibers improve concrete splitting strength about 44.34% and bending strength about 49.05%. The hybrid fiber reinforced concrete has the best impact resistance ability which is 6.8 times more than that of plain concrete.

Ghosni et al., [5] this research project is on utilization of synthetic fibers as intrinsic reinforcement in reinforced concrete beam in order to evaluate the structural behaviour of such element under cyclic loadings. Findings of this research project reveal that where fibres are used in the mix, damping ratio can be greatly enhanced. The natural frequency of undamaged beam drops to 90% comparing to reference concrete using 1% PP fibre in the mix. Using higher percentage of PP fibre in the mix helps with the improvement of damping ratio and also the energy dissipated in the system.

A. Saadun et al., [6] a study was conducted to examine the effect of mixing additives with concrete to increase the strength and durability of the concrete. The observations in this study showed that PP fibre could increase the ultimate dynamic compressive strength of the concrete effectively. The ultimate increase in dynamic compressive strength, namely 76.9%, which contain 2 kg/m<sup>3</sup> PP fibre. Increasing the volume of PP fibre caused an increase in the ultimate dynamic compressive strength of polypropylene fibre reinforced concrete. On the other hand, the lowest critical strain was observed.

### III. PROPOSED METHODOLOGY AND DISCUSSION

The present study consists of experimental study of polypropylene fiber in development of mechanical property of concrete. The experimental method refers to the casting of cubes (150mm x 150mm x 150mm), cylinders (15cm diameter and 30cm long), prisms (500cm x 100mm x 100mm) and structural member beams (1.5m x 150mm x 200mm) for M25 and M30 grade of concrete as per Indian standard method to determine the compressive strength, split tensile strength, flexural strength of concrete for different proportion of polypropylene fiber as 3 kg/m<sup>3</sup>, 4 kg/m<sup>3</sup> and 5 kg/m<sup>3</sup> (i.e. 0.12%, 0.16% and 0.2%). Mix design procedure as per IS: 10262-2009 [7] for M25 grade of concrete.

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### MATERIAL PROPERTY

**Cement:** OPC 53 grade conforming to IS 12269-2013 [8] standards are used in this experimental works. OPC 53 grade of Coromandal King Brand from INDIA Cements Pvt. Ltd. is used. The typical property of cement investigated in the present research work is tabulated below.

**Table I Typical Properties of OPC 53 Grade Cement**

S. No	Properties	Results obtained	IS:12269-2013 Specifications
1	Fineness retained on IS sieve 90 $\mu$	2%	-
2	Soundness (mm)	3.5	10 (max)
3	Normal Consistency	27.5 %	-
4	Initial Setting Time (min)	102	30 (min)
5	Final Setting Time (min)	209	600 (max)
6	3 days compressive strength (MPa)	27.4	27
7	7 days compressive strength (MPa)	37.8	37
8	28 days compressive strength (MPa)	55.2	53
9	Specific Gravity	3.02	3.15

**Aggregate:** The test for aggregate is done as per Indian standard procedure. The typical property of aggregate investigated in the present research work is tabulated below.

**Table II Typical Property of Aggregate**

Property	Fine Aggregate	Coarse Aggregate
Specific gravity	2.42	2.78
Fineness modulus	2.872	6.669
Water absorption (%)	1.315	0.50
Free moisture content (%)	0.2	0
Silt Content	2.6 %	-
Bulk density(kg/m <sup>3</sup> )	1660	1730
Aggregate Impact value	-	13.74
Aggregate Crushing value	-	12.10

**Polypropylene Fiber:** Finely polypropylene mono filaments were used as the fiber. Bajaj Reinforcements LLP Imambada Nagpur, Maharashtra supplied the fibers. The technical specifications of polypropylene fiber used are tabulated below.

**Table III Technical Specifications of Polypropylene Fiber of 36 mm Length**

S. NO.	Characteristics	Material Property
1	Base Resin	Modified Olefin
2	Length	36mm
3	Tensile Strength	550 – 640 MPa
4	Surface Texture	Continuously Embossed
5	No. of Fibers per kg	59,000
6	Specific Gravity	0.90 – 0.92
7	Young's Modulus	6 – 10 GPa
8	Melting Point	159 □ – 179 □
9	Ignition Point	Greater than 450 □

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**Water:** The water used in this experiment is portable tap water available in the laboratory with pH value of  $7.0 \pm 1$  and conforms as per IS and suitable for mixing concrete and curing purpose of specimens.

### IV. EXPERIMENTAL RESULTS

**Cube Compressive Strength:** After finalization of mix proportion of M25 (1:1.40:2.79) with W/C = 0.44, different proportion of polypropylene fiber such as  $0 \text{ kg/m}^3$ ,  $3 \text{ kg/m}^3$ ,  $4 \text{ kg/m}^3$  and  $5 \text{ kg/m}^3$  (i.e. 0%, 0.12%, 0.16% and 0.2%) added and tested for compressive strength. Concrete cube specimens of size 150 mm x 150 mm x 150 mm were cast, cured and tested at 7 and 28 days of maturity as per IS:516-1959 [9]. The results of cube compressive strength at 7 and 28 days maturity for M25 grade concrete is tabulated below.  $P_{ref}$  for 7 and 28 days maturity are 23.41 and 33.48  $\text{N/mm}^2$  respectively.

**Table IV Cube Compressive Strength of M25 Grade of Concrete**

Designation	Polypropylene ( $\text{kg/m}^3$ )	Compressive strength of M25 grade of concrete ( $\text{N/mm}^2$ )			
		7 days		28 days	
		$P_{exp}$	$P_{exp} / P_{ref}$	$P_{exp}$	$P_{exp} / P_{ref}$
M25P0	0	23.41	1.00	33.48	1.00
M25P3	3	23.56	1.01	33.93	1.01
M25P4	4	23.7	1.01	34.37	1.02
M25P5	5	23.11	0.99	32.74	0.98

Experimental setup for cube compressive strength test shown in following figure is used for conducting this test. Loading rate is  $14 \text{ N/mm}^2/\text{minute}$ .



Figure 1: Experimental Setup for Compressive Strength

The compressive strength at 7 and 28 days maturity of M25 grade concrete is initially observed to be increasing upto the addition of  $4 \text{ kg/m}^3$  of polypropylene fiber and then start decreasing with the further increment of  $5 \text{ kg/m}^3$  of polypropylene fiber. Graph between compressive strength vs polypropylene fiber is shown in following figure.

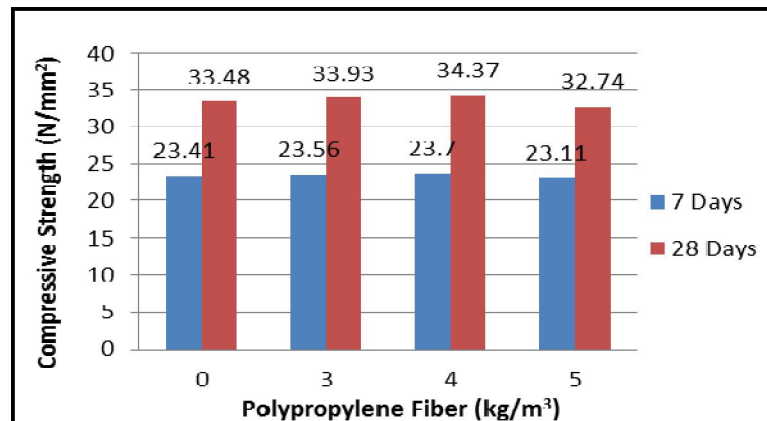


Figure 2: Compressive Strength of M25 Grade of Concrete at 7 and 28 Days of Maturity

**Split Tensile Strength of Concrete:** After finalization of mix proportion of M25 grade concrete, different proportion of polypropylene fiber such as 0 kg/m<sup>3</sup>, 3 kg/m<sup>3</sup>, 4 kg/m<sup>3</sup> and 5 kg/m<sup>3</sup> (i.e. 0%, 0.12%, 0.16% and 0.2%) added and tested for split tensile strength. Concrete cylinder specimens of size 150 mm x 300 mm were cast, cured and tested at 28 days of maturity. The results of split tensile strength at 28 days maturity for M25 grade concrete is tabulated below. Here P<sub>ref</sub> value is 2.76 N/mm<sup>2</sup>.

**Table V Split Tensile Strength of M25 Grade of Concrete**

Designation	Polypropylene (kg/m <sup>3</sup> )	Split tensile strength of M25 grade of concrete (N/mm <sup>2</sup> )	
		P <sub>exp</sub>	P <sub>exp</sub> / P <sub>ref</sub>
M25P0	0	2.76	1.00
M25P3	3	3.04	1.10
M25P4	4	3.18	1.15
M25P5	5	3.25	1.18

Experimental setup for split tensile strength test shown in following figure is used for conducting this test. Loading rate is 2 N/mm<sup>2</sup>/ minute.



Figure 3: Experimental Setup for Split Tensile Strength

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The observed value of splitting tensile strength at 28 days maturity of M25 grade of concrete is observed to be  $2.76 \text{ N/mm}^2$  and increased upto  $3.25 \text{ N/mm}^2$  with the addition of  $5 \text{ kg/m}^3$  of polypropylene fiber. Graph between split tensile strength vs polypropylene fiber is shown in following figure.

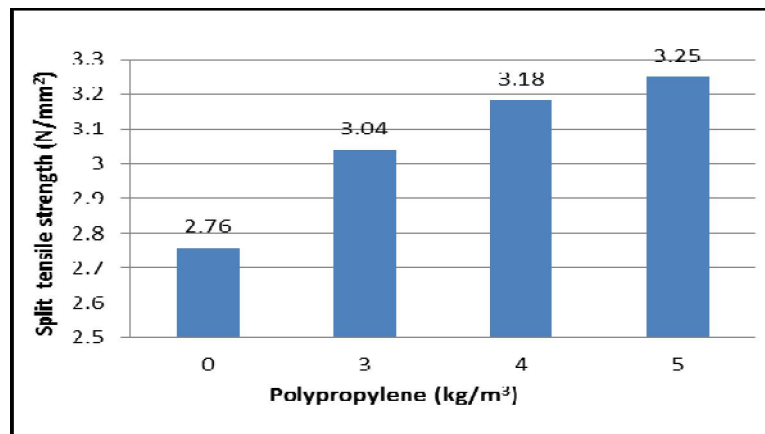


Figure 4: Split Tensile Strength of M25 Grade of Concrete

**Flexural Strength of Concrete:** After finalization of mix proportion of M25, different proportion of polypropylene fiber such as  $0 \text{ kg/m}^3$ ,  $3 \text{ kg/m}^3$ ,  $4 \text{ kg/m}^3$  and  $5 \text{ kg/m}^3$  (i.e. 0%, 0.12%, 0.16% and 0.2%) added and tested for flexural strength. Concrete prism specimens of size  $100 \text{ mm} \times 100 \text{ mm} \times 500 \text{ mm}$  were cast, cured and tested at 28 days of maturity. Experimental setup for flexural strength test shown in following figure is used for conducting this test. Loading rate is  $0.7 \text{ N/mm}^2/\text{minute}$ .



Figure 5: Experimental Setup for Flexural Strength of M25P3

The results of flexural strength at 28 days maturity for M25 grade concrete is tabulated below. Here  $P_{ref}$  value is  $6.1 \text{ N/mm}^2$ .

**Table VI Flexural Strength of M25 Grade of Concrete**

Designation	Polypropylene (kg/m <sup>3</sup> )	Flexural strength of M25 grade of concrete (N/mm <sup>2</sup> )	
		$P_{exp}$	$P_{exp}/P_{ref}$
M25P0	0	6.1	1.00
M25P3	3	6.5	1.07
M25P4	4	6.8	1.11
M25P5	5	6.7	1.10



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The flexural strength at 28 days of maturity of M25 grade of concrete observed to be 6.1 N/mm<sup>2</sup> and increased upto 6.8 N/mm<sup>2</sup> with the addition of 4 kg/m<sup>3</sup> of polypropylene fiber and then start decreasing with the further increment of 5 kg/m<sup>3</sup> polypropylene fiber upto a value of 6.7 N/mm<sup>2</sup>. Graph between flexural strength vs polypropylene fiber is shown in following figure.

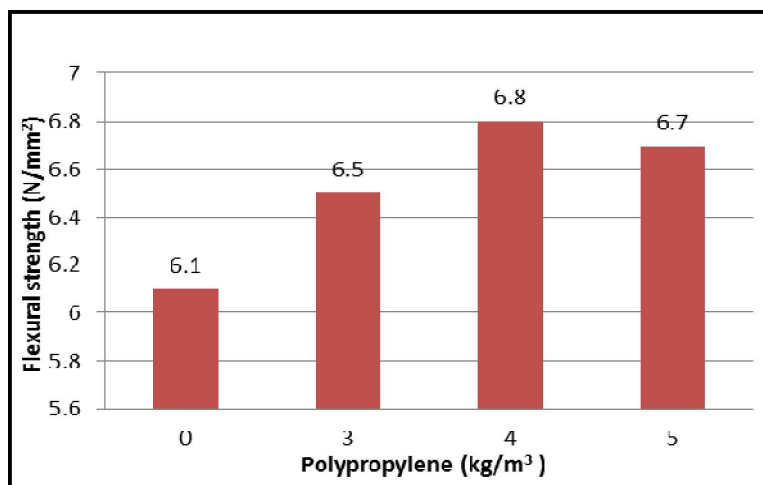


Figure 6: Flexural Strength of M25 Grade of Concrete

**Workability of Concrete:** After finalization of mix proportion of M25 grade of concrete, different proportion of polypropylene fiber such as 0 kg/m<sup>3</sup>, 3 kg/m<sup>3</sup>, 4 kg/m<sup>3</sup> and 5 kg/m<sup>3</sup> (i.e. 0%, 0.12%, 0.16% and 0.2%) added and tested for workability of concrete by slump test.

**Table VII Workability of M25 Grade of Concrete**

Designation	Polypropylene(kg/m <sup>3</sup> )	Workability of M25 grade of concrete (mm)
M25P0	0	53
M25P3	3	51
M25P4	4	46
M25P5	5	39

Workability is observed to be decreasing with the addition of polypropylene fiber. The slump value was initially observed to be 53 mm for 0 kg/m<sup>3</sup> polypropylene fiber and then start decreasing with the increase in polypropylene fiber upto 39 mm for M25 grade of concrete for 5 kg/m<sup>3</sup> of polypropylene fiber. Graph between slump vs polypropylene fiber is shown in following figure.

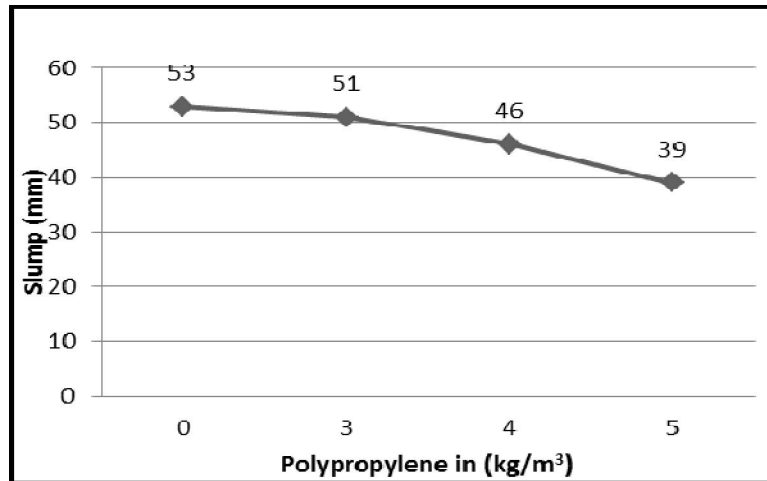


Figure 7: Workability of M25 Grade of Concrete

**Structural Member (RCC Beam):** Structural member such as beams (1.5m x 150mm x 200mm) has been cast for M25 of concrete for with addition of polypropylene as 0 kg/m<sup>3</sup>, 3 kg/m<sup>3</sup>, 4 kg/m<sup>3</sup> and 5 kg/m<sup>3</sup>. The longitudinal reinforcement consisted of 10 mm diameter bars of 500 MPa yield strength, whilst a reinforcing steel of 500 MPa yield strength with a diameter of 8 mm was used as lateral shear reinforcement. 3 number of longitudinal bar is provided and shear reinforcement is provided at spacing of 150 mm in beam. Clear cover of 25 mm provided for beam. Reinforcement detailing of RCC beam is shown in following figure.

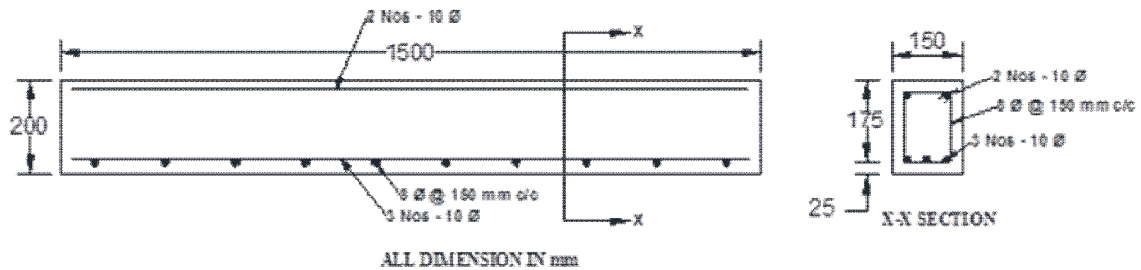


Figure 8: Reinforcement Detailing of RCC Beam

Loading setup for RCC beam is shown in following figure.

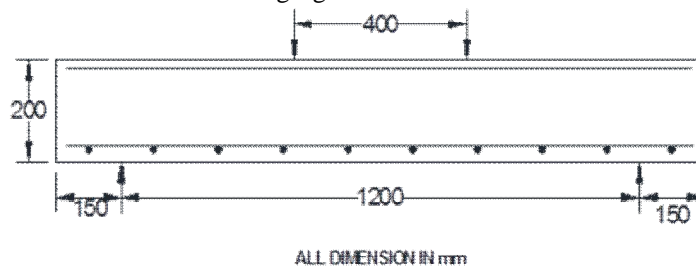


Figure 9: Loading Setup of RCC Beam

The results of flexural strength of RCC beam at 28 days maturity for M25 grade concrete is tabulated below. Here  $P_{ref}$  value is 90.79 kN.



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**Table VIII Flexural Strength of RCC Beam for M25 Grade of Concrete**

Grade of concrete	Polypropylene fiber (kg/m <sup>3</sup> )	Designation	Theoretical capacity P <sub>th</sub> (kN)	Experimental capacity P <sub>ex</sub> (kN)	$\frac{P_{ex}}{P_{th}}$	$\frac{P_{ex}}{P_{ref}}$
M25	0	M25P0	72.54	90.79	1.25	1.00
	3	M25P3	72.54	93.26	1.29	1.03
	4	M25P4	72.54	97.43	1.34	1.07
	5	M25P5	72.54	101.40	1.40	1.12

Experimental setup of RCC beam is shown in following figure. The specimens of beam were subjected to bending testing in servo control compression-cum-flexural testing machine. The entire mechanical testing was undertaken at room temperature condition. The behaviour of RCC beam was monitored closely during the application of bending load to get the ultimate load carrying capacity of the beam. Damaged was characterised essentially as flexural crack and increases at bottom near middle span of the beam. The rate of loading was applied at displacement rate of 1.6 mm/min.

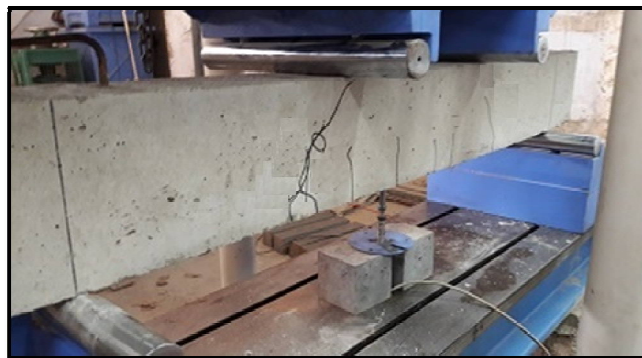


Figure 10: Experimental Setup of RCC Beam

The ultimate load carrying capacity of RCC beam of M25 grade of concrete have increased satisfactory with the addition of polypropylene fiber. The theoretical load carrying capacity was calculated to be 72.54 kN but experimentally observed to be higher i.e. 90.79 kN which further increased upto 101.40 kN with the addition of 5 kg/m<sup>3</sup> polypropylene fiber for M25 grade of concrete. . Graph between load vs displacement is shown in following figure.

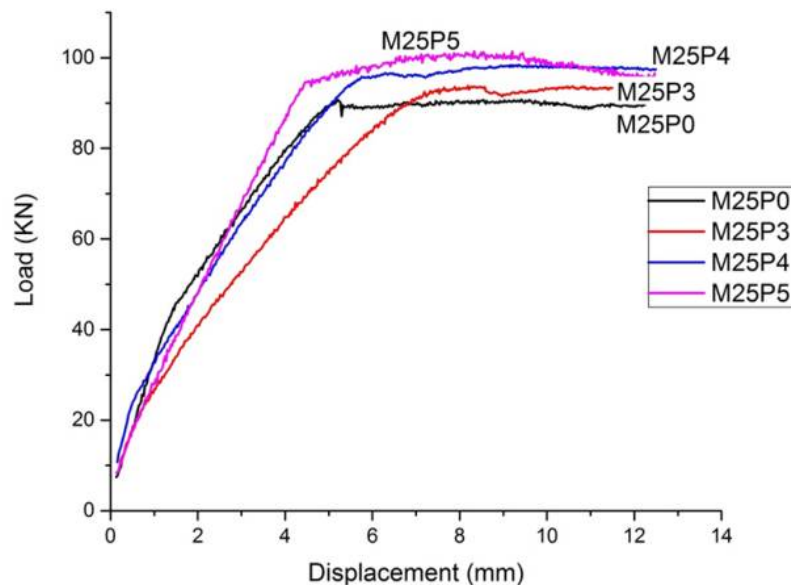


Figure 11: Flexural Strength of RCC Beam for M25 Grade of Concrete

## V. CONCLUSION

Thus the evaluation and comparisons of various strength of polypropylene fiber reinforced concrete with the plain concrete have been discussed in this thesis. On the basis of the experimental investigations and analysis, the following conclusions can be drawn:

- 1) Addition of polypropylene fibers have no significant effect on the compressive strength. Compressive strength increases upto 1 % and 2 % for 7 days and 28 days of maturity period respectively for M25 grade of concrete with the addition of polypropylene fiber at  $4 \text{ kg/m}^3$ . After that further increase of polypropylene fiber cause decrease in compressive strength.
- 2) Split tensile strength increases by about 18% for M25 grade of concrete with the addition of polypropylene fiber at  $5 \text{ kg/m}^3$ .
- 3) Flexural strength shows higher value around 11% increment for M25 grade of concrete with the addition of  $4 \text{ kg/m}^3$  of polypropylene fiber and decreases after further addition.
- 4) Workability is observed to be decreasing with the addition of polypropylene fiber.
- 5) The ultimate load carrying capacity of RCC beam increases upto 12 % for M25 grade of concrete with the addition of  $5 \text{ kg/m}^3$  of polypropylene fiber.

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