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EXPERIMENTAL STUDY ON STRENGTH CHARACTERESTICS OF POLYPROPYLENE FIBRE REINFORCED FLYASH CONCRETE

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Abstract - *This paper presents an experimental study on the polypropylene fibre reinforced fly ash concrete RC beams under flexure. The variables of study include the polypropylene fibre content (0.2 % & 0.4%). The polypropylene fibre and 10% of Fly ash as cement replacement are incorporated in all the concrete mix proportions considered in this study. The experimental test results showed that the compressive strength of concrete increases with the increasing percentage of fibre. The flexural strength of polypropylene fibre reinforced fly ash concrete beams increased considerably than the control concrete beams.*

Key Words: *polypropylene fibres; fly ash; deflection; flexural strength*

I. INTRODUCTION

Concrete has been widely used in civil engineering applications with its high compressive strength, low cost and abundant raw material. But common concrete has some shortcomings, for example, low tensile and flexural strength, poor toughness, high brittleness, and so on that restrict its application. To overcome these deficiencies, additional materials are added to improve the performance of concrete. Fibre reinforced concrete is a composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural tensile strength, permeability and so on. Short fibres have been known and used for centuries to reinforced brittle material like cement or masonry bricks. At that time, fibres were natural fibres, such as horse hair, straw, etc. Now, days numerous fibre types are available for commercial uses, the basic types begin steel, glass, synthetic materials (polypropylene, carbon, nylon, etc.) and some natural fibres. Fibre-reinforcement is predominantly used for crack control and not structural strengthening. Although the concept of reinforcing brittle materials with fibres is quite old, the recent interest in reinforcing cement-based materials with randomly distributed fibres is quite old; the recent interest in reinforcing cement based materials with randomly distributed fibres is based on research starting in the 1960's. Since then, there have been substantial research and development activities throughout the world. It has been established that the addition of randomly distributed polypropylene fibres to brittle cement based materials can increase their fracture toughness and ductility

Several investigations were performed to investigate the flexural response of polypropylene fibre reinforced fly ash concrete members. J. J. Raju and J. John studied the strength properties of high volume fly ash concrete with fibres at 0.1%, 0.2% and 0.3% of cement and with 60 % fly ash replacement with cement. It was found that fibre addition had increased compressive strength by 12.5% over control mix. V. K. Singh and D. Kumar investigated the fibre content variation from 0.1%, 0.3%, 0.5% and 0.7 % by weight of concrete with 75% glass fibre and 25 % polypropylene fibre. The results showed that compressive strength of concrete increased with addition of fibres in M25 grade. For better results 0.5% addition of fibres was optimum. J. P. Mehul and S. M. Kulkarni used fibrillated polypropylene fibre in percentages of 0.5%, 1% and 1.5% in high strength concrete with super plasticizer. It was observed that the compressive strength of concrete increased with addition of fibres. A. Sivakumar et al studied the influence of fibre addition in concrete mix by adding both steel and polypropylene fibres, Addition of steel fibre dosage was done at 1% to 2% volume fraction (vf) and inclusion of polypropylene fibre dosage at 0.1% to 0.3%. It was concluded that maximum increase in compressive strength was observed at 1% volume fraction of glued steel fibres and 0.1% of polypropylene fibres.

K. Murahari and R. M. Rao studied the effect of polypropylene fibres in fly ash concrete using fibre volume fraction of 0.15%, 0.20%, 0.25% and 0.30% with class C fly ash. It was concluded that the compressive strength increased gradually from 0.15% to 0.30% fibre content. B. K. Kashiyani studied the addition of polypropylene fibre in concrete in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in top and bottom layer of the standard paver block and found that addition of 0.4% fibre mixed in concrete paver block had the maximum compressive strength up to 40%.

J. Chamundeswari et al investigated the polypropylene fibre reinforced concrete using fly ash class C in ratios 50%, 55% and 60% with replacement of cement and Polypropylene fibre in dosage of 0.9% for M35 grade. It was concluded that 50% replacement of fly ash gave good strength and at dosage more than 50%, it showed decrease in strength. At extended curing period, fly ash started to react and gain more strength. It could be treated as an eco-friendly concrete.

R. Kolli examined the strength properties of polypropylene fibre reinforced concrete by adding Polypropylene Fibre (PPF) ranging from 0%, 0.5%, 1%, 1.5% and 2%. It was concluded that the maximum increase in compressive strength was 34% as compared to mix without fibres at optimum dosage of fibres as 1.5%. M. V. K. Rao, et al, [31], studied the behavior of polypropylene fibre reinforced concrete deep beams with PP fibre (recron 3S) content (0%, 0.5% and 1%) with 20% fly ash as cement replacement and reported a marginal increase in compressive strength as the fibre content increases.

J. Gummadi et al. studied the effect of particle size and its concentration on the properties of fly ash filled polypropylene composites. The concentration of fly ash

varied from 0%, 10%, 20% and 25% by weight in the polypropylene composite. It was found that finest particles showed best flexural strength at all concentration. Fly ash was found to be good filler for polypropylene matrix composites. With fly ash added to polypropylene improves flexural strength. The spherical shaped fly ash gives significant improvement. Fly ash of smaller particle size showed significant improvement in strength of concrete composite as compared to large sized particles.
Y. Shrivastava and K. Bajaj investigated the performance of fly ash and high volume fly ash concrete in pavement design and found that flexural strength increased with increase of fly ash up to 35% replacement in concrete.
I. Patel and C. D. Modhera examined the fibre reinforced concrete containing high volume fly ash of grades M25, M30, M35 and M40 concrete with different percentages of F type fly ash 50%, 55% and 60%, in addition to polypropylene fibre @ 0.25% by mass of cementitious material. It was concluded that 55% cement replacement showed optimum gain of flexural strength.

II. EXPERIMENTAL PROGRAMME

A. Material Properties

1) Polypropylene Fibre

Polypropylene is used in several ways in nonwoven plants. It is a commonly used staple fibre in blending and carding machines for needle punch and thermal bonding lines. It is also used in spun bond lines where chips are extruded into continuous fibres, caught on a traveling conveyor screen, and cooled into fabric. In the melt blowing process; hot, liquid polypropylene is sprayed by high pressure air onto a conveyor to make a fabric of fine denier fibre. Finished polypropylene fabric can also be treated with heat by calenders, infrared heaters, and ovens to impart additional characteristics to the fabric. Polypropylene is a thermoplastic which means that it can be melted and cooled again. Polypropylene melts at 320 degrees Fahrenheit, is a tough fibre, and resists many chemicals. It is lightweight, with a density less than water. It does degrade in sunlight, but additives can be put in to lessen the degradation. In its natural state it is a milky- white fibre. However, it can be colored during the spinning process. Polypropylene (PP) fibres belong to the newest generation of large-scale, manufactured chemical fibres, having the fourth largest volume in production after polyesters, polyamides and acrylics. PP is one of the most successful commodity fibres, reaching a world production capacity of four million tons a year. Due to its low density (0.9 gm/cc), high crystalline, high stiffness and excellent chemical/bacterial resistance.

Table 1 Polypropylene Fibre Material Properties

S. No	Properties	Polypropylene Fibre
1.	Colour	Brilliant White
2.	Fibre Length	12mm
3.	Sp. Gravity	0.91
4.	Melt Point	160° C
5.	Alkali Resistance	Very Good
6.	UV Stability	Excellent

2) Fly Ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes. The Specific gravity of fly ash is 2.33.

B. Concrete Mix

The detailed mix proportions are shown in Table 2 and 3. The maximum size of coarse aggregate was 20mm and the fine aggregate was river sand with particle size of 0.075-5mm.The specific gravity of fine aggregate and coarse aggregate was 2.63 and 2.72. The concrete specimens were demoulded after 24 hours and then cured in a water storage tank for 28 days.

Table 2 Mix proportion for control concrete

Cement (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (lit/m^3)
425.73	615.09	1182.42	191.58
1	1.44	2.77	0.45

Table 3 Mix proportion for polypropylene fibre fly ash concrete

Cement	Fly ash	F.A	C.A	Water	PP fibre
383.15	42.5	596.85	1146.37	191.58	1.702
1		1.40	2.69	0.45	0.004

C. Compressive test

The cubes of standard size (150mm x 150mm x 150mm), were casted, cured for 28 days. The compressive strength of concrete cubes was determined in the laboratory using compressive testing machine. The corresponding values are presented. The 0.2 & 0.4% of Polypropylene fibre and 10% partial replacement of fly ash by weight of cement were used.

Table 4 Compressive strength of concrete cubes for control concrete

S No	Specimen Code	Compressive Load		Average Compressive Strength (N/mm²)
		Load (T)	Load (N)	
1	C-1	85	850000	37.78
2	C-1	83	830000	36.89
3	C-1	89	890000	39.55
			Average	38.07

Table 5 Compressive strength of concrete cubes for 0.2% polypropylene fibre fly ash concrete

S. No	Specimen Code	Compressive Load		Average Compressive Strength (N/mm²)
		Load (T)	Load (N)	
1	C-2	92	920000	40.88
2	C-2	94	940000	41.77
3	C-2	90	900000	40.55
			Average	41.06

Table 6 Compressive strength of concrete cubes for 0.4% polypropylene fibre fly ash concrete

S. No	Specimen Code	Compressive Load		Average Compressive Strength (N/mm²)
		Load (T)	Load (N)	
1	C-3	93	930000	41.33
2	C-3	92	960000	42.67
3	C-3	96	960000	42.67
			Average	42.22

D. Flexural test

The test program consider of casting and testing of three beams of which one were control beams, all having size of 125 x 250 x 3200mm length and designed as the beam reinforced with 2-10# at bottom, 2-10# at top using 6mm diameter stirrups @165mm c/c. The specimens were tested in a standard load testing frame of 750kN capacity and the proving ring of 50T capacity. All the beams were simply supported over a simple span of 3m and tested under two point loading. Dial gauges capable of measuring to an accuracy of 0.01mm were placed at mid span (D_3) and 1/3 span (D_1 and D_2) that are used for observations of deflections. The demec gauge were fixed at the front phase of the test observation to measure concrete strain .The crack measuring gauge of 0.02mm accuracy were used for measuring effective crack width. The test was continued till the load reaches about 85% of the ultimate load on the descending portion. The load at first crack and ultimate load were recorded for each of the specimen tested.

Fig.1 Steel reinforcement placed in the mould

Fig 2 Casting of Reinforced concrete beam in the laboratory

Fig.3 Testing of RC Beam in the laboratory

Crack pattern

The main Purpose for addition of the fibre is to control cracking caused by loading to observed accurately the micro cracks, fibre reinforced specimens were strained to a predetermined valve The optional microscopic image was analysed using digital image analysis system consisting of a stereomicroscopic, a high resolution video camera, and an image analysis system.

Fig.4 First Crack of RC Beam

Fig .5 Crack Pattern of RC Beam

III RESULTS AND DISCUSSION

S No	Load	Dial Gauge reading			Ultimate Deflection
		Left	Centre	Right	
	N	mm	mm	mm	mm
1	0	0	0	0	0
2	2500	0.27	0.3	0.27	0.04
3	5000	0.61	0.69	0.62	0.08
4	7500	1.06	0.97	0.88	0.2
5	10000	1.78	1.2	1.55	0.32
6	12500	2.18	1.98	2.14	0.48
7	15000	3.23	2.56	4.22	0.64
8	17500	4.24	3.71	4.15	0.92
9	20000	5.08	4.65	5.99	1.08
10	22500	6.01	5.65	6.48	1.32
11	25000	6.88	6.09	7.06	1.36
12	27500	7.89	7.64	8.12	1.56
13	30000	8.92	8.75	8.81	1.72
14	32500	9.82	9.53	9.31	1.84
15	35000	10.09	10.69	10.98	2.12
16	37500	11.84	11	11.93	2.36
17	40000	12.25	11.89	12.88	2.48
18	42500	13.32	13.13	13.42	2.72
19	45000	14.21	15.05	14.97	3.04
20	47500	15.63	16.54	15.42	3.32
21	50000	19.92	21.28	19.8	4.2

The load- deflection relationship corresponding to the control concrete beam and polypropylene fibre reinforced fly ash concrete RC beams are shown in following graphs. The load-deflection curve is observed to be almost linear up to the first crack and non-linear beyond that. An increase in ultimate deflection is noticed for PP fibre reinforced fly ash concrete beams as compared to those of plain concrete, indicating the post-cracking ductility imparted.

Table 7 Load and Deflection – M30 Control Concrete RC Beam

S No	Load	Dial Gauge reading			Ultimate Deflection
		Left	Centre	Right	
	Newton	mm	mm	mm	mm
1	0	0	0	0	0
2	2500	0.19	0.18	0.16	0.04
3	5000	0.64	0.59	0.38	0.12
4	7500	0.96	0.8	0.89	0.16
5	10000	1.09	1	1.05	0.24
6	12500	2.12	1.15	1.96	0.44
7	15000	2.93	2.03	2.35	0.56
8	17500	3.09	2.98	3.38	0.64
9	20000	3.96	3.68	4.06	0.76
10	22500	4.59	4.18	5.09	0.92
11	25000	5.31	4.97	5.78	1.04
12	27500	6.18	5.34	6.13	1.24

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13	30000	6.87	6.47	6.63	1.28
14	32500	7.09	7.02	7.07	1.4
15	35000	8.65	7.85	7.73	1.72
16	37500	9.2	8.55	8.21	1.84
17	40000	10.19	9.02	9.89	2.04
18	42500	10.85	9.77	10.42	2.16
19	45000	11.57	10.27	11.97	2.32
20	47500	12.63	11.42	12.42	2.56
21	50000	15.92	14.8	14.96	3.12
22	52500	17.9	18.85	17.85	3.76
23	55000	19.72	22.39	20.37	4.52

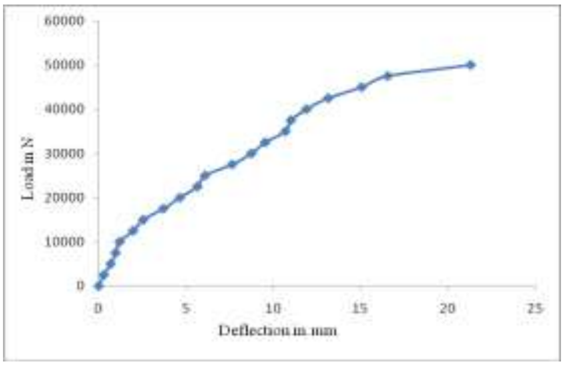

Fig. 6 Load – Deflection Response of Control Concrete RC beam

Table 8 Load and Deflection –0.2% of Polypropylene Fibre Reinforced Fly Ash Concrete RC Beam

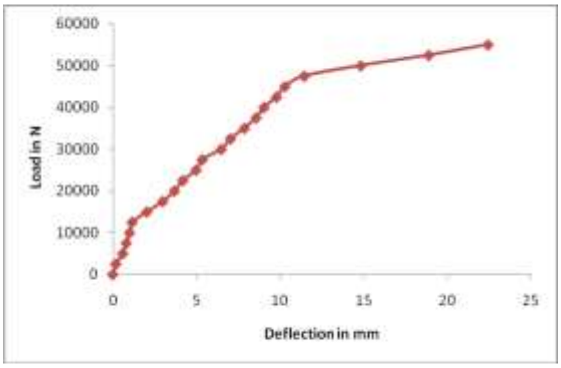

Fig. 7 Load – Deflection Response of 0.2% Polypropylene fibre Concrete RC beam

Table 9 Load and Deflection –0.4% of Polypropylene Fibre Reinforced Fly Ash Concrete RC Beam

S No	Load	Dial Gauge reading			Ultimate Deflection
		Left	Centre	Right	
	Newton	mm	mm	mm	mm
1	0	0	0	0	0
2	2500	0.22	0	0.18	0.04
3	5000	0.68	0.1	0.59	0.12
4	7500	0.89	0.3	0.8	0.16
5	10000	1.02	0.53	1	0.2
6	12500	1.98	1.25	1.67	0.36
7	15000	2.43	2	2.24	0.48
8	17500	3.08	2.8	3.02	0.72
9	20000	3.97	3.89	3.76	0.8
10	22500	4.68	4.97	4.18	0.96
11	25000	5.97	5.81	5.97	1.16
12	27500	6.96	6.6	6.8	1.36
13	30000	7.31	7.26	7.27	1.48
14	32500	8.01	8.9	8.95	1.76
15	35000	9.76	9.59	9.7	1.92
16	37500	10.47	10.45	10.25	2.08
17	40000	12.08	11.31	11.02	2.4
18	42500	13.78	12.97	12.6	2.56
19	45000	14.57	13.9	13.37	2.92
20	47500	15.63	14.8	15.39	3.12
21	50000	17.92	17.09	17.82	3.56
22	52500	19.96	18.15	19.05	4
23	55000	20.88	22.94	20.62	4.56

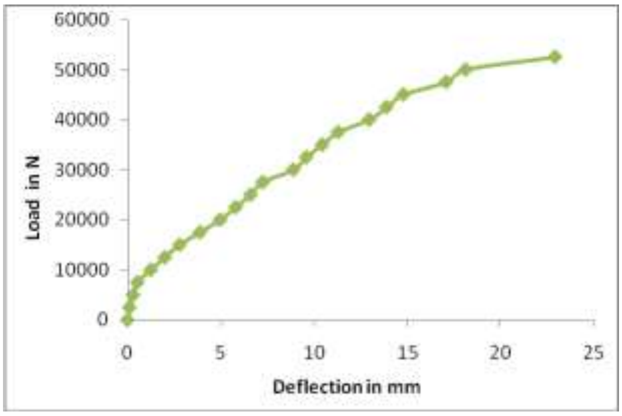

Fig 8 Load – Deflection Response of 0.4% Polypropylene fibre Concrete RC beam

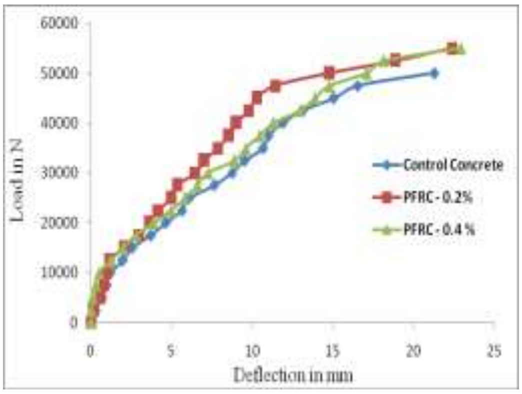

Fig.9 Load-Deflection Response for combined results

IV CONCLUSION

From the experimental results, it is clear that the polypropylene fibre can be used as the replacement of cement in concrete. Addition of fibres in concrete enhances the flexural ability of the concrete. The crack widths are also smaller at service load in the case of polypropylene fibre reinforced fly ash concrete beams as compared to plain concrete beams.

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