Effect of Addition of Polymer on the Properties of Waste Plastic Fibre Reinforced Concrete-An Experimental Investigation

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Abstract: *Recycling technology or reusing technology is not a new technology. Since civilization, man, in one form or the other, is recycling some of the materials for his convenience. Today, the recycling technology is gaining importance because of the reasons of growing quantity of wastes and to save natural resources. As the population is growing, the quantity of waste on this earth is also growing. The greedy nature of man has doubled the quantity of wastes. These wastes are causing an endangering pollution of the environment pollution of their environment. Some of wastes are polluting the environment instantaneously after their release and some of the wastes are polluting the environment slowly. Waste plastic is one of the major environmental pollutants. Plastic is a non bio-degradable material or it is a non-perishable material. It cannot be destroyed easily. Any efforts of destroying it again results in environmental pollution. The main objective of this paper is to throw some light on the effective use of waste plastics in concrete. The effect of addition of waste plastics in the form of fibres into the concrete along with some polymer has been studied in this paper. The strength characteristics of waste plastic fibre reinforced concrete with different percentages of polymer have been found experimentally.*

Keywords: *Polymer, Fibre reinforced concrete, Waste plastic fibre, Strength and Workability characteristics*

I. Introduction

Many efforts are being continuously made to bring down the environmental pollution on this mother earth. The breathing air which sustains the life is being polluted; the drinking water which ushers life into all living beings is being polluted; the mother earth/soil which supports all living beings is being polluted; the hearing sound which is a communication media is being polluted: the edible food which nourishes the living beings is being polluted. Pollution has not left any area. It is spreading its tentacles in all walks of life

As the population is growing, the quantity of waste on this earth is also growing. The greedy nature of man has doubled the quantity of wastes. These wastes are causing an endangering pollution of the environment pollution of their environment. Some of wastes are polluting the environment instantaneously after their release and some of the wastes are polluting the environment slowly.

Many of the wastes and especially the industrial wastes are causing enormous pollution of the environment, among them, the noteworthy are Fly ash, Blast furnace slag, Silica fume, Stone crusher dust, etc. The safe disposal of these industrial wastes has become a major problem to the industrialists as well as to the environmentalists.

In today's circumstances, plastic has become one of the major environmental pollutants. Plastic is a non-bio-degradable material or, it is a non-perishable material. It cannot be destroyed easily. Any efforts of destroying it again results in environmental pollution. Plastics have entered every conceivable field like medical, agricultural, automobile and of course households. They come in handy on account of their useful properties like being light weight and economical. They are one of the useful materials ever created by man. Engineers have shaped plastics that are as rigid as steel or as soft as cotton or sponge. The word plastic comes from the Greek word "Plastikos" which means able to be shaped. Chemically plastics are polymers. A polymer is a substance which contains a particular molecular group repeated hundreds of times linked together in definite pattern. There are hundreds of different plastics. But basically they belong to two primary groups namely" thermosetting Plastics" and Thermo Plastics"

Engineers have created hundreds of different plastics and each has its own properties. Plastic parts are replacing metals in aero planes, cars and other mechanical devices. Airplane wings are now made of plastics which reduce the weight of air craft and there by reduces fuel consumption. Plastic has also replaced metals in building construction materials such as pipes because they are weight and do not corrode. Plastic fibre and fabrics have replaced natural fibres like cotton, silk and wool. We have nylon, linen, polyester fabrics which are more durable. Plastic fibres are excellent for clothing, carpeting and upholstery.The only drawback of plastics is that they are not environmental friendly, because they are non-bio-degradable material. That is why environmentalists have raised big hue and cry against their use. Even though plastic is making wonders in all the fields, it is endangering the environment. It is causing environmental pollution. Plastics cannot be perished. It cannot be dumped in soil. If dumped in soil it causes the soil pollution. It cannot be dumped in water. If dumped in water it causes water pollution.

When the waste plastic did not find any place in America and Europe, they dumped million tonnes of waste plastic in Atlantic and Pacific oceans. This has resulted in many accidents of ships and the death of much aquatic life. It cannot be burnt also. If burnt it causes air pollution by releasing many toxic gases. Many metropolitan and industrial cities of the world have become population less due to the environmental problem caused by the plastic. Thus plastic is causing tremendous environmental pollution. Many researches are going on for uses of this plastic in a safe manner.

II. Experimental work

2.1 Materials Used

- Cement: Ordinary Portland Cement-53 grade was used having a specific gravity of 3.15 and it satisfies the requirements of IS: 12269-1987 specifications.
- Fine aggregates: Locally available sand collected from the bed of river Bhadra was used as fine aggregate. The sand used was having fineness modulus 2.96 and conformed to grading zone-III as per IS: 383-1970 specification.
- Coarse aggregates: The crushed stone aggregate were collected from the local quarry. The coarse aggregates used in the experimentation were 10mm and down size aggregate and tested as per IS: 383-1970 and 2386-1963 (I, II and III) specifications. The aggregates used were having fineness modulus 1.9.
- Recycled aggregates: The recycled aggregates were collected from demolished concrete slabs, beams & columns. The recycled aggregates used in the experimentation were 10mm and down size aggregates and tested as per IS: 383 -1970 and 2386 (I, II and III). The aggregates were having fineness modulus of 1.75.
- Fibres: The waste plastic fibres were obtained by cutting waste plastic pots, buckets, cans, drums and utensils. The waste plastic fibres obtained were all recycled plastics. The fibres were cut from steel wire cutter and it is labour oriented. The thickness of waste plastic fibres was 1mm and its breadth was kept 5mm and these fibres were straight. The different volume fraction of fibres and suitable aspect ratio were selected and used in this investigation
- Water: Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.
- Superplasticizer: To impart the additional desired properties, a superplasticizer (Conplast SP-430) was used. The dosage of super plasticizer adopted in the experimentation was 1% (by weight of cement).
- Polymer: Nafufill BB2 polymer was used in the experimentation manufactured by MC. Bauchemie (India) Pvt. Ltd. Mumbai. The dosage of polymer adopted in the experimentation were 0%, 2%, 4%, 6%, 8% and 10%.

2.2 Experimental Procedure

The main objective of this experimental investigation is to find out the effect of addition of polymer on the workability and strength characteristics of waste plastic fibre reinforced concrete. The results are compared with polymer concrete without waste plastic fibres.

Concrete was prepared by a design mix proportion of 1: 1.435: 2.46 with a W/C ratio of 0.48 which correspond to M20 grade of concrete. The different percentage addition of polymer adopted in the experimental programme are 0%, 2%, 4%, 6%, 8% and 10%. Waste plastic fibres having an aspect ratio 50 (thickness = 1mm, length = 30mm and breadth = 5mm) were added in the dry mix at the rate of 1.5% (by volume fraction). The required percentage of polymer was added and machine mixed. All the specimens were cast with and without waste plastic fibres and tested after 28 days of curing as per IS specifications. When the mix was wet the workability test like slump test, compaction factor test and flow tests were carried out. After 28 days of water curing the specimens were weighed for their density and tested for their strength. The different strength parameters of waste plastic fibre reinforced concrete like compressive strength, tensile strength, flexural strength and impact strength were found for different percentage addition/replacement of cement by Micro silica-600 as the case may be. The compressive strength tests were conducted as per IS: 516-1959 on specimens of size 150 x 150 x 150 mm. The tensile strength tests were conducted as per IS: 5816-1999 on specimens of diameter 150 mm and length 300mm. Indirect tension test (Brazilian test) was conducted on tensile strength test specimens. Flexural strength tests were conducted as per IS: 516-1959 on specimens of size 100 x 100 x 500mm.Two point loading was adopted on a span of 400 mm, while conducting the flexural strength test. The impact strength tests were conducted as per ACI committee-544 on the panels of size 250 x 250 x 30 mm. A mild steel ball weighing 1.216 kg was droped from a height of one meter on the impact specimen, which was kept on the floor. The care was taken to see that the ball was droped at the center point of specimen every time. The number of blows required to cause first crack and final failure were noted. From these numbers of blows, the impact energy was calculated as follows.

$$\text{Impact energy} = mghN = w/g \times g \times h \times N = whN \text{ (N-m)}$$

Where, m = mass of the ball
w = weight of the ball =1.216 kg
g = acceleration due to gravity
h = height of the drop =1m
N = average number of blows to cause the failure.

III. Experimental results

The following tables give the details of the experimental results

3.1 Compressive strength test results -The following Table No. 3.1.1 and 3.1.2 gives the compressive strength test results of polymer concrete with and without waste plastic fibres.

Table 3.1.1: Compressive strength test results of polymer concrete with waste plastic fibres

Percentage addition of polymer	Specimen identification	Weight of specimen (N)	Density (kN/m^3)	Average density (kN/m^3)	Failure load (kN)	Compressive strength (MPa)	Average compressive strength (MPa)	Percentage increase or decrease of compressive strength w. r. t reference mix
0 (Ref mix)	A	76	22.52	22.52	640	28.44	28.74	---
	A	76	22.52		640	28.44		
	A	76	22.52		660	29.33		
2	B	75	22.23	22.23	690	30.66	30.52	+ 6
	B	75	22.23		680	30.22		
	B	75	22.23		690	30.66		
4	C	76	22.52	22.52	720	32	32.44	+ 13
	C	76	22.52		740	32.88		
	C	76	22.52		730	32.44		
6	D	74	21.93	21.93	740	32.88	33.48	+ 16
	D	74	21.93		760	33.77		
	D	74	21.93		760	33.77		
8	E	72	21.33	21.53	760	33.77	34.52	+ 20
	E	72	21.33		770	34.22		
	E	74	21.93		800	35.55		
10	F	74	21.93	21.93	710	31.55	31.7	+ 10
	F	74	21.93		720	32		
	F	74	21.93		710	31.55		

Table 3.1.2: Compressive strength test results of polymer concrete without waste plastic fibres

Percentage addition of polymer	Specimen identification	Weight of specimen (N)	Density (kN/m^3)	Average density (kN/m^3)	Failure load (kN)	Compressive strength (MPa)	Average compressive strength (MPa)	Percentage increase or decrease of compressive strength w. r. t reference mix
0 (Ref mix)	A1	73	21.63	21.43	585	26	25.73	---
	A1	72	21.33		580	25.78		
	A1	72	21.33		572	25.42		
2	B1	72	21.33	21.13	595	26.44	26.07	+ 1
	B1	71	21.04		585	26		
	B1	71	21.04		580	25.77		
4	C1	72	21.33	21.34	660	29.34	29.5	+ 15
	C1	71	21.04		675	30		
	C1	73	21.63		656	29.15		
6	D1	71	21.04	21.04	700	31.12	31.62	+ 23
	D1	71	21.04		710	31.55		
	D1	71	21.04		724	32.17		
8	E1	71	21.04	20.94	730	32.45	32.6	+ 27
	E1	70	20.74		730	32.45		
	E1	71	21.04		740	32.89		
10	F1	70	20.74	20.94	650	28.89	29.04	+ 13
	F1	71	21.04		660	29.34		
	F1	71	21.04		650	28.89		

The above results can be depicted in the form of graph as shown fig 3.1

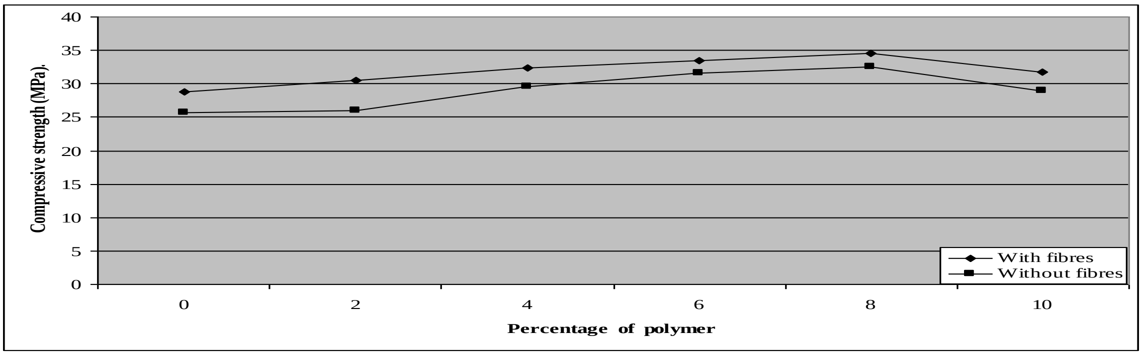

Fig.3.1: Variation of compressive strength test results of concrete with and without waste plastic fibres for different percentage addition of polymer

3.2 Tensile strength test results -The following Table No. 3.2.1 and 3.2.2 gives the tensile strength test results of polymer concrete with and without waste plastic fibres.

Table 3.2.1: Tensile strength test results of polymer concrete with waste plastic fibres

Percentage addition of polymer	Specimen identification	Failure load (kN)	Tensile strength (MPa)	Average tensile strength (MPa)	Percentage increase or decrease of tensile strength w. r. t reference mix
0 (Ref mix)	A	240	3.39	3.82	---
	A	280	3.96		
	A	290	4.1		
2	B	280	3.96	3.96	+ 4
	B	300	4.24		
	B	260	3.67		
4	C	290	4.1	4.29	+ 12
	C	320	4.52		
	C	300	4.24		
6	D	340	4.81	4.67	+ 22
	D	320	4.52		
	D	330	4.66		
8	E	360	5.09	5.04	+ 32
	E	360	5.09		
	E	350	4.95		
10	F	300	4.24	4.52	+ 18
	F	330	4.66		
	F	330	4.66		

Table 3.2.2: Tensile strength test results of polymer concrete without waste plastic fibres

Percentage addition of polymer	Specimen identification	Failure load (kN)	Tensile strength (MPa)	Average tensile strength (MPa)	Percentage increase or decrease of tensile strength w. r. t reference mix
0 (Ref mix)	A	175	2.47	2.5	---
	A	175	2.47		
	A	180	2.54		
2	B	195	2.76	2.7	+ 8
	B	190	2.68		
	B	190	2.68		
4	C	215	3.04	3.15	+ 26
	C	220	3.11		
	C	233	3.29		
6	D	280	3.96	3.92	+ 57
	D	275	3.9		
	D	275	3.9		
8	E	295	4.17	4.17	+ 67
	E	300	4.24		
	E	290	4.1		
10	F	262	3.66	3.53	+ 41
	F	240	3.4		
	F	250	3.53		

The above results can be depicted in the form of graph as shown fig 3.2

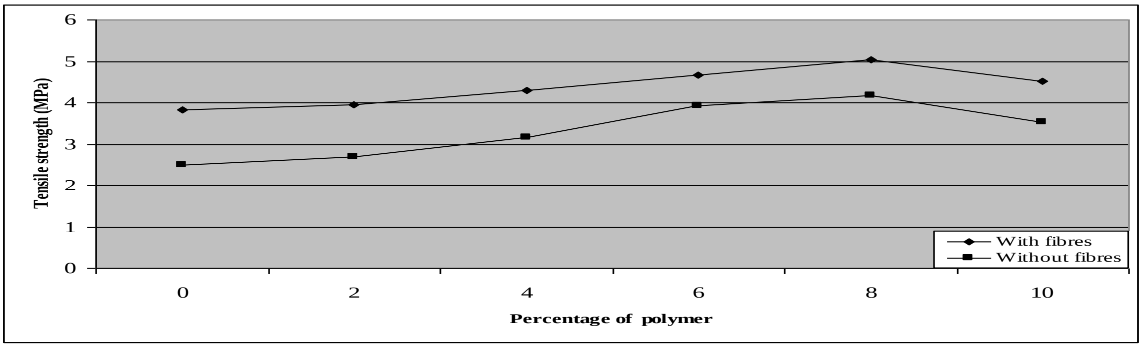

Fig.3.2: Variation of tensile strength test results of concrete with and without waste plastic fibres for different percentage addition of polymer

3.3 Flexural strength test results -The following Table No. 3.3.1 and 3.3.2 gives the flexural strength test results of polymer concrete with and without waste plastic fibres

Table 3.3.1: Flexural strength test results of polymer concrete with waste plastic fibres

Percentage addition of polymer	Specimen identification	Failure load (kN)	Flexural strength (MPa)	Average flexural strength (MPa)	Percentage increase or decrease of flexural strength w. r. t reference mix
0 (Ref mix)	A	13.8	5.52	5.53	---
	A	13.8	5.52		
	A	13.9	5.56		
2	B	14.3	5.72	5.61	+ 2
	B	14	5.6		
	B	13.8	5.52		
4	C	14.5	5.8	5.73	+ 4
	C	14.3	5.72		
	C	14.2	5.68		
6	D	14.7	5.88	5.85	+ 6
	D	14.5	5.8		
	D	14.7	5.88		
8	E	14.8	5.92	5.95	+ 8
	E	14.9	5.96		
	E	14.9	5.96		
10	F	14.1	5.64	5.69	+ 3
	F	14.4	5.76		
	F	14.2	5.68		

Table 3.3.2: Flexural strength test results of polymer concrete without waste plastic fibres

Percentage addition of polymer	Specimen identification	Failure load (kN)	Flexural strength (MPa)	Average flexural strength (MPa)	Percentage increase or decrease of flexural strength w. r. t reference mix
0 (Ref mix)	A1	9.6	3.84	3.78	---
	A1	9.4	3.76		
	A1	9.4	3.76		
2	B1	10.6	4.24	4.21	+ 11
	B1	10.52	4.2		
	B1	10.5	4.2		
4	C1	11.5	4.6	4.7	+ 24
	C1	11.9	4.76		
	C1	11.8	4.72		
6	D1	13	5.2	5.1	+ 35
	D1	12.8	5.12		
	D1	12.5	5		
8	E1	14	5.6	5.62	+ 49
	E1	14	5.6		
	E1	14.2	5.68		
10	F1	12.5	5	4.8	+ 27
	F1	11.5	4.6		
	F1	12	4.8		

The above results can be depicted in the form of graph as shown fig 3.3

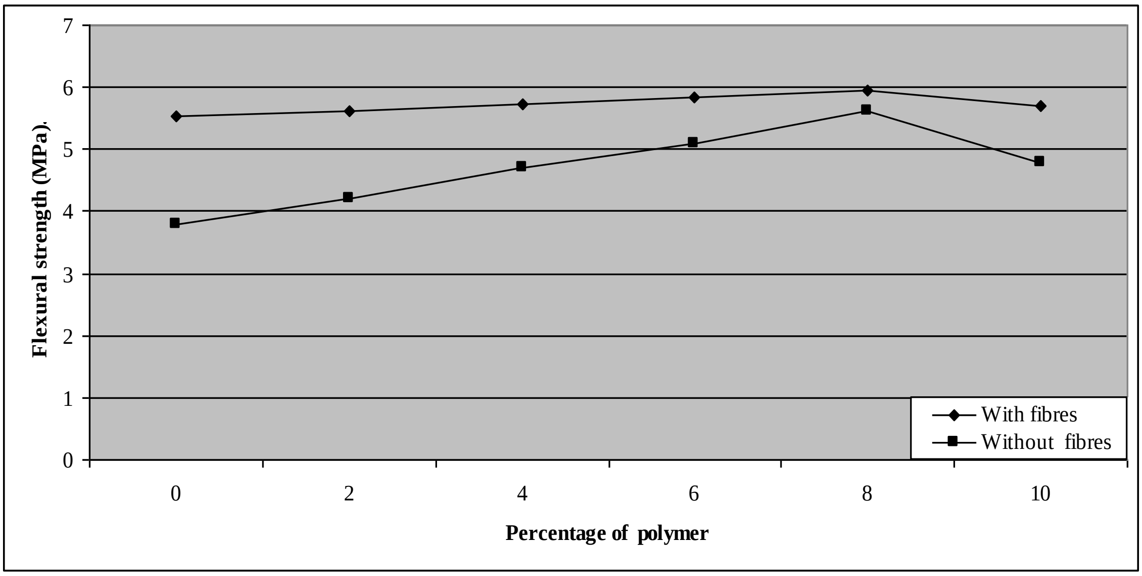

Fig 3.3: Variation of flexural strength test results of concrete with and without waste plastic fibres for different percentage addition of polymer

3.4 Impact strength test results - The following Table No. 3.4.1 and 3.4.2 gives the impact strength test results of polymer concrete with waste plastic fibres

Table 3.4.1: Impact strength test results of polymer concrete with waste plastic fibres

Percentage addition of polymer	Specimen identification	Number of blows required to cause		Average number of blows required to cause		Impact strength (N-m) required to cause		Percentage increase or decrease of impact strength w. r. t reference mix	
		first crack	final failure	first crack	final failure	first crack	final failure	first crack	final failure
0 (Ref mix)	A	6	20	4.34	19.34	52.77	235.17	---	---
	A	4	21						
	A	3	17						
2	B	6	22	5.67	22.34	68.94	271.65	+ 31	+ 16
	B	4	21						
	B	7	24						
4	C	7	24	7	25	85.12	304	+ 61	+ 29
	C	8	28						
	C	6	23						
6	D	10	26	10.67	27	129.74	328.32	+ 146	+ 40
	D	12	30						
	D	10	25						
8	E	12	30	12.67	31	154.06	376.96	+ 192	+ 60
	E	13	33						
	E	13	30						
10	F	9	26	8.34	25.67	101.41	312.14	+ 92	+ 33
	F	8	26						
	F	8	25						

Table 3.4.2: Impact strength test results of polymer concrete without waste plastic fibres

Percentage addition of polymer	Specimen identification	Number of blows required to cause		Average number of blows required to cause		Impact strength (N-m) required to cause		Percentage increase or decrease of impact strength w. r. t reference mix	
		first crack	final failure	first crack	final failure	first crack	final failure	first crack	final failure
0 (Ref mix)	A1	3	16	3.34	16.34	41.61	198.7	---	---
	A1	4	17						
	A1	3	16						
2	B1	4	18	4	18.34	48.64	223	+ 17	+ 12
	B1	4	18						
	B1	4	19						
4	C1	6	24	5.67	22.67	68.94	275.66	+ 66	+ 39
	C1	5	22						
	C1	6	22						
6	D1	7	24	7.34	24.34	89.25	296	+ 115	+ 49
	D1	8	25						
	D1	7	24						
8	E1	9	25	9.34	25.67	113.57	312.14	+ 173	+ 57
	E1	10	27						
	E1	9	25						
10	F1	8	24	7.67	24	93.26	291.84	+ 124	+ 47
	F1	8	23						
	F1	7	25						

The above results can be depicted in the form of graph as shown fig 3.4

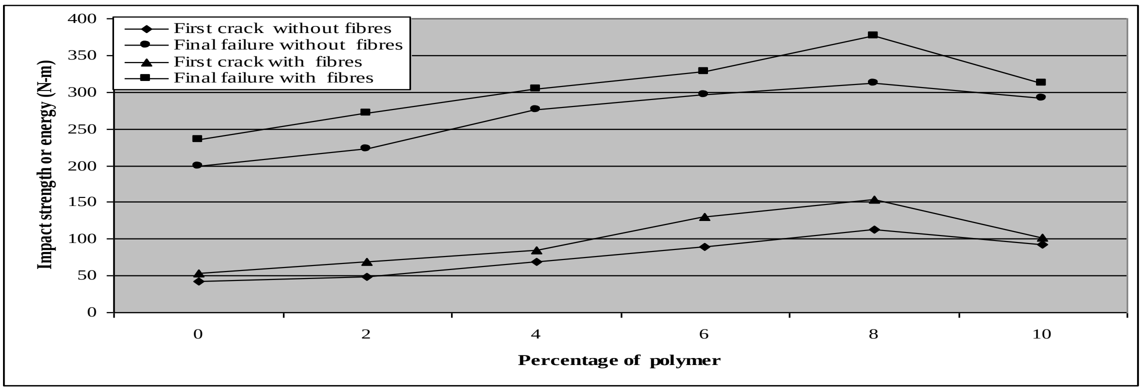

Fig 3.4: Variation of impact strength test results of concrete with and without waste plastic fibres for different percentage addition of polymer

3.5 Workability test results -The following Table No 3.5.1 gives the overall results of workability of polymer concrete with and without waste plastic fibres

Table 3.5.1: Workability of polymer concrete with and without waste plastic fibres

Percentage addition of polymer	Workability of concrete with waste plastic fibres			Workability of concrete without waste plastic fibres		
	Slump (mm)	Compaction factor	Percentage flow	Slump (mm)	Compaction factor	Percentage flow
0 (Ref. mix)	0	0.8	7.9	0	0.8	8.2
2	0	0.8	11.8	0	0.81	12.5
4	0	0.81	17.1	0	0.82	18
6	0	0.84	18.4	0	0.84	19
8	0	0.85	22.3	0	0.86	22.8
10	0	0.82	20.5	0	0.83	21

The above results can be depicted in the form of graph as shown fig 3.5 to 3.7

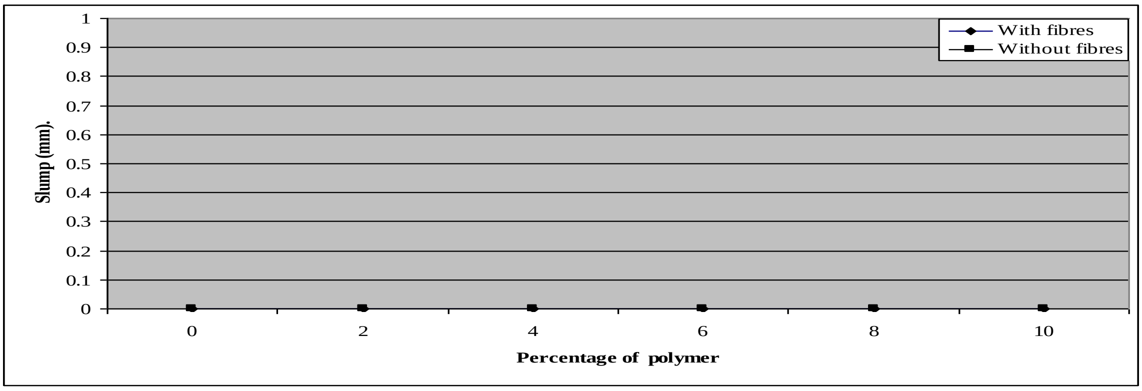

Fig 3.5: Variation of slump of concrete with and without waste plastic fibres for with different percentage addition of polymer

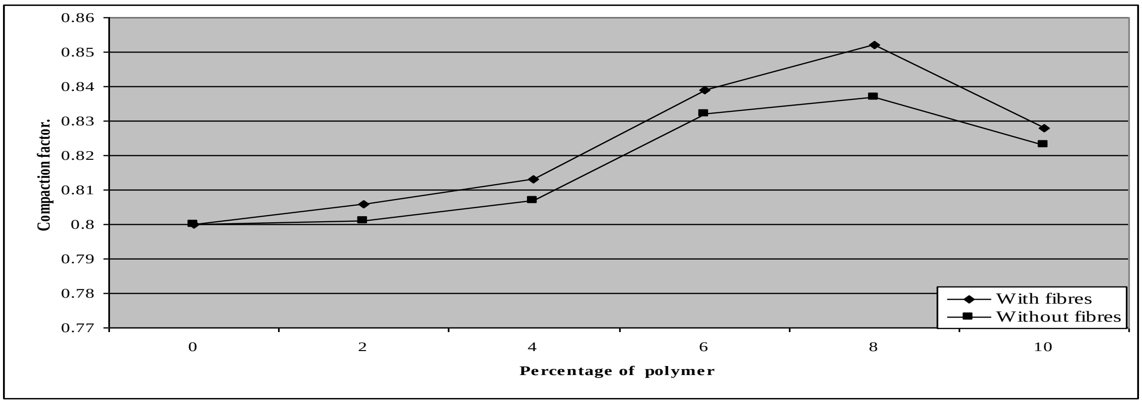

Fig 3.6: Variation of compaction factor of concrete with and without waste plastic fibres for different percentage addition of polymer

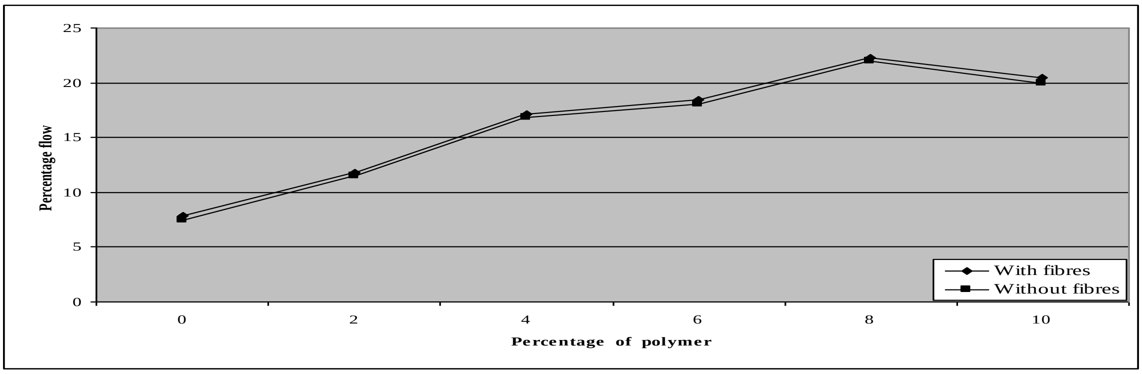

Fig 3.7: Variation of percentage flow of concrete with and without waste plastic fibres for different percentage addition of polymer

IV. Observations and Discussions

Based on the experimental results the following observations are made

1. Both the concretes with waste plastic fibres and without waste plastic fibres show an increasing trend in the compressive strength from 0% addition of polymer up to 8% addition. After 8% of addition of polymer the compressive strength starts decreasing i.e., the maximum compressive strength is obtained when 8% polymer is added. Therefore, the higher compressive strength can be achieved when 8% polymer is added and the percentage increase in the compressive strength is 20% and 27% respectively for concrete with and without waste plastic fibres.

   Both the concretes with waste plastic fibres and without waste plastic fibres show an increasing trend in the tensile strength from 0% addition of polymer up to 8% addition. After 8% of addition of polymer the tensile strength starts decreasing i.e., the maximum tensile strength is obtained when 8% polymer is added. Therefore, the higher tensile strength can be achieved when 8% polymer is added and the percentage increase in the tensile strength is 32% and 67% respectively for concrete with and without waste plastic fibres.

   Both the concretes with waste plastic fibres and without waste plastic fibres show an increasing trend in the flexural strength from 0% addition of polymer up to 8% addition. After 8% of addition of polymer, the flexural strength starts decreasing i.e., the maximum flexural strength is obtained when 8% polymer is added. Therefore, the higher flexural

strength can be achieved when 8% polymer is added and the percentage increase in the flexural strength is 8% and 49% respectively for concrete with and without waste plastic fibres.
Both the concretes with waste plastic fibres and without waste plastic fibres show an increasing trend in the impact strength from 0% addition of polymer upto 8% addition. After 8% of addition of polymer the impact strength starts decreasing i.e., the maximum impact strength is obtained when 8% polymer is added. Therefore, the higher impact strength can be achieved when 8% polymer is added and the percentage increase in the impact strength for final failure 60% and 59% respectively for concrete with and without waste plastic fibres.
This may be due to the fact that addition of 8% polymer may induce more workability and make the mix more homogeneous there by producing higher strength properties.
Thus it can be concluded that addition of 8% polymer can produce higher strengths in concrete with or without waste plastic fibres.

2 It has been observed that the strength properties (compressive strength, tensile strength, flexural strength, and impact strength) of polymer concrete with waste plastic fibres are higher as compared to the polymer concrete without waste plastic fibres.
This may be due to the fact that the addition of waste plastic fibres certainly induces desirable strength properties by arresting the cracks.
Thus it can be concluded that the strength properties of polymer concrete can be enhanced by adding waste plastic fibres into it.

3 It has been observed that the workability of waste plastic fibre reinforced concrete increases upto 8% addition of polymer. After 8% the workability decreases. Therefore, the maximum workability is achieved with the addition of 8% polymer. This is true for concretes with and without waste plastic fibres.
This may be due to the fact that more than 8% addition of polymer may induce stiffness to concrete there by reducing the workability characteristics.
Thus it can be concluded that addition of 8% polymer can produce good workability properties to concrete with or without waste plastic fibres.

4. It has been observed that the workability values of concrete with waste plastic fibres are less as compared to concrete without waste plastic fibres. This is true for all the percentage addition of polymers.
This is obviously due to the fact that the addition of waste plastic fibres obstructs the flow and reduces the workability.
Thus it can be concluded that the workability of polymer concrete with waste plastic fibres is less as compared to workability of polymer concrete without waste plastic fibres.

5. It is observed from the literature (Neelamagum.M et al.,) that the Glass fibre reinforced concrete with polymer impregnation show marginally increases in the strength properties. However the addition of polymer in waste plastic fibre reinforced concrete has yielded better strength characteristics as compared to Glass fibre reinforced concrete.

V. Conclusions

1. Addition of 8% polymer can produce higher strength characteristics in concrete with or without waste plastic fibres.
2. The strength properties of polymer concrete can be enhanced by adding waste plastic fibres into it.
3. Addition of 8% polymer can produce good workability properties to concrete with or without waste plastic fibres.
4. Workability of polymer concrete with waste plastic fibres is less as compared to workability of polymer concrete without waste plastic fibres.

VI. Acknowledgements

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