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INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Effect of Micro Silica on the Strength Properties of Waste Plastic Fibre Reinforced Concrete - an Experimental Investigation

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Abstract

In this paper an attempt has been made to study the effect of addition of Microsilica and replacement cement by Microsilica in different percentages on the properties of workability and strength characteristics of waste plastic fibre reinforced concrete. The strength characteristics viz., compressive strength, tensile strength, flexural strength, impact strength and workability characteristics are found for waste plastic fibre reinforced concrete, when Microsilica was added and replaced by cement in different percentages viz, 0%, 2%, 4%, 6%, 8%, 10% and 12% respectively by weight of cement. Waste plastic fibres having an aspect ratio 50 (thickness = 1mm, length = 50mm and breadth = 5mm) were added at the rate of 0.5% (by volume fraction). The results show that upto 10% of Microsilica can be added and 8% of Microsilica can be replaced by weight of cement into waste plastic fibre reinforced concrete, without adversely affecting the compressive strength and with advantage in other strength properties.

Keywords: Waste Fibre reinforced concrete, Microsilica, Compressive strength, Tensile strength, Flexural strength, Impact strength and Workability characteristics

Introduction

The fibre reinforced concrete is a composite material consisting of cement paste, mortar or concrete with fibres like asbestos, glass, plastic, carbon or steel. Such fibre reinforced concrete may be useful when a large amount of energy has to be absorbed (Ex: In explosive loading), where high tensile strength and reduced cracking are desirable, or even when conventional reinforcement cannot be placed because of the shape of the member. However, the addition of fibre in the brittle cement and concrete matrices can offer a convenient, practical and economical method of overcoming their inherent deficiencies of poor tensile and impact strengths, and enhance many of the structural properties of the basic materials such as fracture, toughness, flexural strength and resistance to fatigue, impact, thermal shock and spalling [1, 7].

The field of concrete technology is advancing at a faster rate. Many inventions in the field of concrete technology have expanded the horizon of the construction industry. These new inventions facilitate to produce the requisite concrete of required nature and property. Many wastes, which are producing environmental pollution, are also finding an effective place in the preparation of concrete. Thus, by using these wastes, which are causing environmental pollution one, can, produce concrete that is having the desirable properties [7].

One such waste, which is causing the environmental pollution, is the plastic. The plastic is a non- biodegradable/non-perishable material. The plastics will neither decay nor degenerate either in water or in soil. In turn it pollutes the water and soil. The plastic if burnt releases many toxic gases, which are very dangerous for the health. Such plastic can be used in concrete in the form of fibres to impart some additional desirable qualities to the concrete [3, 5].

Another environmental air pollutant viz. Silica fume (Microsilica) is an amorphous powder which when added with OPC increases the strength and durability of concrete. It also reduces the permeability of concrete and improves the abrasion and erosion resistance [2, 6, and 8].

In this paper an attempts has been made to study the properties of fibre reinforced concrete produced from waste plastic fibres and Microsilica which are the two environmental pollutions. The strength characteristics of waste plastic fibre

ISSN: 2277-9655
Impact Factor: 1.852

reinforced concrete like compressive strength, tensile strength, flexural strength and impact strength are found when the Microsilica is added and replaced the cement by Microsilica in different percentages. Also the workability characteristic of waste plastic fibre reinforced concrete with Microsilica was studied.

Experimental Work

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.

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 of 1.9.

Fine aggregates: Locally available sand collected from the bed of river Bhadra was used as fine aggregate. The sand used was having fineness modulus of 2.96 and confirmed to grading zone-III as per IS: 383-1970 specification.

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 0.5% volume fraction of fibres and aspect ratio 50 were selected and used in this investigation. Physical properties of these fibres are given in Table No

Microsilica: Microsilica-600 was used in the experiment complies in all respects to NZS 3122:1995 - Specification for Portland and Blended Cements. The Microsilica-600 used in the experimentation was obtained from Bombay. Properties silica fume are given in Table No 2.1.

Superplasticizer: To impart the additional desired properties, a superplasticizer (Conplast SP-430) was used. The dosage of superplasticizer adopted in the experimentation was 1% (by weight of cement).

Water: Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.

Table 2.1.1: Chemical and physical properties of Microsilica-600

Chemical analysis		Particle size analysis	
SiO_2	87.89	100	100
Al_2O_3	4.31	50	99.6
SO_3	0.13	20	97.9
Fe_2O_3	0.59	10	94.5
MnO	0.03	5	84.6
Tio_2	1.16	2	55.6
CaO	0.32	1	35
K_2O	0.49	0.4	12.2
P_2O_2	0.05		
MgO	< 0.02		
Na_2O	0.14		
LOI	5.01		

* Data taken from the product brochure of the supplier

Table 2.1.2: Physical properties of waste plastic fibres

Size of specimen l x b x t in mm	Percentage of elongation	Tensile strength (MPa)	Modulus elasticity (MPa)	Water absorption	Specific gravity
150 x 25 x 1	15.56	15.52	113.90	Nil	1.28

Experimental Procedure

Concrete was prepared by a 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 Micro silica and replacement of cement by Micro silica adopted in the experimental programme are 0%, 2%, 4%, 6%, 8%, 10%, 12% and respectively. Waste plastic fibres having an aspect ratio 50 (thickness = 1mm, length = 50mm and breadth = 5mm) were added in the dry

ISSN: 2277-9655
Impact Factor: 1.852

mix at the rate of 0.5% (by volume fraction). All the specimens were cast and tested after 28 days of curing as per IS specifications.

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 of Microsilica-600 and replacement of cement by Microsilica-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 dropped 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 dropped 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.

Impact energy = mghN
= w/g x g x h x N
= whN (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.

Experimental Results

The following tables give the details of the experimental results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica and replacement of cement by Microsilica.

Compressive strength test results - The following Table No 4.1.1 and 4.1.2 gives the compressive strength test results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica and replacement of cement by Microsilica.

Table 4.1.1: Compressive strength test results of waste plastic fibre reinforced concrete with different percentage of addition of Microsilica

Percentage addition of Microsilica	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	74	21.93	21.93	800	35.55	35.4	+ 23
	B	74	21.93		800	35.55		
	B	74	21.93		790	35.11		
4	C	75	22.22	22.22	820	36.44	35.7	+ 24
	C	75	22.22		800	35.55		
	C	75	22.22		790	35.11		
6	D	74	21.93	21.93	900	40	37.03	+ 29
	D	74	21.93		750	33.33		
	D	74	21.93		850	37.77		
8	E	74	21.93	21.93	860	38.22	40.59	+ 41
	E	74	21.93		980	43.55		
	E	74	21.93		900	40		
10	F	74	21.93	22.22	1005	44.66	44.51	+ 57
	F	75	22.23		1000	44.44		

	F	76	22.52		1000	44.44		
12	G	72	21.33	21.53	850	37.77	39.7	+ 38
	G	73	21.63		930	41.33		
	G	73	21.63		900	40		

Table 4.1.2: Compressive strength test results of waste plastic fibre reinforced concrete with different percentage replacement of cement by Microsilica

Percentage replacement of Microsilica	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	76	22.52	22.52	640	28.44	28.74	---
	A1	76	22.52		640	28.44		
	A1	76	22.52		660	29.33		
2	B1	73	21.63	21.83	670	29.78	29.77	+ 4
	B1	74	21.93		680	30.22		
	B1	74	21.93		660	29.33		
4	C1	75	22.23	21.74	700	31.11	32.14	+ 12
	C1	72	21.34		720	32		
	C1	73	21.63		750	33.33		
6	D1	72	21.34	21.34	770	34.22	34.37	+ 20
	D1	72	21.34		770	34.22		
	D1	72	21.34		780	34.66		
8	E1	72	21.34	21.34	870	38.66	39.4	+ 37
	E1	72	21.34		900	40		
	E1	72	21.34		890	39.55		
10	F1	74	21.93	21.73	860	38.22	38.51	+ 34
	F1	74	21.93		860	38.22		
	F1	72	21.34		880	39.11		
12	G1	72	21.34	21.34	820	36.44	37.33	+ 30
	G1	72	21.34		840	37.33		
	G1	72	21.34		860	38.22		

Tensile strength test results-The following Table No 4.2.1 and 4.2.2 gives the tensile strength test results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica and replacement of cement by Microsilica.

Table 4.2.1: Tensile strength test results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica

Percentage addition of Microsilica	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	3.81	---
	A	280	3.96		
	A	290	4.1		
2	B	280	3.96	3.86	+ 1
	B	270	3.81		
	B	270	3.81		
4	C	290	4.1	4.05	+ 6
	C	290	4.1		

ISSN: 2277-9655
Impact Factor: 1.852

	C	280	3.96		
6	D	300	4.24	4.24	+ 11
	D	310	4.38		
	D	290	4.1		
8	E	320	4.52	4.52	+ 19
	E	330	4.66		
	E	310	4.38		
10	F	330	4.66	4.81	+ 26
	F	340	4.81		
	F	350	4.95		
12	G	300	4.24	4.24	+ 11
	G	290	4.1		
	G	310	4.38		

Table 4.2.2: Tensile strength test results of waste plastic fibre reinforced concrete with different percentage replacement of cement by Microsilica

Percentage replacement of Microsilica	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)	A1	240	3.39	3.81	---
	A1	280	3.96		
	A1	290	4.1		
2	B1	280	3.96	3.96	+ 4
	B1	300	4.24		
	B1	260	3.67		
4	C1	290	4.1	4.19	+ 10
	C1	290	4.1		
	C1	310	4.38		
6	D1	320	4.53	4.38	+ 15
	D1	300	4.24		
	D1	310	4.38		
8	E1	340	4.81	4.71	+ 24
	E1	330	4.66		
	E1	330	4.66		
10	F1	280	3.96	4.05	+ 6
	F1	280	3.96		
	F1	300	4.24		
12	G1	250	3.53	3.77	-1
	G1	260	3.67		
	G1	290	4.1		

Flexural strength test results - The following Table No 4.3.1 and 4.3.2 gives the flexural strength test results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica and replacement of cement by Microsilica.

Table 4.3.1: Flexural strength test results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica

Percentage addition of Microsilica	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		

ISSN: 2277-9655
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2	B	13.9	5.56	5.58	+ 1
	B	14	5.6		
	B	14	5.6		
4	C	14.2	5.68	5.66	+ 2
	C	14.3	5.72		
	C	14	5.6		
6	D	14.1	5.64	5.7	+ 3
	D	14.3	5.72		
	D	14.4	5.76		
8	E	14.4	5.76	5.77	+ 4
	E	14.5	5.8		
	E	14.4	5.76		
10	F	14.8	5.92	5.88	+ 6
	F	14.7	5.88		
	F	14.6	5.84		
12	G	14.5	5.8	5.7	+ 3
	G	14	5.6		
	G	14.3	5.72		

Table 4.3.2: Flexural strength test results of waste plastic fibre reinforced concrete with different percentage replacement of cement by Microsilica

Percentage replacement of Microsilica	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	13.8	5.52	5.53	---
	A1	13.8	5.52		
	A1	13.9	5.56		
2	B1	13.8	5.52	5.57	+ 1
	B1	14	5.6		
	B1	14	5.6		
4	C1	14	5.6	5.66	+ 2
	C1	14.3	5.72		
	C1	14.2	5.68		
6	D1	14.4	5.76	5.78	+ 5
	D1	14.4	5.76		
	D1	14.6	5.84		
8	E1	14.8	5.92	6	+ 8
	E1	15.2	6.08		
	E1	15	6		
10	F1	14	5.6	5.66	+ 2
	F1	14.2	5.68		
	F1	14.3	5.72		
12	G1	14	5.6	5.54	+ 1
	G1	13.7	5.48		
	G1	13.9	5.56		

Impact strength test results - The following Table No 4.4.1 and 4.4.2 gives the impact strength test results of waste plastic fibre reinforced concrete with different percentage addition of Microsilica and replacement of cement by Microsilica.

ISSN: 2277-9655
Impact Factor: 1.852

Table 4.4.1: Impact strength test results of waste plastic reinforced concrete with different percentage addition of Microsilica

Percentage addition of Microsilica	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	4	22	4.67	22.67	56.78	275.66	+ 8	+ 17
	B	4	22						
	B	6	24						
4	C	4	22	5	23.34	60.8	283.81	+ 15	+ 21
	C	5	24						
	C	6	24						
6	D	6	24	6.67	24.67	81.1	299.98	+ 54	+ 28
	D	8	24						
	D	6	26						
8	E	9	25	8.67	26.67	105.54	324.3	+ 100	+ 38
	E	6	27						
	E	11	28						
10	F	12	30	10.34	30.67	125.73	372.94	+ 138	+ 59
	F	10	29						
	F	09	33						
12	G	6	25	7	27	85.12	328.32	+ 62	+ 40
	G	6	26						
	G	9	30						

Table 4.4.2: Impact strength test results of waste plastic reinforced concrete with different percentage replacement cement by Microsilica

Percentage replacement of Microsilica	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	6	20	4.34	19.34	52.77	235.17	---	---
	A1	4	21						
	A1	3	17						
2	B1	6	24	5	22.34	60.08	271.65	+ 14	+ 16
	B1	4	21						
	B1	5	22						
4	C1	5	23	5.67	24.67	68.94	299.98	+ 31	+ 28
	C1	6	25						
	C1	6	26						
6	D1	6	26	6.34	27	77.09	328.32	+ 48	+ 40
	D1	7	28						
	D1	6	27						
	E1	7	28	7.34	28.67	89.25	348.62		

8	E1	7	28					+ 70	+ 48
	E1	8	30						
10	F1	6	24	6	25.34	72.96	308.13	+ 38	+ 31
	F1	7	27						
	F1	5	25						
12	G1	5	21	5	21.34	60.8	259.49	+ 15	+ 10
	G1	6	23						
	G1	4	20						

Workability test results - The following Table No 4.5.1 and 4.5.2 gives the overall results of workability of waste plastic fibre reinforced concrete with different percentage addition of Microsilica and replacement of cement by Microsilica.

Table 4.5.1: Workability test results of waste plastic reinforced concrete with different percentage addition of Microsilica

Percentage addition of Microsilica	Workability through		
	Slump (mm)	Compaction factor	Percentage flow
0 (Ref. mix)	0	0.8	7.5
2	0	0.84	9
4	0	0.84	12.3
6	0	0.85	13.3
8	0	0.86	14.2
10	0	0.86	16.25
12	0	0.84	13

Table 4.5.2: Workability test results of waste plastic reinforced concrete with different percentage replacement of cement by Microsilica

Percentage replacement of cement by Microsilica	Workability through		
	Slump (mm)	Compaction factor	Percentage flow
0 (Ref.mix)	0	0.8	7.5
2	0	0.82	8.25
4	0	0.85	12.75
6	0	0.87	17
8	0	0.89	25.25
10	0	0.86	21.75
12	0	0.84	16.5

Observations and Discussions

Based on the experimental results the following observations were made

1. It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the compressive strength upto 10% addition of Microsilica into it. After 10% addition of Microsilica the compressive strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows a higher compressive strength when 10% Microsilica is added and the percentage increase in the compressive strength is 55%

   It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the tensile strength upto 10% addition of Microsilica into it. After 10% addition of Microsilica the tensile strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows a higher tensile strength when 10% Microsilica is added and the percentage increase in the tensile strength is 26%

   It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the flexural strength upto 10% addition of Microsilica into it. After 10% addition of Microsilica the flexural strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows a higher flexural strength when 10%

Microsilica is added and the percentage increase in the flexural strength is 6%

It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the impact strength upto 10% addition of Microsilica into it. After 10% addition of Microsilica the impact strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows higher impact strength when 10% Microsilica is added and the percentage increase in the impact strength for first crack is 138% and for final failure is 59% respectively.

This may be due to the fact that 10% addition of Microsilica may induce maximum workability through which a thorough compaction can be achieved which aids in higher strengths. Also it may be due to the fact that 10% addition Microsilica may fill all the cavities and induce right pozzolonic reaction.

Thus it can be concluded that 10% Microsilica addition will induce higher strength properties to waste plastic fibre reinforced concrete.

2. It has been observed that the maximum workability is achieved when 10% of Microsilica is added. After 10% addition of Microsilica the workability decreases. The concrete becomes stiff as the percentage of Microsilica increases beyond 10%.

   This may be due to the fact that 10% addition of Microsilica may act as ball bearings thus reducing the friction and enhancing the workability.

   Thus it can be concluded that 10% addition of Microsilica yield good workability in waste plastic fibre reinforced concrete.

3. It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the compressive strength upto 8% replacement of cement by Microsilica into it. After 8% replacement of Microsilica the compressive strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows a higher compressive strength when 8% Microsilica is replaced and the percentage increase in the compressive strength is 37%

   It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the tensile strength upto 8% replacement of cement by Microsilica into it. After 8% replacement of Microsilica the tensile strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows a higher tensile strength when 8% Microsilica is replaced and the percentage increase in the tensile strength is 24%

   It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the flexural strength upto 8% replacement of cement by Microsilica into it. After 8% replacement of Microsilica the flexural strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows a higher flexural strength when 8% Microsilica is replaced and the percentage increase in the flexural is 8%.

   It has been observed that the waste plastic fibre reinforced concrete show an increasing trend in the impact strength upto 8% replacement of cement by Microsilica into it. After 8% replacement of Microsilica the impact strength starts decreasing. Thus, the waste plastic fibre reinforced concrete shows higher impact strength when 8% Microsilica is replaced and the percentage increase in the impact strength for first crack is 70% and final failure is 48% respectively.

   This may be due to the fact that 8% replacement of cement by Microsilica may induce maximum workability through which a thorough compaction can be achieved which aids in higher strengths. Also it may be due to the fact that 8% replacement of cement by Microsilica may fill all the cavities and induce right pozzolanic reaction.

   Thus it can be concluded that 8% replacement of cement by Microsilica can induce higher strength properties to waste plastic fibre reinforced concrete.

4. *It has been observed that the maximum workability is achieved when 8% of cement is replaced by Microsilica. The concrete becomes very stiff as the percentage of Microsilica increases beyond 8%.*
   This may be due to the fact 8% replacement of cement by Microsilica may act as ball bearings thus reducing the friction and enhancing the workability.

   Thus it can be concluded that 8% replacement of cement by Microsilica yield good workability in waste plastic fibre reinforced concrete.

5. It is observed from the literature (Ganesan et al.,) that the steel fibre reinforced concrete with 7.5% replacement of cement by

Microsilica shows an increase of 20% and 24% in compressive strength and tensile strength respectively as against 34% and 24% increase in compressive strength, tensile strength respectively for waste plastic fibre reinforced concrete.

Thus, waste plastic fibre reinforced concrete can very will be compared with that of steel fibre reinforced concrete produced by replacing cement by Microsilica.

Conclusions

The following overall conclusions can be drawn from the experimental investigations carried out

1. It can be concluded that 10% addition of Microsilica will induce higher strength properties and good workability properties to waste plastic fibre reinforced concrete.

2. It can be concluded that 8% replacement of cement by Microsilica can induce higher strength properties and good workability properties to waste plastic fibre reinforced concrete.

3. Thus Microsilica can be used in the production of waste plastic fibre reinforced concrete

Acknowledgements

The authors would like to thank Vice-Chancellor, Christ University, Fr. Benny Thomas, Director and Dr. Iven Jose, Associate Dean, Christ University Faculty of Engineering, Bangalore for their constant encouragement

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