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FIBRE REINFORCED CONCRETE USING DOMESTIC WASTE PLASTICS AS FIBRES

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ABSTRACT

Fiber Reinforced Concrete (FRC) is a composite material consisting of cement based matrix with an ordered or random distribution of fiber which can be steel, nylon, polythene etc. The addition of steel fibre increases the properties of concrete, viz., flexural strength, impact strength and shrinkage properties to name a few. A number of papers have already been published on the use of steel fibres in concrete and a considerable amount of research has been directed towards studying the various properties of concrete as well as reinforced concrete due to the addition of steel fibres. Hence, an attempt has been made in the present investigations to study the influence of addition of polythene fibers (domestic waste plastics) at a dosage of 0.5% by weight of cement. The properties studied include compressive strength and flexural strength. The studies were conducted on a M20 mix and tests have been carried out as per recommended procedures of relevant codes. The results are compared and conclusions are made.

Keywords: fiber reinforced concrete, domestic waste plastics, polythene fibers, compressive strength, flexural strength.

INTRODUCTION

Concrete in general has a higher brittleness with increase in strength. This is a major drawback since brittleness can cause sudden and catastrophic failure, especially in structures which are subjected to earthquake, blast or suddenly applied loads i.e., impact. This serious disadvantage of concrete can at least partially be overcome by the incorporation of fibers, especially, steel. The incorporation of fiber can cause a change in the failure mode under compressive deformation from brittle to pseudo-ductile, thereby imparting a degree of toughness to concrete.

In India, domestic waste plastics are causing considerable damage to the environment and hence an attempt has been made to understand whether they can be successfully used in concrete to improve some of the mechanical properties as in the case of the steel fibres. The primary objective of this investigation is to study experimentally the properties of fiber reinforced concrete containing polythene fibers. The properties of concrete, namely, compressive strength and flexural strength were studied.

EXPERIMENTAL INVESTIGATION

Detailed descriptions about the materials used, specimens tested and testing methods are essentials for an experimental investigation. Hence they are described in detail in the following sections.

Details of specimens

Table-1 shows the details of the various test specimens. It is intended to find experimentally the effect of addition of polythene fibers on the properties of concrete to be used for pavement construction. Hence the investigations are taken up to evaluate compressive strength and flexural strength of plain and fiber reinforced concrete specimens as per standards.

Casting and curing of specimens

The constituent materials of concrete, viz., Cement, Sand and aggregates were tested as per the relevant Indian codes of Practice and their properties are listed in Appendix-1. Concrete of M20 grade was designed as per the procedure given in Appendix 2. Concrete was mixed in a tilting type drum mixer and the specimens were cast as per the recommendations of IS: 516 - 1959. Fibres from the domestic waste were cut (Figure-1) and added to the concrete at a dosage of 0.5% by weight of cement.

Standard steel moulds were used for casting of cubes of size 150mm x 150mm x 150mm and casting of cylinders of 150mm diameter and 300mm height (Figure-2)

Concrete was placed uniformly over the length of the mould in three layers and compacted satisfactorily. After compacting the entire concrete, the excess concrete at the top of the mould was stuck off with a wooden straight edge and the top finished by a trowel. Demoulding was done after 24 hours and the specimens were cured under water. After 7days and 28days, the cube specimens were removed from curing tank and taken for testing. After 28days, the cylinder specimens were removed from tank and taken for testing.

TESTING DETAILS

Two types of tests were performed on all concrete batches, namely, Compressive strength and Split tensile strength.

Compressive strength test

Six cubes of concrete mix were prepared and tested as per IS 516-1959 specifications (Figure-3) at the age of 7days and 28days. Three cylinders of concrete mix were prepared and tested as per IS 516-1959 specifications (Figure-4) at the age of 28days.

Splitting tensile strength test

Splitting tensile strength measurements were made on cylinder specimens according to IS 5816-1999 (Figure-5).

TEST RESULTS

Compressive strength

The 7day and 28 day cube compressive strength of plain concrete and fiber reinforced concrete specimens obtained from tests are given in Tables 2 and 3. 28 day cylinder compressive strength are given in Table-4.

Split tensile strength

The Split tensile strength of plain concrete and fiber reinforced concrete specimens obtained from tests are given in Table-5.

ANALYSIS OF TEST RESULTS

Comparison of compressive strength

The influence of the addition of 0.5% fiber on the mixes tested is compared with plain concrete mix and the results are tabulated in Tables 6, 7 and 8. It is seen from the Tables that the compressive strength is increased by 2.45%. It is well established that addition of fibres do not contribute much to improvements in the compressive strength of concrete and the results of the present study also indicate the same.

Comparison of split tensile strength

Table-9 shows the comparison results of split tensile strength of the concrete mixes with and without fibers. Split tensile strength of fiber reinforced concrete specimen is 26.8% more than plain concrete. Generally, it should be borne in mind that the flexural strengths are increased to the tune of 20-25% with the addition of steel fibers. However, the present fibers, being obtained from domestic waste do not exhibit appreciable improvements in the flexural strength of concrete as in the case of steel fibers.

Table-1. Details of specimens.

S. No.	Name of test	Specimen	% of fiber added	No. of specimens
1.	Compressive strength test	Cube 150mm x 150mm x 150mm	0% 0.5%	6 Nos. 6 Nos.
		Cylinder 150mm dia and 300mm height	0% 0.5%	3 Nos. 3Nos.
2.	Tensile test	Cylinder 150mm dia and 300mm height	0% 0.5%	3 Nos. 3 Nos.

Table-2. Results of 7days cube compressive strength.

Grade of concrete	% of fiber used	Sample No.	Load (N)	Compressive strength (N/mm^2)
M20	0%	1	505000	22.44
		2	500000	22.22
		3	485000	21.56
	0.5%	1	510000	22.67
		2	500000	22.22
		3	490000	21.78

Table-3. Results of 28days cube compressive strength.

Grade of concrete	% of fiber used	Sample No.	Load (N)	Compressive strength (N/mm^2)
M20	0%	1	755000	33.56
		2	745000	33.11
		3	740000	32.89
	0.5%	1	805000	35.78
		2	785000	34.89
		3	765000	34.00

Table-4. Results of 28days cylinder compressive strength.

Grade of concrete	% of fiber used	Sample No.	Load (N)	Compressive strength (N/mm^2)
M20	0%	1	440000	24.90
		2	430000	24.33
		3	425000	24.05
	0.5%	1	460000	26.03
		2	450000	25.46
		3	435000	24.61

Table-5. Results of 28days cylinder split tensile strength test.

Grade of concrete	% of fiber used	Sample No.	Load (N)	Tensile strength (N/mm^2)
M20	0%	1	205000	2.90
		2	200000	2.83
		3	200000	2.83
	0.5%	1	210000	2.97
		2	205000	2.90
		3	200000	2.83

Table-6. Comparison of 7 days cube compressive strength test results.

Grade of concrete	Average Compressive Strength at 7 days (N/mm^2)		Increase in compressive strength of concrete by addition of fiber (C2-C1)/C1 x 100%
	Plain concrete, C1	0.5% with fiber C2	
Sample 1	22.44	22.67	1.02
Sample 2	22.22	22.22	0.00
Sample 3	21.56	21.78	1.02

Table-7. Comparison of 28 days cube compressive strength test results.

Grade of concrete	Average compressive strength at 28 days (N/mm^2)		Increase in compressive strength of concrete by addition of fiber (C2-C1)/C1 x 100%
	Plain concrete, C1	0.5% with fiber C2	
Sample 1	33.56	35.78	6.61
Sample 2	33.11	34.89	5.38
Sample 3	32.89	34.00	3.37

Table-8. Comparison of 28 days cylinder compressive strength test results.

Grade of concrete	Average compressive strength at 28 days (N/mm^2)		Increase in compressive strength of concrete by addition of fiber (C2-C1)/C1 x 100%
	Plain concrete, C1	0.5% with fiber C2	
Sample 1	24.90	26.03	4.54
Sample 2	24.33	25.46	4.64
Sample 3	24.05	24.61	2.33

Table-9. Comparison of 28 days split tensile strength test results.

Grade of concrete	Average split tensile strength at 28 days (N/mm^2)		Increase in Split tensile strength of concrete by addition of fiber (C2-C1)/C1 x 100%
	Plain concrete, C1	0.5% with fiber C2	
Sample 1	2.90	2.97	2.41
Sample 2	2.83	2.90	2.47
Sample 3	2.83	2.83	0.00

Figure-1. Waste domestic plastics are made in to fibre.

Figure-2. Casting of cylinders.

Figure-3. Compressive strength testing on cubes.

Figure-4. Compressive strength testing on cylinders.

Figure-5. Split tensile strength testing on cylinders.

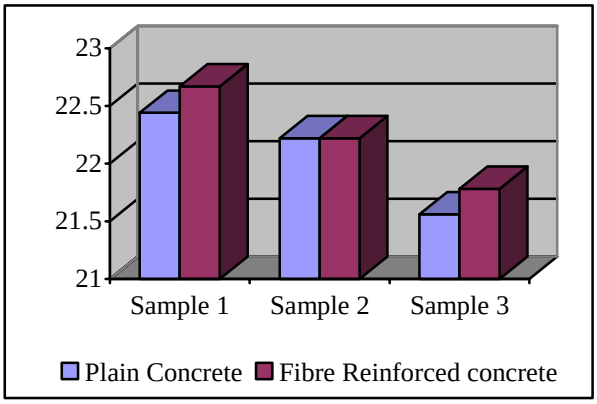

Figure-6. Comparison of 7 days cube compressive strength test results.

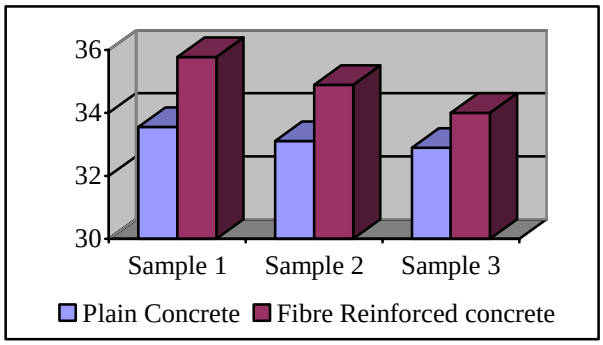

Figure-7. Comparison of 28 days cube compressive strength test results.

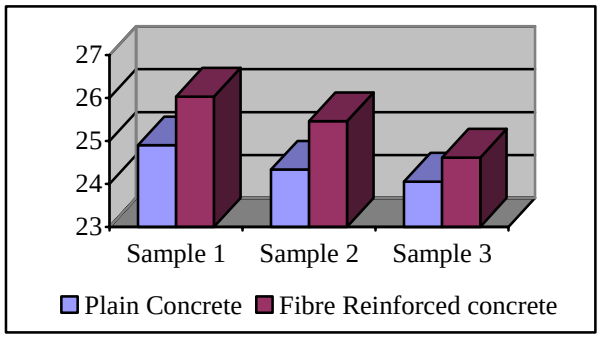

Figure-8. Comparison of 28 days cylinder compressive strength test results.

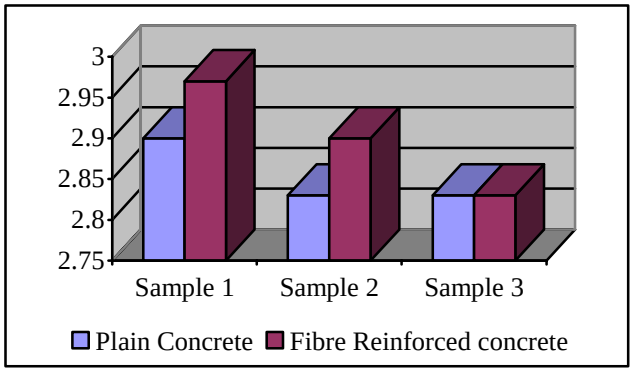

Figure-9. Comparison of 28 days split tensile strength test results

CONCLUSIONS

The following conclusions are presented based on experimental results from the present investigation.
Addition of 0.5% of polythene (domestic waste polythene bags) fiber to concrete

- Increases the cube compressive strength of concrete in 7 days to an extent of 0.68%;
- Increases the cube compressive strength of concrete in 28 days to an extent of 5.12%;
- Increases the cylinder compressive strength of concrete in 28 days to an extent of 3.84%;
- Increases the split tensile strength to an extent of 1.63%; and
- The increase in the various mechanical properties of the concrete mixes with polythene fibers is not in same league as that of the steel fibres.

REFENRENCES

IS: 456. 2000. Indian Standard “Plain and Reinforced Concrete” - Code of practice. Bureau of Indian Standards, New Delhi.

IS: 516. 1959. Indian Standard “Methods of Tests for Strength of Concrete”- Code of practice. Bureau of Indian Standards, New Delhi.

IS: 10262. 1982. Indian Standard “Recommended Guidelines for Concrete Mix Design”- Code of practice. Bureau of Indian Standards, New Delhi.

IS: 383. 1963. Indian Standard “Specification for Coarse and Fine Aggregates from Natural Sources for Concrete”- Code of practice. Bureau of Indian Standards, New Delhi.

APENDIX - 1

PROPERTIES OF MATERIALS

1.1 Cement

Ordinary Portland cement of 53grade was used for the preparation of concrete specimens. Table shows the observations made during the tests conducted on cement as per IS: 14031 - 1988.

Observation on test on cement

S. No.	Property	Test results
1	Fineness	5.00 %
2	Initial setting time	30 minutes
3	Specific gravity	3.15
4	Standard consistency	31 %

1.2 Test on coarse aggregate

Coarse aggregate of maximum size of 20mm was used in concrete. Test on coarse aggregate were conducted as per the code IS: 383 - 1970. Table shows the test results of coarse aggregate.

Test results of coarse aggregate

S. No.	Property	Test results
1	Specific gravity	2.60
2	Water absorption	0.5%
3	Fineness modulus	6.42
4	Crushing strength/value	2.57 N/mm^2
5	Impact value	7.2 %
6.	Abrasion value	4.05 %

1.3 Tests on fine aggregate

Test were conducted on clean river sand as per the code IS 383:1970. The properties of sand are given in the following table.

Properties of sand

S. No.	Property	Test results
1	Specific gravity	2.60
2	Bulking of sand	20%
3	Fineness Modulus	2.78
4	Voids ratio	0.21

1.4 Water

Clean potable water was used for mixing mortar and concrete and curing.

APENDIX - 2

CONCRETE MIX DESIGN

For M20 grade using 20mm size HBG metal

1. DESIGN STIPULATIONS

a) Characteristic compressive strength
b) required in the field at 28 days (N/mm^2) 20
c) Maximum size of aggregate (mm) 20
d) Degree of workability (Compaction Factor) 0.90
e) Degree of quality control Good
f) Type of exposure Mild

2. TEST DATA FOR MATERIALS

a) Cement used - ordinary Portland cement
b) Specific gravity of cement 3.15
c) Specific gravity
   1) Coarse aggregate 2.60
   2) Fine aggregate 2.60
d) Water absorption
   1) Coarse aggregate 0.5 %
   2) Fine aggregate Nil
e) Free (surface) moisture
   1) Coarse aggregate Nil
   2) Fine aggregate Nil
f) Sieve analysis
   1) Coarse aggregate

IS Sieve sizes in mm	Coarse aggregate (percent passing)	Remarks
20	96	Conforming to Table-2 of IS 383-1970
10	43	
4.75	3	

   2) Fine aggregate

IS Sieve Sizes in mm	Fine aggregate (Percent Passing)	Remarks
10	100	Conforming to grading Zone IV of Table-4 of IS:383-1970
4.75	99	
2.36	91.8	
1.18	59.4	
600 micron	25.4	
300 micron	2.20	
150 micron	0.0	

3. TARGET MEAN STRENGTH OF CONCRETE

For a tolerance factor of 1.65 and using Table-1 of IS: 10262-1982, the target mean strength for the specified characteristic strength is:f_{ck} + t*s: 27.59(N/mm^2).

4. SELECTION OF WATER CEMENT RATIO

From Figure-1 of IS: 10262-1982, the free water cement ratio required for the target mean strength is: 0.484. This is lower than the maximum value of 0.55 (for reinforced Concrete) prescribed for ‘Mild” exposure in Table-5 of IS: 456-2000.

5. SELECTION OF WATER AND SAND CONTENT

From Table-4 of IS: 10262-1982, for 20mm nominal maximum size aggregate and sand conforming to grading Zone II, water content per cubic meter of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume = 35 %.

For Change in values in water-cement ratio, compacting factor and sand belonging to Zone IV, the following adjustment is required: (Refer Table-6 of IS: 10262-1982).

Change in condition Stipulated for Tables 4 and 5 of IS; 10262 - 1982	For M20 **a**djustment required in	
	Water content percent	Percentage sand in total aggregate
For sand conforming to Zone IV of Table-4 of IS: 383-1970	0	-3.0
For increase in compacting factor (0.90-0.80) that is 0.10	+3	0
Each 0.05 increase or decrease in free water-cement ratio (0.60-w/c ratio)	0	-2.0
Total	+3 %	- 5.0 %

Therefore, required sand content as percentage of total aggregate by absolute volume is (35-5) = 30%
Required water content = 186 + 186 x 3 /100 = 191.58 l

6. DETERMINATION OF CEMENT CONTENT

Water cement ratio	0.484
Water (liters per m^3 of concrete) =	191.60
Cement (kg/m^3 of concrete)	395.87

This cement content is adequate for mild exposure condition (300kg), according to Table-5 of IS: 456-2000

7. DETERMINATION OF COARSE AND FINE AGGREGATE CONTENT

From Table-3 of IS: 10262-1982, for the specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is 2%. Taking this into account and applying equations from 3.5.1 of IS: 10262-1982

$0.98\ m^3 = (191.6 + 395.87/3.15 + 1/0.300 * f_s /2.60) / 1000$ and
$0.98\ m^3 = (191.6 + 395.87/3.15 + 1/0.700 * f_c /2.60) / 1000$

or f_s	516.93
f_c	1206.16

The mix proportion per meter cube of concrete then becomes:

Water	191.6
Cement	395.87
Fine aggregate	516.93
Coarse aggregate	1206.16

Mix proportion ratio:

Mix grade	water	Cement	Fine aggregate	Coarse aggregate
M20	0.484	1	1.306	3.047

8. ACTUAL QUANTITIES REQUIRED FOR THE MIX PER BAG OF CEMENT

For 50kg of cement, the quantities of materials are worked out as below:

a)	Cement (Bag -50kg)	50
b)	Sand (kg)	65.3
c)	Coarse aggregate (kg)	152.35
d)	Water	
1)	For water-cement ratio quantity of water (in liters)	24.20
2)	Extra quantity of water to be added for absorption in case of coarse aggregate at 0.5 percent by mass	(+) 0.76
3)	Quantity of water to be deducted for free moisture present in sand at 2 percent by mass	(-) Nil
4)	Actual quantity of water to be added	24.96

30%

191.58 l