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Strengths Prediction of Plastic fiber Reinforced concrete (M30)

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ABSTRACT

Now a day we are facing environment protection problems. Many things which are invented for our luxurious life are responsible for polluting environment due to improper waste management technique. One of them is a plastic which has to be disposed or recycled properly to maintain the beauty of our nature. To address this issue the fibers from used plastics were added in various percentages in the M_{30} grade concrete.

This paper describes the performance of plastic fiber reinforced concrete (M_{30}). An experimental work has been carried out on the specimens like cubes and cylinders which were casted in the laboratory and their behavior under the test was observed. The plastic fibers were added from 0.0 % to 3.0 %. The compressive and split tensile strengths of concrete were determined after 28 days of curing period. The test results were compared and the relationships between the observed and predicted strengths were given.

Keywords - **Cement concrete composites, plastic fibers, compressive strength, split tensile strength, strengths prediction..**

1.0 INTRODUCTION

The concrete is one of the most widely used construction material in developed and developing countries. The performance of concrete depends on its ingredients. It is well known that plain concrete is brittle and weak in tension. The major advantage of fiber reinforcement concrete is to transform a brittle concrete into a pseudo ductile material. Adding fibers in concrete can arrest micro cracks which causes gradual failure. The fibers from cheap or waste materials may be used for manufacture of structural units with cement mortar composites have great potential for developing countries like India.

Different fibers like steel, carbon, glass, synthetic organic and natural fibers has been incorporated in concrete and mechanical properties of such concrete is studied by many researchers. But still it is ongoing process to improve properties of concrete.

The present paper reports on effect of the addition of various volume fractions of plastic fibers on behavior of concrete. Effect of plastic fibers in concrete under compression and split tension strength are discussed. Mathematical equations for compressive and split tensile strengths verses % fibres in composite are established.

2.0 HISTIRICAL BACKGROUND

The research work concerning to the various application and methods used for testing of the concrete made by recycled plastics are discussed by many researchers. A comprehensive review of the work carried in the field of using recycled plastics in concrete is as follows.

T.Ochi et al. and Dr. Kenneth W. Stier et al.[1,2] described the method to prepare plastic fiber and stated that these fibers can be easily mixed into concrete up to 3%.volume content and promising results were obtained in compressive and flexure strength. Marzouk et al. and Ismail ZZ et al. [3,4], studied the innovative use of consumed plastic bottle waste as sand substitution aggregate within composite materials for building application. Bottles made of polyethylene terephthalate (PET) were used as partial and complete substitutes for sand in concrete composites. Various volume fractions of sand varying from 2% to 100% were substituted by the same volume of granulated plastic, and various sizes of PET aggregates. They concluded that substituting sand at a level below 50% by volume with granulated PET, whose upper granular limit equals 5 mm, affected the compressive strength of composites but plastic bottles shredded into small PET particles may be used successfully as sand-substitution aggregates in concrete composites. These composites appeared to offer an attractive low-cost material with consistent properties; moreover, they would help in resolving some of the solid waste problems created by plastics production and in saving energy. Dr. Prahallada M.C.and Dr. Prakash K.B [5] investigated that waste plastics can be used in fiber form to improve properties of concrete. They observed that compressive as well as tensile strength of waste plastic fiber reinforced concrete improved as compared to control concrete. Jo Byung-Wan et al.[6], has investigated the mechanical properties like compressive strength (73.7 MPa),flexural strength (22.4 MPa), splitting tensile strength (7.85 MPa), and elastic modulus (27.98 GPa) at 7 days by adding an unsaturated polyster resin based on recycled PET in polymer concrete. Rafat Sddique et al. [7] discussed the effect of recycled and waste plastic on workability, density, compressive strength, splitting tensile strength. The post consumer plastic aggregates used to replace conventional aggregates and the compressive strength of concrete was in the range of 48 and 19 MPa. The splitting tensile strength was reduced by 17 % at 10% at plastic aggregates, but ductile behavior of concrete was observed by them. Venu Malagavelli and Rao.P.N.[8]used two polymer fibers PET in M30 grade of concrete. The workability was reduced for higher percentage of fibers but the compressive strength was increased by 9.11% at 1% of PET fibers. V.K.Sarda et al.[9] also concluded plastic strips has potential to act as secondary reinforcement.

From the above study, the fibers made of recycled polyethelene teraphthalate (PET) are appropriate to concrete reinforcement. The mixing ability of PET fibers is excellent and it is a promising material to reinforce the concrete.

3.0 EXPERIMENTAL WORK

3.1 Materials

The ingredients used for this experimental work are Portland Pozzolana Cement (Fly Ash based) conforming to IS: 1489-1991 (Part I), river sand, crushed aggregates of 20 mm (MSA)and 10(MSA) in the ratio of 60:40 respectively, potable water, plastic (PET) fibers of breath (2 mm) and long (25 mm) with the aspect ratio 35 and Super plasticizer conforms to relevant DIN, BS, IS 9103 – 1999 specification and ASTM – C – 494 was used.

. The physical properties of the above ingredients are computed as per the standard test procedure prescribed in BIS [10-11] and the obtained values are shown in tables 3.1 to 3.3 and the concrete mix proportions [12] used in these experiments is shown in table 3.4

Table: 3.1. Physical Properties of Cement

S.N.	Properties	Values	Units
1	Fineness	2.7	%
2	Normal Consistency	32	%
3	Initial Setting Time	210	Minute
4	Final Setting Time	330	Minute
5	Soundness (Le-chatelier)	1.5	mm
6	Compressive Strength (3d)	29.2	MPa
7	Compressive Strength (7d)	40.4	MPa
8	Compressive Strength (28d)	50.7	MPa

Table: 3.2. Physical Properties of Sand

S.N.	Properties	Values	Units
1	Specific Gravity	2.53	--
2	Water Absorption	1.2	%
3	Bulk Density	1718.52	Kg/cu.m
4	Fineness Modulus	2.65	--
5	Silt Content	0.61	%

Table: 3.2.1. Sieve Analysis of Sand

Sieve Designation	4.75mm	2.36mm	1.18mm	600 µ	300µ	150 µ
% Passing	98.28	96.47	81.79	49.65	8.68	0.40
%Passing as per IS 383-1970 (Zone II)	90 - 100	75 -100	55 - 90	35 - 59	8 - 30	0 - 10

Table: 3.3. Physical Properties of Coarse aggregates

Properties of aggregates	20 mm (MSA)	10 mm (MSA)
Specific gravity	2.85	2.83
Water absorption (%)	1.15	1.23
Bulk density (Kg/cu.m)	1564.2	1694.8
Fineness modulus	7.63	6.42

Table: 3.4 Mix proportions for per cubic meter of control concrete (M30)

Water (Lit)	Cement (Kg)	Fine Aggregates (Kg)	Coarse Aggregates (Kg)
180.3	376	535	1335
The super plasticizer was added 0.6 % by weight of cement to all mixes (IS: 9103-1999)			

The concrete mixture was prepared by adding plastic fibers from 0.5 % to 3.0 % by weight of cement. The specimens without fibres were casted for reference concrete.

3.2 Specimen Preparations

Concrete cubes specimens (150 mm x 150 mm x150 mm) were casted for computing compressive strength. The cylindrical specimens (diameter- 150 mm and length- 300 mm) were casted to determine spilt tensile strength of concrete. All the specimens were cured for a period of 28 days before test. Total twenty four specimens for each test were casted (six numbers for control concrete and three for fiber reinforced concrete).

3.3 Specimen Testing Methods

The tests on fresh and hardened concrete were carried out as per relevant standard (13,14,15). The compression and split tension tests were carried in compression testing machine of capacity 2000 KN.

4.0 RESULT AND DISCUSSION

The compressive and split tensile strength is calculated by using following equations.

Compression strength (MPa)= $\sigma cc = P/A$

Split tensile strength (MPa) = $\sigma t = 2 P / \pi L D$

Where, P = Ultimate load, A = Cross sectional area, L = Length of cylinder, D = Diameter of cylinder

The test results of fresh and hardened concrete are shown in tables 4.1 to 4.3. These results are compared with plastic fiber reinforced concrete graphically also. The governing equations for predicting strengths are established.

Table 4.1 Properties of fresh and hardened concrete

TESTS	% Fibres						
	0.0	0.5	1.0	1.5	2.0	2.5	3.0
Slump (mm)	67	63	57	47	48	42	32
Compaction Factor	0.877	0.873	0.857	0.83	0.813	0.79	0.78
Dry Density (Kg/M^3)	25.382	25.402	25.363	25.323	25.244	25.244	25.185

Tables 4.2 Compressive strength of concrete

Sr. No.	Percentage Addition of Fibres	Failure Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)	Percentage Change in Compressive Strength
1	0.0	980	43.56	41.19	0.00
		860	38.22		
		940	41.78		
		940	41.78		
		960	42.67		
		880	39.11		
2	0.5	920	40.89	41.78	1.43
		960	42.67		
		940	41.78		
3	1.0	940	41.78	42.96	4.30
		1000	44.44		
		960	42.67		
4	1.5	960	42.67	42.67	3.59
		960	42.67		
		960	42.67		
5	2.0	900	40.00	40.30	-2.16
		960	42.67		
		860	38.22		
6	2.5	780	34.67	34.67	-15.83
		760	33.78		
		800	35.56		
7	3.0	700	31.11	31.70	-23.04
		720	32.00		
		720	32.00		

Table 4.3 Tensile strength of concrete

Sr. No.	Percentage Addition of Fibres	Failure Load (KN)	Tensile Strength (Mpa)	Average Tensile Strength (Mpa)	Percentage Change in Tensile Strength
1	0.0	252	3.57	3.48	0.00
		244	3.45		
		252	3.57		
		240	3.40		
		240	3.40		
		248	3.51		
2	0.5	258	3.65	3.67	5.46
		258	3.65		
		262	3.71		
3	1.0	272	3.85	3.87	11.21
		274	3.88		
		274	3.88		
4	1.5	258	3.65	3.72	6.90
		266	3.77		

		264	3.74		
5	2.0	236	3.34	3.36	-3.45
		236	3.34		
		240	3.40		
6	2.5	214	3.03	2.95	-15.23
		212	3.00		
		200	2.83		
7	3.0	186	2.63	2.58	-25.86
		182	2.58		
		178	2.52		

It is observed that the workability (Slump and Compaction factor) of green concrete decreases as fibres content increases. The initial slump of control concrete was 67 mm (0.0 %) and it was reduced to 32 mm (3.0%) i.e 52.3% loss in slump was observed at 3.0 % of fibers. The compaction factor at 0.0 % fibres was 0.877 and finally it was reduced to 0.78 i.e. 11 % loss in compaction factor was found. Similarly dry density also reduced from 25.382 Kg/Cu,m (0.0 %) to 25.185 Kg/Cu,m (3.0%).

The compressive strength of concrete cubes were increased from 41.19 MPa(0.0%) to 42.96 MPa(1.0%) and there after it was reduced to 31.70 Mpa (3.0%).The spilt tensile strength were increased from 3.48 MPa (0.0%) to 3.87 MPa(1.0%) and finally it was 2.58 MPa (3.0%). The trend of change in both strengths was almost same. In this investigation the strengths of plastic fiber reinforced concrete with respect to plain concrete is illustrated in figure 4.1 and 4.2. The relationship between compressive strength and split tensile strength is shown in figure 4.3. During the test it was observed that the failure of fiber reinforced specimens was gradual and did not break into two pieces like control concrete specimens.
The governing equations for predicting strengths are as shown in table 4.4

Table 4.4 Equations for prediction of strengths

Strengths	Equations	Value of R^2	Equation
Compression Strength (σ_{cf})	$\sigma_{cf} = 40.84 + 4.762\ W_f - 2.667 W_f^2$	0.966	1
Split Tensile Strength (σ_{tf})	$\sigma_{tf} = 3.525 + 0.478\ W_f - 0.274\ W_f^{\ 2}$	0.938	2

Where W_f = % fibers in concrete.

The split tensile strength can be predicted if compression strength of plastic fiber reinforced concrete is known or computed from above equation, by using the equation (3) as follows.

$$\sigma_{tf} = 0.105\ \sigma_{cf} - 0.758 \qquad (R^2=0.966) \qquad (3)$$

Where, σ_{cf}= Compressive strength of plastic fiber reinforced concrete in MPa

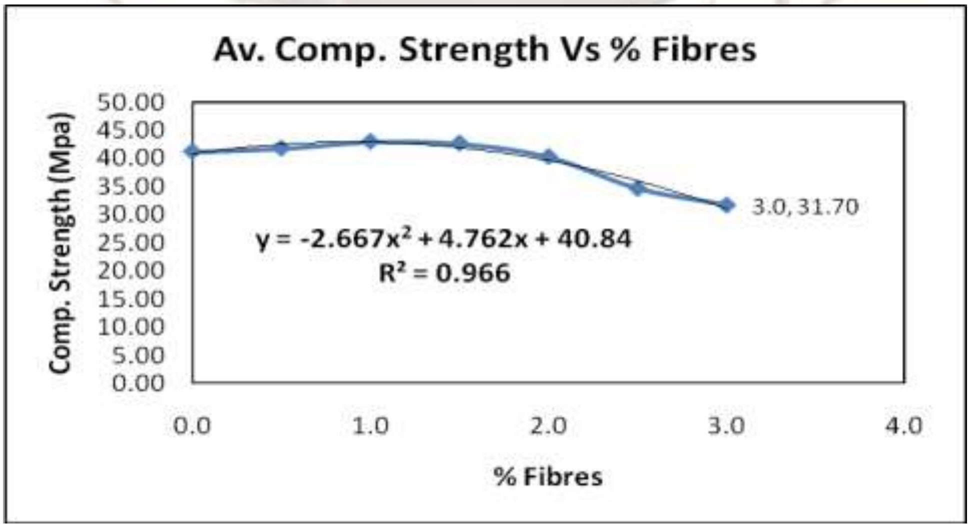

Figure 4.1: Average compressive strength verses % Fibres

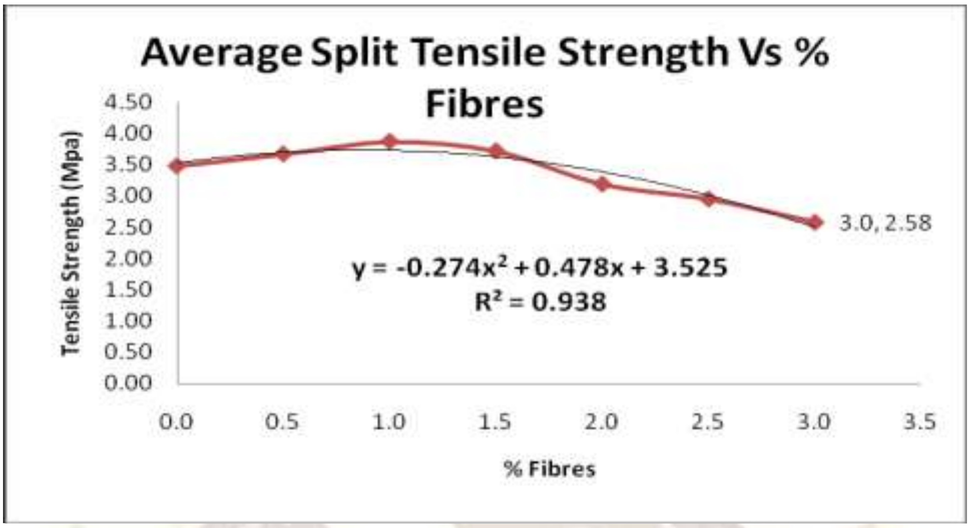

Figure 4.2: Average Split tensile strength verses % Fibres

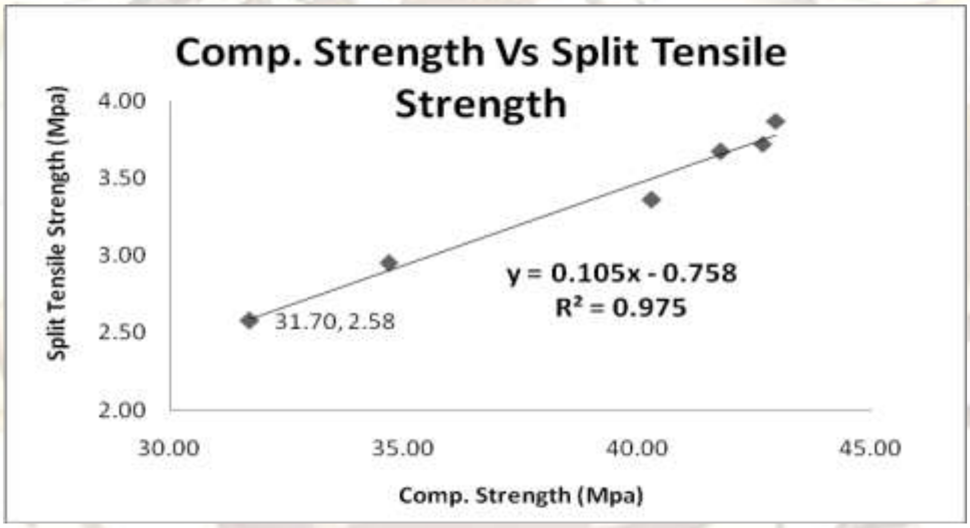

Figure 4.3: Compressive strength verses Split tensile strength

Table 4.5 Prediction of compressive and tensile strength from % fiber content

Sr.No.	% Fibres	Observed Compressive Strength (Mpa)	Predicted Compressive Strength (Mpa) (Eq.1)	% diff w.r.t. observed compressive strength	Observed tensile Strength (Mpa)	Predicted tensile Strength (Mpa) Eq. 2	% diff w.r.t. observed tensile strength
1	0	41.19	40.84	0.85	3.48	3.53	-1.437
2	0.5	41.78	42.55	-1.843	3.67	3.7	-0.817
3	1	42.96	42.94	0.047	3.87	3.73	3.618
4	1.5	42.67	41.98	1.617	3.72	3.63	2.419
5	2	40.30	39.7	1.489	3.36	3.39	-0.893
6	2.5	34.67	36.08	-4.067	2.95	3.01	-2.034
7	3	31.70	31.12	1.83	2.58	2.49	3.488

Table 4.6 Prediction of tensile strength from compressive strength

Sr.No.	% Fibres	Observed Compressive Strength (Mpa)	Observed tensile Strength (Mpa)	Predicted tensile Strength (Mpa) Eq.3	% diff w.r.t. observed tensile strength
1	0	41.19	3.48	3.57	-2.586
2	0.5	41.78	3.67	3.63	1.09
3	1	42.96	3.87	3.75	3.101
4	1.5	42.67	3.72	3.72	0
5	2	40.30	3.36	3.47	-3.274
6	2.5	34.67	2.95	2.88	2.373
7	3	31.70	2.58	2.57	0.388

Th governing equations for prediction of strengths from regression analysis giges matching resuts (Table 4.5 and 4.6)

Figure 4.4 Cube Compression Test

Figure 4.5 Split Tensile Test Specimens after Test

5.0 CONCLUSIONS

The major conclusions based on the results obtained in the experiments are as follows.

1) Inclusion of fibers content affects flow properties of concrete. The density was also affected but made concrete slightly light weight.
2) The maximum compressive and split tensile strength were at 1% of fiber content were 4.30 %, 11.21 % respectively over control concrete (0% fibers content). The significant improvements in strengths were observed with inclusion of plastic fibers in concrete. The optimum strength was observed at 1% of fiber content for both types of strengths, there after reductions in strength were observed.
3) The compressive strength of plastic fiber reinforced concrete can be predicted form the following equation
   $\sigma_{cf} = 40.84 + 4.762\ W_f - 2.667 W_f^2$
4) The split tensile strength of plastic fiber reinforced concrete can be predicted form the following equation
   $\sigma_{tf} = 3.525 + 0.478\ W_f - 0.274\ W_f^{\ 2}$

5) The split tensile strength of plastic fiber reinforced concrete can be predicted, from compressive strength by using the following equation

$$\sigma_{tf} = 0.105\ \sigma_{cf} - 0.758$$

6) If the compressive strength of control concrete is determined then the compressive strength as well as split tensile strength of plastic fiber reinforced concrete of can be predicted with the accuracy more than 95 % to the observed strengths.
7) While testing control cement concrete cube the spalling of concrete was observed. However, the failure mode of fiber concrete was bulging in transverse direction
8) The mode of failure was changed from brittle to ductile failure due to inclusion of plastic fibers into the concrete.

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