American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-02, Issue-12, pp-367-372
www.ajer.org

Research Paper Open Access

A model for compressive strength of PET fiber reinforced concrete

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Abstract: - The waste disposal is the main challenge in every country. The plastic usage is increasing day by day. The post consumer PET mineral water bottles are recycled or disposes into land fill. Improper handling of these waste bottles leads to harm to the environment. That's why, in this study, waste PET mineral bottles were used in fiber form to reinforced plain concrete. The concrete of M_{20} and M_{30} grades were selected for the study. The PET fibers were obtained from used mineral water bottles without any processing. The fibers were of two sizes. The fibers were added in proportions 0.0 % to 3.0 %. The concrete cubes were casted and tested after 28 days of curing and a model for compressive strength of PET fiber reinforced concrete is presented in this paper.

Keywords: – *Concrete, Grades of concrete, Waste bottles, PET fibers, Compressive strength.*

I. INTRODUCTION

The concrete is a versatile material in civil engineering construction. The properties of concrete are mainly affected by its ingredients. Concrete is strong in compression but weak in tension and brittle one. The ductility of concrete can be increase by reinforcing with fibers. The fibers act as micro crack arrester in cement composites. Many commercial fibers like steel, carbon, glass etc. are available for reinforcing the concrete. The research in developing fiber reinforced concrete is ongoing process.

The cheap fibers obtained from waste materials may be used for manufacture of cement composites. It reduces cost of concrete and solves somewhat waste disposal problems. In this study, the fibers obtained from post consumed polyethelene teraphthelne (PET) mineral water bottles were used for reinforcing the concrete. The behavior of PET fiber reinforced concrete was studied under compressive strength at different volume fraction of fibers. From the compressive strength test results a mathematical model is developed and presented here.

II. LITERATURE REVIEW

All over the world, many researchers are inventing materials which can be suitably added into concrete for enhancing its properties. A compressive review of study of researcher used plastic in different form in making concrete is discussed in this section. Batayneh et al. [1] studied the effect of ground plastic on the workability of concrete. Concrete mixes of up to 20% of plastic particles was used to replace the fine aggregates. The decrease in the slump with the increase in the plastic particle content is reported. The slump value at 20% plastic particle content was 58 mm; this value can be considered acceptable. Soroushian et al. [2] has reported reduction in slump of concrete with the use of recycled plastic in concrete composite. Ismail and Hashmi [3] have found that the slump of concrete decreases sharply with increasing the waste plastic content in concrete.

Al-Manaseer and Dalal [4] studied the effect of plastic aggregates on the density of concrete. The bulk density of concrete was decreased with the increase in plastic aggregates content. This reduction in density was attributed to the lower unit weight of the concrete. Marzouk [5] invented the use of consumed plastic bottle waste as sand substitution within cement composite. The polyethylene terephthalate (PET) bottles were used as partial and complete substitutes for sand in concrete composites. The volume fractions of sand varying from 2% to 100%

were replaced 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 and plastic bottles shredded into small PET particles may be used successfully as sand-substitution aggregates in concrete.. Yun Wang Choi et. al. [6] reported that the waste PET light weight aggregate (WPLA) obtained from recycled PET bottles at water/cement of 0.49, the structural efficiency (compressive strength / density ratio) of concrete containing 25 % WPLA was higher than that of for the normal concrete.

Miyazaki Kuniyuki et. al. [7] has reported that fibers made of recycled polyethelene teraphthalate (PET) were appropriate to concrete reinforcement. The mixing ability of PET fibers was excellent. They concluded that PET is a promising material as reinforcement of concrete. T. Ochi, S. et. al.[8] investigated development of recycled PET fiber and its application as concrete-reinforcing fiber. They described a method that can be used to produce PET fiber from post consumed PET bottles. The issue of concern in the development of PET fiber was its alkali resistance; however, they encountered no problems when using the fibers in normal concrete. Sung Bae Kim et. al. [9] presented a method to form short fibers from waste PET bottles. The recycled PET fiber reinforced concrete was compared with polypropylene fiber reinforced concrete for fiber volume fractions of 0.5%, 0.75%, and 1.0%. The results show that compressive strength and elastic modulus decreased as at higher fiber volume fraction. But cracking due to drying shrinkage was delayed in the PET fiber reinforced concrete specimens as compared to normal concrete. Regarding structural member performance, the ultimate strength and relative ductility of PET fiber in reinforced cement concrete beams was significantly larger than those of companion specimens without fiber reinforcement. Dora Foti [10] experimented on possibility of using polyethylene terephthalate (PET) fibers to increase the ductility of the concrete. The fibers were obtained by simply cutting from waste plastic bottles. The improvement in ductility of the concrete was reported. R. N. Nibudey et al. [11] optimized the benefits of using post consumed waste PET bottles in the fiber form in concrete. The post consumed waste mineral water plastic bottles are manually shredded into fibers. The different percentages (0 % to 3 %) of waste plastic fibers for two aspect ratios were added into concrete. The workability (slump, compaction factor), compression, split tension and flexural tests were carried out and the results were compared with plain concrete. The enhancement in mechanical properties of concrete at 1 % addition of fibers was observed.

III. EXPERIMENTAL PROGRAMME

Materials used

Cement: Portland Pozzolana Cement (Fly Ash based) was used in this experimentation conforming to IS: 1489-1991 (Part I) [12]. The physical properties of cement were as follows - Fineness (specific surface) = 322 m^2/kg, Standard consistency = 32 %, Initial setting time = 210 minute, Final setting time = 330 minute, Soundness (Le-Chat.) = 1.5 mm and 28 days compressive strength = 50.7 MPa.

Aggregates: The natural sand from river was used as fine aggregate. The sand was having specific gravity 2.53, water absorption 1.2 %, bulk density 1718.52 Kg/cu.m, fineness modulus 2.65, silt content 0.61% and conformed to grading zone- II as per IS: 383-1970 [13]. The crushed stone aggregates were collected from the local query. The maximum size of aggregates (MSA) were 20 mm and 10 mm in proportion of 60:20 respectively and tested as per IS: 383-1970 and 2386-1963 (Part I,II and III) specifications[14]. The physical properties of coarse aggregates were shown in Table I.

Table I 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	7.05	6.06

Water: Potable water was used for mixing and curing of specimens throughout the experimentation.

Super plasticizer: To impart additional workability a super plasticizer AC-PLAST-BV-M4 was used. It is concrete plasticizer with less than 0.05 % chloride content and conforms to IS: 9103-1999. The super plasticizer was added 0.6 % by weight of cement to all mixes.

Plastic fibers: The post consumed PET mineral water bottles of single brand were collected from local restaurants. The fibers were cut after removing the neck and bottom of the bottle. The length of fibers was kept 25 mm and the breadth was 1 mm and 2 mm. The aspect ratio (AR) of waste plastic fibers were 35 (AR-35) and 50 (AR-50).The plastic fibers used were having specific gravity 1.34, water absorption 0.00 %. The different fractions for two aspect ratios were used in this experimentation.

Concrete mix

Based on the trial mixes for different proportion of ingredients final mix proportion was selected as per IS 10262:2009. [15] The concrete mix proportions was as shown in Table II

Table II Concrete mix proportions

Grade	Water	Cement	Fine aggregates	20 mm (MSA)	10 mm (MSA)
M20	0.52	1	1.60	2.31	1.54
M30	0.48	1	1.42	2.13	1.42

Specimens and Tests

The cube of 150 mm size were casted for compressive strength with different volume fraction of PET fibers. The six specimens for 0.0 % and three specimens for other volume fractions of fibers were casted. The concrete filled moulds were vibrated on table vibrator in the laboratory. The cubes were tested under compression testing machine of capacity 2000 kN as shown in Photograph 1 as per IS 516-1959.[16] and average values of compressive strength are reported.

IV. RESULT AND DISCUSSION

The average compressive strength of six specimens of normal concrete for M_{20} and M_{30} grade of concrete are 28.15 MPa and 41.19 MPa respectively. The experimental compressive strength and predicted compressive strength of PET fiber reinforced concrete by using following equation which is obtained from regression analysis of test data as shown in Table III.

For aspect ratio – 35 the following was used.

$$F_{ckf} = \left(0.007 * V_f^3 - 0.130 * V_f^2 + 0.203 * V_f + 1.623\right) * F_{ck} * e^{-w} \quad (R^2 = 0.928)$$

For aspect ratio – 50 the following was used.

$$F_{ckf} = \left(0.036 * V_f^3 - 0.202 * V_f^2 + 0.330 * V_f + 1.642\right) * F_{ck} * e^{-w} \quad (R^2 = 0.959)$$

Where,

F_{ck} = Compressive strength of normal concrete

F_{ckf} = Compressive strength of PFRC

w = Water cement ratio

Table III Compressive strength of PFRC

Grade of concrete	Fiber aspect ratio (AR)	Volume fraction in percentage (V_f)	Water cement ratio	Average expt. compressive strength (Mpa), F_{ckf}	Predicted compressive strength (Mpa), F_{ckf}
20	35	0.5	0.52	28.44	28.33
20	35	1.0	0.52	29.63	28.50
20	35	1.5	0.52	28.44	27.76
20	35	2.0	0.52	26.37	26.19
20	35	2.5	0.52	24.3	23.89
20	35	3.0	0.52	22.81	20.94
20	50	0.5	0.52	29.63	29.22
20	50	1.0	0.52	30.22	29.22
20	50	1.5	0.52	28.74	27.93
20	50	2.0	0.52	25.78	25.81
20	50	2.5	0.52	23.41	23.30
20	50	3.0	0.52	20.44	20.85
30	35	0.5	0.48	41.78	43.15
30	35	1.0	0.48	42.96	43.41
30	35	1.5	0.48	42.67	42.27
30	35	2.0	0.48	40.3	39.89
30	35	2.5	0.48	34.97	36.38
30	35	3.0	0.48	31.41	31.89
30	50	0.5	0.48	42.97	44.50
30	50	1.0	0.48	43.85	44.50
30	50	1.5	0.48	41.78	42.54
30	50	2.0	0.48	39.11	39.30
30	50	2.5	0.48	35.85	35.48
30	50	3.0	0.48	33.19	31.76

The experimental compressive strength of PFRC was found to increase by 7.35% compare to the normal concrete for M_{20} grade and aspect ratio 50. Thereafter the strength was decreased at higher percentage of volume fractions. From Figure 1 to 4, it is observed that compressive strength of PFRC found higher for M_{20} and aspect ratio 50 but percentage fall in strength was also higher in M_{20} and aspect ratio 50. The increase in strength for M_{30} grade of concrete was little and fall in strength was also low that's why in regression analysis a empirical multiplying factor exp $^{(\text{-water cement ratio})}$ is used to compensate this effect. For higher aspect ratio increase in strength of PFRC was higher and fall in strength at higher aspect ratio was greater.

The compressive strength of PFRC from equation which obtained from regression analysis of test data, are within 1.006 confidence limit as shown in Figure 5 ($R^2 = 0.991$).

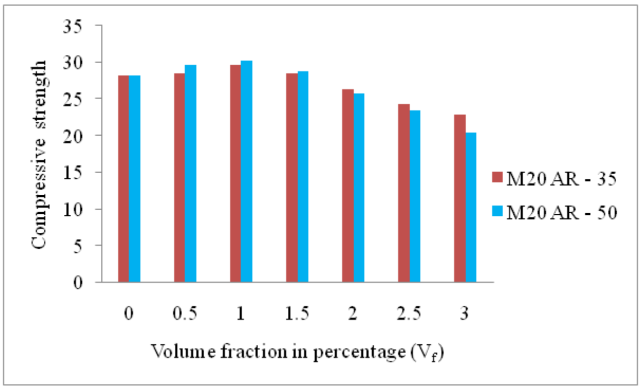

Figure 1 Compressive strength of PFRC verses V_f

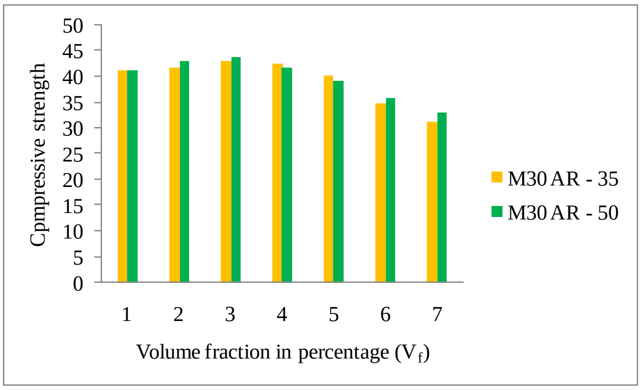

Figure 2 Compressive strength of PFRC verses V_f

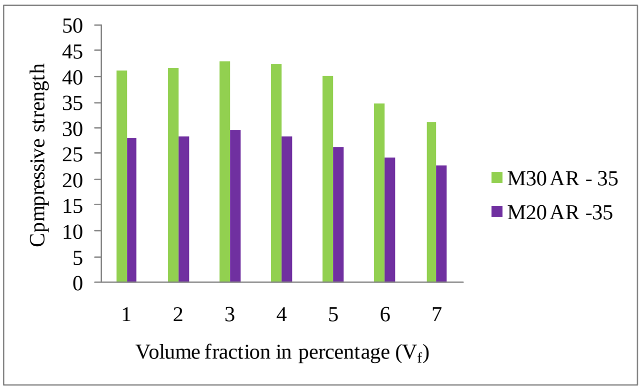

Figure 3 Compressive strength of PFRC verses V_f

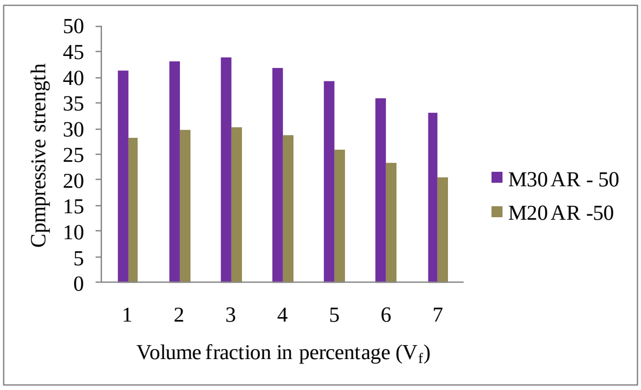

Figure 4 Compressive strength of PFRC verses V_f

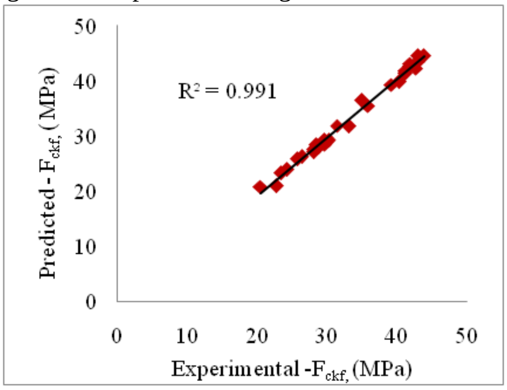

Figure 5 Compressive strength of PFRC verses V_f

V. CONCLUSION

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

1. The maximum percentage increase in compressive strength of PFRC was 7.35 % for M_{20} grade of concrete and aspect ratio 50 at 1 % fiber volume fraction.
2. The fall in compressive strength of PFRC was found 27.07 % for M_{20} grade of concrete and aspect ratio 50 at 3 % fiber volume fraction.
3. For higher grade of concrete (M_{30}) the percentage increase in strength was less as compare to lower grade of concrete (M20).
4. The ductility of normal concrete was found higher in PFRC during test as normal concrete was failed suddenly and cubes were broken into pieces, but PFRC cubes were not broken suddenly at ultimate load, the failed specimens in compression test is shown in Photograph 2.
5. The following equations (for aspect ratio 35 and aspect ratio 50 respectively) can be used to obtain compressive strength of PFRC, if compressive strength of normal concrete is known.

$$F_{ckf} = \left(0.007 * V_f^3 - 0.130 * V_f^2 + 0.203 * V_f + 1.623\right) * F_{ck} * e^{-w} \quad (R^2 = 0.928)$$

$$F_{ckf} = \left(0.036 * V_f^3 - 0.202 * V_f^2 + 0.330 * V_f + 1.642\right) * F_{ck} * e^{-w} \quad (R^2 = 0.959)$$

6. The inclusion of PET fibers obtained from waste mineral water bottles appears to be low cost materials which would helps to resolve disposal problems and protect environment.

Photograph 1 Compression test

Photograph 2 Tested specimens of normal and PFRC

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