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Effect of Poly Ethylene Teraphalate (PET) Fibers on Engineering Properties of Concrete

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Abstract: ***This Paper represent the effect of Poly Ethylene Teraphalate(PET) fibers usage on mechanical properties of concrete like compressive strength, split cylinder tensile strength, flexural capacity along with dry shrinkage and water absorption. Five different percentages of PET fibers i.e., 0.25, 0.50, 1.00, 1.50 and 2.00 were used with respect of cement weight used in concrete mix design. The control concrete specimens are also prepared to compare the results. The PET fiber decreases the compressive strength, tensile strength, modulus of elasticity and water absorption capacity. Whereas, modulus of toughness increased with the induction of PET fiber in concrete. The reduction in compressive strength, tensile strength and Modulus of elasticity of PET fiber concrete is due to poor bonding properties of fibers with matrix and increase in toughness is due to bridging action of fibers between cracks which cause delay in complete failure of specimen.***

Keywords: Concrete, Mechanical properties, PET fiber, compressive strength, tensile strength,

1. Introduction

Concrete consist of cement, sand and aggregates is one of important component of construction industry due to its versatile nature. Concrete can be used in any form and any place. But it is also accepted that concrete is brittle in nature due to its low tensile strength, flexural strength, ductility and strain capacity. The tensile capacity of concrete is only 10 percent of the compressive strength causes undesirable results on the performance of concrete as important construction material (A.M Neville) [1]. There are many ways to overcome these negative aspects of concrete, one of them are usage of fibers e.g. steel, polypropylene, polyethylene terephthalate (PET) etc. Fibers improve the crack controlling properties of concrete due to which improves the tensile strength, ductility.

Plastic is a material consisting of large molecules characterized by light weight, high corrosion resistance, high strength-weight ratios and low melting points. Most plastic are easily shaped or formed. Plastic is characterized into two categories, (i) Thermoplastic, (ii) thermosetting plastic, the former can be melted to reuse in the industry and former cannot be melted easily due to its strong molecule bond relationship. One of the common uses of plastics is in the form of plastic bottles, these plastic bottles manufactured from Polyethylene terephthalate commonly known as PET which belong to thermoplastic.

Polyethylene terephthalate (PET) is thermoplastic resin which is product of two monomers known as Ethylene Glycol and Purified terephthalic acid. According to survey about 60 billion plastic bottles are produced each year which are used for different purposes and most common is in beverages These bottles are fully recyclable but recycle rate is only 25% which mean 75% bottles are going in waste which are non-bio degradable even after long period which cause environmental issues like contamination of soil and underground water.

The solid waste crises are important from both the economic and environmental point of view. So, one of the best possible solution is to use them in concrete because plastic have many good characteristics like, lightness and good chemical resistance which not only enhance the performance of concrete but also helps to reduce the environmental issues associated with it.

2. Literature Review

Several Studies has been conducted on using PET fibres and few one will be discussed below:
Batayneh et al. [2] studied the effect of using plastic on workability of concrete. Fine aggregates are replaced by plastic fibers. It has been observed that with increase of plastic fibers up to 20%, the slump decrease is 25% as compare to plain concrete. He concluded that the decrease is due to sharp edges of PET fibers as compared to fine aggregates.
Soroushian et al. [3] found with the addition of discrete fibers reinforcement cause decrease in slump. Which produce adverse effect on workability of concrete.

Ismail and Hashmi [4] investigated that slump is rapidly decreases with increase of plastic fibers. This reduction is due to angular shape of some particles which cause less fluidity. With decrease of slump, the waste plastic mixture has ease workability and suitable for use in precast construction.
Al-Manaseer and Dalal [5] reported the bulk density decreases with increase of plastic fibers. This reduction was attributed to lower unit weight of plastics. Same results are observed by Ismail and Hashmi. The dry density increases with increases of waste plastic contents
Bayasi and Zeng [6] investigated that air content increase with the increase in length and percentage of fibers. Choi et al. [7] studied the effect of using PET fibers on compressive strength

of concrete. He concluded that with increase of fibers the decrease in compressive was observed. Also at same percentage of fibers the decreases in water cement ratio increase the compressive strength.

Marzouk et al. [8] reported that the flexural strength of concrete decreases with the increase of PET fibers

Shihada [9] concluded that by inclusion of plastic fibers in concrete shrinkage reduces as compared to control specimen.

Foti [10] draw the result that there is modest increase in toughness and tensile strength of concrete by using PET fibers.

Various studies have been made in past by mostly using PET fibers as a replacement of fine aggregated.

But this present study focused on using plastic bottles fibers as a by weight percentage of cement and its effect on the engineering properties of concrete.

3. Scope of Research

The main scope of this research to explore the possibility of using fibers made from plastic bottles in an economical way in concrete.

For this study fibers are made from waste plastic bottles which are purchase through different industries of Lahore. Fibers are cut into required Length and width with the help of cutters.

Concrete having cylinder compressive strength of 21 Mpa and 28 Mpa are used to determine the effect of PET fibers on the compressive strength, split cylinder, water absorption, shrinkage and toughness of concrete. For this fibers having percentage **0.25%, 0.5%, 1.00%, 1.5% and 2.00% with respect to weight of cement are used in concrete.**

4. Experimental Program

4.1 Materials

Locally manufactured Type I Ordinary Portland cement conforming to Pakistan standards PSS 232-1883(R) and British Standards EN 197 was used and its physical properties given in Table 1. The fine aggregates (sand) obtained from Lawrence pur site and its properties presented in Table 2. Whereas, the coarse aggregate passing through 19mm sieve were used in this research collected from Margalla query and its physical properties given in Table 3.

The source of plastic fibers is waste plastic bottles which were obtained from trash market of Lahore. These plastic bottles are cut into fibers of required shape and size with the help of cutters. These fibers are used as percentage of cement weight. Table 4 shows the geometrical properties of PET fibers.

Table 1. Physical Properties of Cement

PROPERTIES	VALUE	STANDARDS
Specific Gravity	3.15	-
Consistency	29%	-
Initial Setting Time	140 mins.	Not < 30 mins.
Final Setting Time	215 mins.	Not ≥600 mins
Finesse	8%	<10

Table 2.Physical Properties of Fine Aggregates

PROPERTIES	VALUE
Specific Gravity	2.63
finesse Modulus	2.18
Loose Bulk Density	1369.55 kg/m3
Compacted Bulk Density	1539.05 kg/m3

Table 3.Physical Properties of Coarse Aggregates

PROPERTIES	VALUE
Specific Gravity	2.33
finesse Modulus	2.18
Loose Bulk Density	1377.25 kg/m3
Compacted Bulk Density	1515.93 kg/m3
Water Absorption	1.00%

Table 4. Geometrical Properties of PET Fibers

Sh	L(mm)	W(mm)	%Age
Strips	30	10	0.25,0.5,1.0,1.25, 1.5,2.0

4.2 Mix Design

4.2.1 Concrete Mix Proportion

The mix design ratio for 21 Mpa and 28Mpa was (**1:2:3.33)** and (**1:1.35:3)** with water cement ratio of 0.55 and 0.47. For both type of concrete control and fiber reinforced 75-100 mm slump value is fixed. Table 5 represents the proportions of materials used in control and fiber reinforced concrete for development of 1cum concrete. These strengths were further divided into six sets for testing purposes. The series were based upon control concrete and percentage of plastic fibers with respect to weight of cement.

Table 5. Design Mix

1:2:3.33	340P00	0.00%	197	340	671	1120	-
	340P25	0.25%	197	340	671	1120	0.86
	340P50	0.50%	197	340	671	1120	1.705
	340P100	1.00%	197	340	671	1120	3.410
	340P150	1.50%	197	340	671	1120	5.115
	340P200	2.00%	197	340	671	1120	6.82
1:1.35:3	400P00	0.00%	187	400	537	1200	-
	400P25	0.25%	187	400	537	1200	0.86
	400P50	0.50%	187	400	537	1200	1.705
	400P100	1.00%	187	400	537	1200	3.410
	400P150	1.50%	187	400	537	1200	5.115
	400P200	2.00%	187	400	537	1200	6.82

Concrete specimens are designated in following coding system 000P11, in which first three digits (000) represent cement content, alphabet “P” represent PET fibers and last two digits (11) represent percentage of PET fibers. i.e. 340P00 represent 340kg/m3 cement for PET fiber and 00 shows percentage of fiber with respect to cement.

4.2.2 Mortar Mix Proportion

Dry shrinkage depends upon cement, fine aggregate and water. So, mortar mixes were prepared because coarse aggregates have no influence on shrinkage. According to standards set by ASTM C 596, the mix proportion for control mix having 1:2 ratio with water cement ratio of 0.5. The water

Table 6: Mortar Mix Design

Sr.	Des.	Mix %	Wt. gm	Cmt gm	Sand gm	Fiber gm
1:2	700P00	0.00	350	700	1400	-
	700P25	0.25	350	700	1400	1.75
	700P50	0.50	350	700	1400	3.50
	700P100	1.00	350	700	1400	7.00
	700P150	1.50	350	700	1400	10.50
	700P200	2.00	350	700	1400	14.00

First term in designation column represent cement content, next represent PET fiber and final term represent percentage i.e., 700P25 shows that total cement content is 700kg/m^3 in which 0.25 percent of PET fibers with respect to cement weight is added.

4.3 Casting and Curing

After achieving the uniform mix of concrete the next step is casting of specimens. Before casting of specimens, the required numbers of molds for cylinder and prism are cleaned and oiled from inside so that the specimens should remove easily without any damage. The molds are filled with concrete in three layers and then placed on vibrating table for proper compaction. After compaction, the top surface of the specimen is leveled with the help of trowel and left for 24 hrs for drying. The specimens for compressive, tensile, flexural and water absorption were prepared according to concrete mix explain in section 3.2.1 and specimens for dry shrinkage were prepared according to section 3.2.2. Table 7 gives complete information about numbers and type of specimens used in this experimental work.

Table 7.

S/N	Purpose	Specimen Description: Type	Specimen Description: Dimensions	Concrete Type	No. of Specimen	Total Specimen
1	Compressive Strength/ Modulus Of Elasticity	Cylinder	Dia.=100 mm Height = 200mm	P00	5	30
				P25	5	
				P50	5	
				P100	5	
				P150	5	
				P200	5	
p p 2	Split Cylinder Tensile Strength	Cylinder	Dia.=100 mm Height = 200mm	P00	5	30
				P25	5	
				P50	5	
				P100	5	
				P150	5	
				P200	5	
3	Water Absorption	Cylinder	Dia.=100 mm Height = 200 mm	P00	5	30
				P25	5	
				P50	5	
				P100	5	
				P150	5	
				P200	5	
4	Flexural Strength/ Load Deflection Test	Prism/ Beam	Length = 510 mm Width = 100 mm Depth = 100mm	P00	5	30
				P25	5	
				P50	5	
				P100	5	
				P150	5	
				P200	5	
5	Shrinkage test	Prism	Length = 285 mm Width = 25mm Depth = 25mm	P00	5	30
				P25	5	
				P50	5	
				P100	5	
				P150	5	
				P200	5	

After 24hrs or 48hrs depending upon conditions the specimens were demoulded with utmost care to avoid any damage to the specimens. Then all specimens for test are placed into curing tank at room temperature for the period of 28 days. After 28 days specimen was placed in open atmosphere for drying.

Similarly, the specimens for dry shrinkage are demolded after 24 or 48 hrs depending upon the condition. Specimens need to be immersed in lime solution for minimum 48 hrs if demolded after 24hrs and vice versa. Total curing time must be 72 hrs from the date of casting depending upon conditions. Two demec points were fixed at each specimen at standard distance for measurement and then they were left in open atmosphere for drying until test date arrives.

Figure 1. Prisms for dry shrinkage

4.4 Test Results

4.4.1 Compressive Strength

Compressive test is one of the common test for determination of strength of concrete. This test is performed using ASTM specification C39. In this research, compressive strength test was performed on cylinder having 100 mm (4") diameter and 200mm (8") height at the age of 28 days. For uniform application of load capping of white cement is done on top of the cylinder. The Specimens were the loaded at the rate of 0.3N/mm^2/s under compression testing machine. Average

Figure 2. Compressive Strength for 21 MPa Concrete

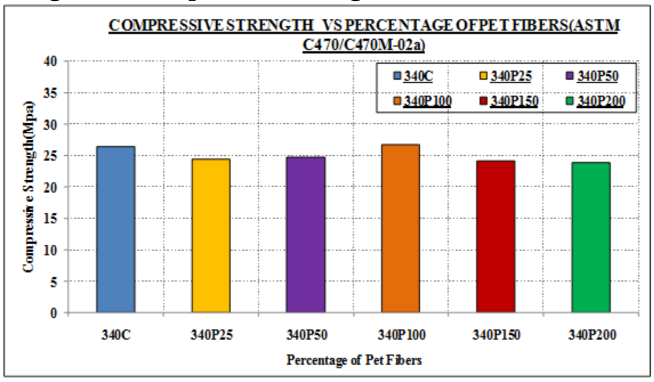
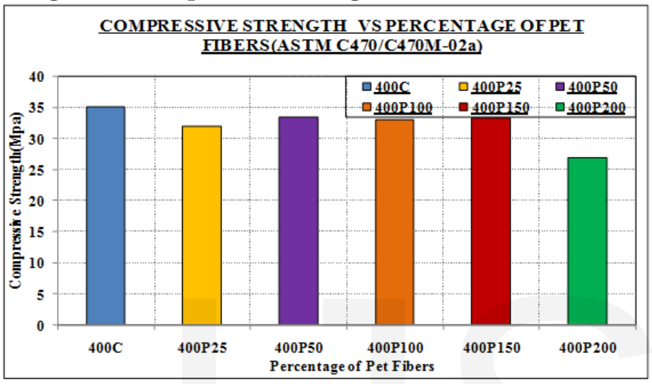


Figure 3. Compressive Strength for 28 MPa Concrete



4.4.2 Modulus of Elasticity

The test result histogram of PET fibers effect on modulus of elasticity of concrete (21 Mpa & 28 Mpa) is shown in fig 4 & 5.

Figure 4. Modulus of Elasticity for 21MPa Concrete

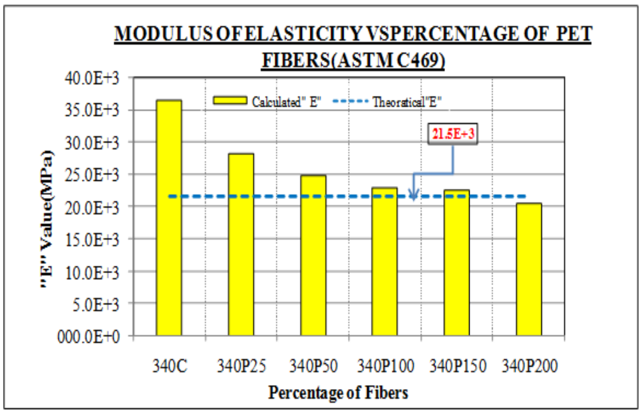
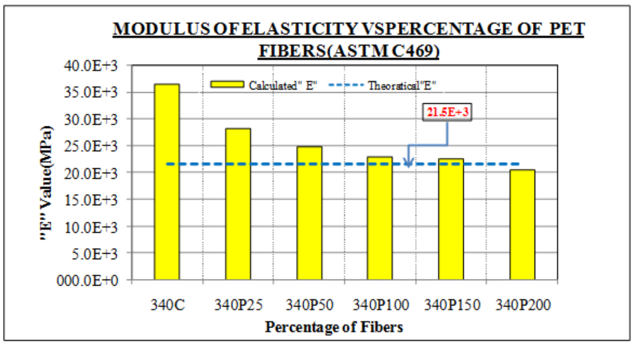


Figure 5. Modulus of Elasticity for 28 MPa Concrete



4.4.3 Split Cylinder Tensile Strength

Split tensile strength tests on fiber reinforced concrete and control specimens are conducted at age of 28 days and results were presented in fig.6&7.

Figure 6. Tensile Strength for 21MPa Concrete

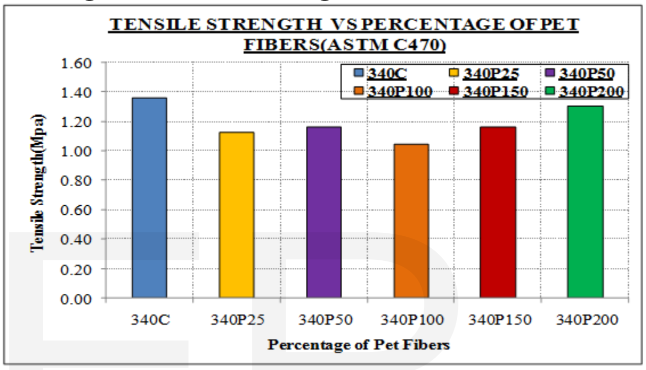
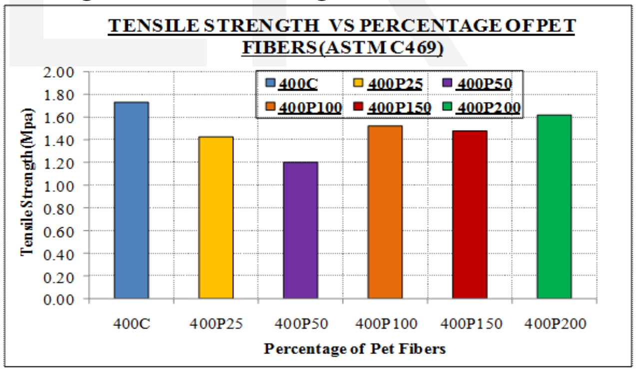


Figure 7. Tensile Strength for 28 MPa Concrete



4.4.4 Water Absorption Test

Water absorption test is conducted on fiber reinforced concrete specimen and control concrete. The results presented graphically presented in fig 8 & 9.

Figure 8. Water Absorption Capacity for 21 MPa Concrete

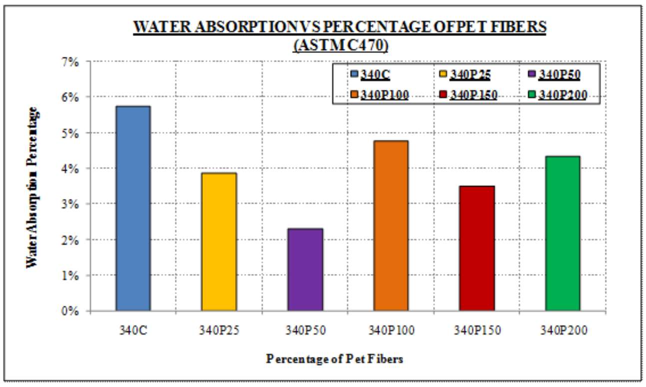
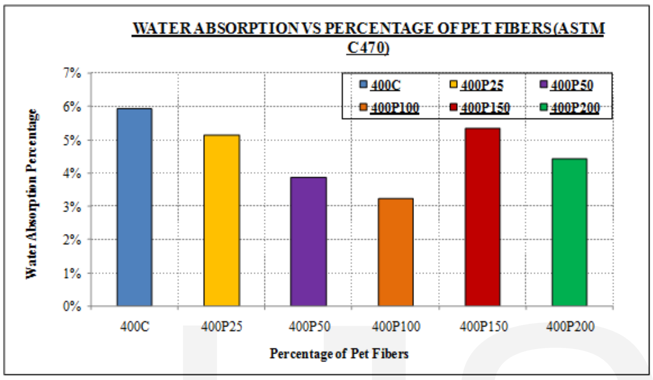


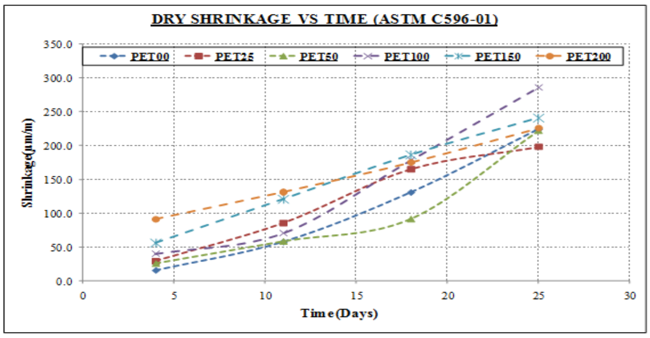
Figure 9. Water Absorption Capacity for 28MPa Concrete



4.4.5 Dry Shrinkage Test

Dry shrinkage of mortar with having Pet fibers were compared with control mortar specimen. Mortar prism of size 25mm x 25mm x285 mm prepared, which were tested at age of 4,11,18 and 25 days. At each age 5 Nos. prisms tested and average value is taken. The results are presented in fig10.

Figure 10.Effect of PET fiber on dry shrinkage



4.4.6 Two Point Load Test (Flexural Strength Test)

Using two-point load test to determine the post cracking behavior of fiber reinforced concrete prism and concrete prism was compared. The specimens were loaded according to specification ASTM C 78 for two-point load test under the strain controlled machine known as Shimadzu universal testing machine. The load is applied at rate of 0.5mm/min on prism having size 100mm x 100mm x 500mm. The required data is automatically recorded in computer from which stress strain curves are prepared and toughness is calculated by measuring area under the curve. The results are shown in fig.11,12,13 and 14.

Figure 11. Load Deflection Curves for 21 MPa Concrete

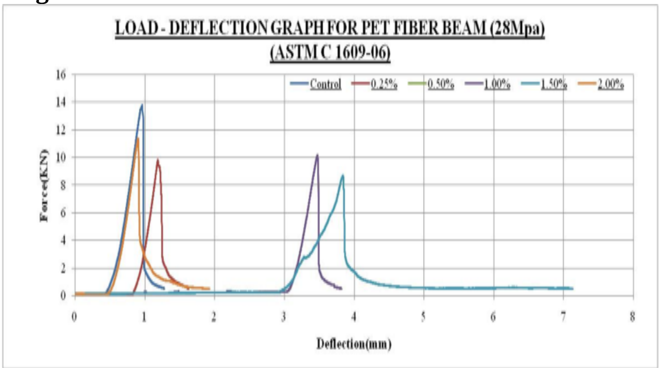


Figure 12. Load deflection Curves for 21 MPa Concrete

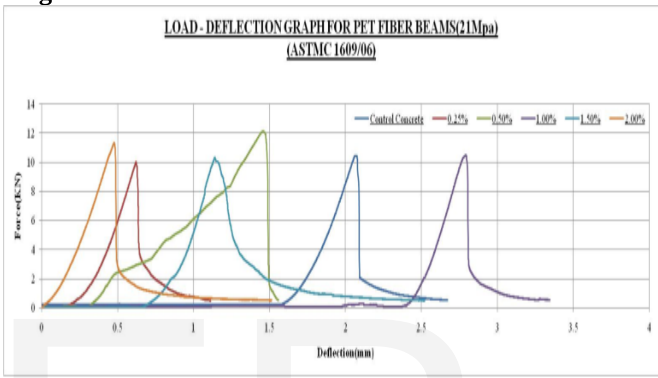


Figure 13. Toughness for 21 MPa Concrete

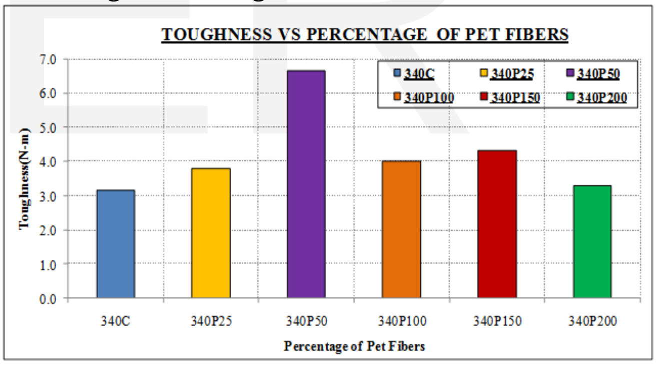
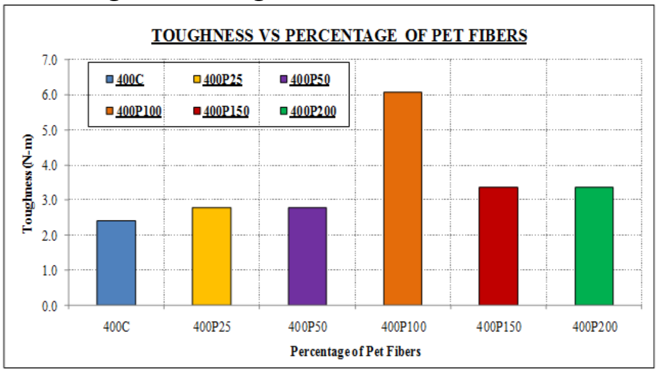


Figure 14. Toughness for 28 MPa Concrete



4.5 CONCLUSION

When PET fiber is added with concrete having concrete strength of 21 & 28 Mpa following is concluded: -

1. With addition of PET fibers in the concrete the compressive strength decreases for both concrete strengths of 21 MPa and 28 Mpa as shown in fig 2 and 3. The average decrease was in between 6 to 9%. The reason behind this decrease is poor bonding between concrete and plastic.

2. The modulus of elasticity also decreases with the addition of Pet fibers for both target strengths (21 Mpa and 28 Mpa) as shown in fig.4 and 5. The average decrease in modulus of elasticity was about 30 percent.

3. In split cylinder, tensile test decrease in tensile strength was observed with pet fibers as compared to controlled concrete specimens in fig.6 and 7. The average decrease is 16 per cent in both targeted strengths. However, it is also observed, during test the specimens with no fibers shows brittle failure whereas, the specimens with PET fibers shows ductile cracking behavior.

4. In water absorption test the fig.8 and 9 shows that the water absorption decrease with the addition of fibers as compare to controlled concrete for both targeted strengths of concrete. The average decrease was about 31 per cent. The Fibers decrease the number of pores/voids in concrete which causes decrease in water absorption capacity.

5. From fig.10 it is concluded that PET fiber reinforced concrete reduces dry shrinkage and it was found that optimum dosage of PET fiber for shrinkage control is 0.5% for normal strength concrete.

6. In two point load test the graphs in fig.11 and 12 for target strength of 21 Mpa and 28 Mpa shows that the controlled specimen break suddenly as the peak load reaches, whereas, the specimens with fibres shows pseudo ductile behaviour with high energy absorption capacity due to bridging action of fibres in concrete. From fig.13 and 14. It is observed that average increase in toughness for both targeted strengths were about 25 percent.

4.6 Acknowledgment

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