Polyethylene Terephthalate (PET) bottles Fibre in Concrete

Tatheer Faizan[1], Khushboo Nabi[2], Rubeena Bashir[3], Er Tahir Hassan[4]

[1,2,3]B.E student, Civil Engineering Department, SSM College of Engineering, Kashmir, India
[4]Associate Professor, Civil Engineering Department, SSM College of Engineering, Kashmir, India

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Abstract - *Food and beverage packets yield 31.1% of plastic waste around the world, bottle and container caps 15.5%, plastic bags 11.8%, and plastic bottles yields around 7.27% plastic waste. More than 480bn drinking bottles made up of plastic were sold in 2016 across the world, up from about 300bn ten years ago. If placed end to end, they would lead more than halfway to the sun. By 2021 this number will increase to 583.3bn. Recycling of these PET bottles costs about 30-31 rupees in India as of 2021. These PET bottles can be disintegrated into fibers which can be used to increase the properties of concrete. Fiber-reinforced concrete has been used for the past 20 years as a new construction material. The tensile strength, ductility, fracture strength, toughness, impact resistance, flexural strength, fatigue resistance, and other properties of concrete is improved by the addition of these fibers. It also helps in reducing bleeding of freshly mixed concrete and makes it impermeable in the hardened stage. Therefore, the fiber-reinforced concrete becomes economical (considering the recycling cost) and the self-weight of concrete is reduced. Thus, it is preferred to use PET fiber reinforced concrete over reinforced concrete from a structural point of view. This paper portrays the strength results of fiber-reinforced concrete with varying percentages of PET fibers. Recycled PET bottles are considered the best eco-friendly alternative for resolving the disposal problems and also a new construction material.*

Key Words: PET fibers, Fibre reinforced concrete, PET bottles, Compressive strength, tensile strength, flexure strength.

1. INTRODUCTION

Concrete is one of the most common building materials used for constructive civil engineering structures. Concrete can be cast in any desirable shape. It exhibits some excellent properties such as good compressive strength, durability, specific gravity, and fire resistance and lacks tensile strength and ductility. The introduction of fibers in concrete makes an excellent composite building material.

Nowadays, fiber reinforced concrete is becoming more popular. It is a composite material consisting of mixtures of water, fine aggregate, coarse aggregate, and discontinuous, discrete, uniformly dispersed suitable fibers. They are of different types like glass, polypropylene, polyethylene terephthalate, polyester, carbon, macro synthetic, micro synthetic, natural, cellulose, etc, and properties with many advantages. Within these different fibers, the character of fiber reinforced concrete changes with varying fiber material, concrete, geometries, orientation, and densities. The length, shape, and dimension of fiber are essential in making reinforced concrete. A short and thin fiber, for instance, will only be effective during the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase its tensile strength. The addition of fibers in the mix improves mechanical characteristics of Fiber Reinforced Concrete i.e., fracture strength, toughness, impact resistance, wear and tear, flexural strength, fatigue resistance. The primary reason for the addition of fibers in concrete is to enhance the post-cracking response of the concrete i.e., to enhance its energy absorption capacity and apparent ductility and to provide crack resistance and crack control. Also, it assists in maintaining structural integrity and cohesiveness in the material. The fiber is described by a parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter. The typical aspect ratio ranges from 30 to 150. The use of Polyethylene terephthalate (PET) as fiber in concrete is especially important as such wastes are continuously increasing, bringing serious ecological and economic problems since the extent of biodegradation of commodity plastics is very low.

Fig -1: Polyethylene Terephthalate (PET) bottle fiber.

Table -1: Properties of PET fiber.

Property	**Unit**	**Value/ Range**
Young's Modulus	MPa	2800-3100
Density	gmL^{-1}	1.35-1.40
Melting Point	^0C	255
Coefficient of thermal expansion $x10^{-6}$	Cm/ (cm ^0C)	6-7
Tensile Strength	MPa	60-85.5
Specific Gravity	……..	1.2-1.4
Elastic Limit	……..	50-150%

2. MATERIAL USED

- **Cement**: Cement OPC-43 grade was used satisfying the requirements of **IS-8112-2013** specifications.
- **Fine aggregate**: We are using river sand. After Sieve analysis and other tests, it was found that it falls under Zone-3 as per **IS-383:1970** specifications with Specific gravity of 2.63.
- **Coarse aggregate:** Aggregates of 20mm having fineness modulus of 6.5 from the local quarry were used in the experiment as per **IS:383:1970** specifications.
- **Water:** Tap water confirming to the standard mentioned in **IS-10500:2012** was used for mixing and curing all through the experiment.
- **Fiber:** PET bottles were collected from incineration site. After removing the top and bottom of the bottle. The breadth and length were kept 1mm and 35mm respectively. The aspect ratio was 35 with a specific gravity of 1.36 and water absorption of 0.00%.

3. EXPERIMENTAL WORK

3.1 CONCRETE MIX

Nominal mix of concrete was prepared using M20 grade with a water-cement ratio of 0.52, corresponding to proportions of 1:1.5:3. Varying percentages from 0-3 of PET fibers were adopted into the mixture. The different specimens were prepared with varying percentages of PET fibers and were tested after 28 days of curing as per IS specifications.

3.2 MIXING

Measured volumes of cement, fine aggregate, and coarse aggregate were thoroughly mixed till they attained uniformity. Then, varying percentages of PET fibers were added to uniformly dispersed in the concrete without forming the fiber ball.

3.3 TESTS

a. **Compressive strength:** The IS standard cubes of the size (150×150×150)mm with varying percentages of PET fibers were cast and marked accordingly. The test specimens were stored at a temperature of 27⁰C and 90% humidity from the time of addition of the water to the dry ingredients. After placing the specimen between the plates of CTM, the gradual load was applied till the specimen was crushed. All the specimens were tested accordingly.

Then the Compressive strength of the specimen was calculated using the following formula.

$$f_{cu} = \frac{P_c}{A}$$

Where, P_c is the failure load in compression (KN) and A is the loaded area of the cube.

Table -2: Compression test results after 28 days.

Specimen identification	Percentage of PET fiber	Failure Load (KN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)	Percentage of avg. compressive strength wr.t reference mix
X Y Z	0 (Ref mix)	625 629 624	27.77 27.98 27.74	27.83	---------
X_1 Y_1 Z_1	0.5	634 637 636	28.16 28.31 28.28	28.25	+1.50
X_2 Y_2 Z_2	1.0	646 645 647	28.70 28.68 28.75	28.71	+3.16
X_3 Y_3 Z_3	1.5	652 655 660	28.97 29.12 29.33	29.14	+4.70
X_4 Y_4 Z_4	2.0	575 572 576	25.57 25.41 25.61	25.53	-8.26
X_5 Y_5 Z_5	2.5	109 410 410	18.17 18.24 18.25	18.22	-34.53
X_6 Y_6 Z_6	3.0	401 403 403	17.84 17.89 17.91	17.88	- 35.75

b. **Split tensile Strength:** A test cylinder specimen of diameter 150mm and height 300mm with varying percentages of PET fibers were cast and marked accordingly. The test specimen was stored at a temperature of 27⁰C and 90% humidity from the time of addition of the water. After removing the specimens from the moulds, they were placed in water and were taken out after 28 days. The compression was applied diametrically and uniformly along the length until the failure of the cylinder along the vertical diameter was observed. The test was performed in accordance with **IS: 5816-1970.**

The Tensile strength of the specimen was calculated using the following formula.

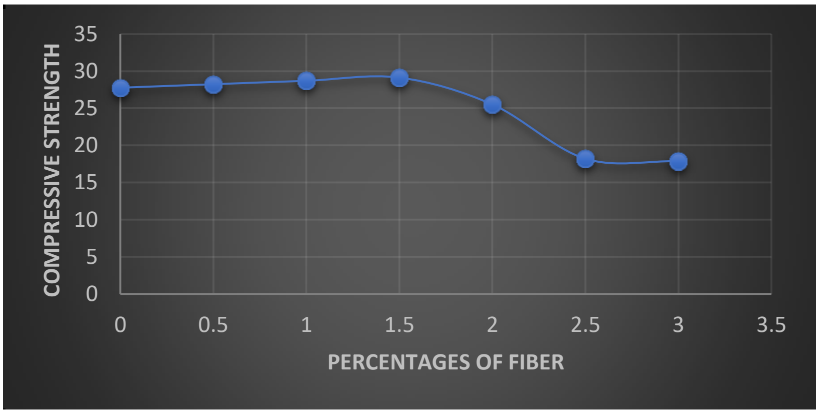
$$\sigma = \frac{2P}{\Pi DL}$$

Where, σ = Compressive strength

P= Applied Load

D= Diameter of the circle

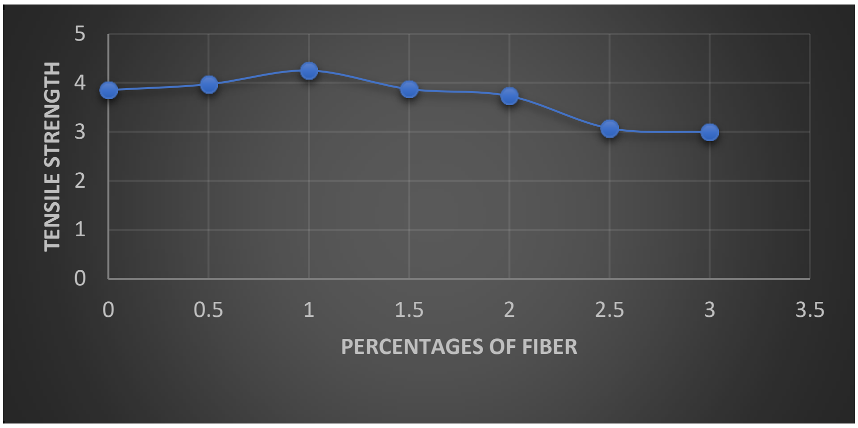
L= Length of the cylinder.



Graph -1: Percentage of PET fiber vs Compressive Strength after 28 days.

Table -3: Tensile test results after 28 days.

Specimen identification	**Percentage of PET fiber**	**Failure Load (KN)**	**Tensile Strength (N/mm²)**	**Average Tensile Strength (N/mm²)**	**Percentage of avg. tensile strength wr.t reference mix**
X Y Z	0 (Ref mix)	274 271 272	3.87 3.83 3.85	3.85	---------
X_1 Y_1 Z_1	0.5	279 282 281	3.95 3.99 3.97	3.97	+3.12
X_2 Y_2 Z_2	1.0	300 301 300	4.24 4.26 4.25	4.25	+10.39
X_3 Y_3 Z_3	1.5	273 276 272	3.86 3.90 3.85	3.87	+0.52
X_4 Y_4 Z_4	2.0	263 266 262	3.72 3.76 3.71	3.73	-3.12
X_5 Y_5 Z_5	2.5	215 220 216	3.04 3.11 3.06	3.07	-20.26
X_6 Y_6 Z_6	3.0	213 212 209	3.02 3.00 2.95	2.99	-22.34



Graph -2: Percentage of PET fiber vs Tensile Strength after 28 days.

c. **Flexure Strength:** A mould of size (150×150×700)mm with varying percentages of PET fibers was cast and then marked accordingly. The test specimen was stored at a temperature of 27^{0}C and 90% humidity from the time of addition of the water. After removing the specimens from the moulds, they were placed in water and were taken out after 28days.

The Flexural strength of the specimen was calculated using the following formula.

$$f_{cr} = \frac{P_f L}{b d^2}$$

Where,

f_{cr} = Flexure Strength, N/mm^2.

P_f = Central load through point loading systems, N.

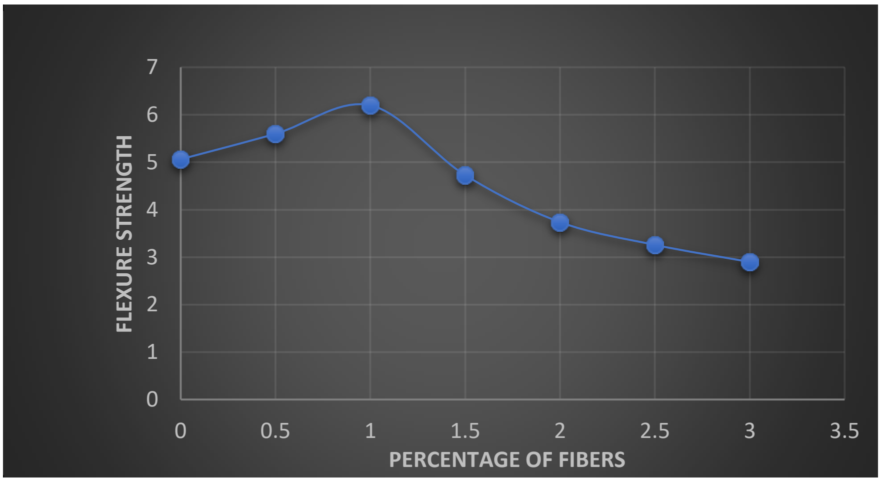
L = Span of the beam.

b = Width of the beam in mm and d = Depth of the beam in mm.

Table -3: Flexure Strength test results after 28 days.

Specimen identification	Percentage of PET fiber	Failure Load (KN)	Flexural Strength (N/mm^2)	Average flexural Strength (N/mm^2)	Percentage of avg. flexural strength wr.t reference mix
X Y Z	0 (Ref mix)	12.5 12.8 12.6	5.00 5.12 5.04	5.06	---------
X_1 Y_1 Z_1	0.5	13.9 14.0 14.1	5.56 5.60 5.64	5.60	+10.67
X_2 Y_2 Z_2	1.0	15.5 15.3 15.7	6.20 6.12 6.28	6.20	+22.52
X_3 Y_3 Z_3	1.5	11.9 11.8 11.7	4.76 4.72 4.68	4.73	-6.52
X_4 Y_4 Z_4	2.0	9.30 9.30 9.40	3.74 3.74 3.76	3.74	-26.08
X_5 Y_5 Z_5	2.5	8.20 7.90 8.40	3.28 3.16 3.36	3.26	-35.57

X_6 Y_6 Z_6	3.0	7.30 7.00 7.50	2.92 2.80 3.00	2.90	-42.68



Graph -3: Percentage of PET fiber vs Flexural Strength after 28 days.

4. CONCLUSION

The introduction of PET bottle fibers in concrete helps the constituents to hold together. It can be concluded that the maximum compressive strength is achieved by the addition of 1.5% of PET fiber volume in the concrete and the addition of more than 1.5% of fiber decreases its compressive strength. It is also noted that at 1% of PET fiber around 10% split strength and 23% flexure strength of concrete is increased. Mixing of PET fiber with concrete was easy when fiber content as high as 3% was introduced. Throughout the experiment, we got to know that the ductility of the specimen was increased with an increase in PET fiber content.

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