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Use of Pet Bottles Scrap as an Additive in Concrete

Kapil P. Nanote¹, Ashok R. Mundhada²

¹Assistant Professor, Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati-444701, India, kapilpnanote@gmail.com

²Professor & Head, Department of Civil Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati-444701, India

Abstract

The management of waste materials is a gargantuan problem these days. Hence, the researchers are trying to use waste materials as an additive to concrete. The present work was aimed at assessing the effect of PET shreds on the quality of concrete in general & its compressive, flexural, split tensile strength in particular. In this research total 45 specimens were cast in M: 20 grade design mix concrete, divided equally over cubes, beams & cylinders. The manually cut PET shreds (2mm wide & 45 mm long) were added in different percentages (between 0.25 & 1%) by volume of concrete. After 28 days of curing & 24 hours air drying, all the specimens were subjected to non-destructive testing like Schmidt hammer test & UV Pulse velocity test. The specimens were then subjected to compressive strength test, flexural strength test & split tensile strength test. The results were encouraging although further studies would be required. Optimum percentage of PET fibers to be added in the concrete was found out to be 0.25%.

Keywords: Concrete, PET Fibers, Compressive Strength, Tensile Strength, Split Tensile Strength.

Introduction

Lots of infrastructural development is going on in the country due to rapid industrialization and urbanization. This process has in turn raised questions to solve the problems generated by this random, disorganized growth. The problems defined are acute shortage of construction materials & increased availability of waste material.

The present Indian concrete industry is consuming about 370 million cubic meter of concrete every year and it is expected that it shall reach about 580 million cubic meters by 2022. The reformation of natural sources is beyond the proportion of mankind. Hence quickly vanishing valuable natural resources is a matter of concern. It, therefore, has become a necessity to choose some alternative material to reduce the quick and huge usage of valuable resources.

Following the growth in population, the amount and type of waste materials have increased accordingly. Many of the non decaying waste materials will remain in the environment for hundreds of years. The non decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problem. Hence the use of such waste materials may become an alternative to the natural resources.

The plastic industry is one of the fastest growing industries off late. The use of waste plastic materials along with the conventional

materials to make concrete is called Green concrete. The plastic is an engineering material available in the form of bags, bottles etc. The plastics have been classified into many types according to their composition with their own recycle rate. One such type PET (Polyethylene Terephthalate) is taken into consideration. PET is an excellent water and moisture barrier material. Plastic bottles made from PET are widely used for soft drinks. To overcome the above said problems, the PET scraps were used as an additive in concrete in known percentage. The PET bottles were manually cut into fibers of width 2 mm and length 45 mm. Usually M: 20 grade concrete is used for most of the construction work, hence in this project M: 20 grade design mix concrete was taken. The optimum percentage which will result in higher compressive strength, flexural strength and split tensile strength was calculated.

Experimental Program

Introduction

The experimental program consisted of two types of non destructive tests and three types of destructive tests. The non destructive tests were Schmidt hammer test and ultrasonic pulse velocity test. The destructive tests were for compressive strength, flexural strength and split tensile strength. The PET fibers were added into concrete in 0.25%, 0.5%, 0.75% and 1% by volume of concrete. These tests examined the effect of PET fiber additive in concrete with the reference concrete. The program

consisted of casting of total 45 nos. of specimens with M: 20 grade of concrete. The 45 specimens consisted of 15 cubes, 15 beams and 15 cylinders. Out of every 15 specimens of cubes, beams and cylinders, three specimens were not added with PET & were for reference, 3 specimens were added with 0.25% of PET fibers, 3 specimens were added with 0.5% of PET fibers, 3 specimens with 0.75% of PET fibers & the remaining 3 specimens (of each category) were added with 1% of PET fibers.

Materials And Their Quality Tests

It is very important to know the properties and characteristics of constituent materials of concrete, as we know, concrete is a composite material made up of several different materials such as aggregate, sand, water, cement and admixture. These materials have properties and different characteristics such as Unit weight, Specific gravity, size gradation and water content. The necessary tests were conducted in the laboratory.

Dense loose bulk density of aggregate (DLBD)

Dense loose bulk density can be defined as the weight of a given volume of graded aggregate. The Dense loose bulk density effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them. The Dense loose bulk density is simply measured by filling a container of known volume with loosely filled aggregate without compaction and weighting.

Dense loose bulk density of Aggregate tested for coarse and fine aggregate is shown in table 1:

Table 1. Dense loose bulk density of Aggregates(DLBD)

Coarse Aggregate	1.228 kg/liter
Fine Aggregate	1.697 kg/liter

Specific gravity of aggregates

Specific gravity is defined as the ratio of the weight of a unit volume of aggregate to the weight of an equal volume of water. Specific gravity expresses the density of the solid fraction of the aggregate in concrete mixes as well as to determine the volume of pores in the mix. The specific gravity of aggregate is to determine the volume of aggregates in a concrete mix as well as to determine the volume of pores in the mix.

$$[\text{Specific Gravity}(S.G)=\frac{\text{density of solid}}{\text{density of water}}]$$

The specific gravity of coarse and fine aggregate is shown in Table 2.

Table 2. Specific gravity of aggregates

Coarse Aggregate (10mm)	2.822
Coarse Aggregate (20mm)	2.895
Fine Aggregate	2.731

Moisture content of aggregate

Since the aggregates can absorb moisture. The water content also affects aggregate proportioning (because it contributes to aggregate weight). As the atmosphere was cloudy throughout the period of casting, condition of aggregate was considered as moderately wet.

Sieve Analysis of Aggregate

The size of aggregate particles differs from one aggregate to another, and for the same aggregate the size is different. So in this test we determined zone of aggregate by combined sieve analysis. From this test, aggregates were found to belong to Zone I as per (IS 383-1970).

Cement

Standard ISI mark cement was used. Testing report of the batch was procured from the manufacturer.

Water

Drinking water was used in concrete mixtures and in the curing.

PET fibers

The PET material has density 1.38 gm/cc. The tensile strength is very good and melting point greater than 250°C. The fibers were obtained by manual cutting of water bottles. The fiber width was kept at 2 mm and length at @45mm.



Figure 1. PET fibers

Mix Proportions

Concrete consists of different ingredients. The ingredients have their different individual properties. Strength, workability and durability of the concrete depend heavily on the concrete mix proportion of the individual ingredients. In this study M:20 grade design mix concrete was used.

Design Requirements

- 1) Characteristic cube concrete strength-20 N/mm²
- 2) Max. water cement ratio(w/c)-0.5
- 3) Max. aggregate size-20mm
- 4) Slump-50mm

The following tables illustrate the mix of concrete

Table 3. Concrete mix for M: 20 concrete grade

Materials	Weight per one cubic meter kg/m ³
Cement	345
Water	172
Fine Aggregate (Sand)	922
Coarse Aggregate(10mm)	370
Coarse Aggregate(20mm)	688
Proportion	1:2.67:3.067

Specimen Categories

Specimens were categorized and distributed according to the percentage of PET fibers added:

1. Grade of Concrete. (M20).
2. Percentage of PET fibers added

Table 4. Details of M20 Grade concrete specimens

M20 Grade of Concrete						
Specimens	PET fiber in Percentage (%)					Total
	0	0.25	0.5	0.75	1	
Cube	3	3	3	3	3	15
Beam	3	3	3	3	3	15
Cylinder	3	3	3	3	3	15
Total Number of Specimens						45

Casting And Curing

Casting procedure

The fresh concrete was prepared as per mix design seen previously. PET fibers were added in known percentage. The entire constituent was homogeneously mixed by hand mixing & then churned in a Mechanical Mixer for a minute.

Compacting

The test specimens were made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete was compacted by tamping & finally by vibration.

Curing

After the fresh concrete had hardened, all samples were submerged completely in water for 28 days.

Laboratory Tests

For determining various mechanical properties of concrete following tests were conducted after 28 days of curing.

Nondestructive Tests (NDTs)

Two types of Non-destructive tests were carried out, Schmidt hammer test and Ultrasonic pulse velocity test.

Destructive Tests

The Destructive tests were of three types Compressive Strength, Flexural Strength and Split Tensile Strength, conforming to the relevant IS codes.

Scrutiny of Results

Observations

Rebound Hammer test on Cube

One reading was taken at the centre of each face of cube. The highest & the lowest readings were discarded. 'Reading average' means the average of the remaining four readings for each cube.

Table 5. Rebound Hammer test for cubes of concrete grade M: 20

Cube No.	% of PET Fibers	Reading Average	Average	Remark
1	0.00	30.75	30.69	Very Good
2	0.00	30.00		
3	0.00	31.32		
4	0.25	31.00	32.94	Very Good
5	0.25	32.50		
6	0.25	32.32		
7	0.50	31.75	30.69	Very Good
8	0.50	30.00		
9	0.50	30.32		
10	0.75	32.32	32.49	Very Good
11	0.75	32.60		
12	0.75	32.55		
13	1.00	32.50	31.05	Very Good
14	1.00	30.32		
15	1.00	30.32		

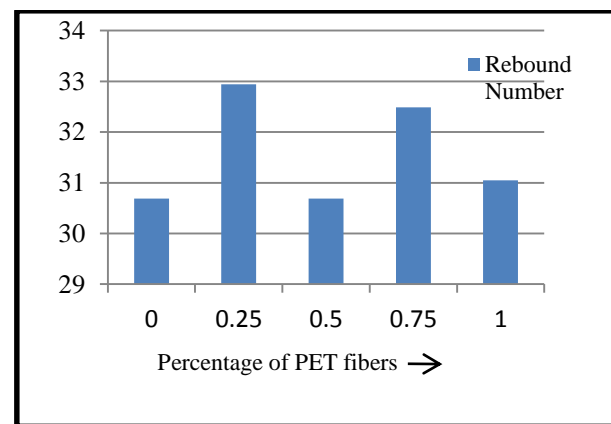


Figure 2. Percentage of PET fibers Vs Rebound Number

Results obtained from the Schmidt Hammer test on cubes are presented in Table 5. Figure 2 above shows the results by means of charts. A cursory glance at these graphs reveals concrete quality was found to be very good for all cases. It was more for the concrete in which the PET fiber percentage was 0.25%.

Rebound Hammer Test on Beam

Two reading were taken at or around the quarter span of each face. The highest & the lowest readings were discarded. 'Reading average' means the average of the remaining six readings for each beam.

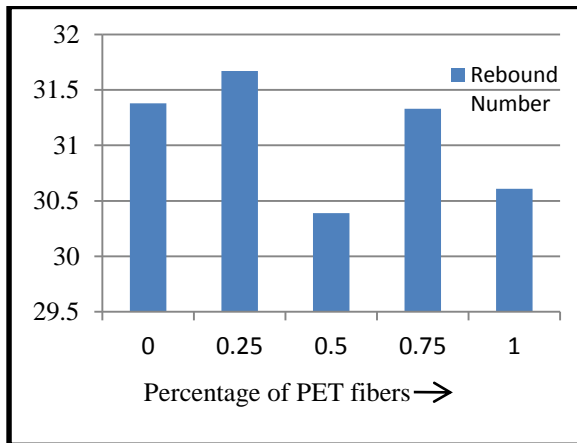


Figure 3. Percentage of PET fibers Vs Rebound Number

Results obtained from the Schmidt Hammer test on beams are presented in Figure 3 above by means of bar charts. A cursory glance at these graphs reveals good concrete quality for all cases but a bit superior for 0.25% PET fibres.

Ultrasonic Pulse velocity test on cube

Total three readings were taken for each cube. Average of the three was considered.

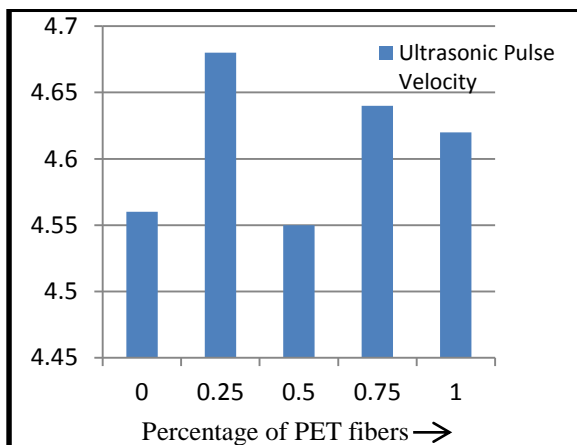


Figure 4. Percentage of PET fibers Vs Ultrasonic Pulse Velocity in km/sec.

Record of the UV Pulse velocity test results can be found in Figure 4 above, by means of bar chart. From the values of UV test it is found that the overall concrete is of very good quality for all cases. But concrete with 0.25% of PET fibers has slightly superior quality as compared to others.

Ultrasonic Pulse velocity test on beam

Total four readings were taken for each beam. Average of the four was considered.

Record of the UV Pulse velocity test results can be found in Figure 5 below by means of bar chart. From the values of UV test it is found that the overall concrete is of very good quality for

all the cases & the difference in values has no significance.

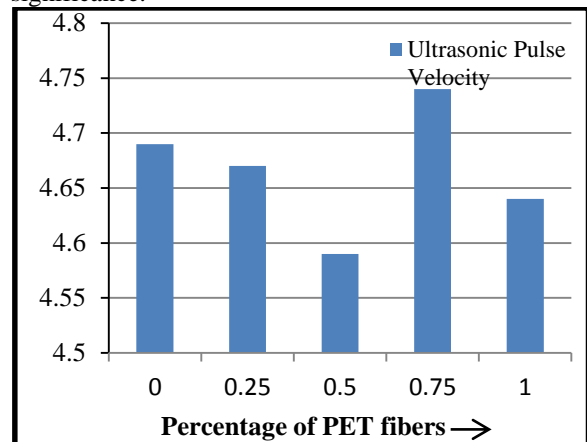


Figure 5. Percentage of PET fibers Vs Ultrasonic Pulse Velocity in km/sec.

Cube Compressive Strength of Concrete

Table 6. Compressive Strength of cube of concrete grade M:20

Cube No.	Percentage of PET Fibers	Failure Load (N)	Compressive Strength (N/mm ²)	Category Average
1	0.00	463000	20.58	21.36
2	0.00	466950	20.75	
3	0.00	511700	22.74	
4	0.25	568980	25.29	25.74
5	0.25	588600	26.16	
6	0.25	580100	25.78	
7	0.50	478000	21.24	20.83
8	0.50	470880	20.93	
9	0.50	457100	20.32	
10	0.75	527000	23.42	23.79
11	0.75	557450	24.78	
12	0.75	521100	23.16	
13	1.00	519930	23.11	22.82
14	1.00	510120	22.67	
15	1.00	510120	22.67	

Results of the destructive compressive strength test have been enlisted in Table number 6 above & Figure 6 below. A careful glance at the plot shows the concrete with 0.25% of PET fibers has more compressive strength as compared to other cases. The compressive strength in fact is always higher than that of reference concrete cubes containing no PET shreds. It is difficult to fathom the reason behind increased compressive strength.

Apparently, it sounds illogical. One plausible explanation could be the increased shear strength owing to the addition of fibers. This was confirmed by the fact that all the specimens (whether cubes, beams or cylinders) showed no disintegration, spalling or peeling of concrete lumps/pieces after failure.

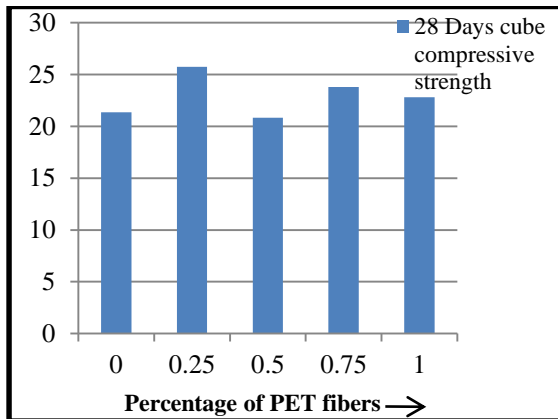


Figure 6. Percentage of PET fibers Vs Compressive Strength

Flexural Strength of Beam

The flexural strength is calculated by testing beam specimen on UTM to failure by two point loading method.

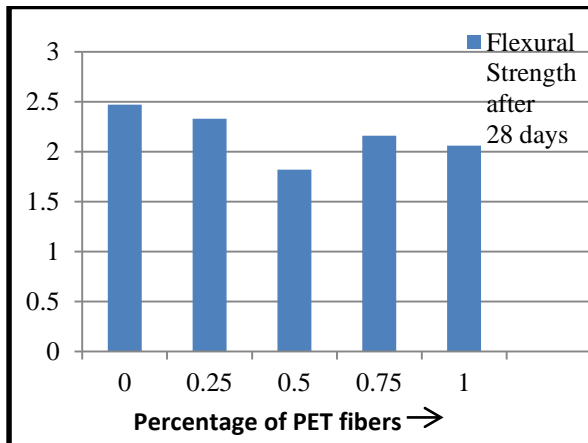


Figure 7. Percentage of PET fibers Vs Flexural Strength

Results of the destructive flexural strength test have been enlisted in Figure 7 above. A careful glance at the bar chart shows, the concrete with 0.25% of PET fibers has more flexural strength as compared to other percentages of PET. But the reference concrete beams always exhibited maximum values. Addition of plastic fibers/shreds is always expected to increase the flexural and tensile strengths of concrete. In that context, the results are once again baffling and do not fulfill the expectations.

Split tensile strength of concrete

The split tensile strength is calculated by testing cylindrical specimen on UTM to failure.

Results of the destructive Split tensile strength test have been graphically depicted in Figure 8. A study of these plots shows that concrete with 0.25% of PET fibers exhibits more split tensile strength as compared to other percentages of

PET. The value is 10% more than that of reference concrete having no PET shreds.

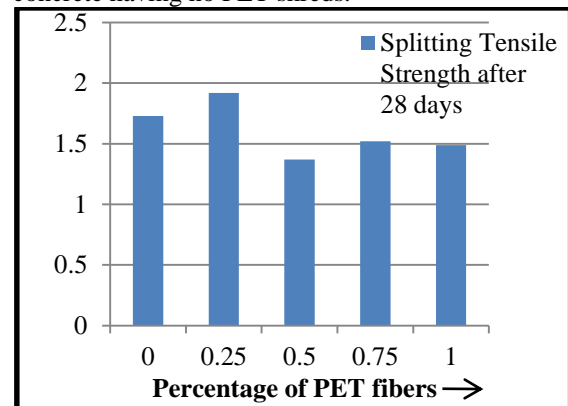


Figure 8. Percentage of PET fibers Vs Splitting Tensile Strength

To surmise, addition of PET shreds seems to be beneficial especially when the quantity added is 0.25% by volume of concrete.

Conclusions

Based on the results & their scrutiny, the following conclusions could be drawn:

1. Disposal of PET bottles is a gargantuan environment hazard across the globe. Shreds obtained from empty bottles can be used to increase the quality & performance of concrete.
2. The test results suggest that the addition of 0.25% of PET shreds gives optimum results so far as quality & performance of concrete is concerned.

Future Scope

The results were inconsistent & illogical at some places. The experiment needs to be repeated for more data & its verification. Furthermore, the aspect ratio of PET shreds could be doubled i.e. @1mm wide & 45mm long.

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