An Investigation on the Strength Development of Concrete Reinforced with PET Bottles

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Abstract

This paper presents a method to strengthen concrete by adding percentages of recycled plastic (polyethylene). Almost 192 samples of concrete are prepared; the mechanical propertiesof concrete (compressive, splitting tensile and flexural strength) are investigated along a time interval of 7 to 28 days. Different proportions of bottle fibres (0.5%, 0.75%, 1%, 1.25%, 1,5%) by weight of cement has been taken into account. 2 cm and 8 cm strips are used for the study. It is found that when the percentage of PET bottle fibresare increased, the workability of concrete decreases. Also compressive strength decreases with increase in percentage addition. Tensile strength is found to be increasing with the percentage and length of fibre added. Flexural strength is found to be decreasing with percentage added.

Keywords

PET fibres, Workability, Tensile strength.

I. INTRODUCTION

Concrete is the most frequently used material in construction world [1].It is the basic building block in construction. Even though concrete is widely used in construction sometimes it fails to show its full properties. This failure is marked throughout the entire process of construction so admixtures are added. Admixtures are any substances other than water added into concrete to enhance its properties like workability, strength, durability etc. Several waste materials,like recycled plastics, glass, cellulose, tyre cords and wood, exhibit extreme versatility, light-weight, durability, resistance to chemicals, excellent thermal and electrical insulation properties [2].

PET (polyethylene terephthalate),or the obsolete PET-P or PETP, is a thermoplastic polymer resin of the polyester. PET does not contain polyethylene. The monomer Ethylene Terephthalate is polymerized with repeating $C_{10}H_8O_4$ units form PET. PET bottles are characterized by high strength, low weight, low permeability of gases (mainly CO_2) as well as the good light transmittance, aesthetic appearance and smooth surface [3]. The high use of plastic bottles also leads to increased waste and endangers our nature. Concrete reinforcement with fibers is a low-cost strengthening technique which enables to enhance tensile strength, structural ductility and thermo-electrical insulation of the concrete matrix. Converting these PET bottles into admixture increases concrete properties as well as disposes the plastic bottles. That is why utilization of PET bottles as admixture has become an attractive alternative for disposal.

Now a days, concrete is the most extensively used construction material due to its long service life, low cost and high compressive strength but the main disadvantage is its low tensile strength. To improve tensile behavior of the concrete matrix generally fibers are used in it [4]. The fibers included in the matrix acts as micro crack arrester and prevents propagation of cracks under load [5].

In our study, we use PET bottle strips as admixture. Through this study, we analyse the effect of PET bottle strips on workability and strength characteristics viz., compressive strength, tensile strength and flexural strength of concrete. PET bottle strips are added in various proportions of 0.5%, 0.75%, 1%, 1.25%, and 1.5% by weight of cement for the analysis. The dimensions of the fibre strips used are 3mm x 2cm, 3mm x 8cm.

II. MATERIALS

A. Cement (OPC)

Cement forms an important ingredient of concrete and a binding medium for specific ingredients with its origin from natural raw material including its mixing with industrial wastes. Cement is available in various forms and chemical compositions. This study deals with the use of 53 grade Ordinary Portland Cement (OPC). Physical properties of cement is shown in Table I.

Table I:Physical properties of cement

Property	Value
Specific gravity	3.05
Fineness	2%
Consistency	26%
Initial setting time	34 min

B. Fine Aggregate

The material smaller than 4.75mm size is called fine aggregate. Natural sands and M sand are generally used as fine aggregate. Specific gravity of sample is 2.650**.** For the study, we use Manufactured sand which belongs to Zone 1. Physical properties of fine aggregate is shown in Table II. The grading of aggregate conformed to the requirement as per Indian Standard Code [6].

TableII: Physical properties of Fine aggregate

Property	Value
Specific Gravity	2.650
Bulk Density	1.75
Void ratios	0.505
Porosity	33.59%
Sieve Analysis	Zone 1

C.Coarse Aggregate

The material retained on 4.75mm sieve is termed as coarse aggregate. Crushed stone and natural gravel are the common material used as coarse aggregate for concrete. Specific gravity of sample used in this study is found to be 2.810. Physical properties of coarse aggregate is given in Table III.

Table III: Physical properties of coarse aggregate

Property	Value
Specific gravity	2.810
Bulk density	1.710
Void ratio	0.47
Porosity	31.7%

D. PET fibres

PET bottles are characterized by high strength, low weight, low permeability of gases (mainly CO_2) as well as the good light transmittance aesthetic appearance and smooth surface. PET fibres allow a better control of the plastic shrinkage cracking.

III. DESIGN OF MIX PROPORTIONS

A. Mix Design

Mix design was done as per Indian Standard method[7] and the design mix obtained is 1:1.466:2.332. This mix was used to prepare the test samples. The design mix proportion is obtained as inTable IV.

Table IV: Design mix proportion

	W (L/m^3)	C (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)
Quantity	197	469	688	1094
Ratio	0.42	1	1.466	2.332

W=Water, C=cement, F.A.=Fine Aggregate, C.A.= Coarse Aggregate.

IV. EXPERIMENTAL SETUP

A. Compaction Factor Test

Compaction factor test is used to determine the workability of fresh concrete [8].The apparatus used is compacting factor apparatus.

$$\text{Compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

B. Slump Test

Workability of concrete is obtained from slump test [8].Slump cone and tamping rod are the apparatus used for the above test.

Slump obtained = Height of subsidence

C. Compressive Strength Test

The compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. Compression testing machine is used for testing the compressive strength of cube. The size of cube specimen is 150mm x 150mm x 150mm.

$$\text{Compression Strength} = \frac{\text{Failure load (N)}}{\text{Sectional area(mm}^2)}$$

D. Split Tensile Strength Test

The size of the cylinder specimen is 150mm (D) × 300mm (L). The split tensile strength of cylinders was found by UTM (universal testing machine), where P is the load at failure.

$$\text{Split Tensile Strength} = \frac{2P}{\pi DL}$$

E. Flexural Strength Test

The flexural test measures the force required to bend a beam under mid-point loading conditions. The flexural strength test has been done on beams of size 100mm x 100mm x 500mm by Universal Testing Machine.

Flexural strength= $\frac{3PL}{2bd^2}$

V. RESULTS AND DISCUSSIONS

The result of compaction factor test and slump test is shown in Table Vand Table VI. Variation of compaction factor with percentage variation is shown in figure 1 and variation of slump with fibre percentage variation is shown in figure 2.

Table V: Compaction factor

Percentage variation	2cm	8cm	Combination of 2cm and 8cm
0	0.97	0.97	0.97
0.5	0.95	0.94	0.94
0.75	0.95	0.92	0.91
1	0.92	0.88	0.9
1.25	0.88	0.86	0.89
1.5	0.86	0.85	0.89

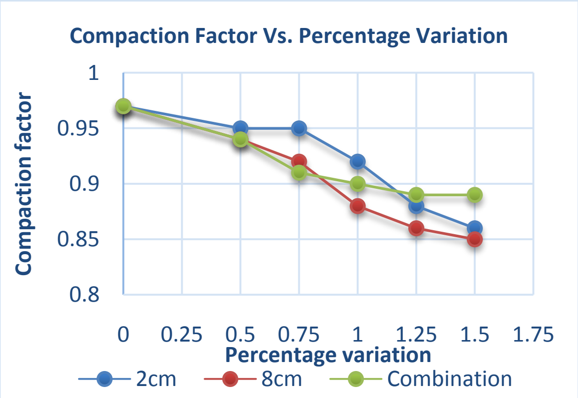

Figure 1: Variation of compaction factor with fibre content

Table VI: Slump value

Percentage variation	2cm	8cm	Combination of 2cm and 8cm
0	130	130	130
0.5	100	90	90
0.75	90	80	70
1	50	40	60
1.25	40	30	40
1.5	10	5	30

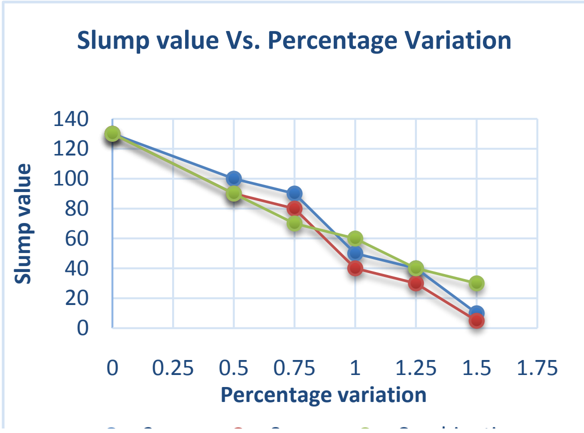

Figure 2: Variation of slump

Compaction factor and slump value decreases with addition of fibre.Workability is slightly more for shorter strips comparing to longer strips.

Results of compressive strength, tensile strength and flexural strength are shown in Table VII, Table VIII and Table IX respectively. The corresponding variations are shown in figure 3, figure 4 and figure 5.

Table VII: Compressive strength (N/mm^2)

Percentage variation	2cm	8cm	Combination of 2cm and 8cm
0	28.89	28.89	28.89
0.5	30.23	27.11	27.11
0.75	31.55	24	26.89
1	29.33	23.11	26.22
1.25	27.5	21.7	26
1.5	28.44	21.7	25.34

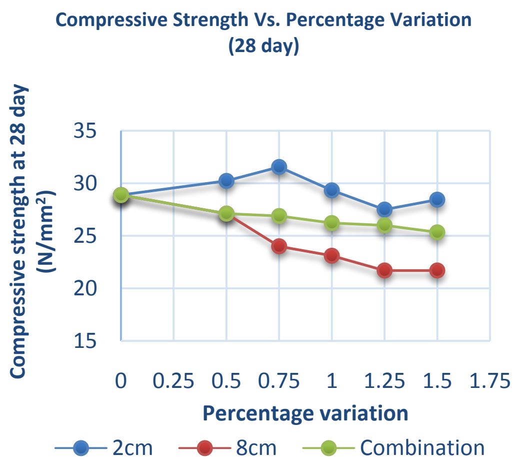

Figure 3: Variation of compressive strength with fibre content

Table VIII: Tensile strength (N/mm²)

Percentage variation	2cm	8cm	Combination of 2cm and 8cm
0	2.33	2.33	2.33
0.5	2.88	3.04	2.92
0.75	3.58	3.68	3.72
1	3.63	3.68	3.65
1.25	3.78	3.74	3.81
1.5	3.93	3.88	3.88

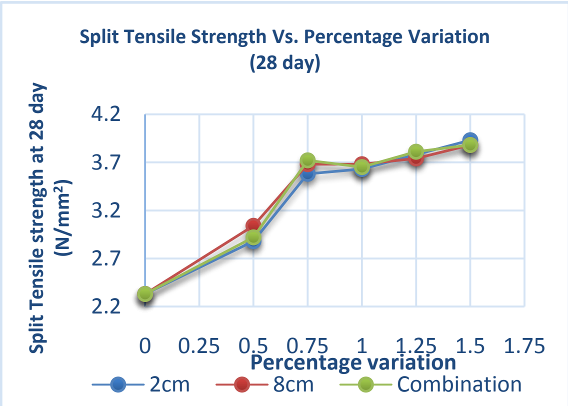

Figure 4: Variation of tensile strength

As percentage variation increases compressive strength decreases. As the length of the fibre increases compressive strength decreases. However, as the percentage variation increases tensile strength increases.

Table IX: Flexural strength (N/mm²)

Percentage variation	2cm	8cm	Combination of 2cm and 8cm
0	3.9	3.9	3.9
0.5	4.4	4.92	4.62
0.75	5.28	5.64	5.16
1	5.23	5.62	5.18
1.25	5.19	5.38	5.14
1.5	5.12	5.26	5.16

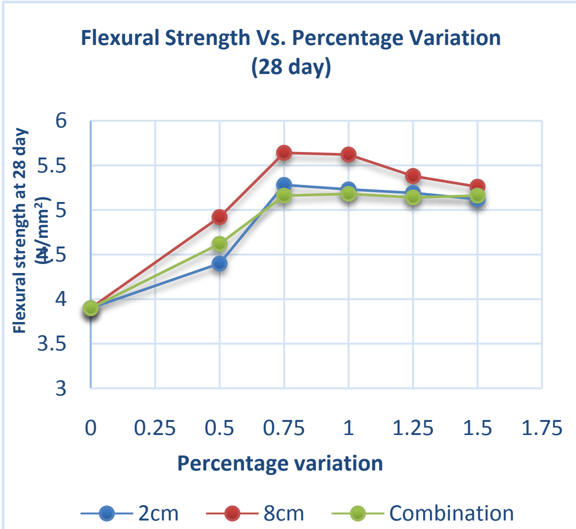

Figure 5: Variation of flexural strength

Flexural strength increases up to 0.75% and then decreases. As length of the fibre increases flexural strength increases.

VI.CONCLUSION

It is found to be convenient and economical to use PET Bottle fibres as an admixture in concrete. Addition of PET Bottle fibres in concrete decreases workability of fresh concrete.

- Workability decreases as percentage variation increases. The mix becomes stiffer with increase in fibre content
- Workability is slightly more for shorter strips comparing to longer strips.
- Compressive strength and flexural strength decreases with increase in fibre content.
- Tensile strength increases with increase in fibre content, which helps the concrete to prevent propagation of cracks.

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