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EFFECT OF WASTE (PET) BOTTLE FIBERS ON THE PROPERTIES OF CONCRETE

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ABSTRACT

In this study, the effectiveness of waste PolyEthylene Terephthalate (PET) fibers in improving the properties of concretewas investigated. Recycling ofwaste PET bottles is a daunting task in developing countries due to inadequate recycling facilities. The addition of PET fibers in concrete has the potential of resisting the growth of minor internal cracks in the concrete, by preventing the crack width from widening under an applied load. The fibers were obtained by shredding the waste PET bottles into microfibers of 50 mm length and 5mm width, the fibers were then added to the concrete mix in fiber volume fractions of 0.5%, 1.0%, 1.5%, and 2.0%. The properties of the fresh concrete mix were measured using a slump test to evaluate the concrete workability. The hardened concrete properties were determined using a compressive strength test to determine the concrete strength at 7 and 28 days. The results of slump test showedthat the use of PET fibers in concrete mixtures slightly reduce the concrete workability. The addition of PET fibers to concrete increases the compressive strength of concrete at lower fiber volume contentand reduces the compressive strength of concrete at higher fiber volume content.The highest compressive strength of concrete was at 1.0% fiber volume addition, with a 15% increase in compressive strength at 28 days than the plain concrete. The study concludes that the addition of waste PET fibers to concrete serves as a means of utilizing the waste generated by PET bottles to increase the strength of concrete.

KEYWORDS: *Concrete, PET Fiber, Fiber Reinforced Concrete, Compressive Strength*

INTRODUCTION

Concrete is the most common material used in the construction of buildings, bridges, dams, etc. all over the world both in developed and developing countries. This is due to the ease, availability, and tendency of producing concrete in any desired shape, making it an important material in the construction of structures.

PolyEthylene Terephthalate (PET)bottles are commonly used as a medium of packaging liquid products like water, carbonated soft drinks, beverages, household sauces etc. (Figure 1) and they constitute waste materials, which contribute to environmental pollution causing considerable damage to the environment. It is imperative to find a sustainable and innovative way of utilizing waste plastic PET bottles in a way that it will not endanger the environment.

Concrete is known to have high compressive strength, low tensile strength, low impact strength, limited ductility, little resistance to cracking and it is very brittle. Microcracks in concrete occur during the hardening of concrete. The crack width increase and propagate as a result of tensile stresses due to load application, making the concrete to be susceptible to brittle failure. When dispersed micro cracks join each other to form one major crack, brittle failure is bound to occur. Brittle failure affects the structural integrity of concrete structures and may lead to the collapse of structures.

Figure 1: Various Types of Household PET Bottles

There is a need for improvement of concrete properties due to some deficiencies in the properties of plain concrete, this has led to the need for further evaluation and development of efficient alternative materials, which can improve the properties of concrete in areas where conventional concrete exhibit flaws. One such development is the application of fiber reinforced concrete (FRC), in which fiber materials are integrated to conventional concrete in other to improve the concrete properties.

Waste plastic (PET) bottle fibers can be used as fiber material for fiber reinforced concrete (FRC). Waste plastic (PET) bottle fibers are flexible fibers that are readily available and cost-efficient. Plastic (PET) bottles which are majorly used as means of packaging liquid products constitute a major source of waste materialgeneration; this is because most consumers discard the PET bottlesafter one-time consumption of its liquid content. Recycling and reuse of the waste plastic PET bottles is a daunting task in undeveloped countries, due to inadequate recycling facilities.

It has been found that the addition of small closely spaced and uniformly distributed fibers to concrete would act as crack arrestorsandsubstantiallyimprovethetensilestrength,crackingresistance,impactstrength,wearandtearandfatigue resistance (Chandrashekar *et al*., 2010).Nibudey*et al* (2013) carried out experimentation on the Compressive Strength Waste Plastic (PET) Fiber Reinforced Concrete using 0% - 3% with 0.5% variation of the shredded fiber of 25mm x 2mmDimensions the optimum strength was observed at 1% fiber content. A similar study was carried out by Kandasamy R. and R. Murugesan (2011), Irwan*et al* (2013) and Prabhu*et al* (2014) and similar results were documented. Ramadevi and Manju (2012) in their study, waste PET bottles fibers were added aspartial replacement of fine aggregate in concretewith1%,2%,4%and6%PET bottle fibers. The optimum strength was observed at 2%replacementofthefineaggregatewith PET bottle fibers.In the present study, a reduced size of the shredded plastic PET bottles with uniformly graded fine aggregates was considered.

Concrete reinforced with Plastic PET bottles can improve concrete properties such as tensile strength, compressive strength etc. PET fibers in concrete have the potential of resisting the growth of minor internal cracks in the concrete, by preventing the crack width from widening under an applied load. The addition of PET fibers in concrete provides crack resistance and control to minor cracks originating internally from the concrete mix, eventually improving the overall properties of the concrete. Use of waste plastic (PET) bottle fibers has many advantages because the waste material is readily available, low in cost and it can solve the problem of disposal of plastic (PET) bottles up to some extent.

MATERIALS AND METHODS

PET Fibers: The PET fibers were obtained by manually cutting and shredding waste PET bottles collected locally. The PET bottles were cut into pieces of equal dimensions of 50mm x 10mm.

Cement: Ordinary Portland cement grade 42.5 was used in mixing the concrete for testing, the properties of the cement are in accordance with the standards of (BS 12:1996).

Fine Aggregates: Natural river sand was used as fine aggregate. The properties of fine aggregates were determined by sampling and testing in accordance with the requirements of (BS 812: Part 103:1985). The particle size distribution for the fine aggregates used is as presented in Table 1.

Table 1: Particle Size Distribution for Fine Aggregate

Sieve Size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative PercentageRetained (%)	Cum. Percentage Passing (%)
20	0.00	0.00	0.00	100.00
8	4.80	1.22	1.22	98.78
4	26.20	6.66	7.88	92.12
2	43.40	11.04	18.92	81.08
1	63.70	16.20	35.12	64.88
0.425	153.90	39.14	74.26	25.74
0.25	53.80	13.68	87.95	12.05
0.125	38.80	9.87	97.81	2.19
0.075	8.60	2.19	100.00	0.00
<0.075	0.00	0.00	100.00	0.00
	393.20			

Coarse Aggregates: Crushed granite obtained from local quarries was used as coarse aggregate. The maximum size of coarse aggregate used was 20 mm. The properties of the coarse aggregates were determined by sampling and testing in accordance with the requirements of (BS 812: Part 103:1985). The particle size distribution for the coarse aggregates used is as presented in Table 2.

Table 2: Particle Size Distribution for Coarse Aggregate

Sieve Size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative PercentageRetained (%)	Cum. Percentage Passing (%)
37.5	0.00	0.0	0.0	100
20.00	329.76	7.2	7.2	92.8
14.00	3059.44	66.8	74	26
10.00	1099.2	24	98	2
5.00	91.6	2	100	0

Water: Portable water free from impurities was used for mixing and curing of the concrete.

Concrete Mix Preparation

The concrete mixes were prepared in a proportion of1:2:4 with a W/C ratio of 0.65 which correspond to an M15 grade of concrete. Percentage variation of waste plastic PET fibers was integrated into the plain concrete in volume percentage of 0.5%, 1.0%, 1.5%, and 2.0%. In order to obtain the required workability and homogeneity of the concrete mix, concrete was mixed manually. Fine and coarse aggregates and cement were added and mixed before 1/3 of the required water was then added and mixed. Then, the shredded PET fibers and the remaining 2/3 of the water was added and mixed. The mixture was then discharged and cast. Different mixes were prepared by varying the amount of PET fiber added.

RESULTS AND DISCUSSIONS

Particle Size Distribution for the Fine Aggregates

The particle size distribution curve for the fine aggregates used are as presented in Figure 2

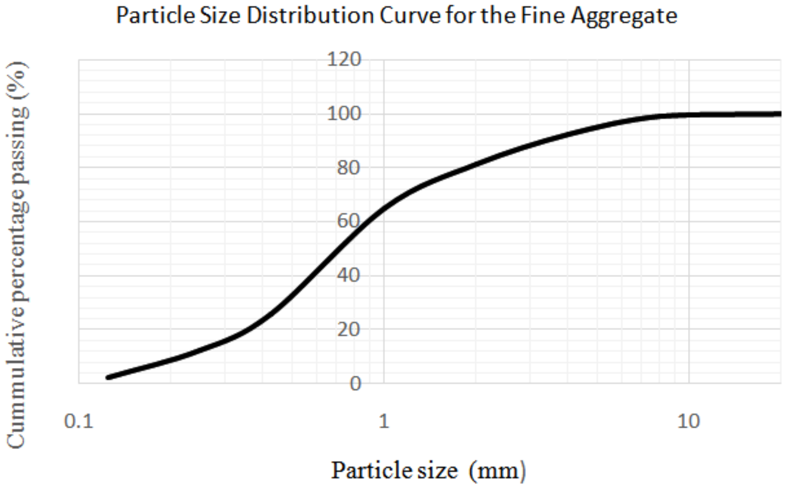

Figure 2: Particle Size Distribution Curve for the Fine Aggregates

Particle Size Distribution for the Coarse Aggregates

The particle size distribution curve for the coarse aggregates used are as presented in Figure 3

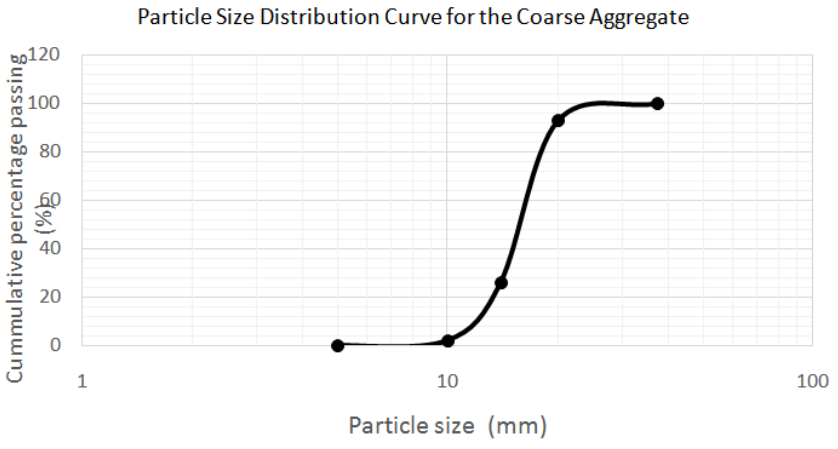

Figure 3: Particle Size Distribution Curve for the Coarse Aggregates

Slump Test Result

Slump test was used to measure workability of the mixtures. The properties of fresh concrete are as presented in Table 3 and Figure 4, the test was carried out accordance with BS 1881: Part 102: 1983 provisions.

The results showed that an increase in the addition of PET fibers to concrete significantly leads to a decrease in the slump compared with the control mixture without PET fibers. This decrease is mainly due to the presence of the long strips PET fibers used in the blend, this reduction in slump values may be attributed to the PET fibers not blending completely with other concrete constituents in the mix.

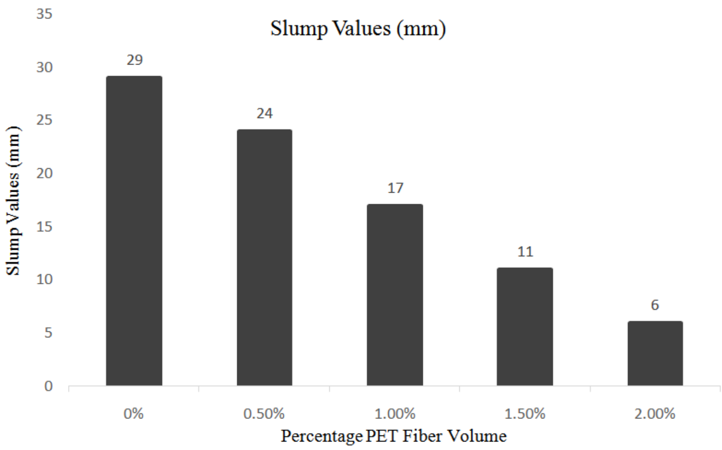

Figure 4: Slump Values of Concrete Mixtures

Table 3: Slump Values of Mixtures

PET Fibers Added (%)	W/C Ratio (kg/m^3)	Cement (kg/m^3)	PET Fiber (kg/m^3)	Water (kg/m^3)	Fine agg. (kg/m^3)	Coarse agg. (kg/m^3)	Slump Values (mm)
0	0.65	19.20	_	12.48	38.40	76.80	29.00
0.5	0.65	19.20	0.734	12.48	38.40	76.80	24.00
1.0	0.65	19.20	1.468	12.48	38.40	76.80	17.00
1.5	0.65	19.20	2.202	12.48	38.40	76.80	11.00
2.0	0.65	19.20	2.936	12.48	38.40	76.80	6.00

Compressive Strength Test

The compressive strength test results of the concrete cubes as tested after 7 and 28 days of curing in waterfor concrete with 0%, 0.5%, 1.0%, 1.5% and 2.0% are shown in Tables 4, 5, 6, 7 and 8 respectively.

At 7 days curing age, the concrete cubes without PET fibers gives the compressive strength of 10.00N/mm^2, the concrete cubes with addition of PET fibers of 0.5%, 1.0%, 1.5% and 2.0% gave the compressive strengths values of 11.00N/mm^2, 13.00N/mm^2, 8.00N/mm^2 and 7.00N/mm^2 respectively. The compressive strength of PET fibers addition of 0.5% and 1.0% are greater than the compressive strength value of control concrete cube, while the compressive strength of PET fibers addition of 1.5% and 2.0% are lesser than the compressive strength value of control concrete cube.

The compressive strength of the concrete cubes for each sample considerably increased at 28 days curing age with the concrete cubes with 0% PET fibers have the compressive strength of 13.50N/mm^2. The concrete cubes with addition of PET fibers of 0.5%, 1.0%, 1.5% and 2.0% have compressive strength values of 14.00N/mm^2, 15.50 N/mm^2, 10.00N/mm^2 and 9.50N/mm^2 respectively.

It was observed that the addition of lower percentage (0.5% and 1.0%) of PET fibers have an increase in compressive strength compared to the reference concrete mix without any PET fibers as shown in Figure 5. Additions of the higher percentage (1.5% and 2.0%) of PET fibers have a decrease in compressive strength compared to the reference concrete mix without any PET fibers.

Table 4: Compressive Strength Test Result of Concrete with 0% Fiber Volume

Curing Period (Day)	Crushing Load (kN)				Gross Area (mm^2)	Compressive Strength (N/mm^2)
	1st Trial	2nd Trial	3rd Trial	Average		
7	225	220	225	225	22500	10.0
28	290	310	295	298	22500	13.2

Table 5: Compressive Strength Test Result of Concrete with 0.5% Fiber Volume

Curing Period (Day)	Crushing Load (kN)				Gross Area (mm^2)	Compressive Strength (N/mm^2)
	1st trial	2nd Trial	3rd Trial	Average		
7	255	245	255	250	22500	11.0
28	320	310	320	320	22500	14.5

Table 6: Compressive Strength Test Result of Concrete with 1.0% Fiber Volume

Curing Period (Day)	Crushing Load (kN)				Gross Area (mm^2)	Compressive Strength (N/mm^2)
	1st Trial	2nd Trial	3rd Trial	Average		
7	290	280	295	285	22500	13.0
28	355	350	350	352	22500	15.5

Table7: Compressive Strength Test Result of Concrete with 1.5% Fiber Volume

Curing Period (Day)	Crushing Load (kN)				Gross Area (mm^2)	Compressive Strength (N/mm^2)
	1st Trial	2nd Trial	3rd Trial	Average		
7	180	180	185	182	22500	8.1
28	235	235	230	233	22500	10.4

Table 8: Compressive Strength Test Result of Concrete with 2.0% Fiber Volume

Curing Period (Day)	Crushing Load (kN)				Gross Area (mm^2)	Compressive Strength (N/mm^2)
	1st Trial	2nd Trial	3rd Trial	Average		
7	150	165	165	160	22500	7.1
28	205	210	215	210	22500	9.3

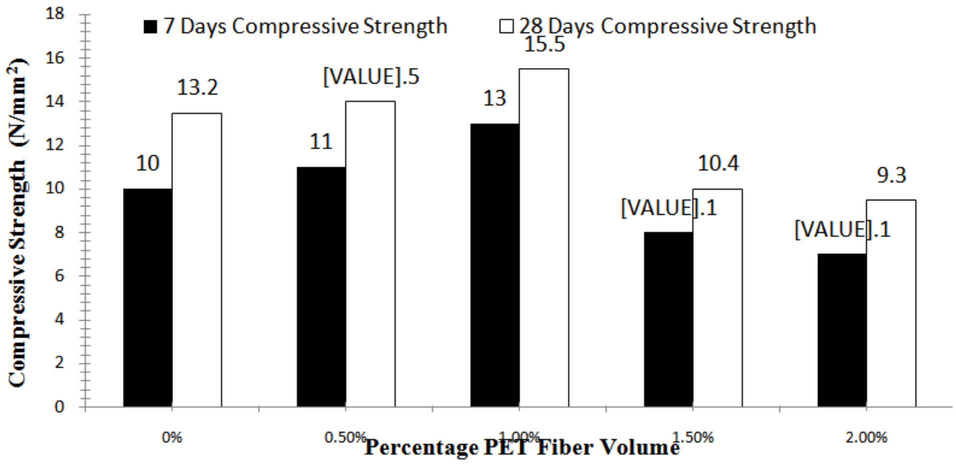

Figure 5: Compressive Strength Result of Concrete Cubes at Age 7 and 28 Days

CONCLUSIONS

Based on the results of the study, the following conclusions were drawn:

- The workability of concrete decreases with increasing PET fiber content.
- The admissible value ofPET fibers addition in improving the compressive strength of concrete ranges from 0.5% to 1.0% PET fiber volume content.
- Increasing PET fibers content more than 1.0% adversely affects the compressive strength. There significant reduction in the strength up to 26%occurred at high PET content of 1.5%. Further reduction in the strength up to 30% was observed when PET waste increased to 2.0%.
- There is a 15% increase in the compressive strength of 1.0% fiber content volume. The optimum percentage of (PET) bottle fibers that will be most effective in improving the properties of concrete is at 1.0%.
- Based on the results obtained in the present work it showed that the addition of waste PET fibers in concrete increases the compressive strength of the concrete, making it a promising technique for developing sustainable materials that can be applied in the civil construction industry.

RECOMMENDATIONS

From the findings of this study, the following are recommended:

- Integrating PET fibers into concrete can increase the concrete strength and can be used when high strength concrete is needed.
- Addition of waste PET fibers with concrete will be suitable in construction where microcracks are not desired in concrete.
- The use of PET fibers in concrete is an eco-friendly way of disposing of the enormous plastic PET waste generated by consumers.

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