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The Mechanical Properties of PET Fiber Reinforced Concrete From Recycled Bottle Wastes

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Abstract. This research is carried out to investigate the performance of concrete containing Polyethylene Terephthalate (PET) bottle waste as fiber. PET bottle waste was chosen because it is being thrown after single use and cause environmental problem. One way to recycle wasted PET bottles is grinded into irregular fiber. Then, it was incorporate with the concrete and test the performance of the concrete. The study was conducted using cylindrical mold of concrete to investigate the performance of the concrete in term of mechanical properties. A total of four batches of concrete were produced namely, normal concrete and concrete containing PET fiber of 0.5%, 1.0% and 1.5% fraction volume. In this research, the mechanical properties that were measured are compressive strength, splitting tensile strength and modulus of elasticity (MOE) following British Standard method. The results revealed that the presence of PET fiber in concrete will increase the concrete performance. Nevertheless, the content of PET fiber was specified in a specific limit to avoid effect of concrete strength.

Introduction

Plastics consumption now days have become an integral part of our lives. The amounts of plastics consumed annually have been increasing steadily. There are several factors that contribute to the rapidly growth of plastics consumption such as low density, fabrication capabilities, long life, lightweight, and low cost of production [1]. Plastic has been used widely in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, land/soil conservation, water desalination, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses. Large applications of plastics in all part of daily activities increase the volume of plastic waste. Table 1 shows the details about the amount of plastic consumption and plastic waste data in Malaysia in 2007 [2].

Table 1 : Consumption rate for different types of plastic resin per day of the respondent companies based on Malaysian Plastic Manufacturers Association (MPMA) [2]

Plastic resin	kg / day
Polyethylene Terephthalate (PET)	4588
Polypropylene (PP)	12827
Polystyrene (PS)	9413
Polycarbonate	1825
Acrylonitrile butadiene styrene (ABS)	13218
Others	4966

From the Table 1, it is reported that the total amount of solid resin consume per day is 46.8 tons. From the data, it shows that the consumption of ABS represent at 28% followed by PP 27%, PS 20%, others resin 11%, PET 10%, and PC 4%. Regarding to the consumption of materials

according to Table 2, the electrical and electronics sectors lead at 39%, followed by automotive 26%, domestic 19%, packaging 10%, building and construction and agricultural sectors, each contributing 3% [2]. According to the report from the Malaysian Plastic Industry [3], the increase of plastic consumption from 2010 to 2011 is 26.1%. A study done by Agamuthu [4] shows that the plastic component generate in Municipal Solid Waste (MSW) from Kuala Lumpur is 24% by weight whereas the national mean is about 15%. Therefore, it can be concluded that in Malaysia, the consumption of plastic is between ten to 15% in 2005 [3] [4].

PET widely known use in food and beverage packaging product and most of them will be discarded to landfill. The problem further complicated since plastic waste is undegradable and may cause environmental disturbance. Treatment method through incineration will provide toxic gas like dioxin that could be dangerous to human health. One of the potential means to the problem is to recycle the PET in construction industry. Various studies by Kim [5], Fraternalli [6], Foti [7], and Ochi [8] had studied the use of PET as fiber in concrete as stated in Table 3. Study carried out by Fraternalli [6] showed that the additional of PET fiber decrease the thermal conductivity, while increases the compressive and first crack strength, and also ultimate ductility [6]. Ochi [8] also proved that additional of PET fiber results of increase compressive strength. Meanwhile, in the studies done by Kim [5] and Foti [7], the different results on the compressive strength were shown. Both showed that the PET fiber added decrease the compressive strength by almost nine percents of its normal strength [5] [7]. The properties on ductility remained the same as the added PET fiber in concrete increases its strength. Based on the previous researches, it is clearly showed contradiction of result. Therefore, a study on material properties should be carried out. The shape of PET fiber in irregular shape has yet to be tested in fiber reinforced concrete. Therefore, the straight grinded recycled PET bottle wastes that were used are in inrregular shape with three different volume fractions as fiber in concrete as to figure out its mechanical properties.

Table 2 : Consumption (in %) of plastics according to industrial sectors by MPMA [2]

Sectors	Plastic consumption [%]
Domestic	19
Agriculture	3
Electrical and electronics	39
Automotive	26
Packaging	10
Building and construction	3

Table 3 : Summary of previous research

Research	Volume fraction of PET fiber [%]	Shape of PET fiber	Water-cement ratio	Compressive strength
Kim [5]	0.50, 0.75, 1.00	Strip	0.41	Decrease
Fraternalli [6]	1.00		0.53	Increase
Foti [7]	0.26	Strip & circular	0.70	Decrease
Ochi [8]	0.50, 1.00, 1.50	Monofilament	0.55, 0.60, 0.65	Increase

Experimental

The cement used in this research was ordinary Portland cement and the mix proportions are given in Table 4. Straight PET fiber were used from recycled bottle wastes. The PET fiber were grinded using granulator machine and produced fiber in irregular shape. The grinded PET fiber passed sieve 6 to 10 mm were used. In this research, four different fiber volume fraction were studied; 0%, 0.5%, 1.0%, and 1.5% [8]. Cylinder mold 300 mm (height) and 150 mm (diameter) were used in this research followed by the BS 1881 – 110: (1983). The mechanical properties of the PET FRC

studied are compressive strength, splitting tensile strength, and MOE. All parameter test setup were followed by BS 1881 – 116, 117 & 121. Samples were prepared for three different duration; seven, 14, and 28 days.

Table 4 : Mix proportion

Specimens	W/C ratio	Unit weight [kg/m³]				Fiber volume fraction [%]	Density of PET [kg/m^3]
		C*	FA*	CA*	W*		
NC*	0.65	290	900	982	185	0	0
PET FRC 0.5						0.5	0.9
PET FRC 1.0						1.0	1.8
PET FRC 1.5						1.5	2.7

**NC = Normal concrete, C = Cement, FA = Fine aggregate, CA = Coarse aggregate, W = water*

Result and Analysis

Compressive strength and modulus of elasticity (MOE). Table 5 shows the outcomes of compression test over normal concrete; 0% and PET FRC respectively for 0.5%, 1.0% and 1.5% fiber volume fractions. The compressive strength for 0.5% PET FRC specimens increase by 9.1% compared to normal concrete for 28 days whereas the compressive strength of PET FRC specimens at 1.0% and 1.5% decrease about 0.45 and 17.65%. The results reveal that only a small amount of fiber increase the concrete strength. It shows a good bonding between aggregate and binder increasing in increasing of fiber content resulted decreasing in concrete strength. Study done by Kim [5] using 0.5 to 1.0% of PET volume fraction also found that the compressive strength of PET FRC decreases in the range 1 to 10%.

Table 5 also shows the result for MOE test over normal concrete; 0% and PET FRC, respectively for 0.5%, 1.0% and 1.5% fiber volume fractions. The MOE for 0.5% PET FRC specimens increase by 8.3% compared to normal concrete whereas the MOE for 1.0% and 1.5% PET FRC decrease by 8.3 and 20.8%. The trend of this study agrees with previous study where the MOE decrease with the increasing of PET fiber content [5].

Table 5 : Result of compressive strength and modulus of elasticity (MOE) test

PET content [%]	Compressive strength [Mpa]			MOE [Gpa]
	7 days	14 days	28 days	
0	16.43	19.73	22.00	24
0.5	15.70	16.45	24.00	26
1.0	16.06	18.79	21.90	22
1.5	14.44	16.29	20.93	19

Table 6: Result of splitting tensile test

PET content [%]	Splitting tensile strength [Mpa]		
	7 days	14 days	28 days
0	1.98	2.34	2.97
0.5	2.10	2.87	3.24
1.0	2.15	2.95	3.43
1.5	2.27	3.08	3.67

Splitting tensile strength. From Table 6, it shows that PET fiber can enhance the tensile splitting strength of concrete cylinder. Table 6 shows that strength of concrete containing PET fiber at 0.5% to 1.5% increase compare to the normal concrete at all ages. At 28 days, the increment of splitting tensile strength of concrete contains PET fiber at 0.5%, 1.0% and 1.5% increase by 9.1%, 15.5% and 23.6% respectively. From the previous research done by Foti [7] and Ochi [8], it stated that the bending strength of concrete increase when the PET fiber was added. In Foti [7], the result shows that the bending strength increase by 3.9% compared to control when PET in strip shape fiber was added. The same trend for bending strength was shown in Ochi [8] where the PET fiber concrete increase by 7.8% to 25.7% compared to the control. As the role of fiber added in concrete is to bridging across the crack and improve the bonding of its element in concrete [9], therefore we can conclude that the PET fiber added will improve the bending strength as well as the splitting tensile strength.

Conclusion

This paper presented the results of mechanical properties of PET FRC which are compressive strength, splitting tensile strength, and modulus of elasticity. Comparison with normal concrete is also presented. The compressive strength, tensile splitting strength and modulus of elasticity value have increase with 0.5% PET fiber content in the concrete mix in compare to normal concrete. Concrete containing 1% and 1.5% PET fiber is lower than the normal concrete in compressive and splitiing tensile strength and elastic modulus. Therefore it is concluded that, the fiber content will affect the strength of the concrete. The strong fibers are desired and used to improve concrete strength and ductility, but may lead to loss in segregation, increased porosity, and overall reduction in concrete strength. In addition, high dosages of fiber will cause workability problems because of their relatively surface area [10]. The addition of this essentially PET fiber is an option to construction industry. It is a better means of recycling waste plastic resulted to a sustainable environment.

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