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Research paper

Plastic Waste Contribution in Concrete Strength Improvement At Early and Long Curing Ages

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Abstract

In general, the concrete suffering of brittleness and weakness to resist the direct and tensile stresses. In Malaysia, millions of tons of the polyethylene terephthalate (PET) plastic waste accumulated from the single use of drinking water bottles, its accumulation creates threat on the civilian life and the environment. Inclusion of shredded PET waste in concrete may help mitigate the negative impact of plastic waste on the environment and further produce green/sustainable concrete and solve the weakness of tensile strength. In current research, 0.0 to 1.75% of coarse aggregate weight was replaced by PET waste to delve into the behavior of low velocity impact strength of concrete containing PET at early and long curing age. It was positive that some of the ratios helped to enhance the impact strength at age 28 days, where the number of blows increased to 80%, and at age 90 days, the number of blows increased up to 4 times compared with age 28 days. The results exhibited to the possibility of utilizing PET waste by low volumes to produce new concrete has good strength and contributes in reducing the plastic waste negative impact on the environment.

Keywords: *Friendly-environment; green concrete; impact resistance; plastic waste; polyethylene terephthalate.*

1. Introduction

The most significant industrial metal over the last century is plastics, and today, it has easily become a household item. Replacing or compensating for plastic and other materials are becoming more and more commonplace, judging from the increasing trend of plastic waste build-up. The existence of such waste would surely lead to negative environmental impact. It obstructs the drainage of water via the soil, which then pollutes the soil with diseases caused by mosquitoes and diseases coming from the flood water flow [1-2]. Currently, the world cities is producing about 1.3 billion tons of solid waste annually and this volume is expected to increase to 2.2 billion tons by the year 2025 [3].

Concrete has been the first choice for construction in many countries these days, causing the natural resources to vanish rapidly. Using non-recyclable plastic in concrete to address of the double issues of the shortage of raw material and safe disposal of leftover plastic to environment may well be worth experimenting [4]. The utilization of plastic waste in concrete reduced the density, it has been the central focus of a number of studies [5-9]. The concrete strength increased by the presence of low volume of plastic waste such as polyethylene terephthalate PET [10-13]. The presence of plastic in concrete with high volume may lower the impact resistance [14]. Utilizing different geometric forms of waste plastic fiber in concrete and tested at 28 days and at 90 days curing age helped increase the impact resistance between 1.5 to 3 times as compared to the normal concrete [15,16]. Test results reveal that the geometry of fibers has a marginal effect on the workability but significantly enhances the mechanical strength of the concrete [17]. The use of granules plastic with crumbs size not more than a few millimeters mostly had negative effect on the concrete's me

chemical properties [9,13,18,19]. The concrete suffering of the brittle phenomenon, when exposed to impact (shock) can crack easily. Thus, the exploitation of shredded plastic waste bottles (drinking water bottles) by low volume substitution ratios and rectangular shape of crumb will be studied, to reinforce the concrete and to confirm its ability to resist shock or at least slow down the failure resulting from those impacts at early and long curing ages.

2. Materials and methods

In this study, the ordinary Portland cement produced by Tasek Company is used. The coarse aggregate with maximum size 14mm and fine aggregate size 4.75 mm are used, the water/cement ratio 0.4 used for all mixes, and the water was stored in the laboratory tanks was used. The PET crumbs (Fig1) shredded from single use drinking water bottle size 1.2cm x 0.2cm and density 1100kg/m^3 are used as a partial substitution of the total volume mix with ratios P0.25%, P0.75%, P1.25% and P1.75%. Having prepared all the materials, the mix dry process was conducted to obtain the homogenous mixture and to guarantee that PET crumbs were distributed well through the mixture before adding the water and starting to mix it up. Two specimens with dimensions 65cm x 60 cm x 6cm for every ratio of PET were prepared and every age test including the control specimens to test low velocity impact at 28 and 90 days was conducted. The drop ball

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frame manufactured in Malaysia-Bangi used the low velocity impact test (Fig 2.a). By accounting for the number of blows which caused the first failure cracks and final failure cracks (Fig 2.b) we can get the energy of the concrete bearing of the impact resistance. According to ACI committee 544-89 [20] equation (1) is used to calculate the energy. Table 1 shows the mix design proportions.

$$Energy \quad (N.M) = g \times h \times bw \times nb \tag{1}$$

where g is the acceleration (9.8 m/sec^2), h denotes the distance between the highest point in the frame and the specimen's surface (2.4 m), bw represents the drop-ball weight (1.8 Kg), and nb refers to the number of blows.

Table 1: Mix design proportions

PET ratio %	Cement weight kg/m^3	Water weight kg/m^3	F. Agg weight kg/m^3	C. Agg weight kg/m^3	Plastic weight kg/m^3
P0.0	466	187	699	1072.00	0.0
P0.25	466	187	699	1069.25	2.75
P0.75	466	187	699	1063.75	8.25
P1.25	466	187	699	1058.25	13.75
P1.75	466	187	699	1052.75	19.25

Fig.1: Sample of shredded PET waste

3. Results and discussion

Tests were conducted in the specific ages on the specimens which are free of plastic (Control) and specimens containing plastics in all proportions. The results show that the presence of the PET crumbs has increased the ability of the specimens on resisting the impact blows, with the addition of plastic material contributing to the enhancement of concrete impact resistance [21]. Without a doubt, the concrete strength increases by the equally increasing curing age. However, the presence of plastic is enhanced to develop strength. At age 28 days , the number of blows for specimens P0.25%, P0.75%, P1.25% as shown in table 2 and figure 3 increased by 40%, 60% and 80% of blows for the first cracks and 28% , 28% and70% of blows for the final cracks compared with the control specimens, respectively, further increasing the calculated energy.

The increasing PET percentage caused a reduction in the number of blows where the ratio P1.75% gave a result similar to the control concrete specimens for first cracks and (-15%) for final cracks, respectively. At age 90 days, the curing age and presence of PET are enhanced to increase the impact failure resistance. As shown in table 3 and figure 4 the ratios P0.75% and P1.25%% contributed to the increasing number of blows until the first and final cracks were obtained by (22%, 7.7%) and (36%, 23%), respectively. Meanwhile, the increasing PET caused the decreasing number of blows to (-14%, -20%) for the first and final cracks, respectively.

The result of comparison between specimens at 28 days and 90 days was consistent with the number of blows increased to 4 times for the control concrete specimens at 90 days, and the increased blows of specimens containing PET at the same age reached 3.3 times compared with 28 days specimens especially for the ratio P1.25%. The good strength of PET crumbs, geometric form for PET crumbs and low volume contributed in improved the hardened concrete to resist the impact and delay cracks appearance. Also, it is found that the optimum ratio of PET at 28 and 90 days ages was P1.25%, and it can be concluded that the concrete contains low volume of plastic waste emphases the fact that PET is allowed to be used in some of structural parts such as the block masonry and road base pavement, shoulders road curbstones and interlock stones used for pedestrian roads.

(a) (b)

Fig. 2: a) Low velocity impact test Frame .b) crack form of Specimen installed in frame

Table 2: Number of blows and energy caused impact failure of concrete specimens at 28 days

PET ratio %	Number of blows for		Total energy (N.M)	
	First cracks	Final cracks	First cracks	Final cracks
P0.0	5	7	211.25	296.55
P0.25	7	9	296.55	381.0
P0.75	8	9	338.68	381.0
P1.25	9	12	381.0	508.0
P1.75	5	6	211.25	254.0

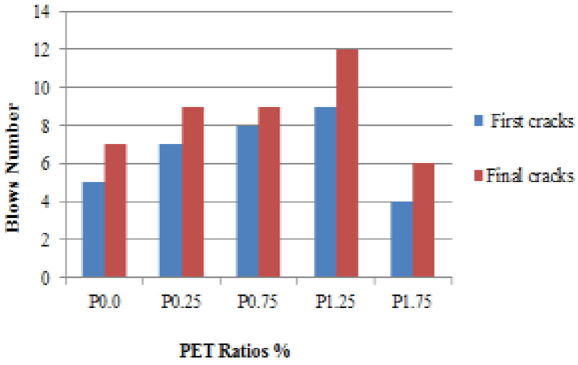

Fig.3: Effect of PET crumbs on the specimens' resistance of impact blows at curing age 28 days

Table 3: Number of blows and energy caused impact failure of concrete specimens at 90 days

PET ratio %	Number of blows for		Total energy (N.M)	
	First cracks	Final cracks	First cracks	Final cracks
P0.0	22	26	931.4	1100
P0.25	25	27	1058.4	1143.0
P0.75	27	28	1143.0	1185.4
P1.25	30	32	1270	1354.7
P1.75	30	30	1270	1270

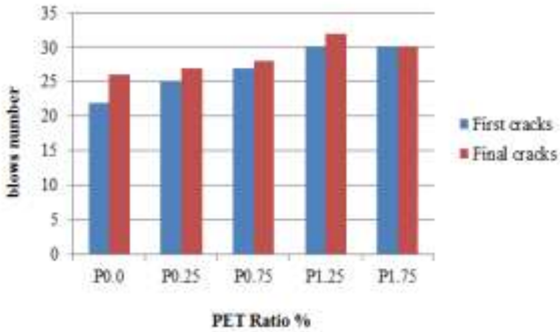

Fig.4: Effect of PET and curing age on the concrete specimens' impact blows at age 90 days

4. Conclusion

In this study, the utilization of low volume plastic waste in concrete to investigate the behavior of low velocity impact strength of concrete at early and long curing age was performed. The result shows that there is a big improvement in the low velocity impact strength (number of blows) through the presence of PET and the increasing curing age. The impact strength increased to 80% for the concrete containing PET with the ratio 1.25% at age 28 days, and it increased up to 4 times at age 90 days. The result further confirms that the use of low volume waste plastic as a partial replacement is a better way to produce acceptable, green and sustainable concrete with good impact strength.

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