Impact Resistance of Concrete with Partial Replacements of Coarse Aggregate by Plastic Waste of Vehicles

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Abstract

Plastic waste of vehicle causes serious health and environmental problems all over the world such as fire hazards and provides breeding grounds for rats, mice, vermin's and mosquitoes. Effects of partial replacements of coarse aggregate by plastic waste of vehicle on the performance of concrete under low velocity impact loading were investigated. Specimens were prepared for 5%, 10% and 15 % replacements by volume for coarse aggregate. For each case, six cubes of 100 mm ×100 mm × 100mm were subjected to 4.5 kg hammer from 457mm height. The number of blows of the hammer required to induce the first visible crack of the cubes were recorded. The results are presented in terms of impact energy required for the first visible crack. The plastic waste of vehicle increased the impact energy for the first crack with coarse aggregate replacement by plastic waste of vehicle until 10% replacements and then decreased, but is still higher than that of plain concrete.

Keywords: Plastic waste of vehicle; Cement concrete; Compressive strength; Impact energy.

1. Introduction

The plastic waste of vehicle is considered as one of the major environmental problems faced by every country due to their health hazards and difficulty for land filling [1]. Hence, there is an urgent need to identify alternative solutions to reuse the plastic waste of vehicle for other applications, and concrete has been identified to be one of the feasible options. On the other hand the concrete has limited properties such as low tensile strength, low ductility, and low energy absorption [2].

Substantial research was carried out on the application of polymers in concrete [3-15].

Choi et al. [3] investigated the effects of recycle polyethylene terephthalate (PET) plastic waste on properties of concrete. The plastic waste could reduce the weight by 2–6% of normal weight concrete. Rebeiz [4] study the strength properties of polymer concrete using an unsaturated polyester resin based on recycle PET plastic waste. He found that addition of waste tire in concrete enhanced the fracture properties, while both compressive and flexural strengths were decreased.

Batayeneh et al. [5] showed the deterioration of compressive strength with an increase in the proportion plastic content. For the plastic proportion of 20% of sand, the compressive strength was reduced up to 70% compared to that of normal concrete. Recently, Marzouk et al. [6] studied the use of consumed plastic bottle waste as sand substitution aggregate within composite materials for building applications and showed the effects of PET waste on the density and compressive strength of concrete. It was found that the density and compressive strength decreased when the PET aggregates exceeded 50% by volume of sand.

Al-Tayeb et al. [7] investigated the effect of partial replacements of sand and cement by waste rubber on the fracture characteristics of concrete. They found that addition of waste tire in concrete enhanced the fracture properties, while both compressive and flexural strengths were decreased. Al-Tayeb et al. [8] conducted tests to examine the performance of rubberized concrete with 5 %, 10 % and 20 % replacements by volume of sand by waste crumb rubber under static and impact load conditions. Their results showed that the addition of rubber improved the impact load behavior of concrete.

However, the mechanical properties of concrete with partial replacements of coarse aggregate by plastic waste of vehicles under impact load are yet to be explored. In this study, effects of partial replacements of coarse aggregate by plastic waste of vehicle on the performance of concrete under low velocity impact loading were investigated. Specimens were prepared for 5%, 10% and 15 % replacements by volume for coarse aggregate. For each case, six cubes of 100 mm ×100 mm × 100mm were subjected to 4.5 kg hammer from 457mm height. The number of blows of the hammer required to induce the first visible crack of the cubes were recorded.

2. Materials and methods

2.1. Materials

Concrete with 40MPa compressive strength was prepared as the controlled mix. The maximum coarse aggregate size was 20 mm, and the fine aggregate was natural sand. The composition of this concrete is presented in Table 1. The specific gravities of coarse and fine aggregates were 2.65and 2.67 respectively. Concrete mixes were prepared with replacements of coarse aggregate volume by 5, 10, and 20% with plastic waste of particle size 0.1–10 mm (Figure1). The compositions of plastic waste concrete are presented in Table 2. Figure 2 shows the images of plastic waste sample (relative density, 0.8) used in the present study.

For the compression test, cubic specimens of 100mm side were prepared with the aforementioned proportions of plastic waste. For split-tensile test, three cylinders of 160mm height and 100 mm diameter were used for each type. In the case of impact test, 6 cubic specimens of 100mm side were prepared for each type. All specimens were cured in water for 28 days in accordance with ASTM C 192/C192M-98 [16].

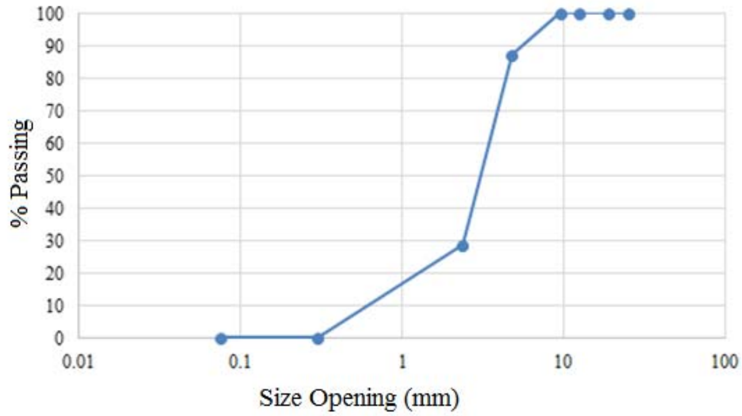

Fig. 1: Particle size distribution of plastic waste.

Figure 2: Images of the plastic waste.

Table 1: Mixture properties of normal concrete

Unit	Cement	Water	Fine aggregate	Coarse aggregate
Weight (kg)	454	195	670	1072
Volume(m^3)	144	195	251	405

Table 2: Mixture properties of powder rubber concrete

Unit	Rubber percent	Cement	Water	Fine aggregate	Coarse aggregate	Plastic waste
Weight (kg)	-	454	195	670	1018	16.2
Volume(m^3)	5%	144	195	251	384	20.3
Weight (kg)	-	454	195	670	965	32.4
Volume(m^3)	10%	144	195	251	364	40.5
Weight (kg)	-	454	195	670	911	48.6
Volume(m^3)	15%	144	195	251	344	60.8

2.3. Experimental set-up and procedure

Figure 3 shows the hammer of modified proctor which was used as drop weight machine to investigate the impact resistance of plastic concrete.

Fig. 3: Hammer of modified proctor.

A 4.5 kg impact drop hammer was raised to 457 mm above the specimen, and then released by following the procedure of Al-Tayeb et al. [8]. The hammer was dropped repeatedly and the number of blows required to produce the first visible crack in the specimen was recorded. The impact energy imparted by the hammer for 'n' number of bows (U) with a hammer velocity 'v' was calculated as follows:

$$\mathrm{U} = n * 1/2(\mathrm{m}v^2) \quad (1)$$

where,

$$v = \sqrt{2 * (0.9g) * h} \quad (2)$$

m = mass of the hammer, h = drop height, and g = gravitational acceleration. The factor, 0.9 accounts for effect of the air resistance and friction between the hammer and the guide rails [8].

3. Results and discussion

3.1 Compressive strength and splitting-tensile stress

As seen in Fig. 4, the average compressive stress of the plain concrete in 28 days is 43MPa. As the coarse aggregate is replaced by plastic waste, the compressive stress reduces by 29, 39 and 52% with 5, 10, and 15 % of volumes respectively

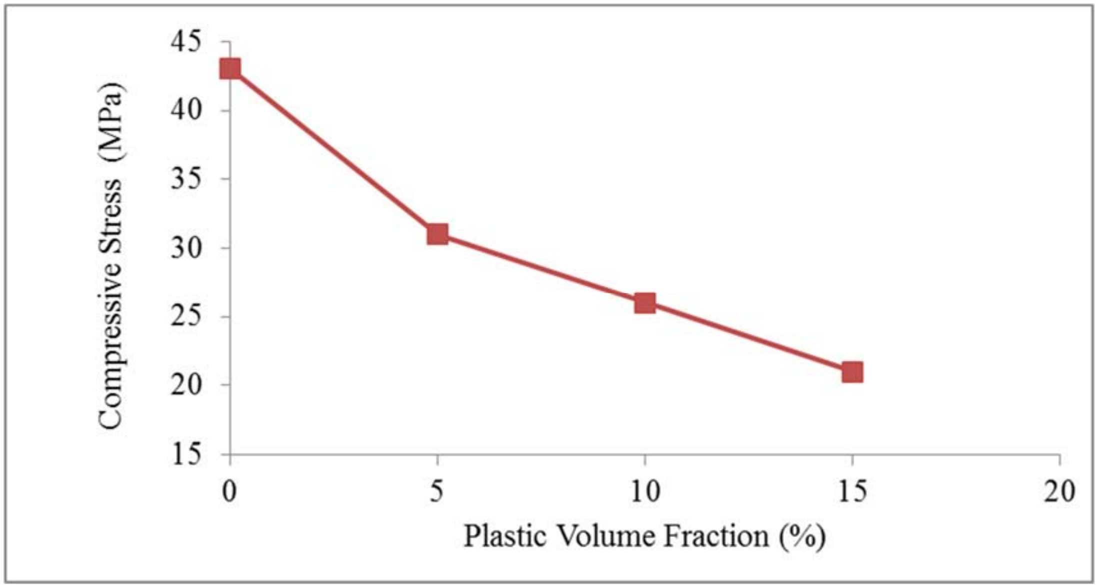

Fig. 4: Compressive stress against volume fraction of plastic waste.

Fig .5 shows the result of splitting-tensile test, which indicates that the plain concrete is yielded at 4.1MPa, while with the coarse aggregate replacement by plastic waste with 5, 10, and 15 % of volumes, the splitting-tensile stress reduces by 15, 29 and 41% respectively. In general, the above results indicate that partial replacements of coarse aggregate by plastic waste cause decrease in both compressive and tensile strengths as also observed by the previous workers [3-6]. Specifically, the coarse aggregate replacement by plastic waste causes more reduction in compressive strength than that in tensile strengths.

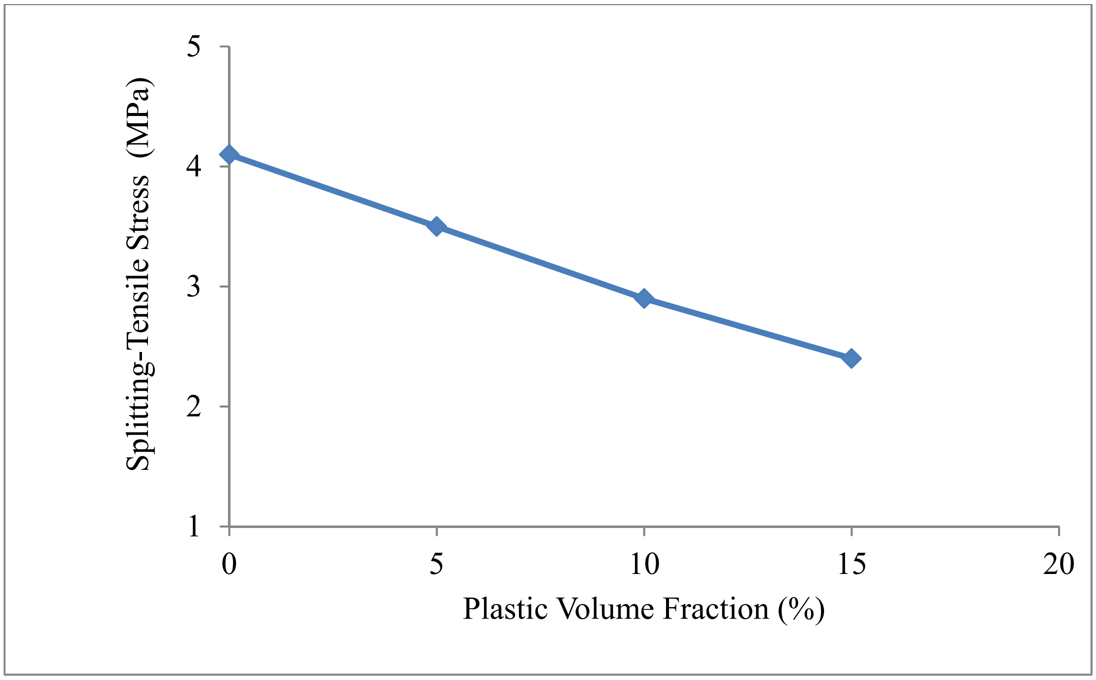

Fig. 5: Splitting tensile stress against volume fraction of plastic waste.

3.1 Impact test

The number impact blows required for producing the first visible crack for each type of concrete specimen are listed in Table 3, and the corresponding plot is shown in Fig. 6. Figs. 7 present the results in terms of first crack impact energy.

It can be deduced from the results that the first crack resistance increases by 13% and 30% with 5% and 10% replacements of coarse aggregate by plastic waste respectively; at 15% replacement, although a reduction is observed, it is still 4% higher than that of the plain concrete. The reduction in first crack resistance at 15% is attributed to the fact that, although the ductility and ability to absorb the impact energy are increased by the addition of plastic waste, the reduction of coarse aggregate content in the concrete causes significant reduction in the resistance of the mix.

Table 3: Impact test results for plain and plastic concrete.

Type of concrete	Rubber (%)	No. of blows of first crack	Average no. of blows	Impact energy (kN mm) First crack	Average impact energy (kN mm)
Plain	0	78	68	1653	1441
	0	71		1504	
	0	63		1335	
	0	61		1293	
	0	62		1314	
	0	73		1547	
Coarse aggregate replaced with plastic waste	5%	57	77	1208	1632
	5%	83		1759	
	5%	89		1886	
	5%	77		1632	
	5%	83		1759	
	5%	73		1547	
	10%	88	89	1865	1886
	10%	92		1949	
	10%	89		1886	
	10%	95		2013	
	10%	91		1928	
	10%	79		1674	
	15%	61	71	1293	1504
	15%	76		1610	
	15%	73		1547	
	15%	68		1441	
	15%	72		1526	
	15%	77		1632	

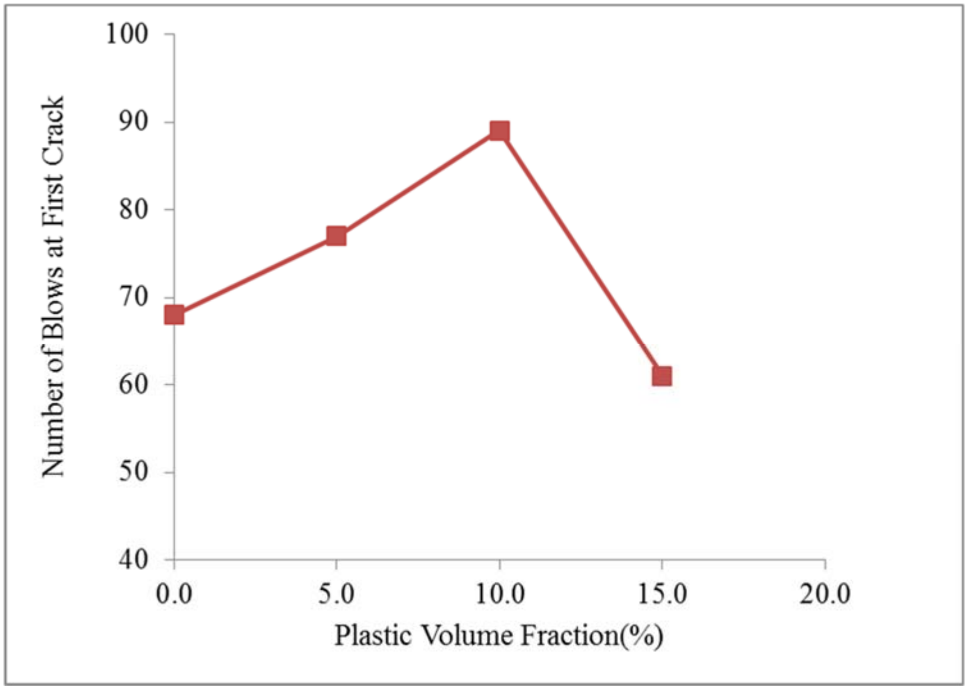

Fig. 6: First crack impact resistance against volume fraction of plastic.

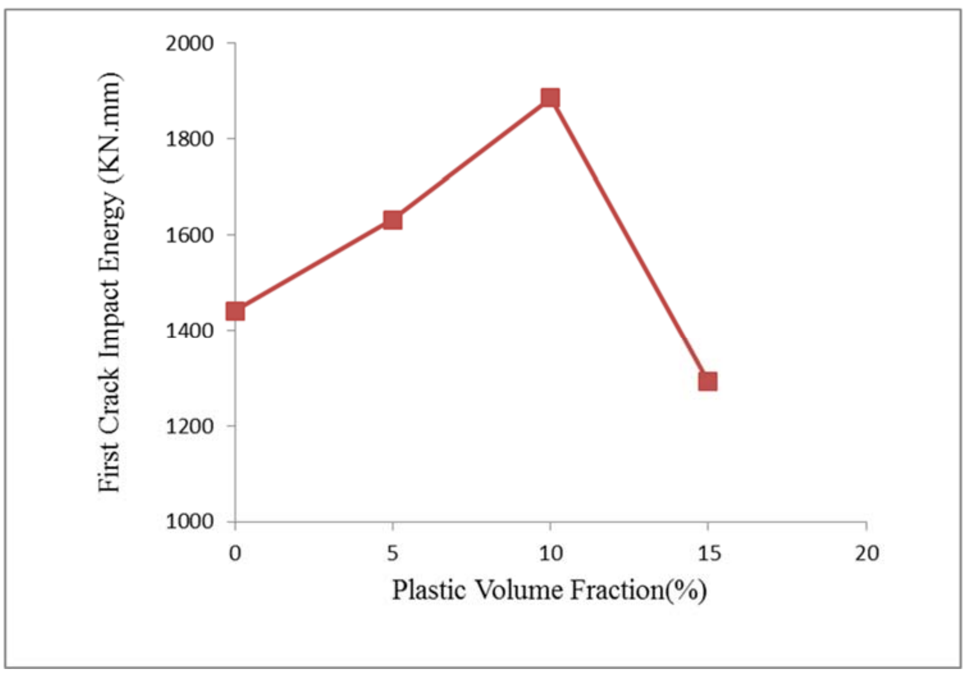

Fig. 7: First crack impact energy against volume fraction of plastic.

In a similar work [8], it was reported that, the replacement of coarse aggregate by chipped rubber caused increase in impact energy up to the replacement volume of 20% beyond which it was declining.

4. Conclusion

The first crack impact resistance was mainly investigated for concrete with partial replacements (5%, 10%, and 15% by volume) of coarse aggregate by plastic waste. For each case, six cubes of 100 mm ×100 mm × 100mm were subjected to 4.5 kg hammer from 457mm height. The number of blows of the hammer required to induce the first visible crack of the cubes were recorded. The impact resistance was increased by the replacement of coarse aggregate by plastic waste up to 10% by volume; at 15% replacement, although a reduction is observed, it is still higher than that of the plain concrete. Extended work is underway, to investigate the mechanical properties of the concrete with partial replacements of sand by plastic waste.

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