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Technical note

Impact resistance and energy absorption capacity of concrete containing plastic waste

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A B S T R A C T

PET (Polythene terephthalate) bottles and cans are mostly discarded after a single use cycle, creating environmental and waste management concerns. This study reports an experimental work carried out, in which PET bottles were shredded and used as aggregate (fine and coarse) in concrete at various replacement percentages, i.e., 5%, 10%, 15% and 20% by weight of concrete. Concrete parameters such as compressive strength, impact resistance and energy absorption capacity of concrete containing PET waste were studied. In addition, the residual compressive strength of concrete containing PET waste was investigated for exposure to 300 °C and 600 °C elevated temperatures. The analysis of test results indicated lower compressive strength of concrete containing waste plastic PET aggregate. However, results showed better resistance to impact loading in case of plastic concrete when compared to control concrete.

1. Introduction

As one of the substantial breakthrough in industrial material engineering, plastic has resulted in an enormous shift in the quality of human life [35]. In today's world plastic dominates in nearly every phase and aspect of our life from water bottles to electrical appliances [31,26,28]. The low mass, strength, simplicity of shape, durability and low costing are some of the beneficial characteristics off plastic based products which have led to an incremental annual consumption worldwide. Discarded plastic products after completion of their required service life have led to a huge accumulation of solid waste in nearly every developing country [30,19,28]. Polythene terephthalate (PET) is the second most discarded form of plastic after polythene [8,9]. PET used for packing soft-drink, drinking water, food and other consumer goods is one of the most manufactured and widely used plastics in the whole world [10,17]. In 2007 the projected world's annual consumption of PET bottles was 250,000 million with an incremental growth rate of 15% every year. In India, nearly 20,000 million units were produced during the year 2006. The resulting disposal of used bottles results in humongous amount of generation of plastic waste [20].

Two of the most popular form of plastic disposal is either by landfill or incineration [23]. Since plastic waste has low biodegradability and is present in large quantities disposal of plastic waste through landfill is causing serious environmental problems and health hazards. Disposal of PET waste through incineration is also inappropriate as combustion of plastic waste produces dangerous gases that could be harmful to human health, [11]. Recycling of PET wastes is also not proving to be effective as it requires massive manpower and large processing cost making it uneconomical. Manufacture of new plastic products by recycling of PET waste is also limited due to coloring effect and degradation in the quality of finished products. Thus, a more environment and cost friendly recycling solution is needed for PET wastes [17,27].

Many researchers suggested that reusing plastic waste is the most optimum solution for reducing the environmental impact of plastic waste at minimum cost [5,9,31,3,7]. Industry of construction engineering area with its high consumption capacity seems to be the most appropriate industry to reuse the PET waste. The utilization of aggregate based on PET waste in concrete will provide an eco-friendly outlet towards the recycling of waste plastics and, further, will release the mining burden for natural aggregate [2,33,22].

Concrete is a highly versatile construction material in nature, well suited for many applications [17,36]. Concrete properties such as workability, strength and durability is affected by the quality and type of aggregate as it accounts for nearly 65–80% of the concrete volume. With the increasing requirement of concrete in construction areas, these materials are getting deficient day by day

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and thus asking for the alternatives. The disposal method of plastic waste as aggregate has resulted in many studies by various researchers.

Inclusion of plastic waste in concrete affects its various properties. Workability of concrete with plastic waste decreases gradually with increasing plastic waste percentage [34]. This observation was also confirmed by Kumar et al. [18] who used plastic bags in fiber form to replace cement in concrete. However, Ghernouti et al. [12] reported increase in workability when utilizing recycled plastic bag waste (PBW) material as fine aggregate in concrete.

No clear trend was found in the literature for the effect of plastic waste on compressive strength of concrete. Various researchers reported reduction in compressive strength with the increase in plastic waste content in concrete [21,34,24,12,10]. Borg et al. [7] analyzed the reinforced concrete with polyethylene terephthalate (PET) and found that compressive strength reduced with increasing fiber volume fractions. However, Al-Hadithi and Hilal [4] carried out an experimental study using waste plastic fibers in self-compacting concrete and reported higher compressive strength on increasing the amount of waste plastic.

Researchers also analyzed the influence of plastic waste on flexural strength of concrete. It was reported by various authors that introduction of plastic waste in concrete increases the flexural strength [25,24,12,29]. However, Al-Hadithi and Hilal [4] used waste plastic fibres in self-compacting concrete and reported higher flexural strength of concrete containing waste plastic.

The objective of this research study is to experimentally investigate the property of waste plastic concrete under impact loading. PET waste was used in shredded form to replace fine aggregate and coarse aggregate.

2. Experimental investigation

2.1. Materials

Cement used in the study was 43 grade ordinary Portland cement (OPC). Table 1 presents the physical properties of cement.

The river based natural sand was used as fine aggregate in this study. Sieve analysis results are shown in Fig. 1. As per the guidelines of BIS: 383-1970, the sand belonged to zone II gradation. Specific gravity was observed to be 2.63.

The coarse aggregate used in this study was as per BIS: 383-1970 [14]. Sieve analysis results of coarse aggregates are shown in Fig. 2. The observed specific gravity for coarse aggregate was 2.74.

Waste PET bottles were collected from the local waste supplier in shredded form. Plastic waste was shredded in two sizes, i.e., between 0 and 4.75 mm for fine aggregate (FA) replacement and between 4.75 and 20 mm for coarse aggregate (CA) replacement as shown in Figs. 3 and 4. It was bought from the same source throughout the study. The waste was not given any special treatment except sun drying.

Table 1
Physical properties of cement.

Sr. No.	Physical properties	Requirement as per IS codes	Test results
1	Consistency	26–33%	32%
2	Initial setting time	30 min (min.)	130 min
	Final setting time	10 h (max.)	213 min
3	Specific gravity	3.12–3.19	3.13
4	7 day compressive strength	33 MPa	34.95 MPa
	28 day compressive strength	43 MPa	45.29 MPa

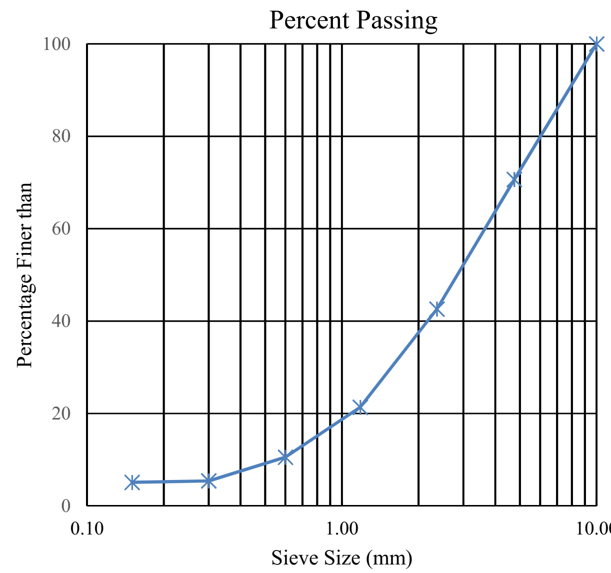

Fig. 1. Sieve analysis of natural fine aggregate.

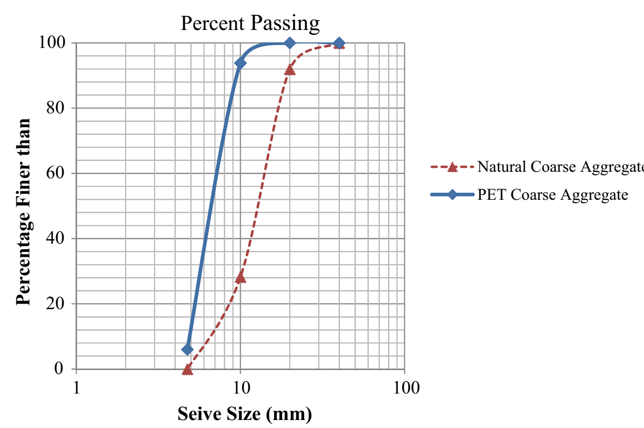

Fig. 2. Sieve analysis of natural and PET coarse aggregate.

Fig. 3. Plastic waste for fine aggregate replacement.

2.2. Mix proportions

Concrete mix proportioning followed was so as to replace 0%, 5%, 10%, 15% and 20% of fine and coarse aggregate. Details of mix proportion are presented in Table 2.