Research Journal of Recent Sciences ISSN 2277-2502
Vol. **7(6),** 1-6, June **(2018)** *Res. J. Recent Sci.*

A blend of carbon and polyethylene terephthalate (PET) as fine aggregate

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Available online at: www.isca.in, www.isca.me
Received 15th November 2017, revised 21st April 2018, accepted 25th May 2018

Abstract

This paper aims at incorporating carbon in Polyethylene Terephthalate (PET) and identifying it as a construction material. A blend of carbon soot and PET bottle waste was prepared in molten state. Carbon soot was added at a percentage of 0%, 5%, 10%, 15%, 20%, 25% and 30% to the molten PET waste and were cooled and crushed into the required size of fine aggregate. Tests on fine aggregates were performed to examine the effect of carbon addition with various percentage to PET waste. Specific gravity, water absorption, grading, bulking and bulk density test results were obtained for the above samples and also for natural sand to perform comparative analysis. The results of each sample were compared and analyzed with the result of natural sand to determine the most feasible percentage of addition of soot carbon in the PET bottle waste. It was found that an optimum of 10% soot carbon filled PET fine aggregate gave similar results to that of natural sand and better results than that of 0% carbon added PET waste fine aggregate.

Keywords: Carbon soot, PET waste, percentage of addition, fine aggregate, comparative analysis.

Introduction

Plastic is cheap, easily available and waterproof material with wide convenient usage. Polyethylene Terephthalate is abundantly used plastics in the form of bottles and containers for packaging of soft-drink and foods. PET bottles are lightweight and leak-proof storage containers which can be easily molded into desired shapes for the ease of usage and storage. Due to its convenience, demand and use of PET bottles have been exponentially increasing. With its use and wide growth in demand they cause huge problems on the environment as a waste material in landfill sites and oceans. The same properties of plastic which makes it a good material and contributes to its wide use has led to a negative impact on the environment since PET has a long decomposition period and cause the problem of solid waste management by overflowing of landfill sites. A total of 10 million tons of PET bottles were produced on global scale in the year 2007. This quantity is increasing up to 15% annually[1]. Mostly, the PET bottles are discarded by the consuming population after using which generates PET waste management problems in the landfill sites. The burden on the landfill site is generally reduced by the method of recycling and incineration of the waste which cannot be economically recycled. The quantity of recycled bottles is very low. Incineration of PET waste in uncontrolled environment generates air pollution and results in the wastage of resources which could be employed in other potential areas. The exponential advance of PET waste in the Landfill sites indicate the need for an alternate means of resource management[2].

We are in a peak era of infrastructure development and concrete is the most commonly used material in almost any construction. Sand is one of the most important constituents of concrete and mortars used in constructions. They act as filler materials and fills the voids between the aggregates. Natural sand constitutes of 60-75% of concrete volume[3]. Thus there is a huge demand for sand in the construction industries. The sand in ocean contains high salinity and cannot be employed in the construction. But the demand for new infrastructures is growing which had led to increase in the demand of sand. Excessive sand extraction has led to exposing the lands to erosion, silting and disturbance of aquatic life.

Carbon soot is produced in the exhaust pipes of vehicles, boiler section of the industries and in any other combustion unit. Soot is produced as a waste by product after the combustion of wood, coal and fuel in the lining of the chimney wall. Soot carbon is one of the contributing anthropogenic cause of global warming.

Incorporating PET waste in concrete will not only reduce the waste burden on the land fill sites but also help in curving the environmental damages due to excessive extraction of sand[4,5]. The overall weight of the construction reduces which results in the reduction of the dead load and also the cost of construction[6]. The light weight concrete can be employed in the earthquake resistant buildings[7]. PET waste when pulverized mechanically into fine grains to form fine aggregate retains pallet structure which causes bonding problems between the aggregate and the cement which results in lowering of the strength of concrete. Melting the PET bottle at maximum temperature of 135 degrees Celsius and cooling them down at room temperature results in the formation of crystalline and opaque (white or yellow) structure which when crushed become granular with smooth sharp surfaces. This crystalline structure shows better result compared to the pulverized form of PET. Thus the strength of PET in concrete seems to be increasing as the material attains crystalline and granular form to overcome the problems of bonding due to the smooth pallet structure of pulverized PET. This paper focuses on a new construction material developed from incorporating soot carbon powder into molten PET waste to obtain PET in rough granular form with better bonding. The addition of carbon into the molten PET enhances the crystalline property of plastic and generates fine grains of granular structure with more roughness and cohesiveness. In this paper soot carbon was added in 0%, 5%, 10%, 15%, 20%, 25% and 30% to the molten PET. The maximum percentage of addition was 30 percent beyond which PET and carbon formed a separate layer which made blending difficult. The PET bottles were melted at 135 degrees Celsius considering the fact that polymers melt easily without the evolution of gas at 130-140 degree Celsius[8].

Steel is an alloy of iron and carbon. It is produced from cast iron with the addition of small percentage of carbon. The percentage a carbon addition is not more than 2 percent. As carbon is added to cast iron the small fine molecules of the carbon occupies the space between the iron molecules of the body centered cubic crystal lattice of iron and results into the formation of rigid structures with lesser ductility and more strength. As the percentage of carbon addition in the iron increases, the ductility of steel keeps on decreasing and there comes a state where the steel becomes too brittle and breaks like glass[9]. PET is a polymer chain of ethylene terephthalate and when it is melted and cooled, the chains deform and folds resulting in the formation of opaque crystalline structures. PET is more ductile compared to iron and hence we tried adding carbon into PET to generate similar effect as that of carbon in steel, for rough brittle structure[10]. For this the optimum percentage of addition of carbon in PET was determined to obtain the desired properties so that it can be used as fine aggregate when crushed[11]. The paper also displays the distribution of the property of this material when compared with the properties of natural sand and 0% carbon added PET. Through the tread line generated from the graphs plotted for the properties of the material, an optimum percentage of addition of carbon in PET will be determined.

Materials and methods

Waste PET bottles were collected from different institutions, College canteens and landfills for the experiment. The collected PET waste were cut, washed and melted at a temperature of 135 degree Celsius as shown in the Figure-1. Carbon soot obtained as a waste from the boiler section and chimneys of the factories and industries was used for the experiment. Fines of Carbon soot was added to the molten PET and stirred thoroughly as depicted in Figure-2. Then it was left to be cooled at room temperature for 24 hours as shown in Figure-3. The cooled Carbon-PET mixture was crushed mechanically maintaining the standard number of blows accurate grading analysis. The sample of crushed mixture is shown in Figure-4. Natural sand of zone II was used in the experiment extracted from the river banks for the comparative analysis with the test sample.

Figure-1: Melting of PET.

Figure-2: Carbon addition.

Figure-3: Cooling of blend.

Figure-4: Crushing into size.

Experimental Tests: Water Absorption: For water absorption test, the sample was oven dried for 24 hours and was weighed as shown in Figure-5. The mean of the water absorption for each sample was calculated. The test was conducted as per IS: 2386-1963 (PART III)[12].

Grading and zonation: Each sample including the natural sand was weighed and placed in the sieve shaker for 10 minutes which contained sieve size varying from 75 microns above the pan to 10mm at the top as shown in Figure-6. The test was conducted as per IS:2386-1963 (PART I)[13].

Bulking: In a 250ml measuring cylinder, 200ml of sand was poured by dividing the aggregate into three parts. Each part was tamped 25times with a tamping rod of 6mm diameter. Then sufficient water was poured into the cylinder to submerge the fine aggregate and stirred well as shown in Figure-7. The test was conducted as per IS:2386-1963 (PART III).

Figure-5: Oven drying.

Figure-6: Sieve Analysis.

Figure-7: Bulking test.

Specific Gravity Test: The specific gravity test was done by using picnometer in a set of three for each sample as shown in Figure-8. And it was done for all sample starting from natural sand to 0%, 5%, 10%, 15%, 20%, 25% and 30% of carbon addition in PET. The test was conducted as per IS: 2386-1963 (PART III).

Bulk Density: A cylindrical metal measure was used which was filled to one third of its volume using the fine aggregate and was tamped 25 times using a rod of 6mm diameter. The cylinder was filled to its rim and the extra portion was removed using a spatula. The net weight in the cylinder was measured and the value of bulk density is calculated for each sample as shown in Figure-9. The test was conducted as per IS: 2386-1963 (PART III).

Figure-8: Picnometer for specific Gravity test.

Figure-9: Cylindrical moulds for bulk density test.

Results and discussion

Water absorption: The mean of the water absorption for each sample was calculated and the graph obtained is displayed in Figure-10.

Grading and zonation: The grading of each sample is given in Figure-11. The zonation of each sample is shown in Table-1.

Table-1: Zonation of Fine Aggregate.

Fine Aggregate	Grading Zones
Natural Sand	Zone II
0%	Zone I
5%	Zone II
10%	Zone II
15%	Zone I
20%	Zone I
25%	Zone I
30%	Zone I

Bulking: The Bulking result for each sample is shown in Figure-12 for analysis.

Specific Gravity Test: The mean specific gravity for each sample is calculated and shown in Figure-13.

Bulk Density: The net weight in the cylinder was measured and the value bulk density is calculated and displayed for each sample in Figure-14.

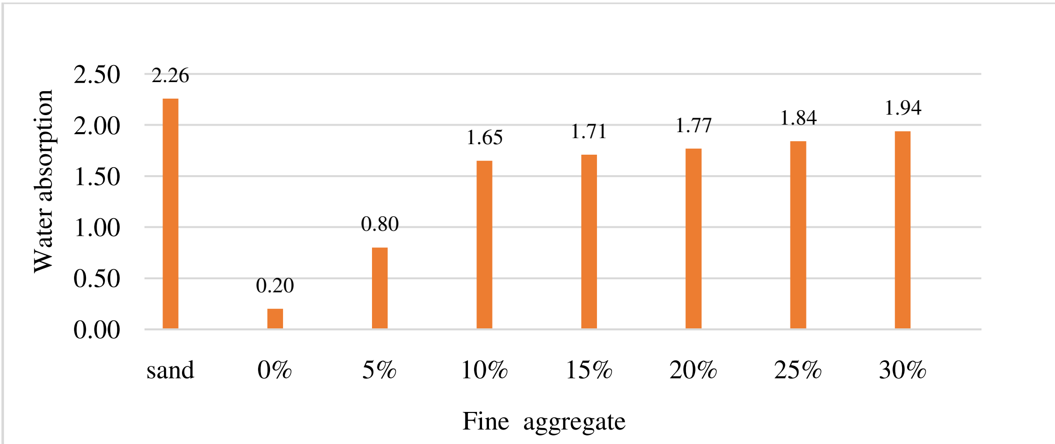

Figure-10: Water absorption test result.

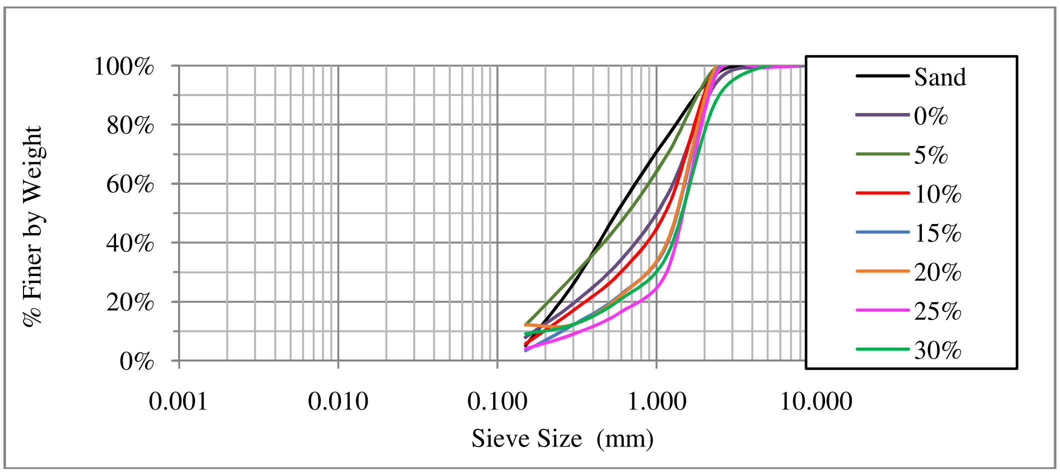

Figure-11: Grading of Fine Aggregate.

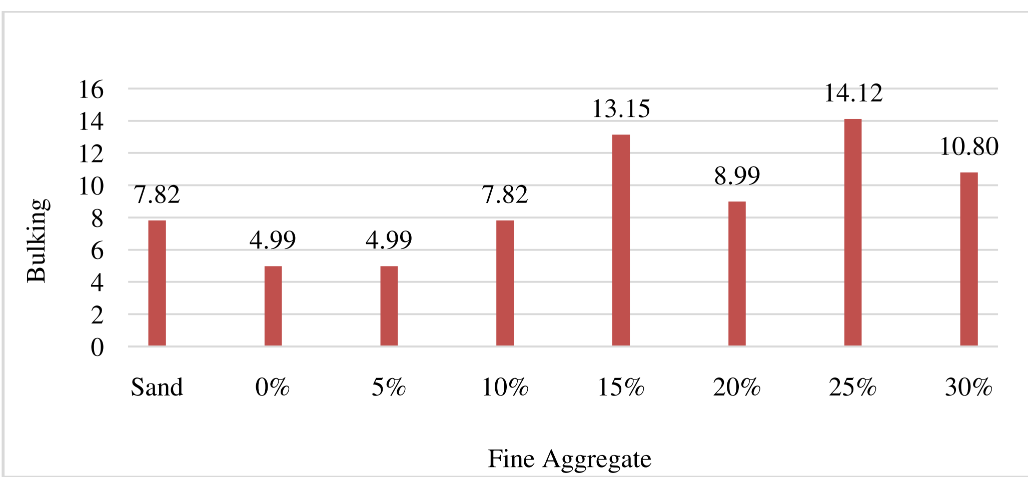

Figure-12: Result of Bulking Test.

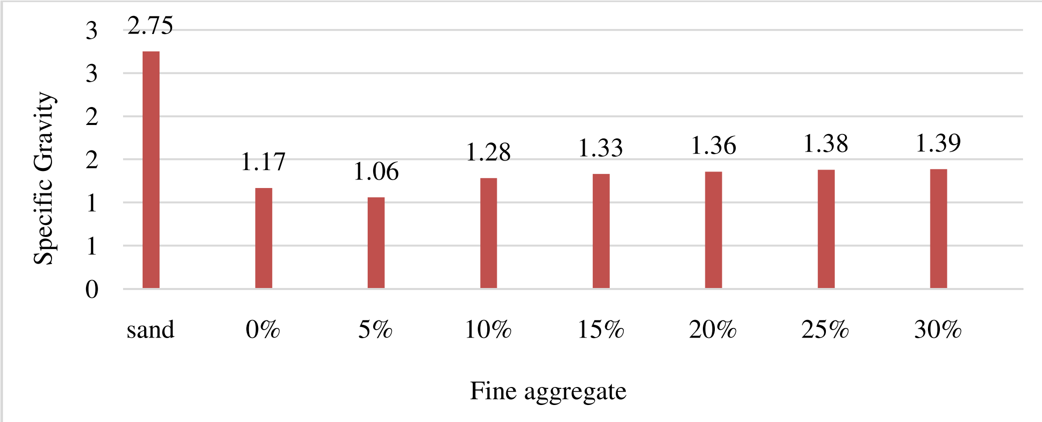

Figure-13: Result of Specific Gravity Test.

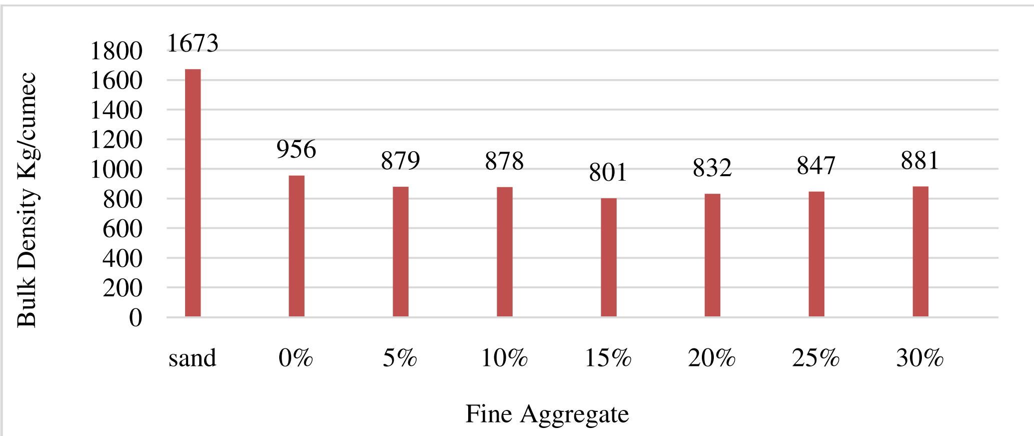

Figure-14: Result of Bulk Density Test.

Conclusion

Further increase in the addition of Carbon in PET beyond 30% shows difficulty in mixing and blending.

By comparing the test results of each sample with natural sand, 10% addition of carbon gives the most feasible result. The test was conducted under the constraints of time and limited availability of facilities hence the scope of this paper can be further enhanced with additional test and better facilities.

Further test on other important properties of the material, and the studies on the effect of its use when employed in concrete is an ongoing target for the next paper.

References

1. Frigione M. (2010). Recycling of PET bottles as fine aggregate in concrete. *Waste Management*, 30, 1101-1106. http://dx.doi.org/10.1016/j.wasman.2010.01.030.

2. Yazoghli Marzouk O., Dheilly R.M. and Queneudec M. (2007). Valorization of post-consumer waste plastic in cementitious concrete composites. *Waste management*, 27(2), 310-318.

3. Soloaga I.S., Oshiro A. and Positier M. (2014). The use of recycled plastic in concrete, An alternative to reduce ecological footprint. *Journal of Construction*, 13(3), 19-26.

4. Tam V.W., Tam C.M. and Wang Y. (2007). Optimization on proportion for recycled aggregate in concrete using two-stage mixing approach. *Construction and Building Materials*, 21(10), 1928-1939.

5. Pacheco-Torgal F., Castro-Gomes J.P. and Jalali S. (2008). Adhesion characterization of tungsten mine waste geopolymeric binder. Influence of OPC concrete substrate surface treatment. *Construction and Building Materials*, 22(3), 154-161.

6. Koide H., Tomon M. and Sasaki T. (2002). Investigation of the Use of Waste Plastic as an Aggregate for Lightweight Concrete. *Sustainable Concrete Construction, London*, 177-186.

7. Saikia N. and de Brito J. (2013). Waste polyethylene terephthalate as an aggregate in concrete. *Mater. Res.*, 16(2), 341-350.

8. Rajasekaran S., Vasudevan R. and Paulraj S. (2013). Reuse of Waste Plastics Coated Aggregates-Bitumen Mix

Composite for Road Application–Green Method. *American Journal Engineering Research (AJER)*, 2(11), 1-13.

9. Sherby O.D., Wadsworth J., Lesuer D.R. and Syn C.K. (2008). Revisiting the Structure of Martensite in Iron-Carbon Steels. *Materials Transactions*, 49(9), 2016-2027.

10. Benning C.J. (1983). Plastic Films for Packaging. Lancaster, Pennsylvania, Technomic Publishing Co.

11. Lui Y., Zhizhongsu Li X., Guo. W., Li. Q. and Wu. C. (2014). Effect of Dispersion of Carbon Black on Electrical and Thermal Properties of Poly (Ethylene Terephthalate)/Carbon Black Composites. *Journal of Macromolecular Science*, Part B: Physics, 48, 146-156.

12. IS: 2386 (Part III) – (1963, 1997). Methods of test for aggregates for concrete Part III. *Bureau of Indian Standards*, New Delhi.

13. IS: 2386 (Part I) – (1963, 1997). Methods of test for aggregates for concrete Part I. *Bureau of Indian Standards*, New Delhi.