International Journal of Civil Engineering (IJCE)
ISSN (P): 2278–9987; ISSN (E): 2278–9995
Vol. 8, Issue 6, Oct–Nov 2019; 17–24

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE MADE WITH PET BOTTLES WASTE AS FINE AGGREGATE

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ABSTRACT

A substantial growth in the consumption of plastic is observed all over the world in recent years that has led to dumping of huge quantities of plastic related wastes. This is an environmental issue as waste plastic bottles are difficult to biodegrade and involves processes either to recycle or reuse. Recycling of plastic waste to produce construction material like concrete appears as one of the best solutions for the disposal of plastic waste. This project deals with the possibility of using the PET bottles waste as the partial replacement of fine aggregate in concrete with 5%, 10%, 15%, 20% and 25% in the volume of river sand. Mechanical and durability properties were studied with PWAC (Plastic waste aggregate concrete) and compared with the control concrete. An attempt is made to find the optimum percentage of replacement of conventional aggregate by plastic waste aggregate for making the concrete. The main objective of this study is to reduce the wastage of plastic and to improve the eco-friendly environment.

KEYWORDS: *Compressive Strength, Durability, Environment, PET Bottle, Plastic Waste*

Article History

Received: ***23 Oct 2019*** **|** ***Revised:*** ***30 Oct 2019*** **|** ***Accepted:*** ***07 Nov 2019***

INTRODUCTION

Quarrying large amount of sand from river bed is being used as fine aggregate in concrete making. This is hazardous to environment, moreover, now-a-days the river sand has become highly expensive and also scarce. Thus, it becomes almost obligatory to find alternatives to natural sand. Out of the many available alternatives, crushed stone sand, a by-product of crushing units during production of 20 mm and 10 mm size aggregates has emerged as the most easily available material. Due to this, Indian construction industries using crushed stone sand as fine aggregate for the production of concrete.

On the other hand, Plastic pollution is currently one of the biggest environmental concerns. The government of India has also banned the use of plastics in order to save the environment. Polyethylene terephthalate (PET) is one of the most common consumer plastics used. Generally, the PET packaging is discarded by the consumer after use and becomes PET waste. Due to the rapid increase in the use of PET bottles, solid waste problem is raised. Disposal of these wastes is the major problem to the environment. Even though there are several methods for the disposal of these materials, such as land filling, incineration or recycling, recycling is the best solution due to its economic and ecological advantages (Albano, 2009, 3). Such plastic wastes are collected by recycling companies, then it is crushed, pressed into bales. It is further shredded into smaller fragments. The shredded PET bottles waste can be used as aggregate in concrete. The use of PET waste in concrete will provide benefit in the disposal of wastes and, in addition, will reduce the environmental damages due to the use of natural mineral aggregates resources (Tam et al., 2007; Fernando et al., 2008). Considerable researches and studies on plastics in concrete were carried out in many countries but there have been very limited studies in India. In this present study, crushed stone sand was used as fine aggregate instead of conventional fine aggregate (river sand) in all concrete mixes. Also, an attempt on the utilization of waste PET bottle particles as fine aggregate by partially replacing the crushed stone sand. The purpose of this project is to evaluate the possibility of using plastic waste materials and crushed stone sand as an alternate substitute for the river sand.

MATERIALS USED AND TESTS ON MATERIALS

Cement

Cement used in this experiment was Ordinary Portland Cement (OPC) 53 grade confirming to the Indian standards requirements stipulated in IS: 12269–2013. The specific gravity of cement sample was 3.11.

Fine Aggregate (Crushed Stone Sand)

Crushed granite stone sand (Figure 1) was used as fine aggregate as specified in IS 383-1970. Specific gravity, sieve analysis and bulk density tests were conducted by following the procedure described in IS: 2386-Part I and Part III-1963. Figure 3 shows the gradation curve for crushed stone sand. The Specific gravity and the fineness modulus of CSA were 2.55 and 2.59, respectively. The particles were confirming to zone II of IS recommendations. Bulk density of crushed stone sand in Loose and compacted state was 1680 kg/m^3 and 1849kg/m^3, respectively.

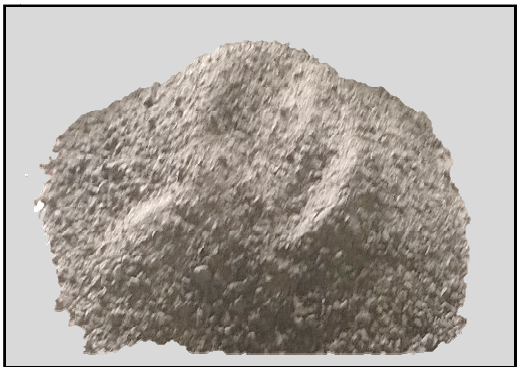

Figure 1: Crushed Stone S and Plastic Waste Aggregate (PWA).

PET bottle wastes were collected and washed, then they were shredded by means of industrial machines and ground into smaller components, pulverized in order to get plastic particles lower than 4.75 mm size. A commercial old plastics vendor in Vadalur, Tamil Nadu was helped to obtain such size of particles. Specific gravity, Sieve analysis tests were conducted on PWA as per IS procedures. During specific gravity test, most of the particles were submerged in water. Some particles were floated on water surface. Such floated thin particles were removed and this procedure is adopted for all the tests in this experiment. Figure 2 shows the PWA that is used in this experiment and the gradation of PWA particles. Figure 3 shows the gradation curve of PWA. Specific gravity and fineness modulus of PWA were 1.26 and 4.01, respectively. The grading of PWA was prepared to have similar gradation as that of CFA which were confirming to Zone II. Bulk density of PWA in Loose and compacted state was 453 kg/ m^3 and 576 kg/ m^3 respectively.

Coarse Aggregate

Crushed Granite of size 20mm and below were used as coarse aggregate. The specific gravity was 2.77.

Figure 2: Plastic Waste Aggregate and its Gradation.

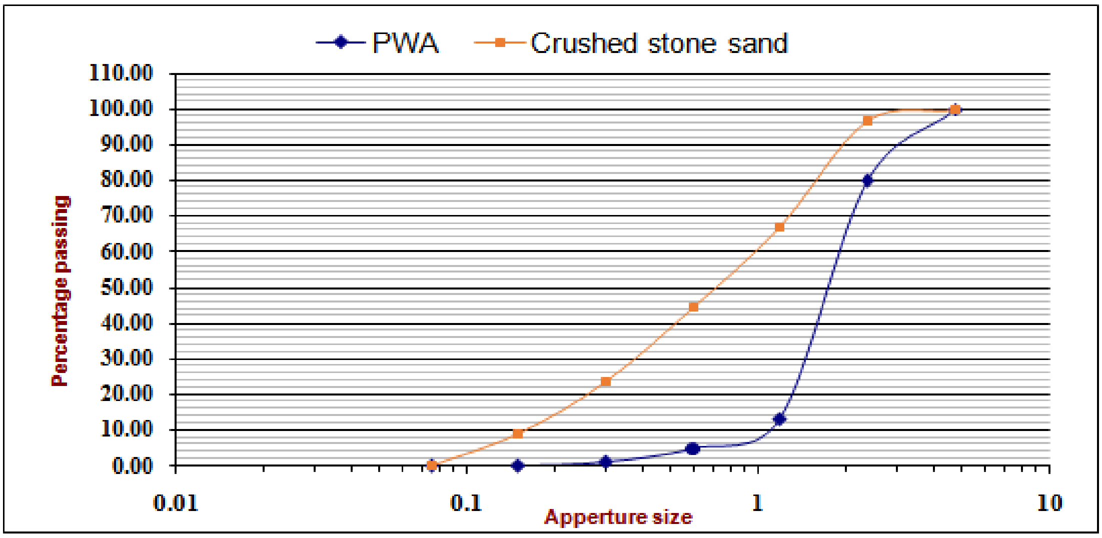

Figure 3: Sieve Analysis for Plastic Waste Aggregate and Crushed Stone Sand.

EXPERIMENTAL INVESTIGATION

Mix Proportions

Mix proportions for control concrete (CC) of M_{20} grade was arrived based on IS 10262: 2009. Mix proportions for plastic waste aggregate concrete (PWAC) was arrived for various percentages (5%, 10%, 15% 20% and 25%) of plastic waste aggregates by replacing the crushed stone sand in its volume. Mixed proportions for CC and PWAC are presented in Table 1.

Table 1: Mix Proportions for CC and PWAC

Material	Plastic Waste Aggregate in %					
	0%	5%	10%	15%	20%	25%
Cement	383.16	383.16	383.16	383.16	383.16	383.16
CFA	663.76	630.572	597.384	564.196	531.008	497.82
PWA	-----	16.40	32.80	49.20	65.60	82.00
CA -20mm	709.40	709.40	709.40	709.40	709.40	709.40
CA -12mm	416.63	416.63	416.63	416.63	416.63	416.63
Water	191.58	191.58	191.58	191.58	191.58	191.58

Specimens Cast and Test Methods

Three numbers of cube specimens of 100 mm × 100 mm × 100 mm size for each mix and totally 18 cubes were cast and cured for 28 days. Compressive strength of concrete is the most frequently used measure of concrete quality in design and QA during construction (USTechnical report, 2012). Therefore, compressive strength test was conducted to know the optimum dosage of plastic waste aggregate as fine aggregate in making the concrete. After knowing the optimum percentage of replacement, mechanical properties and durability properties were studied for the PWAC made with this optimum percentage of plastic aggregate and compared with corresponding control concrete.

Prism specimens of size 100 mm × 100 mm × 500 mm and cylinder specimens of size 150 mm diameter and 300 mm height were cast to determine its flexural strength and modulus of elasticity, respectively. Three specimens from each mix were taken for all the tests. Mechanical properties were studied by following the procedures described in IS 516-1959. Durability tests such as rapid chloride penetration test (RCPT) and water absorption test were also conducted in this experiment. RCPT was conducted as per ASTM: C 1202-97 with 100 mm diameter, 50 mm thick specimens. These are prepared from 100 mm diameter and 200 mm height cylinder specimens. They were cut into 50 mm thick cylinders and middle pieces of specimens were used for this test. Water absorption test was conducted on cube specimens of size 100 mm as per ASTM C 642-06. Both mechanical and durability tests were conducted for the concrete specimens cured under water for 28 days.

RESULTS AND DISCUSSIONS

Compressive Strength and Optimum Dosage of PWA

The results of compressive strength for CC and PWAC are shown in Figure 5. From the results obtained, it is found that the compressive strength decreases with increase in PWA. But decrement is very small and comparable up to 10% replacement, after this it is reduced to greater value when compared to the strength of control concrete. Therefore, 10% of plastic waste aggregate may be used as fine aggregate in concrete for non-structural works, and for making light weight aggregate concrete (Semiha Akcaozog˘lu, 2010).

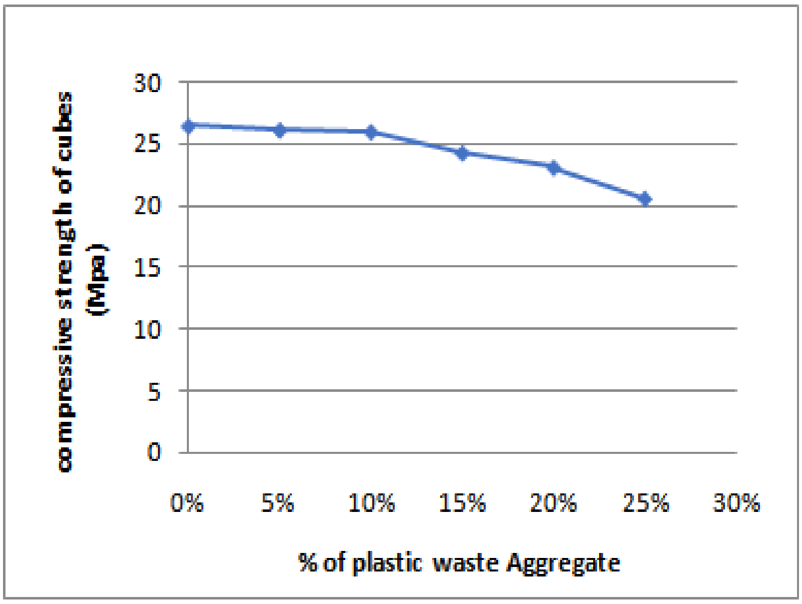

Figure 4: Compressive Strength of Concrete with Different Percentages of PWA.

Mechanical Properties

Flexural strength test and modulus of elasticity tests were conducted for PWAC-10% specimens. The test results were tabulated in Table 5. From the table, it is understood that the strength is reduced when adding plastic waste aggregate in concrete. This may be due to flat shape of the PWA particles and weaker bond between the cement matrix and PWA (Bandodkar, 2011, Rahmani, 2013). To enhance the strength, it is suggested that, the plastic waste aggregate can be used as fine aggregate in concrete after some process like sand or glass powder coating to the plastic particles or preparing sand like particle by heating process. Further it is understood that the expression arrived for PWAC-10% is closer to the value of CC. Therefore, 10% of plastic waste aggregate can be utilized to replace the conventional fine aggregate for making the concrete.

Durability Properties

From the durability studies, the test results of RCPT and water absorption for PWAC-10% and CC is tabulated in Table 6. From the table, it is clear that PWAC-10% is more durable than CC. This may be due to the plastic particles.

Table 2

Property	CC (Theoretical)	CC (Experimental)	PWAC-10%	Expression for PWAC
Compressive strength (Mpa)	----	26.01	25.98	----
Flexural strength (Mpa)	$0.7\sqrt{fck} = 3.57$	3.53	3.49	$0.68\sqrt{fck}$
Modulus of elasticity (Mpa)	$5000\sqrt{fck} = 2.55\times 10^4$	2.23×10^4	2.14×10^4	$4198.5\sqrt{fck}$
RCPT in coloumbs	----	744 (Low)	631 (very low)	----
Water absorption (%)	----	0.67	0.52	----

CONCLUSIONS

- Plastic wastes may be used for lean concrete and plain cement concrete works. The PWA concrete reduced the weight of concrete and therefore PWA can be used as aggregate for making Light weight concrete.
- Use of PWA as fine aggregate in concrete will be helpful to reduce the consumption of natural resources and gives solution to disposal of plastic waste.
- Plastic waste aggregate concrete is an eco-friendly concrete.
- Compressive strength decreases with increase in PWA. But decrement is very small and comparable up to 10% replacement. Therefore, 10% of plastic waste aggregate may be used as fine aggregate in concrete.
- The reduction in 28 days compression strength can be controlled with the use of certain strength improving admixtures.

REFERENCES

1. *Albano, C., Camacho, N., Hernandez, M., Matheus, A and Gutierrez, A (2009), "Influence of content and particle size of waste pet bottles on concrete behaviour at different w/c ratios", Waste Management 29, 2707–2716.*

2. *ASTM C 1202-97, "Standard Test Method for Electrical indication of concretes ability to resist chloride ion penetration", Annual Book of ASTM Standards: American Society for Testing and Materials.*

3. *ASTM C 642-06, "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete", Annual Book of ASTM Standards: American Society for Testing and Materials.*

4. *Bandodkar L.R, Gaonkar A.A, Gaonkar N.D and Gauns Y.P (2011), "Pulverized PET bottles as partial replacement for sand", International Journal of Earth sciences and Engineering, vol.4, No.6,SPL, Oct 2011, pp. 1009–1012.*
5. *Fernando, P.T., Castro Gomes, J.P., Said, J (2008), "Adhesion characterization of tungsten mine waste geo-polymeric binder. Influence of OPC concrete substrate surface treatment", Construction and Building Materials 22 (3), 154–161.*
6. *IS 12269 Specification for 53 grade ordinary Portland cement, Bureau of Indian standards, New Delhi, (1987).*
7. *IS:383-1970 Specifications for coarse and fine aggregates from natural resources for concrete.*
8. *IS 2386 (Part I and Part III), Methods of test for aggregate for concrete, Bureau of Indian standards, New Delhi, (1963).*
9. *IS 10262:2009, Recommended guidelines for concrete mix Design, BIS. NewDelhi, India, 2009.*
10. *IS 516 – 1959, Methods of Tests for Strength of Concrete—Bureau of Indian Standards, New Delhi.*
11. *Rahmani E, Dehestani M, Beygi M.H.A, Allahyari H and Nikbin I.M (2013), "On the mechanical properties of concrete containing waste PET particles", Construction and Building Materials 47 (2013) 1302–1308.*
12. *Semiha Akcaozog˘lu, Cengiz Duran Atis and Kubilay Akcaozog˘lu (2010), "An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete", Waste Management 30 (2010) 285–290.*
13. *Tam, W.Y.V., Tam, C.M., Wang, Y (2007), "Optimization on proportion for recycled aggregate in concrete using two-stage mixing approach", Construction and Building Materials 21 (10), 1928–1939.*
14. *Technical Report on Estimation of Key PCC, Base, Subbase, and Pavement Engineering Properties from Routine Tests and Physical Characteristics - Publication No. FHWA-HRT-12-030, August-2012.*

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