Journal of Building Material Science
https://ojs.bilpublishing.com/index.php/jbms

ARTICLE

Feasibility Study on Use of Plastic Waste as Fine Aggregate in Concrete Mixes

Sudarshan D. Kore

School of Construction Management, National Institute of Construction Management and Research (NICMAR), Balewadi, Pune, India

ARTICLE INFO

Article history
Received: 1 April 2019
Accepted: 26 August 2019
Published: 20 November 2019

Keywords:
Plastic waste
Concrete
Mechanical Properties

ABSTRACT

Plastic is used in many forms in day-to-day life. Since plastic is non-biodegradable, landfills do not provide an environment friendly solution. Hence, there is strong need to utilize waste plastic. This creates a large quantity of garbage every day which is unhealthy and pollutes the environment. In present scenario solid waste management is a challenge in our country. The production of solid waste is increasing day to day and causes serious concerns to the environment. In this study, the recycled plastics are used in the concrete as a partial replacement of fine aggregate in concrete. The main purpose of this study is to investigate the mechanical properties of concrete such as workability, compressive, flexural and split tensile strengths of concrete mixes with partial replacement of conventional fine aggregate with aggregate produced from plastic waste. The use of plastic aggregate as replacement for fine aggregate enhances workability and fresh bulk density of concrete mixes. The mechanical properties of concrete such as compressive, flexural, and tensile strengths of concrete reduced marginally up to 10% replacement levels..

1. Introduction

There are about 15342 tons of plastic waste produced in India every day, only 9205 tons recycled and dumped onto the soil[1]. Environmental sustainable development is one of the most important problems facing the world today. The use of plastic is quickly growing for different reasons worldwide. It can have damaging impacts because of the use of chemical additives in plastic production. This plastic waste must therefore be monitored or recycled. Plastic bags are not degradable and take 1000 years to degrade, causing groundwater contamination. It produces issues such as soil, water and air pollution because of the non-degradation property of plastics. Thus, these materials can be used suitably in other sectors to decrease these effects on the environment[2]. Concrete is one of the most common and widely used construction materials in the world[3]. Concrete industry conducts numerous tests for using such waste[4] to decrease environmental burdens. The use of various types of solid waste as building material may decrease the demand for natural raw materials. This reduces the demand for natural resources to achieve sustainable development by using plastic waste

**Corresponding Author:*
Sudarshan D. Kore,
School of Construction Management, National Institute of Construction Management and Research (NICMAR), Balewadi, Pune, India
Email: sudarshankore123@gmail.com, skore@nicmar.ac.in

DOI: https://doi.org/10.30564/jbmr.v1i1.1204

in concrete mixtures.

1.1 Generation of Plastic Waste

Approximately 6.3 billion tonnes of plastic waste was produced worldwide in 2016, while the amount of plastic waste produced in India amounts to 15.342 tonnes everyday.

Figure 1.1 Dumping of Plastic Waste in Open Lands

1.1.1 State of Art

The investigation of concrete combinations with the use of plastic waste to replace fines in several percentages, 10%, 20%, 30% and 40% by Ghernouti, Rahebi, Safi, & Chaid (2009) in their investigation[5]. There has been an increase in workability because the plastic waste has nonabsorbent property. There have been significant reductions in flexural and compressive strength. The volume of void in concrete rises by plastic waste, which reduces the concrete's compactness.

Ismail & Al-Hashimi (2010)[6] reported the addition of polymeric material leads to the formation of polymer film during hydration resulting in co-matrix during which polymer is amalgamated with cement hydrate[7]. Another study by Raghatate (2012) revealed a decrease in mechanical properties by incorporating plastic as fine aggregate into concrete[8]. But mechanical properties decreased by 10% and according to BIS 456 (2000)[9], this is acceptable. The findings achieved by earlier scientists have been contradicted by Mathew et al., (2013)[10]. Khilesh (2014) in his study, reports that the use of plastic waste together with the addition of steel fiber into concrete enhances the mechanical properties of concrete[11].

The substitution of natural ground aggregate with plastic aggregates improves the concrete compressive strength by roughly 10 per cent relative to control concrete, at a replacement of 20 per cent. Chen et al. (2015) recorded the observation of only a 15 percent loss of strength at 10 percent replacement level, whereas a remarkable decrease was noted at another replacement level[12]. It also has been indicated that the HDPE is able to limit the formation of cracks due to the increase in tensile strength. Mashaly et al. (2015) indicated that replacing 10% coarse aggregate from plastic wastes in concrete marginally lowered workability and dry density[13]. The concrete that has been modified using plastic waste as fine aggregates (1% 3% and 5% by weight) reduces the mechanical characteristics of the concrete marginally and that reduction of 10% is acceptable[14].

The substitution of sand by plastic waste (10%, 15% and 20%) decreased the working ability of mixed concrete by uneven size and overall shape, which lowered the fluidity[15]. The hydrophobic property of the plastic reduces the hydration process, which reduces the mechanical strengths of concrete mixtures.

Studies by previous researchers have shown that the use of plastic wastes as a good aggregate in concrete blends has no adverse effect. The present study focuses on the use of fine aggregates produced from the crushing of solid plastic waste in concrete mixes as replacement 5%, 10%, 15%, 20% and 25% by weight for conventional fine aggregate. The mechanical characteristics of concrete are assessed, including working ability, compressive strength, split tensile strength and flexural strength.

2. Material Characterization

In this research the cement used meets the limitation of BIS 1489 Part 1-1991 (1991)[16]. Table 2 shows the physical characteristics assessed in the laboratory.

Table 2.1 Properties of Cement

Initial setting time	30 min.
Final setting time	610 min.
Compressive strength	
3 day	28 N/mm^2
7 day	37 N/mm^2
28 day	59 N/mm^2
Consistency	28 %
Specific gravity	3.14

The fine and coarse aggregate confirms the BIS: 383-1960 (1997)[17]. The physical characteristics of aggregates

 DOI: https://doi.org/10.30564/jbmr.v1i1.1204

are listed below in Table 2.2. Figure 2.1 shows the gradation of aggregates.

Table 2.2 Properties of Aggregates

Sr. No	Property	Natural Sand	Plastic Aggregate	Natural Coarse Aggregate
1	Specific gravity	2.73	-	2.90
2	Water absorption (%) by weight	1.62	Nil	0.60
3	Grading Zone	Zone II As per Table 4 of BIS 383	Zone II As per Table 4 of BIS 383	As per Table 2 of BIS 383

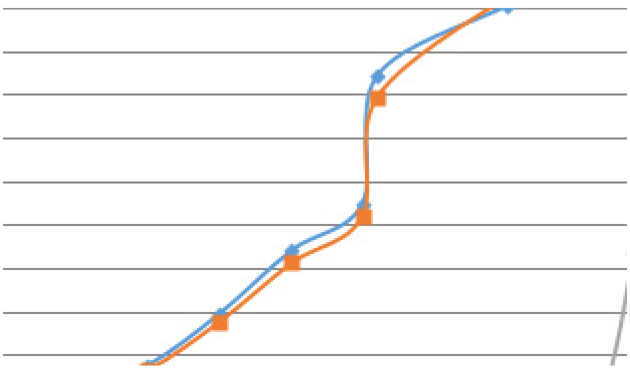

Figure 2.1 Gradation of Aggregates

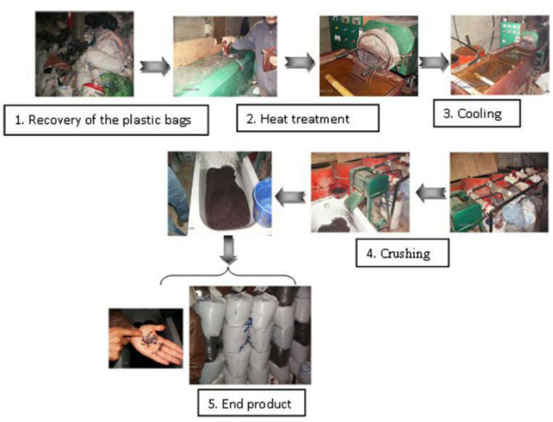

Figure 2.2 Production of Aggregate from Plastic Waste

The plastic waste aggregate is of a variety of sizes. The particle size ranges between 0.15 mm and 12 mm in length and between 0.15 and 4 mm in thickness. Table 2.2 shows the physical characteristics of the plastic aggregate, and Figure 2.2 shows the manufacturing method.

3. Methodology

3.1 Mix Proportioning

The concrete M20 mixture is designed with a water-cement ratio of 0.55 in accordance with the BIS 10262:2009 (1999)[18]. All the ingredients were mixed dry for 3 minutes and added water to obtain the homogeneous mixture. The sand has been substituted by a plastic aggregate of 5%, 10%, 15%, 20% and 25% at separate levels. Table 3.1 shows the mix proportions.

Table 3.1 Mix Proportion

Mix code	Water (lit/m^3)	Cement (kg/m^3)	Natural sand (kg/m^3)	Plastic aggregate (kg/m^3)	Natural Coarse Aggregate (kg/m^3)
C0	197	394	703	0	1219
C5	197	394	668	35	1219
C10	197	394	633	70	1219
C15	197	394	598	106	1219
C20	197	394	563	141	1219
C25	197	394	528	176	1219

Note:

C0 - Shows reference mix designed as per BIS 10262-2009

C5,C10, C15, C20, C25 - Shows concrete mix containing 5%, 10%, 15%, 20%, 25% plastic waste as fine aggregate respectively.

3.2 Experimental Program

The cubes of 150 mm × 150 mm × 150 mm and beams of 600 mm × 150 mm × 150 mm were cast as per BIS: 516 (1959) for compressive and flexural strength determination[19]. For the determination of Split Tensile Strength of concrete the specimens of size 300 mm × 150 mm were used. All samples were held aside at room temperature after casting, 24 hours later. BIS 1199 (1959) used evaluate concrete workability[19]. The compressive and flexural strengths of concrete samples were calculated at the age of 7 and 28 days as per BIS: 516-1959 (2002)[20]. At the age of 7 and 28 days of curing the compressive and Flexural strengths of concrete specimens were determined as per BIS: 516-1959 (2002)[20].

4. Result and Discussion

4.1 Workability Test

The freshly prepared concrete mix was used to measure the workability of concrete by using slump test and results were presented in Figure 4.1.

Mix code	Water (lit/m^3)	Cement (kg/m^3)	Natural Sand (kg/m^3)	Plastic Aggregate (kg/m^3)	Natural Coarse Aggregate (kg/m^3)
C0	197	394	703	0	1219
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C10	197	394	633	70	1219
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Figure 4.1 Workability of Concrete Mixes

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Results of the slump cone test showed the working ability of the plastic aggregate substitution to be increased considerably. The working ability of concrete mixes was improved by roughly 12%, by 15%, 19%, 26% and 33%, respectively, in relation to C5, C10, C15, C20 and C25. Due to the incorporation of plastic waste into concrete, a soft surface and plenty of open water led to enhanced working capacity. The plastic aggregate does not absorb water, so the followability of concrete can also be increased.

4.2 Density

The fresh wet densities of all the concrete mixtures are presented in Figure 4.2.

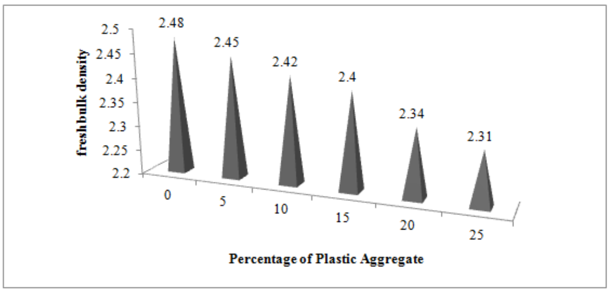

Figure 4.2 Density of Concrete Mixtures

The finding shows that, the fresh density tends to decline by 1.20%, 2.42%, 3.2%, 5.6% and 6.8% at 5%, 10%, 15%, 20% and 25% respectively to that of reference mixture. The density of concrete is mostly governed by the densities of the ingredients used in the blend. This is helpful in lightweight concrete manufacturing because of the low density of plastic waste as compared to sand.

4.3 Compressive Strength

Figure 4.3 presents the compression strength of concrete made using plastic waste as a fine aggregate. The compressive strength is determined at 7 and 28 days and compared with the reference mixtures.

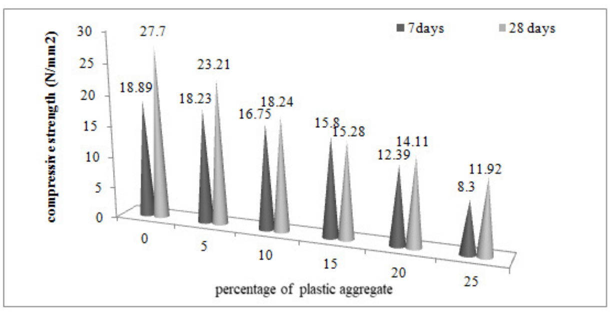

Figure 4.3 Compressive Strength of Concrete Mixtures

In all the concrete mixtures made with plastic aggregates, the significant reduction was observed. At 7 days, the compressive strength decreased from 3% to 56% at 28 days it approximately decreased from 16% to 57% at 5% to 25% replacement ratios respectively relative to that of reference blend. This reduction was probably caused by the poor adhesive strength in the concrete blends between the plastic aggregate layer and the cement paste.

4.4 Flexural Strength

The difference in flexural strength of all concrete mixes for 7 days and 28 days are shown in Figure 4.4.

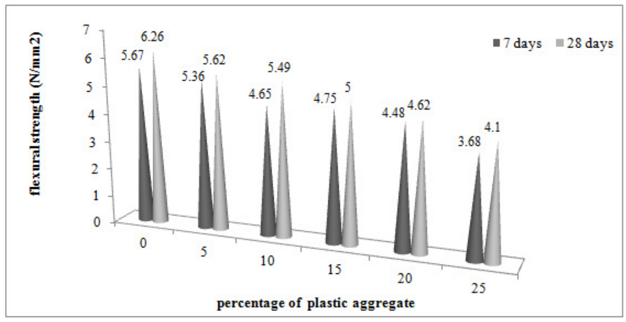

Figure 4.4 Flexural Strength of Concrete Mixtures

The flexural strength of concrete prepared with plastic aggregate gradually decreased. The 7-day flexural strength of concrete mixture with plastic aggregate reduced from 5% to 35 %, at 28 days it reduced by 10% to 35% at replacement levels of 5% to 25% respectively. This decline was due to the low cohesive bond between the plastic aggregate and cement paste. Also, plastic aggregates are of hydrophobic nature which restricts cement hydration resulting in a loss in strength.

4.5 Split Tensile Strength

The results obtained in the laboratory testing of split tensile strength are shown in Figure 4.5.

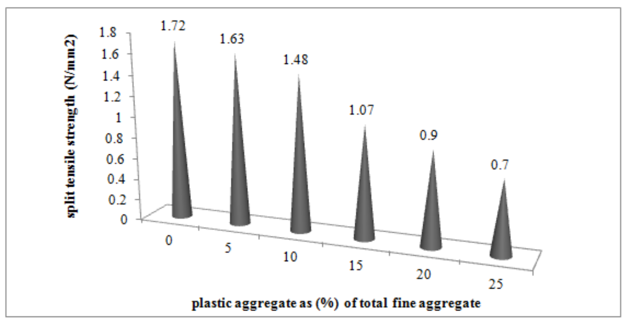

Figure 4.5 Split Tensile Strength of Concrete Mixtures

The findings showed that the split tensile strength of waste plastic concrete mixtures at each curing age is prone to decrease with the replacement of plastic aggregate. The split tensile strength of concrete produced with plastic aggregate decreased by roughly 5% to 50% at replacement rates of 5% to 25% as concerning that of reference blend. The findings of this test are consistent

 DOI: https://doi.org/10.30564/jbmr.v1i1.1204

with the compressive strength test.

5. Conclusion

An investigation was conducted to examine the mechanical characteristics of plastic-modified concrete as a substitute for natural sand and was noted that,

• There was an increase in slump values in concrete blends generated by plastic aggregates. In order to decrease the water-cement ratio, excess water would be used.

• The compressive strength of the prefabricated concrete mixture was significantly reduced as the substitution percentage increased.

• Flexural and split tensile strength findings are as in the compressive strength test line.

The concrete produced was generally appropriate in mechanical characteristics for the use of this plastic waste. A more thorough research is needed to preserve the mechanical characteristics of concrete mixtures made as a whole with plastic waste. This means that the issue of landfill and dumping can be substantially decreased by using such waste in concrete.

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