Properties of Concrete Containing Waste Plastic Aggregate

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Abstract. In our modern life style environment, the usage of plastic materials is increased day by day. Production of plastics globally would result in generating plastic-based waste. In recent times, many researches have been carried out to utilize the waste plastic waste materials in the concrete mix to make eco-friendly. The present study investigates the properties of concrete when replacing natural coarse aggregates (NCA) by bio non-degradable plastic aggregate up to 30%. Furthermore, fine plastic powder has been used in fine aggregate (FA) as partial replacement. Mechanical properties such as compression test, tensile strength test and flexural strength test have been carried out and the experimental results are discussed in detail. When the plastic aggregate percentage replacement increases, strength has been decreased because of poor bonding observed between the plastic aggregate and concrete reduces the strength properties.

Keywords: Waste plastic, plastic aggregate, mechanical properties, bonding, concrete.

1. Introduction

The waste obtained from plastics are non-degradable even when it is exposed to natural environment for long period. Those wastes should be properly handled otherwise it would create major problems to modern way of living [1]. Incorporation of plastic waste in concrete can be the better solution for minimizing the plastic waste [2]. Plastic has remarkable properties such as easy processing, strength and durability [3]. As per the statistics of Central Pollution Control Board (CPCB) nearly 150 tonnes plastics are produced every year [4]. The use of plastic waste in concrete reduces unrecycled plastic waste and the plastic waste have been used as fine aggregate or coarse aggregate as partial replacement for fine aggregate and coarse aggregate [5]. The addition of polymeric material with less than 10 percent in volume will not show variation in concrete mechanical properties [6]. An abrasion resistance property has direct relationship with strength properties. When the strength of the concrete is higher, abrasion resistance property will also be higher [7-9]. Concrete produced with glass and marble powder exhibits better service life when exposed to severe condition [10]. Due to light weight in nature tire shreds have demonstrated low horizontal stresses. For successful completion of the project form work selection plays major role. Iron scrap incorporation in the concrete increases
flexural strength of concrete. The properties such as surface roughness and less fire resistance would result in variation of properties in concrete [11]. Ficus Exasperata Leaf Ash (FELA) could be effectively used in concrete as a partial replacement of cement. It has also been noticed that FELA concrete showed better durability properties [12]. The optimum amount of nano silica in cement showed significant improvement in strength and durability properties [13-15]. This study dealt the effect of waste plastic aggregate in concrete as a replacement of NCA and FA.

2. Materials used

2.1. Cement
Ordinary Portland Cement (OPC) of 43 grade with specific gravity 3.15 was used. Relevant tests have been carried out to study the physical and chemical properties of concrete. The property of OPC is in accordance with IS12269-1987.

2.2. Aggregates
Manufacturing Sand confirming to grade Zone II of IS 303:1970 was used. Specific gravity of fine aggregate is 2.65. Blue granite metal (crushed) of size 12 mm was used as natural coarse aggregate. The specific gravity of coarse aggregate is determined as 2.8.

2.3. Water
Water used for drinking purpose at KPR Institute of Engineering and Technology, Coimbatore, India was used in this study.

2.4. Waste plastic
Waste plastics are gathered from plastic manufacturing plants, Coimbatore. Plastic aggregates have been obtained by crushing the waste plastic and segregated with the help of suitable sieve.

2.5. Mix design
Mix design was prepared according to IS 10262-2009. M 20 grade was used in the present study. The coarse aggregate and fine aggregate were replaced by plastic fine and coarse aggregate by 0%, 5%, 10%, 15% and 20%. Five mixes have been prepared by maintaining same water cement ratio of 0.4. Mixes were designated as PA0, PA5, PA10, PA15 and PA20 which denotes Plastic aggregate with 0%, 5%, 10%, 15% and 20%. Mix with 0% plastic aggregate refers conventional concrete mix and the same was referred for comparing results with other mixes.

3. Results and discussion

3.1. Compressive strength test
Compressive strength on concrete replaced by plastic aggregates determined by testing the specimens at 7 and 28 days and therefore the same was presented in Table 1. Three numbers of specimens were tested at relevant period to review the behaviour. While comparing with conventional control mix (PA0), Mix PA5 has demonstrated lesser compressive strength. It’s been noticed that PA5, PA10, PA15 and PA10 mix showed 5.5%, 5.8%, 9.4% and 9.9% lesser compressive strength than PA0 mix. It is because of poor bonding property between aggregate and also the concrete.

Table 1. Compressive strength properties

| Mix Name | Compressive Strength (N/mm²) |
|----------|-----------------------------|
|          | 7 days  | 28 days |
| PA0      | 16.5    | 27.5    |
| PA5      | 15.6    | 26.0    |
| PA10     | 14.7    | 24.5    |
| PA15     | 13.3    | 22.2    |
| PA20     | 12.0    | 17.5    |
3.2. Split tensile strength test
Split tensile strength on concrete replaced by plastic aggregates was determined by testing cylindrical specimens at 7 days and 28 days and the same was tabulated in Table 2. At relevant period three numbers of specimens were tested to study the behaviour. The test results revealed that compared with conventional control mix (PA0), Mix PA5, PA10, PA15 and PA20 have demonstrated 3.7%, 7.7%, 8.3% and 9.1% lesser split tensile strength. This is due to lesser bonding property observed in mix containing plastic aggregate.

Table 2. Split tensile strength properties

| Mix Name | Tensile strength (N/mm²) |
|----------|--------------------------|
|          | 7 days | 28 days |
| PA0      | 1.6    | 2.7     |
| PA5      | 1.5    | 2.6     |
| PA10     | 1.4    | 2.4     |
| PA15     | 1.3    | 2.2     |
| PA20     | 1.2    | 2.0     |

3.3. Flexural strength test
Table 3, demonstrates the flexural strength properties of concrete replaced by plastic aggregates at the age of seven days and 28 days. From the 28-day test results it's been noticed that at the PA5, PA10, PA15 and PA20 have exhibited 2.9%, 5.9%, 6.3% and 6.7% lesser flexural strength than control mix OPC. Lesser bonding observed between plastic aggregates and concrete ends up in reduction of strength values.

Table 3. Flexural strength properties

| Mix Name | Flexural strength (N/mm²) |
|----------|---------------------------|
|          | 7 days | 28 days |
| PA0      | 2.8    | 3.5     |
| PA5      | 2.7    | 3.4     |
| PA10     | 2.6    | 3.2     |
| PA15     | 2.5    | 3.0     |
| PA20     | 2.3    | 2.8     |

4. Conclusion
Mechanical strength properties tests have been performed and the conclusion is as follows:
1. Mix containing 5% (PA5) plastic aggregate have reached minimum target strength so up to 5% replacement of plastic aggregate can be effectively used in concrete.
2. When the replacement percentage of plastic aggregate exceeds 5%, it has been noticed that there is decrement in strength properties. This is due to lesser bonding between plastic aggregates and concrete.
3. It has also been noticed that when compared with conventional concrete, waste plastic a hydrophobic material restricts the hydration process that indirectly reduced the strength properties.
4. With respect to the tensile and flexural strength, the result observed in compressive strength property is resembled.
5. The observed test results proved that crushed waste plastic can be effectively used in concrete for sustainable construction in cost effective manner.
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