

Utilization Of Waste Plastic in Mix Design of Concrete

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ABSTRACT

The growing problem of plastic waste and the harm it causes to the environment from improper disposal call for new solutions for managing resources sustainably. One promising method is to use waste plastics in building materials like concrete. This approach helps reduce the amount of trash in landfills and improves material sustainability. This study looks at how feasible it is to add waste high-density polyethylene (HDPE) to the mix design of M20 grade concrete, which has a standard compressive strength of 20 N/mm². By replacing coarse aggregates with processed HDPE fragments at 10%, 20%, and 30% by weight, the research examines the mechanical properties, workability, and structural performance of the altered concrete. The results show that replacing up to 10% of coarse aggregates by weight with HDPE maintains 85–90% of the compressive strength of traditional M20 concrete. This suggests its potential use for non- structural purposes. However, when the replacement level is higher (20–30%), there is a significant drop in strength (40–60%) because of poor bonding and the naturally low tensile strength of plastic concrete. The study highlights the environmental advantages of recycling plastic waste and emphasizes the importance of optimizing mix designs. It also suggests looking into hybrid approaches, such as blending with fibers, to reduce strength loss. This research supports sustainable construction practices by providing a practical strategy for recycling waste plastics.

Keywords:- 1. Compressive strength, fineness modulus, IS Code Method, Mix design, plastic aggregates, specific gravity.

1. INTRODUCTION

Concrete is the most widely used building material in the world. It is a major part of walls, driveways, foundations, and other infrastructure projects. However, there are now serious environmental and resource-related issues as a result of the world's fast industrialization and urbanization. Both a severe shortage of traditional building materials and a concerning rise in the buildup of solid waste have resulted from this quick development. Because plastic waste is mostly non-biodegradable and can linger in the environment for up to 1,000 years, it has become a serious environmental threat. Solid waste management is a major global issue, especially in nations like Nigeria and India where waste generation is directly impacted by population growth. For example, only 20–30% of Nigeria's estimated 32 million tons of solid waste are properly collected each year. Common disposal techniques, like landfilling, are becoming more and more impractical due to their large land requirements, potential for soil fertility loss, drainage system clogging, and extensive environmental pollution.

The idea of "Green Concrete," which emphasizes the incorporation of waste materials into the concrete matrix, has gained popularity in reaction to these difficulties. According to Jibrin Sule et al. [1], replacing fine or coarse aggregates with waste plastic is a workable way to solve disposal issues while protecting natural resources. According to M Mahesh et al. [2], this dual-advantage strategy lessens the threat that plastic waste poses to the environment in addition to addressing the scarcity of raw materials. Many plastics, including polyethylene (PE) and polyvinyl chloride (PVC), are being studied for their potential as non-conventional aggregates. According to Batayneh et al., the addition of plastic frequently results in a decrease in workability and compressive strength, but it also presents opportunities for creating lightweight concrete. In certain construction applications where high load-bearing capacity is not the primary requirement, such lightweight materials can help reduce the self-weight of structural members. The purpose of this study is to assess the mechanical performance and viability of employing recycled plastic waste to produce more affordable and environmentally friendly building materials.

Objectives

The primary objective of this study is to assess the viability of utilizing waste plastic as a fine aggregate replacement in M20 concrete. Specific objectives include:

1. To determine the mechanical properties (compressive strength, flexural strength, and workability) of concrete with 0%, 5%, 10%, and 15% waste plastic replacement.
2. To identify the optimal percentage of plastic substitution that maintains the desired strength and workability of M20 concrete.
3. To evaluate physical properties and workability, determine how plastic aggregates affect the density (unit weight) and workability (slump) of the concrete mix compared to standard concrete.
4. To find the best replacement levels, identify the right percentage of plastic replacement that reduces strength loss while making the most of waste materials.

2. LITERATURE REVIEW

The researchers suggest and developed multiple solutions to improve performance of concrete and also to improve durability of concrete structures. The literature review of published papers is as follows.

M Mahesh (2016) Re-Use of Polyethylene Plastic Waste in Concrete- Due to the increase in population day by day and the changing in lifestyle has resulted in a rise in the quantity of plastic wastages. This research particularly deals with the possibility of using the waste polyethylene as partial replacement of fine or coarse aggregate in concrete. Concrete with 2%, 4%, 6% pulverized/non pulverized polyethylene material is prepared after doing the mix design. Mix design using IS Code method is carried out and cubes and cylinders are casted for M25 grade. The properties of concrete like compressive strength, split tensile strength are tested and compared with the results of standard specimen.

Osagic Ibhadoode (2017) Use of Waste Plastics in Cement-Based Composite for Lightweight Concrete Production - Concrete is the one of the most widely used construction material in overall world. These materials are used in residential driveways, paving, house foundations and gutter applications. Sustainable concrete structures are very beneficial as it consumed less energy, and follows the sustainable technology and release less greenhouse gases into the atmosphere, and also lesser cost. This paper focused on the utilization of waste plastics as replacement for fine aggregates in concrete for the preparation of lightweight concrete. The main aim of the research is to study that what is the effect of addition of granulated waste plastics on the compressive strength and density of concrete. Portland cement was mixed with th to produce the concrete of Grade 20 concrete design strength of mix ratio 1: 2.3: 3.5 and 0.65 w/c ratio was used for the experiment. Replacement proportions can be taken as a 0%, 5%, 10%, 15%, 20%, and 30% of plastic waste. Slump cone test should also be conducted by casting it into moulds of 150 mm by 150 mm by 150 mm sizes; cured for 3, 7, 14, and 28 days. The compressive strength and density of the concrete cubes were determined. The results shows that the slump and compressive strength of concrete decreased with increase in the percentage of replacement of plastic. It can be conclude from this research that, waste plastics are not too much good materials that can be used to improve compressive strength development in concrete matrix but they can be used in the production of lightweight concrete in construction.

Natarajan Venugopal (2015) Utilization of Waste Plastics as a Partial Replacement of Coarse Aggregate in Concrete Blocks- Day by day rapid industrialization and urbanization in the country improve lot of infrastructure development. This process creates to several problems like shortage of construction materials, increased productivity of wastages and other products. This research deals with the reuse of waste plastics as partial replacement of coarse aggregate in M20 grade concrete. Basically, M20 concrete is used for most construction works. Waste Plastics were added in 0%, 2%, 4%, 6%, 8% and 10% for the replacement of Aggregate. Tests were conducted on coarse aggregates, fine aggregates, cement and waste plastics to determine their physical properties. Paver Blocks and Solid Blocks of size 200 mm X 150 mm X 60 mm and 200 mm X 100 mm X 65 mm were casted and tested for 7, 14 and 28 days strength. The result pretend that the compressive strength of M20 concrete with waste plastics is 4% for Paver Blocks and 2% for Solid Blocks.

Manhal A Jibrael and Farah Peter (2016) Strength and Behavior of Concrete Contains Waste Plastic- This paper represents a method of strengthening a concrete by the addition of different percentages of recycled waste plastic (polyethylene). In these research, almost 126 samples of concrete are prepared, the Strength of concrete such as (compressive, splitting tensile and flexural strength) are investigated for a time interval of 7 to 28 days by 1%, 3% and 5% from fine aggregate recycled waste plastic (polyethylene). It is found that when waste plastic bottles increased from range of 0 % to 5% of the sand in the mix, compressive, tensile and flexural strength of concrete decreased by the ratios of 12.81, 10.71, and increase by 4.1% respectively at 7 days age and also these concrete strength decrease by the ratios 7.93, 28.6, and 23.6% at 28 days age.

3. EXPERIMENTAL INVESTIGATION

Material Used:

The material for the research are

The Cement: OPC 43 grade, (IS 8112:1989).

Aggregates: Natural sand, conforming to (IS 383:1970), and 20 mm crushed stone.

Plastic Waste: Clean, shredded high-density polyethylene (HDPE) waste, density 0.94 g/cm^3 . are mixed accordingly for the production of lightweight concrete.

Testing Procedure

The experimental program was designed to evaluate the mechanical integrity of concrete composites integrated with waste plastic aggregates. The procedure involved the casting, curing, and destructive testing of cubical and cylindrical specimens to determine compressive and splitting tensile strengths.

Test for compressive strength

The cubical specimen has been tested as per the procedure in IS 515:1959 code. the testing was done on pair of surfaces against which the cubes were casted. The compressive strength of 150mm x 150mm x 150mm cubes for 7, 14, 28 days were determined using a cubes compressive strength testing machine.

Test results

Presentation of test results the results of the test conducted on partial replacement of aggregate with waste plastic in concrete for mechanical properties have been tabulated as follow.

3.3.2 Compressive strength of concrete

The term “concrete strength” is usually used to indicate the uniaxial compressive strength of concrete. The compressive strength of concrete is defined as the strength of 28 days old specimens tested under monotonic uniaxial compressive load. Testing of Cube specimens of $15 \text{ cm} \times 15 \text{ cm} \times 15 \text{ cm}$ are being used.

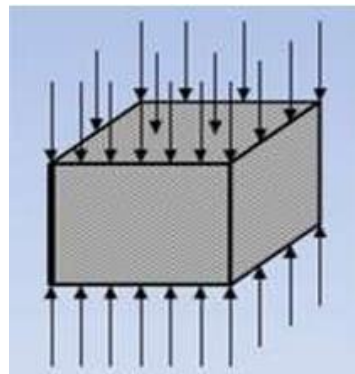


Figure 1. cube and cylinder subjected to loading

There are three failure modes for Cube.

- Under axial compression concrete fails in shear.
- The separation of the specimen into columnar pieces by what is known as splitting or columnar fracture.
- Combination of shear and splitting failure.



Figure No 2. Modes of failure of the specimen

Mix Proportion

The mix proportion used in this study was 1:2:4, which corresponds to M20 grade concrete. We used a total of 12 kg of cement, along with 13.23 kg of fine aggregate and 26.46 kg of coarse aggregate. We added waste plastic aggregates as a partial replacement for fine and coarse aggregates at replacement levels of 5%, 10%, and 15% by weight. We cast nine concrete cubes containing granulated waste plastic using $150 \text{ mm} \times 150 \text{ mm} \times 150 \text{ mm}$

molds to evaluate compressive strength and density. The fine aggregates were partially replaced with waste plastic at replacement percentages of 5%, 10%, and 15%. We followed standard procedures for mixing, casting, compaction, and curing, and all specimens were cured for 14 days. After the curing period, we measured the compressive strength of the concrete cubes.

4. RESULTS

Table 1. Compressive Strength test

Sr No.	Percentage Use	Cross sectional Area (mm ²)	Load (N)	Compressive Strength (N/mm ²)	Average
1	5.00%	225 mm ²	665 N	2.9 N/mm ²	2.66 N/mm ²
2		225 mm ²	600 N	2.67 N/mm ²	
3		225 mm ²	543 N	2.41 N/mm ²	
4	10.00%	225 mm ²	471 N	2.09 N/mm ²	2.01 N/mm ²
5		225 mm ²	457 N	2.03 N/mm ²	
6		225 mm ²	446 N	1.93 N/mm ²	
7	15.00%	225 mm ²	421 N	1.87 N/mm ²	1.80 N/mm ²
8		225 mm ²	401 N	1.78 N/mm ²	
9		225 mm ²	396 N	1.76 N/mm ²	

The results show that the compressive strength of concrete goes down as the percentage of waste plastic replacement increases. The average compressive strength of concrete with 5% waste plastic replacement was 2.66 N/mm². This was higher than the average compressive strength of concrete with 10% and 15% waste plastic replacement. The average compressive strength for concrete with 10% waste plastic replacement was 2.01 N/mm², while the strength for concrete with 15% waste plastic replacement was 1.80 N/mm². The 14 days compressive strength results are calculated. The compressive strength of concrete goes on reducing with increase in percentage of plastic pieces.

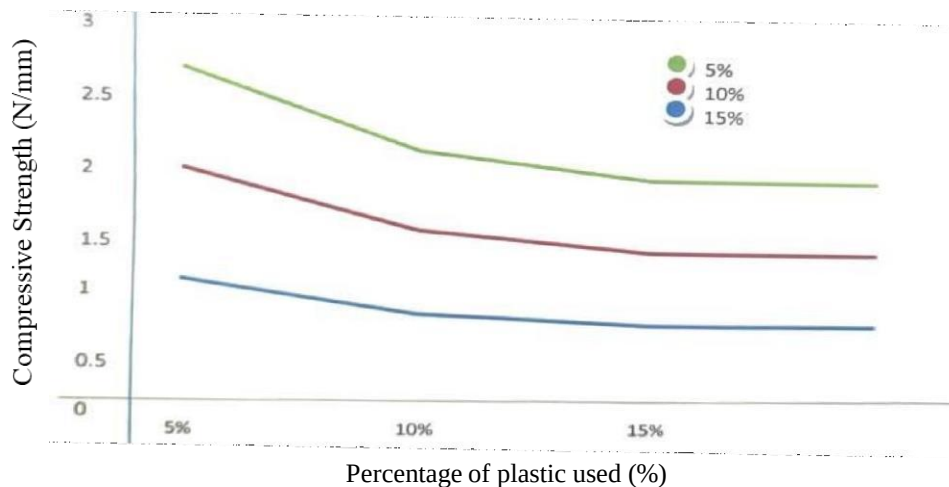


Figure 3. Comparison of compressive strength of concrete for various percentage of plastic.

5. CONCLUSION

- Using waste plastic as a partial substitute for fine aggregate in M20 grade concrete helps reduce plastic waste in the environment and supports the conservation of natural aggregates.
- The study shows that the replacement level should not exceed 5%. Going beyond this limit could lead to a notable drop in the compressive strength of the concrete.
- With the addition of waste plastic, the workability of the concrete improved.
- However, more experiments are needed to determine the best percentage of waste plastic that can be safely and effectively used in concrete without harming its mechanical performance.

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