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Research Paper

# EXPERIMENTAL INVESTIGATION ON THE MECHANICAL PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATE BY PLASTIC WASTE

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## ABSTRACT

This study presents an experimental investigation on the mechanical properties of concrete with partial replacement of fine aggregate by plastic waste. The increasing demand for natural river sand and the environmental issues associated with plastic waste disposal have led to the exploration of sustainable alternatives in concrete production. In this research, waste plastic materials such as polyethylene terephthalate (PET) and other recyclable plastics are processed into fine particles and used as a partial replacement for sand in concrete.

Concrete mixes are prepared by replacing fine aggregate with plastic waste at varying percentages, and the mechanical properties of the resulting concrete are evaluated. The study focuses on parameters such as compressive strength, split tensile strength, flexural strength, and workability of concrete at different curing periods (7, 14, and 28 days). The experimental results are compared with conventional concrete to assess performance.

The results indicate that the inclusion of plastic waste reduces the density of concrete and affects workability. An optimum percentage of plastic replacement is identified at which the concrete exhibits satisfactory strength and improved durability characteristics. Beyond this limit, the strength properties tend to decrease due to weak bonding between plastic particles and the cement matrix. However, the use of plastic waste contributes to sustainable construction by reducing environmental pollution and conserving natural resources.

The study concludes that partial replacement of fine aggregate with plastic waste is a viable approach for producing eco-friendly concrete suitable for non-structural and lightweight applications.

**Keywords:** Plastic Waste, Fine Aggregate Replacement, Sustainable Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength, Eco-Friendly Construction.

## I. INTRODUCTION

### 1.1 Background

Concrete is one of the most widely used construction materials in the world due to its strength, durability, and versatility. It is composed mainly of cement, fine aggregate (sand), coarse aggregate, and water. Among these constituents, fine aggregate plays a significant role in influencing the workability, strength, and overall performance of concrete. However, the excessive extraction of natural river sand has led to serious environmental concerns such as riverbed depletion, ecological imbalance, and reduction in groundwater levels.

At the same time, the rapid increase in plastic consumption has resulted in a huge accumulation of plastic waste, which is non-biodegradable and poses a major threat to the environment. Disposal of plastic waste through landfilling or incineration leads to pollution and health hazards. Therefore, there is an urgent need to develop sustainable solutions for managing plastic waste effectively.

### 1.2 Need for Study

The use of plastic waste as a construction material offers a promising approach to address both environmental and material scarcity issues. By incorporating processed plastic waste into concrete as a partial replacement for fine

aggregate, it is possible to reduce dependence on natural sand while simultaneously utilizing waste materials. This approach not only helps in waste management but also contributes to sustainable construction practices.

However, the inclusion of plastic waste in concrete may affect its mechanical properties such as compressive strength, tensile strength, and durability. Therefore, it is necessary to experimentally investigate the behaviour of concrete containing plastic waste to determine its suitability for construction applications.

### 1.3 Problem Statement

The disposal of plastic waste and the depletion of natural sand resources are two major challenges faced by the construction industry. While plastic waste can be used as an alternative material, its impact on the mechanical properties of concrete is not fully understood. There is a need to study how different percentages of plastic replacement influence the strength and performance of concrete.

### 1.4 Objectives

- To study the mechanical properties of concrete with plastic waste as fine aggregate
- To evaluate compressive, tensile, and flexural strength of modified concrete
- To analyze the effect of different percentages of plastic replacement
- To determine the optimum replacement level
- To compare the performance with conventional concrete

### 1.5 Scope of Study

This study focuses on the experimental investigation of concrete with partial replacement of fine aggregate by plastic waste. The research includes preparation of concrete mixes with varying percentages of plastic, testing of fresh and hardened concrete properties, and analysis of results. The study is limited to laboratory conditions and does not include large-scale structural implementation.

## II. LITERATURE REVIEW

The use of plastic waste in concrete has gained increasing attention in recent years due to environmental concerns and the need for sustainable construction materials. Various

researchers have investigated the effects of plastic waste as a partial replacement of fine aggregate on the mechanical and durability properties of concrete.

Frigione (2010) studied the use of recycled polyethylene terephthalate (PET) as fine aggregate in concrete and observed that the addition of plastic reduces the density of concrete while maintaining acceptable strength at lower replacement levels. The study highlighted that plastic waste can be effectively utilized in non-structural applications.

Hannawi, Kamali-Bernard, and Prince (2010) investigated the mechanical properties of mortar containing plastic aggregates such as PET and polycarbonate. They reported that the inclusion of plastic reduces compressive strength but improves ductility and energy absorption capacity.

Rahmani et al. (2013) studied the effect of replacing sand with PET particles in concrete. Their results showed that compressive strength decreases with an increase in plastic content, but the material exhibits improved flexibility and reduced brittleness.

Saikia and de Brito (2014) analyzed the influence of PET aggregates on concrete properties and concluded that plastic aggregates reduce density and strength but can be used effectively in lightweight concrete applications. They also observed that the size and shape of plastic particles significantly affect concrete behaviour.

Guendouz and Debieb (2016) investigated the use of plastic waste in sand concrete and found that partial replacement (10–20%) of sand with plastic can improve compressive and flexural strength due to better particle distribution. However, higher replacement levels resulted in strength reduction.

Charudatta P. Thosar and M. Husain (2017) studied the replacement of natural sand with plastic waste in concrete and reported that up to 20–40% replacement provides satisfactory results in terms of strength and durability for certain applications.

Shyam and Drishya (2018) examined the use of high-density polyethylene (HDPE) powder as a replacement for fine aggregate and found that

workability decreases with increasing plastic content. The study identified an optimum replacement level of around 5% for achieving better strength and workability.

Elango and Ashok Kumar (2018) conducted experimental studies on concrete with plastic fine aggregates and observed a reduction in compressive strength with increasing plastic content. However, the concrete showed improved resistance to chemical attack and enhanced elasticity.

Hargovind Shukla et al. (2019) reviewed various studies on plastic waste in concrete and concluded that plastic can be used as a partial replacement for fine aggregate to produce eco-friendly concrete with acceptable mechanical properties.

### III. DATA COLLECTION

#### 3.1 Overview

The methodology adopted in this study focuses on the experimental investigation of concrete with partial replacement of fine aggregate by plastic waste. The process involves collection and preparation of materials, mix design, casting of specimens, curing, and testing of both fresh and hardened concrete properties. A systematic procedure is followed to ensure accuracy and reliability of results.

#### 3.2 Materials Used

The materials used in this study include Ordinary Portland Cement (OPC), fine aggregate (sand), coarse aggregate, water, and plastic waste. Cement acts as the binding material, while fine and coarse aggregates provide strength and stability to the concrete.

Plastic waste such as PET bottles, plastic bags, and other recyclable plastics is collected from local sources. The plastic is cleaned, dried, and processed into fine particles to match the size of sand. Potable water is used for mixing and curing of concrete.

#### 3.3 Preparation of Plastic Aggregate

The collected plastic waste is washed thoroughly to remove impurities and then dried. The plastic is cut or shredded into small particles of size ranging from 1 mm to 4.75 mm, similar to fine aggregate. The processed plastic particles are sieved to obtain uniform grading.

Basic tests such as specific gravity and sieve analysis are carried out to determine the properties of plastic aggregate. The prepared plastic is stored in dry conditions before use.

#### 3.4 Mix Design

Concrete mix design is carried out as per IS 10262:2009 guidelines. M20 grade concrete is selected for the study. The mix proportion is determined based on standard procedures, maintaining a suitable water-cement ratio.

Fine aggregate is partially replaced with plastic waste at different percentages such as 0%, 5%, 10%, 15%, and 20%. The control mix (0% replacement) is also prepared for comparison. Adjustments are made to maintain workability of the concrete mix.

#### 3.5 Mixing Procedure

The mixing of concrete is carried out manually or using a mixer. Initially, dry materials such as cement, sand (with plastic replacement), and coarse aggregate are mixed thoroughly. Water is then added gradually while mixing to achieve a uniform and workable mix.

Proper care is taken to ensure uniform distribution of plastic particles within the concrete mix.

#### 3.6 Casting of Specimens

The prepared concrete is poured into standard moulds of required dimensions:

- Cubes (150 × 150 × 150 mm) for compressive strength
- Cylinders (150 mm diameter × 300 mm height) for split tensile strength
- Beams (100 × 100 × 500 mm) for flexural strength

The concrete is compacted using tamping or vibration to remove air voids. The moulds are kept undisturbed for 24 hours.

#### 3.7 Curing of Specimens

After 24 hours, the specimens are demoulded and placed in a water curing tank. Curing is carried out at a temperature of approximately 27±2°C. The specimens are cured for different durations such as 7 days, 14 days, and 28 days. Proper curing ensures adequate hydration of cement and development of strength.

#### 3.8 Testing Methods

The following tests are conducted to evaluate the properties of concrete:

- **Compressive Strength Test** (IS 516)
- **Split Tensile Strength Test** (IS 5816)
- **Flexural Strength Test**
- **Workability Test (Slump Test)**

The tests are carried out at different curing periods, and the results are recorded for analysis.

### 3.9 Data Collection and Analysis

The experimental data obtained from various tests is recorded systematically and presented in tabular form. Graphs are plotted to compare the performance of concrete with different percentages of plastic replacement.

The results are analyzed to determine the effect of plastic waste on mechanical properties and to identify the optimum replacement level.

## IV. RESULTS

### Workability of Concrete

The workability of concrete is evaluated using the slump test and compaction factor test. The results indicate that the workability decreases with an increase in the percentage of plastic waste. This is mainly due to the hydrophobic nature and irregular shape of plastic particles, which reduce the bonding with cement paste.

Concrete with 0% plastic shows maximum workability, while higher percentages such as 15% and 20% show reduced slump values. This indicates that the addition of plastic affects the flow characteristics of concrete.

### Compressive Strength of Concrete

The compressive strength of concrete is determined at 7, 14, and 28 days of curing. The results show that the strength initially increases with a small percentage of plastic replacement and then decreases with further increase in plastic content.

At lower replacement levels (around 5% to 10%), the compressive strength is comparable or slightly higher than conventional concrete. However, beyond this level, the strength decreases due to weak bonding between plastic particles and the cement matrix.

The maximum compressive strength is observed at the optimum replacement percentage.

### Split Tensile Strength of Concrete

The split tensile strength test results indicate that concrete containing plastic waste shows a similar trend to compressive strength. There is a slight improvement in tensile strength at lower replacement levels, followed by a decrease at higher percentages.

The reduction in tensile strength at higher plastic content is due to poor adhesion and increased voids in the concrete matrix.

### Flexural Strength of Concrete

Flexural strength of concrete beams is tested to evaluate the bending performance. The results show that flexural strength increases gradually with the addition of plastic up to an optimum level.

Beyond the optimum percentage, the flexural strength decreases due to reduced cohesion and bonding in the concrete. The presence of plastic particles improves energy absorption but affects overall strength at higher percentages.

### Density of Concrete

The density of concrete decreases as the percentage of plastic waste increases. This is because plastic has a lower specific gravity compared to natural sand. The reduction in density makes the concrete lighter, which can be beneficial for lightweight construction applications.

### Observations and Discussion

The experimental results indicate that the use of plastic waste as a partial replacement for fine aggregate significantly affects both fresh and hardened properties of concrete. The reduction in workability and strength at higher replacement levels is mainly due to weak bonding and increased porosity.

However, at optimum replacement levels, the concrete shows satisfactory performance and can be used for non-structural and lightweight applications. The use of plastic waste also contributes to environmental sustainability by reducing landfill waste and conserving natural resources.

### Important Findings

- Workability decreases with increase in plastic content
- Compressive strength increases at low replacement levels and decreases at higher levels

- Optimum replacement percentage gives maximum strength
- Tensile and flexural strength follow similar trends
- Density of concrete decreases with plastic addition
- Suitable for lightweight and non-structural applications

## V. CONCLUSIONS

The present experimental investigation on the mechanical properties of concrete with partial replacement of fine aggregate by plastic waste demonstrates that plastic waste can be effectively utilized as an alternative material in concrete production. The study confirms that the inclusion of plastic waste influences both fresh and hardened properties of concrete.

The results indicate that the workability of concrete decreases with an increase in plastic content due to the hydrophobic nature and irregular shape of plastic particles. However, proper mix design and compaction can help in maintaining acceptable workability for practical applications.

The compressive, split tensile, and flexural strengths of concrete show improvement at lower replacement levels of plastic waste. An optimum percentage of replacement is observed, at which the concrete achieves maximum strength. Beyond this level, the strength decreases due to weak bonding between plastic particles and the cement matrix and increased porosity.

It is also observed that the density of concrete decreases with the addition of plastic waste, resulting in lightweight concrete. This makes the material suitable for applications where reduced weight is advantageous, such as non-structural elements, pavements, and lightweight construction.

Overall, the study concludes that partial replacement of fine aggregate with plastic waste is a sustainable and eco-friendly solution for concrete production. It helps in reducing environmental pollution caused by plastic waste and conserves natural sand resources. With proper proportioning and quality control, plastic waste can be effectively used in concrete for various construction applications.

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