Experimental Investigation of Sustainable Concrete Incorporating Recycled LDPE And PET Plastic Waste as Partial Fine Aggregate Replacement

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Abstract*—The rapid increase in plastic waste generation and the depletion of natural construction resources have created a need for sustainable and environmentally sustainable alternatives in the construction industry. This study presents an experimental investigation on the utilization of recycled Low-Density Polyethylene and Polyethylene Terephthalate plastic waste as partial replacement of fine aggregate in concrete. Concrete specimens were prepared by replacing natural sand with processed plastic waste at replacement levels of 15 percent and 30 percent. The experimental program included material selection, processing of plastic waste, mix preparation, cube casting, curing, and compressive strength testing. The study also explores the concept of integrated green concrete by promoting the use of recyclable and eco-friendly materials for sustainable infrastructure development. The results indicate that concrete containing a moderate level of plastic replacement demonstrates better mechanical performance than higher replacement levels, with the 15 percent mixes showing more favorable compressive strength characteristics than the 30 percent mixes. The proposed approach contributes to reducing plastic waste disposal, conserving natural aggregate resources, and encouraging the adoption of circular economy principles in civil engineering applications. This investigation highlights the potential of recycled plastic waste as a viable material for the development of sustainable concrete.

Index Terms*—Green concrete, low-density polyethylene, partial fine aggregate replacement, polyethylene terephthalate, sustainable construction.

I. INTRODUCTION

The rapid growth of urbanization and industrialization has led to a significant increase in the generation of plastic waste, creating serious environmental and waste management challenges worldwide. Conventional methods of plastic disposal, such as landfilling and incineration, have adverse ecological impacts and demand the development of sustainable recycling strategies. At the same time, the construction industry is experiencing a continuous rise in the consumption of natural resources, particularly river sand, which is extensively used as fine aggregate in concrete production. The excessive extraction of natural sand has resulted in resource depletion and environmental degradation, potential to reduce the environmental footprint of construction activities [4]–[10].

Sustainable concrete has emerged as an effective solution by incorporating recycled and industrial by-products into conventional concrete mixtures. Among these, recycled plastic waste has gained considerable attention due to its abundance, durability, and potential to reduce the environmental footprint of construction activities. This study investigates the feasibility of utilizing recycled Low-Density Polyethylene and Polyethylene Terephthalate plastic waste as partial replacement of fine aggregate in concrete. Experimental concrete mixes were prepared with 15 percent and 30 percent replacement levels, and their performance was evaluated through standard casting, curing, and compressive strength testing procedures.

The primary objective of this research is to assess the suitability of recycled plastic waste for sustainable concrete production while promoting efficient waste utilization and conservation of natural resources.

The findings of this investigation contribute to the advancement of green construction practices and support the adoption of circular economy principles in the civil engineering sector.

II. MATERIALS AND METHODOLOGY

This study investigates the feasibility of utilizing recycled Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) plastic waste as partial replacement of fine aggregate in sustainable concrete. The experimental program involved the collection and processing of plastic waste, selection of conventional concrete ingredients, preparation of concrete mixes with different replacement levels, casting of cube specimens, curing, and evaluation of compressive strength using a Compression Testing Machine (CTM). The overall methodology adopted for the investigation is is illustrated in Fig. 1

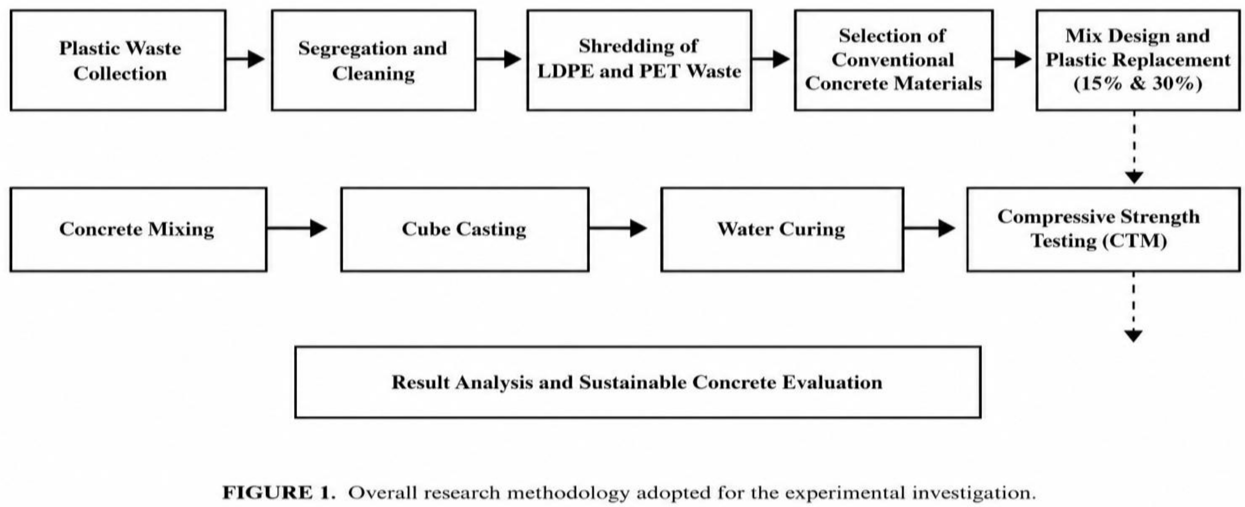

Figure 1. Overall research methodology adopted for the experimental investigation.

A. Materials Used

Figure 2. Raw materials used in the experimental program

The materials used in the present investigation consist of Ordinary Portland Pozzolana Cement (PPC), natural fine aggregate, coarse aggregate, potable water, recycled LDPE plastic waste, and recycled PET plastic waste. The research is also through the conceptual incorporation of supplementary sustainable materials such as fly ash, quarry dust, glass powder, ceramic powder, brick powder, rice husk ash, coconut fibres, and textile fibres. These materials contribute to reducing environmental impact and promoting sustainable construction practices.

Figure 2 presents the conventional and sustainable materials utilized for the preparation of the experimental concrete mixes.

B. Experimental Procedure

The experimental procedure involved the collection, segregation, cleaning, and shredding of recycled LDPE and PET plastic waste. Concrete mixes were prepared with 15% and 30% replacement levels by partially replacing fine aggregate with processed plastic waste. The constituent materials were weighed, mixed thoroughly, cast into standard cube moulds, cured under normal water curing conditions, and tested for compressive strength using a calibrated Compression Testing Machine (CTM).

III. EXPERIMENTAL PROGRAM AND MIX DESIGN

The experimental investigation was carried out to evaluate the feasibility of utilizing recycled Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) plastic waste as partial replacement of fine aggregate in concrete. Ordinary Portland Pozzolana Cement (PPC), natural fine aggregate, coarse aggregate, potable water, and processed plastic waste were used for the preparation of concrete specimens. The experimental program involved material characterization, mix preparation, cube casting, water curing, and compressive strength testing. Plastic waste was incorporated at replacement levels of 15% and 30% by weight of fine aggregate for both LDPE and PET mixes. Standard concrete cubes were cast, cured under normal water conditions, and the experimental procedures and testing methods were performed in accordance with the relevant provisions of IS 456:2000, IS 10262:2019, and IS 516:2021[1]–[3].

Figure 3 illustrates the sequential stages involved in the preparation of sustainable concrete mixes, including dry mixing of cement and aggregates, incorporation of recycled LDPE/PET and supplementary materials, concrete mixing and mould filling, and cube casting with adequate compaction before curing.

(a) Dry mixing of cement and aggregates.
(b) Addition of shredded LDPE/PET and supplementary materials.
(c) Concrete mixing and mould filling.
(d) Cube casting and compaction.

Figure 3. Concrete mixing and cube casting process.

A. Material Properties

Table I. Material properties of material used in the study.

Material	Description / Typical Property
Cement	Ordinary Portland Pozzolana Cement (PPC), IS 1489 (Part 1)
Fine Aggregate	Natural river sand, clean and well graded
Coarse Aggregate	Crushed angular aggregate (20 mm nominal size)
Water	Potable water suitable for concrete production
LDPE Plastic Waste	Cleaned and shredded recycled LDPE particles
PET Plastic Waste	Processed and shredded recycled PET particles
Supplementary Materials	Fly ash, glass powder, ceramic powder, brick powder, rice husk ash, quarry dust, fibres

B. Mix Proportions

Table II. Mix proportions of experimental concrete mixes

Mix ID	Plastic Type	Replacement Level of Fine Aggregate
CC	Conventional Concrete	0%
L15	LDPE	15%
L30	LDPE	30%
P15	PET	15%
P30	PET	30%

IV. RESULTS AND DISCUSSION

The experimental investigation was conducted to evaluate the influence of recycled Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) plastic waste on the compressive strength characteristics of sustainable concrete. Concrete specimens containing 15% and 30% replacement of fine aggregate with recycled plastic waste were prepared and tested using a Compression Testing Machine (CTM) after the specified curing period. The obtained results were compared with those of conventional concrete to assess the effect of plastic incorporation on the mechanical performance of the mixes.

The experimental observations indicate that the incorporation of recycled plastic waste influences the compressive strength of concrete depending upon the replacement percentage. Moderate replacement levels exhibited comparatively better performance than higher replacement levels, with the 15% replacement mixes demonstrating more favorable compressive strength characteristics than the 30% replacement mixes. This behavior may be attributed to the improved distribution of plastic particles within the concrete matrix at lower replacement levels, whereas excessive plastic content tends to reduce the bonding efficiency between the aggregate and cement paste.

A. Compressive strength analysis

The compressive strength values obtained from the CTM tests were analyzed and compared for all experimental concrete mixes. Conventional concrete exhibited the highest compressive strength of 30.05 MPa, while the incorporation of recycled LDPE and PET plastic waste resulted in a reduction in strength with increasing replacement percentage.

The 15% replacement mixes demonstrated comparatively better mechanical performance than the 30% replacement mixes, indicating that moderate plastic incorporation is more suitable for sustainable concrete applications. The comparative compressive strength values are presented in Fig. 5.

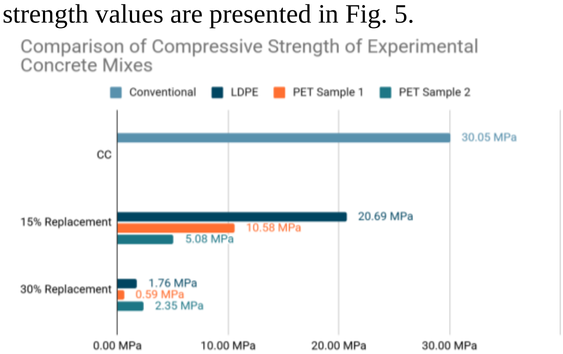

Figure 5. Comparison of Compressive Strength of Experimental Concrete Mixes.

Figure 5 presents the comparative compressive strength values obtained for conventional concrete and concrete mixes containing 15% and 30% recycled LDPE and PET plastic waste as partial replacement of fine aggregate.

B. Effect of Plastic Replacement Percentage

The influence of plastic replacement percentage on compressive strength was evaluated by comparing the performance of 15% and 30% replacement levels for both LDPE and PET concrete mixes. The trend observed from the experimental results indicates that increasing the replacement percentage beyond an optimum value lead to a gradual reduction in compressive strength. The variation in compressive strength with plastic replacement percentage is illustrated in Fig. 6.

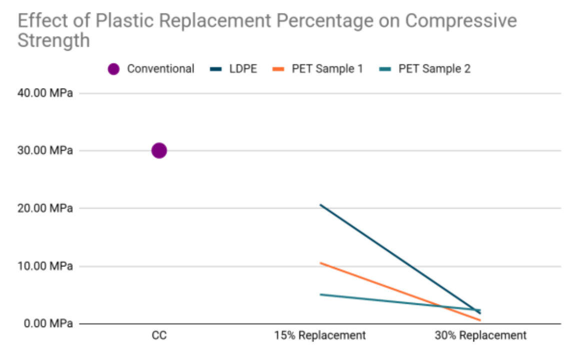

Figure 6. Effect of plastic replacement percentage on compressive strength

As illustrated in Fig. 6, an increase in the percentage of recycled plastic waste replacement resulted in a progressive reduction in compressive strength for both LDPE- and PET-modified concrete mixes. The reduction was more pronounced at the 30% replacement level, indicating that excessive plastic incorporation adversely affects the concrete matrix and aggregate–paste bonding characteristics.

C. Compression Testing and Failure Pattern Analysis

The cast concrete specimens were tested using a standard Compression Testing Machine after the curing period. The testing process and the corresponding failure patterns observed in the cube specimens provide valuable information regarding the structural behavior of sustainable concrete mixes. The CTM testing arrangement and representative failure patterns are shown in Fig. 7 and Fig. 8, respectively.

Figure 7 shows the experimental setup adopted for evaluating the compressive strength of concrete cube specimens.

Figure 7. Compression Testing Machine (CTM) setup and testing procedure.

Figure 8. Failure patterns of concrete cube specimens after compression testing.

Figure 8 illustrates the typical crack patterns and modes of failure observed in conventional and plastic-modified concrete specimens following compression testing.

Table III. Compressive strength results of experimental concrete mixes

Mix ID	Plastic Type	Replacement Level (%)	Compressive Strength (MPa)
CC	Conventional Concrete	0	30.05 MPa
L15	LDPE	15	20.69 MPa
L30	LDPE	30	1.76 MPa
P15-1	PET	15	10.58 MPa
P30-1	PET	30	0.59 MPa
P15-2	PET - 1	15	5.08 MPa
P30-2	PET - 2	30	2.35 MPa

Table III summarizes the compressive strength values obtained for the conventional concrete and recycled plastic concrete mixes. The experimental results indicate that lower plastic replacement levels provide comparatively better mechanical performance than higher replacement levels.

The experimental investigation demonstrated that concrete containing 15% recycled LDPE and PET plastic waste exhibited superior compressive strength performance compared with the 30% replacement mixes. The observed trend suggests that moderate incorporation of recycled plastic waste can contribute to sustainable concrete production while maintaining acceptable mechanical properties.

V. SUSTAINABILITY ASPECTS

The utilization of recycled LDPE and PET plastic waste in concrete offers a sustainable approach for mitigating the environmental impacts associated with plastic disposal and excessive consumption of natural fine aggregate. The incorporation of waste plastic materials into concrete promotes the principles of resource conservation, waste valorization, and circular economy by transforming non-biodegradable waste into value-added construction materials.

The proposed sustainable concrete system contributes to reducing the quantity of plastic waste directed to landfills and minimizes the extraction of natural river sand, thereby lowering the ecological footprint of construction activities. In addition, the incorporation of supplementary materials such as fly ash, rice husk ash, glass powder, ceramic powder, brick powder, and quarry dust further enhances the environmental sustainability of the concrete by promoting the beneficial utilization of industrial and agricultural by-products.

Although the experimental results indicate a reduction in compressive strength at higher plastic replacement levels, the study demonstrates the potential application of recycled plastic concrete in non-structural and low-load-bearing elements where environmental benefits and waste management considerations are of primary importance. The adoption of such sustainable construction practices supports the development of greener infrastructure and advances the implementation of circular economy principles within the civil engineering sector.

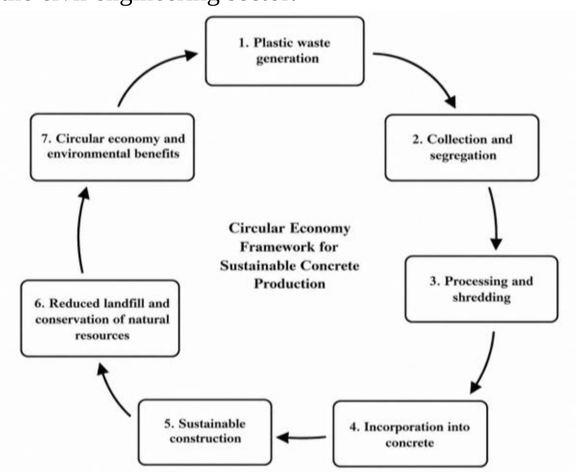

Figure 9. Circular economy framework for sustainable concrete production.

Figure 9 illustrates the integration of plastic waste recycling into the concrete production cycle, promoting resource conservation and sustainable construction practices.

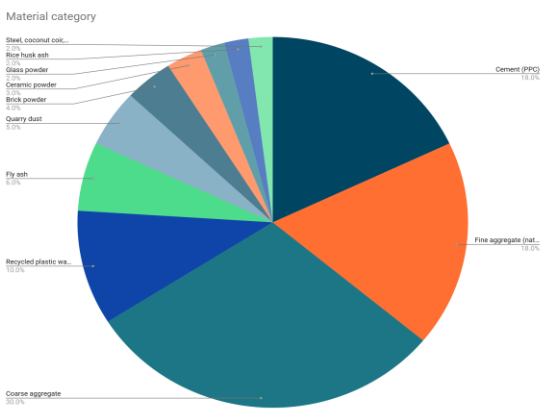

Figure 10. Relative contribution of sustainable materials incorporated in the proposed green concrete concept for the 30% replacement mix.

Figure 10 presents the conceptual distribution of recycled and supplementary sustainable materials considered in the development of the proposed green concrete system for the 30% replacement mix. The chart is intended to illustrate the relative contribution of constituent materials and does not represent the exact laboratory mix proportions.

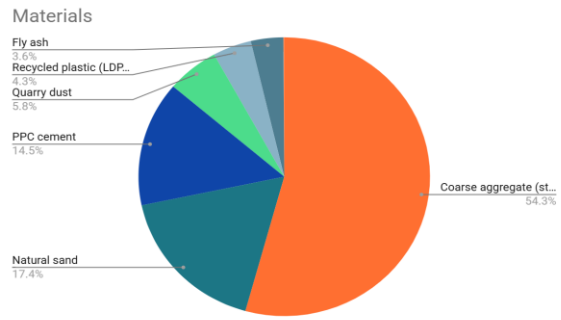

Figure 11. Relative contribution of constituent materials in the 15% recycled plastic concrete mix.

Figure 11 presents the percentage distribution of the primary constituent materials used in the 15% recycled plastic concrete mixture based on the actual experimental mix proportions.

VI. CONCLUSION AND FUTURE SCOPE

The present study investigated the feasibility of utilizing recycled Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) plastic waste as partial replacement of fine aggregate in sustainable concrete. Experimental concrete mixes containing 15% and 30% plastic replacement levels were prepared and evaluated through standard cube casting, curing, and compressive strength testing. The experimental results demonstrated that the incorporation of recycled plastic waste significantly influences the mechanical performance of concrete, with higher replacement levels resulting in a noticeable reduction in compressive strength. Among the investigated mixes, lower replacement levels exhibited comparatively better structural performance and practical applicability.

The study highlights the potential of recycled plastic waste as an environmentally responsible construction material capable of reducing landfill disposal and conserving natural aggregate resources. In addition to promoting sustainable waste management, the

proposed approach supports the adoption of circular economy principles within the construction industry.
Future investigations may focus on optimizing the particle size and surface treatment of recycled plastics to improve bonding characteristics within the cement matrix. Further research may also evaluate the long-term durability, flexural strength, tensile strength, water absorption, thermal performance, and field applications of plastic-modified concrete. The combined utilization of recycled plastics with other supplementary cementitious materials may provide additional opportunities for the development of high-performance and sustainable green concrete systems.

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