Journal of Gateway to Sustainable Research
February 2026, Vol. 1, Issue No. 1, pp: 1-5

An Experimental Studies On Partial Replacement Of Fine Aggregate With Recycled Plastic Waste In Concrete

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Abstract: Plastics have become an integral part of modern life because of their widespread use in everyday activities. As a result, their production and consumption continue to rise annually. However, most plastics are non-biodegradable and can persist in the environment for hundreds to thousands of years before breaking down. This prolonged degradation period leads to serious environmental concerns, negatively affecting ecosystems, wildlife, and human health. The exponential growth in construction industry, the demand for natural aggregates increased but leads to depletion of natural resources. To overcome this issue various types of plastic waste, including high density polyethylene (HDPE) are used as a partial replacement of fine aggregates in concrete. M40 grade of concrete through a series of laboratory experiments, various properties of plastic waste in concrete were done. The potential of plastic waste incorporated enhanced the performance and sustainability of concrete. This project contributed the advancement of eco-friendly construction practices and thus promoting circular economy principles in the construction industry.

Keywords: Plastic waste, Concrete, Fine Aggregates, Compressive Strength.

1. Introduction: Rapid industrialization and urbanization have led to a significant rise in solid waste generation, particularly plastic waste, which poses serious environmental and public health concerns. Due to its durability and versatility, the use of plastics is on the rise all over the world with millions of tonnes being produced every year and a significant proportion of it being produced in countries like India. Nevertheless, plastics are extremely slow to decompose, and they stay in the environment decades long and cause land, water, and marine pollution. Poor disposal may plug up drainage systems, pollute ground water, kill wildlife and give out deadly emissions during the burning process. Recycling activities are in place but they are not full of solution to increased waste levels. Certain sustainable management methods to be employed in the field of civil engineering are making use of plastic waste as an alternative to fine aggregate in concrete (which minimizes the overall environmental impact of concrete) and making use of plastic waste as a partial replacement of fine aggregate, thus minimizing the environmental impact of concrete and enhancing resource efficiency.

Recent research has determined the possibility of using plastic and other waste products in concrete as alternative substitutes of natural aggregates. According to Vivek et al. [1], the compressive strength of M20 concrete was significantly decreased when LDPE replaced it hence it could only be used as a non-structural material. In the same way, Saha et al. [2] and Almohana et al. [3] investigated polyethylene- and PET-based aggregates, which also demonstrated positive economic gains and enhanced thermal and acoustic performance in increased replacement levels, but are mainly applied to lightweight or non-structural components. Dalal et al. [4] found out that pharmaceutical blister waste had the ability to substitute fine aggregate in codal limits even though there was a decrease in its strength. Jahami et al. [5] noted that a combined waste incorporation must tend not exceed 25% in order to preserve mechanical performance. Rajawat et al. [6] and Namburi et al. [7] found that optimum strength was achieved at low replacement (approximately 310 percent) and then, the properties decreased. Ullah et al. [8] demonstrated enhanced confinement behavior with E-waste aggregate, and Nwaubani et al. [9] and Dawood et al. [10] showed inconsistent influences of dosage on strength and durability. Together, the literature suggests that partial substitution of aggregates with plastic waste, under controlled conditions, may help in the construction of a sustainable house, but the performance of the said method is highly contingent on the type, percentage, and treatment of the waste substance.

2. Materials:

Cement: PPC cement is made by thoroughly combining pozzolanic ingredients with clinker and gypsum. Pozzolanic materials are finely divided siliceous or aluminous materials that, when combined with calcium hydroxide in the presence of water, generate cementitious compounds. Fly ash, calcined clay, and volcanic ash are among the most commonly utilised pozzolanic ingredients in PPC. PPC cement has various advantages, including greater workability, less heat hydration, increased durability, and a lower environmental effect.

Fig 1. Portland Pozzolana Cement

Fine Aggregate: Fine aggregate, sometimes referred to as sand, is a granular material that is usually made up of particles with a diameter of less than 4.75 millimeters. It is one of the basic ingredients of concrete, along with water, cement, and coarse aggregate. Concrete's workability, durability, and strength are all greatly influenced by fine aggregate.

Fig. 2 Fine Aggregate

Coarse Aggregate: Coarse aggregates are rock-based construction materials that cannot pass through a 4.75mm IS sieve. Natural gravel or crushed stone is used in concrete to offer strength and durability. Materials used include natural gravel, crushed stone, and reclaimed concrete debris.

Fig 3 Coarse Aggregate

Water: Water is a key component in the hydration process of cement, directly influencing the strength development of concrete. Therefore, both the quantity and quality of water must be carefully controlled to ensure proper performance. The water used should not contain harmful organic or inorganic impurities that could adversely affect the concrete properties. In construction practice, water plays a crucial role not only in mixing but also in curing, in accordance with the provisions of IS 456:2000. For this study, clean potable water free from visible contaminants was utilized.

Plastic Waste: High-Density Polyethylene (HDPE) is a thermoplastic polymer derived from petroleum and widely used due to its durability and lightweight nature. It is categorized as Type 2 plastic and is extensively recycled for manufacturing products such as plastic lumber and composite materials. HDPE is commonly found in everyday items including milk cans, oil containers, shampoo and detergent bottles, and bleach packaging. Owing to its high strength-to-density ratio, HDPE offers excellent mechanical performance while remaining relatively light. In this study, HDPE waste processed into granular form was utilized as a material component.

Fig. 4 Plastic Waste

3. Methodology & Mix Design: The experimental program included material testing, mix design preparation, casting, curing, and mechanical testing.

Mix Design: M40 grade concrete was designed as per IS 10262:2019 guidelines. Target mean strength:

$$f_{target} = f_{ck} + 1.65S \quad (1)$$

For M40 grade with standard deviation of 5 MPa, the target strength was calculated as 48.25 MPa.

Adopted water-cement ratio: 0.36

Cement content: 533 kg/m^3

Water content: 192 kg/m^3

The final mix proportion was: 1 : 0.65 : 1.27 (Cement : Fine Aggregate : Coarse Aggregate) with W/C ratio = 0.36

Plastic waste replaced fine aggregate at 0%, 10%, 20%, 30%, and 40%.

4. Experimental Investigation

4.1 Tests on Cement: The cement was tested to identify the basic properties of the cement and to ensure its applicability in making concrete; the tests undertaken are as follows: the fineness test, the standard consistency test to test the water content required to prepare cement of normal consistency, the initial and final setting test and specific gravity test to test the relative density of cement. All tests gave results within the bounds of the IS code.

4.2 Tests on Aggregates: Sieve analysis, water absorption test, and specific gravity tests were used to verify that it was suitable to be used in the manufacture of concrete.

4.3 Fresh Concrete Test: Slump Test, Workability reduced gradually as the plastic content increased because the density became lower and the plastic particles had poor bonding qualities.

4.4 Hardened Concrete Tests: Compressive strength of cube specimens of dimensions 150 mm x150mm x150mm was tested at curing ages of 3, 7, 14 and 28 days. The findings revealed that the control mix attained the target strength. The 10% replacement mixture showed a slight decrease in the strength, and the 20% replacement was still reasonable and acceptable strength levels. But mixes of 30 percent and 40 percent replacement showed a significant decrease in compressive strength of the mix compared to the control mix.

Split Tensile Strength Test: Cylindrical samples (300 mm height × 150 mm diameter) were on test. The same tendency could be noted, optimum performance was at 10-20 percent replacement.

5. Results and Discussion: This part shows and discusses the experimental results of the experiments that were performed on cement, aggregates, fresh concrete, and hardened concrete in which recycled plastic waste was added as a partial substitute of fine aggregate.

5.1 Properties of Cement: Cement fineness was determined to be 6% residue on 90 0m sieve, which is within the requirements of IS 4031 (Less than10%). This implies that there should be sufficient particle size distribution to achieve hydration and development of strength. The mean consistency was derived at 33.5 and this is within the allowable ranges. The time initially taken by setting was measured as 35 minutes, and the time taken at the end of setting was 570 minutes. The two values meet codal requirements, which proves that the cement applied was good in structural concrete. Cement specific gravity was 2.83 which is within the normal range of PPC (2.8 to 3.15). The results of this provided reliability in mix design calculations.

5.2 Properties of Aggregates and Plastic Waste: Coarse and fine aggregate met the requirements of grading and physical property according to the IS 383. The values of the specific gravity were: Fine aggregate = 2.62 Coarse aggregate = 2.74 . Plastic wastes (HDPE grains) possessed remarkably low specific gravity (0.88) and this had a direct impact on the specific concrete density and workability. Plastic particles are lightweight and hydrophobic, which is why they are more likely to decrease the internal friction and bonding efficiency with an increased percentage of their use.

5.3 Fresh Concrete – Workability: Slump Test Results: The slump value reduced with increasing rate of the percentage of plastic waste.

Table 1: Slump Values and Workability Characteristics of Concrete with Varying Plastic Replacement Levels

Mix	Plastic Replacement (%)	Slump (mm)	Observation
M1	0%	25	True slump
M2	10%	23	Slight reduction
M3	20%	21	Moderate reduction
M4	30%	18	Low workability
M5	40%	15	Harsh mix

The observed reduction in slump with increasing plastic content can be attributed to several material characteristics of the plastic particles. Due to their low specific gravity, plastic grains tend to reduce the overall cohesion of the concrete mix. Additionally, the smooth and non-absorbent surface of plastic limits effective bonding with the cement paste, thereby decreasing internal friction and consistency. At higher replacement levels, the presence of plastic also contributes to increased internal voids within the mix, further reducing workability. Despite this gradual decline, concrete mixtures containing up to 20% plastic replacement remained adequately workable without the use of chemical admixtures. However, when the replacement level exceeded 30%, compaction became comparatively difficult, indicating a noticeable loss in workability.

5.4 Hardened Concrete Properties: Compressive strength Compressive strength was tested at 3, 7, 14, and 28 days. The 28-day results are summarized below:

Table 2: 28-Day Compressive Strength of Concrete with Different Percentages of Plastic Waste Replacement

Mix	Plastic Replacement (%)	28-Day Compressive Strength (MPa)
M1	0%	48.5
M2	10%	46.8
M3	20%	44.2
M4	30%	39.5
M5	40%	34.8

The results indicate that a 10% replacement of natural sand with plastic resulted in only a marginal reduction in compressive strength (approximately 3–4%). When replaced by 20 percent, a moderate reduced by approximately 8-10 percent was recorded, still the strength was structurally acceptable and checked higher than the intended characteristic strength of M40 concrete. Conversely, replacement level of 30 and 40 resulted in huge loss of strength. The decrease in strength at increased replacement percentages could be explained by the existence of the weak interfacial transition zone (ITZ) between the plastic particles and cement paste, the lesser stiffness of plastic particles than natural sand, and the high content of the voids in the matrix. In general, the replacement level to 20% can be said to be structurally viable.

5.5 Split Tensile Strength: The 28-day split tensile strength results are presented below:

Table 3: Twenty-Eight Day Compressive Strength of Concrete Incorporating Various Percentages of Plastic Waste as Fine Aggregate Replacement

Mix	Plastic Replacement (%)	Split Tensile Strength (MPa)
M1	0%	4.2
M2	10%	4.1
M3	20%	3.9
M4	30%	3.5
M5	40%	3.1

The tensile strength exhibited a trend similar to that of compressive strength. The 10 percent replacement had the most insignificant reduction, which meant that a small amount of plastic could have a small effect of crack-bridging due to the elasticity of the plastic particles. But after 20 percent substitution, tensile strength was seriously reduced because of reduced aggregate interlock, due to the less stiffness of plastic than natural aggregates, and due to the poor bonding surface between plastic particles and cement matrix.

5.6. Density and Failure Pattern:

Density: As a result of low specific gravity of plastic waste, concrete density reduced as the percentage of replacement increased. This implies that there is a possibility of making lightweight concrete components.

Pattern of failure: Control mix showed normal brittle failure. Specimens with plastic modifications exhibited a bit slower cracking and this suggested slight enhancement of ductility of the specimens at low replacement.

6. Conclusions: Based on the experimental investigation, the following conclusions are drawn:

- Workability decreases with increasing plastic percentage.
- Optimum replacement level lies between 10% and 20% for M40 grade concrete.
- Higher replacement levels (above 30%) significantly reduce compressive strength.
- Plastic-modified concrete is suitable for non-structural elements such as pavements, partition walls, and lightweight blocks.
- Utilization of plastic waste contributes to sustainable construction and resource conservation.

References:

1. Vivek, S., Krishna, P. H., & Rao, T. G. (2023). A study on the mechanical behavior of concrete made with partial replacement of fine aggregate with waste plastic (LDPE). Materials Today: Proceedings.
2. Saha, S., Sau, D., & Hazra, T. (2023). Economic viability analysis of recycling waste plastic as aggregates in green sustainable concrete. Waste Management, 169, 289-300.
3. Almeshal, I., Tayeh, B. A., Alyousef, R., Alabduljabbar, H., & Mohamed, A. M. (2020). Eco-friendly concrete containing recycled plastic as partial replacement for sand. Journal of Materials Research and Technology, 9(3), 4631-4643.
4. Dalal, S. P., Dalal, P., Motiani, R., & Solanki, V. (2022). Experimental investigation on recycling of waste pharmaceutical blister powder as partial replacement of fine aggregate in concrete. Resources, Conservation & Recycling Advances, 14, 200076.
5. Jahami, A., & Issa, C. A. (2023). Exploring the use of mixed waste materials (MWM) in concrete for sustainable construction: A review. Construction and Building Materials, 398, 132476.
6. Rajawat, S. P. S., Rajput, B. S., & Jain, G. (2022). Concrete strength analysis using waste plastic as a partial replacement for sand. Materials Today: Proceedings, 62, 6824-6831.
7. Varma, N. R., & Chekravarthy, D. (2022). An experimentation made on plastic and demolished waste in concrete mix. Materials Today: Proceedings, 62, 3473-3478.
8. Ullah, S., Qureshi, M. I., Joyklad, P., Suparp, S., Hussain, Q., Chaiyasarn, K., & Yooprasertchai, E. (2022). Effect of partial replacement of E-waste as a fine aggregate on compressive behavior of concrete specimens having different geometry with and without CFRP confinement. Journal of Building Engineering, 50, 104151.
9. Nwaubani, S. O., & Parsons, L. A. (2021). Properties, durability and microstructure of concrete incorporating waste electrical and electronic plastics as partial replacement for aggregates in concrete. Case Studies in Construction Materials, 15, e00731.
10. Dawood, A. O., Hayder, A. K., & Falih, R. S. (2021). Physical and mechanical properties of concrete containing PET wastes

as a partial replacement for fine aggregates. Case Studies in Construction Materials, 14, e00482.