Experimental Study on the Use of E-Waste Plastic as Partial Replacement of Coarse Aggregate in M30 Concrete

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Abstract

Rapid urbanisation has increased the consumption of natural aggregates in concrete, leading to environmental degradation and depletion of natural resources. Simultaneously, the generation of electronic waste (E-waste), particularly plastic components, has emerged as a major environmental challenge due to its non-biodegradable nature. This study investigates the feasibility of utilising shredded E-waste plastic as a partial replacement for natural coarse aggregates in M30 grade concrete. Concrete mixes were prepared with 0%, 5%, 10%, and 15% replacement of coarse aggregates by E-waste plastic. The workability of fresh concrete was evaluated using the slump test, while mechanical properties were assessed through compressive strength, split tensile strength, and flexural strength tests at curing ages of 7, 14, 28, 56, and 90 days. The results indicate a gradual reduction in workability and strength with increasing E-waste content. However, concrete containing 5% E-waste plastic exhibited mechanical performance comparable to conventional concrete, with marginal strength reduction and improved sustainability benefits. The study concludes that limited replacement of coarse aggregate with E-waste plastic is feasible for producing eco-friendly concrete suitable for selected structural and non-structural applications.

Keywords: E-waste plastic, sustainable concrete, coarse aggregate replacement, M30 concrete, mechanical properties

1. Introduction

The construction industry is one of the largest consumers of natural resources, particularly river sand and crushed stone aggregates. Excessive extraction of these materials has resulted in ecological imbalance, riverbed degradation, and increased material costs. At the same time, the rapid advancement of electronic technology has led to the generation of enormous quantities of electronic waste, much of which contains plastic components that are difficult to recycle and dispose of safely.

Incorporating waste materials into concrete has been widely recognised as an effective approach for achieving sustainability in construction. Previous studies have demonstrated that plastic and E-waste materials can be used as aggregate substitutes; however, their influence on workability and mechanical performance varies significantly depending on replacement levels. The smooth, hydrophobic nature of plastic particles often leads to weaker bonding with cement paste, affecting strength development.

This study aims to experimentally evaluate the mechanical and workability properties of M30 grade concrete incorporating shredded E-waste plastic as a partial replacement for coarse aggregate. The research focuses on identifying an optimum replacement level that balances structural performance with environmental benefits.

2. Materials and Methods

2.1 Materials

Ordinary Portland Cement (OPC) of 53 grade conforming to IS 12269 was used. Natural river sand (Zone II) and crushed granite coarse aggregates of 20 mm nominal size were employed as fine and coarse aggregates, respectively. E-waste plastic was collected from discarded electronic devices such as keyboards and computer casings, cleaned, and mechanically shredded into particles of size 10–20 mm. Potable water conforming to IS 456 was used for mixing and curing.

2.2 Mix Proportions

Concrete mixes were designed for M30 grade as per IS 10262:2019. Four mixes were prepared with 0%, 5%, 10%, and 15% replacement of coarse aggregate by E-waste plastic (by weight). Cement, water, and fine aggregate contents were kept constant for all mixes.

2.3 Experimental Programme

Workability was assessed using the slump cone test. Mechanical properties were evaluated through:

- Compressive strength test (IS 516:2018)
- Split tensile strength test (IS 5816:1999)
- Flexural strength test (IS 516:2018)

Specimens were cured and tested at 7, 14, 28, 56, and 90 days. The results were recorded and analysed to assess the influence of E-waste plastic content.

3. Results and Discussion

3.1 Workability

Slump values decreased consistently with increasing E-waste content. The reduction is attributed to the hydrophobic and smooth surface of plastic particles, which reduces cohesion and paste–aggregate interaction. The control mix showed the highest workability, while the 15% replacement mix exhibited the lowest slump.

3.2 Compressive Strength

Compressive strength increased with curing age for all mixes. However, strength values decreased as the percentage of E-waste plastic increased. The 5% replacement mix showed strength values close to the control concrete, while 10% and 15% replacements resulted in noticeable reductions due to weaker interfacial bonding and lower stiffness of plastic aggregates.

3.3 Split Tensile Strength

Split tensile strength followed trends similar to compressive strength. The 5% E-waste mix exhibited acceptable tensile performance, whereas higher replacement levels led to reduced tensile resistance.

3.4 Flexural Strength

Flexural strength decreased with increasing E-waste content; however, the 5% replacement mix maintained satisfactory bending performance. The improved ductility provided by plastic particles contributed to better energy absorption at lower replacement levels.

4.1 Workability Results

The workability of fresh concrete was assessed using the slump cone test. The results showed a clear reduction in slump with an increase in E-waste plastic content. The control mix (0% E-waste) exhibited the highest slump value, indicating better workability. As the percentage of E-waste increased to 15%, the slump value decreased significantly.

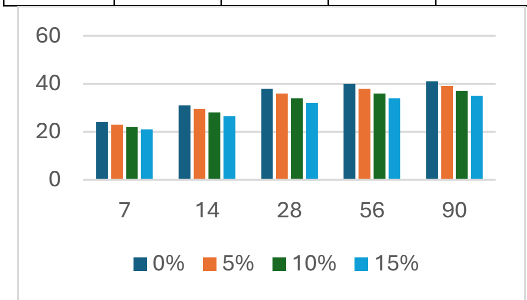
This reduction in workability is mainly attributed to the smooth, hydrophobic surface of E-waste plastic particles, which reduces cohesion and limits effective bonding with the cement paste. Although workability decreased, mixes with up to 5% E-waste plastic remained workable for normal concreting operations.

4.2 Compressive Strength Results

Table 1 presents the compressive strength results of M30 concrete with varying percentages of E-waste plastic at different curing ages.

Table 1: Compressive Strength of Concrete with E-Waste Plastic (MPa)

Age (Days)	0%	5%	10%	15%
7	24.0	23.0	22.0	21.0
14	31.0	29.5	28.0	26.5
28	38.0	36.0	34.0	32.0
56	40.0	38.0	36.0	34.0
90	41.0	39.0	37.0	35.0



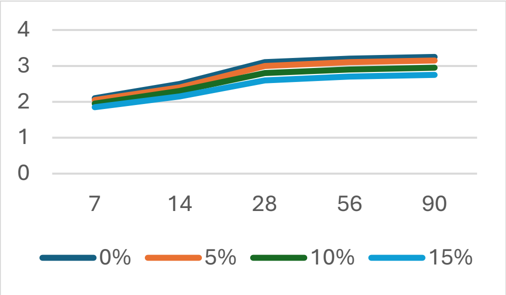
Compressive strength increased with curing age for all mixes, indicating continued hydration. However, an increase in E-waste content resulted in a gradual reduction in strength. The 5% replacement mix showed strength values close to the control mix, with only marginal reduction. At higher replacement levels (10% and 15%), the reduction became more pronounced due to weaker interfacial bonding and lower stiffness of plastic aggregates.

4.3 Split Tensile Strength Results

The split tensile strength results are shown in Table 2.

Table 2: Split Tensile Strength of Concrete with E-Waste Plastic (MPa)

Age (Days)	0%	5%	10%	15%
7	2.10	2.05	1.95	1.85
14	2.50	2.40	2.30	2.15
28	3.10	3.00	2.80	2.60
56	3.20	3.10	2.90	2.70
90	3.25	3.15	2.95	2.75



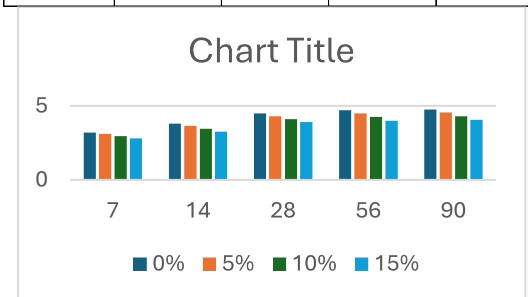
Similar to compressive strength, split tensile strength increased with curing age but decreased with higher E-waste replacement levels. The 5% E-waste mix exhibited tensile strength values close to the control concrete, while mixes containing 15% E-waste showed the lowest tensile resistance. The reduction is attributed to weak bonding at the aggregate–paste interface and reduced load transfer capability.

4.4 Flexural Strength Results

Flexural strength results obtained from beam specimens are presented in Table 3.

Table 3: Flexural Strength of Concrete with E-Waste Plastic (MPa)

Age (Days)	0%	5%	10%	15%
7	3.20	3.10	2.95	2.80
14	3.80	3.65	3.45	3.25
28	4.50	4.30	4.10	3.90
56	4.70	4.50	4.25	4.00
90	4.75	4.55	4.30	4.05



Flexural strength followed trends similar to compressive and tensile strengths. The control mix exhibited the highest flexural strength at all ages. The 5% E-waste replacement mix maintained satisfactory flexural performance, while higher replacement levels showed a reduction due to decreased stiffness of plastic aggregates. However, improved ductility and energy absorption were observed at lower replacement levels.

4.5 Optimum Replacement Level

Based on the overall results, a **5% replacement of coarse aggregate with E-waste plastic** was identified as the optimum level. At this percentage, concrete exhibited acceptable workability and mechanical strength with minimal reduction compared to conventional concrete, while providing significant environmental benefits through waste utilisation.

5. Conclusions

Based on the experimental investigation, the following conclusions are drawn:

1. Incorporation of E-waste plastic reduces workability and mechanical strength with increasing replacement levels.
2. Concrete containing 5% E-waste plastic exhibited mechanical properties close to conventional M30 concrete.
3. Higher replacement levels (10% and 15%) caused significant reductions in strength due to weak bonding and reduced density.
4. An optimum replacement level of **5% E-waste plastic** is recommended for achieving a balance between strength performance and sustainability.
5. The use of E-waste plastic in concrete contributes to waste reduction, conservation of natural aggregates, and environmentally responsible construction practices.

5. References

[1] Bureau of Indian Standards, *IS 10262:2019 – Concrete Mix Proportioning – Guidelines*, New Delhi, India, 2019.

[2] Bureau of Indian Standards, *IS 456:2000 – Plain and Reinforced Concrete – Code of Practice*, New Delhi, India, 2000.

[3] Bureau of Indian Standards, *IS 516:2018 – Methods of Tests for Strength of Concrete*, New Delhi, India, 2018.

[4] Bureau of Indian Standards, *IS 5816:1999 – Splitting Tensile Strength of Concrete*, New Delhi, India, 1999.

[5] Bureau of Indian Standards, *IS 1199:1959 – Methods of Sampling and Analysis of Concrete*, New Delhi, India, 1959.

[6] Bureau of Indian Standards, *IS 383:2016 – Specification for Coarse and Fine Aggregates from Natural Sources for Concrete*, New Delhi, India, 2016.

[7] A. M. Neville, *Properties of Concrete*, 5th ed., Pearson Education, 2011.
[8] P. K. Mehta and P. J. M. Monteiro, *Concrete: Microstructure, Properties and Materials*, 4th ed., McGraw-Hill, 2014.
[9] S. Mindess, J. F. Young, and D. Darwin, *Concrete*, 2nd ed., Prentice Hall, 2003.
[10] R. Kumar and S. Baskar, “Utilization of electronic waste in concrete,” *Int. J. Earth Sciences and Engineering*, vol. 4, no. 6, pp. 918–925, 2011.
[11] M. Senthil Kumar and K. Baskar, “Recycling of E-waste plastics in concrete: A review,” *Waste Management & Research*, vol. 32, no. 10, pp. 1014–1020, 2014.
[12] A. Choudhary, J. Gupta, and R. Jain, “Use of plastic waste as partial replacement of coarse aggregate in concrete,” *J. Eng. Research and Applications*, vol. 4, no. 1, pp. 55–60, 2014.