Improving Concrete Strength with E-Waste

Arun Kumar Hardaha[1], Prof. Anubhav Rai[2], Prof. Siddhartha Deb[3]

[1] MTech Student, Department of Civil Engineering, Gyan Ganga Institute of Technology & Science Jabalpur Madhya Pradesh 482003

[2,3] Assistant Professor, Department of Civil Engineering, Gyan Ganga Institute of Technology & Science Jabalpur Madhya Pradesh 482003

Abstract- *This study explores the use of electronic waste (e-waste) as a partial replacement for coarse aggregate in M35 grade concrete to promote sustainable construction. Initial tests examine e-waste's physical properties to assess its compatibility with traditional concrete materials. A concrete mix is developed with varying proportions of e-waste as a substitute for conventional aggregates. Mechanical properties like compressive and flexural strength are evaluated. Results determine the optimal e-waste replacement level for enhanced concrete performance. While the findings support the use of e-waste in concrete, limitations related to material variability, specific concrete grades, and environmental factors suggest areas for future research. This research highlights the potential of e-waste in sustainable concrete solutions.*

Keywords- E waste, concrete, coarse aggregate, compressive strength, flexural strength.

I. INTRODUCTION

Electronic waste (e-waste), which includes discarded electronic devices such as smartphones, computers appliances, is a growing environmental concern due to its hazardous contents like lead, mercury, and cadmium. The rapid turnover of technology has led to a significant increase in e-waste, posing serious risks to human health and the environment. However, by recycling e-waste, valuable materials such as metals can be recovered and reused, providing a sustainable solution to both waste disposal and resource conservation.

This research investigates the potential of incorporating e-waste materials as an alternative to traditional aggregates in concrete production. The study focuses on evaluating various proportions of e-waste components, such as metals in concrete mixtures to enhance their mechanical properties, including compressive strength and durability. Moreover, the optimal replacement ratio of e-waste is determined to ensure a balanced mix that maintains workability while improving structural performance.

The results suggest that the incorporation of e-waste not only reduces landfill waste but also conserves natural resources and lowers construction costs. By supporting the use of recycled materials, this approach aligns with sustainable construction practices and contributes to a circular economy, where waste is transformed into valuable building resources, benefiting both the environment and the construction industry.

Incorporating waste materials like marble dust, iron ore tailings, glass fibers, and e-waste into concrete provides diverse environmental, economic, and performance advantages. Environmentally, it reduces landfill waste and decreases reliance on natural resources by substituting traditional raw materials like sand and gravel. This approach also cuts carbon emissions, especially with the use of supplementary materials like fly ash and blast furnace slag, which can lower the need for cement. Economically, waste materials are generally more affordable than standard concrete ingredients, resulting in potential cost savings for construction projects. Industries generating by-products can further reduce waste management costs by repurposing these materials in concrete mixes. Performance-wise, waste materials like polypropylene and glass fibers enhance tensile and flexural strength, while additives like slag and fly ash bolster concrete's resistance to chemicals and increase durability. Some by-products also improve the workability of concrete, making construction processes easier. The integration of e-waste brings additional benefits, as it allows the recovery of valuable components such as metals reducing the demand for new materials. E-waste use also supports waste reduction, addresses disposal challenges, and enhances material properties like compressive strength. Embracing recycled e-waste aligns with sustainable construction principles by creating a circular economy where waste is transformed into valuable building resources, thereby lowering overall ecological impact and cutting project costs.

II. LITERATURE REVIEW

Numerous studies have examined the potential of utilizing e-waste as a partial substitute for natural aggregates in concrete to enhance its mechanical properties, improve durability, and promote sustainability. Padmapriya et al. (2023) [3] explored the effect of replacing 15% of coarse aggregate with e-waste in M30 grade concrete, observing improvements in compressive strength at both 7 and 28 days, with this percentage identified as the optimal level for strength gains. Similarly, Dixit et al. (2022) [6] investigated the use of e-waste, particularly ground printed circuit boards (PCBs), as a partial coarse aggregate substitute, noting that its addition can effectively increase the compressive strength of concrete.

Goh et al. (2022) [10] employed a life cycle assessment (LCA) using SimaPro software to examine environmental impacts of e-plastic in concrete, testing various scenarios with partial or full substitution of cement with GGBS and fly ash. The results showed a reduction in global warming potential (GWP) for e-plastic concrete mixes, although some scenarios indicated increased emissions from manufacturing additives, highlighting trade-offs in environmental performance.

Suleman et al. (2020) [7] found that e-plastic replacements at 5.5% and 11% enhanced the 28-day compressive strength of concrete, although strength declined at higher replacement levels. Needhidasan et al. (2019) [8] observed that M20 concrete incorporating 10% e-waste replacement showed higher compressive and flexural strengths, while a 12.5% substitution improved split tensile strength, indicating that e-waste can offer comparable performance to traditional aggregates.

Other studies focused on the impact of e-waste on durability and workability in concrete. For instance, Ullah et al. (2021) [11] investigated the effect of substituting natural aggregates with e-waste and found improvements in workability, durability, and resistance to thermal and abrasion damage, even though mechanical strengths slightly decreased with increased e-waste content. Raut et al. (2018) [13] highlighted the potential of e-waste as an alternative to both fine and coarse aggregates, underscoring its sustainability benefits.

Akram et al. (2015) [4] found that when combined with fly ash, e-plastic could yield concrete strengths comparable to standard mixes, supporting the reduction of natural aggregate demand and aiding resource conservation. Arora et al. (2013) [5] showed a 5% increase in compressive strength and a reduction in production costs when fine aggregates were replaced with e-waste and plastic waste at optimal levels.

These findings underscore e-waste's promise as a sustainable aggregate alternative, potentially reducing dependency on natural resources and addressing challenges posed by electronic waste disposal.

III. METHODOLOGY

This study outlines a systematic approach for assessing the potential of e-waste as a partial substitute for coarse aggregate in concrete, focusing on both mechanical properties and sustainability. Initially, all raw materials—cement, fine aggregates, coarse aggregates, and e-waste—are tested to confirm their suitability for concrete production. Based on these findings, a concrete mix design is created with varying percentages of e-waste replacing traditional aggregates.

The methodology includes the following steps:

Material Testing: Assessment of cement, fine aggregates, coarse aggregates, and e-waste to confirm quality and compatibility for concrete mix.
Concrete Mix Design: Development of a concrete mix with varying proportions of e-waste as a partial replacement for coarse aggregate.
Specimen Preparation: Casting of concrete specimens in different shapes— cubes and beams—with the prepared mix.
Testing and Analysis: Evaluation of the mechanical properties of hardened concrete, including compressive and flexural strengths, to analyze the impact of e-waste incorporation.
This methodology is designed to provide valuable insights into the sustainable use of e-waste in concrete, highlighting ways to conserve natural resources while maintaining or improving concrete quality.

IV. EXPERIMENTAL SETUP

In this study, a series of preliminary tests were conducted to evaluate the properties of all materials prior to the mix design process. These tests included specific gravity, fineness, consistency, and setting time of cement; sieve analysis and specific gravity of fine and coarse aggregates; and sieve analysis and specific gravity of e-waste. Once these evaluations were complete, an M35 grade concrete mix design was developed with e-waste replacement levels of 5%, 10%, 15%, 20%, 25%, and 30%, based on insights from existing literature. For each replacement level, concrete cubes and beams were cast for 7-day and 28-day testing, with six cubes and six beams prepared for each replacement level, including the nominal mix.

Table 1 Replacment levels of mixes

Trial mix	No of Cube (7 days + 28 day)	No of Beam (7 days + 28 day)
M1 (Nominal mix)	3+3=6	3+3=6
M2 (5 % E waste)	3+3=6	3+3=6
M3 (10 % E waste)	3+3=6	3+3=6
M4 (15 % E waste)	3+3=6	3+3=6
M5 (20 % E waste)	3+3=6	3+3=6
M6 (25 % E waste)	3+3=6	3+3=6
M7 (30 % E waste)	3+3=6	3+3=6

The trial mixes were designed following the guidelines outlined in IS 10262:2019 to ensure consistency and reliability in our experimental process [1].

Table 2 mix design of the specimens

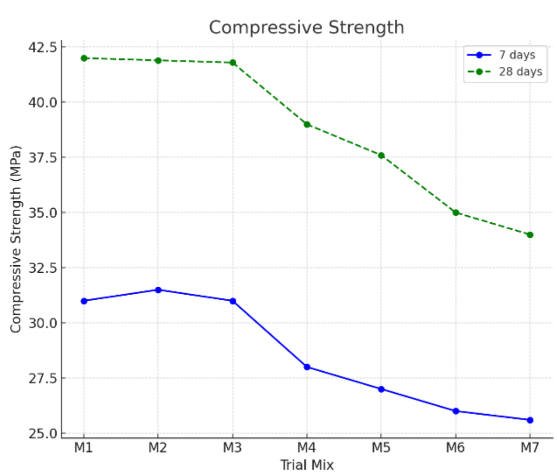
Trial mix	No of Cube (7 days + 28 day)	No of Beam (7 days + 28 day)
M1 (Nominal mix)	3+3=6	3+3=6
M2 (5 % E waste)	3+3=6	3+3=6
M3 (10 % E waste)	3+3=6	3+3=6
M4 (15 % E waste)	3+3=6	3+3=6
M5 (20 % E waste)	3+3=6	3+3=6
M6 (25 % E waste)	3+3=6	3+3=6
M7 (30 % E waste)	3+3=6	3+3=6

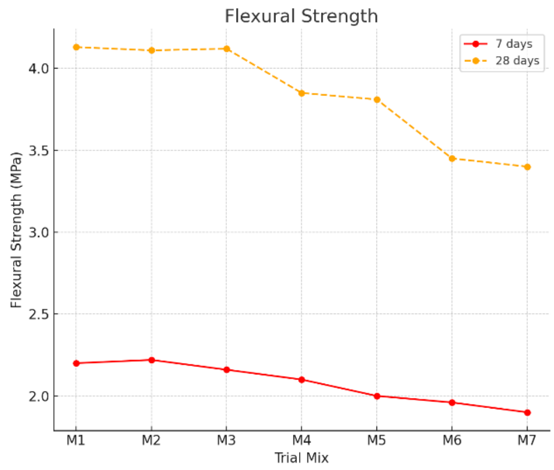
a total of 84 concrete specimens were prepared to examine the effects of e-waste as a partial replacement for coarse aggregate on the mechanical properties of concrete. Each of the seven mix designs—ranging from 0% to 30% e-waste replacement—consisted of 12 specimens, with 6 allocated for compressive strength testing and 6 for flexural strength testing. For each mix, specimens were divided equally to assess the properties at 7 and 28 days, providing insights into the development of strength over time. This structured approach facilitated a comprehensive evaluation of the performance of e-waste-incorporated concrete under different replacement levels, ensuring a robust comparison of compressive and flexural strengths across the specified replacement levels.`

V. DISCUSSION OF THE FINDINGS

The trial mixes demonstrate the effects of incorporating e-waste as a partial replacement for coarse aggregate in concrete. The nominal mix (M1) showed the highest compressive strengths of 31 MPa at 7 days and 41.9 MPa at 28 days. Introducing 5% e-waste (M2) resulted in a slight improvement in 7-day compressive strength (31.5 MPa), with similar performance at 28 days. However, as the e-waste content increased beyond 10%, there was a noticeable decline in both compressive and flexural strength. Specifically, mixes M4 (15% e-waste) to M7 (30% e-waste) showed significant strength reductions. This suggests that low levels of e-waste (up to 10%) have minimal impact on strength, but higher levels decrease the concrete’s mechanical properties. Further research is needed to optimize e-waste content for concrete applications.

Trial mix	Compressive strength (Mpa)		Flexural strength (Mpa)	
	7 days	28 days	7 days	28 days
M_1 (Nominal mix)	31	41.9	2.2	4.11
M_2 (5 % E waste)	31.5	41.9	2.22	4.11
M_3 (10 % E waste)	31	41.8	2.16	4.10
M_4 (15 % E waste)	28	39	2.1	3.85
M_5 (20 % E waste)	27	37.6	2	3.81
M_6 (25 % E waste)	26	35	1.96	3.45
M_7 (30 % E waste)	25.6	34	1.9	3.4





VI. CONCLUSIONS

1. Optimal E-Waste Replacement: 5-10% replacement provides the closest performance to the nominal mix in both compressive and flexural strength.
2. Performance Decline: Higher E-waste percentages (above 15%) lead to notable reductions in both strengths at 7 and 28 days.
3. 3. Best Mix: 5% E-waste replacement offers a balance, maintaining strengths similar to the nominal mix, making it a feasible substitute within this range.

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