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Sustainable Development Of Concrete By Partial Replacement Of Coarse Aggregate With E-Waste

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Abstract:
E-waste i.e., electrical & electronic waste is growing very fast these days with increase in electrical and electronic industries worldwide. The disposal of e-waste has been a global threat to the environment for many years. The recycling of e-waste materials in making concrete is not only being considered as most feasible solution to this global problem of disposal of e-waste to a great extent but it saves our natural resources of aggregate also. The work was conducted on M-35 grade of concrete mix replacing the coarse aggregate with e-waste in the range of 0%, 3%, 6%, 9%, 12%, 15%, 18%, 21% and 24%. For each of the substituted e-waste concrete mix, the compressive strength, split tensile strength and flexural strength was tested. The test results showed that increase in strength was achieved in the E-waste concrete compared to the conventional concrete. Thus, the use of e-waste as partial replacement of coarse aggregate results in not only increase in strength but also waste reduction, natural resource conservation and protection of environment.

Keywords: *E-waste, compressive strength, split tensile strength and flexural strength.*

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I. Introduction

Concrete remains the most commonly used construction material today, prized for its strength and durability. At the same time, the growing accumulation of electrical and electronic waste (e-waste) has become a major environmental concern, with disposal posing significant pollution risks. One of the most effective and sustainable ways to address this challenge is by recycling e-waste into concrete production. The rapid development and widespread use of electronic devices—such as computers, phones, and appliances—have made e-waste the fastest-growing waste stream worldwide. According to the United Nations' fourth *Global E-waste Monitor (GEM)*, published on March 20, 2024, global e-waste generation is increasing five times faster than the rate at which it is being properly recycled. In 2022 alone, 62 million tons of e-waste were generated—enough to fill approximately 1.55 million 40-tonne trucks, which could stretch around the Earth in a continuous line.

Due to the increasing scarcity of natural coarse aggregates used in concrete production, a study was undertaken to investigate the partial replacement of coarse aggregates with electronic waste (e-waste). The experiment was conducted using an M-35 grade concrete mix, which is the minimum grade commonly employed in the construction of concrete roads. In this study, coarse aggregates were replaced with e-waste at varying percentages: 0%, 3%, 6%, 9%, 12%, 15%, 18%, 21%, and 24%. The resulting concrete specimens were tested to evaluate their **compressive strength**, **tensile strength** and **flexural strength**. The performance of the e-waste-modified concrete was then compared with that of the control mix to assess the viability of e-waste as a substitute for conventional coarse aggregates.

II. Materials And Methods

Materials:

- **Cement:** Portland Pozzolana Cement (PPC), conforming to IS: 1489 (Part 1), was used in this study. It was collected from the local market and consistent quality was ensured in all the mixes.
- **Water:**
  Potable water was used for both mixing and curing operations to maintain the integrity and performance of the concrete specimens.
- **Coarse Aggregate:**
  Angular, locally sourced crushed stone with a nominal maximum size of 20 mm was used as coarse aggregate. The material passed through a 20 mm sieve and was retained on a 4.75 mm sieve, in accordance with IS: 383–2016.
- **Fine Aggregate:**

Well-graded river sand was employed as fine aggregate. It passed through a 4.75 mm sieve and was retained on a 150-micron sieve, conforming to Grading Zone II as per IS: 383–2016.

- **E-Waste:**
  Processed e-waste derived from discarded electrical and electronic devices was used as a partial replacement for coarse aggregate. The e-waste was crushed and subjected to sieve analysis to obtain particles passing through a 20 mm sieve and retained on a 2.36 mm sieve.
- **Superplasticizer:**
  A sulfonated naphthalene formaldehyde-based superplasticizer (Conplast SP430) was used to enhance workability. Applied at a dosage of 0.5% by weight of cement, it complied with IS: 9103 (1999) and maintained the concrete slump within the range of 75–100 mm.

Methodology:

- **Concrete Mix Design:** IRC 15-2017 specifies minimum grade of concrete for road construction to be as M35. So, concrete mix M35 grade was used for investigation. The design mix proportion was obtained by Indian Standard Method of mix design (IS:10262-2009,2019). The mix proportion obtained was 1:1.73:3.23 by volume with w/c ratio 0.384.
- **Determination of optimum replacement level of conventional aggregate with e-waste shredded pieces:**

Optimum replacement level of conventional coarse aggregate was determined on the basis of flexural and compressive strength of e-waste concrete achieved by replacing the aggregate in different ratios, viz., 0%, 3%,6%,9%,12%,15%,18%,21% and 24%.

Specific gravity, water absorption and bulk density were tested for the aggregate and e-waste and the results are given in table 1.

Table No.1: Physical properties of Constituents

Properties	Fine aggregate	Coarse aggregate	E-waste	Cement-PPC
Specific gravity	2.62	2.74	1.90	2.90
Water absorption %age	1.0%	0.50%	0.2%	-
Bulk density	1600kg/cum	1500kg/cum	550kg/cum	1440kg/cum
Shape	-	Angular	Angular	-

Table No. 2: The dimensions of specimen used for the study

Test Details	Shape	Dimension of specimen
Compressive strength	Cube	150x150x150mm
Flexural strength	Beam	100x100x500mm
Split tensile strength	Cylinder	150x300mm

III. Results And Discussion

(I) Compressive Strength

The compressive strength test results are summarized in Table 3. The concrete cubes were tested using a compression testing machine with a capacity of 2000 KN. The maximum compressive strength observed after 7 days of curing was 27.25 MPa, and after 28 days of curing, it reached 45.41 MPa, for the concrete mix where 15% of the coarse aggregate was replaced with e-waste.

Compared to the conventional M35 grade concrete, which exhibited compressive strengths of 23.42 MPa (at 7 days) and 41.09 MPa (at 28 days), the modified mix demonstrated an increase of:

- 16.35% at 7 days
- 10.51% at 28 days

These results indicate that partial replacement of coarse aggregate with e-waste at 15% significantly enhances the compressive strength of the concrete, especially at early curing stages.

Table No.3: Compressive Strength Test Result

S.no.	Proportion of e-waste added	Compressive strength MPa (7days)	Compressive strength MPa (28days)
1.	0%	23.42	41.09
2.	3%	24.08	41.52
3.	6%	25.10	41.95
4.	9%	25.43	42.38
5.	12%	25.13	42.60
6.	15%	27.25	45.41
7.	18%	25.26	42.82
8.	21%	23.35	38.92
9.	24%	20.76	34.60

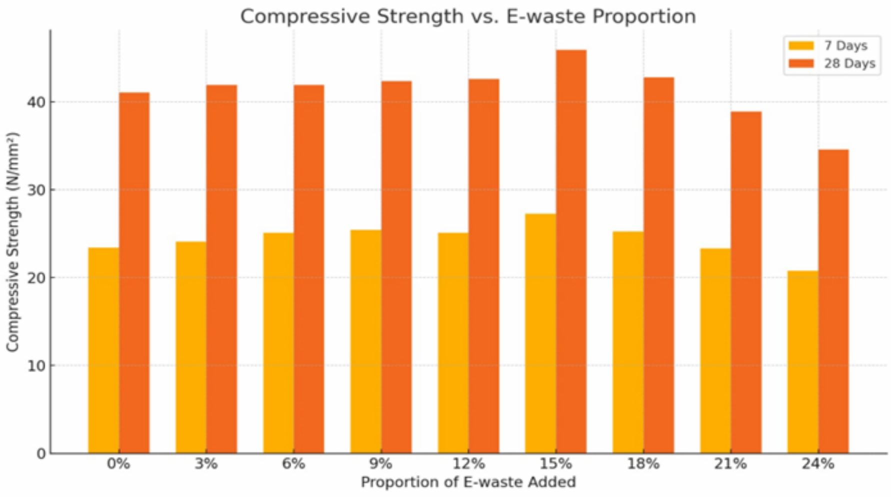

Figure No.1: Effect of e-waste percentage on compressive strength

(II) Flexural Strength

The flexural strength results are shown in Table 4. It was observed that replacing 15% of the coarse aggregate with e-waste yielded optimal results, with flexural strengths of 2.97 MPa after 7 days and 4.71 MPa after 28 days of curing. These values are 4.2% and 9.35% higher, respectively, than those obtained for standard M35 grade concrete.

Table no.4: Flexural Strength Test Result

S.No.	Proportion of E-waste added	Flexural Strength MPa (7days)	Flexural Strength MPa (28days)
1.	0%	2.71	4.52
2.	3%	2.77	4.54
3.	6%	2.79	4.58
4.	9%	2.86	4.61
5.	12%	2.88	4.65
6.	15%	2.97	4.71
7.	18%	2.75	4.58
8.	21%	2.63	4.38
9.	24%	2.45	4.08

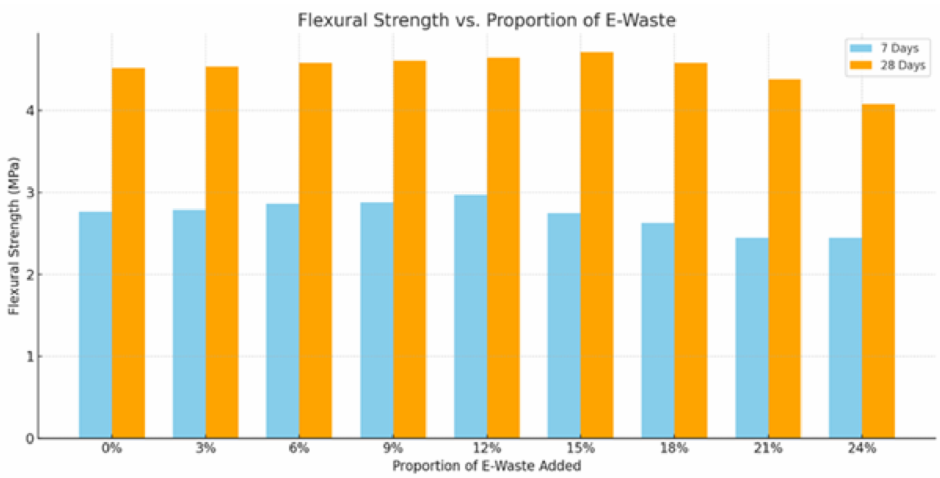

Figure no.2: Effect of e-waste percentage on flexural strength

(III) Split Tensile Strength

The results of split tensile strength test performed over cylindrical specimens of 150mm diameter and 300mm length are shown in table no.5 given as under. This result shows that the optimum level of replacement of coarse aggregate by e-waste is 15% at which the split tensile strength was found as 2.34 and 3.77 MPa respectively, that is; 9.35% and 5.60% higher than the respective grade of standard cement concrete after said days of curing.

Table no.5: Split Tensile Strength Test Result

S.No.	Proportion of E-waste added	Split tensile Strength MPa (7days)	Split tensile Strength MPa (28days)
1.	0%	2.14	3.57
2.	3%	2.15	3.52
3.	6%	2.21	3.62
4.	9%	2.29	3.69
5.	12%	2.27	3.72
6.	15%	2.34	3.77
7.	18%	2.17	3.61
8.	21%	2.09	3.42
9.	24%	1.96	3.22

Figure no.3: Effect of e-waste percentage on split tensile strength

IV. Conclusion

The analysis of strength characteristics of M35 grade concrete with partial replacement of coarse aggregate by e-waste led to the following conclusions:

a) **Compressive Strength:**
The compressive strength of concrete increased with the replacement of coarse aggregate by e-waste, reaching a peak at **15% replacement**. Beyond this level, the rate of strength gain began to decline.

b) **Strength Improvement Beyond 15%:**
Even at **18% replacement**, the compressive strength remained higher than that of conventional concrete, indicating the potential for limited further substitution.

c) **Maximum Strength Gain:**
After 28 days of curing, the concrete with **15% e-waste** replacement exhibited the highest compressive strength, which was **10.51%** greater than that of standard M35 grade concrete.

d) **Flexural Strength:**
The flexural strength at 15% replacement after 28 days increased by **4.2%** compared to standard concrete. While this increase is relatively modest, it is still beneficial, particularly from an environmental sustainability perspective.

e) **Split Tensile Strength:**
At 15% replacement, the **split tensile strength** reached **3.77 MPa**, which is **7%** higher than that of conventional M35 grade concrete, as shown in Table 5.

f) **Environmental Benefits:**
The reuse of e-waste in concrete contributes to **waste reduction**, **natural resource conservation**, and **environmental protection**, offering a sustainable approach to construction.

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