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Investigation on the Performance of Concrete Using E-Waste as a Partial Coarse Aggregate Replacement

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Abstract -Concrete is one of the most essential materials in civil engineering, and the addition or replacement of certain constituents can significantly alter its performance and sustainability. This study investigates the performance of concrete by partially replacing coarse aggregate with e-waste. M30 grade concrete was selected for the mix design. The properties and characteristics of cement, fine aggregate, coarse aggregate, and supplementary materials were examined in accordance with Indian Standard specifications. Compressive strength, split tensile strength, and flexural strength tests were conducted for different replacement levels of coarse aggregate: 0%, 10%, 15%, and 20%. The results indicate that at 15% partial replacement of coarse aggregate with e-waste, the concrete achieved higher compressive strength at both 7 and 28 days. Therefore, the optimum content of e-waste as a partial replacement for coarse aggregate was determined to be 15%.

***Key Words*:**Concrete, E-waste, Coarse aggregate replacement, M30 grade, Compressive strength, Split tensile strength, Flexural strength, Sustainable construction.

1.INTRODUCTION

Concrete is one of the most widely used construction materials due to its versatility, strength, and durability. However, the rapid depletion of natural resources and the environmental impact caused by concrete production have become major global concerns. The continuous extraction of coarse aggregates from natural sources contributes to ecological imbalance, while the disposal of electronic waste (e-waste) has emerged as another critical environmental issue.

E-waste, consisting mainly of discarded electrical and electronic equipment such as computers, mobile phones, and circuit boards, contains a variety of materials including plastics, metals, and oxides. Improper disposal of e-waste leads to soil, water, and air contamination due to the presence of hazardous elements like lead, mercury, and cadmium. Recycling and reusing e-waste in construction materials, particularly as a partial replacement for coarse aggregates in concrete, offers a sustainable solution to both waste management and resource conservation challenges.

This study aims to evaluate the performance of M30 grade concrete incorporating e-waste as a partial replacement for coarse aggregates at varying proportions (0%, 10%, 15%, and 20%). The mechanical properties, such as compressive, split tensile, and flexural strengths, are analyzed to determine the optimal replacement level. Utilizing e-waste in concrete not only reduces environmental pollution but also promotes sustainable construction by minimizing the use of natural aggregates and lowering waste disposal problems.

2. AIM AND OBJECTIVES

Aim:

To investigate the performance of concrete incorporating e-waste as a partial replacement for coarse aggregate and to evaluate its mechanical and microstructural properties.

Objectives:

1. To determine the properties of the fundamental concrete-making materials such as cement, fine aggregate, coarse aggregate, e-waste, and water.
2. To compare the properties of e-waste with those of conventional coarse aggregates and assess its suitability for use in concrete.
3. To evaluate the mechanical properties of e-waste concrete and compare them with those of the control mix.
4. To analyze the composition and crystal formation in e-waste concrete and compare it with control concrete using Scanning Electron Microscopy (SEM) analysis.

Scope:

1. To effectively reduce the demand for natural resources used in concrete production.
2. To minimize the cost and consumption of conventional coarse aggregates.
3. To reduce environmental pollution caused by landfilling and improper disposal of e-waste.
4. To promote waste utilization and recycling, thereby contributing to the reduction of greenhouse gas emissions.

3.METHODOLOGY

REVIEW OF LITERATURE
↓
COLLECTION OF MATERIALS
↓
TESTING OF MATERIALS
↓
MIX DESIGN
↓
MIXING AND CASTING OF CONCRETE SPECIMEN
↓
CURING OF CONCRETE SPECIMEN

↓

TESTING OF SPECIMEN

↓

ANALYSIS OF TEST RESULTS

Figure 1 flow chart of methodology

4. MATERIALS COLLECTION

The materials used in this study include cement, fine aggregate, coarse aggregate, e-waste, and water. All materials were tested in accordance with relevant Indian Standard (IS) codes to ensure their suitability for concrete production.

4.1.1 Cement

Ordinary Portland Cement (OPC) of 43 grade, manufactured by Penna, conforming to IS 269:2015, was used. It is widely employed in the construction of high-rise buildings, roads, bridges, and dams due to its adequate strength and reliability. Physical and chemical properties were tested as per IS 4031:1988 and IS 4032:1985. The cement exhibited a specific gravity of 3.14, standard consistency of 29%, and initial and final setting times of 180 min and 290 min, respectively. The compressive strength at 28 days was 51.43 N/mm², satisfying the IS requirements.

4.1.2 Fine Aggregate

Manufactured sand (M-sand) obtained from SS Crusher, conforming to IS 383:2016, was used. It consisted of hard granite particles with a size less than 4.75 mm. The fine aggregate had a specific gravity of 2.65, water absorption of 1.62%, and fineness modulus of 3.6, placing it in Grading Zone II. Sieve analysis confirmed the material's compliance with IS 2386 specifications.

4.1.3 Coarse Aggregate

Crushed granite aggregates from SS Crusher, conforming to IS 383:2016, were used in two sizes: 12.5 mm and 20 mm. The aggregates had specific gravities of 2.78 and 2.75, with water absorption values of 0.42% and 0.61%, respectively. The crushing, impact, and abrasion values were below 15%, indicating good quality. Combined gradation curves showed proper particle distribution suitable for dense concrete.

4.1.4 Specific Gravity Test

The specific gravity test determines the quality and strength of aggregates. It is defined as the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Aggregates with higher specific gravity generally indicate better strength and quality. The test was conducted using a pycnometer as per standard procedure-waste particles exhibited a significantly lower specific gravity (1.01) compared to natural aggregates, indicating lower density. However, their inclusion helps in reducing the self-weight of concrete and promotes sustainability through waste utilization.

4.1.5E-WASTE

Electronic waste or e-waste describes discarded electrical or electronic devices.Used electronicswhicharedestinedfor reuse,resale,salvage,recyclingor disposal are also considered as e-waste.

Informal processing of electronic waste in developing countries may cause serious health and pollution problems, as these countries have limited regulatory oversight of e-waste processing.

E-wastes were crushed to the size of coarse aggregates shown in figure 4.6 and used in concrete. The result obtained after testing of e waste is as follows;

Fig2. CrushedE-Waste

5. Mix Design Details

Table 1 Mix Design Ratio

Water	Cement	Fine aggregate	coarse aggregate
186	413 kg	567 kg	1237 kg

Ratio: 0.45: 1: 1.37: 3

Table 2 Quantity of Materials Required for Compression Test (Per Cube)

Replacement of Coarse Aggregate (%)	Weight of Cement (kg)	Weight of Sand (kg)	Weight of Fresh Coarse Aggregate (kg)	Weight of Recycled Coarse Aggregate (kg)	Quantity of Water (liters)
0	1.66	2.27	4.98	-	0.82
10	1.66	2.27	4.48	0.49	0.82
15	1.66	2.27	4.23	0.74	0.82
20	1.66	2.27	3.98	0.99	0.82
25	6.64	9.08	17.67	2.22	3.28

6.Tests on Fresh Concrete

The fresh concrete properties were evaluated through workability (slump), air content, bleeding, and setting time tests as per IS standards. Slump Test (IS 1199:1959): Workability was measured using a standard slump cone of 300 mm height.

The concrete mix showed a slump value of 180 mm, indicating good workability for placement and compaction.

Tests on Hardened Concrete

The hardened concrete properties were evaluated for strength and durability. Strength tests included compressive, split tensile, and flexural tests as per IS 516:1959 and IS 5816:1999.

Compressive Strength:150 mm cubes were tested at 7, 14, and 28 days using a compression testing machine at a loading rate of **5.2 kN/s**. The compressive strength was calculated as:

$f_c=P\backslash A$ where P = ultimate load (N) and A = loaded area (mm²).

Split Tensile Strength: Cylindrical specimens (150 mm × 300 mm) were tested under diametral compression. The tensile strength was computed using:

$f_t=2P/\pi LD$where P = load (N), L = length (mm), and D = diameter (mm).

Flexural Strength: Beams of size 500 × 100 × 100 mm were tested under two-point loading to determine the modulus of rupture using:

$f_b=PL/BD^2PL$

where P = load (N), L = span (mm), B = width (mm), and D = depth (mm).

7. RESULT AND DISCUSSION

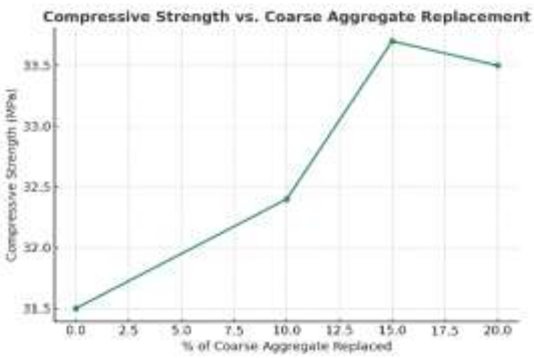

Fig.3 Variation of Split tensile Strength (MPa) with Percentage Replacement of Coarse Aggregate at 28 Days

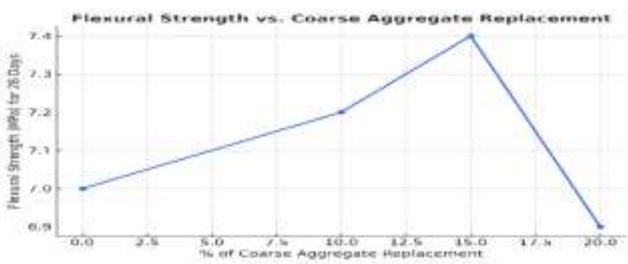

Fig.4 Variation of Flexural Strength (MPa) with Percentage Replacement of Coarse Aggregate at 28 Days

Fig. 5Variation of Split tensile Strength (MPa) with Percentage Replacement of Coarse Aggregate at 28 Days.

- At 28 days, the control mix (0% replacement) attained a compressive strength of 31.5 MPa. With the inclusion of E-waste, the strength showed progressive improvement. At 10% replacement, the strength increased by 2.86%, and at 15%, it achieved a maximum enhancement of 6.98% compared to the control mix. However, a slight decrease of 0.59% was observed at 20% replacement, indicating marginal strength reduction beyond the optimum level. The overall results confirm that incorporating E-waste up to 15% as a partial replacement of coarse aggregates enhances the compressive strength and performance of concrete at 28 days.
- At 28 days, the control mix (0% replacement) exhibited a flexural strength of 7.0 MPa. With the addition of E-waste, strength increased steadily, reaching 7.2 MPa at 10% replacement (an increase of 2.86%) and attaining a maximum of 7.4 MPa at 15% replacement, reflecting an improvement of 5.71% over the control mix. However, at 20% replacement, the flexural strength slightly decreased to 6.9 MPa, showing a 1.43% reduction. The results clearly indicate that the optimum flexural strength was achieved at 15% E-waste replacement, beyond which the performance marginally declined due to reduced bonding efficiency and increased brittleness.
- At 28 days, the control mix (0% replacement) exhibited a split tensile strength of 4.6 MPa. With the inclusion of E-waste, a consistent improvement was observed up to 15% replacement. At 10% replacement, the strength increased to 4.9 MPa, showing an enhancement of 6.52% over the control mix. The maximum strength of 5.1 MPa was achieved at 15% replacement, indicating a significant improvement of 10.86% compared to the control concrete. This improvement is attributed to better particle interlocking, enhanced bonding between the E-waste aggregates and the cement matrix, and reduced internal microcracks. However, beyond the optimum level, at 20% replacement, the strength slightly decreased to 4.7 MPa, a 2.17% reduction compared to the control mix. This decline can be linked to increased voids and reduced bonding strength at higher E-waste content. Hence, 15% replacement is identified as the optimum level for achieving superior split tensile performance.

8. CONCLUSIONS

The following conclusions are drawn based on the 28-day strength results of concrete incorporating E-waste as a partial replacement for coarse aggregates:

- E-waste as a partial replacement of coarse aggregate in concrete exhibited good performance in both fresh and hardened states. At lower replacement levels, it provided better strength and workability compared to higher replacement levels.
- The use of E-waste as a coarse aggregate replacement up to 15% showed a significant improvement in the 28-day compressive, split tensile, and flexural strengths compared to conventional concrete.
- Partial substitution of coarse aggregate by E-waste effectively enhanced the compressive strength of concrete up to a sustainable level at 15% replacement.
- An increase in split tensile strength was also observed up to 15% replacement, indicating a more pronounced effect of E-waste on tensile behavior.
- Similarly, flexural strength increased with the addition of E-waste up to 15% replacement, confirming improved flexural performance at this level.
- Overall, based on 28-day test results, it can be concluded that 15% replacement of coarse aggregate with E-waste yielded the most favorable results in terms of strength and performance, making it an effective and sustainable alternative in concrete production.

9. Scope further studies

The present study demonstrates that incorporating E-waste up to 15% replacement enhances compressive, split tensile, and flexural strengths of concrete at 28 days. Further research can focus on long-term durability performance, such as chloride penetration, sulphate resistance, and water absorption. Microstructural analysis using SEM and XRD can be conducted to understand the bonding mechanism. Additionally, studies on reinforced structural elements and field-scale applications will help validate the practical suitability of E-waste concrete for sustainable construction.

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