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Analysis of Concrete with Partial Replacement of Coarse Aggregate by using E-Waste

Akash Deshmukh[1], Prof. Girish Sawai[2]

[1] Research Scholar, Department of Civil Engineering, VM Institute of Engineering & Technology, Nagpur, India
[2] Assistant Professor, Department of Civil Engineering, VM Institute of Engineering & Technology, Nagpur, India

Abstract- Concrete is the most widely used construction material in the world due to its strength, durability, and versatility. However, the rapid growth in infrastructure development has led to excessive consumption of natural resources such as coarse aggregates, resulting in environmental degradation and resource depletion. At the same time, the generation of electronic waste (E-waste) has increased significantly due to rapid technological advancements and frequent replacement of electronic devices. Improper disposal of E-waste leads to serious environmental and health hazards because it contains toxic substances such as lead, mercury, and cadmium. This study focuses on the experimental investigation of concrete with partial replacement of coarse aggregate using E-waste materials. The primary objective is to evaluate the feasibility of utilizing E-waste as an alternative construction material and to determine the optimum replacement percentage that provides desirable strength and performance. In this research work, M30 grade concrete was selected for mix design as per IS 10262:2009. Coarse aggregate was partially replaced with E-waste at different percentages of 0%, 10%, 15%, and 20%. Various tests were conducted on both fresh and hardened concrete. Fresh concrete properties such as workability (slump test), air content, bleeding, and setting time were studied. Hardened concrete properties including compressive strength, split tensile strength, and flexural strength were evaluated at curing periods of 7, 14, and 28 days. The experimental results indicate that the incorporation of E-waste affects both fresh and hardened properties of concrete. Workability was observed to decrease slightly with an increase in E-waste content due to the irregular shape and lower bonding characteristics of E-waste particles. However, the strength properties showed improvement up to a certain level of replacement. The compressive strength, split tensile strength, and flexural strength increased up to 15% replacement and then showed a marginal reduction at 20% replacement.

KEYWORDS: E-waste, Sustainable Concrete, Coarse Aggregate Replacement, Compressive Strength, Split Tensile Strength, Flexural Strength, M30 Concrete, Recycling, Eco-Friendly Construction, Waste Utilization

I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its high compressive strength, durability, adaptability, and economic feasibility. It is used in almost all types of civil engineering structures such as buildings, bridges, dams, pavements, tunnels, and water retaining structures. The basic ingredients of concrete include cement, fine aggregate, coarse aggregate, and water. Among these, aggregates occupy approximately 70–80% of the total volume, making them a critical component influencing the strength and durability of concrete. In recent decades, rapid urbanization, industrialization, and infrastructure development have led to a significant increase in the demand for concrete. This has resulted in excessive extraction of natural aggregates such as crushed stone and river sand, causing depletion of natural resources and environmental degradation. At the same time, the advancement in electronic technology has led to a drastic increase in electronic waste (E-waste) generation. E-waste includes discarded electrical and electronic devices such as computers, televisions, mobile phones, circuit boards, and other electronic components. These materials contain hazardous substances such as lead, mercury, cadmium, and plastics, which pose serious threats to the environment and human health if not properly managed. Therefore, there is a growing need to explore sustainable alternatives that can reduce the consumption of natural aggregates and utilize waste materials effectively. One such promising solution is the use of E-waste as a partial replacement of coarse aggregate in concrete.

II. METHODOLOGY

The methodology adopted in the present study is based on a systematic experimental approach to investigate the behavior of concrete when coarse aggregate is partially replaced with E-waste materials. The entire research work is carefully structured to ensure accuracy, reliability, and compliance with relevant Indian Standard (IS) codes.
Concrete is one of the most widely used construction materials, and any modification in its composition requires a thorough understanding of material behavior, mix design principles, and testing procedures. Therefore, this study follows a step-by-step methodology, beginning with theoretical understanding and progressing toward experimental validation. The methodology is divided into multiple phases, each of which plays a crucial role in achieving the final objective of determining the optimum percentage of E-waste replacement without compromising the strength and durability of concrete.

Research Approach:

The research approach adopted in this study is experimental in nature, supported by theoretical background and literature review. The study involves:

- Selection of suitable materials
- Laboratory testing of materials
- Mix design preparation
- Casting and curing of specimens
- Testing of concrete specimens
- Analysis and interpretation of results

The experimental investigation ensures that the findings are based on practical observations rather than theoretical assumptions.

Step 1: Review of Literature

This is the first stage of the study where previous research papers, journals, and technical documents related to E-waste concrete are reviewed. This helps in understanding:

- Existing research findings
- Strength and durability trends
- Suitable replacement percentages
- Research gaps

Step 2: Collection of Materials

In this step, all required materials are collected from reliable sources. The quality of materials plays a crucial role in determining the performance of concrete.

Step 3: Testing of Materials

Before using materials in concrete, their physical and chemical properties are tested as per IS codes to ensure suitability.

Step 4: Mix Design

Concrete mix design is carried out as per IS 10262:2009 to achieve required strength and workability.

Step 5: Mixing and Casting

Concrete is prepared by mixing all materials in proper proportions and casting into moulds.

Step 6: Curing

Specimens are cured in water for specific durations (7, 14, 28 days) to gain strength.

Step 7: Testing of Specimens

Hardened concrete specimens are tested for strength properties.

Step 8: Analysis of Results

Results are analyzed to determine performance and optimum replacement percentage.

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MATERIALS COLLECTION:
The materials used in this study are selected based on availability, quality, and compliance with IS standards.
List of Materials

- Cement
- Fine Aggregate
- Coarse Aggregate
- E-Waste
- Water

Table 3.2: Physical Properties of Cement

S.No	Property	Result	IS Limit
1	Standard Consistency (%)	29	-
2	Initial Setting Time (min)	180	≥30
3	Final Setting Time (min)	290	≤600
4	Specific Gravity	3.14	3.15
5	Compressive Strength (MPa)	51.43	≥43
6	Fineness (%)	1.88	≤10

Table 3.3: Properties of Fine Aggregate

Property	Value
Specific Gravity	2.65
Water Absorption (%)	1.62
Fineness Modulus	3.6
Grading Zone	II

Table 3.4: Properties of Coarse Aggregate

Property	12.5 mm	20 mm	IS Limit
Specific Gravity	2.78	2.75	-
Water Absorption (%)	0.42	0.61	-
Crushing Value (%)	14.97	14.97	≤30
Impact Value (%)	13.43	13.43	≤30

Table 3.5: Properties of Water

Property	Value	IS Limit
pH	8.68	≥6
Chloride	193 mg/l	≤500
Sulphate	1.0 mg/l	≤400

Table 3.6: Properties of E-Waste

Property	Value
Specific Gravity	1.01
Nature	Lightweight
Shape	Irregular

Table 3.7: Mix Proportion

Material	Quantity
Water	186 L
Cement	413 kg
Fine Aggregate	567 kg
Coarse Aggregate	1237 kg
W/C Ratio	0.45

Table 3.8: Specimen Details

Specimen	Size
Cube	150×150×150 mm
Cylinder	150×300 mm
Beam	100×100×500 mm

Figure 3.2: Concrete Casting Process

Figure 3.3: Demoulded specimens

Figure 3.4: Curing

Figure 3.5: Slump Test

Figure 3.6: Bleeding Test

Figure 3.7: Compressive Strength Test

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III. RESULTS AND DISCUSSION

RESULTS OF FRESH CONCRETE:

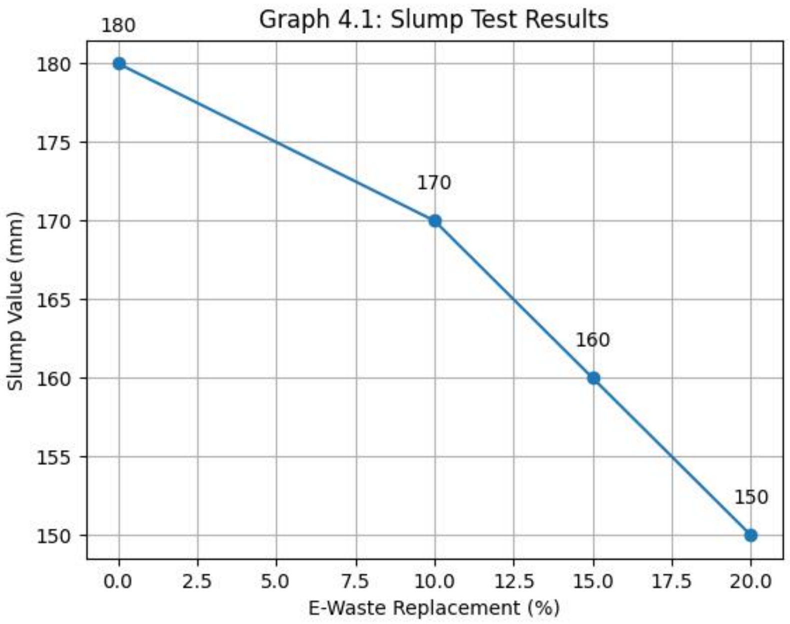
Fresh concrete properties play a very important role in determining the overall performance of concrete before it hardens. These properties directly influence the ease of mixing, placing, compacting, finishing, and overall quality of concrete. If fresh concrete does not possess adequate workability and stability, it may lead to defects such as segregation, bleeding, honeycombing, and reduced strength, which ultimately affect the durability and service life of the structure. In the present study, the fresh concrete behavior was analyzed for different percentages of E-waste replacement (0%, 10%, 15%, and 20%). Since E-waste materials are lightweight, irregular in shape, and have low water absorption, they significantly influence the fresh properties of concrete.

The following fresh concrete tests were conducted as per relevant IS codes:

1. Slump Test (IS 1199:1959)
2. Air Content Test
3. Bleeding Test
4. Setting Time Test

Table 4.1: Slump Test Results

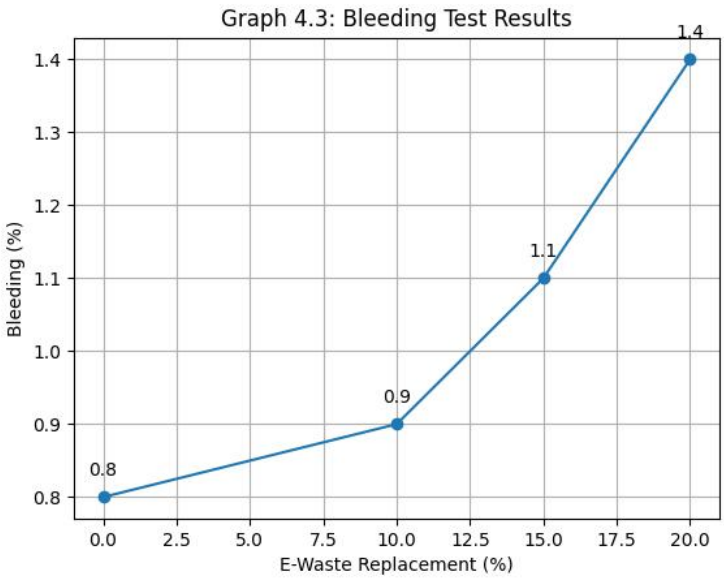
% Replacement	Slump (mm)	Workability
0%	180	Medium
10%	170	Medium
15%	160	Medium-Low
20%	150	Low



Graph 4.1: Slump Test Results

Table 4.2: Air Content Results

% Replacement	Air Content (%)
0%	2.1
10%	2.3
15%	2.6
20%	2.9



Graph 4.2: Air Content Results

Table 4.3: Bleeding Results

% Replacement	Bleeding (%)
0%	0.8
10%	0.9
15%	1.1
20%	1.4

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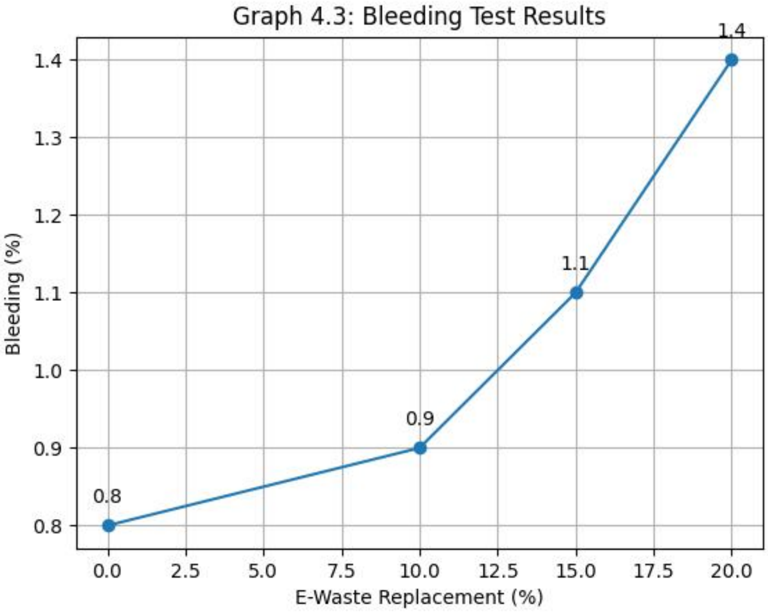
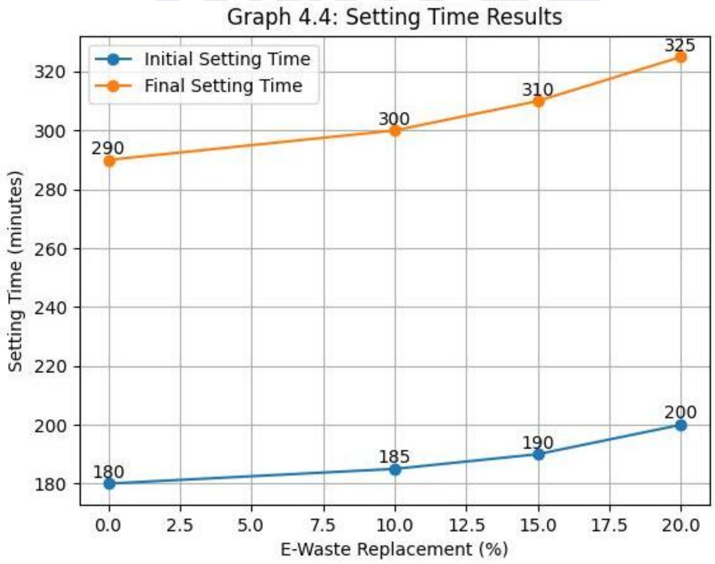


Graph 4.3: Bleeding Results

Table 4.4: Setting Time Results

% Replacement	Initial (min)	Final (min)
0%	180	290
10%	185	300
15%	190	310
20%	200	325



Graph 4.4: Setting Time Results

Discussion:

- Setting time slightly increases with E-waste.
- Due to non-reactive nature of E-waste.
- Beneficial in hot weather conditions.

HARDENED CONCRETE RESULTS:

Hardened concrete properties are the most important parameters in evaluating the structural performance, strength, durability, and service life of concrete. Unlike fresh concrete, which focuses on workability and placement, hardened concrete determines whether the material is capable of safely carrying loads and resisting environmental conditions.

In the present study, the hardened concrete properties were evaluated for concrete mixes with partial replacement of coarse aggregate using E-waste at different percentages:

1. 0% (Control Mix)
2. 10% Replacement
3. 15% Replacement
4. 20% Replacement

The specimens were tested at curing ages of:

- 7 Days (Early Strength)
- 14 Days (Intermediate Strength)
- 28 Days (Final Design Strength)

The following hardened concrete tests were conducted as per relevant IS codes:

- Compressive Strength Test (IS 516:1959)
- Split Tensile Strength Test (IS 5816:1999)
- Flexural Strength Test (IS 516:1959)

These tests help in evaluating:

- Load carrying capacity
- Resistance to cracking
- Structural behavior
- Suitability for practical construction

Compressive Strength:

Table 4.5: Compressive Strength Results

% Replacement	7 Days	14 Days	28 Days
0%	20.5	29.9	31.5
10%	21.3	30.8	32.4
15%	21.7	32.0	33.7
20%	19.5	28.2	33.5

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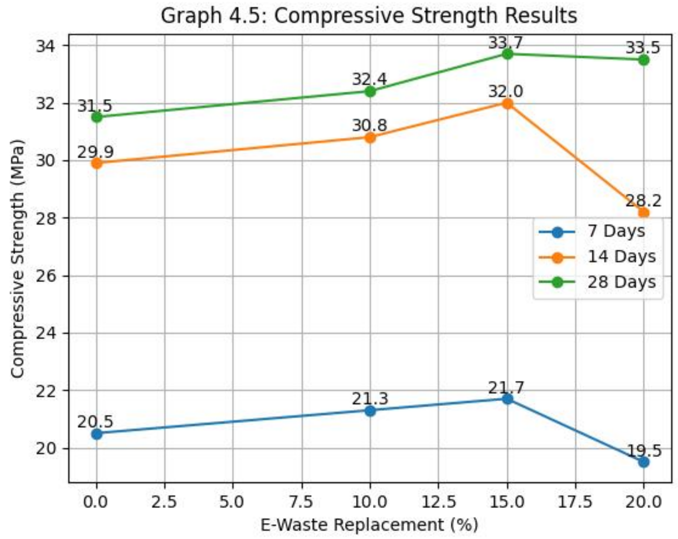


Graph 4.5: Compressive Strength Results

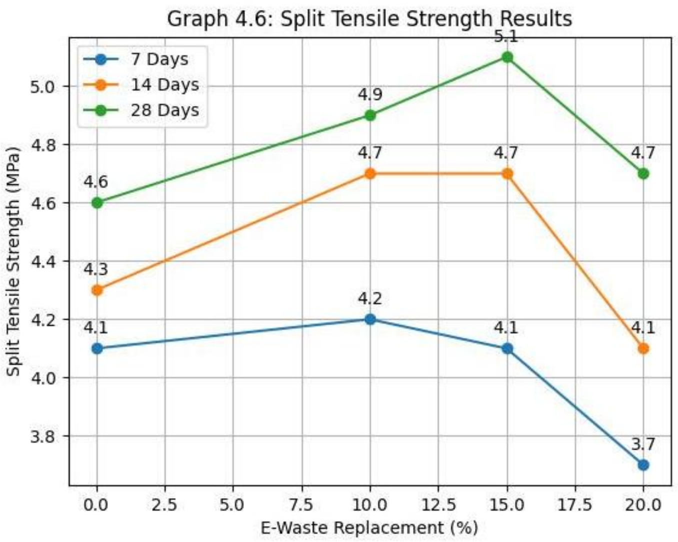
Discussion:

- Strength increases up to 15% replacement
- Maximum strength = 33.7 MPa
- Beyond 15%, slight reduction due to:
    - Weak bonding
    - Low strength of E-waste

Split Tensile Strength:

Table 4.6: Split Tensile Strength

% Replacement	7 Days	14 Days	28 Days
0%	4.1	4.3	4.6
10%	4.2	4.7	4.9
15%	4.1	4.7	5.1
20%	3.7	4.1	4.7



Graph 4.6: Split Tensile Strength

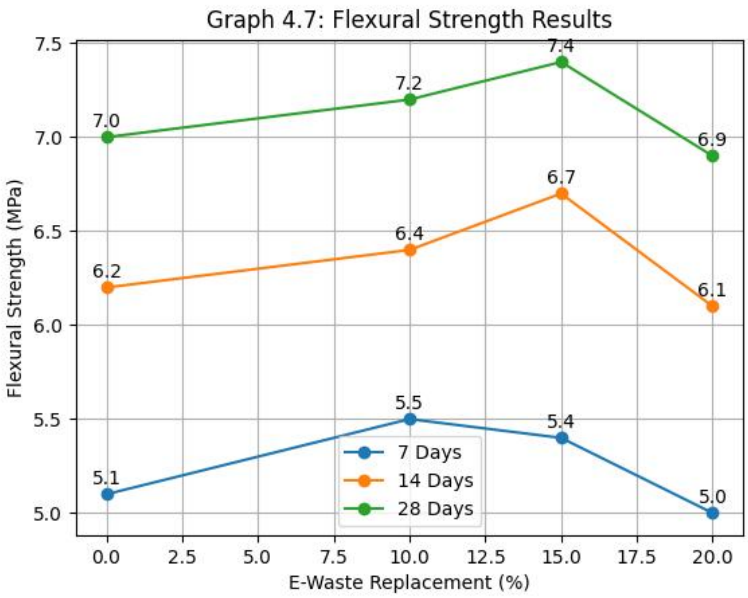
Discussion:

- Maximum tensile strength at 15% replacement
- Decreases at higher replacement
- Due to poor interfacial bonding

Flexural Strength:

Table 4.7: Flexural Strength

% Replacement	7 Days	14 Days	28 Days
0%	5.1	6.2	7.0
10%	5.5	6.4	7.2
15%	5.4	6.7	7.4
20%	5.0	6.1	6.9



Graph 4.7: Flexural Strength

Discussion:

- Flexural strength increases up to 15%
- Maximum = 7.4 MPa
- Decreases at 20% due to reduced stiffness

CONCLUSION

Based on the experimental study, it is concluded that E-waste can be effectively used as a partial replacement of coarse aggregate in concrete, helping to reduce environmental pollution and conserve natural resources. The workability of concrete decreases with increasing E-waste content, but acceptable performance is achieved up to 10–15% replacement. Compressive, split tensile, and flexural strengths of concrete improve up to 15% E-waste replacement, with maximum values observed at this level, after which strength decreases due to weak bonding and lower stiffness of E-waste particles. The optimum replacement level is found to be 15%, where both strength and workability are satisfactory. Overall, the use of E-waste in concrete promotes sustainable and cost-effective construction by reducing landfill waste and dependence on natural aggregates while maintaining good structural performance.

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