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Performance of Non-Metallic E-Waste in Concrete

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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 concrete, non-metallic electronic waste, Plastic aggregates, Printed circuit board waste, Sustainable concrete, green construction, Workability, Compressive strength, Durability, Lightweight concrete.

I. INTRODUCTION

The construction industry plays a vital role in the economic development of any country, as it supports infrastructure growth, urban development, transportation systems, and housing facilities. However, it is also one of the largest consumers of natural resources, particularly aggregates such as crushed stone, gravel, and sand. It is estimated that aggregates constitute nearly 70–80% of the total volume of concrete, making their consumption extremely high. With the rapid growth of population, urbanization, and industrialization, the demand for construction materials has increased tremendously over the past few decades. This increasing demand has led to excessive extraction of natural aggregates from quarries, riverbeds, and other sources, resulting in depletion of natural resources, ecological imbalance, and environmental degradation.

The extraction and processing of aggregates involve various operations such as drilling, blasting, crushing, and transportation, which consume large amounts of energy and contribute significantly to air pollution, noise pollution, and greenhouse gas emissions. The removal of natural aggregates from riverbeds also disturbs the natural flow of rivers, leading to erosion, lowering of groundwater levels, and loss of aquatic habitats.

Therefore, the construction industry is under increasing pressure to adopt sustainable practices and reduce its environmental impact by finding alternative materials. At the same time, the world is facing another major environmental challenge in the form of electronic waste (E-waste). With the advancement of technology and the rapid increase in the use of electronic devices such as computers, mobile phones, televisions, and other electrical appliances, the generation of E-waste has increased at an alarming rate. E-waste is considered one of the fastest-growing waste streams globally. It contains a complex mixture of materials, including metals, plastics, glass, and hazardous substances such as lead, mercury, cadmium, and brominated flame retardants, which pose serious risks to human health and the environment. In India, the situation is particularly critical, as the country is among the top producers of E-waste in the world. The rapid growth of the information technology sector, increasing consumer demand for electronic goods, and shorter life cycles of devices have contributed to the significant rise in E-waste generation. However, the infrastructure for proper collection, segregation, and recycling of E-waste is still inadequate. As a result, a large portion of E-waste is disposed of through informal methods such as open dumping, burning, and landfilling, which leads to severe environmental pollution. Improper disposal of E-waste results in soil contamination, as toxic substances leach into the ground and affect soil quality. It also causes groundwater pollution, as hazardous chemicals seep into water sources, making them unsafe for consumption. Additionally, the burning of E-waste releases harmful gases into the atmosphere, leading to air pollution and health hazards such as respiratory problems, skin diseases, and even cancer. These issues highlight the urgent need for effective and sustainable methods of E-waste management.

One of the most promising approaches to address this problem is the reuse and recycling of E-waste in construction materials, particularly in concrete. Researchers have explored the possibility of using E-waste as a partial replacement for natural aggregates. Materials such as plastic components, printed circuit boards (PCB), and other non-metallic parts of E-waste can be processed into suitable sizes and used as coarse aggregates in concrete. These materials are generally lightweight, non-biodegradable, and readily available in large quantities, making them suitable candidates for reuse. The incorporation of E-waste in concrete offers several advantages. It helps in reducing the demand for natural aggregates, thereby conserving natural resources. It also provides a solution for the safe disposal of E-waste, reducing the burden on landfills and minimizing environmental pollution. Additionally, the use of E-waste can lead to the production of lightweight concrete, which may be beneficial in certain structural applications where reduced dead load is required. Several experimental studies have been conducted to evaluate the performance of concrete with E-waste as a partial replacement of coarse aggregate. These studies generally indicate that concrete exhibits satisfactory strength and durability at lower replacement levels (typically up to 10–15%), while higher percentages may lead to a reduction in strength due to weaker bonding and lower stiffness of E-waste materials.

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.

Research Approach:

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

1. Selection of suitable materials
2. Laboratory testing of materials
3. Mix design preparation
4. Casting and curing of specimens
5. Testing of concrete specimens
6. Analysis and interpretation of results

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

Materials Collection:
The materials used in this study are selected based on availability, quality, and compliance with IS standards.
List of Materials
1. Cement
2. Fine Aggregate
3. Coarse Aggregate
4. E-Waste
5. Water

Table 2.1: Properties of E-Waste

Property	Value
Specific Gravity	1.01
Nature	Lightweight
Shape	Irregular

Mix Design:
Mix design is carried out to achieve target strength of M30 grade concrete.

Table 3.2: Mix Proportion

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

Figure 3.1: Concrete Casting Process

Figure 3.2: Demoulded specimens

Figure 3.3: Curing

Figure 3.4: Slump Test

Figure 3.5: Bleeding Test

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Figure 3.6: Compressive Strength Test

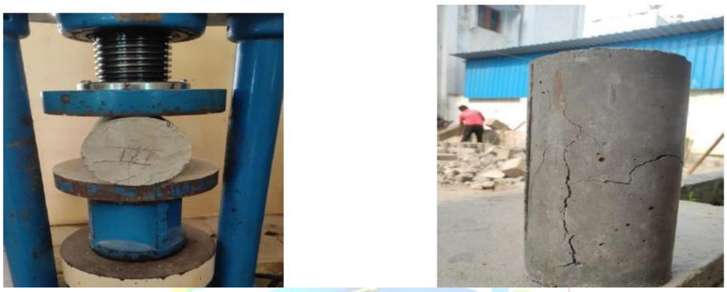

Figure 3.7: Split Tensile Strength Test

Figure 3.8: Flexural Strength Test

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

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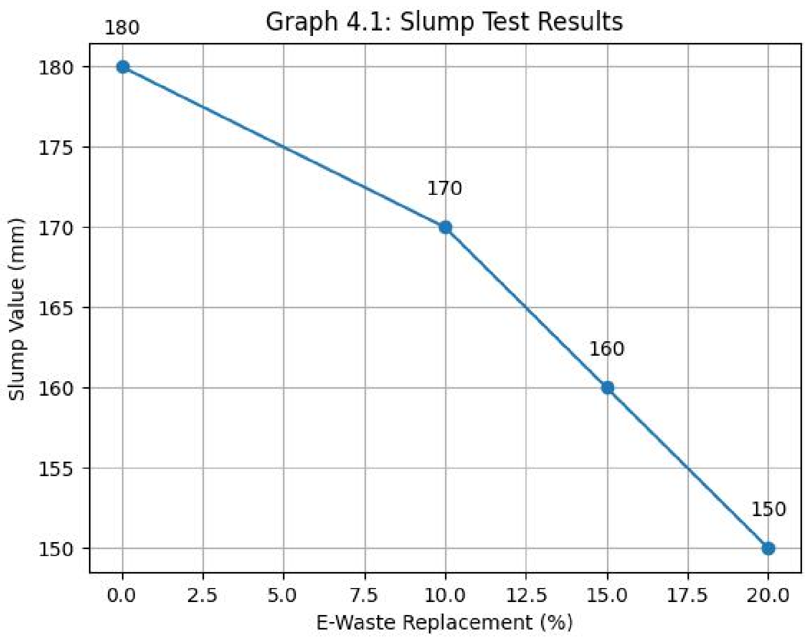
Workability (Slump Test):
The slump test was conducted as per IS 1199:1959.

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

Discussion:
- Slump value decreases as E-waste content increases.
- E-waste particles are irregular and rough, reducing flowability.
- At 20% replacement, workability becomes poor.
- Suitable workability observed up to 15% replacement.

Air Content Test:

Table 4.2: Air Content Results

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

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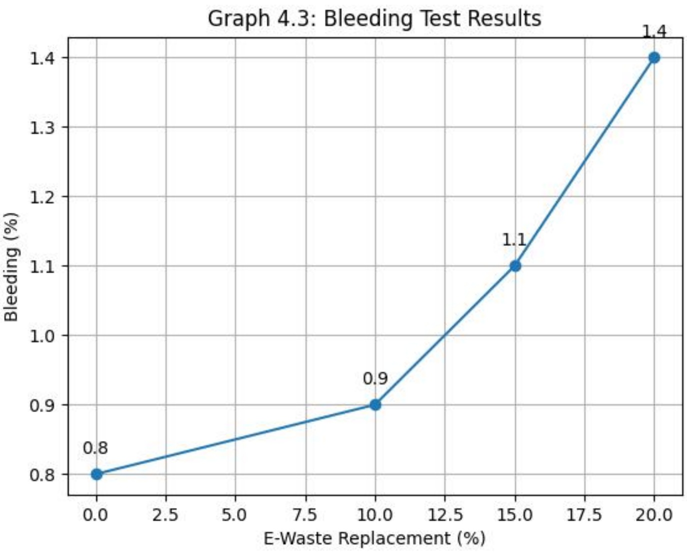


Graph 4.2: Air Content Results

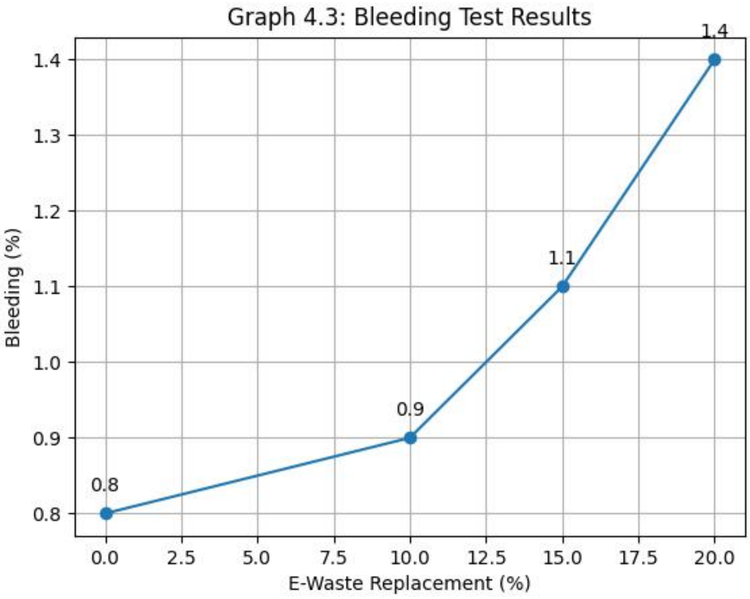
Discussion:

- Air content increases with E-waste addition.
- Due to voids and porous structure of E-waste.
- Higher air reduces strength beyond optimum level.

Bleeding Test:

Table 4.3: Bleeding Results

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



Graph 4.3: Bleeding Results

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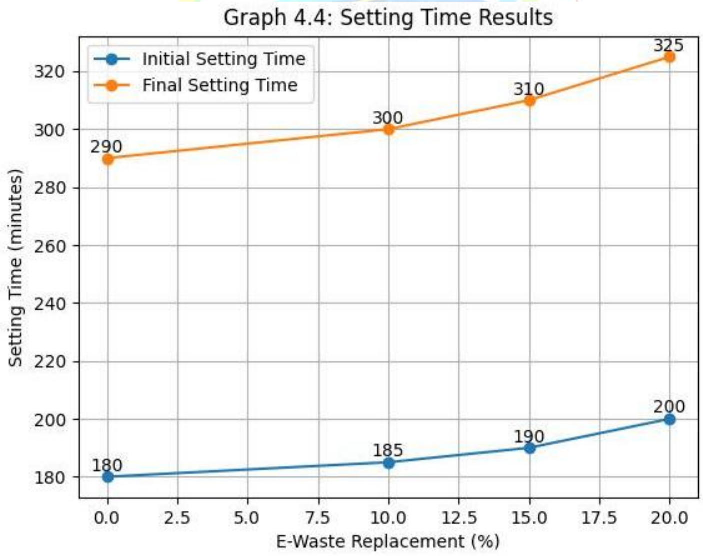
Discussion:

- Bleeding increases with E-waste content.
- E-waste has low water absorption, causing water separation.
- Excess bleeding leads to:
    - Weak surface
    - Reduced durability

Setting Time:

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

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The specimens were tested at curing ages of:
1. 7 Days (Early Strength)
2. 14 Days (Intermediate Strength)
3. 28 Days (Final Design Strength)

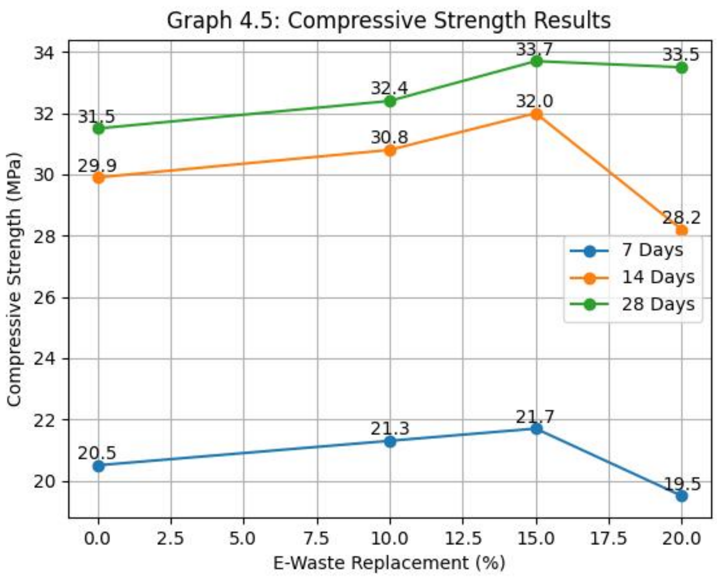
The following hardened concrete tests were conducted as per relevant IS codes:
1. Compressive Strength Test (IS 516:1959)
2. Split Tensile Strength Test (IS 5816:1999)
3. Flexural Strength Test (IS 516:1959)

These tests help in evaluating:
1. Load carrying capacity
2. Resistance to cracking
3. Structural behavior
4. 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



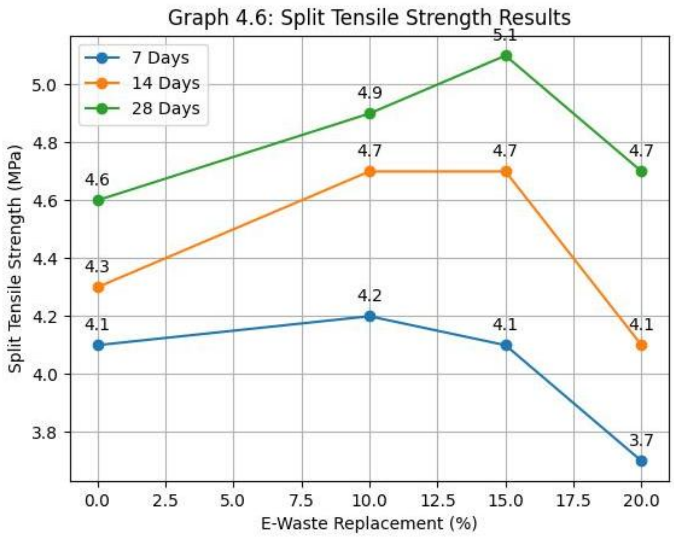
Graph 4.5: Compressive Strength Results

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



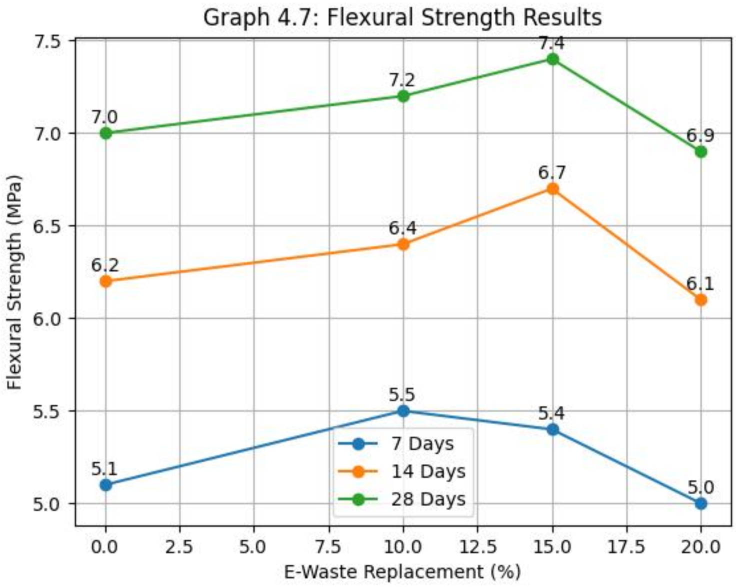
Graph 4.6: Split Tensile Strength

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

The present study concludes that E-waste can be effectively used as a partial replacement of coarse aggregate in concrete. The incorporation of E-waste helps in reducing environmental pollution and conserving natural resources. Experimental results showed that workability decreases with increase in E-waste content, but acceptable workability was obtained up to 15% replacement. The compressive, split tensile, and flexural strengths improved up to 15% replacement and then decreased beyond this limit. Maximum performance was achieved at 15% E-waste replacement, making it the optimum replacement level. The study also confirms that the use of E-waste in concrete promotes sustainable and economical construction practices by reducing landfill waste and dependence on natural aggregates.

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