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EXPLORING THE POTENTIAL OF E-WASTE AS CONSTRUCTIONAL MATERIAL

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Abstract - *This report investigates the feasibility and benefits of utilizing electronic waste (e-waste) as a sustainable alternative in the construction industry. With the rapid increase in electronic device usage, the world is witnessing a parallel surge in e-waste generation, raising serious environmental and health concerns due to the presence of toxic materials. The report explores how recycled components from e-waste—such as plastics, metals, and glass—can be repurposed as partial substitutes for conventional building materials like cement, sand, and aggregates. Through this approach, the construction sector can reduce its reliance on natural resources, lower material costs, and contribute to environmental conservation by diverting harmful waste from landfills. The report also discusses the technical, environmental, and economic implications of this practice, along with the challenges related to safe recycling and public acceptance. Ultimately, the study highlights the potential of e-waste reuse as a promising step toward greener construction practices and improved waste management, while emphasizing the need for further research and technological development to ensure safety, performance, and scalability.*

Key Words: E-waste, Sustainable construction, Electronic waste management, Circular economy, E-waste recycling.

1. INTRODUCTION

The increasing use of electronic devices has resulted in a sharp rise in electronic waste (e-waste), which poses significant environmental and health hazards due to the presence of toxic elements. One innovative and sustainable way to tackle this growing problem is by integrating e-waste into construction materials. This method involves recycling components like plastics, metals, and glass from discarded electronics to partially replace traditional raw materials used in concrete and other building products. Incorporating e-waste in construction not only helps conserve natural resources but also reduces the negative impact associated with conventional e-waste disposal methods, such as landfilling or incineration. Moreover, this approach can lower construction costs and reduce energy consumption by minimizing the demand for energy-intensive material extraction. Despite these benefits, there are certain challenges to address, such as ensuring the safe processing of hazardous components and gaining public trust in the durability and safety of these alternative materials.reusing e-waste in construction offers a promising, eco-friendly, and economically viable strategy for managing electronic waste while also meeting the material demands of the construction sector. Nevertheless, further advancements in recycling technologies and quality control are essential to fully realize its benefits.

1.1 Aim & Objective

To explore and promote the effective reuse of electronic waste in various construction applications—such as filling materials, pavements, and minor infrastructure works—with the objective of reducing environmental pollution, minimizing the demand for natural resources, and supporting sustainable construction practices.

1. Innovative Reuse of E-Waste: To develop creative and practical techniques for recycling electronic waste, converting discarded components into useful materials for construction applications.
2. Minimize Environmental Harm: To reduce the ecological hazards linked to improper e-waste disposal such as soil and water contamination caused by hazardous substances like lead, mercury, and cadmium by incorporating e-waste into construction processes.
3. Promote Eco-Friendly Construction: To support the shift toward sustainable building practices by replacing traditional raw materials (such as sand, gravel, and cement) with recycled e-waste, encouraging the production of environmentally responsible "green concretes."
4. Reduce Construction Expenses: To investigate the potential for lowering construction costs through the use of e-waste as an alternative to costly raw materials, without compromising the quality or strength of the final structures.
5. Boost Resource Efficiency: To increase the recovery and reuse of valuable elements from e-waste such as metals, plastics, and glass thereby reducing the dependence on newly mined or manufactured resources.

6. Enhance Material Performance: To evaluate the impact of e-waste inclusion on the performance characteristics of construction materials, including improvements in thermal properties, strength, and overall durability.
7. Advance Sustainable Building Goals: To contribute to more sustainable, affordable, and environmentally conscious construction practices by utilizing e-waste in the production of building materials.
8. Alleviate Resource Shortages: To address the growing scarcity of natural aggregates by identifying e-waste as a viable alternative source for construction inputs..

2. Literature Review

Contributions of researchers are presented as follows,

S. Lehar, I. Lehar (2019) [1] this study emphasizes the growing interest in transforming waste and recycled materials into sustainable construction resources. The authors highlight that the negative environmental effects of traditional construction materials have led researchers to explore eco-friendly alternatives. The paper reviews various types of waste—such as industrial, agricultural, and electronic—and examines how their by-products can be used in construction to reduce the environmental footprint of building practices.

S.K. Kalifyavardhan, P.R. Prem, P.S. Ambinly [2] this paper explores how the rapid expansion of the electronics industry and changing consumer lifestyles have resulted in a significant increase in electronic waste. The authors discuss the challenges posed by the disposal of electrical and electronic equipment and underline the importance of finding sustainable solutions for managing this waste. They suggest that reusing or recycling e-waste in construction could be one effective way to manage the growing volume of discarded electronics.

M. Masuduzzaman, S.K.S. Amit (2018) [3] this conference paper introduces electronic waste as a promising material for use in the concrete industry. The authors explain that e-waste can be repurposed as a partial substitute for conventional concrete ingredients. Their findings suggest that using e-waste in concrete production is not only technically feasible but also one of the most effective ways to manage electronic waste while supporting the development of smart, sustainable urban infrastructure..

A. Bahadoran, J.R. De Lile, S. Masudy-Panah (2022) [4] this review paper discusses the development and application of photocatalytic materials derived from e-waste. The authors examine various studies indexed in major databases like Springer, Scopus, and ScienceDirect, focusing on the physical and chemical properties of these materials. They point out that certain properties of e-waste-derived substances are comparable to those found in conventional construction materials, making them suitable for use in various civil engineering applications, including structural elements.

3. MATERIAL AND PROPERTIES

Materials Used in the Project

The materials used in this study were collected from various reliable sources. Prior to their application, each material underwent appropriate testing to determine its suitability for use in construction work.

The primary materials used in this project include:

1. Cement
2. Coarse Aggregates
3. Fine Aggregates (Sand)
4. Electronic Waste (E-Waste)

3.1.1 Cement

Cement is a key binding material known for its adhesive and cohesive properties, which allow it to hold other materials together. When mixed with water, it forms a paste that hardens over time, making it suitable for construction purposes. Most modern cements are classified as hydraulic cements, meaning they can set and harden under water. These are typically composed of compounds such as calcium silicates and aluminates, usually derived from limestone and clay.

For this project, Ordinary Portland Cement (OPC) was selected due to its widespread use and proven reliability in general concrete applications.

Types of Cement Used:

- Ordinary Portland Cement (OPC): OPC is the most common type of cement, suitable for a variety of construction works. It is available in different strength grades, such as 33, 43, and 53, with the 53-grade being known for its high early strength, which helps in faster construction.

- Portland Slag Cement (PSC): PSC is produced by blending Portland cement clinker with granulated blast furnace slag and gypsum. It is a durable and environmentally friendly alternative to OPC. This cement is especially useful in mass concreting works due to its lower heat of hydration and improved long-term performance.

3.1.2 Aggregate

Aggregates are one of the most significant components of concrete, making up approximately 80% of its total volume. Their properties have a direct impact on the strength, durability, and overall behavior of the concrete mix. Aggregates are generally categorized into two types:

- Fine Aggregates
- Coarse Aggregates

Fine Aggregates
Fine aggregates consist of particles that pass through a 4.75 mm IS sieve. These materials act as fillers between coarse aggregates and play a critical role in enhancing the workability, cohesion, and uniformity of the concrete mix. Additionally, they help the cement paste bind the coarse aggregate particles together, providing a stable matrix. According to IS 383:1970, fine aggregates are classified into four grading zones based on their particle size distribution:

- Zone I (coarser particles)
- Zone II
- Zone III
- Zone IV (finer particles)

Coarse Aggregates

Coarse aggregates are particles retained on a 4.75 mm IS sieve. They form the structural skeleton of concrete and significantly influence its mechanical strength. The standard size for general concrete applications is 20 mm. However, depending on the structural requirements and spacing of reinforcement:

- 40 mm aggregates may be used where there are no size constraints.
- 10 mm aggregates are suitable for sections with closely spaced reinforcement.

3.1.3 Sand

Fine aggregate, commonly known as sand, is a vital ingredient in concrete mixtures. It significantly affects the mix's performance by enhancing workability, increasing strength, and contributing to the durability of the final structure. By occupying the spaces between coarse aggregates, fine aggregates help create a compact and uniform concrete matrix.
Key Functions of Fine Aggregate in Concrete:

- **Improved Workability**: Fine aggregates help in creating a smooth and cohesive mix, making the concrete easier to mix, transport, place, and compact.
- **Densification of Mix**: Sand fills the gaps between coarse aggregates, resulting in a denser and more compact structure. This minimizes the presence of voids, contributing to improved strength and resistance to wear and tear.
- **Reduced Water Demand**: A well-graded blend of fine and coarse aggregates can reduce the required amount of water, allowing for a lower water-cement ratio. This improves the concrete's strength and reduces risks of shrinkage and cracking.
- **Enhanced Cohesion**: The fine particles offer a greater surface area, which improves the bond between the cement paste and aggregates. This prevents segregation (separation of components) and bleeding (water accumulation on the surface) during placing and curing.
- **Aesthetic Contribution**: The color and texture of fine aggregates can influence the surface finish and visual appeal of the concrete, especially in decorative or architectural applications.
- **Increased Durability**: A denser concrete mix formed with fine aggregates offers better resistance to environmental factors such as moisture and temperature changes, enhancing the long-term durability of the structure.
- **Structural Properties**: Fine aggregates play a crucial role in determining the thermal behavior, elastic response, and dimensional stability of concrete, contributing to the overall structural integrity.

3.1.4 E-waste

Electronic waste (e-waste) is increasingly being explored as an alternative material in concrete production, particularly as a partial replacement for coarse aggregates. This approach not only offers an innovative use for growing volumes of discarded electronics but also contributes to more sustainable construction practices.
Sustainable Waste Management
Integrating e-waste into concrete helps divert electronic components from landfills, thereby reducing environmental pollution. This also aids in conserving natural aggregate resources and supports the principles of a circular economy by giving waste materials a second life.
Partial Replacement of Aggregates
Crushed and processed components of e-waste, such as plastics, circuit boards, or non-toxic glass, can be used to replace a portion of conventional coarse aggregates in concrete mixtures. This replacement typically ranges from 5% to 30%, depending on the specific application and desired properties.
Key Advantages of Using E-Waste in Concrete:

- **Improved Performance:** Research suggests that, when used in suitable proportions, e-waste can improve the compressive strength and durability of concrete while reducing its overall environmental impact.
- **Reduced Structural Weight:** Since e-waste materials are generally lighter than natural aggregates, their inclusion can lower the unit weight of concrete, which is beneficial in lightweight construction.
- **Cost Efficiency:** Substituting a portion of natural aggregates with readily available e-waste can reduce material costs,

making construction more economical without compromising quality.

3.2 TESTS ON MATERIALS

This chapter deals with the results obtained during the analysis work. This study was depends upon the analysis of existing distribution system and optimization of it. Results obtained

3.2.1 Sieve analysis

A test used to determine the particle size of fine and coarse aggregates is known as the sieve analysis test.
Collected sample aggregates are thoroughly sieved through appropriate IS Sieve to determine the particle size.

Well, concrete bonding will not happen when the same size of aggregates has been used in concrete, and it reduces the strength of the concrete.
Sieve Analysis test helps.

- To determine the quality of aggregates based on the size.
- Select the appropriate size of aggregates for particular construction work. For example, 40mm aggregates are used for PCC, and 12mm, 20mm aggregates are used in reinforced concrete works.
- To identify the flaky and irregular shape of aggregates, which is not suitable for construction works.

○ **Apparatus Required**

- IS sieve for Fine aggregates – 10mm, 4.75mm, 2.36mm, 1.18mm, 600 microns, 300 microns, 150 microns, and 75 microns.
- IS sieve for Coarse aggregates – 25mm,20mm 12.5mm, 10mm, 4.75mm.
- Weighing Balance
- Pan

Observation table:

Sr.no.	Sieve size (mm)	Mass retained (gm)	% retained	% passing	Cumulative % retained
1	4.75	4	0.3	99.7	0.3
2	2.26	8	48.8	98.9	1.1
3	1.18	186	18.8	80.1	19.9
4	0.600	193	19.5	60.6	39.4
5	0.300	474	48.5	12.1	87.9
6	0.150	120	12.0	0.1	99.9
7	Pan	4.5		-	
8				Total=	238.5

3.2.2 Specific gravity

○ specific gravity of aggregate test by pycnometer

○ The specific gravity of aggregates is a measure of their quality and strength. When using a pycnometer for this test, the procedure typically involves the following steps:

1. **Preparation**: A clean, dry pycnometer is weighed empty.
2. **Sample Addition**: A known weight of fine aggregate (usually about 1 kg) is added to the pycnometer.
3. **Water Filling**: Water is added to the pycnometer to immerse the aggregate completely. The pycnometer is then shaken to remove any entrapped air.
4. **Weighing**: The pycnometer, now filled with water and aggregate, is weighed again.
5. **Final Step**: The aggregate is removed, and the pycnometer is refilled with water to the same level as before and weighed.

○ **Calculation**

Let me explain the formula for specific gravity using a pycnometer.

The specific gravity (SG) of aggregates is calculated as:

SG=Weight of aggregate in airWeight of an equal volume of water displaced by the aggregateSG

For this test, the formula becomes:

SG=W2−W1/(W4−W1)−(W3−W2)

Where:

- W1 = Weight of the empty pycnometer.
- W2 = Weight of the pycnometer with the dry aggregate.
- W3 = Weight of the pycnometer with water and aggregate.
- W4 = Weight of the pycnometer filled with water only.

○ Steps for the calculation:

1. Subtract the weight of the empty pycnometer (W1W_1) from the weight of the pycnometer filled

with dry aggregate (W2W_2) to get the weight of the aggregate.

2. Subtract the weight of the pycnometer filled with water and aggregate (W3W_3) from the weight of the pycnometer filled with water only (W4W_4) to find the weight of the displaced water.

Weight of empty pycnometer, W1 = 600 g

- Weight of pycnometer + dry soil, W2 = 850 g
- Weight of pycnometer + soil + water, W3= 1400 g
- Weight of pycnometer filled with water only, W4 = 1300 g

SG=850−600/(1300−600)−(1400−850)

SG=250150=1.67

The specific gravity of the material is **1.67**

3.2.3 Impact value test of aggregate

1. Apparatus Setup:

   a. Ensure you have the impact testing machine, cylindrical steel cup, a tamping rod, a 2.36 mm IS sieve, a balance, and a hammer.

2. Sample Preparation:

- Take the aggregates that pass through the 12.5 mm IS sieve and are retained on the 10 mm IS sieve.

- Wash the aggregates thoroughly and dry them in an oven at a temperature of 100–110°C for about 4 hours. Allow them to cool before testing.

3. Weighing the Sample:

- Measure about 350 grams of the prepared aggregate sample.

4. Filling the Cup

- Place the aggregates into the cylindrical steel cup in three equal layers.

- Compact each layer by tamping it 25 times with the tamping rod.

5. Impact Application:

- Mount the cup with the sample on the base of the impact machine.

- Adjust the hammer to fall freely from a height of 380 mm.

- Allow the hammer to strike the sample 15 times, with an interval of one second between blows.

6. Sieving:

- After the test, remove the sample and sieve it through a 2.36 mm IS sieve.

- Collect the material that passes through the sieve (called fines).

7. Weighing the Fines:

- Weigh the fines (material passing through the 2.36 mm sieve) and record the weight as (B).

- Also, record the initial weight of the sample before the test as (A).

8. Calculation:

- Use the formula:

AVI = B/A X100

Where

A = Total weight of the sample used for the test.

B = Weight of the fines (material passing through a 2.36 mm sieve) after the test.

- This provides the Aggregate Impact Value as a percentage.

- Weight of sample before test (A) = 500 g
- Weight of fines passing 2.36 mm sieve (B) = 125 g

AIV=125500×100=25%

result:
The Aggregate Impact Value is **25%**, indicating the toughness of the aggregate. Aggregates with AIV less than 30% are generally considered suitable for road construction

4. RESULT AND DISCUSSION

The chapter presents the results of various concrete mix proportions tested for their strength characteristics. It includes the compressive strength tests performed on cube specimens of size 15 cm x 15 cm x 15 cm, with a focus on M20 grade concrete and mixes incorporating different percentages of e-waste. The compressive strength of the concrete was tested at 7, 14, and 28 days of curing using a compression testing machine. The results show that while the compressive strength of conventional M20 concrete increases steadily with time, the addition of e-waste (at 15% and 20% replacements) results in a decrease in strength compared to the control mix. Specifically, the M20 mix with 15% e-waste showed compressive strengths of 11.69 MPa at 7 days, 15 MPa at 14 days, and 19 MPa at 28 days, while the 20% e-waste mix exhibited lower strengths, ranging from 9.50 MPa at 7 days to 18 MPa at 28 days. This data highlights the impact of e-waste on the strength development of concrete over time.

Results are tabulated as below,

4.1 Compressive strength test for cube

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

Following is the method to calculate compressive strength of concrete.

The cube specimen is of the size 15*15*15 cm. If the largest nominal size of the aggregate does not exceed 10mm. 10cm cubes may also use alternatively. Here, For M20 grade Concrete of all six mixes of different trails tested on Compression testing machine for 7 days, 14 days and 28 days with normal water curing.

Dimensions of the cube = 15cm*15cm*15cm

Area on which load is acting = 150 mm*150 mm = 22500mm2

Hence, compressive strength of cube = load/area=load/22500

Type of concrete/time	07 days	14 days	28 days
M 20	15	24.94	39.86
M20 (15% e-waste)	11.69	15	19
M20 (20% e-waste)	9.50	14	18

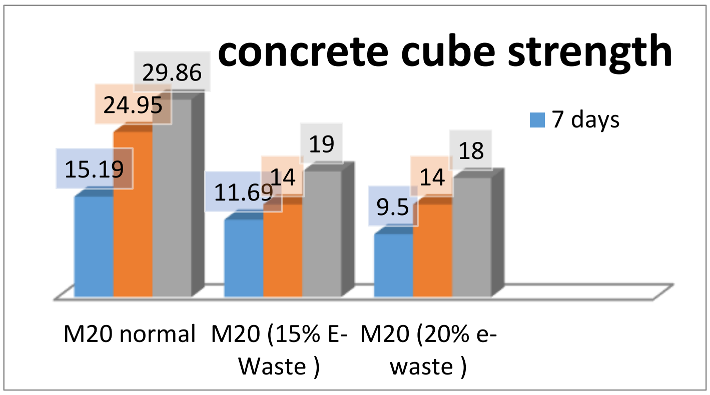

Fig.4.1 Strength of concrete cube

6. CONCLUSIONS

It can be concluded that incorporating e-waste as a partial replacement for coarse aggregates in concrete is a promising approach toward sustainable construction. The study showed that using up to 15% e-waste in the concrete mix yielded the highest compressive strength at 28 days, indicating that a moderate amount of e-waste can enhance or maintain the strength properties of M20 grade concrete. However, increasing the e-waste content to 20% resulted in a reduction in strength, suggesting that there is an optimal limit for replacement. Additionally, it was observed that proper crushing and processing of e-waste is essential to ensure its compatibility with conventional aggregates and to achieve desirable strength performance. This approach not only supports waste management efforts but also promotes the conservation of natural resources and the development of eco-friendly construction materials.

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