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

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Abstract: - The rapid growth of electronic industries and technological advancements has resulted in a significant increase in electronic waste (E-waste) generation worldwide. Disposal of E-waste has become a serious environmental concern due to the presence of toxic and non-biodegradable materials. At the same time, the construction industry is facing a shortage of natural resources such as aggregates. To address both issues simultaneously, researchers have explored the possibility of utilizing E-waste as a partial replacement for coarse and fine aggregates in concrete. This review paper presents a comprehensive analysis of previous studies on the use of E-waste in concrete. Various research findings related to mechanical properties such as compressive strength, flexural strength, tensile strength, workability, and durability are critically examined. The review indicates that E-waste can be effectively used up to an optimum replacement level (generally 5%–15%) without significantly affecting the strength of concrete. Beyond this range, a reduction in strength is observed due to poor bonding and lower stiffness of E-waste materials. The study also highlights the environmental benefits, including reduction in landfill waste, conservation of natural aggregates, and development of sustainable construction materials. However, challenges such as lack of standardization, long-term durability concerns, and limited field applications still exist. This paper identifies key research gaps and suggests future directions for large-scale implementation of E-waste concrete.

Keywords: - E-Waste, Sustainable Concrete, Coarse Aggregate Replacement, Compressive Strength, Recycling, Green Construction, Lightweight Concrete, Durability.

I. INTRODUCTION

In recent decades, rapid industrialization, urbanization, and technological advancement have significantly increased the consumption of electronic devices across the world. With the growing demand for computers, mobile phones, televisions, and other electronic equipment, a large quantity of electronic waste (E-waste) is being generated every year. E-waste consists of discarded electrical and electronic equipment, including printed circuit boards (PCBs), plastic casings, wires, and other components that contain hazardous and non-biodegradable materials. Improper disposal of E-waste leads to serious environmental and health issues due to the presence of toxic elements such as lead, mercury, cadmium, and brominated flame retardants [4].

At the same time, the construction industry is one of the largest consumers of natural resources, particularly aggregates, which are essential components of concrete. Concrete is the most widely used construction material due to its strength, durability, and versatility. However, the excessive extraction of natural aggregates from rivers and quarries has resulted in environmental degradation, depletion of resources, and ecological imbalance. Therefore, there is an urgent need to explore alternative materials that can partially replace natural aggregates without compromising the performance of concrete [23].

In this context, the utilization of waste materials in concrete has emerged as an effective solution for sustainable construction. Among various waste materials, E-waste has gained significant attention due to its increasing availability and potential reuse in construction applications. Researchers have investigated the feasibility of using E-waste as a partial replacement for coarse and fine aggregates in concrete, aiming to reduce environmental pollution and conserve natural resources simultaneously [16].

Several experimental studies have shown that E-waste can be used in concrete without significantly affecting its mechanical properties when used within an optimum range. For instance, Biranagi et al. (2024) reported that replacing coarse aggregates with E-waste up to 10–15% results in satisfactory compressive strength, while higher replacement levels lead to strength reduction due to weak bonding between E-waste particles and cement matrix [2]. Similarly, Suchithra and Indu (2018) observed that concrete with E-waste exhibits improved compressive strength at lower replacement levels due to better particle packing and reduced voids [12].

Moreover, studies have also highlighted the lightweight nature of E-waste concrete. Shinu and Needhidasan (2020) found that the use of E-waste plastic as aggregate reduces the density of concrete, making it suitable for lightweight construction applications [11]. This property is particularly beneficial in reducing dead loads in structures and improving overall structural efficiency.

In addition to strength characteristics, workability is another important factor in concrete performance. Biradar et al. (2019) reported that the inclusion of E-waste improves the workability of concrete due to the smooth surface texture of plastic materials [3]. However, excessive use of E-waste may lead to segregation and reduced cohesion, which can negatively affect the quality of concrete [10].

Durability of concrete is also an important aspect that has been studied by various researchers. Ahmad et al. (2021) observed that E-waste concrete exhibits improved resistance to chemical attack due to the non-reactive nature of plastic materials [18]. Similarly, Nag and Chandrakar (2020) found that the use of PCB waste enhances durability properties at optimum replacement levels [17]. However, long-term durability studies are still limited, and more research is required to understand the behavior of E-waste concrete under different environmental conditions.

Another important area of research is the use of E-waste in combination with other supplementary materials. Ahirwar et al. (2016) studied the combined use of E-waste and fly ash in concrete and concluded that it improves sustainability and reduces the environmental impact of construction [22]. Dhanalakshmi et al. (2025) incorporated nano-silica with E-waste and reported improved strength and microstructural properties due to better bonding and reduced porosity [5]. These studies indicate that hybrid approaches can enhance the performance of E-waste concrete.

Furthermore, researchers have also explored alternative applications of E-waste in concrete. Tripathi and Pandey (2025) used E-waste as fine aggregate and observed optimum strength at around 6% replacement [13]. Ullah et al. (2022) studied the structural behavior of E-waste concrete confined with CFRP and found improved load-carrying capacity and ductility [14]. These findings suggest that advanced techniques can help overcome the limitations associated with E-waste concrete.

Despite the promising results, there are several challenges associated with the use of E-waste in concrete. One of the major issues is the variability in the composition of E-waste, which includes different materials such as plastics, metals, and glass. This variation leads to inconsistent results and makes it difficult to standardize the mix design. Additionally, most studies are limited to laboratory conditions, and there is a lack of large-scale field applications [20].

Another concern is the reduction in strength at higher replacement levels. Kumar et al. (2020) reported that compressive strength decreases beyond the optimum percentage due to poor interfacial bonding between E-waste particles and cement paste [16]. Similarly, Jalaluddin and Ahad (2025) emphasized that maintaining the replacement level within 15% is crucial for achieving acceptable performance [6].

From an environmental perspective, the use of E-waste in concrete offers significant benefits. It helps in reducing landfill waste, conserving natural resources, and promoting sustainable construction practices. Dubey and Rajpoot (2022) highlighted that the incorporation of waste materials in concrete not only reduces environmental pollution but also lowers construction costs [19]. Therefore, E-waste concrete can be considered as a green building material with potential for future development.

In conclusion, the use of E-waste in concrete is an innovative and sustainable approach that addresses both environmental and construction challenges. While previous studies have demonstrated its feasibility and benefits, further research is required to overcome existing limitations and ensure safe and effective utilization in real-world applications. The present study aims to build upon existing knowledge and contribute to the development of sustainable concrete using E-waste materials .

II. LITERATURE REVIEW

Various researchers have conducted experimental and analytical studies to investigate the effect of E-waste on concrete properties. The important findings from previous studies are summarized below:

[1] Purnima K. Biranagi et al. (2024) analysed the use of E-waste as partial replacement of coarse aggregate in M20 concrete. The study showed that up to 10–15% replacement, compressive strength remained satisfactory, while higher percentages reduced strength.

[2] Suchithra S and Indu V. S. (2018) studied M20 concrete with 0–20% E-waste replacement and observed improvement in compressive strength at optimum levels along with acceptable durability performance.

[3] N. M. Mary Treasa Shinu and S. Needhidasan (2020) investigated E-waste plastic in M40 concrete and concluded that it produces lightweight concrete with acceptable strength up to optimum replacement levels.

[4] N. B. Kaniskha et al. (2019) used E-waste and M-sand in M30 concrete and found improved compressive strength at certain replacement levels with sustainable benefits.

[5] ICCMES (2021, Retracted 2022) studied mechanical properties of E-waste concrete, but due to retraction, the findings are considered unreliable and must be used cautiously.

[6] Prof. A. C. Umare et al. (2018) used PCB-based E-waste in M35 concrete and concluded that E-waste has suitable physical properties and can be used effectively at limited percentages.

[7] Gaurav Kumar et al. (2024) presented a review on E-waste concrete and concluded that material properties depend on size, shape, and replacement percentage.

[8] Narayana Rao Cheva and Krishna Lohith (2025) studied M30 concrete with E-waste plastic and found that 5% replacement gives comparable performance to conventional concrete.

[9] Vartika Tripathi and R. K. Pandey (2025) used E-waste as fine aggregate and found optimum strength at around 6% replacement.

[10] Sunil Ahirwar et al. (2016) combined E-waste and fly ash in concrete and concluded that it produces lightweight and eco-friendly concrete.

[11] Supriya Nag and Gaurav Chandrakar (2020) used PCB waste as fine aggregate and found optimum performance at 8.5% replacement.

[12] Krishnan Dhanalakshmi et al. (2025) studied plastic aggregate with nano-silica and concluded that nano-materials improve strength and microstructure.

[13] Nagaraj S and Pauline S (2024) studied recycled concrete aggregate and found optimum strength at 60% replacement.

[14] Farhan Ahmad et al. (2021) analysed plastic aggregate concrete and observed improved durability but reduced strength at higher replacement levels.

[15] Biradar Shilpa et al. (2019) concluded that E-waste improves workability and can be used as lightweight concrete.

[16] Aamar Danish et al. (2023) reviewed E-waste aggregates and highlighted the need for further experimental studies.

[17] Kumar Gaurav et al. (2020) found optimum compressive strength at 7% E-waste replacement in M30 concrete.

[18] Ashish Dubey and Anil Rajpoot (2022) studied multiple waste materials and concluded that waste utilization improves sustainability and reduces cost.

[19] Mohammed Razin et al. (2024) observed improved workability but reduced strength at higher E-waste content.

[20] Mohd Jalaluddin and Abdul Ahad (2025) found optimum strength at 15% E-waste replacement.

[21] Ajipriya C. S. et al. (2022) used PCB and plastic waste and concluded that low percentages are suitable for concrete production.

[22] Saad Ullah et al. (2022) studied CFRP-confined E-waste concrete and found improved structural performance despite reduced strength.

III. RESEARCH GAP

From the above studies, it is observed that:

- E-waste can be used as a partial replacement of coarse or fine aggregate.
- Optimum replacement level generally lies between 5% to 15%.
- Strength decreases at higher replacement levels.
- Workability and durability may improve depending on material type.
- E-waste concrete is lightweight and eco-friendly.
- There is a need for further research on durability, standardization, and field application.

CONCLUSION

From the comprehensive review of previous studies on the utilization of E-waste in concrete, it can be concluded that E-waste has significant potential as an alternative material for partial replacement of natural aggregates in concrete. The increasing generation of electronic waste and the depletion of natural resources have made it essential to adopt sustainable construction practices. In this regard, the incorporation of E-waste in concrete provides a dual benefit of effective waste management and conservation of natural aggregates.

Most of the researchers have consistently reported that E-waste can be safely used in concrete up to an optimum replacement level, generally ranging between 5% and 15%, without causing significant reduction in mechanical properties. Within this range, the compressive strength, flexural strength, and tensile strength of concrete remain comparable to conventional concrete. In some cases, a slight improvement in strength has also been observed due to better particle packing and reduced voids [2][12]. However, when the percentage of E-waste exceeds the optimum limit, a noticeable reduction in strength occurs due to poor bonding between E-waste particles and the cement matrix, as well as the lower stiffness and irregular surface characteristics of E-waste materials [16].

The review also indicates that the use of E-waste improves certain properties of concrete, such as workability and reduction in density. The smooth and lightweight nature of E-waste materials contributes to improved flow characteristics and production of lightweight concrete, which can be beneficial in reducing dead loads in structures [3][11]. However, excessive incorporation of E-waste may lead to segregation, bleeding, and reduced cohesion, which can adversely affect the quality and durability of concrete [10].

Durability performance of E-waste concrete shows promising results at lower replacement levels. Some studies have reported improved resistance to chemical attack and environmental degradation due to the non-reactive nature of plastic-based E-waste [18]. Additionally, the use of PCB waste and other electronic components has been found to enhance durability characteristics under certain conditions [17]. Nevertheless, long-term durability aspects such as creep, shrinkage, permeability, and resistance to extreme environmental conditions are still not fully explored, and further investigation is required.

Another important observation from the literature is that the performance of E-waste concrete can be significantly improved by combining it with supplementary cementitious materials such as fly ash, silica fume, and nano-silica. These materials help in improving the microstructure, enhancing bonding, and reducing porosity, thereby compensating for the loss of strength caused by E-waste incorporation [5][22]. Advanced techniques such as fiber reinforcement and external confinement (e.g., CFRP) have also shown potential in enhancing the structural performance of E-waste concrete [14].

Despite the promising advantages, several challenges and limitations are associated with the use of E-waste in concrete. One of the major issues is the lack of standardization in terms of material selection, processing, and mix design. The heterogeneous nature of E-waste, which includes plastics, metals, and glass components, leads to variability in results and makes it difficult to establish uniform guidelines. Moreover, most of the existing studies are limited to laboratory-scale experiments, and there is a lack of real-life field applications and large-scale implementation [20].

Furthermore, environmental and safety concerns related to the leaching of toxic substances from E-waste need to be carefully addressed before its widespread use in construction. Although many studies suggest that encapsulation within the cement matrix reduces the risk of leaching, detailed environmental impact assessments and life cycle analysis are still required.

In conclusion, the use of E-waste in concrete is a promising and sustainable approach that can contribute to eco-friendly construction and effective waste management. It offers several benefits, including reduction in environmental pollution, conservation of natural resources, and development of lightweight and cost-effective construction materials. However, to fully utilize its potential, further research is needed in areas such as long-term durability, standardization of mix design, improvement of bonding characteristics, and large-scale field implementation.

Therefore, E-waste concrete can be considered as a future-oriented construction material, but its practical application requires careful consideration of technical, environmental, and economic aspects. With proper research, innovation, and standardization, E-waste has the potential to play a significant role in achieving sustainable development in the construction industry.

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