

# E-Waste Utilization in Concrete: A Systematic Literature Review and Metadata Analysis

Sourav Ghosh<sup>1</sup>[\[0009-0006-2629-8409\]](https://orcid.org/0009-0006-2629-8409), Munshi Izaz Refaz<sup>2</sup>, and Mainak Maiti<sup>3</sup>

<sup>1</sup>Narula Institute of Technology, 81, Nilgunj Rd, Jagarata Pally, Deshpriya Nagar, Agarpara, Kolkata, West Bengal 700109, India, [souravghosh.jeet@gmail.com](mailto:souravghosh.jeet@gmail.com)

<sup>2</sup>Jadavpur University, 188, Raja Subodh Chandra Mallick Rd, Jadavpur, Kolkata, West Bengal 700032, India, [izazcivil@gmail.com](mailto:izazcivil@gmail.com)

<sup>3</sup>Jadavpur University, 188, Raja Subodh Chandra Mallick Rd, Jadavpur, Kolkata, West Bengal 700032, India, [mainakm.civil.rs@jadavpuruniversity.in](mailto:mainakm.civil.rs@jadavpuruniversity.in)

## Abstract

The rapid escalation of electronic waste has emerged as a global threat due to its hazardous composition, environmental risk, and limited disposal options. According to the Central Pollution Control Board, 1,70,338 TPD was generated from 2021-22, out of which 91,512 TPD was treated the rest was disposed of in water bodies. In response, the researchers have pioneered the potential incorporation of electronic waste in concrete as a sustainable solution for waste management and conservation of resources. This piece presents a systematic literature review (SLR) of published work regarding e-waste-infused concrete, drawing focus on multiple parameters such as mechanical strength, workability, and durability. Following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) method, articles from the last two decades were analysed to understand the trends, methodology, and research gaps. Metadata analysis was performed to examine keyword mapping and thematic clustering of the research domain, along with regional contribution. The finding emphasises the benefits of reducing e-waste from the environment, maintaining adequate strength in a certain replacement level, and posing as a cost-saving approach. However, the challenges regarding durability remain a concern due to the leaching property. Ultimately, this study bridges the domains of waste management and construction sustainability, while providing a critical insight for researchers to advance circular economy practices through e-waste valorisation in concrete.

**Keywords:** E-waste, Metadata analysis, bibliometric analysis, Mechanical strength.

## Abbreviations

PCBD: PCB dust, ABSP: ABS weep, EPW: E-plastic waste, EWF: E-waste fibre, PCB-NSP: PCB without super plasticizer, PCB-SP: PCB with super plasticizer, P: Plastic, EW: E-waste, SEW: Scrape e-waste, EPWCA: Electronic plastic waste coarse aggregate, SS: Steel slag, CDW: Crushed discarded waste, PA: Plastic aggregates, PPF: Polypropylene fibers, JF: Jute fiber, EWC: E-waste coarse aggregate, WEEPC444: Waste electrical and electronic plastic cement 444, WEEPC333: Waste electrical and electronic plastic cement 333, WEEPC400: Waste electrical and electronic plastic cement 400, IRP: Irradiated recycled polycarbonate,, EWA: E-waste aggregate, EW-C: Electronic wastes coated, HDPE-C: High-density polyethylene coated, HDPE-UC: High-density polyethylene uncoated, RSF: Recycled steel fibers, EPA/PA: E-plastic aggregate/plastic aggregate, GF: Glass fiber, SF: Steel fiber, CF:

Carbon fiber, NIOP: Nano iron oxide particles, PCA: Plastic coarse aggregate, OPF: Polymer optical fibers, HIP: High impact polystyrene, PVC: Polyvinyl chloride, PP: Polypropylene, EP: Elec-tronic plastic, CRT: Cathode ray tube, G: Funnel glass, GS: Spherical CRT funnel glass, PR: Polystyrene resin, REPW: Recycled electronic plastic waste, PC: Polycar-bonate

## 1 Introduction

The demand for concrete is increasing every day due to rapid urbanization. This leads to the rapid destruction of natural coarse aggregate (NCA), with approximately 6 billion tons extracted annually, the extraction of NCA reaches up to 6 billion tons to prepare concrete [1]. Simultaneously advancement of electronics in the last 2 dec-ades led to an increment in discarded electronic parts or electronic waste (E-waste), contributing to waste generation; however, according to UNITAR, sixty two million tons of e-waste are generated globally each year [2]. The large amount of e-waste that is being dumped at landfills further leads to the leaching of heavy metals in the ground and contaminates the groundwater, which further affects the human health that relies on that water. Filling of landfills with e-waste reacts with other decomposa-ble waste and releases detrimental gases, i.e., carbon dioxide, methane, and non-methane organic compounds, etc, leading to green greenhouse gas effect and bad odor, which is a threat to the environment and a reason for climate change. and also becomes a shelter for harmful and disease-spreading animals like rats, snakes, harm-ful worms, etc. Thus, an urgent issue is needed to address the growing issue of E-waste accumulation through the development of sustainable solutions. It was given that the building sector is responsible for high consumption of natural resources; therefore, an alternative strategy must be adopted by utilizing the waste in concrete. The utilization of e-waste like circuit boards, gadgets, glass, etc, in concrete mixture has been an area of study for the scientific community [3]. Experiments on these studies reveal that NCA can be replaced by e-waste without compromising the sustainability, mechani-cal strength and durability of the concrete. This alternative process not only addresses the issue of E-waste but also adheres to sustainable habits. Utilizing e-waste in con-crete can be beneficial by decreasing the requirement for new material, reducing and reusing waste, leading to cheaper construction [4].

This article presents a systematic literature review of articles from the last decade. In a nutshell, it has been revealed that the research articles have been spiked throughout the past decade. The review highlights the global awareness of e-waste, which can cause detrimental effects to the environment. In this review article, a comparison was made in the field of mechanical properties and durability with traditional concrete (OPC, PPC, PSC). The paper also calls attention to the environmental impact of those mixtures compared to traditional concrete and their contribution to greenhouse gas emission. The review Sheds light on the development of the zones towards “Green concrete and sustainable material”

## 2 Methodology

This systematic literature review (SLR) was followed by the PRISMA method as mentioned in Fig.1 as a PRISMA table. The keywords ( ( "e-waste " OR "electronic waste " OR "electrical waste " ) AND ( "concrete" ) AND ( "compressive strength" OR "Flexural strength" OR "Tensile strength" OR "Durability test " OR "permeability test" OR "bond strength " OR "Workability" OR "thermal conductivity" OR "Thermal insu-lation" OR "UPV" OR "soundness test" OR "RCPT" OR "Rebound hammer" ) ) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND ( LIMIT-TO ( SUBJAREA , "ENGI" ) OR LIMIT-TO ( SUBJAREA

, "MATE" ) OR LIMIT-TO ( SUBJAREA, "ENVI" ) ) have been input under the field of TITLE-ABS-KEY in both the index i.e. Scopus and ScienceDirect. primarily, 298 articles were collected. After rigorous review and sorting meticulously, the number was shortened to 136, which was further finessed to 63. The SLR sheds light on the advancement of civil engineering, materials science, and environmental in the past 10 years. The review article elucidates the environmental effects of e-waste and delves into the advancement of sustainable building materials on a global scale. The data extracted from the studies were systematically framed through different tables and figures as part of the meta-analysis.

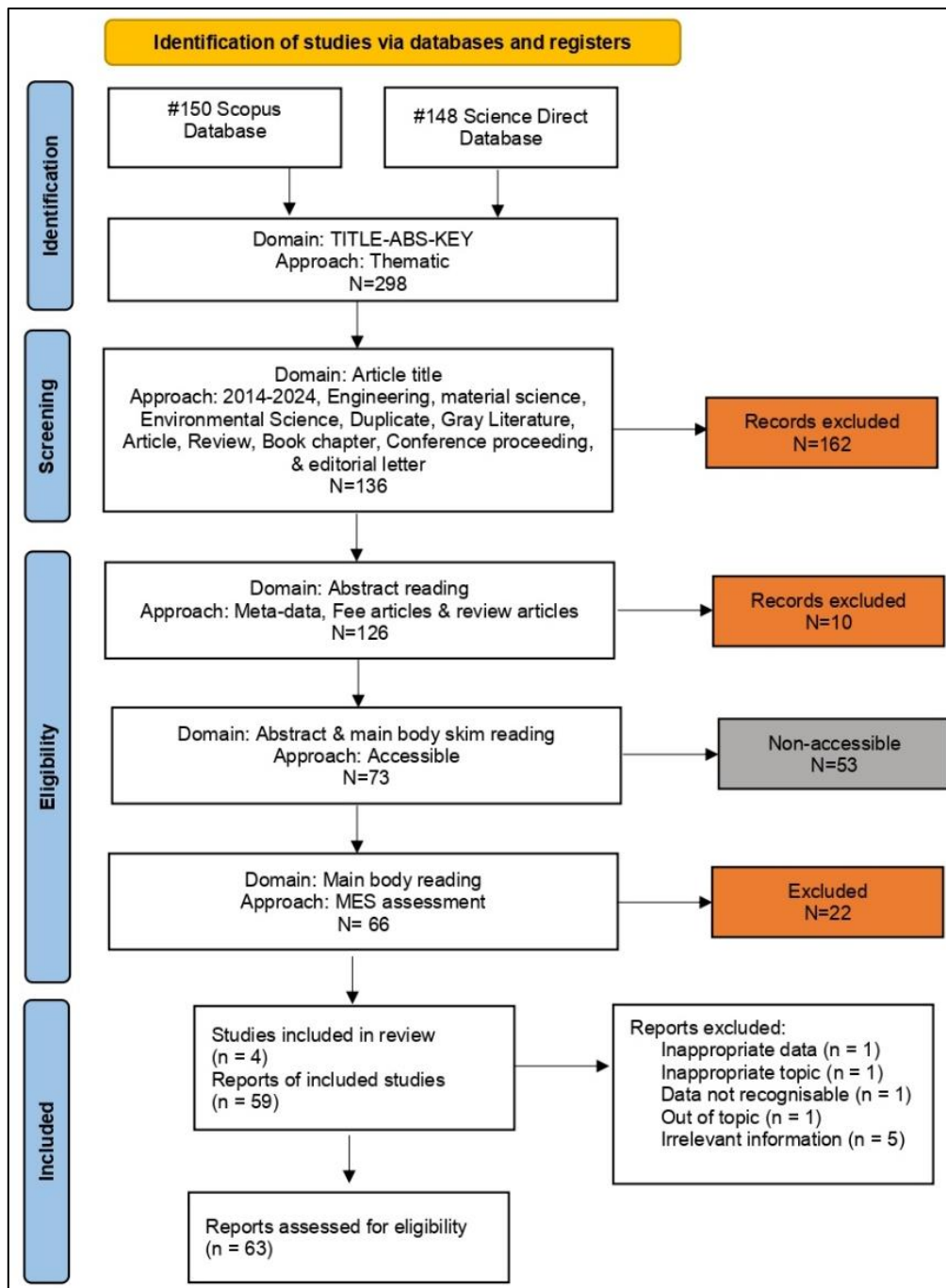
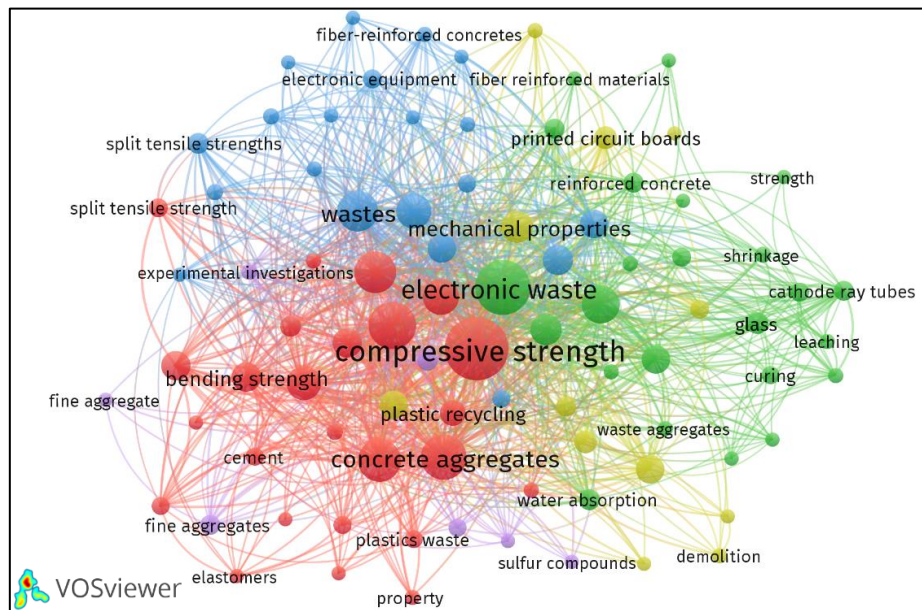


Fig. 1. Detailed Prisma table

### 3 Results and discussions

#### 3.1 Bibliometric analysis



**Fig. 2.** Keyword Co-occurrence Network (Total Link Strength based)

The bibliometric analysis is performed under the segment of ‘Network Visualization’. Those index and author keywords that have occurred a minimum of five times have been considered. 5 clusters and a total 88 number of keywords have been identified. A total of 2212 links (co-occurrences) have been generated. Total link strength has been calculated as 7203. The keyword that occurs most is compressive strength (102 times). Other top five keywords which have occurred abundantly are electronic waste (75 times), concrete aggregates (53 times), e-wastes (45 times), waste (42 times) and tensile strength (44 times). Other than “cement” and “concretes” from sustainable concrete, concrete mixture (22 times), and durability (25 times) have been identified as wastes under the current preconditions. Link strength of compressive strength is 958, cement replacement and bending strength have co-occurred most of the time. The keyword co-occurrence network is shown in Figure 2. Analyzing the scientific landscape in the current context, it may not be an exaggeration to state that, in India, though the research related to geopolymers is accelerating in present times but the research related to the inclusion of different waste into it hasn’t significantly emerged yet.

#### Cluster analysis

The red cluster represents the theme of concrete & strength by introducing keywords like bending strength, compressive strength, cement, split tensile strength, etc. However, it strongly focuses on the testing and comparison of the mechanical strength of waste-incorporated concrete. The green cluster represents the theme of recycling & environmental impact, which includes distinct materials like leaching, cathode ray tubes, waste aggregates, etc. It strongly focuses on durability and environmental safety. Blue cluster represents the theme of fibers & materials, the keywords like electronic equipment, fiber-reinforced concretes, and polymer fiber show the advanced composite with e-waste. The yellow cluster represents the theme of demolition & sustainability, which includes keywords like secondary

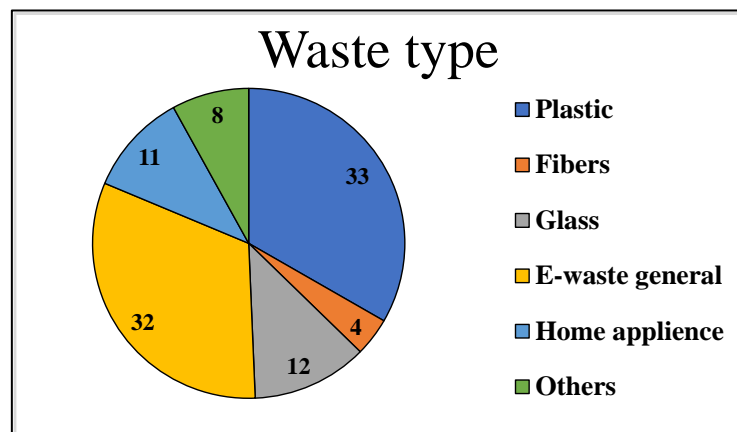
recycling, long-term performance, etc. They highly recommend sustainable practices and long-term performance.

### Research gap

It has been seen that the mechanical properties dominate, while environmental aspects like the leaching effect, life-cycle assessment, and toxicity are less centralised. Hence, the long-term durability of e-waste-infused concrete remains underexplored compared to studies focusing on strength. Additional remarks indicate that fibre-reinforced composites with e-waste appear but are not as heavily connected, suggesting emerging opportunities.

In future research, multi-year leaching tests, UPV and water absorption percentage, processing parameters, assess regional regulations, and mention multidisciplinary approaches to ensure sustainability, and durability of e-waste concrete.

### 3.2 Waste material



**Fig. 3.** Research output and waste type distribution throughout the literature review

Fig. 3 illustrates the diversified version of e-waste observed throughout the survey, where we can see that plastic items such as plastic waste, wrappers, bottles, and straws contribute 33% of the total waste, according to the report from the last ten years. This waste causes harm to aquatic animals as well as pollutes the water bodies. Fibrous waste such as optical fibres, cables, and polystyrene, accounted for 4% of waste as per the survey, also poses a highly hazardous. Mismanagement of these types of waste generates dioxins and furans, which may cause respiratory illness and neurological damage. Glass waste cups, watches, and oven plates form 12% adding a significant burden to global solid waste. E-waste generated is 11% from home appliances, such as shredded and dismantled electronics, including plastic, metals, and glass, which represents the second dominant share. Other waste, such as steel waste and wires used in cables and transformers, is about 8%. The additional insight in the review indicates that the research on e-waste is primarily focused in India, China, and Europe.

### 3.3 Workability of concrete

The slump value of e-waste-infused concrete denotes that the slump, ranging from 20 mm to 170 mm, reflects the strong workability. E-plastic waste (EPW) and e-plastic aggregate (EPA) waste exhibited the highest workability, at (248 mm, W/C ratio 1:2) and (185 mm, W/B/S ratio 1:2.5:0.02), respectively, but also posed a potential risk of segregation. The lower slump values are observed in plastic coarse aggregate (PS, 10 mm, W/C/S 1:1.95:0.03) and Plastic aggregate

(PA, 22.9 mm, W/C 2.04:1), resulting in a honeycomb formation and poor compaction. Moderate values were obtained for most other mixes, such as EW (81 mm, W), EW (114 mm, W/C: 5:1), and HDPE-UC (48 mm), PCBD (29 mm, W/C/S: 1:2.99:0.6).

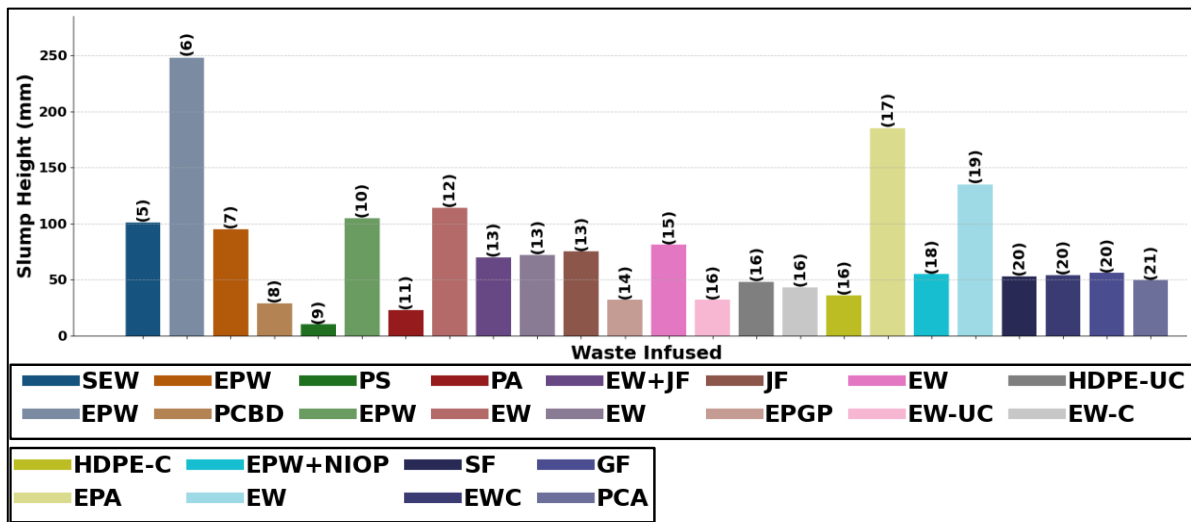


Fig. 4. Slump height of the concrete

### 3.4 Mechanical strength

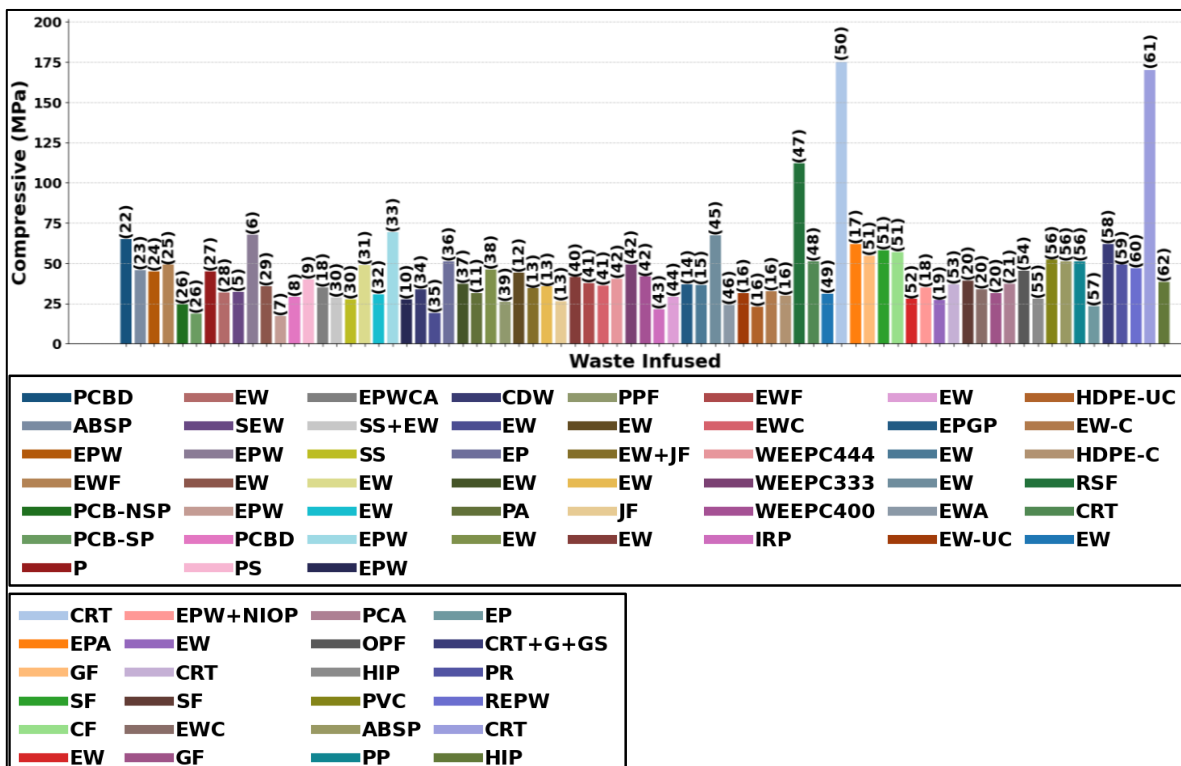


Fig. 5. Variation of compressive strength in different e-waste-infused concrete

From Fig. 5, it can be observed that not all e-waste does not contributes to strength. Waste like HIP, CRT-G, RSF, and EPA, amplifies the compressive strength, whereas coarse aggregate like CA and PCA drastically reduces it. Even processing methods such as irradiation, coating, and superplasticiser addition also play an important role in improving the bond and strength that make e-waste viable for structural concrete.

Properly processed and selected e-waste can not only create benchmarks (40-60 MPa) but also can be a suitable alternative.

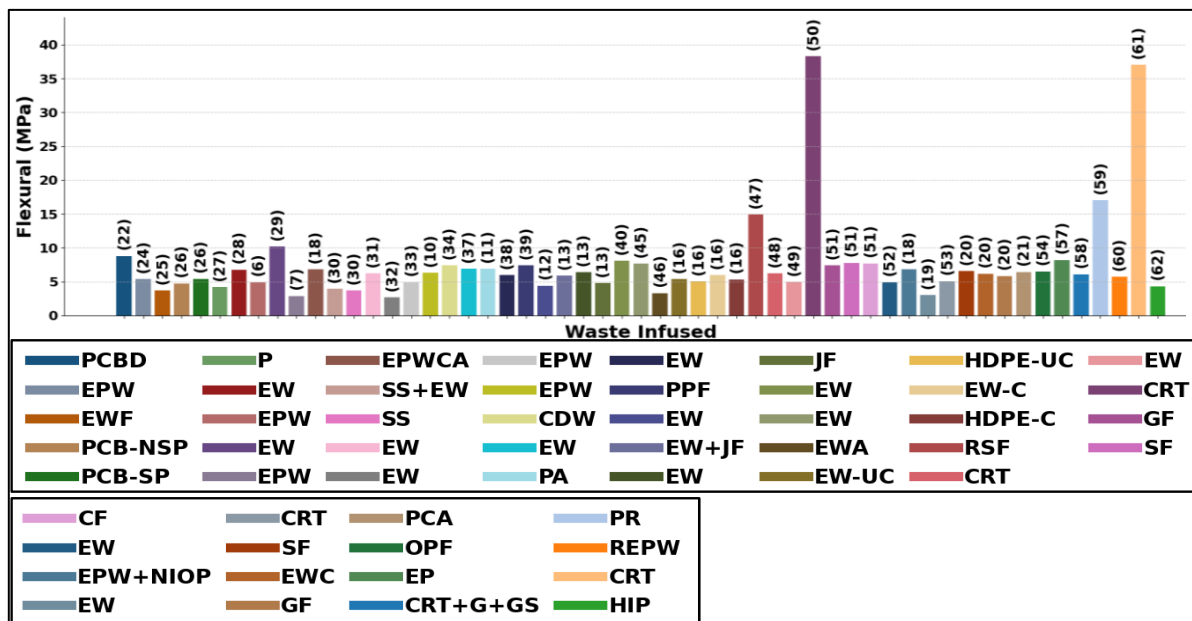


Fig. 6. Variation of flexural strength in different e-waste-infused concrete

Fig. 6 illustrates that all sorts of waste cannot amplify the flexural strength of concrete, unlike fibrous materials such as SF, CF, and GF. These fibrous waste increases the flexural strength. Throughout the flexural strength, it has been seen that CF-infused concrete showed the peak result. The optimisation key indicates that the proper incorporation method and choice of additive significantly affect the flexural strength. Selecting and incorporating the right waste, especially the treated one or engineered fibre, can make a sustainable concrete.

As mentioned in Fig. 7, selective waste like SF, CF, and GF drastically increased the tensile strength and achieved a value of about 9 MPa. Along with that, most of the plastic, e-waste aggregates, and untreated fillers showed moderate and low improvement. The wise selection and processing of certain e-waste, like notable fibres, can significantly redefine mechanical strength for sustainable concrete.

The waste-infused concrete frames a strong independence among tensile, compressive, and flexural strength. The fibres like CF, SF, and GF deliver the highest strength in all mechanical properties. Often overthrows conventional concrete. In contrast, some e-waste and basic plastics usually showed modest strength or have been seen in reducing it.

E-waste concrete may leach trace metals over time, framing environmental risks; regional regulations, and durability-focused implementation are crucial to ensure safe, compliant, and sustainable infrastructure applications. The leaching effects are scarcely mentioned in the article due to a lack of focus on the durability of concrete, as mentioned in Table 1,

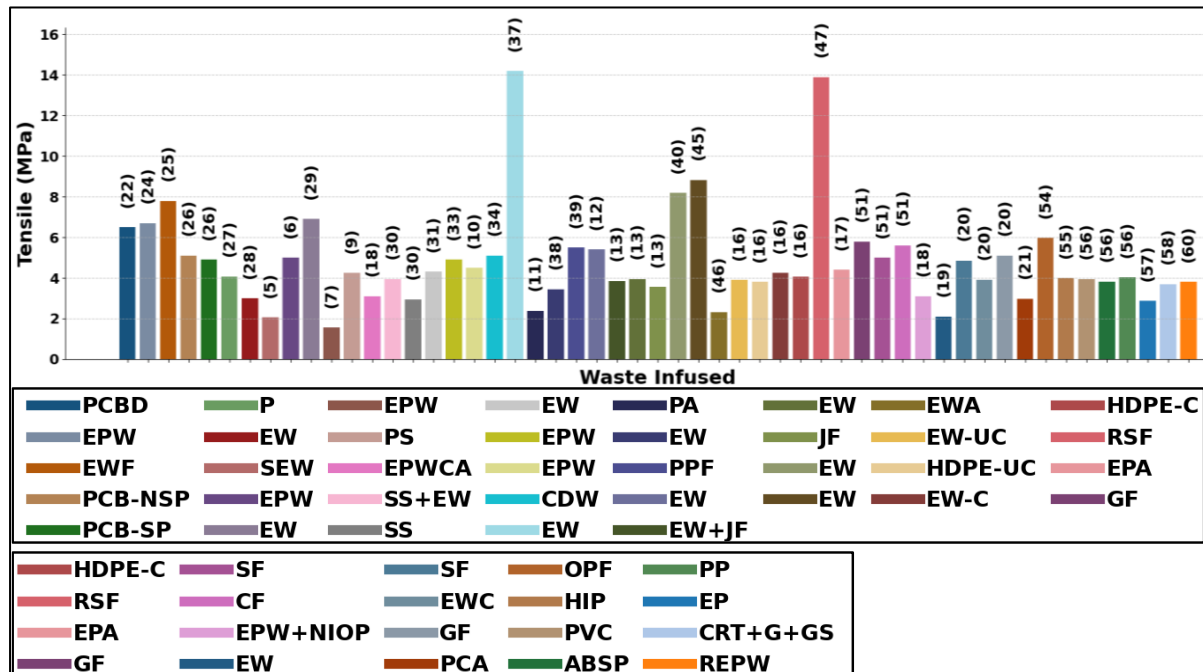


Fig. 7. Variation of split tensile strength in different e-waste-infused concrete

Table 1. The leaching effect of the concrete

Ref	Waste	Mg/L
[53]	CRT	0.003
[53]	CRT	0.002
[58]	CRT+G+GS	0.8
[61]	CRT	0.2

This method of processing waste and incorporation amplifies the positive impact and leads to comparable trends in all three strengths. Thus, both waste type and treatment are critical: when appropriately chosen and processed, waste materials can increase the performance of concrete in the context of compressive, tensile, and flexural strengths, enabling eco-friendly and structurally sound solutions for construction. It has also been observed that Polymer coatings, irradiation, and superplasticisers optimise e-waste concrete, reducing metal leaching, enhancing bonding, and ensuring workability and durability.

#### 4 Conclusion

The systematic literature demonstrates the sustainable path for waste management and resource conservation by infiltrating e-waste and plastic waste in concrete. The Findings highlight that not all e-waste types contribute equally to mechanical performance; fibrous materials such as CF, GF, and SF are perfect for better compressive, tensile, and flexural strength. It has further been noted that the untreated e-waste and coarse aggregate from e-waste reduce the mechanical properties, which indicates the importance of selecting proper materials, such as fiberising, coating, or using admixtures

The review also sheds light on mechanical property, compressive strength to be exact, while the environmental issues, such as leaching effect and long-term durability, are less explored in the research community. For practical deployment, further attention must be given to the durability, processing methods, and environmental safety. Over-all, the valorisation of e-waste in concrete presents a compelling opportunity to advance circular economy practices in construction, offering a blend of environmental stewardship and structural efficacy.

A meta-analysis of e-waste concrete studies enables statistical evaluation of optimal replacement levels, quantifying mechanical performance, identifying thresholds, and using visual tools like forest plots for evidence-based, robust recommendations.

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