

REVIEW**Perspective of E-Waste in Concrete: A Review****Kiran Devi* Amit Kumar**

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ABSTRACT

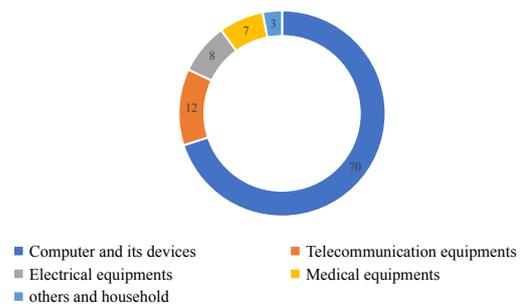
In this digital era, usage of electric and electronic devices has become the need of people. Evolution of technology triggers the adoption of new devices over old and discarded appliances turned into the electronic wastes also termed as e-waste/s. E-waste from any source has become a major concern to the society. The disposal of these wastes into the landfills causes many hazardous impacts to the ecosystem. As a promising solution construction industry can utilize the e-wastes effectively. The wastes may be used either as fine filler or aggregates in concrete and bituminous based constructions efficiently. Usage of waste/s conserves the natural resources also. Present study magnifies the scenario of application of electronic wastes in different forms i.e., plastic, metal etc. in bituminous and concrete based mixtures. A critical review has been carried the effects of electronic wastes in concrete and bituminous mixes and findings confirm the praxis of electronic wastes is possible within certain limits.

1. Introduction

Advancement in technology pushes the use/dependence of electric and electronic appliances i.e., computer, mobile, television, refrigerator etc. in day-to-day life and use to people can switch to advanced devices very easily at affordable prices. Obsolete old devices turn into the e-waste and also increasing along with the production/manufacturing of new devices at rumoring speed globally^[1].

In 2018, 50 MT of electronic wastes (e-wastes) was generated globally and half of this related to personal devices i.e., computers, monitors, chargers, screens, smart phones, motherboards, tablets and TVs etc. while rest were the large household appliances i.e., comfort equipments. Figure 1 depicts the sources of e-waste. According to a study, only 20% of global e-waste is recycled per annum i.e. 40 million tonnes of e-waste is dumped in landfill, burned or illegally traded and treated in a substandard

way. As the land is precious resource, therefore it should be conserved rather than dumped every waste into it. In India, e-waste in the form of computer along its devices, telecommunication, electricity and medical equipment and household scraps is generated. Mumbai is the leading city in waste generators followed by Delhi, Bangalore, Chennai and Kolkata^[2].

**Figure 1.** E-wastes generation from different sources^[2]**Corresponding Author:*

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In electronic wastes, there are more than thousand different types of toxic elements i.e. lead, mercury, cadmium etc. The ferrous metal, non-ferrous metal, glass, plastics and others are present in e-waste. The percentage of materials in electronic wastes has been shown in Figure 2. Approximately 20 to 50 million tonnes of e-wastes are discarded globally and 12 million were from Asia only (178million in China and 80 million in India of total 716 million computer users globally). In 2016, 44.7 million metric tonnes of e-waste were generated which is equal to almost 4500 Eiffel towers. Every year 20-25 million tonnes of e-waste are generated globally. The expected generation of e-wastes year-wise has been shown in Figure 3. In India, 2 million metric tonnes of e-waste are generated in 2016^[3].

Natural resources are deteriorating at a faster rate due to technological development, changes in consumption habits and rapid population growth. The wastes like plastic, industrial wastes, agricultural wastes, medical wastes, construction & demolition wastes and organic or electronic wastes are generating with the growth of industrialisation. Like all wastes, the generation of electronic wastes is increasing globally due to consumption of electrical and electronic devices with the advancement in information technology. The usages life of these devices has been shortened. Therefore, the e-wastes have emerged as fast-growing solid wastes in various dimensions^[4-6].

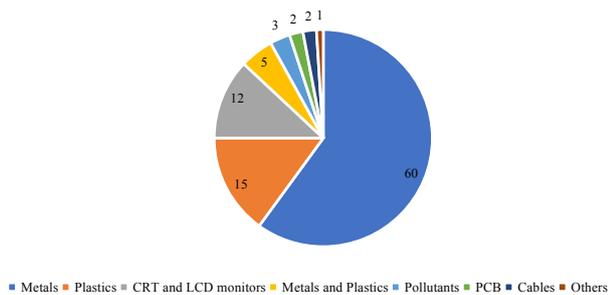


Figure 2. Materials in e-wastes (%)^[3]

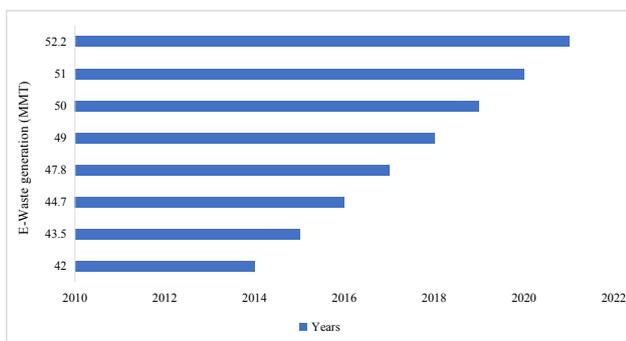


Figure 3. Year-wise generation of e-wastes (Needhidasan and Agarwal, 2019)

Approximately 40 million tons e-wastes were generat-

ed globally in 2015 and it increased to 47 million tons in 2017. But, only 10% of e-wastes is safely recycled and the rest is disposed of either in landfills, burned in incinerators or shipped to developing countries where rudimentary recycling of e-wastes takes place. Electronic waste is complex and consists of valuable i.e. metals and renewable materials as well as toxic or harmful elements i.e. plastic, liquid crystal and organic matter. The improper handling or disposal of e-wastes causes serious environmental pollution and threat to human health. This recent situation demands for recycling of wastes safely. The methods and technologies used in the recycling of e-wastes are very different from that of minerals. The recycling of e-wastes is more complex as compared to minerals. The techniques include physical separation, pyrometallurgical technology, mild extraction technology, electrochemical technology and vacuum metallurgical technology are the economical and eco-friendly; and recycles valuable resources effectively^[7].

The disposal of huge quantity of e-waste plastic cause serious issue to ecosystem due to low biodegradability. The reuse of e-waste plastic either as fine aggregates (FA)/coarse aggregates (CA) or filler in the concrete or pavement construction not only lower the cost but also solve the huge disposal problems. A possible and feasible solution of e-waste is harnessed in the construction industry. In the present study, the effect of electronic wastes of various forms in bituminous or concrete mixes construction has been reviewed. The various properties of cement composites containing electronic waste i.e. workability, compressive strength (CS), split tensile strength (STS), flexural strength (FS), chemical resistance, chloride ion permeability etc. have been studied and reviewed.

2. Literature Review

The e-waste has been used in concrete and pavement construction as partial substitution to natural resources. The effects of partial replacement of raw materials by e-wastes in bituminous and concrete mixes have been given in Table 1 and 2 respectively.

2.1 Bituminous Construction

Increase in e-waste plastic reduced the ductility gradually and increased the penetration value, viscosity and softening point. E-waste plastic powder at 10% can be used for the road pavement^[8] as given in Table 1. Increase in e-waste powder in bitumen increased the penetration value, softening point, flash and fire point, viscosity, specific gravity and decreased the ductility value. Modified bitumen had higher stability value^[9].

2.2 Concrete Construction

Table 2 showed the effect of e-wastes in the cement composites on the various fresh properties and hardened properties and discussed as below.

2.2.1 Fresh Properties

10% e-waste slump value increased afterward it decreased (S, 2020). Waste PCB increased the air content and water retention property and decreased the bulk density of mortar [10]. The workability of concrete decreased with the increase in e-plastic waste due to its hydrophobic nature and its rough surface and angular shape result into increase in inner friction and reduced flow [11, 12, 14, 18, 19, 26].

Table 1. E-waste in bituminous mix

References	Waste (%)	Conclusions
Santhanam et al., 2019 [8]	E-waste plastic as aggregate at 5%, 10% and 15%	Increase in e-waste plastic reduced the ductility gradually and increased the penetration value, viscosity and softening point. E-waste plastic powder at 10% can be used for the road pavement.
Kumar et al., 2020 [9]	Electronic circuit boards (E-PCB) in the form of fine powder use, softening point, flash and fire 0%, 6%, 12% & 18% and non-metallic chips at 0%, 5%, 10% and 15%	Increase in e-waste powder in bitumen increased the penetration value, softening point, flash and fire point, viscosity, specific gravity and decreased the ductility value. Modified bitumen had higher stability value.

Table 2. Cement composites consisting e-waste

Authors	Wastes	Results
Wang et al., 2012 [10]	Waste printed circuit boards non-metallic powder (PCB) as admixture	Waste PCB increased the air content and water retention property but decreased the bulk density of mortar. Waste PCB less than 15% did not decrease CS and FS rapidly afterward it decreased gradually.
Kumar and Baskar, 2015 [11]	E-plastic waste as CA (10%, 20%, 30%, 40% and 50%)	The workability and density of concrete decreased with the increase in e-plastic waste. The addition of e-plastic waste lowered the CS and FS and had high deformability behaviour before failure.
BT, 2016 [12]	E-plastic waste as aggregates (0%, 10%, 20% and 30%)	Increase in e-plastic waste reduced the workability and strength of concrete.
Bulut and Sahin, 2017 [6]	E-plastic/filling (0%, 5%, 15% and 25%)	CS increased with the increase in the ratio of resin. The ratio of resin at 15% and e-plastic/filling at 5% were optimum content for CS. Use of 5% e-waste in polymer concrete did not have negative effect in concrete.

Martínez et al., 2019 [13]	Gamma irradiated polycarbonate particles (3%, 6% and 15%) as aggregates	The gamma irradiated polycarbonate particles as aggregates in concrete increased the CS.
Needhidasan et al., 2019 [14]	E-waste plastic as CA (0%, 12%, 17% and 22%)	Addition of e-waste powder increased the workability, CS, STS and FS.
Santhanam et al., 2019 [15]	E-waste plastic as CA (0%-20%)	E-waste plastic decreased the unit weight, CS and FS and increased the slump value and STS.
Shinu and Needhidasan, 2019 [16]	E-waste plastic as CA (12%, 17% and 22%)	Unit weight of consisting e-waste plastic reduced. E-waste plastic reduced the CS, STS and FS of concrete.
Needhidasan et al., 2019 [17]	E-waste plastic as CA (0%, 10% and 12.5%)	E-waste plastic decreased the slump, CS and FS but increased the STS.
Santhanam and Anbuarasu, 2019 [18]	E-waste plastic as CA (0%, 8%, 12% and 16%)	Increase in e-waste plastic content decreased the slump value and increased the CS, STS and FS.
Needhidasan and Sai, 2020 [19]	E-plastic waste as CA (0%, 8%, 12% and 16%) and fly ash	Increase in e-plastic waste decreased the slump value and increased CS, STS and FS.
Evrarn et al., 2020 [20]	Waste electronic waste as aggregates (0%, 10%, 20%, 30%, 40%); and waste marble dust (MD) as cement substitution (0%, 5%, 10%, 15%)	The addition of MD decreased the slump and improved the strength of concrete. The increase in e-plastic reduced the need of SP, strength, elastic modulus and unit weight.
Mane et al., 2020 [21]	E-waste as partial substitution of manufactured fine aggregates (M-sand) (0%, 10%, 20%, 30% and 40%)	Workability decreased with the increase in e-waste content. The optimum content of e-waste substitution was 20% in terms of strength and chloride permeability.
Bharani et al., 2020 [22]	Steel slag by sand (10%, 20%, 30%) and E-waste by CA (0%, 10%, 20%, 30%)	The steel slag at 20% and 20% steel slag+20% e-waste had optimum replacement content in terms of strength of concrete.
S, 2020 [23]	E-plastic waste as CA (10%, 20%, 30%)	At 10% E-waste slump value increased afterward it decreased. The e-plastic waste upto 20% enhanced the strength afterward it decreased.
Raju et al., 2020 [24]	LCD glass powder as partial substitution to cement (5%, 10%, 15% and 20%)	The waste at 5% had the optimum content in terms of strength, sorptivity and chloride ion penetration. LCD glass powder at 20% had better performance against sulphate and acid attack
Rajkumar et al., 2020 [25]	Electronic waste (EW) (0%, 5%, 10%, 15%, 20%) and jute fibre (JF) (0%, 0.5%, 1%, 2%)	The slump value decreased with EW and JF. JF (1%) and EW (15%) had the optimum content for strength and JF was more effective.
Kalpna et al., 2020 [11]	E-waste as fine aggregate at 10%, 15%, 20% and 25%	Addition of e-waste upto 15% in concrete increased the CS, STS and FS.
Suleman and Needhidasan, 2020 [26]	E-plastic waste as partial substitution to FA (0%, 5.5%, 11%, 16.5%)	Increase in e-plastic waste reduced the workability. The e-plastic waste upto 5.5% increases the CS afterward it decreased. STS and FS increased with e-plastic waste upto 11% afterward it declined.

The increase in e-plastic reduced the need of SP to maintain the slump value due to zero water absorption capacity and smooth texture of e-plastic. MD decreased the slump too^[20]. The slump value decreased with the addition of EW and JF as compared to plain mix^[25]. Workability of concrete increased with the increase in e-waste plastic content due to its lower water absorption capacity^[14-15].

2.2.2 Hardened Properties

CS increased with the increase in the ratio of resin due to strong adherence because of resin's better wetting and covering the filling materials. The ratio of resin at 15% and e-plastic/filling at 5% were optimum content for CS. Increase in resin ratio increased FS upto 15% then reduced slightly. The optimum resin/filling ratio and e-plastic/filling ratio were 15-85% and 5- 15% for STS. Use of 5% e-waste in polymer concrete did not have negative effect in concrete^[6]. The gamma irradiated polycarbonate particles as aggregates in concrete increased CS and the lowest strength was obtained at 3%^[13].

The inclusion of MD enhanced the performance of concrete due to filling effect. Strength, elastic modulus and unit weight reduced as compared to reference mix due to smooth surface, lower modulus of elasticity and strength of e-plastic aggregates. The minimum reduction in CS and toughness was at 20% e-waste^[20]. The density and strength of concrete decreased with the increase in e-plastic waste due to reduction in adhesive strength between the materials and its hydrophobic nature restrict the cement hydration; high porosity and poor bonding between plastic waste and cement mortar^[11, 12, 16]. The optimum content of e-waste substitution was 20% in terms of strength and chloride permeability due to optimal size distribution formation of dense microstructure and low bond strength of plastic waste^[21, 23]. The steel slag at 20% and 20% steel slag+20% e-waste had optimum replacement content in terms of strength of concrete^[22]. Waste PCB increased the air content and water retention property and decreased the bulk density of mortar. Waste PCB less than 15% did not decrease CS and FS rapidly afterward it decreased gradually^[10]. The waste at 5% had the optimum content in terms of strength, sorptivity and chloride ion penetration due to the improved structure. LCD glass powder at 20% had better performance against sulphate and acid attack^[24]. JF (1%) and EW (15%) had the optimum replacement content for strength. JF gave high strength and stability as it reduces the crack formation^[25]. Addition of e-waste upto 15% in concrete increased the CS, STS and FS^[1]. Increase in e-plastic waste increased CS, STS and FS^[14, 18, 19]. E-waste plastic decreased the unit weight, CS

and FS and increased the STS^[15]. E-plastic waste upto 5.5% increases the CS afterward it decreased. STS and FS increased with e-plastic waste upto 11% afterward it declined^[26]. E-waste plastic decreased the CS and FS but increased the STS^[17].

3. Conclusions

In today world, people are very much dependant on the electric and electronic devices for routine daily life activity. With very fast advancement in technology, older devices are replaced with new and better one. The former becomes the waste and thus generation of electronic wastes is becoming the serious threat to the environment and human health. The reuse of electronic waste in the construction industry may conserve the natural resources and reduce the waste problems. A review has studied on the utilization of wastes into concrete and bitumen. Increase in e-waste in bitumen increased the penetration value, softening point, viscosity, specific gravity and decreased the ductility value. The addition of electronic waste decreased the slump value of concrete. Up to the certain limit, e-waste as aggregates in concrete improved the strength and durability characteristics. Therefore, the electronic waste can be effectively used as construction materials. The utilization of wastes in the concrete promotes the reuse of these wastes and solves the disposal problem.

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