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An Overview of Electronic Waste as Aggregate in Concrete

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***Abstract*—**Rapid growth of world population and widespread urbanization has remarkably increased the development of the construction industry which caused a huge demand for sand and gravels. Environmental problems occur when the rate of extraction of sand, gravels, and other materials exceeds the rate of generation of natural resources; therefore, an alternative source is essential to replace the materials used in concrete. Now-a-days, electronic products have become an integral part of daily life which provides more comfort, security, and ease of exchange of information. These electronic waste (E-Waste) materials have serious human health concerns and require extreme care in its disposal to avoid any adverse impacts. Disposal or dumping of these E-Wastes also causes major issues because it is highly complex to handle and often contains highly toxic chemicals such as lead, cadmium, mercury, beryllium, brominates flame retardants (BFRs), polyvinyl chloride (PVC), and phosphorus compounds. Hence, E-Waste can be incorporated in concrete to make a sustainable environment. This paper deals with the composition, preparation, properties, classification of E-Waste. All these processes avoid dumping to landfills whilst conserving natural aggregate resources, and providing a better environmental option. This paper also provides a detailed literature review on the behaviour of concrete with incorporation of E-Wastes. Many research shows the strong possibility of using E-Waste as a substitute of aggregates eventually it reduces the use of natural aggregates in concrete.

***Keywords*—**Disposal, electronic waste, landfill, toxic chemicals.

I. Introduction

CONCRETE is the second most essential material consumed after water. For many years, efforts have been made to use industrial by-products such as fly ash, silica fume, ground granulated blast furnace slag, etc. as admixtures in concrete constructions. The extraction of natural resources for construction materials creates environmental problems, and therefore, attention is being focused on the environment and safeguarding of natural resources and recycling of waste materials.

Gaps in the current scenario:

- Shortage of river sand,
- Skyrocketing cost of construction materials,
- Increasing environmental concern, and
- Adaptation of unscrupulous practices.

Therefore, a substitute is required with

- Similar grain size,
- Similar mechanical properties,
- Workable,
- Cost-effective, and
- No effect on cement chemistry.

Electronic waste (E-Waste) is one of the new waste materials that are emerging in the concrete industry. Disposal of large amounts of E-Waste material can be reused in the concrete industry where it also solves the disposal problem. Hence, the recycling and reusing of E-Waste in the concrete industry is considered as the most feasible application. E-Waste is a serious pollution problem for humans and also the environment. Therefore, some options are needed to be considered, especially on recycling material units. E- Waste is a loosely discarded surplus, broken, electrical or electronic devices. Rapid technology change and low initial cost have resulted in a fast growing surplus of E-Waste around the globe. Several tonnes of E-Waste need to be disposed per year. E-Waste contains numerous types of substances and chemicals creating serious human health and environment problems if not handled properly. Fig. 1 shows a view of E-Waste disposal.

Fig. 1 A pictorial view of E-Waste (Courtesy Google) [12]

II. Sources of E-Waste

- IT and Telecom equipment
- Large household appliances
- Small household appliances
- Consumer and lighting equipment
- Electrical and electronic tools
- Toys and sports equipments
- Medical devices
- Monitoring and control instruments

Printed circuit boards (PCB) are one of the electronic devices. PCB contains about 30% metals and 70% non-metals waste. It is classified into three groups, namely organic, metals and ceramic. The organic group in PCB consists of plastics with flame retardants and paper. The metallic group in PCB

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contains a large amount of base metals like copper, iron, aluminium and also contains precious metallic components like tantalum, gallium, silver and palladium. Ceramic in PCBs consists of silica and alumina. It also includes alkaline earth oxides, mica and barium. In PCB, generally hazardous components like chromium, lead, beryllium, mercury and cadmium are also present. Metals are sent to recovery operations and non-metals can be reused [5]. Fig. 2 shows the percentage generation of E-Waste in India.

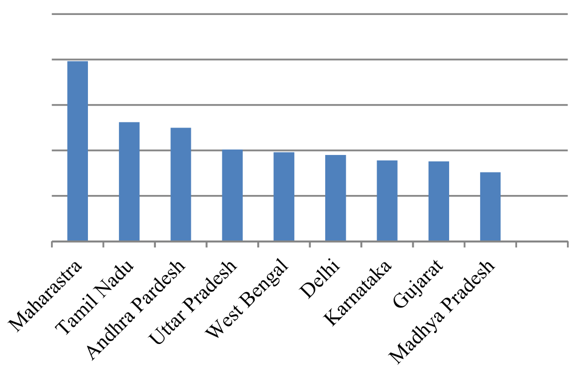

Fig. 2 Percentage generation of E-Waste in India (Courtesy Google) [13]

III. Composition of E-Waste

Most hazardous toxic materials present in E-Waste are silica, lead, barium, cadmium, aluminium, ferrous. The percentage composition of E-Waste is shown in Fig. 3.

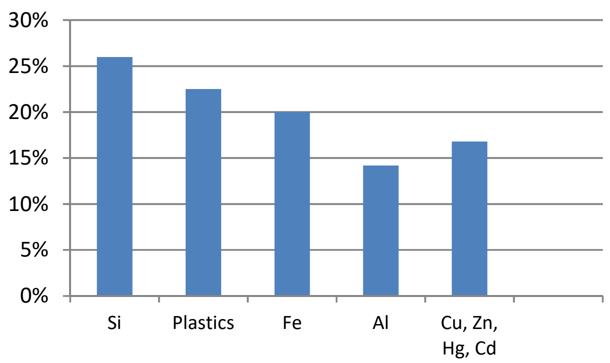

Fig. 3 Percentage composition of E-Waste (Courtesy Google) [14]

IV. Method of E-Waste Disposal

There are some of the methods for the disposal of E-Waste:

- Landfill
- Incineration
- Reuse
- Recycling

A. Landfill

Landfill is a technique where trenches are made on the surfaces. Soil is excavated from the trenches and waste materials are buried in it, and it is covered with clay which acts as thick impervious layer. It is done for the collection and transferring of E-Waste to treatment plants. However, landfill is not an environment friendly technique for disposing the E-Waste as it contains some of the toxic substances like cadmium, mercury and lead. This can very often lead to ground water contamination.

B. Incineration

It is a controlled way of disposing of E-Waste and involves a complete combustion process. In this technique, the waste materials are burned in specially designed incinerators at a high temperature of 900 ˚C – 1000 ˚C. This E-Waste disposal method is advantageous where it reduces the volume of waste to a greater extent and the energy obtained is also utilized. The major disadvantage of this technique is the emission of harmful gases to the environment.

C. Acid Baths

This method involves the process of soaking the E-Waste to concentrate of sulphuric, hydrochloric and nitric acid solution. This helps to free the metals from electronic pathways. The retrieved metals are used in the manufacturing of other products.

D. Reuse

Reuse is a quite common technique where it constitutes direct second hand use or use after slight modifications to the original functioning equipment. This includes computers, mobile phones and other electronic equipment. It is estimated that 3%-5% of the computers that have been designated surplus by their users are reused.

E. Recycling

In the recycling technique, the old raw materials are recovered in making new products. However, the costs of recycling of E-Wastes are high. Due to the scarcity of land, the dumping of E-Waste has become a major issue and it is difficult to get new dumping sites. Therefore, recycling is the best possible option for the management of E-Waste.

V. Recycling Process of E-Waste

Fig. 4 shows a schematic representation of the recycling process of E-Waste. E-Waste components are collected and segregation is done. Glass waste and hazardous waste are separated. Shredding is a process in which it reduces and separates component materials such as plastic, aluminium, copper, steel and precious metals.

E-Waste such as PCBs can be crushed to coarse grain particles using a jaw crusher then fine pulverizing is done to make as a fine powder. This can be achieved with the cryogenic grinding method. In this method, samples are made brittle and pulverized through crushing, shearing or impact actions. Electrostatic separation is a process in which it separates the insoluble mixtures resulting with the separation of metals and non-metals. Metals can be recovered and non-metals can be reused.

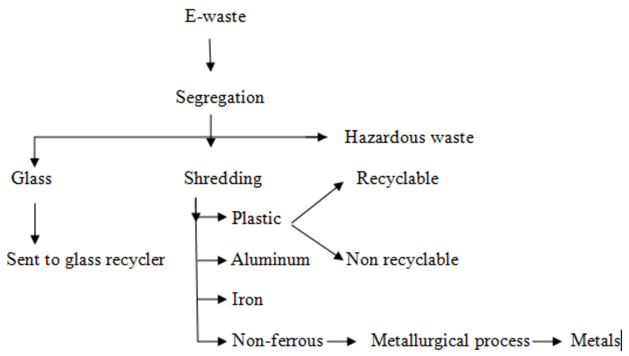

Fig. 4 Schematic representation of E-Waste recycling

VI. Past Studies

Alagusankareswari et al. [3] experimented with E-Waste as a replacement material for fine aggregate. The rate of strength attainment of control mix, E10, E20, E30 was observed. The compressive strength and split tensile strength of concrete pertaining to E-Waste aggregate is slightly less in comparison with the control mix concrete sample. It can be consumed as light weight aggregate because the self-weight of the concrete decreases with the increase in percentage of E-Waste.

Ahirwar et al. [9] stated that the workability of concrete increases when the percentage of E-Waste increases. The workability of fly ash with E-Waste concrete gives better results than conventional concrete. The compressive strength of concrete decreased with increase in percentage of E-Waste. It has been observed, when cement is replaced by fly ash in concrete with E-Waste as a coarse aggregate, its compressive strength is increased. Cement with 30% of fly ash replacement shows a better result.

Vivek et al. [10] stated that 7.5% of fine aggregate replaced by E-Waste gives optimum results of compressive strength. The compressive strength of concrete is gradually decreased when fine aggregate are replaced beyond 15% with E-Waste.

Suchithra et al. [8] stated that the addition of E-Waste shows better compressive strength up to 15% replacement. E-Waste has more pronounced effect on the flexural strength than the split tensile strength. Also, the results of the durability study show that sulphate attack and chloride attack do not affect the strength of concrete and the optimum mix was found to be more durable than the control mix.

Nagajothi and Felixkala [6] reported that up to 2.5% replacement of E-fibre waste in concrete gives twice the compressive strength as compared to the control mix. The compressive strength increased constantly with the addition of E-fibre waste.

Arora and Dave [1] studied the low amount replacement of fine aggregate by E-Wastes in mortars. They concluded that 4% replacement of E-Waste as fine aggregate in mortars gives acceptable strength gain.

Gautam et al. [7] studied the use of glass waste as fine aggregate in concrete. Replacement of 20% glass waste as fine aggregate in concrete, gives better strength results at 28 days. Marginal decrease in strength was observed at the 30% to 40% replacement level. This study indicated that waste glass can effectively be used as fine aggregate replacement up to 40% without substantial change in strength. The optimum replacement level of waste glass as fine aggregate was found to be 10%.

Lakshmi and Nagan [4] studied on the utilization of E-Waste as coarse aggregate in concrete. It is experimented with replacement level of 0% to 30%, and the mechanical properties of concrete were observed and exhibited a good strength gain. The addition of fly ash in the concrete mix considerably improves the strength for control mix as well as E-Waste concrete.

Zheng et al. [11] studied the properties of flexure and fracture behaviour of polypropylene composites. It is observed that the flexural strength and flexural modulus of the composites can be successfully enhanced by filling non-metals recycled from waste PCB into polypropylene (PP). By using scanning electron microscopy (SEM), the influence of non-metals on fracture behaviour of PP composites is evaluated by in-situ flexural test.

Chen et al. [2] demonstrated the replacement of E-glass waste in concrete as fine aggregate. Replacement at the 40% level shows compressive strength as 17%, 27% and 43% higher than control concrete at the ages of 28 days, 91 days and 365 days, respectively. It is also observed that the E-Waste particles act as crack resistors in concrete.

VII. Properties of E-Waste

- Physical properties
- Workability properties
- Strength properties

A. Physical Properties

1. Crushing Test

Electronic waste has more resistance to wear and tear than natural aggregate.

2. Impact Test

It is the good indicator of strength and durability. Electronic waste has wide difference of impact and crushing value, where the aggregates of E-Waste are stronger than that of natural aggregate.

3. Abrasion Test

The abrasion value of natural coarse aggregate is much higher than electronic waste.

TABLE I
PHYSICAL PROPERTIES OF E-WASTE [4]

S. No	Property	Result
1	Specific gravity	1.01
2	Water absorption	<0.2
3	Colour	White & Dark
4	Shape	Angular
5	Crushing Value	<2%
6	Impact value	<2%

Table I shows the physical properties of E-Waste. Table II shows the workability properties of E-Waste. Table III shows the properties compressive strength of concrete.

B. Workability Properties

1. Slump Cone Test

Table II shows the slump value in mm with different percentages of E-Waste. Results indicate that there is a decreasing trend of workability with the increase in E-Waste.

TABLE II
WORKABILITY PROPERTIES OF E-WASTE [15]

S. No	Replacement of fine aggregate with E-Waste in %	Slump value in mm
1	0	50
2	5	48
3	10	40
4	15	36
5	20	31

C. Strength Properties

1. Strength

Ahirwar et al. [9] experimented with different proportions of E-Waste, and the compressive strength for 7 days, 14 days, and 28 days were determined. Table III shows the compressive strength of E-Waste with different proportions. Results indicate that there is an increasing trend of compressive strength with increase in the age of the concrete specimens. However, it shows that the compressive strength of E-Waste specimens is lower than normal aggregate specimens.

TABLE III
COMPRESSIVE STRENGTH OF E-WASTE [9]

S. No	E-Waste %	Compressive strength		
		7days	14days	28days
1	0	31.46	37.155	42.85
2	5	30.91	35.71	40.51
3	10	30.26	34.84	39.42
4	15	29.32	33.085	36.85
5	20	27.12	32.995	38.87
6	25	26.78	31.775	36.77
7	30	25.92	30.665	35.41

VIII. SUMMARY AND INFERENCES

- Recycling of E-Waste is not just a viable solution to eliminate the harmful effects of disposal, but a sound business proposition in itself.
- Disposal of untreated E-Waste in landfills causes major health and environment hazards. Therefore, recycling of E-Waste becomes a major beneficial effect.
- By recycling these E-Wastes, landfill space can be conserved.
- Materials obtained through recycling can be re-used as raw material where it reduces the consumption of manufacturing fresh materials.

From the results of the literature review, it is evident that E-Waste can be used in concrete as aggregate both fine and coarse. It is concluded that,

- It can be consumed as light weight aggregate in concrete.
- Increase in percentage of E-Waste leads to reduction in the self weight of concrete.
- Workability of concrete decreases when percentage of the E-Waste is increased.
- Mechanical properties of concrete with E-Waste as aggregate shows slightly lesser than the controlled mix.

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