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# Partial Replacement of E- Waste with Coarse Aggregate in Concrete: An Investigation

Khalid Iqbal[1], Tauseef Ansari [2], Yakub Ansari[3],
Abdullah Khan[4], Akram Mansoori[5]
*[1,2,3,4] Department of Civil Engineering, MMANTC, Mansoora, Malegaon, India*
*[5] Department of Civil Engineering, JIEMS, Akkaluwa, India.*

***Abstract:*** *Waste Electrical and Electronic Equipment (WEEE) or E- waste is one of the fastest and important growing waste streams in the world. Population growth by leaps followed by industrialization and a dynamic change in amount of waste generated. These hazardous and non-wastes pose a great threat to the human health and environment. The problem and issue of proper management of wastes, is critical to the protection of livelihood, health and environment. These studies related to the use of recycled E-Waste & Plastics as coarse aggregate in concrete.*
***Keywords:*** *E-waste, Replacement of Coarse Aggregate, Compressive Strength.*

## I. Introduction

E-Waste is loosely discarded, surplus, obsolete, broken, electrical or electronic devices. Rapid technology changes, low initial cost has resulted in a fast growing surplus of electronic waste around the globe. Several tonnes of E-Waste required being disposed per year. Traditional landfill or other method is not an environmental friendly solution also the disposal process is also very difficult to meet EPA regulations. Therefore how to reuse the non-disposable E-waste becomes an important research topic regarding environmental point of view.

In many countries, WEEE is equals 1% of total solid waste on an average. It is expected to grow to 2% by 2010. It accounts for 1% to 3% of the total municipal waste generation In USA. In EU every five years WEEE increases by 16-28% , which is three times faster than average annual municipal solid waste generation. A recent source estimates that total amount of WEEE generation in EU ranges from 5 to 7 million tonnes per annul or about 14 to 15 kg per capita and is expected to grow at a rate of 3% to 5% per year. In developing countries, it ranges from 0.01% to 1% of the total municipal solid waste generation. In countries like China and India, though annual generation per capita is less than 1 kg, it is growing at an exponential pace. The increasing “market penetration” in developing countries, “replacement market” in developed countries and “high obsolescence rate” make WEEE/E- waste one of the fastest waste streams. The content of WEEE / E- waste is differs in products across different categories. It contains more than a 1000 different substances, which fall under “hazardous” and “non-hazardous” categories. WEEE consists of ferrous and non-ferrous metals, plastics, glass, wood, circuit boards, concrete and ceramics, rubber and other items. Steel and iron constitutes about 49% of the WEEE followed by plastics (22%), non-ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminum and precious metals like silver, gold, platinum, palladium etc. The presence of elements like lead, mercury, arsenic, cadmium, selenium, beyond threshold quantities in WEEE / E-waste classifies them as hazardous waste. WEEE/ E- waste dismantling or incineration is considered toxic. The recovery of metals is a profitable business, which results in local, trans-boundary and global trade. Technically, electronic waste is only a subset of WEEE.

## II. Litrature Survey And E-Waste In India

In India E- waste inventory based on this obsolescence rate and installed base for the year 2005 has been estimated to be 146180.00 tones. This value is expected to exceed 8, 00,000 tonnes by 2012. In India, E-Waste is mostly generated in large cities like Delhi, Mumbai and Bangalore. In these cities a complex E- waste handling infrastructure has developed mainly based on a long tradition of waste recycling. Sixty five cities in India generate more than 60% of the total e waste generated in India. Ten states generate 70% of the total waste generated in India. Maharashtra is ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, in the list of E- waste generating states in India. Among top ten cities generating E- waste, Mumbai ranks first followed by Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pane, Seurat and Nagpur. But there is no large scale organized E- waste recycling facility in exists in unorganized sector India. Expert reported waste glass can be used by grinding it into a fine glass powder

(GLP) for incorporation into concrete as a pozzalanic material. It under goes beneficial pozzalanic reactions in the concrete and could replace up to 30% cement in some concrete mixes with satisfactory strength development. The amount of plastics consumed annually in the growing tends of Indian and US scenario was discussed. The possibilities of a comprehensive investigation of the technical economic and ecological aspects of recycling were addressed by the author. It was noticed that the mechanism of expansion of concrete caused by glass aggregate is different from that by traditional ASR expansion. It has been conferred that the expansion of concrete containing glass aggregate reacts with Alkalis in the cement to from alkali silicate or NCSH which absorbs water and cause expansion. The author suggested that it is necessary to control the pH of the concrete under 12 in order to avoid deleterious expansion and cracking of concrete containing large glass particles.

**Tabel 1:** Average Weights and Composition of Selected Electrical and Electronic Appliances

| Appliances | Average weight (kg) | Fe % Weight | Non Fe-metal % Weight | Glass % Weight | Plastic % Weight | Electronic component s % weight | Others % weight |
|---|---|---|---|---|---|---|---|
| Refrigerators and freezers | 48 | 64.4 | 6 | 1.4 | 13 | - | 15.1 |
| Washing-Machine | 40 to 47 | 59.8 | 4.6 | 2.6 | 1.5 | - | 31.5 |
| Personal Computer | 29.6 | 53.3 | 8.4 | 15 | 23.3 | 17.3 | 0.7 |
| TV sets | 36.2 | 5.3 | 5.4 | 62 | 22.9 | 0.9 | 3.5 |
| Cellular Telephones | 0.080 to 0.100 | 8 | 20 | 10.6 | 59.6 | - | 1.8 |

Composition of WEEE/ E- waste components is very diverse and may contain more than 1000 different substances, many of which fall under “hazardous” category. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitutes about 50% of the WEEE/ E- waste followed by plastics (21%), nonferrous metals (13%) and other constituents.

E- Waste also includes many toxic substances viz. heavy metals like lead, cadmium, mercury, arsenic, selenium, hexavalent chromium etc. About 70% of the heavy metals (mercury & cadmium) in landfills come from electronic waste. Consumer electronic is the root cause for the presence of about 40% of the lead in landfills. These toxins can cause brain damage, allergic reactions and cancer. E- Waste also contains considerable quantities of valuable materials like gold, copper and other ordinary metals. • Iron and steel are the most common materials found in electrical and electronic equipment and amounts to nearly half of the total weight of WEEE.

• Plastic are the second largest component by weight representing approximately 21% of WEEE.

• Non-ferrous metals represent approximately 13% of WEEE (With copper accounting for 7%). The constituents and their components of WEEE are given in Table 2.

**Table 2: WEEE Material Composition** [Lakshmi and Negan (2011)]

| Constituents | Components in % | Constituents | Components in % |
|---|---|---|---|
| Iron and Steel | 47.9 | Printed circuit board | 3.1 |
| Non flame retarded plastic | 15.3 | Wood and plywood | 2.6 |
| Copper | 7.0 | Concrete and ceramics | 2.0 |
| Glass | 5.4 | Other metals ( non-ferrous ) | 1.0 |
| Flame retarded plastic | 5.3 | Rubber | 0.9 |
| Aluminium | 4.7 | Other | 4.6 |

## III. Methodology

### 3.1 Materials

#### 3.1.1. Cement:

OPD of 53 grades available in local market used in the investigation. The cement has been tested for various proportion as per IS 4031-1988 & found to be conforming to various specification of IS 12269-1987. The specific gravity was 2.96 & fineness was 3200 cm2/ gm.

#### 3.1.2. Course Aggregate:

Crush angular metal of 20 mm size from a local source was used as course aggregate. The specific gravity of 2.71 & fineness modulus7.31 was used.

### 3.1.3. Fine Aggregate:
River sand was used as a fine aggregate. The specific gravity of 2.60 & fineness modulus 3.25 was used in the investigation.

### 3.1.4. E- waste:
Usually E- waste from electrical & electronic equipment's such as computer, TV, Refrigerator, A. C. radio etc. E- Waste is crush into small pieces (up to 10mm) size in Grinder Machine.

### 3.1.5. Mix Proportion:
The concrete mix is designed as per the guidelines given in the various Indian standard namely IS 10262-1982, IS 456-2000 for M15 grade. The water cement ratio was maintained as per required proportion of 1:2:4.

### 3.1.6. Mixing and Casting:
Mixing is an important aspect of any successful experiment to get desired results, most care has been taken in the mixing and casting process. Specimens were prepared by the following the standard methods of mould preparation. Total 36 cubes of the size of 150x150x150 mm were prepared for testing compressive strength.

### 3.2. Data for Design:
The E- waste material is calculated on weight basis as coarse aggregate in the conventional mix: The fineness modulus of coarse aggregate with various E- waste contents is observed as 6.9. The divided particle size is assumed to be between 10mm and 20mm. Then E- waste particles can be considered as partial coarse aggregates.

The following data are required to design of a concrete mix:

a. Characteristic compressive strength of concrete at 28 days (fck).
b. Desired degree of workability.
c. The water-cement ratio and the minimum cement to ensure adequate durability.
d. Maximum size and of aggregate to be used,
e. Standard deviation (s) of compressive strength of concrete.

## 3.2 Experimental Testing

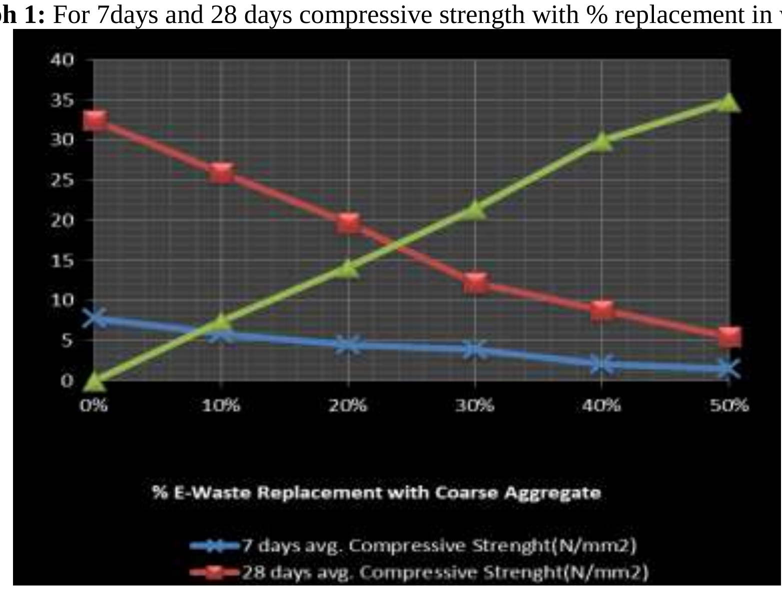
**Table 3:** For 7days and 28 days compressive strength with % replacement in weight

| Percentage of E-Waste in concrete | Curing (Day) | Sr. No. | Crushing load (kN) | Crushing strength (kN/m$^2$) | Weight (Kg) | Density (Kg/m$^3$) |
|---|---|---|---|---|---|---|
| **For 0% E-waste Replacement** | 7 Day | 01 | 6.76 | 300 | 8.73 | 2582 |
| | | 02 | 9.24 | 410.66 | 8.85 | 2623 |
| | | 03 | 7.53 | 334.66 | 8.65 | 2563 |
| | | **Average** | **7.84** | **348.44** | **8.74** | **2590** |
| | 28 Day | 01 | 29.91 | 1330 | 8.72 | 2584 |
| | | 02 | 25.07 | 1114.22 | 8.85 | 2623 |
| | | 03 | 27.35 | 1216 | 8.65 | 2563 |
| | | **Average** | **27.44** | **1220** | **8.74** | **2590** |
| **Percentage of E-Waste in concrete** | **Curing (Day)** | **Sr. No.** | **Crushing load (kN)** | **Crushing strength (kN/m$^2$)** | **Weight (Kg)** | **Density (Kg/m$^3$)** |
| **For 10% E-waste Replacement** | 7 Day | 01 | 6.4 | 284.44 | 8.34 | 2441.81 |
| | | 02 | 5.67 | 252.44 | 8.21 | 2432.59 |
| | | 03 | 5.33 | 236.88 | 8.11 | 2402.96 |
| | | **Average** | **5.80** | **257.92** | **8.22** | **2425.78** |
| | 28 Day | 01 | 24 | 1066.66 | 8.34 | 2441.81 |
| | | 02 | 26.78 | 1190.22 | 8.21 | 2432.59 |
| | | 03 | 27.56 | 1224.88 | 8.11 | 2402.96 |
| | | **Average** | **26.11** | **1160.58** | **8.22** | **2425.78** |
| **For 20% E-waste Replacement** | 7 Day | 01 | 4.27 | 189.77 | 7.58 | 2245.92 |
| | | 02 | 4.27 | 189.44 | 7.56 | 2240 |
| | | 03 | 4.96 | 220.44 | 7.68 | 2275.55 |
| | | **Average** | **4.50** | **200** | **7.60** | **2251.85** |
| | 28 Day | 01 | 19.91 | 884.88 | 7.58 | 2245.92 |
| | | 02 | 20.44 | 908.44 | 7.56 | 2240 |
| | | 03 | 18.66 | 829.33 | 7.68 | 2275.55 |
| | | **Average** | **19.67** | **874.22** | **7.60** | **2251.85** |
| **For 30% E-** | 7 Day | 01 | 3.38 | 150.22 | 7.02 | 2080.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **waste Replacement** | | 02 | 4.66 | 207.11 | 7.04 | 2085.92 |
| | | 03 | 3.56 | 158.22 | 6.82 | 2020.74 |
| | | **Average** | **3.87** | **172.00** | **6.96** | **2062.22** |
| | 28 Day | 01 | 8.02 | 355.55 | 7.02 | 2080.00 |
| | | 02 | 14.72 | 655.11 | 7.04 | 2085.92 |
| | | 03 | 13.86 | 616 | 6.82 | 2020.74 |
| | | 03 | 13.86 | 616 | 6.82 | 2020.74 |
| | | **Average** | **12.20** | **542.22** | **6.96** | **2062.22** |
| **For 40% E-waste Replacement** | 7 Day | 01 | 1.99 | 88.44 | 6.09 | 1804.44 |
| | | 02 | 2.13 | 94.66 | 6.15 | 1822.22 |
| | | 03 | 2.20 | 97.77 | 6.12 | 1813.33 |
| | | **Average** | **2.10** | **93.33** | **6.12** | **1813.33** |
| | 28 Day | 01 | 8.90 | 395.55 | 6.09 | 1804.44 |
| | | 02 | 8.40 | 373.33 | 6.15 | 1822.22 |
| | | 03 | 9.20 | 408.88 | 6.12 | 1813.33 |
| | | **Average** | **8.83** | **392.44** | **6.12** | **1813.33** |
| **For 50% E-waste Replacement** | 7 Day | 01 | 1.42 | 63.11 | 5.83 | 1727.40 |
| | | 02 | 1.46 | 64.88 | 5.83 | 1727.40 |
| | | 03 | 1.81 | 80.44 | 5.71 | 1691.85 |
| | | **Average** | **1.56** | **69.33** | **5.79** | **1715.55** |
| | 28 Day | 01 | 4.78 | 212.44 | 5.83 | 1727.40 |
| | | 02 | 6.14 | 272.88 | 5.83 | 1727.40 |
| | | 03 | 5.77 | 256.44 | 5.71 | 1691.85 |
| | | **Average** | **5.56** | **247.11** | **5.79** | **1715.55** |

Graph 4.1 for 7days and 28 days compressive strength with % replacement in weight. The below graph shows that compressive strength of partially replacement of E-waste with coarse aggregate and weight loss in concrete.

**Graph 1:** For 7days and 28 days compressive strength with % replacement in weight




## IV. Result And Discussion

**Table 4:** For 7days and 28 days compressive strength with % replacement in weight

| Sr.no | % replacement | 7 days N / mm$^2$ | 28 days N / mm$^2$ | Weight Kg | %saving in weight | Cost of producing1 m$^3$ of concrete (Rs) | %of saving cost |
|---|---|---|---|---|---|---|---|
| 1 | 0 % | 7.84 | 27.44 | 8.74 | 0 % | 4352/- | - |
| 2 | 10 % | 5.80 | 26.11 | 8.22 | 7.43 % | 4290/- | 1.53% |
| 3 | 20 % | 4.50 | 19.61 | 7.60 | 14.18 % | 4220/- | 3.06% |
| 4 | 30 % | 3.87 | 12.20 | 6.96 | 21.51 % | 4152/- | 4.62% |
| 5 | 40 % | 2.10 | 8.83 | 6.12 | 29.97 % | 4066/- | 6.59% |
| 6 | 50 % | 1.56 | 5.56 | 5.79 | 34.89 % | 4017/- | 7.72% |

As the table discussed, adding of E- waste is increases, the % of weight of concrete is decreases with respect to ordinary concrete e.g. 30 % use of E- waste decreases 21.61 % of weight. As the cost is consider there is very little variation in percentage of cost after increasing the % of E- waste replace with aggregate**.**

## V. Conclusion

The following conclusions were drawn from the present study.

- Up to 24% of partial replacement of E- waste with coarse aggregate is found to be satisfactory.
- Compressive strength of concrete containing E- waste up to 24% is above 15 N/mm2.
- The percentage loss in weight of concrete containing 24% E- waste is 17%. Hence resulting in production of light weight concrete.
- Considerable consumption of E- waste in concrete reduces environmental problems. Hence, production of environment friendly or sustainable concrete.
- During the crushing of relevant cubes under UTM, it is observed that this type of concrete is more elastic than the conventional concrete
- From the compressive strength tests, it has been confirmed that no major changes found in the compressive strength of concrete with the presence of E-plastic as partial replacement with coarse aggregate. However, when 30% of the coarse aggregate is replaced by E-plastic, the compressive strength was reduced by 20% compared to normal mix.
- In general strength gain of E-waste concrete is satisfactory and it has been concluded that 20% E-waste particles can be incorporated as aggregate replacement without any long term detrimental effects up to 24% of partial replacement of E-waste there is little saving in production cost of (3%) concrete.

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