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# A STUDY ON EFFECT OF E-WASTE AS PARTIAL REPLACEMENT FOR COARSE AGGREGATE ON FRESH AND HARDENED PROPERTIES OF CONCRETE.

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***Abstract:*** The experimental study deals with assessing the potential of electronic waste or E- waste as partial replacement for coarse aggregate in concrete. The coarse aggregate partially replaced with 10%, 12% and 15% of E-waste by weight. The physical properties of electronic waste were assessed and compared with coarse aggregate. The fresh and hardened properties of conventional concrete and E-waste blended concrete were performed. The results concluded that the fresh properties such as slump and compaction factor of E-waste based concrete decreased with increase in percentage of replacement of E-waste as compared to conventional concrete. The hardened properties such as compressive strength and split tensile strength were also decreased with increase in percentage of replacement of E-waste by weight of coarse aggregate as compared to conventional concrete but 12% of E-waste replacement shown comparable result with conventional concrete. Thus, we can conclude that 12% is the optimum percentage of E-waste replacement by weight of coarse aggregate in concrete.

***Keywords:*** E-waste, Coarse aggregates, Fresh properties and hardened properties.

## 1. INTRODUCTION

Due to rapid urbanization and increase in population, the demand for construction activities also increased. Construction activity demands construction materials procured from nature, which leads to the depletion of natural resources. The aggregates are one of the constituents in concrete, which occupy more volume hence the demand for aggregates is also high leading to the scarcity and depletion of natural resources, there is quest to search for alternative materials to be used in concrete to overcome the above problem-waste is a "Waste Electrical and Electronic Equipment including all components, sub-assemblies comprise of discarded old computers, TVs, refrigerators, radios –any electrical or electronic appliances that has reached its end of life. 50 million tons of E- waste is produced each year worldwide. The total E-waste generated in India is about 1, 46,180 tons per year. The environmental protection agency estimates that only 15-20% of E-waste is recycled, the rest of these electronics go directly into landfills and incinerators. The processing of electronic waste in developing countries causes serious health and pollution problems because electronic equipment contains serious contaminants such as lead, cadmium, Beryllium etc. (Ashwini Manjunath B T, "partial replacement of E-plastic Waste as Coarse-aggregate in Concrete", 2016, ELSEVIER, Science Direct, Procedia Environmental sciences 35.) Hence an attempt has been made to use E-waste as an alternative to coarse aggregates in concrete by partial replacement in varying percentages.

### 1.1 Processing of E-waste

- First step of E-waste is recycling i.e., removal of dangerous substances from E-waste.
- Second step is grinding of E-waste to reuse as coarse aggregate in concrete. There are various types of grinders to convert E-waste into chips of 20mm down size.

## 2. OBJECTIVES

- To assess the fresh properties of E-waste based concrete and compared with conventional concrete.
- To ascertain the hardened properties of E-waste based concrete and compared with conventional concrete.
- To optimize the efficacy of replacing E-waste with coarse aggregate.

## 3. MATERIALS AND METHODS

Concrete mixes are prepared with Portland pozzolana cement, M Sand, Coarse aggregate and E-waste. This section presents the properties of materials used in the experimental program and the procedures adopted to perform each of the tests.

### 3.1 Portland Pozzolana cement (PPC)

The physical properties of PPC are determined as per IS: 1489 Part 1-1991 and physical properties are depicted in table 1.

**Table 1:** Physical properties of Portland pozzolana cement.

| Sl No. | Tests | Results | Requirements as per IS: 1489 | Test code |
|---|---|---|---|---|
| 1. | Specific gravity. | 2.90 | 3 to 3.15 | IS4031(Part 4):1988 (Reaffirmed2005) |
| 2. | Normal consistency | 29% | | IS4031(Part 5):1989 (Reaffirmed2005) |
| 3. | Setting time<br>Initial<br>Final | <br>150 min<br>320 min | <br>Min 30mins<br>Max 600 mins | IS4031(Part 5):1989 (Reaffirmed2005) |
| 4. | Soundness | 1 mm | Max 10mm | IS:4031(Part3)-1988 |
| 5. | Fineness | 315 $m^2$/Kg | Min 300 $m^2$/Kg | IS:4031-(Part3):1999 (Reaffirmed2004) |

### 3.2 Fine Aggregate (M Sand)

The physical properties of M-sand are determined as per IS: 2386 Part 1-4 1963 and physical properties are given in table 2 as per IS: 383-2016.

**Table 2:** Physical properties of Fine aggregate.

| Sl No. | Tests | Results | Requirements as per IS: 383-2016 | Test code |
|---|---|---|---|---|
| 1. | Specific gravity | 2.6 | | IS: 2386(Part 3) Reaffirmed (2002) |
| 2. | Water absorption | 5% | | IS: 2386(Part 1) Reaffirmed (2002) |
| 3. | Sieve analysis | Zone-II | Zone I- Zone-III | IS: 2386(Part 3) Reaffirmed (2002) |
| 4. | Fineness modulus | 3.01 | 2.2 - 3.2 | IS: 2386(Part 1) Reaffirmed (2002) |

### 3.3 Coarse Aggregate

The physical properties of coarse aggregate are also determined as per IS: 2386 Part 1-4 1963 and physical properties are given in table 3 as per IS: 383-2016.

**Table 3:** Physical properties of coarse aggregate.

| Sl No. | Properties | Results | Requirements as per IS: 383-2016 | Test Code |
|---|---|---|---|---|
| 1. | Specific gravity | 2.67 | | IS: 2386(Part 3) Reaffirmed (2002) |
| 2. | Water absorption | 0.3% | < 0.6% | IS: 2386(Part 3) Reaffirmed (2002) |
| 3. | Angularity number | 7.94 | 0 -11 | IS: 2386(Part 1)- 1963 Reaffirmed (2002) |
| 4. | Crushing value | 25.01% | Not greater than 45% | IS: 2386(Part 4)-1963 Reaffirmed (2002) |
| 5. | Shape test<br>Flakiness Index<br>Elongation Index | <br>13.87%<br>24.27% | <br>< 30% | IS: 2386(Part 1)-1963 Reaffirmed(2002) |



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### 3.4 Electronic waste (E-waste)

The physical properties of E-waste are also determined and properties are given in table 4.

**Table 4:** Physical properties of E waste.

| Sl No. | Properties | Results |
|---|---|---|
| 1. | Specific gravity | 1 |
| 2. | Water absorption | 0% |
| 3. | Angularity number | Negative |
| 4. | Crushing value | 0.22% |
| 5. | Shape test<br>Flakiness Index<br>Elongation Index | Flaky material |

### 3.5 Chemical Admixture

Super plasticizer (Conplast SP 430) was used as water reducer for better workability and it reduces 29% of water content as per mix design.

### 3.6 Mix Proportioning

The mix proportioning is done as per IS: 10262-2009 by considering the properties of the cement, M sand, Coarse aggregate, E-waste and chemical admixture. The mix corresponds to 1:2.48:3.56, with water to cement ratio of 0.5 and dosage of chemical admixture of 1% by weight of cement is used. Concrete mixes are prepared by replacing 10%, 12% and 15% E-waste by weight of coarse aggregate and optimum percentage of replacement were determined. The details of the constituents are shown in table 5.

**Table 5:** Mix Proportions Conventional Concrete and E-waste based Concrete mixes.

| Mix Designation | Cement (Kg) | M sand (Kg) | Coarse aggregate (Kg) | E waste (Kg) | Water (Kg) | Chemical Admixture (Kg) |
|---|---|---|---|---|---|---|
| 0% E waste | 320 | 796.58 | 1141.42 | 0 | 160 | 3.2 |
| 10% E waste | 320 | 796.58 | 1027.08 | 114.12 | 160 | 3.2 |
| 12% E waste | 320 | 796.58 | 1004.22 | 136.97 | 160 | 3.2 |
| 15% E waste | 320 | 796.58 | 770.21 | 171.21 | 160 | 3.2 |



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### 3.6 Fresh Properties of concrete

The fresh properties of concrete mixes were assessed by conducting slump test and compaction factor test and conducted as per IS: 1199-1959.

### 3.7 Hardened Properties of concrete

The hardened properties of concrete mixes were assessed by conducting compression test and split tensile strength test as per IS: 1199-1959.Three cubes are tested at 7 and 28 days, for each mix variants, three cylinders are tested as per IS: 58161999 at 7 and 28 days, for each of the mix variants.

## 4. RESULTS &DISCUSSIONS

### 4.1 Fresh Properties of concrete

#### 4.1.1 Slump Test

The table 6 shows the slump value of all concrete mixes. The slump of all the concrete mixes are designed to achieve 100mm slump.

**Table 6:** Slump Value Results

| Sl. No. | Water cement ratio % | % of E-waste | Slump (mm) |
|---|---|---|---|
| 1. | 0.5 | 0 | 130 |
| 2. | 0.5 | 10 | 102 |
| 3. | 0.5 | 12 | 87 |
| 4. | 0.5 | 15 | 68 |

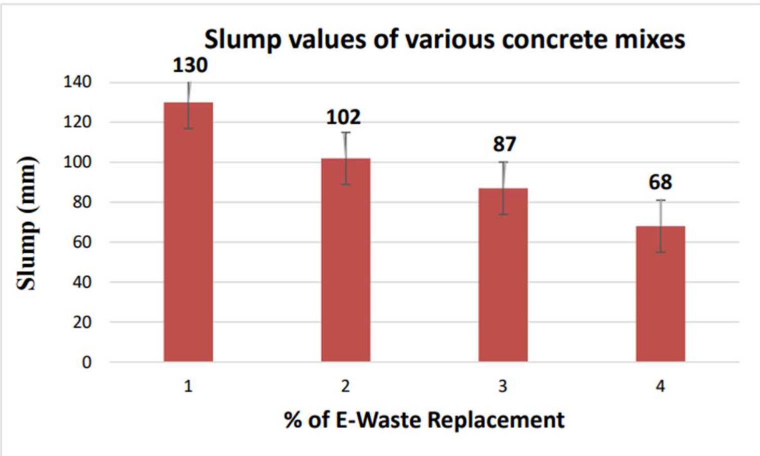


**Fig.1:** Slump values of concrete mixes at various replacement level



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The concrete mixes were designed for a desired slump of 100mm. From figure1, it is observed that the conventional concrete achieved 130mm slump value but with the replacement of E-waste by 10%, 12% and 15% corresponding slump values were decreased to 102, 87 and 68 mm respectively with constant water cement ratio of 0.5 along with constant chemical admixture of 1%. This decrease in slump value with replacement in E-waste attributed to flaky particles of E-waste and it has less bonding capacity as compared to natural coarse aggregate.

#### 4.1.2Compaction Factor Test

The table 7 shows the compaction factor value of all concrete mixes.

**Table 7:** Compaction factor Value Results

| Sl. No. | % of E-waste | Compaction factor |
|---|---|---|
| 1 | 0 | 0.87 |
| 2 | 10 | 0.85 |
| 3 | 12 | 0.79 |
| 4 | 15 | 0.76 |

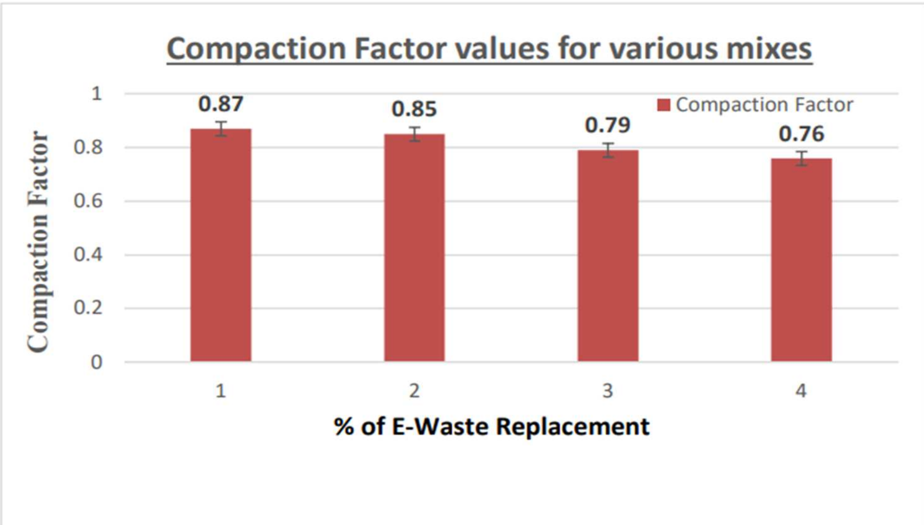


**Fig.2:** Compaction factor values of concrete mixes at various replacement level

The concrete mixes were designed to achieve a compaction factor of 1.0. From figure2, it is observed that the compaction factor value of conventional concrete is 0.87 but with the replacement of E-waste by 10%, 12% and 15% corresponding compaction factor values were decreased by 0.85, 0.79 and 0.76 respectively. The results are correlating with the slump results.



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### 4.2 Hardened Properties of concrete

#### 4.2.1 Compressive Strength

The concrete mixes were designed for a compressive strength of 20Mpa. The table 8 depicts the compressive strength of all concrete mixes which they are designed to attain the minimum strength of 20MPa.

**Table 8:** Compressive strength Results

| Specimen | Compressive Strength (MPa) | |
|---|---|---|
| | 7 days | 28 days |
| 0% E-waste Replacement | 25.36 | 32.81 |
| 10% E-waste Replacement | 10.35 | 23.84 |
| 12% E-waste Replacement | 12.46 | 25.80 |
| 15% E-waste Replacement | 9.24 | 22.90 |

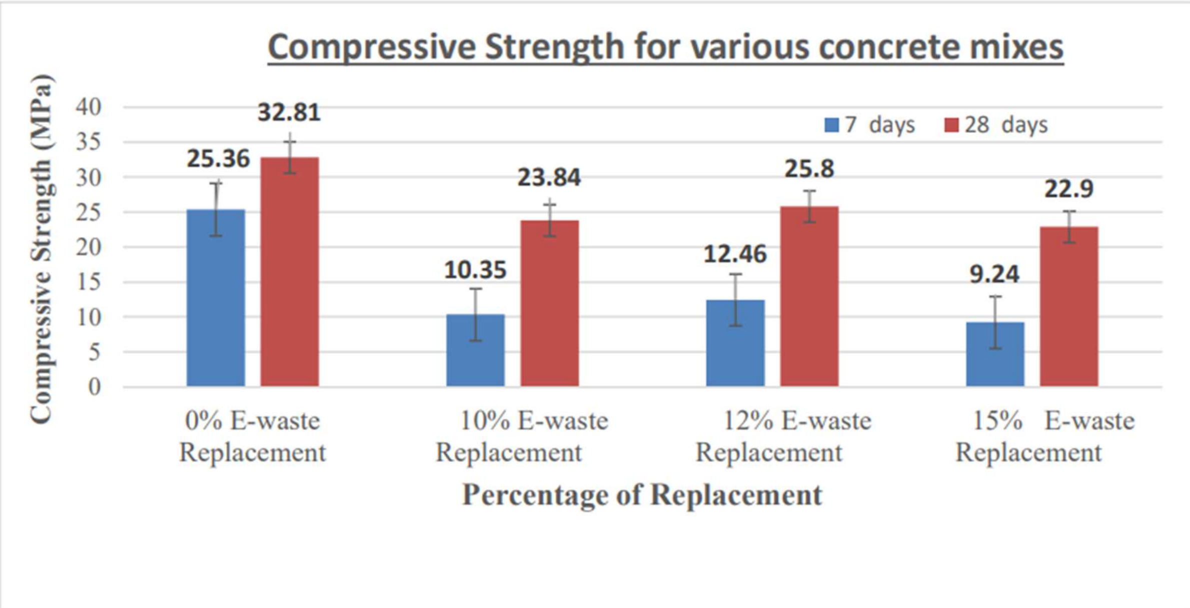


**Fig. 3:** Compressive strength of concrete mixes at various replacement level

The figure 3 depicts the decrease in compressive strength of E-waste based concrete with increase in percentage of replacement of E-waste by 27.34% for 10%, 21.36 for 12% and 30.26 % for 15% as compared to conventional concrete. This decrease in strength of E-waste based concrete is due to lesser specific gravity of E-waste will decrease the density of E-waste based concrete



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correspondingly the strength also and flakiness in an E-waste material will create more voids which tend to decrease the compressive strength. The 12% replacement level showed better performance as compared to other replacement levels and all replacement level has achieved the minimum compressive strength at the age of 28 days.

### 4.2.2 Tensile Strength

The table 9 depicts tensile strength of all concrete mixes.

**Table 9:** Split tensile strength of various concrete mixes.

| **Specimen No.** | **Split Tensile Strength (MPa)** |
|---|---|
| | 28 days |
| 0% E-waste Replacement | 3.27 |
| 10% E-waste Replacement | 2.76 |
| 12% E-waste Replacement | 2.86 |
| 15%E-waste Replacement | 2.66 |

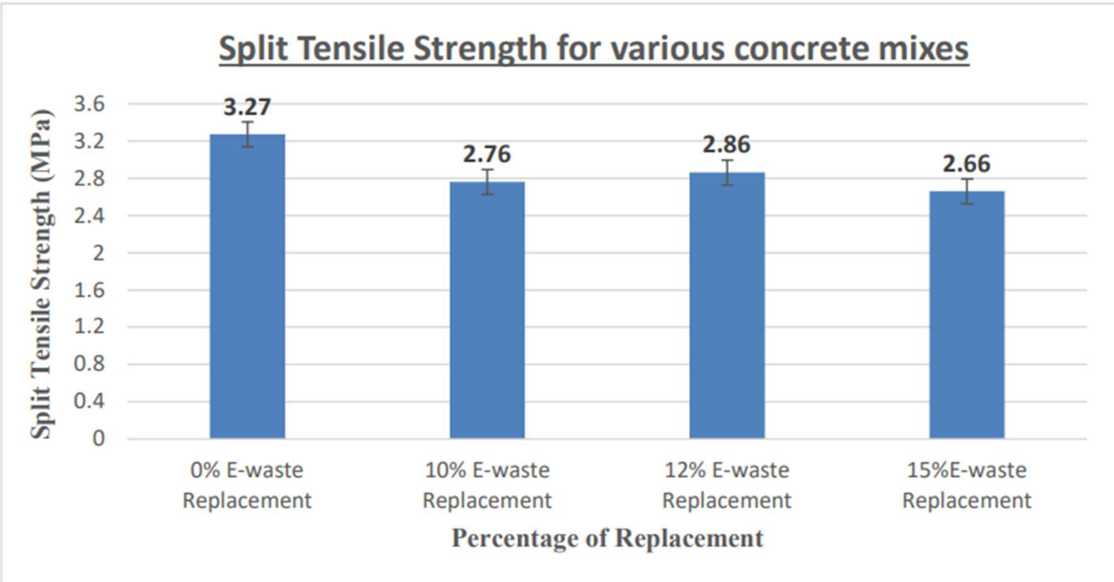


**Fig. 4:** Split tensile strength of concrete mixes at various replacement level



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The figure 4 indicated that increase in percentage of replacement of E-waste by 10%, 12% and 15% there will be decrease in split tensile strength also by 22.27%, 12.51%, and 32.03 % respectively as compared to conventional concrete. This decrease in strength is also due to lesser specific gravity of E-waste will decrease the density of E-waste based concrete correspondingly the strength also and flakiness in an E-waste material will create more voids which tend to decrease the tensile strength. The 12% replacement showed better performance as compared to other replacement levels.

**4.3 Problems Identified/Barriers in E-waste concrete**

1. The figure 5 indicates that after demoulding of specimen, the shape of the specimen shows irregularity at the edges due to lesser bonding between the cement and the E-waste material.


**Fig. 5:** Damaged edges at the periphery of specimen

2. The increase in replacement of E-waste in the concrete, the settlement of E-waste at the top takes place due to low density of the material and low bonding between cement and E-waste. Therefore, it decreases the strength of E–waste concrete as the percentage of replacement of E-waste increases beyond the limit.

## 5. CONCLUSION

1. The physical properties and mechanical properties of E-waste were less as compared to the coarse aggregate.
2. The fresh properties of E-waste based concrete at all replacement levels decreased with increase in replacement of E-waste as compared to conventional concrete.
3. The compressive strength of E-waste based concrete strength decreases by 27.34% for 10% replacement, 21.36% for 20% replacement and 30.20% for 15% replacement as compared to conventional concrete.
4. The split tensile strength of E-waste based concrete tensile strength decreases by 22.27% for 10% replacement, 12.51% for 12% replacement and 32.03% for 15% replacement as compared to conventional concrete.
5. It can be concluded that 12% replacement level of E-waste will be considered as optimum level of replacement to coarse aggregate.



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