Study on Properties of Concrete with Electronic Waste

Estudio sobre las Propiedades del Hormigón con Residuos Electrónicos

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Abstract

In this paper, we attempted to make an investigation to use E-waste as fractional substitution intended for coarse aggregate. The accumulation of electronic waste is a major concern in big metropolitan cities and certain tier 2 cities in which huge quantities of the order of several thousand tones is being dumped discharged and grows in an exponential haphazard manner. Bakelite waste is taken as E waste, which is heat resistant and also inert to chemical reactions obtained by crushing the outer casing of television sets. The grade of concrete which is adopted for the investigation is M25, designed according to the method of the code IS. Number of trial mixes were tried and the control mix was selected which had the compressive strength slightly more than the target strength. The coarse aggregate of the control mix was partially replace 5 to 20% by weight of coarse aggregate. After 3, 7 and 28 age curing of cube specimen, the compressive intensity was found. Similarly the 7 and 28 age tensile strength, young’s modulus, modulus of rupture be calculated by casting cylinders and prisms. The best possible quantity E-waste be added to retain the target mean strength was also determined. Through research it is being into being that the volume of the e-waste accumulated can be reduced in a substantial manner by the above method in the field of construction and thereby protect the earth from the threatening environment.

Keywords: E-Waste, coarse aggregate replacement, young’s modulus of concrete, modulus of rupture of concrete, Bakelite

Resumen

En este trabajo, intentamos hacer una investigación para utilizar los residuos electrónicos como sustitución fraccionada destinada a los áridos gruesos. La acumulación de residuos electrónicos es una de las principales preocupaciones en las grandes ciudades metropolitanas y en algunas ciudades de nivel 2. En estas se vierten enormes cantidades, del orden de varios miles de toneladas, que crecen de forma exponencial y desordenada. Los residuos de baquelita se toman como residuo E, que son resistentes al calor y también inertes a las reacciones químicas, obtenidos por la trituración de la carcasa exterior de los televisores. El grado de hormigón adoptado para la investigación es M25, diseñado según el método del código IS. Se probaron varias mezclas de ensayo y se seleccionó la mezcla de control, cuya resistencia a la compresión era ligeramente superior a la deseada. El agregado grueso de la mezcla de control se sustituyó parcialmente entre el 5 y el 20% en peso del agregado grueso. Después de 3, 7 y 28 días de curado de la muestra de cubo, se encontró la intensidad de la compresión. Asimismo, se calculó la resistencia a la tracción, el módulo de Young y el módulo de ruptura mediante la fundición de cilindros y prismas, a los 7 y 28 días. También se determinó la mejor cantidad posible de residuos electrónicos para mantener la resistencia media deseada. A través de la investigación, se ha descubierto que el volumen de los residuos electrónicos acumulados puede reducirse de forma sustancial mediante el método anterior en el ámbito de la construcción y, por tanto, proteger la tierra de la amenaza del medio ambiente.

Palabras clave: Residuos electrónicos, sustitución de áridos gruesos, módulos Young del hormigón, fórmulas de rotura del hormigón, Baquelita

1. Introduction

Fractional resolution to ecological issues is using waste materials and goods. E-waste composition is complex, also comes into the categories of ‘dangerous’ and ‘non-hazardous’(Kaya, 2016); (Luhar and Luhar, 2019); (Gollakota et al., 2020); (Sikarwar et al., 2020); (Velvizhi et al., 2020); (Gomez et al., 2020); (Mohd Hasan et al., 2019). Ferrous and non-ferrous metals, plastics and other products are usually included (Suriapparao et al., 2018); (Singh et al., 2017). E-waste comprises of all garbage that has met its closure or is no longer suitable for its original stated purpose and is meant for reuse, recycling or disposal (Kang et al., 2020); (Sovacool, 2020); (Casey et al., 2019). Workability decreases as e waste is replaced as a fine aggregate (Mane et al., 2020). E-waste be a partial alternate of the aggregate resulted a higher strength relative to standard concrete (Neecheidhsan and Sai, 2020). E-Waste can be a possible substitute for a large aggregate when its properties are accelerated by microorganisms (Rohini and Padmapriya, 2020). The including e waste substitute of the aggregate helps to minimize unit weight of concrete (Hamsavathi et al., 2020). The compressive potency, flexicurity of e waste concrete decrease with an e-waste percentage increase (Neecheidhsan et al., 2020). E-plastic used as substitute for coarse aggregate which indicates a small improves steel slag replacement (Bharani et al., 2020). E-Waste is feasible alternate material for CA which used for non-structural applications (Shinu and Neecheidhsan, 2020). E-plastic as CA of concrete mixture does not influence compressive strength & tensile potency up to 20% of the e-plastic waste (Arivalagan, 2020). Adding plastic waste results in lower final strength, modulus of elasticity and longevity (Evram et al., 2020). It has been concluded that use of E-plastic waste can improve its mechanical characteristics and that one of the cost-effective ways to dispose of it can be environmentally friendly (Santhanam and Anubasr, 2020). E-waste plastics

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be used as CA by substituting 0 per cent, 12 per cent, 17 per cent and 22 per cent of the CA in concrete by means of super plasticizer (Needhidasan et al., 2020). The addition of a standard super plasticizer in concrete with FRCA results in a rise in shrinkage deformation up to 44 per cent at 7 days of age and a decrease of up to 2 per cent at 91 days (Cartuxo et al., 2015). Concrete with super plasticizers decreases the workability from 15 cm to 7–8 cm (Papayianni et al., 2005). Objective of study is to find concrete properties with e-waste substitution for CA.

2. Methodology work

Literature related to E-waste use in building material had been collected in order to study the past works and planned to go one step ahead. E-waste is collected from firms Municipal Corporation, Salem. Since E-waste consists of different materials, it is crushed into small size and mixed up to make it homogeneous. Material properties and E-waste best possible proportion to be replace in concrete determined.

3. Material properties

3.1 Cement

PPC (fly ash based) with 3.16 specific gravity used for work. Tested corresponding to code (IS-12269, 2013). Properties are given in (Table 1).

<table>
<thead>
<tr>
<th>S No.</th>
<th>Characteristics</th>
<th>Values obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal consistency</td>
<td>33%</td>
</tr>
<tr>
<td>2</td>
<td>Initial setting time</td>
<td>32 minutes</td>
</tr>
<tr>
<td>3</td>
<td>Final setting time</td>
<td>225 minutes</td>
</tr>
<tr>
<td>5</td>
<td>Specific gravity</td>
<td>3.16</td>
</tr>
</tbody>
</table>

Table 1. Properties of cement

3.2 Fine aggregates

Sand with a specific gravity of 2.81 used for the experimental programme. Analyzed As per code (Bureau of Indian Standards (BIS), 1963).

3.3 Coarse Aggregates

Coarse aggregates with specific gravity 2.80, having the maximum size of 20mm where worn in the current work. Confirms to code (IS-383, 1970). CA properties are listed in (Table 2).

<table>
<thead>
<tr>
<th>S No.</th>
<th>Characteristics</th>
<th>Values obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>2.8</td>
</tr>
<tr>
<td>2</td>
<td>Impact value in %</td>
<td>11.935</td>
</tr>
<tr>
<td>3</td>
<td>Crushing value in %</td>
<td>8.17</td>
</tr>
</tbody>
</table>

Table 2. Properties of coarse aggregate
3.4 Properties of E-waste

E-waste is the mostly available material in small electronic firms and municipal corporations. E-waste was collected from Prasad electronics, Kannur, Manju electronics, Suramangalam, Salem and Salem Municipal Corporation. Throughout the study to maintain uniform specific gravity, the E-waste used is bakellite which is heat resistant and also inert and obtained by crushing the outer casing of television sets. Properties (E waste) listed in (Table 3).

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>1.13</td>
</tr>
<tr>
<td>Crushing Value</td>
<td>0.9%</td>
</tr>
<tr>
<td>Impact value</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Table 2. Thermal and mechanical properties of concrete and soil foundation

The E-waste materials, an old CRT television and computer parts namely the motherboards, keyboards and computer parts were collected from Prasad electronics, Kannur and Computer care, Thavakkara, Kannur respectively. The E waste is crushed manually with the hammer and dismantled into pieces. The selected plastic E-wastes, which was used for this study is shown in (Figure 1). From collected E- waste, capacitors are segregated as given in (Figure 2).

Figure 1. Plastic E-Waste selected to be used in concrete
Capacitors cannot be replaced partially as coarse aggregate in concrete as it contains dielectric medium thereby conductivity problems are likely to happen if there occurs an electric field nearby. Also during crushing toxic gases are likely to be liberated.

3.5 Water

Water from underground sources is used.

4. Mix design

Design is conceded as per code (Bureau of Indian Standards (BIS), 2009). Three trial mixes were premeditated by reducing cement and the one with the compressive strength above and close to target mean strength was fixed as the control mix and shown in (Table 4).

<table>
<thead>
<tr>
<th></th>
<th>Cement</th>
<th>Fine aggregate(kg)</th>
<th>Coarse aggregate(kg)</th>
<th>Water (l)</th>
<th>Chemical Admixture/SP (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight kg</td>
<td>360</td>
<td>677</td>
<td>1264</td>
<td>169</td>
<td>7.2</td>
</tr>
<tr>
<td>Proportion</td>
<td>1</td>
<td>1.88</td>
<td>3.51</td>
<td>0.47</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The compressive strength of control mix for M25 concrete is given in (Table 5).
Out of the results collected, the test mix which gives maximum strength selected as control mix. Since the compressive strength value was similar to and above the target strength.

5. **Experimental investigation**

5.1 **Fresh property slump test**

Slump test employed to test fresh properties and results are shown in (Table 6). Based on fresh property (slump test) only we fixed W/C = 0.47, because it gives more slump value and flowing ability comparing other W/C.

5.2 **Hardened properties**

5.2.1 **Compressive strength test**

(100*100*100) mm concrete cube casted for all mix with replacement to determining compressive strength. E-waste was added in percentage of 5%, 10%, 15% and 20% as substitution for coarse aggregate. Compressive strength results with and without admixture obtained given in (Figure 3) and (Figure 4) respectively. For optimize the workability melamine based super plasticizer was mixed with concrete.

### Table 5. Average Compressive strength result for control mix

<table>
<thead>
<tr>
<th>Days</th>
<th>Control mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td>14.67</td>
</tr>
<tr>
<td>7 days</td>
<td>21.07</td>
</tr>
<tr>
<td>28 days</td>
<td>36.18</td>
</tr>
</tbody>
</table>

### Table 6. Slump value for fresh concrete

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>W/C ratio</th>
<th>Weight of Water added</th>
<th>Slump (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45</td>
<td>900</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>0.46</td>
<td>920</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>0.47</td>
<td>940</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>0.48</td>
<td>960</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>0.49</td>
<td>980</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>0.50</td>
<td>1000</td>
<td>7</td>
</tr>
</tbody>
</table>
5.2.2 Ultrasonic pulse velocity test

Ensuring quality in hardened UPV was conducted. Direct, indirect and semi-direct method was performed for prisms with E waste containing 5%, 10%, 15% and 20% by volume of coarse aggregate and the results are summarized as below in (Table 7).

<table>
<thead>
<tr>
<th>% replacement of E-waste in M25 concrete</th>
<th>Ultrasonic pulse velocity by direct method (km/s)</th>
<th>Ultrasonic pulse velocity by semi direct method (km/s)</th>
<th>Average ultrasonic pulse velocity (km/s)</th>
<th>Nature of concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>5.37</td>
<td>4.23</td>
<td>4.20</td>
<td>Good</td>
</tr>
<tr>
<td>10%</td>
<td>4.87</td>
<td>5.23</td>
<td>4.11</td>
<td>Good</td>
</tr>
<tr>
<td>15%</td>
<td>4.76</td>
<td>4.25</td>
<td>3.72</td>
<td>Good</td>
</tr>
<tr>
<td>20%</td>
<td>4.65</td>
<td>4.23</td>
<td>3.61</td>
<td>Good</td>
</tr>
</tbody>
</table>

Figure 3. Compressive strength of Concrete with Different percentage E-Waste as Coarse Aggregate (Without Super Plasticizer/Chemical admixture)

Figure 4. Compressive strength of Concrete with Different percentage E-Waste (With Super Plasticizer/Chemical admixture)
5.2.3 Split tensile strength

(300*150) sized cylinders casted to measure the tensile strength of concrete. E-waste was added in percentage of 5%, 10%, 15% and 20% as substitution for coarse aggregate. The tensile strength with and without admixture obtained given in (Figure 5) and (Figure 6). To improve the workability melamine based super plasticizer was mixed with concrete.

![Figure 5](split_tensile_concrete_without_superplasticizer.png)

**Figure 5.** Split Tensile strength of Concrete with Different percentage E-Waste (Without Super Plasticizer/Chemical admixture)

![Figure 6](split_tensile_concrete_with_superplasticizer.png)

**Figure 6.** Split Tensile strength of Concrete with Different percentage E-Waste (With Super Plasticizer/chemical admixture)

5.2.4 Flexural Strength test

500*100*100 sized beam casted to test the flexural strength of concrete. E-waste was added in percentage of 5%, 10%, 15% and 20% as alternate for coarse aggregate. 28 days Flexural strength results for with and without admixture was given in (Figure 7).
5.2.5 Modulus of Elasticity

The cylinder subjected to uniaxial compression and with the help of dial gauges deformations measured. The young’s modulus was found by using compress meter and the results for with and without admixture is shown in (Figure 8).

![Figure 8. Modulus of Elasticity of Concrete with Different percentage E-Waste (With and Without Super Plasticizer/Chemical admixtures)](image)

6. Results & discussion

A comprehensive experimental study was conducted on the impact on strength on E-waste partial substitution for CA. Percentage loss in compressive strength up to an optimum of 15% is very nominal. However the tensile power, the rupture modulus and Young’s modulus are reduced by an enormous margin.
6.1 Compressive Strength

Compressive strength of concrete with 5 percentage E-waste as coarse aggregate (without chemical admixture) gives 18 percentage more strength (17.44 N/mm²) at 3 days when compared to control mix strength (14.67 N/mm²). When increasing the percentage of replacement of E waste as coarse aggregate to 10 % and 15 percentages, again the 3 days compression strength increases by 6 percentages (15.69 N/mm²) and 33 percentages (19.62 N/mm²) respectively. When replacement percentage reached 20 percentages, there we found reduction in compression strength at 3 days. Concrete with 20 percentage E waste as coarse aggregate gives 7 percentage less strength (18.63 N/mm²) when compared to concrete with 15 percentage of E waste as coarse aggregate (19.62 N/mm²), but by control mix it is more only. Comparative results through our study shows that replacement of 15 percent of E-waste as coarse aggregate gives maximum strength. At age of 7 days concrete with 5%, 10%,15% and 20 % replacement of E-waste gives 2%,11 %, 14 % and 19 % more compressive strength compared to control mix. When age of concrete increased to 28 days, the strength for all mixes with E-waste replacement gives more or less similar to control mix. Super Plasticizer ( SP- Chemical Admixtures) was used to enhance the workability. When the SP was applied, the compressive strength decreased by 1.9 per cent for 5 per cent of the CA by means of E-waste compared to control concrete and decreased by 0 per cent for 10 per cent of the gross aggregate with E-waste and decreased by 13.33 per cent for 15 per cent of the gross aggregate with E-waste and by 20 per cent for the CA replacement.

6.2 Split Tensile Strength

Tensile strength for the 5 per cent replacement of the CA with E-waste decreased by 9.24 per cent compare by control mix and for 10 percent alternate the CA with E-waste decreased by 18.49 per cent and for the 15 per cent replacement of the gross aggregate with E-waste decreased by 22.83 per cent and for the 20 per cent replacement of the gross aggregate with E-waste. The chemical admixture mixing was used to enhance the workability. When the mixture was applied, the tensile strength for 5 percent replacement of the gross aggregate with E-waste decreased by 9.01 percent compared to the control mix and for 10 percent replacement of the gross aggregate with E-waste decreased by 13.11 percent and for 15 percent replacement of the gross aggregate with E-waste decreased by 14.75 percent and for 20 percent replacement of the gross aggregate with E-waste. So from Split tensile test results, we identified that replacement of E-waste as coarse aggregate will gives more compressive strength and less tensile strength. E-waste not helps in tensile properties of concrete.

6.3 Flexural Strength

Flexural strength decreased by 5.84 per cent compared to the control mix for 5 per cent replacement of the gross aggregate with E-waste and decreased by 12.98 per cent for 10 per cent replacement of the gross aggregate with E-waste and by 20.34 per cent for 15 per cent replacement of the gross aggregate with E-waste and by 24.89 per cent for 20 per cent replacement of the gross aggregate with E-waste. As like split tensile strength concrete with E-waste as a coarse aggregate will result in reduction in flexural strength. So we found that e waste as CA will not enhance Flexural property of concrete.

6.4 Ultrasonic pulse velocity

Concrete With 5%,10%,15% and 20 % E waste as CA gives average ultrasonic velocity 4.20 km/s,4.11 km/s,3.72 km/s and 3.61 km/s respectively. UPV Test results shows that increase in percentage of E waste replacement as coarse aggregate leads to reduction in average ultrasonic pulse velocity.

6.5 Young’s Modulus

Control mix, 5%, 10%, 15 % and 20 % CA replacement with E waste gives 21910 N/mm², 18010 N/mm², 17582 N/mm², 14743 N/mm² and 12732 N/mm² respectively. Young’s modulus result helped us to understand that, when increase in percentage of replacement of E-waste as coarse aggregate (without admixture & with admixture) lead to reduction in E (Young’s modulus).

7. Conclusion

Consequences drawn from study listed one by one.

1. The study indicates compressive strength decrease when adding more than 15 % E-waste is substitute the CA in M25 concrete.
2. 15% E-waste replacement as coarse aggregate’s compressive strength was found to be significantly higher than the design goal mean strength. It shows that E-waste can also be used in concrete as a building material.

3. Compression strength of concrete with 15 percent E waste as coarse aggregate (without chemical admixture) gives better result at 3 days (19.62 N/mm²) and 14 days (23.83N/mm²) Compared to control mix Strength at 3 days and 7 days (14.67 N/mm² and 21.07 N/mm²).

4. In the same time concrete with 15 percent E waste as coarse aggregate (without chemical admixture) gives minimum strength at 28 days (33.27 N/mm²) when compared to control mix (36.18 N/mm²).

5. Also we found that when using melamine based chemical admixture to concrete with replacement of E-waste as coarse aggregate, it leads to reduction of compression strength.

6. Our results show that there is a huge reduction in Split tensile and flexural strength of concrete with E waste replacement .The reduction in tensile strength was 22.83% for 15% replacement of E-waste as CA without chemical admixture and 14.75% when chemical admixture was added. The reduction in flexural strength was 20.84% for 15% replacement of E-waste as coarse aggregate.

7. The results of non-destructive concrete testing by ultrasonic pulse velocity method showed that concrete is of good strength up to 15% replacement.

8. Therefore for members subjected to pure compression, the application of Bakelite E-waste up to 15% is justified and the volume of waste accumulated particularly in metropolitan cities can be reduced in a substantial manner and thereby we can protect ourselves from threatening environment.

8. References


