Experimental Investigation on concrete containing E-waste as course aggregate

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Abstract: Electrical and Electronic waste (e-waste) is increasing rapidly in the world, and is passing severe toxic waste issues to the human beings and the environment. About 80% to 85% of various electronic items, wastes are decomposed in landfills which might include or discharge lethal gases into air, may have an effect on human beings and environment. For solving and minimizing the discarding of huge quantity E-waste substance, recycle of E-waste materials in concrete production is well thought-out as the mainly possible purpose. It helps to eliminate the concrete materials deficiency issues that are currently going on in construction industry and it also helps to develop the strength of concrete mix and decrease the rate of concrete. In the current study, a novel attempt has been made by adding optimum weight polypropylene fiber with partial replacement of 20 mm E-waste particles as course aggregate. E-waste with pp fiber is employed in concrete in order to improve the strength of concrete mix. The work was carried out on M35 grade concrete specimen (without use of E-waste particles and pp fibers) and with a partial substitution of course aggregates with E-waste particles in range of 0%, 10%, 20% and 30% with respect to the weight of aggregate and pp fibers in the range of 0%, 0.2%, 0.4% and 0.6% with respect to the weight of cement. Comp. strength, Tensile strength and flexural strength of fibrous concrete with E-waste materials and not including e-waste materials as course aggregates was experimented which presented an excellent strength gain.

Keywords: E-waste; compressive strength; tensile strength; flexural strength; UPV test; Concrete.

1. Introduction

E-waste (shown in fig - 1) is the waste generated from the redundant electronic devices like laptops, computer, TVS, refrigerators etc. Basically, E-waste is known as any electrical appliances that have
reached to its end of time. It has become a serious concern causing severe pollution troubles to the human beings and environment. The devastated materials coming from electrical and electronic industries are categorized into dangerous and harmful inert waste materials. The inert wastes or electronic waste describes superseded, surplus and broken electrical or electronic devices. It is not easy to dispose-off the E-waste materials without causing any damage to the environment [1,2].

In 2019 A.D., it is projected that the world produced more than 53 million tons of E-waste materials, and only about 18% of that e-waste was authoritatively recognized as appropriately recycled and reused. It increased with 1.8 Million tons since 2014, but the overall e-waste production amplified by 9.2 Million tons till now. This shows that recycling actions are not at observance speed. In India, It is projected that the yearly production of E-waste is more than 5 million tons because of higher utilization and increasing economy. Re-use of e-waste materials as course aggregate in concrete provides a decent approach to securely decompose these waste products without affecting environment and also reduce the rate of materials. Use of concrete is extremely huge so there is less accessibility of natural material like aggregate [3,4]. To meet up the necessity of industries, we have to substitute e-waste to some extent. Due to inadequacy of coarse aggregate, partial substitution of e-waste materials with coarse aggregate was attempted in concrete. The experiment was conducted on M35 mix design. In this experiment, the substitution is in the range of 0%, 10%, 20% and 30% of coarse aggregate with E-waste materials.

Fiber reinforced concrete is used in several of engineering works because of its suitable and excellent performance in the industries area and construction field. Concrete reinforced with Polypropylene fiber is used for numerous purposes that include rigid pavement, beams, self-compacting concrete and other applications as well. PP comes from the set of polyolefin and is moderately crystalline and non-polar. It has alike properties as polyethylene, but it is harder and more heat resistant. It is a white rough material with a high chemical resistance. And polypropylene fibers helps to increase the strength, controls cracking due to both drying shrinkage and plastic shrinkage and also reduce the permeability of concrete which helps to decrease bleeding of water. M35 grade mixes used polypropylene fiber with content 0%, 0.2%, 0.4% and 0.6%, will be casted with 20 mm e-waste particle. At last, durability and mechanical properties of these mixed concrete specimens was compared with conventional concrete specimens [5–7].

The Scope of the present study is to partially substituting 20 mm e-waste material as course aggregate and
adding 12 mm PP fiber in concrete mix, the strength of concrete can be determined. In addition, to formulate a possible alternate method for the disposal and management of electronic waste in eco-friendly way. This scope will help in concluding the behavior of concrete while adding E-waste materials and PP fiber in concrete [8,9].

Various researchers all around the world have focused on the possible methods to control E-waste and futuristic aspects. The most relevant and prominent publication are concluded as; had researched the employ of E-waste materials in the range of 0% to 30% with coarse aggregates in concrete to find out the M20 grade mix strength of concrete. They performed Compressive, Tensile and Flexural strength test of Concrete with E-waste particle alternation and found good strength gain of concrete specimen. examined E-waste particles and plastic waste particles in concrete mix. They replaced E-waste materials and plastic waste materials in the range of 0% to 4% of the fine aggregates i.e. sand. They performed Compressive and flexural strength test on specimen and compared with normal mix and observed that there is rise in compressive strength by 5 percent and reduction in the rate of concrete manufacture by 7 percent at optimum percentage of grinded waste and exhibits good strength. explored an impression on the E-waste utilization as a partial substitution of course aggregate in concrete mix [10,11]. They have demonstrated impact and consequences of E-waste particle on concrete properties by performing compressive and split tensile strength test. M20 grade mix with partial substitution of coarse aggregate with E-waste particle within the series of 0% to 20% with regular interval of 5 percent. They have also used chemicals like sulphate and chloride in concrete mix and conducted test to examine the consequences. They found that there was good strength gain in compressive strength test up to 15% substitution of E-Waste with aggregate. Thus, the researcher had recommended utilizing E-waste in concrete. worked on the research to analyze the concrete strength when e-waste materials is used partially with coarse aggregate in the range of 5%, 10%, 15%, 20%, 25% and 30%. Then they analyzed the outcome with normal concrete mix in their research [12,13]. When they replaced coarse aggregate with e-waste by 15 percent, they found that the compressive, flexure and tensile strength have improved and after that the strength found declining gradually. They investigated that the concrete flattered more light weight and can also bear more seismic loads then normal concrete mix. M20 grade, replacing the course aggregate with E-waste particle ranging 0 percent, 5 percent and 10 percent. They used M-sand for economical purpose so that E-wastage was used for reduction of E-wastage and it will reacts with the concrete in eco-friendly manner The values which was obtained was slightly changed or decreased on compressive, tensile and flexural strength. They recognized that there was no cracks coming on the cubes, cylinders and prisms and concluded that e-wastage is eco-friendly with the concrete. M20 grade concrete with partial substitution of Course aggregate with E-waste particles in the range of 5%, 10%, 15%, 20%, 25% and 30%. They explored out that compressive strength criteria is 20.35% higher when e-waste substitution is 15% with coarse aggregate studied the consequences of inclusion of grinded and crushed printed circuit board (PCB) sheet by partially substituting coarse aggregates upto 15 percent and observed that comp. strength of concrete specimen is improved when coarse aggregate is substituted by 5 percent and comp [14–16]. strength of concrete specimen starts declining when replacement of e-waste PCB is increased by 10 percent and 15 percent.

The findings literature considered can be concluded as, a number of research works have been reported for the employment of e-waste in cement concrete mix. Mostly, Researchers have worked on M20 grade mix ranging 0% to 25%. In addition, Minimal work had carried out along with polypropylene fiber and e-waste particle in concrete. Present manuscript focuses on the analysis is being performed on M35 mix design concrete by replacing course aggregate with E-waste particles in the range of 0% to 30% and adding pp fiber in the range of 0% to 0.6% [17,18].

The need of the study emphasised, to discover a possible green technique for disposal and administration of e-waste in eco-friendly manner. To design the fibrous concrete mix by partially substituting e-waste as a course aggregate and adding PP fiber. To study the effect of substituting E-waste and adding PP fiber in
concrete mix on various test for strength of concrete mix. To evaluate the properties of convensional concrete cubes with modified fibrous concrete cubes. To arrive at the optimum percentage replacement of E-waste in the design fibrous concrete mix.

2. Materials and Methods

2.1 Materials

Cement: - The ordinary Portland cement of 43 grades (IS 12269-1987) is employed. Tests are performed in accordance with procedures represented in IS 4031:1968. Fine Aggregates: - Locally accessible sand passed through 4.75 mm IS sieve is employed as fine aggregate. Before using it, the sand is well cleaned, washed and sieved to eradicate impurities. Coarse Aggregate: - Coarse Aggregate might be within the form of irregular, uneven broken stones. The size of aggregate ranges from 20 mm to 4.75 mm is employed as course aggregate which was obtained from local quarry conforming to IS: 383-1970. Water: - Water plays a really vital role in mixing, compacting, setting and hardening of concrete. Potable water was employed throughout the research mentioned in IS 456-2000. E-waste: - E-waste refers to electronic equipments nearing the end of their valuable life. E-wastes from Electronic Products such as laptops, TVs, computers, refrigerators, etc. were crushed in 20 mm and employed in the place of 20 mm coarse aggregate. Polypropylene fiber: - PP comes from the group of polyolefin and is crystalline to some extent and non-polar. PP shows same properties as polyethylene, but it is harder and most heat resistant. It is a white rough object with a high chemical resistance. PP improves the strength criteria and durability of concrete. PP fiber was employed in the range of 0%, 0.2%, 0.4% and 0.6% by weight of cement in fibrous concrete specimen. The properties of are incorporated in table – 1 to table - 6 below.

Table: - 1 Properties of Polypropylene fiber

| Sr. no. | Parameters               | values     |
|---------|--------------------------|------------|
| 1.      | Length (in mm)           | 12 mm      |
| 2.      | Specific gravity         | 0.90-0.921 |
| 3.      | Diameter(in mm)          | 0.04       |
| 4.      | Tensile strength (Mpa)   | 400 Mpa    |
| 5.      | Modulus of elasticity    | 3500 Mpa   |
| 6.      | Melting point(C)         | 160        |
| 7.      | Heat resistance(C)       | <125       |
| 8.      | Acid and Alkali resistance | Very good |

Table – 2 Specific gravity test of materials

| Materials     | S.G. values |
|---------------|-------------|
| Cement        | 3.14        |
| Fine aggregate| 2.65        |
| Course Aggregate | 2.7      |
| E-waste       | 1.85        |

Table 3: Water Absorption Test of the materials

| Materials     | Water absorption values |
|---------------|-------------------------|
| Fine aggregate| 0.35%                   |
Table 4: Impact Value Test of the materials

| Materials   | Impact values |
|-------------|---------------|
| Course Aggregate | 16%          |
| E-waste     | 4%            |

Table 5: Crushing Value Test of the materials

| Materials   | Crushing values |
|-------------|-----------------|
| Course Aggregate | 18.6%        |
| E-waste     | 2.4%            |

Table 6: Fineness modulus Test of the materials

| Max size of aggregate | Fineness modulus |
|-----------------------|------------------|
| Fine Aggregate         | 3.5              |
| Course Aggregate       | 8.45             |
| E-waste                | 7.35             |

2.2 Methodology

The research work was done before starting the work by reviewing the previous research papers published. Concrete tests are performed for the investigation and partial substitution of E-waste for course aggregate. In this experiment, the materials used are OPC grade 43, natural sand as fine aggregate, natural aggregate as coarse aggregate, Polypropylene fiber of 12 mm and crushed 20 mm retained e-waste was used in this investigation project.

E-waste is replaced partially in the percentage of 0%, 10%, 20% and 30% with coarse aggregate in the fibrous concrete mix. Polypropylene fiber is used in the range of 0% to 0.6%. The partially replaced fibrous e-waste concrete is compared with normal concrete.

M35 mix design of 1:1.53:2.54 proportions with 0.45 water cement ratio was used to prepare entire specimens. For compressive strength test, 1 set cube was prepared without e-waste and 2 sets of cubes were prepared for each proportion of e-waste substitution. 1st set test was done after 7 days curing and 2nd set after 28 days curing. Ultra Sonic Pulse Velocity test was also performed on both set of specimen. For split tensile and flexural strength test, 2 set of cubes were prepared for each proportion e-waste substitution and 28 days test performed.

3. Experimentation

3.1. Compressive strength Test

Compression test machine of 2000 KN capacity is used to examine the compression strength of concrete. The compression test is conducted on fibrous concrete specimen of size of (15X15X15)cm with various ratio of e-waste 0%, 10%, 20% and 30% by weight of course aggregate and addition of PP fiber with various ratio of 0%, 0.2%, 0.4% and 0.6% by weight of cement. Strength of each specimen was analyzed after curing for 7 days and 28 days. Results are concluded in table – 7 and fig – 2
3.2. Split Tensile strength test

This test was performed on Universal Testing Machine. Cylindrical specimens of 300mm*150mm diameter were casted with various ratio of e-waste 0%, 10%, 20% and 30% by weight of course aggregate and addition of PP fiber with various ratio of 0%, 0.2%, 0.4% and 0.6% by weight of cement for performing experiment after 28 days curing. The outcome are showcased in table – 8 and fig - 3.

3.3. Flexural strength test

It is the ability to resist bending. Flexural strength test was performed on Universal Testing Machine. Beam mould size of 100mm*100mm*500mm were casted with various ratio of e-waste 0%, 10%, 20% and 30% by weight of course aggregate and addition of PP fiber with various ratio of 0%, 0.2%, 0.4% and 0.6% by weight of cement for performing experiment after 28 days curing. The performance variation are incorporated in table – 9 and fig - 4.

3.4. Ultrasonic Pulse Velocity Test

This test helps in determination of trapped air/Voids, internal flaws, cracks, segregation, honey combing, compaction, durability of the concrete specimen. From IS-Code = 516(part – 5/ Sec-1) 2018, Direct method of Ultrasonic pulse velocity test was performed on the entire cubes specimen. The performance outcomes are showcased in Table - 10 below.

4. Result and Discussion

After 7 days and 28 days curing, all fibrous concrete specimens were taken to lab and compressive strength of cubes specimen was measured on compression testing Machine. Split Tensile strength test of cylindrical specimen and Flexural strength test of beam specimen was performed on universal testing machine.

The result shows that up to 10% substitution of aggregate with e-waste material and adding of 0.2% PP fiber with respect to cement weight is showing good enhancement in compressive strength. Although, we can see at 20% substitution it has given quite good result. And more than 20% substitution of e-waste materials with course aggregate and adding more PP fiber caused decreasing in strength.

| Sr. | % of E-waste replacement + % addition of PP fiber | Comp. strength(N/mm²) 7 days | Comp. strength(N/mm²) 28 days |
|-----|-----------------------------------------------|-----------------------------|-----------------------------|
| 1.  | 0%                                            | 23.1                        | 36.1                        |
| 2.  | 10%+0.2%                                      | 22.8                        | 36.8                        |
| 3.  | 20%+0.4%                                      | 21.2                        | 35.6                        |
| 4.  | 30%+0.6%                                      | 16.2                        | 31.5                        |

Percentage of E-waste replacement with coarse aggregate plus percentage addition of PP fiber with respect to cement weight.
Fig. 2 Average comp. strength of concrete with % substitution of e-waste and % addition of PP fiber w. r. t. cement weight

Table-8 Test result for split tensile strength

| Sr. | % of E-waste replacement + % addition of PP fiber | Tensile strength(N/mm²) of 28 days |
|-----|-----------------------------------------------|----------------------------------|
| 1.  | 0%                                            | 3.64                             |
| 2.  | 10%+0.2%                                       | 3.21                             |
| 3.  | 20%+0.4%                                       | 3.34                             |
| 4.  | 30%+0.6%                                       | 2.47                             |

Percentage of E-waste replacement with coarse aggregate plus percentage of PP fiber with respect to cement weight
Fig. 3 Split tensile strength of concrete with % substitution of e-waste material and % addition of PP Fiber

From the figure-3, the max strength was found at 20% substitution of e-waste material and 0.4% PP fiber addition in concrete with respect to cement weight.

| Sr. | % of E-waste replacement+ % addition of PP fiber | Flexural strength (N/mm²) 28 Days |
|-----|--------------------------------------------------|----------------------------------|
| 1.  | 0%                                               | 3.83                             |
| 2.  | 10%+0.2%                                         | 3.49                             |
| 3.  | 20%+0.4%                                         | 3.12                             |
| 4.  | 30%+0.6%                                         | 2.06                             |

Percentage of E-waste replacement with coarse aggregate plus percentage addition of PP fiber with respect to cement weight

From the figure-4, a good strength gain was found at 10% substitution of coarse aggregate by e-waste material and addition of 0.2% of PP fiber in concrete. However, at 20% substitution also gave acceptable result.
From the result, it is observed that ordinary Portland cement with 20% E-waste and 0.4% of PP fiber in concrete specimen has quite good strength criteria when compared to normal concrete cube specimen. More than 20% of E-waste material substitution and addition of pp fiber, there is decrease in strength found than the normal concrete mix.

Ultrasonic Pulse Velocity Test is a non-destructive test. From table 10, it shows that the concrete is of good quality up to 20% e-waste substitution.

**Table -10 UPV Test Result**

| % of E-waste replacement + % addition of PP fiber | UPV Test (28 Days) |
|------------------------------------------------|--------------------|
|                                                | Velocity (Km/Sec)  | Concrete Quality |
| 0%                                              | 4.0314             | Good             |
| 10%+0.2%                                        | 3.8212             | Good             |
| 20%+0.4%                                        | 3.5714             | Good             |
| 30%+0.6%                                        | 2.8565             | Poor             |

5. Conclusion

This investigation is intended to discover the scenario of employment of e-waste materials in fibrous concrete by partially substituting coarse aggregate and improving the strength criteria by adding pp fiber.
The findings are listed as under:

1. When 20% of course aggregate is substituted by e-waste materials and addition of 0.4% of pp fiber with respect to cement weight in concrete, the strength criteria like compressive, tensile and flexural strength is found increased.
2. The result shows that the rising percentage substitution of coarse aggregate by e-waste material more than 20% has resulted reduction in strength.
3. It is recognized that e-waste can be inclined by utilizing them as construction materials.
4. PP fiber has superb effect on increment of strength criteria of Concrete specimen than normal concrete specimen.
5. UPV test result also showed good quality concrete up to 20% replacement of e-waste particle.
6. Considerable employment of e-waste in concrete turns down environmental issues. Hence, it is environment friendly way.
7. It can be accomplished that 20% of e-waste materials as course aggregate substitution and 0.4% of pp fiber utilization has no any damaging property and with up to standard strength improvement properties.

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