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Experimental Investigation on Strength and Workability Properties of Concrete with Partial Replacement of Coarse Aggregate by E-Waste.

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KEYWORDS
E-waste, Coarse aggregate, M30 Concrete, Slump test, Workability strength, Compressive strength, Tensile strength and Flexural strength.

ABSTRACT:
E-waste is a highly hazardous material with a poor recycling rate, and as such, its management and recycling are expanding quickly. E-waste is a useful resource for IT sectors. This issue has consumed a significant portion of the world's solid waste output. Utilizing e-waste will lower the cost of aggregate and give roads and buildings good strength. It saves energy and will lower the cost of landfills. The construction industry is working to substitute some of the fine or coarse particles in concrete with non-biodegradable e-waste components. The goal of this research is to improve the environment's E-waste generation by incorporating it into M30 Concrete and evaluating the concrete's workability and compressive strength both when it's fresh and after it has hardened. This work contributes to the optimization of e-waste generation and its application in the building sector. Using E-waste particles as coarse aggregates in concrete at replacement percentages of 0%,10%,20%, and 30% depending on the M30 concrete strength requirements. Three tests were used to determine the properties of fresh concrete: the vee bee, the compaction factor, and the slump cone test. Additionally, the mechanical qualities of the concrete were ascertained through the observation of its compressive strength, tensile strength, and flexural strength, both with and without the addition of e-waste aggregates. It has been demonstrated that using E-waste particles to partially replace coarse aggregate is feasible. A sufficient number of cubes, cylinders, and beams were formed for this experimental examination to examine the concrete's compressive, tensile, and flexural strengths. Our findings indicate that adding E-waste to cubes initially increases their compressive strength, but eventually causes it to decrease. The compressive strength of concrete reaches 34.1 N/mm2 when 10% E-waste is added, and thereafter it begins to decline.

1. Introduction

1.1 General:

Concrete is a necessary component of all construction activities in the current context. In the construction business, concrete is the most commonly utilized building material. Its popularity stems primarily from its tremendous strength and longevity. Today's globe is advancing at an alarming rate, and our surroundings is gradually altering. The environment, natural resource conservation, and garbage recycling are all receiving attention. E-waste is one of the new waste resources used in the concrete industry. The reuse of E-waste in the concrete industry is regarded as the most realistic application for addressing the disposal of a huge amount of E-waste material. E-waste is one of the world's fastest-growing trash streams. Previously, it was roughly 1% of total in wealthy countries. It is between 0.01% and 1% of the entire amount of municipal solid garbage generated in developing nations. A growing problem that seriously pollutes both the environment and people is e-waste. It is necessary to explore new, efficient waste management choices, particularly with regard to recycling ideas. Electronic or electrical gadgets that are broken, surplus, outdated, or carelessly disposed of are referred to as e-waste. The quick advancement of technology combined with inexpensive beginning costs has led to an ever-expanding global glut of electronic trash. Every year, several tonnes of E-waste must be disposed of. If not managed appropriately, the many kinds of compounds and chemicals found in e-waste more than a thousand in total can lead to major health and environmental issues for both humans and the environment.

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E-waste may already be used as a concrete aggregate, according to numerous studies. It was attempted to partially replace E-waste with coarse aggregate due to the shortage of coarse material needed for concrete preparation. The M20 grade mix was used for the work. In this work, 0%, 10%, 20%, and 30% are the percentages at which different amounts of coarse aggregate substitution with E-waste are made. Lastly, a comparison will be made between the mechanical characteristics of the concrete mix specimens that resulted from the inclusion of these components and those that were obtained using a control concrete mix.

1.2 Objectives of Research:

The following are the Objectives of this research.

i. Develop an ecologically beneficial concrete mix by utilizing electronic waste as a building material to reduce toxic substances in specific devices.
ii. Decrease environmental contamination from E-waste, and determine the optimal strength achieved through the recommended replacement percentage.
iii. To examine the concrete containing e-waste aggregate's compressive strength, split tensile strength, and flexural strength after 7, 14, and 28 days of curing, respectively.

2. Review of Literature

Lakshmi and Nagan (2011) examined the use of E-waste particles as coarse aggregates in concrete, replacing a percentage of the original material in the range of 0% to 30% depending on the M20 concrete's strength requirements. Concrete with and without E-waste as aggregates was tested for compressive strength, tensile strength, and flexural strength; the results show a good strength boost. Concrete was utilized by Arora and Dave (2013) to include plastic and e-waste. 0%, 2%, and 4% of the fine aggregates were used in place of the ground up plastic and E-waste. Tests and comparisons with control concrete were conducted to determine the compressive and flexural strengths. They discovered that, at the ideal proportion of ground waste, the compressive strength of concrete has increased by 5% and the cost of producing concrete has decreased by 7%.

Prasanna et al (June 2014) investigated the effects of adding 5%, 10%, 15%, and 20% of e-waste in place of coarse aggregate in one batch. They also created a second batch with the same percentage of e-waste and 10% fly ash. It has been discovered that replacing 15% of the coarse material with e-waste maximizes the strength of the concrete.

Suchithra et al. (2015) investigated the replacement of coarse aggregate in M20 grade mixes with E-waste products. The percentages of coarse aggregate replaced were 0%, 5%, 10%, 15%, and 20%. The concrete mix's durability and mechanical properties were contrasted with that of the control mix. The test findings demonstrated that e-waste concrete could be used in concrete successfully and had a satisfactory increase in compressive strength when compared to conventional concrete. The use of E-waste materials from abandoned old computers, TVs, refrigerators, and radios was done by Devi et al. (2017). For M20 concrete, e-waste was used to partially replace coarse aggregates, ranging from 0% to 20%. They discovered that e-waste demonstrates strength improvement when utilized as coarse aggregates.

Amiya Akram et al (July 2015) created two batches: one with only e-plastic and the other with e-plastic and fly ash. They do this by using shredded e-plastic and fly ash to partially replace the coarse aggregate. They substitute e-plastic for coarse aggregate in one batch at percentages of 5%, 10%, and 15%. They examine the concrete's flexural and compressive strengths. When e-plastic was added to concrete, it became more ductile; in the flexure strength test, the specimen collapsed silently because it became less brittle. They also discovered that the compressive strength would improve at 10% but then decline.

Balasubramanian et al (July 2016) examined to assess the split tensile strength, compressive strength, and flexural strength when e-waste is used to partially replace coarse aggregate. In their research, concrete mixtures were prepared by substituting e-waste for coarse aggregate at percentages of 5%, 10%, 15%, 20%, 25%, and 30%. Then, the results were compared with the standard concrete mixture, and they discovered that when coarse aggregate is replaced with e-waste up to 15% of the mixture, the strength starts to decrease. They have discovered that, in comparison to traditional concrete, the new concrete is lighter and better capable of withstanding earthquake loads.

3. Experimental Work

The experimental program's goal is to compare the characteristics of concrete that uses e-waste as coarse aggregate to concrete that doesn't. The following discusses the fundamental tests and their characteristics performed on aggregates, sand, and cement, which are used to cast concrete samples:

3.1 Materials:

A. Cement: Ordinary Portland Cement (OPC) 53-grade Sri chakra cement, which is widely accessible in the market and has a specific gravity of 3.14, was utilized in this research project. According to IS 8112:1989, the following characteristics of cement were measured: initial setting time of -54 minutes (≥30 minutes); final setting time of 385 minutes (≤600 minutes); fineness of 1.8% (≤10%); consistency of 29%.

B. Fine Aggregate: By passing the river sand through a 4.75mm sieve, higher-quality river sand was utilized as fine aggregate. Specific gravity, fineness modulus, and water absorption tests yielded results of 2.66, 2.96, and 1.6%, respectively.

C. Coarse Aggregate: Locally accessible 20 mm natural stone coarse aggregates were used as the coarse materials in this study. According to IS: 2386 (part III)-1963, laboratory tests were conducted on coarse aggregate to ascertain various properties. The results showed that the specific gravity, fineness modulus, and water absorption were 2.71, 6.275, and 0.47%, respectively.

D. E-Waste Coarse Aggregate: We used printed circuit boards (PCBs) as e-waste in our investigation. Local electronics stores provide us with their E-waste. The aggregate ranges in size from 1.18 mm to 2.36 mm. By hand, every metal that was fastened to the PCB was extracted. To determine the characteristics of e-waste, the fundamental tests are carried out in the same manner as for coarse aggregate (Table 1).

Table 1: Physical Properties of Fine Aggregate, Coarse Aggregate and E-Waste

Properties	Fine Aggregate	Coarse Aggregate	E-Waste
Specific gravity	2.66	2.71	1.20
Fineness modulus	2.96	6.275	5.059
Water Absorption	1.6%	0.47%	0.05%
Color	-	Dark	Dark&Ivory

D. Water: Clean water free of hazardous levels of oils, acids, alkalis, organic compounds, or other harmful substances must be used to mix concrete. For the purpose of this experiment, we cast concrete and cured the specimens using portable tap water that complied with IS456-2000 requirements from the college campus water plant.

3.2 Mix proportions: To attain M30 grade strength, the concrete was designed in accordance with IS 10262-2009, and a water-to-cement ratio of 0.5 was employed. Distinct mixes of Coarse aggregate by varying proportions of 0%,10%,20%, and 30% with E-waste were tested to analyze the strength characteristics in terms of Compressive Strength, Split Tensile Strength, and Flexural Strength. Nine cubes, Nine Cylinders, and Nine Beams were cast for each mix and tested for Compressive Strength, Split Tensile Strength, and Flexural Strength.

3.3 Testing methods

3.3.1. Workability test: The workability of the concrete is checked through slump value and compaction factor values. These workability tests were performed for all mixes.

3.3.2. Compression test: The test program considered the cast and testing of concrete specimens of the cube (150mm) and (150 x 150 mm). The specimen was cast M30 grade concrete using OPC, Natural River sand, coarse aggregate (20mm to 4.75mm), and E-waste aggregates. Each three numbers of specimens is made to take the average value. The Specimens were removed from the cube after 24 hours. The specimens were allowed to the curing periods of 7,14 and 28 days. Tests were conducted to ascertain the strength criteria in concrete are described below in detail.

3.3.3 Split Tensile Test: The test program considered the cast and testing of concrete specimens of cylinders 100mm in diameter and 300mm in height. The specimen was cast M30 grade concrete using OPC, Natural River sand, coarse aggregate (20mm to 4.75mm), and E-waste aggregates. Each three numbers of specimens is made to take the average value. The Specimens were removed from the cube after 24 hours. The specimens were allowed to the curing periods of 7,14 and 28 days. Tests were conducted to ascertain the strength criteria in concrete are described below in detail.

3.3.4 Flexural Test: The test program considered the cast and testing of concrete specimens of the Beams 100mmx50mmx50mm. The specimen was cast M30 grade concrete using OPC, Natural River sand, coarse aggregate (20mm to 4.75mm), and E-waste aggregates. Each three numbers of specimens is made to take the

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average value. The Specimens were removed from the cube after 24 hours. The specimens were allowed to the curing periods of 7,14 and 28 days. Tests were conducted to ascertain the strength criteria in concrete are described below in detail.

4. Test Result and Discussions

4.1. Workability: The workability of the control mix and E-waste mixed concrete was measured according to IS Standards. Workability is tested in terms of slump cone, and compaction factor test, which decreases as E-Waste is replaced with Coarse aggregate, respectively. The slump cone and compaction factor test with % replacement is depicted in the graphs below (Fig 1 & Fig 2).

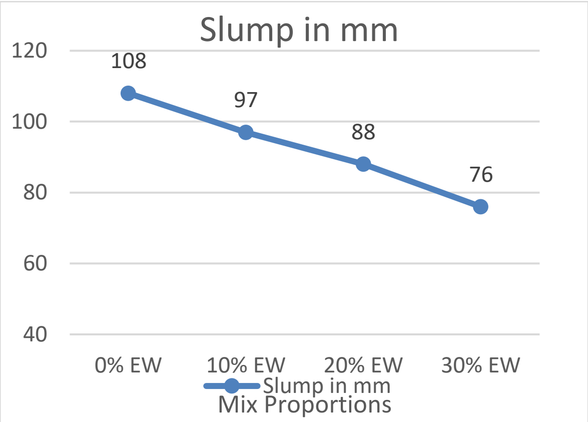

Fig 1: Slump with different mixed proportions of E-Waste.

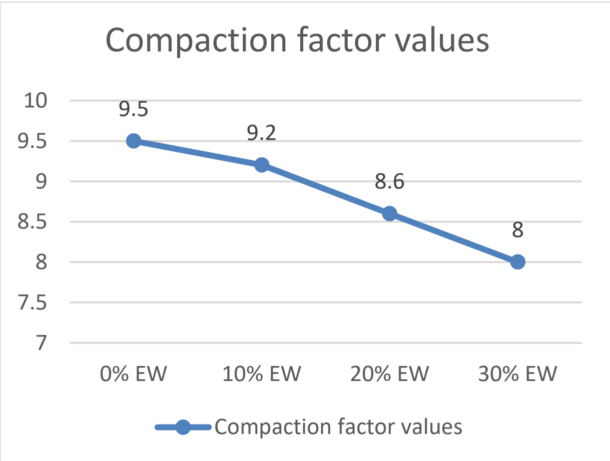

Fig 2: Compaction factor with different mixed proportions of E-Waste.

The workability test results show that the workability decreases as the percentage of E-waste increases. The slump value for the nominal mix was around 108 mm, and it steadily dropped to 76 mm. In terms of the compacting factor, the nominal mix demonstrated the highest workability. The dropping of workability is mainly due to the increasing waste-plastic ratio at all curing stages. This may be attributed to the decrease in the adhesive strength between the materials. In addition, waste plastic is a hydrophobic material which may restrict the hydration of cement.

4.2 Casting of specimens:

The molds that were used to cast cubes were carefully cleaned. A thin layer of oil was applied to the interior surface of the molds to prevent concrete adherence and leakage. Then, using a tamping rod, the concrete was poured into the greased molds (cubes, beams, and cylinders). Tests were conducted at 7, 14 and 28 days of age.

4.3 Methods of curing: Water unsuitable for drinking is generally considered unsuitable for curing concrete as well. The water used for normal water curing of concrete samples was taken from the concrete technology laboratory, JNTUA. The concrete samples were tested after 7, 14, and 28 days of age.

4.4 Compressive strength: The uniaxial compressive test results are depicted (Fig 3). In comparison to the control mix, the compressive strength of E-waste steadily increased up to 7.62% after 28 days of curing and subsequently dropped (Table 2). This study determined that 10%EW was the best combination.

Table 2: Compression strength of M30 grade concrete on 7, 14 and 28 days

% of coarse aggregate replaced	7 days	14 days	28 days
0%	20.19	29.3	31.5
10%	21.67	31.4	34.1
20%	20.23	28.7	32.5
30%	18.47	27.1	31.7

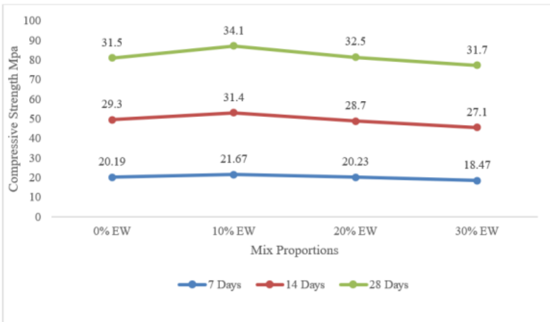

Fig 3: Compressive strength with different mixed proportions of E-Waste.

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4.5 Split Tensile Strength: From the lab results, the Split tensile strength was maximum when Coarse aggregate was replaced with E-Waste aggregate at 10% (Table 3). In comparison to the control mix, the Split tensile strength of E-waste aggregate concrete steadily increased up to 11.47% and subsequently dropped (Fig 4). This study determined that 10%EW was the best combination.

Table 3: Split tensile strength of M30 grade concrete on 7, 14 and 28 days

% of coarse aggregate replaced	7 days	14 days	28 days
0%	4.13	4.32	4.63
10%	4.37	4.71	5.23
20%	4.15	4.22	4.69
30%	3.98	4.11	4.32

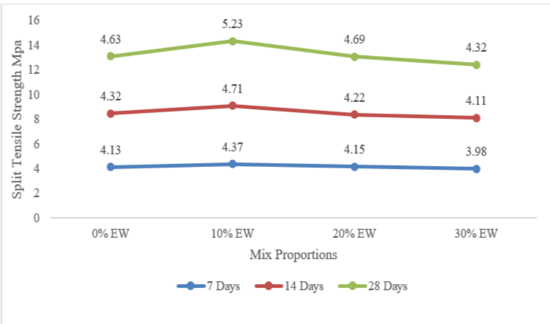

Figure 4: Split Tensile strength with different mixed proportions of E-Waste.

4.6 Flexural Strength: From the lab results, the Flexural strength was maximum when Coarse aggregate was replaced with E-Waste aggregate at 10% (Table 4). In comparison to the control mix, the Flexural strength of E-waste aggregate concrete steadily increased up to 4% and subsequently dropped (Fig 5). This study determined that 10%EW was the best combination.

Table 4: Flexural strength of M30 grade concrete on 7, 14 and 28 days

% of coarse aggregate replaced	7 days	14 days	28 days
0%	5.2	6.3	7.2
10%	5.6	6.6	7.5
20%	5.0	6.1	7.0
30%	4.7	5.8	6.7

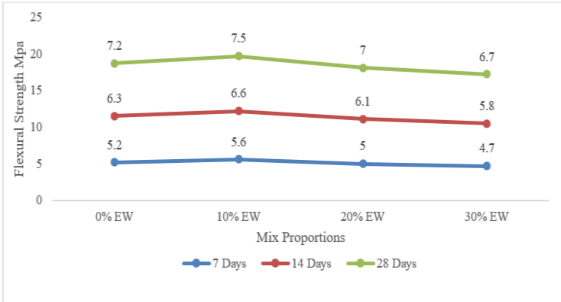

Figure 5: Flexural strength with different mixed proportions of E-Waste.

5. Conclusion

In this work, the effect of the use of E-Waste to partially replace Coarse aggregate was investigated. Based on the early research, mix 10%EW was determined to be the optimum mix in terms of compressive strength, Split tensile strength, and Flexural strength. All mixes were put through a workability test. Mechanical characteristics such as cube compressive strength, splitting tensile strength, and flexural strength were determined for all of the mixes. The results obtained were compared to the control mix. The following results were reached according to the experimental investigation.

i. The workability of the concrete as measured by the slump and compaction factor reveals that as E-waste replacement increases, the slump decreases. The compaction factor also decreases as E-waste content increases, and the findings are within the typical range of concrete.

ii. The e-waste obtained has lower specific gravity than the Coarse aggregate they replaced, which means mass replacement will produce a significantly higher volume of cementitious materials.

iii. The introduction of plastics in concrete tends to make concrete ductile, hence increasing the ability of concrete to significantly deform before failure. This characteristic makes the concrete useful in situations where it will be subjected to harsh weather such as expansion and contraction, or freeze and thaw.

iv. E-waste Plastics can be used to replace some of the aggregates in a concrete mixture. This contributes to reducing the unit weight of the concrete. This is useful in applications requiring non-bearing lightweight concrete, such as concrete panels used in facades.

v. Compressive strength increased up to 10% with E-waste and then dropped at the remaining proportions, because of the fact that the E-waste plastic aggregates reduce the bond strength of concrete. Therefore, the failure of concrete occurs due to the failure of the bond between the cement paste and plastic aggregates. The compressive strength was increased by around 7.62% on the 28th day compared to the control mix.

vi. The cylinder's splitting tensile strength was maximum at 10% replacement of E-waste and thereafter reduced at all ages. The percentage improvement in splitting tensile strength over the control mix was approximately 11.47%.

vii. The flexural strength of the beam was greatest for mix 10%EW. The strength of this mix was around 4% stronger than the nominal mix.

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