Study on Replacement of Coarse Aggregate by E-Waste in Concrete

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Abstract--Electronic waste is an emerging issue posing serious pollution problems to the human and the environment. The disposal of which is becoming a challenging problem. For solving the disposal of large amount of E -waste material, reuse of E -waste in concrete industry is considered as the most feasible application. Due to increase in cost of normal coarse aggregate it have forced the civil engineers to find out suitable alternatives to it. E- waste is used as one such alternative for coarse aggregate. Owing to scarcity of coarse aggregate for the preparation of concrete, partial replacement of E-waste with coarse was attempted. The work was conducted on M20 grade mix. The percentage of replacing coarse aggregate with E-waste in the range of 0%, 5%, 10%, 15%, and 20%. Finally the mechanical properties and durability of the concrete mix specimens obtained from the addition of these materials is compared with control concrete mix. The test results showed that a significant improvement in compressive strength was achieved in the E-waste concrete compared to conventional concrete and can be used effectively in concrete. The reuse of E-waste results in waste reduction and resources conservation.

Keywords-- E- waste, Durability, Compressive strength, Split tensile strength, Flexural strength

I. INTRODUCTION

In the present scenario, no construction activity can be imagined without using concrete. Concrete is the most widely used building material in construction industry. The main reason behind its popularity is its high strength and durability. Today, the world is advancing too fast and our environment is changing progressively. Attention is being focused on the environment and safeguarding of natural resources and recycling of wastes materials. One of the new waste materials used in the concrete industry is E -waste. For solving the disposal of large amount of E -waste material, reuse of E -waste in concrete industry is considered as the most feasible application. E -waste is one of the fastest growing waste streams in the world. In developed countries, previously, it was about 1% of total solid waste generation and currently it grows to 2% by 2010.

In developing countries, it ranges 0.01% to 1% of the total municipal solid waste generation. E-waste is an emerging issue posing serious pollution problems to the human and the environment. New effective waste management options need to be considered especially on recycling concepts. E -waste describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices. Rapid technology change ,low initial cost have resulted in a fast growing surplus of electronic waste around the globe .Several tonnes of E -waste need to be disposed per year. E-waste contains numerous types (more than 1000 different) of substances and chemicals creating serious human health and environment problems if not handled properly.

Many researchers have already found it possible to use E- waste as a concrete aggregate. Owing to scarcity of coarse aggregate for the preparation of concrete, partial replacement of E-waste with coarse was attempted. The work was conducted on M20 grade mix. In this work, thepercentage of various replacement levels of coarse aggregate with E-waste in the range of 0%, 5%, 10%, 15%, and 20%. Finally the mechanical properties and durability of the concrete mix specimens obtained from the additionof these materials will be compared with that obtained by using control concrete mix.

II. MATERIALS AND METHODS

A. Materials

The most commonly available Portland cement of 43 grades was selected for the investigation. The cement used was dry, powdery and free from lumps. All possible contact with moisture was avoided while storing cement. Concrete mixes were prepared using locally available river sand. Ordinary crushed stone with size 20mm was used as coarse aggregate in concrete mixes. They generally possess all the essential qualities of a good building stone showing very high crushing strength, low absorption value and least porosity. In general, water fit for drinking is suitable for mixing concrete. Impurities in the water may affect concrete setting time, strength, shrinkage or promote corrosion of reinforcement. Hence locally available purified drinking water was used for thework. E-waste was collected locally from a PCB cutting unit in the form of long chips. Copper strips present at the bottom of PCB were removed manually and broken in to half inch length pieces. Specific gravity, water absorption, crushing value and impact value were tested for E- waste and the results are given in Table 1.

TABLE1. PHYSICAL PROPERTIES OF AGGREGATES AND E-WASTE

Properties	Fine Aggregate	Coarse Aggregate	E- waste
Specific gravity	2.69	2.74	1.9
Water absorption (%)	1.2	0.05	0.2
Color	Dark	Dark	Dark and Ivory
Shape	-	Angular	Angular
Crushing value (%)	-	26.8	<2
Impact value	-	24.9	<2

B. Concrete Mixes

The mixes were designated with the grade of concrete and the type of fine aggregates used. IS method of concrete mix was used to achieve a mix with cube strength of 20 MPa. Mix proportions were arrived and E-waste was added to the concretemix with a w/c ratio 0.5. The percentage of E- waste added by weight was 0, 5, 10, 15 and 20. Control mix concrete and modified concretes with varying percentage of E-waste and the percentage for various replacement levels are presented in Table 2.

TABLE 2.DETALS OF CONCRETE MIX

Mix Specification	Control Mix	Modified Mix 1	Modified Mix 2	Modified Mix 3	Modified Mix 4
Proportion of E- waste added	0 %	5%	10%	15%	20%

Water curing is the most effective method of curing. It produces the highest level of compressive strength. If a concrete is not well cured, it cannot gain the properties and durability to endure long life service. A proper curing greatly contributes to reduce the porosity and dry shrinkage of concrete and thus achieves higher strength and greater resistance to physical and chemical attacks in aggressive environments. With these results in mind, proper curing was done for specified days after the specimens are removed from the moulds.

III. EXPERIMENTAL PROCEDURE

A. Preparation Of Test Specimens

The aggregates were soaked in part of the mixing water for about 5 min, prior to the start of the mixing operations. Coarse aggregate was placed in the drum first and batch water was increased to account for the adsorption of the aggregates during rotation. After mixing for 10 to 15 sec, the fine aggregates with correct proportions were introduced and mixed in for a period of 15 to 20 sec. This was followed by E-waste and water. Finally cement was added. The mixture was allowed to mix for a total time of 60 sec from the placing of coarse aggregate. The adopted water cement ratio is 0.5. The concrete was filled in different layers and each layer was compacted. After 24 hrs the demoulded specimens were cured in water for 7 & 28days and then tested for its compressive, split tensile and flexural strength. Cube specimens were also cast for the investigation of durability of E-waste concrete. The dimensions of specimens used for the study are listed in Table 3.

Fig 1 Preparation of test specimens

TABLE 3. DETAILS OF TEST SPECIMENS

Test Details	Shape and Dimension of the specimens
Compressive strength	Cube: 150x 150x150 mm
Splitting Tensile strength	Cylinder: 150x 300 mm
Flexural strength	Beam:100x100x500 mm
Durability test	Cube: 150x 150x150 mm

IV. TESTING OF SPECIMENS

A. Comparison of Compressive, Split Tensile, and Flexural Strength

After completing the curing period of the test specimens all specimens were kept in dry place for few hours to attaining surface dry condition. Compressive strength was determined using compression testing machine (CTM) of 2000 KN capacity. Compressive strength test was carried out on 150mm X 150 mm X 150 mm cube specimen for which three cubes were prepared for each mix. Strength of each cube was evaluated after 7 and 28days. Cylindrical specimens were also cast for finding the split tensile strength and beam specimens were also cast for flexural strength for each mix specification following the standard test procedures. The obtained values are given in table 4.

TABLE 4. RESULTS OF COMPRESSIVE, SPLIT TENSILE AND FLEXURAL STRENGTH

Sl. No	Proportion E- waste added	Compressive Strength in N/mm²		Split Tensile Strength in N/mm²		Flexural strength in N/mm²	
		7 days	28 days	7 days	28 days	7 days	28 days
1.	0%	17.88	28.66	2.11	3.67	2.89	3.84
2.	5%	20.8	31.6	2.65	3.63	4.9	5.07
3.	10%	21.67	33.2	2.83	3.802	5.23	6
4.	15%	23.87	35.5	3.1	3.95	5.75	6.38
5.	20%	17.35	25.77	2.65	2.98	4.04	5.09

B. *Chloride attack*

Chloride attack is one of the most important aspects for consideration when we deal with the durability of concrete. Chloride attack is particularly important because it primarily causes corrosion of reinforcement. Statistics have indicated that over 40 per cent of failure of structures is due to corrosion of reinforcement. The Bureau of Indian Standard earlier specified the maximum chloride content in cement as 0.05 per cent. But it is now increased the allowable chloride content in cement to 0.1 per cent. The cubes were cast at size of 150mm x 150mm x 150mm and kept at a temperature of 27°C ± 2°C and at least 90spercent relative humidity for 24 hours. After 24 hours the cubes were removed from the mould and immersed in clean fresh water until taken out for testing. After 28 days curing the cubes were immersed in a 5% diluted hydrochloric acid. After 30 days of curing, measurement of the weight and the compressive strength of cubes were calculated.

TABLE 5. EFFECT OF CHLORIDE ATTACK ON WEIGHT AND COMPRESSIVE STRENGTH OF CUBES

Sl.No	Proportion E- waste added	Loss in Weight (%) At 30 Days	Loss in Compressive Strength (%) At 30 Days
1.	0%	4.4	11.91
2.	5%	2.76	8.18
3.	10%	2.81	8.02
4.	15%	2.23	7.69
5.	20%	2.90	8.35

C. *Sulphate Attack Test*

The term sulphate attack denotes an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. In the hardened concrete, calcium aluminate hydrate (C-A-H) can react with sulphate salt from outside. The product of reaction is calcium sulphoaluminate, forming within the framework of hydrated cement paste. Because of the increase in volume of the solid phase which can go up to 227 per cent, a gradual disintegration of concrete takes place. The cubes were cast at size of 150mmx150mmx150mm and kept in the mould at a temperature of 27°C ± 2°C and at least 90 percent relative humidity for 24 hours. After 24 hours the cubes were removed from the mould and immersed in clean fresh water until taken out for testing. After 28 days curing the cubes were immersed in a 10% Sodium sulphate solution. After 30 days of curing, measurement of the weight and compressive strength of cubes werecalculated.

TABLE 6. EFFECT OF SULPHATE ATTACK ON WEIGHT AND COMPRESSIVE STRENGTH OF CUBES

Sl. No	Proportion E- waste added	Loss in Weight (%) At 30 Days	Loss in Compressive Strength (%) At 30 Days
1.	0%	2.7	3.67
2.	5%	2.51	3.65
3.	10%	2.4	3.6
4.	15%	1.78	3.52
5.	20%	2.5	4.5

V. RESULTS AND DISCUSSION

A. *Compressive Strength*

The results of compressive strength were presented in Table 4. The test was carried out to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity
2000KN. From Fig 3 the compressive strength is up to 23.87 N/mm² and 35.5 N/mm² at 7 and 28 days. The maximum compressive strength is observed at 15% replacement of E- waste with.

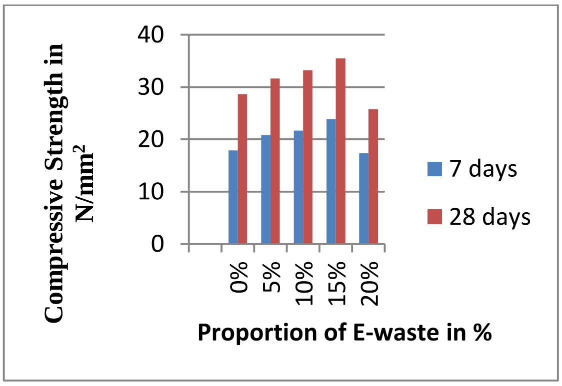

Fig 2. Effect of E-waste on compressive strength

B. Split Tensile Strength

The results of split tensile strength were presented in Table 4. The test was carried concrete at the age of 7 and 28 days.Split tensile strength of the cylinders were tested using Compression Testing Machine (CTM) of capacity 2000KN. From Fig.3 the split tensile strength is up to 3.10 N/mm^2 and 3.95 N/mm^2 at 7 and 28 days.The maximum increase in split tensile strength is observed at 15% replacement of E- waste.

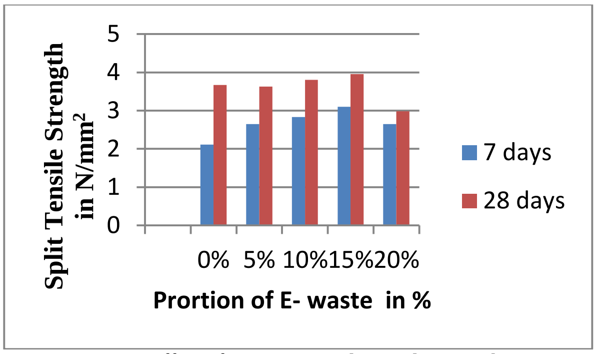

Fig 3. Effect of E-waste on split tensile strength

C. Flexural strength

The results of flexural strength of normal concrete and replaced concrete were presented in Table 4. The test was carried out conforming to obtain Flexural strength of concrete at the age of 7 and 28 days. The beams were tested using Universal Testing Machine (UTM) of capacity 1000 tonnes. From Fig 4the maximum increase in flexural strength is observed as 5.75 $N/mm^2$and 6.38 N/mm^2 at 7 and 28 days when E-waste is replaced by 15%.

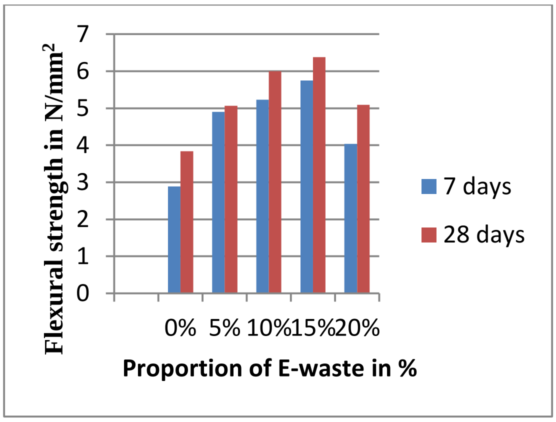

Fig 4. Effect of E-waste on flexural strength

D. Chloride Attack Test

The Chloride attack test parameters observation was presented in Table 9. Figure 5 shows the influence of chloride attack on conventional concrete and concrete with E- waste. The average loss of weight and loss of compressive strength of E-waste concrete is considerably lesser than the corresponding loss of weight and loss of compressive strength of conventional concrete. It shows that E-waste particles in the concrete are notinfluenced by chloride. This indicates that incorporation of E-waste in concrete could be considered to be reasonable.

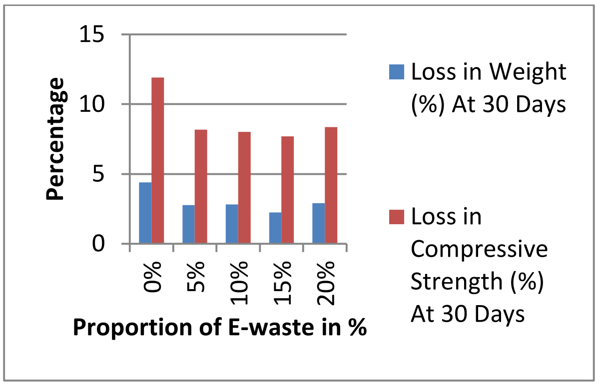

Fig 5.Influence of chloride attack on concrete

E. Sulphate Attack Test

The Sulphate attack test observance is presented in Table 10. Figure 6 shows comparison of the influence of Sulphate attack on conventional concrete and concrete with E- waste. Here also the average loss of weight and loss of compressive strength of E-waste concrete is considerably lesser than the corresponding loss of weight and loss of compressive strength of conventionalconcrete. It shows that E-waste particles in the concrete are not influenced by Sulphate. As was seen earlier, the addition of E-waste concrete resulted in comparatively lesser loss of weight and loss of compressive strength of concrete.

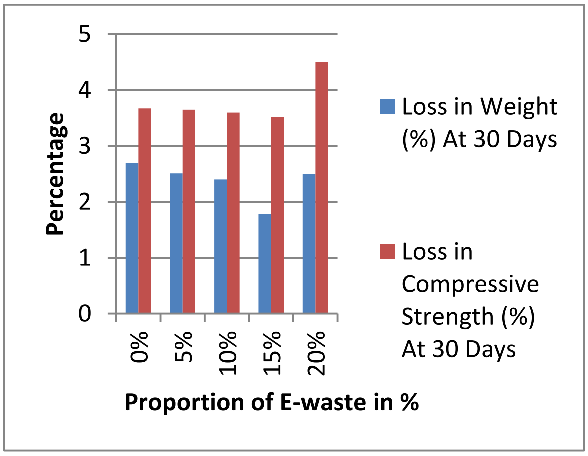

Fig 6. Influence of Sulphate attack on concrete

VI. CONCLUSION

This study intended to find the effective ways to reutilize the E-waste particles as concrete aggregate. Analysis of the strength characteristics and durability of concrete containing E-waste gave the following results.

- The addition of E-waste shows increase in compressive strength up to 15% replacement.
- Increase in split tensile strength is almost insignificant whereas gain in flexural tensile

strength have occurred even up to 15 % replacements. E-waste seems to have a more pronounced effect on the flexural strength than the split tensile strength.

- When compared to other mix the loss in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69.

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