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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 has 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 aggregate was attempted. The work was conducted on M20 grade mix. The replacement 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 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.**

***Index Terms*— 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 210. 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 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 has 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 of substances and chemicals creating serious human health and environment problems if not handled properly.

Owing to the 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, the percentage 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 addition of these materials will be compared with that obtained by using control concrete mix.

II. MATERIALS AND METHODS

A. Materials

The most commonly available Portland Pozzolana cement of 33 grade 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 M 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 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 the work. 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 20mm size. Specific gravity and water absorption 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

B. Concrete Mixes

The mixes were designated with the grade of concrete and the type of fine aggregate 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 concrete mix 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 concrete 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

For the purpose of testing specimens, various concrete specimens were prepared for different mixes using rotating drum mixer. Preparation of concrete specimens aggregates, cement and E-waste was added. After thorough mixing, water was added and the mixing was continued until a uniform mix was obtained. The concrete was then placed in to the moulds which were properly oiled. After placing of concrete in moulds, proper compaction was given using the table vibrator. For compressive strength test, cubes of size 150mmx150mmx150mm were cast. For splitting tensile strength test, cylinders of size 150mm diameter and 300mm height were cast and for flexural strength test, beams of size 150mmx100mmx100mm with and without reinforcement were cast. Specimens thus prepared were demoulded after 24 hours of casting and were kept in a curing tank for curing. For durability test, cubes of 150mmx150mmx150mm were cast for acid and sulphate attack. The durability test was done after 28 days of water curing. The dimensions of specimens used for the present study are listed in Table 3.

Fig1. 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. TESING OF SPECIMENS

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

After completing the curing period of the test specimens were kept in dry place for few hours to attaining surface dry condition. Compressive strength machine (CTM) of 2000KN capacity. Compressive strength test was carried out on 150mm x 150mm x 150mm cube specimen for which three cubes were prepared for each mix. Strength of each cube was evaluated after 7 days and 28 days. Cylinder specimens were also cast for finding 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 of 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	3.1	3.95	5.23	6
4.	15%	23.87	35.5	2.85	3.802	5.75	6.38
5.	20%	17.35	25	2.65	2.98	4.04	5.09

B. Chloride attack

Cubes of sizes 150mm x 150mm X150mm of control mix and optimum mix were cast and after 24 hours the cubes were removed the mould and immersed in a clean fresh water until taken out for testing. After 28 days of water curing, the initial weight of the specimen was calculated and the specimen was immersed in the 5% hydrochloric acid solution for 30 days and 90 days acid curing. The concentration is to be maintained throughout the period. After 30 days and 90 days the specimen were taken from acid solution. The surface of the specimens was cleaned and weight was measured. The specimen was tested in the compression testing machine. The weight loss and strength of specimen due to hydrochloric acid attack was determined.

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

Percentage of E-waste added	Percentage strength loss in Kg		Percentage weight loss in N/mm²	
	30days	90days	30days	90days
0%	28.5	42.58	3.2	5.85
15%	21.3	35.62	3.08	4.13

C. Sulphate attack

The 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 sulphate. In the hardened concrete, calcium aluminate hydrate can react with sulphate sail from outside. The product of reaction is calcium sulphoaluminate, forming within the frame work of hydrated cement paste. The cubes were cast at size of 150mm X 150mm X 150mm and kept in the mould 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 initial weight of specimen was calculated and the cubes were immersed in a 5% sodium sulphate solution for 30 days and 90 days of alkali curing. After the curing the cubes were removed from alkali solution and final weight of the specimen along with compressive strength was calculated after thoroughly washing it with fresh water. The percentage loss in compressive strength and percentage loss in weight was determined.

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

Proportion of E-waste added	Percentage strength loss in Kg		Percentage weight loss in N/mm²	
	30 days	90 days	30 days	90 days
0%	25.18	42	2.7	5.12
15%	23.8	38.7	1.78	4.89

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 of capacity 2000KN. From the figure 3 the compressive strength is maximum when replacing 15% of coarse aggregate by E-waste in concrete.

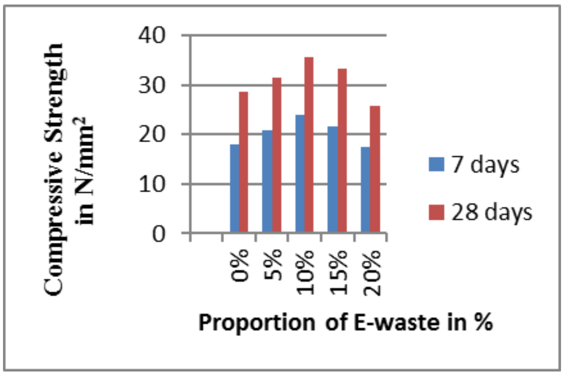

Fig 2. Effect of E-waste on compressive strength

B. Split Tensile Strength

The results of split tensile strength were presented in Table 4. The test was carried out to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using compression testing machine of capacity 2000KN. From the figure 3 the maximum split tensile strength was observed at 10% replacement of coarse aggregate by E- waste in concrete.

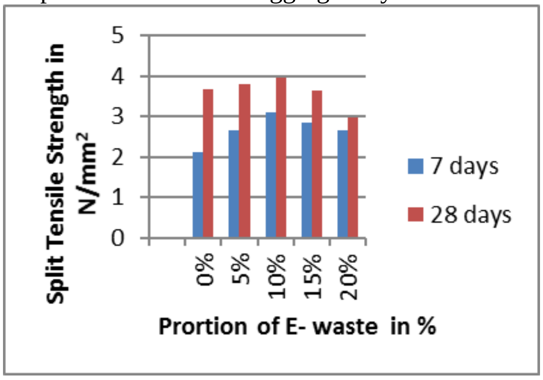

Fig 3. Effect of E-waste on split tensile strength

C. Flexural Strength

The results of flexural strength of normal concrete and replaced concrete were presented in Table 4. The test results shows the maximum flexural strength is obtained when 15% replacement of coarse aggregate by E-waste in concrete.

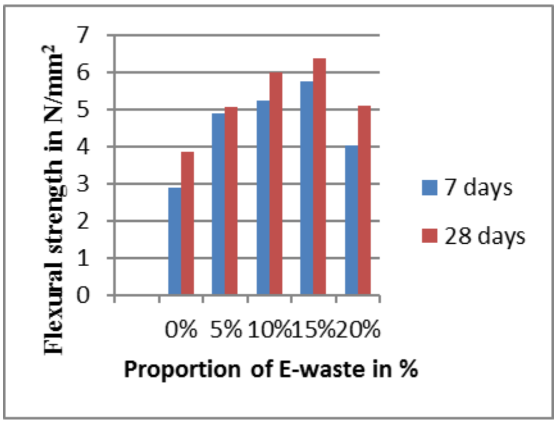

Fig 4. Effect of E-waste on flexural strength

D. Chloride Attack Test

The chloride attack test was presented in Table 9. Figure 5 shows the influence of chloride attack on conventional 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 compressive strength of conventional concrete. It shows that E-waste particles in the concrete are not influenced by chloride. This indicates that incorporation of E-waste in concrete could be considered to be reasonable.

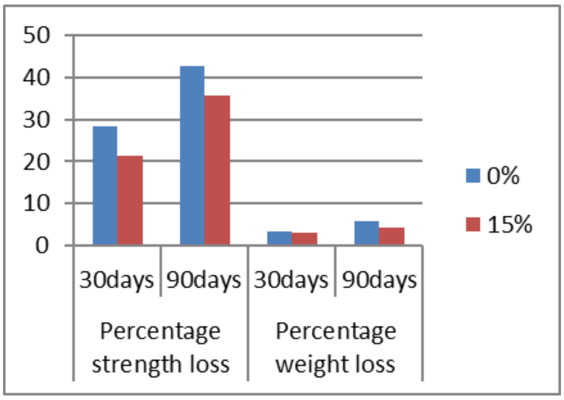

Fig 5.Influence of chloride attack on concrete

E. Sulphate Attack Test

The sulphate attack test results were presented in Table 10. Figure 6 shows that E-waste particles in the concrete are not influenced by sulphate.

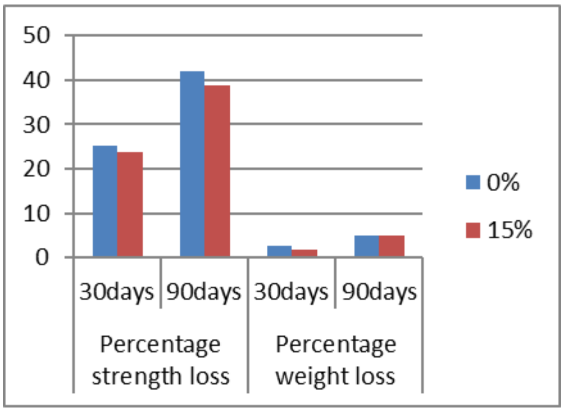

Fig 6. Influence of Sulphate attack on concrete

VI. CONCLUSION

- 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.
- From the durability study the sulphate attack and chloride attack, which does not affect the strength of concrete and the optimum mix is more durable than the control mix. It can be used in marine conditions.
- The use of E-waste in concrete is possible to improve its mechanical properties and can be one of the economical ways for their disposal in environment friendly manner.

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