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Experimental Investigation on the Strength Properties of M25 Grade Concrete with Partial Replacement of Coarse Aggregate by E-Waste

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***Abstract* - Electronic waste (E-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 one of 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 may be used as one such alternative for coarse aggregate.**

In this work, effect of partial replacement of coarse aggregate by E-waste in concrete was studied. The type of E-waste selected was high impact polystyrene which is non-degradable and also impermeable. The replacement of coarse aggregate by E-waste was in the range of 10%, 15%, and 20%. The mix design for M25 grade concrete was done by IS code method. The compressive strength, split tensile strength and flexural strength of concrete were found for various percentage replacements of E-waste in concrete and compared with that of the control mix. The optimum dosage of E-waste to be added in M25 grade of concrete was determined. In the above investigation, it was found that use of E- waste as partial replacement for aggregates results in the formation of concrete which has lesser weight than that of conventional concrete. This study also ensures that reusing E-waste as above gives a good approach to reduce cost of materials and also provide a solution for disposal of solid waste problems posed by E-waste.

Keywords - E-waste; Compressive strength; Split tensile; Flexural strength; High impact polystyrene; M25 concrete

I INTRODUCTION

Electronic waste includes discarded computers, office electronic equipment, printer, scanner etc. It also includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal [4]. E-waste is one of the fastest growing waste streams in the world. The increase of electrical and electronic products, consumption rates and higher obsolescence rate leads to higher generation of e-waste. The e-waste inventory based on this obsolescence rate in India shows an increase every year. In developed countries, previously, it was about 1% of total solid waste generation and it had grown to 2% by 2010. In developing countries, it ranges from 0.01% to 1% of the total municipal solid waste generation [8]. Electronic waste (e-waste) now makes up 5% of all municipal solid waste worldwide, nearly the same amount as all plastic packaging, but it is much more hazardous. Characterization of this waste stream is of paramount importance for developing a cost effective and environmental recycling system. It has been studied statistically that the total quantity of E-waste accumulated in India as on 2005 was 146180 tonnes. This geometrically progressed to 8,00,000 tonnes as per 2012 statistics. Sixty five cities in India generate more than 60% of total E-waste generated in India. Among top ten cities generating E waste Mumbai ranks first followed by Delhi, Bangalore, Chennai, Kolkotta, Ahmedabad, Hyderabad, Pune, Surat and Nagpur. Ten states generate 70% of the total E-waste generated in India [1]. Maharashtra ranks first followed by Tamil Nadu, Andra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab in the list of E-waste generating states in India. On the other hand, Electronic waste contains many toxics such as heavy metals, including lead, cadmium, mercury, barium, beryllium, plastics, including Polychlorinated Biphenyls (PCBs), Poly Vinyl Chloride (PVC), Polystyrene (PS) etc. It causes a serious threat to the health of communities and their environment. Most electronic and electrical appliances after use are treated as waste at present, which should be recycled from the stand point of the effective utilization of natural resources and restraint of waste [1].

II SCOPE OF INVESTIGATION

New waste management options are needed to divert End-Of-Life (EOL) electronics from landfills and incineration. Increasing the need for landfills is a burden to our environment. Also with the storage of landfill capacity and an increased concern about environmental quality, newer waste treatment methods are desired. While developing a successful diversion strategy, it must be based on its economic sustainability, technical feasibility and a realistic level of social support from the society. Reuse of EOL electronic products in construction industry is one of the environmentally friendly aspects [10]. Use of E-waste in concrete not only serves as an effective means of disposal but also helps in reducing the cost of concrete manufacturing. It also has numerous benefits such as reduction in landfill cost, avoid serious threat to environment, saving in energy, and protecting the environment from possible pollution effects. Hence the current study is aimed at utilizing E-waste in concrete and determining the mechanical properties of E-waste added concrete.

The E-waste is suitable to be replaced as coarse aggregate in concrete. By using E-waste i.e. high impact polystyrene it makes the concrete impermeable and non-degradable like coarse aggregate. It is attempted to determine the optimum dosage of E-waste that could be added to M25 grade concrete.

III. MATERIALS AND METHODS

A. Materials

1) Cement

The most commonly available Ordinary Portland cement of 43grade was selected for the investigation. The cement used was dry, powdery and free from lumps. The following tests were conducted on cement and the results are shown in table 1.

2) Fine Aggregate

Natural sand conforming to zone II as per IS383-1970 was used as fine aggregate. The following tests were conducted on fine aggregate and the results are as given in table 2.

TABLE 1 PROPERTIES OF CEMENT

S No.	Characteristics	Values obtained
1	Normal consistency	31%
2	Initial setting time	40 minutes
3	Final setting time	360 minutes
4	Fineness	3.5%
5	Specific gravity	3.15
6	Soundness	2 mm

TABLE 2 PROPERTIES OF FINE AGGREGATE

S No.	Characteristics	Values obtained
1	Fineness Modulus	2.3
2	Specific Gravity	2.63
3	Grading Zone	Zone II
4	Free Moisture	Nil

3) Coarse Aggregate

Coarse aggregate used was locally available granite crushed stone having maximum size of 20mm. The following tests were conducted on the aggregate as per IS 2386-1963 (Part-IV) and the results are as given in table 3.

TABLE 3 PROPERTIES OF COARSE AGGREGATE

S No.	Characteristics	Values obtained
1	Type	Crushed
2	Maximum size	20mm
3	Specific gravity	2.59
4	Total water absorption	Nil
5	Fineness modulus	6.78
6	Impact value	12%
7	Crushing value	9.26%

4) Water

Locally available impurities free, clean and portable water was used for casting the specimens and also for curing.

5) E-Waste

The type of E-waste that was used in this investigation was High impact Polystyrene which is versatile, economical and impact resistant plastic that is easy to machine and fabricate. It is frequently used for manufacturing consumer products like TV and audio visual equipment parts and office products like computer housing. E-waste crushed and passing through 20 mm sieve and retained on 10 mm sieve was used in making concrete. The following tests were conducted and the test results are given in table 4.

TABLE 4 PROPERTIES OF E-WASTE

S No.	Characteristics	Values obtained
1	Specific gravity	1.14
2	Colour	White & Dark Black
3	Shape	Angular
4	Crushing Value	0.9%
5	Impact value	1.2%

IV CONCRETE MIX DESIGN

Mix design for M25 grade concrete was done by IS Code method and concrete cube specimens were cast for trial mixes. The mix proportions adopted are shown in table 5.

TABLE 5 MIX PROPORTIONS OF TRIAL MIXES FOR M25 GRADE CONCRETE

CONCRETE MIXES	MIX PROPORTIONS			
	CEMENT KG	FINE AGGREGATE KG	COARSE AGGREGATE KG	WATER/ CEMENT RATIO
MIX 1	340	673	1136	0.46
MIX 2	360	669	1123	0.45

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V EXPERIMENTAL PROCEDURE

A.Casting of Specimen

To the above concrete mixes various percentages of E-waste was added as partial replacement for coarse aggregate. Cubes, Cylinders and Prisms were cast of size 150mmx150mmx150mm, 150 mm x 300 mm and 100 mm x 100 mm x 500 mm using moulds.

B. *Testing of Specimen*

The specimens cast were tested for determining the compressive strength, split tensile strength and the flexural strength of concrete.

1) Compressive Strength: The cubes were tested on a compression testing machine as shown in figure 1 after a curing period of 7 days and 28 days and the compressive strength were determined for the two trial mixes for M25 grade concrete the results of which are given in table 6.

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TABLE 6 COMPRESSIVE STRENGTH OF TRIAL MIXES FOR M25 GRADE CONCRETE

Trail Mixes	Compressive strength of concrete	
	7 days	28 days
MIX 1	27.79	32.67
MIX 2	21.07	36.18

The value of compressive strength obtained for Mix 1 was closer to the value of target strength for M25 grade and hence it was considered as the control mix.

E-waste was added in M25 grade concrete with mix proportion as shown for Mix 1 (control mix) as partial replacement for coarse aggregate in percentages of 10, 15 and 20. The Compressive strength results for various percentages of addition of e-waste is shown in table 7.

TABLE7 COMPRESSIVE STRENGTH RESULTS FOR E-WASTE ADDED CONCRETE IN MPA

No. of days after which specimen was tested after curing	Compressive strength of Control mix	Compressive strength of concrete for various percentage replacement of coarse aggregate by E-waste		
		10%	15%	20%
7 days	27.79	27.43	22.24	19.15
28 days	32.67	35.45	29.35	20.78

The value of compressive strength obtained for M25 grade concrete with various percentages of E-waste shows an increase in strength for 10% replacement of M25 grade concrete.

Fig.1 Compressive strength test of concrete cube specimen

2) Split Tensile strength test: Cylindrical specimens were cast with the above mix proportion and with various percentage replacements of e-waste. The concrete cylinders were tested after 7 days and 28 days and the results of split tensile strength are given in table 8.

TABLE.8 SPLIT TENSILE STRENGTH OF E-WASTE ADDED CONCRETE IN MPA

No. of days after which specimen is tested after curing	Split tensile strength of Control mix	Split tensile strength of concrete for various percentage replacement of coarse aggregate by E-waste		
		10%	15%	20%
7 days	2.96	3.10	2.43	1.97
28 Days	3.88	3.93	3.14	2.82

Fig.2 Testing of cylinder specimen for Split tensile strength

3) Flexural Strength Test: The prisms were cast with the above mix proportion and tested for 28days strength. Also specimens were cast with coarse aggregate replacement by e-waste in various percentages and tested. The test results are shown in table 9.

TABLE 9 FLEXURAL STRENGTH OF E-WASTE ADDED CONCRETE IN MPA

No. of days after which specimen is tested after curing	Flexural strength of Control mix	Flexural strength of concrete for various percentage replacement of coarse aggregate by E-waste		
		10%	15%	20%
28 days	5.75	5.18	4.84	3.92

Fig.3 Flexural strength test of prism specimen

VI DISCUSSION

An analysis was made on the test results of various strengths obtained on high impact polystyrene type e-waste mixed concrete. The 7days and 28days compressive strength results of M25 grade concrete and that with various percentage replacement of coarse aggregate by e-waste are shown in table 6 and table 7. The comparison of the test results are shown in Fig.4 and Fig.5. It is observed that compressive strength for M25 grade concrete with the mix proportion 1:1.98:3.34:0.46 shows increase in strength for upto 10% replacement of coarse aggregate by e-waste. From figure 5, it is observed that 28days compressive strength of M25 grade concrete containing 10% replacement of coarse aggregate by E-waste exceeded the strength of control mix by 8.51%. Also the tensile strength is achieved for10% replacement. There is a slight reduction in flexural strength for 10% replacement.

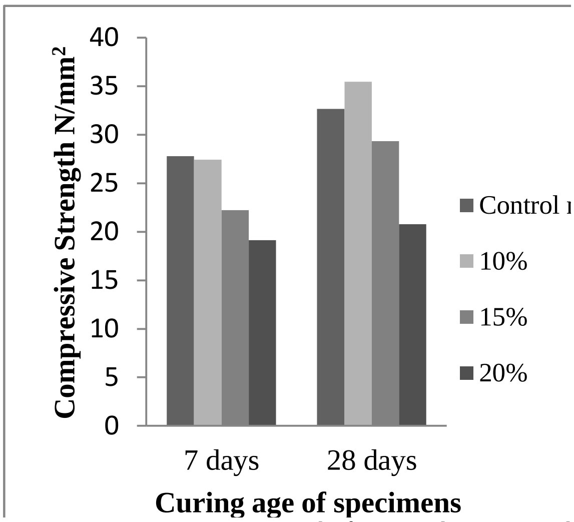

Fig.4 Variation in compressive Strength of M25 Grade concrete with various percentages of e-waste

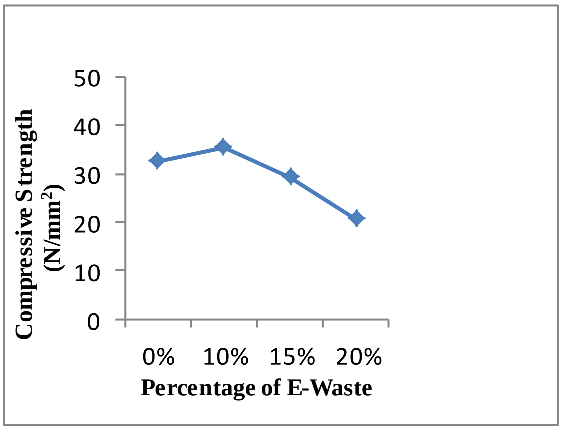

Fig.5 Compressive Strength in M25 concrete after 28 days with various percentage replacement of CA by E-waste

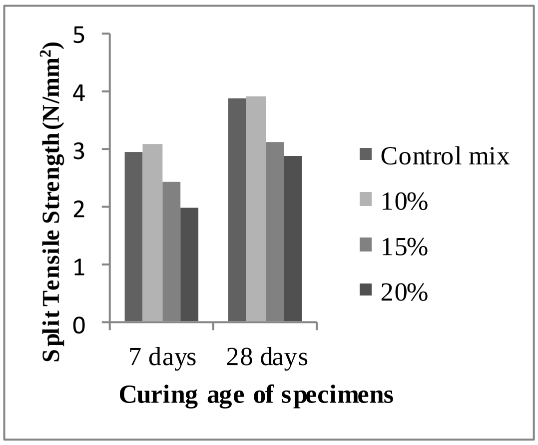

Fig.6 Split Tensile Strength of M25 grade concrete with various Percentage replacement of CA by E-waste

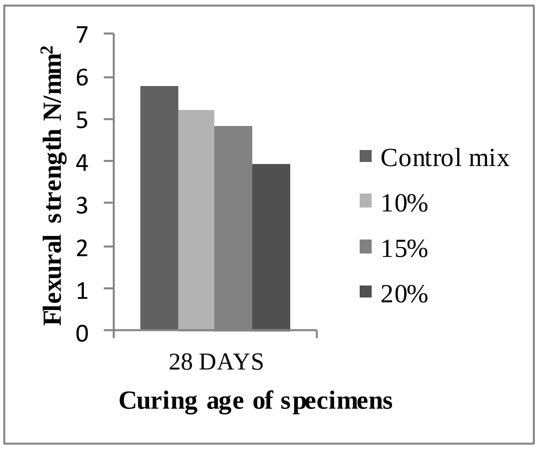

Fig.7 Flexural Strength of M25 Grade concrete with various percentages of e-waste

VII CONCLUSION

A detailed experimental study was performed to study the effect of partial replacement of coarse aggregate by e-waste in M25 grade concrete. This study was intended to find the effective ways to reutilize the high impact polystyrene E-waste as replacement for coarse aggregate in concrete. Analysis of the results of the effect of using E-waste as partial replacement for coarse aggregate on the strength of concrete leads to the following conclusions.

1. It is identified that e-waste can be effectively used as construction material.
2. The mechanical properties of concrete could be maintained by using e-waste up to a certain quantity and can be one of the economical ways for their disposal in an environment friendly manner.
3. The optimum percentage of E-waste that can be used as replacement for coarse aggregate in M25 grade concrete was found to be 10%.

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