E-Waste :An Alternative to Partial Replacement of Coarse Aggregate in Concrete

Biradar Shilpa
(PG student)
Department of Civil Engineering,
Pillai HOC College of Engineering & Technology,
Rasayani, India

Prof. Gayatri Deshpande
(Lecturer),
Department of Civil Engineering
Pillai HOC College of Engineering & Technology,
Rasayani, India

Prof. Karthik Nagarajan[1] Prof. Raju Narwade[2]
(Associate Professor)[1,2]
Department of Civil Engineering
Pillai HOC College of Engineering & Technology,
Rasayani, India

Abstract **Globally, the management and disposal of E-waste is causing serious concerns as it is non-decomposable and hazardous to environment. One of the best management practices of E-waste is its reuse in concrete as E-Waste concrete (EWC) which will also be a partial solution to escalating cost of construction material. The significance of this research is to resourcefully use E-waste in concrete by achieving optimum performance by testing physical, workability & mechanical properties. The E-waste generated at Pillai HOC College of Engineering and Technology (PHCET), Rasayani was used as partial replacement of coarse aggregate (CA) in combination with fly ash. By replacing 0-30% of CA, concrete cubes were cast and slump cone test for determining workability and compression strength test were conducted after 28 days. The results indicate a remarkable increase in workability and strength of EWC thus making it feasible to use EWC as light weight concrete.**

Keywords —E-waste, E-waste concrete, Compressive strength of concrete, Reusable Material, Sustainable Material, Strength optimization.

I. INTRODUCTION

The rapid growth of technology, up gradation of technical innovations and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world which consist of end of life Electrical and Electronic Equipment (EEE). The countries of the European Union (EU) and other developed countries to an extent have addressed the issue of e-waste by taking policy initiatives and by adopting scientific methods of recycling and disposal of such waste. The EU defines this new waste stream as 'Waste Electrical and Electronic Equipment' (WEEE). Since there is no definition of the WEEE in the environmental regulations in India, it is simply called 'e-waste'. Considering the current scenario, prohibition or even reduction in use of electrical items is not possible. With the advancement of technology, the demand and consumption of electronic items is also increasing at an alarming rate and with it comes the problem of disposal of these waste EEE (WEEE). E-waste is one of the parts of EEE. Several tonnes of E waste need to be disposed per year. Conventional landfill method is not an environmental friendly solution and the landfills are also reaching their maximum capacity. Mumbai leads the country for generating the highest E-Waste, followed by Delhi and Bangalore. An estimated 50 million tons of E-waste are produced each year. The Environmental Protection Agency estimates that only 15–20% of e-waste is recycled, the rest of these electronics go directly into landfills and incinerators. According to United Nations report, India is the fifth biggest producer of e-waste in the world, discarding 1.7 million tonnes (Mt) of electronic and electrical equipment in 2014 and warned that the volume of global e-waste is likely to rise by 21 per cent in next three years.

1.1 E-waste generation

All over the world, the quantity of electrical and electronic waste produced each year, especially computers and televisions, has attained startling proportions. Globally, about 20-50 MT (million tonnes) of e-wastes are disposed each year, which accounts for 5% of all municipal solid waste. Even though no explicit certified data exists on how much waste is generated in India, or how much is disposed off, there are some analysis available based on independent studies conducted by the NGOs or government agencies. According to the Comptroller and Auditor- General's (CAG) report, over 7.2 MT of industrial hazardous waste, 4 lakh tonnes of electronic waste, 1.5 MT of plastic waste, 1.7 MT of medical waste, 48 MT of municipal waste are generated in the country annually. In 2012, the Central Pollution Control Board (CPCB) estimated India's e-waste at 1.47 lakh tonnes or 0.573 MT per day. According to the Comptroller and Auditor- General's (CAG) report 2015, there are 148 registered dismantlers/ recyclers in India. A study released by the Electronics Industry Association of India (ELCINA) at the electronics industry expo Componex Nepcon 2009 had estimated the total e-waste generation in India at a whopping 4.34 lakh tonnes by end of 2009. The CPCB has estimated that it will exceed the 8 lakh tonnes or 0.8 MT mark by 2012[3]. There are 10 States that contribute to 70 per cent of the total e-waste generated in the country, while 65 cities generate more than 60 per cent of the total e-waste in India. Among the 10 largest e-waste generating States, Maharashtra ranks first, followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Among the top ten cities generating e-waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat andNagpur.

India is taking initiatives to manage this e-waste in an eco-friendly way. The central Government has set up rules likes Extended Producer Responsibility (EPR) which is a policy approach under which producers are given a significant responsibility – financial and/or physical – for the treatment or disposal of post-consumer products.

As per Central Pollution Control Board (CPCB), there are 312 authorised E-Waste dismantlers/recyclers as on 27.06.2019. The installed capacity of these dismantlers/ recyclers is 782080.62 MTA.

Despite having these regulations, the implementation has not been achieved yet. Considering the current scenario, along with Government regulations, alternate eco-friendly methods need to be figured out. One of the best management practices to discard the e-waste and an alternative to escalating cost of construction material is using e-waste as aggregate in concrete.

1.2 E-waste

Owing to the advancement of technology, many electronic items reach their end of life after a few years of use. This end of life electronic waste is known as e-waste.

The composition of e-waste is diverse and falls under 'hazardous' and 'non-hazardous' categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete, ceramics, rubber and other items. Iron and steel constitute about 50% of the waste, followed by plastics (21%), non-ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminum and precious metals like silver, gold, platinum, palladium and so on. The presence of elements like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants beyond threshold quantities make e-waste hazardous in nature.

The study area of this research, PHCET College, has many computer labs which have many computers and other electronic items like cables, speakers, keyboards. Over the years, a large amount of E-waste is generated from these labs which are stored in store room in college premises. The disposal of this e-waste is a tedious job in itself. Hence, in this research, a small attempt has been made to resolve this issue.

1.3 Objectives of the Research

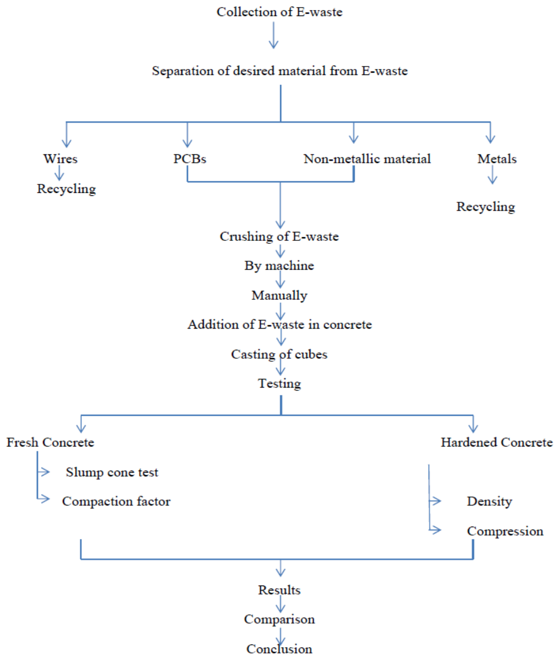
- To identify that e-waste can be discarded by using them as construction material.
- . Replacement of e-waste as coarse aggregate along with Fly ash.
- To determine the compressive strength of concrete containing the replaced materials viz, E-Waste and Fly ash.

II. PROPERTIES OF E-WASTE CONCRETE

E-waste Concrete can be defined as a composite material consisting of mixtures of cement mortar or concrete and uniformly dispersed suitable e-waste material. In this research, we have used only printed circuit boards (PCBs). PCBs are used as a coarse aggregate material in concrete to study its effects on the compressive strength, economize concrete and to reduce environmental problems created by the improper disposal
of e-waste.

Fig 1: E-waste collected from college

III. METHODOLOGY



Materials used in this study

Cement: Ordinary Portland cement (OPC ULTRA TECH) free from any lumps and no moisture content is used throughout the experimental study. 8% as fineness, initial setting time of 35 min, final setting time of 550 min, specific gravity of 3.15

Fine aggregate: Manufactured sand meeting the requirements to Zone I with a specific gravity 2.416 was

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used. The maximum size of fine aggregate was taken to be 4.75 mm. The testing of sand was done as per Indian Standard Specifications IS: 383-1970.

*Coarse aggregate***:** In this study two types of aggregates are used viz. e-waste and coarse aggregate.

E-waste: Electronic waste or e-waste is a term used for electronic products that have become unwanted, non-working or obsolete, and have essentially reached the end of their useful life. In this study, only printed circuit boards (PCB) are used as e-waste. The e-waste was collected from Pillai HOC College of Engineering and Technology.

Desired material like printed circuit boards (PCBs) and non-metallic material were sorted out. The metals present in e-waste are very precious like gold, silver and palladium hence the metals were separated for recycling. The other items like batteries were manually removed from the PCBs. The segregated non-metals and PCBs were first cut into strips using metal cutting machine available in research lab of the college. Further the strips were cut into approximate 20 mm size, to be used as coarse aggregate.

The processed e-waste is then passed through the 20 mm sieve and the e-waste retained on the 10mm sieve is collected and used in the preparation of concrete mix. E-waste thus used in the study has specific gravity of 2.056.

TABLE 1: PHYSICAL PROPERTIES OF E-WASTE & COARSE AGGREGATE

Sr. No.	Properties	E-waste	Coarse Aggregate
1.	Specific Gravity	2.056	208
2.	Absorption	<0.2	0.55
3.	Color	Green & Brown	Dark
4.	Shape	Angular	Angular
5.	Crushing Value	<2%	21%
6.	Impact Value	<2%	17%

Water: Potable water is used for mixing and curing. Water cement ratio of 0.5 is adopted in this study.

Fly Ash

Plasticizer

Concrete Mix Design: All the calculations are done per meter cubic. M25 mix design is done as per the standards of IS 456. As the mix prepared contains E-waste and coarse aggregate, the corresponding weights per meter cubic of concrete for different proportions are represented in table 2.

*Proportions of Materials for Different Combinations***:** The coarse aggregate used in this study is the combination of e-waste and the coarse aggregate. In this study different combinations of e-waste and coarse aggregate are prepared and are tested for workability and compression. The proportions of materials in Kgs for 1 m^3 of concrete used for different combinations are shown in the table 2.

Combination 1 (C1): Conventional aggregate; Standard mix

Combination 2 (C2): 10% e-waste + 90% coarse aggregate as replacement of conventional aggregate.

Combination 3(C3): 20% e-waste +80 % coarse aggregate as replacement of conventional aggregate.

*Combination 4 (C4):*30% e-waste + 70 % coarse aggregate as replacement of conventional aggregate.

TABLE 2: PROPORTIONS OF VARIOUS MATERIALS

Combination	**Cement(Kg)**	**Water(Ltr)**	**Fine Aggregate(Kg)**	**Coarse Aggregate(Kg)**	**E-waste(Kg)**	**Fly ash(Kg)**	**Admixture(Kg)**
C1	7.25	2	7.25	14.5	0	0	0
C2	5.075	2	7.25	13.05	1.45	2.175	0.0456
C3	5.075	2	7.25	11.6	2.9	2.175	0.0456
C4	5.075	2	7.25	10.15	4.35	2.175	0.0456
Total	22.48	8	29	49.3	8.7	6.525	0.1824

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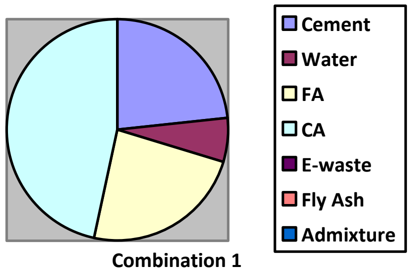
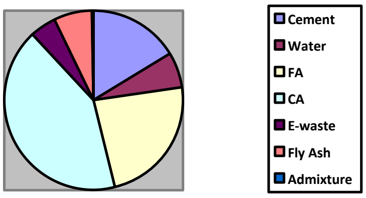
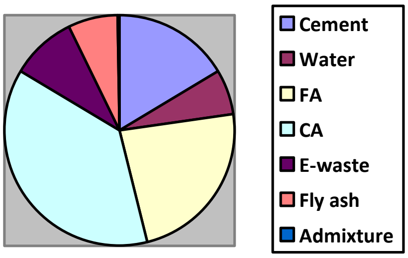


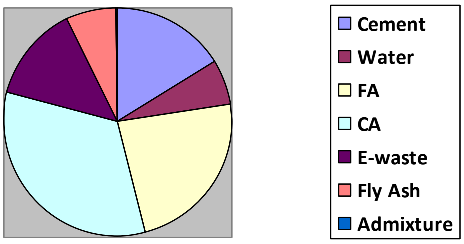
Combination 1



Combination 2



Combination 3



Combination 4

Fig 2: Mixing of E-waste concrete

Fig 3: Casting of E-waste concrete cubes

This research includes 12 mortar mixing samples with 0%, 10%, 20% & 30% substitution of coarse aggregate with e-waste. In all samples the ratio of water to cement is 0.50. For preparation of samples, we used pure cement, manufactured sand and coarse aggregate with identified weight in a mixing tray and mixed it by hand for about 2 to 3 minutes. Then the calculated amount of e-waste was added in 2 steps and all the components were thoroughly mixed in order to obtain a homogenous mixture. Then the required amount of water was added to make concrete mixture. The mixture was vibrated for uniform sampling.

- The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the moulds and kept submerged in clear fresh water for curing. The curing was done for 28 days.

IV.RESULTS AND DISCUSSION

Results of workability test: The slump cone test was performed on the concrete mixes in order to assess

the workability of e-waste concrete in comparison with conventional concrete. The workability results in mm are given in table 3.

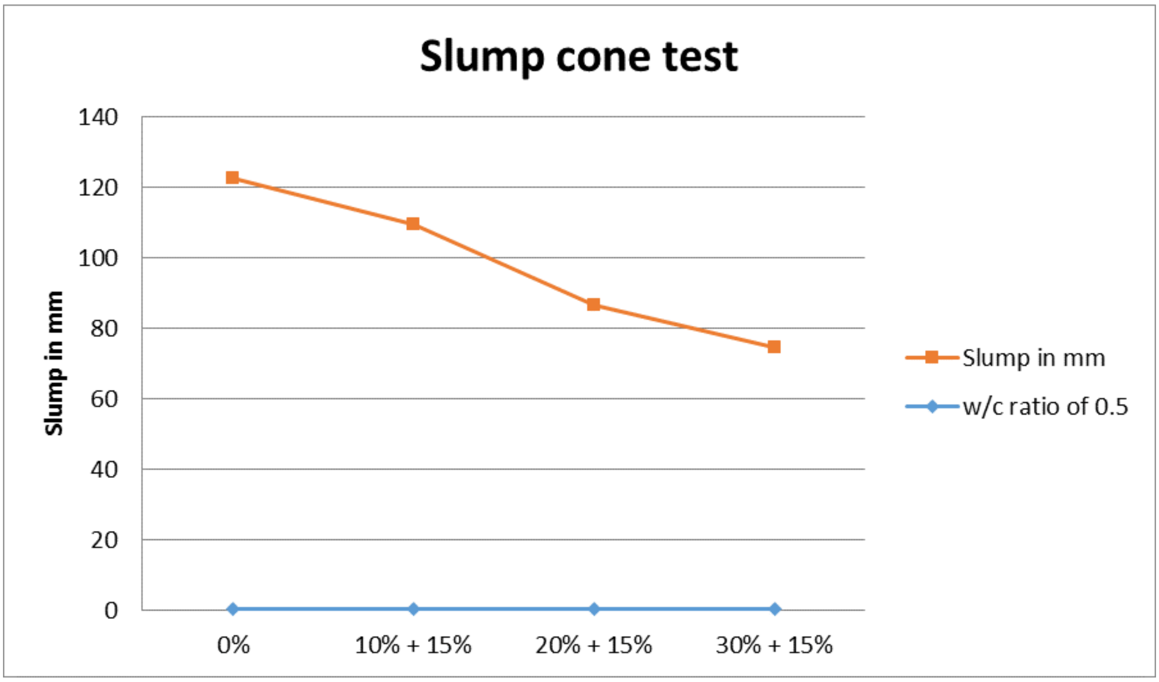
Results Of Compressive Strength Test: The compressive strength tests for the specimens were performed at 28-days in accordance with the provisions of the Indian Standard Specification IS: 516-1959 in compression testing machine (CTM) having maximum load capacity of 2000 kN.

28 Day Compressive Strength: The compressive strengths of the specimens are evaluated in N/mm^2 for 28 days and are represented in Graph-1.

5.1. Workability of fresh concrete:
Following are the results obtained for workability of fresh concrete as shown in table 3.

TABLE 3: SLUMP CONE TEST RESULTS

Sr.No.	% of E-waste+ Fly ash	Water cement ratio	Slump in mm	Workability
1.	0%	0.5	122	High
2.	10% + 15%	0.5	109	Medium
3.	20% + 15%	0.5	86	Medium
4.	30% + 15%	0.5	74	Medium



Graph 1: Slump test results for M-25 Grade Concrete (Cube)

It can be observed that with the increase in percentage of e-waste, the workability of concrete decreases.

5.2. Result for Compressive Strength of Cube: Following are the results, which are obtained by the mix design, with partial replacement of coarse aggregate with E-Waste by 10%, 20% and 30% and constant weight of Flyash by 15% of the weight of the cement.

Size of the cube =15cmx15cmx15cm

Area of the specimen =225 cm^2

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Fig 4: Testing of E-waste sample in CTM

Fig 5: Failure of E-waste sample under load

TABLE 4: COMPRESSIVE STRENGTH TEST RESULTS FOR M25 GRADE CONCRETE

Sr. No.	Grade	% E-waste+Fly Ash	Max Load Recorded (kN)	Compressive stress (N/mm^2)	Average Compressive stress (N/mm^2)
			28 Days	28 Days	
1	M25	0%	664.65	29.54	29.76
2			690.30	30.68	
3			653.85	29.06	
4		10% +15%	638.48	28.377	25.46
5			537.99	23.911	
6			542.09	24.093	
7		20%+15%	625.502	27.80	27.68
8			596.92	26.53	
9			645.97	28.71	
10		30%+15%	495.18	22.008	23.74
11			549.18	24.408	
12			558.38	24.817	

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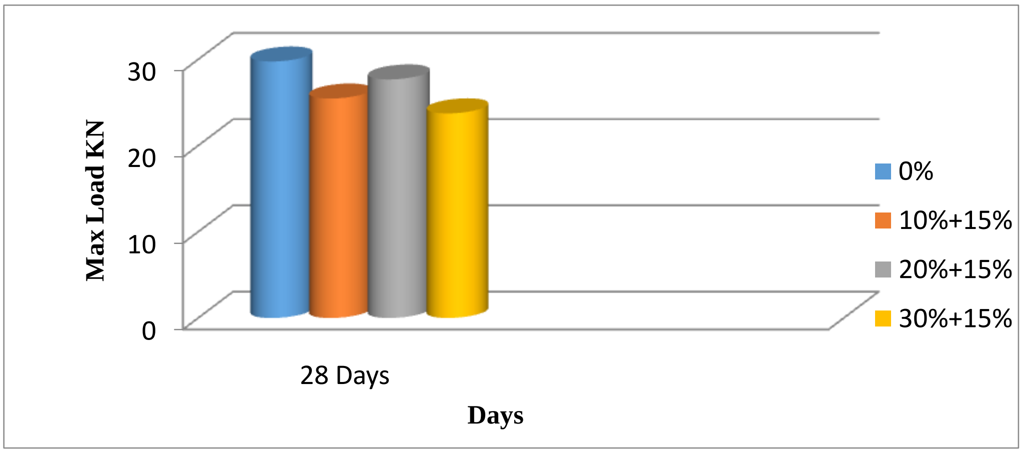

Graph 2: Compressive Stress of M-25 Grade Concrete (Cube)

V. CONCLUSION

As per the comparison test of the results, it can be observed that there are variations in properties of concrete according to the changes in percentages of e-waste and fly ash. From the results obtained, it can be observed that:

- When M-25 grade concrete with 10% of e-waste and 15% of fly ash is compared with plain M-25 grade concrete, it can be observed that there is a decrease in compressive strength of concrete by 15%.
- When M-25 grade concrete with 20% of e-waste and 15% of fly ash is compared with plain M-25 grade concrete, it can be observed that there is a decrease in compressive strength of concrete by 7%, it can be noted that there is an increase by 8% compared to previous specimen.
- The compressive strength again decreases when M-25 grade concrete with 30% of e-waste and 15% of fly ash is compared with plain M-25 grade concrete by 20%.

From the observations, it can be concluded that:

- Replacement of coarse aggregate with e-waste can give optimum results at 20% replacement. Further addition of e-waste reduces the strength of concrete. However, the target mean strength of 25 N/mm^2 for M-25 grade concrete can be achieved by replacing E-waste in combination with fly ash by 10% to 20%.
- This EWC can be used as light weight concrete since there is reduction in density of concrete due to replacement with e-waste.
- The EWC can optimally be used along with conventional concrete and it can serve as one of the best solutions to e-waste disposal.
- Using e-waste in concrete can satisfactorily solve the problem of e-waste disposal upto a certain extent.
- EWC can also serve as a partial solution to escalating cost of construction material.

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