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Study & Performance of Recycled Polymer E-Waste in Concrete

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Abstract: In today's digital environment, both population growth and the use of technological items are expanding quickly. Both developed and developing nations, in particular, produce enormous amounts of garbage and electronic items. Concurrently, the construction industry is expanding at a substantial scale and has not yet reached its peak in the upcoming decades. Therefore, there may be an increase in demand for raw materials such as cements, fine aggregate and coarse aggregate. The development of the construction business is impacted by the scarcity of raw materials, which compels us to consider alternate building materials. The use of polymer E waste as building materials in place of traditional course aggregate is being experimentally examined in this study. Both the issue of electronic waste and the need for raw materials for concrete can be addressed by using them in concrete. In this work, crushed polymer electronic trash was used as a coarse aggregate in concrete to partially replace it. From 10 mm to 12.5 mm, the course aggregate made from non-melted electronic waste varied in size. Based on the results of previous studies published in journal articles, different percentages of E waste—such as 5%, 10%, 15%, 18%, and 20%—were added to concrete by volume.

Keywords: Population growth, technological waste, electronic waste, construction industry, raw materials, cement, fine aggregate, coarse aggregate, alternative building materials, polymer E waste, concrete.

1. Introduction

Technology has been facing advancement since the mankind evolved. From the rock, stones converted to spear, knifes, human has created revolution in inventing so many gadgets, which plays a major role in our everyday life. Without those gadgets life seem to be miserable. Such technological advancement is much higher in the 20th and 21st century. These developments in modern times have been undoubtedly improved the quality of our life. At the same time the management of huge amount of waste generated due to mechanization of the entire world poses a great challenge nowadays. It is listed in Table 1.1 as the amount of waste generated from various sectors.

1.1 Polymer E-waste

Electronic Waste or E-waste has been the most rapidly growing solid waste problem in the world. It is a collective name for discarded electronic equipment's that enters the waste stream from various sources. It includes a broad and growing range of electrical and electronic equipment, such as obsolete computers, televisions and monitors, mobile phones, personal digital assistants (PDAs), video cassette recorders (VCRs), MP3 players, fax and copying machines, air conditioners, refrigerators and other electronic applications, products, components and accessories.

The fast growth in E-waste and fast product outdated nature has realized the significant issues of E-waste on human wellbeing, animals, and ecology (Park *et al.,* 2017). It is irrefutable that less developed nations have a generous offer of E-waste as well. China and the United States of America reported 6.3 million metric tons and 7.2 million metric tons of E-waste accumulated in the year 2016 respectively (Richer, 2017). The landfill, open dumping, and casual recycling were singled out as the least options due to their harmful effects on human well-being and ecology. Landfill option poses danger as it results in leaching when rainwater filters through waste in a landfill, (Lombard *et al*., 2017).

Table 1.1 Waste generations

S.NO	Types of sectors	Waste generated (MT/day)	% waste composition
1	Domestic household	1870	37.18
2	Commercial establishments	350	6.95
3	Hotels & Restaurants	666	13.24
4	Institutions	125	2.48
5	Parks and Gardens	69	1.38
6	Street sweeping	325	6.47
7	Waste from drains	175	3.47
8	Markets	479	9.52
9	Temples	35	0.70
10	Chicken, mutton, fish stalls	164	3.26
11	Cinema halls	15	0.30
12	Function halls	88	1.74
13	Hospitals	35	0.69
14	Construction and demolition	635	12.62

1.2 The characteristics of E-waste

Broadly E-waste may be classified based on proportions of materials recovered from the E-waste. Steel constitutes 50%, copper, aluminium and other metals 13% and plastics 21% [ETC/SCP], however E-waste is made of wide variety of substances in thousands. The hazardous and toxic metals constitute about 1% of the total weight and rest of the material like precious metals constitute gold 0.1%, Silver 0.2% and palladium 0.005% respectively.

1.2.1 The quantity of E waste

Due to the extreme rates of obsolescence, E waste produces much higher volumes of waste in comparison to other consumer goods. It could represent as much as 5% of municipal solid waste disposal (E Waste in India, Rajya Sabha Report, 2011). It is to be remembered that this figure has been adduced from less than 5% of E-waste which is generated in India, as only less than 5% of E-waste enters the formal sector for recycling in India, whereas the remaining 95% of E-waste is handled by the informal sector in our country. That is more than beverage containers, more than disposable diapers, and about the same level as all plastic packaging. But no exact data is available on how much E-waste exists in the world and in our country, as tons and tons of these keep pouring in day after day.

1.3 The top ten states in India generating E- Waste

From the below table 1.2 it is noted that Andhra Pradesh and Karnataka stands 3rd and 7th respectively in the list among the E- Waste generators. As regards to the cities, Bangalore is 2nd and Hyderabad is 5th in generation of E Waste. Northern India is not a leading generator, it happens to be the leading processing center of E waste in the country. There are three formal recyclers in the South of India (at Chennai, Hyderabad and Bangalore) and one in Western India.

Table 1.2 E Waste / WEEE Generation in Top Ten States

S. No	States	WEEE(Tones)	Percentage %
1	Maharashtra	20270.59	18.49
2	Tamil Nadu	13486.24	12.30
3	Andhra Pradesh	12780.33	11.66
4	Uttar Pradesh	10381.11	9.47
5	West Bengal	10059.36	9.18
6	Delhi	9729.15	8.87
7	Karnataka	9118.74	8.32
8	Gujarath	8994.33	8.20
9	Madhya Pradesh	7800.62	7.11
10	Punjab	6958.46	6.35
	Total	**109578.93**	**100**

1.4 Growth of E-waste

The study on Electronic Waste Management in the counties, which was conducted to mark World atmosphere Day, aforesaid as Indians become richer and pay additional on electronic things and appliances. This is followed by communication system (12%), electrical instruments (8%) and medical instruments (7%). Alternative instruments, together with house E-Scrap account for the remaining 4%.

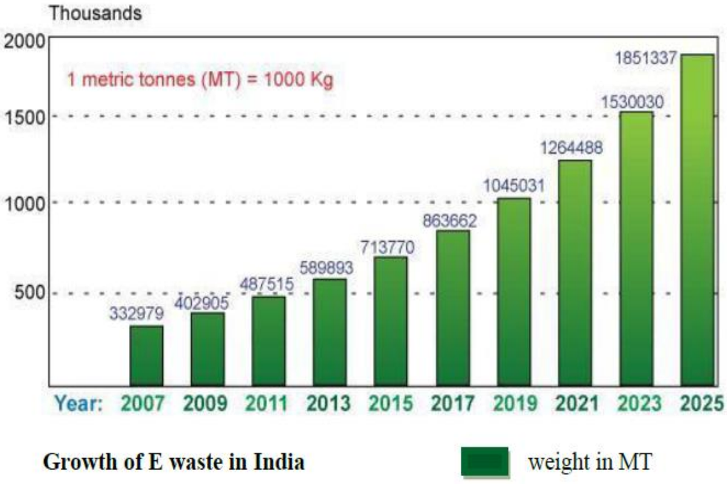

Figure 1.3 Growth of E-waste

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2. Literature Review Several studies have explored the comparative analysis of materials:

- **Kohler and Erdmann (2004)** explained that the home appliance like automatic ovens, fridge or chilling machines and many others which also work on programming and computer related activities are very or electronic family.
- **Wang *et al.*, (2011)** difficult to differentiate from WEEE as they are also part of either electrical has written in detail that electronic & electrical waste is actually a family and it has many branches which includes all personal, commercial, educational, transportation, private or public products which mainly work on power and have at least some sort of automation to function in order to meet the requirement.
- **Jirang Cui and Eric Forssberg, 2003** Global environmental activities are developing with expansion of living and nonliving resources and related social activities. The relationship of environmental issues with the electronic and electrical industries begins with the generation of E-waste and the pollution possibilities. Waste Electronic and Electrical Equipment (WEEE) is diverse and complex in terms of materials and components as well as the manufacturing process. Characterization of this waste stream is of paramount importance for developing a cost effective and environmental friendly recycling system. According to a report by United Nations Environment Protection Agency (USEPA) titled, Recycling from E-waste to resource, estimates that 20 to 25 million tonnes of electronic waste are generated worldwide every year. Globally one million mobile phones were sold in 2007, up from 896 million in 2006. The report assesses current policies, skills, waste collection networks and informal recycling in 11 representative developing economies in America, Africa and Asia.
- **Zollo and Hays, (1994)** have stated that the fibre reinforced cellular concrete panels have been successfully employed in building construction and perform satisfactorily which initiates the concept of development of plastic fibre panels which can serve well on energy conservation.
- **Kenneth Stier and Gray Weede, (1999)** identified that the post-consumer waste stream consisted of commingled plastics which came from greeting card racks that were produced by a company. It was described that the plastic greeting card racks were shredded with a plastic granulator. Using a multi strand die the plastic granules were extruded to produce fibers approximately >0.010 to 0.030 in diameters and cut into one inch lengths for use in the concrete. With experimental investigation, the author confirmed the concrete containing recycled plastics fiber showed promising results in compression, tension and flexure.
- **Subramanian, (2000)** described the need for an integrated waste management approach involving reduction, recycling and reuse of plastics. The amount of plastics consumed annually in the growing trends of Indian and US scenario was discussed. The possibilities of a comprehensive investigation of the technical, economic and ecological aspects of recycling were addressed.

3. Methodology

3.1 Materials

3.1.1 Cement

The 43 grade ordinary portland cement was used in this investigation. The different physical properties of the cement were tested as per IS 4031:1988 code. The test results are tabulated in Table 3.1.

Table 3.1 Physical properties of cement

Physical properties	Observations
Specific gravity	3.14
Standard Consistency	33%
Initial setting time	30 min
Final setting time	8 hrs 35 min
Compressive strength	43.86 N/mm^2

3.1.2 Water

Clean potable water is used for casting and curing operation of the specimens. The water used for entire testing was having pH value 7.5 – 8.0.

3.1.3 Fly Ash

The fly ash of class F samples was obtained from Mettur Thermal power plant (MTTP) through ACC, Ltd. Coimbatore, Tamil Nadu. Fly ash with specific gravity of 2.37 was used to cast the specimens. The chemical composition of fly ash is tested as per IS procedure and presented in Table 3.2.

Table 3.2 Chemical composition of fly ash (mass %)

$SiO_2+Al_2O_3+Fe_2O_3$	SiO_2	CaO	SO_3	Na_2O	MgO	Loss on ignition
90.5	58	3.6	1.8	2.0	1.91	2.0

3.1.4 Fine Aggregate

The well graded river sand was used as fine aggregate which conforming to grading zone II as per IS 383-1970 with a specific gravity of 2.76.

3.1.5 Coarse Aggregate

Locally available crushed and angular coarse aggregate with a specific gravity of 2.80 was used.

3.2 Mix Proportions

Mix proportion for M25 grade of concrete was calculated using design process as per IS10262:1982. The estimated mix proportion was 1:1.56:2.56 with water, cement ratio of 0.45. The E waste material was used as coarse aggregate in concrete and different quantity of E waste were decided to cast the cubes. The following quantities were finalized to replace the course aggregate by E waste by volume in addition to the controlled concrete with w/c ratio of 0.45. The percentages of E wastes in concrete were 0%, 5%, 10%, 15%, 18% and 20%. The series of mixtures were detailed in Tables 3.3.

Table 3.3 Mix Specifications – M25 Grade

Type of concrete	Controlled concrete	M1	M2	M3	M4	M5
% of E waste added	0%	5%	10%	15%	18%	20%

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3.3 Casting and Curing

The concrete specimens with electronic waste ranging from 0% to 20% were prepared. The prepared mix was tested for slump value. Regular tap water was used for casting and curing of all the specimens. A sufficient number of cubes, cylinders, prisms, beams, T beams and RC beams were casted and cured at a room temperature of almost 27oC ± 2oC. The casted concrete specimens were demolded and immersed in clean, fresh water and chemicals until the standard curing period.

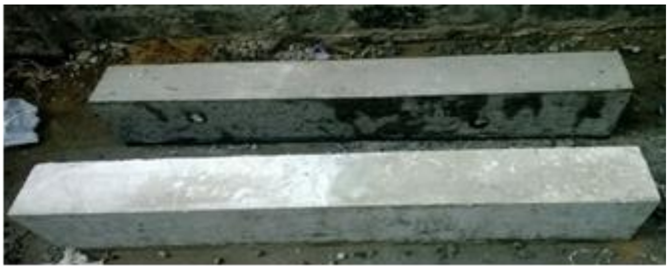

Figure 3.1 Casted Rectangular Concrete Beams

3.4 Durability Tests on Concrete

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality and serviceability when exposed to environment. For determining the resistance of concrete specimens for the aggressive situation such as acid attack, the durability testing methods as described in ASTM C 666 has been adopted.

4. Results

4.1 Compressive strength

Compressive strength was determined using 2000 kN capacity compression testing machine. For all tests, each value was taken as the average of three samples. Test results for controlled concrete at 14, 28 and 60 days curing were tabulated in Table 4.1.The testing arrangements are shown in Figure 4.1 & 4.2.

Figure 4.1 & 4.2 Compressive strength testing specimen in concrete & Concrete cube specimen after testing

From the compressive strength tests, it is found that a gradual improvement of strength in E waste concrete up to 10% replacement of coarse aggregate in concrete by polymer E waste. The compressive strength of the concrete is dropping down gradually above 10% replacement. The average compressive strength obtained for 10% replacement by E waste in concrete was higher by nearly 5 N/mm2 than the controlled concrete. From the results for 14, 28 and 60 days, it is very clear about the gradual improvement of strength in all combinations. Figure 4.3 shows the trend of compressive strength with respect to various combinations

Table 4.1 Compressive strength results for concrete cubes

% of E waste	Load, kN			Compressive Strength(N/mm^2)		
	14 days	28 days	60 days	14 days	28 days	60 days
0	612	679	685	27.20	30.17	30.44
5	639	683	692	28.40	30.35	30.76
10	683	781	788	30.36	35.02	35.02
15	661	778	782	29.38	34.71	34.76
18	655	699	706	29.11	31.06	31.38
20	585	660	665	26.00	29.33	29.56

Table 4.2: Density of E waste concrete cubes

E waste (%)	Wet weight in kg	Dry weight in kg
0%	8.72	8.70
5%	8.65	8.38
10%	8.37	8.28
15%	8.27	8.26
18%	7.97	7.97
20%	7.80	7.78

The density of concrete is decreasing gradually while replacing the course aggregate by E waste in concrete, because the specific gravity of E waste is lesser than the specific gravity of coarse aggregate.

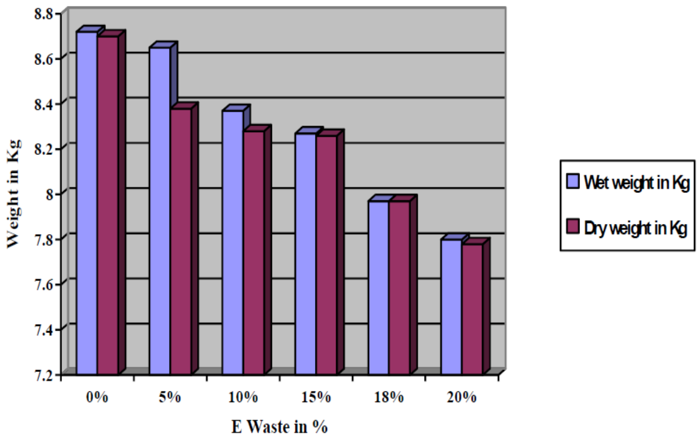

Figure 4.3: Density comparison for cubes

The addition of E wastes in concrete more than 10% will increase the porosity of concrete and making the density of concrete low. The excess E waste affects the hydration process of concrete and loses their workability. Due to low workability of E waste concrete with excess deflection, the concretes gets porous and it also affects the strength of the concrete.
By adding fly ash in E waste concrete, the workability may be increased due to the presence of silica which could react with calcium hydroxide which leads to form C-S-H gel in concrete. It seems to increase the density of E waste concrete matrix and refine the pore structure Murthi *et al.*, (2008).

5. Conclusion

In this research work, E waste management were discussed based on the various tests to find out the different physical and chemical properties of fresh and hardened concrete. Based on the obtained results the following conclusions were derived.

- A gradual improvement of strength in E waste concrete upto 10% replacement of coarse
- aggregate in concrete by polymer E waste and followed by decreasing gradually.
- Density of concrete is decreasing gradually against increase in quantity of E waste in
- concrete, because the lesser specific gravity of E waste.
- The addition of E wastes in concrete more than 10% will increase the porosity of concrete and making the density of concrete low.
- Maximum split tensile strength of concrete cylinder was obtained at 15% at 28 days curing.
- The compressive strength at 10% replacement by E waste gets maximum value.

The split tensile strength was resulted maximum at 15% addition of E waste.

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