ROOPA M
SRIRAKSHA R DAS
SANJANA M
and
THUNGASHREE B S

Study on partial replacement of e-plastic waste as coarse aggregates

The electronics sector has been experiencing fast expansion, owing to constant technological advancements and the introduction of new technologies to the market. As a result, e-plastic waste has become one of the world's fastest growing solid wastes. This paper outlines the experimental work carried for the partial replacement of e-plastic in volumes of 5%,10%,15% and 20% as coarse aggregates. On hardened concrete, strength tests were performed. The results reveal that using e-plastic waste as coarse aggregates results in concrete that is substantially more workable and less dense. This research presents a cost-effective, environmentally acceptable, and efficient disposal solution for e-plastic waste, which can be used as a partial replacement for coarse aggregates in concrete. Researchers have recently begun to examine an alternate source of aggregate in concrete by employing e-plastic waste as a building material, which increases the water retention characteristic of new mortar while lowering the bulk density of hardened mortar.

Keywords: Solid waste, workable concrete, less dense concrete, efficient disposal

1.0 Introduction

Advances in the field of science and technology brought about industrial revolution in the 18th Century which marked a new era in human civilization. In the 20th Century, the information and communication revolution has brought enormous changes in the way we organize our lives, our economies, industries and institutions. India has been on a rapid economic growth path and the past two decades of economic reforms have succeeded in a growth rate in the range of 8.5% [1]. All the countries in the world depend largely on information and communication technology for augmenting their prosperity and in the developing countries, such as India and China, the services sector has dominated the rapidly growing economies. While the services sector, which is largely driven by the information technology industry, has resulted in an increased amount of electronic equipment, such as personal computers (PCs), printers, and other work-related equipment, the almost-doubled per-capita incomes in metro cities such as Mumbai and Delhi have resulted in increased access and usage of electronic and electrical items, such as mobile phones, refrigerators, air conditioners, etc. Improved living standards and the share of services sector and the use of electronic equipment is on the rise and results in increased electronic waste generation.

The main objective of this work is to reduce the pollution by using the non-degradable recycled e-plastic waste as green building material.

2.0 Materials

2.1 Cement

Cement is one of the most important binders, which are defined as substances that set and harden independently and can bind other materials together. Cements used in construction are characterized as hydraulic or non-hydraulic. Hydraulic cements are materials which set and harden after combining with water, as a result of chemical reactions with the mixing water and, after hardening, retain strength and stability even under water.

Ordinary Portland cement, conforming to specifications for 53 – grade ordinary Portland cement, as per the IS code 12269-2013 was used in this study.

2.2 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

Tap water, consumable with no salts or synthetic elements was utilized in the examination. The water source was used from Environmental Laboratory, SSIT, Tumakuru.

2.3 Aggregates

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong

Mss. Roopa M, Assistant Professor, Department of Civil Engineering, Sri Siddhartha Institute of Technology, Sriraksha R Das, Sanjana M and Thungashree B S, Bachelor of Engineering Students, Department of Civil Engineering, Sri Siddhartha Institute of Technology, Tumkur 572105. E-mail: srirakshardas@gmail.com

particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates are divided into two distinct categories, fine aggregates and coarse aggregates. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch (9.5 mm) sieve. Coarse aggregates are any particles greater than 0.19 inch (4.75 mm).

2.4 M-Sand (fine aggregate)

Manufactured sand is sand produced from crushing of granite stones in required grading to be used for construction purposes as a replacement for river sand. The manufactured sand has required gradation of fines, physical properties such as shape, smooth surface textures and consistency which make it the best sand suitable for construction.

2.5 Coarse aggregate

In this experiment, locally available crushed coarse aggregate conforming to Indian Standard 383-1970 was used. Particle size distribution confirms to requirements of as per IS (2386 part I). Nominal size passing through size 20mm and retain on 10 mm is sieve used.

2.6 E-plastic waste

The e-plastic used as a partial replacement for coarse aggregate was in the form of chips, which was flaky in shape and black in colour. The properties are found as per IS 2386 (Part I– IV)-1963. The e-plastic waste was collected from E-Waste Traders, Bengaluru.

Fig.1: Collected e-plastic waste

3.0. Methodology

Process in detail

1. Collection of Raw Materials
    - The e-plastic waste was collected from the local e-plastic waste traders and it converted into e-plastic waste coarse aggregates by grinding it.
    - The coarse and fine aggregates collected from nearest crusher.
    - OPC 53 grade cement of good quality was used.
2. Basic tests were conducted on the collected raw materials to check the physical properties.
3. Mix design was developed for M20 grade of concrete as per the IS: 10262- 2019 and IS: 456-2000.
    - Different mixes were developed for different proportions of e-plastic waste as partial replacements in coarse aggregates by 5%, 10%, 15% and 20%.
    - The water cement ratio, cement content and fine aggregates were kept constant for all proportion. Variations made in the e-plastic waste replacements in the coarse aggregates.
4. Workability of the fresh concrete, slump test conducted for different mixes.
5. Specimens (cube and cylinder) of standard sizes casted with and without e-plastic waste in concrete of M20 grade. The specimens were kept in laboratory curing tank for the period of 7, 14 and 28 days.
6. The compressive strength and the split tensile strength which indicates the strength parameters of the e-plastic waste plastic concrete performed on 7, 14, and 28 days cured specimens

Concrete mix design

Data for mixing proportion

1. Target strength for mix proportioning:

- $f'ck = fck + 1.65 \times S$ [IS:10262 – 2019 for M20 S = 4 N/mm^2]
- $f'ck = 20 + 1.65 \times 4$
- $f'ck = 26.6$ N/mm^2

2. Selection of water cement ratio

- Maximum water cement ratio = 0.55 [IS: 456 – 2000 for M20 grade]

3. Selection of water content

- Max water content = 186 litres [IS: 10262 – 2019 for 25 – 50 mm slump range]
- Estimated water content for 100 mm slump = 186 + 6/100 × 186 = 197 litres.

4. Calculation of cement content

- Water cement ratio = 0.55,
- Water cement ratio/cement content = 0.55, cement content = 358.18 kg/m^3
- 20mm down size = 0.62
- Volume of coarse aggregate = 0.62, volume of fine aggregate = 1 – 0.62 = 0.38

Mix calculations

a. Volume of concrete = 1m^3
b. Volume of entrapped air in wet concrete = 0.01 m^3

c. Volume of cement = 0.166m^3

d. Volume of water = 0.197m^3

g. Volume of all in aggregate =0.677m^3

h. Mass of coarse aggregate =1103.91kg

j. Mass of fine aggregate = 689.45kg

Mix proportions

- Mass of cement = 358.18 kg/m^3
- Fine aggregate (FA) = 689.45 kg/m^3
- Coarse aggregate (CA) = 1103.91 kg/m^3
- Cement: FA: CA = 358.18: 689.45: 1103.91

Mix ratio cement

FA : CA = 1 : 1.92 : 3.08

The ratio of water: cement: fine aggregate was fixed,

Fig.2: Slump test of e-plastic waste concrete

Table 1: Slump test results

Mix type	Slump (mm)
Conventional concrete	90
5% e-plastic waste	80
10% e-plastic waste	70
15% e-plastic waste	60
20% e-plastic waste	50

coarse aggregate was replaced with different percentages of e-plastic by volume (5, 10, 15, 20%)

The concrete specimens of cylindrical and cube shapes are casted and the dimension details of the specimens to be casted.

Results and comparision

Workability of concrete

Workability by slump cone was determined by using Methods of Sampling and Analysis of Concrete. Slump test was conducted to study the workability of concrete. The concrete mix was designed for slump test and the design slump was achieved with conventional concrete. The increase of e-plastic in the concrete mix resulted in decrease of workability, which affected the slump and fresh density. The shape and size of the e-plastic aggregates influence the consistency of the concrete mix.

Compressive strength test

The compressive strength of specimens is determined after 7, 14 and 28 days of curing respectively with surface dried condition. Cast specimen (cube shape) of size 150×150×150mm was used for evaluation of compressive strength. Cube specimens were placed centrally within the machine. The load was applied in an exceedingly continuous and uniform fashion without shock. Compressive strength is calculated by dividing the maximum load obtained on the cross-sectional area of the specimen. During this test the maximum load carried by every specimen has been recorded and made average of it. The compressive strength of cube specimens for 7, 14 and 28 days are shown in Table 2.

The Variation in compressive strength for different percentage of e-plastic waste replacement is shown, which clearly depicts that 5% and 10% e-plastic waste replacement

Table 2: Compressive strength of cube specimens for 7 days

Specimen mix details	Maximum load (kN)	Compressive strength (N/mm^2)
0% replacement	307	13.65
5% e-plastic waste	302	13.42
10% e-plastic waste	295	13.11
15% e-plastic waste	255	11.33
20% e-plastic waste	239	10.62

Table 3: Compressive strength of cube specimens for 14 days

Specimen mix details	Maximum load (kN)	Compressive strength (N/mm^2)
0% replacement	385	17.11
5% e-plastic waste	382	16.98
10% e-plastic waste	378	16.80
15% e-plastic waste	342	15.20
20% e-plastic waste	309	13.73

Fig.3: Compressive strength test in UTM

in concrete achieved the compressive strength near to the conventional mix. Further, increasing in percentage of e-plastic Waste the compressive strength has reduced sharply.

The variation in compressive strength showed a sudden fall after 10% e-plastic waste replacement. It is mainly due to the increase in e-plastic waste which may cause poor bonding with cement mortar.

The compressive strength variation for 28 days is shown. As the ageing period is increased to 28 days only 5% e-plastic waste replacement shows good compressive strength near to the conventional mix. Compressive strength has fallen sharply with increase in e-plastic waste percentage.

Split tensile strength test

Tensile splitting strength of concrete was found out as per IS: 516-1959. Cylinders of size 150 ×300 mm were used for getting tensile splitting strength of concrete throughout experiment. Split tensile strength test has been carried out in compression testing machine. Calculation of the splitting tensile strength of the specimen is as follows. The calculated

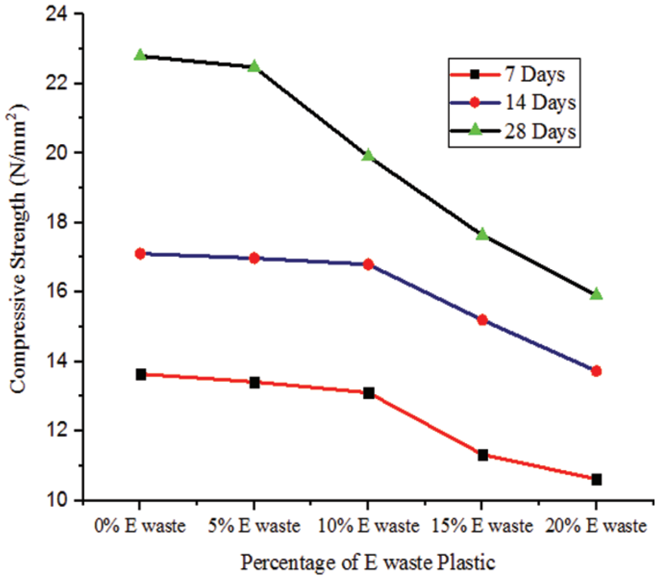

Fig.4 Variation in compressive strength with age and e-plastic waste content

tensile strength for cylindrical specimen for 7, 14 and 28 days are shown in the Table.

$$\frac{2P}{nLD}$$

where, T = Splitting tensile strength

P = Maximum load applied

L = Length

D = Diameter

Variation in tensile strength for 7 days period is shown, which clearly indicates that the tensile strength gradually reduced from conventional mix concrete to 10% e-plastic waste and then after it is reduced sharply when the percentage of e-plastic increased to 15% and 20%.

TABLE 4: COMPRESSIVE STRENGTH OF CUBE SPECIMEN FOR 28 DAYS

Specimen mix details	Maximum load (kN)	Compressive strength (N/mm^2)
0% replacement	513	22.8
5% e-plastic waste	506	22.48
10% e-plastic waste	448	19.91
15% e-plastic waste	397	17.64
20% e-plastic waste	358	15.91

TABLE 5: SPLIT TENSILE STRENGTH FOR CYLINDRICAL SPECIMENS FOR 7 DAYS

Specimen mix details	Maximum load (kN)	Tensile strength (N/mm^2)
0% replacement	155	2.19
5% e-plastic waste	147	2.07
10% e-plastic waste	138	1.95
15% e-plastic waste	125	1.76
20% e-plastic waste	120	1.69

Variation in tensile strength for 14 days of curing period is shown, which shows a good tensile strength at 5% e-plastic waste replacement next to the conventional mix concrete. Further increase in e-waste plastic percentage shows a decline in tensile strength.

Fig.5: Split tensile strength test in UTM

TABLE 6: SPLIT TENSILE STRENGTH FOR CYLINDRICAL SPECIMENS FOR 14 DAYS

Specimen mix details	Maximum load (kN)	Tensile strength (N/mm^2)
0% replacement	197	2.78
5% e-plastic waste	194	2.74
10% e-plastic waste	182	2.57
15% e-plastic waste	174	2.46
20% e-plastic waste	154	2.17

TABLE 7: SPLIT TENSILE STRENGTH FOR CYLINDRICAL SPECIMENS FOR 28 DAYS

Specimen mix details	Maximum load (kN)	Tensile strength (N/mm^2)
0% replacement	226	3.19
5% e-plastic waste	221	3.12
10% e-plastic waste	204	2.88
15% e-plastic waste	188	2.65
20% e-plastic waste	173	2.44

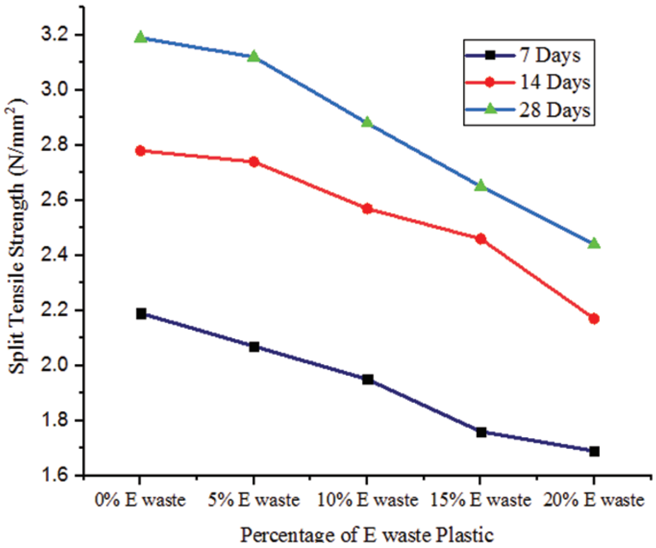

Fig. 6: Variation in split tensile strength with age and e-plastic waste content

The tensile strength for the ageing period of 28 days is shown. It is clearly indicated in the plot that tensile strength has reduced with increase in e-plastic waste percentage in concrete mix.

But tensile strength of 5% e-plastic waste replacement is near the value of tensile strength of conventional mix concrete.

4.0 Conclusions

- E-plastic can be used to replace coarse aggregates in concrete by volume (5%, 10%, 15% 20%).
- The recycling of e-plastic waste to produce new materials, such as cement concrete composites, appears as one of the best solutions for disposing of electronic plastic waste, instead of combustion and land filling.
- The e-plastic waste aggregates have poor shape and surface texture is smooth which greatly influenced the fresh and hardened properties of concrete.
- With 5% and 10% e-plastic waste volume replacement, the characteristics of M20 concrete are achieved with good compressive and split tensile strength.
- E-plastic waste replacement by 5% by volume indicates good mechanical properties near at that of the conventional mix concrete. So, in this study best results achieved with 5% e-plastic waste replacement.
- As e-plastic waste replacement increased above 10% a sudden reduction in both compressive strength and tensile strength is observed.
- It can be recommended that 15 and 20 % replacement by volume can be used for non-structural elements.

Scope for further work

E-plastic waste replacement as coarse aggregates gives a better option for recycling of e-plastic waste and would be a green structural element. Further the e-waste plastic of different kind can be replaced with both fine and coarse aggregate. Structural elements like roofs and beams fabricated with e-plastic waste concrete would be analyzed which may explore new ways of fabricating better concrete with e-waste.

References

1. Rajya Sabha Secretariat (ed.) (2011): E-waste in India. New Delhi, India research unit (Larrdis): Rajya Sabha Secretariat, June 2011.
2. S. Yedla, (2015): 'Development of a methodology for electronic waste estimation: A material flow analysis-based SYE-Waste Model'.
3. J. Babafemi, B. Šavija, S. C. Paul, and V. Anggraini, (2018): 'Engineering Properties of Concrete with Waste Recycled Plastic: A Review'.
4. A. Kumar, M. Holuszko, D. Crocce, and R. Espinosa, (2017): 'Resources, Conservation and Recycling E-waste: An overview on generation, collection, legislation and recycling practices', "*Resources, Conserv. Recycl*., vol. 122, pp. 32–42.
5. S. Arya and S. Kumar, (2020): 'E-waste in India at a Glance: Current Trends, Regulations, Challenges and Management Strategies', J. Clean. Prod., p. 122707.
6. S Bharani, MNA Gulshantaj, G Rameshkumar and V B Senthilnathan 'Mechanical properties of concrete as partial replacement of coarse aggregate by e-waste I. O. P. C. Series and M. Science.
7. M. Belmokaddem, A. Mahi, Y. Senhadji, and B. Yilmaz, (2020): 'Mechanical and physical properties and morphology of concrete containing plastic waste as aggregate', *Constr. Build. Mater,* vol. 257, p.119559.
8. V. Rathore and A. Rawat, (2019): 'Effective utilization of electronic waste in concrete mixture as a partial replacement to coarse aggregates', AIP Conference Proceedings, vol. 020037, September.
9. M. Sab and J. R. Vargas, (2018): 'Use of e-plastic waste in concrete as a partial replacement of coarse mineral aggregate' *Computers and Concrete* Vol.21, no.4, pp 377-384.
10. A. A. Kumar and R. S. Selvan, (2017): 'Performance of Recycled E-waste as Aggregates in Green Concrete', *Nat. Env. & Poll. Tech.* Vol. 16, pp. 1135-1140.
11. M. L. Sankarshan, Shrihari K. Naik, M. V. Deepthi and S. D. (2016): Anitha Kumari, Potential Use of E-Plastic in Concrete, 'Urbanization Challenges in Emerging Economies 484', no. Mundada 2004, pp.484–490.
12. Ashwini Manjunath B T, (2016): 'Partial replacement of E-plastic waste as Coarse-aggregate in Concrete', Procedia Environ. Sci., vol. 35, pp. 731–739.
13. K. Senthil and K. Kaliyamoorthy, (2014): 'Recycling of E-plastic waste as a construction material in developing countries'.