EXPERIMENTAL INVESTIGATION ON THE USE OF NEW GENERATION WASTE MATERIAL IN M-40 GRADE CONCRETE

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Abstract

Electronic items that are unwanted, outdated, or nearing the end of their 'useful life' are classified as e-waste. Today, Electronic items such as cell phones, computers, televisions, Remote controls, stereos, copiers, and fax machines are omnipresent. The ongoing and impending issue of ways to dispose of unwanted electronics is almost five decades old, dating back to the 1970s. However, the situation seems to have only gotten worse since then, particularly in terms of the amount of electronics discarded nowadays. With the advancement of technology, the electronic industry has experienced unparalleled growth, resulting in a massive spike in the E-waste generated every day around the world.

Electronic waste, or simply E-waste, is considered one of the most harmful type of wastes in today's new age world. Drinking water supplies are becoming polluted, and environment and ecosystems are being impacted all around the world as a result of the unceasing increase of these technological wastes. Current environmental issues can be mitigated to some extent by experimenting with and utilizing electronic waste materials in the construction industry. Along with traditional aggregate alternatives like fly ash and rice husk ash, the industry is now experimenting with E-waste to determine if it can be a viable material for improving concrete strength and longevity. The primary objective of this research is to better understand the behavior of M40 grade high strength concrete when coarse aggregate is replaced by E-waste plastics in various percentages. The strength of concrete containing E-waste plastic was tested at different time intervals after coarse aggregates were partially substituted with specific % of E-plastic waste by volume ranging from 0% to 30%. Testing was performed after 28 days of curing for determining compressive, tensile and flexural strength and it was observed that concrete with E-waste replacement exhibited strength results comparable or nearly equal to those of normal cement concrete mix. When the E-waste plastic component percentage is considerably high, however, there is a decline in strength after a certain point.

Keywords:-E-waste, Flexural strength, tensile strength, Compressive Strength

1. INTRODUCTION

Today's technologically advanced society is demanding and causing a massive growth in electronic waste creation. According to the Global E-waste Monitor, India is one of the countries that

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produces very high amounts of E-waste, and is leading in E-waste generation. People are being pushed to acquire new technology as it becomes available, and old devices are being discarded as they become obsolete. This trend, combined with a lack of awareness about safe electronic item disposal and a lack of infrastructure to manage these massive E-waste loads, has resulted in majority of the E-waste being dumped directly into the ground, resulting in solid dangerous waste. The chemical "lead" present in E-plastic trash is almost certain to impair human health in kidneys, nervous system etc. Researchers all over the world are concerned about the management, disposal, and handling of E-plastic waste. Research activities are focused on adopting numerous strategies to manage E-waste plastics, one of which is utilizing this E-waste plastic in the construction industry. As of today, natural resources utilized in construction materials are depleting at an alarming rate, necessitating the search for a replacement.

Maharashtra is the leading producer of E-waste in India, followed by Tamil Nadu and Andhra Pradesh [10,11]. According to a United Nations Environment Program assessment, India's E-Waste generation will increase by 500% in the next decade [12]. Every year, the United States disposes of around 3 million tonnes of electronic garbage, placing it first in the world. China is closely following the the United States in terms of E-Waste disposal, with 2.3 million tonnes in 2013 and 6 million tonnes in 2014 [13]. According to the Environmental Protection Agency, about 15–20 percent of e-waste is recycled, with the rest ending up in landfills or incinerators.

During 2007, the Manufacturers' Association for Information Technology (MAIT) conducted an e-waste inventory based on three electronic day-to-day products: mobile or cell phones, laptops, and televisions. In India, the total amount of e-waste generated in 2007 was 3,32,979 metric tonnes (MT) (Televisions: 275000MT, Computer: 56324MT, Mobile Phones: 1655MT). According to this estimate, the volume of e-waste reached about 0.7 million MT in 2015, and is expected to reach 2 million MT by 2025 [5] (**Fig.1**).

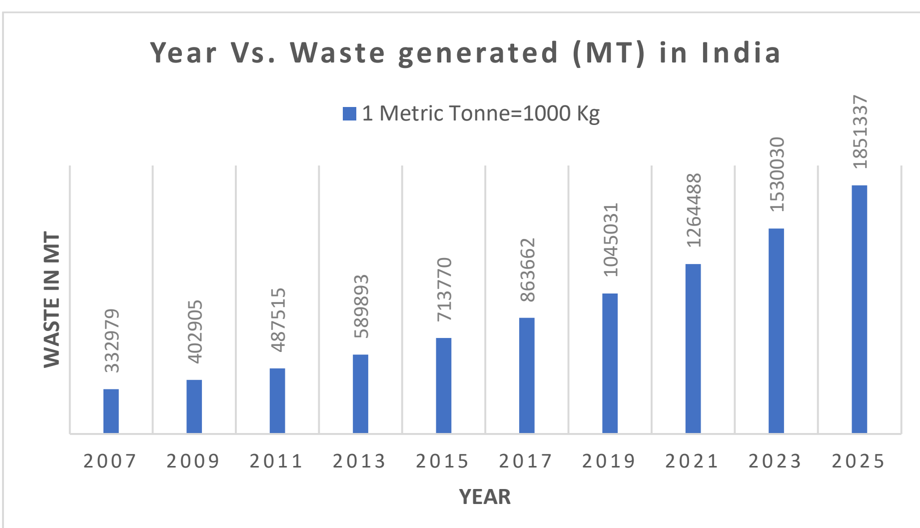

Figure 1 - Growth of E-waste in India

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Lakshmi and Nagan (2010) [3] conducted research on the partial substitution of coarse aggregates by E-Waste particles in proportions ranging from 0% to 30%. According to their findings, when the E-plastic component was increased by 20%, the strength fell. Shamili et al. (2017) [1] gave a comprehensive overview of E-Waste composition, preparation, characteristics, and classification. Alagusankareswari et al. (2015) [2] experimented with E-Waste used as a fine aggregate replacement. Their research found that relative to a conventional concrete, the strength parameter values reduced for concrete with E-waste percentage. Arora and Dave (2013) [4] examined the concrete strength when fine aggregate was substituted with E-waste and plastic waste in percentages of 0%, 2%, and 4%. Their research revealed that the Concrete strength rose 5% while the cost of concrete manufacture decreased 7%.

The objective of this experiment is to determine if using E-waste plastic as a partial replacement for coarse aggregate in M-40 grade concrete with cement OPC 53 grade complying to IS 8112 in the proportions of 0,5,10,15,20,25, and 30% is feasible. On the 7th, 14th, and 28th days of curing, compression strength is evaluated and compared, while tensile strength and flexural strength are compared on the 28th day of curing. The purpose of the experimental work was to use non-biodegradable E-waste components as a partial replacement for coarse aggregate. The results from the study revealed that M-40 grade samples exhibit good strength in compression at 15% substitution of CA by E-waste. Crushed E-waste plastic material could be used as a substitute material in the construction industry, thereby lowering the cost of concrete construction and manufacturing.

Objectives:

1. To investigate physical and chemical properties of ground E-waste materials to understand pozzolanic reactivity of these materials.
2. To study the influence of E-waste materials on mechanical properties of concrete such as Compressive strength, flexural strength, tensile strength.
3. To investigate the performance of the E-waste in concrete.
4. To check suitability of new generation waste material as an ingredient of concrete.
5. To test optimize mix proportion of concrete as research output.

2. MATERIALS

2.1. E-plastic waste

Every day, tones of e-waste is generated across the country and around the world. The E-plastic waste used in this study comes from discarded electronic equipment, household electronic goods, etc. After being cut into 10 mm pieces, the discarded and crushed circuit boards and chips are used as a substitute for coarse aggregates in varied amounts.

The features of E-waste material used in this investigation are listed in **Table 1**, and Figure (2) depicts the E-waste material collected for this study.

Combination no.	**P.C.B. (gm)**	**Kit material. (gm)**	**Steel. (gm)**	**Plastic. (gm)**	**Other combined materials**	**Total Wt.**

1st	1360 gm	439 gm	78gm	105 gm	18 gm	2000 gm
2nd	1540 gm	390 gm	30 gm	33 gm	7 gm	2000 gm
3rd	1460 gm	408 gm	62 gm	60 gm	10 gm	2000 gm
4th	1520 gm	410 gm	42 gm	22 gm	6 gm	2000 gm
Total (%)	73.5%	20.5875%	2.65%	2.755%	0.512%	100%

Table 1: Classification of E-waste material

Figure 2- E-waste material collected for replacement

2.2. Cement

The tests were conducted on OPC of grade 53, and cement properties were examined according to IS 2386 (PART-1) 1963. **Table 2** lists the properties of cement that were examined and used in the experimental study.

Sr. No.	Characteristics	Value
1	Consistency of Cement	31 %
2	IS Time	87 min
3	FS Time	350 min
4	FC	94 %
5	Soundness of Cement	2 mm

Table 2: Classification of Cement

2.3. Fine aggregate

A sieve with mesh of 4.75 mm is used to separate aggregate from undesired stones and impurities. Fine aggregate is material that has passed through a 4.75 mm mesh screen. IS-2386 from 1963 (PART-1) Is a term used to describe the properties of fine aggregates. **Table 3** displays the fitness modulus, bulking, water content absorption, and relative density values of these fine aggregates.

Sr. No.	Characteristics	Value
1	FM of FA	4.96

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2	Bulking (%)	3%
3	Water content absorption	1 .2%
4	SG	2 .74

Table 3: Classification of FA

2.4. Coarse aggregate

For the experiment, coarse aggregates with 20 mm size were used. The investigation was carried out in accordance with IS 2386 (PART-1) 1963 criteria. Table 4 shows the properties of coarse aggregate, including water absorption, impact value, relative density, and crushing value.

Sr. No.	**Characteristics**	**Value**
1	FM of Course Aggregate	8.69
2	Specific gravity of CA	2.74
3	Impact value of CA	10.52%
4	Crushing Value of CA	16.90%
5	Abrasion value of CA	16.76%
6	Water Absorption of CA	Nil

Table 4: Classification of CA

3. METHODOLOGY

3.1. Mix Design:

The MD for high strength concrete M40 was prepared using the following data. OPC 53 is the cement grade. The aggregate nominal size limit is 20 mm. 0.45 is the maximum water cement ratio. Cement has a relative density of 3.15. Coarse aggregate has a relative density of 2.74. Fine aggregate has a relative density of 2.74. CS, FT, and STT are performed on the moulds after they have been cast, cured, and tested. Figures (3) and (4) depict the various shapes of concrete mould specimens. After the specimens are casted, they are held in a curing tank for a specified number of days before being tested for the various experiments.

Figure 3- Cube mould

Figure 4- Cylinder and beam mould

The mix design As Per IS-10262-2009-for high strength concrete M40 was prepared by using the following data.

DETAILS FOR PROPORTIONING:

i) Grade of concrete	M 40
ii) Cement type	OPC 53 grade as per IS 8112
iii) size of coarse aggregate	20 mm
iv) cement	320 kg / m3 (minimum)
v) w/c	0.45
vi) Workability	100 mm (slump value)
vii) Condition of exposure	Severe (for reinforced concrete)
viii) Supervision degree	Good
ix) Aggregate type	Angular crushed aggregate
x) Max. content of cement	450 kg /m3

DATA FOR TESTING OF MATERIALS:

i) Cement	OPC 53 grade conforming to IS 8112
ii) SG of cement	3.15
iii) SG of:	
1) CA	2.74
2) FA	2.74
iv) Water absorption:	
1) CA	Nil
2) FA	1.2 percent
v) Free (surface) moisture:	
1) CA	Nil (absorbed moisture also nil)

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2) FA	Nil
vi) Sieve analysis:	
1) CA	Conforming to Table 2 of IS 383
2) FA	Conforming to grading Zone I of Table 4 of IS 383

3.2. Replacement:

Coarse aggregates are replaced in percentages of 0,5,10,15,20,25 and 30% by E-waste material which has undergone various tests as per table 5.

3.3. Casting:

Cubes of dimensions 15*15*15cm were cast to test the CS of the various mixes of concrete at various days. Similarly, 15*30 cm cylinders were mould and casted for testing concrete's strength in tension, and 10*10*50 cm beams to test the FS of concrete. Figure (5) depicts the casting of moulds that will be cured and evaluated.

3.4. Curing:

Cubes, cylinders, and beams casted were cured in water tanks under appropriate conditions and tested at designated days of curing. Figure (6) shows the curing process for the samples.

Figure 5- Casting of moulds

Figure 6- Curing of moulds

3.5. Testing of material:

Tests were conducted on E-waste, as per respective IS codes. **Table 5** represents respective data for the same.

Sr. No.	Characteristics	Value
1	SG	1.77
2	IV	12.03%
3	CV	17.74%
4	Abrasion value	2.258
5	Water absorption	Nil

Table 5: Test data for E-waste material

3.6. Tests conducted on materials:

3.6. 1. Slump cone test

Workability of concrete at varying percentages of replacement was tested using slump test. CS,FS, and STT were used to determine the strength of
the concrete after 7, 14, and 28 days of curing when partial substitution of CA by E-waste material was in proportions of 0%, 5%, 10%, 15%, 20%, 25%, and 30%.

The test examines the workability of freshly mixed concrete and, subsequently, its flowability. The slump values for M-40 grade concrete are tested when CA is substituted with E-waste in proportions of 0%, 5%, 10%, 15%, 20%, 25%, and 30%. Figure (7) depicts the slump cone test in action with results noted down in **Table 6**.

Figure 7- Slump cone test

3.6.2. Compressive strength test

The compression test is performed on standard cubes with size of 150 mm * 150 mm * 150 mm at 7, 14, and 28 days of curing, as illustrated in Figure (8), and the results are listed in Table 9. The specimen's compressive strength was calculated by-

Fck = Pc/A

Figure 8- Compressive strength test

3.6.3. Flexural strength test

The stress in a material right before it yields in a flexure test is defined as flexural strength, also known as modulus of rupture. The standard specimen size in this investigation was 100 mm width, 100 mm depth, and 500 mm length. The beam specimen's flexural strength was computed by-

$$\mathbf{Fb = PL/bd^2}$$

Observations were noted down for each specimen and the values obtained for 0%, 5%, 10%, 15%, 20%, 25% and 30% are given in **Table 7.**

3.6.4. Split tensile test

Concrete is weak in tension due to its brittle nature, and it is not expected or trusted to withstand direct tension. Splitting tensile strength test on concrete cylinder is a method used to assess the tensile strength of concrete. Tensile cracking can occur in concrete structures due to a variety of processes and applied loads, making tensile strength a critical attribute of concrete. However, tensile strength in concrete is quite low when compared to compressive strength. The values obtained for various replacement proportions are shown in **Table 8** for 300 mm long and 150 mm diameter cylinders placed in the machine with load applied on the opposite sides of the cylinder.

Split tensile strength calculation is given below:

$$\mathbf{F = 2P/\pi DL}$$

4. RESULTS AND DISCUSSION:

Coarse aggregates were partially substituted by E-waste in various proportions namely 0%, 5%, 10%, 15%, 20%, 25% and 30%, and Various tests were conducted to test different properties of concrete after the specified days of curing. Acquired results are discussed below.

4.1. Slump cone test

Test was conducted on the mixes with percentage of replacement for 0%, 5%, 10%, 15%, 20%, 25% and 30% and the result values are given below in Table 8.

Table 6 shows the workability of the mix with % of E-waste replacement and slump value.

Figure (9) represents the graphical representation of slump value vs. e-plastic waste percentage.

Sr. No.	Grade of Concrete	% Replacement	Mix Type	Slump (mm)	Degree
1	M-40	0%	M-401	100	High
2	M-40	5%	M-402	100	High
3	M-40	10%	M-403	100	High
4	M-40	15%	M-404	96	Medium
5	M-40	20%	M-405	95	Medium
6	M-40	25%	M-406	94	Medium
7	M-40	30%	M-407	90	Medium

Table 6: Test result data for Slump cone test

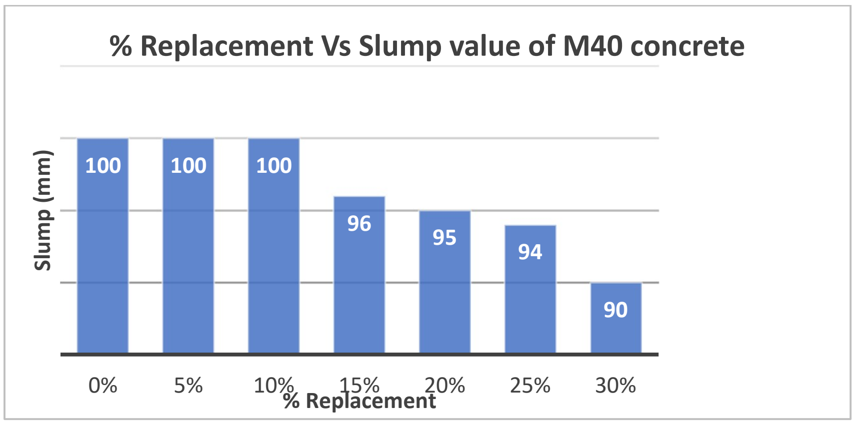

Figure 9- Slump cone test results

4.2. Compressive strength test

Table 9 and Figure (10) shows the comparison of compressive strength for 7, 14 and 28 days. The test results showed higher strength for 28 days for up to 15 percentage replacement by E-waste plastic. The compressive strength for M40 grade of concrete at 28 days is achieved up to replacement of 15%.

		Compressive strength at days of curing (N/mm2)		
% Replacement of CA by E-waste	Mix Type	7 days	14 days	28 days
0	M-401	26.37	31.26	41.93
5	M-402	23.11	29.33	41.04
10	M-403	22.37	28.00	40.30
15	M-404	19.40	25.93	40.10
20	M-405	16.59	22.37	33.48
25	M-406	13.33	20.15	29.63

30	M-407	11.85	18.07	27.26

Table 9: Test result data for Compressive strength test

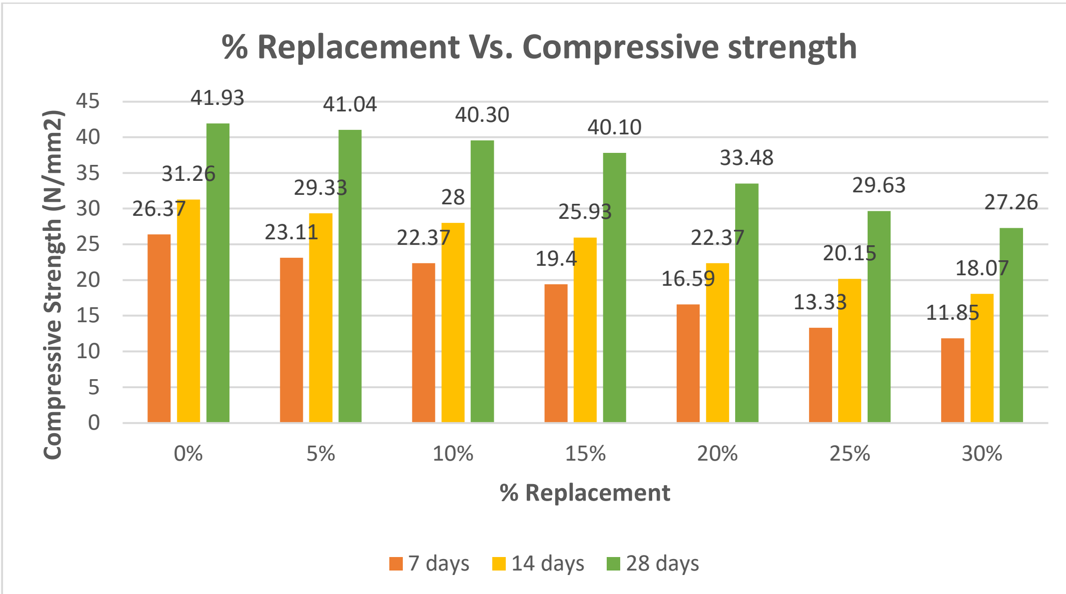

Figure 10- Compressive strength test results

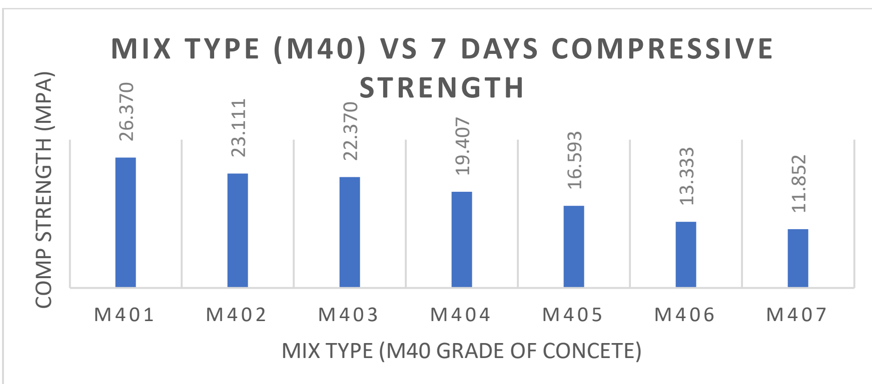

Figure 11- test results for Compressive strength (7 days curing)

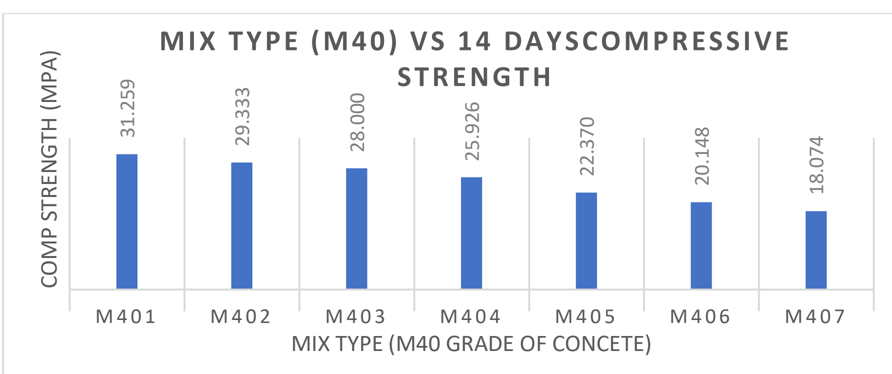

Figure 12- test results for Compressive strength (14 days curing)

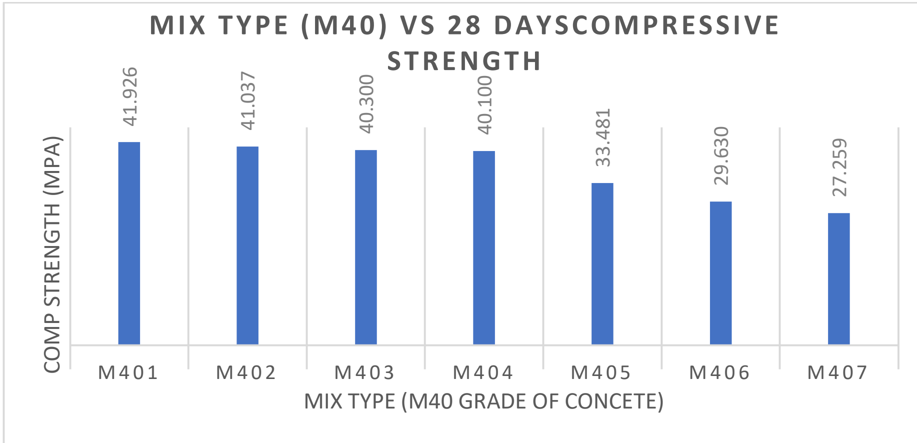

Figure 13- test results for Compressive strength (28 days curing)

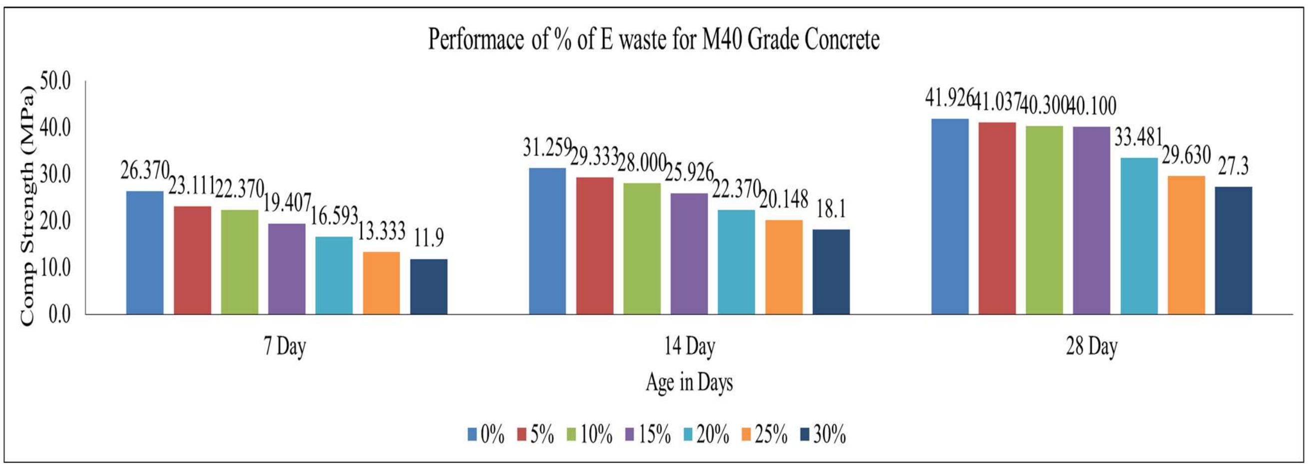

Figure 14- Compressive strength test results comparison

4.3. Flexural strength test

Table 7 and Figure (15) shows the comparison of flexural strength for 28 days of curing at specified proportions of percentage substitution of CA with E-waste plastics. The test result shows flexural strength at 28 days for mixes with varying % of E-waste plastics. Replacing 15% gives better value as Flexural strength slightly declines with further increase in E-waste proportion.

Table 7:

Test result data for Flexural strength test

	Flexural strength at days of curing (N/mm2)
% Replacement of CA by E-waste	**28 days**
0	4.33 N/mm2
5	4.42 N/mm2
10	4.33 N/mm2

15	4.17 N/mm2
20	3.92 N/mm2
25	2.92 N/mm2
30	2.17 N/mm2

Table 7: Test result data for Flexural strength test

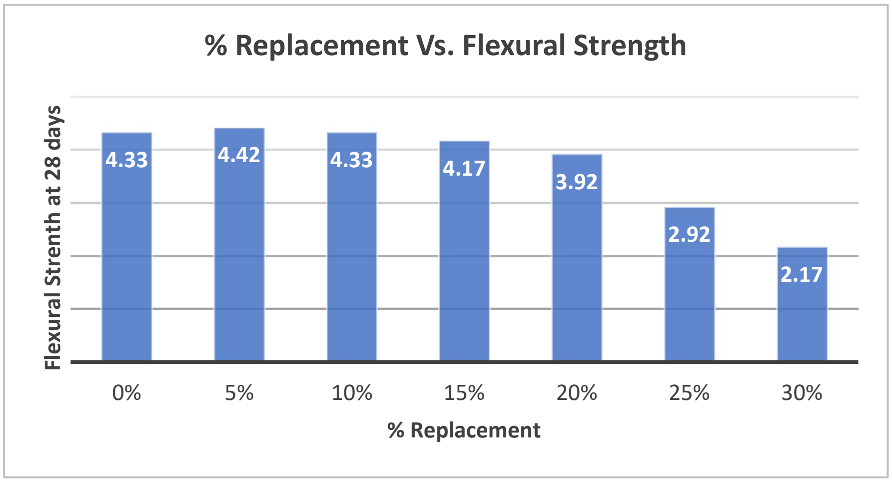

Figure 15- Flexural strength test results

4.4. Split tensile test

Table 8 and Figure (16) displays the comparison of tensile test results for 28 days of curing with varying percentage of E-waste plastics.

	Tensile strength at days of curing (N/mm2)
% Replacement of CA by E-waste	**28 days**
0	4.38 N/mm2
5	4.19 N/mm2
10	4.01 N/mm2
15	3.17 N/mm2
20	3.00 N/mm2
25	2.49 N/mm2
30	1.93 N/mm2

Table 8: Test result data for tensile strength test

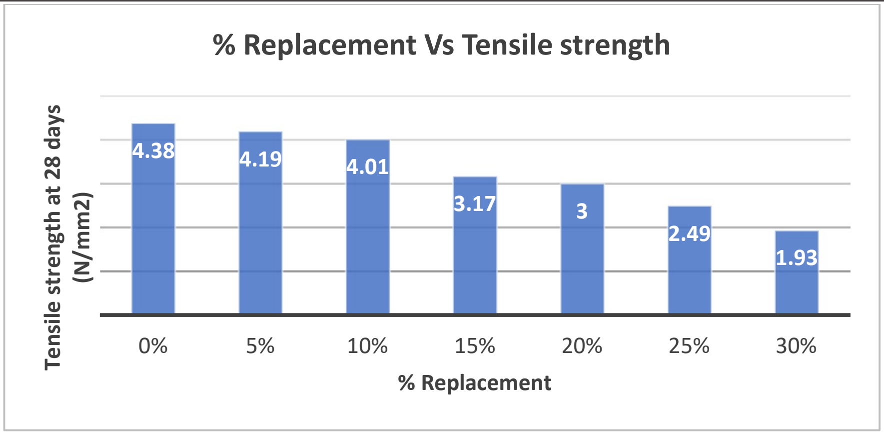

Figure 16- Tensile strength test results

5. CONCLUSION

Experiments on M40 grade concrete using E-waste as a partial replacement for CA showed that after curing under appropriate conditions for 28 days, the concrete mix with 15% E-waste replacement had compressive strength nearly equal to that of concrete without any replacement. Thus, 15% of E- waste can be used as a PR for CA. This mix with 15% E-waste replacement had flexural strength of 4.17 N/mm2 and tensile strength of 3.17 N/mm2, respectively after curing for 28 days and up to 10% replacement workability of concrete is constant in terms of slump 100 mm after that it will be decrease.

E-waste reuse and recycling can potentially help in reducing E-waste and solid waste while also helping to conserve the environment to some extent. The utilization of e-waste in construction sites can lower construction costs, and additional research in this field around the world can yield greater outcomes. As a result, using E-plastic wastes in building can be cost-effective, efficient, and beneficial to not only one industry, but the entire environment.

6. REFERENCES

[1] S.R. Shamili, C. Natarajan, J. Karthikeyan, An overview of electronic waste as aggregate in concrete, Int. J. Struct. Constr. Eng. 11 (2017) 1444–1448.

[2] K. Alagusankareshwari, S. Sandeepkumar, K.B. Vignesh, K. Abdul H. Niyas, An experimental study on E-waste concrete, Ind. J. Sci. Technol. 9 (2) (2016) 1–5.

[3] R. Lakshmi, S. Nagan, Studies on concrete containing E-waste plastic, Int. J. Environ. Sci. Vol-1 (2010) 270–281.

[4] A. Arora, U. Dave, Utilization of E-waste and plastic bottle waste in concrete, Int. J. Students Res. Technol. Manage. 1 (2013) 398–406.

[5] Report on “E-waste Inventorisation in India”, MAIT-GTZ Study, 2007

[6] IS : 2386 (Part I) – 1963,Indian Standard Methods of test for Aggregate for Concrete Part, Size and Shape, Bureau of Indian Standard, New Delhi.

[7] A.R.Ingole, S.K. Gulhane, S.S. Shirbhate, M.P. Chavhan, T.N. Makde, Use of Electronic Waste Concrete for Road Construction, Int. J. of Engg. And Adv. Tech. Vol-9, Issue-5 (2020)
[8] S.R. Raut, R.S. Dhapudkar, M.G. Mandaokar, Experimental Study on Utilization of E -Waste in Cement Concrete, Int. J. of Engg. And Sci. (2018) 1805 PP 82-86
[9] S.Ahirwar, P.Malviya, V.Patidar, V.K.Singh, An Experimental Study on Concrete by using EWaste as Partial Replacement for Course Aggregate, Int. J. of Sci., Tech. and Engg., Vol 3, Issue 4 (2016)
[10] Aditya, Shubhan Soni, Dinesh Sutar, Praveen Patel, Utilization of E-plastic waste in concrete, Int. J. Eng. Res. Technol. 5 (2016) 594–601.
[11] M. Manikandan, Arul Prakash, P. Manikandan, Experimental study on E-waste concrete and comparing with conventional concrete, J. Ind. Pollut. Control 33
(S3) (2017) 1490–1495.
[12] Sharif Mohd, Vijay Kaushal, E-waste management in India: current practices and challenges (2018) 1–13.
[13] Jianjie Fu, Haiyan Zhang, Aiqian Zhang, Guibin Jiang, E-waste recycling in China, Environ. Sci. Technol. 52 (12) (2018) 6727–6728.
[14] M.U.Donadkar, S.S. Solanke, Review of E-Waste Material used in Making of Concrete, Int. J. of Sci., Tech. and Engg., Vol 2, Issue 7 (2016)