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Experimental Evaluation of New-Generation Waste Material as a Substitute in M-50 Concrete Mixes

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Abstract:

The journey of concrete began around 600 BC, when the ancient Romans began widely using concrete for construction by mixing volcanic ash, lime, and seawater. Centuries later, it was in 1824 that Joseph Aspdin invented Portland cement by burning finely crushed chalk and clay until the carbon dioxide was eliminated. Between 1850 and 1880, Francois Coignet used Portland cement extensively for the first time in the construction of homes in England and France [17]. Since then, though there have been vast innovative leaps, improvements and inventions in the material used in construction, the construction industry is still heavily reliant on Portland cement and aggregates. This excessive use and mass dependence on concrete is now a concern for the construction industry as the natural resources used in concrete like sand and gravel are slowly being depleted. In addition, the environmental concerns relating to CO2 emissions from concrete have forced the industry to start looking for alternatives for the ingredients used in concrete.

On the other hand, electronic waste, also known as electronic waste, is considered one of the harmful types of electronic waste in today's new age world. Drinking water supplies are becoming polluted, and the environment and ecosystems are being impacted all around the world as a result of the unceasing increase of these technological wastes. Both of these 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 such as 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 M-50 grade high strength concrete when coarse aggregate is replaced by E-waste plastics in staggered percentages. The strength of concrete containing E-waste plastic was tested at different time intervals after coarse aggregates were replacement with varying percentages of E-plastic waste by the volume range from 0 to 30 percentage. When compared to normal concrete, concrete with E-waste had comparable compressive, flexural, and tensile strength for 28 days up to a specified percentage of replacement. When the E-waste plastic component percentage is considerably high, however, there is a decline in strength after a certain point

Introduction

The massive leaps that technology has taken over the past few decades have proven to be both a boon and a curse for our world.This rapidly advancing 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 which 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 amounts of E-waste, has resulted in the majority of E-waste being dumped directly into the ground, resulting in hazardous solid waste. The chemical "lead" present in E-waste is almost certain to impair human health which hasresearchers all over the world concerned about the management, disposal, and handling of E-plastic waste. Research activities are now being focused on adopting numerous strategies to manage E-waste plastics, one of which is utilizing this E-waste plastic in the construction industry. This serves a greater purpose as today, natural resources utilized in construction materials are depleting at an alarming rate, necessitating the search for a replacement.

During 2007, the Manufacturers' Association for Information Technology (MAIT) in India conducted an e-waste inventory based on 3 products: mobile phones, laptops and TV. In India, the total amount of e-waste generated in year 2007 was 3, 32,979 (MT) (Computer: 56324MT, Mobile Phones: 1655MT, and Televisions: 275000MT). According to this estimate, the volume of e-waste reached about 0.7 million MT in year 2015, and is expected to reach 2 million MT by 2025 [14](**Fig.1**).

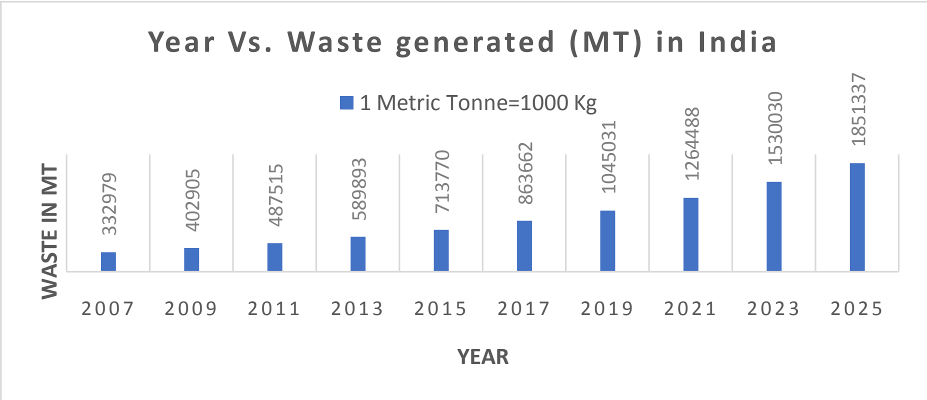

Figure 1 - Growth of E-waste in India

Alagusankareswari et al. (2015) [7] experimented with E-Waste as a fine aggregate replacement. According to their research, the CS, FS, TS of concrete reduced when check with a control mix. Lakshmi and Nagan (2010) [8] conducted research on the partial replacement of CA with E-Waste particles in proportions range from 0 to 30 percentage. According to research, when the E-plastic component was increased by 20%, the strength fell. Shamili et al. (2017) [6] gave a comprehensive overview of E-Waste composition, preparation, characteristics, and classification.

Arora and Dave (2013) [9] examined the strength of concrete when fine aggregate was replaced with E-waste and plastic waste in percentages of 0%, 2%, and 4%. Their research revealed that the strength of concrete rose by 5% while the cost of concrete manufacture decreased by 7%.

The objective of this experiment is to determine if using E-waste plastic as a partial replacement for coarse aggregate in M-50 grade concrete with cement OPC 43 grade complying to IS 8112 in the proportions of 0 to 30% is feasible. On the age of 7,14,28 days of curing, compression strength is evaluated and compared, while tensile strength and flexural strength are compared on the 28th, 56th and 90th day of curing. The purpose of the experimental work was to use E-waste components as a partial replacement for coarse aggregate. The results from the study revealed that mix types exhibit good compressive strength in concrete with 15% replacement in M50 grade concrete. Crushed E-waste plastic material could be used as an alternative material in the construction industry, thereby lowering the cost of concrete construction and manufacturing while also helping with the environmental concerns with respect to concrete.

1. Materials

1.1. E-plastic waste: Every day, tons 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 replacement for Coarse Aggregate in varied amounts.

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

Classification of E-waste material

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%

Figure 2- Crushed E-waste material collected for replacement

1.2. Cement: The tests were conducted on OPC of 53grade and all properties of cement 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.

Table 2:

Sr. No.	**Characteristics**	**Value**
1	Consistency	31 %
2	Initial Setting Time	87 min
3	Final Setting Time	350 min
4	Fineness	94 %
5	Soundness	2 mm

1.3. Fine aggregate: The sieve size is used for test is 4.75 mmfor fine aggregates, removing undesirable stones and impurities. Fine aggregate is aggregate that has passed through a 4.75 mm sieve. IS-2386 (PART-1) 1963 I Is used to characterize fine aggregate properties. **Table 3** depicts the Fineness Modulus, bulking, Water Absorption, and Specific Gravity values of Fine Aggregate.

Sr. No.	**Characteristics**	**Value**
1	FM of Fine Aggregate	4.96
2	Bulking (%)	3

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3	Water Absorption (%)	1.2
4	Specific Gravity	2.74

1.4. Course aggregate: For the experiment, coarse aggregates with a size of 20 mm 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, Crushing Value, Impact value and Specific gravity.

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

2. Methodology

2.1 Concrete Design: (IS-10262-2019)

Material (kg/m30	0%	5%	10%	15%	20%	25%	30%
Cement	427	427	427	427	427	427	427
Water	192	192	192	192	192	192	192
Fine aggregate	701	701	701	701	701	701	701
Coarse aggregate 20 mm	572	572	572	572	572	572	572
Coarse aggregate 10 mm	572	535	516	480	461	425	406
E waste	0	12	36	48	72	84	108
Water-cement ratio	0.5	0.5	0.5	0.5	0.5	0.5	0.5


Figure 3- Cube mouldFigure 4- Casting

2.2. Replacement: Course Aggregate 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.

2.3. Casting: Cubes of dimensions 15*15*15cm were cast to test the Compressive Strength of the various mixes of concrete at 7^{th},14^{th}and28^{th}days. Similarly, 15*30 cm cylinders are cast to test the Tensile Strength of concrete, and 10*10*50 cm beams are cast to test the Flexural Strength of concrete.

Testing for tensile strength and flexural strength was done at 28, 56 and 90 days. Figure (5) depicts the casting of moulds that will be cured and evaluated.

2.4. Curing:(IS: 516): Cubes, cylinders, and beams cast were cured in water tanks under appropriate conditions and tested at designated days of curing. Figure (6) shows the curing process for the samples.

2.5. 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	Specific Gravity	1.77
2	Impact Value	12.03%
3	Crushing Value	17.74%
4	Abrasion Value	2.258
5	Water Absorption	Nil

2.6 Tests conducted on materials:

2.6.1. Slump cone method(IS: 1199)

The workability of concrete at varying percentages of replacement was tested using SCT. CS, FST, and STT were used to determine the strength of

the concrete after 7, 14,28 days of curing when partial replacement of coarse aggregate by E-waste material was in the proportions of 0, 5, 10, 15, 20, 25, and 30 percentage. The slump values for M-50 grade concrete are tested when CA is replaced 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**.

3. Results and discussion:

The different tests conducted to find the different properties of concrete after partially substituting CA with E-waste plastics of varied percentages, namely 0%, 5%, 10%, 15%, 20%, 25% and 30%, and the acquired results are shown below.

Test result data for Compressive Strength test: The test compressive strength & % Replacement results of 7,14,28 days are shown in Fig.5 as per the results, upto 15% replacement getting the positive results in compression at the age of 28 days curing after 15% replacement results goes on decreasing.

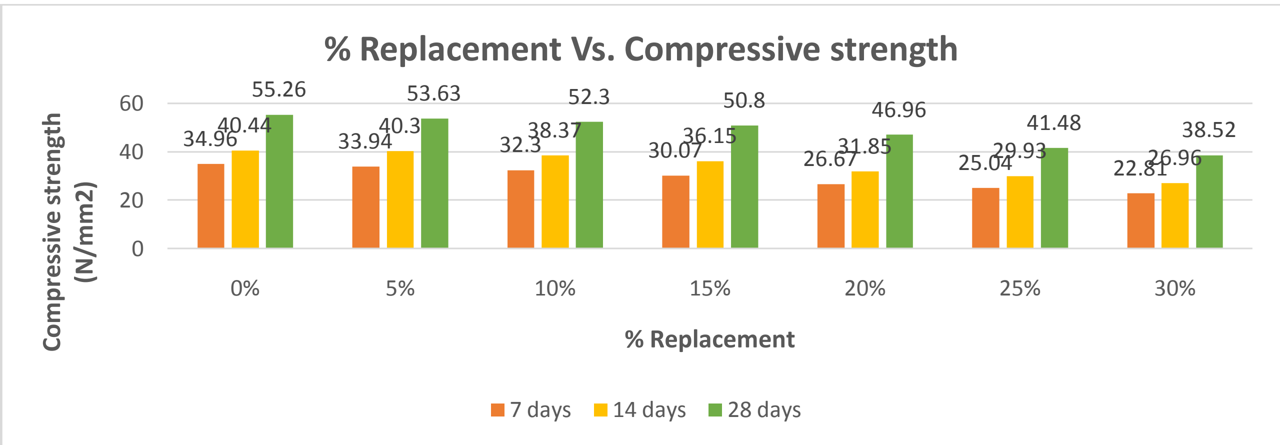


Figure 5-CS test results

The test compressive strength Vs Age in days results of 7, 14, 28 days are shown in Fig.6shown in Fig.5 as per the results, the shown in below at the early age strength goes on increasing upto 14 days after that rate of gain of strength is slower.

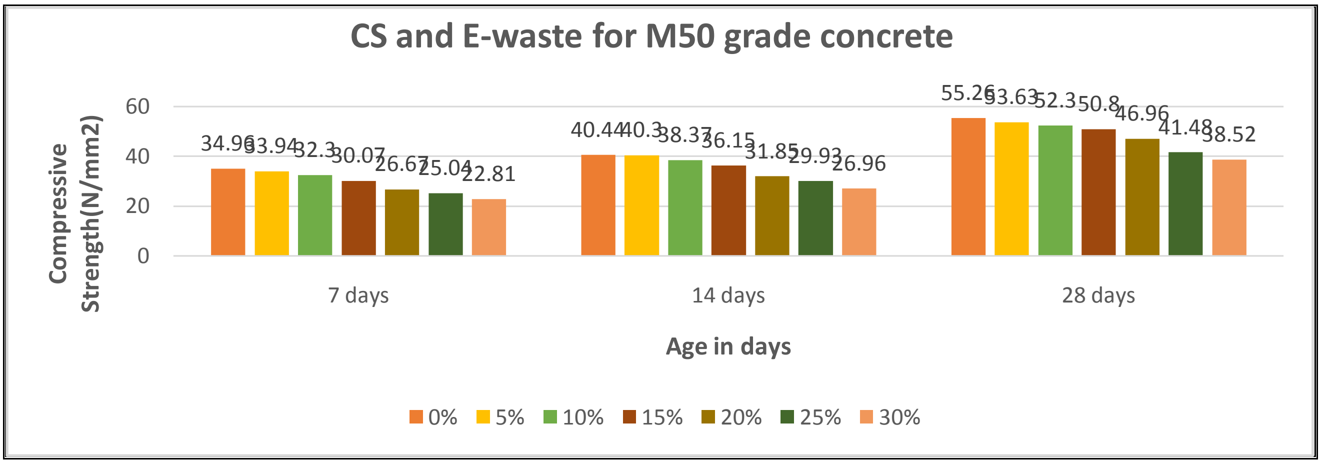
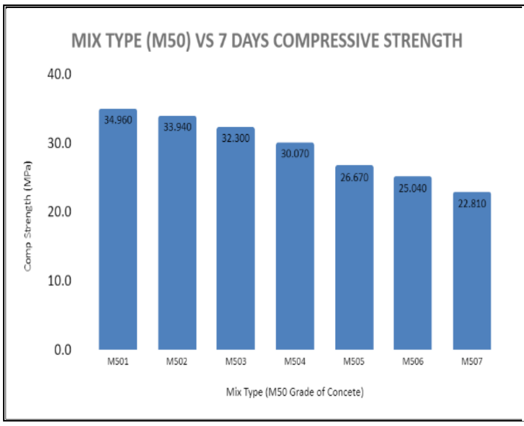


Figure 6- Compressive strength results at various days of curing

The test compressive strength Vs days curing results of 7, 14 and 28 days are shown in Fig.7,8,9as per the results, the shown in below 7 days curing gain the strength upto 68% for control mix and for 30% replacement it is 44% similarly for 14 days and 28 days curing strength goes on decreasing.



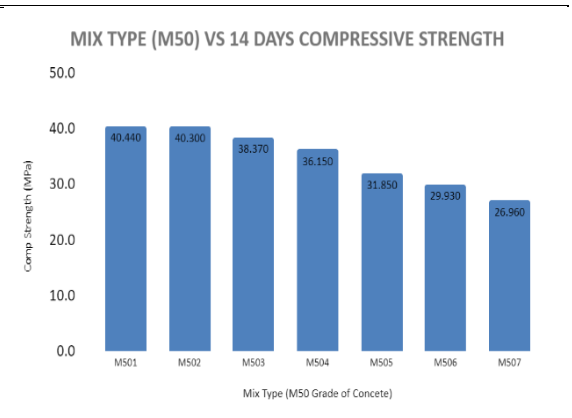


Figure 7- 7 days curingFigure 8- 14 days curing

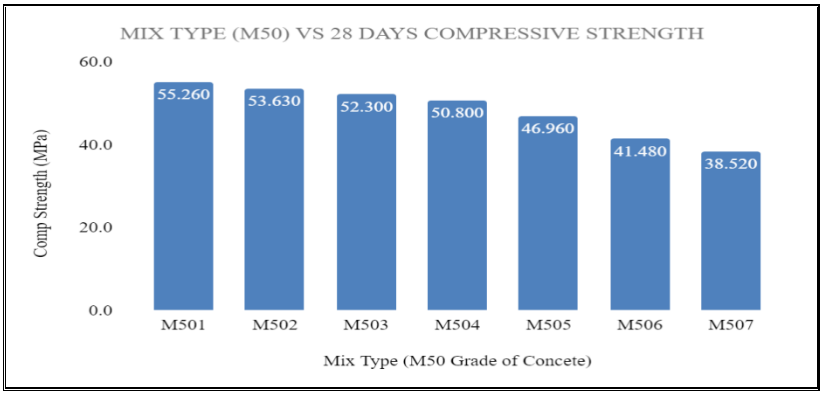


Figure 9- 28 days curing

Test result data for Flexural strength test: The test flexural strength & % Replacement results of 28, 56, 90 days are shown in Fig.10 in flexural test as per IS code strength is same upto the replacement 15% and after this it is decrease with an increase in partial replacement.

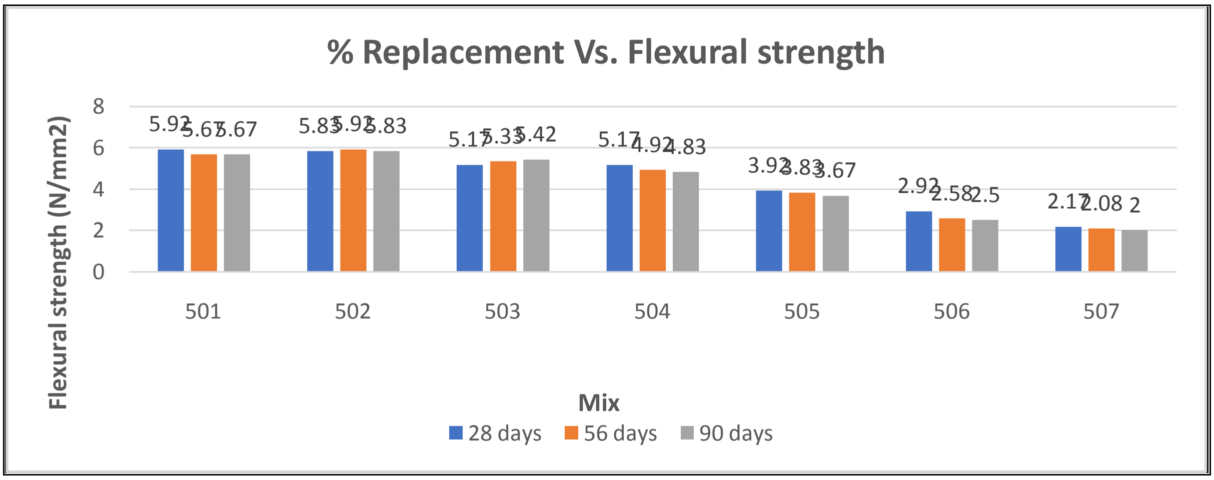


Figure 10- Graphical representation of Flexural strength test results

The test Flexural strength Vs Age in days results of 28, 56, 90 days are shown in Fig.11as per the results, the shown in below at the early age flexural strength upto 28 days after replacement of 15% it is decrease by 12.67%.

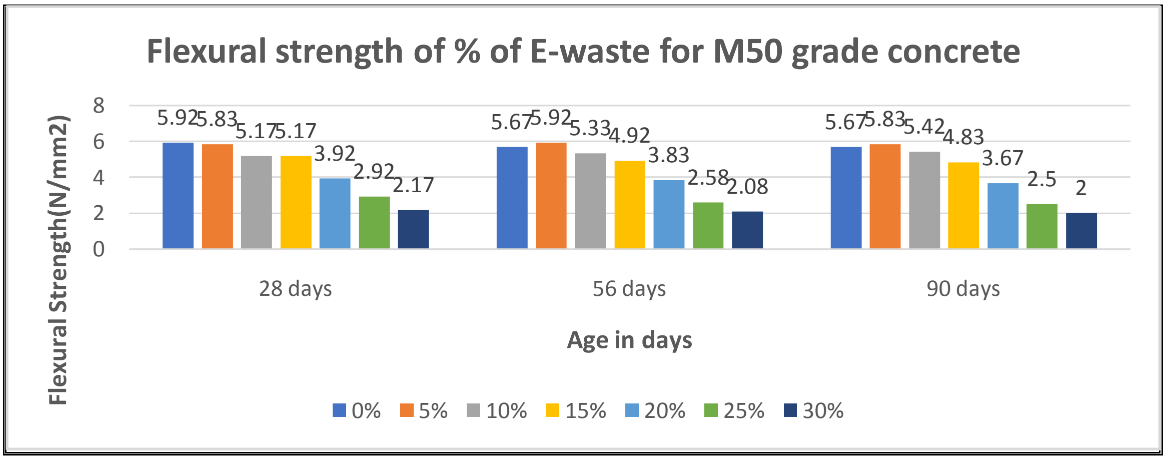


Figure 11- Graphical representation of Flexural strength results at various days of curing

The test Flexural strength Vs days curing results of 28, 56and 90 are shown in Fig.12, 13, 14as per the results, the shown in below at the early age flexural strength upto 56 and 90 days after replacement of 15% it is decrease by 13% and 14%

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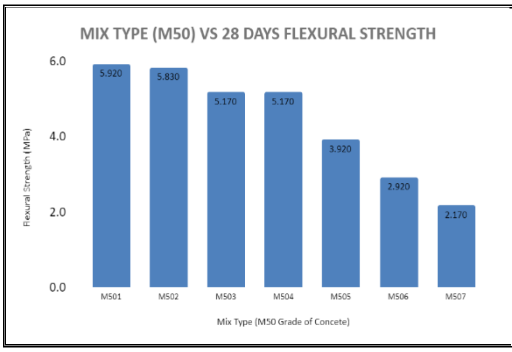


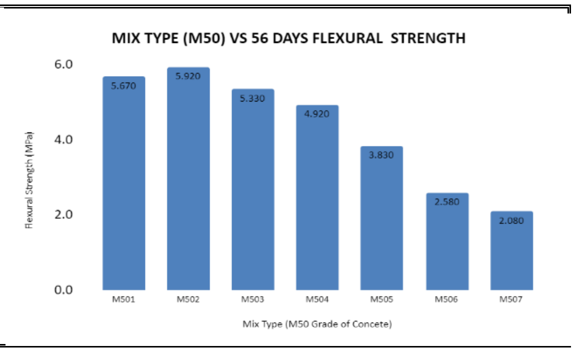


Figure 12- FT results for 28 days curingFigure 13- FT results for 56 days curing

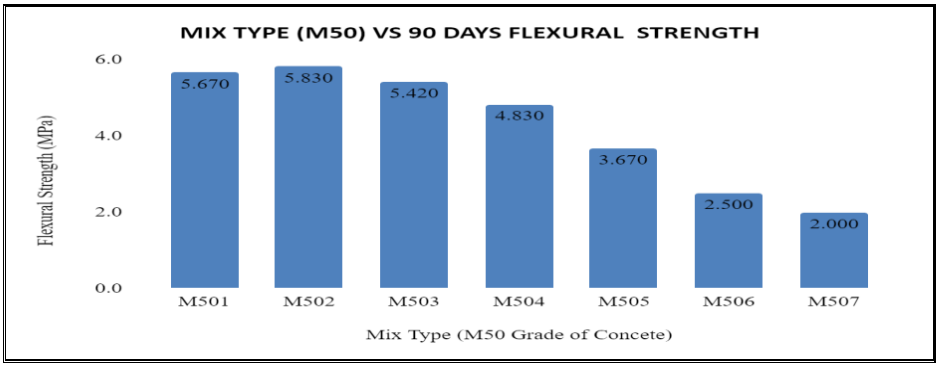


Figure 14- FT results for 90 days curing

Split tensile test

Test result data for Tensile strength test: The test tensile strength & % Replacement results of 28, 56, 90 days are shown in Fig.15 The test tensile strength & % Replacement results of 28, 56, 90 days are shown in Fig.10 in tensile test as per IS code strength is same upto the replacement 15% and after this it is decrease with an increase in partial replacement.

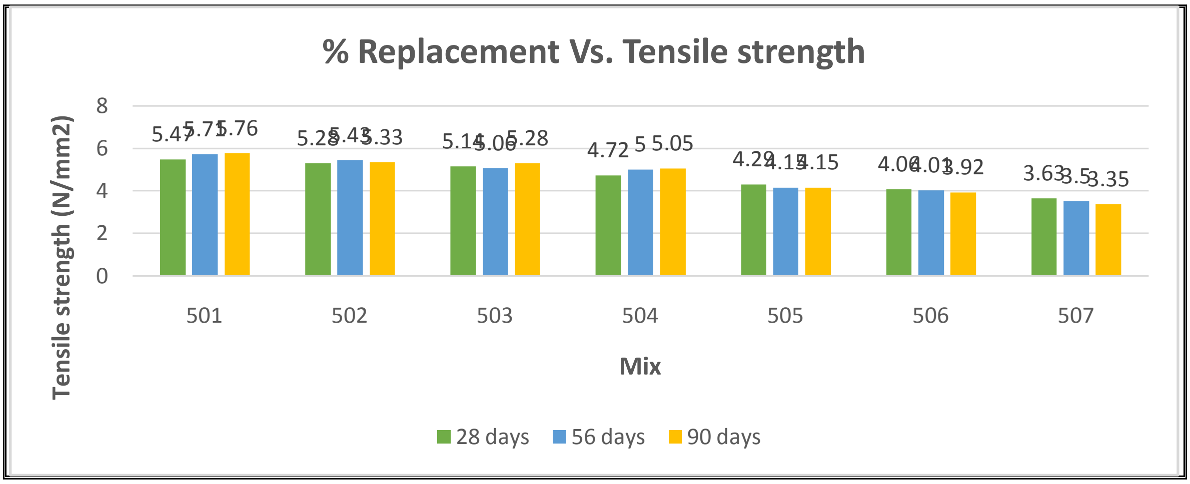


Figure 15- Graphical representation of Tensile strength test results

The test Tensile strength Vs Age in days results of 28, 56, 90 days are shown in Fig.16as per the results, the shown in below at the early age tensile strength upto 28 days after replacement of 15% it is decrease by 13.71% at the age of 28 days curing.

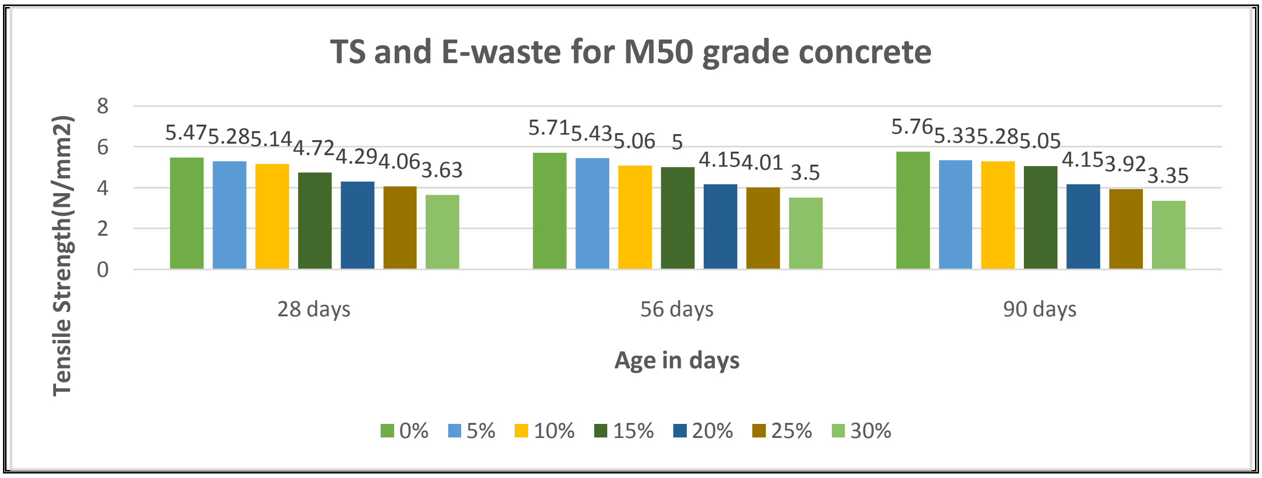
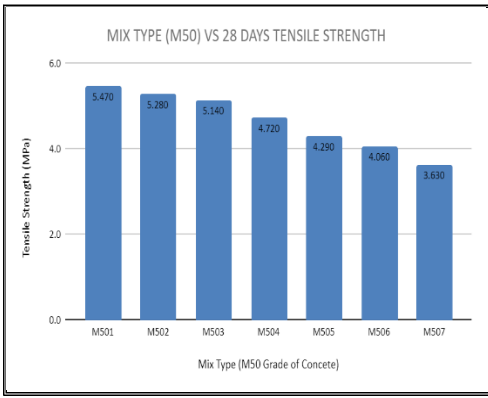


Figure 16- Graphical representation of Split tensile strength results at various days of curing

The test Tensile strength Vs days curing results of 28, 56 and 90 are shown in Fig.17, 18, 19as per the results, the shown in below at the early age flexural strength upto 56 and 90 days after replacement of 15% it is decrease by 12% and 13%**.**



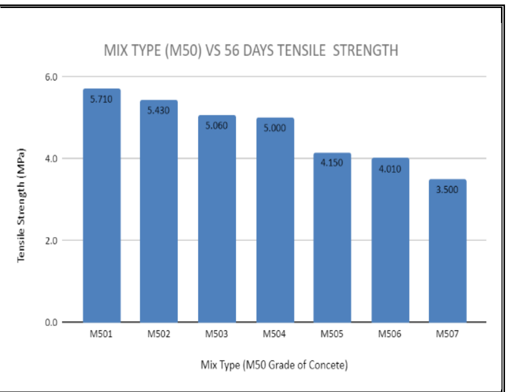


Figure 17- Tensile strength test results for 28 days Figure 18- Tensile strength test results for 56 days

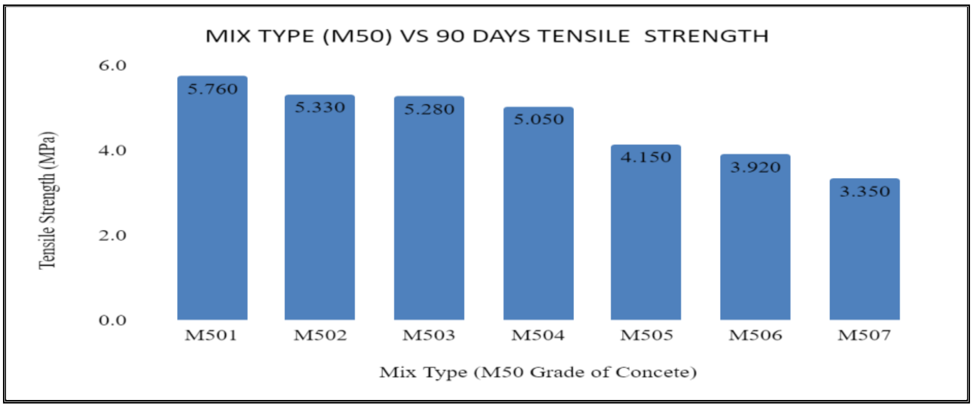


Figure 19- Graphical representation of Tensile strength test results for 90 days curing

5. Conclusion:

Experiments on M50 grade concrete using E-waste as a partial replacement for coarse aggregate showed that at the age of 28 days for curing period, the concrete 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 partial replacement for coarse aggregate. At the age of 28 days for curing period, theConcrete with 15% E-waste replacement had flexural strength of 5.17 N/mm2 and tensile strength of 4.72 N/mm2, respectively.

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.

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