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Experimental Investigation into the Use of E-Waste Plastic as a Partial Replacement for Coarse Aggregate

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Abstract: The aim is to reduce the cost of construction and enhance the properties of the concrete. Also, E-Waste is a global problem for both developing and developed nations. The reason is, there is no method of disposal of E-Waste other than some traditional ones. Landfill and incineration are commonly used for disposal of E-Waste but, landfill needs a wide landmass and also pollute the groundwater by leaching.
In the present thesis coarse aggregate is replaced by E-Waste plastic with various percentages which are 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%. Concrete structures have a lifespan of about 50-100 years. But, deterioration of structure starts in 10 years and sometimes within a year of the construction. Small cracks are generated into the structure after certain years which are either structural cracks or superficial cracks. Thus, the study deals with economical aspect not only for construction but also for maintenance purposes.
Keywords: E-Waste, coarse aggregate, fine aggregate, admixture, Landfill and incineration

I. INTRODUCTION

Concrete is a composite material, consisting of chemically unreactive substances such as coarse aggregate and fine aggregate which are usually referred to as gravel and sand which are bonded together by cement and water. Concrete is used in almost all types of civil engineering works, railways, airports, defence installation etc. In ancient times people used clay as binding substances. Later on, Egyptians started using lime and gypsum together. That was the time when lime came to be considered as the primary construction material.
In 1824 "Joseph Aspdin" burned limestone and clay grounded them and developed Portland cement. Aggregates are to be chosen very carefully because they are inert substances and any impurity in them can react with other components of concrete. In aggregates, the aggregates with size less than 4.75mm are considered as fine aggregates and more than 4.75mm are considered as coarse aggregate.

A. Material and Their Properties

Following are the materials required.

- Cement (OPC 43 grade)
- Fine Aggregate (Sand)
- Natural Coarse Aggregate (NCA)
- E-Waste plastic
- Admixtures
- Water

1) Cement - The cement used in the entire project is ordinary Portland cement. The ordinary Portland cement is classified on the basis of compressive strength obtained after 28 days. Basically, there are three categories of ordinary Portland cement which are OPC 33 Grade, OPC 43 Grade and OPC 53 grade. Here, the numbers i.e. 33, 43 and 53 represent the compressive strength of the cement after 28 days.

2) Fine Aggregate (Sand) - Locally available fine aggregates (sand) are used for making concrete mix. The fine aggregates are sieved from the set of sieves of size ranges from 4.75 mm to 150 microns, and sand finer than 4.75 mm are used thoroughly over the study. The various properties of fine aggregates sand such as specific gravity, gradation of sand to obtain fineness modulus, are tested as per the IS 2386-1870 code recommendation. Table 3.2 showing the grading of Fine aggregates. The grading observed for sand (fine aggregate) belong to Zone II.
3) E-Waste - The Electrical and Electronic Equipment (EEE) and its parts which are discarded or thrown away by the possessor, without intention of reuse is termed as “E- Waste”. E-Waste contain Metal, Plastic, Glass, etc. In this study we deal only with non- hazardous and inert components of E-Waste or more specifically E-Plastic generated out of computers, mobile phones, and washing machines etc. The purpose of the study is to propose a new practice to use the discarded electrical and electronic equipment as beneficial raw material for the concrete.

II. LITERATURE REVIEW

A. Literature of E-Waste as Coarse Aggregate Replacement

1) Gavhane, et al. (2023), In their study they replace coarse as well as fine aggregate by E-Waste which is collected from broken computer parts such as mouse, keyboard, CPU, etc. at various percentages of 0%, 10% and 20% and tested at 7, 14 and 28 days. The specific gravity of the collected E-Waste was found to be 0.84. By replacing coarse aggregate by 10% of E-Waste gives almost same results as conventional concrete in compression. But when they are tested for split tensile strength and flexure strength the strength reduced by 10.62% and 19.65% as compared to conventional concrete. In the same way replacement of coarse aggregate by 20% gives undesirable results i.e. both compressive as well as tensile strength decreases..
2) Manjunath (2023), Replacement of coarse aggregate was done by E- plastic waste. The replacement percentages are 0%, 10%, 20% and 30% with specific gravity of 1.1. The specimens were tested at 7, 14 and 28 days. By increasing E-Waste, the workability decreases. In the same way compressive strength will also decreases as increase in percentage of E-Waste. But at 10% replacement the compressive strength is somehow equivalent to that of control mix. It could be concluded from this study that, effect of water-cement ratio on strength is not useful for E-Waste plastic due to reduction in bond strength because of plastic aggregates.
3) Dawande, et al. (2022), For the study the E-Waste was collected from the local area contains TV, Radio, CD, etc. with specific gravity of 1.17. The coarse aggregate was replaced by e-plastic with 0%, 10%, 15% and 20% and tested at 7, 14 and 28 days. Here, the study comprises two parts, one is replacement of coarse aggregate with e-plastic waste and another is replacement of coarse aggregate with e- plastic along with 10% fly ash as additive.
4) Kumar and Baskar (2022), High Impact Polystyrene (HIPS) plastic was used which is taken from the computer and its accessories with size 6-12mm and specific gravity 1.29. Partial substitution of coarse aggregate is done as 10%, 20%, 30%, 40% and 50%. Three different grades of concrete were prepared i.e., M20, M25 and M30 with water- cement ratio of 0.45, 0.49 and 0.53. 7 and 28days of testing were done. The observations show a decrease in slump with a percentage increase in HIPS content.

B. Compressive Strength Test

The mould is prepared for cubes used in the compression test having a size of 0.15mX0.15mX0.15m. After preparing cubes rest on the compression testing machine and load is applied. After applying load the value noted from the dial gauge. Compressive strength determine at 7 & 28 days.

C. Flexural Strength Test

The mould is prepared for beams used in the bending test having a size of 0.10mX0.10mX0.50m. After preparing beams rest on the flexural testing machine and load is applied. After applying load the value noted from the dial gauge. Bending strength determine at 7 & 28 days

D. Split Tensile Strength

The mould is prepared for cylinder used in the tensile test having a size of 0.15m diameter and 0.30m height. After preparing cylinder rest on the compression testing machine and load is applied. After applying load the value noted from the dial gauge. Tensil strength determine at 7 & 28 days

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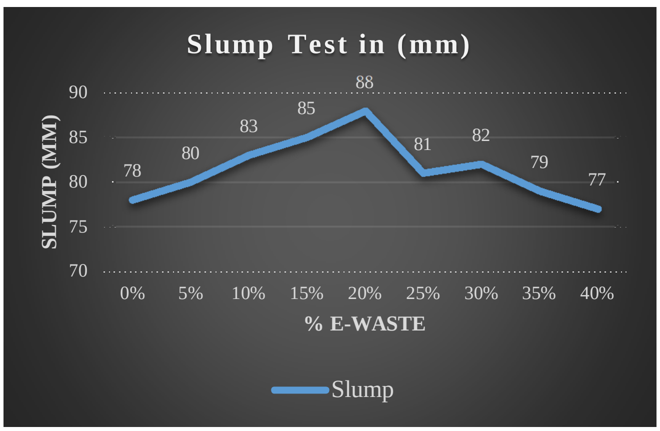
III. TEST RESULTS

A. Workability

As shown in below table 2 for different percentage of micro silica slump value were calculated..

Table 2: Workability Result

Mix	E-Waste (R)	Slump (mm)
C	0%	78
R1	5%	80
R2	10%	83
R3	15%	85
R4	20%	88
R5	25%	81
R6	30%	82
R7	35%	79
R8	40%	77



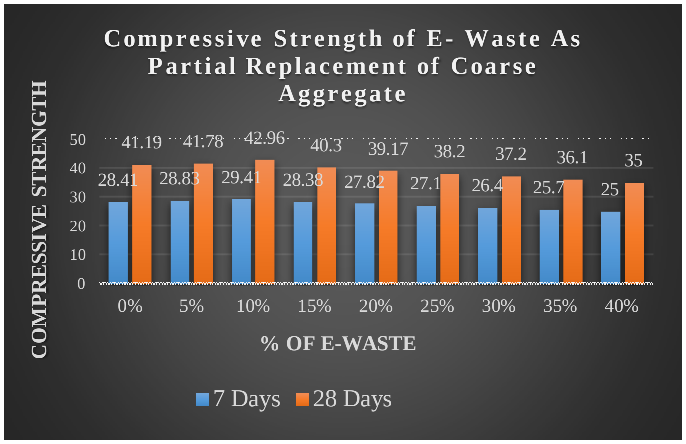
Value of Slump for different concrete mixes

B. Compressive Strength

Tests are performed at the age of 7-days & 28 days of the specimens. Specimens are placed in the test machine as per IS: 516-1959 clause no 5.5.1 page no 11, also loading is applied on the specimen as per the same IS code.

Table 3: Compressive Strength Result

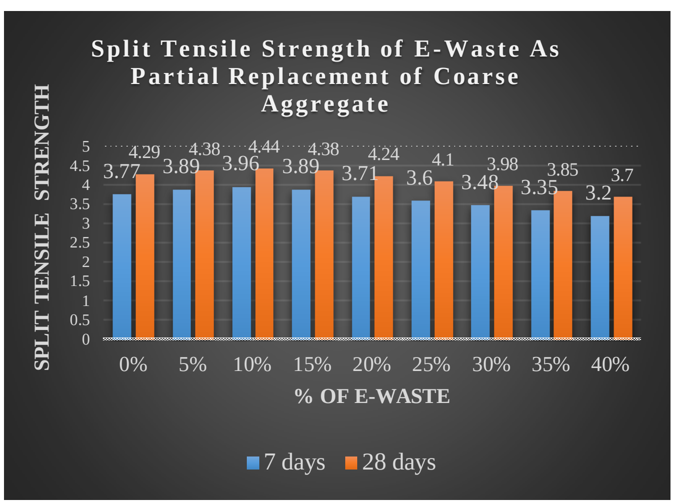
Mix	E-Waste (%)	Compressive Strength (MPa)	
		7 days	28 days
C	0%	28.41	41.19
R1	5%	28.83	41.78
R2	10%	29.41	42.96
R3	15%	28.38	40.3
R4	20%	27.82	39.17
R5	25%	27.10	38.20
R6	30%	26.40	37.20
R7	35%	25.70	36.10
R8	40%	25.00	35.00



7 days and 28 days Compressive Strength at varying percentage of E-Waste

C. *Split Tensile Strength*

Mix	E-Waste (%)	Split Tensile Strength (MPa)	
		7 days	28 days
C	0%	3.77	4.29
R1	5%	3.89	4.38
R2	10%	3.96	4.44
R3	15%	3.89	4.38
R4	20%	3.71	4.24
R5	25%	3.60	4.10
R6	30%	3.48	3.98
R7	35%	3.35	3.85
R8	40%	3.20	3.70



7-days and 28 days Split Tensile Strength at varying percentage of E- Waste

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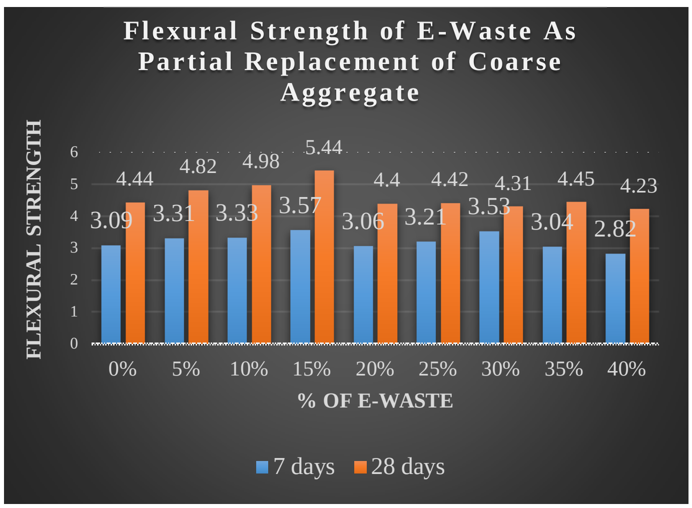
D. Flexural Strength

Beams of size 10cm*10cm*50cm are casted for determining flexural strength. Test on beams are performed at the age of 7 days & 28 days of the specimen. Placement of specimen in machine is done as per IS: 516-1959 in the clause no 8.3.1 page no 17

Table 4: Flexural Strength Result

Mix	E-Waste (%)	Flexural strength (MPa)	
		7 days	28 days
C	0%	3.09	4.44
R1	5%	3.31	4.82
R2	10%	3.33	4.98
R3	15%	3.57	5.44
R4	20%	3.06	4.40
R5	25%	3.21	4.42
R6	30%	3.53	4.31
R7	35%	3.04	4.45
R8	40%	2.82	4.23



7-days and 28 days Flexural Strength at varying percentage of E- Waste

IV. DISCUSSION ON TEST RESULTS

Based on the experimental results, it is observed that the compressive strength of concrete increases with E-waste replacement up to 10%, after which a continuous reduction in strength occurs. The maximum compressive strength was achieved at 10% E-waste replacement for both 7-day and 28-day curing periods. Beyond 10% replacement, the decrease in compressive strength can be attributed to poor bonding between E-waste particles and cement matrix, increased voids, and reduced workability. As the percentage of E-waste increases beyond 20%, the strength reduction becomes more significant.

Therefore, for higher replacement levels of 25%, 30%, 35%, and 40%, the compressive strength was estimated based on the observed decreasing trend. The results indicate that concrete with higher E-waste content shows lower compressive strength at both 7 and 28 days when compared to control mix.

Hence, it can be concluded that 10% E-waste replacement is the optimum percentage for achieving maximum compressive strength.

The split tensile strength of concrete incorporating E-waste shows an increasing trend up to 10% replacement level. The maximum split tensile strength was observed at 10% E-waste replacement for both 7-day and 28-day curing periods.

Beyond 10% replacement, a gradual reduction in split tensile strength is observed. This reduction may be attributed to weak interfacial bonding between E-waste particles and cement paste, increased porosity, and non-uniform stress transfer under tensile loading

The flexural strength of concrete was evaluated by replacing coarse aggregate with different percentages of E-waste. From the results, it is observed that the flexural strength increases initially with the increase in E-waste content. The maximum flexural strength was obtained at 15% replacement (R3 mix), which shows 2.57 MPa at 7 days and 5.44 MPa at 28 days, higher than the conventional mix (C).

However, beyond 15% replacement, the flexural strength gradually decreases. This reduction may be due to the weaker bonding and lower stiffness of E-waste particles compared to natural aggregates. Therefore, it can be concluded that 15% replacement of coarse aggregate with E-waste is the optimum percentage for achieving better flexural strength of concrete.

V. CONCLUSIONS

From the above research work the conclusion are as follows:

The slump test results show the workability of concrete with different percentages of E-waste used as a replacement for coarse aggregate. The slump value of the control mix (C) is 78 mm. As the percentage of E-waste increases from 5% to 20%, the slump value gradually increases from 80 mm to 88 mm, indicating an improvement in the workability of the concrete mix. The maximum slump value is observed at 20% replacement (R4).

A. Conclusion on Compressive Strength

1) 7-Days Compressive Strength

The 7-day compressive strength of the control mix (0% E-waste) was 28.41 MPa.

With the incorporation of E-waste, the compressive strength increased and reached a maximum value of 29.41 MPa at 10% replacement.

- At higher replacement levels (25%–40%), a noticeable reduction in early compressive strength was observed.
- Hence, 10% E-waste replacement is optimum for 7-day compressive strength.
- Thus, the optimum 7-day compressive strength of 29.41 MPa was achieved at 10% E-waste replacement.

2) 28-Days Compressive Strength

- The 28-day compressive strength of conventional concrete was 41.19 MPa.
- The strength increased with E-waste replacement and attained a maximum value of 42.96 MPa at 10% replacement.

B. Conclusion on Split Tensile Strength

1) 7- Days Split Tensile Strength

- The 7-day split tensile strength of the control mix was 3.77 MPa.
- The strength increased with E-waste content and reached a maximum value of 3.96 MPa at 10% replacement.

2) 28- Days Split Tensile Strength

- The 28-day split tensile strength of conventional concrete was 4.29 MPa.
- The incorporation of E-waste improved tensile strength up to 10%, where the maximum value of 4.44 MPa was recorded.

C. Conclusion on Flexural Strength

1) 7- Days Flexural Strength

The 7-day flexural strength results show that the strength of concrete initially increases with the increase in E-waste content. The control mix (C) shows a flexural strength of 3.09 MPa. When E-waste is used as a partial replacement of coarse aggregate, the strength gradually increases and reaches the maximum value of 3.57 MPa at 15% replacement (R3).

2) 28 -Days Flexural Strength

The 28-day flexural strength results indicate a similar trend. The control mix shows a strength of 4.44 MPa, while the strength increases with the increase in E-waste content up to 15% replacement (R3), where the maximum value of 5.44 MPa is obtained.

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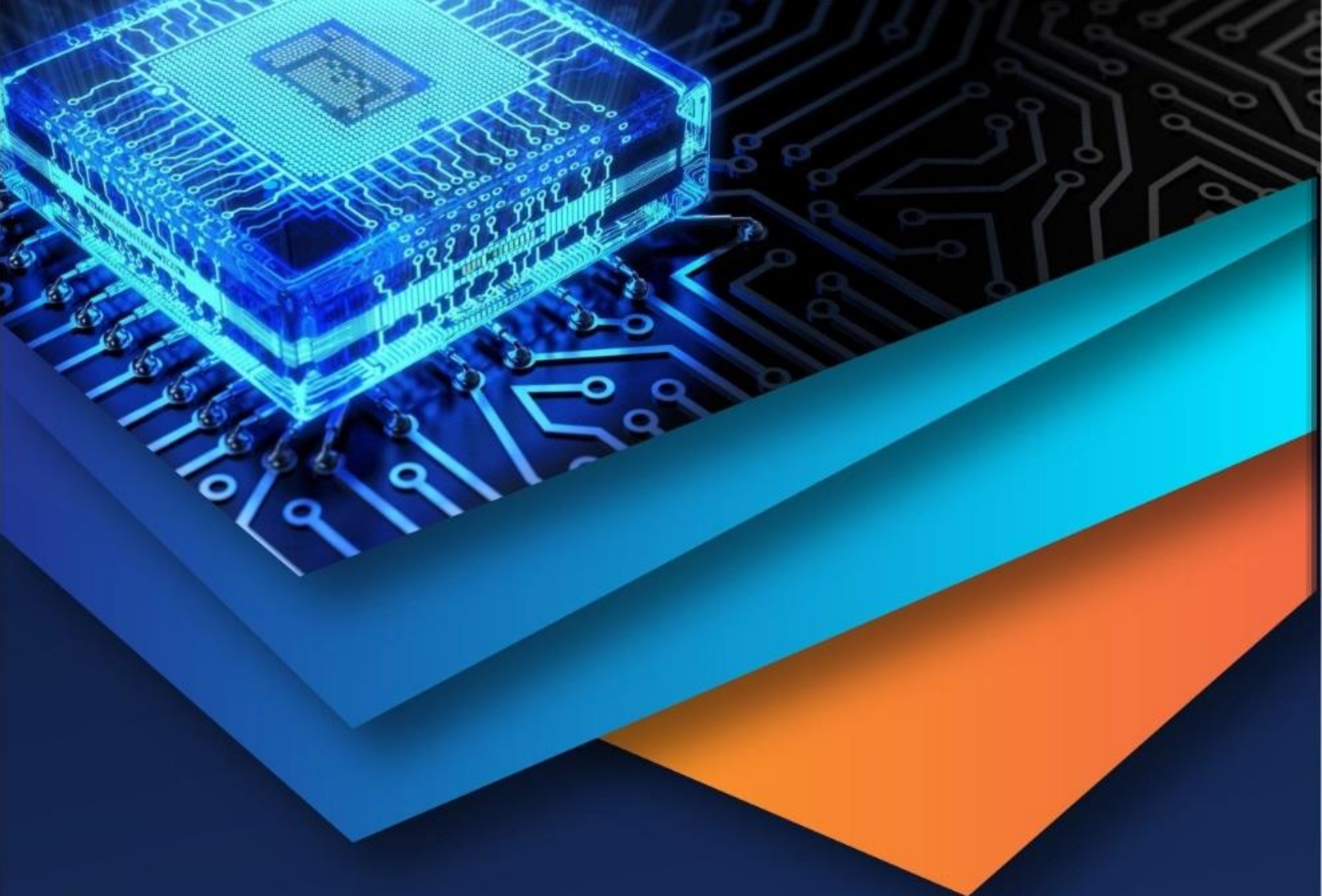

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