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Utilizing Solid Waste and E-Waste as a Replacement for Aggregate in Concrete

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➢ ABSTRACT

Over the past several years, there has been a significant global growth in the creation of Electronic trash (E-waste). The prevalence of electronic devices has significantly increased in recent decades, leading to a corresponding rise in the number of discarded electronic gadgets worldwide. Electronic garbage, often known as E-waste, commonly consists of home electronics, abandoned electronic devices, and circuit boards. Due to the increasing prevalence of consumer electronics, a substantial amount of electronic trash is generated on a daily basis. The utilisation of discarded electronic waste plastics as aggregates or fillers in various construction applications can be seen as a cost-effective and technically feasible solution for managing the disposal of a significant volume of waste. These plastics can be employed as aggregates and fine fillers in concrete or for constructing flexible pavements. The objective was to ascertain the feasibility of utilising E-waste plastic components as a substitute for traditional materials such as bitumen, as a filler in the bituminous mix for a flexible pavement construction. This is a viable alternative approach to mitigate the increasing volume of electronic trash.

Key Words: E-waste**,** Coarse aggregate, Solid waste Strength properties

➢ INTRODUCTION

E-waste, or electronic and electrical trash, does not undergo disintegration or degeneration. The widespread use of electronic and electrical devices has resulted in the emergence of a very dangerous form of garbage known as "electronic waste" or simply e-waste. Electronics that have been categorised for reuse, resale, salvage, recycling, or destruction are also classified as e-waste.

While the advancement of electrical items has undoubtedly improved the convenience of daily living, it has also fostered a disposable mindset. In contemporary times, individuals tend to favour purchasing a new appliance rather than undergoing the effort of repairing their existing one. This tendency not only results in a rise in the quantity of electrical and electronic trash but also presents a significant risk to human health and the environment. The amount of electronic garbage (e-waste) has been increasing at an exponential rate in recent years due to the fast growth of markets for these products. Currently, electronic trash is one of the fastest-growing types of garbage.

Regularly, numerous obsolete computers, mobile phones, television sets, and radio equipment are discarded, with the majority being either dumped in landfills or illegally recycled. The informal processing of electronic trash in underdeveloped nations can lead to significant health and environmental issues, as many countries have minimal regulatory supervision over e-waste processing.

The issue of discarding and managing solid waste products has emerged as a significant environmental, economic, and social concern in all countries. An integrated waste management system, encompassing strategies such as source reduction, reuse, recycling, landfilling, and incineration, must be implemented to effectively address the growing issue of garbage disposal. Generally, e-plastics are not recycled into the same sort of plastic items that are manufactured from recyclable plastics. There is a growing trend towards the utilisation of biodegradable polymers. If any of these polymers are mistakenly combined with other plastics during the recycling process, the resulting recovered plastic cannot be recycled due to the differences in characteristics and melting temperatures.

➢ PAST STUDIES

Kaniskha et al. (2019) examined the concrete compositions including different proportions of electronic trash. When it comes to getting rid of a significant quantity of E-waste, using it in the concrete industry is seen as the most practical and viable option. The study was carried out using M30 concrete. The substitution of coarse aggregate with E-waste at varying percentages of 0%, 5%, 10%, 15%, 20%, and 25%. Ultimately, the mechanical characteristics of the concrete mix samples resulting from the inclusion of these substances are contrasted with those of the standard concrete mix. The test findings demonstrated a noteworthy enhancement in compressive strength in the e-waste concrete when compared to conventional concrete, indicating its effective use in concrete. Balasubramaniam et al. (2018) conducted an empirical study on electronic trash. It has been verified that the addition of e-plastic does not significantly affect the compressive strength of concrete. Nevertheless, when

The addition of 1% e-plastic to a 5cm mixture results in a 2.59% decrease in compressive strength compared to the control mix. The inclusion of e-plastic-4cm and e-Plastic-3cm results in a significant enhancement in compressive strength, with gains of up to 5.9% and 10.6% respectively compared to the control mix. Furthermore, they have verified that the tensile strength of concrete is enhanced by the use of e-plastic. Adding 1% of e-plastic to a 5cm sample increases the tensile strength by 2.3%. Adding 1% of e-plastic to a 4cm sample increases the strength by 4.6%. Adding 1% of e-plastic to a 3cm sample initially increases the tensile strength by 4.6% compared to the control mix after 28 days of curing, but then the strength decreases with further increases in percentage. Therefore, they have determined that the e-plastic concrete exhibited more strength in comparison to traditional concrete. Raut et al. (2018) discovered that e-waste may be substituted for coarse aggregate, and their research provided solid evidence for the feasibility of using e-waste as a replacement for both fine and coarse aggregate. Increasing the use of this waste material helps decrease the need for natural resources in concrete production. It is crucial to seek alternatives for coarse aggregate. Manjunath (2017) performed an empirical study on the use of e-waste in concrete. The study examined the effects of adding different proportions of e-waste to M20 grade concrete on its compressive strength, tensile strength, and flexural strength. Utilising e-waste materials in concrete not only provides cost-effectiveness but also aids in mitigating waste disposal issues. Complete substitution of concrete is unattainable as no other material possesses the same level of strength, durability, and workability as concrete.

Akram (2017) noted a drop in strength when e-waste was added, resulting in the inclusion of 10% fly ash. According to reports, incorporating e-waste into concrete can save disposal expenses and conserve energy. It would indirectly safeguard the ecosystem against the negative impacts of solid waste contamination. Waste creation poses the greatest ecological challenges for the ecosystem. E-waste products, particularly, are more hazardous and poisonous than other types of solid trash. In their 2015 study, Selvam et al. examined the strength properties of e-waste concrete by conducting experiments using e-waste. The results indicated that replacing up to 20% of the coarse aggregate in concrete with e-waste led to improvements in both compressive and tensile strength. When more than 20% of e-waste is used to replace the coarse aggregate in concrete, the strength of the concrete is lowered by 30.7% compared to ordinary concrete after 28 days. E-waste may be effectively disposed of by using it as building materials. However, it is not ideal for replacing fine aggregate, but it can be used as a substitute for coarse aggregate. The compressive strength and split tensile strength of concrete containing flexible aggregate are often maintained at a similar level compared to controlled concrete specimens. However, it has been shown that the strength decreases when the plastic component exceeds 20%. Furthermore, it has been determined that up to 20% of e-waste aggregate may be substituted for coarse aggregate in concrete without causing any negative long-term consequences and while maintaining satisfactory strength characteristics.

In his study, Kumar (2018) examined the partial substitution of coarse aggregate with electronic trash. He fabricated concrete cubes using e-waste at concentrations of 5%, 7.5%, and 12.5%, and subsequently evaluated the compressive strength of M25 grade concrete in comparison to regular M25 grade concrete cubes. According to his research, it has been shown that electronic trash may be used as a substitute for coarse aggregate, with a maximum replacement rate of 12%. It offers an efficient method for disposing of electronic trash. By using lightweight materials, the density of the concrete is decreased, resulting in a reduction of its own weight. Increases the flexibility of the concrete, allowing it to effectively withstand seismic stresses. It alleviates the strain on the Earth's natural resources. It enhances the workability of concrete. Feasible sustainable development is achievable. It decreases the likelihood of damage to the land.

In their study, Prasanna & Rao (2014) investigated the substitution of coarse aggregate with e-waste at varying percentages of 5%, 10%, 15%, and 20% in one batch. They also created another batch using the same percentages of e-waste, but with the addition of 10% fly ash. The optimal concrete strength is achieved by replacing 15% of the coarse material with e-waste.

➢ E-WASTE CONCRETE

The components of electronic waste include cathode ray tubes (found in TVs, computer monitors, ATMs, video cameras, etc.), printed circuit boards (thin plates that hold chips and other electronic components), gold-plated components such as chips, plastics from printers, keyboards, monitors, etc., and computer wires. E-waste is a specific form of concrete that incorporates e-waste elements through partial replacement. The most viable application for addressing the disposal of a substantial quantity of recovered plastic waste is the use of plastic in the concrete industry. Recycled plastic has the potential to use as coarse aggregate in concrete.

The main objective of this experimental investigation is to find electronic trash that may be effectively disposed of by using it as construction material. (a) Substitution of electronic waste with coarse aggregate. The purpose is to restrict the presence of hazardous compounds in certain electronic items. (d) To enhance and advance the technologies used in the management of electronic waste. (e) To mitigate the environmental contamination resulting from the informal recycling of electronic trash. To assess the compressive and flexural strength of concrete that includes e-plastic aggregate.

MATERIALS AND METHODS

- Cement: Prozolona Portland cement, 53 grade con- forming to IS: 455-1987 and other properties like finess,specific gravity etc., are pointed in Table 1.
- Fine aggregate: Locally available manufacturing sandconforming to grading zone II of IS: 383-1970
- Coarse aggregate: Locally available crushed blue granite stones conforming to a graded aggregate of nominal size 12.5 mm as per IS: 383-1970.
- Tables 2 and 3 explain the properties of fine and coarseaggregate respectively.
- Water: Potable water
- E-waste used: Chipboard (plastic e-waste)

E-waste

This experimental study explores the use of e-waste, specifically high impact polystyrene (HIPS) plastic from electronic gadgets and accessories, as a partial replacement for coarse aggregate in concrete. Different percentages of HIPS plastic are used as substitutes for coarse aggregate. In this experimental study, a chipboard is utilised as a substrate for electronic trash.

MIX DESIGN AND METHODOLOGY

Design Mix prepared based on Indian Standard Code of Practice and the below mix proportions were derived, are Shown in Table 4. Mix Proportion

Cement=438.1 kg/m^3, Fine aggregate=641.07 Kg.m^{-3},Coarse aggregate =1120.82 7 Kg.m^{-3}, Water content=197.16 L.m^{-3}, Mix Ratio = 1 : 1.46 : 2.55 : 0.45

Mix Ratio = Cement: Fine aggregate: Coarse aggregate: Water

EXPERIMENTAL INVESTIGATION

Slump Cone Test

The slump test is a method used to evaluate the viscosity of newly mixed concrete. It is employed indirectly as a method of verifying if the appropriate quantity of water has been included into the mixture. The steel slump cone is positioned on a stable, impervious, flat foundation and filled with newly mixed concrete in three uniform levels. Table 5 displays the examinations conducted on hardened concrete following a time of curing.

Compression Strength

The determination of concrete's compressive strength is conducted at two specific time intervals: 7 days and 28 days. The specimens are fabricated and examined in accordance with the IS: 516-1959 standard. The compressive strength of cubes is evaluated by substituting 10%, 15%, and 20% of the coarse aggregates' mass with e-waste, using a certain quality of water. The tests are conducted on a cube with dimensions of 150x150x150 mm, in accordance with the specifications of IS: 516-1959. The test specimens are extracted from the moulds and, unless necessary for the test within 24 hours, promptly immersed in uncontaminated water and kept submerged until shortly before the test. The test is conducted using a typical compression testing equipment with a capacity of 3000 kN. The specimen is positioned within the steel plates of the compression-testing apparatus. The load is delivered steadily and consistently.

Table 1: Properties of cement.

S.No.	Property of Cement	Values
1	Fineness of cement	7.5%
2	Grade of cement	43
3	Specific gravity	3.15
4	Initial setting time	28 min
5	Final setting time	600 min

Table 2: Properties of fine aggregates.

S.No.	Characteristics	Value
1	Type	M-sand
2	Specific gravity	2.68
3	Total water absorption	1.02%
4	Grading Zone	II

Table 3: Properties of coarse aggregate.

S.No	Characteristics	value
1	Type	Crushed
2	Maximum size	20mm
3	Specific gravity(20mm)	2.825
4	Total water absorption(20mm)	3.645%

Fig. 1: Slump cone test.

Table 4: Mix Proportion for a different mix.

Mix	E-waste %	Cement (Kg.m-3)	F.A (Kg.m-3)	C.A (Kg.m-3)	E-waste (Kg.m-3)	Mix proportion (C: F.A: C.A: E-waste)
M0	0	438.1	641.07	1120.82	0	1: 1.46 : 2.55 : 0
M1	10	438.1	641.07	1008.73	112.08	1: 1.46 : 2.30 : 0.25
M2	15	438.1	641.07	952.69	168.12	1: 1.46 : 2.17 : 0.38
M3	20	438.1	641.07	896.65	224.16	1: 1.46 : 2.04 : 0.51

Table 5: Test on hardened concrete.

S.No.	Type of Test	Properties studied	Size of the Specimen
1.	Compression Test	Compression Strength	150X150X150 mm
2.	Flexural Strength Test	Flexural Strength	500X100X100 mm prism
3.	Split Tensile Strength Test	Tensile Strength	150 mm diameter cylinder

Flexure Strength Test

The flexural strength of concrete was measured after 28 days. The specimens were fabricated and examined in accordance with the standards outlined in IS: 516-1959. The compressive strength of cubes is evaluated by substituting 20% of the cement mass with a certain grade of electronic trash. The load applied during testing is 0.5% of the total load, with a loading rate of 400 Kg.min-1 for 15.0 cm specimens and 180 Kg.min-1 for 10.0 cm specimens.

Split Tensile Test

The tensile strength of concrete is measured after it has been curing for 28 days. The specimens are fabricated and examined in accordance with the IS: 516-1959 standard. The compressive strength of cubes is evaluated by substituting 20% of the cement mass with a certain grade of E-waste, and 0.7% of CONPLASTSP-36 with a specific grade of water. The load was consistently delivered without sudden impact at a rate ranging from 0.7 to 1.4 MPa.min-1 (1.2 to 2.4 MPa.min-1 according to IS 5816 1999). The maximum load at which a material or structure fails is recorded.

➢ RESULTS AND DISCUSSION

The compressive strength values for the M25 grade of E-waste concrete trial mixes at 7 and 28 days are presented in Table 6. The compressive strengths of M25 grade e-waste concrete trial mixes are enhanced by including fly ash and superplasticizer at replacement levels of 10%, 15%, and 20% for coarse aggregate.

The blends underwent testing after 7 and 28 days. The compressive strengths of the M25 grade e-waste concrete trial mixes containing 15% and 20% at 28 days were observed to be 25 and 24 MPa respectively. Similarly, at 7 days, the compressive values were found to be 18 and 17 MPa respectively.

Table 6 displays the compressive strength of concrete mixtures including e-plastic aggregates. The mixtures are categorised as M0 (0% e-plastic), M1 (10% e-plastic), M2 (15% e-plastic), and M3 (20% e-plastic). Graphs 1 and 2 provide the graphical representations of the compressive strength for all mixes M0, M1, M2, and M3 at 7 and 28 days. Therefore, the highest compressive strength was seen when 15 percent of the coarse particles were replaced with e-waste in M25 grade concrete.

Table 6: Compressive strength at 7 days and 28 days.

Mix	E-Waste (%)	Compressive Strength (MPa) 7 days	28 days
M0	0	19	27
M1	10	15	23
M2	15	18	25
M3	20	17	24

Fig. 2: Compressive strength test.

Fig. 3: Flexural strength test.

The flexural test results of e-waste concrete are presented in Table 7. The impact of electronic trash on concrete at various ratios is presented in the table below.

The mixtures were testing at both 7 and 28-day intervals. The flexural strengths of the E-waste concrete trial mixes for M0, M1, M2, M3, and M4 at the age of 7 days were 2.65, 2.25, 2.59, and 2.43 MPa respectively. At the age of 28 days, the flexural strengths were 4.15, 3.54, 3.81, and 3.63 MPa respectively for the same trial mixes.

The table labelled as Table 7 provides the experimental data for flexural strength. The blends underwent testing after 7 and 28 days. The flexural strengths of the M25 grade E-waste concrete trial mixes, labelled as M0, M1, M2, M3, and M4, were reported to be 2.4, 2.05, 2.31, and 2.26 MPa respectively at the age of 7 days. At the age of 28 days, the flexural strengths for the same trial mixes were 3.45, 3.13, 3.34, and 3.28 MPa respectively. According to the data in Table 8, the flexural strength of concrete is at its highest when 15% of the coarse material is replaced with e-waste. The study examines the tensile strengths of M25 grade concrete trial mixes with varying percentages (10%, 15%, and 20%) of e-waste as a replacement for coarse particles, and compares them.

The mixtures underwent testing at both 7-day and 28-day intervals. The tensile strengths of M25 grade e-waste concrete trial mixes containing 10%, 15%, and 20% e-waste were reported to be 2.4, 2.05, 2.31, and 2.26 MPa respectively at 7 days. At 28 days, the tensile values were 3.45, 3.13, 3.34, and 3.28 MPa respectively. The measured value for tensile strength is presented in Table 8. According to the data in Table 8, the tensile strength of concrete increases significantly when 15% of the coarse aggregate is replaced with e-waste.

Through several strength tests conducted on e-waste concrete, it has been discovered that substituting coarse aggregate with e-waste leads to an augmentation in compressive strength, flexural strength, and split tensile strength.

Table 7: Flexural strength at 7 days and 28 days.

		Flexural Strength (MPa)	
Mix	E-WASTE (%)	7 days	28 days
M0	0	2.65	4.15
M1	10	2.25	3.54
M2	15	2.59	3.81
M3	20	2.43	3.63

Table 8: Tensile strength at 7 days and 28 days.

		Split Tensile Strength (MPa)

Mix	E-Waste (%)	7 days	28 days
M0	0	2.4	3.45
M1	10	2.05	3.13
M2	15	2.31	3.34
M3	20	2.26	3.28

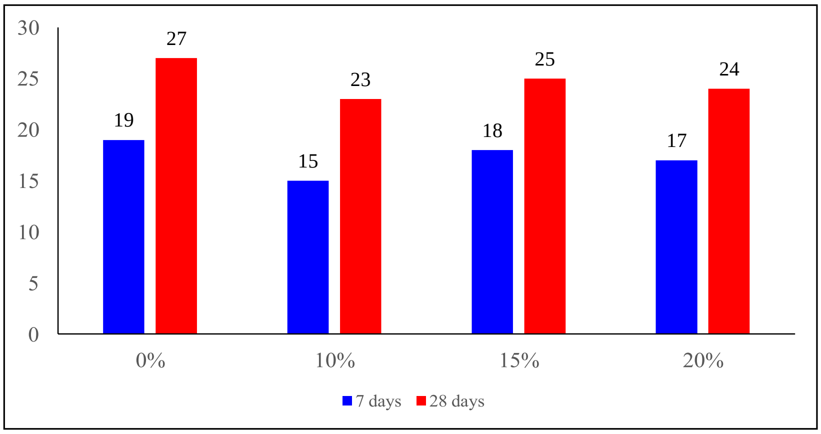

Fig. 4: Compressive strength of E-waste concrete at 7days and 28 days.

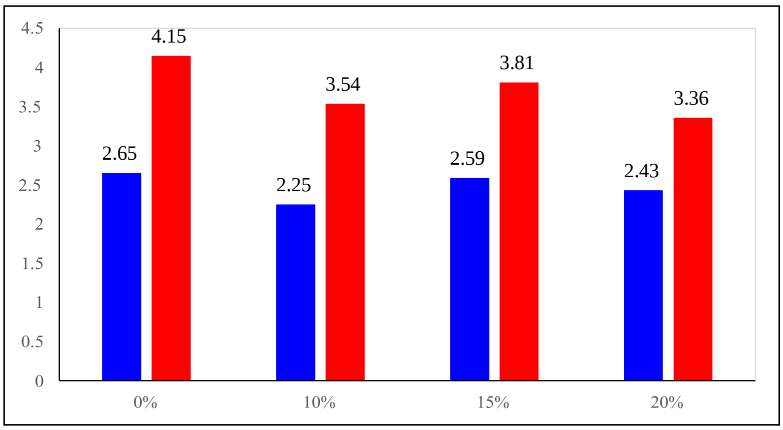

Fig. 5: Flexural strength of E-waste concrete at 7days and 28 days.

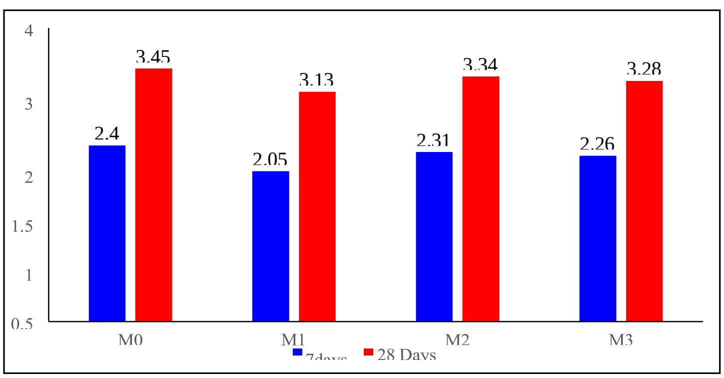

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Fig. 6: Tensile strength of E-waste concrete at 7days and 28 days.

CONCLUSION

• The following are the findings that may be drawn from the studies conducted by various experimental investigations. Electronic waste plastics have the potential to serve as a substitute for some components in a concrete mixture. This aids in decreasing the density of the concrete. This is beneficial in applications that necessitate the use of lightweight concrete that does not carry weight.

• The influence of the water-cement ratio on the development of strength is not significant in the case of flexible concrete. The reason behind this is that plastic particles diminish the adhesive strength of concrete. Consequently, the concrete fails as a result of the link between the cement paste and plastic particles breaking down.

• The use of e-waste plastics in the concrete mixture reduces the density, compressive strength, and tensile strength of the concrete, given a specific water-to-cement ratio (w/c).

•Introducing recycled aggregates into the concrete of the structures being studied has proven to be beneficial in terms of energy efficiency.

•The experimental analysis has conclusively shown that e-waste may serve as a viable substitute for conventional concrete materials, hence reducing the amount of e-waste that is disposed of in the environment. Consequently, this leads to a decrease in pollutants.

Therefore, it may be inferred that e-waste has the potential to serve as a partial substitute for coarse aggregates in concrete, offering a sustainable solution to the depletion of natural resources such as aggregates and reducing their usage.

SCOPE FOR FUTURE WORK

- E-waste material can be used instead of fine aggregatesand strength can be verified.
- Along with e-waste some other chemical and mineraladmixtures can be added and tested.

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