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Analysis of E-waste recycling in Green Concrete

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***Abstract*— Electronic waste, sometimes known as e-waste, refers to electronic items that have become undesirable, non-functional, or outmoded, and have effectively reached the end of their useful life. The number of e-waste materials that must be disposed of is growing by the day, making e-waste a growing concern that is posing major environmental challenges to people and the environment not only in India but throughout the world. Because concrete is the most often used building material in the construction sector, reusing e-waste in concrete is regarded the most practical application for resolving the disposal of significant amounts of e-waste material. It is also demonstrated that the usage of e-waste as a replacement for aggregate is a significant potential. Its usage in concrete is becoming increasingly significant and crucial in light of the fact that natural aggregate sources are dwindling, and it is unquestionably necessary to investigate suitable natural aggregate substitutes. In this study, coarse aggregate is largely substituted with electronic trash, starting with 5% and steadily increasing by 5% until it reaches 25%. All of these mixtures are also being tested for compressive strength. The test findings revealed that as the proportion of e-waste added to the mixture increases, the workability of the concrete diminishes. The inclusion of e-waste, on the other hand, results in a 15% increase in compressive strength. It was also discovered that sulphate and chloride attacks on e-waste concrete had no effect on its strength.**

***Keywords*— Electronic waste, Recycle, Concrete, Compressive Strength, Workability**

1. INTRODUCTION

Electronic trash, often known as e-waste, refers to electronic items that have become undesirable, non-functional, or obsolete, and have effectively reached the end of their useful life. Because technology evolves at such a rapid pace nowadays, many electronic items become obsolete after only a few years of use. Computers, TVs, monitors, mobile phones, PDAs, VCRs, CD players, fax machines, printers, and other electronic devices all contribute to e-waste.

E-waste contains a wide range of compounds and toxins. Metals such as iron, copper, aluminium, gold, and other metals make for more than 60% of the total, while plastics account for around 30%, and hazardous pollutants account for only 2.70 percent. That is why, if not adequately managed, e-waste can cause major human health and environmental issues.

It is estimated that the globe creates over 50 million tonnes of e-waste per year. When e-waste is discarded, it frequently ends up in landfills or incinerators. Exporting them to Asia was the most recent approach. Developed countries send e-waste to underdeveloped countries on a regular basis. Inspections of 18 European seaports in 2005 revealed that up to 47% of rubbish destined for export, including e-waste, was unlawful. In 2003, it was discovered that at least 23,000 metric tonnes of undeclared or "grey" market electronic trash had been illegally exported to the Far East, India, Africa, and China from the United Kingdom. According to reports, 50-80 percent of rubbish collected for recycling in the United States is exported using the same manner.

India, the world's second-largest mobile market, is also the world's fifth-largest producer of e-waste, with around 18.5 lakh tonnes of electronic garbage discarded each year. Mumbai is the most populous city in the country, accounting for 70% of all e-waste created, followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat, and Nagpur.

E-waste is a new concern that is causing major environmental difficulties for people and the environment not just in India but throughout the world. According to the US EPA, the amount of e-waste created worldwide will rise by 5 to 10% every year. However, they also said that only 5% of the garbage gets recovered. As a result, the amount of e-waste that needs to be disposed of in an environmentally acceptable manner is steadily rising. Starting immediately, options such as recycling and reuse should be examined.

Because concrete is the most often used building material in the construction sector due to its great strength and durability, reusing e-waste in the concrete industry is regarded the most practical application for solving the disposal of vast amounts of e-waste material. Some published literatures also suggest that using E-waste as a substitute or replacement for aggregate is a viable option. Its usage in concrete is becoming increasingly significant and crucial in light of the fact that natural aggregate sources are dwindling, and it is unquestionably necessary to investigate suitable natural aggregate substitutes.

This task's major goal is to limit the buildup of worn and abandoned electronic equipment as much as possible, as well as to convert trash into socially and industrially beneficial raw material utilising simple, low-cost, and environmentally friendly technologies.

In this study, coarse aggregate is largely substituted with electronic trash, starting with 5% and steadily increasing by 5% until it reaches 25%. All of these mixtures are also being tested for compressive strength. Finally, the mechanical qualities and durability of e-waste concrete are compared to ordinary concrete.

2. SCOPE of RESEARCH

The amount of e-waste that has to be disposed of in an environmentally acceptable manner is steadily rising. To keep End-of-Life (EOL) electronics out of landfills and incineration, new waste management methods are desperately needed. However, in order to build an effective diversion plan, various aspects must be taken into account. This plan must be founded on the program's economic viability, long-term viability, technological feasibility, and a reasonable degree of social support. Recent studies have also demonstrated that reusing extremely finely crushed e-waste in concrete can save money and time when it comes to disposing of significant amounts of e-waste. Recycling aggregates conserves natural resources and landfill space while also contributing to the preservation of a clean environment.

3. METHODOLOGY

For this study, grade 33 Portland cement was employed. The cement that was utilised was dry, powdery, and lump-free. M sand, which is readily available in the area, was used to make concrete mixtures. In concrete mixtures, ordinary crushed stone with a size of 20mm was utilised as coarse aggregate. The procedure was done with filtered drinking water that was readily accessible in the area. Long chips of e-waste were gathered locally from a PCB cutting device. Copper strips at the bottom of the PCB were manually removed and broken into 20mm pieces.

The concrete grade and kind of fine aggregate used in the mixes were labelled. The IS technique of concrete mixing was utilised to create a mix with a cube strength of 20 Mpa. As a partial replacement for coarse aggregate, 0 to 25% electronic trash (E-waste) was added to the concrete mix. After the mixture has been made, 150 x 150 x 150mm cubes are cast, and they are tested after 7, 14, and 28 days of curing. Crushing value test, impact value test, abrasion value test, specific gravity test, fineness modulus, and water absorption are some of the tests done on materials and concrete to assess the properties of the material as well as its behavior.

Slump cone tests are done on new concrete to verify workability, and compressive strength tests are performed on hardened 150mm concrete cubes after 7, 14, and 28 days of curing.

4. RESULTS and DISCUSSIONS

A series of experiments on material and hardened concrete were carried out in order to acquire the workability strength properties of electronic waste for future application as structural concrete. The findings of material tests, such as water absorption, specific gravity, aggregate crushing value, and aggregate impact value, are shown and discussed below.

A. *Test on Materials:*

1) *Crushing Value Test:* The aggregate crushing value is a relative measure of an aggregate's resistance to crushing when subjected to a gradually applied compressive stress. In circumstances when the aggregate crushing value is 30 or above, the result may be unusual, thus the ten percent fines value should be computed instead. E-waste, it turns out, is more resistant than natural aggregate.

TABLE I: Aggregate Crushing Value Test Result

Aggregate	**Crushing Value**
Natural Coarse Aggregate	13.98%
Electronic Waste	2.38%

2) *Impact Value Test:* The aggregate impact value is a measure of resistance to abrupt impact or shock, which may differ from resistance to a progressive compressive force. This test may also be used to determine the strength and durability of a product. There is a significant difference between natural and e-waste aggregate,

indicating that electronic waste aggregate is more powerful than natural waste aggregate.

TABLE II: Aggregate Impact Value Test Result

Aggregate	**Impact Value**
Natural Coarse Aggregate	7.85%
Electronic Waste	1.92%

3) *Fineness Modulus:* The fineness modulus is commonly used to determine the coarseness or fineness of an aggregate. A higher fineness modulus value suggests a coarser aggregate, whereas a lower fineness modulus value indicates a finer aggregate. Sand with a fineness modulus more than 3.2 is often not utilised to make decent concrete. The fineness modulus can also be used to blend two aggregates in order to get the desired grade.

TABLE III: Fineness Modulus Test Result

Aggregate	**Fineness Modulus**
Natural Coarse Aggregate	2.72
Natural Fine Aggregate	1.88
Electronic Waste	2.52
Cement	4.32

3) Abrasion Value Test: As per IS: 2386 (Part IV) – 1963, this test can be used to measure the abrasion value of coarse aggregates.

TABLE IV: ABRASION VALUE TEST RESULT

Aggregate	**Abrasion Value**
Natural Coarse Aggregate	11.87%
Electronic Waste	3.65%

4) *Water Absorption:* This approach is used to assess the water penetration vulnerability of unsaturated concrete. The rate of absorption of concrete at the surface differs from that of a sample obtained from the inside. The outside surface receives less curing than desired and is subjected to the most potentially hazardous circumstances. The water absorption rate of the inside as well as the surface or outside of the concrete is measured using this test method. Drilling a core and cutting it transversely at various depths allows the absorption to be measured at various distances from the exposed surface. A horizontal or vertical core can be drilled.

TABLE V: WATER ABSORPTION TEST RESULT

Aggregate	Water Absorption
Natural Coarse Aggregate	0.60%
Natural Fine Aggregate	0.30 %
Electronic Waste	0.04 %

4) *Specific Gravity Test:* A comparison of the weights of a volume of a certain substance to the weight of the same amount of water at a given temperature is known as specific gravity. The specific gravity of an aggregate is used to determine the material's strength or quality. Low specific gravity stones are often weaker than those with greater specific gravity.

TABLE VI
SPECIFIC GRAVITY TEST RESULT

Aggregate	Specific Gravity
Natural Coarse Aggregate	2.73
Natural Fine Aggregate	2.62
Electronic Waste	1.18
Cement	3.12

B. *Slump Cone:* The workability of concrete is usually determined by its slump value, which reflects the water-cement ratio. However, a variety of parameters such as material qualities, mixing procedures, dose, and admixtures, among others, might influence the value.

TABLE VII Slump Cone Test Result

Electronic Waste	Slump (mm)
0%	27
5%	31
10%	38
15%	47
20%	61
25%	70

The slump test indicates a Increasing trend of workability when the percentage of electronic waste increased.

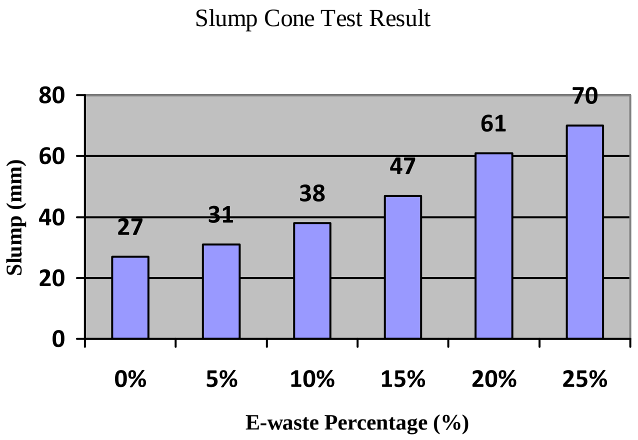

Fig. 1 Slump Cone Test Result Bar Chart

C. *Compression Test Result and Analysis:* The concrete cube test for compressive strength gives you an overview of all the properties of concrete. This one test can establish whether or not the concreting was done correctly. Concrete's compressive strength is determined by a variety of parameters, including the water-cement ratio, cement strength, concrete material quality, and quality control during the manufacturing process, among others.

TABLE VIII Compressive Strength Test Result

Electronic Waste	Compressive Strength (N/mm^2)		
	7 Days	14 Days	28 Days
0%	17.87	24.25	28.65
5%	20.77	25.68	31.48
10%	21.68	27.38	33.22
15%	23.82	30.16	35.55
20%	17.36	23.28	25.08
25%	13.16	19.90	22.64

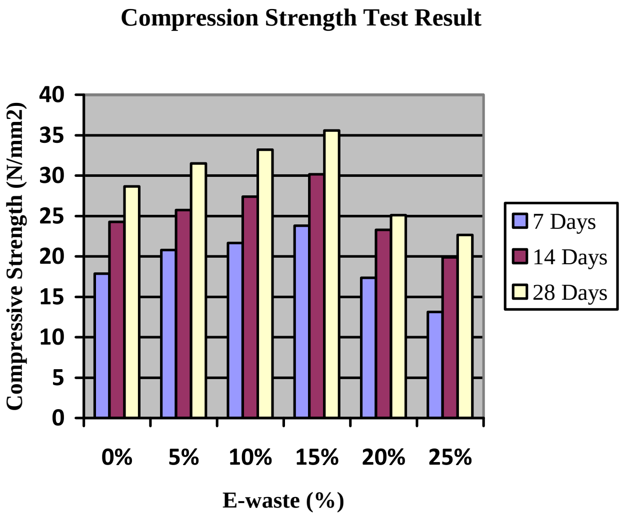

Fig. 2 Compressive Strength Test Result Bar Chart

The compressive strength of concrete specimens increases with age when tested with the CTM (Compressive Testing Machine). The older the concrete, the more durable it becomes. It also shows that when 15 percent of the aggregate is replaced with electronic trash, the compressive strength achieves its maximum value.

D. *Chloride Attack Test:* The effect of chloride attack on ordinary concrete with e-waste is demonstrated. The average weight loss and compressive strength loss of E-waste concrete is significantly lower than the weight and compressive strength loss of conventional concrete.

TABLE IX Chloride Attack Test Result

Electronic Waste	Percentage Strength Loss (N/mm^2)		Percentage Weight Loss (kg)	
	30 Days	90 Days	30 Days	90 Days
0%	28.5	42.58	3.22	5.85
15%	21.3	35.62	3.08	4.13

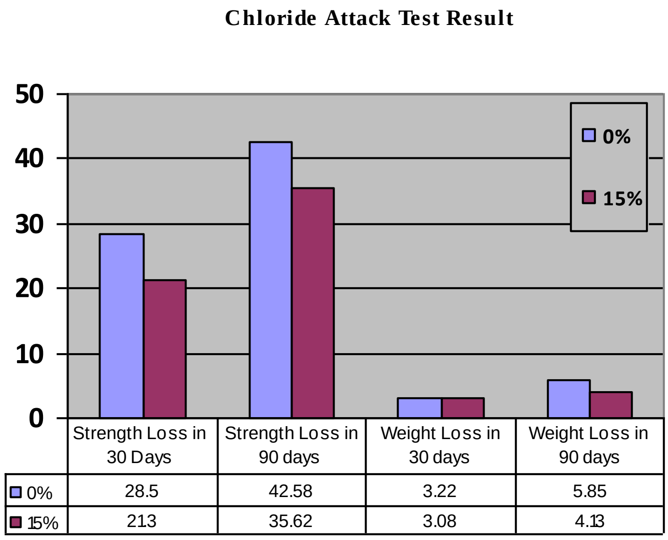

Fig. 3 Chloride Attack Test Result Bar Chart

It demonstrates that chloride has no major effect on E-waste particles in concrete. This suggests that incorporating E-waste into concrete could be a viable option.

d) Sulphate Attack Test: The overall goal of these tests is to determine the relative sulphate resistance of various binder options, ranging from traditional (basically low C3A content) sulphate resistant cements to blended cements that have recently been discovered to have exceptional properties in this area of concrete technology. The findings of the sulphate attack test indicate that sulphate has no major effect on E-waste particles in concrete.

TABLE X Sulphate Attack Test Result

Electronic Waste	Percentage Strength Loss (N/mm^2)		Percentage Weight Loss (kg)	
	30 Days	90 Days	30 Days	90 Days
0%	25.18	42	2.7	5.12
15%	23.8	38.7	1.78	4.89

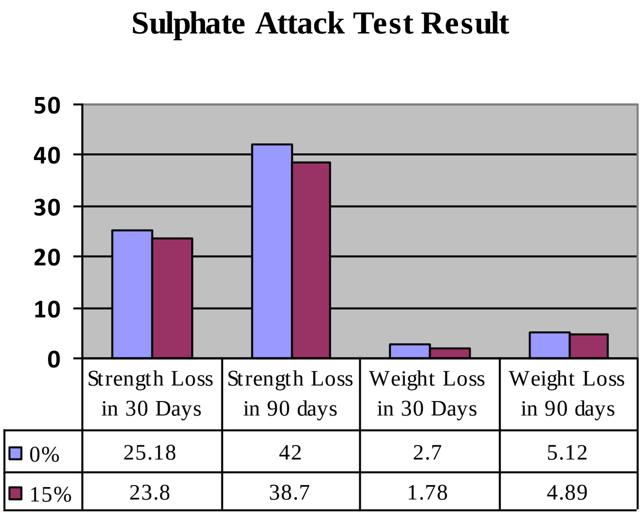

Fig. 4 Sulphate Attack Test Result Bar Chart

5. CONCLUSIONS

The test findings revealed that as the amount of electronic trash added to the mixture increases, the workability of the concrete diminishes. However, the inclusion of e-waste results in a 15% rise in compressive strength, at which point it achieves its maximum value. According to the durability research, sulphate and chloride attack have no effect on concrete strength, and the optimal mix is more durable than the control mix. As a result, it may be employed in aquatic environments.

To summarise, using electronic waste in concrete can increase mechanical characteristics and can be a cost-effective method to dispose of them in an environmentally responsible manner, but only up to a specific amount. Electronic garbage is reused, resulting in waste reduction and resource conservation.

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