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A Study On The Application Of Recycled Electronic Plastic Waste As A Partial Aggregate In Concrete

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ABSTRACT :

The management of E-plastic waste, a hazardous and valuable by-product of IT industries, is a growing concern due to its low recycling rate. This study explores using non-biodegradable E-plastic waste, derived from discarded electronics like computers and TVs, as a partial substitute for coarse aggregates in concrete. The use of E-plastic waste aims to lower aggregate costs while maintaining good strength for structures. The experimental investigation focused on M20 grade concrete, with E-plastic replacing coarse aggregates at percentages of 0%, 10%, 20%, and 25%. Key properties such as compressive, tensile, and flexural strength were tested, showing that concrete with E-plastic exhibited good strength. The study concludes that it is feasible to use E-plastic particles as a partial replacement for coarse aggregate. It was found that a 10% E-plastic content provided stability and high compressive strength with 53 grade cement.

Note: While the abstract and title refer to replacing *coarse aggregate*, the detailed methodology and results sections of the study focus on replacing *fine aggregate* with E-plastic powder.

Introduction and Background

The management and recycling of electronic plastic (E-plastic) waste is a critical issue, as it is a rapidly growing waste stream containing hazardous substances and has a low recycling rate. This non-biodegradable waste, which includes plastics from old computers, televisions, and refrigerators, typically ends up in landfills, leading to soil pollution. This study investigates the potential of incorporating E-plastic into concrete as a partial replacement for conventional aggregates. The primary goals are to reduce the cost of aggregates, provide a durable construction material, mitigate landfill costs, and save energy.

The production of cement, a key ingredient in concrete, is a major contributor to greenhouse gas emissions, accounting for an average of 7% of emissions to the atmosphere. Consequently, extensive research is underway to utilize waste materials like E-plastics and industrial by-products as substitutes in concrete manufacturing. Prior research has indicated that the addition of materials like E-plastic powder can enhance concrete's properties, such as compressive, flexural, and tensile strength, and improve its durability by making the structure denser and reducing water absorption.

Literature Review: The Context of E-Waste

A review of existing literature highlights the severity of the E-waste problem. According to a study by Ashok Kumar Das on E-waste management in India, electronic products contain an assortment of toxic and carcinogenic chemicals. These materials are complex and difficult to recycle in an environmentally sustainable manner, posing a threat to public health, especially at their end-of-life stage. The impact is particularly severe in developing countries like India, where informal sector workers often handle untreated E-waste without any safety measures, leading to significant health hazards. The Central Pollution Control Board (CPCB) has identified over 88 critically polluted industrial zones due to such activities.

From a material science perspective, researchers have explored using E-waste powders in concrete because their primary chemical component is silica, which is also a fundamental constituent in cement production. This chemical similarity suggests that E-waste can be a viable component in construction materials.

Materials and Methodology

The experimental program involved a systematic process of material testing, mix design, specimen casting, and strength analysis.

Materials Used

- Cement: 43 grade Ordinary Portland Cement (OPC) conforming to IS: 8112–1989 was used. It had a specific gravity of 3.15. It is worth noting a discrepancy, as the abstract mentions 53 grade cement was used.
- Fine Aggregate: Natural sand, a granular material composed of finely divided rock and mineral particles, was utilized. Its specific gravity was 2.67.
- Coarse Aggregate: Hard stones with a maximum size of 20 mm served as the coarse aggregate. This material had a specific gravity of 2.63.
- Water: Potable laboratory water, with a pH value of 7±1.0 and conforming to IS 456-2000, was used for mixing and curing the concrete specimens.
- E-Plastic Waste: The study used E-plastic waste in powder form as a partial replacement for fine aggregate.

Testing Procedures on Materials

A series of standard tests were conducted to determine the properties of the constituent materials.

- Cement Consistency Test: This test determines the standard consistency of cement paste, defined as the consistency that permits a Vicat plunger to penetrate to a depth of 33-35 mm from the top of the mould. This parameter is essential for determining setting times.
- Initial Setting Time: Using the paste of standard consistency, the initial setting time was recorded as the period between adding water to the cement and the point at which the Vicat needle penetrates the test block to a depth of 33-35 mm from the top.
- Specific Gravity of Aggregates: The specific gravity for both fine and coarse aggregates was determined using a pycnometer. The calculation follows the formula: $G=((M4-M1)-(M3-M2))(M2-M1)$ where M1 is the mass of the pycnometer, M2 is the mass with dry soil, M3 is the mass with soil and water, and M4 is the mass with only water.
- Other Tests: A sieve analysis was performed to assess particle size distribution, an aggregate impact value (AIV) test was conducted to measure resistance to sudden shock, and a Deval Attrition Testing Machine was used to test for attrition.

Concrete Mix Design (M20 Grade)

The mix design was developed in accordance with the Indian Standard method, IS 10262-2009, for M20 grade concrete.
Design Stipulations:

- Characteristic compressive strength (28 days): 20 N/mm²
- Maximum size of aggregate: 20 mm
- Maximum water-cement ratio: 0.45
- Workability: 100 mm slump
- Minimum cement content: 320 Kg/m³

Mix Calculation Steps:

1. Target Mean Strength: The target mean strength was calculated to ensure the final concrete meets the required characteristic strength, accounting for quality control variations. The formula used was $fck'=fck+ts$, resulting in $fck'=20+(1.65\times4)=26.6N/mm2$.
2. Water Content: For a 20 mm aggregate and a target slump of 100 mm, the estimated water content was calculated to be 197 liters per cubic meter of concrete.
3. Cement Content: With a water-cement ratio of 0.45, the required cement content was calculated as 197/0.45=437.78 Kg/m3.
4. Aggregate Proportion: The volume of coarse aggregate was set to 0.61, and the volume of fine aggregate was set to 0.39. This led to a mass of 1057.15 kg for coarse aggregate and 647.4 kg for fine aggregate per cubic meter.

Results and Discussion

The study prepared and tested concrete cubes with 0% (conventional), 5%, 10%, 15%, 20%, and 25% of the fine aggregate being replaced by E-plastic waste powder. While the study's title refers to coarse aggregate replacement, the experimental proportions and results tables explicitly detail the replacement of fine aggregate.

Failure Load Data

The following table summarizes the average failure loads observed during the compression tests on the cubes at 28 days.

Replacement %	**Specimen Type**	**28-Day Failure Load (kN)**	**Source(s)**
0% (Control)	**Conventional Concrete**	**550**	

5%	**Cube 1: 560, Cube 2: 575**	**567.5 (Avg)**	
10%	**Cube 1: 550, Cube 2: 55**	**297.5 (Avg)***	
15%	**Cube 1: 560, Cube 2: 565**	**562.5 (Avg)**	
20%	**Cube 1: 350, Cube 2: 350**	**350 (Avg)**	
25%	**Cube 1: 440, Cube 2: 430**	**435 (Avg)**	

***Note:** A potential typographical error exists in the source data for the 10% replacement at 28 days, listing one failure load as 55 kN. The compressive strength data below appears to be derived from different load values.

Compressive Strength Analysis

The failure loads were used to calculate the compressive strength in N/mm². The table below presents the final strength values after 7, 14, and 28 days.

Replacement %	7 Days Strength (N/mm²)	14 Days Strength (N/mm²)	28 Days Strength (N/mm²)	Source(s)
0% (Control)	11.55	15.50 - 15.70	24.50	
5%	11.11	15.68	25.75	
10%	12.70	16.40	23.80	
15%	13.55	17.40	25.85	
20%	13.90	16.50	26.80	
25%	10.65	17.05	26.35	

The 28-day results demonstrate that the replacement of fine aggregate with E-plastic yielded promising results. The mixes with 5%, 15%, 20%, and 25% E-plastic all surpassed the compressive strength of the conventional concrete. The peak compressive strength of 26.80 N/mm² was achieved at the 20% replacement level. Only the 10% replacement mix showed a marginal decrease in strength compared to the control mix.

Conclusions

Based on the comprehensive experimental investigation, the following conclusions were drawn:

- The replacement of fine aggregate with E-plastic waste powder up to 25% is considered a favorable and viable option for producing concrete.
- The compressive strength of the concrete mix with 15% E-plastic replacement showed a notable increase compared to the conventional concrete.
- The study also concluded that the mixture with 25% E-plastic demonstrated better strength gain when compared to the 5% and 10% mixtures.
- By substituting a portion of natural aggregates with E-plastic waste, it is possible to achieve concrete with adequate strength while also contributing to the reduction of environmental pollution.

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