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Partial Replacement of Fine Aggregate with E-Waste and Cement with Bagasse Ash in Concrete

Nusfa Karuvattil[1], Fathima Shibina AK[2], Muhammed Razal CV[3], Muhammed Rashid KT[4]
[1, 2, 3, 4]*Department of Civil Engineering, MEA Engineering College*

Abstract: Concrete is essential in modern construction, but its environmental impact, especially from cement production, has driven the search for sustainable alternatives. This study examines the use of E-waste and sugarcane bagasse ash (SCBA) as partial replacements for fine aggregate and cement in M20-grade concrete. Both are abundant waste materials with properties suitable for concrete. The optimal mix—10% E-waste and 10% SCBA achieved a compressive strength of 21.4 N/mm², split tensile strength of 2.56 N/mm², and flexural strength of 3.85 N/mm². These results show that E-waste and SCBA can enhance concrete sustainability without compromising strength, supporting eco-friendly construction practices.
Keywords: SCBA, E-waste, compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

The Construction is one of the largest consumers of natural resources; therefore, the environmental concerns about depletion of natural aggregates and high carbon emissions from cement production are great. In this regard, the use of waste materials in concrete has become very promising. This paper investigates e-waste and bagasse ash as partial replacements for fine aggregates and cement in concrete, respectively.

Electronic waste, disposed of at an alarming rate worldwide, accumulates as e-waste. If not handled properly, this type of waste contains materials hazardous to the environment and human beings. Reusing e-waste as a partial replacement for fine aggregates in concrete helps solve disposal issues and reduces the demand for natural sand, offering sustainable construction solutions. Another residual waste is bagasse ash, obtained from burning sugarcane bagasse. With its pozzolanic characteristics, bagasse ash can be used as a supplementary cementitious material to replace cement in concrete, partly decreasing the carbon footprint of concrete by reducing cement (a significant contributor to CO2 emissions) and adding value to an agricultural waste product. The report discusses the effects of using e-waste as a partial replacement for fine aggregates and bagasse ash a partial replacement for cement in concrete.

II. MATERIALS

Various materials used in the study are sugarcane bagasse ash, E-waste, ordinary portland cement, fine aggregate, coarse aggregate and water.

A. Sugarcane Bagasse Ash

Bagasse ash is a by-product from sugar industries that is burnt to generate the power required for different activities in the factory. The burning of bagasse leaves bagasse ash as a waste, which has a pozzolanic property that would potentially be used as a cement replacement material.

It has been known that the worldwide total production of sugarcane is over 1500 million tons. Sugarcane consists about 30% bagasse whereas the sugar recovered is about 10%, and the bagasse leaves about 8% bagasse ash as a waste, this disposal of bagasse ash will be of serious concern.

B. E-waste

One of the fastest growing waste sectors in the world is the electrical and electronic waste (e-waste). The used electronic devices and house hold appliances which are unfit for their original intended use form the Electronic waste. They can be recovered, recycled or disposed. It refers to end of life for the products such as Computers, ACs, televisions, printers and mobile phones made of plastics, metals, etc.

C. Ordinary Portland Cement

Ordinary Portland cement, made from limestone and clay, acts as the primary binder in concrete. It is produced mainly from two basic raw materials; limestone and clay It undergoes crushing, grinding, and heating to produce clinker. Different cement types affect hydration rates and strength development. For this study, JSW 53-grade cement was used to ensure quality concrete production.

D. Fine Aggregate

Fine aggregate is the natural material that fills the voids between coarse aggregates. Clean and dry M-sand, sourced locally, was used. The grains passing through the IS 4.75mm sieve were used for casting all the specimens.

E. Coarse Aggregate

Coarse aggregates, with a size greater than 4.75 mm and passing through a 20mm IS sieve, should be hard, strong, durable, dense, and clean. They must be free from harmful substances like disintegrated pieces, alkalis, vegetable matter, and other impurities, and should be well graded.

F. Water

Water is crucial in concrete as it initiates the chemical reaction in cement, forming the strength-giving cement gel. The quality and quantity of water must be carefully considered. For this study, potable water was used for casting, ensuring it was pure to avoid side reactions that could weaken the concrete.

III.EXPERIMENTAL PROCEDURES

The experimental procedure consists of several step beginning with testing material properties to ensure the suitability of E-waste and SCBA to partially replace fine aggregate and cement respectively. The designed mixes were then prepared cured and conducted strength test to determine the optimum replacement ratios of SCBA, E-waste. To determine the compressive strength, split tensile strength, flexural strength and workability of the concrete prepared with optimum replacement. Finally, a comparison between concrete with and without replacement is made to analyze the change in strengths and workability.

A. Determination of Material Properties

For a material to be considered as construction material, it should have required engineering properties suitable for construction work. Additionally, it is essential to conduct test on materials like E-waste and SCBA so as to ensure its suitability to partially replace cement and fine aggregate respectively in concrete. Various test conducted on cement are specific gravity test, fineness test and consistency test. The tests conducted on SCBA are specific gravity and fineness test. Various test carried out on fine aggregate are bulking of sand and sieve analysis. The sieve analysis test is also carried out on coarse aggregate and E-waste. The results of these tests are shown in TABLE 1.

TABLE I

RESULT OF PRELIMINARY TESTS

Sl No.	Material	Experiment	Result	Limit
1	Cement	Standard consistency	32%	26%-33%, IS 4031 Part 4
		Specific gravity	3.16 g/cc	3.1-3.18g/cc, IS4031-Part 2
		Fineness of cement	6%	<10%, IS: 460 Part 1&3
2	SCBA	Fineness test	4%	<10%, IS: 460 Part 1&3
		Specific gravity	3.1g/cc	3.1-3.16g/cc, IS2720-Part 3
3	Fine aggregate	Bulking of sand	36.84%	>30%, fine sand IS 2386
		Sieve Analysis	FM= 3	2.2-3.2, IS 2386 1963
4	E-waste	Sieve analysis	2.29	2.2-3.2, IS 2386 Part 1
5	Coarse aggregate	Sieve Analysis	FM= 7.37	6.5-8, IS 2386 1963

B. Design of Experiments

For studying explaining the tests conducted for investigating the feasibility and effectiveness of using E-waste as partial replacement of fine aggregate and SCBA as partial replacement of cement with different percentage. To determine the compressive strength, split tensile strength, flexural strength and workability of the concrete prepared with optimum replacement.

1) *Mix design:* It refers to selection of the proper amount of ingredients to make a batch of concrete in TABLE 2.

TABLE 2
MIX DESIGN

Mix design	Cement replacement with SCBA	Fine aggregate replace with E-waste
Mix design 1	SCBA 8%	E-waste 8%
Mix design 2	SCBA 8%	E-waste 10%
Mix design 3	SCBA 8%	E-waste 12%
Mix design 4	SCBA 10%	E-waste 8%
Mix design 5	SCBA 10%	E-waste 10%
Mix design 6	SCBA 10%	E-waste 12%
Mix design 7	SCBA 12%	E-waste 8%
Mix design 8	SCBA 12%	E-waste 10%
Mix design 9	SCBA 12%	E-waste 12%

2) *Workability:* Workability of fresh concrete refers to the ease with which it can be placed, compacted, and finished without issues like bleeding or segregation. It is influenced by the internal work required to achieve proper compaction. Workable concrete ensures good strength, durability, and appearance while reducing labor costs. Unworkable concrete, on the other hand, is harder to compact, may result in honeycombing, and may compromise the final product's quality. The slump cone test is used to determine workability in this study.
3) *Compressive Strength:* Compressive strength refers to the ability of concrete to resist loads before failing. Of the many tests applied to the concrete, the compressive strength test was the most important, as it gives an idea about the characteristics of the concrete. It is conducted using a Compression Testing Machine (CTM) to determine the concrete's strength.
4) *Split tensile strength:* The splitting tensile strength of concrete is a method of indirectly measuring its tensile strength by applying compressive force to a cylindrical specimen, causing it to split along a vertical plane. This test is crucial for assessing the structural integrity of concrete, particularly in situations where tension is a critical factor. It is conducted using a UTM to determine the strength.
5) *Flexural strength:* Flexural strength in concrete refers to its ability to resist bending forces. It's essentially the maximum tensile stress a concrete beam can withstand before cracking under flexural loading.

IV. RESULT AND ANALYSIS

The results of workability, compressive strength test, split tensile strength and flexural strength conducted is given TABLE3.

TABLE 3
RESULTS OF WORKABILITY, COMPRESSIVE STRENGTH TEST, SPLIT TENSILE STRENGTH AND FLEXURAL STRENGTH

Trial No	SCBA	E-waste	Slump (mm)	Compressive strength (Nmm^2)	Split tensile strength (Nmm^2)	Flexural strength (Nmm^2)
1	8%	8%	11	18.5	2.22	3.33
2	8%	10	17	18.7	2.25	3.37
3	8%	12%	22	18.9	2.27	3.41
4	10%	8%	11	19.8	2.38	3.57
5	10%	10	18	21.4	2.56	3.85
6	10%	12%	20	20.7	2.48	3.73
7	12%	8%	12	20.1	2.41	3.63
8	12%	10	18	17.1	2.06	3.09
9	12%	12%	24	14.1	1.96	2.69

The optimum replacement level for both SCBA and E-waste in concrete is 10%. Beyond this, compressive, split tensile, and flexural strengths decrease due to reduced cement content with excess SCBA and higher water absorption by E-waste. However, slump increases with higher E-waste content.in concrete.

V. COMPARISON WITH CONVENTIONAL CONCRETE

1) The compressive strength of M20 concrete with a water-cement ratio of 0.5 and no replacement was 21.12 N/mm². With 10% SCBA and 10% E-waste replacements, the strength increased to 21.4 N/mm², showing a 1.3% improvement.
2) The split tensile strength of M20 concrete with a water-cement ratio of 0.5 and no replacement was 2.36 N/mm². With 10% SCBA and 10% E-waste replacements, the strength increased to 2.56 N/mm², showing a 8.4% improvement.
3) The flexural strength of M20 concrete with a water-cement ratio of 0.5 and no replacement was 3.79 N/mm². With 10% SCBA and 10% E-waste replacements, the strength increased to 3.85 N/mm², showing a 1.4% improvement.

VI. CONCLUSION

This study ultimately explored the sustainable use of E-waste and sugarcane bagasse ash (SCBA) as partial replacements for fine aggregate and cement in M20 concrete. Laboratory tests show that replacing 10% of fine aggregate with E-waste and 10% of cement with SCBA at a 0.45 water-cement ratio yields optimal results. This mix achieved a compressive strength of 21.4 N/mm² (1.3% higher than conventional M20), a split tensile strength of 2.56 N/mm² (8.4% increase), and a flexural strength of 3.85 N/mm² (1.4% increase). The study highlights the environmental and structural benefits of using recycled materials in concrete, supporting eco-friendly and sustainable construction practices.

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