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An Experimental Investigation On The Effective Utilization Of Sugarcane Bagasse Ash As A Partial Replacement For Cement And Marble Waste As A Partial Replacement For Fine Aggregate

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Abstract: This experimental study explores the sustainable and effective utilization of industrial and agricultural waste materials in concrete production, focusing on Sugarcane Bagasse Ash (SCBA) as a partial replacement for cement and Marble Waste (MW) as a partial replacement for fine aggregate. The primary objective is to analyze the mechanical and durability properties of concrete incorporating these waste materials, thereby reducing environmental hazards and promoting circular economy practices. Concrete mixes were prepared with varying proportions of SCBA (5%, 10%, 15%, and 20%) and MW (10%, 20%, 30%, 40%, and 50%). Standard tests such as compressive strength, split tensile strength, flexural strength, and water absorption were conducted on the cured specimens. The results indicate that moderate inclusion levels of SCBA and MW enhance the strength and durability characteristics of concrete. The use of these waste materials also significantly reduces cement consumption and natural sand extraction, offering a sustainable solution for the construction industry. This study concludes that SCBA and MW can be effectively utilized in concrete up to optimum levels without compromising structural performance.

Keywords: Agricultural waste, Sugarcane Bagasse Ash, Marble Waste, Compressive Strength.

I.INTRODUCTION

Concrete, the second most consumed material on Earth after water, is an indispensable construction material in modern civil infrastructure. The primary ingredients of conventional concrete — cement, fine aggregates (sand), coarse aggregates, and water — are responsible for the physical and mechanical performance of concrete. However, with increasing environmental concerns and resource scarcity, the sustainability of concrete has become a significant topic of interest. The cement industry alone accounts for approximately 7-8% of global CO_2 emissions, due to the calcination of limestone and the high energy requirements during its manufacturing. Similarly, the excessive extraction of natural river sand for fine aggregates is leading to environmental degradation, loss of biodiversity, and destabilization of river beds.

In this context, there has been a growing emphasis on developing sustainable and eco-friendly alternatives to conventional concrete constituents. Among various industrial and agricultural wastes, Sugarcane Bagasse Ash (SCBA) and Marble Waste (MW) have gained attention due to their potential use as supplementary materials in concrete production. Utilizing these materials not only promotes sustainability but also helps mitigate the environmental challenges posed by their disposal.

1.2. Research Gap and Need for the Study

Several studies have independently investigated the use of either SCBA or MW in concrete. However, limited research has been conducted on the combined effect of SCBA and MW on the mechanical and durability properties of concrete. The potential synergies between SCBA's pozzolanic behavior and MW's filler characteristics could lead to improved concrete performance, especially in terms of compressive strength, split tensile strength, flexural strength, and long-term durability.

Moreover, there is a lack of standardized mix design practices and performance guidelines when using both these waste materials in combination. This study seeks to bridge this knowledge gap and offer experimental insights into optimum replacement levels, performance metrics, and practical applicability of SCBA and MW in sustainable concrete production.

1.3. Objectives of the Study

The main objectives of the experimental investigation are:

- To evaluate the physical and chemical properties of Sugarcane Bagasse Ash and Marble Waste.
- To determine the optimum percentage of cement replacement with SCBA and fine aggregate replacement with MW.
- To assess the workability and mechanical properties (compressive strength, tensile strength, flexural strength) of concrete containing SCBA and MW.
- To examine the durability characteristics, including water absorption, permeability, and resistance to aggressive environmental conditions.
- To compare the performance of the modified concrete mixes with control concrete and identify the most efficient and sustainable composition.

1.4. Scope of the Study

This study focuses on M25 grade concrete, incorporating SCBA as a partial replacement for cement (5%, 10%, 15%, 20%) and MW as a partial replacement for fine aggregate (10%, 20%, 30%, 40%). A total of 16 mix combinations will be tested and analyzed. The tests will be conducted in accordance with IS standards (IS 10262:2019, IS 456:2000, IS 516:1959, etc.), and both fresh and hardened concrete properties will be studied.

The experimental investigation will help evaluate:

- Whether SCBA and MW can be safely and effectively used in structural applications.
- The extent to which these waste materials contribute to the mechanical strength and durability of concrete.
- The environmental and economic feasibility of implementing such waste-based concrete on a commercial scale.

II. METHODOLOGY

The present chapter elaborates the methodology of the study. To attain the objective of the study the below mentioned methodology has been adopted. The methodology of the study was shown in Fig 3.1.

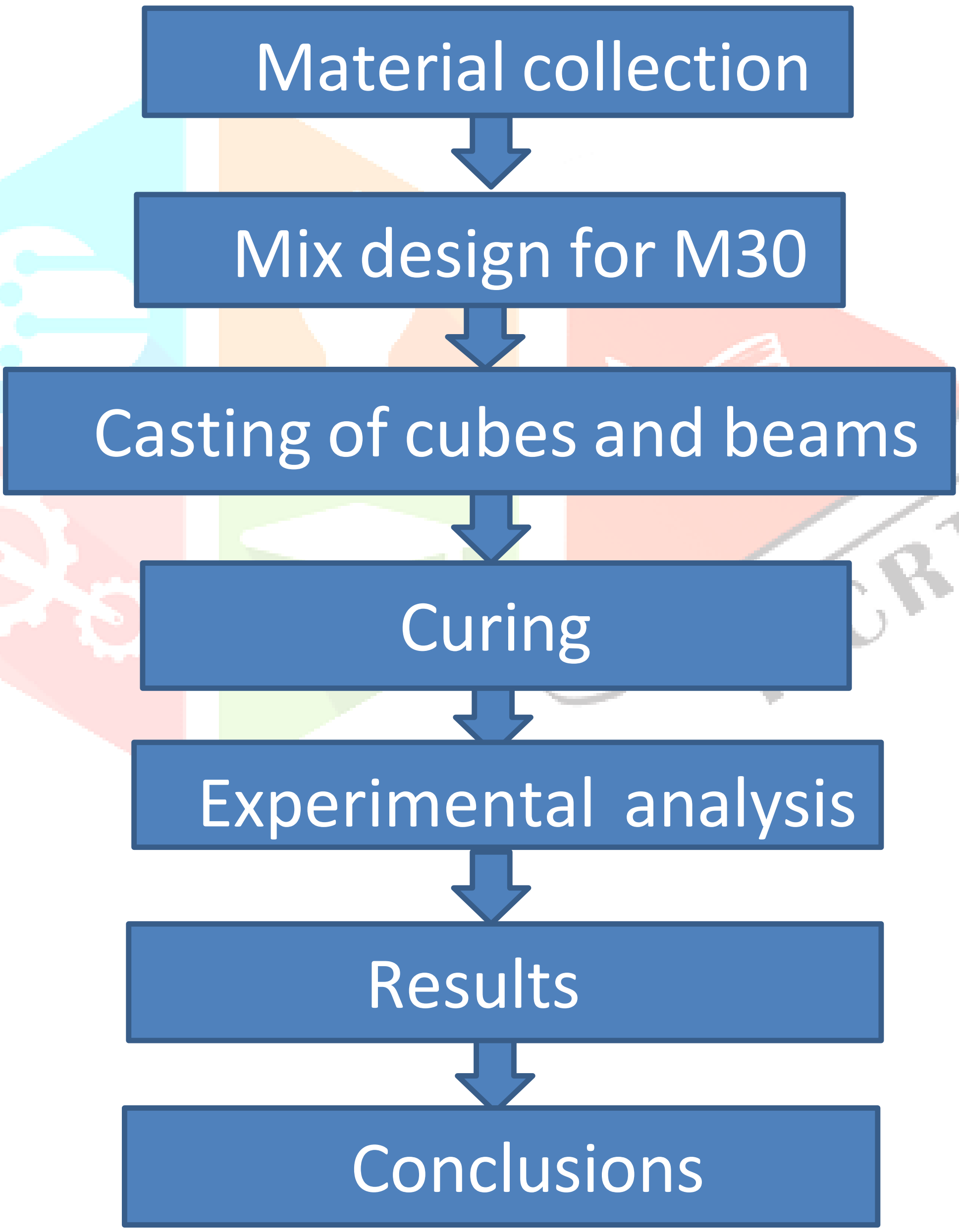

Fig 2.1 Methodology frame work of the study

III .Mix Design for M30 Grade Concrete

As per IS 10262:2019 (Target strength = 30 + 1.65×S = 38.25 MPa, assuming S = 5 MPa)

Design Mix (Control Mix - 0% SCBA & 0% MW):

Component	Quantity (kg/m³)
Cement	394
Water	157.6 (W/C = 0.4)
Fine Aggregate	656
Coarse Aggregate	1186
Superplasticizer	0.8% by wt. of cement (≈3.15 kg)

IV.TESTING

4.1 COMPRESSIVE STRENGTH TEST

Compressive strength test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

Table 4.1 SCBA Replacement (Cement Replacement only, MW fixed at 20%)

SCBA (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0% (Control)	28.1	33.6	39.5
5%	29.2	34.8	41.0
10%	30.4	36.2	42.8
15%	27.8	32.5	38.1
20%	25.4	30.1	35.0

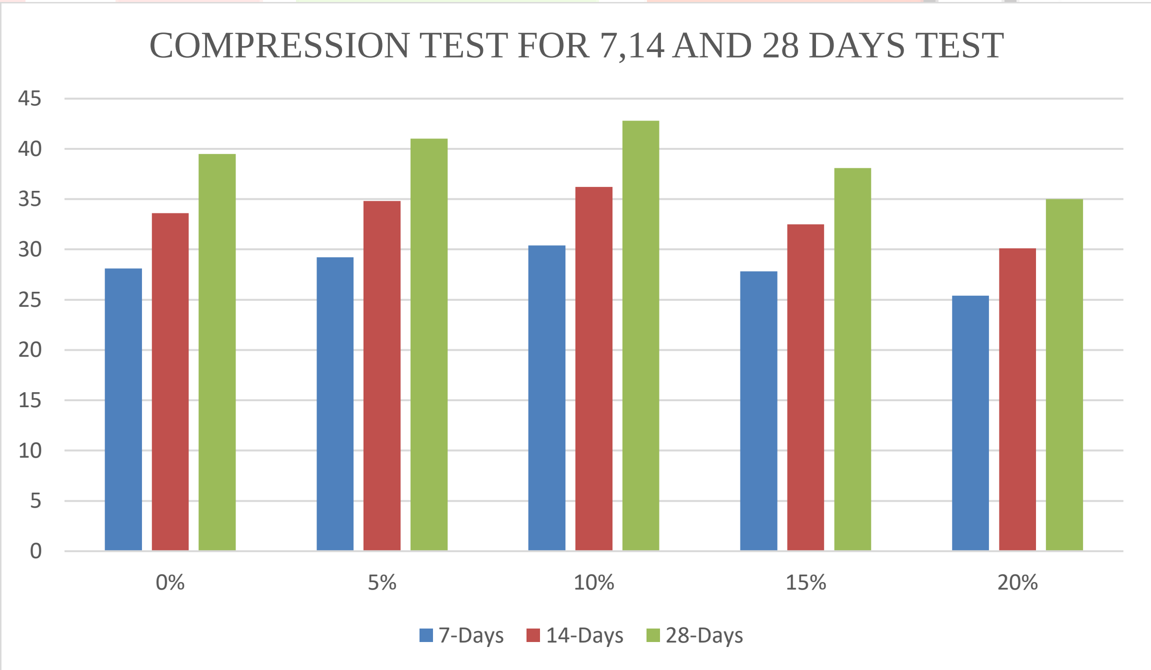

Fig.4.1 Compression test for 7,14 and 28 days test

- **At 5% and 10% SCBA**: There is an improvement in strength at all curing ages. This is due to the **pozzolanic activity of SCBA**, which reacts with calcium hydroxide and forms additional calcium silicate hydrate (C-S-H), thereby increasing strength.

- **At 15% and 20% SCBA**: A decrease in strength is noted, especially at early ages. This is likely because **excess SCBA dilutes the cement content**, reducing the available calcium hydroxide for pozzolanic reaction and lowering early strength. SCBA has slower reactivity compared to cement, thus high replacement levels affect initial strength development.

Table 4.2 Marble Waste Replacement (FA Replacement only, SCBA fixed at 10%)

MW (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0% (Control)	28.1	33.6	39.5
10%	29.7	35.0	41.3
20%	30.4	36.2	42.8
30%	28.5	33.9	39.9
40%	26.8	31.6	37.4
50%	24.7	28.2	33.5

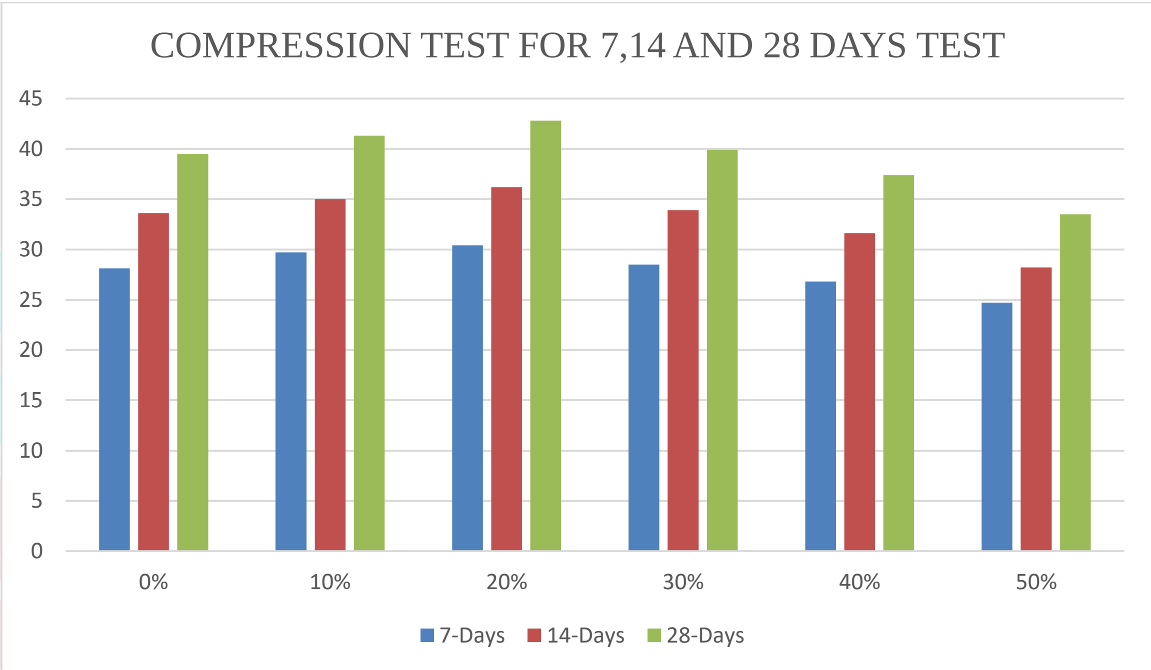

Fig.4.2 Compression test for 7,14 and 28 days test

- **At 10%–20% MW**: Strength increases due to the **filler effect of fine marble powder**, which improves particle packing and reduces voids, thus enhancing compressive strength.
- **Beyond 30% MW**: Strength decreases due to:
  - **Lack of bonding**: Marble waste is inert and smooth in texture, which reduces interfacial bonding.
  - **Water demand**: Marble waste absorbs more water due to its fine size, which may reduce effective water for hydration.
  - **Dilution of sand**: Excessive replacement reduces the angular and interlocking characteristics of natural sand.

V. Results And Conclusions

5.1 Results:

- **SCBA:** Optimum compressive strength was achieved at **10% SCBA replacement**, showing a **~8% increase** over the control mix at 28 days.
- **MW:** Maximum strength observed at **20% MW replacement**, with a **~7-8% gain** in compressive strength.
- Higher percentages of SCBA (>15%) and MW (>30%) **led to a reduction in strength**, likely due to increased porosity and reduced workability.
- **Durability (Water Absorption):**
  - Control: 4.2%
  - 10% SCBA + 20% MW: 3.6%
  - Indicates **reduction in permeability** with moderate waste usage.

5.2 Conclusions:

1. **SCBA and MW can be used effectively** as partial replacements for cement and fine aggregate respectively, enhancing the mechanical properties of concrete up to their optimum limits.
2. **10% SCBA and 20% MW** replacement levels are ideal for M30 grade concrete without compromising compressive strength and durability.
3. **Eco-friendly concrete**: Significant reduction in use of cement and natural sand, promoting sustainability and cost-efficiency.
4. **Circular economy**: This study supports reusing industrial and agricultural waste, aligning with sustainable development goals.

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