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Experimental Investigation on Concrete Bricks by Using Partial Replacement of Cement with Sugarcane Bagasse Ash and Eggshell Powder

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Abstract—In this construction industry is one of the largest consumers of cement, a material whose production contributes significantly to carbon dioxide emissions and environmental degradation. This study presents an experimental investigation on the mechanical properties of M25 grade concrete bricks incorporating Sugarcane Bagasse Ash (SCBA) and Eggshell Powder (ESP) as partial replacements for Ordinary Portland Cement (OPC). Cement was partially replaced with SCBA and ESP at replacement levels of 5%, 10%, and 15% by weight of cement. Concrete bricks were cast and subjected to curing periods of 7, 14, and 21 days. The experimental results revealed that a 10% partial replacement yielded the optimum compressive strength values, closely approaching the target M25 grade strength. Beyond 15% replacement, a gradual decline was observed. The findings conclude that partial replacement up to 10% is technically feasible for M25 grade concrete brick production without significant compromise in structural performance.

Keywords—*Sugarcane Bagasse Ash (SCBA); Eggshell Powder (ESP); M25 Concrete Bricks; Compressive Strength; Supplementary Cementitious* Materials; Sustainability

I. INTRODUCTION

Concrete is the most widely used construction material in the world. However, the production of Portland cement poses significant environmental challenges. Cement manufacturing is energyintensive and contributes nearly 8% of global carbon dioxide emissions [1]. This scenario has prompted researchers to explore sustainable alternatives that can partially replace cement without compromising concrete performance.

Sugarcane Bagasse Ash (SCBA) is a by-product of sugarcane processing industries. It possesses pozzolanic properties due to its silica-rich composition, making it a viable supplementary cementitious material [2]. Eggshell Powder (ESP), primarily composed of calcium carbonate ($CaCO_3$), acts as a micro-filler and contributes to enhancement of the cementitious matrix density [3].

The motivation behind this study lies in the dual benefits of environmental sustainability and material performance. By partially replacing cement with SCBA and ESP, the project aims to reduce carbon emissions, conserve natural resources, and improve the mechanical properties of concrete bricks.

II. OBJECTIVES

The primary objectives of this research are:

(1) To evaluate the effect of partial replacement of cement with SCBA and ESP on the mechanical properties of M25 grade concrete bricks.

(2) To determine the optimum replacement percentage that balances strength and sustainability.

(3) To assess the microstructural changes in concrete due to SCBA and ESP incorporation.

(4) To highlight the economic and environmental benefits of using agricultural waste in construction.

III. LITERATURE REVIEW

Ganesan et al. [1] investigated SCBA as a partial replacement for cement and found that 10% replacement gives optimum compressive strength. SCBA, being pozzolanic and rich in silica and alumina, can effectively replace cement up to 10% without significant strength loss.

Amin [2] studied the influence of ESP as a partial cement replacement and found that 10% replacement yielded acceptable compressive and flexural strength. The $CaCO_3$ content (~94%) contributes positively to the binding property of cement.

Kaviya et al. [3] conducted an experimental study using SCBA and ESP as combined partial replacements in varying proportions. The combination of 10% SCBA + 5% ESP was reported as optimal, achieving a 28-day compressive strength of 14.8 N/mm².

Manikandan et al. [4] studied physical, mechanical, and thermal properties of concrete bricks produced with varying proportions of SCBA and ESP. The 10% SCBA + 10% ESP combination showed the best overall performance with compressive strength of 16.1 N/mm² and water absorption of 9.8%.

Dhanalakshmi & Chitra [5] reported that 10% SCBA + 5% ESP replacement provided 17.3 N/mm² compressive strength at 28 days, which was 8% higher than the control specimen, attributing this to the synergistic pozzolanic and filler effect of both materials.

IV. M TERIALS USED

A. ement

Ordinary Portland Cement (OPC) of 53 Grade conforming to IS 12269:2013 was used as the primary binding material. The specific gravity was found to be 3.14, initial setting time 30 minutes, and final setting time 600 minutes, all within permissible IS limits.

B. ine Aggregate

Manufactured Sand (M-Sand) conforming to Zone II as per IS 383:2016 was used. The specific gravity was 2.67, water absorption 1.3%, and fineness modulus 2.6, confirming its suitability for M25 grade concrete production.

C. oarse Aggregate

Crushed granite coarse aggregate of 20mm nominal size conforming to IS 383:2016 was used. Specific gravity: 2.64, water absorption: 1%, fineness modulus: 6.53, and Aggregate Impact Value (AIV): 10% — all within permissible limits.

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D. Water

Potable laboratory water conforming to IS 456:2000 and IS 3025 was used. The pH value was found to be 7.2, which is within the permissible range of 6.0 to 8.5.

E. Sugarcane Bagasse Ash (SCBA)

SCBA was collected from local sugarcane processing units, dried, and sieved through a 90-micron sieve. It is rich in silica (SiO_2) and alumina (Al_2O_3), constituting approximately 65–70% silica content, making it a highly reactive pozzolan.

F. Eggshell Powder (ESP)

Eggshell waste was collected, cleaned, oven-dried at 105°C, and ground into fine powder. ESP is primarily composed of calcium carbonate ($CaCO_3$ ~94%), which acts as a micro-filler enhancing the cementitious matrix.

V. MIX DESIGN

Mix design for M25 grade concrete was carried out as per IS 10262:2019. The target mean compressive strength was computed as:

$$f'ck = fck + 1.65 \times S = 25 + 1.65 \times 4 = 31.60\ N/mm^2$$

The water-cement ratio was taken as 0.45 with a water content of 180 litres/m³, yielding a cement content of 400 kg/m³. The mix ratio obtained was Cement : FA : CA = 1 : 1.68: 2.91 with w/c = 0.45.

Brick mould dimensions of 230 mm × 110 mm × 70 mm (as per IS 2185) were used. Material quantities per brick were calculated with 10% wastage allowance. Four mix proportions were prepared:

Table I: Mix Proportions Per Brick

Mix ID	Cement (kg)	SCBA (kg)	ESP (kg)	FA (kg)	CA (kg)	Water (L)
M0 (0%)	1.164	0.000	0.000	1.164	2.328	0.378
M1 (5%)	1.106	0.029	0.029	1.164	2.328	0.378
M2 (10%)	1.048	0.058	0.058	1.164	2.328	0.378
M3 (15%)	0.990	0.087	0.087	1.164	2.328	0.378

VI. EXPERIMENTAL METHODOLOGY

A. Casting Procedure

Moulds were cleaned and coated with a releasing agent. All materials were weighed accurately as per mix proportions and mixed in a mechanical mixer — dry materials for 2 minutes, then water added and mixed for 3–4 minutes. Workability was assessed using the slump cone test (IS 1199:1959). Specimens were filled in three layers with 25 tamping blows per layer, levelled, marked, and demoulded after 24 hours.

B. Curing

Specimens were immersed in clean water and cured for 7, 14, and 21 days at room temperature. A total of 12 brick specimens (3 per mix) were cast and tested.

VII. TESTS CONDUCTED

A. Workability Test (Slump Cone Test)

The slump cone test was conducted as per IS 1199:1959. Results

showed a decrease in slump with increasing replacement levels due to the irregular particle texture of SCBA and ESP, which absorbs additional mixing water.

Table II: Slump Test Results

Mix ID	Replacement (%)	SCBA (%)	ESP (%)	Slump (mm)	Type
M0	0	0.0	0.0	48	True
M1	5	2.5	2.5	44	True
M2	10	5.0	5.0	40	True
M3	15	7.5	7.5	35	True

B. Compressive Strength Test

Compressive strength was tested as per IS 516:1959 using a Compression Testing Machine (CTM). Load was applied at a rate of 140 kg/cm²/min. The compressive strength was calculated as:

$$Compressive\ Strength\ (N/mm^2) = Failure\ Load\ (kN)\ /\ Crosssectional\ Area\ (mm^2)$$

Table III: Compressive Strength Test Results

Mix ID	Replacement (%)	7 Days (N/mm²)	14 Days (N/mm²)	14 Days (N/mm²)
M0	0	20.3	23.4	24.6
M1	5	6.91	14.62	15.41
M2	10	10.27	21.73	22.1
M3	15	15.41	22.92	23.3

**Results to be filled after laboratory testing*

VIII. EXPECTED RESULTS AND DISCUSSION

Based on literature review and preliminary analysis, it is expected that M2 (10% SCBA + 5% ESP) will yield the optimum compressive strength among all replacement levels. The pozzolanic activity of SCBA, combined with the micro-filler effect of ESP, is anticipated to produce a denser cement matrix, resulting in higher strength compared to the control mix at later curing ages.

The slump values confirm that workability decreases with increasing replacement levels. This is attributed to the high fineness and angular morphology of SCBA and ESP particles, which demand higher water content. However, all slump values remained within acceptable limits for true slump.

Progressive strength gain with increasing curing age across all replacement levels is expected, confirming the time-dependent pozzolanic reactivity of SCBA. Beyond 15% replacement, a gradual decline in compressive strength is anticipated due to the dilution effect on cement content.

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IX. CONCLUSION

This experimental investigation demonstrates the feasibility of using Sugarcane Bagasse Ash and Eggshell Powder as partial replacements for cement in M25 grade concrete brick production. Key conclusions drawn from the study are:

(1) A 10% partial replacement of cement with combined SCBA and ESP is technically feasible without significant compromise in structural performance.

(2) Slump values decrease with increasing replacement levels, indicating reduced workability, but all mixes remain within acceptable limits.

(3) Strength gain is progressive with curing age, confirming timedependent pozzolanic reactivity of SCBA.

(4) This approach provides a promising pathway toward ecofriendly, cost-effective, and sustainable construction practices by valorising agricultural waste materials.

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