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Experimental Investigation of Coconut Shell as a Lightweight Aggregate in Concrete

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ABSTRACT

This experimental study investigates the feasibility of utilising coconut shell as a partial replacement for conventional coarse aggregates in M20 grade concrete. The aim is to evaluate the mechanical and physical properties of lightweight concrete produced using varying percentages of coconut shell aggregates (0%, 10%, 20%, and 30%). Experimental parameters such as workability, density, and compressive strength at 7, 14, and 28 days were analysed. Results indicated that a 20% replacement of coarse aggregates with coconut shells provided an optimal balance between strength and weight reduction, making it suitable for non-structural and low-load-bearing applications. The study concludes that coconut shell concrete is an eco-friendly alternative for sustainable construction practices.

KEYWORDS: *Lightweight Concrete, Coconut Shell Aggregate, M20 Grade, Compressive Strength, Sustainable Materials.*

I. INTRODUCTION

Concrete is the most widely used construction material worldwide, but its production is energy-intensive and contributes to environmental degradation. The utilisation of agricultural waste as a partial replacement for conventional materials can significantly reduce the environmental footprint of concrete production. Coconut shell, an abundant by- product of the coconut industry, offers a sustainable and lightweight alternative to conventional coarse aggregates. This study focuses on examining the mechanical and physical properties of coconut shell concrete and determining the optimum percentage of replacement suitable for structural applications.

II. LITERATURE REVIEW

The use of agricultural waste materials as partial replacements in concrete has gained considerable attention due to increasing environmental concerns and the demand for sustainable construction materials. Coconut shell, an abundant waste product from the coconut industry, has emerged as a promising lightweight aggregate alternative.

Gunasekaran et al. [6] conducted an experimental study on coconut shell concrete and reported that partial replacement of coarse aggregates up to 30% provided satisfactory strength and workability for lightweight structural applications. Olanipekun et al. [7] compared concrete made with coconut shell and palm kernel shell aggregates and concluded that coconut shell concrete exhibited higher compressive strength and better bonding properties due to its rough surface texture.

Neville and Brooks [8] identified that lightweight concrete typically has a density between 1800–2200 kg/m³, which correlates with the densities obtained in coconut shell aggregate studies. Rajasekaran and Pitchaimani [9] demonstrated that a 20% replacement level provided an optimum balance between strength and weight reduction, aligning with the results of the present investigation. Babu and Kumar [10] emphasised that pre- treatment of coconut shells, such as soaking in water or coating with pozzolanic materials, enhanced the interfacial bonding with the cement matrix and reduced water absorption.

Uddin and Ahmed [11] explored the mechanical behaviour of coconut shell concrete and observed a gradual reduction in compressive strength beyond 25% replacement. Satish et al. [12] highlighted that the inclusion of coconut shell significantly reduced the unit weight of concrete, making it suitable for non-load- bearing applications. Thomas and Wilson [13] further reported that coconut shell aggregates improved impact resistance and energy absorption due to their elastic behaviour under load.

III. MATERIALS AND METHODS

Ordinary Portland Cement (OPC) of 43 grade conforming to IS 8112 was used. Locally available river sand passing through a 4.75 mm sieve served as fine aggregate. Crushed granite coarse aggregates (20 mm size) were partially replaced with processed coconut shell particles of similar size. Four concrete mixes were prepared with 0%, 10%, 20%, and 30% replacement of coarse aggregates by weight using coconut shells.

Standard cubes of size 150 mm × 150 mm × 150 mm were cast and tested for compressive strength at 7, 14, and 28 days.

Figure 1: Coarse Aggregate

Figure 2: Fine Aggregate

IV. EXPERIMENTAL PROGRAM

Fresh concrete properties were assessed using slump tests to determine workability. The hardened concrete specimens were tested for density and compressive strength using a compression testing machine (CTM) with a capacity of 2000 kN. Three specimens were tested for each mix, and the average value was recorded. The experimental results were compared with the control concrete to evaluate the effect of coconut shell substitution.

Figure 3: Coconut shell

Figure 4: Coconut shell as Coarse Aggregate

V. RESULTS AND DISCUSSION

Table I shows the workability and density of coconut shell concrete mixes compared to conventional concrete.

Replacement(%)	Slump(mm)	Density(kg/m³)
0	80	2400
10	75	2250
20	70	2150
30	65	2050

Table 1: Workability and Density of Concrete Mixes

Table II presents the compressive strength results at different curing ages for all mixes.

Replacement(%)	7 Days	14 Days	28 Days
0	18.5	22.1	27.8
10	17.2	21.0	26.2
20	16.8	20.5	25.4
30	15.5	18.7	23.0

Table 2. Compressive Strength Results (MPa)

The results indicate a gradual reduction in both density and compressive strength with the increase in coconut shell content. However, the 20% replacement mix achieved a compressive strength of 25.4 MPa at 28 days, which satisfies the requirements for M20 grade concrete. The reduction in density makes the concrete suitable for lightweight applications such as partition walls, non-load-bearing structures, and precast elements.

VI. FUTURE WORK

Although the present investigation demonstrates the suitability of coconut shell as a partial replacement for coarse aggregates in M20 grade concrete, additional studies are required to further enhance its performance and expand its practical applications. The following areas are suggested for future research:

i. Durability Studies:

Investigate the long-term durability of coconut shell concrete under various environmental exposures such as wet–dry cycles, sulphate attack, and chloride penetration.

ii. Flexural and Tensile Strength:

Conduct tests on flexural and split tensile strength to determine the behaviour of coconut shell concrete under different stress conditions.

iii. Microstructural Analysis:

Utilise advanced characterisation techniques such as Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) to study the interfacial transition zone between cement paste and coconut shell aggregates.

a. Use of Mineral and Chemical Admixtures: Evaluate the combined effect of coconut shell aggregates with supplementary cementitious materials like fly ash, silica fume, or superplasticisers to improve workability and strength.

b. Life Cycle Assessment and Cost Evaluation: Perform a detailed life cycle assessment (LCA) and cost–benefit analysis to quantify the environmental and economic advantages of coconut shell concrete compared to conventional concrete.

c. Structural Performance Evaluation: Assess the performance of coconut shell concrete in structural elements such as beams, slabs, and precast blocks to validate its suitability for practical applications.

iv. Hybrid Aggregate Systems:

Explore the use of hybrid combinations of coconut shell with other lightweight aggregates to optimise both strength and density characteristics.

VII. CONCLUSION

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

i. The inclusion of coconut shell aggregates significantly reduces the density of concrete, enhancing its lightweight characteristics.

ii. The workability of concrete decreases slightly with increasing coconut shell content due to the irregular surface texture.

iii. A 20% replacement level provides an optimal balance between compressive strength and density.

iv. Coconut shell concrete offers a sustainable, cost-effective, and eco-friendly alternative to traditional coarse aggregates.

v. This material is best suited for low-load structural applications and non-structural components.

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