Experimental Investigation on the Use of Coconut Shell as Coarse Aggregate in Concrete

Prof. M. M. Ahirrao[1], Prof. N. R. Borase[2], Prof. S. K. Pawar[3], Dhangar Hitesh D.[4], Fulpagare Harshal A.[5], Fulpagare Karan R.[6], Galankar Harshraj D[7], Gangurde Sudhir B[8]

[1,3]*Assistant Professor, Civil Engineering Department, NESS'S Gangamai College of Engineering, Nagaon*

[2]*Head, Civil Engineering Department, NESS'S Gangamai College of Engineering, Nagaon*

[3]*Assistant Professor, Civil Engineering Department, NESS'S Gangamai College of Engineering, Nagaon*

[4,5,6,7,8]*UG Student, Civil Engineering Department, NESS'S Gangamai College of Engineering, Nagaon*

***Abstract*—The construction industry consumes large quantities of natural aggregates, leading to depletion of natural resources and environmental degradation. Simultaneously, agricultural waste disposal poses a serious environmental challenge. Coconut shell, an agricultural by-product, is generated in significant quantities in tropical countries like India and is often disposed of without productive use. This study investigates the feasibility of using coconut shell as a partial replacement for conventional coarse aggregate in concrete. Concrete mixes were prepared by replacing natural coarse aggregate with coconut shell at various replacement levels. The mechanical properties such as compressive strength, split tensile strength, and workability were experimentally evaluated. The results indicate that coconut shell concrete can be effectively used for lightweight and non-structural applications, contributing to sustainable construction practices.**

***Index Terms*—Coconut shell concrete, lightweight concrete, sustainable construction, agricultural waste, coarse aggregate replacement.**

I. INTRODUCTION

Concrete is the most widely used construction material due to its versatility, strength, and durability. Conventional concrete production requires large quantities of natural aggregates, whose excessive extraction has resulted in ecological imbalance, depletion of riverbeds, and environmental pollution. In recent years, sustainable construction practices have emphasized the utilization of waste materials as alternatives to natural resources.

Coconut shell is a hard, lignocellulosic agricultural waste obtained after the consumption of coconut meat and water. India is one of the largest producers of coconuts, generating enormous quantities of coconut shell waste annually. Due to its high strength, low density, and resistance to crushing, coconut shell has the potential to be used as a lightweight aggregate in concrete. This research aims to study the structural and mechanical behavior of concrete produced using coconut shell as a partial replacement for conventional coarse aggregate.

II. LITERATURE REVIEW

Several researchers have explored the use of agricultural waste in concrete to enhance sustainability. Studies on coconut shell aggregate concrete indicate that it produces lightweight concrete with reduced density compared to conventional concrete. Previous investigations have reported a decrease in compressive strength with increased coconut shell content; however, the strength achieved remains acceptable for non-load-bearing and lightweight structural applications.

Researchers have also observed improved ductility and energy absorption characteristics in coconut shell concrete. The rough surface texture of coconut shells enhances bonding with cement paste, contributing to satisfactory performance. These findings indicate that coconut shell can be a viable alternative coarse aggregate for eco-friendly construction.

III. MATERIAL USED

A. Cement

Ordinary Portland Cement (OPC) of 43 grade was used in this study. The cement conformed to IS 8112 specifications.

B. Fine Aggregate
Natural river sand conforming to Zone II as per IS 383 was used as fine aggregate.

C. Coarse Aggregate
Crushed stone aggregate of nominal size 20 mm was used as conventional coarse aggregate.

D. Coconut Shell
Coconut shells were collected locally, cleaned to remove organic matter, broken into required sizes, and air-dried. The shells were lightweight, hard, and irregular in shape.

E. Water
Potable water free from impurities was used for mixing and curing.

Table No. 1 Material Property Value

Material	Property	Value
Cement	Specific Gravity	3.15
Fine Aggregate	Specific Gravity	2.65
Coarse Aggregate	Specific Gravity	2.70
Coconut Shell	Specific Gravity	1.20-1.30
Coconut Shell	Water Absorption (%)	15-20
Coconut Shell	Bulk Density (kg/m³)	550-650

IV. METHODOLOGY

A. Mix Proportion
Concrete mixes were prepared by replacing coarse aggregate with coconut shell at different percentages (e.g., 0%, 10%, 20%, and 30%). The mix design was carried out as per IS 10262 guidelines.

Table No. 2 Mix Proportions of concrete

Mix ID	Coconut Shell Replacement (%)	Cement (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Coconut Shell (kg/m³)
CS 0	0	380	700	1200	0
CS 10	10	380	700	1080	120
CS 20	20	380	700	960	240
CS 30	30	380	700	840	360

B. Casting of Specimens
Concrete was mixed thoroughly and cast into standard molds:
Cubes (150 mm × 150 mm × 150 mm) for compressive strength

Cylinders for split tensile strength
Specimens were demolded after 24 hours and cured in water for 7 and 28 days.

V. EXPERIMENTAL TESTS

A. Workability Test
The slump test was conducted to evaluate workability. It was observed that workability decreased with an increase in coconut shell content due to its higher water absorption capacity.

B. Compressive Strength Test
Compressive strength tests were performed as per IS 516. Results indicated a gradual reduction in strength with increased coconut shell replacement; however, the strength values were acceptable up to a certain replacement level.

C. Split Tensile Strength Test
Split tensile strength was determined using cylindrical specimens. Coconut shell concrete showed comparatively lower tensile strength than conventional concrete but exhibited better crack resistance.

VI. RESULTS AND DISCUSSION

The experimental investigation was carried out to evaluate the effect of partial replacement of conventional coarse aggregate with coconut shell on the mechanical and physical properties of concrete. The results obtained from workability, compressive strength, split tensile strength, and density tests are discussed in detail below.
A. Workability of Concrete
The workability of fresh concrete was assessed using the slump test. It was observed that the slump value decreased with an increase in the percentage replacement of coarse aggregate by coconut shell. The control mix (CS0) exhibited medium workability, whereas mixes containing higher coconut shell content showed reduced slump values. This reduction in

workability is primarily due to the irregular shape, rough surface texture, and higher water absorption capacity of coconut shells. As a result, additional water demand increases with higher replacement levels.

Table No. 3 workability results

Mix ID	Coconut Shell Replacement (%)	Slump value	workability
CS0	0	85	Medium
CS10	10	75	Medium
CS20	20	65	Low
CS30	30	50	Very low

B. Compressive Strength

The compressive strength results at 7 days and 28 days indicate a gradual reduction in strength with an increase in coconut shell replacement. The control mix achieved the highest compressive strength, while mixes with coconut shell showed comparatively lower values. At 28 days, concrete with 10% and 20% coconut shell replacement attained strength values close to conventional concrete, indicating satisfactory performance.

The reduction in compressive strength at higher replacement levels can be attributed to the lower crushing strength and stiffness of coconut shell compared to natural coarse aggregate. However, up to 20% replacement, the strength reduction remains within acceptable limits for non-load-bearing and lightweight structural applications.

Table No. 4 compressive strength results

Mix ID	Coconut Shell Replacement (%)	Compressive Strength (MPa) at 7 Days	Compressive Strength (MPa) at 28 Days
CS0	0	22.5	31.8
CS10	10	20.8	29.2
CS20	20	18.6	26.5
CS30	30	15.2	22.1

C. Split Tensile Strength

Split tensile strength results followed a trend similar to compressive strength. The tensile strength decreased as the coconut shell content increased. This behavior is mainly due to weaker interfacial bonding between coconut shell aggregate and cement paste compared to conventional aggregate. Despite this reduction, coconut shell concrete exhibited better crack resistance and ductility, which is advantageous in lightweight construction.

Table No. 5 Split tensile strength results

Mix ID	Coconut Shell Replacement (%)	Split Tensile Strength (MPa)
CS0	0	3.10
CS10	10	2.85
CS20	20	2.55
CS30	30	2.10

D. Density of Concrete

The density of concrete decreased significantly with the increase in coconut shell replacement. The control mix represented normal-weight concrete, whereas mixes containing coconut shell fell under the category of lightweight concrete. At higher replacement levels, a substantial reduction in self-weight was achieved, making coconut shell concrete suitable for applications where reduced dead load is desired.

Table No. 6 density of concrete

Mix ID	Coconut Shell Replacement (%)	Density	Type of Concrete
CS0	0	2450	Normal Weight
CS10	10	2280	Semi-Lightweight
CS20	20	2100	Lightweight
CS30	30	1950	Lightweight

E. Overall Performance

From the experimental results, it is evident that coconut shell concrete offers a balance between strength and sustainability. Although there is a reduction in mechanical strength with increased coconut shell content, the benefits of reduced density, utilization of agricultural waste, and environmental sustainability make it a viable alternative for eco-friendly construction. The optimum replacement level of coconut shell as coarse aggregate was found to be up to 20%, beyond which significant strength loss was observed.

VII. CONCLUSION

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

1. Coconut shell can be successfully used as a partial replacement for coarse aggregate in concrete.

2. The density of concrete decreases with an increase in coconut shell content, producing lightweight concrete.
3. Compressive and tensile strength decrease with higher replacement levels but remain acceptable up to 20% replacement.
4. Coconut shell concrete is suitable for non-load-bearing structures, partition walls, and low-cost housing.
5. The use of coconut shell contributes to sustainable construction and effective waste management.

REFERENCES

[1] IS 10262:2019, Concrete Mix Proportioning – Guidelines, Bureau of Indian Standards, New Delhi.
[2] IS 516:1959, Methods of Tests for Strength of Concrete, BIS.
[3] IS 383:2016, Specification for Coarse and Fine Aggregates, BIS.
[4] Gunasekaran, K., et al., "Mechanical properties of coconut shell concrete," Construction and Building Materials, vol. 25, no. 2, pp. 120–125.
[5] Neville, A. M., Properties of Concrete, Pearson Education.