Sustainable Utilization of Coconut Shell Waste in Concrete as Partial Coarse Aggregate Replacement

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***Abstract*—In the construction industry, the escalating cost of building materials has become a major concern. With prices continuing to rise, there is a growing need to explore sustainable and cost-effective alternatives. One such approach is the utilization of waste materials as construction components, which can not only reduce expenses but also promote environmental sustainability. Coarse aggregate forms a significant portion of concrete, and in this study, coconut shell is investigated as a partial replacement for conventional coarse aggregate. This paper presents the findings from experimental tests conducted on M20 grade concrete (mix ratio 1:1.5:3), where coconut shell was used to replace coarse aggregate at varying levels of 0%, 25%, 50%, and 100%. For each replacement level, three concrete cube samples were cast and tested to determine compressive strength. In addition to evaluating performance, the study also aims to raise awareness about the potential of coconut shell as an eco-friendly material in civil engineering applications.**

***Index Terms*—Construction material, coconut shell, compressive strength of coconut shell, Coconut shell concrete, Waste Utilization**

I. INTRODUCTION

Concrete is a fundamental material in civil engineering, composed of essential components such as cement, sand, aggregates, water, and necessary admixtures. With the rapid pace of global infrastructural development, the demand for construction materials continues to rise. This growing demand highlights the need to explore alternative, sustainable materials for use in concrete. Simultaneously, the increasing volume and variety of waste materials are contributing to significant environmental concerns. Coconut, cultivated in over 93 countries, is native to Southeast Asia. India ranks as the third-largest producer, with approximately 1.78 million hectares under cultivation. Coconut shells, a byproduct of this large-scale cultivation—particularly prevalent in coastal regions such as Kerala, Andhra Pradesh, Goa, and the Konkan belt—can be considered as a potential replacement for conventional coarse aggregates in concrete. Due to their hard, fibrous structure, coconut shells are resistant to decomposition and often persist as solid waste for extended periods, making them a viable option for recycling into construction material.

II. COCONUT SHELL AS COARSE AGGREGATE

Produced using coconut shell aggregates meets the basic requirements for structural concrete. Due to the smooth surface texture on one side of the shell, coconut shell concrete exhibits improved workability compared to conventional mixes. It also demonstrates higher impact resistance than standard concrete. Coconut shells have greater moisture retention and water absorption capabilities than traditional aggregates. As a result, a higher quantity of cement may be needed when using coconut shells as coarse aggregates to achieve similar strength properties. Additionally, the natural sugars present in the shells—provided they are not in a free sugar form—do not adversely affect the setting time or the strength development of concrete. Studies have shown that wood-based materials like coconut shells, being tough and organic, offer promising potential as alternative aggregates in concrete production.

III. INTENTION

"To demonstrate that coconut shell concrete is a lightweight and cost-effective material suitable for use in civil engineering applications."

IV. RESEARCH MATERIAL AND TESTING

4.1 MATERIALS

Research material are cement, natural fine aggregate, coarse aggregate, water and coconut shell.

4.2 COCONUT SHELL

Coconut shells were sourced primarily from temples and similar places, then sun-dried for a minimum period of one month before being manually crushed. The resulting shell particles ranged in size from 5 mm to 20 mm. For the entire experimental study, Ordinary Portland Cement (OPC) of 53 grade, complying with Indian Standard IS 12269-1987, was used.

4.3 FINE AGGREGATE

Naturally available fine aggregate from Neyyar River

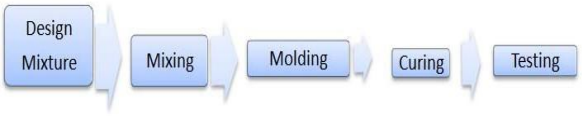
4.4 COARSE AGGREGATE

Crushed hard basalt stones with a maximum size of 20 mm were used as coarse aggregate in the concrete mix. The aggregate had a bulk density of 1545 kg/m³ and a specific gravity of 2.77.

4.5 WATER

Clean, drinkable water complying with IS 456-2000 standards was used for both casting and curing of the concrete.

4.6 TESTING METHODOLOGY



V. CONCRETE MIX DESIGN

Mix design is the method of choosing suitable concrete components and calculating their required proportions to produce concrete that meets the desired strength, durability, and workability—while keeping it as cost-effective as possible.

5.1 Factor to be considered for mix design

1. The grade designation specifies the required characteristics of the concrete.
2. The type of cement used affects the rate at which the concrete's compressive strength develops.
3. The maximum nominal size of aggregate used in concrete should be as large as allowed within the limits specified by IS 456-2000. The cement content must be controlled to prevent issues such as shrinkage, creep, and cracking
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5.2 Designs for M20 Grade of Concrete

1. For the experimental work, the mix design of M20 grade concrete was selected according to IS 456-2000.
2. Sieve analysis was performed to determine the zone classification, as per the guidelines outlined in IS 383-1970.
3. The exposure condition is classified as moderate, according to IS 456-2000 (page 20, Table 7). For M20 grade concrete, the minimum cement content is 300 kg/m³, and the maximum permissible water-cement (W/C) ratio is 0.5.
4. Ordinary Portland Cement (OPC) is used for this mix.
5. The aggregate size ranges from 4.76 mm to 12.5 mm and is angular in shape.
6. The concrete mix design should ensure that the concrete has sufficient workability for the placement conditions and can be properly compacted.
7. The required workability is classified as medium. The level of supervision is considered to be good

VI. MIX PROPORTION

Mix proportioning is the process of selecting suitable ingredients for concrete and determining their relative quantities with the objective of producing a concrete of the required strength, durability, and workability as economically as possible. M20 grade concrete was designed as per the Indian standard specification IS: 10262-2009.

Table6.1 Mix proportioning 0% Replacement

Materials	For 3 Cubes
Cement	5.7kg
Fine aggregate	10.38kg
Coarse aggregate	16.14 kg
Water	2.85litres
W/C ratio	0.5

Table 6.2 Mix proportioning 0% Replacement

Materials	For 3 Cylinders
Cement	6.9 kg
Fine aggregate	12.54 kg
Coarse aggregate	19.35 kg
Water	3.45 litres
W/C ratio	0.5

VII. SPECIMEN DETAILS

7.1. The specimens like cubes, cylinders and beams are used to conduct the strength tests according to IS: 100086 – 1982. 1. Compressive strength test- In this research, moulds of size 150×150×150mm were tested for knowing the compressive strength of different mixes at 7,14and 21days. 2. Split tensile strength test.

7.2. Cylindrical moulds of 150mm diameter at 300mm height were tested for knowing the tensile strength of different mixes at 7, 14 and 21days.

Fig 7.2 cylinders

VIII. RESULTS AND DISCUSSION

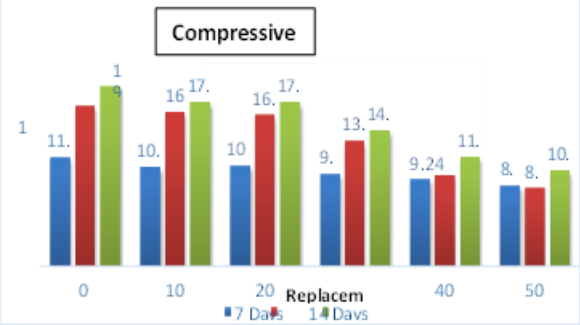
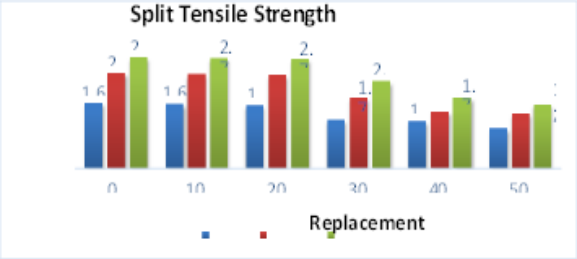


Fig 8.1: Graph of Compressive Strength V/S Replacement



Graph of Split Tensile Strength V/S Replacement

IX. CONCLUSION

1. By studying the results obtained we conclude that Coconut shell can be replaced up to 10-20% as a coarse aggregate.
2. It is concluded that Increase in percentage replacement by coconut shell reduces compressive strength of concrete.
3. Similar to compressive strength, the split tensile strength also decreased with increase in Coconut Shell replacement.
4. Increase in percentage replacement by coconut shell increases workability of concrete.
5. Use of coconut shells in cement concrete can help in waste reduction and pollution reduction. The need of this project is to encourage the use of the waste product as a construction material in low-cost housing.

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