



# Mechanical Properties of Concrete Partial Replacement of Coarse Aggregates With Coconut Shell

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**Abstract:** This study explored the use of coconut shells, an abundant agricultural waste, as a partial replacement for traditional coarse aggregates in concrete. The primary goal was to evaluate the impact of this substitution on the concrete's compressive strength, a crucial factor determining its suitability for various construction applications. Concrete samples were prepared with varying percentages of coconut shell replacement, ranging from 0% to 30%. These samples were then subjected to compressive strength tests after standard curing periods. The results consistently showed a decrease in compressive strength as the percentage of coconut shell replacement increased. While lower replacement levels (up to 10-15%) resulted in a moderate reduction in strength, making the concrete suitable for specific applications like lightweight and non-structural elements, higher replacement levels (beyond 20%) led to a significant decline, rendering the concrete unsuitable for high-load-bearing structures.

This research highlights the potential of coconut shells as a sustainable and environmentally friendly alternative to conventional coarse aggregates. By utilizing this agricultural waste, the construction industry can reduce its environmental impact. However, the trade-off between environmental benefits and reduced compressive strength must be carefully considered for specific applications.

**Key Words** - Compressive Strength, Coconut Shell, Partial Replacement, Coarse Aggregate, Concrete, Sustainable Materials, Waste Utilization, Lightweight Concrete.

## I. INTRODUCTION

The construction industry seeks economical and eco-friendly materials to enhance concrete's properties and reduce its environmental impact. One innovative approach involves using substitute materials like coconut shells as a partial replacement for traditional coarse aggregates. This research explores the use of coconut shells in concrete, focusing on their impact on mechanical properties such as compression test. By utilizing agricultural waste like coconut shells, the construction industry can promote sustainability and reduce its carbon footprint, addressing the environmental concerns associated with traditional concrete production [1][29]. To assess the structural integrity of concrete incorporating coconut shell aggregate, a compressive strength test is conducted. This test aims to identify the maximum load the concrete can withstand before failure. Concrete specimens, varying in coconut shell aggregate content, are cast into standard molds (cylindrical or cubic). A compression testing machine, capable of applying up to 2,000 kN of load, is employed to gradually compress the specimens. The load at which the specimen fails is recorded,

providing a measure of its compressive strength. Proper curing of the specimens in a water tank is crucial to ensure accurate results[4][18].

## LITERATURE REVIEW

A 2023 study by L. Krishnaraj and Atul Kumar investigated the potential of using agricultural waste as a partial replacement for sand in cement block production. By recycling agricultural waste, this research aims to promote sustainable building practices and reduce environmental pollution. Rath's 2023 study explored the use of fly ash and pond ash as replacements for cement and sand in concrete, aiming to enhance the sustainability and durability of concrete constructions in Chhattisgarh, India. By utilizing locally available waste materials, this research seeks to reduce carbon emissions and promote sustainable building practices. Ayyappa's 2023 study experimentally examined the effects of eggshell and coconut shell powders on concrete's workability and strength. By varying the proportions of these additives in M20 grade concrete, the study aimed to evaluate the split tensile and compressive strength of concrete cylinders and cubes. The research sought to understand how these additives influence the overall properties of concrete. A 2022 study by Siti Aminah Bt Tukiman and Sabarudin Bin Mohd explored the feasibility of using grained palm kernel and coconut shell as a lightweight aggregate in concrete. The study suggests that this approach could reduce construction costs. A study by R. Ramya Swetha and M. Swaroopa Rani (2021) explored the use of agricultural wastes, bagasse ash (BA) and rice husk ash (RA), as partial replacements for cement in M30 grade self-compacting concrete (SCC). The optimal mix, combining 4% RA and 10% BA, achieved compressive strengths of 29.43 MPa at 7 days, 42.29 MPa at 28 days, and 42.73 MPa at 56 days, while improving workability with added superplasticizer.

## MATERIALS

Cement is a crucial component of concrete, contributing to its strength and binding properties. 53 grade cement, a popular choice, is known for its high early strength and rapid setting. As defined by the BIS, it achieves a compressive strength of 53 MPa after 28 days. This premium cement is widely used in construction projects requiring exceptional strength and durability. Fine aggregates, commonly known as sand, are essential components in concrete. They fill the gaps between coarse aggregates, contributing to a dense and workable concrete mix. Understanding the composition and role of fine aggregates is crucial for producing high-quality concrete. These aggregates, derived from natural sources like riverbeds or quarries, or produced by crushing stone, consist of tiny rock and mineral particles. Coarse aggregates, typically sized between 4.75 and 80 mm, are crucial components of concrete. They form the skeleton of concrete, providing bulk, strength, and durability. Understanding the properties and significance of coarse aggregates is essential for producing high-quality concrete for various construction applications[20]. The construction industry is increasingly seeking sustainable solutions to reduce its environmental impact. One innovative approach involves using coconut shells, a common agricultural waste product, as a replacement for traditional coarse aggregates in concrete. By utilizing this abundant waste material, we can reduce pollution, conserve natural resources, and promote sustainable construction practices. The chemical composition of coconut shells makes them a viable alternative to traditional aggregates, offering a promising solution for environmentally friendly and cost-effective building methods[8][16][26].





Fig. 1. Cement, Fig. 2. Fine aggregate, Fig. 3. Coarse aggregate, Fig. 4. Coconut Shell

## II. METHODOLOGY

### Mix Design

Concrete mix design as per IS: 10262-2009[9]. We're tasked with designing a concrete mix with a target strength of 40 MPa. To do this, we need to determine the optimal proportions of cement, water, fine aggregate, and coarse aggregate.

Step-by-Step Process:

1. Target Strength:

We set a target mean strength of 48.25 MPa, which is calculated based on the desired strength and a safety factor.

2. Air Content:

To improve concrete's durability and workability, we aim for a 1% air content.

3. Water-Cement Ratio:

A lower water-cement ratio generally leads to higher strength. In this case, we've selected a ratio of 0.36.

4. Water Content:

The water content is determined based on the desired workability. For this mix, we've calculated a water content of 191.58 kg/m<sup>3</sup>.

5. Cement Content:

Using the water-cement ratio, we calculate the cement content to be 532.16 kg/m<sup>3</sup>.

6. Volume of Aggregates:

The total volume of aggregates is calculated based on the air content and water-cement ratio.

The volume of coarse and fine aggregates is determined based on a specific ratio (in this case, 0.5:0.5).

7. Mass of Aggregates:

The mass of aggregates is calculated based on their volume and specific gravity.

### Final Mix Proportions:

- Cement: 532.16 kg/m<sup>3</sup>
- Water: 191.58 kg/m<sup>3</sup>
- Fine Aggregate: 578 kg/m<sup>3</sup>
- Coarse Aggregate: 1100 kg/m<sup>3</sup>
- Water-cement: 0.36

Table.1 Mix Design values

S. No	Main Type	Cement ( $kg/m^3$ )	Fine Aggregate ( $kg/m^3$ )	Coarse Aggregate ( $kg/m^3$ )	Coconut Shells (kg)	W/C Ratio	S.P Dosa ge
1	CASC 0%	532.16	578	1100	0	0.36	0.08
2	CASC 5%	532.16	578	1045	55	0.36	0.08
3	CASC 7.5%	532.16	578	1017.5	82.5	0.36	0.08
4	CASC 10%	532.16	578	990	110	0.36	0.08
5	CASC 12.5%	532.16	578	962.5	137.5	0.36	0.08
6	CASC 15%	532.16	578	935	165	0.36	0.08
7	CASC 17.5%	532.16	578	907.5	192.5	0.36	0.08
8	CASC 20%	532.16	578	880	220	0.36	0.08
9	CASC 22.5%	532.16	578	852.5	247.5	0.36	0.08
10	CASC 25%	532.16	578	825	275	0.36	0.08
11	CASC 27.5%	532.16	578	797.5	302.5	0.36	0.08
12	CASC 30%	532.16	578	770	330	0.36	0.08

### Compressive Strength Test

To assess coconut shell concrete's strength, specimens are cast, cured, and tested in a compression machine to determine their maximum load-bearing capacity.

Following IS 10262, design a concrete mix (e.g., M40) and progressively replace coarse aggregate with coconut shells (5% - 30%) [2]. Maintain constant water-cement ratio for consistent comparison.

**Preparation of Coconut Shell:** Coconut shells are thoroughly washed and dried to eliminate impurities. Subsequently, they are crushed to achieve a uniform size of 10-20 mm, facilitating optimal bonding with other concrete components.

#### Process:

Accurately measure cement, fine aggregate, reduced coarse aggregate, coconut shells, and water based on the mix design. Thoroughly mix these components to achieve a uniform concrete mixture. Standard 150×150×150 mm cubes are filled with concrete in three layers, each compacted with 25 rod strikes. The surface is leveled, and the molds are covered to retain moisture. After 24 hours, demold the cubes and immerse them in a water tank for curing periods of 7, 14, and 28 days. Cured cubes are removed, dried, and placed in a CTM. A uniform load is applied at a rate of 140 kg/cm<sup>2</sup>/min until failure. The maximum load (P) at which the cube fails is recorded [3][14].



**Fig. 5. Curing the cubes, Fig. 6. Compressive Strength**

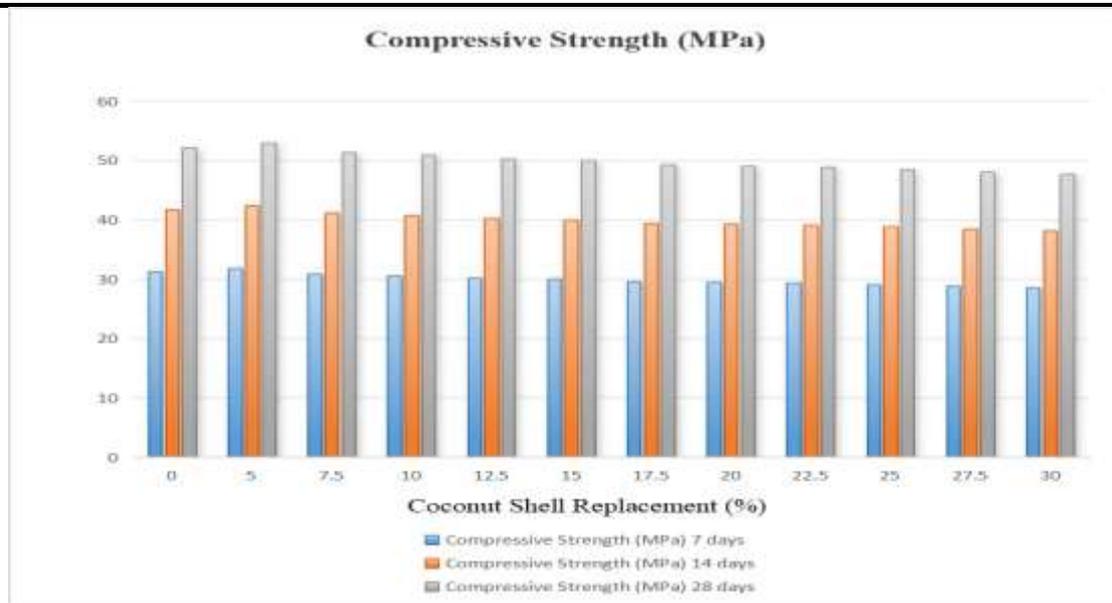
**Table.2 . Compressive Strength Test Results**

S.NO	CSCA Replacement(%)	Compressive Strength( $kg/m^3$ )		
		7 days	14 days	28 days
1	0	31.29	41.72	52.15
2	5	31.79	42.39	52.99
3	7.5	30.82	41.10	51.38
4	10	30.53	40.71	50.89
5	12.5	30.16	40.22	50.28
6	15	29.97	39.96	49.96
7	17.5	29.57	39.43	49.29
8	20	29.43	39.24	49.05
9	22.5	29.37	39.16	48.96
10	25	29.12	38.83	48.54
11	27.5	28.81	38.41	48.02
12	30	28.59	38.12	47.65

### III. RESULTS AND DISCUSSION

Replacing 5-10% of coarse aggregate with coconut shell resulted in slight decreases in compressive strength, but the concrete remained suitable for various structural applications with minimal impact on properties. However, increasing the replacement level to 12.5-15% significantly reduced strength due to decreased density and weaker bonding, limiting suitability for high-strength applications. Further increases to 17.5-30% led to significant strength reductions due to increased porosity and weaker bonding, making the concrete unsuitable for load-bearing or most structural applications.

Coconut shell aggregate weakens concrete. Normal concrete (0% replacement) is the strongest, reaching 50 MPa after 28 days. With 5% replacement, strength slightly decreases but still reaches 47 MPa after 28 days. At 30% replacement, strength significantly drops to 40 MPa after 28 days. While coconut shell concrete gains strength over time, the process is slower compared to normal concrete.



**Figure. 7. Compressive strength result at different percentages of coconut shells coarse aggregate**

#### IV. CONCLUSIONS

Coconut shell aggregate weakens concrete's compressive strength. As the amount of coconut shell increases, the concrete's strength decreases. This is due to the lightweight and porous nature of coconut shells, which increases the concrete's overall porosity and weakens the bond between the aggregates and cement paste. Due to this strength reduction, coconut shell concrete is best suited for non-structural applications like lightweight blocks or pavements. The study recommends a 5-10% replacement range as the optimal balance between sustainability and strength. Exceeding 15% replacement requires careful consideration of the specific application and load-bearing requirements. While using coconut shell as a replacement offers a sustainable solution, it's essential to ensure the concrete's mechanical properties remain acceptable, especially for load-bearing structures.

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