International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

STUDY OF CONCRETE USING COCONUT SHELL AS A PARTIAL REPLACEMENT OF COARSE AGGREGATE IN CONCRETE

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ABSTRACT:

This research investigates the potential of coconut shell as a partial replacement for conventional coarse aggregates in concrete, focusing on its effects on compressive strength, workability, durability, and cost. Coconut shell, an agricultural waste, offers environmental and economic benefits while reducing the density of concrete for lightweight construction applications. Concrete mixes with varying replacement levels (10%, 20%, and 25%) were tested for compressive strength over curing periods of 7, 14, and 28 days. Results indicate that up to 25% replacement is viable for M20 grade concrete, with marginal strength reduction and improved workability. The study highlights future research directions for enhancing durability and broader applications of coconut shell concrete.

Keywords : Coconut shell concrete, coarse aggregate replacement, compressive strength, lightweight concrete, sustainable construction

1. Introduction

Concrete is the most widely used construction material worldwide, traditionally relying on natural aggregates such as gravel and crushed stone. However, the extraction of these natural aggregates contributes to environmental degradation, necessitating the search for sustainable alternatives[12]. Agricultural waste materials, such as coconut shells, offer a promising substitute due to their availability, low cost, and environmental benefits (Arvind Krishan, 2015; Anink et al., 2012)[2].

Coconut shells are lightweight, porous, and possess a rough texture, potentially enhancing the bond with cement paste (Singh & Kumar, 2020). Incorporating coconut shell in concrete reduces its density, making it ideal for lightweight applications where load reduction is critical[3] (Ganesan et al., 2018)[3]. This study explores the effects of coconut shell as a partial coarse aggregate replacement on the mechanical and durability properties of M20 grade concrete.

2. Literature Review

The use of agricultural waste materials such as coconut shells as a partial replacement for coarse aggregates in concrete has gained increasing attention in recent years due to environmental concerns and the demand for sustainable construction materials. Various researchers have explored the mechanical, thermal, and durability properties of coconut shell concrete, highlighting its potential and limitations.

2.1 Mechanical Properties

Ganesan et al. (2018) conducted an experimental investigation on coconut shell concrete, where they replaced coarse aggregates with coconut shells at varying percentages. Their results indicated that the compressive strength of concrete decreased with an increase in coconut shell content, primarily due to the lower density and higher porosity of the shells compared to conventional aggregates. However, the reduction was within acceptable limits for non-structural applications, with up to 25% replacement showing promising results for lightweight concrete.

Similarly, Singh and Kumar (2020) studied the effect of coconut shell aggregate on compressive and tensile strength. They found that while compressive strength reduced slightly at higher replacement levels, the workability improved[6], which they attributed to the irregular shape and rough surface texture of coconut shells enhancing the paste-aggregate bonding. Their study also emphasized the importance of curing duration, with strength increasing significantly from 7 to 28 days[7].

2.2 Durability and Water Absorption

The durability of coconut shell concrete has been a subject of investigation by several researchers, Ganesan et al. (2018)91 noted that the high porosity and water absorption capacity of coconut shells could lead to increased shrinkage and reduced durability if not properly treated8. They suggested presoaking or surface treatment of coconut shells before mixing to improve durability. Further research by Olanipekun et al. (2019) reported that coconut shell concrete showed satisfactory resistance to sulfate attack and freeze-thaw cycles when adequate curing practices were followed, indicating its potential in various environmental conditions9.

2.3 Thermal and Acoustic Properties

Anink et al. (2012) discussed the thermal insulation properties of coconut shell concrete, highlighting its lower thermal conductivity compared to conventional concrete. This characteristic makes it suitable for energy-efficient buildings, especially in tropical climates. The lightweight nature of coconut shell concrete also contributes to better acoustic insulation, as noted by Arvind Krishan (2015)[1], making it an attractive option for residential and institutional buildings seeking sustainable solutions.

2.4 Economic and Environmental Impact

From an economic perspective, the use of coconut shells, an abundant agricultural waste, offers significant cost savings by reducing reliance on natural aggregates (Singh & Kumar, 2020). The reduction in dead weight due to lightweight concrete also lowers structural costs. Environmentally, the substitution of natural coarse aggregates with coconut shells helps in waste management, reduces landfill use, and decreases the carbon footprint associated with aggregate mining and transportation (Arvind Krishan, 2015).

2.5 Gaps and Research Opportunities

While existing studies provide encouraging results, gaps remain in the optimization of mix design, durability under long-term environmental stresses, and enhancing tensile strength and bonding characteristics. Research by Olanipekun et al.(2019) [2] recommended combining coconut shells with supplementary cementitious materials like fly ash or silica fume to improve mechanical properties and durability. Hybrid concrete mixes with other agro-waste materials could also open new avenues for sustainable construction materials.

3. Materials and Methods

3.1 Materials

- Cement: Ordinary Portland Cement (OPC) conforming to IS 12269-1987.
- Coarse Aggregates: Conventional crushed stone aggregates and pre-treated coconut shells (dried, cleaned, sieved).
- Fine Aggregates: Natural river sand.
- Water: Potable water for mixing.
- Admixtures: Super-plasticizers used to enhance workability.

3.2 Coconut Shell Characteristics

Coconut shells are larger, lightweight, and irregularly shaped compared to conventional aggregates. Their rough surface texture enhances cement paste bonding, but high porosity leads to increased water absorption, necessitating adjustments in the water-cement ratio (W/C) (Singh & Kumar, 2020).

TABLE 3(A) Properties of Coarse Aggregate (Coconut shell):

S.NO	PARAMETERS	RESULTS
1	**Specific Gravity**	**1.25**
2	**Water absorption (%) Bulk density kg/cm3**	**20**
3	**Shell thickness (mm)**	**2-6**

3.3 Mix Design

Concrete mixes were prepared by replacing 0%, 10%, 20%, and 25% of coarse aggregate volume with coconut shells. The water-cement ratio was adjusted to 0.45, considering the shells' water absorption3. The mix proportions for M20 grade concrete were based on IS 10262:2019 guidelines4.

Mix Proportion TABLE 3 (B):

Content /Bag	Water (lit)	Cement (kg)	Fine agg. (kg)	Coarse agg. (kg)	Coconut shell (kg)
M-20	**0.45**	**1**	**1.5**	**2.25**	**0.75**
20% cs	**22.5**	**50**	**75.19**	**117.10**	**39.03**
5-% cs	**22.5**	**50**	**75.19**	**75.19**	**75.19**

3.4 Specimen Preparation and Curing

The compressive strength test is a key parameter in evaluating the load-bearing capacity and overall quality of concrete (Neville, 2011). In this study, coconut shell was used as a partial replacement for coarse aggregate to analyze its effect on concrete strength (Gunasekaran et al., 2012)[7].

(a) Making of Specimen

Concrete was mixed using OPC, river sand, and crushed, pre-treated coconut shells as partial coarse aggregate (Awang & Abdul Rahman, 2015). A water-cement ratio was selected based on standard M20 mix design and adjusted for the high water absorption of coconut shell (Gunasekaran et al., 2013). The mix was poured into 150 mm cube molds in layers, each layer tamped 25 times and leveled (IS 516:1959)[9].

(b) Curing

After 24 hours of setting, the cubes were removed from the molds and cured in water for 7, 14, and 28 days under controlled conditions (IS 456:2000). Proper curing was essential to support hydration and strength development, especially with porous coconut shell aggregate (Gunasekaran et al., 2013)[5].

3.5 Testing Procedure

Compressive strength tests were conducted using a calibrated compression testing machine according to IS 516:1959. Load was applied at a constant rate until failure, and strength was calculated as7:

After curing, cubes were surface-dried and placed in the center of a calibrated compression testing machine (IS 516:1959). Load was applied at a constant rate of 0.2 MPa/s until failure9. Compressive strength was calculated using:

$Fc = P/A$

Where P is the load at failure and A is the cross-sectional area of 22500 mm². Results were averaged across three specimens per age group for consistency (Gunasekaran et al., 2012).

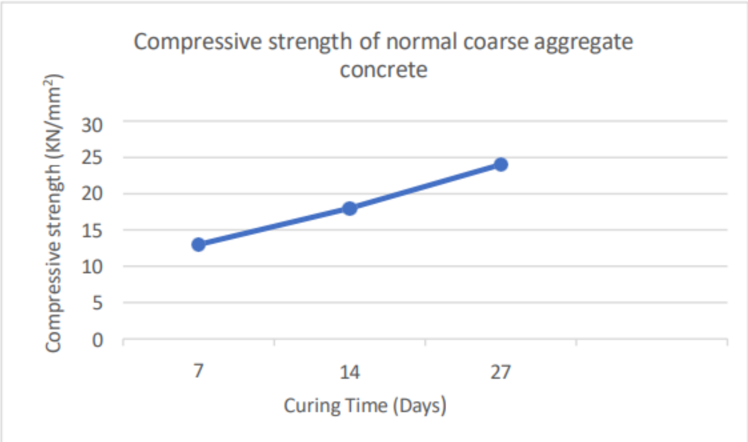
4. Results and Discussion

4.1 Compressive Strength

The compressive strength results (Tables 5(a), 5(b), and 5(c)) show a decreasing trend with increased coconut shell content. The average 28-day strength for control concrete was 24 MPa, whereas concrete with 25% coconut shell replacement achieved 22 MPa. The reduction is attributed to the lower strength and higher porosity of coconut shells[3].

Table 4(a) Compressive strength of normal coarse aggregate concrete cubes

S.NO.	Days	Compressive strength of normal coarse aggregate concrete
1	7	13
2	14	18
3	27	24
Average		18.33

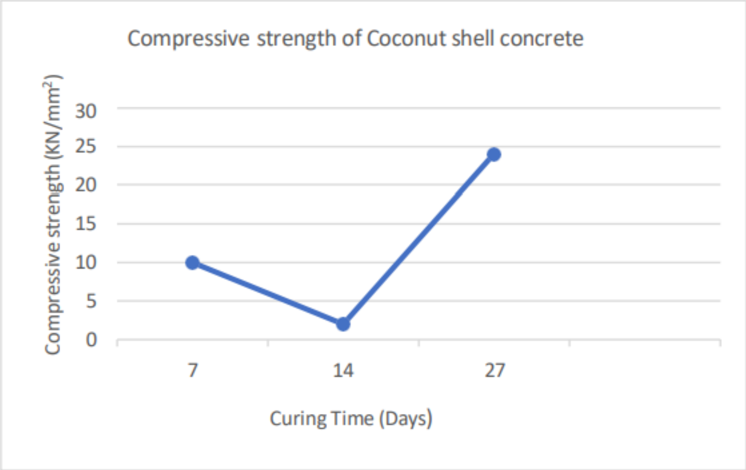


(Fig 4.1.1) Compressive strength graph on cubes

Table 4(b) Compressive strength of Coconut shell concrete cubes

S.NO.	Days	Compressive strength of coconut shell concrete
1	7	10
2	14	12
3	27	22

Average	**14.66**



(Fig 4.1.1) Compressive strength of Coconut shell concrete cube

Graphical representation (Fig 4.1.1) and 4.1.2) indicates that while strength decreases, it remains within acceptable limits for non-structural applications up to 25% replacement. The results align with previous studies by Singh & Kumar (2020) and Ganesan et al. (2018).

4.2 Workability

Mixes with coconut shells showed improved workability due to the shells' shape and texture, reducing the need for excess water. Use of super-plasticizers further enhanced the flowability.

4.3 Durability

Though not extensively tested in this study, literature suggests potential durability issues such as moisture retention and shrinkage in coconut shell concrete (Ganesan et al., 2018). Proper treatment and curing can mitigate these effects.

4.4 Cost Analysis

Coconut shell replacement reduced material costs by up to 15% due to the low cost and local availability of shells, supporting sustainable and affordable construction.

5. Conclusion

- Coconut shell can replace up to 25% of coarse aggregate in M20 concrete with marginal reduction in compressive strength.
- Workability improves with coconut shell addition due to their texture and shape.
- Lightweight concrete produced offers benefits in reducing dead load and improving insulation.
- Cost savings and environmental benefits make coconut shell concrete a sustainable alternative.
- Further research is needed on durability enhancement and tensile strength improvements.

6. Future Scope

- Optimization of mix design with supplementary cementitious materials to improve strength and durability.
- Long-term environmental performance studies, including freeze-thaw and chemical resistance.
- Development of precast products using coconut shell concrete for wider applications.
- Exploration of hybrid mixes combining coconut shells with other agro-waste materials.

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Websites and Online Databases

1. ScienceDirect – https://www.sciencedirect.com
   → Search for peer-reviewed papers like coconut shell concrete or agricultural waste in concrete.
2. ResearchGate – https://www.researchgate.net
   → Many authors publish experimental results related to coconut shell aggregate here.
3. National Ready Mixed Concrete Association (NRMCA) – https://www.nrmca.org
   → Learn about trends and standards in lightweight and sustainable concrete.
4. Civildigital – https://civildigital.com
   → Articles on concrete innovations, test procedures, and student project examples.
5. Bureau of Indian Standards (BIS) – https://www.bis.gov.in
   → Use IS 456:2000, IS 10262:2019 for concrete mix design and strength standards.
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