International Journal of Recent Advances in Multidisciplinary Topics
Volume 5, Issue 5, May 2024
https://www.ijramt.com | ISSN (Online): 2582-7839

Partial Replacement of Coarse Aggregate with Coconut Shell and Cement with Coconut Shell Ash

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***Abstract*: The rapid growth of the construction industry has led to a global increase in the demand for concrete, a major construction material known for its significant environmental impact. In India, the current state of the construction industry requires a substantial amount of cement and concrete for sustainable development. However, the production of cement, an essential component of concrete, is one of the most energy-intensive industries and contributes significantly to co2 emissions. Additionally, there are concerns about the resource depletion of natural resources. To address these issues, several investigations are underway to identify suitable alternative material for use in concrete. Coconut, a significant crop in many tropical countries, generate large quantities of waste in the form of coconut shell, which are often disposed of in landfills due to the high demand of coconut-based products. This project aims to explore the use of coconut shell ash as the partial replacement for cement and crushed coconut shell as the partial replacement for coarse aggregate in concrete. These substitutions are intended to reduce the environmental impact of concrete production while maintaining the structural performance requirements. The pozzolanic properties and low water absorption of coconut shell make them suitable for use in concrete, and utilizing waste materials in this way not only helps in their disposal but also provide additional benefits such as cost savings in energy and landfill management, as well as environmental protection.**

***Keywords*: Coconut shell, Coconut shell ash.**

1. Introduction

The construction industry is a significant contributor to global resource consumption and environmental impact. Due to shortages of traditional supplementary cementitious materials, researchers and practitioners are exploring alternative materials and practices to reduce the environmental footprint of construction projects. One innovative approach involves replacing traditional construction materials like cement and coarse aggregate with more sustainable alternatives. Disposal of agricultural waste materials like rice husk, groundnut husk, corn cob, and coconut shell poses an environmental challenge, highlighting the need to convert them into useful materials to minimize their negative effects on the environment. Coconut, widely found and utilized in tropical countries, is especially abundant in India, the third-largest coconut cultivating country.

South Indian states are predominant in coconut cultivation. Coconut shell, a major waste product of the coconut industry, contributes to greenhouse gas emissions, soil pollution, and water pollution when landfilled. However, it is a non-fossilized, biodegradable organic material that can replace fossil fuels and supplement other renewable energy sources. Coconut shell's lightweight nature makes it suitable for incorporation into concrete, producing lightweight concrete with improved properties such as thermal insulation and lower cost. Additionally, coconut shell ash, rich in amorphous silica, can be used as a supplementary cementitious material, increasing the compressive and flexural strength of cement. When using coconut shell in concrete as a replacement for coarse aggregate, it should be sun-dried and have a particle size of 20mm or less. For use as cement, the shell should be broken into pieces and burnt in open air for 24 hours, resulting in a black color due to the high amount of unburned carbon. Coconut shell ash contains silicon dioxide, or silica, which in fine-grained form exhibits high pozzolanic activity, enhancing the strength of concrete. The lignin content in coconut shell contributes to the workability of concrete and its weather resistance, while the cellulose content indicates low water absorption. Selecting coconut shell ash with low unburned carbon content is beneficial for concrete, as a large percentage of losses during combustion can decrease its strength by reducing pozzolanic activity.

2. Materials and Methodology

A. Materials

1) Cement

Cement is a versatile binder, a chemical compound used in construction to bond materials together. When mixed with water, cement undergoes a process called hydration, transforming into a solid mass that adheres to other materials, such as sand, gravel, or bricks. This property makes cement an essential ingredient in the production of concrete, mortar, and grout, which are fundamental in construction projects ranging from buildings and bridges to roads and dams. We use OPC 53 grade cement for our project, specifically Dalmia brand.

2) Fine aggregate

Fine aggregates, such as natural sand or crushed stone particles, are essential components in construction, providing stability and cohesion to concrete and mortar mixes. M-Sand, a

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type of manufactured sand, can also serve as a reliable fine aggregate, offering a sustainable alternative to natural sand. The quality and source of fine aggregates greatly influence the strength and durability of construction materials, making their selection and sourcing crucial aspects of any project.

3) Coarse aggregate

Coarse aggregates are large stone particles used in construction to create solid and durable structures. These aggregates, typically larger than 4.75 millimeters in size, include materials such as gravel, crushed stone, or recycled concrete. Coarse aggregates provide strength and stability to concrete mixes, making them ideal for building foundations, roads, and structures where strength and durability are paramount. Aggregates having nominal size of 20mm is utilized in this project.

4) Coconut shell ash

Coconut shell ash is a waste material obtained as a result of burning of coconut shell under high temperature. Finely sized CSA is obtained from India mart, an online shop. After obtaining the CSA its size is determined. Coconut shell ash is used to replace cement in this project. Fig. 1 shows coconut shell ash.

Fig. 1. Coconut shell ash

5) Coconut shell

Coconut shell is a major waste material in the coconut industry. After collecting the coconut shell from the houses, it is dried in sunlight for 24 hours and remove the unwanted dust and fibers from it. The CS is then crushed into smaller sizes of an average 20mm or less manually. Then it is sieved through 20mm IS sieve. Fig. 2 shows the crushed coconut shell.

Fig. 2. Crushed coconut shell

B. Methodology

Coconut shell is partially utilized in concrete. Cement is replaced with coconut shell ash and coarse aggregate is partially replaced with coconut shell. The percentage variation of 0%, 5%, 10%, 15%, 20% are done in the M20 concrete mix. The intial level of replacement is 0%, that is conventional concrete. The strength obtained from other mixes were compared with the conventional mix. Workability of concrete is tested by slump cone test and compaction factor test. The result obtained is tabulated and analysed. The strength obtained through compressive strength, split tensile strength and flexural strength. Durability obtained through water absorption test of cube in 28 days.

1) Workability Test

a) Compaction Factor Test

Compaction factor test is carried as per IS: 1199-1959. In this test the freshly prepared mix is tested by taking its partially compacted weight in a container and taking the weight of compacted concrete in that same container.

$$FC=\frac{weight\ of\ partially\ compacted\ concrete}{weight\ of\ fully\ compacted\ concrete}$$

b) Slump Cone Test

Slump test are commonly used in concrete to identify its workability. Different slump patterns were obtained which indicates the nature of the concrete. The height of the slump. obtained is measured and take the difference between height of the apparatus and height of the slump.

Slump Value = Height of the apparatus – height of slump

c) Compressive Strength Test

Compressive strength of cube after 7days and 28 days of curing are tested. The specimens are tested by applying load using compression testing machine. Take the load at which the specimen breaks. Compressive strength is calculated by the equation

$$F = P/A$$

Where,
P= Maximum load applied (N)
F= Compressive strength (MPa)
A= Cross sectional area of the specimen (mm^2)

d) Tensile Strength Test

Cylinder specimens having diameter 150mm and length 300 mm are prepared and its split tensile strength is tested by applying load using compression testing machine. Split tensile strength is calculated using the equation,

$$F= 2P/(\pi\ DL)$$

Where,
P= Load at failure (N)
L= Length of the specimen (mm)

F= Tensile Strength (MPa)
D= Diameter of specimen (mm)

e) Flexural Strength Test

The specimen having dimension 100×100×500 mm is casted and allow it for curing of 28 days. This test will help to identify the ability to withstand bending without breaking. Flexural strength is calculated using the equation:

$$F = 3PL/(bd^2)$$

Where,
P= Load at Failure (N)
F= Flexural Strength (MPa)
L= Effective span of the beam (mm)
b= Breadth of the Specimen

Table 1
Compressive strength result

Type of Specimen	Compressive Strength (N/mm^2)	
	7th day	28th day
CSC1	21.48	27.48
CSC2	23.76	33.48
CSC3	25.86	34.16
CSC4	23	32.3
CSC5	20.4	29.19

d= Diameter of the specimen

f) Water Absorption Test

Water absorption test is conducted to determine the durability of concrete. The water absorption of the smallest specimen, that is cube is tested after 28 days. It is calculated using the equation,

$$W = \frac{B-A}{A}$$

Where,
A= Dry weight of the specimen (kg)
B= Wet weight of the specimen (kg)
W= Water absorption

3. Result and Discussion

A. Compressive Strength Test Result

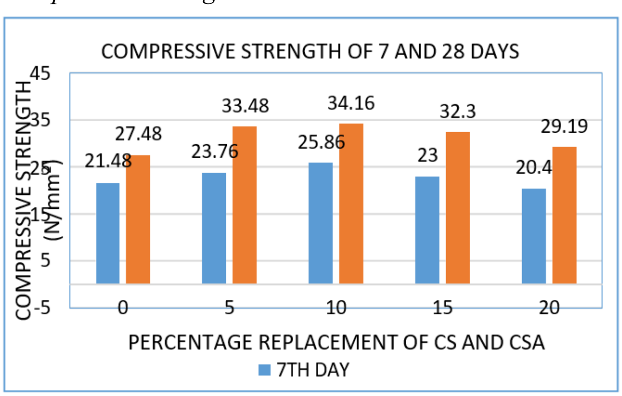

Fig. 3. Graph of compressive strength test result

B. Split Tensile Strength

Table 2
Tensile strength test result

Type of Specimen	Split Tensile Strength (N/mm^2) (28 days)
CSC1	2.52
CSC2	2.78
CSC3	2.87
CSC4	2.6
CSC5	2.31

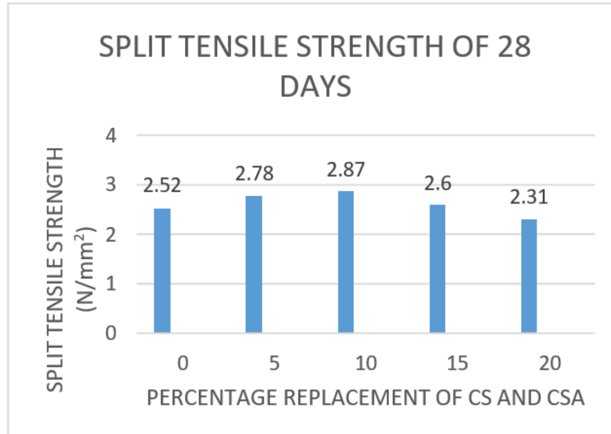

Fig. 4. Graph of split tensile

C. Flexural Strength Result

Table 3
Flexural strength result

Type of specimen	Flexural strengthResult (N/mm^2)
CSC1	3.36
CSC2	3.7
CSC3	3.9
CSC4	3.82
CSC5	3.22

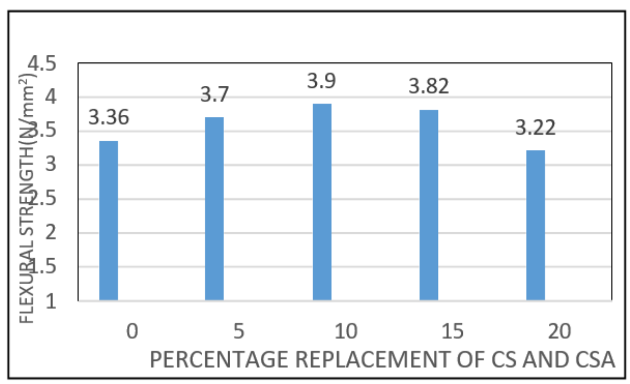

Fig. 5. Graph of flexural strength result

D. Water Absorption Test

Table 4
Water absorption test result

Type of specimen	Water absorption
CSC1	2.93
CSC2	2.4
CSC3	2.02
CSC4	1.84
CSC5	1.74

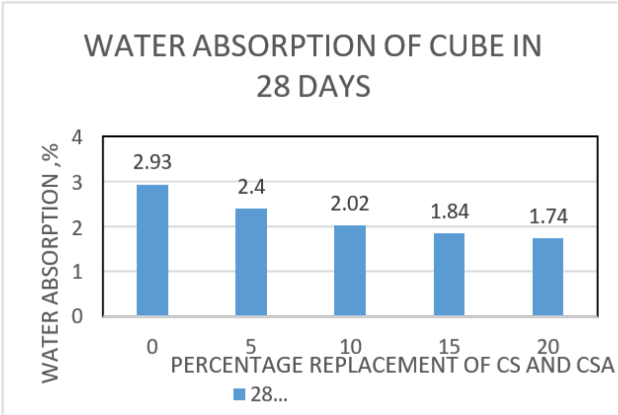

Fig. 6. Graph of water absorption of cube

4. Conclusion

When the strength of conventional concrete is compared with coconut shell included concrete, it can be identified that at a certain level of coconut shell and coconut shell ash the concrete attaining good strength. At 10% replacement the value of strength obtained is maximum. As the percentage of coconut shell in the concrete increases initially the compressive strength shows an ascending pattern but beyond 10% the strength results fall. At 10% replacement, the compressive strength increases at a percentage of 23.4%, split tensile strength increased at a range of 13.8% and flexural strength increased 16.07%. the water absorption of cube decreasing as increasing in percentage of coconut shell. That means coconut shell offers a better durability. And also, the workability of concrete improved as the percentage of coconut shell increased, that shows it is easy for placing. CSC can contribute to minimize the environmental impact of concrete.

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