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Performance of Coconut Shell as Coarse Aggregate in Concrete

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Abstract: A large amount of waste coconut shell is generated in India from temples and industries of coconut product and its disposal need to be addressed. Researchers have proposed to utilize it as an ingredient of concrete. This experimental investigation aimed to quantify the effects of replacing partially the conventional coarse aggregate with coconut shells to produce concrete. It was found that with an increasing proportion of coconut shells, there is a decrement in compressive strength. In our experimental study, we replaced coarse aggregate with coconut shell by 10%, 20%,30%, and 40%. Results revealed that with 10%,20%,30%, and 40% replacement of conventional coarse aggregate by coconut shells, the decrease in 28 days compressive strength is 15.4%,35.7%,46.1%, and 61.5% respectively. For 10%,20%30%, and 40% replacement of coconut shells, the decrease in 28 days tensile strength is 9%,18%,27.5%, and 36.5% respectively. For 10%,20%30%, and 40% replacement of coarse aggregate by coconut shells, the decrease in 28 days flexural strength is 22.7%,45.47%,68%, and 90.86% respectively. It is visualized that coconut shell replacement up to 20% with coarse aggregate exhibit better strength. The advantages of replacing conventional coarse aggregate with coconut shells include efficient utilization of waste coconut shells, reduction in natural source depletion, production of lightweight concrete, etc, the use of coconut shells in concrete seems to be a feasible option. Such a study will help to arrive at a final decision regarding the number of coconut shells for replacing conventional aggregates in concrete production.

Keywords: Coconut shells, Compressive strength, Flexural strength, Split-tensile strength, Concrete

I. INTRODUCTION

In the present scenario, no construction activity can be imagined without concrete. It is one of the most commonly used materials in the construction industry and is the 2nd most consumed substance in the world after water. More than 10 billion tons of concrete is produced every year. Annual production represents approximately 1.5 tons for every person on the planet. Aggregates are the largest constituent in the concrete. About 70– 80% of the volume of structural concrete is occupied by aggregates, of which 25–30% is occupied by fine aggregate and 40–50% is occupied by coarse aggregate. The quantity and properties of coarse aggregate have a considerable impact on various characteristics and properties of concrete. Conventionally, crushed rocks are used as coarse aggregate and river sand as fine aggregate. Both are naturally available materials. Due to the rapid growth of construction activities, conventional aggregate sources are depleting very fast resulting in a scarcity of resources. The properties of coconut shell and coconut shell aggregate concrete are examined and the use of coconut shell aggregate in construction is tested. Moisture content and water absorption were 4.20% and 24% respectively and these values are more compared to conventional aggregate. Coconut shell exhibits more resistance against crushing, impact, and abrasion compared to conventional aggregate. The density of coconut shells is in the range of 550-650 kg/m^3 and these are within the specified limits for lightweight aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption. The presence of sugar content in the coconut shell, as long as it is not in a free sugar form, does not affect the setting and strength of the concrete. Hydration test on coconut shell fines with cement indicates that the inhibitory index for coconut shell fines with cement can be classified as low and no pre-treatment is required. The coconut shell-cement ratio has been optimized to satisfy the criteria of structural lightweight concrete. Coconut shells can be used as an ingredient in the partial or complete replacement of coarse aggregate in manufacturing/ making light structures. Coconut shell (CS) as coarse aggregates in concrete satisfies the basic strength requirements. During the preparation of the concrete mix, there was no segregation and bleeding of the fresh concrete obtained. The mixture was homogenous and compactable. Prepared concrete had very low slump values. Studies suggest that with the addition of a coconut shell, the workability decreases.

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Fig.1.Concrete using coconut shell

II. LITERATURE REVIEW

Z. Ibrahim (2021) Coconut shell as a lightweight aggregate for manufacturing structural lightweight aggregate concrete-Utilization of concrete in the construction industry has increased in the last decades. Although concrete has a lot of advantages, it is important to consider its negative impacts on the environment. One of the negative impacts is the depletion of natural resources. To protect the environment and make the concrete industry sustainable it is needed to find alternative materials, which can be used in the concrete mixture. The agricultural sector has many wastes which would be proper alternatives in manufacturing sustainable concrete. This study presents experimental test results of green concrete made of coconut shell as an alternative for normal coarse aggregate in concrete mixtures for developing a sustainable lightweight aggregate concrete.

Radha Tomar and Kamal Kishore (2020) presented a "Comprehensive study of waste coconut shell aggregate as raw material in concrete" which says that the eminence exploitation of raw materials from the environment causes the natural sources to degrade and limits future practices in the construction sector. The production of such materials either consumes a good amount of energy, responsible for the causes of CO2, NOx, and SOx, in the atmosphere, or leads to the restriction on the usage of available natural sources in the future. The use of an agricultural by-product i.e. coconut shell can be a promising material for manufacturing concrete in the partial replacement of coarse aggregates. The result indicates that coconut shells can be used as lightweight concrete which can be used in non-load bearing structures, strip footings, and non-structural elements. Environmental concerns can also be minimized by making such sustainable efficient practices by the use of these waste coconut shells.

Apeksha Kanojia and Sarveshk Jain (2017) presented a paper on "Performance of coconut shell as coarse aggregate in concrete" with 40% replacement of conventional coarse aggregate by coconut shell, decrease in 28 days compressive strength is only 21.5%. 40% replacement makes the concrete lighter by 7.47%. This experimental investigation aimed to quantify the effect of replacing partially the conventional coarse aggregate with coconut shells to produce concrete. The results confirm that although there is an increase in cost due to additional cement requirements, the advantages being many, including efficient utilization of waste coconut shells, reduction in natural source depletion, etc, the use of coconut shells in concrete seems to be a feasible option. Such a study will help to arrive at a final decision regarding the number of coconut shells for replacing conventional aggregates in concrete production.

Sagar Shrivastava (2019) conducted an experimental analysis on the use of coconut shells as partly substitution for coarse aggregate. The study result shows that Coconut Shell Concrete (CSC) can be used as lightweight concrete. The use of Coconut Shell as a substitute for aggregate will not only is cost-effective and eco-friendly but also help to resolve the problem of shortage of conventional material such as coarse aggregate. The use of such materials also reduces the problem of disposal of waste material.

III. METHODOLOGY

Materials Required

Cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together. The density of cement is 1.45 g/cm³. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel.

Fig.2. Cement

Fine aggregate

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Fine aggregates are essentially any natural sand particles worn from the land through the mining process. The size of fine aggregate is defined as 4.75 mm or smaller. Include things such as sand, silt, and clay.

Fig.3. Fine aggregate

Coarse aggregate

Coarse aggregates are irregular in shape, broken stones, or naturally occurring round gravels that are used to make concrete. Coarse aggregates for structural concrete contain broken stones of hard rock like granite and limestone or river gravel.

Fig.4. Coarse aggregate

Crushed coconut shell

Coconut shells are used in the production of activated carbon due to their hardness and high carbon content. Coconut shell particles are used as reinforcing material for investigation. The coconut shell was sundried for 30 days before being crushed manually. Shells were broken by hammer into smaller sizes. The crushed materials were then washed and allowed to dry under ambient temperature for another 30 days. The coconut shell concrete was prepared by replacement of conventional crushed coarse aggregate with waste coconut shell. Coconut shells replaced conventional aggregate by 10%, 20%, 30 and 40% respectively by volume, and the effect on compressive strength and density of concrete was observed. Shell particles of size between 20 mm and 600μ are prepared in a grinding machine.

Fig.5. Crushed coconut shell

Tests

Tests on cement

Test conducted	Result obtained
Fineness test	7.9%
Standard consistency	32%
Initial setting time	90 min

Table: 1

Test on fine aggregate

Bulk density	1.688kg/m³
Void ratio	0.564
Porosity	0.36

Table: 2

Test on coarse aggregate

Bulk density	1.5kg/m³
Void ratio	0.73
Porosity	0.42

Table: 3

Test on coconut shell

Bulk density	0.52kg/m³
Void ratio	1.477
Porosity	0.59

Table: 4

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Test on Fresh Concrete

Slump test -Workability

Normal concrete	25 cm
Coconut shell concrete	24 cm

Table: 5

Test on hardened concrete

Compressive strength test

% replacement	28th-day strength	% decrease
0%	20	-
10%	16.92	15.4
20%	13.85	30.75
30%	10.78	46.1
40%	7.7	61.5

Table: 6

Split tensile strength

% replacement	28th-day strength	% decrease
0%	2	-
10%	1.82	9
20%	1.69	18
30%	1.45	27.5
40%	1.27	36.5

Table: 7

Flexural strength

% replacement	28th-day strength	% decrease
0%	13.13	-
10%	10.15	22.7
20%	7.16	45.47
30%	4.2	68
40%	1.2	90.86

Table: 8

IV. ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages obtained through experimental results are as follows

Advantages

- Producing economic concrete by reducing the cost of the material.
- Useful for low-cost housing and partition wall.
- They have good water resistance with low absorption, improved acid resistance, low shrinkage, high impact resistance, and excellent sound and thermal insulation.

Disadvantages

- Coconut shells cannot be used in large proportions in concrete.
- Coconut shells are not useful for high-rise buildings.
- Lifespan will be less as compared to conventional concrete.
- Water absorption is more.

V. CONCLUSIONS

The experimental study aimed to explore the feasibility and possibility of partial replacement of conventional coarse aggregate by waste coconut shell for concrete production. Based on the results of this experimental investigation, the following conclusions:

- Coconut shells can be used as a partial replacement for conventional stone aggregates in concrete production.
- For 10%, 20%, 30%, and 40% replacement of coarse aggregates by coconut shells, the decrease in 28 days compressive strength is 15.4%, 30.75%, 46.1%, and 61.5% respectively. Decrease in 28 days tensile strength is 9%, 18%, 27.5%, and 36.5% respectively. Decrease in 28 days flexural strength is 22.7%, 45.47%, 68%, and 90.86% respectively.
- It is visualized that the coarse aggregate replacement up to 20% with coconut shells exhibits better strength.
- Coconut shell concrete has better workability because of the smooth surface on one side of the shells and the smaller size of coconut shells. So, we could use coconut shell concrete in concretes where high workability is desirable.

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