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Coconut Shell as a Substitute for Coarse Aggregate in Concrete

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Abstract**—***The high demand for concrete in the construction using normal weight aggregates such as gravel and granite drastically reduces the natural stone deposits and this has damaged the environment thereby causing ecological imbalance. There is a need to explore and to find out suitable replacement material to substitute the natural stone. In India, commercial use of non-conventional aggregates in concrete construction is not practiced yet. India is the third largest producer of coconut products in the world. Coconut trees are widely cultivated in the southern states of India, especially Kerala. Coconut shells as a substitute for coarse aggregates in concrete is gaining importance especially in this region in terms of possible reduction of waste products in the environment and finding a sustainable alternative for non-renewable natural stone aggregates. The properties of concrete using crushed coconut shell as coarse aggregate were investigated in an experimental study. Coarse aggregate was replaced by crushed coconut shells in three different percentages namely 25%, 50% and 100%. Workability, compressive strength, flexural strength and splitting tensile strength of the above said mixes were compared with normal concrete properties. The results from the study is expected promote the use of coconut shell as a substitute for conventional coarse aggregates*.

Keywords**—** *Coconut shells, coarse aggregate replacement, light weight aggregate concrete*.

I. Introduction

Lightweight aggregate concrete (LWAC) is an important and versatile material in modern construction. It has gained popularity due to its lower density and superior thermal insulation properties. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete (LWC) structures found throughout the world. Lightweight concrete has strengths comparable to normal concrete; yet is typically 25–35% lighter. Structural LWC offers design flexibility and cost savings due to self-weight reduction, improved seismic structural response, and lower foundation costs. Although commercially available lightweight aggregate has been used widely for manufacture of LWC, more environmental and economic benefits can be achieved if waste materials can be used as lightweight aggregates in concrete.

In developed countries, many natural materials like Pumice, scoria and volcanic debris and manmade materials like expanded blast-furnace slag, vermiculite and clinker are used in construction works as substitutes for natural stone aggregates. In India, commercial use of non-conventional aggregates in concrete construction is not so popular. India is the third largest producer of coconut products in the world. Coconut trees are widely cultivated in the southern states of India. Coconut shells thus get accumulated in the mainland without being degraded for around 100 to 120 years. Disposal of these coconut shells is therefore a serious environmental issue. In this juncture, the study on use of coconut shells as a substitute for coarse aggregates in concrete is gaining importance in terms of possible reduction of waste products in the environment and finding a sustainable alternative for non-renewable natural stone aggregates.

In recent years, researchers have also paid more attention to some agriculture wastes for use as building material in construction. Periwinkle shell was chosen as a substitute for coarse aggregate in concrete [1] and palm kernel shell was used as a replacement for fine aggregate in concrete by some researchers [2]. Certain investigations used crushed, granular coconut and palm kernel shells as substitutes for conventional coarse aggregate and the results of the tests showed that the compressive strength of the concrete decreased as the percentage of the shells increased [3], [4]. The properties of concrete using coconut shell as coarse aggregate were investigated in an experimental study and the study concluded coconut shell concrete can be classified under structural lightweight concrete [5].

From the research works reviewed above, it can be understand that coconut shells can be successfully used as a substitute for coarse aggregate in concrete. The study presented here is focussing on finding out the optimum range of replacement of coarse aggregate with coconut shells based on its strength properties. The study also aims to find out the advantage of commercially produced coconut shell concrete work in terms of self-weight reduction.

II. Experimental Study

The freshly discarded shells were collected from an oil mill. The coconut shells were crushed using concrete hammers to a size such that it passes through a 20mm sieve and retained on 4.75 sieve. Crushed shells were washed to remove fibres, mud, etc. from them. The washed shells were dried in sunlight for 2 days. The crushed edges were rough and spiky as shown in figure 1. The surface texture of the shell was fairly smooth on concave and rough on convex faces. Coconut shell aggregates used were in saturated surface dry (SSD) condition.

Portland Pozzolana Cement (PPC) 43 Grade was used as a binder (Malabar Cements). River sand (passing through 4.75mm sieve) was used throughout the study as the fine aggregate. Crushed stone (passing through 20 mm sieve and retained on 4.75 mm sieve) was used as coarse aggregate along with coconut shells. Potable water was used for mixing and curing. A nominal mix of 1:2:4 with a water-cement ratio of 0.5 was used throughout. Four different mixes were made

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with 0%, 25%, 50%, 100% replacement of coarse aggregate with coconut shells.

Fig. 1. Crushed coconut shells.

Specimens were cast in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. Compaction was achieved through use of a table vibrator. Here in this experiment we replaced coarse aggregate with coconut shell, by volume. Specimens were cast by replacing 25%, 50%, 75%, and 100% of coarse aggregate with Coconut shells. Tests were conducted on the cast specimens after 28 days as mentioned in the IS code. Tests for workability, flexure, compression and split tensile strength were conducted and results were obtained. Table I shows the set of experiments and number of samples used for measuring the properties of the different mixes.

TABLE I. Type of strength tests and specimens.

Type of Test	Specimen Properties	Number
Compressive test	Cubes;150x150x150mm	3 x 4 = 12
Flexure test	Beams; 100x100x500mm	1 x 4 = 12
Split tensile test	Cylinders;150mm dia.,300mm long	3 x 4 = 12

III. Results and Discussion

Workability test. Workability of concrete is defined as the easiness with which it can be transported, placed into moulds and compacted with sufficient surface finishing without segregation of concrete. Slump cone test was employed to find the workability of the different mixes in which consistency of each mix was measured. The results for workability are presented in Table II below.

TABLE II. Workability Test results.

% Replacement of Coarse Aggregate	Slump Cone Value(mm)
0	5
25	7
50	10
100	14

The workability was found to be increasing with increase in the replacement percentage of aggregates with coconut shell. Coconut shell concrete probably has better workability due to the smooth surface on one side of the shells and also due to the smaller size of coconut shells compared to conventional aggregates.

Compressive strength test. Three cubes were cast for each variety and the average compressive strength of these were taken as the compressive strength values for each mix. Compressive strength was calculated as follows: Compressive strength=P/A ,
where P= Maximum load applied (N) and A= Area of the load applied face (mm^2).

Fig. 2. Compressive Strength Test (a) While testing (b) Crushed cubes.

Figure 2 shows the testing of coconut shell concrete for compressive strength. The compressive strengths of the CSC cube samples for all the mixes are shown in Table III.

TABLE III. Compressive Strength test results.

% Replacement of Aggregate	Trial No.	Load (kN)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
0	1	513	22.800	24.00
	2	531	23.600	
	3	576	25.600	
25	1	548	24.356	22.62
	2	490	21.778	
	3	489	21.733	
50	1	365	16.222	14.93
	2	330	14.800	
	3	310	13.778	
100	1	105	4.667	5.48
	2	130	5.778	
	3	135	6.000	

The 25% replacement mix got an average compressive strength of 22.62 MPa which is about 94.25% strength of normal concrete (24MPa). Likewise we got a compressive strength of 14.93MPa and 5.48MPa for 50% and 100% replacement respectively. The result shows that coconut shell concrete can be even used in high strength applications with replacements within or around 25%. Further we can use higher percentage replacement for non-load bearing structures. An examination of the failure surfaces showed breakage of the Coconut shell aggregate, indicating that the individual shell strength had a strong influence on the resultant concrete strength.

Flexural strength test. As per IS-516-1959, Flexure test was done by two point loading method. The load was applied on the beam without shock and was increased until it failed, and the maximum load applied during the test was recorded. The flexural strength of the specimens was calculated as follows:

Modulus of rupture, $f_b=PL/bd^2$

where P = Maximum load applied (N), L = Supported length of the specimen (mm), b = Measured width of the specimen (mm), d = Measured depth of the specimen at the point of failure (mm).

Figure 3 shows the Flexure strength testing of coconut shell concrete. The results of this test are provided in Table IV.

Fig. 3. Flexure Strength Test (a) While testing (b) After testing.

TABLE IV. Flexure strength test results.

% Replacement of Coarse Aggregate	*P*(N)	f_b*(MPa)*
0	13400	5.36
25	10800	4.32
50	6000	2.40

The flexural strength was found to be 80.6% (4.32MPa) and 44.8% (2.40MPa) of normal concrete flexural strength (5.36MPa) for 25% and 50% replacement mixes respectively. The 100% replacement concrete mix showed negligible flexural strength. The beam cast with 100% coarse aggregate replaced with coconut shells broke under its self-weight itself. The flexural strength percentages are slightly lower than compressive strength percentages. In concrete with conventional aggregates, the failure in tension occurs as a result of breaking of bond between the matrix and the surface of the aggregate used or by fracture of the concrete matrix itself. Thus the surface properties of coconut shells also play an important role in determining the flexural properties of concrete.

Splitting Tensile strength test. The test specimen was placed in the centring jig with packing strip and/or loading pieces carefully positioned along diametrically vertical planes at the top and bottom of the specimen. The maximum diametrical load applied was recorded. The measured splitting tensile strength f_{sp} of the specimen was calculated using the following formula:

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

where P = maximum load applied to the specimen (N), D = cross sectional diameter of the specimen (mm) and L = length of the specimen (mm).

Figure 4 shows the splitting tensile strength testing of coconut shell concrete. The results of this test are provided in Table V.

Fig. 4. Splitting tensile strength test.

TABLE V. Splitting tensile strength test results.

% Replacement of Coarse Aggregate	*P*(KN)	f_{sp}(MPa)
0	175	2.48
25	157	2.22
50	90	1.27
100	35	0.495

The 25% replacement mix got a splitting tensile strength of 2.22 MPa which is about 89.5% strength of normal concrete (2.48MPa). Likewise we got a splitting tensile strength of 1.27MPa and 0.495MPa for 50% and 100% replacement respectively.

Reduction in self-weight. The reduction in self weight was found to be 9.56%, 19.16%, 38.32% when 25%, 50% and 100% of coarse aggregate was replaced by coconut shell respectively. The details of the calculations are presented in Table VI.

TABLE VI. Reduction in self-weight calculations.

% Replacement of Coarse Aggregate	Weight of Components In Concrete of 1m^3 Volume in kN (Mix 1:2:4)				Weight per m^3 of Concrete (kN)	% Reduction in Weight
	Cement	Fine Aggregate	Coarse Aggregate (Normal)	Coarse aggregate (coconut shell)		
0	3.57	7.14	14.292	0.00	25.00	-
25	3.57	7.14	10.72	1.18	22.61	9.56
50	3.57	7.14	7.15	2.35	20.21	19.16
100	3.57	7.14	0.00	4.71	15.42	38.32

IV. CONCLUSION

The study gave a deeper understanding of the effects of replacing the coarse aggregate with coconut shells. Even though the results are based a few tests, the following conclusions can be made from the study.

- Coconut shell concrete has better workability because of the smooth surface on one side of the shells and the size of coconut shell used in this study.
- The strength tests done on the different mixes showed that coconut shell concrete where 25% of the coarse aggregate is replaced, shows properties similar to the nominal mix

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and 50% replaced CSC shows properties similar to light weight concrete which can be used as filler materials in framed structures.

- There is significant self-weight reduction due to replacement of coarse aggregates with coconut shells which can be utilised advantageously in concrete structures.

REFERENCES

[1] A. P. Adewuyi and T. Adegoke, “Exploratory study of periwinkle shells as coarse aggregates in concrete works,” *ARPN Journal of Engineering and Applied Sciences*, vol. 3, issue 6, pp. 1-5, 2008.

[2] U. J. Alengaram, H. Mahmud, and M. Z. Jumaat, (2010, November). “Development of lightweight concrete using industrial waste material, palm kernel shell as lightweight aggregate and its properties,” in *IEEE 2nd International Conference on Chemical, Biological and Environmental Engineering*, pp. 277-281, 2010.

[3] E. A. Olanipekun, K. O. Olusola, and O. Ata, “A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates,” *Building and environment*, vol. 41, issue 3, pp. 297-301, 2006.

[4] T. Siti Aminah, and M. Sabarudin, “Investigate the combination of coconut shell and grained palm kernel to replace aggregate in concrete: A technical review,” 2009.

[5] K. Gunasekaran, P. S. Kumar, and M. Lakshmipathy, “Mechanical and bond properties of coconut shell concrete,” *Construction and Building Materials*, vol. 25, issue 1, pp. 92-98, 2011.