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A Study on the Utilization of Coconut Shell as Coarse Aggregate in Concrete

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***Abstract*— Natural resources such as river sand and coarse aggregate are depleting at an alarming level in developing countries like India. The possibility of utilizing recycled coconut shell aggregates in concrete as coarse aggregate is examined in the present study. An optimum percentage replacement of coarse aggregate with coconut shell aggregate is determined from the study. Coarse aggregate made from coconut shells were used in proportions of 5%, 10%, 15%, 20%, 25%, 30% and 35% to replace coarse aggregate in conventional concrete. A constant water to cement ratio of 0.5 was used throughout the study. Tests were carried out to determine the compressive strength, split tensile strength and flexural strength using cube, cylinder and beam specimens respectively. Together, 24 cubes, 21 cylinders and 21 beam samples were tested. It was observed that when coconut shells aggregates in proportions of 15% was used in conventional concrete, compressive strengths comparable to that of conventional concrete can be obtained.**

Keywords*— *Coconut Shell, Coarse Aggregate, Sustainable Development, Concrete

I. INTRODUCTION

Concrete is a widely used construction material that consists of a mixture of cement, aggregates, water and admixtures. Inert granular materials such as sand, crushed stone or gravel form the major part of the aggregates. Traditionally aggregates have been readily available at economic prices and of qualities to suit all purposes. But, the continued extraction of aggregates from nature has caused its depletion at an alarming rate. Therefore, there is a growing demand to find alternate materials that can be used as coarse aggregate in concrete. India produces about 20% of the coconut produced in the world. Within India, Kerala produces 45% of it. Disposal of coconut shells poses environmental issues as it is not easily degradable. Aggregates made by crushing coconut shells can be effectively used in concrete by partially replacing coarse aggregate up to a certain amount. This will not only reduce the unit weight of resulting concrete made, but also provides an efficient solution to the disposal of coconut shells.

II. REVIEW OF LITERATURE

Olanipekun, Olusola and Atia [1] investigated the strength characteristics of concrete produced using crushed, granular coconut and palm kernel shells as substitutes for conventional coarse aggregate in gradation of 0%, 25%, 50%, 75% and 100%. It was observed that the compressive strength of the concrete decreased as the percentage of the shells increased in the mixes. However, concrete obtained from coconut shell aggregate exhibited a higher compressive strength than palm kernel shell concrete in the two mix proportions. Abdulfatah and Saleh [2] conducted experiments to determine the suitability of coconut shell as full replacement for coarse aggregate in concrete works. A total of 72 concrete cubes of size 150×150×150 mm with different mix ratios of 1:2:4, 1:1.5:3 and 1:3:6 were casted, tested and their physical and mechanical properties were determined. Compressive strengths comparable to that of plain concrete were observed. The study concluded that cost of producing concrete can be reduced up to 48%. Gunasekaran [3] used coconut shell as lightweight aggregate in concrete. It was observed that coconut shell exhibits more resistance against crushing, impact and abrasion compared to conventional aggregate. The density of coconut shell was in the range of 550 - 650 kg /m^3 and was within the specified limit for qualifying as lightweight aggregate. Amarnath and Ramachandrudu [4] studied the effect of fly ash on concrete with coarse aggregate partially replaced with coconut shell aggregate. It was observed that coarse aggregate replaced with equivalent weight of fly ash had no influence when compared to the properties of corresponding coconut shell replaced concrete. Delsye, Mannan and John [5] investigated the flexural behaviour of reinforced concrete beams produced from oil palm shell (OPS) aggregates. The investigation revealed that the flexural behaviour of reinforced OPS concrete beams was comparable to that of other lightweight concretes. Daniyel [6] used a concrete mix of 1:2:4 as control concrete, while coconut shells were used to replace crushed granite by volume. The density and compressive strength of concrete were found to reduce as the percentage replacement increased. Concrete produced with 20%, 30%, 40%, 50% and 100% replacement attained 28-day compressive strengths of 19.7 N/mm^2, 18.68 N/mm^2, 17.57 N/mm^2, 16.65 N/mm^2 and 9.29 N/mm^2 corresponding to 94%, 89%, 85%,79.6% and 44.4% of the compressive strength of the control concrete. The study recommended that concrete produced by replacing 18.5% of the crushed granite with coconut shell aggregate can be economically used in reinforced concrete. A review of the state of the art use of coconut shell aggregate in concrete was reported by Maninder[7].

III. EXPERIMENTAL PROGRAMME

If structural light weight concrete (LWC) can be developed from coconut shells (CS), which is locally available in abundance in Kerala, it would be a milestone achievement for the local construction industries. Therefore, the main objective of the study was to determine the feasibility of using solid waste CS as coarse aggregate for structural LWC.

TABLE I. PHYSICAL AND MECHANICAL PROPERTIES OF COCONUT SHELL AGGREGATE

Property	Value
Specific gravity	1.29
Bulk density(kg/m^3)	1681
Void ratio	0.894
Porosity (%)	47.2
Aggregate abrasion value	4.66
Impact value (%)	5
Aggregate crushing value (%)	5
Fineness modulus	1.4

The study primarily aims to (i) evaluate the engineering properties of coconut shell aggregate, (ii) compare the properties of coconut shell aggregate with conventional aggregate and (iii) find an optimum percentage replacement of coconut shell in concrete as coarse aggregate.

Firstly, the engineering properties of coconut shell aggregate were determined. Engineering properties such as specific gravity, grain size distribution, abrasion value, impact value and crushing value were determined in the laboratory. These properties are shown in Table I.

Secondly, physical and engineering properties of concrete with coarse aggregate partially replaced with coconut shell aggregate were tested. The compressive strength, split tensile strength and beam flexure tests were conducted to evaluate the compressive, tensile and flexural behavior of concrete modified with coconut shell aggregate. In order to test the above properties and compare with that of concrete without any coconut shell aggregate, a control concrete mix was designed as per IS 10262 – 2009 [8] for concrete of grade of M20. Based on the mix design, a mix ratio of 1: 1.63: 3.13 with water to cement ratio of 0.5 was adopted.

The experimental investigation aimed at utilizing coconut shell aggregates as a partial replacement of coarse aggregate in concrete at different cement contents. The cement content was kept varying so as to compensate for the loss in strength with the addition of coconut shell aggregate (CSA). The compressive strength, split tensile strength and modulus of rupture were evaluated for various percentages of CSA, namely, 5%, 10 %, 15%, 20%, 25 %, 30 % and 35 % by volume of coarse aggregate. In the present study, coarse aggregate is partially replaced by CSA of size ranging from 8 – 16 mm in length.

A total of 24 cubes, 21 cylinders and 21 beam samples with various percentages of CSA, namely, 5%, 10 %, 15%, 20%, 25 %, 30 % and 35 % by volume of coarse aggregate were tested to evaluate the mechanical properties with reasonable accuracy. For each strength data, a minimum of 3 samples were tested and average value was recorded.

TABLE II. RESULTS WITH 0% REPLACEMENT OF COCONUT SHELL AGGREGATE

Mechanical property	7 days	28 days
Compressive strength(N/mm^2)	18	26
Split tensile strength (N/mm^2)	1.43	2.82
Flexural strength (N/mm^2)	2.05	3.17

Results from samples with individual variation exceeding the limit specified in IS 456:2000[9] were discarded. Compressive strength, split tensile strength and modulus of rupture were determined at 7 and 28 days.

IV. RESULTS AND DISCUSSIONS

Table II shows the observed values of compressive strength, split tensile strength and modulus of rupture of concrete when coconut shell aggregate(CSA) was added to control concrete of grade M20. The cement content was kept at 383kg/m^3.

TABLE III. RESULTS WITH 5% REPLACEMENT OF COCONUT SHELL AGGREGATE

Mechanical property	7 days	28 days
Compressive strength(N/mm^2)	17.9	24
Split tensile strength (N/mm^2)	1.05	2.45
Flexural strength (N/mm^2)	1.98	2.28

TABLE IV. RESULTS WITH 10% REPLACEMENT OF COCONUT SHELL AGGREGATE

Mechanical property	7 days	28 days
Compressive strength(N/mm^2)	16.9	24
Split tensile strength (N/mm^2)	1.32	2.54
Flexural strength (N/mm^2)	2.01	3.1

TABLE V. RESULTS WITH 15%, 20%, 25%, 30% AND 35% REPLACEMENT OF COCONUT SHELL AGGREGATE

Mechanical property @ 28 days	15%	20%	25%	30%	35%
Compressive strength(N/mm^2)	24.6	20.4	20.9	21.2	21
Split tensile strength (N/mm^2)	2.57	1.98	2.45	2.45	2.41
Flexural strength (N/mm^2)	2.89	2.6	3.1	3.23	3.32

Table III shows the observed values of compressive strength, split tensile strength and modulus of rupture of concrete when 5% coconut shell aggregate(CSA) was used to replace coarse aggregate in concrete. The cement content was kept at 383 kg/m^3.

The slight increase in the compressive and tensile strengths at 5% replacement could be compensated with an increase in the cement content.

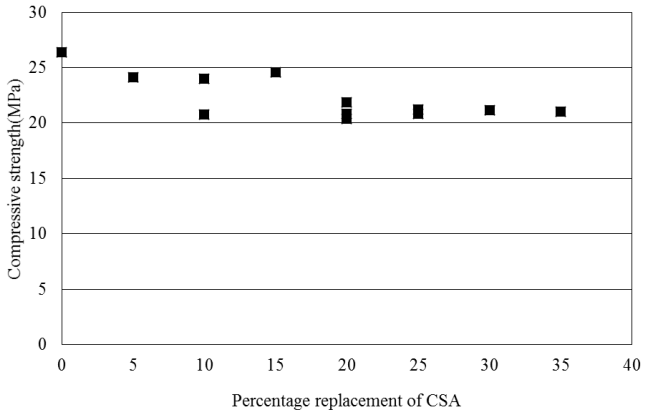

Fig. 1. Variation of compressive strength with various percentage replacement of CSA

Table IV shows the observed values of compressive strength, split tensile strength and modulus of rupture of concrete when 10% of coconut shell aggregate(CSA) by volume was used to replace coarse aggregate in concrete. The cement content was increased to 386.5 kg/m^3.

From Table IV, it can be observed that the strength properties for 10% replacement with CSA were comparable to that of control concrete reported in Table II.

The results with 15%, 20%, 25%, 30% and 35% replacement of CSA are summarized in Table V. The cement contents used were 387, 390, 391, 392 and 393 kg/m^3 respectively.

It is observed from Table V that, the compressive strength progressively decreases as the amount of CSA increases. The same trend was not visible for split tensile and flexural strengths.

Fig. 1 shows the variation of compressive strength at 28 days with various percentage replacement of coconut shell aggregate (CSA) in concrete. It was observed that the compressive strength was near to the target mean strength value of M20 grade concrete when the percentage replacement with CSA was between 5–15%.

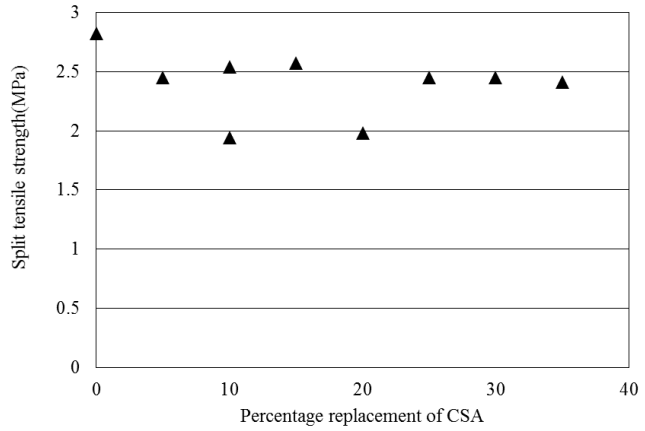

Fig. 2. Variation of split tensile strength with various percentage replacement of CSA

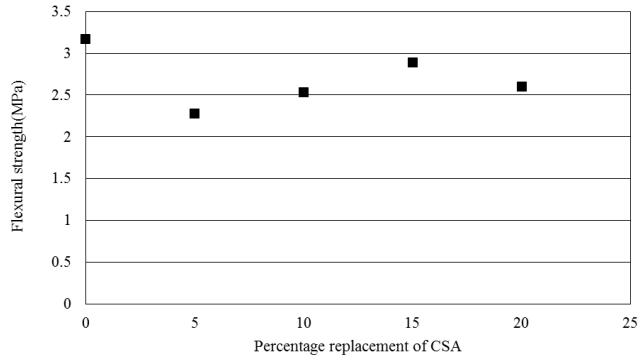

Fig. 3. Variation of flexural strength with various percentage replacement of CSA

The compressive strength varied from 26 to 21 N/mm^2 for 0% to 35% percentage replacement of coarse aggregate with CSA.

The split tensile strength (Fig. 2) for 0% CSA at 28 day was 2.82 N/mm^2. It was observed that the split tensile strength was near to the target value when the percentage replacement is between 5 – 15%.

With 0% CSA, the flexural strength (Fig. 3) obtained was 3.17 N/mm^2 at 28 days. Here also, the flexural strength was comparable to that of control concrete (M20 grade), when the percentage replacement was between 5 – 15%.

V. CONCLUSIONS

India is the largest producer of coconut in the world accounting for 20% of the world's production. Hence, the disposal of coconut shell creates environmental issues since it is not easily degradable. The test results obtained from this study provides significant understanding on basic properties of coconut shell aggregate concrete. The properties of coconut shell and coconut shell aggregate concrete were determined and the use of coconut shell aggregate as coarse aggregate in concrete was examined.

Based on the limited number of experimental investigation carried out to determine the mechanical properties of concrete namely, compressive strength, split tensile strength and flexural strength of concrete, an optimum replacement of coarse aggregate with coconut shell aggregate, corresponding to the mix ratio 1: 1.63: 3.13, was determined as 15%. Cement content for 15% replacement was kept at 387 kg/m^3. The observed value of 28 day compressive strength, split tensile strength and flexural strength were 24.6 N/mm^2, 2.57 N/mm^2 and 2.89 N/mm^2 respectively. This indicates that concrete made with coconut shell aggregate has strength comparable with that of conventional concrete.

The possibility of recycling and reuse of coconut shells which are discarded as waste led to the present study on its possible use as coarse aggregate in the development of lightweight concrete. The study established that coconut shell aggregate can replace conventional coarse aggregate in the production of lightweight concrete structures effectively without compromising on strength aspects.

Acknowledgment

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