Flexural Behavior of Reinforced Concrete Beam Using Coconut Shell and Fly Ash

M. Senthilkumar[1], N. Sivakami[2]

[1]Student, Department of Civil Engineering, Alagappa Polytechnic College, Karaikudi, Tamilnadu, India

[2]Lecturer, Department of Civil Engineering, Alagappa Polytechnic College, Karaikudi, Tamilnadu, India

Abstract: ***Concrete is the premier construction material around the world and is most widely used in all types of construction works, including infrastructure, low and high-rise buildings, and domestic developments. It is a man-made product, essentially consisting of a mixture of cement, aggregates, water and admixture (s). 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 extensive extraction use of aggregates from natural resources has been questioned because of the depletion of quality primary aggregates and greater awareness of environmental protection. The properties of concrete using coconut shell (CS) as coarse aggregate were investigated in this experimental study. The cement was replaced with 5%, 10%, 15% and 20% of fly ash and optimum percentage was found. The crushed coconut shells were used as substitute for conventional coarse aggregate in proportions of 50% and 100%. For the selected mix, a comparison has been done for CS concrete with and without fly ash. Compressive strength, split tensile strength and flexural test were investigated in the laboratory. The results showed that, density of the concretes decreases with increase in CS per cent. Workability decreased with increase in CS replacement. Compressive strength of CS concrete was lower than control concrete. Permeable voids, absorption and sorption were higher for CS replaced concretes than control concrete. A potential exists for the use of coconut shells as replacement of conventional aggregate in both conventional reinforced concrete and lightweight reinforced concrete construction. The use of coconut shells as partial replacement for conventional aggregates should be encouraged as an environmental protection and construction cost reduction measure.***

Keywords: Coconut shells; Compressive strength; Split tensile strength; Sustainability

1. Introduction

Concrete is acknowledged to be the most widely used construction material in most parts of the globe. Concrete is also one of the most widely consumed material by mankind in the modern world, second only to fresh water. Its production involves large quantities of natural resources. As a measure of ensuring the ecological balance, it is necessary to implement the use of various non-conventional and renewable resources in cement and concrete production. It has been observed that large amount of industrial, domestic and agricultural wastes are recyclable as substitute to cement or aggregate in concrete. Approximately 70 to 80% of the total volume of concrete is consumed by aggregates. One of the main problems that undermine the use of natural coarse aggregates is sustainability, as it leads to other ecological problems. Hence, the role of alternative aggregates evolves into a significant phase in the present construction scenario due to economic, environmental and technological benefits derived from their use. The best alternative to achieve sustainable development in concrete production is the use of waste and by-product materials instead of natural materials.

Concrete with a density less than 2000 kg/m3 and a compressive strength greater than 20 N/mm2 is referred to as structural LWC. Adding different types of lighter aggregates to the matrix is a common way to reduce the density of a concrete. The crushed stone and sand are the conventional ingredients replaced with lightweight aggregate (LWA) to produce LWC. Structural LWC provides design flexibility and significant cost savings by reducing dead load, improving seismic structural response, and lowering foundation costs, among other benefits. Lightweight partitions, walls, and secondary structural components are among the applications, as are primary structural components. Some of the LWC are foamed type concrete, no fines, and lightweight natural and artificial aggregates concrete.

Natural LWA is typically obtained from volcanic rocks such as pumice, which have densities ranging from 500 to 900 kg/m^3. To enable LWC and attain compressive strengths up to 100 N/mm^2, artificially generated LWA from various natural materials such as expanded clay, expanded shale, foamed slag, blast furnace slag, pulverised fuel ash, and perlite has recently been used. LWA is distinguished by its high porosity, which results in a low specific gravity. Instead of using standard crushed stone aggregate, porous LWA with a low specific gravity can be utilised to make LWC. Although commercially supplied LWA has been utilised in numerous studies to replace crushed stone aggregates in the manufacturing of LWC, using waste materials as an aggregate in the creation of LWC may provide additional environmental and economic benefits. The usage of aggregates from by-products and/or solid waste materials from various sectors is particularly desirable in light of the rising environmental challenges.

CS offers excellent durability, toughness, and abrasion resistance capabilities, making it ideal for long-term use. CS is mostly used as an adornment, in the manufacture of fine objects, household utensils, and as a source of activated carbon through its charcoal. The powdered shell is also utilised in the creation of insect repellant in the form of mosquito coils and agarbathis, as well as in the plastics, glues, and abrasive materials industries. Another option to make use of the contributions a coconut tree can make is to investigate CS as a substitute for aggregates. The goal of this study is to create a concrete containing CS as the coarse aggregate. The entire thing might be referred to as coconut

Paper ID: SR131024173558 DOI: 10.21275/SR131024173558

shell aggregate concrete (CSAC). The shell is normally discarded as rubbish when the coconut is scraped out. Because a large portion of this abandoned CS resource has yet to be commercialised, its application as a building material, particularly in concrete, along the lines of other LWA, is an intriguing research issue. The study of CS will not only create a new construction material, but it will also aid in the protection of the environment while also boosting the economy by introducing new applications for the material. As a result, efforts have been made to use CS as a coarse aggregate and design a novel structural LWC.

2. Materials used

A. Coconut shell aggregate

After removing the copra from the coconut, the coconut shells become a waste and discarded section. This discarded waste coconut shell is collected from local coprapreparation drying yard and washed thoroughly to remove the iron content from the surface of coconut shell. The concave part of coconut shell is smooth but the convex part is rough due to the presence of coconut fibre and husks. Hence for better work ability, the fibres and husks in the convex side of coconut shell are removed before crushing. Since different species of coconut shells are processed together, the shells are found to have varying thicknesses, in the range of 2–5 mm. Due to high water absorption of CS, it is necessary to mix at saturated surface dry (SSD) condition based on 24 hours submersion in potable water. No pretreatment is required for the shells except this water submersion process.

Figure 1: Sizes of coconut shell aggregate and normal aggregate

B. Concrete Ingredients

Ordinary Portland Cement (OPC) 43 Grade conforming to Indian Standard IS 12269: 1987 is used as a binder. Well graded crushed quarry aggregate, with specific gravity 2.71, was used as coarse aggregate. A maximum aggregate size of 12.5 mm was used. River sand is used throughout the investigation as fine aggregate conforming to grading zone III as per IS 383-1970 with specific gravity 2.6 and maximum size 4.75 mm was used. The class F fly ash obtained from Mettur thermal power plant is used in this investigation. The specific gravity of fly ash found as 2.08. The potable water available in the University premises was used for mixing and curing.

3. Mixture Proportion

The physical and mechanical qualities of lightweight aggregate influence the mix design for lightweight concrete used for structural applications. There are no specific procedures for designing lightweight concrete mixes. Trial mixes are commonly used to develop lightweight concrete mix designs. The mix design of concrete with agro-waste components could not be done using ACI or Indian Standard procedures. Enough trial mixes through weigh batches have already been generated and established for the optimization of a mix ratio by considering cement content, wood–cement ratio, and water–cement ratio for the manufacturing of coconut shell aggregate concrete (CSAC). The chosen and established mix ratio for CSAC is 1: 1.47: 0.65: 0.42 by weight of cement, with a cement content of 510 kg/m^3, and this mix also meets the ASTM C 330 structural LWC standards. For this study, the established mix ratio was used. CS's physical and mechanical qualities were discussed.

Table 2: Physical Properties of Coconut Shell

S. No	Physical and mechanical properties	Coconut Shells
1	Maximum size (mm)	12.5
2	Moisture content (%)	4.20
3	Water absorption (24 h) (%)	24.00
4	Specific gravity	1.05–1.20
5	Impact value (%)	8.15
6	Crushing value (%)	2.58
7	Abrasion value (%)	1.63
8	Bulk density (kg/m3)	650
9	Fineness modulus	6.26
10	Shell thickness (mm)	2–8

4. Methods of Experiment

In this investigation, two proportions were to be employed. The 60 Cubes of size 150mm X 150mm X 150mm, 30 Cylinders of 150mm diameter and 300 mm length, and 4 Beams of 1700 X 100mm X 150mm were all tested for the given mix ratio. Varied quantities of fly ash and coconut shell were used to cast different numbers of specimens.

5. Results and Discussion

A. Water absorption

The coconut shell's moisture content was found to be 5.13 percent. These were taken into account while calculating batched quantities and the concrete mix's overall water demand. The CS's water absorption capacity was discovered to be 6.17 percent. The porosity of an aggregate is measured by its absorption capacity. Because the results are so low, it's safe to assume that the shells absorb very little mixing water during concrete manufacturing. These figures are also within the range of lightweight aggregates' absorption capacity, which has been estimated to be between 5 and 20%. (Portland Cement Association).

B. Density

The shells have a density of 1738 kg/m^3 and a specific gravity of 1.74, respectively. These values are below the usual weight aggregates' specific gravity range of 2.5–3.0. As a result, the CSs can be classified as lightweight aggregates, with increased density and specific gravity. The obvious variations in specific gravities of the shells (1.74) and cement (3.15) explained why the material quantities had to be determined using the method of absolute volume in this inquiry.

C. Durability

The resistance of an aggregate to wear, moisture penetration, deterioration, and disintegration is measured by its durability. The durability test employing the Los Angeles

Paper ID: SR131024173558 DOI: 10.21275/SR131024173558

abrasion method was used to determine the hardness of the CSs. The test results for CSs revealed high levels of 98.6 percent.

D. Compressive strength of concrete

The results showed that the compressive strength of the concrete decreased as the percentage of the shells increased in the selected mix ratios (Fig.2–3).

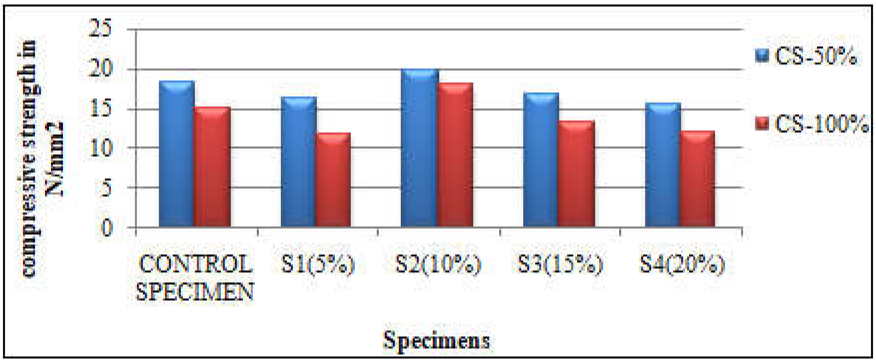

Figure 2: Compressive Strength of CSAC (7 days)

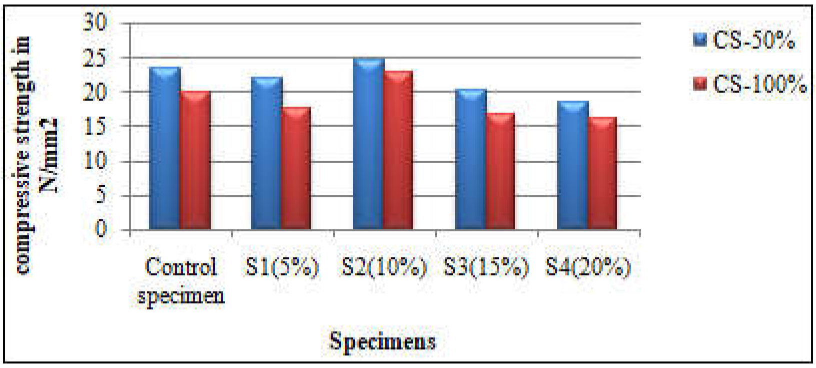

Figure 3: Compressive Strength of CSAC (28 days)

From the above graph it is clear that the addition of fly ash content in CSAC did not given any strength to the concrete and also the compressive strength get reduced here. The strength is high in the proportion of 10% of fly ash content in CSAC.

E. Split tensile strength of concrete

The results showed that the split tensile strength of the concrete decreased as the percentage of the shells increased in the selected mix ratios (Fig 4).

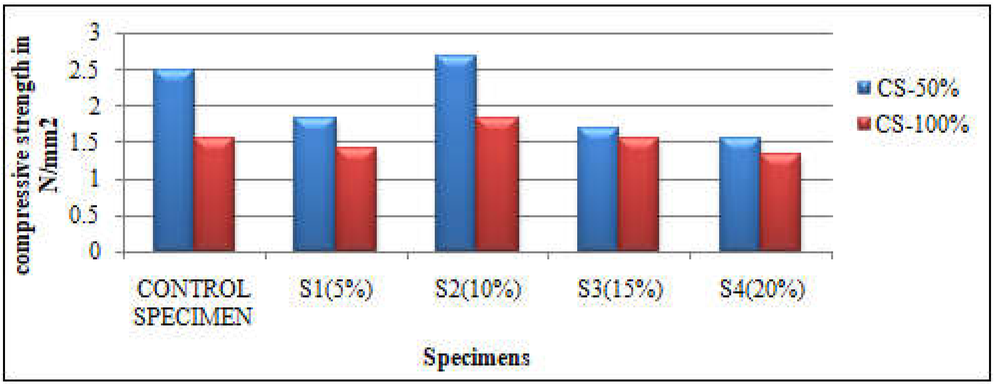

Figure 4: Split tensile strength of CSAC (28 days)

F. Flexure test

The result of the flexure carried out on the 4 beam specimen and load Vs deflection are shown in fig 5&6 at the time of conducting the flexure test of the specimen, ultimate load and deflection were measured by LVDT.

Table 3: Flexure Test Result

Beam designation	Load		Deflection		Max crack width in mm
	1st crack load in KN	Ultimate load in KN	Mid span deflection at 1st crack in mm	Mid span deflection at Ultimate load in mm	
CS-100%, FA-0%	9.24	27.72	2.85	15.72	4
CS-100%, FA-10%	8.47	26.95	2.43	18.44	5
CS-50%, FA-0%	6.93	35.42	1.5	12.98	4
CS-50%, FA-10%	7.7	33.88	1.02	22.79	3

G. Load-deflection behaviour

The measured load Vs deflection is shown in (Fig 5 & Fig 6). The plot shows that all beam specimens exhibit similar behaviour but with an increase in ductility due to reduce in stiffness of the beams.

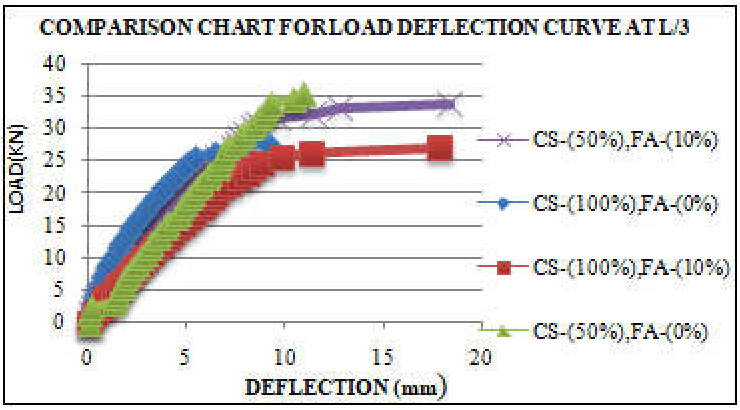

Figure 6: Comparison Chart for Load Deflection Curve [at] L/3

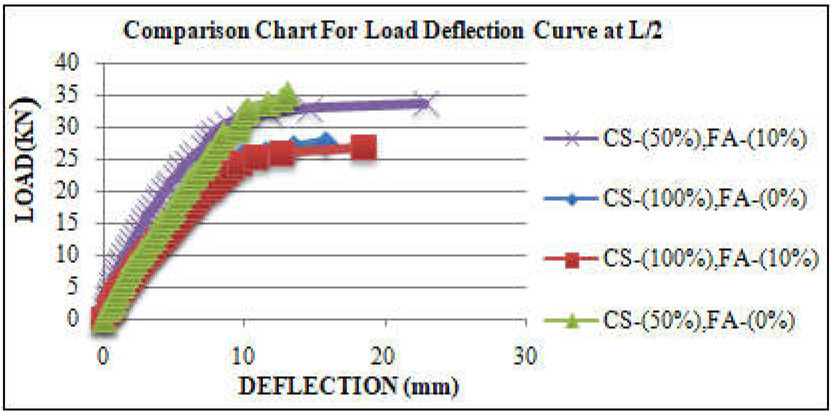

Figure 5: Comparison Chart for Load Deflection Curve [at] L/2

From the above graph it is clear that the maximum deflection can occur by the addition of fly ash content in beam. Other specimens were undergone small deflections.

H. Ductility

Ductility index is defined as the ratio of ultimate mid span deflection to deflection at initial crack load of the beam are presented in Table 4.

Table 4: Ductility Index

Beam designation	First crack mid span deflection (mm)	Ultimate mid span deflection (mm)	Ductility Index
CS-100%, FA-0%	2.85	15.72	5.51
CS-100%, A-10%	2.43	18.44	7.5
CS-50%, FA-0%	1.5	12.98	8.6
CS-50%, FA-10%	1.02	22.79	22.34

From the above table it is clear that the specimen CS-50%, FA-10% beam has higher ductility index than other beams.

I. Stiffness

Stiffness may be defined as load required causing unit deflection. The stiffness value of various beams at ultimate load and first load are presented in Table 5 & 6.

Beam designation	Initial Crack Load (kN)	Initial Crack mid span deflection (mm)	Stiffness (kN/mm)
CS-100%, FA-0%	9.24	2.85	3.24
CS-100%, A-10%	8.47	2.43	3.10
CS-50%, FA-0%	6.93	1.5	4.62
CS-50%, FA-10%	7.7	1.02	7.55

From the above table it is clear that the specimen CS-50%, FA-10% has higher stiffness values at initial crack than other beams.

Table 6: Stiffness Values at Ultimate Load

Beam designation	Ultimate Load (KN)	Ultimate mid span deflection (mm)	Stiffness (KN/mm)
CS-100%, FA-0%	27.72	15.72	1.76
CS-100%, A-10%	26.95	18.44	1.46
CS-50%, FA-0%	35.42	12.98	2.73
CS-50%, FA-10%	33.88	22.79	1.49

From the above table it is clear that the specimen CS-50%, FA-0% has higher stiffness values at ultimate load than other beams.

6. Conclusion

From the investigation carried out, below conclusions were found:

- From the graphs shows the compressive strength and split tensile strength are decreasing with increase in the

Paper ID: SR131024173558 DOI: 10.21275/SR131024173558

proportion of CSA. The addition of fly ash content increases the strength.

- The optimum percentage of fly ash for the replacement of cement was found to be 10% from compressive strength and split tensile strength results. When the fly ash content in CSAC increase it decreases the compressive strength and split tensile strength.
- In the proportion of 10% fly ash content, the strength increases for both 50% & 100 % of CSA compare to the other proportions.
- The load carrying capacities of coconut shell beam with fly ash content were higher than the beam without addition of fly ash content; beam with fly ash has undergone more deflection than other beams.
- The specimen CS-50%, FA-10% has higher ductility index than other beams. The specimen CS-50%, FA-0% has higher stiffness values at ultimate load than other beams. The crack patterns of the entire beam were studied.
- The density of light aggregate is very much less than conventional concrete. The reduction of density will play important factor in the economy of the project because the total dead loads of the building were reduced and it helps in economic design of foundation.

References

[1] Gunasekaran K, Kumar PS. Lightweight concrete using coconut shell as aggregate. In: Proceedings of the ICACC-2008. International conference on advances in concrete and construction, Hyderabad, India, 7–9 February, 2008. p.450–9.

[2] Gunasekaran K, Kumar PS. Lightweight concrete mix design using coconut shell aggregate. In: Proceedings of the IBMSDCP-2008. International conference on Innovations in building materials, structural designs and construction practices, Sathyamangalam, India, 15–17 May, 2008. p.375–82.

[3] Weigler H, Sieghart K. Structural lightweight aggregate concrete with reduced density lightweight aggregate foamed concrete. Int J Lightweight Concr 1980; 2 (2): 101–4.

[4] Mannan MA, Ganapathy C. Mix design for oil palm shell concrete. CemConcr Res 2001; 31: 1323–5.

[5] IS: 516-1959, Indian Standard for methods of tests for strength of concrete, edition 1.2 (1991-07). Short and W. Kinniburgh, Lightweight Concrete, Applied Science Publishers, London, 1978.

[6] Gerritse A. Design consideration for reinforced lightweight concrete. Cem Comp Lightweight Conc 1981; 3 (1): 57–69.

[7] Adeyemi AY. An investigation into the suitability of coconut shells as aggregates in concrete production. Journal of Environment Design and Management, Obafemi Awolowo University, Ile-Ife 1998; 1 (1, 2): 17–26.

[8] William H. Langer, Lawrence J. Drew, Janet S. Sachs. Aggregate and the environment, American Geological Institute, 2004.

[9] Transport Research Laboratory. A review of the use of waste materials and by-products in road construction. contractor report 358, 1994.