PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH COCONUT SHELL IN THE CONCRETE

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Abstract

The high cost of conventional construction material affects economy of structure. With the increasing concern over excessive exploitation of natural aggregates, synthetic lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material. It is becoming more difficult to find natural resources. Therefore the coconut shell as partial replacement for coarse aggregate in concrete is studied. The density, slump and compressive strength of concrete are tested. The replacement of coarse aggregate by coconut shell by 0%, 10%, 20% and 30%. The tests were carried out and the results obtained suggested that the replacement more than 20% leads to lightweight aggregate concrete. The slump found out to be increases as the percentage replacement increased. Similarly the density is reduced as the percentage replacement increased. The compressive strength found to be decreases as the percentage replacement increases.

Keywords: coconut shell, lightweight aggregate, compressive strength, slump and density

1. Introduction

Infrastructure development across the world created demands for construction material. Concrete is the premier civil engineering materials used in the structure. Concrete manufacturing involves consumption of ingredients like cement, aggregates, water and admixtures. Among all the ingredients, aggregates form the major parts. Production is expected to increase to more than billions tons per year by the year. Use of natural aggregates in such a rate leads to a question about the preservation of natural aggregate sources. Using alternative materials in place of natural aggregates in concrete production makes concrete as sustainable and environmentally friendly construction material. The chemical composition of coconut shell is similar to wood and it contains 33.61% cellulose, 36.51 % lignin and 0.61% ash.

Lightweight aggregate concrete can be used produced using a variety of lightweight aggregate. Lightweight aggregate can be originated from natural materials like pumice, the thermal treatment of natural raw materials like clay slate or shale. The other byproduct may include fly ash. The required properties will have bearing on the best type of lightweight aggregate used. the benefits of using lightweight aggregate concrete includes reduction in dead load, improved thermal properties, improved fire resistance and reduction in formwork.

2.0 Literature review:

It was studied that palm kernel shell and coconut shell, both of which belongs to the family of palm shells. These are agricultural waste products and are available in large quantities in the tropical regions of the world. Research

showed that coconut shell are more suitable as low strength giving light weight aggregate when used to replace common coarse aggregate in concrete production ([1], [2]).

The researcher suggested that one of the alternatives for coarse aggregate is coconut shell. It is one of the most common agricultural solid wastes in many tropical countries. Density of coconut shell concrete of the typical mixes ranged from 1930 kg/cum to 1970 kg/cum ([3], [7]).

There was researched on the coconut shell use as aggregate in the study which showed that with global economic recession coupled with the market inflator trends. The average compressive strength for concrete cubes with coconut shell 15.6 N/mm² for 28 days [4].

It was studied the compressive strength, split tensile strength, water absorption and sorption for different coconut shell replaced concrete. By replacement of coconut shells in place of aggregates, 10% & 20% replacement will have been decreased marginally the strength properties of concrete compared to the normal concrete [18].

The researcher experimented three different concrete mixes namely M20, M35 and M50 grade with different combination of natural material CS content in the proportion 0%, 10%, 20%, 30% and 40% replaced. It was studied that coconut shells are suitable as low strength giving lightweight aggregate [19].

Also the researcher experimented to determine the compressive strength, split tensile strength and flexural strength cube, cylinder and beam section. It was

concluded that when coconut shell aggregates in proportions of 15% was used in the conventional concrete comparable compressive strength results were obtained [20].

There was study on experimentation that coconut shell can be grouped under lightweight aggregate because 28 days air dry densities of coconut shell aggregate concrete are less than 2000 kg/cum. It was concluded that this type of concrete can be used in rural areas and wherever the natural aggregates are costly [21].

The experimentation conducted that density of concrete decreases with increases in CS percentage. Workability decreases with increase in CS percentage. Compressive and split tensile strength of CS concrete were lower than normal concrete [22].

It was observed that coconut shell concrete is very suitable for low cost construction in rural areas. It can replace the natural coarse aggregate up to certain limits. This type of aggregate will serve to counteract the scarcity of natural aggregates [23].

3.0 Materials

3.1 Material Specification

For the production of concrete, the constituent materials are cement, fine aggregate, coarse aggregate and water. To get better workability and strength, the material used should have better quality. To maintain the safety of any structure, provisions are provided as per IS 456:2000.

3.1.1 Cement:

In the experimental work cement used is Ordinary Portland cement. Various properties were evaluated such as fineness of cement, setting time, soundness test and compressive strength as shown in the following table no.1.

Table 1. : Properties of cement

Sr. No.	Particulars	Experimental values
1	Fineness of grinding (Residue on I.S. sieve no.9)	1%
2	Normal Consistency (%) water consistency	31%
3	Setting time Initial setting time (min) Final setting time (min)	85 min 290 min
4	Compressive strength (average of three cubes)	26.35 N/mm ²
5	Soundness Test (expansion after boiling)	1 mm

3.1.2 Fine Aggregate

The various properties of fine aggregate such as specific gravity, fineness modulus, bulk density were determined as per IS 456:2000. Locally available sand was used as fine aggregate in the experimental work. The test is carried out for deciding the fineness modulus. Also the sieve analysis is carried out. Fineness modulus of sand is found to be 3.25 and it confirms to grading zone II as per grading limit for fine aggregate as per IS 383:1970. Fineness modulus is well within 2.5 to 3.37. the bulk modulus is found to be 2.65. Sieve analysis of sand is mentioned in table no.2

Table 2 : Sieve analysis of sand

Sr. N o.	I.S. sieve size	Weight Retained (Kg)	Cumulative Weight Retained (Kg)	Cumulative % Retained	Cumulative % Passing
1	4.75 mm	0.02	0.02	2.0	98.00
2	2.36 mm	0.2	0.22	22.00	78.00
3	1.18 mm	0.29	0.51	51.00	49.00
4	600 micron	0.16	0.67	67.00	33.00
5	300 micron	0.198	0.868	86.80	13.20
6	150 micron	0.102	0.97	97.00	3.00
7	pan	0.030	-	-	-
-	-	1 Kg (Total)	-	325.00	-

Fineness modulus (F.M.) = $325.00/100 = 3.25$

3.1.3 Coarse Aggregate

Coarse aggregate of maximum size 10 mm used in the experimental work. Coarse aggregate were tested for different properties such as fineness modulus, bulk modulus as per IS 383:1970(3). Sieve analysis of coarse aggregate is shown in the following table no.3.

Table 3: Sieve analysis of coarse aggregate

Sr. No.	Sieve size	Weight retained (Kg)	Cumulative % retained	% passing
1	40 mm	Nil	Nil	Nil
2	20 mm	0	0	100
3	10 mm	1.465	29.2	70.7
4	4.75 mm	2.165	72.6	27.4
5	2.36 mm	0.96	91.8	8.2
6	1.18 mm	0.145	94.7	5.3
7	600 micron	0.075	96.2	3.8
8	300 micron	0.1	98	1.8
9	150 micron	0.09	98.2	1.5
10	Pan	0.02	-	-
	Total	5.0	482.6	-

The physical properties of coarse aggregate are mentioned in the following table 4

Table 4: Physical properties of coarse aggregate

Sr. No.	Properties	Results
1	Particle shape, size	Angular, 20 mm
2	Bulk density	1.585
3	Specific gravity	2.76

3.1.4 Coconut shell:

Coconut shells used in the study are brought from local temple. The coconut shells are sundried for five days before using it as an aggregate. The cleaning of coconut shell is carried with the help of sand paper, the smaller extractions on the outer face of coconut is cleaned with the help of water. The outer shell is then broken in smaller parts up to 20 mm. The broking of coconut shell is done with the help of 30 kg hammer. Then the broken pieces are passed through IS 20 mm sieve and pieces are retained on a IS 16mm sieve are used.

3.1.5 Water:

The water used in the study was clean and clear. It was free from bacteria and other impurities. There was no acid content in it. The water cement ratio for the concrete mix is 0.6.

4.0 Methodology:

The concrete mix design was carried out for the present work. The concrete mix design is a process of selecting the suitable ingredient of concrete and determining their most optimum proportions economically.

The approximate value for the coarse aggregate volumes are given in IS 10262-2009 for the water cement ratio. For more workable concrete that can flow around any congested reinforcement bars, it may be desired to reduce

the coarse aggregate content. The value for the coarse aggregate for different zone of fine aggregate is shown in following table no.5.

Table 5: The approximate value for the coarse aggregate

Nominal size of aggregate (mm)	Volume of coarse aggregate per unit volume of concrete for different zone of fine aggregate			
	Zone I	Zone II	Zone III	Zone IV
10	0.5	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

Also the approximate values for fine aggregates are mentioned in the table 6.

Table .6: The approximate value for fine aggregate

Sr. No.	Particulars	Quantity/Formula
1	Volume of concrete	1 cum
2	Volume of cement	(mass of cement/SG of cement)/1000
3	Volume of water	(mass of water/SG of water)/1000
4	Volume of coconut shell (CS)	(mass of CS/SG of CS)
5	Volume of all aggregate	[(A-(B+C+D))]
6	Mass of coarse aggregate	E*volume of coarse aggregate*SG of coarse aggregate*1000
7	Mass of fine aggregate	E*volume of fine aggregate*SG of coarse aggregate*1000

The material requirement, quantity and properties of the material required for the concrete is shown in the following table no. 7.

Table 7: Mix design for the concrete of M20 grade

M-20 concrete mix design for conventional concrete cube as per IS 10262:2009		
A-1	Stimulation for proportioning	
1	Grade designation	M-20
2	Maximum nominal aggregate size	20 mm
3	Maximum water cement ratio	0.5
4	Workability	20-50 mm
5	Exposure condition	Mild
6	Degree of supervision	Good
7	Type of aggregate	Angular aggregate
8	Zone	III

A-2	Test data for material	
1	Specific gravity of cement	3.15
2	Specific gravity of water	1.0
3	Specific gravity of coarse aggregate	2.74
4	Specific gravity of fine aggregate	2.74
5	Water absorption of coarse aggregate	0.5%
6	Water absorption of fine aggregate	1.0%
7	Free surface moisture of coarse aggregate	Nil
8	Free surface moisture of fine aggregate	Nil
A-3	Target strength of mix proportioning	
	Target mean strength ($F_{ck}=F_{ck}+k*s$)	(20+1.65*4)=26.60 MPa
A-4	Selection of water cement ratio	
	Maximum water cement ratio	0.5
A-5	Selection of water content	
	Maximum water content	197
A-6	Calculation of cement content	
	Water cement ratio	0.5
	Cement content	394
A-7	Mix calculation	
1	Volume of concrete (cum)	1.0
2	Volume of cement (cum)	0.125
3	Volume of water (cum)	0.197
4	Volume of coarse aggregate	0.433
5	Volume of fine aggregate	0.25
A-9	Mix proportion for 1 cum	
1	Mass of cement (kg/cum)	394
2	Mass of water (kg/cum)	197
3	Mass of fine aggregate (kg/cum)	591

4	Mass of coarse aggregate (kg/cum)		1182
5	Water cement ratio		0.5
Trial Proportion			
Water	Cement	Fine aggregate	Coarse aggregate
197 lit	394 kg	591 kg	1182 kg

5.0 Results

In the present work coarse aggregate is replaced with the coconut shell, by volume. Specimens were casted by replacing 0%, 10%, 20% and 30% of coarse aggregate with coconut shell. Tests were conducted on the cast specimens after 7, 14, 21 and 28 days as mentioned in the IS code. There is no need to treat the coconut shell before use as an aggregate except for water absorption. Tests for workability and compression were conducted and results were obtained. Coconut shell concrete has better workability because of the smooth surface on one side of the shell and the smaller size of coconut shell. The table no. 8 is mentioned below detailing the properties of concrete.

Graph .1: Percentage replacement of coarse aggregate v/s Density (Kg/cum)

From the above graph it is observed that as the percentage replacement of coarse aggregate by coconut shell is increased, the density is decreased. This can lead to light weight concrete up to some extent and therefore the applications are filler materials in framed structure, flooring tiles, thermal insulating concrete, etc. Also the slump Value of different mix of the concrete is shown.

Graph 2: Concrete Mix v/s Slump Value

From the above graph the slump value is increased as the percentage of the replacement of coarse aggregate by coconut shell is increased. Therefore the construction work requiring the more slump value, this type of concrete is suitable. The compressive strength of concrete is detailed in the table 8.

Table .8: Compressive strength of concrete

Mix name	Compressive strength (MPa)			
	7 day	14 day	21 day	28 day
M1	16.8	19	23.68	24.2
M2	12.5	16.23	22.7	23.4
M3	10.1	15.1	20.12	21.3
M4	9.2	12.4	14.8	16.7

From the above table it is clear that the compressive strength holds well up to 10% replacement of coarse aggregate by coconut shell. The percentage as increases above 10% the compressive strength decreases significantly. The concrete gives good strength after testing the concrete cube on 14 days. Also the average compressive strength is detailed in the table no. 11.

Table 11: Average compressive strength of concrete

% replacement of aggregate	Trial no	Load (Kn)	Compressive strength (MPa)	Average compressive strength (MPa)
0	1	378	16.8	19.82
	2	428	19	
	3	532	23.68	
10	1	281	12.5	17.37
	2	365	16.23	
	3	510	22.7	
20	1	227	10.1	15.96
	2	339	15.1	
	3	452	20.12	
30	1	207	9.2	11.92
	2	280	12.4	
	3	318	14.18	

From the above table the compressive strength holds well only up to 10% replacement of coarse aggregate by coconut shell.

8. Conclusion

Use of coconut shell in cement concrete can help in waste reduction and reduction in pollution. The need of the hour is to encourage such a use of the wastes as construction material in low cost housing. The construction industries have identified many artificial and natural lightweight aggregate that have replaced conventional aggregates thereby reducing the size of the members in the structure. From the experimental work it is clear that the with CS percentage increase the 7 days strength gain also

increased with the corresponding 28 days curing strength. Workability of concrete is increases as the replacement increases. Specific gravity of the concrete reduces as the replacement of coarse aggregate increases. The density of concrete is decreases as the replacement increases. Density of concrete should not be less than 2000 kg/cum.

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