EXPLORATORY STUDY OF COCONUT SHELL AS COARSE AGGREGATE IN CONCRETE

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ABSTRACT

This work is about exploratory study of coconut shell as coarse aggregate in concrete. The approach adopted is experimental to determine the suitability of coconut shell as full replacement for coarse aggregate in concrete works. Physical and mechanical properties of coconut shell and crushed granite rock were determined and compared. A total of 72 concrete cubes of size 150x150x150mm with different mix ratios of 1:2:4, $1:1^{1/2}$:3 and 1:3:6 were casted, tested and their physical and mechanical properties determined. Aggregate crushing value (ACV) for coarse aggregate is 21.84 and 4.71 for coconut shell. Elongation and flakiness index are 58.54 and 15.69 respectively for gravels, while for coconut shell is 50.56 and 99.19 respectively. Compressive strength in N/mm^2 of coconut shell at 7,14,21 and 28 days with mix ratios of 1:2:4, $1:1^{1/2}$:3, and 1:3:6 are (8.6, 8.9,6.4,),(9.6,11.2,8.7),(13.6,13.1,10.7) and (15.1,16,5,11) respectively, likewise (19.1,18.5,9.6), (22.5, 23.0, 10.4), (26.7, 24.9, 12.9) and (28.1, 30.0, 15) respectively for gravel. Since the concrete strength of coconut shell with mix ratio $1:1^{1/2}$:3, attained $16.5N/mm^2$ at 28 days it can be used in plain concrete. Hence cost reduction of 48% will be achieved.

INTRODUCTION

The overall relevance of concrete in virtually all civil engineering practice and building construction works cannot be over emphasized. Concrete is an artificial material similar in appearance and properties to some natural limestone rock. It is a man-made composite, the major constituent being natural aggregates such as gravel or crushed rock, sand and fine particles of powder (cement) all mixed with water. The concrete hardened as time goes on producing a required strength to carry or withstand force or load. One of the most important properties of concrete is the ease with which it can be moulded to any shape before hardening takes place. The growing concrete of resource depletion has challenge many engineers and researchers to seek and develop new materials for construction, this include the use of by-product and industrial waste in building construction. Many of these by-products may serve as aggregate in concrete. According to Falade (1992), the use of palm kernel shell as coarse aggregate in concrete. With global economic recession coupled with the market inflationary trends, the constituent materials used for those structures have lead to a very high cost of construction. Hence researcher in material science and engineering are committed to having local materials to partially or fully replace these costly conventional materials. Numerous researches have been carried out in these regard as well as sustainability development, reduction in cost and the ability to produce light weight structures are added advantage of such materials. For instance sludge from treatment of industrial and domestic wastewater has been found very suitable as partial replacement for cement in concrete work and also in the production of building blocks, other similar effort in

the direction of waste management strategies includes structural performance of concrete using periwinkle shell as light weight aggregate.

Civil engineering practice and construction works in Nigeria depend on a very large extent on concrete. Concrete is one of the major building materials that can be delivered to a project site. Hence the overall cost of concrete production depends largely on the availability of the constituent. In Nigeria a 50kg bag of cement is sold at almost uniform price with slight variation in every state of the federation and fine aggregate are readily available in most part of the country. However, the cost of concrete is directly proportional to the cost of crushed stone or gravel which increases from North to South. The cost of construction in Niger Delta area especially the south-south zone is the highest, these alternative light weight materials are adopted for non-load bearing walls and non-structural floors in building.

RESEARCH METHODOLOGY

In the course of this research, there are series of experiments carried out in the laboratory to ascertain the suitability of coconut shell as coarse aggregate in concrete and ensuring that standard method of assessment are dully followed. The experiments carried out on all the materials used for the research work according to BS 4550 and BS 812 is as follows:

1. **Cement**

a. Standard consistency test
b. Initial and final setting time

2. **Fine and Coarse aggregate**

a. Specific gravity on fine and coarse aggregate
b. Aggregate impact value (AIV) (coarse aggregate)
c. Aggregate crushing value (ACV) (coarse aggregate)
d. Silt content test (fine aggregate)
e. Sieve analysis on fine and coarse aggregate
f. Flakiness and elongation

3. **Concrete**

a. Workability test on concrete (compacting factor)
b. Compressive strength of concrete cubes.

RESULTS AND DISCUSSION

The results of this work are obtained mainly through laboratory test and analysis. From the various laboratory test and analysis carried out the results obtained are contained in following tables.

Table 1: Standard Consistency- Initial and final setting time

Cement Initial and Final Setting Test
Concrete Laboratory

Cement
Depth of Penetration

S/No	Wt.Of	Vol.	Of	Consistency	Initial	Initial	Setting	Final	Setting	W/C%

	Cement	Water		Setting	Time	Time	
1	400g	138	10				
2	400g	135	12.5				
3	400g	134	7	7.5	1.35min	4.10min	0.34

Table 2: Cement Soundness Test
Cement

S/No	Wt.Of Cement	Vol. Of Water	W/C	Dist. B/W Pointer Before Heating (L1)	Dist. B/W Pointer After Heating (L2)	L2-L1	Average	Remark
1	400	134	0.34	12	13.9	1.9		
2	400	134	0.34	13	14	1		
3	400	134	0.34	13	13.8	0.8		
4	400	134	0.34	13	14	1	1.18	

Table 3: Silt and Clay Content of Fine Aggregate

Description		
Sample number	1	
Mass of sample	200	G
Volume of water	100	W
Depth of sample (TOTAL)	50	L_1
Depth of sharp sand	47.5	L_2
Depth of silt	1	L_3
Depth of clay	1.5	L_4
Silt content	L_3/L_1 X 100	2
Clay content	L_4/L_1 X 100	3
Sand content	L_2/L_1 X 100	95

Table 4: Specific Gravity Of Fine, Coarse Aggregate And Coconut Shell

AGGREGATES

SAMPLE	FINE		COARSE		COCONUT SHELL	
Mass of gas jar + soil and water m_3 g	1540	1530	1860	1856	1298	1296
Mass of gas jar and soil m_2 g	900	900	1400	1400	500	500
Mass of gas jar + water m_4 g	1240	1240	1240	1240	1240	1240
Mass of gas jar m_1 g	400	400	400	400	400	400
$m_2 - m_1 = m_5$ g	500	500	1000	1000	100	100
$m_4 - m_1 = m_6$ g	840	840	840	840	840	840
$m_3 - m_2 = m_7$ g	610	630	460	456	798	796
$m_6 - m_7 = m_8$ ml	230	210	380	384	42	44
Specific gravity of soil particles	2.17	2.38	2.63	2.60	2.38	2.27

AVERAGE	2.61	2.62	2.33

Table 5: Sieve Analysis on Fine Aggregate (Sand) 1000g

Sieve No mm	Weight retained (mm)	Weight passing	% weight passing
7	118.0	882	88.2
10	103.5	778.5	77.85
14	157.2	621.3	62.13
18	194.1	427.2	42.72
25	357.3	69.9	6.99
36	34.0	35.9	3.59
52	25.0	10.9	1.09
72	4.5	6.9	0.64
100	5.0	1.4	0.14
150	0	0	0
200	0	0	0
Base pan	0	0	0

Table 6: Sieve Analysis on Coarse Aggregate (Gravel) 3000g

Sieve No mm	Weight retained (mm)	Weight passing	% passing
38.1	0	3000	100
20	2404	596	19.97
13.20	405	191	6.37
12.50	98	93	3.1
9.50	46	47	1.57
6.75	24	23	0.77
4.76	12	11	0.37
Base pan	4	5	0.17

Table 7: Sieve Analysis on Coconut Shell (200g)

Sieve No mm	Weight retained (mm)	Weight passing	% passing
38.1	0	200	100
20	36	164	82
13.2	70	94	47
12.50	57	37	18.5
9.50	20	17	8.5
6.75	10	7	3.5
4.76	5	2	1.0
Base pan	2	0	0

Table 8: Aggregate Impact Value (Coconut Shell)

S/NO	SAMPLE REF	A	B
1	Mass of sample B/4 test (A)	700	700
2	Mass retained on No. 7 sieve (B)	655	643
3	Mass of sample passing No. 7 sieve (A-B)=C	45	57
4	Impact value C/A X 100%	6.4	8.1
Average	7.25		

Table 9: Aggregate Impact Value (Coconut Shell)

S/NO	SAMPLE REF	A	B
1	Mass of sample B/4 test (A)	300	300
2	Mass retained on No. 7 sieve (B)	290	286
3	Mass of sample passing No. 7 sieve (A-B)=C	10	14
4	Impact value C/A X 100%	3.30	5.19
Average		4.26	

Table 10: Aggregate Crushing Value (Coarse Aggregate)

S/NO	SAMPLE	**A**	**B**
1	Weight of material in mould 2	3780	**3**815
2	Weight of material passing sieve 12.36mm	824	835
3	ACV= weight 2 x 100 / weight 1	21.80	21.89
	AVERAGE 21.85		

TABLE 11: AGGREGATE CRUSHING VALUE (COCONUT SHELL)

S/NO	SAMPLE	A	B
1	Weight of material in mould 2	1250	1232
2	Weight of material passing sieve 1 12.36mm	55	58
3	ACV= weight 2 x 100 / weight 1	4.40	4.71
	AVERAGE 4.56		

Table 12: Flakness Index

SAMPLE DESCRIPTION	AGGREGATES				
Aggregate type		Coarse		Coconut shell	
Aggregate size	mm inch	Passing	Retained	Passing	Retained
		3/4	1/2	3/4	1/2
Total weight of dry aggregate (g)	W_1	1503		356	
Weight of flaky aggregate after passing(g)	W_2	235		346	
Flakness index (%)	$(W_2/W_1)x$ 100	15.64		97.19	

Table 13: Elongation Index

SAMPLE DESCRIPTION	AGGREGATES				
Aggregate type		Coarse		Coconut shell	
Aggregate size	mm inch	Passing	Retained	Passing	Retained
		$1^{1/2}$	2	$1^{1/2}$	2
Total weight of dry aggregate (g)	W_1	1503		356	
Weight of aggregate after passing length guage (g)	W_2	880		180	
Flakness index (%)	$(W_2/W_1)x$ 100	58.54		50.56	

Table 14: Workability Test (Compacting factor)

SAMPLE.	**FRESH CONCRETE**		
Mix ratios	1:2:4	$1:1^{1/2}:3$	1:3:6
Weight of partially compacted W_1	13450	12800	13300
Weight of fully compacted W_1	14300	14100	14200
Compacting factor **(**W_1 /W_2)	0.94	0.91	0.94

The densities of all the mix ratios fall within the range of light weight aggregate (160kg\m-1920kg\m).The result obtained from the tests carried out are as follow: the test on cement are all within the acceptable limit as stipulated by BS 4550 part 3 of 1978 which stipulated a minimum initial setting time of 45 minutes and a maximum of 2 hours while the maximum unit for final setting time is 10 hours and maximum expansion of 12mm. Incidentally the cement tested did not exceed the limit. As 1 hour 35 minutes was recorded as the initial setting time, and 4 hours 10 minutes as the final setting.

The specific gravity for fine aggregate obtained shows that the result obtained is within the BS 812 specifications. The BS 812 specified 2.60-2.63 for the fine aggregate but in the course of this test 2.61 was obtained. For the coarse aggregate 2.62 was also obtained. And 2.33 was recorded as the specific gravity of coconut shell. The percentage silt content obtained during the experiment conforms to the B.S specification. As the average silt content calculated was 2.04%. The result of percentage of sand signifies that the sand can be used for in seasons (dry and rainy). For the compressive strength, the specification for concrete in general for 28 days is between the range of 28-29 N/mm^2, according to specification the average compressive strength for the ratio 1: 1½ :3 is 25 N/mm^2, 1:2:4 is 20 N/mm^2 and 1:3:6 is 15 N/mm^2 respectively. But the result of the average compressive strength obtained for ratio 1: ½:3 was 30.0 N/mm^2 and 15.1 N/mm^2 for ratio 1:3:6. The compressive strength of concrete using coconut shell as a partial replacement of gravel gave the following results. The average compressive strength for 100% of ratio 1: 1½ :3 was 16.1 N/mm^2, for ratio 1:2:4 was 15.1 N/mm^2 and for ratio 1:3:6 was 11.0 N/mm^2 .

CONCLUSION

Comparing the compressive strength of concrete cubes produced with gravel and coconut shell, it was observed that for seven (7) days curing, the average compressive strength for concrete cubes produced with coconut shell of mix ratio 1:2:4, $1:1^{1/2}$:3, 1:3:6 were 8.6,8.9,6.4 N/mm^2 respectively and 15.1,16.5, 11N/mm^2 respectively for 28 days. The 7days cured concrete cubes produced with gravel have an average compressive strength of 19.6, 18.5, 9.6 N/mm^2 and 28.1, 30.0, 15.6 N/mm^2 at 28days with mix ratios of 1:2:4, $1:1^{1/2}$:3, 1:3:6. The Cost of 0.0163 m^3 of gravel is ₦92.00, and coconut shell ₦47.00 showing a cost reduction of about 48% when coconut shell is used in place of gravel. From the research, mix ratio $1:1^{1/2}$:3 of coconut shell with strength 16.5N/mm^2 at 28 days can be used as plain concrete.

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