International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 3 ǁ March. 2013 ǁ PP.54-59

A reinvestigation of the prospects of using periwinkle shell as partial replacement for granite in concrete

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ABSTRACT: *A large majority of civil engineering construction companies in Nigeria use granitic chippings as coarse aggregate for making concrete. These chippings are frequently bought at distant quarries and hauled at high cost to various construction sites across the country, thereby increasing the cost of construction projects. Efforts to reduce construction costs in coastal communities have led some earlier researchers to investigate the suitability of using periwinkle shells as replacement for granitic chippings in concrete-making. This work seeks to strengthen or reject some of their findings with respect to whether concrete produced by partially replacing granitic chippings with periwinkle shells meets minimum compressive strength requirements. Saturated surface dry (SSD) bulk density and compressive cube strength (CCS) tests were carried out at 7 and 28 days for concrete produced using different percentage replacements of granitic chippings with periwinkle shells, with a constant water: cement ratio of 0.65 and three sets of cement: sand: coarse aggregate mix ratios, namely 1 : 1.5 : 3; 1 : 2 : 3; and 1 : 2.5 : 3. The results showed that the density of the concrete decreased with increase in the percentage of periwinkle shells, from 2466.67 Kg/m^3 for 25% periwinkle shell replacement at a mix ratio of 1 : 1.5 : 3 to 2103.33 Kg/m^3 for 75% periwinkle shell replacement at a mix ratio of 1 : 2.5 : 3. Values of 28-day compressive strength ranged from 24.15 N/mm^2 for 75% periwinkle shell replacement to 33.63 N/mm^2 at 25% replacement. Most of these values satisfy the minimum 25 N/mm^2 requirement of BS 8110 and strongly confirm the findings of earlier researchers that, on the basis of required compressive strength, periwinkle shells could be used as partial replacement of granitic chippings in making concrete for reinforced concrete works.*

Keywords: *coarse aggregate, concrete, compressive strength, percentage replacement, periwinkle shells, granitic chippings*

I. INTRODUCTION

Granitic chippingsare commonly used as coarseaggregate for making concrete used in the construction of load-bearing reinforced concrete members by a large majority of civil engineering construction companies in Nigeria. These chippings are generally obtained by crushing deposits of granite at quarries. Unfortunately, the quarries are found only in a few localities, from where the granitic chippings are bought and hauled at high cost to various construction sites across the country.This greatly increases the cost of procuring concrete, especially in communities that are distant from quarry locations, for which the cost of transporting the granitic chippings could even be higher than their purchase price at the quarries. For example, a 5m^3 truck load of granitic chippings in Owerri, Imo State, Nigeria costs about N50,000.00whereas it is sold for about N20,000.00 at the Abakaliki or Okigwe quarries, from where the chippings are obtained. As part of efforts to reduce construction costs in order to provide low-cost housing for the teeming populace, the suitability of using locally-available substitutes to granitic chippings in concrete-making has to be more seriously investigated. Possible materials in this regard are the various natural coarse aggregates such as sandstone, river gravel, and local stones that are plentifully available in different hinterland communities. Yet, that would still not solve the problem for coastal communities where these natural aggregates are scarcely found. Thus, some earlier researchers have pioneered investigation of the suitability of using periwinkle shell as coarse aggregate for making concrete in such coastal communities. Periwinkle shell is an agricultural waste material commonly found in coastal communities. They are relatively non-degradable, and, as such, constitute a great deal of environmental problems. Many of these environmental problems could be solved by using the periwinkle shells as primary production materials, especially in concrete making. Stow (1969), Balogun (1993),and Ibearugbulem (2009) have classified the shells as lightweight coarse aggregates in accordance with ASTM specifications for concrete.Falade (1995) has also studied the shells as possible coarse aggregates and discovered that concrete made with them falls in the range of lightweight concrete. Orangun (1974) carried out a pilot study on the suitability of periwinkle shells as coarse aggregate for structural concrete and reported that strengths of concrete made with periwinkle shells were greater than 15.0 N/mm^2. Beredugo (1984) investigated the use of periwinkle shells as concrete aggregate and noted that the resultant lightweight concrete has density range of 1923-2050 kg/m^3. Adewuyi and Adegoke (2008) carried out an exploratory study of periwinkle shells as coarse aggregates in concrete works and concluded that up to 42.5% replacement of crushed granite with periwinkle shells by weight still gives concrete with acceptable compressive strengths. Osarenmwinda and Awaro (2009) also investigated the potentials of periwinkle shell as coarseaggregate for concrete and found that concrete produced with different cement:sand:periwinkle mixes had compressive strength values ranging from 14.00 N/mm^2 to 25.67 N/mm^2 at 28 days of age.Agbede and Manasseh (2009) have specifically investigated the suitability of periwinkle shell as partial replacement for river gravel in concrete. They found that the 28-day density and compressive strength of periwinkle shell concrete were 1944 kg/m^3 and 13.05 N/mm^2 respectively. Falade, Ikponmwosa, and Ojediran (2010) investigated the behaviour of lightweight concrete containing periwinkle shells at elevated temperature and found that the compressive strength decreased with increase in water/cement ratio and temperature.Kamang and Job (1997) tried to relate the strength of periwinkle shell concrete to its non-destructive parameters; Falade and Tella (2002) examined the structural performance of reinforced beams containing periwinkle shells as coarse aggregate; Ohimain, Bassey, and Bawo (2009) carried out a general study on the uses of sea shells for civil construction works in coastal Bayelsa State; while Osadebe and Ibearugbulem (2009) applied Scheffe's simplex model in optimizing the compressive strength of periwinkle shell granite concrete. All of these researches suggest a high potential of using periwinkle shells as coarse aggregate for making concrete. This study aims at reinvestigating the suitability of using periwinkle shells instructural concrete works, with a view to confirming or rejecting some of the critical findings of earlier researchers. It specifically seeks to determine whether concrete produced by partially replacing granitic chippings with periwinkle shells would meet the BS 8110 minimum required compressive strength for reinforced concrete works, which is 25N/mm^2.

II. MATERIALS AND METHODS

The periwinkle shellsused for this study were obtained from Eleme, Port-Harcourt, Nigeria. Theywerewashed and dried before use. Granitic chippings were obtained from a quarry at Umuchieze village in Abia State. They were of 20mm nominal size. Clean sharp sandobtained from OtamiriRiver in Owerriwas used as fine aggregate. Ibeto brand of Ordinary Portland Cement in conformity with BS 12 (1978) was used as binder; while waterwas obtained from a public tap for potable water in Owerri.

Saturated surface dry (SSD) bulk density and compressive cube strength (CCS) tests of concrete at 7 and 28 days were conducted. Three sets of cement: sand: coarse aggregate mixes were used, namely1 : 1.5 : 3; 1 : 2 : 3; and1 : 2.5 : 3.For each mix ratio, graniticchippings were partially replaced with periwinkle shells at seven levels, namely 25%, 35%, 45%, 50%, 55%, 65%, and 75%. This gives a total of twenty-one mix ratios with partial periwinkle replacement. In addition, a control mix with 100% granitic chippingsas coarse aggregate was used for each of the three mix ratios. Thus, the total number of concrete mixes used in this work was twenty-four, twenty-one sets with periwinkle replacement and three control sets with no periwinkle replacement, as shown in table 1. A constant water: cement ratio of 0.65 was used for all the mixes. Batching was by weight. Six cubes were cast for each of the twenty-four mixes, making a total of 144 cubes. Three cubes for each mix were cured for 7 days and the remaining three for 28 days, after which they were weighed and crushed to determine their compressive strength.Both the Saturated Surface Dry (SSD) bulk density and the Compressive Cube Strength (CCS) tests were in conformity with BS 1881: Part 115 (1986).

III. RESULTS AND DISCUSSIONS

Saturated Surface Dry (SSD) Bulk Density

The results of the SSD bulk density tests are presented in table 2. The values obtained indicate that for the percentage replacements used in this work the concrete produced by partially replacing granitic chippings with periwinkle shells is normal weight concrete. As would be expected, the density of the concrete decreases with increase in the percentage of periwinkle shells. Thus, the lowest and maximum densities were recorded at 75% and 25% periwinkle shell replacement respectively. This was so for all the three sets of mix ratios, with typical values for 28 days as follows: (i) First set of mix ratios (1 : 1.5 : 3) gave concrete density of 2103.33 Kg/m^3 for 75% periwinkle shell replacement and 2410 Kg/m^3 for 25% periwinkle shell replacement; (ii) Second set of mix ratios (1 : 2 : 3) gave concrete density of 2106.68 Kg/m^3 for 75% periwinkle shell replacement and 2406.67 Kg/m^3 for 25% periwinkle shell replacement; (iii) Third set of mix ratios (1 : 2.5 : 3) gave concrete density of 2130 Kg/m^3 for 75% periwinkle shell replacement and 2466.67 Kg/m^3 for 25% periwinkle shell replacement. All of these values are much lower than values obtained for 100% granitic chippings that came as high as 3585.33 Kg/m^3 for 1 : 2 : 3 mix ratio. This means the use of periwinkle shells as partial replacement for granitic chippings results in concrete elements with much less self-weight than those made with 100% granitic chippings.

Table 1: Concrete mixes used for this work

	Cement	Sand	Granite	Periwinkle
First set of mix ratios—1 : 1.5 : 3				
U1	1	1.5	0.75	2.25
U2	1	1.5	1.05	1.95
U3	1	1.5	1.35	1.65
U4	1	1.5	1.5	1.5
U5	1	1.5	1.65	1.35
U6	1	1.5	1.95	1.05
U7	1	1.5	2.25	0.75
Second set of mix ratios—1 : 2 : 3				
U8	1	2	0.75	2.25
U9	1	2	1.05	1.95
U10	1	2	1.35	1.65
U11	1	2	1.5	1.5
U12	1	2	1.65	1.35
U13	1	2	1.95	1.05
U14	1	2	2.25	0.75
Third set of mix ratios—1 : 2.5 : 3				
U15	1	2.5	0.75	2.25
U16	1	2.5	1.05	1.95
U17	1	2.5	1.35	1.65
U18	1	2.5	1.5	1.5
U19	1	2.5	1.65	1.35
U20	1	2.5	1.95	1.05
U21	1	2.5	2.25	0.75
Control mixes				
U22	1	1.5	3	
U23	1	2	3	
U24	1	2.5	3	

Compressive Cube Strength (CCS)

The results of the compressive cube strength (CCS) tests are presented in table 3. The results confirm the theoretical expectation and findings of earlier researchers that values of compressive cube strength increase with decrease in percentage of periwinkle shells. The lowest recorded 28-day CCS value was 24.15 N/mm^{2}for 75% periwinkle shell replacement of granite in a mix ratio of 1: 1.5: 3.The other 28-day compressive strength values at 75% periwinkle shell replacement for the remaining two mix ratios were 28.44 N/mm^2 and 27.55 N/mm^2. These lower range of values obtained for higher percentages of periwinkle shell replacement are still greater than the 25 N/mm^2 bench mark of BS 8110 (1997) for structural concrete. Much higher 28-day compressive strength values were obtained for lower percentages of periwinkle shell replacement: 30.59 KN/mm^2 at 50 percent replacement and 33.63 KN/mm^2 at 25 percent replacement. These values compare favourably with the highest average value of 39.56 KN/mm^2 obtained for 100% granitic chippings at 1: 2: 3 mix ratio. Moreover, values of cement content for the three sets of mix ratios used in this work are 16%, 15%, and 14%. These are all higher than the 250 Kg/m^3 (approximately 10.2%) minimum requirement of BS 8110.

Table 2: Saturated Surface Dry (SSD) density of concrete cubes

Sample	%Periwinkle	7 days (Kg/m^3)				28 days (Kg/m^3)			
		1	2	3	Average	1	2	3	Average
First set of mix ratios– 1: 1.5 :3									
U1	75	2100	2090	2160	2116.67	2110	2100	2100	2103.33
U2	65	2080	2080	2110	2090	2130	2100	2110	2118.33
U3	55	2160	2150	2150	2153.33	2110	2130	2130	2123.33
U4	50	2220	2230	2160	2203.33	2360	2290	2222	2290.67
U5	45	2250	2230	2300	2260	2380	2260	2320	2320
U6	35	2290	2350	2280	2306.67	2350	2880	2320	2350
U7	25	2420	2360	2130	2303.33	2330	2420	2480	2410
U22	0 (Control)	2440	3200	3111	2917	3556	3644	3556	3585.33
Second set of mix ratios–1:2:3									
U8	75	2240	2070	2140	2150	2060	2060	2200	2106.68
U9	65	2240	2120	2210	2190	2190	2180	2120	2163.33
U10	55	2180	2220	2210	2203.33	2220	2310	2280	2270
U11	50	2320	2270	2260	2283.33	2330	2290	2310	2310
U12	45	2350	2270	2290	2303.33	2390	2360	2300	2350
U13	35	2310	2310	2470	2363.33	2390	2390	2330	2370
U14	25	2240	2410	2410	2420	2410	2390	2420	2406.67
U23	0 (Control)	2560	2410	2400	2460	2520	2460	2410	2450
Third set of mix ratios–1:2.5:3									
U15	75	2190	2210	2180	2193.33	2190	2100	2100	2130
U16	65	2260	2170	2200	2210	2160	2210	2120	2183.33
U17	55	2210	2270	2290	2256.67	2190	2150	2200	2180
U18	50	2360	2240	2290	2296.67	2270	220	2260	2250
U19	45	2280	2300	2290	2290	2320	2310	2280	2303.33
U20	35	2320	2500	2410	2410	2330	2380	2400	2370
U21	25	2420	2420	2380	2406.67	2450	2450	2500	2466.67
U24	0 (Control)	1956	2400	2044	2133.33	2378	2398	2644	2473.33

IV. CONCLUSIONS AND RECOMMENDATIONS

This reinvestigation confirms some of the observations made by earlier researchers and particularly strengthens the fact that on the basis of required compressive strength, periwinkle shells could be used as partial replacement of granitic chippings in making concrete for reinforced concrete works.The use of periwinkle shells for this purpose would greatly reduce the cost of concrete works in riverine communities with plentiful supply of these shells. As much as 75% replacement could still produce concrete of satisfactory strength for structural members under mild conditions of exposure, given good supervision of the concrete making process. Lower percentage replacements would be suitable for worse conditions of exposure.For example, 50 percent replacement would be satisfactory for moderate conditions of exposure that require a minimum concrete compressive strength of 30N/mm^2; and 25 and lower percentage replacements could be suitable for severe conditions that require strengths of 35N/mm^2 or more. The reduced density of concrete produced when granitic chippings are partially replaced with periwinkle shells also results in lower self-weight of structure. This is particularly beneficial in coastal communities where the soils have relatively low bearing capacities.

Table 3: Values of compressive cube strength for the mixes

Sample	%Periwinkle	7 days (N/mm^2)				28 days (N/mm2)			
		1	2	3	Average	1	2	3	Average
First set of mix ratios– 1: 1.5 :3									
U1	75	20.44	22.67	18.67	20.59	25.78	22.22	24.44	24.15
U2	65	24.00	20.44	24.59	23.11	27.56	26.60	28.00	27.39
U3	55	21.33	22.22	19.56	21.04	24.88	27.56	25.33	25.92
U4	50	25.78	21.44	20.00	22.41	26.67	30.22	28.00	27.41
U5	45	27.56	25.78	26.67	26.67	31.11	33.33	31.56	30.96
U6	35	25.78	30.22	26.80	27.60	30.66	33.33	33.51	32.50
U7	25	26.67	24.33	29.33	28.44	33.11	36.44	34.66	33.70
U22	0 (Control)	24.44	32.00	31.11	29.18	35.56	28.00	35.56	35.55
Second set of mix ratios–1:2:3									
U8	75	21.33	22.22	23.11	24.74	28.88	27.11	28.44	28.44
U9	65	18.67	22.22	22.22	21.04	26.67	32.00	27.56	27.11
U10	55	25.78	26.67	28.44	26.96	30.22	28.66	32.44	31.55
U11	50	24.00	24.44	24.00	24.15	28.88	28.66	29.33	28.96
U12	45	30.22	28.89	27.11	28.74	33.33	31.11	32.00	32.15
U13	35	24.44	27.11	25.78	25.78	29.78	31.11	30.22	30.30
U14	25	30.60	30.5	30.1	30.4	32.00	33.33	35.56	33.63
U23	0 (Control)	32.15	33.1	32.15	32.4	40.89	39.11	38.67	39.56
Third set of mix ratios–1:2.5:3									
U15	75	20.00	17.75	16.44	18.06	28.89	28.00	26.67	27.55
U16	65	17.78	16.00	16.00	16.59	25.78	26.67	26.22	26.22
U17	55	20.44	20.00	16.00	18.81	28.89	29.78	27.56	28.74
U18	50	20.44	20.00	20.44	20.29	30.22	30.67	30.89	30.59
U19	45	17.78	20.44	17.78	19.41	26.67	28.89	27.11	28.22
U20	35	27.50	24.44	25.75	25.91	35.56	31.11	32.00	32.89
U21	25	22.20	20.44	24.89	22.52	28.89	29.33	31.11	29.78
U24	0 (Control)	26.35	30.00	30.02	28.8	33.78	33.78	36.44	34.69

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