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LIGHTWEIGHT CONCRETE ELEMENTS FROM BURNT PALM NUT SHELLS

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ABSTRACT

This paper investigates the characteristics. technology and the use of burnt palm kernel shells as a replacement for aggregates in light weight concrete. The need to find alternative sources to imported and expensive building materials for construction led to the investigation of burnt palm kernel shells as a possible substitute for some aggregates.

Investigation into the physical and structural characteristics of the burnt palm kernel shells was conducted. The paper was used concrete mix 1:2:4 design. Different tests were also performed on the wet and cured light weight concrete prepared by replacing 0%. 10% and 25% of the fine and coarse aggregates with the shells burnt to 100°C, 300°C, 500°C and those shells burnt in the open air.

The result indicated that compressive strength of concrete with burnt shells was lower than that of concrete with unburnt shells at the same percentage replacement. The compressive and tensile strength were found to be decreasing with temperature increase of the burnt shells up to 300°C but picked up tremendously with shells burnt to 500°C

The result showed that burnt palm kernel shells is a viable substitute for aggregates for light weight concrete in floors. partitions. insulated panels and lawn tennis concrete floors.

INTRODUCTION

Concrete is one of the most important materials used in the building industry. However. the high cost of its material components. their unavailability and the need for various types of concrete have called for the use of different materials as substitute for the constituents of concrete.

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Normal concrete is composed of cement. sand. gravel and water. It has a unit weight of between 2400 to 2500 kg/m^3. Heavy weight/dense concrete has density of up to 6000 kg/m^3 and aggregates used include barities. steel shorts. steel punchings. limonite and geothite. Concrete classified as light weight has less density than 2400 kg/m^3. Light weight concrete type is used when there is need for reduction in dead weight of structures. Materials used as light weight concrete elements include foamed slag. expanded or sintered clay. fly ash and saw dust. Light weight concrete is characterised by the ease of handling, working and reduced cost in formwork (1).

Palm kernel is a product of oil palm tree is produced in abundance in Western and Eastern Nigeria. The shell has been economically under-utilised because a small percentage is used either as domestic fuel or by the gold and blacksmiths (4). The rest is disposed as industrial waste in palm oil production industries.

Carbonised shells are far lighter than raw palm kernel shells and the lightness increases with increase in temperature. Burnt palm nut shell would not ignite until a temperature range of 300-400^{0}C. The weight of light weight concrete is proportional to its density but its resistance to weathering is about the same as that of the normal concrete (3). when compared with the normal sand/gravel concrete it has certain advantages which include:

- Savings in structural steel support
- decrease in foundation size because of decreased dead load
- better fire resistance
- better insulation against heat and sound (2) (2) (4)

The principal use of lightweight is in the construction of floors. parapet walls and roof slabs where substantial savings can be effected in decreasing dead weight.

This paper discusses the physical characteristics of burnt and unburnt palm but shells and strength characteristics of light weight concrete with burnt palm nut shells as aggregates. Palm nut shells were burnt to 100^{0}C. 300^{0}C and 500^{0}C and those burnt in the open air. The unburnt and burnt palm nut shells were employed to cast 150 x 150 x 150 mm cubes light weight concrete at mix 1:2:4 with 0% and 25% replacement in fine and coarse aggregate alternatively. The results are herein discussed.

MATERIALS AND METHODS OF BURNT PALM NUT SHELL SPECIMENS

The original intention was to burn the palm nut shells from 0^{0}C to 1200^{0}C but it was discovered that nearly all the shells turned to ashes at about 600^{0}C. Temperature range of 0^{0}C to 500^{0}C was then selected. Five samples of burnt shells were considered in all comprising of one sample unburnt (0^{0}C). 3 samples burnt to 100^{0}C. 300^{0}C and 500^{0}C and last sample burnt in the open air.

In the process of burning the palm nut shells various physical and chemical changes took place. When burnt to about 100^{0}C, whitish fumes were given off through the exhaust indicating the escape of moisture from the shells. Shells burnt to 100^{0}C had no significant change in volume. The whitish fumes continued till about 250^{0}C when reddish brown fumes were observed. At this stage the fibres at the back of the shells started to decompose. At about 300^{0}C the shells had lost all fibres and had shown slight reduction in volume (about 15%). At about 300^{0}C the reddish brown fumes gave way to ox-blood coloured fumes signalling the ignition of the palm nut shells. The ignition continued till about 48^{0}C when the ox-blood fumes started to give way to whitish fumes indicating the beginning of the disintegration of the shells to ashes and subsequent reduction in volume. At 500^{0}C all the inorganic matters in the shells had decomposed with about 65% reduction in volume. Another sample of the shells was burnt in the open air.

TESTS ON CARBONISED PALM KERNEL SHELLS SPECIMENS

The 5 basic specimens of burnt palm nut shells are:

(a) Unburnt shells (0^{0}C)

(b) Shells burnt to 100^{0}C

(c) Shells burnt to 300^{0}C

(d) Shells burnt to 500^{0}C

(e) Shells burnt in the open Air.

The physical tests performed on the burnt shells specimens were to determine the gradation unit weight, absorption and abrasion.

Gradation Test: Simple gradation of the burnt shells is an important physical test as it showed the proportion of different sizes of particles in each of the specimens. The test showed that presence of smaller particles in burnt shells increased with temperature increase.

Unit Weight: Unit weight of the palm nut shells burnt to different temperature, fine and coarse aggregates were determined. Unit weight of burnt shells were found to be decreasing with decrease in burning temperature from 1426.7 kg/m^3 to 106 kg/m^3, and are far less than the unit weight of fine and coarse aggregates

$$\text{Unit weight} = \frac{W_1}{V_2 - V_1} \text{ kg/m}^3$$

where:

W_1 = weight of sample. kg

v_1 = Volume of sample

v_2 = Volume of water to fill cylinder with sample.

Moisture contents test

Moisture content of burnt shells to be used in lightweight concrete production is very important as this affects the rate at which the shells absorb water used in mixing concrete and consequently affects strength of the concrete. Moisture content is defined as weight of solid in an element usually expressed in percentage (5). Moisture content of burnt shells were found to be decreasing with temperature increase from 3.34% to 0.13%.

$$\text{Moisture content} = \frac{W_3 - W_5}{W_5} \quad 100$$

where:

w_1 = weight of container

w_2 = weight of container + sample

w_3 = weight of sample = $w_2 - w_1$

w_4 = weight of oven dry sample + container

w_5 = weight of oven dry sample = $w_4 - w_1$

$$\text{\% of moisture content} \quad \frac{W_3 - W_5}{W_5} = 100$$

Absorption capacity test

Absorption capacity test was conducted on all the specimens as this deals with the porosity of shells burnt at different temperature. Investigation showed that absorption capacities of the samples increased as the temperature increased from 8.83% to 19.30% indicating that shells burnt to lower temperature would not absorb much of the water during concrete mixing.

Absorption capacity = $(W_1 - W_2) \times 100$

Weight of saturated surfaces dry sample = W_1

Weight of over dry sample = W_2

Abrasion test: Abrasion test was conducted on the specimens to determine their durability by the use of Los Angeles abrasion machine. The abrasion tests showed that percentage durability decreases with temperature increase from 95% to 66%.

Uniformity coefficient test: Uniformity coefficient of the specimen was also investigated and found to be increasing with temperature increase from 3.6 to 8.9.

$$\text{Uniformity Coefficient} = \frac{D_{60}}{D_{10}}$$

D_{60} = shell diameter at 60% finer (mm)

D_{10} = shell diameter at 10% finer (mm)

Preparation of Light Weight Concrete with Percentage Replacement of Aggregate with shells burnt to varying degree of temperature

The quantities of light weight concrete components to fill one 150 x 150 x 150 mm cube is shown in Table X_2. These values were arrived at after allowing 50% and 10% for shrinkage and wastage respectively.

Table X_2: Quantities of Materials Used in Casting one cube (150 x 150 x 150 mm) of light weight concrete mix 1:2:4 with burnt shells as aggregates

Percentage replacement	Volume of burnt shells	Volume of fine aggregates (m^3)	Volume coarse aggregates (m^3)	Volume of cement (m^3)
0%		1.592×10^{-3}	3.184×10^{-3}	7.96×10^{-3}
10% Coarse	3.184×10^{-4}	1.592×10^{-3}	2.865×10^{-3}	7.96×10^{-4}
25% Coarse	7.96×10^{-4}	1.592×10^{-3}	2.388×10^{-3}	7.96×10^{-4}
10% Fine	1.592×10^{-4}	1.4328×10^{-3}	3.184×10^{-3}	7.96×10^{-4}
25% Fine	3.98×10^{-4}	1.194×10^{-3}	3.184×10^{-3}	7.96×10^{-4}

Preparation of Formwork

150 mm cube cast iron moulds were used to cast the lightweight concrete cubes. the cubes were properly cleaned and oiled before usage to allow for easy removal of the light weight concrete cubes.

A total of 210 cubes of 150 x 150 x 150 mm light weight concrete mix 1:2:4 with specified percentage replacement of fine or coarse aggregate with shells burnt to varying temperatures were produced.

Strength characteristics of light weight concrete with burnt palm nut shells as aggregates

The major experiments performed included the slump tests which was carried out on wet mixes as well as density. compressive tensile and flexural strengths on curved light weight concrete cubes. as shown in the appendix

RESULTS AND DISCUSSION

Physical tests conducted on the burnt palm kernel shell on different aspects gave the following results:

- Sieve analysis of samples involved sample gradation of unburnt shells and those burnt to different temperature. fine and coarse aggregate. Result of the sieve analysis showed that presence of smaller particles in burnt shells increased with increase in temperature.
- Unit weights of burnt shells were found to be decreasing with increase in burning temperature from 1443.36 kg/m^3 to 968.25 kg/ m^3. Unit weight of burnt shells were less in value than those of fine and coarse aggregates.
- The specific gravity of burnt shells were found to be decreasing as the temperature increased varying from 1.44 to 0.917. The specific gravity for burnt shells were also found to be lower than those of fine and coarse aggregates.
- Moisture contents of burnt shells were found to be decreasing with temperature increase from 3.34% to 0.3%. The moisture contained in the shells burnt to 500°C which ignited and totally disintegrated can be attributed to those absorbed from the atmosphere during cooling.
- Absorption capacities of the samples increased as the burning temperature increased from 8.83% to 19.90%. This is an indication that palm kernel shells burnt to lower temperature would not absorb much of the water during concrete mixes

- Abrasion tests performed on the burnt shells showed that their percentage durability increased with temperature increase.

- Uniformity coefficient of burnt shells increased with temperature.

CONCLUSION

This project has described the influence of replacing certain percentage of aggregates in concrete with palm nut shells burnt to different temperature. The following conclusions are drawn:

- Density of light weight concrete cubes decreased with increase in temperature of burnt shells.
- Substantial decrease in the densities of lightweight concrete occurred with changes in the percentages of burnt shells.
- substantial decrease in the densities of lightweight concrete occurred with increased replacement of coarse aggregate with burnt palm nut shells.
- the compressive strength of the lightweight concrete increased with curing age
- the compressive strength of the lightweight concrete decreased with increase in the percentage replacement of burnt shells
- The compressive strength of the lightweight concrete decreases with increase in temperature of burnt palm nut shells up to 300^0C in the same percentage replacement.
- The comprehensive strength of the lightweight concrete with burnt palm nut shells replacement in coarse aggregates was more than that of the fine aggregate at the same burnt shell percentage replacement for the same temperature and curing ages.

Considering the gradual reduction in unit weight. specific gravity. moisture content. absorption capacity. density. compressive strength with increase in temperature (up to 300^0C to which the shells were burnt). it was concluded that palm nut shells burnt to 300^0C can be used as light weight concrete aggregate. It can be especially used in place of coarse aggregate.

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APPENDIX

Experiments on the strength characteristics of the concrete specimen

Slump test

Result of the slump tests for the light weight concrete cubes shown in Table X showed the slump value decrease with temperature increase but picked up for shells burnt to 500°C and those in the open air. This is due to the presence of smaller particles in the samples as could be seen in the sample gradation test.

Table X_3: **Slumps characteristics of wet light weight concrete with different shells (burnt to different temperature) percentage replacement**

Temperature to which shells were burnt	% of aggregates replaced with burnt shells	Slump (mm)
Unburnt	0%	14 mm
	10% coarse	12 mm
	25% coarse	7 mm
	10% fine	8 mm
	25% fine	9 mm
100%	10% coarse	10 mm
	25% coarse	5 mm
	10% fine	7 mm
	25% fine	9 mm
300^0C	10% coarse	3 mm
	25% coarse	1 mm
	10% fine	1 mm
	25% fine	2 mm
500^0C	10% coarse	67 mm
	25% coarse	42 mm
	10% fine	56 mm
	25% fine	60 mm
Burnt in the open air	10% coarse	55 mm
	25% coarse	38 mm
	10% fine	48 mm
	25% fine	52 mm

Table X_0: Density of concrete with different shells (burnt to different temperature) percentage replaced at different curing ages

Temperature	% Replacement	Curing Ages (Days)			
		Same Day		2 days	
		Weight kg	Density kg/m^3	Weight kg	Density kg/m^3
Unburnt	0%	8.25	244.4	8.38	2483.0
	10% Coarse	7.75	2296.3	7.95	2355.6
	25% Coarse	7.56	2240.0	7.74	2293.3
	10% fine	8.16	2417.8	8.29	2456.3
	25% fine	7.86	2328.9	7.99	2367.4
100^{0}C	10% Coarse	7.69	2278.5	7.85	2325.9
	25% Coarse	7.44	2204.4	7.59	2248.9
	10% fine	7.99	2367.4	8.15	2414.8
	25% fine	7.88	1334.8	8.06	2388.2
300^{0}C	10% Coarse	7.79	2308.2	7.94	2352.6
	25% Coarse	7.57	2243.0	7.65	2266.7
	10% fine	7.91	2343.7	8.01	2373.3
	25% fine	7.76	2299.3	7.89	2337.8
500^{0}C	10% Coarse	7.83	2320.0	8.03	2397.3
	25% Coarse	7.76	2299.3	7.89	2337.8
	10% fine	7.83	2367.4	8.11	2403.0
	25% fine	7.89	2337.8	7.95	2355.6
Burnt in the open air	10% Coarse	7.84	2323.0	7.96	2358.5
	25% Coarse	7.60	2257.9	7.74	2293.3
	10% fine	7.96	2358.5	8.04	2382.2
	25% fine	8.25	2444.4	8.36	2483.0

Temperature	% Replacement	Curing Ages (Days)			
		21 Days		28 days	
		Weight kg	Density kg/m^3	Weight kg	Density kg/m^3
Unburnt	0%	8.25	2444.4	8.30	2459.3
	10% Coarse	8.05	2385.2	8.05	2378.2
	25% Coarse	7.80	211.1	7.80	2311.1
	10% fine	8.30	2459.3	8.30	2459.3
	25% fine	8.10	2400.0	8.05	2414.8
100^0C	10% Coarse	7.90	2240.7	7.90	2340.7
	25% Coarse	7.65	2266.7	7.70	2281.5
	10% fine	7.85	2325.9	7.90	2340.7
	25% fine	7.90	2340.7	7.90	2340.7
300^0C	10% Coarse	7.90	2340.7	8.00	2340.7
	25% Coarse	7.65	2265.7	2.70	2281.5
	10% fine	8.10	2400.0	8.05	2385.2
	25% fine	7.00	2370.4	8.00	2370.4
500^0C	10% Coarse	8.25	2444.4	8.20	2439.6
	25% Coarse	7.65	2266.7	7.70	2281.5
	10% fine	8.25	2444.4	8.15	2414.2
	25% fine	8.30	2429.6	8.20	2429.6
Burnt in the open air	10% Coarse	8.00	2370.4	8.05	2385.2
	25% Coarse	7.65	2266.7	7.65	2266.1
	10% fine	8.10	2400.0	8.10	2400.2
	25% fine	8.45	2503.7	8.50	2518.5

Compressive Strength

The compressive strength obtained from crushing the lightweight concrete cubes are shown in Table X_5. The result obtained showed that compressive strength was decreasing with increase in burning temperature of burnt shells up to 300°C while the strength picked up again at 500°C. It also shows that compressive strength of concrete with burnt shells at the same temperature increases with curing age.

Table X_4 Contd.

Lightweight Concrete Elements from Burnt Palm Nut Shells

Temperature	% Replacement	Curing Ages (Days)			
		Same Day		2 days	
		Weight kg	Density kg/m^3	Weight kg	Density kg/m^3
Unburnt	0%	**8.30**	**2459.3**	**8.25**	**2444.4**
	10% Coarse	8.00	2370.4	8.00	2370.4
	25% Coarse	7.07	2281.5	7.75	2296.3
	10% fine	8.30	2459.3	8.30	2459.3
	25% fine	8.00	2370.3	8.05	2385.2
.100^{0}C	10% Coarse	7.85	2335.9	7.85	2325.9
	25% Coarse	7.60	2257.9	7.65	2266.9
	10% fine	7.10	2400.0	7.90	2340.7
	25% fine	7.30	2459.3	7.70	2381.5
300^{0}C	10% Coarse	8.00	2370.4	7.90	2340.7
	25% Coarse	7.65	2266.7	7.60	2251.9
	10% fine	8.00	2370.0	8.01	2400.0
	25% fine	7.90	2106.7	7.00	2370.4
500^{0}C	10% Coarse	8.00	2370.0	8.15	2414.8
	25% Coarse	7.75	2296.3	7.60	2251.8
	10% fine	8.10	2400.0	8.20	2429.6
	25% fine	8.00	2370.4	8.20	2429.6
Burnt in the open air	10% Coarse	8.00	2470.4	8.00	2370.4
	25% Coarse	7.75	2281.5	7.65	2266.7
	10% fine	8.10	2400.0	8.05	2385.2
	25% fine	8.35	247.1	8.40	2488.9

Table X_2: **Quantities of Materials Used in Casting one cube (150 x 150 x 150 mm) of light weight concrete mix 1:2:4 with burnt shells as aggregates**

Percentage replacement	Volume of burnt shells	Volume of fine aggregates (m^3)	Volume coarse aggregates (m^3)	Volume of cement (m^3)
0%		1.592×10^{-3}	3.184×10^{-3}	7.96×10^{-3}
10% Coarse	3.184×10^{-4}	1.592×10^{-3}	2.865×10^{-3}	7.96×10^{-4}
25% Coarse	7.96×10^{-4}	1.592×10^{-3}	2.388×10^{-3}	7.96×10^{-4}
10% Fine	1.592×10^{-4}	1.4328×10^{-3}	3.184×10^{-3}	7.96×10^{-4}
25% Fine	3.98×10^{-4}	1.194×10^{-3}	3.184×10^{-3}	7.96×10^{-4}

Table X_5: Compressive strength of light weight concrete with burnt shells in $N\ mm^2$

Temperature	% Replacement	Curing Ages (Days)			
		7	14	21	28
Unburnt	0%	21.24	29.42	32.53	27.96
	10% Coarse	18.43	23.38	24.67	28.00
	25% Coarse	15.48	20.80	23.56	24.00
	10% Fine	16.53	21.33	22.76	24.98
	25% Fine	13.16	16.80	20.89	23.47
100^0C	10% Coarse	12.18	16.71	17.16	21.69
	25% Coarse	9.02	11.38	11.64	14.67
	10% Fine	11.82	15.64	16.09	20.36
	25% Fine	8.18	10.40	10.67	13.42
300^0C	10% Coarse	10.40	14.22	15.04	17.96
	25% Coarse	8.18	10.31	11.29	12.98
	10% Fine	9.50	12.62	13.87	15.91
	25% Fine	7.02	8.89	9.69	11.11
500^0C	10% Coarse	14.41	17.02	18.31	20.98
	25% Coarse	11.04	11.56	13.78	15.78
	10% Fine	13.00	14.93	17.51	20.09
	25% Fine	9.40	9.82	12.62	14.49
Burnt in the open air	10% Coarse	11.21	13.42	17.60	14.20
	25% Coarse	10.21	12.80	16.76	18.31
	10% Fine	10.55	13.24	17.33	18.93
	25% Fine	9.98	11.73	15.38	16.80

Tensile strength:

The tensile strengths obtained from compressive strength are shown in Table X_6. The tensile strengths were calculated from compressive strengths using the formular:

where: $$f_{ct} = 0.375\,(0.3 + 0.7)\,\frac{D_{lc}}{D_{oc}}\sqrt{f_{cu}}$$

f_{ct} = Tensile strength

D_{lc} = Air dry density of light weight concrete

D_{oc} = Air dry density of Ordinary concrete

Table X_6: **Tensile strength of light weight concrete with burnt shells in N mm^2 calculated from compressive strength**

Temperature	% Replacement	Curing Ages (Days)			
		7	14	21	28
Unburnt	0%	1.26	1.49	1.56	1.68
	10% Coarse	1.19	2.32	1.36	1.45
	25% Coarse	1.08	1.25	1.33	1.34
	10% Fine	1.11	1.26	1.31	1.37
	25% Fine	0.99	1.12	1.25	1.33
100°C	10% Coarse	0.96	1.12	1.13	1.26
	25% Coarse	0.82	0.93	0.93	1.05
	10% Fine	0.94	1.10	1.10	1.24
	25% Fine	0.78	0.89	0.89	1.00
300°C	10% Coarse	0.88	1.03	1.08	1.16
	25% Coarse	0.78	0.88	0.92	0.99
	10% Fine	0.84	0.97	1.02	1.09
	25% Fine	0.73	0.82	0.85	0.91
500°C	10% Coarse	1.09	1.13	1.17	1.25
	25% Coarse	0.91	0.93	1.02	1.09
	10% Fine	0.99	1.06	1.15	1.23
	25% Fine	0.84	0.86	0.97	1.04
Burnt in the open air	10% Coarse	0.92	1.00	1.15	1.20
	25% Coarse	0.88	0.98	1.12	1.17
	10% Fine	0.89	1.00	1.14	1.19
	25% Fine	0.87	1.94	1.07	1.12