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MIXTURE PROPORTIONING METHODOLOGY FOR CONCRETE CONTAINING COCONUT SHELL

H. O. Aminulai, M. Abdullahi, B. Alhaji, M. Abubakar

Department of Civil engineering, Federal University of Technology, Minna

ahas92@yahoo.com , aminulaihammed@yahoo.com

*Mobile no:*07039256803, 07037751963

ABSTRACT:

This research has considered crushed coconut shell and crushed granite as coarse aggregate for the production of concrete. Studies were carried out on the physical properties of crushed coconut shell and crushed granite. Thirty one random mixes were generated using a statistical software package known as Mini Tab 14. A total of 108 cubes were cast and cured for 28 days after which they were crushed under machine and their compressive strength determined. From the result obtained, models were developed using Mini Tab 14 of which direct comparism was made between the modal data and experimental data. The concrete cubes had a compressive strength ranging from 8.94N/mm^2 – 27.11N/mm^2

Keywords: Minitab 14, slump test, compressive strength, density

INTRODUCTION:

The relevance of concrete in virtually all civil engineering practice and building industry cannot be over emphasized. There has been an alarming increase in resources depletion and global pollution which posed a major challenge in the country. A comprehensive and rational design of concrete mixes is influenced by numerous factors which depend upon the sources of materials and their properties, method of preparation, placement, compaction, curing of concrete and the requirements of a construction job. For an aggregate from a particular source having a specific gravity, the optimum design of a concrete mix involves selection of proportions of ingredients that yield concrete of the desired workability, strength and durability at minimum cost. The most important factors which influence such a mix design are the water-cement ratio (w/c), aggregate-cement ratio (TA/C) and coarse-total aggregate ratio (CA/TA): Abbasi et al (1987). Since these factors are inter-dependent, proper and analysis of experiments for studying their influences on the mix proportions is necessary. Several researches have been conducted to develop new innovations on materials relying on renewable resources. These include the use of by-products and waste products such as periwinkle shell, rice husk, palm kernel, coconut shell, just to mention but a few. According to Adewuyi and Adegoke (2008), many of these by-products are used as aggregate for the production of lightweight concrete. Although, there has been much research conducted on the structural performance of lightweight aggregate concrete which mostly confined to naturally occurring aggregates, In a country like Nigeria, where there is a global economic down-turn coupled with the market inflammatory trends, the cost of procuring concrete materials for construction works have over the years constrained the users to compromise quality standard. Hence, it is exigent to carry out research on the available local waste materials that will partially or fully substitute costly conventional materials. Numerous results have been achieved with these regards, and the subject is attracting attention due to functional benefits of recycling and suitability in concrete work. Reduction in construction costs and the ability to produce lightweight structures are added advantages. In Nigeria, particularly in the south-south region and the eastern zone of Nigeria, coconut shells are quite abundant and are considered as waste which results into environmental hazards thereby constituting nuisance to our environment as well as huge capital cost in the process of removing these waste. The aim of this research work is to optimize the concrete containing coconut shell as a coarse aggregate. In this work, physical properties of the aggregate were determined, full factorials experimental design is implemented to develop the settings to enable the development of the models and perform optimization.

RESEARCH SIGNIFICANCE

The research work will be a major breakthrough in Nigeria, particularly in the Niger-Delta and the eastern area, because the research material coconut shell is a waste material, which is quite abundant in the area waiting for disposal. So, using it for concrete work will result in the elimination of the material as waste in the environment and also such concrete will be unprecedentedly very cheap. This results in lessburden on the utilization of rock fragment used as normal aggregate. This work is limited to experimental work in the laboratory to determine the properties of the concrete and its ingredients. Models were developed using Minitab package to relate the mix ingredients to the resources such as slump and compressive strength.

Experimental work

The fine aggregate (sharp sand) used was obtained from River Kpakungwu in Minna, and the particles were those passing through sieve with aperture 5mm and retained on sieve with aperture 0063mm. The fine aggregate has a density of 2550kg/m^3 and was free from clay/silt. The coarse aggregate used in this experiment was coconut shells, which was obtained from Bosso in Minna Niger State. They were dried under ambient condition, crushed to a particular size of about 20mm before used in the concrete mixes. The cement is ordinary Portland cement whose properties conforms to British Standard BS 812 (1975). The dry densities of the constituent materials were determined in the laboratory.

The particle size analysis was carried out on the samples of the air-dried aggregates, a total of ninety three (93) 150mm concrete cubes were cast, demoulded after 24hrs and cured in the curing tank containing clean water until the age of the test.

MATERIALS AND METHOD

Materials

The materials used for this research work were sourced locally and they are as follows:

i. Natural sand (fine aggregate)
ii. Crushed coconut shell and granite as coarse aggregate
iii. Ordinary Portland cement
iv. Clean water

The coconut shell used was obtained from Bosso, dried and crushed to a particular size of about 20mm. The natural sand used was obtained from River Kpakungwu and dried before the tests were carried out. The water used for mixing and curing was obtained from tap. The physical examination of the water revealed that it was clean, free from deleterious materials and fit for drinking. The cement used is the ordinary Portland cement (Dangote) with specific gravity3.15.

Methods:
The following tests were carried out on the aggregates.

i. Sieve analysis
ii. Natural moisture content
iii. Specific gravity test
iv. Bulk density test

Sieve analysis:
Sieve analysis, also called particle size distribution is a process whereby materials are separated into various fractions within specific limits of the opening of standard test sieves in accordance with BS 812 (1975).

Natural moisture content:
There is a variation in moisture content from one stock pile to another as a result of weather the moisture content must be determined frequently (Neville 2000). The total water content of the moist aggregate is equal to the moisture content and absorption in the aggregate. Several methods are available but accuracy depends on sampling. BS 812 part 109: 1990 prescribed the best method to be used in the laboratory.

Specific gravity:
Specific gravity according to ASTM (127 – 93), is the ratio of the mass of a unit volume of material to the mass of the same (absolute) volume of water at the stated temperature. This to a large extent depends on the amount of voids and the specific gravity of the materials of which it is composed.

Bulk density test:
Bulk density is the mass of material in a given volume. It is used in converting quantities by mass to quantities by volume and it is affected by several factors which include the amount of moisture present plus the amount of effort introduced in filling the measures. Bulk density depends on how densely the aggregate is packed and consequently on the size distribution and the shape of particles. BS 812 part 2: 1975 recognises two degrees: loose and compacted (Neville, 1987).

Slump test:
In accordance with BS 812 (1975), the slump test is used to determine the workability of fresh concrete that is normally undertaken at the point of delivery to ensure the concrete is of adequate consistency for placement. Slump is of three types:

i. The collapse slump which is between 150mm – 250mm (6in – 10in)
ii. The true slump which is 125mm or 5in.
iii. The shear slump which is up to 150mm or 6in.

Casting of concrete cubes:

The metal moulds used were (150mm × 150mm × 150mm) in dimension. The water – cement ratio used for the casting of the cubes was 0.5. The moulds were lubricated with engine oil in order to reduce friction and to enhance removing of cubes from the moulds. They were than filled with concrete in three layers and each layer was tamped 25 times. The hardened cubes were remove after 24 hours and taken to the curing tank (BS1881: part 108:1983).

Curing of concrete cubes:

Curing is the process of keeping concrete under a specific environmental condition. Good curing is typically considered to be in a moist environment which promotes hydration. More specifically, the object of curing is to keep concrete saturated until the originally water filled space in fresh cement paste has been filled to the desired extent by the products of hydration of cement.

Tests on hardened concrete:

Destructive compressive test was the test that was carried out on the hardened concrete. The hardened concrete assumed an important property that retained the life span of the concrete and these properties are density, strength and deformation under load and durability among others. Generally density and strength of hardened concrete is considered as far as this research is concerned. The density of concrete is the unit weight of a given volume of concrete. The density was determined for 28days of curing.

Density test:

The concrete cubes were removed from the curing tank, allowed to dry and the weight obtained. The density of the concrete was calculated from the mathematical expression below:

$$Density = \frac{weight}{volume} \left(\frac{kg}{m^3}\right) \qquad 3.1$$

Compressive strength:

Strength is the most significant property of hardened concrete because it gives the load that the concrete could sustain in its life time. It is measured by testing the compressive strength which is the maximum compressive load a concrete can withstand per unit area of the concrete cast. It is calculated mathematically from:

$$compressive\ strength = \frac{crushing\ load}{surface\ area\ of\ concrte\ cubes} \left(\frac{N}{mm^2}\right) \qquad 3.2$$

Results and Discussion

Table 1: Physical properties of constituent materials

Parameter	Sand	Crushed granite	Coconut shell
Specific gravity	2.61	2.74	1.32
Moisture content (%)	4.0	0.5	5.2

Bulk density (loose) (Kg/m^3)	1468.46	1370.17	476.99
Bulk density (compacted) (Kg/m^3)	1602.54	1500.29	593.18
Fineness modulus	4.58	6.6	5.5
Void ratio	0.44	0.5	0.64
Porosity (%)	8.4	8.67	19.58

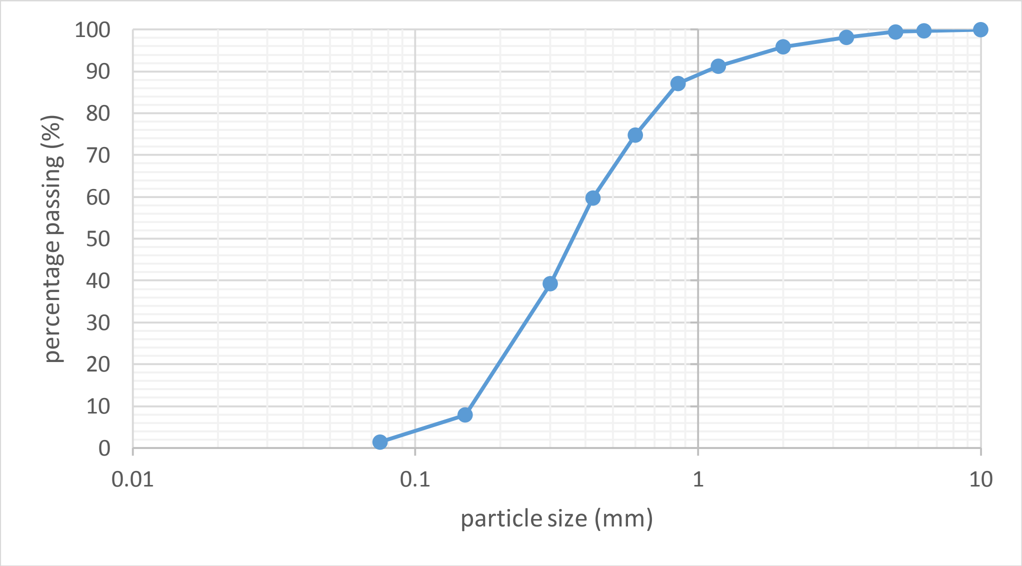

Fig. 1: Sieve Analysis for Fine Aggregate

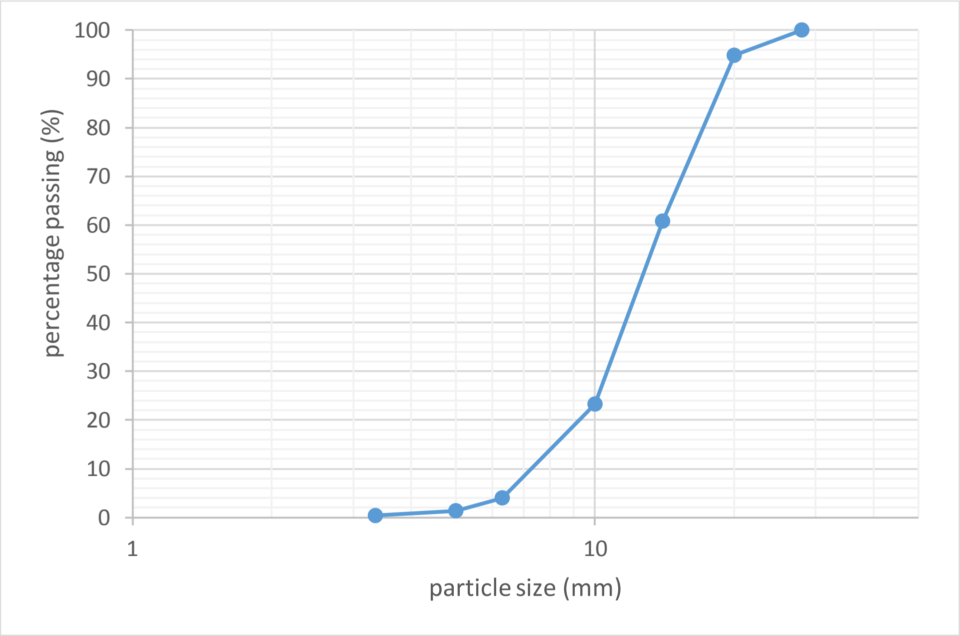

Fig. 2: Sieve Analysis for crushed coconut shell

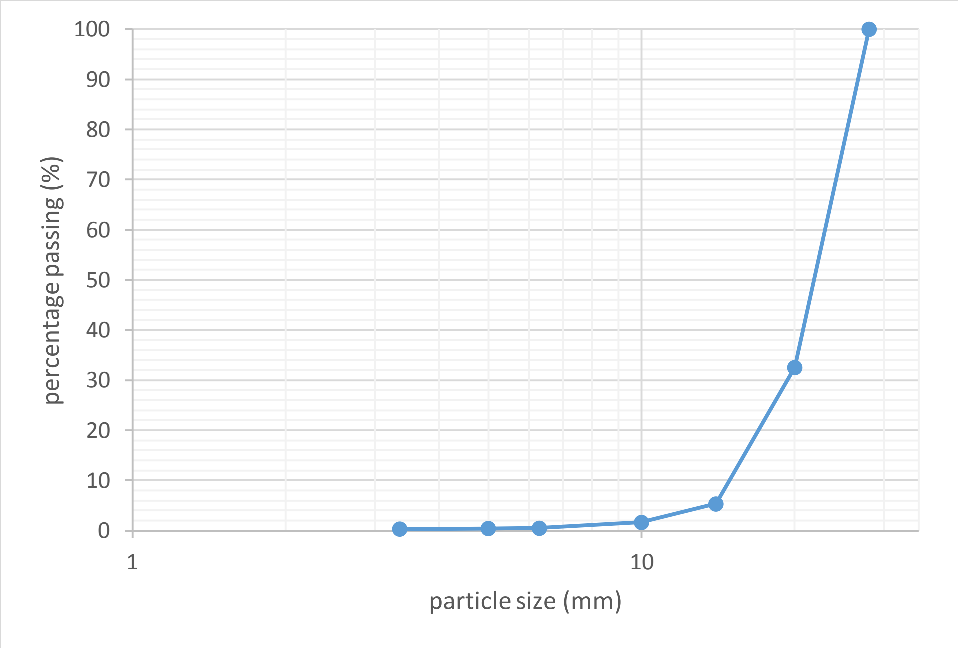

Fig. 3: Sieve Analysis for gravel (crushed aggregate)

Table 2: Result of mean slump, density and compressive strength of concrete cubes

Mix No.	X_1	X_2	X_3	X_4	Slump (mm)	Mean compressive strength (N/mm^2)	Mean density (Kg/m^3)
1	0.36	0.60	4.00	0.24	0	10.05	1979.3
2	0.40	0.65	3.00	0.36	20	17.2	1961.3
3	0.50	0.67	4.00	0.24	5	15.91	2038.5
4	0.40	0.55	3.00	0.36	10	15.78	1997
5	0.40	0.65	5.00	0.12	0	11.29	2094.8
6	0.50	0.60	5.41	0.24	0	6.28	1970.4
7	0.60	0.65	5.00	0.12	20	12.65	2154.1
8	0.60	0.55	5.00	0.36	10	9.33	1982.22
9	0.40	0.55	3.00	0.12	20	20.88	2198.52
10	0.60	0.65	3.00	0.36	120	8.95	1896.3
11	0.50	0.60	4.00	0.41	0	11.61	1917.04
12	0.50	0.60	4.00	0.24	10	19.7	2091.85
13	0.60	0.55	5.00	0.12	10	15.2	2106.07
14	0.50	0.60	4.00	0.24	0	17.17	1985.19
15	0.60	0.65	5.00	0.36	0	10.8	1920
16	0.40	0.55	5.00	0.12	0	8.79	1982.19
17	0.50	0.60	4.00	0.24	10	16.71	1991.11
18	0.50	0.53	4.00	0.24	10	18.03	2071.11
19	0.40	0.65	5.00	0.36	0	3.51	1757.04
20	0.60	0.55	3.00	0.12	125	15.35	2080

21	0.50	0.60	4.00	0.24	5	13.75	1914.07
22	0.50	0.60	4.00	0.24	15	12.74	2071.11
23	0.40	0.65	3.00	0.12	20	27.11	2225.19
24	0.50	0.60	2.59	0.24	70	18.8	2044.44
25	0.60	0.65	3.00	0.12	135	16.71	2109.63
26	0.50	0.60	4.00	0.07	25	23.63	2198.52
27	0.60	0.55	3.00	0.36	90	11.64	1994.07
28	0.50	0.60	4.00	0.24	20	19.64	2145.19
29	0.50	0.60	4.00	0.24	10	18.4	2005.19
30	0.40	0.55	5.00	0.36	0	4.3	1851.85
31	0.64	0.60	4.00	0.24	60	11.54	2035.55
32	0.5	0.55	3.50	0.24	10	12.8	2133.33
33	0.45	0.60	4.50	0.30	0	4.84	1917.04
34	0.6	0.65	5.00	0.18	10	11.47	2162.96

Identification Test

The properties of the aggregate used in the research work is summarized in table 1. Figure 1 – 3 shows their particle size distribution curve. The result of percentage passing BS Sieves complied with grading limit of fine aggregate zone II (BS 882:1978), therefore the sand is suitable for concrete work. From figure 1, the curve is smooth which indicate that the aggregate contain particle of different sizes in good proportion. This type of soil is known as well graded soil. The specific gravity of sand and crushed granite are2.61 and 2.74 which lies within the range for natural aggregate given as 2.5 and 3.0 (Neville, 2000). Also the specific gravity of coconut shell which amount to 1.32 (table 1) is very low compared with that of natural aggregate. This is an indication that coconut shell is much lighter than most natural aggregate. The uncompacted bulk density of coconut shell is 476.99Kg/m^{3}which is in agreement with that of Aguwa and Amadi (2010), who reported that coconut shell has a bulk density of 489Kg/m^3 and can be used as a lightweight aggregate in concrete production. The uncompacted bulk density was used in this research work because in practice, the material is not likely to be compacted before use in mixing. The porosity of coconut shell is 19.58% as shown in table 1. This value is very high compared with most natural aggregate, which have their porosities in the range of 6 – 10%. Hence less strength is expected, because the higher the porosity of aggregate, the lower the strength and durability of concrete. Table 1 also shows the moisture content for the coconut shell aggregate to be 5%. This indicates that the aggregate is not too dry but at the same time will absorb some amount of water from concrete and additional water has to be added to compensate for this absorption. The same applied to the fine aggregate having a moisture content of 4.1%. However, the moisture content for granite (coarse aggregate) is 0.5% indicating that the aggregate is very dry and would absorb little water from the concrete. The result of the mean compressive strength at 28days shows that mix 23 has the highest compressive strength of 27.11N/mm^2 with a mean density of 222.52Kg/m^3.

Table 3: Result of mean load and mean weight for model concrete cubes

Mixes	Crushing Load (KN)	Weight (Kg)	Mean crushing load (KN)	Mean weight (Kg)

32	268,292,304	7.44,7.4,7.02	288	7.20
33	111,88,128	6.26,6.54,6.6	109	6.47
34	254,259,262	254,259,262	258.3	7.30

Table 4: result for model development

Mixes	Density (Kg/m³)	Compressive strength (N/mm²)	Slump (mm)	Date of casting/crushing
32	2133.33	12.8	10	12/08/2011 – 09/09/2011
33	1917.04	4.84	0	12/08/2011 – 09/09/2011
34	2162.96	11.48	10	12/08/2011 – 09/09/2011

Model development:

Several models were generated with the use of statistical software called Minitab 14. The statistical package generated and analysed several models for slump, compressive strength and density of the concrete cubes cast. The models explained the relationship between the experimental data obtained from the laboratory and model data generated. These models data generated includes slump model, compressive strength model and density model.

Slump model:

A full quadratic method of modelling was found to be most appropriate for the slump model. Its residual values were reasonable when compared with other models generated for slump. The slump model generated is as follows:

$$Y_1 = 53.37 + 72.21X_1 - 33.19X_3 + 1087.33{X_1}^2 + 14.47{X_3}^2 - 225X_1X_3$$

$R_SQ = 94.8\%$, $R_SQ(ADJ) = 93.8\%$

Model verification

Table 5: Experimental data for model verification

MIXES	X_1	X_2	X_3	X_4	Y_I (mm)	Y_2 (N/mm²)	Y_3 (Kg/m³)
1	0.5	0.55	3.5	0.24	10	12.8	2133.33
2	0.45	0.6	4.5	0.3	0	4.84	1917.04
3	0.6	0.65	5	0.18	10	11.47	2162.96

$$Y_1 = 53.37 + 72.21(0.5) - 33.19(3.5) + 1087.33(0.5^2) + 14.47(3.5^2) - 225.0(0.5 \times 3.5)$$

$$Y_1 = 28.65mm$$

$$Y_1 \approx 30.0mm$$

Thus,

$Y_1 = 53.37 + 72.21(0.45) - 33.19(4.5) + 1087.33(0.45^2) + 14.47(4.5^2) - 225.0(0.45 \times 4.5)$

$Y_1 = -5.91mm$

$Y_1 = 0.0\ mm$

Also,

$Y_1 = 53.37 + 72.21(0.6) - 33.19(5) + 1087.33(0.6^2) + 14.47(5^2) - 225.0(0.6 \times 5)$

$Y_1 = 8.93mm$

$Y_1 \approx 10.0mm$

Compressive strength model:

The full quadratic method of modelling was used in generating models for compressive strength as it was found most suitable when compared with the other models. The model is stated as:

$$Y_2 = -17.636 + 222.2X_1 - 23.286X_2 - 0.06X_3 - 31.032X_4 - 268.57{X_1}^2 + 124.68{X_2}^2 - 1.923{X_3}^2 + 43.367{X_4}^2 - 147.125X_1X_2 + 30.256X_1X_3 + 42.135X_1X_4 - 7.113X_2X_3 - 84.687X_2X_4 + 3.38X_3X_4$$

$R_SQ = 91.2\%$, $R_SQ(ADJ) = 83.6\%$

Model verification

$$Y_2 = -17.636 + 222.2(0.5) - 23.286(0.55) - 0.06(3.5) - 31.032(0.24) - 268.57(0.5^2) + 124.68(0.55^2) - 1.923(3.5^2) + 43.367(0.24^2) - 147.125(0.5 \times 0.55) + 30.256(0.5 \times 3.5) + 42.135(0.5 \times 0.24) - 7.113(0.55 \times 3.5) - 84.687(0.55 \times 0.24) + 3.38(3.5 \times 0.24)$$

$Y_2 = 18.03N/mm^2$

Also,

$$Y_2 = -17.636 + 222.2(0.45) - 23.286(0.6) - 0.06(4.5) - 31.032(0.3) - 268.57(0.45^2) + 124.68(0.6^2) - 1.923(4.5^2) + 43.367(0.3^2) - 147.125(0.45 \times 0.6) + 30.256(0.45 \times 4.5) + 42.135(0.45 \times 0.3) - 7.113(0.6 \times 4.5) - 84.687(0.6 \times 0.3) + 3.38(4.5 \times 0.3)$$

$Y_2 = 11.62N/mm^2$

And

$$Y_2 = -17.636 + 222.2(0.6) - 23.286(0.65) - 0.06(5) - 31.032(0.18) - 268.57(0.6^2) + 124.68(0.65^2) - 1.923(5^2) + 43.367(0.18^2) - 147.125(0.6 \times 0.65) + 30.256(0.6 \times 5) + 42.135(0.6 \times 0.18) - 7.113(0.65 \times 5) - 84.687(0.65 \times 0.18) + 3.38(5 \times 0.18)$$

$Y_2 = 11.95 N/mm^2$

Density model:

Full quadratic method of modelling was also adopted for this model generations as it was found to be the most appropriate. It is expressed thus as:

$$Y_3 = 2971.72 + 246.47X_1 - 2013.18X_2 - 195.88X_3 + 1473.44X_4 - 1722.76{X_1}^2 + 2778.35{X_2}^2 - 16.97{X_3}^2 + 575.82{X_4}^2 - 1148.37X_1X_2 + 487.06X_1X_3 + 1435.05X_1X_4 + 99.94X_2X_3 - 5277.19X_2X_4 - 32.40X_3X_4$$

$Rsq = 87.9\%$, $Rsq(adj) = 72.3\%$

Model verification:

From the experimental data above, the density model can be verified thus:

$$Y_3 = 2971.72 + 246.47(0.5) - 2013.18(0.55) - 195.88(3.5) + 1473.44(0.24) - 1722.76(0.5^2) + 2778.35(0.55^2) - 16.97(3.5^2) + 575.82(0.24^2) - 1148.37(0.5 \times 0.55) + 487.06(0.5 \times 3.5) + 1435.05(0.5 \times 0.24) + 99.94(0.55 \times 3.5) - 5277.19(0.55 \times 0.24) - 32.40(3.5 \times 0.24)$$

$Y_3 = 2068.14 Kg/m^3$

Also,

$$Y_3 = 2971.72 + 246.47(0.45) - 2013.18(0.6) - 195.88(4.5) + 1473.44(0.3) - 1722.76(0.45^2) + 2778.35(0.6^2) - 16.97(4.5^2) + 575.82(0.3^2) - 1148.37(0.45 \times 0.6) + 487.06(0.45 \times 4.5) + 1435.05(0.45 \times 0.3) + 99.94(0.6 \times 4.5) - 5277.19(0.6 \times 0.3) - 32.40(4.5 \times 0.3)$$

$Y_3 = 1941.0 Kg/m^3$

And,

$$Y_3 = 2971.72 + 246.47(0.6) - 2013.18(0.65) - 195.88(5) + 1473.44(0.18) - 1722.76(0.6^2) + 2778.35(0.65^2) - 16.97(5^2) + 575.82(0.18^2) - 1148.37(0.6 \times 0.65) + 487.06(0.6 \times 5) + 1435.05(0.6 \times 0.18) + 99.94(0.65 \times 5) - 5277.19(0.65 \times 0.18) - 32.40(5 \times 0.18)$$

$Y_3 = 2091.43 Kg/m^3$

Where,

Y_1 = slump test, in mm

Y_2 = Compressive strength, N/mm^2

Y_3 = Density, Kg/m^3

Table 6: Result of experimental data and model data

Factors				Experimental Data			Model Data		
X1	X2	X3	X4	Y1	Y2	Y3	Y1	Y2	Y3
0.50	0.55	3.50	0.24	10	12.80	2133.3	30	18	2068.14
0.45	0.60	4.50	0.30	0	4.84	1917	0	11.61	1941
0.60	0.65	5.0	0.18	10	11.47	2163	10	11.95	2091.43

CONCLUSION

Having carried out various tests and investigation on aggregates, hardened concrete made from crushed coconut shell and crushed granite and the results obtained with reference to to various section of this work, the following conclusions are made

1. Coconut shell exhibits all the properties of lightweight aggregate in terms of moisture content of 5.2% as shown in table 2
2. The bulk density of crushed coconut shell aggregate lies within the practical range of lightweight aggregates
3. The strength of concrete made from crushed coconut shell should be improved using higher cement content and appropriate admixtures so as to meet the ASTM standard for structural lightweight concrete

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REFERENCES

Abbasi A. F., Ahmad M. and Wasim M. (1987), Optimization of concrete mix proportioning using reduced factorial technique. American Concrete Institute, ACI Material journal, Aug. 1987

Adewuyi A. P. and Adegoke T. (2008), Exploratory study of Coconut/Periwinkle shell in concrete works. ARPN Journal of Engineering and Applied Science

Aguwa, J.I. and Amadi, A.A. (2010), Performance of coconut shell as coarse aggregate for production of lightweight concrete, Global journal of Engineering and Technology, vol.3, no. 4, (2010) Pp. 695- 701

BS 12 (1996), Specification for Portland cement. British Standard Institution, Her Majesty Stationary office London

BS 812: part 1 (1975): Method for determination of particle size and shape. British Standard Institution, Her Majesty Stationary office London

BS 812: part 2 (1975), Physical properties of aggregate. British Standard Institution, Her Majesty Stationary office London

BS 812: part 109 (1990), Method of determination of moisture content. British Standard Institution, Her Majesty Stationary office London

BS 882 (1983) Aggregate from natural sources for concrete, British Standard Institution, Her Majesty Stationary office London

BS 1881: Part 108 (1983), Methods for determination of slump of fresh concrete, British Standard Institution, Her Majesty Stationary office London

BS 1881 Part 116 (1983), Method for determining compressive strength of concrete cubes, British Standard Institution, Her Majesty Stationary office London

BS 1377 (1990), Methods of testing for civil engineering purposes, British Standard Institution, Her Majesty Stationary office London

Neville, A.M (2000), Properties of Concrete. 4th Edition, Pitman Publishing Ltd, 39 parker Street, London