Strength Properties of Concrete Containing Coconut Shell as Coarse Aggregate Replacement

Duna, Samson *[1] and Musa, Abdullahi [2]

*[1] Associate Professor, Department of Civil Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria
[2] Graduate Student, Department of Civil Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria

Abstract: *This paper presents the results of the investigation into the strength properties of concrete containing coconut shells as coarse aggregate replacement. Control concrete with normal aggregate and binary concrete mixes (containing 10, 20, 40, 60, 80 and 100 % coconut by weight of coarse aggregate) were produced and cured for 7, 14, 28, 56 and 90 days respectively. A total of one hundred and five (105) cubes and beams were cast and tested for compressive strength, flexural strength as well as the density. The results showed that generally strengths decrease with increase in coconut shell content and increase with prolong curing period. The results also showed that, the density of the concrete decreases with increase in coconut shell content. Concrete cubes made with (10-20) % coconut shell and cured for beyond 28 days, achieved the 28 days target strength of 20 N/mm^2. The optimum replacement level was observed at CS-20% cured for beyond 28 days. The data obtained were subjected to regression analysis and analysis of variance (ANOVA) in the MINITAB 16 statistical software. Models were developed to predict compressive strength, flexural strength and concrete density with curing period and coconut shell content as predictors at 5% level of significance, the result showed that, there is no significant difference between the predicted and the experimental values. The coefficients of determination, R^2 of 93.4%, 91.0% and 94.3% for the models of compressive strength, flexural strength and density are reasonably high, indicating a good correlation between the response and the predictor variables.*

Key words: *Coconut shells, Compressive strength, Density, Flexural strength and Regression.*

1. INTRODUCTION

Concrete is a building material obtained from the mixture of sand, gravel, cement and water. The continuous increase in the price of construction materials, the growing depletion of natural resources and increase in human population globally are partly responsible to the insufficient concrete produce when compared to their demand in the construction industries [1]. Among the components of concrete, aggregates formed the major part of it. For instance, over 2 billion tones of aggregate are being produced and used each year in the United State and the production is expected to reach more than 2.5 billion tons each year by the year 2020 [2]. Similarly, in 1960 the production of aggregate was about 110 million tons in United Kingdom and has increased to about 275 million tons in 2006 [2]. The negative consequences of ever increasing demand of aggregate for concrete production include depletion of natural aggregate deposits; environmental degradation and ecological imbalance. [3]. In view of this, considerable efforts have been made worldwide to utilize natural waste or bye-product as coarse aggregate most of them are cheap, available lightweight material that will not compromise strength and durability properties of the concrete. This had been achieved through the use of waste such as fly ash, recycled aggregate, crumb rubber and glass to mention just a few [3-5]. Apart from the above mention waste materials, there exist little studies on coconut shell as aggregate replacement in concrete [6].

Coconut is one of the most important natural fillers produced in tropical countries such as Malaysia, Thailand, Sri Lanka, Ghana and Nigeria [6]. Research had showed that coconut is grown in more than 86 countries globally, with a total production of 54 billion tons per annum [7]. For instance, India occupies the first position with 13 billion tons annual coconut production followed by Indonesia and then Philippines [7]. The coconut shells are mostly dumped as waste resulting into

ISSN 2229-5518

environmental pollution hence the need to incorporate it in concrete but, sometimes it is used as a source of fire in rural areas.

Research carried out by [8] compared concrete made with coconut shell and palm kernel shell as replacement of coarse aggregate and concluded that coconut shell performed better than palm kernel shell in concrete in terms of strength. Studies by [8] also indicated some of the advantages of using coconut shell as coarse aggregate replacement in concrete include high strength, reduction of dead load, modulus properties and lignin content. The high lignin content makes coconut shell aggregate concrete to be weather resistant and hence suitable for application as construction materials. More so, research by [9] reported that the shells absorbs less moisture due to its low cellulose content, others are superior mechanical properties, reduction of shrinkage in concrete, reduction in permeability of concrete, increase resistance against chemical effect which results in the formation of denser concrete. Reference [10] also identified that there is about 48% reduction in cost if coconut shells are properly used to replace coarse aggregate in concrete [10]. This study is therefore, aimed at assessing the strength properties of concrete containing coconut shell as coarse aggregate replacement in concrete.

2. MATERIALS AND METHODS

Materials: The coconut shells were collected as a dumped waste at Muda Lawal market refuse site in Bauchi state Northeast Nigeria. It was sorted out, washed and sun dried before crushing it by a mechanical crusher to a maximum size of 18 mm. Ashaka brand of Ordinary Portland Cement (OPC) was used for this study, and the properties of the cement used conform to BS EN 197 (1992)-part 1 specification. The coarse aggregates used for the study was normal weight dry aggregates from an igneous rock source with a maximum size of 20 mm, the coarse aggregates was procured from Triacta quarry site in Bauchi state Northeast Nigeria. The fine aggregates (sharp sand) used for the study was obtained from a stream at Bayara town along Bauchi-Dass road, Northeast Nigeria. The fine aggregates were tested in accordance with BS 882: (1983) specification. The water used for the study was from tap source which is free from impurities and almost fit for drinking.

2.1 Mix Proportion

A grade 20 concrete was design using a mix proportion of 1:2:4 by weight of ordinary Portland cement, river sand, coarse aggregate/coconut shell was obtained and used to cast the concrete. The comprehensive mix proportion of the constituent materials is presented in Table 1.

2.2 physical properties of the constituent materials

The physical properties of ashaka cement, coconut shells, coarse aggregate and fine aggregate were carried out at the structures laboratory of Department of Civil Engineering, Abubakar Tafawa Balewa University (ATBU), Bauchi. The test result of the physical properties of coarse aggregate, fine aggregate, coconut shell and Ashaka cement is presented in Table 2.

2.3 preparation of sample using constituent materials

The constituent materials were measured using beam balance. Water used was measured by volume. Hand mixing was adopted in accordance with BS EN 12390 (2000), Part 2: specification. The concrete were cured by complete water immersion for 7, 14, 28, 56 and 90days. The levels of replacements for coarse aggregates with coconut shells were at 0, 10, 20, 40, 60, 80 and 100 percent. A total of one hundred and five (105) samples of concrete cubes and beams were cast, cured and tested. For each curing period, three (3) samples were produced and the average of the three results were recorded and used.

Table 1: Mix proportions of constituent materials used for coconut shell concrete production

MIX ID	Constituents materials (kg/m^3)				
	Cement (k bng/m^3)	Water (kg/m^3)	Fine (kg/m^3)	Coarse (kg/m^3)	Coconut shell (kg/m^3)
CS-00	345	185	623	1170	0
CS-10	345	185	623	1160	10
CS-20	345	185	623	1150	20

CS-40	345	185	623	1130	40
CS-60	345	185	623	1110	60
CS-80	345	185	623	1090	80
CS-100	345	185	623	1070	100

2.4 Slump Test

Slump test of the freshly prepared concrete was carried out to determine the effect of coconut shell aggregate replacement on the workability of concrete at the structures laboratory of Department of Civil Engineering, ATBU, Bauchi. The test was conducted in accordance with BS EN 12350: Part 2 (1999) specifications.

2.5 Compressive strength test

Concrete cubes of size 100 mm x 100 mm x 100 mm were produced for determination of compressive strength. The samples were tested using the ELE motorized compression machine. The test was conducted in accordance with BS EN 12390, Part 4 (2000) specifications. The compressive strength of the concrete cubes was determined using equation (1).

$$compressive\ strength = \frac{Failure\ \ Load\ \ (KN)}{Area\ \ of\ \ Specimen\ \ (mm^2)} \quad ...(1)$$

2.6 Flexural strength test

Flexural strength test was carried out on hardened concrete beams of 100 mm x 100 mm x 500 mm. The flexural strength of the concrete beam was determined for each curing period. This test was conducted at the structures laboratory of the Department of Civil Engineering, ATBU Bauchi. The test was conducted in accordance with BS EN 12390 Part 5: (2000) specification. The flexural strength is expressed as a modulus of rupture (MOR) in (N/mm^2), and it was determined using the equation (2).

$$\text{Modulus of rupture } (MOR) = \frac{PL}{bd^2} \quad ...(2)$$

Where:

P = Maximum load (kN)
L = Span of the beam (i.e. 500 mm)
d = Depth of the beam (i.e. 100 mm)
b = Breadth of the beam (i.e. 100 mm)

2.7 Density test

The density of the hardened concrete samples was determined in accordance with BS EN 12390 Part 7: (2000). The densities were calculated using equation (3).

$$Density, \rho = \frac{Mass,\ m\ (kg)}{Volume\ ,v\ (mm^3)} \quad ...(3)$$

3. RESULTS AND DISCUSSIONS

3.1 Physical Properties of Coconut Shell (CS)

The result of some physical properties of coconut shell is presented in table 2. The specific gravity obtained was 1.51, while that of coarse aggregate is 2.70. This indicates that coconut shell is lighter than coarse aggregate and more volume of coconut shell will be required to replace equal weight of coarse aggregate in concrete. The bulk density of coconut shell obtained is 648 which is far less than about 1437 of coarse aggregate implying its good for lightweight concrete. The aggregate crushing value of coconut shell is 3.34 which is also less than that of coarse aggregate which has a value of 22.33 indicating it's relatively good for concrete works.

Table 2: Some Physical Properties of Cement, GP, MK, Fine Aggregate and Coarse Aggregate

Property	Cement	CS	Fine Aggregate	Coarse Aggregate
Specific Gravity	3.15	1.51	2.62	2.70
Bulk Density (Kg/m^3)	-	648	1588	1437
Loss on	1.0	-	-	-

Ignition				
Blaines Fineness (m^2/Kg)	370	-	-	-
Aggregate Crushing value (%)	-	3.34	-	22.33

3.3 Workability of Coconut Shell Blended Concrete

The results of the slump test carried out on the fresh concrete with varying percentage of coconut shells as coarse aggregate replacement are presented in table 4 while figure 1 shows the plot of slump versus percentage replacement of coarse aggregate with coconut shell. The result also shows that the slump decreases with increase in the amount of coconut shell used, which indicates that more water is required to maintain the same consistency as coconut shell content increases. For instance at 10%, 20%, 40%, 60%, 80% and 100% coconut shell content, the slump decreases by 19.05%, 33.33%, 42.86%, 52.38% and 76.92% respectively. This implies that coconut shell absorbs more water than ordinary Portland cement in concrete. All the slump values obtained falls within the limit for class S1 (10 mm-40 mm) specified by BS-EN 206-part 1: (2000) as true type of slump which is suitable for most concrete works, except that of 100% coconut shell coarse aggregate.

Table 3: Slump Test Result of Coconut Shell Concrete

Mix-ID	Slump (mm)
CS-00	26
CS-10	21
CS-20	17
CS-40	14
CS-60	12
CS-80	10
CS-100	6

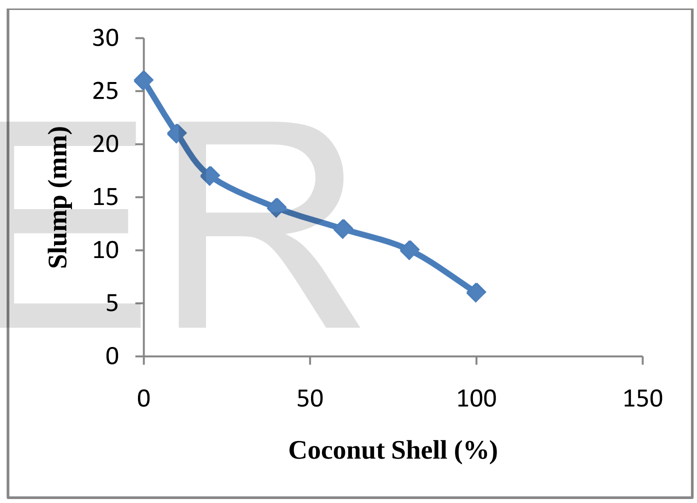

Figure 1: Plot of slump versus coconut shell content

3.4 Compressive strength test result

The compressive strength test result is presented in table 5, while figure 2 shows the plot of compressive strength of concrete versus percentage of coconut shell used to replace coarse aggregate in concrete. It can be seen from the figure that, the compressive strength generally decreases as the percentage of coconut shell increases. For instance at CS-10 coarse aggregate replacement level, there was a strength decreases of 7.41%, 8.41%, 8.41%,, 6.65% and 5.34% when compared to the compressive strength of control specimen(CS-00) at 7, 14, 28, 56 and 90 days of curing periods respectively. Similarly, CS-20 exhibited strength decrease of 11.67%, 14.79%, 15.11%, 10.15% and 7.52% at 7, 14, 28, 56 and 90 days of curing periods respectively. All the remaining coarse aggregate replacement levels, exhibited similar pattern of strength loss when compared to the strength of the control sample. From all the results presented, it can be observed that higher coconut

ISSN 2229-5518

shell replacing coarse aggregate in concrete, results in greater reduction of compressive strength. This behavior may be attributed to two reasons. First, the replacement of coarse aggregate with coconut shell in concrete, results in the increase of surface area for hydration, thus requiring more cement to bond with aggregate [11]. Secondly, since the coarse aggregate is much stronger than coconut shells, reducing the quantity of coarse aggregate and increasing the amount of coconut shells in the mix resulted in reduced strength when compared to plain OPC concrete [11]. However, compressive strength above the design mix of 20 N/mm^2 where observed at CS-10 and CS-20 when cured beyond 28 days.

Table 4: Compressive Strength Test Result for Coconut Shells Concrete

Mix ID	Compressive strength (N/mm^2)				
	7 days	14 days	28 days	56 days	90 days
CS-00	15.24	18.32	21.05	22.85	23.95
CS-10	14.11	16.78	19.28	21.33	22.67
CS-20	13.46	15.61	17.87	20.53	22.15
CS-40	11.83	14.49	15.66	17.06	19.35
CS-60	10.18	12.73	14.74	16.28	18.42
CS-80	8.09	10.24	12.59	14.27	16.53
CS-100	5.81	6.63	8.12	9.42	10.75

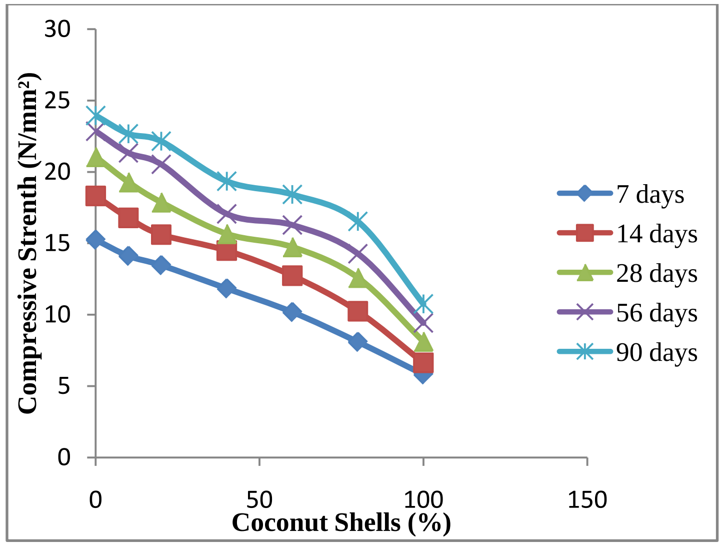

Figure 2: Plot of compressive strength versus coconut shell content

Figure 3 shows the plot of compressive strength of concrete versus curing periods. It can be observed that the compressive strength of the concrete containing coconut shell as aggregate increases as the curing age is prolonged irrespective of the replacement levels. According to the experimental findings, CS-10 at 7 days curing period, exhibited 20.21%, 38.12%,49.93% and 57.15% increase in strength as compared to the control concrete at the end of 14, 28, 56 and 90 days respectively. Similarly, CS-20 exhibited 18.92%, 36.64%, 50.46% and 60.67% increase in strength as compared with the corresponding strength of the plain concrete at the end of 7, 14, 28, 56 and 90 days of curing. All the remaining replacement levels, showed a similar pattern of strength increase. It can be seen from the values presented above that the percentage increase in strength for all concrete containing coconut shell as aggregate replacement increases slowly up to 28 days curing period. However, the percentage increase in compressive strength increases significantly at 56 and 90 days of curing. This shows that there is a significant strength gain with prolong curing. The possible explanation to this behavior also is that at early ages (28days and below), the coconut shell act as a filler in the concrete with no significant contribution to strength, but at latter ages(beyond 28 days) coconut shell react with Calcium Hydroxide released during hydration to produce the strength forming calcium silicate hydrates(C-S-H) [12]. The optimum replacement level was observed at CS-20 because it gives better increase in strength than the

ISSN 2229-5518

remaining replacement levels. The increase in compressive strength may be due to decrease in the size of coconut shell aggregate used when compared to aggregate from igneous source and thus improve bonding between the aggregate particles and the cement paste, by extension increase in bonding between the particles result in higher compressive strength [13].

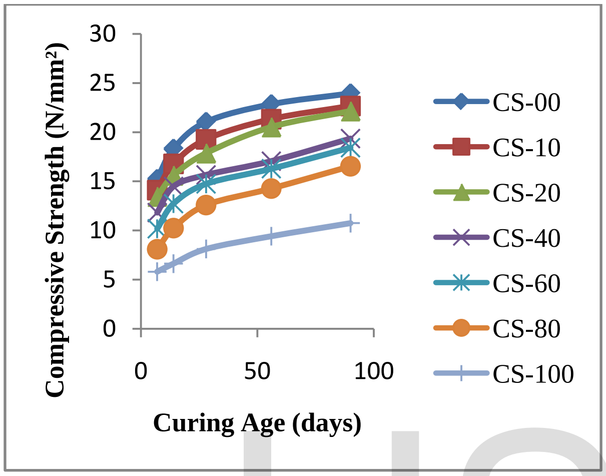

Figure 3: Plot of compressive strength versus age of curing

3.5 Flexural strength test result

Table 5 shows the result of the flexural strength of concrete while the variation of flexural strength with percentage replacement of coarse aggregate with coconut shell is presented in figure 4. And the variation of flexural strength versus curing period is presented in figure 5. It can be seen from the figure that, the flexural strength decrease with increase in coconut shell content. For instance at CS-10 coarse aggregate replacement level, there was a flexural strength decreases of 2.13%, 3.24%, 8.62%, 9.04% and 1.81% when compared to the flexural strength of control specimen(CS-00) at 7, 14, 28, 56 and 90 days of curing periods respectively. Similarly, CS-20 exhibited flexural strength decrease of 14.59%, 9.03%, 14.31%, 15.70% and 6.92% at 7, 14, 28, 56 and 90 days of curing periods respectively. All the remaining coarse aggregate replacement levels, exhibited similar pattern of flexural strength loss when compared to the strength of the control sample. The decrease in flexural strength may be attributed to low workability of the concrete due to coconut shell aggregate content [13]. Similarly, strength of coconut shell is lower than that of coarse aggregate from igneous rock. In the same vein, coconut shell absorbs most of the water in the mix, resulting in poor hydration hence, greater strength reduction [14].

Table 5: Flexural Strength Test Result for Coconut Shells Concrete

Mix ID	Flexural strength (N/mm^2)				
	7 days	14 days	28 days	56 days	90 days
CS-0	3.29	4.32	5.45	5.86	6.07
CS-10	3.22	4.18	4.98	5.33	5.96
CS-20	2.81	3.93	4.67	4.94	5.65
CS-40	2.43	3.46	4.26	4.55	5.35
CS-60	2.03	2.83	3.58	3.88	4.82
CS-80	1.65	2.28	3.04	3.37	4.13
CS-100	0.91	1.54	2.43	2.69	3.14

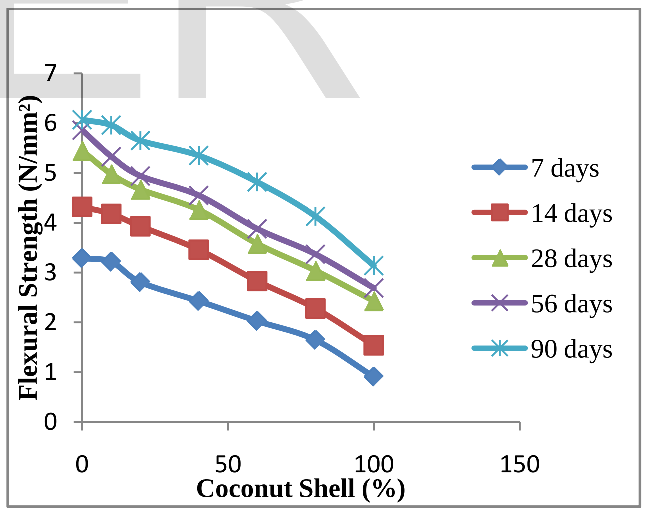

Figure 4: Plot of flexural strength versus coconut shell content.

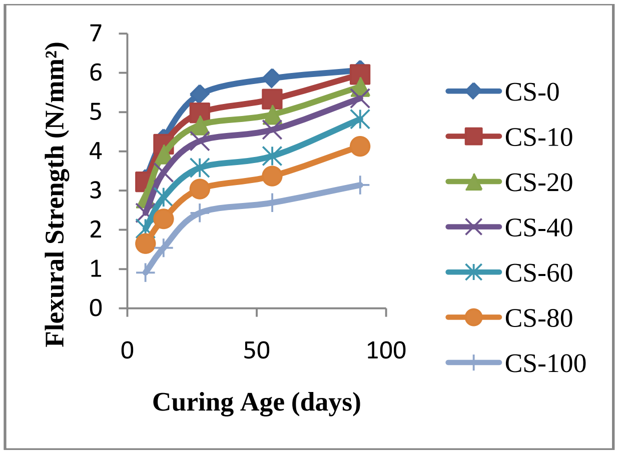

Figure 5: Plot of flexural strength versus curing age.

3.6 Density test

Table 6 shows the result of the density of concrete while the variation of density with percentage replacement of coarse aggregate with coconut shell is presented in figure 6. And the variation of density versus curing period is presented in figure 7. The density test result is expected in view of the specific gravity of coconut shell (1.51) as against (2.70) for coarse aggregate from igneous rock source. The aggregate from the igneous rock is heavier by 44%. It can be seen that the maximum density of 2,380 kg/m^{3}was obtained at 0% replacement, this value falls within the range of 2,000 – 2,600 kg/m^3 specified by BS EN 206 part 1 (2000) for normal weight concrete while the minimum density of 1,246 kg/m^3 was obtained at 100% replacement, this value is within the range of 800 – 2,000 kg/m^3 specified by BS EN 206 part 1 (2000) for normal lightweight concrete. This implies that concrete made with coconut shell as coarse aggregate replacement can comfortably be used as lightweight concrete material.

Table 6: Density Test Result for Coconut Shells Concrete

Mix ID	Density (kg/m^3)				
	7 days	14 days	28 days	56 days	90 days
CS-00	2043	2197	2328	2359	2380
CS-10	1842	1954	2065	2176	2288
CS-20	1691	1826	1953	2077	2199
CS-40	1597	1712	1836	1948	2059
CS-60	1489	1601	1709	1815	1924
CS-80	1360	1473	1588	1691	1795
CS-100	1246	1398	1407	1510	1621

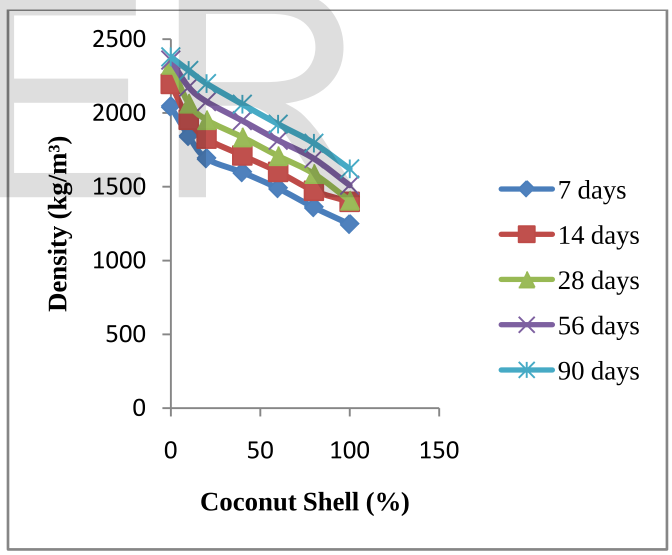

Figure 6: Plot of density versus coconut shell content.

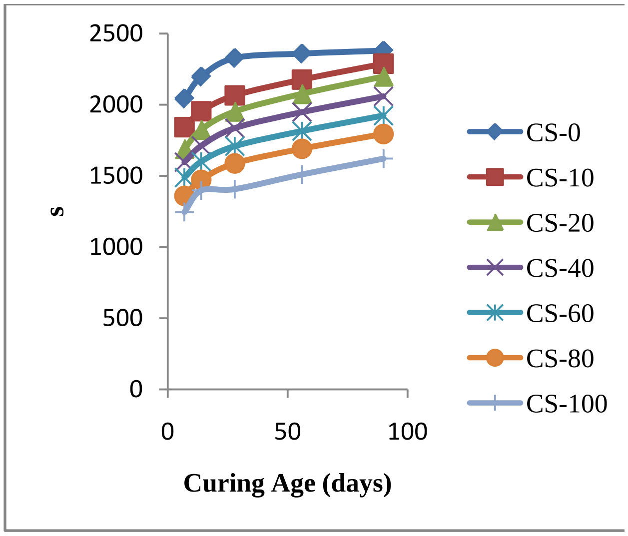

Figure 7: Plot of density versus curing age.

3.7 Regression Models for Concrete Containing Coconut Shell as Coarse Aggregate

The regression models generated for predicting compressive strength, flexural strength and density for concrete containing coconut shell as coarse aggregate are given by equations (4-6) respectively.

$$c_s = 16.9 + 0.859x_1 - 0.110x_2 \quad \ldots (4)$$

$$f_s = 3.93 + 0.0280x_1 - 0.0276x_2 \quad \ldots (5)$$

$$d_s = 1983 + 4.66x_1 - 7.50x_2 \quad \ldots (6)$$

Where: c_s is the concrete compressive strength, f_s is the concrete flexural strength, d_s is concrete density, x_1 is the curing age of concrete and x_2 is the percentage of coconut shells used to replace coarse aggregates in concrete respectively.

The P-values is a measure of the likelihood that the true coefficient is zero. From the p-values of the terms in the model, it can be seen that at ($P < 0.05$) level of significance, from the regression analysis, p-value = 0.000 for both curing age and coconut content in the concrete and thus are useful predictors in the regression model developed, signifying that the variation in the concrete compressive strength, flexural strength and the density is caused by curing age and coconut shell content [15]. The coefficient of determination (R^2) of the selected model obtained was 93.4%, 91.0% and 94.3% respectively and it indicate that the variation in concrete compressive strength, flexural strength and density is significantly dependent on the percentage of coconut shell and curing age [16]. The standard deviations of the model equations (S) of 1.28478, 0.422242 and 6.2356 respectively are reasonably small. The smaller the S value, the better the model equation fits the data, which shows a perfect correlation between predictors and the response [17]. The residuals and normality plots (figures 8 and 9; 10 and 11; 12 and 13) where drawn for the compressive strength, flexural strength and density of concrete respectively to further examine how well the models fit the data used [18]. It was observed that there were few large residuals and limited apparent out-lier which confirms that the models are adequate for prediction [19].

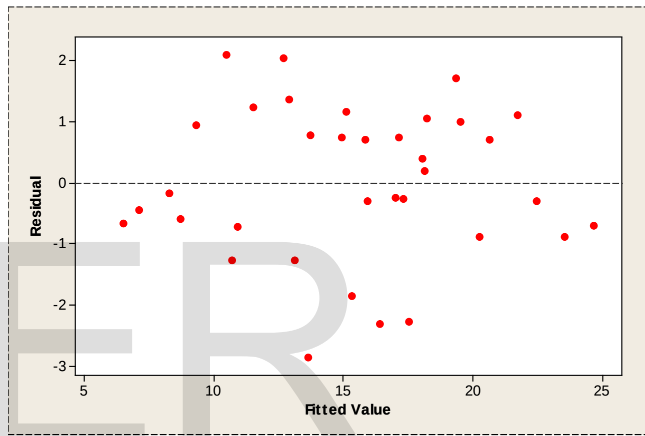

Figure 8: Residual versus Fitted values for Compressive Strength of Concrete

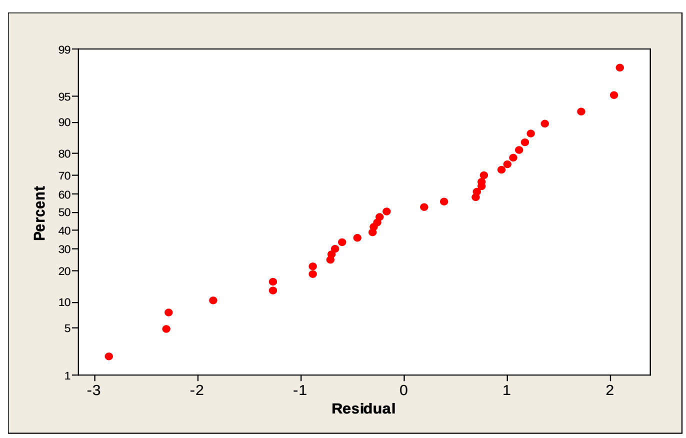

Figure 9: Normal Probability of Residuals for Compressive Strength of Concrete

ISSN 2229-5518

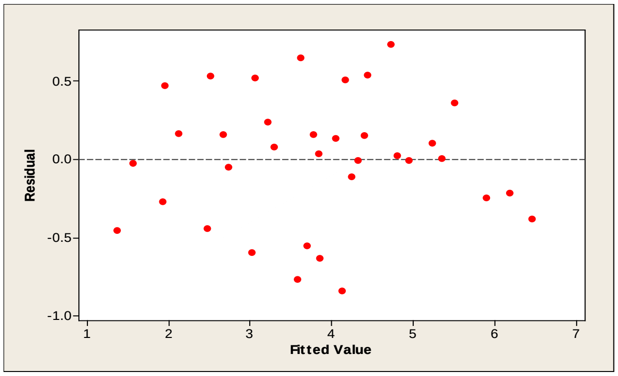

Figure 10: Residual versus Fitted values for Flexural Strength of Concrete

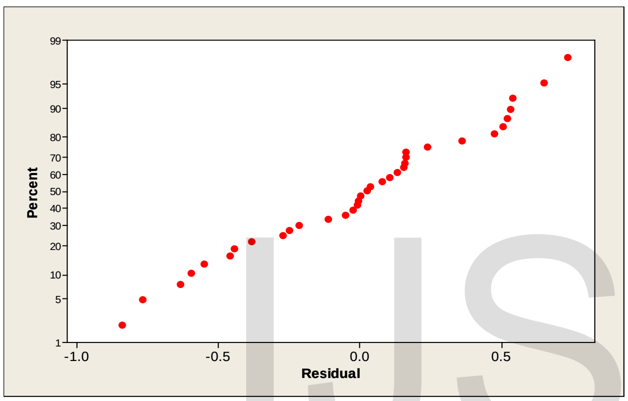

Figure 11: Normal Probability of Residuals for Flexural Strength of Concrete

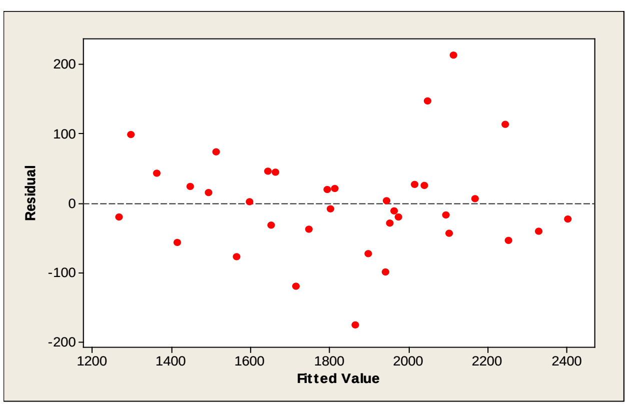

Figure 12: Residual versus Fitted values for Density of Concrete

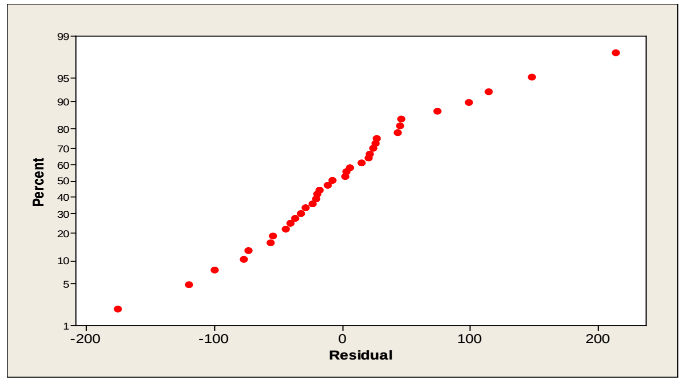

Figure 13: Normal Probability of Residuals for Density of Concrete

4. CONCLUSIONS

Based on the results obtained, the following conclusions were drawn:

i. The workability reduces by the addition of more coconut shell in concrete, hence more water is required to maintain uniform slump.

ii. The compressive strength, flexural strength and the density generally decreases with increase in coconut shell content and increase with increase in curing period. However, coconut shell satisfied requirement of ASTM C 330 (2004) for lightweight aggregates.

iii. The optimum replacement level of the blended concrete was obtained at CS-20% and cured beyond 28 days. The concrete performed relatively better at the optimum level when compared to the control sample than other cement replacement levels.

iv. The statistical models developed provide good prediction for the compressive strength, flexural and density, implying there is no statistical significant difference between the experimental and predicted strength values at 5 % level of significance.

v. Curing period and coconut shell content are useful predictors of the regression models for compressive strength, flexural strength and density with R^2 values of 0.934, 0.91 and 0.943 respectively.

REFERENCES

[1] Nwofor, T.C., and Sule, S. (2012). Stability of Groundnut Shell Ash (CSA)/Ordinary Portland Cement (OPC) Concrete in Nigeria. *Pelajia Research Library*, ***3****(4)*: 2283-2287.

[2] Jiusu, L., Hanning, X., and Yong, Z. (2009). Influence of Coating Recycled Aggregate Surface with Pozzolanic Powder on Properties of Recycled Aggregate Concrete. *Construction and Building Materials*, ***2****(3)*: 1287-1291.

[3] Bui Le, A. T., Chao-Lung, H., Kae-Long, L., and Yuan-Yuan, C. (2013). Development of Lightweight Aggregate From Sewage Sludge and Waste Glass Powder for Concrete. *Construction and Building Materials*, ***4****(7)*: 334-339.

[4] Falade, F., Efe, I., and Fapohunda, L. (2012). Potential of Pulverized Bone as a Pozzolanic Material. *International Journal of Scientific and Engineering Research*, ***3****(7)*: 1-6.

[5] Castro, S., and Binto, J. (2012). Evaluation of the Durability of Concrete Made with Crushed Glass Aggregates. *Journal of Cleaner Production*, ***2****(41)*: 7-14.

[6] Gunasekran, K., Kumar, P. S., and Lakshmipathy, M. (2011). Mechanical and Bond Properties of Coconut Shell Concrete. *Construction and Building Materials*, ***25****(1)*: 92-98.

[7] Amarnath, Y., and Ramachandrudu, C. (2012). Properties of Concrete with Coconut Shell as Aggregate Replacement. *International Journal of Engineering Inventions*, ***1****(6)*: 21-31.

[8] Olanipekun, E. A. (2006). A Comparative Study of Concrete Properties Using Coconut Shells and Palm Kernel Shells as Coarse Aggregate.

[17] Elinwa, A. U., and Abdulkadir, S. (2011). Characterizing Sawdust Ash for Used as an Inhibitor for Reinforcement Corrosion. *New Clues in Sciences*, ***2****(4)*: 1-10.

[18] Razak, H. A., and Wong, H. S. (2004). Strength Estimation Models for High Strength Concrete Incorporating Metakaolin and Silica Fumes.

.

Journal of Building and Environment, ***41****(3)*: 297-301.

[9] Daniel, Y. O. (2013). Experimental Assessment on Coconut Shells as Aggregate in Concrete. *International Journal of Engineering Science Inventions*, ***2****(5)*: 7-11.

[10]Abdulfatah, A., and Mohammed, A. S. (2012). Exploratory Study of Coconut Shells as Aggregate in Concrete. *Journal of Engineering and Applied Sciences*, ***3****(11)*: 60-66.

[11] Utsev, J. T., and Taku, J. K. (2012). Coconut Shell as Partial Replacement of Ordinary Portland Cement in Concrete Production. *International Journal of Scientific and Technology Research*, ***1****(2)*: 86-89.

[12] Ettu, L. O., Ezeh, J. C., Anya, U. C., and Njoku, K. O. (2013). Strength of Binary Blended Cement Composite Containing Coconut Husk Ash. *International Journal of Science and Engineering Research*, ***2****(4)*: 282-286.

[13] Neville, A. M and Brooks, J. J. (1997). Concrete Technology (4^{th} edition) Longman Publishers Limited, England, Pp 8-20, 34-37 and 420-430.

[14] Yilmaz, K. (2012). Study on the Effect of Fly Ash and Silica Fume Substituted Cement Paste and Mortars. *Scientific Research and Essays*, ***5****(19)*: 990-998.

[15] Ogork, E. N., Uche, O. A. U., and Elinwa, A. U. (2014). Strength Prediction Models of Groundnut Husk Ash Concrete. *American Journal of Civil and Structural Engineering*, ***1****(4):* 104-110.

[16] John Pan (2013). Minitab Tutorial and Design of Experiment. *International Journal of Scientific and Engineering Research*, ***2****(6):* 1-32.

Cement and Concrete Research, ***3****(5)*: 668-695.

[19] Ewansiha, C. J., Ebhoaye, J.E., Ekebafe, L.O., and Ehigie, C. (2012). Proximate and Mineral Composition of Coconut Shell. *International Journal of Pure and Applied Sciences and Technology*, ***13****(1)*: 57-60.