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SUITABILITY OF USING BUSH PEBBLE (COARSE AGGREGATE) IN THE PRODUCTION OF CONCRETE

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ABSTRACT

This study is aimed at evaluating the suitability of using Bush pebble (aggregate) as coarse aggregatein the production of concrete.Slump (workability) test, compaction factor test and compressive strength tests were conducted on concrete. Moreover, 1:2:4 and 0.45, 0.55 and 0.65 were used as a mix ratio and water-cement ratios respectively. The results of workability (slump) and compaction factor show that as the water-cement ratio increases the workability (slump) and compaction factor increase.On the other hand, the compressive strength of concrete produced with Bush pebble increases as the curing age and water-cement ratio increase. Furthermore, the densities of concrete produced with the water-cement ratios fall within the limits of 2200 kg/m^3 to 2600 kg/m^{3}for normal concrete. The regression model developed for the compressive strength of concrete is adequate for predicting the compressive strength of concrete produced with Bush pebble (aggregate). It was concluded that, based on different tests carried out, the Bush pebble (aggregate) can be used in the production of concrete as a substitute for normal coarse aggregate.

Keywords: Bush Pebble (Aggregate), compaction factor, workability, compressive strength and regression model.

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1. INTRODUCTION

Concrete is a construction material composed of crushed rock or gravel and sand, bound together with a hardened paste of cement and water. A range of different types of cement and aggregates, chemical admixtures and additions can be used to make an array of concretes that have the required properties in both the fresh and hardened states for a wide range of applications. Depending on the quality and properties of ingredients used in the mix, the properties of concrete can vary. However, the type and quality of aggregate play an important role in concrete. Studies have shown that the size and fineness of aggregates promote the flow and passing ability of concrete in a congested area of reinforcement (Shehu *et al.,* 2016). Shehu *et al.,* (2016) further stated that the Bida bush gravel (coarse aggregate) has shown tremendous performance in concrete works, but there is very little information on the use of Bush gravel (coarse aggregate) in the production of self-compaction concrete. The authors also noted that the smaller the size of the coarse aggregate the better the slump in terms of flow. According to Bui *et al*., (2002) higher aggregate spacing requires a lower flow and higher viscosity of the paste to achieve satisfactory deformability and segregation resistance of self-compacting concrete (SCC). Oluwatosin and Chinwuba (2020) reported that the workability of concrete produced by the replacement of fine and coarse aggregate with ceramics waste decreases as the percentage level increases, except concrete produced by replacement of stone dust with ceramics waste whose workability increases as the percentage level increases. Aliu (2013) reported that the maximum compressive strength of concrete with a mix ratio of 1:2:6 for unwashed Bush gravel was found to be14.89 N/mm2. A study carried out by Shehu *et al.,* (2016) revealed that the use of Bida bush gravel demonstrated good flowability and high strength as compared to the control. However, the compressive strength generally increases with lesser coarse aggregate for unwashed Bush gravel while the reverse is the case for a washed and sorted coarse aggregate. Ajamu and Ige (2015) stated that the flexural strength of the concrete beam is directly affected by the increase in coarse aggregate size, while compressive strength is inversely proportional to flexural strength as coarse aggregate size increases when subjected to the same condition(s). Obi (2017) reported that the workability decreased with slight differences when the coarse aggregate size was increased, however, the increase in the coarse aggregates yielded an appreciable increase in the compressive strength of concrete. He recommended that coarse aggregates with the appropriate size must be used in the production of concrete following the specified concrete strength and workability. Ogundipe *et al*., (2018) reported that the compressive strength increases with increasing aggregate size up to 12.5 mm, while the concrete produced using 20 mm had greater compressive strength than those produced using 25 mm aggregate. They recommended that careful attention must be paid to the sizes of aggregate used in the production of concrete for structural purposes. Salau and Busari (2015) reported that workability, density and compressive strength at a constant water-cement ratio increase with the increase in the coarse aggregate particle size and also with curing age. They concluded that coarse aggregate with a maximum particle size of 19.5 mm should be used where high-strength lateralized concrete is required but it is significant to consider the dimensions of the concrete member. According to a study carried out by Chhetri *et al.,* (2021) from 7 days and 28 days of compressive strength results for different aggregate sizes, the well-graded aggregate of size between 4.75 mm to 25 mm gave higher compressive strength for both 7 days and 28 days than other sizes of aggregate. However, they concluded that coarse aggregate size and source have a significant effect on the compressive strength of concrete based on 7 days and 28 days of a compressive strength test result that was verified by the statistical test result.

The main objective of this study is to determine the suitability of using bush gravel (aggregate) in the production of concrete.

2. MATERIALS AND METHODS

2.1 Materials

The materials sourced and used are cement, fine aggregate, coarse aggregate (Bush Pebble) and water.

2.1.1 Cement

The cement used for this study was Dangote Limestone Portland cement (OPC) with grade

42.5R. It's a finely powdered, greyish-binding material.

2.1.2 Fine Aggregate

The fine aggregate used was the upstream riverbed natural fine siliceous sand which was used as a replacement for the fine lightweight aggregate in concrete.

2.1.3 Coarse Aggregate (Bush Pebble)

The coarse aggregate used in this study was coarse fractions of the lightweight aggregate (Bush pebbles), sourced from the Kangiwa village in Kebbi Niger state collected randomly from the area, the maximum size which was 20 mm.

2.1.4 Water

Potable water from the concrete materials laboratory Civil Engineering Department Laboratory of Ahmadu Bello University, Zaria

2.2 Methods

Concrete with a mix ratio of 1: 2: 4 was designed using the absolute volumemethod, Table1 presents the proportion of concrete constituent materials used.

Table 1: Proportions of Concrete Constituent Materials for Concrete Cubes.

Water Cement Ratio	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (g)	Water (g)
0.45	13.37	26.75	53.50	6.02
0.55	12.95	25.89	51.79	7.12
0.65	12.55	25.09	50.18	8.15

2.2.1 Cement Consistency

The standard consistency test on cement paste was carried out following BS EN 197-1:2009 standard. The penetration of the plunger to 5 to 7 mm above the soffit of the paste mould indicates normal consistency.

2.2.2 Specific Gravity of Fine Aggregate and Bush Pebble

The specific gravity test was performed on the aggregates and bush pebblesaccording toBS 812, Part 2, (1975).

2.2.3 Bulk Density Test of Fine Aggregate and Bush Pebble

The bulk density test was carried out on the fine aggregate and bush pebbles according to BS EN 1097-3:1998.

2.2.4 Water Absorption Test of Fine Aggregate and Bush pebble

The water absorption test was carried out to determine the absorbabilityof fine aggregate and bush pebbles according to BS EN 1097-3:1998.

2.2.5 Sieve Analysis Test of Fine Aggregate and Bush Pebble

The sieve analysis tests were carried out according to BS 812-103.1 (1985) to determine the particle size distribution of fine aggregate and bush pebbles,and the results were presented in Figure 1.

2.2.6 Porosity Test of Fine aggregate and Bush Pebble

The porosity test was carried out to determine the interstitial void within the matrixfine aggregate and bush pebbles according to BS EN 1097-3:1998.

2.2.7 Aggregate Impact Value (AIV) of Coarse Aggregate

The aggregate impact value test was carried out in accordancewithBS 812-110:1990,).

2.2.8 Moisture content Test of fine aggregate and Bush pebble (aggregate)

This test was carried out to ascertain the amount of moisture present in the fine aggregate and Bush pebbles according to BS EN 1097-5:2008

2.2.9 Slump Test

The ease at which the fresh concrete flows was assessed using the slump test in accordance with BS 1881:102 (1983) standard.

2.2.10 Compaction Factor

The compaction factor test was carried out to assess the flow of fresh concrete. It was performed according to BS 1881:102 (1983).

2.2.11 Compressive Strength Test

The resistance of the concrete to crushing when the normal aggregate was replaced with bush gravel (aggregate) was conducted in accordance with BS EN 12390, Part 3. It was conducted at Civil Engineering Department, A.B.U Zaria. Three samples per specimen were crushed (compressive strength test) each after curing in water for 7, 14 and 28 days and the average of the three results was taken as a representative result.

2.2.12 Statistical Modelling of Concrete produced with Bush Pebbles

A statistical model was developed from experimental data using DATAFIT 9 software to predict the compressive strength of the bush pebble concrete. In developing the model, two effects were considered; the influence of the water-cement ratio and curing age. The software generateda model equation and graph that best fit the experimental data.

3. RESULTS AND DISCUSSION

3.1 Physical properties of fine aggregate and Bush aggregates

The results of the physical properties of fine aggregate and Bush pebbles are presented in Table 2. It was observed that fine aggregate has a specific gravity, moisture content, water absorption and bulk density of 2.66, 2.77 %, 4.73 % and 1591.33 (kg/m^3) respectively. While Bush Pebble has a specific gravity of 2.65 and porosity and aggregate impact value of 18.8 % and 24.15 % respectively. However, all the values are within the specified limit and this shows that both fine aggregate and Bush pebble are suitable for the production of concrete.

Table 2: Physical Properties of Fine Aggregate and Bush Pebble (Gravel)

Property	Fine Aggregate	Bush Pebble
Specific Gravity	2.66	2.65
Moisture Content (%)	2.77	2.32
Water Absorption (%)	4.73	3.98
Bulk Density (kg/m^3)	1591.33	1345.10
Porosity (%)	9.80	18.80
Aggregate Impact Value (AIV%)	23.81	24.15

3.2 Particle Size Distribution of Fine Aggregate and Bush Pebble (Aggregate)

The results of the particle size distribution of fine aggregate and Bush pebble are presented in Figure 1. It was observed from Figure 1 that the fine aggregate used fallsunder Zone 1 of BS 882 (1992) grading limits for fine aggregate. It was also noted that the coarse aggregate used was also noted to be well-graded.

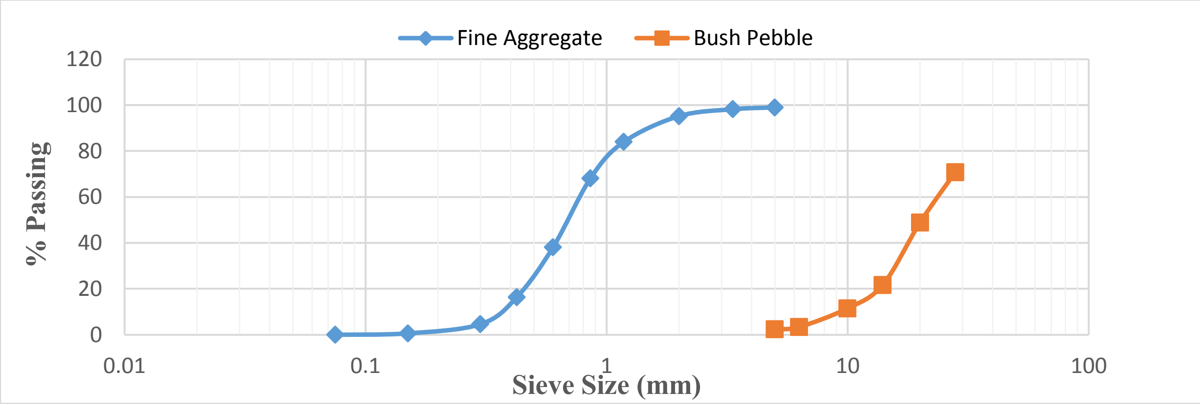

Figure 1: Particle Size Distribution of fine aggregate and Bush Pebble (Coarse Aggregate)

3.3 Compaction Factor Test

Figure 2 showed the relationship between the compaction factor and water-cement ratio. It can be observed that the compaction factor increased as the water-cement ratio increased. The behavior may be a result of more water being added as the water-cement ratio increases.

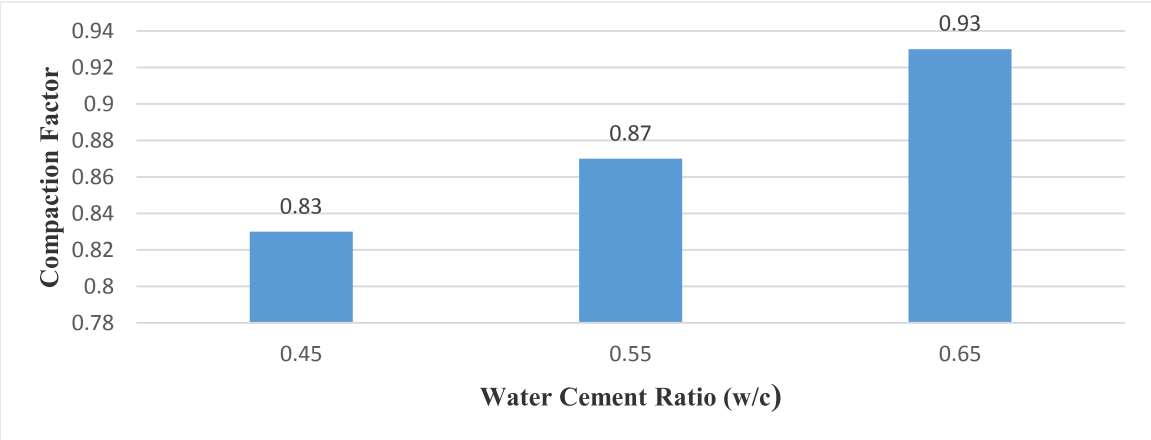

Figure 2: Compaction Factor against Water-cement Ratio

3.4 Slump Test

Figure 3 shows the results of the slump test carried out on fresh concrete. It was observed the value of the slump increases as the water-cement ratio increases. The increase in the slump of fresh concrete is a result of the increase in the water content of the mix with a water-cement ratio increase.

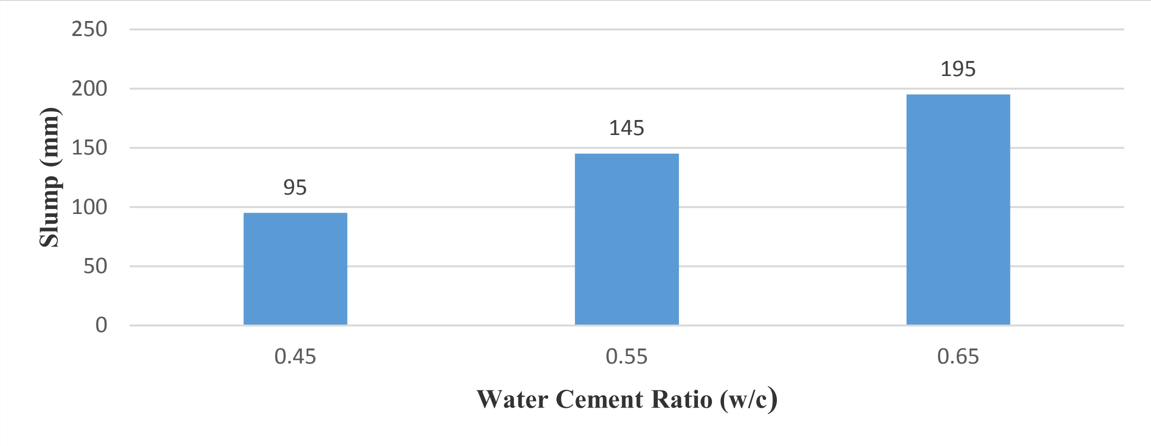

Figure 3: Slump against Water-cement Ratio

3.5 Compressive Strength

The relationship between the compressive strength of hardened concrete and curing age is presented in Figure 4. It was observed that the compressive strength of concrete increased as the curing age increased, the increase in strength with age is because time allows for proper cement hydration and the production of more calcium-silica-hydrates (C – S –H) responsible for the strength. Also, a strength increase was observed with an increase in a water-cement ratio which could be a result of the presence of more H^+ ions in the mix needed for C – S – H formation.

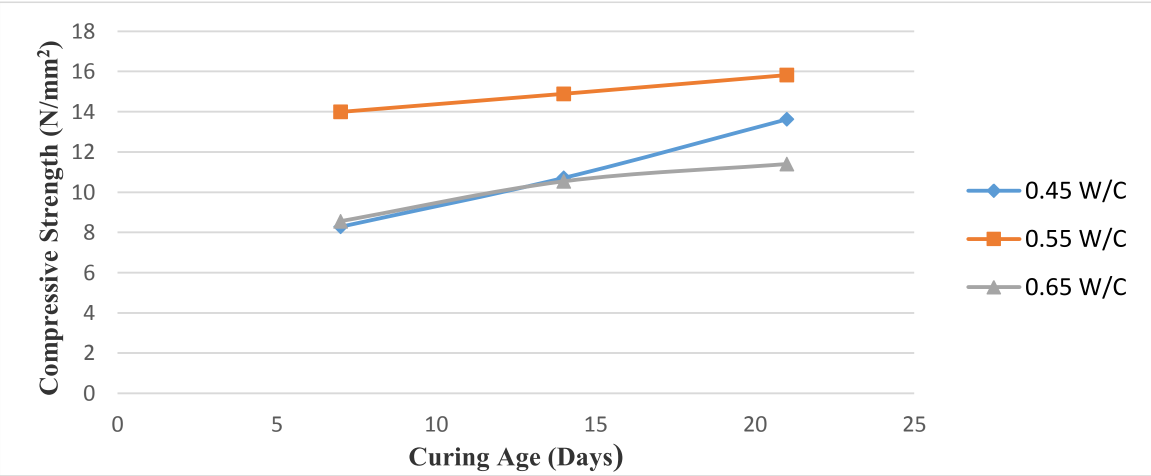

Figure 4: Compressive Strength against Curing Age (Days)

3.6 Density

Figure 5 shows the densities of concrete produced with Bush pebbles as coarse aggregate. It can be seenthat all the densities of concrete fall within the limits of 2200 kg/m^3 to 2600 kg/m^3 for normal concrete.

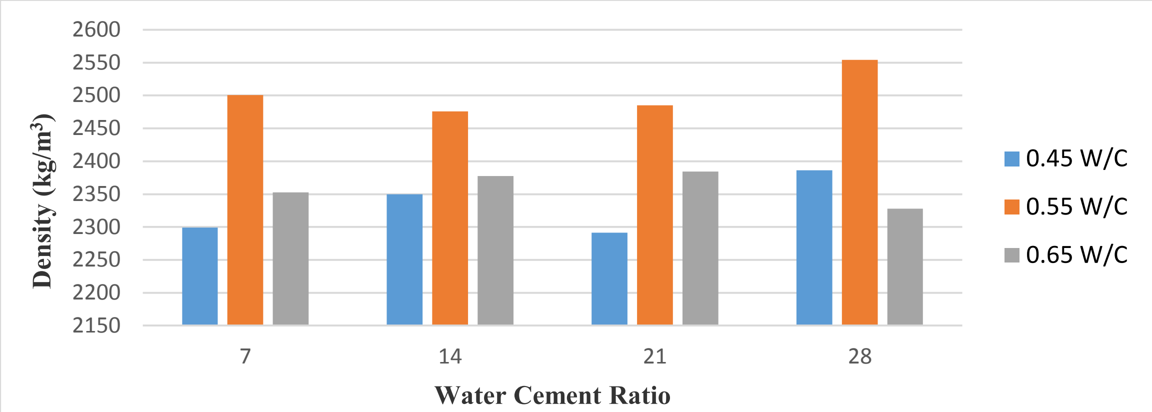

Figure 5: Density against Water-cement Ratio

3.7 Regression Model of Compressive Strength of Concrete Produced with Bush Pebbles

The regression equation generated from DataFit statistical software for the model is presented in equations 3.1 and 3.2, while the result of the statistical analysis is shown in equation 1

$$f_c = 0.32695C + 363.071W - 3631.875W^2 - 89.48 \ldots\ldots \quad (1)$$

Where f_c is the compressive strength of concrete, C is curing age and W is the water-cement ratio. The developed model has a Coefficient of Multiple Determination (R^2) = 0.865 and an adjusted coefficient of multiple determination ($AdjR^2$) of 0.814.

Table 3: Statistical Analysis of Compressive Strength of Concrete Model

Variables	Coeff	Standard Error	T-ratio	P - Value
Constant (Y)	– 89.48	26.549	– 3.37029	0.000978
A	0.32695	0.05371	6.0877	0.00029
B	363.071	98.2149	3.69674	0.000607
C	– 331.875	89.1636	– 3.727089	0.00078

The test of significance and goodness of fit of compressive strength of the concrete model was carried out using the T and P values to determine if the slopes in the regression model are equal to zero as formulated in the null hypothesis.

The null hypothesis considered that the water-cement ratio and curing age of samples do not influence the compressive strength of concrete. At 0.05 level of significance; from Table 3, all the P-values are < 0.001 for both the water-cement ratio and curing age of concrete. Therefore, the null hypothesis (H_O) is rejected in both cases because of the very low P-value and shows that both variables are highly significant ($P < 0.05$) signifying that the variation in the compressive strength of concrete is a result of the water-cement ratio content and curing age. The validation of the compressive strength of the concrete model was carried out by considering the Coefficient of Determination and also the Analyses of residuals. The coefficient of determination, (R^2) is 86.5 %, this indicates that the variation of concrete compressive strength is significantly dependent on the variations of water-cement ratio and curing age. The residual and normality plots shown in Figure 6were used to check how well the model fits the data used for the compressive strength of concrete. This confirms that the model is adequate for prediction.

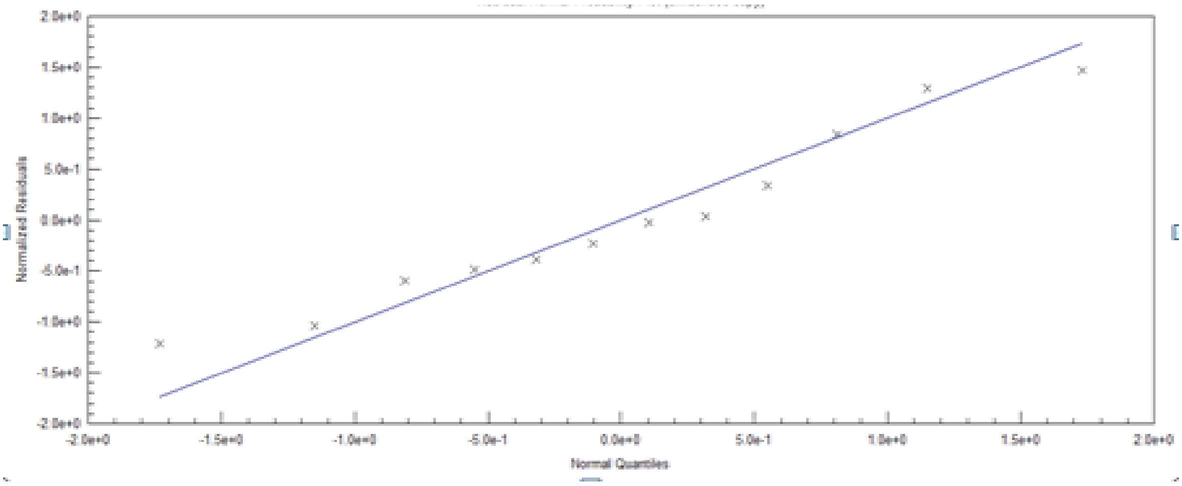

Figure 6: Normalized Residuals against Normal Quantiles

4. CONCLUSIONS

Based on the analysis of the results of this study, the following conclusions were drawn.

i. The bush pebble used has an average specific gravity of 2.65, average water absorption of 4.73%, moisture content of 2.32%, aggregate impact value (AIV) of 23.81%, aggregate impact value of 23.81 %;a porosity of 18.80%, bulk density of and 1345.10kg/m^3.

ii. The slump and compaction factor of bush pebble concrete increased with an increase in the water-cement ratio.

iii. The compressive strength of concrete produced with bush pebbles increasedas the curing age increased.

iv. Based on the coefficient of multiple determination (> 80 %) obtained for the developed predictive model. The model is sufficient for the prediction of the strength of the concrete as a function of the mix parameters.

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