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Application of Statistical Model for Predicting the Compressive Strength of Sandcretes Made with different Fine Aggregates Available in Nsukka

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Abstract

The masonry unit commonly used for wall partitioning in Nigeria is Sandcrete and is comprised of cement, fine aggregate (sand), and water. This research is aimed at ascertaining the effect of different fine aggregates available in Nsukka Local Government Area of Enugu State Nigeria, on the compressive strength of sandcrete. This is also, to contribute to quality maintenance in the production of sandcretes in Nsukka. A mix ratio of 1:6 for cement and sand was used in the production of the sandcrete cubes and a water-cement ratio of 0.6 was maintained in all the mix. The Sandcrete cubes were produced using the three major fine aggregates (river sand, gutter sand, and obimo sand) available in Nsukka. The results obtained show that sandcrete cubes produced with the obimo sand gave the highest strength in compression, while the gutter sand attained the least strength in compression. The E-view software was used to formulate a statistical model for predicting the compressive strength of sandcrete cubes using any of the different fine aggregates considered in this study.

Keywords: Cement, Compressive Strength, Fine Aggregate, Model and Sandcrete

1.0 INTRODUCTION

The use of mud blocks is giving way to the use of masonry units especially sandcrete [1]. Sandcretes are masonry units and the main constituent materials are cement, water, and fine aggregates, compressed or compacted into the desired shape, to be utilized in construction industries. Sandcretes have been used in all types of masonry constructions in Nigeria, and other parts of the world. Over 90% of physical infrastructures in Nigeria are made with sandcretes [2].

The usual requirement for a good sandcrete is its satisfactory compressive strength [3], however research [3-7] has shown that the compressive strength of sandcretes produced commercially in several parts of Nigeria, is below the recommended standard as stipulated in the Nigerian Industry Standard (NIS) [8]. According to Anosike and Oyebade (2012) [5], sandcrete manufacturers in Nigeria do not adhere to the guidelines for sandcrete production as stipulated by the NIS, and this could be traced to poor implementation and monitoring on the part of the Federal Government of Nigeria to ensure adherence to the code.

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The compressive strength of sandcretes is a factor of the constituent materials which includes; cement, fine aggregate, and water, and the method employed in the production. The effect of orientation and compaction methods on the strength properties of sandcrete have been examined, and the research showed that for any compaction method, different orientations produced different strength properties [9]. The results also showed that differences exist in the strength of sandcretes having the same orientation but different compaction modes. The compressive strength of sandcretes is affected by the type of fine aggregate selected in the production, hence the variation in the characteristics of constituent elements (cement, fine aggregate, and water) affects the properties of the sandcretes produced [10].

Several works [11-13] have been done to modify and achieve optimum strength of sandcrete by varying the different constituent elements and through the use of admixtures. Therefore, this study was aimed at investigating the effect of using the different fine aggregates available in Nsukka Local Government Area of Enugu State, Nigeria, on the compressive strength of sandcretes produced. A mathematical model for predicting the compressive strength of the sandcrete cubes produced with any of the fine aggregates considered in this study was formulated via the E-view software. Several mathematical models [14] [15] have been developed for the prediction of the compressive strength of sandcretes, however, this model is unique as it was formulated specifically for the fine aggregates considered in this study.

2.0 MATERIALS AND METHODS

The following materials were used in the production of the sandcretes.

2.1 Cement

The Dangote 3x grade 42.5R brand of cement was used in the production of all the sandcrete cubes. This cement complies with all the prescribed requirements in the Nigerian Industries standard (NIS 444-1:2003) [16].

2.2 Fine aggregates

The fine aggregates used in the production of the sandcretes include the river sand (Sample A), the gutter sand (Sample B), and the obimo sand (Sample C). these fine aggregates were obtained within Nsukka Local Government Area of Enugu state.

The particle size distribution of the fine aggregates (river, gutter, and obimo sand) was conducted in line with the BS 812-103.1:1985, (1985) [17]. The grading for the different samples was obtained in terms of the coefficient of uniformity C_u, and coefficient of curvature C_c. Equation (1) and (2) was adopted in calculating the coefficient of uniformity C_u, and coefficient of curvature C_c.

$$\mathrm{Cu} = \frac{D_{60}}{D_{10}} \quad (1)$$

$$\mathrm{Cc} = \frac{D_{30}D_{30}}{D_{10}D_{60}} \quad (2)$$

Where D_{60} is the common diameter at which 60 percent of the sand's weight is finer, D_{30} is the diameter at which 30% by weight of the sand is finer in size and D_{10} is the unique diameter by which the sand is smaller in size by 10 percent in weight.

Specific gravity test was also carried out on the fine aggregates in line with the ASTM standard [18]. Equation (3) was used to calculate the specific gravity for the three aggregates

$$\mathrm{GS} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

These three fine aggregates are the predominant fine aggregates used by block industries for the commercial production of sandcrete blocks.

2.3 Water

Water fit for drinking, from a borehole, was used in all manufacturing processes and in the curing of the sandcrete cubes produced.

2.4 Experimental procedures

2.4.1 Mix proportions

The constituent materials for the sandcrete production were mixed manually and as specified by the Nigerian Industrial Standard [19], the batching process was by weight. A mix ratio (one portion of cement to six portions of fine aggregate) of 1:6 was used in the production of sandcrete cubes, while a water-cement ratio of 0.6 was maintained for all the sandcrete mixes. A total of 65 sandcrete cubes of 100×100×100mm was produced. The cement content and the water-cement ratio were kept constant in all the mix-proportions; however, the three (3) fine aggregates were used separately. Also, combining these fine aggregates at different proportions, the combinations were used to produce sandcrete cubes. The sandcrete cubes were cured by water sprinkling for 28 days and they were crushed to ascertain the strength of the sandcrete cubes in compression. The sprinkling method of curing is frequently used by individuals and industries, that produce sandcretes for commercial purposes.

Table 1: Mixed proportions used for the production of specimen

Obs	**Cement (KG) (1)**	**Fine Aggregate (KG) (6)**			**Water (KG) (0.6)**
		% Sample A (River)	**% Sample B (Gutter)**	**% Sample C (Obimo)**	
1	1	6	0	0	0.6
2	1	0	0	6	0.6
3	1	0	6	0	0.6
4	1	4.5	0	1.5	0.6
5	1	3	0	3	0.6
6	1	1.5	0	4.5	0.6
7	1	4.5	1.5	0	0.6

Obs	Cement (KG) (1)	Fine Aggregate (KG) (6) % Sample A (River)	% Sample B (Gutter)	% Sample C (Obimo)	Water (KG) (0.6)
8	1	3	3	0	0.6
9	1	1.5	4.5	0	0.6
10	1	0	4.5	1.5	0.6
11	1	0	3	3	0.6
12	1	0	1.5	4.5	0.6
13	1	4.2	0.9	0.9	0.6
14	1	0.9	0.9	4.2	0.6
15	1	0.9	4.2	0.9	0.6
16	1	2	2	2	0.6

2.4.2 Compressive strength

The compressive strength was obtained from the ratio of maximum load to cross-sectional area of the cube, as shown in equation (4).

$$\text{Strength (Y)in} \frac{\text{N}}{\text{mm2}} = \frac{Maximum\ Load}{Cross - Sectional\ Area} \quad (4)$$

An automatic concrete testing machine (QT-CTN-4331) with a maximum load capacity of 3000KN was utilized for this test.

2.4.3 Model formulation

A statistical model was formulated using the E-view software. The E-view Software employs multiple linear regression techniques in the formulation of mathematical models. Equation (5) for instance, shows a relationship involving Y, X_1, and X_2.

$$Y = a + bX_1 + cX_2 + \in \quad (5)$$

Where Y is the dependent variable representing strength, while X_1 and X_2 are independent variables representing the different fine aggregates in the context of this research. Also, ϵ is an error term and a, b, c are coefficients of the regression equation.

From equation (5), when the least square sum is minimized, the equation (6), (7) and (8) will be obtained:

$$\sum Y = an + b\sum X_1 + c\sum X_2 + \in \quad (6)$$

$$\sum YX_1 = a\sum X_1 + b\sum X_1^2 + c\sum X_1X_2 + \in \quad (7)$$

$$\sum YX_2 = a\sum X_2 + b\sum X_1X_2 + c\sum X_2^2 + \in \quad (8)[18]$$

3.0 RESULT AND DISCUSSION

3.1 Sieve Analysis Test

The particle size distribution results for the three (3) fine aggregate are presented in Figures 1, 2, and 3, while the coefficient of uniformity, coefficient of curvature of the samples, and the percent (%) of fines (particles finer than the 0.063mm sieve) are shown in Table 1.

The particle size distribution results show that the three fine aggregates used in this research are pure sand with little fine particles, as the particles finer than the 0.063mm sieve is less than five (5) percent for all three soil samples.

Also, the values of the coefficient of uniformity (Cu) obtained is less than six (6) why the values of coefficient of curvature (Cc) are less than one (1) for all three fine samples. Hence, they are all classified according to the Engineering soil classification system [20], as Poorly Graded sand.

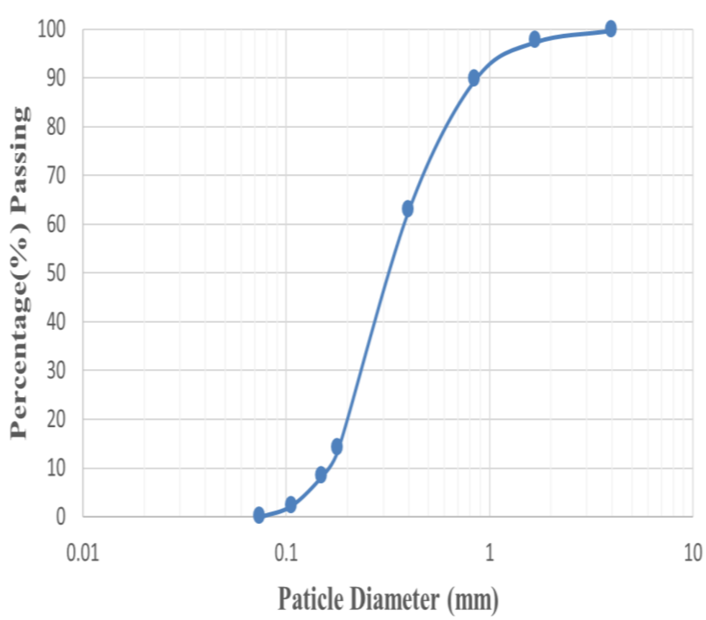

Figure 1: Particle size distribution of river sand

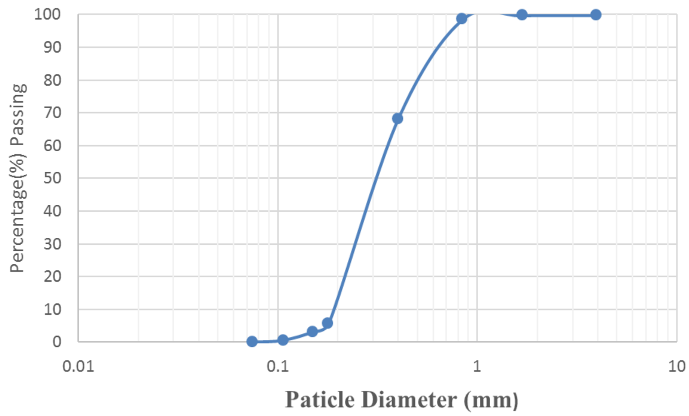

Figure 2: Particle size distribution of gutter sand

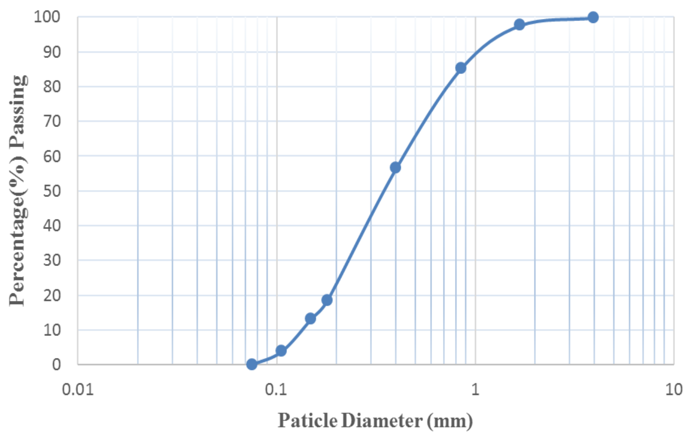

Figure 3: Particle size distribution of Obimo sand

Figure 1-3, shows the particle size distribution of the three fine aggregates obtained for the production of sandcretes in the experiment.

Table 1: Uniformity coefficients, coefficient of curvature, and percent of fines

S/N	Fine aggregates	Cu	Cc	% Fines
1	River sand	2.31	0.82	2.16
2	Gutter Sand	1.94	0.84	0.85
3	Obimo Sand	3.5	0.96	3.78

3.2 Specific gravity

The specific gravity of the fine aggregates (river sand, gutter sand, and obimo sand) used in this study is shown in Table 2. The results of the specific gravity for the three fine aggregates fall within the range of soils or solid as specified by the ASTM standard [21], which ranged between 2.0 - 3.0. The ASTM standard [21], also specified that tropical iron-rich lateritic soils could be higher than 3.0 as observed in the gutter sand.

Table 2: Specific gravity of fine aggregates

S/N	Fine aggregates	Specific gravity
1	River sand	2.67
2	Gutter Sand	3.07
3	Obimo Sand	2.50

3.3 Compressive strength results

The compressive strength results obtained from the three fine aggregates and the results obtained when these aggregates were combined at different percentage is shown in Table 3. Also, figure 4 shows a graphical representation of the strength obtained at different percentage combinations of the three (3) fine aggregates.

Table 3: Summary of Compressive Strength Result of Sandcrete Cubes

S/N	% Sample A (River Sand)	% Sample B (Gutter Sand)	% Sample C (Obimo Sand)	Average Compressive Strength (N/mm^2)
1	100	0	0	4.91837
2	0	0	100	5.98684
3	0	100	0	2.01024
4	75	0	25	3.76218
5	50	0	50	4.18981
6	25	0	75	4.01316
7	75	25	0	2.50853
8	50	50	0	2.33796
9	25	75	0	2.28070
10	0	75	25	2.35270
11	0	50	50	2.49780
12	0	25	75	2.77900
13	70	15	15	3.48438

14	15	15	70	3.59832
15	15	70	15	2.20760
16	33.33	33.33	33.33	4.30739

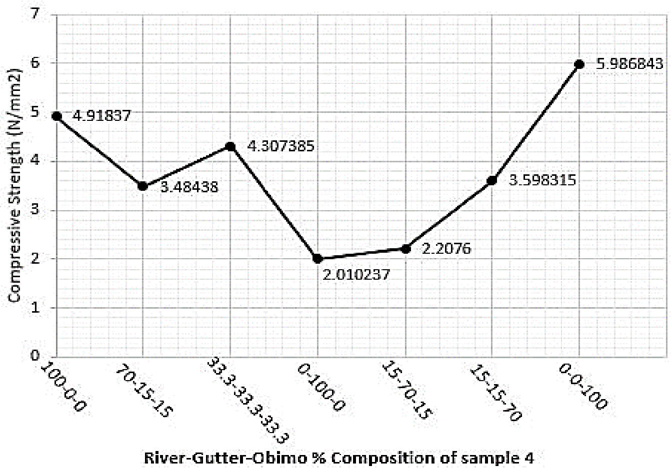

Figure 4: Compressive Strength of Sandcrete cubes at different percentages Composition of River-Gutter-Obimo sand

From the results shown in figure 4, the obimo sand gave the highest compressive strength of 5.99N/mm^2 after 28 days of curing followed by the river sand (4.91N/mm^2) and the gutter sand gave the lowest compressive strength (2.01N/mm^2). The strength characteristics of sandcretes produced with the three fine aggregates could be traced to the percent of fine (particles finer than0.063mm) present in the sand (3.78% for the obimo sand, 2.16% for the river sand, and 0.85% for the gutter sand). The percent of fine shows the extent to which the soil particles are well-graded and it also shows the degree to which these aggregates can be compacted. When the gutter sand was combined with the obimo sand the compressive strength increased as the percentage of the obimo sand in the sandcrete mix increased. A similar trend was also observed when the gutter sand was combined with the river sand as shown in Table 3.

3.4 Model formulation using the E-view software

The compressive strength results were used to formulate a mathematical model using the E-view software and the results of the analysis are shown in Table 4 and Table 5. The details of the experimental data and the method used in the model formulation are shown in Table 4, while the constants of the regression equation and the standard errors are shown in Table 5.

Table 4: Eview software results

Dependent Variable: STRENGHT
Method: Least Squares
Date: 10/05/19 Time: 19:58
Sample: 2002 2017
Included observations: 16

Table 5: E-view software results (model coefficient)

Variable	Coefficient	t-Statistic	Prob.
C	10458.76	1.452645	0.1720
RIVER	-104.5490	-1.452099	0.1721
OBIMO	-104.5426	-1.452010	0.1721
GUTTER	-104.5735	-1.452439	0.1720

3.4.1 Model summary

Equation (9) shows the empirical model for predicting the compressive strength of sandcrete cubes, using any of the three (3) fine aggregates or a combination of these aggregates.

$$Y = 10458.7631131 - 104.549000338 * X_1 - 104.573453187 * X_2 - 104.542584686 * X_3 \quad (9)$$

Where Y = Strength of sandcrete cube
X_1 = % of River Sand in the sandcrete mix
X_2 = % of Gutter Sand in the sandcrete mix
X_3 = % of Obimo Sand in the sandcrete mix

3.4.2 Model verification

The residual plot and the R-square value of the regression model are shown in Table 6.

Table 6: Model Verification

Obs	Actual	Fitted	Residual	Residual Plot
1	4.91837	3.86308	1.05529	| . | . * |
2	5.98684	4.50464	1.48220	| . | . *|
3	2.01024	1.41779	0.59245	| . | *. |
4	3.76218	4.02347	-0.26129	| . *| . |
5	4.18981	4.18386	0.00595	| . * . |

<table>
<tr><td>6</td><td>4.01316</td><td>4.34425</td><td>-0.33109</td><td>| . * | . |</td></tr>
<tr><td>7</td><td>2.50853</td><td>3.25176</td><td>-0.74323</td><td>| * | . |</td></tr>
<tr><td>8</td><td>2.33796</td><td>2.64044</td><td>-0.30248</td><td>| . * | . |</td></tr>
<tr><td>9</td><td>2.28070</td><td>2.02912</td><td>0.25158</td><td>| . |* . |</td></tr>
<tr><td>10</td><td>2.35270</td><td>2.18951</td><td>0.16319</td><td>| . |* . |</td></tr>
<tr><td>11</td><td>2.49780</td><td>2.96122</td><td>-0.46342</td><td>| . * | . |</td></tr>
<tr><td>12</td><td>2.77900</td><td>3.73293</td><td>-0.95393</td><td>| * . | . |</td></tr>
<tr><td>13</td><td>3.48438</td><td>3.59252</td><td>-0.10814</td><td>| . *| . |</td></tr>
<tr><td>14</td><td>3.59832</td><td>3.94538</td><td>-0.34706</td><td>| . * | . |</td></tr>
<tr><td>15</td><td>2.20760</td><td>2.24761</td><td>-0.04001</td><td>| . * . |</td></tr>
<tr><td>16</td><td>4.30739</td><td>4.30739</td><td>5.1E-07</td><td>| . * . |</td></tr>
<tr><td></td><td colspan="3">R value obtained for predicted vs actual values plot</td><td>0.84</td></tr>
</table>

4.0 CONCLUSION

The following conclusions were drawn from the study. The results obtained, have clearly shown that the type of sand (fine aggregate) employed in the production of sandcrete, has a significant impact on the compressive strength of the block produced.

It was also observed that the obimo sand, gave the best compressive strength (5.99N/mm^2) when used in the production of sandcrete cubes, while the river sand gave strength on the average of 4.92N/mm^2 and the gutter sand gave the least strength in compression (2.01N/mm^2). The results of the compressive strength obtained in this research are in line with the results obtained in similar research [22-24].

The gutter sand gave the least compressive strength, however from the results obtained, the strength of sandcrete cubes made with the gutter sand can be improved when it is properly combined with the river and obimo sand.

The regression model formulated in this research work can help to predict the compressive strength of sandcrete cubes produce using any of the three fine aggregates considered in this study. The model applies when every other predictor variable is assumed to be constant at a mix ratio of 1:6 and a water-cement ratio of 0.6 is maintained.

RECOMMENDATION

From the findings in this study, the following recommendations are made:

- The use of gutter sand alone for the production of sandcretes should be discouraged as it could not give the minimum compressive strength of 2.5N/mm^2 as specified by the Nigerian Industry Standard NIS-0.74[24]. The gutter sand should be used, only when it is combined appropriately with either the river sand or the obimo sand as obtained in the experiment above.
- The use of the obimo sand for the production of sandcretes should be encouraged and practiced in Nsukka, as it has been shown to give the highest strength in compression for sandcrete block production.
- The combination of the three different grains of sand used in this research for the production of sandcretes should be guided using the mathematical model obtained from this research work or the graph charts obtained from this research work.

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