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Mathematical Relationships between the Compressive Strength and Some Other Structural Properties of Sand-Quarry Dust Blocks

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Abstract: *This work developed mathematical relationships between the compressive strength and some other properties of sand quarry dust blocks notably water absorption, flexural strength and split tensile strength. Regression analyses were performed on data obtained from tests on appropriate specimens prepared using fifteen different mix ratios. The cement/combined aggregate ratio ranged from 1: 6 to 1: 10 with the percentage of quarry dust being 10 to 40 % of the combined aggregate content. Validity of the models was confirmed using the standard deviation and coefficient of determination. The models will be very useful especially to block producers in Nigeria in predicting the other properties of the blocks given that, in most instances, only the compressive test is carried out.*

Keywords: *Sand-quarry dust block, Compressive strength, Water absorption, Flexural strength, Split tensile Strength, Regression analyses,*

I. Introduction

In most concrete tests, major emphasis is placed on the determination of the 28 day compressive strength. Often, not much is done to determine the values of the other parameters; the general assumption being that the compressive strength gives a good summary of the overall behavior of the concrete in all conditions they may be exposed to during their lifetime. This generalization has been found not to be always true, most especially with regards to the durability properties [1]. The use of compressive strength as the sole parameter for determining the quality of concrete has not only been attributed to the ease of carrying out the compressive strength test but also to the fact that the determination of the other parameters is costly, cumbersome and time consuming [2].Compressive strength test is also the most common test made on sandcrete blocks. Although the Nigerian Industrial Standard [3] recommended both the compressive strength and water absorption tests forsandcrete blocks, only the former is usually performed. The standard is silent on the other parameters as the flexural strength which may be necessary in determining the stress at which cracks will develop in bending. If the compressive strength is the only test to be performed based on economic considerations, it becomes imperative that mathematical relationships which relate the compressive strength to the other structural properties be established. Not much literature exist on the mathematical relationship between the compressive strength and the other properties of sandcrete blocks. Danso [4] studied the variation of flexural strength and some other block properties of sandcrete blocks with compressive strength. He did not, however extend it to when there is partial replacement of the sand with quarry dust (sand-quarry dust blocks), a practice which is now popular with some block producers in Nigeria. The inclusion of quarry dust as a partial replacement of sand in sandcrete block has been shown to improve the structural properties of the blocks [5, 6].

The objective of this work is to establish simple mathematical relationships between the compressive strength and other properties of sand-quarry dust blocks, notably flexural strength, split tensile strength and water absorption. Regression analyses will be employed to data obtained from tests on appropriate specimens. In the absence of any other test other than the compressive strength test the developed relationships, if any, can be used to estimate the other parameters of the block and thus help selecting mixes that meet given requirements.

II. Materials and Methods

The materials used for this work are Water, Cement, Sand and Quarry dust. Potable water obtained from a borehole was used in all the processes of manufacture and curing of blocks. Ibeto brand of Ordinary Portland cement which conforms to NIS 444 [7] was used. The river sand has a specific gravity of 2.65, bulk density of 1564kg/m^3 and fineness modulus of 2.76. The corresponding values for the quarry dust are 2.74, 1296kg/m^3 and 2.97.

1.1 Mix Proportions

Batching of the constituents was by weight. Fifteen different mixes with cement/combined aggregate ratios ranging from 1: 6 to 1: 10 and percentage replacement of sand with quarry dust of 10 to 40 were used for testing each property. The aggregates were batched in their dry condition.

1.2 Sample preparations and testing

(a) Compressive strength and Water absorption

Ninety hollow block samples, 450 x 225 x 225mm were used for the compressive strength and water absorption tests. The blocks were made using a Rosa Commetta block moulding machine. The compressive strength, fc was determined from the relationship:

$$fc = F/A \quad (1)$$

F and A are the failure load and cross sectional area respectively.

The water absorption test on cured blocks was in accordance to BS 1881-122 [8]. The water absorption, (Wa) of the block was calculated as the difference between the mass of the saturated block, Mw and the dry mass, Md expressed as a percentage of the dry mass. That is:

$$Wa = \frac{Mw - Md}{Md} * 100\% \quad (2)$$

Forty five of the blocks each were used for the compressive strength and water absorption tests.

(b) Flexural strength

The flexural strength test was done in accordance to BS EN 12390-5 [9] using test specimens of 600 x 150 x 150mm dimensions that were prepared in accordance to BS EN 12390-1 [10]. The specimens were cured for 28 days by completely immersing them in water. The three point load system was used and the flexural strength determined using the relationship:

$$ff = Fa/(bd^2) \quad (3)$$

Where: ff = flexural strength, F = the failure load, a = span, b = width of the beam, d = the depth of the beam.

The flexural strength for each mix ratio was taken as the average of three test results

(c) Split tensile strength

The split tensile strength test was carried out on cylinders, 300 x 150mm diameter in accordance BS EN 12390-6 [10]. The split tensile stress was calculated using the relationship

$$f_{st} = 2F / (\pi Ld) \quad (4)$$

Where: f_{st} is the split tensile strength, F is the failure load, L is the length of specimen and d is the diameter of the specimen.

Three samples were produced for each mix ratio and the average result taken as the split tensile strength for the mix.

III. Results and Discussion

The results of the various tests on the structural characteristics of the sand-quarry dust blocks for the fifteen mix ratios are shown in Table 1.

Regression analyses were performed using Minitab Release 16 [12] to establish empirical linear and quadratic relationships between the compressive strength and each of the other three parameters. Figures 1-3 show the variation of water absorption, flexural strength and split tensile strength with compressive strength respectively.

The developed relationships for water absorption are respectively given as:

$$Wa = 12.2973 - 1.8004fc \quad (5)$$

$$Wa = 19.8396 - 5.7589fc + 0.4971fc^2 \quad (6)$$

The standard error of regression, S, are 0.270 and 0.124% while the coefficient of determination, R^2 are 0.96 and 0.99 respectively.

The linear and quadratic relationships for flexural strength are given respectively as:

$$ff = 0.4921 + 0.7069fc \quad (7)$$

$$ff = 1.4200 - 0.219983fc + 1.0612fc^2 \quad (8)$$

The values of S are respectively 0.144Nmm^{-2} and 0.147Nmm^{-2}; the corresponding values of R^2 being 0.93 and 0.94.

Table 1. Experimental test results

S/No	Component proportions				Block Characteristics			
	Water	Cement	Sand	Quarry dust	fc (Nmm^{-2})	ff (Nmm^{-2})	fst (Nmm^{-2})	Wa (%)
1	0.520	1	5.4	0.6	4.57	3.68	2.92	4.16
2	0.805	1	4.8	3.2	3.50	2.77	2.48	5.48
3	0.620	1	5.7	1.3	3.67	3.28	2.80	5.41
4	0.720	1	6.0	2.0	3.37	2.79	2.50	6.07
5	0.860	1	6.0	3.0	3.19	2.57	2.39	6.53
6	0.750	1	9.0	1.0	2.76	2.47	2.28	7.86
7	0.875	1	7.5	2.5	3.07	2.69	2.43	6.86
8	0.735	1	7.5	1.5	3.04	2.57	2.35	6.95
9	0.680	1	6.3	1.7	3.39	2.69	2.43	6.02
10	1.000	1	6.0	4.0	2.91	2.68	2.43	7.25
11	0.610	1	3.6	2.4	5.27	4.33	3.33	3.20
12	0.760	1	5.7	2.3	3.20	2.90	2.56	6.50
13	0.635	1	7.2	0.8	3.09	2.81	2.51	6.80
14	0.565	1	4.5	1.5	4.91	3.82	3.12	3.54
15	0.665	1	4.8	2.2	4.01	3.44	2.79	4.78

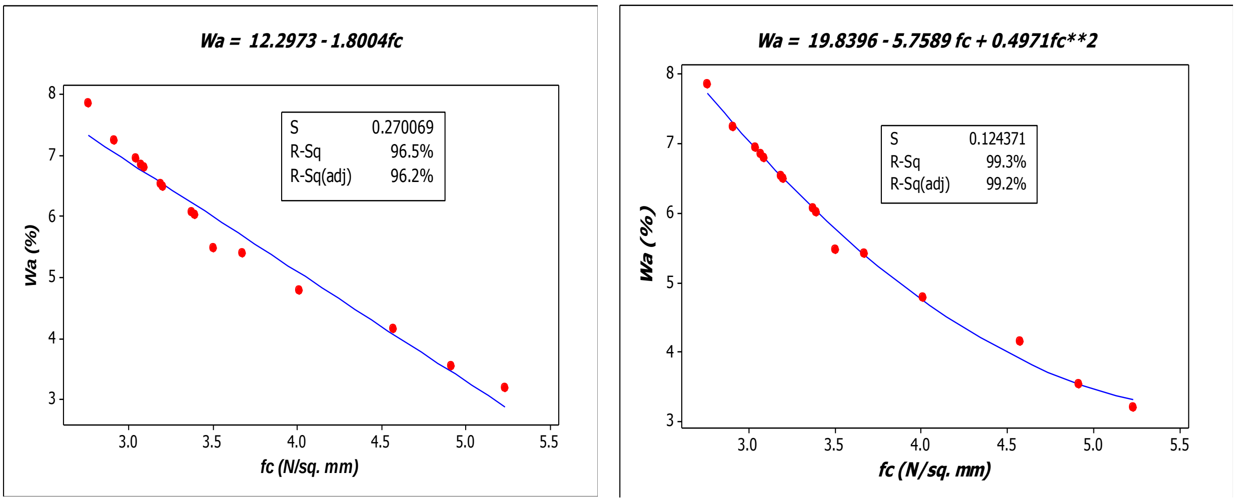
The linear and quadratic relationships between the compressive strength and Split tensile strength are respectively:

$$fst = 1.216 + 0.3908fc \qquad (9)$$

$$fst = 1.7603 + 0.10501fc + 0.3588fc^2 \qquad (10)$$

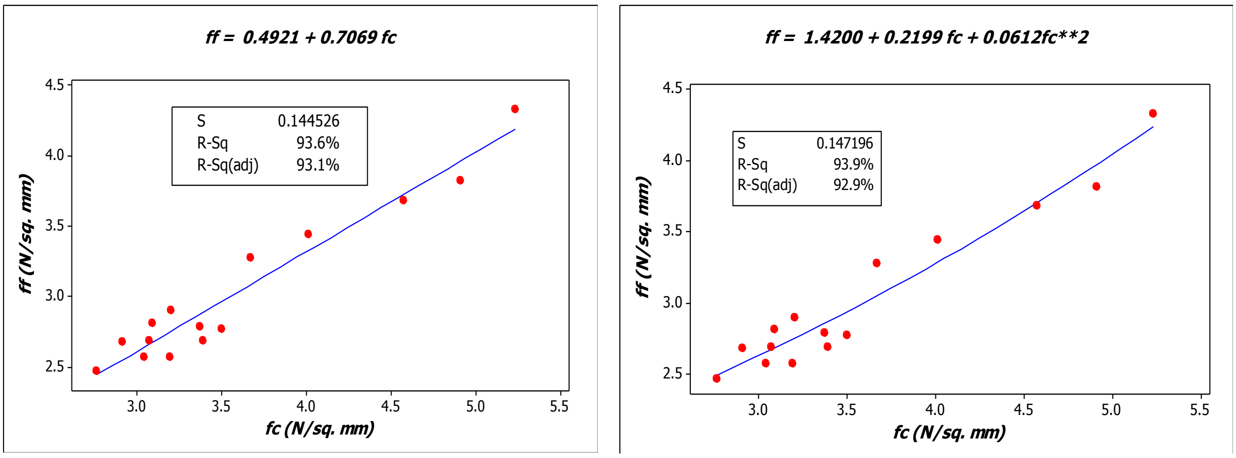
Values of S and R^2 for the linear model are $0.083Nmm^{-2}$ and 0.931 respectively. The corresponding values for the quadratic model are 0.084 and 0.934.

The adequacy of the models can be determined using the S and R^2 statistics. All the models have very low S values. The R^2 values are also greater than 0.9 for all the models. The low S and R^2 values indicate the adequacy of the models. There is also not much difference between the S and R^2 values for linear and quadratic models. Each of them can be used for predicting the 28 day response of the parameter in question. However, given their simplicity, the linear models may be preferred.



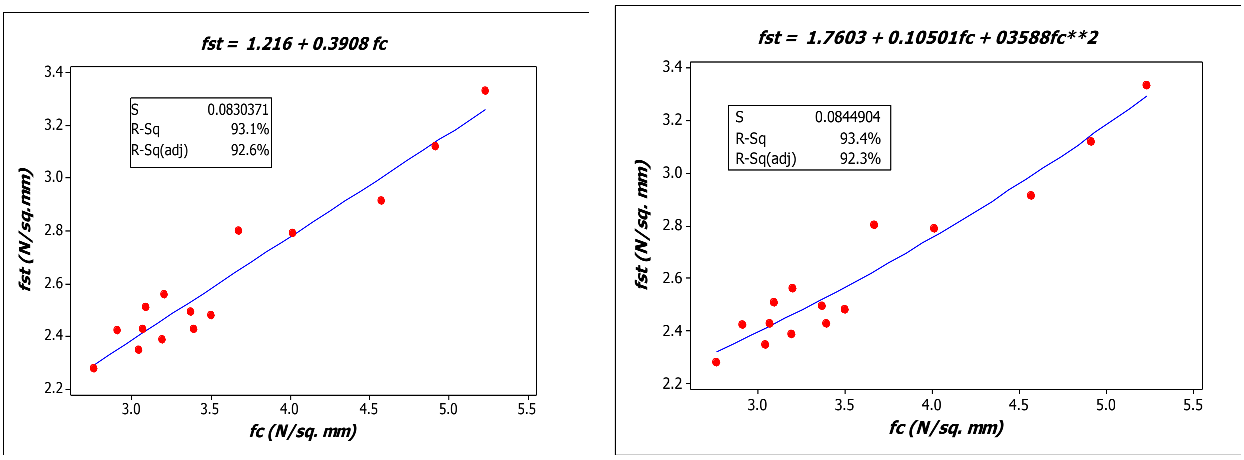
(a) Linear fit **(b) Quadratic fit**

Fig. 1 Variation of Water absorption with Compressive strength



(a) Linear fit **(b) Quadratic fit**

Fig. 2 Variation of Flexural strength with Compressive strength



(a) Linear fit **(b) Quadratic fit**

Fig. 3 Variation of Split tensile strength with Compressive strength

IV. Conclusion and Recommendation

Linear and quadratic models that relate the water absorption, flexural strength and split tensile strength to the compressive strength of sand-quarry dust blocks were developed. There is an inverse proportionality relationship between compressive strength and water absorption whereas the flexural strength and split tensile strength of the blocks are proportional to the compressive strength. The models were developed for the range of mixes normally employed in sandcrete block production. It is recommended that where the compressive strength is the only test made, the developed models can be used to estimate the values of the other characteristics of blocks thus, leading to savings in time and resources. The models will especially be useful in Nigeria where sandcrete blocks are widely used in forming walls of residential buildings.

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