Compressive Strength and Costs of Sandcrete Blocks and blocks made with quarry dust in Nigeria: A Case study of Abakaliki Quarry

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ABSTRACT

This work focus on the analysis of compressive strength and cost of sandcrete blocks and blocks made with quarry dust. It adopted the combination of survey and experimental research design. It was conducted at Abakaliki in Ebonyi State. The study is aimed at introducing a low cost indigenous material with acceptable quality into the construction industry. Having reviewed some relevant related past literatures to the study, samples of the required basic materials were collected and used in molding some numbers of two forms of blocks. These blocks were tested in the laboratory as to ascertain their levels of compressive strength. Rates were also prepared using the prevalent market prices of the relevant constituent materials and their respective finished products to enable comparison of their cost implications. The finding proves that blocks made with quarry dust are stronger and cheaper than sandcrete blocks. It is therefore recommended to the government and construction industry stakeholders that the quarry dust materials should be used for optimum performance of walling units to enhance housing delivery in Nigeria, especially in igneous quarrying related environments.
Keywords: *Compressive Strength, sandcrete blocks, quarry dust, construction*

INTRODUCTION

The quality and cost effectiveness of construction materials employed in housing development are among the major factors that determines the optimal delivery of housing projects in Nigeria (Akutu, 1983). Therefore, materials to be used for building construction must provide objective evidence of quality and cost effectiveness in terms of functional requirements and low income economy respectively. In view of this, the search for low-cost material that is socially acceptable and economically available, at an acceptable quantity within the reach of an ordinary man becomes a subject of continuous interest. The belief that the African region is full of raw materials suitable for local uses encourages this, yet the construction sector is not making optimal use of them (Ramachandran, 1983). The most significant element of a house in housing development is the wall which is a component of many constituent materials. In most villages, mud and clay materials are still being used for wall making with their acceptability as last alternative for the poor but, with some level of quality attendant problem (Nwanga, 2005), especially in an area of high flooding potential. Hence, many of such houses are deprived of their social acceptability. In every quarry site in the town, the dust produced is most often handled as waste (ion.traindafilou@fhwa.dot.gov(1993). However, some road construction workers and individual house developers use the quarry dust as a base course for road work and landscape materials respectively. Geographically, Varghese (2008) recognizes granite material from which quarry dust is generated as an igneous rock. It is being formed by tectonic activities of volcanic eruption, ejecting up to the terrestrial or the outer crust some molten magma that later solidify into igneous rocks (Becksmann, 1995). This deposit is usually used for concrete of high compressive strength in the construction industry. There is no doubt, that the byproduct of granite (quarry dust) which in most cases undergoes no significant chemical change in its production is very good for walling units. This production would help to increase the availability of local building materials and in turn would influence positively the cost of housing development in Nigeria.

MATERIALS AND METHOD

Abakaliki, the Ebonyi State capital as the study sample area in Nigeria is known however, for quarrying activities. This is as a result of large deposit of granite in the area from which the quarry dust is produced. The objective of the study is targeted at comparing the mechanical strength and cost effectiveness of blocks made with quarry dust with that of ordinary sand. By the nature of the study, both experimental and descriptive methods of research works were adopted. The experimental or laboratory tests were carried out on all the material samples with scientific equipment for their mechanical strength. While, direct observations were made on the samples when collected and also at various stages of the laboratory tests, with a view to noting behaviors of the different cubes at yield points to complement their laboratory test results for easier and reliable analysis of findings. Validity and reliability of the research instrument were ascertained for their effectiveness and reliance. Besides, the major instruments used for the research work are: weighing balance, universal testing machine and a set of sieves. On confirming the standard condition of universal testing machine at least, the following measures were verified and confirmed.

i. Ensuring that the calibrator is moving
ii. Confirming that there is no leakage of the hydraulic fluid from joints.
iii. Checking to ensure that the electric motor is moving.

Nevertheless, the two main tests carried out are as follows:

a. **Sieve Analysis –** it determines the quantity and percentage of the constituent particles in the samples as well as their grading distributions (Akroyd, 1957).
b. **Compressive Strength Test –** this guides to determine the compressive strength of both the sandcrete and quarry dust blocks respectively.

The results obtained from these tests together with the conceptual theory formed the basis upon which conclusion and recommendations were made. In the research work, efforts were made to identify that quarry dust materials in the Abakaliki area are of white and black colours. The colours are predicated on the geological composition of the molten magma and the area of deposition during and after the tectonic eruption of the igneous rock materials (Nwanga, 2005). In the study area, granite lumps were obtained from two major sources, which are the Abakaliki mine and the Umuoghara mine. The Abakaliki mine produces the white coloured igneous material (intrusive), while the Umuoghara mine produces the black coloured igneous materials which are deposited mostly on the ground surface level (extrusive). The dust from these granite lumps are however, considered as waste. They are not usually separated instead both the white and black dust are dumped together to form heaps. The sand used for the sandcrete block sample was sourced as river sharp sand while the cement used for the entire experiment is ordinary Portland cement. Also the water used for the batching and mixture processes is portable water, good enough for human consumption. As mentioned earlier, the two major laboratory test carried out are: Sample particle size distribution analysis and Compressive strength test. To determine the quantity of dust or silt contained in the samples of the two given aggregates and the relative proportion of different sizes of their constituent particles, a set of sieves, weighing balance and a shaker were provided. Procedurally, a sample size of 500g both sand and quarry dust respectively were obtained, these samples were differently placed on an already arranged set of sieves and shaken uniformly for about 5 minutes in each case. The samples weight retained in the sieves were recorded against the sieves numbers and their percentages calculated. The sieve numbers were arranged in a descending order, having the one with the largest diameter on the top. The cumulative percentage retained and that passing was also recorded.

RESULTS AND DISCUSSION

Nevertheless, table 1 and 2 reveal that the particles of the samples are uniformly graded. There are 90.8% and 83.8% of sand size particles in the river sharp sand and quarry dust samples respectively. The quarry dust sample contains 11.8% of silt/dust size particles and 4.4% of gravel size particle, while the river sharp sand contains 9.2% of silt/dust size particle, with no particle coarser than sand size. Consequently, the quarry dust sample has greater quantity of silt/dust particle size than the river sharp sand sample hence; "Q" samples would have reduced porosity than "S" samples. However, the presence of coarser particles in "Q" sample counters the demerit of the higher presence of fine particles inherent in the sample. The curves of the samples particle size distributions as derived from table 1.0 and 2.0 above were plotted on figure 1.0. The sizes of the sieve are represented in the horizontal axis while the percentage passing is in the vertical axis, as shown in the figure below. These curves in the graph reveal that these aggregates are poorly sorted in their processes of formation or transportation and deposition with an insignificant quantity of silt and dust. This characteristic suggests their suitabilities for block making due to their effective internal bonding. The "S" curve represents river sharp sand sample particle size distribution, while the "Q" represents quarry dust sample particle size distribution. (fig. 1).

Compressive Strength Test: This test is aimed at determining the compressive strength of blocks made with quarry dust as compared to that made with ordinary sand. Objectively, 150 x 150 x 150 steel molds, 16mm diameter tamping rod, metallic base plate, water storage facility, tubs, shovels and universal testing equipment were provided. Sandcrete blocks were made with a mix ratio of 1:6 (i.e., 1 part of cement and 6 parts of sand) and water (0.50 workability). Every necessary procedures and cautions for good masonry wall units were ensured with 25 strokes of blow for sound compaction. Finally, metallic flat base was used to further compact the mold mixture up to 4 times. A total of 9 cubes mark with inscriptions were molded for test in three age categories of sandcrete block. The molded samples were loosed of their steel molds and later cured very well. The whole processes were repeated using quarry dust and marked with inscription "Q" on another 9 cubes. 3 samples of "S" cubes and "Q" cubes respectively were selected at random after 7 days for first category of compressive strength test. On the 14th day another 3 samples of "S" and "Q" cubes were respectively selected again for the second category test. The last category test was carried out on the 28th day with the remnant "S" and "Q" cubes respectively, for their compressive strengths. The basic principle underling this test is the yield value. When the system and the arrangement were set, and the load applied in a vertical direction without sign of failure, the pressure was continuously increased gradually with varying additional loads until the sample was observed to have yielded (i.e., no greater loaded can be sustained). The yield strength or value at failure was recorded. In the whole, quarry dust block is cheaper to make than the sandcrete block. And the most significant factor for the difference in their cost implication is the great difference in the cost of their basic material (i.e. sand and quarry dust). The cost of quarry dust is less than 50% of the cost of river sharp sand material.

Table 1: Comprehensive Composition of the River Sharp Sand Sample According to the Proportion of the Constituent Particles Sizes

s/n	Sieve sizes/particles grades	Weight retained (g)	Weight retained (%)	Cumulative weight retained (%)	Weight passing (g)	Weight passing (%)
1	Gravel (d™20mm > 4.75mm)	0	0	0	500	100
2	Coarse sand (d" 4.75 > 2.0)	2	0.4	0.4	498	99.6
3	Medium sand (d™ 2.0 > 0.425)	28	5.6	6.0	470	94
4	Fine sand (d" 0.425 > 0.075)	424	84.8	90.8	46	9.2
5	Silt (d™ 0.075 > 0.002)	32	6.4	97.2	14	2.8
6	Clay (d™ 0.002)	12	2.4	99.6	2	0.4
7	Base (receiver)	2	0.4	100	-	-

Source: Experimentation, 2011

Table 2: Particle Size Distribution Result for the Quarry Dust sample.

s/n	Sieve sizes/particles grades	Weight retained (g)	Weight retained (%)	Cumulative weight retained (%)	Weight passing (g)	Weight passing (%)
1	Gravel (d™20mm >4.75mm)	22	4.4	4.4	478	95.6
2	Coarse sand (d™ 4.75 > 2.0)	8	1.6	6.0	470	94
3	Medium sand (d" 2.0 > 0.425)	41	8.2	14.2	429	85.8
4	Fine sand (d™ 0.425 > 0.075)	370	74	88.2	59	11.8
5	Silt (d" 0.075 > 0.002)	39	7.8	96	20	4
6	Clay (d" 0.002)	14	2.8	98.8	6	1.2
7	Base (receiver)	6	1.2	100	-	-

Source: Experimentation, 2011

Table 3: Compressive Strength of Sandcrete Block on the 7th day

Sample	Age of block at test	Weight (kg)	Load at failure (kn)	Compressive strength (n/mm^2)
1	7	5.91	32	1.40
2	7	6.17	33	1.42
3	7	6.08	31	1.38

Source: Experimentation, 2011.

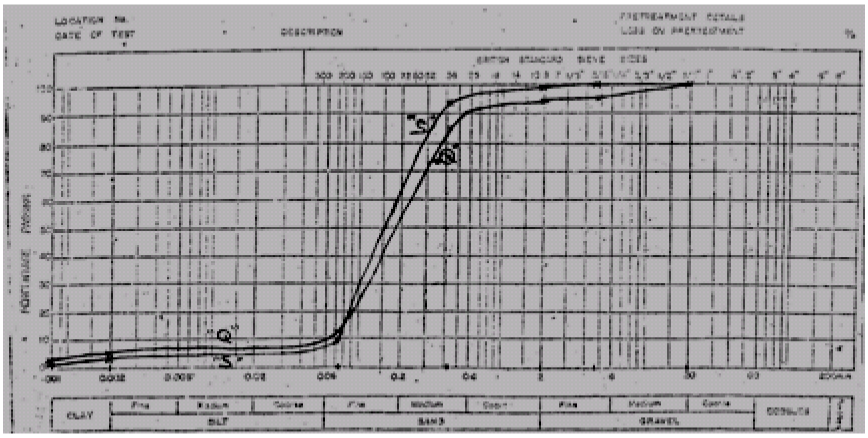

Fig. 1: Particle size distribution curves ***Source:*** Experimentation, 2011.
"S" = River sharp sand sample curve. **"Q"** = Quarry dust sample curve.

Table 4: Compressive Strength of Sandcrete Block on the 14th day

Sample	Age of block at test	Weight (kg)	Load at failure (kn)	Compressive strength (n/mm^2)
1	14	6.16	39	1.74
2	14	6.19	40	1.77
3	14	6.21	41	1.79

Source: Experimentation, 2011.

Table 5: Compressive Strength of Sandcrete Block on the 28th day

Sample	Age of block at test	Weight (kg)	Load at failure (kn)	Compressive strength (n/mm^2)
1	28	6.68	46	1.96
2	28	6.63	43	1.88
3	28	6.70	48	1.99

Source: Experimentation, 2011.

Table 6: Compressive Strength of Quarry Dust on the 7th day

Sample	Age of block at test	Weight (kg)	Load at failure (kn)	Compressive strength (n/mm^2)
1	7	6.61	41	1.80
2	7	6.57	39	1.74
3	7	6.50	38	1.70

Source: Experimentation, 2011.

Table 7: Compressive Strength of Quarry Dust on the 14th day

Sample	Age of block at test	Weight (kg)	Load at failure (kn)	Compressive strength (n/mm^2)
1	14	6.70	54	2.42
2	14	6.62	50	2.26
3	14	6.68	52	2.34

Source: Experimentation, 2011.

Table 8: Compressive Strength of Quarry Dust on the 28th day

Sample	Age of block at test	Weight (kg)	Load at failure (kn)	Compressive strength (n/mm^2)
1	28	6.69	54	2.42
2	28	6.73	57	2.52
3	28	6.70	55	2.46

Source: Experimentation, 2011.

Consequently, from the presentation on table 5 and 8, the mean strength for the 28th day old cubes of sandcrete and quarry dust blocks were calculated using the following formula:

$$\overline{X} = \frac{\sum X}{N},\ S^2 = \frac{\sum (x-\overline{x})^2}{n-1} \qquad \text{as the sample variable}$$

$$ð = \sqrt{S^2} \qquad \text{as the standard deviation.}$$

The statistical values of the 7th and 14th days could as well be calculated but, for the benefit of doubt which shows that the weights and compressive strength on the 28th day of the samples are always high, the values of the 28th days were used for comparison analysis.

Statistical Values of Sandcrete Blocks on the 28th day

$\overline{x}$ = mean compressive strength $= \frac{\sum X}{n} = \frac{5.83}{3} = 1.94$

Where variance, $S^2 = \frac{\sum (x-\overline{x})^2}{n-1}$

Table 9: Statistics Table for River Sharp Sand

s/n	Compressive strength	$x-\overline{x}$	$(x-\overline{x})^2$
1	1.96	0.02	0.0004
2	1.88	- 0.06	0.0036
3	1.99	0.05	0.0025
	$\sum x = 5.83$		$\sum (x-\overline{x})^2$ = 0.0065

Sample variance $S^2 = \frac{0.0065}{2} = \underline{\underline{0.0033}}$

Standard deviation $ð = \sqrt{S^2} = \sqrt{0.0033} = 0.057 N/mm^2$

Statistical Values of Quarry Dust Blocks on the 28th Day

$\overline{X}$ = mean compressive strength

Table 10: Statistics Table for Quarry Dust

s/n	Compressive strength	$x-\overline{x}$	$(x-\overline{x})^2$
1	2.42	0.05	0.0025
2	2.52	- 0.05	0.0025
3	2.46	0.01	0.0001
	$\sum x = 7.4$		$\sum (x-\overline{x})^2$ = 0.0051

Sample variance $S^2 = \frac{0.0051}{2} = 0.0026$

$ð = \sqrt{S^2} = \sqrt{0.0026} = 0.051 N/mm^2$

Determination of Cost of Sandcrete and Quarry Dust Blocks for Comparison on Cost Effectiveness

A. SANDCRETE BLOCK COST ESTIMATION

I. Materials: - cement and sand (1:6) plus clean water

$1m^3$ of cement	=	28.8 bags, each weighing 50kg.
Therefore, $1m^3$ of cement	=	28.8 x 50kg = 1,443kg
Then, cost/bag of cement	=	N1,600
Transportation	=	N80/bg
Loading/off loading	=	N15/bg
Total cost	=	N1,695/bg
For $1m^3$ = 29 bags by N1695	=	N49,155
For $6m^3$ of sand		
5 c. yrd trip	=	$5m^3$ at N9, 500
Therefore, $1m^3 = \frac{N9,000}{5}$	=	$N1,900/m^2$
Where $6m^3$ = 6 x N1, 900	=	N11,000
Water is 50% of cement		
Which implies $0.5m^3$	=	N350
Cost of sandcrete (1:6) ratio	=	N49,155 + N11,400 + N350 = N60,905
Then add waste and shrinkage at 5% and 10% respectively.		
15% of N60,905	=	N9,135
		Total = N70,040

II. Labour

Assume hand molding	=	N300 bags		
Then for 29bags	=	300 x 29bags	=	N8,700
Total cost of labour and material	=	N70,040 + 8,700	=	N78,740
Thus, 1 bag	=	35 blocks of 150 x 150 x 450 specification		
Therefore, 29bags	=	35 x 29	=	1,015blocks
Therefore, cost/block (150)	=	$\frac{N78,740}{1015}$	=	N77.58
		Note: Without profit and overhead		

B. QUARRY DUST BLOCK

I. Materials:

Cement and quarry dust (1:6) ratio
Cost/m^3 cement = N49,155 (established)
For quarry dust:
Quarry dust per 5c.yrd trip = N4,500 for $5m^3$

Then for 6 part of quarry dust = $\frac{N4,500}{5m^2}$ = N900/m^3

= 900 x 6 = N5, 400
Water quantity is constant at 50% of cement = $0.5m^3$ = N350 = (established)
Therefore cost of quarry dust block materials = N49,155 + N5,400 + N350
Total = N54,905
Then add for waste and bulk loss at 5% and 10% of the total material cost respectively.
15% of N54,905 = N8, 235
Total = N63, 140

II. Labour (Hand Mould)
Each bag cost N300 for mixture and molding.
The 29 bags = 29 x N300 = N8, 700 as established
Then the total cost of labour and material = N63, 141 + 8,700 = N71, 840
For 29bags of cement, 1015 blocks would be obtained as already established for 150 x 150 x 450 size.

Therefore, each block of quarry dust material would cost = $\frac{N71,840}{1015}$ = N70.78

Note: Without profit and overhead

CONCLUSION AND RECOMMENDATIONS

The Nigeria Industrial Standard (2005) recommendation for the compressive strength of sandcrete block in Nigeria serves as a standard with which the result of the study was assessed. The mean compressive strength (x) of the 28th day sandcrete block sample from the analysis of the laboratory result was 1.94 with standard deviation of 0.057 N/mm^2, which of course is within the specified range; while that of the quarry dust block was 2.47 and the 0.051 N/mm^2 respectively, which are higher than the required specification. Nevertheless, the distribution of the particle size of the samples determine the degree of sorting of the sample grains and the silt/dust content. The river sharp sand normally contains almost only sand size particles as in the case of the experimented sample; hence is poorly sorted. It contains an insignificant quantity of silt thereby having much pore spaces for the mixtures anchorage to increase internal bonding of the block work. Much as this may serve as a standard, the quarry dust sample has rougher or more irregular particle structures and little coarser particles that would result to greater internal bonding, even when it has a little greater silt value than the river sharp sand sample. Besides, according to the prevalent prices of materials in the local market, blocks made with quarry dust are cheaper than their sandcrete counterpart. In a nut shell, Blocks made with quarry dust are stronger and cheaper than that of sandcrete. It is therefore, more appropriately graded for higher strength with stronger internally bonding among the constituent composition than the river sharp sand. The choice of any building material is being determined by its extent of availability, functional consideration and the cost (Ikechukwu, 2010), this study therefore, recommends that quarry dust should be encouraged for block making in areas they are available. The manufacturers of quarry dust block and all the stake holders in the building industry should create strong awareness on the existence and suitability of such materials for block making, in order to stabilize its marketability. Finally, government should formulate a policy, sustainable and technical strategic measures that would ensure the maximum exploitation of indigenous resources for construction works in the industry, to help stabilize the national economy.

REFERENCES

Akroyd, T. N. (1957). *Laboratory Testing in Soil Engineering.* London: Publ. Soil Mechanics Ltd Old Church Dtr.

Akutu, G. O. (1983). *Reducing the Cost of Building Project. IMT Building Journal.* Enugu: Chika Printing Company

Beckmann, P. (1995). *Structural Aspects of Building Conservation.* England: Publ. MC Graw-Hill Book Company,

Ikechukwu, U. F. (2010). The Implication of Graded Soil Pavement to Quality of Rural Roads in the Nanka Sand Formation of Anambra State. A Paper Accepted for Publ. in Imo State University, for Rural Development Seminar, Imo State.

Ion.traindafilou@fhwa.dot.gov. (1993). Recovery and Utilization of Quarry by Products for Use in High Way Construction. Federal Highway Administration, Denver, Colorado.

Nigeria Industrial Standard (NIS) (2005). Standardization of Sandcrete Blocks in Nigeria, Abuja.

Nwanga, H. A. (2005). Comparative Analysis of Quality and Cost of Sandcrete Blocks and Blocks made with Quarry Dust in Ebonyi State. Post Graduate Thesis, Department of Building, Nnamdi Azikiwe University, Awka.

Ramachandran, A. (1983). Appropriate Building Materials for Low Cost Housing in Africa. A Symposium Proceeding on November. Nairobi.

Varghese, P. C. (2008). *Building Materials.* New Delhi: Prentice Hall of Indian Pvt Ltd.