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International Journal of Current Research
Vol. 9, Issue, 09, pp.57976-57980, September, 2017

INTERNATIONAL JOURNAL
OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

EFFECTS OF FINE AGGREGATE TYPES ON THE STRENGTH PROPERTIES OF BUILDING BLOCKS

[1]Arimanwa J. I., [2]Anyanwu T. U., [3,]*Iwuoha, S. E. and [4]Arimanwa, M. C.

[1, 2, 3]Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria
[4]Department of Civil Engineering, Federal Polytechnic, Nekede, Owerri, Imo State

ARTICLE INFO

Article History:
Received 26th June, 2017
Received in revised form
14th July, 2017
Accepted 19th August, 2017
Published online 30th September, 2017

Key words:

Effects,
Fine aggregate types,
Flexural strength,
Compressive strength,
Building blocks.

ABSTRACT

This work studied the effects of fine aggregates on the strength properties of building blocks. The fine aggregates used were sharp sand, quartz sand, granite dust and run-off sand. A cement-fine aggregate mix ratio of 1:6 and a water-cement ratio of 0.5 were used throughout the work. Sixteen hollow blocks of dimension, 450mm x 225mm x 150mmand 12 solid blocks of dimension 600mm x 150mm x 150mm were cast for each of the fine aggregate samples. The bulk density of the fine aggregates used were1600kg/m3, 1550kg/m3 , 1400kg/m3 and 1500kg/m3while the water absorption rates were 6.12%, 4.65%, 10% and 5% for sharp sand, quartz sand, granite dust and run-off sand respectively. Mixing of the particles was done manually using spades on a clean relatively impervious surface. The samples were cast on a level surface and cured by sprayingwater morning and evening for 7, 14, 21 and 28 days. For each of the curing ages, 4 samplesmade with each of the aggregate types were tested for the compressive strength of the hollow blocks while 3 samples each were tested for the flexural strength of each of the solid building blocks. The highest and lowest values of the compressive strengths of the hollow blocks which were obtained for quartz sand and granite dust block samples respectively after curing for 28 days were 5.14N/mm^2 and 3.42N/mm^2. For the same period of curing, the flexural strengths of 5.03N/mm^2 and 2.86N/mm^2 were the highest and lowest values which were obtained for blocks made with sharp and run-off sands respectively. Results of the tests show that quartz sand is an excellent alternative to sharp sand for the production of building blocks. It was concluded that the compressive and flexural strengths of building blocks are significantly affected by the type of fine aggregates used in their production.

Citation: Arimanwa J.I., Anyanwu T.U., Iwuoha, S.E. and Arimanwa, M. C. 2017. "Effects of fine aggregate types on the strength properties of building blocks", *International Journal of Current Research*, 9, (09), 57976-57980.

INTRODUCTION

Shelter is one of man's basic needs. In many parts of the world, buildings are used as shelters for storage, residential, office and industrial purposes. Such buildings, in most cases, are made up of rooms, which are separated by walls. The walls are made of materials which constitute an essential element in housing delivery. According to Raheem *et al.* (2012), it is estimated that, walling materials cover about 22% of the total cost of a building. The choice of a walling material, depends on the cost, availability, durability, aesthetics and climatic conditions in a particular environment. (Barry, 1996), defined a wall as a continuous vertical structure made of brick, block, stone, concrete, timber or metal; thin in proportion to its length and height, which encloses and protects buildings and/or divides them into compartments or rooms. As seen in (Barry, 1996), one of the materials from which a wall is made is sandcrete block.

***Corresponding author:* Iwuoha, S.E.,**
Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria.

In Nigeria, and other West African countries, sandcrete blocks are among the common materials used as walling units. In fact, Baiden and Tuulii (2004) reported that Over 90% of physical infrastructure in Nigeria are constructed using sandcrete blocks. The wide use of sandcrete blocks in the building and construction industry, has made it a very important material. The Nigeria Industrial Standard- NIS 87 (2000), defines sandcrete block as a composite material made up of cement, sand, and water, molded into different sizes. Sandcrete blocks are available for the construction of load bearing and non-load bearing walls. Load bearing walls are walls primarily designed to carry an imposed vertical load in addition to their own weight (BS 5628-1 1992), while non-load bearing walls carry no imposed loads and are generally used for partitioning. In view of the use of sandcrete blocks for the construction of load bearing and non-load bearing walls, an investigation of the strength properties and hence the quality of the blocks, becomes necessary. Sand, which is a major raw material for the production of sandcrete blocks, can be obtained from various sources in Nigeria. Abdullahi (2005), reported that some parts of Ondo and Ekiti states in Nigeria, have many rivers. The availability of these rivers, makes it easier to use river sand rather than clay, for block production in those areas. In Minna and its environs, sand is sourced from borrow pits and river beds. The use of sand for block molding, thrives in areas where the material is readily available. Even though there is sufficient sand in Nigeria for the production of sandcrete blocks, Abdullahi (2005), reported that the strengths of the blocks produced are usually inconsistent with the specified standard range of strength (2.5N/mm^2 to 3.45N/mm^2) given by the Nigeria Industrial Standard (NIS 87, 2000). This inconsistency, however, is due to the different production methods employed, duration of curing, and the properties of constituent materials. Given that the methods of block production in Nigeria are either manual or mechanical and the cement commonly used in block molding is the ordinary Portland cement, there is need to investigate the strength properties of blocks made with alternative fine aggregate materials. This research was, therefore, conducted to assess the suitability of quartz sand, granite dust and run-off sand as partial or total replacement for sharp sand in the production of building block.

MATERIALS AND METHODS

Materials

Dangote brand of Ordinary Portland Cement (hydraulic binder that sets and hardens by chemical interaction with water), having an initial setting time of 45 minutes and a final setting time of 297 minutes and conforming to BS 12 (1978), was used for this work. The fine aggregates used were sharp river sand, quartz sand, granite dust and run-off sandall of which passed through the 5 mm sieve aperture. Both the sharp river sand, which was used as the control sample and the quartz sand, were obtained from Otamiri River in Owerri West Local Government Area, Imo State. They were both free from clay, silt, organic and chemical matter. The bulk density and specific gravity of the sharp sand were 1600kg/m^{3}and 2.38, while those of the quartz sand were 1550kg/m^3 and 2.89 respectively. The granite dust (a bye product of the blasting/crushing of limestone), was obtained from the Abakaliki quarry industry in Ebonyi State, Nigeria, while the run-off sand was obtained from within the Federal University of Technology, Owerri, Imo State. For all the fine aggregate types, only the portion passing through 5mm British Standard Sieve was used. The bulk density and specific gravity of the granite dust were 1400kg/m^3 and 2.24, while those of the run-off sand were1500kg/m^3 and 2.65 respectively. The water used for the laboratory experiment, was obtained from a potable source.

Methods

The fine aggregates, were air dried and passed through the set of standard sieves in accordance with BS 812 (1984). The portion, passing through the 5mm sieve and retained on the 150µm, was used as the fine aggregates. Batching was done by volume using a standard block mix ratio of 1:6 and mixing was done manually using spades on a relatively clean and impermeable surface. After proper mixing was achieved, the sandcrete was cast and carefully vibrated into moulds measuring 450mm x 225mm x 150mm for hollow blocks and 600mm x 150mm x 150mm for solid blocks. The blocks were de-moulded and allowed for 24 hours before the commencement of curing activities. The hollow blocks were cured every morning and evening by spraying, for specified periods before being tested for compressive strength, while the solid blocks were cured by immersion in a curing tank before being tested for flexural strength. Curing for both block types was done for 7, 14, 21, and 28 days respectively. Sixteen hollow blocks were crushed at the end of each of these time intervals (7, 14, 21 and 28 days) in accordance with BS 6073-1 (1981) Of these sixteen blocks, four blocks each, was made from each of the fine aggregate types. The average compressive strength for the hollow blocks made with each fine aggregate type, was determined. The flexural test was carried out on the solid blocks, using the flexural testing machine in accordance with BS 1881-118 (1983). Dimensional variations of the blocks were checked in accordance with BS 6073-1 (1981). A total of 48 solid blocks were tested for flexural strength. That is, 12 were tested at the end of each of the 7, 14, 21, and 28 days of curing. The loads at which the blocks failed were obtained and recorded.

RESULTS AND DISCUSSION

The results obtained from this research work are presented in this section using tables and graphs where appropriate and are discussed with respect to standard works of other researchers.

Water Absorption Test Results of Fine Aggregates

Results of the Water Absorption tests carried out on the four aggregates types used in this work, are shown in Table 1. The results show that granite dust absorbed more water than any of the other aggregates type. The knowledge of water absorption rate is essential to enable building block manufacturers determine the quantity of water to add in a mix to compensate for the water in the fine aggregate especially in rainy season. Also, this knowledge will assist a builder or materials personnel to choose the type of building block for external walling which is subject to wetting by any other means.

Sieve Analysis Test Results

The particle size distribution results for the different aggregate types are shown on Tables 2-5. Results of the particle size distribution analysis of the four aggregate types shown on Tables 2 – 5 are illustrated graphically in Figure 1. The coefficients of uniformity of the fine aggregate types were 4.44, 4.76, 4.26 and 1.33 for the sharp sand, quartz sand, granite dust, and run-off sand respectively while their coefficient of curvature were 1.1, 1.07, 1.22 and 0.93. When compared with the standards of the unified soil classification system, it was realized that the run-off sand was uniformly graded, while the others were well graded. A close the graphical representation of the different fine aggregate types, will confirm the nature of their grading.

Compressive and flexural strength test results for the hollow and solid blocks

The average compressive strengths in N/mm^2 at different curing ages for the different hollow block types are presented in Table 6 while the average flexural strength test results for the solid blocks are shown in Table 7. A graphical representation of the data presented in Table 6, is shown in Figure 2. Figure 2, shows that the best result for the compressive strength of hollows blocks made with different fine aggregate materials at 28 days curing age was 5.14N/mm^2

Table 1. Water absorption results of fine aggregate Samples

S/N	Specimen No.	Sharp Sand	Quartz sand	Granite Dust	Run-off sand
1	Mass of saturated surface dried sample in (kg) (A)	0.52	0.45	0.55	0.42
2	Mass of dried sample in (kg) (B)	0.49	0.43	0.50	0.40
3	Water Absorption $\frac{A-B}{B}x100\%$	6.12%	4.65%	10%	5%

Table 2. Particle size distribution of sharp sand (Initial mass = 200g)

Sieve sizes (mm)	Mass retained (g)	Percentage mass (%)	Cumulative mass retained	Cumulative percentage mass retained (%)	Percentage passing (%)
4.75	0.00	0.00	0.00	0.00	100
3.35	3.00	1.50	3.00	1.50	98.50
2.36	2.00	1.00	5.00	2.5	97.50
1.70	20.00	10.00	25.00	12.5	87.50
1.18	5.00	2.50	30.00	15.00	45.00
0.60	80.00	40.00	110.00	55.00	15.00
0.425	60.00	30.00	170.00	85.00	13.00
0.30	4.00	2.00	174.00	87.00	13.00
0.212	22.00	11.00	196.00	98.00	2.00
Pan	4.00	2.00	200	100	0.00

Table 3. Particle size distribution of granite dust (Initial Mass = 200g)

Sieve sizes (mm)	Mass retained (g)	Percentage mass (%)	Cumulative mass retained	Cumulative percentage mass retained (%0	Percentage passing (%)
4.75	0.00	0.00	0.00	0.00	100
3.35	7.00	3.50	7.00	35.00	96.00
2.36	10.00	5.00	17.00	8.50	91.00
1.70	35.00	17.50	52.00	26.00	74.00
1.18	3.00	1.50	55.00	27.50	72.50
0.60	54.00	27.00	109.00	54.60	45.40
0.425	27.00	13.00	136.00	68.00	32.00
0.30	3.00	1.50	139.00	69.50	30.50
0.212	28.00	14.00	167.00	83.50	16.50
Pan	33.00	16.50	200.00	100	0.00

Table 4. Particle size distribution of quartz sand (Initial mass: 200g)

Sieve sizes (mm)	Mass retained (g)	Percentage mass (%)	Cumulative mass retained	Cumulative percentage mass retained (%0	Percentage passing (%)
4.75	0.00	0.00	0.00	0.00	100
3.35	50.00	25.00	50.00	25.00	75.00
2.36	31.00	15.50	81.00	40.5	59.50
1.70	50.00	25.00	131.00	65.50	34.50
1.18	6.00	3.00	137.00	68.50	31.50
0.60	42.00	21.00	179.00	89.50	10.50
0.425	10.00	5.00	189.00	94.50	5.50
0.30	2.00	1.00	196.00	95.50	4.50
0.212	5.00	2.50	196.00	98.00	2.00
Pan	4.00	2.00	200	100	0.00

Table 5. Particle size distribution of Run-off sand (Initial mass: 200g)

Sieve sizes (mm)	Mass retained (g)	Percentage mass (%)	Cumulative mass retained	Cumulative percentage mass retained (%0	Percentage passing (%)
4.75	0.00	0.00	0.00	0.00	100
3.35	0.00	0.00	0.00	0.00	100
2.36	1.00	0.50	1.00	0.50	99.50
1.70	5.00	2.50	6.00	3.00	97.00
1.18	1.00	0.50	7.00	3.50	96.50
0.60	40.00	20.00	47.00	23.50	76.50
0.425	60.00	30.00	107.00	53.50	46.50
0.30	90.00	45.00	197.00	98.50	1.50
0.212	2.00	1.00	199.00	99.50	0.50
Pan	1.00	0.50	200	100.00	0.00

Table 6. Compressive strength test results of the hollow blocks at different curing ages (N/mm^2)

Curing Age (days)	Fine Aggregate Type			
	Sharp Sand	Run-off Sand	Granite Dust	Quartz Sand
7	2.92	2.39	2.17	3.73
14	3.10	2.86	2.36	4.03
21	3.63	3.40	2.89	4.46
28	4.02	3.76	3.42	5.14

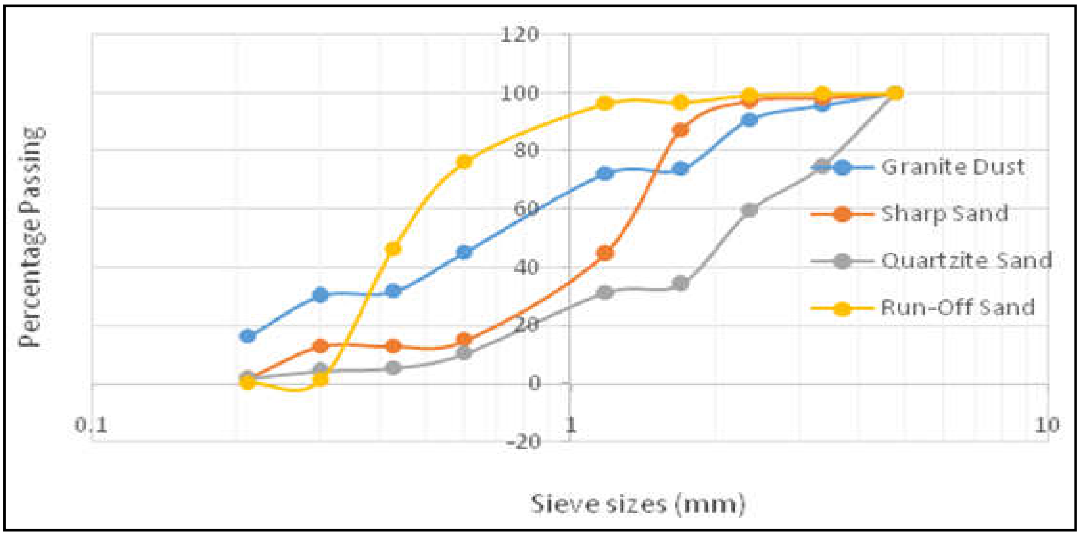

Figure 1. Results of the particle size distribution analysis of the four aggregate types

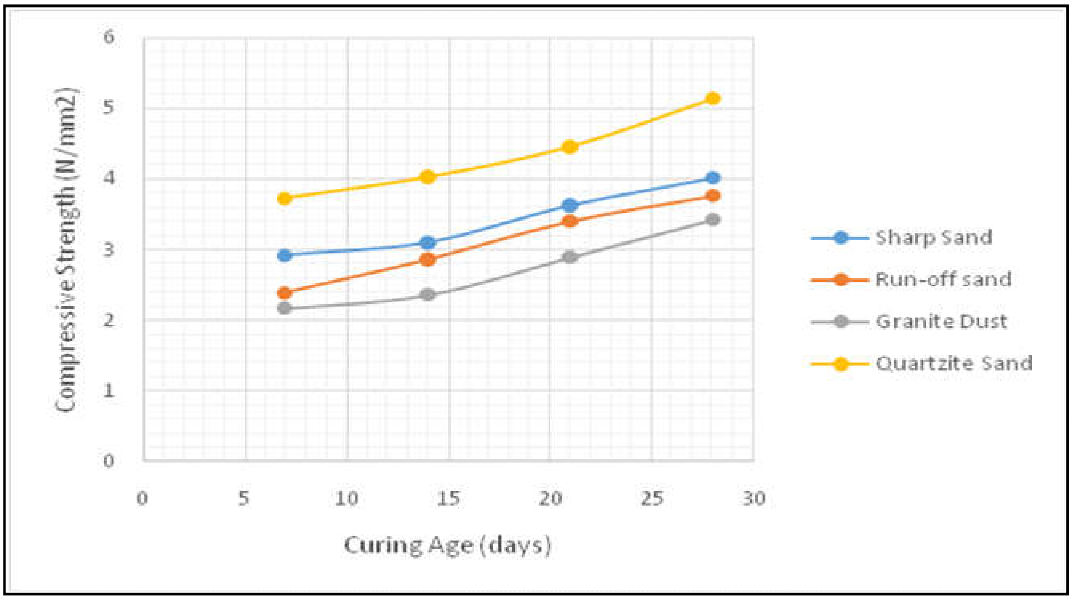

Figure 2. Graph of the compressive strength of hollow blocks at different curing ages

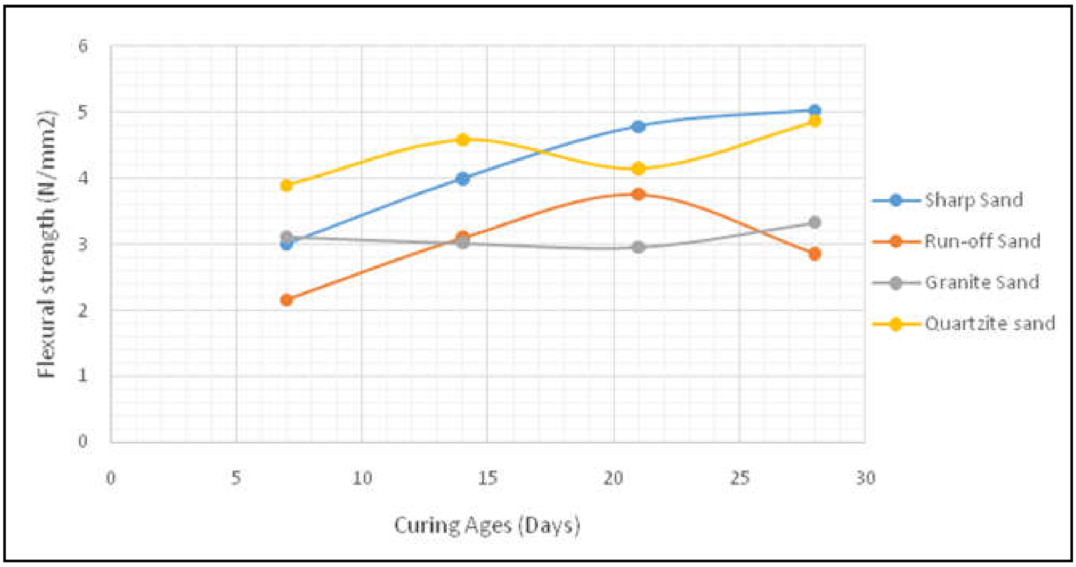

Figure 3. Graph of Flexural Strength at Different Curing Ages

obtained for building blocks made from quartzsand while the worst was 3.42 N/mm^2 for blocks produced with granite dust and cured for the same period. It was observed that for all curing ages, both the quartz sand and sharp sand gave results which are consistently higher than the standard range of 2.5-3.45N/mm^2 given by the NIS for load bearing blocks. It was also observed from Fig 2, that for curing ages of above 14 days, the strength of the blocks made with run-off sand, met the NIS standard for load bearing blocks, while for curing ages below 14 days, the compressive strength results met the NIS standard of 1.75N/mm^2 for non-load bearing blocks. The strength of the blocks made with granite dust was found to be lower than 2.5N/mm^2 at 7 days and 3.45N/mm^2 at 28 days of curing respectively. This shows that blocks made with granite dust are not fit to be used as load bearing blocks. However, the minimum strength (2.17N/mm^2) obtained from these blocks, was found to be higher than the requirement (1.75N/mm^2) for a non –load bearing blocks. For a better and more detailed analysis of the flexural strength of the solid blocks at different curing ages, the graphs of the flexural strengths against the curing ages of all the block types, are shown super-imposed in Figure 3. From Figure 3, it was seen that, the best values for the flexural strength of solid blocks were 5.03N/mm^2 and 4.87N/mm^2, which were obtained for sharp sand and quartzs and respectively while the least value of 2.17 N/mm^2 was obtained for run-off sand. It was also observed that the flexural strength of blocks made from sharp sand was consistently increasing with the curing age; that of the run-off sand, increased consistently up to the 21 days curing age and then dropped significantly.

Conclusion

From the results obtained, the analysis and the discussions made in this study, the following conclusions have been arrived at:

- The compressive and flexural strengths of blocks are significantly affected by the type of fine aggregates used in their production.
- Quartz sand, is an excellent alternative to sharp sand for block manufacturing.
- For a cement-sand mix ratio of 1:6,a water-cement ratio of 0.5 and curing period of 28 days, building blocks made with sharp, quartz and run-off sands should be used as load bearing walls while those made with granite dust should be used as non-load bearing walls.
- Given that granite dust absorbs more water than any of the fine aggregates types investigated, it is also concluded that building blocks made with granite dust absorb more water than blocks made with any of the fine aggregate types used in this research effort. Blocks produced with the material should, therefore, be used in locations where exposure to water is not critical.

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