

A comparative study of the quality of sandcrete cement blocks and quarry dust cement blocks

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ABSTRACT

With the increase of construction activities in Ghana, there is an increasing demand in building materials leading to the shortage of the conventional materials. The informal sector is gradually seeing the introduction of quarry dust as a substitute of sand in block production. This paper focuses on a comparative analysis of the quality of sandcrete blocks and quarry dust cement blocks. Block samples were gathered from various suppliers around the Prampram and Dawhenya areas and through various laboratory tests were tested for their dimension tolerance, water absorption and compressive strengths. Aggregate samples were also taken from suppliers for sieve analyses. The study revealed that the quarry dust cement blocks contained relatively higher percentages of coarse grade particles compared to the sandcrete blocks. The total average water absorption of sandcrete blocks was found to be 3.90% while quarry dust showed an improved value of 3.28%. Sandcrete blocks were averagely found to be of a higher compressive strength of 4.31N/mm², with quarry dust at 3.0N/mm². The study suggested the likelihood of a lesser use of cement in the production of quarry dust cement blocks due to the similarities in colour between the quarry dust and cement, hence, negatively affecting its compressive strength.

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1. Introduction

The increasing desire by individuals to own their own houses and the high demand in rented properties have influenced the fast development of the informal sector in Ghana. The sector typically undertakes the majority of construction in incremental housing, shops, fence walls and some private institutional facilities (Hedidor and Bondinuba, 2018), and hence, exponentially raising the manufacturing centres of sandcrete blocks within the same sector (Baiden and Asante, 2004). With the failure of a nation like Ghana taking decisive and sustainable action on building materials to enable the production of housing (Badu & Owusu-Manu, 2011), it comes as no surprise that housing shortage has hit government officials, leading to political turmoil (Oppong, and Badu, 2012). From time immemorial, earth and other natural building materials have recognisably been used as cheap materials for the construction of houses based on human experiences (Hadjri et al., 2007), but that is not the case now as the increase in construction activities has led to the acute shortage of conventional materials (Balamurugan and Perumal, 2013).

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In developing countries, the rapid infrastructure growth has raised the demand in river sand, hence leading to its shortage and increasing threat to the environment (Sankh et al., 2014). In a country like India, administrative restrictions of sand have escalated its cost even in places where river sand is available nearby (Balamurugan & Perumal, 2013). This has forced the need for the introduction of different materials as substitutes to conventional materials. Construction materials such as quarry dust have been used to alleviate such shortages in different parts of the world, for road construction and the production of building materials, such as lightweight aggregates, bricks, tiles, and autoclave blocks (Sivakumar & Prakash, 2011; Rai et al., 2014). Materials to be used for building construction must provide objective evidence of quality in terms of functional requirements (Ikechukwu, 2012). Few studies tend to bring to light comparisons between the use of quarry dust and the use of pit sand in block production.

Work by Anya (2015) shows that the inclusion of quarry dust in the production of sandcrete blocks improved the compressive strengths and water absorption properties of the blocks. This was also supported in a study which stipulates that the water absorption capacity of sandcrete blocks were improved because of the inclusion of granite fines as part of the constituents which according to Oyekan and Kamiyo (2008) makes the samples less permeable for liquid flow which decreases as the percentage of granite substitute for sand increases. A comparative study conducted at Abakaliki in Ebonyi State, Nigeria by Ikechukwu (2012), based extensively on the constituent particles and compressive strength of blocks of river sand and quarry dust, revealed that the river sand and quarry dust samples contained 90.8 % and 83.8 % of sand size particles respectively. The quarry dust contained 11.8 % of the silt size particles and 4.4 % of gravel size particles while the river sharp sand contained 9.2 % of silt size particle, with no particle coarser than sand size. Consequently, the quarry dust sample had a higher quantity of silt particle size than the river sharp sand sample hence; quarry dust samples would have reduced porosity than river sharp sand samples. However, the presence of coarser particles in quarry dust cement block counters the demerit of the higher presence of fine particles inherent in the sample (Ikechukwu, 2012). The study revealed the maximum compressive strength of sandcrete block sample to be 1.94 N/mm² while that of the quarry dust block sample was 2.47N/mm² respectively. Another study by Olufisayo (2013) to investigate the strength properties of Sandcrete blocks in Ado-Ekiti, Akure and Ile-Ife, Nigeria, identified compressive strengths of sandcrete blocks to be as low as 0.31 N/mm², with a maximum to be 1.35 N/mm², a little below findings made by Ikechukwu (2012). However, the Nigerian Industrial Standard (NIS 87:2000) stipulates the standard compressive strength for blocks to be 2.5 N/mm², contrary to findings made on site for sandcrete blocks. A study made by Baiden and Asante (2004) to investigate the effects of orientation and compaction methods of manufacture on strength properties of sandcrete blocks in the Kumasi metropolis, Ghana revealed most load bearing blocks in the informal sector, which are manually manufactured, fell below The Ghana Building Code standard of 2.75 N/mm².

An extensive literature review tells of limited studies done in Ghana on quarry dust cement blocks. Studies already made focus much on sandcrete blocks despite the increasing use of quarry dust cement blocks in the informal sector. Hence, raising a need for a comparative analysis of both block types to document proper scientific evaluations for safe construction activities in the country. This study is considerably geared towards filling this gap.

2. Methodology

2.1 Site and materials selection

Ten block factories within the Prampram area were chosen randomly for the analyses of five inches sandcrete blocks. Six pieces of the five inches blocks were bought from each of the ten sites with three of the sample blocks being tested for water absorption and the other three being tested for the compressive strength test. Dimension tolerance check was conducted on all the blocks. Curing of the blocks by the producers was at least up to a day. Testing of blocks was done in the Ghana Ports and Harbours Authority (GPHA) laboratory. The period taken for the achievement of this project was six weeks and within this

period visitation of the ten sites were done in a week with five sites visited on a day and another five on another day thus making visitation twice a week to check on certain practices required in Sandcrete block production. Ten small scale block factories around parts of Prampram and Dawhenya towns were randomly selected for the analyses of quarry dust cement blocks. They were visited at least once a week for five weeks. Samples of fine aggregate (quarry dust) were obtained from the individual block producing firms for sieve analysis/grading to ascertain the suitability of quarry fines for block production. Sieving was conducted in the Central University civil Engineering laboratory. Six pieces of five inches blocks were selected from the ten sites. Of the six number of blocks obtained from each factory, three blocks were tested for water absorption, and three blocks were checked for compressive strength and dimension tolerance. The block samples selected had undergone curing by the producers for at least one day. The block samples were transported to the Ghana Standards Authority Civil Engineering Laboratory for further tests.

Upon visitation, observations were made to gather information about batching, mix ratios, curing methods and duration, mixing process, method of compaction and quality of water for producing the blocks. Oral Interviews of owners and workers on site were carried out, and structured questionnaires were issued to the block producers in order to obtain information about source/quality of water, source and storage of materials, a form of training provided for workers, quality control method, challenges faced by producers, etc. Data obtained from questionnaires and interviews were qualitatively analysed and used to correlate with information obtained from test results.

2.2 Laboratory investigations

Sieve Analysis

Sand and quarry dust samples obtained from all sites went through the same procedure of sieve analysis. The sample obtained was first dried in an oven at a temperature of 110°C for a time duration of 24 hours. After the sample was taken from the oven, 1000g of each of the samples was weighed and poured in the rightly arranged series of sieves as shown in Fig. 1. Available sieves arranged from top to bottom are as follows, 9.5 mm, 4.75 mm (No. 4), 2.36 mm (No. 8), 1.18 mm (No. 16), 600 micron (No. 30), 300 micron (No. 50), and 150 micron (No. 100).



Fig. 1. Samples prepared for oven drying

The samples of fine aggregate (sand) and quarry dust were in turns poured in the top sieve was covered with a lid and shaken in motions making sure particles were sieved through the various sieves. After shaking, particles retained on the various sieve sizes were weighed and data of their weights were taken down. Percentage of sand retained was computed as:

$$\text{Percent retained} = \frac{\text{weight retained}}{\text{total weight of sample}} \times 100 \quad (1)$$

The calculation of the cumulative percentage retained was done by adding the percentage weight retained on the preceding sieve to the weight on the succeeding sieve. The percentage passing was then computed by multiplying the cumulative percentage retained on each by 100 and compared to the permissible percentage passing as per ASTM C136 shown in Table 1.

Table 1. Permissible Percent passing for Fine Aggregates (As per ASTM C136)

SIEVE SPECIFICATION	PERCENT PASSING BY WEIGHT
9.5mm	100
4.75mm (No. 4)	95-100
2.36mm (No. 8)	80-100
1.18 mm (No. 16)	50-85
600 micron (No. 30)	25-60
300 micron (No. 50)	5-30
150 micron (No. 100)	0-10

Water absorption

Firstly, block samples were placed in an oven at 105°C for 72 hours. This is done to take out any moisture in the sample block and to render the block dry. After drying in the oven, sample blocks are weighed and their dry weight was recorded, the blocks are then totally immersed in a distilled water tank for 24 hours as shown in Fig. 2. The surface of the sample block is then cleaned with an absorbent cloth immediately after sample block is removed from the distilled water tank and then their weights were recorded.



Fig. 2. Block Samples Immersed in Water

Water absorption is the ratio of mass increase to the dry mass of the sample expressed as a percentage. It is expressed as: $\frac{M_2 - M_1}{M_1} \times 100\%$; where M_2 and M_1 are wet and dry mass of the sample, respectively.

Compressive strength

To provide a firm basis for comparison of results, blocks were obtained from producers using the same type of cement. Three blocks from producers were crushed using the universal compression testing machine to determine their compressive strength in accordance with GS 297-1:2010 (Annex A). Compressive strength is influenced by the level of quality control employed (Afolayan et al., 2008); good selection of materials and adequate curing method (Abdullahi 2005), type of cement used etc. The blocks were placed in the universal testing machine (Fig. 3) such that the line of action of force passes through the centroid of the blocks and the edges of the blocks parallel to the edges of the steel plates. The first lever was engaged, and the machine was switched on. The second was engaged immediately the meter begins to read above the zero mark. The machine was switched off at the point the meter stops graduating or remains stationary i.e. the point of failure has been detected. The failure load was read and recorded and after that the levers were returned to their initial positions in reverse order.



Fig. 3. Block Sample in an ADR Compressive Machine

Requirements by the Ghana Standards (GS: 297-1:2010) shown in Table 2 were used to compare the individual compressive strength of the blocks.

Table 2. Ghana Standard specifications for compressive strength of sandcrete blocks.

PROPERTY(UNIT)	BLOCK CLASS	MINIMUM REQUIREMENT
Compressive strength (N/mm ²)	Class A	4.0
	Class B	3.0
	Class C	2.5

Class A-For external use, load-bearing wall; Class B-For internal and external, use load-bearing walls (if protected); Class C- For internal and external use non-load bearing wall. (GS 297:2010)

For the analyses of water absorption and compressive strength, the average result values from all samples of each supplier were found, hence presented in the graphs as shown under the results and discussion.

3. Results and discussion

3.1. Sieve Analysis

The Percent passing for block samples are plotted in Fig. 4 and Fig. 5. Percent passing for samples of all suppliers is plotted against the log of the sieve sizes and compared with the permissible Percent passing values for fine aggregates. This is shown in Figs. 4 and 5. It can be deduced that the quarry dust is coarser than the sandcrete aggregate for sieve sizes between 1.18 mm and 9.5 mm whilst quarry dust is slightly finer than the sandcrete aggregate within the sieve size range of 0.15mm and 1.18mm.

3.2 Water absorption

The average water absorption of block samples is shown in Fig 6 and Fig. 7. From these two Figures, water absorption values for all the suppliers of sandcrete and quarry dust cement blocks are seen to be reasonably low as compared to results obtained by Anosike and Oyebade (2011). The Ghana Standard (GS 297-1:2010) does not specify the maximum percentage of water absorption value for sandcrete blocks. However, the Nigerian Industrial Standard specifies maximum water absorption value of 12%. The water absorption values falling below the specified maximum value can be attributed to the fact that all the suppliers used machine compaction. The highest individual average water absorptions as shown in Figs. 6 and 7 for sandcrete blocks and quarry dust cement blocks were 4.02% and 4.46%, respectively. The average water absorptions were 3.90% and 3.28% for sandcrete and quarry dust cement blocks respectively. The water absorption of quarry dust cement blocks is found to be lower than sandcrete blocks. This agrees with findings made in a study by Oyekan and Kamiyo (2008), where the water absorption of sandcrete blocks decreased with the introduction of quarry dust as substitute for sand. Quarry dust is found to be less permeable for liquid flow than sand.

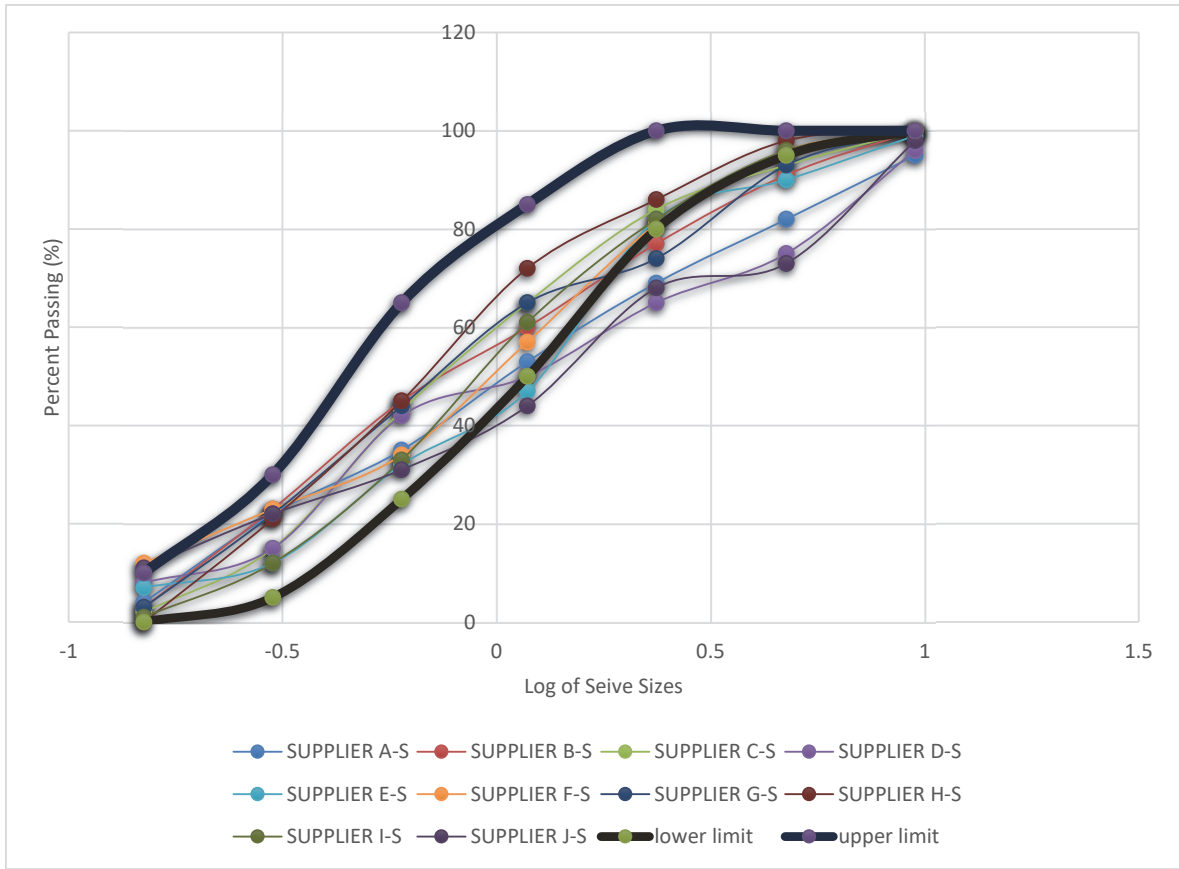


Fig. 4. Sieve Analyses of Sandcrete Blocks

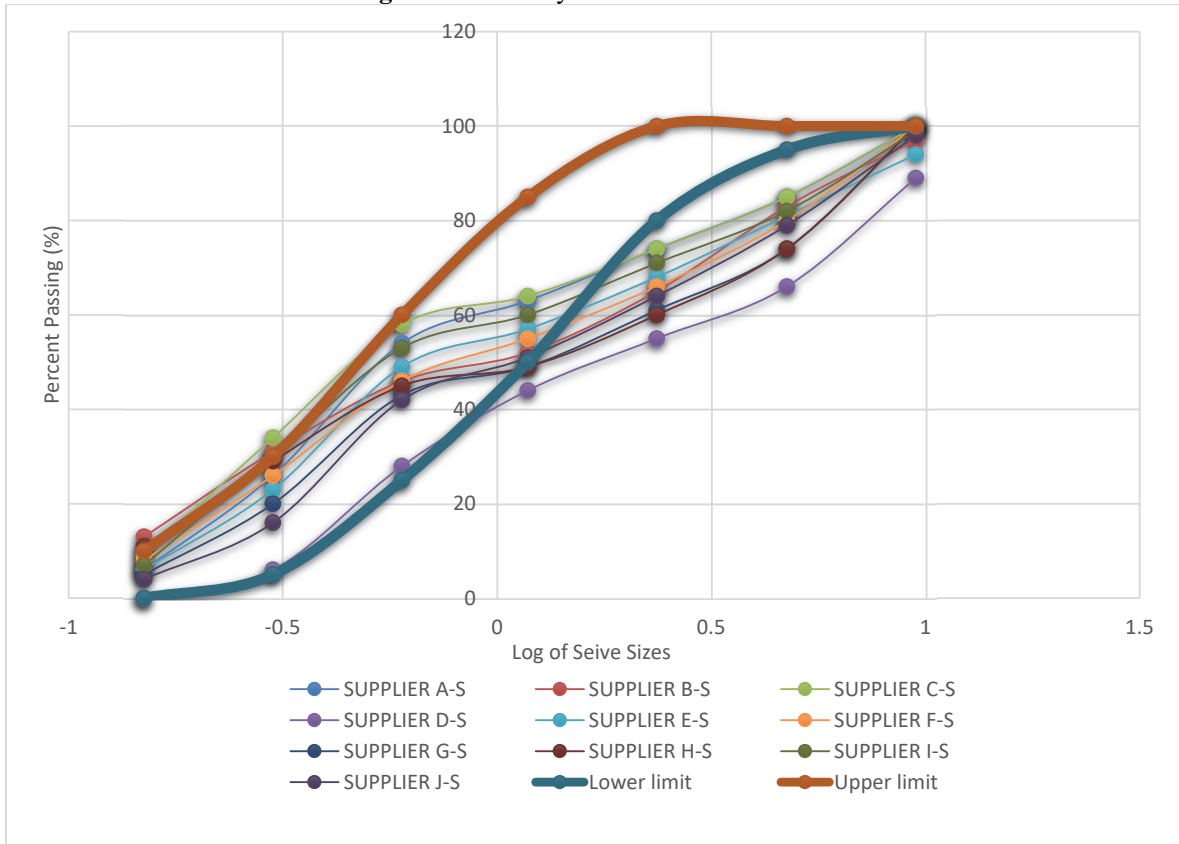


Fig. 5. Sieve Analyses of Quarry Dust Cement Blocks

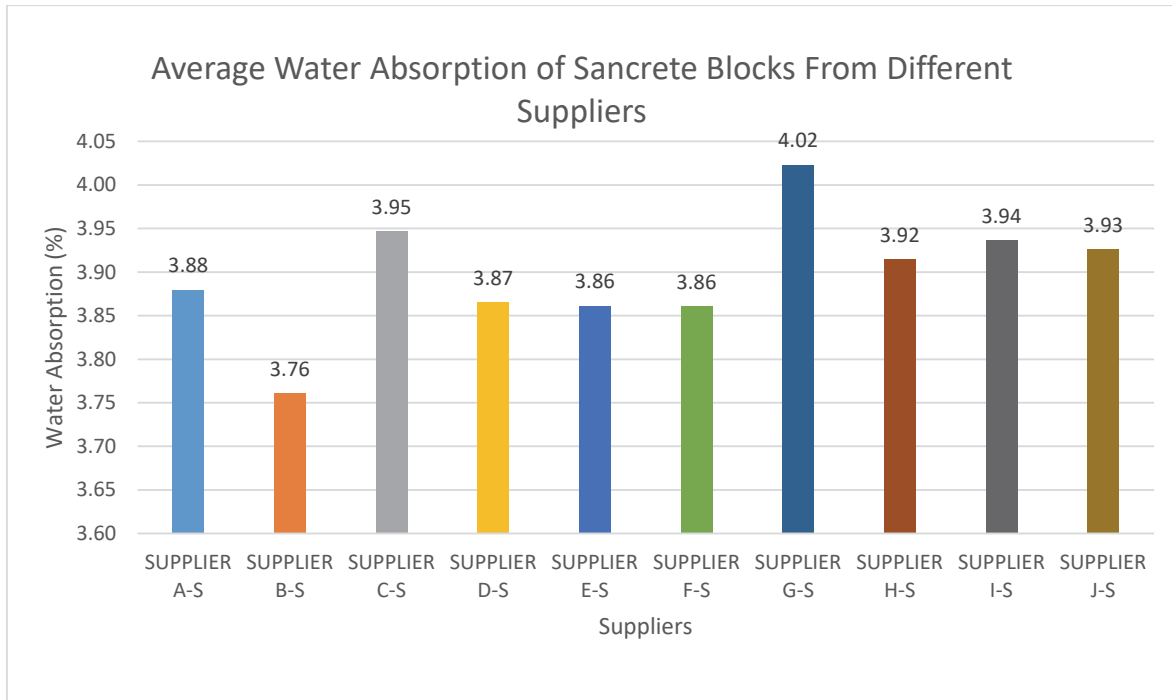


Fig. 6. Average Water Absorption of Sandcrete Blocks From Different Suppliers

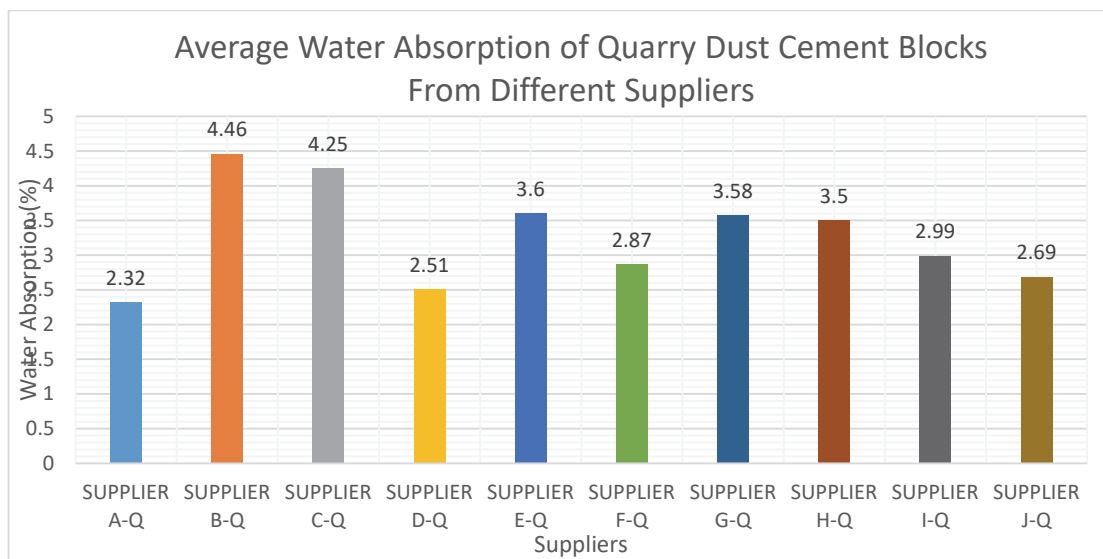


Fig. 7. Average Water Absorption of Quarry Dust Cement Blocks From Different Suppliers

3.3 Compressive Strength

Average compressive strengths of block samples are shown in Figs. 8 and 9. The Ghana standard specifies minimum compressive strength requirements of 4.0N/mm^2 , 3.0N/mm^2 and 2.5N/mm^2 for class A, class B and class C, respectively. Class A – for external use load-bearing wall; Class B – for internal and external (if protected) use load-bearing wall; Class C – for internal and external use non-load bearing wall. The lowest average compressive strengths are recorded to be 3.0N/mm^2 and 2.0N/mm^2 for sandcrete blocks and quarry dust cement blocks, respectively. The highest average compressive strengths were recorded to be 5.60N/mm^2 and 7.11N/mm^2 for sandcrete blocks and quarry dust cement blocks, respectively. The total average of all the suppliers were 4.31N/mm^2 with a standard deviation of 2.1

N/mm^2 and 3.0 N/mm^2 with a standard deviation of 1.4 N/mm^2 for sandcrete blocks and quarry dust cement blocks respectively. It is hence seen that sandcrete blocks had higher compressive strength than quarry dust blocks.

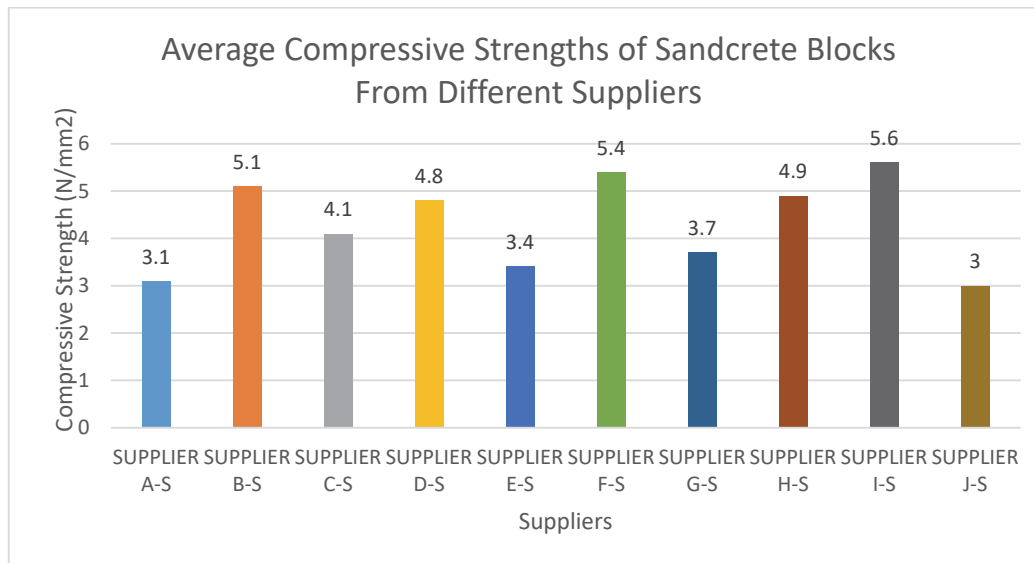


Fig. 8. Average Compressive Strengths of Sandcrete Blocks From Different Suppliers

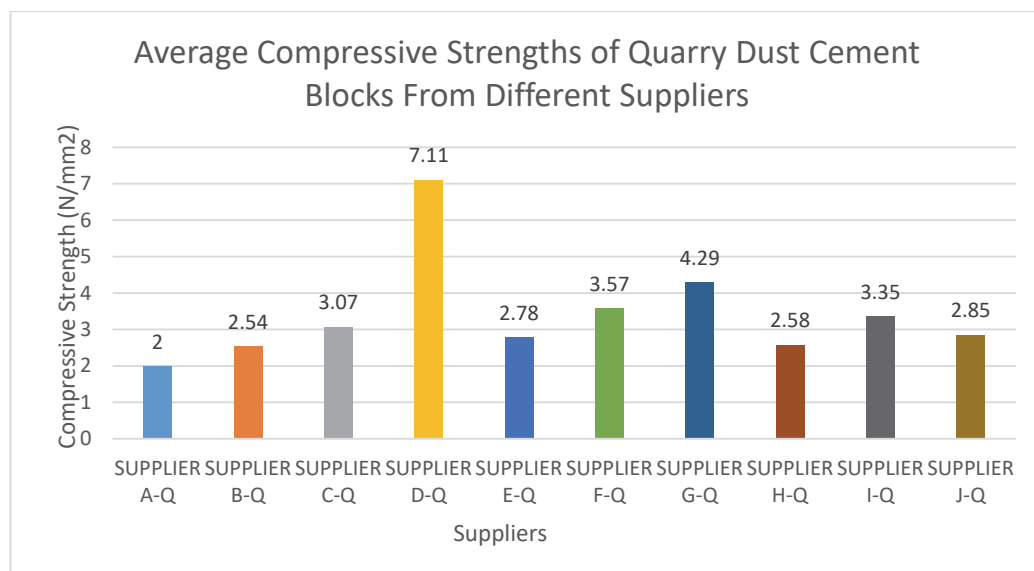


Fig. 9. Average Compressive Strengths of Quarry Dust Cement Blocks From Different Suppliers

4. Concluding remarks

Based on the standard specifications of the American Standard for Testing Materials (ASTM), it can be deduced that the quarry dust is coarser than the sandcrete aggregate for sieve sizes between 1.18 mm and 9.5 mm whilst quarry dust is slightly finer than the sandcrete aggregate within the sieve size range of 0.15 mm and 1.18 mm..

The water absorption values fell below the specified maximum value of 12% per the Nigerian Industrial Standard. The overall average water absorptions were 3.90% and 3.28% for sandcrete and quarry dust

cement blocks, respectively. Generally blocks made from quarry dust have a lower absorption rate than those from the natural sand.

The total average compressive strength for the sandcrete blocks was found to be 4.31 N/mm² with a standard deviation of 2.1 N/mm². While that of quarry dust cement blocks was found to be 3.0N/mm² with a standard deviation of 1.4 N/mm². The Ghana Standard specifies the base minimum to be 2.5 N/mm², which makes samples fall averagely within the specifications. However, the sandcrete blocks appeared to be of higher compressive strength than the quarry dust cement blocks. This could be due to the proportion of cement in the mix for the production. There is the likelihood of using less cement in the production of quarry dust cement blocks because of the colour of the block being similar to that of cement.

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