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Effect of Sand Grading on the Compressive Strength of Sandcrete Block

Nasiru Sani Rimintsiwa
Lecturer, Department Name of Civil Engineering, Baze University, Nigeria
Abdullahi Muhammed
Professor, Department of Civil Engineering, Federal University of Technology, Nigeria
AbdulRahman Aminu
Researcher, Department of Civil Engineering, Kano University is Science and Technology, Nigeria

Abstract:
The effect of grading of sand on the compressive strengths of sandcrete blocks produced from different sands obtained in River Wudil, Kano State was investigated. The mode of curing in all the block samples was by spraying/sprinkling water on the blocks twice daily for two days. This method of curing especially at the early stages could have negative effect on the strength. This is due to the fact that most of the water required for hydration process must have evaporated. Blocks produced from finer sand came first in terms of compressive strength which is higher than that required by standard, while blocks produced with fine sand have their compressive strengths to be second at 14days of curing. Blocks produce from sharp sand came third in terms of compressive strengths based on the analysis of this study. Compressive strength test indicates that the average compressive strength of sandcrete blocks ranges between 0.11N/mm^2 to 1.3N/mm^2. The values fall below the standard prescribed for load bearing sandcrete blocks. Nigerian Industrial Standard (NIS 87: 2000) specified that the lowest compressive strength of individual load bearing blocks shall not be less than 2.5 N/mm^2 and average compressive strength of five blocks shall not be less than 3.45 N/mm^2. The results also indicate poor quality control in the sense that the strength results show wide range within the same lot.

Keywords: *Compressive strength, fine sand, sharp sand and sandcrete block*

1. Introduction

1.1. Background of Study

Oyekan (2011) revealed that hollow Sandcrete blocks containing a mixture of sand, cement and water are used extensibly in many countries of the world especially in Africa, Sandcrete block unit are commonly used in Nigeria for the construction of load bearing wall, they are also useful for the creating partitions in building, hording of construction wall, fencing, creating barriers and other protective purposes. Awodiji (2014) reported that, they are also rectangular and have various sizes, the commonest being 450mmx225mmx225mm, 450mmx150mmx225mm, 450mmx125mmx225mm 450mmx100mmx225mm. The first two referred to as hollow sandcrete block appear with holes, which run from top to bottom and about one-third of the volume of the blockwhile the last two are manufactured without holes and are called solid sandcrete blocks.

According to Anisike and Oyebande (2012), the composition of sandcrete block is usually (1:6) mix of cement and sand moistened with water and allows drying naturally. It has a composite material made up of cement, sand and water, molded into different sizes (NIS 87:2000). As seen in Kamiyo (2011), the high and increasing cost constituent materials of sandcrete block have contributed to the non-realization of adequate housing for both urban and rural dwellers. Hence, availability of alternatives to these materials for construction is very desirable in both short and long terms as stimulant for socio-economic development. In particular materials that can complement cement in the short run, especially if cheaper, will be of great interest.

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 condition 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. 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 is constructed using sandcrete blocks. The wide use of sandcrete blocks in the building and construction industry has made it 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 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. The availability of these rivers makes it easier to use river sand rather than clay, for blocks production in those areas. In minna and its environs, sand is sourced from wheelbarrow pits and river beds. The use of sand for block molding thrives in area 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 strength 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 block production method 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.

Therefore, this research work focuses on the investigation and comparison of the compressive strength of sandcrete blocks produced using different graded varying sand within river Wudil, Kano state.

1.1. Problem Statement

Nowadays development of infrastructure is becoming number one priority in the world, particularly in developed countries. This has led to high demand for the sandcrete block. Sandcrete block are being produced in commercial quantities but with low standard. Omopariola (1970) reported that, several researchers have confirmed the low qualities of sandcrete blocks in Nigeria. None of this works discussed the quality of sandcrete block in Wudil, Kano state. As a result, research, contractors, consultants and other professionals-built environment lack the knowledge of quality of sandcrete blocks produced in Wudil, Kano state.

1.2. Aim and Objectives

The aim of this project is to investigate the effect of grading of sand on the compressive strengths of sandcrete blocks produced from different sands obtained in River Wudil, Kano State.

The objectives of this work are:

- To determine the physical properties of the sand obtained from three locations within River
- Wudil, Kano State.
- To determine the compressive strengths of sandcrete blocks produced using sand obtained from River Wudil, Kano state.
- To compare the compressive strengths obtained in (ii).

1.3. Justification

Determination of the effect of sand grading on compressive strength of sandcrete block from the different places and the comparison between them will be of great importance to block industries especially in selecting the best sand for a particular sandcrete production.

1.4. Scope and Limitations

This research work is limited to three (3) different places i.e. Three samples D, E, F (sample D sharp sand, sample E fine sand and sample F finer sand) at the Garindau village side within River Wudil Kano state, it includes collection of the varying sand from the three places, determination of the properties of these sands, moulding of sandcrete blocks (30) and subjecting the blocks to compressive strengths tests.

2. Literature Review

According to Abdullahi (2005), the word sandcrete block has no standard definition, what most workers have done were to define it in a way to suit their own purpose. The qualities of the block were inconsistent to the different inconsistent materials. Sandcrete block are usually bedded or joined together in Nigeria using cement mortar in stretcher bond. The spate of the collapse of building has put in the front burner the need to investigate the quality of building material available to and commonly used builders and developers, one important area of concern is the quality of sandcrete blocks especially when they are used in construction of load bearing walls. Available evidence shows that the quality of sandcrete block differs from one block manufacturing industry to the other. However, Elinwa (2002) agrees that, the quality and standardization of sandcrete block are paramount importance in the study of building component since this will serve as yardsticks for measurement, reflecting the level of development attained by a nation.

2.1. Component of Sandcrete Blocks

The following components were used in producing the sandcrete blocks used in this research work.

- Sand.
- Cement.
- Water

2.1.1. Sand

Sand which is an extremely needful material for any construction is the product of natural or artificial disintegration of rocks and minerals. Sharp, fine and finer sand free from waste stone and impurities were used in the production of the sandcrete blocks used in this research work.

2.1.2. Cement

There are various types of cement for block work. According to standard, cement to be used for block work should be ordinary Portland land cement (Dangote cement) produced in accordance to the requirements and shall be delivered in the original sealed bags of the manufacturer or registered bulk delivery trucks.

Cement is manufacture from clay and chalk mixed in certain proportions. Portland cement is the type most generally used for block work, but other types are manufacture mainly for used in reinforced concrete construction. Among these are rapid hardening, high aluminous [super rapid hardening] and water resisting cements. Hodge (1971), cement is kin to hydraulic lime, but is much stronger. This does not mean, however that they are better suited for all types of block work.

2.1.3. Water

Portable water which is free from suspended particles, salts and oil contamination were used throughout this study as specified by a method of test BS3148

2.2. Type and Sizes of Sandcrete Blocks

Sandcrete blocks come in variety of sizes. Blocks are produced to meet the standard sizes in accordance with NIS 87:2000.

The standard and most common sizes of the sandcrete blocks are;

- 450mm x 225mm x 225mm
- 450mm x 150mm x225mm
- 450mm x 125mm x 225mm
- 450mm x100mm x225mm

Every walling material undergoes dimensional changes with changes in temperature, especially if accompanied by drying and wetting. These kinds of changes can cause cracking of block walls unless adequate precautions are taken. The changes may be small but with sandcrete blocks, the problem may be aggravated due to additional non-reversible shrinkage caused by chemical chase associated mainly with the process of carbonization, hydration and curing. Adequate curing of blocks is essential to ensure sufficient hydration of the cement. The method of curing employed can significantly affect the properties of the blocks, since it contains cement and sand. Strength can only be gained if blocks are subject to conditions in which moisture is retained long enough for the setting of the cement.

2.3. Standard Production Process of Sandcrete Blocks.

Sandcrete blocks are produced with a mixture of sand, cement and water. The process consists of about six steps as explained as shown in Figure 1.1.

2.3.1. Step I: Batching

Batching is the measuring of the materials for the production of the blocks. There are two methods of batching: batching by weight and by volume. In most cases batching by volume is the practice by small-scale firms. Batching by volume is carried out with the aid of head-pan or wheelbarrow. In the case of batching by weight, the raw materials are discharged into a weigh batcher, which measures the correct proportion of dry materials for the mix (http://www.arch.virginia.edu/build/concrete).

2.3.2. Step II: Mixing

After batching, the next step is mixing of the materials together. Mixing could be done manually or mechanically. For the small-scale firms, the mixing is done manually. Sand and cement are mixed thoroughly before water is added to it. It is recommended that the water should be drinkable, and the same water content should be maintained in the subsequent batches, so there would not be any difference in quality.

2.3.3. Step III: Filling the Moulds

After mixing, the next step is the filling of the moulds with the mixed materials.

2.3.4. Step IV: Compaction

After filling the moulds, the material is compacted to remove voids inside the mixed materials. This enhances the quality and durability of the blocks. The compacted blocks are then pushed out of the moulds onto a flat wooden pallet and placed in a prepared location.

2.3.5. Step V: Curing

This is the wetting of the sandcrete blocks with water. As seen in Ezeji (1994), the application may be done by watering can, rubber hose or buckets, or simply splashing water on the blocks by hand. Most producers in Nigeria use water hoses. The quality of sandcrete blocks is improved by water curing (Foraminifera Market Research, 2014)

2.3.6. Step VI: Stacking

This is the arrangement of the blocks one on top of the other, ready for sale or use.

2.4. Previous Work

Also, from Okapor and Ewa (2012), Sandcrete block are the commonest and most popular masonry unit in Nigeria. The most essential and expensive constituent of the block is cement; to minimize cost and maximize profit, commercial producers of this blocks reduce the quality of cement needed to give acceptable quality required standards. Baiden and Tuili (2004), Sandcrete block are the most widely used walling unit in Nigeria, accounting 90% of houses.

The Nigerian Industrial Standard (NIS 87:2000) provides the minimum range of compressive strength of sandcrete blocks between $2.5N/mm^2$ and $3.45N/mm^2$. The objective of Nigerian Industrial Standard (NIS 87:2007) is that all block manufacturers meet the minimum standard. Improper use of these blocks lead to micro cracks on the wall after construction (Anosike and Oyebande 2012: Baiden and Tuili, 2004). In most cases the producers and users of these blocks lack adequate engineering knowledge on the strength requirement of sandcrete blocks.

Abdullahi (2005) revealed that the compressive strength of commercial sandcrete block in minna, Nigeria was below the standard recommended by Nigerian Industrial Standard (NIS 87:2000). The compressive strength of the block was found to vary between $0.11N/mm^2$ and $0.75N/mm^2$. Oyetola & M.A (2006), the poverty level among the West African countries and particularly Nigeria has made this block widely acceptable among the people so as to minimize the cost of construction. These blocks are produced with low amount of ordinary Portland cement.

From some of the conclusions that could be drawn from the results of test by workers likeVallengers (1988), the strength of all sandcrete materials tested with compressive strength increasing with increased cement content. However, it is important to understand the true significant of the foreword to (BS3921:1965) point out that strength is not to be taken as an indication of durability. The bricks or block may be badly affected by adverse climatic condition such as alternating damp and severe frost. In most applications, durability is the important properties of block work (BS3921:1965).

2.5. Blocks

A block is a masonry unit of a larger in all dimensions than specified for bricks but no dimension should exceed 650mm nor should the height (in its normal aspect) exceed either its length or six times its thickness.

2.5.1 Classification of Sandcrete Block

Baiden and Tuuli (2004), Over 90 percent of houses and many other types of building in Nigeria are constructed using sandcrete blocks. It is a load bearing and non-load bearing wall unit. The blocks are supposed to have adequate compaction pressure so that they can confidently be used in building of walls and other structures at various levels during construction. Hamza et (2009), considering the three main classification types of sandcrete blocks i.e. solid, cellular and hollow, the hollow sandcrete block is more economical in terms of weight, density and compressive strength and is commonly used in construction work. The British standard 6073:1981 part 1 defines block as a masonry unit of large size in all dimension specified for bricks but no dimension should exceed 650mm nor should the height exceed either its length or six times its thickness. In harden state, sandcrete block has high compressive strength and this strength increases with density.

According to NIS (2001), hollow sandcrete blocks are classified as:

- Type A: dense aggregate concrete blocks, density of $1500kg/m^3$.
- Type B: light weight aggregate blocks for load bearing walls, density greater than $625kg/m^3$.
- Type C: light weight aggregate blocks for non-load bearing position, density is less than $625kg/m^3$.

Types of Block	Actual Size, Length, Height, Width	Nominal Size, Length, Height, Width
Dense aggregate blocks	440 by140 by 90	450 by 150 by 100
	440 by 225 by 225	450 by 225 by 225
	440 by 225 by 140	450 by 225 by 150
Lightweight aggregate blocks (load bearing)	440 by 140 by 90	450 by 150 by 100
	440 by 215 by 140	450 by 225 by 150
	140 by 150 by 225	150 by 150 by 225
	440 by 140 by 65	450 by 150 by 75
Non-load bearing lightweight blocks	450 by 215 by 40	450 by 225 by 50
	440 by 215 by 65	450 by 225 by 75

Table 1: Block Sizes According to BS 6073-Part 1and 2:1981

Manufactures Designation (Mm)	Block Size (Mm)	Web Thickness (Mm)
1	450 by 225 by 100	25.0
2	450 by 225 by 150	37.5
3	450 by 225 by 225	50.0

Table 2: Shows Block Size According to NIS 87:2000

2.6. Properties of Sandcrete Blocks

2.6.1. Strength

The compressive strength of the weakest individual block must not be less than 80% of the average compressive strength of 10 blocks. In this way control is exercised on quality of the block in the consignment as a whole. The average compressive strength of blocks in wet state at 28 days age is required to be 2.8 N/mm2. This strength requirement was lowered to 2.5 N/mm2 or 360 P.S.I, NIS74:1976.

2.6.2. Durability

Unlike bricks, moist works are covering with a covering finishes such as rendering, painting, and tyro-leans title. This finish serves as to protect the block from direct contact with adverse weather conditions. In industrial areas, atmospheric pollution may be particularly strong affecting the durability of facing block. The type of weather conditions that prevail in most tropical areas, no problem should be encounter with the durability of sandcrete hollow block works.

2.6.3. Fire Resistance

The fire resistance of hollow sandcrete block wall depends on the geometry and density of the block. The geometry affects thickness. The fire resistance of a block wall increases as the block density increases. Samson et al. (2002) reveal that hollow sandcrete blocks are non-combustible material with class 'zero' rating of flame speed. An un-plastered thickness of 100mm gives two hours of fire resistance with a wide range of material including block work.

2.6.4. Sound Transmission

Fencing block with an open texture may be unsuitable as a barrier to sound transmission unless at least one side is properly plasticized or painted to seal the cavity in the texture. Light weight aggregate blocks perform better in this regard.

2.6.5. Thermal Insulation

Light weight sandcrete blocks provide good insulation. In general, the lighter and more porous the block, the better will be its insulation value. Therefore, holes in blocks should not be filled during operation.

2.7. Factors Affecting the Strength and Properties of Blocks

Gooding and Thomas (2003) portrayed that the strength characteristics of sandcrete are influenced by a variety of factors whose effect is not sufficiently understood to permit accurate forecasting particularly under test condition. The time of mixing of sandcrete and also the time lapse between mixing and compaction has been found to affect the strength; experiment conducted has confirmed the strength loss due to compaction delay. Improper curing also affects the strength of block, experiment conducted at university of Warwick have shown that the strength lost due to poor curing can easily reduce the final block bulk strength by 20%, as the block surface losses water first, strength loss in these regions is still higher.

2.8. Improvement on Sandcrete Blocks

According to the Thomas and Gooding (2003), there are four main areas in which improvement may be made to the sandcrete block production, curing practice, production methodology, soil/sand selection and processing compaction equipments. The poor curing practice observed in the field cause a significant under attainment of compressive strength and durability. This is usually 20% but depend on the degree of adversity experienced by the block during curing.
Similarly, immediate improvements, either reduction in cost or increase in quality, will result from improved understanding used to implement better production practice. Reduction in batched time, optimum moisture (water) content used for moulding and consistent compaction all increases the quality of the cured block.

2.9 Compaction on Sandcrete Block

According to Baidan and Asante (2004), Manual tamping method should be discouraged as they are unable to consolidate the mix properly and consequently produce blocks of unacceptable strength. The best method of compaction of sandcrete blocks should be by using machine vibration. Typical dimension of sandcrete block is shown in Figure 2.2

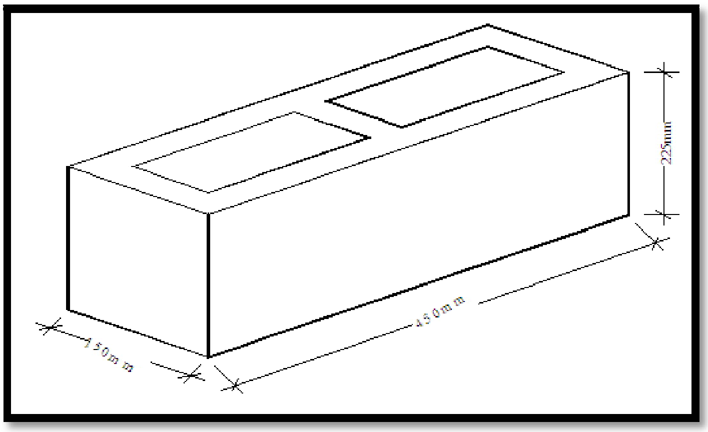

Figure 1: Typical Dimension of Sandcrete Block

3. Materials and Method

3.1. Materials

<u>3.1.1. Cement</u>

The cement used was Ordinary Portland Cement (OPC) i.e. Dangote cement, bought from a cement depot at Wudil, Kano State and it was conformed to specification for Portland cement.

<u>3.1.2. Sand</u>

The sand collected from three different places i.e. three samples (D, E, F) at Garindau village side within river Wudil Kano state were varying sand used as sharp, fine and finer sand also free from clay and organic matter.

<u>3.1.3. Water</u>

Portable water was used for the mixing and it was properly examined to ensure that it was clean, free from contaminants either dissolved or in suspension and good or fits for drinking.

3.2. Methods

The following experimental works were conducted in this research.

<u>3.2.1. Sieve Analysis Test</u>

3.2.1.1. Apparatus

Electric weighing balance, scoop, mechanical sieve shaker, weighing pan, set of brush.

<u>3.2.1.2. Test Procedure</u>

According to BS882:1992, This was carryout in the laboratory using different sets of sieve sizes of numbers (5.00mm, 3.35mm, 2.00mm, 1.18mm, 850um, 600um, 425um, 300um, 150um, 75um and collecting pan).
The samples collected from each place (i.e. Sample D, E, F) were dried and 1000g of it was used for sieve analysis. Each sieve was weighed empty and the weight was recorded. 1000g sand was poured in to the arranged sieve and was carefully placed on the sieve shaker. The machine (sieve shaker), was then put on and the sieve was allowed to be shaken or vibrates for 10 minutes. The sieves were gently removing from the machine, and were separated in sizes. The weight of each sieve and sample retained were noted and recorded. The result obtained was tabulated and graphs were plotted, and shall be shown in chapter four.

<u>3.2.2. Specific Gravity Test</u>

3.2.2.1. Apparatus

Pyconometer, cylindrical bottle (1000ml), digital weighing balance, rubber stopper (cork), oven, water and dried sample of sand.

3.2.2.2. Test Procedure

The samples sand collected from each place were used for the experiment in accordance to BS 882: (2004). The weight of the cylinder was taken and recorded as M_1. The sand sample was then poured into the cylinder and weighed as M_2. Small amount of water was added to the cylinder containing the sand sample and was thoroughly shacked, the cylinder was then filled up with water, and the outside of the cylinder was wiped dry and cylinder plus sand plus water was weighed and recorded as M_3. The weight of cylinder plus water full was taken and recorded as M_4. The experiment was then repeated for each sample from different places.

Therefore, the specific gravity of the sand shall be calculated from equation below and the result will be shown in chapter four.

$$\text{SpecificGravity} = \frac{(M_1 - M_2)}{(M_4 - M_1) - (M_3 - M_2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Were,

M_1 = weight of cylinder
M_2= weight of cylinder + soil
M_3 = weight of cylinder + soil + water
M_4 = weight of cylinder + water only.

3.2.3. Bulk Density Test

3.2.3.1. Apparatus

Weighing balance, compaction mould, measuring ruler, metal hammer (tamping rod) and sand sample.

3.2.3.2. Test Procedure

The internal volume Vcm^3 of the mould / container was determined in accordance to BS 882: (2004). The mass of the mould was determined and recorded as M_1, the mould was then filled with sample in three layers, with each layer receiving 25 blows from approximately height of 75cm. the top of the mould was then leveled, and the mould containing compacted sand was weighed and recorded as M_2. The experiment was repeated for at least three times for each sample taken from three places.

For uncompacted bulk, the same procedure was also followed. But in this case, the sample was only poured in the mould without compaction and the weight of the mould plus sand sample (uncompacted) was determined and recorded as M_2. The result obtain from the experiment will be shown in chapter four.

Bulk density shall be calculated from this equation;

$$\text{BulkDensity} = \frac{M_a}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

$Ma = M_2 – M_1$

Where;

M_1= mass of mould
M_2 = mass of mould + compacted / uncompacted soil
V = volume of mould expressed in Cm^3

3.2.4. Moisture Content Test

3.2.4.1. Apparatus

Weighing balance, oven, moisture content can

3.2.4.2. Test Procedure

Two dry and empty moisture cans were weighed for each from three different places. Small sample were poured on these containers and weighed as can plus wet sample, and were placed in Oven for 24hrs. After 24hrs, the samples were then removed from the oven and were weighed and recorded as can plus dry sand. The values obtained tabulated in chapter four as specified in BS 882: 2004.

The moisture content is calculated from the relationship below,

$$\text{WaterContent} = \frac{\text{WeightofWater}}{\text{WeigthofDrySample}} (\%) \quad \ldots\ldots\ldots (3.4)$$

3.2.5. Water Absorption Capacity

Each specimen of the deployed block sample was first weigh in a dry state to obtain its dry mass (M_1) and then fully immersed in water for 24hours when the samples were completely wetted, they were removed and the trace of water were wipe off with a damp cloth and then weigh again to obtain wet weight(M_2). This procedure was repeated on other samples and the result was computed as;

$$\text{Water Absorption Capacity (\%)} = \frac{M_2 - M_1}{M_1} \times 100 \quad (3.1)$$

The result obtained from the above formula is as shown in chapter four (Table 4.1-4.6). The average of the results obtained was regarded as the water absorption of the block and shall not exceed 12% (NIS 583:2007).

3.3. Mixing and Moulding

The mixes of sand-cement at 1:8 by weight were prepared for each sand from each placei.e. three samples, 10 blocks of size 450mm x225mmx 150mm were moulded for each place. A total of (30) blocks were produced manually and cured under laboratory condition for 7, 14 days. To ensure even distributions of blows in the mould, 200mm square sheet of 15mm thick plywood was placed on the mixture in the mould and compaction was done on it with each block receiving approximately 7 blows of rammer falling from a height 25cm height. The freshly moulded blocks were carefully extruded in good shape on a clean, hard and flat surface.

3.4. Curing

The sandcrete blocks produced were left for at least 24hrs without watering to set. After setting, the blocks were wet by watering it surface twice every day for 7, 14 days respectively.

3.5. Compressive Strength Test

3.5.1. Apparatus

Crushing machine, weighing balance, duster or cloth

3.5.2. Test Procedure

The different sets of blocks moulded were tested for strength using the universal testing machine. The machine consists of two metal plates (one on top and the other at the bottom of the block) were used during the testing, so that the blocks being tested were put under fairly constant compressive load until the point of failure was reached in each case.
The testing machine is calibrated in kilo-Newton (KN). The failure point in the machine was indicated each time by the reversal of the direction of one of the two pointers movement. The other pointer staying gave the maximum compressive force. The compressive strength was calculated for each compressive force [crushed load] using the formula below;

$$\text{CompressiveStrength} = \frac{\text{CrushingLoad}}{\text{CrossSectionalArea}} (\text{N}/\text{mm}^2) \ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

4. Results and Discussion

4.1. Sieve Analysis

The sieve analysis results are shown in Table 4-4.4 and the particle size distribution curves of the sand are shown in Table 4-4.4. The results show that all the aggregates samples satisfy the overall grading limit according to BS 882: (1992). The aggregates are therefore suitable for block making purpose. Aggregate sample from sharp sand are fine grading which satisfy the overall grading limit except the percentage finer than 150um sieve size which was 1.99% falling outside the range of (0-15%). Sample from fine sand and finer sand are fine grading which satisfy the overall grading limit except the percentage finer than 150um sieve size which was 3.51% falling outside the range of (0-15%). This evident as their grading curve can be seen to fall toward the left (lower bound) the sand samples agree reasonably well and are recommended for construction purpose. It does not mean that any grading is recommended: a wide range of grading may be acceptable through a trial and error approach.

Bs Sieve	Percentage by Mass Passing Sieve			
	Overall grading	Coarse grading	Medium grading	Fine grading
10.0 mm	100			
5.0 mm	89 – 100			
2.36 mm	60 – 100	60 – 100	65 – 100	80 – 100
1.18 mm	30 – 100	30 – 90	45 – 100	70 – 100
600 µm	15 – 100	15 – 54	25 – 80	55 – 100
300 µm	5 – 70	5 – 40	5 - 48	5 – 70
150 µm	0 – 15			

Table 3: BS Requirements for Fine Aggregate

The results of obtained from the experiment carried out is calculated and shown in tabular form in the following tables 4.2 -4.4

Sieve Sizes	Sieve Weight (g)	Sieve Weight + Sample (g)	Weight of Sample Retained (g)	Percentage Retained	Cumulative % Retained	Percentage Finer
5.00mm	479.5	505.6	26.1	2.61	2.61	97.39
3.35mm	468.4	479.9	11.5	1.15	3.76	96.24
2.00mm	420.1	466.1	46.0	4.6	8.36	91.64
1.18mm	391.1	502.9	111.8	11.18	19.54	80.46
850um	358.7	474.8	116.1	11.61	31.15	68.85
600um	336.0	550.1	214.1	21.41	52.56	47.44
425um	329.5	535.6	206.1	20.61	73.17	26.83
300um	316.2	474.1	157.9	15.79	88.96	11.04
150um	295.7	386.2	90.5	9.05	98.01	1.99
75um	296.9	307.1	10.2	1.02	99.03	0.97
Pan	304.3	306.8	2	0.2	99.23	0.77
			992.3			

Table 4: Particle Size Distribution Of Sharp Sand

Total weight of sample = 1000g

$$\text{PercentageRetained} = \frac{\text{WeightofSandRetainedonSieve}}{\text{TotalWeightofSandRetainedonSieve}} \times 100$$

Cumulative % Retained = summation of % retained on each sieve
Percentage finer = 100 - cumulative % retained

Sieve Sizes	Sieve Weight (g)	Sieve Weight + Sample (g)	Weight of Sample Retained (g)	Percentage Retained	Cumulative % Retained	Percentage Finer
5.00mm	479.5	492.1	12.6	1.26	1.26	98.74
3.35mm	468.4	480.9	12.5	1.25	2.51	97.49
2.00mm	420.1	455.1	35	3.5	6.01	93.99
1.18mm	391.1	483.3	92.1	9.2	15.21	84.79
850um	358.7	437.8	79.1	7.91	23.12	76.88
600um	336.0	439.1	103.1	10.31	33.43	66.57
425um	329.5	450.0	120.5	12.05	45.48	54.52
300um	316.2	561.2	245	24.9	70.38	29.62
150um	295.7	556.8	261.1	26.11	96.49	3.51
75um	296.9	326.8	29.9	2.99	99.48	0.52
Pan	304.3	312.0	7.7	99.48	100	0
			998.6			

Table 5: Particle Size Distribution of Fine Sand

Sieve Sizes	Sieve Weight (g)	Sieve Weight + Sample (g)	Weight of Sample Retained (g)	Percentage Retained	Cumulative % Retained	Percentage Finer
5.00mm	479.5	480.5	1.0	0.1	0.1	99.9
3.35mm	468.4	473.2	4.8	0.48	0.58	99.42
2.00mm	420.1	436.1	16	1.6	2.18	97.82
1.18mm	391.1	481.6	90.5	9.05	11.23	88.77
850um	358.7	525.2	166.5	16.65	27.88	72.12
600um	336.0	595.1	259.1	25.91	53.79	46.21
425um	329.5	515.8	186.3	18.63	72.42	27.58
300um	316.2	457.5	141.3	14.13	86.55	13.45
150um	295.7	395.1	99.4	9.94	96.49	3.51
75um	296.9	311.1	14.2	1.42	97.91	2.09
Pan	304.3	310.2	5.9	0.59	98.5	1.5
			985			

Table 6: Particle Size Distribution of Finer Sand

4.2. Specific Gravity

The average specific gravity obtained for samples of sand are 2.67, 2.68 and 2.57 which fall within the range of 2.4-3.0 (BS 2004).

Sample	Weight of Cylinder (M_1) (g)	Weight of Cylinder + Sand (M_2) (g)	Weight of Cylinder + Sand + Water (M_3) (g)	Weight of Water Only (M_4) (g)	Specific Gravity (GS)
Sharp Sand	125	197	415	370	2.67
Fine Sand	125	176	405	373	2.68
Finer Sand	125	161	380	358	2.57

Table 7: Specific Gravity of Sand

4.3. Bulk Density

From the results, the compacted bulk density for sharp sand sample D is higher than the loose bulk density. This is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids were replaced by more aggregates, there- by increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 according to Neville, (1983) in standard ratio of loose bulk density to compacted bulk density.

Number of Trial	Mass of Mould (M_1) (g)	Mass of Mould + Compacted Sand (M_2) (g)	Mass of Compacted Sand ($M_2 - M_1$) (Kg)	Bulk Density Kg/m³	Average Bulk Density Kg/m³
1	1068	3743	2.677	155.30	156.11
2	1068	3764	2.696	156.52	
3	1068	3765	2.698	156.52	

Table 8: Bulk Density of Sharp Sand (Compacted)

Number of Trial	Mass of Mould (M_1) (g)	Mass of Mould + Uncompacted Sand (M_2) (g)	Mass of Uncompacted Sand ($M_2 - M_1$) (Kg)	Bulk Density Kg/m³	Average Bulk Density Kg/m³
1	1068	3514	2.446	141.95	141.56
2	1068	3504	2.436	141.37	
3	1068	3504	2.436	141.37	

Table 9: Bulk Density of Sharp Sand (Uncompacted)

Number of Trial	Mass of Mould (M_1) (g)	Mass of Mould + Compacted Sand (M_2) (g)	Mass of Compacted Sand ($M_2 - M_1$) (Kg)	Bulk Density Kg/m³	Average Bulk Density Kg/m³
1	1068	3854	2.786	161.68	161.80
2	1068	3858	2.790	161.92	
3	1068	3856	2.788	161.80	

Table 10: Bulk Density of Fine Sand (Compacted)

Number of Trial	Mass of Mould (M_1) (g)	Mass of Mould + Uncompacted Sand (M_2) (g)	Mass of Uncompacted Sand ($M_2 - M_1$) (Kg)	Bulk Density Kg/m³	Average Bulk Density Kg/m³
1	1068	3615	2.547	147.81	147.72
2	1068	3609	2.541	147.47	
3	1068	3616	2.548	147.87	

Table 11: Bulk Density of Fine Sand (Uncompacted)

From the results, the compacted bulk density for fine sand sample E is higher than the loose bulk density; this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 according to Neville, 1983 in standard ratio of loose bulk density to compacted bulk density.

Number of Trial	Mass of Mould (M_1) (g)	Mass of Mould + Compacted Sand (M_2) (g)	Mass of Compacted Sand ($M_2 - M_1$) (Kg)	Bulk Density Kg/m³	Average Bulk Density Kg/m³
1	1068	3760	2.692	156.23	157.76
2	1068	3786	2.715	157.56	
3	1068	3816	2.748	159.48	

Table 12: Bulk Density of Finer Sand (Compacted)

Number of Trial	Mass of Mould (M_1) (g)	Mass of Mould + Uncompacted Sand (M_2) (g)	Mass of Uncompacted Sand ($M_2 - M_1$) (Kg)	Bulk Density Kg/m³	Average Bulk Density Kg/m³
1	1068	3528	2.460	142.76	144.89
2	1068	3602	2.534	147.07	
3	1068	3564	2.496	144.85	

Table 13: Bulk Density of Finer Sand (Uncompacted)

From the results, the compacted bulk density for finer sand sample F is higher than the loose bulk density; this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, there b increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 according to Neville, 1983 in standard ratio of loose bulk density to compacted bulk density.

4.4. Moisture Content

From the result shown in Table 14 the absorption value of sand was found to be 3.8,4.44 and 4.41 are the absorption value for sample D,E and F, this implies that the aggregates would require the corresponding values of their respective dry weight of water required by the samples to be in their saturated and surface dry states. The results also conform to the specification in BS 882 (2004).

Sand Sample	**Sharp**	**Fine**	**Finer**
Weight of cont. W_1(g)	25	25	22
Weight of cont. + wet sand W_2 (g)	73.8	53.2	57.5
Weight of cont. + dry sand W_3 (g)	72	58	56
Weight of moisture (W_2-W_3)g	1.8	1.2	1.5
Weight of dry soil (W_3-W1)g	47	37	34
Water Content = (w_2-w_3)/(w_3-w_1) x 100(%)	3.83	4.44	4.41
Average water content	4.23		

Table 14: Moisture Content of Sand

4.5. Water Absorption Capacity of Sandcrete Block Result.

The tables below show water absorption capacity of all the specimens collected from various commercial manufacturing industries as determine using the relationship below;

Absorption Capacity (%)= $\frac{M_2 - M_1}{M_1}$X 100

Where M_1 = Weight of dry block before immersion and

M_2 = Weight of wet block after immersion.

Sample Number	**Block size (mm)**	**Weight of Dry Block before immersion, M_1(Kg)**	**Weight of Wet Block after immersion, M_2(Kg)**	**Change in Weight, $(M_2 - M_1)$ (Kg)**	**Absorption Capacity (%),$\frac{M_2-M_1}{M_1}$X 100**	**Average Absorption capacity (%)**
1	450x225x150	18.05	19.50	1.45	14.04	
2	450x225x150	16.90	21.50	4.60	16.22	
3	450x225x150	17.10	20.95	3.15	19.03	
4	450x225x150	17.60	20.75	3.15	18.23	
5	450x225x150	18.60	20.50	1.90	16.31	16.77

Table 15: Water Absorption Capacity Test Result for Sharp Sand

Sample Number	**Block size (mm)**	**Weight of Dry Block before immersion, M_1 (Kg)**	**Weight of Wet Block after immersion, M_2 (Kg)**	**Change in Weight, (M_2-M_1) (Kg)**	**Absorption Capacity (%),$\frac{M_2-M_1}{M_1}$X100**	**Average Absorption capacity (%)**
1	450x225x150	18.80	21.85	2.30	12.17	
2	450x225x150	17.50	21.20	3.70	21.10	
3	450x225x150	17.80	20.52	2.72	15.30	15.57
4	450x225x150	16.95	19.95	3.00	17.60	
5	450x225x150	17.50	21.00	2.10	11.67	

Table 16: Water Absorption Capacity Test Result fine sand

Sample Number	**Block size (mm)**	**Weight of Dry Block before immersion, M_1 (Kg)**	**Weight of Wet Block after immersion, M_2 (Kg)**	**Change in Weight, (M_2-M_1) (Kg)**	**Absorption Capacity (%),$\frac{M_2-M_1}{M_1}$X100**	**Average Absorption capacity (%)**
1	450x225x150	18.85	22.10	3.25	17.24	
2	450x225x150	18.40	21.45	3.04	16.58	
3	450x225x150	16.80	19.85	3.05	18.16	
4	450x225x150	16.88	18.70	1.82	10.78	15.44
5	450x225x150	17.91	20.50	2.59	14.46	

Table 17: Water Absorption Capacity Test Result for Finer Sand

The table below shows the water absorption capacity for all samples collected from various places, with an average value of 16.26% water absorption capacity. As such the pore spaces between the particles are large and absorb appreciable water, this is because the sand particle is smaller and contain high amount of silt that absorb much water which affect the strength properties of sandcrete block.

Sample	Sharp Sand	Fine Sand	Finer Sand
Water Absorption capacity (%)	16.77	15.57	15.44

Table 18: Result of 6" Block Water Absorption for the Three Samples

Sample	Sharp sand	Fine sand	Finer sand
Moisture Content (%)	3.83	4.44	4.41
Grading Zone	Coarse Grading 2	Medium Grading 3	Fine Grading 2
Specific Gravity	2.67	2.68	2.57
Compacted Bulk Density (kg/m^3)	156.11	161.80	157.76
Uncompacted Bulk Density (kg/m^3)	141.56	147.72	144.89
Water Absorption capacity (%)	16.77	15.57	15.44

Table 19: Properties of the Natural Sand

4.6. Compressive Strength

The test result in Table 14-4.17 shows that the compressive strength of sandcrete blocks does not depends on the weight of the blocks; because some blocks that has high weight does not have high compressive strength, while some blocks with low density have high compressive strength, why? Because the density is proportional to the compressive strength.

Compressive strength = Crushing load/Effective surface area of block

Effective surface area of block = Total surface area of block - Area of hollow

= (450mmx150mm) - 2(160x85) mm = 41050mm^2

Block Sample	Number	Weight (Kg)	Crushing Load (KN)	Average Weight (Kg)	Average Crushing Load(KN)	Compressive Strength (N/mm^2)
Sharp	1	14.69	28.21	14.67	27.98	0.681
	2	14.48	30.67			
	3	14.76	26.00			
	4	14.52	30.00			
	5	14.92	25.00			

Table 20: Compressive Strength of Block at 7days Age of Curing

Block Sample	Number	Weight (Kg)	Crushing Load (KN)	Average Weight (Kg)	Average Crushing Load(KN)	Compressive Strength (N/mm^2)
Fine	1	14.28	29.00	14.47	27.2	0.663
	2	14.50	26.00			
	3	14.61	28.00			
	4	14.62	30.00			
	5	14.33	23.00			

Table 21: Compressive Strength of Block at 7days Age of Curing

Block Sample	Number	Weight (Kg)	Crushing Load (KN)	Average Weight (Kg)	Average Crushing Load(KN)	Compressive Strength (N/mm^2)
Finer	1	14.89	60.00	14.80	52.60	1.2814
	2	14.61	56.00			
	3	14.99	59.00			
	4	15.11	63.00			
	5	14.32	25.00			

Table 22: Compressive Strength of Block at 7days Age of Curing

Block Sample	Number	Weight (Kg)	Crushing Load (KN)	Average Weight (Kg)	Average Crushing Load(KN)	Compressive Strength (N/mm²)
Sharp	1	14.50	30.00	14.30	33.40	0.8136
	2	14.30	42.00			
	3	14.55	29.00			
	4	14.12	31.00			
	5	14.00	35.00			

Table 23: Compressive Strength of Block at 14days Age of Curing

Block Sample	Number	Weight (Kg)	Crushing Load (KN)	Average Weight (Kg)	Average Crushing Load(KN)	Compressive Strength (N/mm²)
Fine	1	13.98	36.00	13.99.	34.20	0.833
	2	14.10	34.00			
	3	14.02	35.00			
	4	14.05	37.00			
	5	13.78	29.00			

Table 24: Compressive Strength of Block at 14days Age of Curing

Block Sample	Number	Weight (Kg)	Crushing Load (KN)	Average Weight (Kg)	Average Crushing Load(KN)	Compressive Strength (N/Mm²)
Finer	1	14.86	61.00	14.72	53.00	1.2911
	2	14.72	56.00			
	3	14.91	60.00			
	4	14.81	63.00			
	5	14.32	25.00			

Table 25: Compressive Strength of Block at 14days Age of Curing

4.7. Discussions of the Compressive Strength of Blocks

From the analysis of result in Table 13 properties of natural sand. The samples from various sources fall within different zones based on BS 882:1992. This is an indication that blocks produced will have varying compressive strengths according to the zone to which each fall.

Looking critically to the values of compressive strengths in the table below, blocks produced with finer sand has the highest average compressive strength at 14days. This is due to the following reasons,

- The sand used in producing these blocks is uniformly graded and falls within fine grading BS 882: 1992. It indicates that the sand is fit for sandcrete block making.
- The specific gravity of the sand used is higher. The higher the specific gravity, heavier the particle. This proves itself from the result of density obtained for finer sand; it has the highest value of average density (weight). This is an indication that this sand will be produced heavier and strong blocks because density is proportional to the strength.
- The moisture content of the sharp sand is low when compare with moisture content of fine sand that fall within zone 2, and sharp sand which falls within zone 2. This indicates that the silt in this sand is low. The higher the silt content, the lower the compressive strengths as the silt tends to alter or affect the cement properties there by reducing blocks strengths.
- From the result for the compressive strength test on the sandcrete block as shown above for the three samples of sand, it was observed that the compressive strength increases with age at curing. For all the ages at curing, the highest strength was obtained from sand made with finer sand and the lowest strength was recorded with the block contain sharp sand. The amount of void spaces to be filled and the total surface of the fine aggregate to be coated (Mindess, Young and Darwin)

Sand Sample	7 Days		14Days	
	Weight (Kg)	Comp. Strength (N/mm²)	Weight (Kg)	Comp. Strength (N/mm²)
Sharp	14.67	0.6812	14.30	0.8136
Fine	14.47	0.6626	13.99	0.8330
Finer	14.80	1.2814	14.72	1.2911

Table 26: Summary of the Compressive Strength of Blocks

5. Conclusions and Recommendations

5.1. Conclusions

From the outcome of this work, the following conclusions are made:

- The mode of curing in all the block samples was by spraying/sprinkling water on the blocks twice daily for two days. This method of curing especially at the early stages could have negative effect on the strength. This is due to the fact that most of the water required for hydration process must have evaporated. Ejeh S.P and O.R Benuso, (2008).
- Blocks produced from finer sand came first in terms of compressive strength which is higher than that required by standard, while blocks produced with fine sand have their compressive strengths to be second at 14days of curing. Blocks produce from sharp sand came third in terms of compressive strengths based on the analysis of this study.
- The result of the compressive strength of blocks is shown in Tables 4.18-4.23 Test indicates that the average compressive strength of sandcrete blocks ranges between 0.11N/mm^2 to 1.3N/mm^2. The values fall below the standard prescribed for load bearing sandcrete blocks. Nigerian Industrial Standard (NIS 87: 2000) specified that the lowest compressive strength of individual load bearing blocks shall not be less than 2.5 N/mm^2 and average compressive strength of five blocks shall not be less than 3.45 N/mm^2. The results also indicate poor quality control in the sense that the strength results show wide range within the same lot.

6. Recommendations

- Since sandcrete blocks have failed by the compressive strength, proper laws and regulation should be enacted to regulate the production of these blocks so that they can meet minimum requirement and reduce the collapse of structure due to poor material use.
- Improved curing practice, use of appropriate method of curing and maintaining the moulding moisture content of at least seven days should be enforced by (NSE) and (COREN) on the block producer.
- Constant training should be provided by the government in collaboration with (COREN) to the block makers demonstrating that finer sand should be used in block making for improvement in block quality resulting from good curing practice.
- Structural engineer should be encouraged to carry out more research on the methodology of sandcrete block production and to produce more paper on the topic.
- Effective supervision must be exercised on the production site to ensure these of appropriate mix ratio and adherence to the right compaction time. Government should enforce it in the manufacturers, stating the penalty of non-compliance with the rule.
- In order to provide adequate housing and structures for ever increasing population of people within Garindau, Wudil finer sand should be used in making blocks, as it produces blocks with the highest strengths.

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Appendix

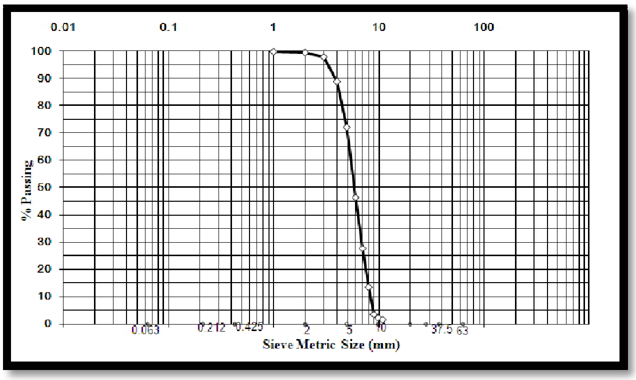

Figure 2: Sieve Analysis Graph of Sharp Sand

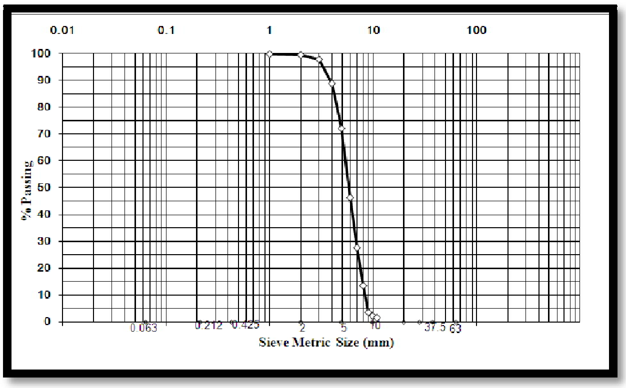

Figure 3: Sieve Analysis Graph of Fine Sand

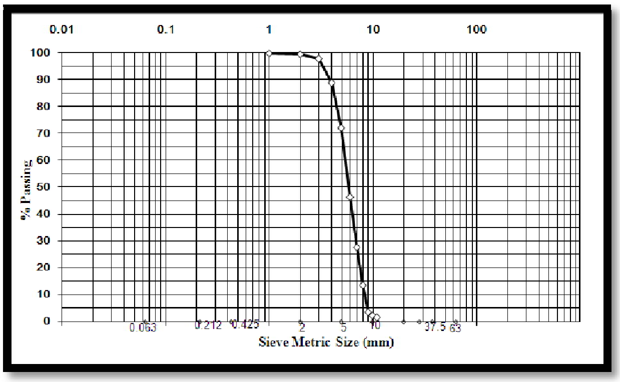

Figure 4: Sieve analysis graph of finer sand

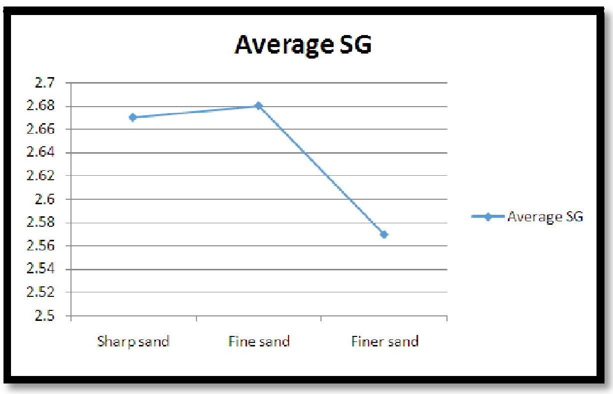

Figure 5: Average Specific Gravity Graph

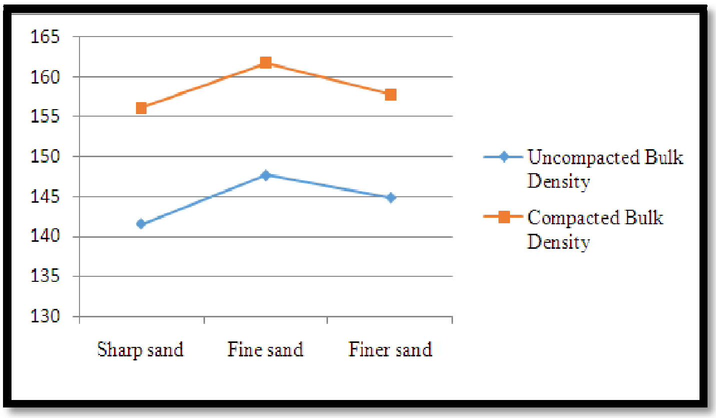

Figure 6: Average Bulk Density for Compacted and Uncompacted

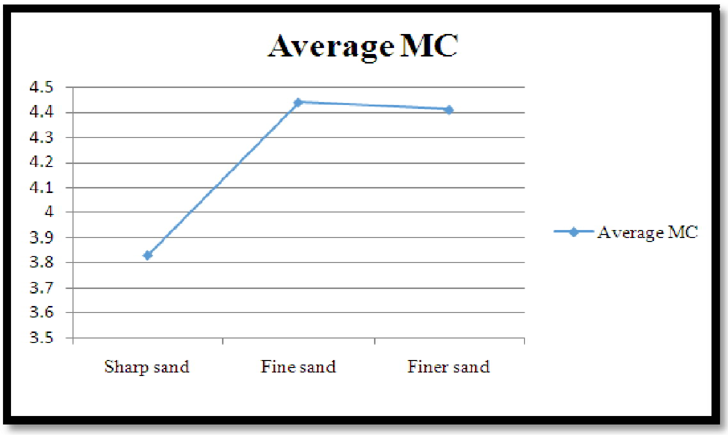

Figure 7: Average Moisture Content

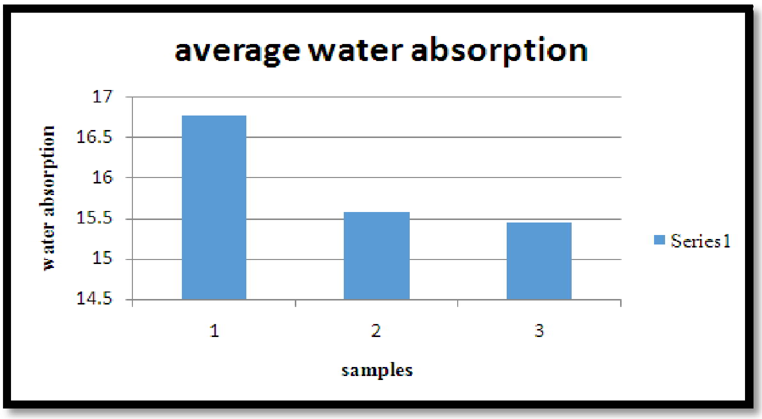

Figure 8: Average Water Absorption

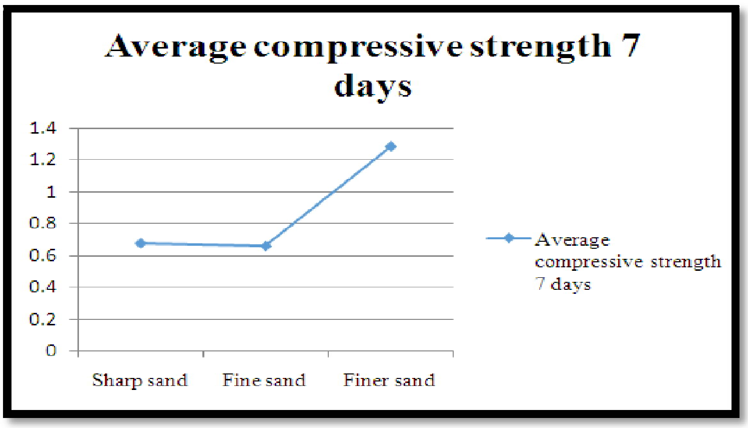

Figure 9: Compressive Strength at Age of 7 Days

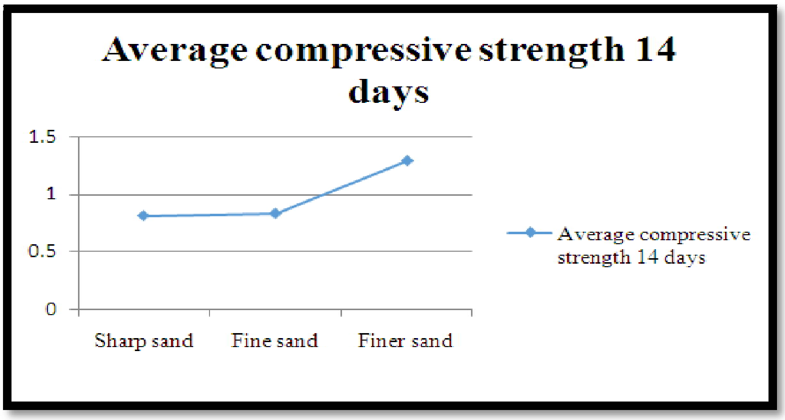

Figure 10: Compressive Strength at Age of 14 Days