UNIVERSITY OF EDUCATION, WINNEBA

INVESTIGATING THE PROPERTIES OF SANDCRETE BLOCKS USING DIFFERENT SOURCES OF SAND IN THE GHANAIAN CONSTRUCTION INDUSTRY.

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(200014338)

A DISSERTATION IN THE DEPARTMENT OF CONSTRUCTION AND WOOD TECHNOLOGY, FACULTY OF TECHNICAL EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT FOR THE AWARD OF THE MASTER OF PHILOSOPHY DEGREE IN CONSTRUCTION TECHNOLOGY.

FEBRUARY, 2022

DECLARATION

STUDENT'S DECLARATION

I, Acquah Edward declare that this thesis, with the exception of quotations and references contained in published works which have been identified and acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Candidate's Signature: …………………………… Date: ………………………

Name of Student: Edward Acquah

SUPERVISOR'S DECLARATION

I, hereby declare that the preparation and presentation of the thesis was supervised in accordance with guidelines and supervision of thesis laid down by the University of Education, Winneba.

Supervisor's Signature: …………………………… Date: ………………………

Principal Supervisor: Emmanuel Appiah Kubi PhD

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DEDICATION

To my wife Mrs. Mabel Acquah, my mother Obaapanyin Esi Ewusiwa, and all my children for their moral and enthusiastic support, prayers and motivation.

ABSTRACT

Sandcrete block has been one of the materials used in construction industry. The source of sand is one of the factors that influence the properties of sancrete blocks. In this experiment the properties of sandcrete blocks made with three (3) different sources of sand were investigated. The properties examined were; particle size distribution, density, water absorption, compressive strength, split tensile strength and abrasion. Materials used for the study were; pit sand, river sand, sea sand, cement and water. The sand used for the experiment conforms with ASTMC33/C33M. The cement used for the experiment conforms with ASTMC150/C150M and the water used also conforms with ASTMC1602/C1602M. ASTMC33/C33M was used as guide to conduct the particle size distribution analysis. 126 specimens were used to conduct the experiment. The mix design used was 1:6 (cement : sand) at a constant water cement ratio of 0.5. Batching of material was done by weight. Mixing of the materials was done manually and moulding of the bricks was done mechanically by hydraulic pressure brick moulding machine of size 100mm×100mm×130mm. The specimen was cured using water spraying method for 7, 14, 21, and 28 days respectively. The density, water absorption and compressive strength were determined using ASTMC90 as a guide. Split tensile strength of the specimen was also determined using ASTMC 496/C 496M as a guide and the abrasion of the specimen was determined using ASTMC944/C944 as a guide. The results revealed that the specimens made with pit sand had a higher density, compressive strength and split tensile strength for the curing days of 7, 14, 21and 28 respectively. It was again revealed that, water absorption of 8.02% for pit sand specimen was 5.09% and 5.40% lower than the river and sea sand respectively. The Anova analysis revealed that there was a significant difference between pit sand, sea sand and river sand whereas there were no significant differences between river sand and sea sand. The study therefore, concluded that the source of sand influences the properties of sandcrete block.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Shelter is one of the dreams of every man, and that to own a house or have an access to a decent shelter or an accommodation is an ambition of all persons. According to Ajagbe et al (2013), different materials are used around the globe for structural applications especially for load bearing wall construction.

Ogunbayo (2018) argued that, good housing projects need a standard design, good planning, and good building materials that would be managed and controlled by government bye laws and construction professionals. Again, Abdullahi (2005) is of the opinion that, best procurement of materials and proper curing process enhance good quality of sandcrete blocks. In terms of quality of a walling material, Odeyemi et al (2015) argued that, building failures have resulted in loss of lives and properties in Nigeria and in some cases, even though the building has not totally collapsed, the aesthetics value is lost to cracks and other defects. These concerns for sudden building failure in Nigeria and other parts of the world request that materials used for construction of buildings meet minimum requirements. Moreover, housing is a necessity of man and it is good to have access to decent shelter. For this matter, different materials are used around the world for buildings (Ajagbe et al., 2013).

Oke (2011) posited that poor quality of materials has accounted for more than 50 percent of causes of building collapse in Nigeria. However, Gollu et al. (2016) also stated that, unsuitable materials, unsound aggregates, reactive aggregate, contaminated aggregate as among the sources of failure in buildings and also in recent years, the strength of sandcrete blocks produced and used as walling units in Ghana's construction sector has been a source of concern (Coffie, Adzivor, & Afetorgbor, 2019). This `is because of the poor quality of sandcrete blocks used as walling units, it is claimed that the load-bearing walls were not strong enough to handle the applied load.

Although sandcrete blocks are being used as building materials in many parts of Nigeria, it has been intimated by Odeyemi et al. (2018) that many of the blocks produced do not conform with the minimum standard requirement for compressive strength value of 2.5 N/mm^2 and 3.45 N/mm^2 for non-load resisting wall and load resisting walls respectively as well as maximum specified 12% water absorption recommended by Nigeria Industrial standard (NIS 87:2000, 2000). These revelations may be as a result of the type or the source of sand, since there are different sources of fine aggregates in the construction industry. The various types of sand used for structural purposes in the construction industry are pit sand, river sand, sea sand, and quarry/stone dust. According to Neville (2011), fine aggregates exist abundantly as a surface deposit along the courses of rivers, on the shores of lakes and the sea, and in the construction industry. The availability of sand for construction works is becoming rare due to the excessive mining as a result of increasing demand for shelter and other infrastructural facilities especially in the developing countries (Peprah, 2013). This has resulted in high cost of sand for construction works (Oyedepo et al, 2014). Research has shown that, the sources of sand such as pit sand, river sand, sea sand and quarry/stone dust affect the properties of sandcrete blocks for structural purposes. Examples can be found in studies by Odeyemi et al. (2019); Ogunbayo and Aigbavboa (2020); and Taiwo and Olamoju (2019).

Research has compared the properties of sandcrete blocks made with different sources of sand. However, there is limited knowledge on the properties of sandcrete blocks manufactured with pit sand, river sand and sea sand. Hence the purpose of this study is to investigate the properties of sandcrete blocks produced from different sources of sand, that is pit sand, river sand and sea sand in the Ghanaian construction.

1.2 Statement of the problem

Sandcrete blocks constitute a unique class amongst man-made structural components for building in civil engineering work. For example, in buildings, walls are constructed using blocks as either load bearing or non- load bearing to provide shelter, protection, conveniently divide space, privacy and also to provide security for man and his properties. This means that, the importance of these blocks cannot be over emphasized, due to their importance in the construction industry. According to Ghana Building Code, (2018) Sandcrete blocks are available as hollow and solid concrete blocks, and solid lightweight blocks, autoclave aerated concrete blocks, concrete stone masonry blocks, sandcrete blocks and soil-based blocks. In many parts of Ghana, sandcrete blocks are made without regard to any international or national standards (Anosike & Oyebade, 2012).

However, the global concerns for sudden collapses of buildings across the world, and Nigeria in particular demand that materials used for construction of buildings meet minimum requirement (Ukpata, 2006). Amusan (1991) also found out that building collapse is no respecter of size of the structure.

According to Onwuka et al (2013), sandcrete blocks, which are the major construction material cannot be unconnected to some of these problems faced in the construction industry. Many firms in the business of manufacturing sandcrete blocks in Ghana use sand from various sources in the production of these blocks. Again, most of the sandcrete blocks being produced and used in construction have compressive strength which are lesser than the values recommended by the Nigerian Industrial Standard (NIS) which is $2.5N/mm^2$ for machine compacted blocks and $2.0\ N/mm^2$ for hand compacted blocks (Onwuka et al, 2013). However, the compressive strength of masonry units in a wall of a one or two-story house or of a one or two-story building divided into flats shall not be less than $2.75N/mm^2$ for sandcrete blocks and $5.2N/mm^2$ for bricks (Ghana Building Code, 2018).

Banuso and Ejeh (2008), Abdullahi (2005), Afolayan et al (2008) have confirmed that tested samples of sandcrete blocks in Kaduna state, Minna and Ondo state of Nigeria respectively, exhibited compressive strength far below that recommended in the British standard of $3.5N/mm^2$.

The properties of Sandcrete blocks, namely, density, water absorption, abrasiveness, split tensile, compressive strength etc. may be influenced by prevailing climatic and weather conditions in the area and the quality of Sandcrete blocks produced may also depend on the quality of fine aggregates with regards to their sources. It is relatively common to find block producers reducing the amount of cement for mixing or substituting some of the amount with clay material. This is aimed at minimizing the cost of production and hence the potential of substandard quality blocks.

This practice is in sharp contrast with Valenger (1971) which revealed that, the compressive strength of Sandcrete materials increases with increased cement content. Similarly, British Standards Institution. 1965. BS 3921, Points out that strength is not to be taken as indication of durability. Thus, properties of Sandcrete blocks may be influenced by prevailing climatic conditions in an area and the quality of Sandcrete blocks produced also depends on the quality of fine aggregates (Baiden & Tuuli, 2004).

With regard to this assertion about the quality of a sandcrete block particularly the properties of the constituents of materials as a major factor in determining the quality of blocks, the determination of the density of sandcrete blocks, water absorption rate, abrasive, split tensile and the compressive strength of the sandcrete block would be very necessary in this study as it aimed at investigating the properties of sandcrete blocks produced from different sources in the Ghanaian construction industry.

1.3 Purpose of the study

The purpose of this study is to investigate the properties of sandcrete blocks produced from different sources of sand in the Ghanaian construction industry and make appropriate recommendations to the construction industries on which sand per the source is appropriate for a particular type and purpose of a building.

1.4 Specific Objectives of the study

The specific objectives of the study are as follows:

1. To determine the particle size distribution of pit, river, and sea sand for sandcrete blocks produced in the Ghanaian construction industry.
2. To determine the physical properties (density and water absorption) of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.
3. To determine the mechanical properties (compressive and split tensile strength) of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.
4. To determine the abrasion resistance of sandcrete block made with different sources of sand in the Ghanaian construction industry.

1.5 Research questions

1. What is the particle size distribution of pit, river, and sea sand for sandcrete blocks produced in the Ghanaian construction industry?
2. What is the density and water absorption of sandcrete blocks made with different sources of sand in the Ghanaian construction industry?
3. What is the compressive and split tensile strength of sandcrete blocks produced from the different sources of sand in the Ghanaian construction industry?

4. What is the abrasion resistance of sandcrete blocks produced from different sources of sand in Ghanaian construction industry?

1.6 Significance of the study

Walling materials constitute an essential element in housing delivery. It is estimated that it covers about 22% of the total cost of a building. The choice of walling material is a function of cost, availability of material, durability, aesthetics and climatic condition. The global concerns for sudden collapses of buildings across the world, and Nigeria in particular demand that materials used for construction of buildings meet minimum requirement.

This has compelled the researcher to find out the properties of the sandcrete blocks from various sources of sand, its merits and demerits and suggest solutions to it. It is hoped that the findings of the research would;

- Help policy makers especially ministry of works and housing and the Ghanaian construction industry with valuable information for enhancing policy guidelines and procedures that would ensure their smooth operations.
- Further assist policy makers to formulate comprehensive and workable policies on the mix ratio for the sandcrate blocks regarding their different sources of the fine aggregates for its manufacture.
- Also inform the stakeholders such as Ghanaian construction industry, masons, and block manufacturers about properties of sandcrate blocks manufactured from different sources.

1.7 Delimitation of the study

The study was carried out in the Ekumfi District in the Central Region of Ghana. The study was done in three communities in the Ekumfi District of the central region. The three (3) communities are: Ekumfi Arkra, a coastal community to obtain the sea sand, Ekumfi Ekotsi which is closed to River Okye to obtain the river sand and Ekumfi Adansi where sand winning is ongoing to obtain the Pit sand. The study was also delimited to issues such as the particle size distribution, density, water absorption rate, the compressive strength, and splitting tensile of sandcrete blocks produced from different sources.

1.8 Organisation of the thesis

The thesis is in five chapters. The first chapter is the introduction. This comprises background to the study, statement of the problem, purpose and specific objectives of the study, research questions, significance of the study and the delimitation of the study. The second chapter explores relevant related studies, theoretical explanations and conceptual framework for the study. The literature also explains some concepts in the study.

The methodology which is chapter three explains how the study had been carried out. The methodology lays emphasis on the study design, the study method and procedures for material collection and data analysis procedures. Chapter four presents findings from the study, discusses the findings and makes meaning from the findings. The last chapter which is chapter five gives summary to the findings, conclusions and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter discusses the theory underpinning the study which is built around three themes that are derived from the research questions. The themes are:

- The particle size distribution of pit sand, river sand and sea sand that was used to produce the blocks.
- Physical properties of blocks, that is Density and water absorption of sandcrete blocks made with different sources of sand.
- The mechanical properties of blocks, that is compressive strength and split tensile strength of sandcrete blocks made with sand obtained from different sources.
- The abrasion resistance of sandcrete blocks made with sand obtained from different sources.

2.1 Particle size distribution

This research question assumes that, the particle size of the various sand types differs depending upon the sources and for that reason this could affect the density, water absorption, compressive strength, split tensile strength and abrasion nature of sandcrete block.

Characterization of quality of materials is important to ensure good use of resources from environmental and economic perspectives. Sieve analysis is a laboratory test that measures the particle size distribution of a soil by passing it through a series of sieves. Soil retained on is termed as gravel fraction.

Particle size distribution of materials is one of the widely used tests in geotechnical engineering to evaluate quality of materials. Sieve analysis test has been used as the main method to determine particle size distribution of granular materials including coarse materials for many decades. Atkinson (1993); Neville and Brooks (2002); and Shetty (2004) posited that “Fineness Modulus (FM)’ as a ready index of coarseness or fineness of a material. It is the empirical factor obtained by adding the cumulative percentages of materials retained on each standard Sieve ranging from 80 mm to 150 µm and dividing this sum by an arbitrary number 100.

It entails allowing particles to pass through stack of sieves with known opening sizes and shaken for 10 minutes as recommended by Bowles (1992), using a mechanical test sieve shaker.

Hodge (1971) has argued that, the quality of blocks is a function of the method employed in the production and the properties of the constituent of materials available for the construction of load bearing and non-load bearing structures. However, Neville (2011), opined those fine aggregates exist abundantly as a surface deposit along the courses of rivers, on the shores of lakes and the sea, and in arid regions. Moreover, Neville (1997) again describes sand as a natural aggregate that can be separated by such gentle mechanical means as agitation in water which implies that it is a cohesionless aggregate of rounded angular or sub angular fragments of more or less unaltered rocks or minerals. Particles with a size of up to 5 mm are referred to as sand.

Fine aggregates (sand) are obtained from different sources and therefore have numerous characteristics and properties. Some of these important properties are:

1. The Size and shape: the size and the shape of aggregate greatly influence the quality of mortar and concrete mix. For the preparation of economical mortar and concrete mix, the rough textured, angular, and elongated particles require more water for the formula. However, it will need less water to produce workable concrete when the aggregates are smooth, rounded and compact. The size of fine aggregate should be equal to or less than 4.75mm. More so, sand of irregular nodular shape is preferable to completely round grained

sand. Shape of the aggregate plays a more important role in coarse aggregate rather than fine aggregate.

2. Specific Gravity: it is the ratio of the density of aggregate to the density of water.
3. Bulk Density: it is the ratio of weight of aggregate (including voids) to its unit volume.
4. Moisture Content (% water absorption): it is the ratio of weight of water absorbed to weight of dry aggregate, measured in percentage. Therefore, the fine aggregate density depends on the inside solid material and void content, thus you need to measure the absorption rate prior to ensure how much water will be required in a mix.
5. Bulking: Bulking of sand means increase in volume of sand due to surface moisture.
6. Surface Texture: Surface texture is the property which defines whether a particular surface is polished, dull, smooth or rough. Generally rough surface aggregate is preferable to smooth aggregates.
7. Soundness: soundness means the ability of the aggregate to resist excessive change in volume as a result of change in physical condition.
8. Durability: some of the aggregate contain reactive silica, which reacts with alkalies in cement hence reduce the durability. Durability is the ability to resist against the weathering actions, chemical attack, etc.
9. Silt content: it is defined as the total quantity of fine particles of deleterious materials having particle from 0.06mm to 0.002mm present in sand.

Fine aggregate is the technical term for sand. Sand, gravel, crushed rock, expanded shale, or expanded clay is all-natural or manufactured aggregates, according to Article 7.22.3 of the Ghana Building Code (2018). Fine aggregates are particles of aggregates which pass through 4.75mm mesh and are entirely retained on 0.15mm mesh. Most commonly used fine aggregates are sand, crushed stone etc. Aggregates that do not pass through 4.75mm mesh are termed as coarse aggregate. The quality of fine aggregate can vary significantly due to the geographic location and environmental condition. According to Oke (2011) poor quality of materials has accounted for more than 50 percent of causes of building collapse in Nigeria.

The British Standard (BS-882) defined aggregate as a granular material obtained by processing natural materials while Taylor (2002) defined aggregates as mineral filler materials used in concrete. Laterite as a fine aggregate According to Mahalinga-Iyer and Williams (1997), laterite is generally found in tropical and sub-tropical countries and has been found useful as sub-base or base materials in road construction.

The availability of sand for construction works is becoming rare due to the excessive mining as a result of increasing demand for shelter and other infrastructural facilities especially in the developing countries (Peprah, 2013). This has resulted in high cost of sand for construction works (Oyedepo et al, 2014).

Again, Ayininuola and Olalusi (2004) and Ede (2011) stated that the use of substandard materials for concrete is the leading cause of building collapse in Nigeria. However, Gollu et al. (2016) also mentioned unsuitable materials, unsound aggregates, reactive aggregate, contaminated aggregate as among the sources of failure in buildings. Sand is an extremely important part of building materials, but why is it so important? It is quite simple, sand is a hard material, it is strong in nature and made up of very fine mineral particles. Sand gives strength and sustainability to the building. Sand that is used for construction should be clean, neat and free from stones, clay balls, and impurities. Below are the grades of sand in five categories:

- Fine sand (1/8mm-1/4mm diameter)
- Very fine sand (1/16mm-1/8mm diameter)
- Medium sand (1/4mm-1/2mm diameter)
- Coarse sand (1/2mm-2mm diameter), and

- Very coarse sand (2mm-4.5mm diameter)

River sand is obtained by dredging from river beds and has the major characteristics that since it has been subjected to years of abrasion, its particle shape is more or less rounded and smooth, and since it has been subjected to years of washing, it has very low silt and clay contents and is usually a whitish grey colour. Natural river sand is commonly used as fine aggregates in traditional cement mortar for sandcrete blocks in Ghana (Mensah et al, 2021).

River sand is usually in white grey colour and has a very fine quality and it is well graded for all types of concrete and masonry works.

This product (sand) has a lower bleeding of water in concrete as well as reduced honey combing and high resistivity to aggressive environment. It is good for concrete purposes due to the moisture trapped in between particles and it is widely used construction industry for its minimum permissible silt content which is about 3%. It is highly recommended for plastering, RCC and blocks as well as brickwork.

Pit sand is a natural and coarse type of sand which is extracted by digging 2-3m underneath the ground. It is in red-orange colour due to the presence of iron oxide around the grains. These grains are free from salts; hence it does not react with the moisture content present in the atmosphere. Due to its superior binding properties pit sand is used in construction. As mentioned above, pit sand is a coarse type of sand and this is not recommended if the sand is coarser than the acceptable limits.

Sea sand is obtained from the sea shore and can become a potential resource capable of supplying fine aggregate materials for domestic civil engineering and construction usage. In addition, using sea sand is economical than using other sources. Sea sand mainly contains much salinity as sodium chloride and if the salt is not treated and directly utilized for civil engineering and construction concrete project, the durability of the structure may be affected and as a result the concrete might be swelling, precipitating, sulphating and other adverse consequences. Therefore, the salt content of the sea sand must be eliminated before it is utilized to avoid the potential hazards.

Sandcrete blocks are the most prominent of the concrete masonry units in the building industry today especially in the construction of residential, industrial and commercial buildings (Ejeh, 1982). Sandcrete blocks are the most widely used walling unit in Nigeria, accounting for 90% of houses (Ewa & Ukpata 2013). Block is the composition of usually (1:6) mix of cement and sharp sand with barest minimum of water mixture, and in some cases admixtures, moulded and dried naturally. NIS 87:2000 defines sandcrete block as a composite material made up of cement, sand and water, moulded into different sizes. According to them, they are masonry units which when used in its normal aspects exceed the length or width or heights specified for bricks. Mehta and Monteiro (2001) stated that, aggregates exercise a significant influence on strength, dimensional stability, and durability of concrete and in addition to these important properties of hardened concrete, aggregate also affect greatly the cost and workability of the concrete mixtures.

2.1.1 Cement

The most common type of cement for construction work is Ordinary Portland Cement (OPC) (Anosike & Oyebade, 2012). Ordinary Portland cement is the most common type of cement used to make sandcrete blocks in Ghana today (Umar, 2016). Portland cement to be used for the production of sandcrete blocks must comply with all the prescribed requirements in British Standard (BS-12), Nigerian Industrial Standard NIS 444-1:2003 and and Ghana Building code (2018). According to Adepegba (1975), Cement stabilized laterite and cement stabilized sand (Sandcrete) increases in strength with cement content and that at high cement content, the granules of sandcrete blocks behave elastically. It was also however observed that, the most economic range of the use of cement stabilized sand lies between 1-10 percent cement content by weight (Ejeh, 1982).

2.1.2 Mix Ratio

The optimum mix ratio and size of sandcrete block produced from different sources of sand can influence the compressive strength of sandcrete block.

The rule of thumb stipulates that, the standard mix ratio for sandcrete block should range between 1:6 to 1:8, or not more than twenty-five (25) blocks are allowed to be produced for each bag of cement of 50kg. In this case one would not know whether the ratio applied to the fine aggregate (sand) obtained from different source can affect the compressive strength of the sandcrete block. Again, sandcrete blocks are made from a cement/sand mix usually one part of cement to six or eight parts of sand (1:6 or 1:8) with water/cement ratio of between 50 t0 75% (B.S 3921: 1965).

Historically, most concrete masonry units are manufactured on the local level and industry standards are not always adhered to (Ewa & Ukpata, 2013; Aiyewalehinmi & Tanimola, 2013; Mahmoud et al, 2010; Abdullahi, 2005). Variations in shape, size and surface texture are common features. There is no complete standardization of sizes in the industry for sandcrete blocks and sizes must be checked in each locality.

2.1.3 Blocks

Blocks are those building unit used in the construction of walls and partitions. According to Nigerian Industrial Standard NIS 087:2000, Sandcrete block is a composite material made up of cement, sand, water, moulded into different sizes. Sandcrete blocks are available as hollow and solid concrete blocks, and solid lightweight blocks, autoclave aerated concrete blocks, concrete stone masonry blocks, sandcrete blocks and soil-based blocks (Ghana Building Code, 2018). The most commonly available sizes are 450mm x 225mm x 225mm and 450mm x 150mm x 225mm. It is widely used in Nigeria and other countries like Ghana as walling unit.

The quality of blocks produced however, will differ due to different sources of obtaining the fine aggregate (sand) for the production of the sandcrete blocks and this therefore may affect the compressive strength of sandcrete blocks. Properties of Sandcrete blocks may be influenced by prevailing climatic conditions in an area and the quality of Sandcrete blocks produced also depends on the quality of fine aggregates (Baiden & Tuuli, 2004).

Sandcrete blocks constitute a unique class amongst man-made structural components for building in civil engineering work. For example, in buildings, walls are constructed using (blocks), as either load bearing or non- load bearing to provide shelter, protection, conveniently divide space, privacy and also to provide security for man and his properties (Allen, 1985). This means that the importance of these blocks cannot be over emphasized, due to their importance in the construction industry.

The strength characteristics of sandcrete blocks are influenced by a variety of factors whose effect is not sufficiently understood to permit accurate forecasting particularly under test condition. It has been found that the time of mixing sandcrete with cement does influence its strength characteristics but can the same be said of the different sources of sand. Sandcrete blocks possess an intrinsic low compressive strength making them susceptible to any tragedy such as seismic activity.

Ukpata (2006) and Amusan (1991) found out that building collapse is no respecter of size of the structure and according to Onwuka et al. (2013) sandcrete blocks, which are a major construction material cannot be unconnected to some of these problems faced in the construction industry.

Omoregie and Alutu (2006) also argued that, sandcrete blocks frequently fail to meet load-bearing specifications recommended by the Nigerian Federal Ministry of Works and it is not surprising to hear reoccurring cases of collapse under self-weight of some of these blocks. The

Compass Newspaper in 2010 reported a recent case of a collapsed building in which the sandcrete blocks did not show any appreciable hardness and that would be indicative of the use of substandard materials. Meanwhile, Oyininuola and Olalusi (2004) opined that, a great number of buildings collapse weekly in the country, but did not receive public or official notice and some of those collapsed buildings showed that their load bearing walls were not of adequate strength to withstand the applied load on them. The rapid changes in the use of brick to block in Nigeria have encouraged the investigation in to the use of sandcrete blocks to be more elaborate (Abdullahi, 2005). This will aid in the long run-in adoption of some currently untested local construction materials and methods in Ghana. However, Gooding and Thomas (1995) reported that some of the factors influencing the strength of sandcrete blocks were the curing procedure, optimum water content and quality control.

The quality of Sandcrete blocks produced also depends on the quality of fine aggregates (Baiden & Tuuli, 2004). Fine aggregates (sand) should comply with British Standard Institution BS 882:1996. Specification for aggregate from Natural sources for Sandcrete blocks production.

According to the British Standard Institution. BS 2028:1970, all blocks should be weighed and tested for compressive strength using the compressive testing machine in accordance with its specifications. Sieve analysis test should be carried out on the sand samples to ascertain their suitability for block making in accordance to British Standard Institution. BS 1377:1990.

Water reacts with cement to bring about hydration. The workability and strength of sandcrete depends to a large extent on the amount of water used in mixing. Water to be used for the production of concrete or sandcrete must be free of suspended particles, inorganic salts, acids and alkalis, oil contamination and algae British Standard (BS-3148:1980). Potable water that meets the NIS 554:2007 standard is recommended for the production of sandcrete blocks.

Murdock et al, (1991) defines compressive strength of sandcrete block as widely accepted as the leading parameter for quality control and this quality is largely dependent upon the type and properties of the constituent materials. Ephraim (2009) found out that the compressive strength of sandcrete blocks increased with age of curing for all mixes tested at the water cement ratio of 0.5.

Ettu et al, (2013) also stated that the strength at ages 7, 14, and 21 days were 43% 75% and 92% of the 28 days strength respectively. More so, compressive strength is the ratio of the crushing load that a sample can sustain to its net area. Again, compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to which withstands loads tending to elongate and it is the key value for design of structures. Nigerian Industrial Standards (NIS 87:2000) Specifies that the lowest compressive strength of individual load bearing blocks shall not be less than 2.5N/mm^2 and average compressive strength of five blocks shall not be less than 3.45N/mm^2. However, the compressive strength of masonry units in a wall of a one or two-story house or of a one or two-story building divided into flats shall not be less than 2.75N/mm^2 for sandcrete blocks and 5.2N/mm^2 for bricks (Ghana Building Code, 2018).

Odeyemi et al, (2015) observed that the average compressive strength of manually produced blocks and machine compacted blocks at 28th days of curing were 2.83N/mm^2 and 2.96N/mm^2 respectively. These results revealed that machine compacted blocks have a higher compressive strength than the manually compacted blocks. This can be attributed to the fact that the machine has a higher vibration impact on the sandcrete blocks than the manually applied hand rammers. The final compressive strength of sandcrete can be as high as 4.6N/mm^2, which is much less than concrete's 40N/mm^2. However, webster dictionary defines compressive strength as the maximum compressive stress that under gradually applied load a given solid material will sustain without fracture.

Again, compressive strength is when a compressive force is applied to the top and bottom of a test sample, until the sample fractures or is deformed. Moreover, the compressive strength of blocks is the capacity of block to resist or withstand under compression when tested on compressive testing machine (CTM). The compressive strength of a material is determined by the ability of the material to resist failure in the form of cracks and fissures. The compressive strength test is very significant or important in the construction industry thus: compressive strength test of cement mortar cubes is determined in order to verify whether the cement conforms to Indian Standard (IS, or other standards like ASTM, BS etc.) specifications and whether it will be able to develop the concrete or sandcrete block of required compressive strength. Again, compressive strength test is done on cement, when it is used as cement mortar and concrete, however, as a construction material, sandcrete block, concrete is employed to resist the compressive stress. While, at locations where tensile-strength or shear strength is of primary importance, the compressive strength is used to estimate the required property of cement mortar cubes. The mortar is used for plastering and brick masonry. The first case gives mortar heavy load in form of construction on it by placing blocks on mortar, that is why it is important to know the strength of the mortar. Finally, the compressive strength of cement mortar cubes or concrete is one of the most important and useful property and for this reason the strength of the binder (cement) therefore has a significant effect on the performance characteristics of the mixture of cement and sand to ensure the overall quality of the finished product. The compressive strength of cement mortar cubes depends on the strength and weakness of the mortar cubes. but if mortar cube is strong, then the compressive strength of the mortar cube will be high.

However, the global concerns for sudden collapses of buildings across the world, Ghana and Nigeria in particular demand that materials used for construction of buildings meet minimum requirement (Ukpata, 2006).

Amusan (1991) found out that building collapse is no respecter of size of the structure. According to Onwuka et al, (2013) sandcrete blocks, which are the major construction material cannot be unconnected to some of these problems faced in the construction industry. Many firms in the business of manufacturing sandcrete blocks in Ghana use sand from various sources in the production of these blocks. Again, most of the sandcrete blocks being produced and used in construction have compressive strength which are lesser than the values recommended by the Nigerian Industrial Standard (NIS) which is 2.5N/mm^2 for machine compacted blocks and 2.0 N/mm^2 for hand compacted blocks (Onwuka, et al, 2013).

Banuso and Ejeh (2008): Abdullahi (2005): Afolayan et al. (2008) have confirmed that tested samples of sandcrete blocks in Kaduna state, Minna and Ondo state of Nigeria respectively, exhibited compressive strength far below that recommended in the British standard value of 3.5N/mm^2. The properties of Sandcrete blocks may be influenced by prevailing climatic and weather conditions in the area and the quality of Sandcrete blocks produced may also depend on the quality of fine aggregates with regard to their sources. It is relatively common to find block producers in the study area reducing the amount of cement for mixing or substituting some of the amount with clay material. This is aimed at minimizing the cost of production and hence the potential of substandard quality blocks.

2.1.4 Curing

Curing is also one of the crucial factors that determine the attainment of the desired strength of sandcrete blocks. The method and the duration of curing must be given proper attention for the blocks to have attained their designed strength, even if the materials are of the required quality and mix ratio is adequate.

2.2 Density

Density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in g/cm^3

It is however important to note that, bulk density reflects the soils ability to function for structural support, water and solute movement, and soil aeration. Bulk densities above thresholds indicate impaired function. Bulk density is also used to convert between weight and volume of soil. It is again used to express soil physical, chemical and biological measurements on a volumetric basis for soil quality assessment and comparisons between management systems.

2.3 Water absorption

Water absorption rate is determined by measuring the decrease in mass of saturated block and surface dry sample. Absorption is defined as the taking of one thing into the area of another, it is the taking up or sucking up of liquids or gases, like the way roots absorb water. Water absorption can be defined as the rate at which water is taken in to, and morphed into another object or phase. Water can be absorbed into the atmosphere, and change into another state, such as gas, or it can be absorbed into an object, like a sponge, the amount of water absorbed by a composite material when immersed in water for a stipulated period of time. Also the absorption capacity (AC) or absorption represents the maximum amount of water the aggregate can absorb. A weighing balance and a curing tank are usually used in the water absorption test on the sandcrete block. The water absorption rate of the sand from different sources may differ and may therefore produce sandcrete blocks with different water absorption rate which in the end will turn to affect the compressive strength of sandcrete blocks produced. Again, this is the weight of water a block unit absorbs when immersed in water at a normal dry temperature for a stated length of time and it is expressed as a percentage of the weight of the dry unit block. It is expressed mathematically as mass of saturated block (kg)-mass of dry block (kg)÷volume of block (m^3). According to ASTM C140 (2001), the recommended maximum water absorption capacity of sandcrete blocks is 240kg/m^3. This will therefore be necessary to look at the water absorption rate of each block produced from different sources in this study because if the rate of water absorption is high, it may affect the hydration of mortar and result in poor bonding between blocks and mortar.

2.4 Compressive Strength of Sandcrete Block

This theme is derived from the research question one which states "What is the compressive strength of sand obtained from different sources for the production of sandcrete block in Ghana? This research question assumes that, the compressive strength and other factors like water absorption rate, the abrasive nature of the sand obtained from different sources can affect the compressive strength of sandcrete block produced from different sources.

The Compressive strength often referred to for sandcrete /masonry is based on the gross area of the unit, that is, the total area including any pore spaces.

However, the following factors affecting quality of sandcrete blocks have been proposed. Compressive strength of sandcrete blocks is widely accepted as the leading parameter for quality control and this quality is largely dependent upon the type and properties of the constituent materials (Murdock et al, 1991). The compressive strength of bricks and blocks for non-loadbearing partitions shall not be less than 1.4N/mm^2 according to Ghana Building Code (2018), provided the bricks and blocks are satisfactory in all other respects. The compressive strength of masonry units in a wall of a one or two-story house or of a one or two-story building divided into flats shall not be less than 2.75N/mm^2 for sandcrete blocks and 5.2N/mm^2 for bricks (Ghana Building Code, 2018). However, according to Nigerian Industrial Standard NIS

087:2000, the range of minimum strength of sandcrete blocks is between 2.5N/mm^2 to 3.45N/mm^2.

Again, the time lapse between mixing and compaction has been found as a factor that affects the compressive strength of sandcrete blocks. A time lag will not only diminish the hardening effect of the cement but will require extra energy to breakdown the aggregation of particles to achieve the desired density. An increase in strength with age and curing temperature has been reported for cement stabilized sandcrete, but this depends on the nature and texture of sand and the percentage of cement added. Sandcrete block should be left to mature for at least 28 days (by curing them) before they are laid, if enough strength is needed (Hamza & Yusuf, 2009). With all these assertions with regards to factors that affects the compressive strength of sandcrete block the current researcher also believes that different sources of sand have different characteristics and properties that could affect the compressive strength of sandcrete block hence the research.

British Standards Institution (1965) pointed out that strength is not to be taken as indication of durability. Thus, properties of Sandcrete blocks may be influenced by prevailing climatic conditions in an area. With regard to point made by the British Standard Institution what it means is that, fine aggregate (sand) obtained from different sources (areas) possess different characteristics and properties which will in the end affect the compressive strength of the sandcrete block and this therefore need to be researched into to ascertain the fact surrounding it.

According to Valenger (1971) the compressive strength of Sandcrete materials increases with increased cement content. Similarly, British Standards Institution. 1965. BS 3921, pointed out that strength is not to be taken as indication of durability.

2.5 Abrasion

According to Scott and Safiuddin (2015) abrasion resistance is the ability of a surface to resist being worn away by rubbing or friction. Abrasion resistance is particularly dependent on good curing but also relies upon other factors including materials and surface finishing, aggregate hardness, mix proportion, aggregate/paste bond, placing and compaction. Abrasion resistance of concrete pavement is a surface property that is mainly dependent on the quality of the surface layer characteristics (Ghafoori and Sukundar, 1995; Humpola, 1996).

According to Shackel (1994) cement content, water-cement ratio, cement type, the use of pigments and curing regime are the factors that influence abrasion resistance. There are a lot of equipment (machines) which are used for abrasion test but in this study Sutherland method in accordance with ASTM D 5264-98: 2004 will be used.

With reference to the above literature, what it means is that different sources of fine aggregates can affect the strength of the product made out of it, for example blocks and concrete and this has motivated the current researcher to investigate the compressive strength of sandcrete blocks using different sources of sand in the Ghanaian construction industry. Again, this study aims to provide important information on the physical properties and compressive strength of sandcrete block produced from different sources of sand in Ghana.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter deals with the systematic experimental approach employed in carrying out the study. It also outlined the materials used for conducting the study and their appropriateness. It describes the details of experimental procedures and methods.

3.1 Materials

The materials used in this study were pit sand, river sand, sea sand, cement and water.

3.1.1 Sand

The sand required for the study was obtained from three (3) different sources namely: Pit sand, River sand and Sea sand.

Pit sand for this study was obtained from a notable sand winning site at Ekumfi Adansi in the Ekumfi District of the Central Region as shown in fig. 3.1. The pit sand was free from clay, silt, salt and organic matters which conform with ASTMC33/C33M (2011). The pit sand was put in a head pan and filled into sacks and transported to the laboratory of Akenten Appiah Menka University of Skills Training and Entrepreneurial Development, Kumasi.

Figure 3. 1: pit sand

River sand was obtained from the banks of the River Okye at Ekumfi Ekotsi in the Ekumfi District of the Central Region. The river sand was free from clay, silt, salt and organic matters which conform with ASTMC33/C33M (2011). The river sand was put in a head pan and filled into sacks and transported to the Akenten Appiah Menka University of Skills Training and Entrepreneurial Development laboratory, Kumasi for the experiment.

Sea sand was also obtained from a coastal community called Ekumfi Arkra in the Ekumfi District of the Central Region as shown in fig. 3.2. The sea Sand was washed, left in the open to allow sun shine on it in other to get rid of the salt content in the sand thus weathering. The sea sand was free from clay, silt, and organic matters which conform with ASTMC33/C33M (2011). The sea sand was put in head pan and filled into sacks and transported to the laboratory for the experiment.

Figure 3. 2: Sea sand

3.1.2 Cement

Ordinary Portland Cement which was fine, consistent, good setting time and good soundness which conforms with ASTMC150/C150M (2012) was used for the production of sandcrete blocks for the study.

The cement was procured from retailing outlet in Tanoso, Kumasi and was transported and kept at the Laboratory.

3.1.3 Water

Portable water from the Ghana water company which was free from salt, colourless, odourless and free from organic materials which conforms with the ASTM C1602/C 1602M (2006) and Ghana Building Code (2018) was used for the experiment.

3.2 Methods

This section covers particle size distribution of pit sand, river sand and sea sand, sampling details, batching of aggregates, mixing of the materials, moulding of the specimens and curing of the specimens.

3.2.1 Particle size Distribution of the sand

ASTM C33/C33M (2011) was used as guide to conduct the particle size distribution analysis on three different sources of the sand, namely; Pit sand, river sand, and sea sand used for the study. The test was carried out with utilization of a set of sieves arranged from 5mm, 3.35mm, 2.36mm, 2mm, 1.18mm, 0.6mm, 0.3mm, 0.075mm up to the pan. The sieve separates larger particles from smaller particle size as shown in fig. 3.3 a.

The sand samples were oven dried at an average temperature of 105°C for a period of 30 minutes to get rid of the moisture content. 1kg of the oven dry sand sample was weighed and recorded. The weighed sand was poured into the 5mm sieve and covered. The sieves containing the materials were subjected to five minutes shaking. The particles retained on each sieve was weighed and recorded as shown in fig 3.3 b.

Figure 3. 3: Particle size distribution analysis

3.2.2 Sampling details

ASTMC140/C140 (2021) was used as a guide to determine the number of specimens used for the experiment. Table: 3.1 shows the sampling details used for the study.

Table 3. 1: Sampling details

Type of Test	Type of Sand	Curing Periods (Days)				Total
		7	14	21	28	
1. Density	Pit sand	3	3	3	3	12
	River sand	3	3	3	3	12
	Sea sand	3	3	3	3	12
2. Water absorption	Pit sand	-	-	-	3	3
	River sand	-	-	-	3	3
	Sea sand	-	-	-	3	3
3. Compressive	Pit sand	3	3	3	3	12
	River sand	3	3	3	3	12
	Sea sand	3	3	3	3	12
4. Split tensile	Pit sand	3	3	3	3	12
	River sand	3	3	3	3	12
	Sea sand	3	3	3	3	12
5. Abrasion test	Pit sand	-	-	-	3	3
	River sand	-	-	-	3	3
	Sea sand	-	-	-	3	3
Total specimen		27	27	27	45	126

3.2.3 Batching of materials

Weight batching was used to determine the quantities of materials used for the study. The mix proportion used was 1:6 (one part cement: six parts of sand) at a constant water cement ratio of 0.5 as used by Odeyemi et al. (2019); and Ogunbayo and Aigbavboa (2020).

3.2.4 Mixing of materials

The material was mixed manually as shown in fig. 3.4 a and b. The following procedure was followed in the mixing of materials.

A platform of hard metal surface was prepared. The measured sand was first batched onto the platform and spread over the surface. Then the measured required cement was spread on the sand. The sand and the cement were mixed by turning it over and over until a uniform mixture and colour was obtained as shown in fig 3.4 b. The measured amount of water was added. The mixture was then turned over and over again until a semi wet uniform mixture was obtained as shown in fig, 3.4 c.

Figure 3. 4: Mixing of materials

3.3 Moulding of the specimen

A hydraulic pressure brick moulding machine which has a dimension 100mmx100mmx130mm as shown in figure 3.5 a. was used for the moulding of the specimen. The mould was cleaned with a scraper and cloth to remove all dirt as shown in figure 3.5 b. The interior of the mould was lubricated with mould oil to ensure easy demoulding and obtain a smooth surface as shown in fig 3.5 c. The measured material was then poured in the mould in three layers and each of the layers was uniformly tamped seven times using metal tamping rod to ensure that all the materials in the mould were uniformly compressed as shown in the fig. 3.5 d. The excess materials on top of the mould were removal with a hand trowel and the top cover of the mould was then covered and tightened. A pressure of 140 bar was applied from the hydraulic jack of the mould until the materials in the mould were uniformly compressed. The compressed bricks were gently removed from the mould and placed on a wooden pallet as shown fig. 3.5 e.

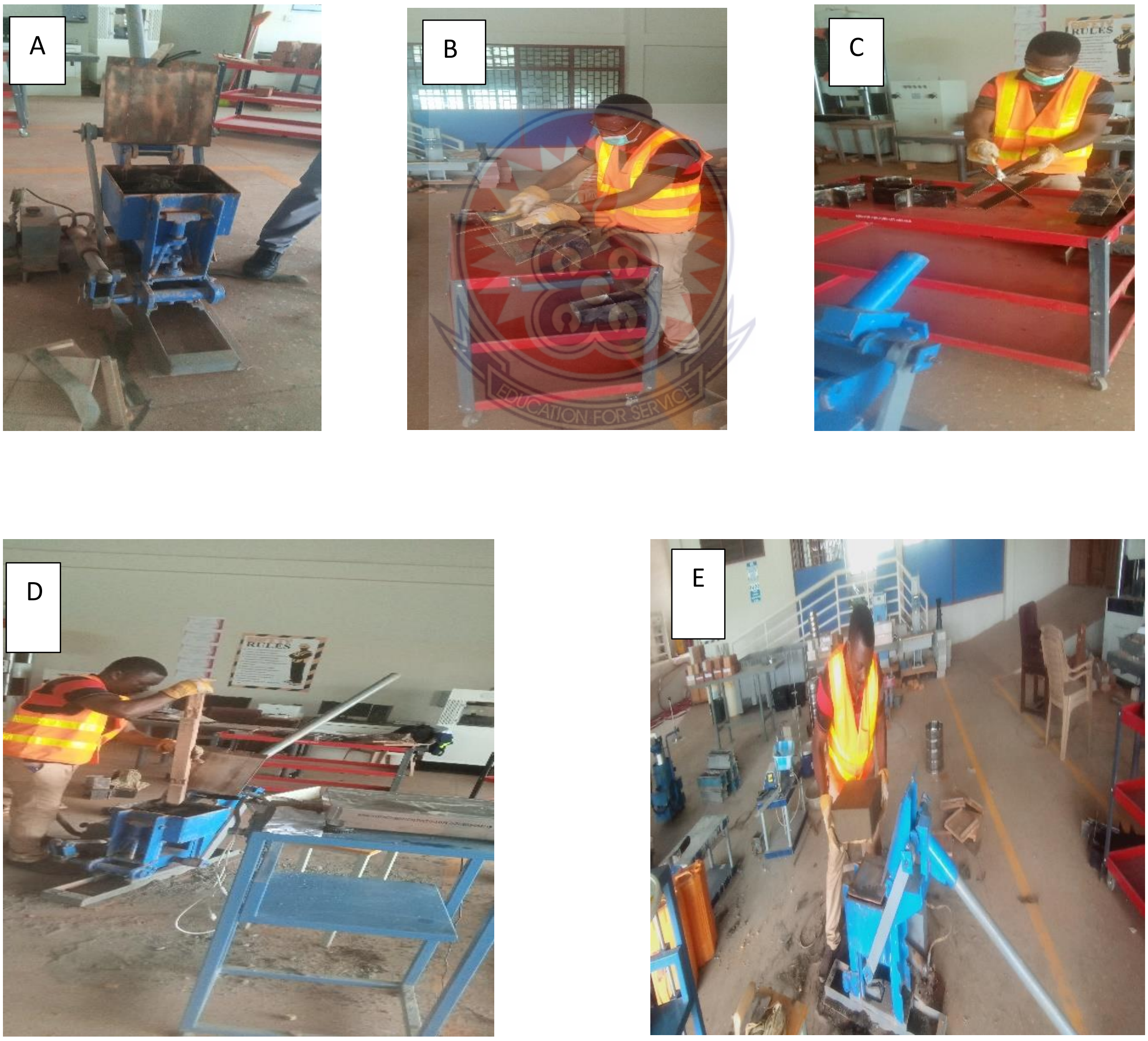

Figure 3. 5: Moulding of the specimens

3.4 Curing of specimens

The specimens were cured using the water spraying method in the laboratory for 7 days, 14 days, 21 days, and 28 days respectively as shown in figure 3.6 a and 3.6 b for all the sandcrete specimens.

Figure 3. 6: Curing of the specimens

3.5 Testing Procedures.

Specimens of 7, 14, 21, and 28 curing days for the three sand samples used for the experiment were tested for their density, water absorption, compressive strength, Split Tensile, and abrasive resistance.

3.5.1 Density test

ASTMC140/C140 (2021) was used as a guide to determine the air-dry density of specimen of 7, 14, 21, and 28 curing days as shown in fig. 3.7 a and fig. 3.7 b and using the formula; D=m/v (kg/m^3).

Where;

D=Density of the specimen in kg/m^3

m=mass of the specimen in kg.

v=volume of the specimen in m^3

Figure 3. 7. Determining the density test

3.5.2 Water Absorption Test

ASTMC140/C140 (2021) was used as a guide to determine the water absorption of specimen of 28 curing days. The specimen was oven dried at a constant temperature of 105 degree Celsius for 24 hours as shown in fig 3.8 b. The weight of oven dried specimen was measured using electronic balance as shown in fig, 3.8 a. The oven dried weight of the specimen was recorded as (Dw). The specimen was immersed in water at an average temperature 25 degree Celsius for a period of one hour as shown in fig 3.6c. After an hour of immersion of the specimens, the specimens were removed from the water and kept on a dry surface for 2 minutes to allow the water to drain. The saturated weight of the immersed specimens was measured and recorded as (Sw). Water absorption (Wa) in percentage of the specimen was determine using the formula;

$Wa = (Sw - Dw/Dw) \times 100.$

Where;

Wa =water absorption in percentage (%).

Sw=saturated weight in kg.

Dw=oven dry weight in kg.

Figure 3. 8: Determining the water absorption

3.5.3 Abrasive resistance test

ASTMC944/C944 (2019) was used as a guide to determine the abrasion resistance of specimen of 28 curing days as shown in figure 3.9 a, b, c and d. The initial weight of specimen before brushing was determined and recorded as *(Mi)*. The specimens were placed on top of a dry surface and protected against sliding. The top of the specimen was brushed with sixty strokes of a wire brush in forward and backward motion for sixty seconds. The weight of the brushed specimens was determined and recorded as *(Mii)*. The cross-sectional area of the brushed surface of the specimen was determined and recorded as *(A)*. The abrasion of the specimens in percentage was calculated using the formula;

$Ar = (A / Mi - Mii) \times 100$

Where;

Ar=Abrasion in percentage

A=cross sectional area the brushed surface in m^2

Mi=initial weight of the specimen before brushing in kg

Mii=weight of the specimen after brushing in kg

Figure 3. 9: Conducting the Abrasion test.

3.5.4 Compressive strength test

ASTMC90 (2009) was used as a guide to determine the compressive strength of specimens of 7, 14, 21, and 28 curing days using the universal testing machine as shown fig 3.10 a. The bearing surface of the testing machine and the specimens were cleaned. The specimen was cleaned and placed in the machine in such a manner that load would apply to the entire opposite surface areas. The blocks were centrally aligned on the base plate of the machine. The upper movable portion of the machine was rotated gently by electrical means so that it touched the top surface of the brick. Load of 0.05N/mm^2/s was gradually applied to the specimen till they failed as shown in fig 3.10 b. This load is known as 'Failure Load' or 'maximum applied load'. Then the maximum applied load was recorded as *(N)*. Then the cross-sectional area of the brick was calculated and recorded as *(A)*. The maximum compressive strength of the specimen was calculated using the formula;

$F = N/A$

Where;

F=compressive strength of the specimen in (N/mm^2).

N=maximum applied load in (N).

A=cross sectional area of the specimen in (mm^2).

Figure 3. 10: **Compressive strength test**

3.5.5 Split Tensile test

ASTMC496/C496M (2004) was used as a guide to determine the split tensile strength of specimen of 7, 14, 21, and 28 curing days using the universal testing machine as shown fig. 3.11 a.

The bearing surface of the testing machine was cleaned. Split tensile plates were used as shown in fig. 3.11 b. Split template was placed at the base of the machine. The first block was placed in the machine centrally on the split template, after that the top splitting template was also placed centrally on the specimen. The specimen was placed in the machine in such a manner that load would apply to the entire opposite surface areas. The bricks were centrally aligned on the splitting base plate of the machine. The upper movable portion of the machine was rotated gently by electrical means so that it touches the top surface of the brick as shown in fig. 3.11 c. Load of $0.05N/mm^2/s$ was gradually applied to the specimen till they split as shown in fig 3.11 d. Then the maximum applied load was recorded as *(2P)*. Then the cross-sectional area of the brick was calculated and recorded as (πLd). The tensile strength of the specimen was calculated using the formula;

$T=2P/\pi Ld$

Where;

T=splitting tensile strength of the specimen in (MPa).

P=maximum applied load indicated by testing machine (N).

L=length of the specimen in (mm).

d=diameter (mm)

Figure 3. 11. Determining the split tensile strength

3.6 Data Analysis

The data obtained from the laboratory was analysed using excel V.16 and was presented using tables and charts.

A one-way (ANOVA) analysis was done to determine significant differences between the compressive strength of the specimen for 28 curing days.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the analysis of the results as discussed according to the order of the research objectives and questions. This chapter presents the results of particle size distribution analysis of pit, river and sea sand for sandcrete blocks production, the results of density and water absorption test of sandcrete blocks produced with different sources of sand, the results of compressive and split tensile strength test of sandcrete blocks produced with different sources sand, and the results of abrasion test for sandcrete blocks produced with different sources of sand.

4.1 Results of Particle Size Distribution

This section presents the results of particle size distribution analysis of river sand, sea sand and pit sand used for the study.

Table 4. 1: Particle size distribution table of river sand

Sieve Sizes (mm)	Mass Retained (kg)	Percentage (%) Retained	Cumulative Percentage (%) Retained	Percentage (%) Passing
5	0.013	1.25	1.25	98.75
3.35	0.008	0.79	2.04	97.96
2.36	0.029	2.93	4.98	95.02
2	0.035	3.54	8.51	91.49
1.18	0.247	24.75	33.26	66.74
0.6	0.315	31.56	64.82	35.18
0.3	0.177	17.73	82.55	17.45
0.075	0.157	15.69	98.24	1.76
Pan	0.018	1.76	100.00	0.00
Total	**0.998**	**100.00**		

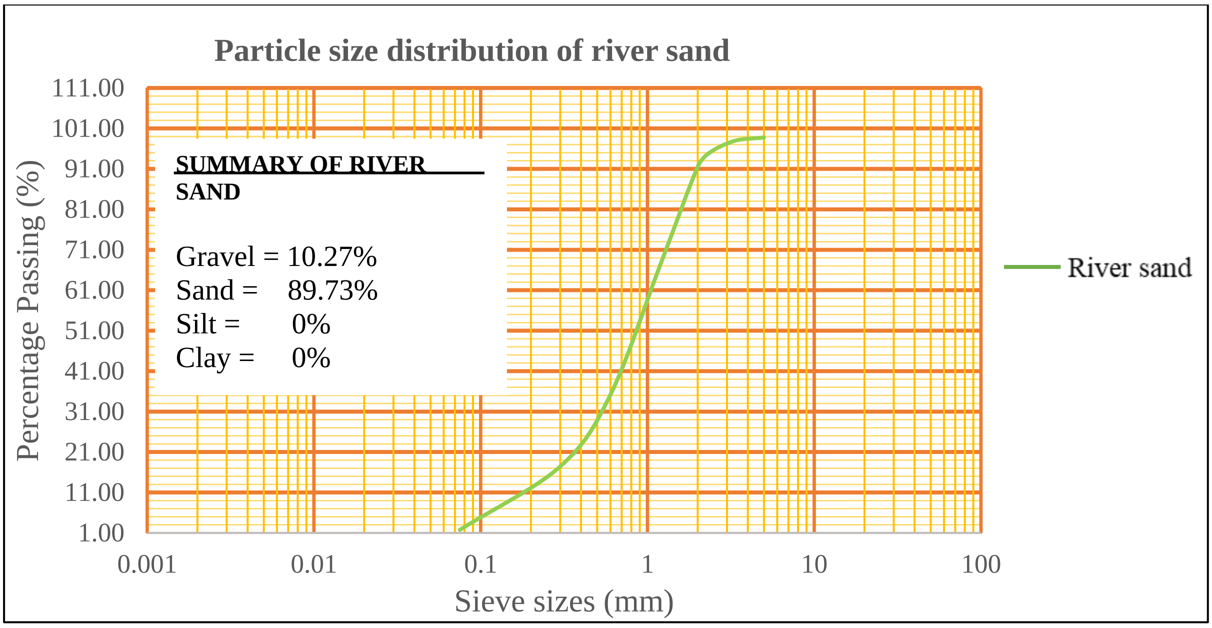

Figure 4. 1: **Particle size distribution curve for river sand.**

Figure 4.1, shows the results of particle size distribution curve of river sand. The results indicate that, the gravel and sand content in the river sand were 10.2% and 89.73% respectively, whereas the silt and clay content were 0%.

Table 4. 2: Particle size distribution table of sea sand

Sieve Sizes (mm)	Mass Retained (kg)	Percentage (%) Retained	Cumulative Percentage (%) Retained	Percentage (%) Passing
5	0.0044	0.44	0.44	99.56
3.35	0.0454	4.57	5.01	94.98
2.36	0.0839	8.45	13.46	86.54
2	0.0619	6.23	19.70	80.30
1.18	0.246	24.77	44.47	55.53
0.6	0.3111	31.33	75.80	24.20
0.3	0.1466	14.76	90.56	9.44
0.075	0.0918	9.24	99.81	0.19
Pan	0.0019	0.19	100.00	0.00
Total	**0.993**	**100.00**		

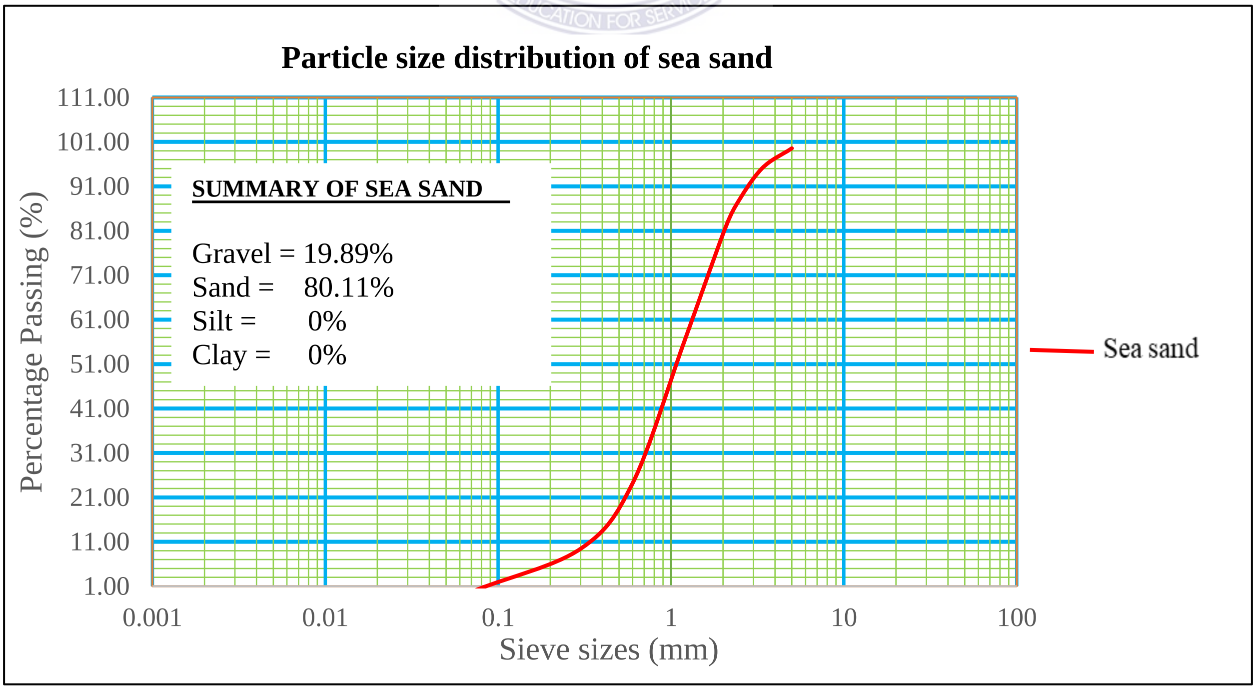

Figure 4. 2: Particle size distribution curve for sea sand.

Figure 4.2 shows the results of particle size distribution curve of sea sand. The results indicate that, the gravel and sand content in the pit sand were 19.89% and 80.11% respectively, whereas no silt and clay content were present in the sea sand.

Table 4. 3: Particle Size distribution table of pit sand

Sieve Sizes (mm)	Mass Retained (kg)	Percentage (%) Retained	Cumulative Percentage (%) Retained	Percentage (%) Passing
5	0.0046	0.46	0.46	99.54
3.35	0.0021	0.21	0.67	99.33
2.36	0.0049	0.49	1.16	98.84
2	0.004	0.40	1.56	98.44
1.18	0.0348	3.49	5.05	94.95
0.6	0.4869	48.78	53.83	46.17
0.3	0.414	41.48	95.31	4.69
0.075	0.0454	4.55	99.86	0.14
Pan	0.0014	0.14	100.00	0.00
Total	**0.998**	**100.00**		

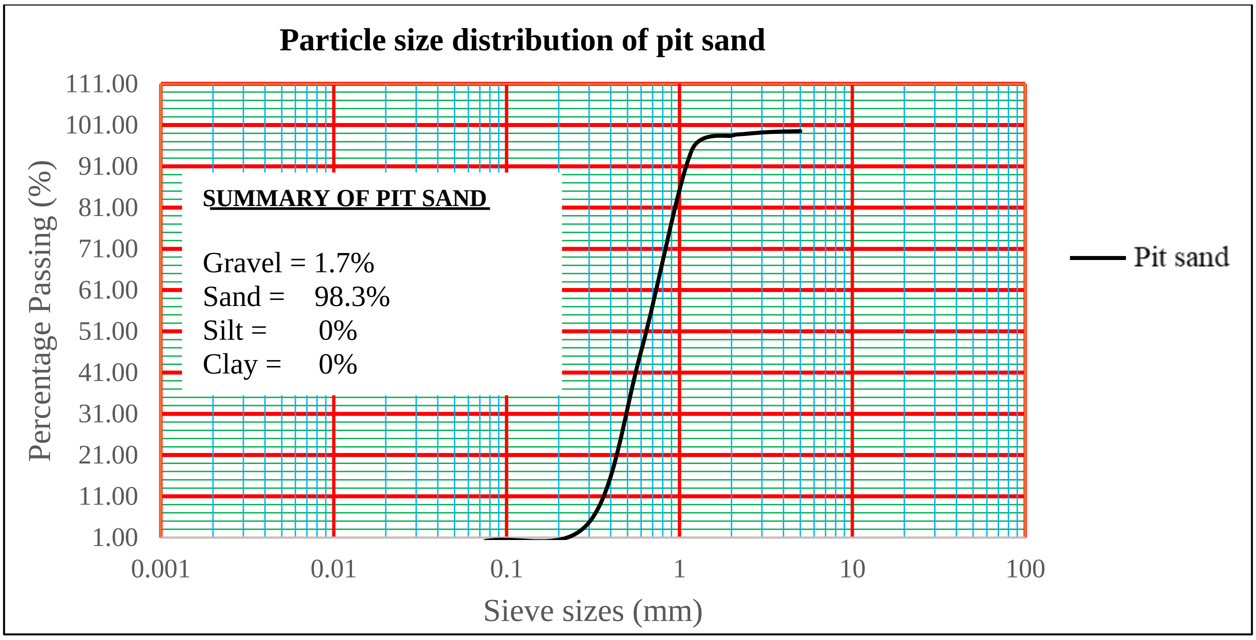

Figure 4. 3: **Particle size distribution curve of pit sand.**

Figure 4.3 shows the results of particle size distribution curve of pit sand. The results revealed that, the gravel and sand content in the pit sand were 1.7% and 98.3% respectively. Also 0% silt and clay content were recorded in the pit sand.

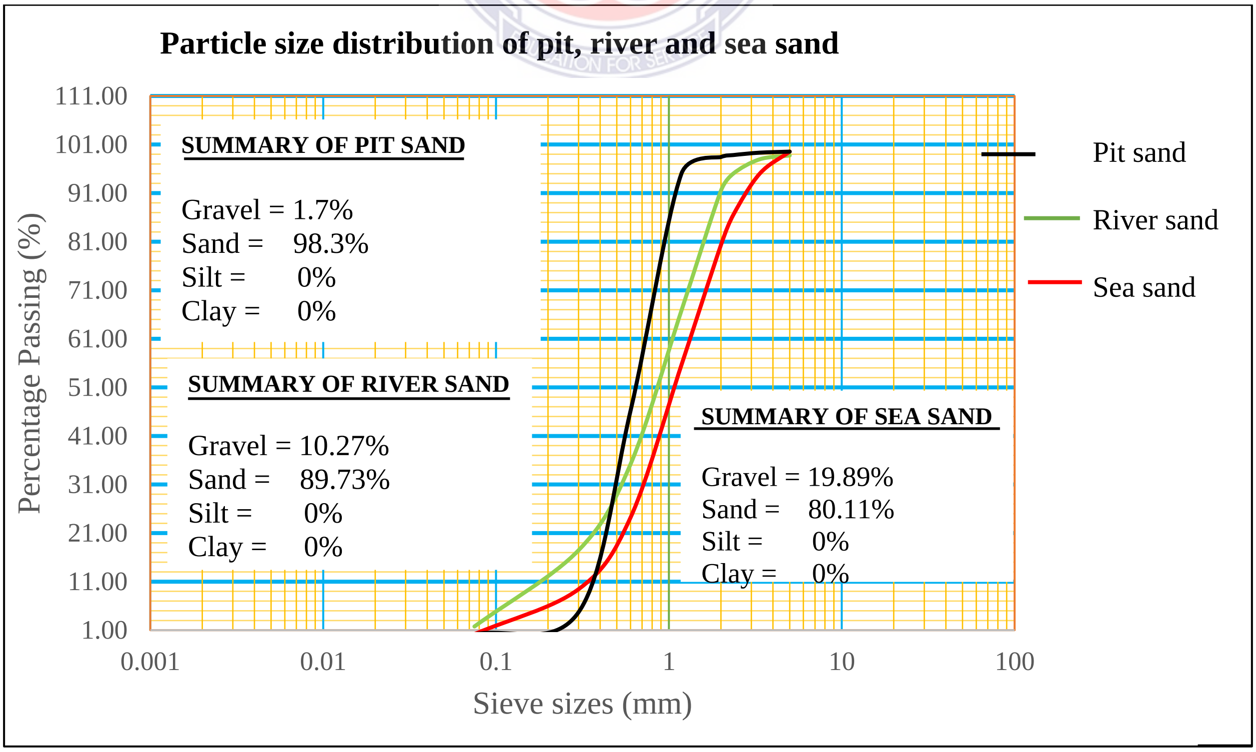

Figure 4. 4: Summary particle size distribution curve of pit, river and sea sand.

Figure 4.4, shows the summary results of particle size distribution curves of river, sea and pit sand. The results indicate that, the gravel and sand content in the river, sea and pit sand were 10.2% and 89.73%, 19.89% and 80.11% and 1.7% and 98.3% respectively, whereas the silt and clay content of all the sand were 0%.

4.2 Results of density test of sandcrete blocks produced with different sources of sand

Figure 4.5 shows the results of air-dry density of specimen of 7, 14, 21, and 28 curing days respectively for pit sand, river sand and sea sand.

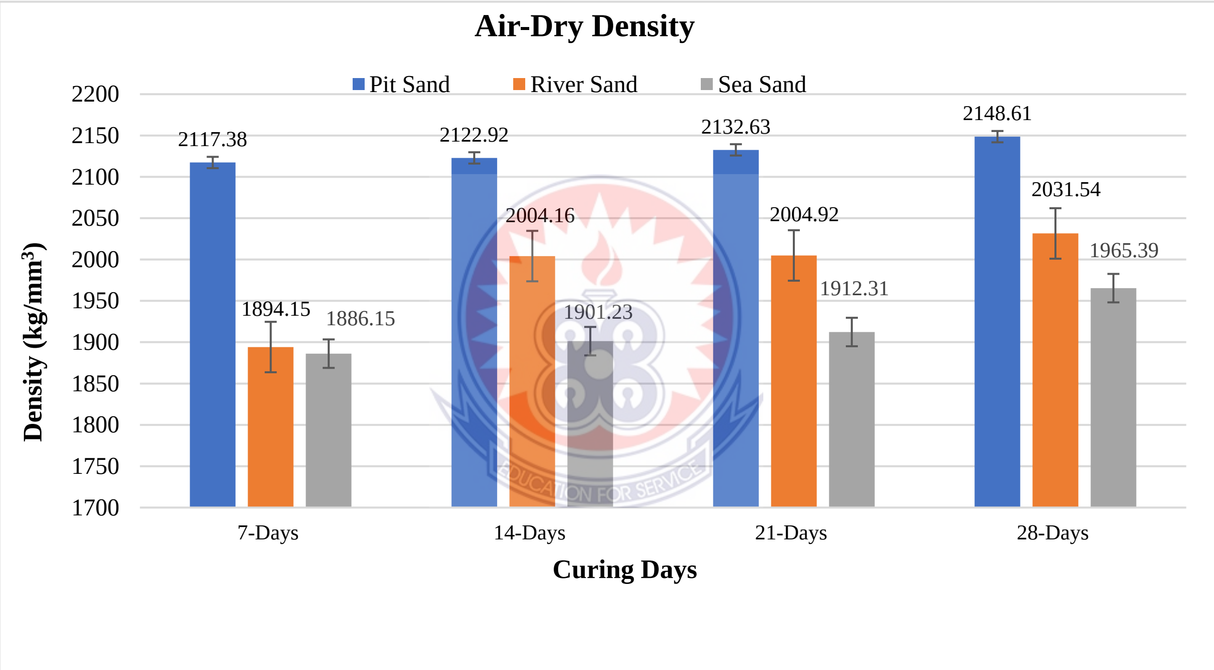

Figure 4. 5. Results of Air Dry – Density of Specimens

Figure 4.5 revealed that, the density of specimens for pit sand, river sand and sea sand increased respectively as the curing days increased. It was also revealed that the pit sand showed a higher density from 2117.38 kg/mm^3 up to 2148.61 kg/mm^3 for the curing days, followed by the river sand. It was observed that the pit sand was finer as compared to the river and the sea sand which makes it to be more consolidated with minimal micropores, which resulted in high density of the specimen made with pit sand. Similar trend was observed by Ajibose and

Olamoju (2019). The density 2117.38kg/mm^3, 2122.92kg/mm^3, 2132.63kg/mm^3, and 2148.61kg/mm^3, for specimens of 7,14, 21 and 28 curing days respectively for pit sand, exceeds the minimum density 2000kg/mm^3 for normal weight masonary unit recommended by ASTM C90 (2009). The density 2004.16kg/mm^3, 2004.92kg/mm^3, and 2031.54kg/mm^3, for specimens of 14, 21 and 28 curing days respectively for river sand, exceed the minimum density 2000kg/mm^3 for normal weight masonary unit recommended by ASTM C90 (2009). Finally, the density 1886.15kg/mm^3, 1901.23kg/mm^3, 1912.31kg/mm^3, and 1965.39kg/mm^3, for specimens of 7,14, 21 and 28 curing days respectively for sea sand, met the minimum density for medium weight masonary unit recommended by ASTM C90 (2009).

4.3 Results of water absorption test of sandcrete blocks produced with different sources of sand

Figure 4.6 shows the results of water absorption in percentage of specimens of 28 curing days for pit sand, river sand and sea sand respectively.

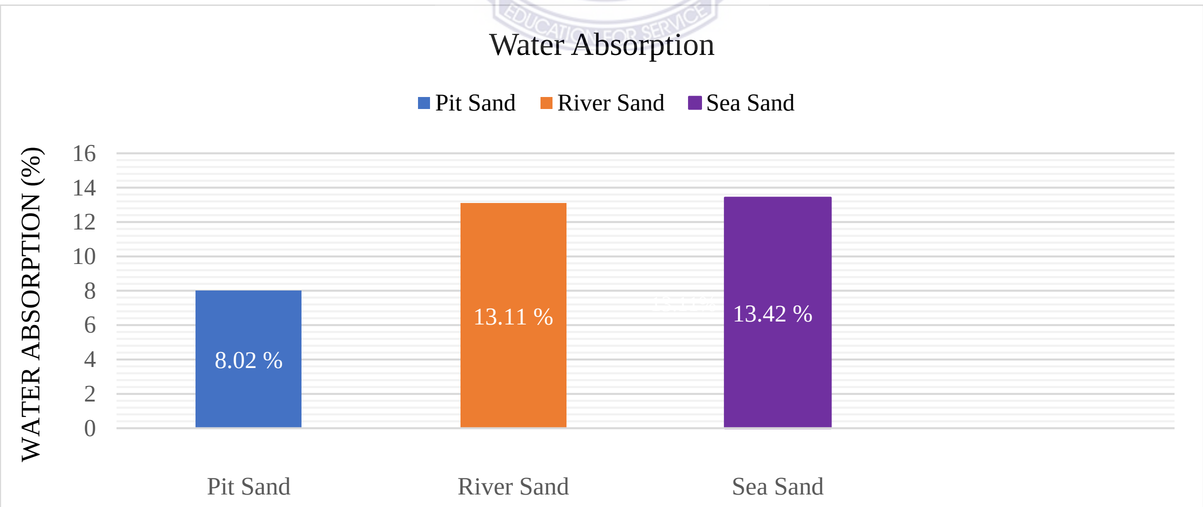

Figure 4. 6. Results of Water Absorption of Specimens

Figure 4.6 shows that, the water absorption of specimens for, river sand and sea sand after 28 days of curing was higher as compared to the pit sand. The water absorption of 8.02% for specimens made with pit sand was 5.09% and 5.40% lower than the river and the sea sand respectively. This indication revealed that the specimens made with river and sea sand absorbed more moisture than the specimens made with pit sand. The increase in water absorption of specimens made with river and sea sand could be possible indication of presence of micropores in the specimens as argued by Alengaram et al. (2019). The water absorption of 8.02% for pit sand specimen after 28 curing days met the minimum water absorption 12% recommended by ASTMC90 (2009).

4.4 Results of compressive strength test of sandcrete blocks produced with different sources of sand.

Figure 4.7 shows the results of compressive strength of specimens of 7, 14, 21, and 28 curing days respectively for pit sand, river sand and sea sand.

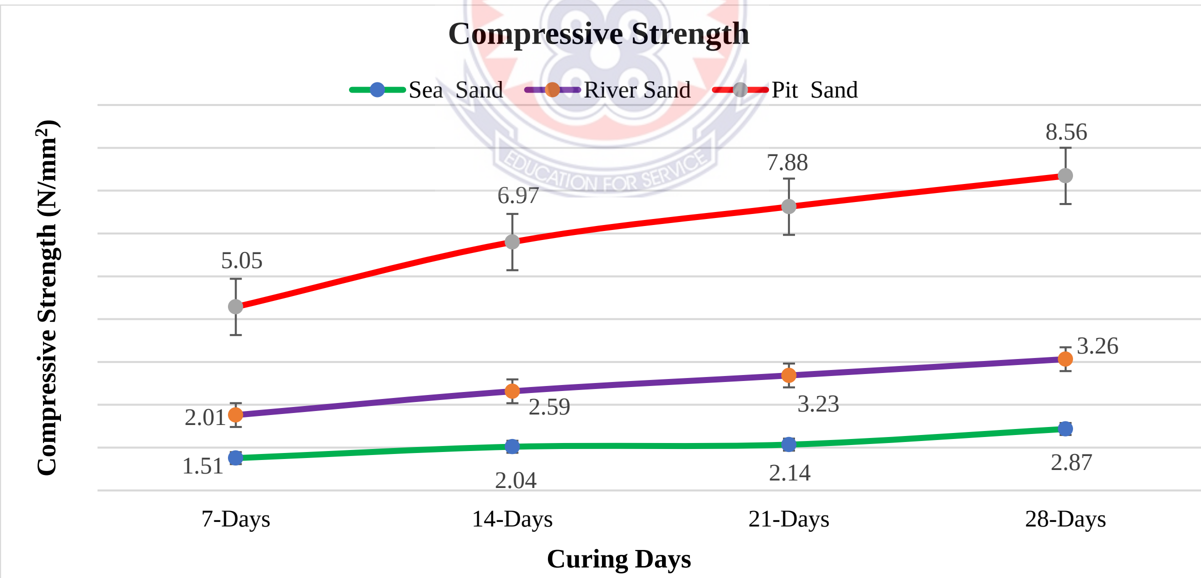

Figure 4. 7: Results of Compressive Strength of Specimens

Figure 4.7 shows the results of the test conducted to determine the compressive strength of the specimens of 7, 14, 21 and 28 curing days respectively for the pit sand, river sand and sea sand.

It was observed that, the compressive strength of specimens for pit sand, river sand and sea sand increased respectively as the curing days increased. It was observed that the compressive strength of specimens made with pit sand was highest, followed by river sand for all the curing days respectively. The results of this study are consistent with the study by Ajibose and Olamoju (2019). The study revealed that the compressive strength for pit sand, river sand and sea sand respectively for 7, 14, 21 and 28 curing days is below the compressive strength 13.1 N/mm^2 for load bearing masonry unit recommended by ASTMC90 (2009) and higher than the compressive strength of masonry units in a wall of a one or two-story house or of a one or two-story building divided into flats shall not be less than $2.75N/mm^2$ for sandcrete blocks and $5.2N/mm^2$ for bricks (Ghana Building Code, 2018). And also, higher than Nigerian Industrial Standard NIS 087:2000, of minimum strength of sandcrete blocks between $2.5N/mm^2$ to $3.45N/mm^2$.

4.5 One-Way-ANOVA test results of the compressive strength

Table 4.4 shows the results of One-Way-ANOVA analysis of the compressive strengths for 28-curing days to determine whether there is a significant difference between the means of the specimens respectively for pit sand, river sand and sea sand.

Table 4. 4: **One-Way-ANOVA test results of the compressive strengths (28-Curing days)**

Treatment Name	N	Missing	Mean	Std Dev	SEM
Pit sand	3	0	8.560	0.630	0.364
River sand	3	0	3.260	0.615	0.355
Sea sand	3	0	2.867	1.313	0.758

All Pairwise Multiple Comparison Procedures (Holm-Sidak method)

Comparison	**Diff of Means**	**T**	**P**	**P<0.050**
Pit Sand vs. Sea Sand	5.693	8.459	0.003	Yes
Pit Sand vs. River Sand	5.300	7.875	0.003	Yes
River Sand vs. Sea Sand	0.393	0.584	0.590	No

The one-way-ANOVA test result of the compressive strength for 28 curing days respectively for pit sand, river sand and sea sand revealed in table 4.4 shows that, there was a significant difference between the pit sand and the sea sand at t 8.459 and at p 0.003. This indicates that the sea sand cannot be used where pit sand is used for structural application.

It was again revealed from the table 4.4 that, there was a significant difference between the pit sand and the river sand at t 7.875 and at p 0.003. This indicates that, the river sand cannot be used at where pit sand is used for structural application. Parallel trend was observed when comparing the pit sand and the sea sand. Finally, there was an indication that, there was no significant difference between the river sand and sea sand at t 0.584 and at p 0.590 respectively. This indicates that both river sand and sea sand can be used for the same structural application. From the ANOVA analysis, it can be posited that the source of sand namely: Pit sand, river sand and sea sand influences the properties of sandcrete blocks.

4.6 Results of split tensile test of sandcrete blocks produced with different sources of sand.

Figure 4.8 shows the results of spilt tensile strength of specimens of 7, 14, 21, and 28 curing days respectively for pit sand, river sand and sea sand.

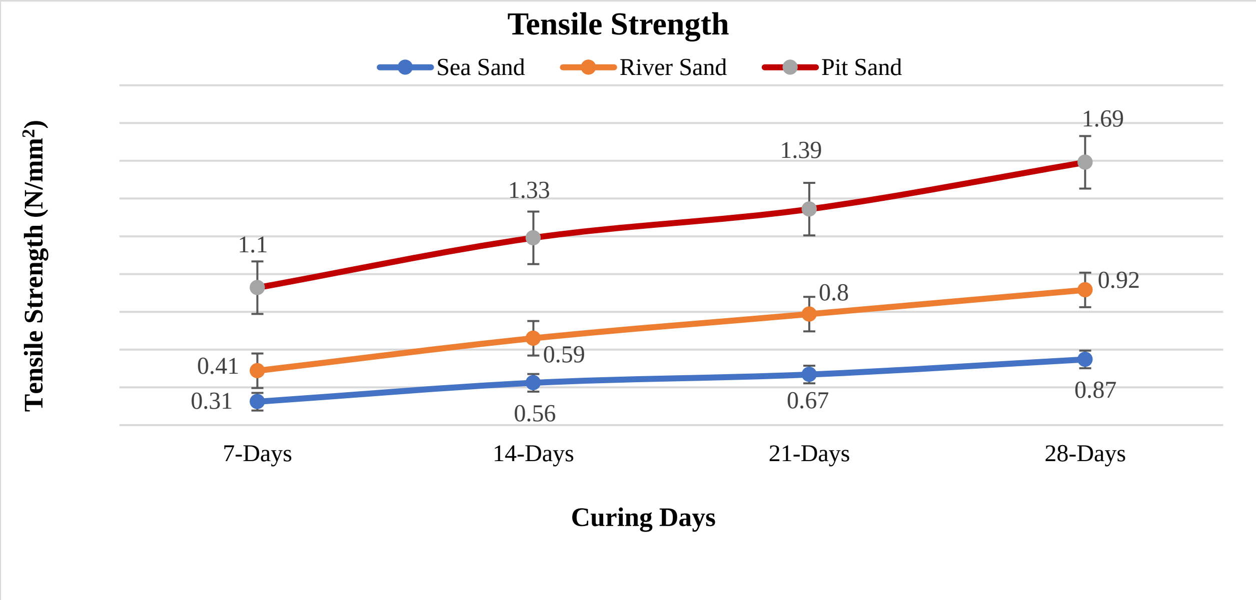

Figure 4. 8: Results of Splitting Tensile Strength of Specimens

Figure 4.8 shows the split tensile strength for specimens of 7, 14, 21 and 28 curing days respectively for pit, river and sea sand. The test revealed that, the tensile strength of specimens for pit sand, river sand and sea sand increased respectively as the curing days increased. The tensile strength for pit sand increased from 1.10 N/mm^2, 1.33 N/mm^2, 1.39 N/mm^2, up to 1.69 N/mm^2 respectively for 7, 14, 21 and 28 curing days, followed by the river sand. Parallel observation was made on the compressive strength and density test results.

4.7 Results of abrasion test of sandcrete blocks produced with different sources of sand.

Figure 4.9 shows the results of abrasion of specimen of 28 curing days respectively for pit sand, river sand and sea sand.

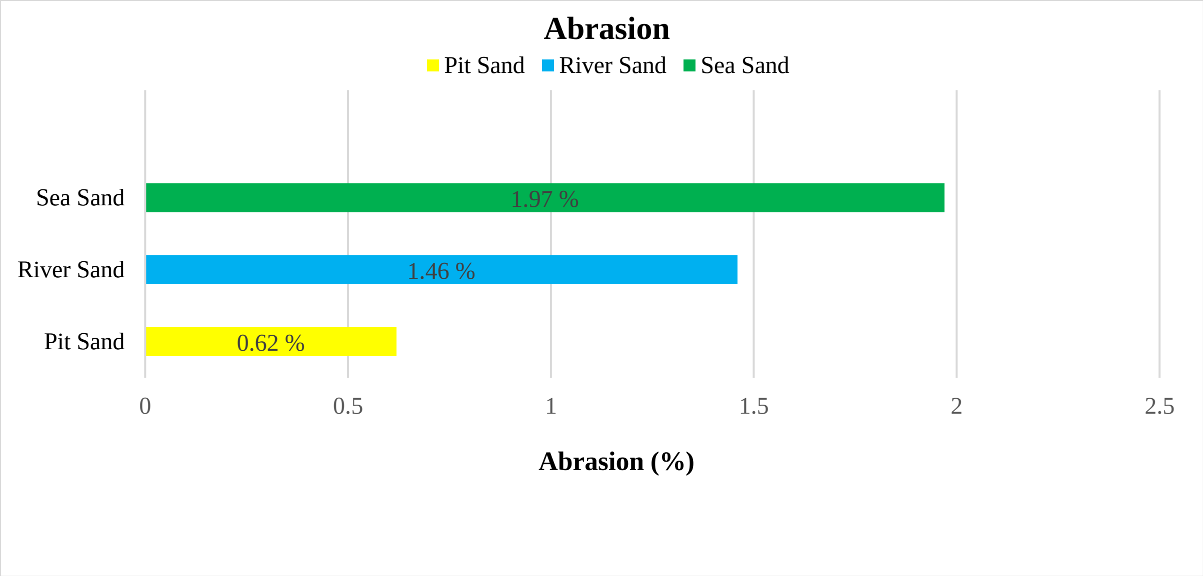

Figure 4. 9. Results of Abrasion of Specimens.

Figure 4.9 shows that, the abrasion of specimens for river sand and sea sand increased respectively as compared to the pit sand specimens for 28 curing days. The abrasion 0.62% for specimens made with pit sand was 0.84% and 1.34% lower than the river and the sea sand specimens respectively. Similar observation was made on the water absorption test results. This indication revealed that the river and sea sand specimens have lower abrasion resistance than the pit sand specimens. A Lower abrasion value of material indicates high abrasion resistance and good bond between the particles. Hence, lower abrasion value reported for pit sand specimens could be possible indication of good bond of the particles of the pit sand specimens which resulted in high density, high compressive strength, high tensile strength, low water absorption and good abrasion resistance when compared to the specimens made with river and sea sand respectively.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

5.0 Introduction

This chapter comprises a summary of findings, conclusion, and recommendations.

5.1 Summary of findings

The summary of findings is presented under the headings of specific objectives set for the study;

- To determine the particle size distribution of pit, river, and sea sand for sandcrete blocks produced in the Ghanaian construction industry.
- To determine the physical properties (density and water absorption) of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.
- To determine the mechanical properties (compressive and splitting tensile strength) of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.
- To determine the abrasion resistance of sandcrete block made with different sources of sand in Ghanaian construction industry.

5.1.1 Particle size distribution

1. **The particle size distribution of pit, river, and sea sand for sandcrete blocks produced in the Ghanaian construction industry.**

   The main findings were as follows;

   a. It was revealed that the silt content and the clay content in the pit sand, river sand and sea sand were all 0%, whiles the gravel and sand content in pit sand were 1.7% and 98.3% respectively. Again, the gravel and sand content in the river sand were 10.27%

and 89.73% respectively. Finally, the gavel and sand content in the sea sand was also found to be 19.89% and 80.11% respectively.

b. It was also revealed that the pit sand was finer as compared to the river and the sea sand which makes it to be more consolidated with minimal micropores, which resulted in high density, low water absorption, high compressive strength, high tensile strength and good abrasion resistance of the specimens made with pit sand.

5.1.2 Physical Properties

2. The density of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.

The key findings were as follows:

a. It was revealed that, the density of sandcrete specimens containing pit sand, river sand and sea sand increased as the curing days increased.

b. It was also revealed that the specimens made with pit sand show a higher density ranging from 2117.38 kg/mm^3 up to 2148.61 kg/mm^3 for the different curing days, followed by the specimens made with river sand.

c. The density 2117.38kg/mm^3, 2122.92kg/mm^3, 2132.63kg/mm^3, and 2148.61kg/mm^3, for specimens of 7,14, 21 and 28 curing days respectively for pit sand, exceeds the minimum density 2000kg/mm^3 for normal weight masonary unit recommended by ASTM C140/C140 (2021).

3. **The water absorption of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry**.

The main findings were as follows:

a. It was revealed that, the water absorption of sandcrete specimens containing river sand and sea sand increased respectively at 28 curing days as compared to the pit sand.

b. It was again revealed that, the water absorption of 8.02% for specimens made with pit sand was 5.09% and 5.40% lower than the river and the sea sand respectively.

c. It was found that the water absorption of 8.02% for pit sand specimens for 28 curing days met the minimum water absorption of 12% recommended by ASTMC90 (2009).

5.1.3 Mechanical Properties

5.1.3.1 The compressive strength of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.

The main findings were as follows:

a. It was revealed that, the compressive strength of specimens for pit sand, river sand and sea sand increased respectively as the curing days increased.

b. It was also revealed that, the compressive strength of specimens made with pit sand was highest followed by river sand and then sea sand for all the curing days.

c. The study again revealed that the compressive strength for pit sand, river sand and sea sand respectively for 7, 14, 21 and 28 curing days was below the minimum compressive strength of 13.1 N/mm^2 for load bearing masonry unit recommended by ASTMC90 (2009).

5.1.3.2 The split tensile strength of sandcrete blocks produced with different sources of sand in the Ghanaian construction industry.

The main findings were as follows:

a. The study revealed that, the tensile strength of sandcrete specimens with pit sand, river sand and sea sand increased as the curing days increased.

b. The tensile strength for pit sand of 1.10 N/mm^2, 1.33 N/mm^2, 1.39 N/mm^2, and 1.69 N/mm^2 respectively for 7, 14, 21 and 28 curing days. Again, the tensile strength for river sand of 0.41 N/mm^2, 0.59 N/mm^2, 0.80 N/mm^2 and 0.92 N/mm^2 respectively for 7, 14, 21, and 28 curing days. Finally, the split tensile strength for the sandcrete specimens made with sea sand of 0.31 N/mm^2, 0.56 N/mm^2, 0.67 N/mm^2, and 0.87 N/mm^2 for 7, 14, 21, and 28 curing days respectively.

5.1.3.4 Abrasion resistance

1 The abrasion of sandcrete block made with different sources of sand in the Ghanaian construction industry.

The main findings were as follows;

a. It was revealed that abrasion 0.62% for specimen made with pit sand was 0.84% and 1.34% lower than the river and the sea sand specimens respectively.

b. It was revealed that the river and sea sand specimens have lower abrasion resistance than the pit sand specimens.

5.2 Conclusions

Sandcrete blocks have been one of the walling units used in the Ghanaian construction industry. The source of sand is one of the factors that influence the properties of sancrete blocks. In this experiment the properties of sandcrete blocks made with pit sand, river sand and sea sand were investigated. The results revealed that the specimens made with pit sand showed a higher density from 2117.38 kg/mm^3 up to 2148.61 kg/mm^3 for the curing days, followed by the specimens made with river sand. It was again revealed that, the water absorption of 8.02% for specimen made with pit sand was 5.09% and 5.40% lower than the specimens made with river and the sea sand respectively at 28 curing days. It was found that the water absorption of 8.02%

for pit sand specimens at 28 curing days met the minimum water absorption of 12% recommended by ASTMC140/C140 (2021). The study again revealed that the compressive strength for pit sand, river sand and sea sand respectively for 7, 14, 21 and 28 curing days was below the minimum compressive strength of 13.1 N/mm^2 for load bearing masonry unit recommended by ASTMC90 (2009). It was again revealed that, the tensile strength for specimens made with pit sand increased from 1.10 N/mm^2, 1.33 N/mm^2, 1.39 N/mm^2, up to 1.69 N/mm^2 respectively for 7, 14, 21 and 28 curing days followed by the specimens made with river sand. It was revealed that the river and sea sand specimens have a higher abrasion value than the pit sand specimens. Lower abrasion value reported for pit sand specimens could be possible indication of good bond of the particles of the pit sand specimens which resulted in high density, high compressive strength, high tensile strength, low water absorption and good abrasion resistance when compared to the specimens made with river and sea sand respectively. The ANOVA analysis revealed that there was a significant difference between pit sand, sea sand and river sand whereas there were no significant differences between river sand and sea sand. The study therefore, concludes that the source of sand influences the properties of sandcrete block.

5.3 Recommendations

The study recommends that;

1. Pit sand should be used for moulding of blocks since the specimens made with pit sand show better performance as compared to specimens made with river sand and sea sand.
2. Different mix design should be investigated on the three sources of sand to determine their possible effects on the strength properties of sandcrete block.
3. The chemical resistance of the three sources of sand should also be investigated to determine which sand is more resistant to chemical attack.

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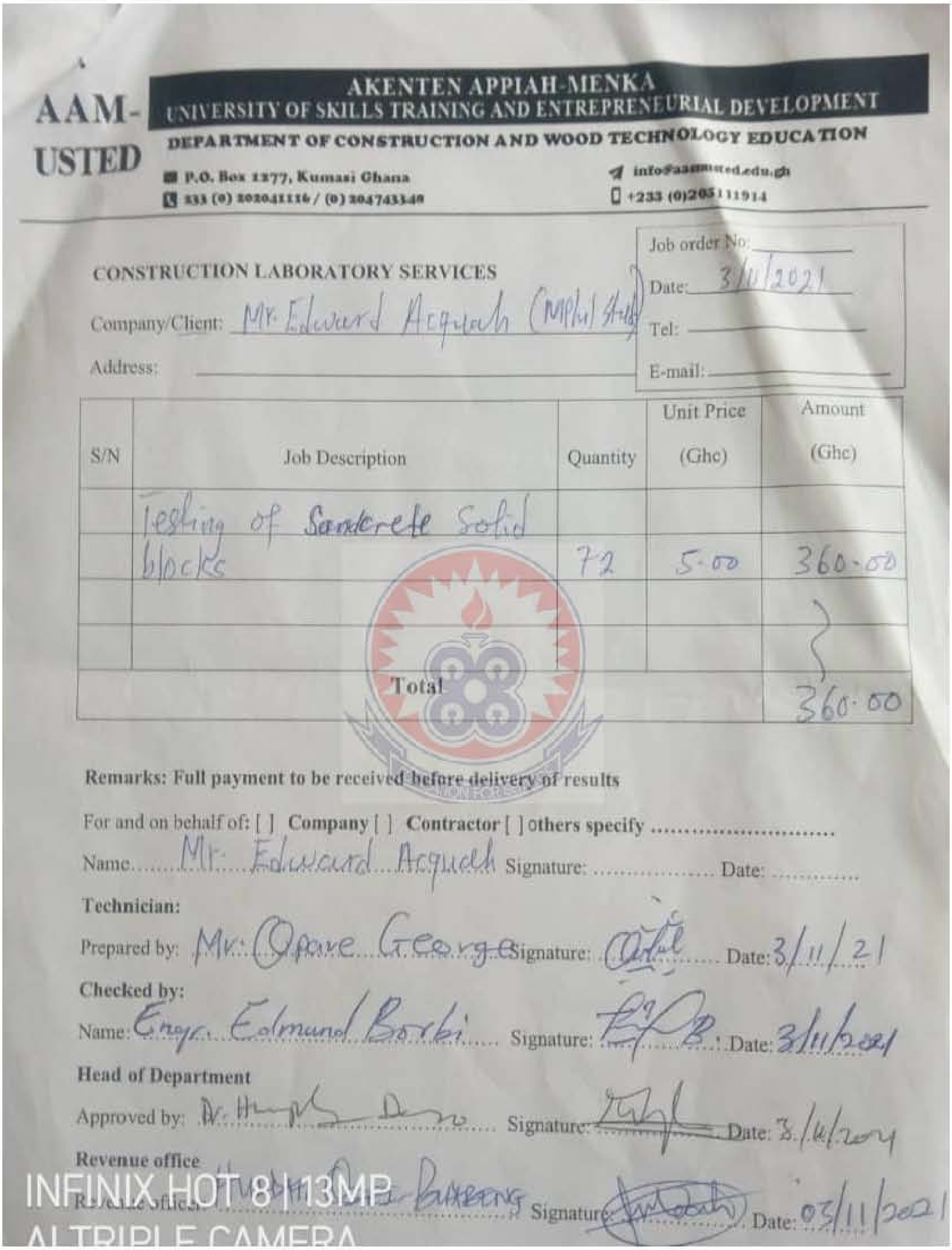
APPENDIX



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CONSTRUCTION LABORATORY SERVICES

Job order No: ____
Date: 3/11/2021
Tel: ____
E-mail: ____

Company/Client: Mr. Edward Acquah (MPhil Std)

Address: ____

S/N	Job Description	Quantity	Unit Price (Ghc)	Amount (Ghc)
	Testing of Sandcrete Solid blocks	72	5.00	360.00
Total				360.00

Remarks: Full payment to be received before delivery of results

For and on behalf of: [ ] **Company** [ ] **Contractor** [ ] others specify ....

Name: Mr. Edward Acquah Signature: .... Date: ....

Technician:

Prepared by: Mr. Opare George Signature: ____ Date: 3/11/21

Checked by:

Name: Engr. Edmund Borbi Signature: ____ Date: 3/11/2021

Head of Department

Approved by: Dr. Humphrey Danso Signature: ____ Date: 3/11/2021

Revenue office

Revenue officer: ____ Boateng Signature: ____ Date: 03/11/2021

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RECEIPT 282983

Date: 03/11/2021

Received from: Mr. Edward Acquah (MPhil Stds)

S/No.	PURPOSE	CODE	AMOUNT GH¢	Gp
1.	Admin/Registration Overhead			
2.	Examination Fees			
3.	Handbook			
4.	Sports Fee			
5.	I. D. Card			
6.	Medical Exam Fees			
7.	Environmental Sanitation			
8.	Hall Affiliation Fee			
9.	Teaching Practice Fee			
10.	Academic Facilities User Fees			
11.	Tuition Fees (Sandwich)			
12.	Residential Facilities User Fees			
13.	Photocopy			
14.	Telephone			
15.	Application Form			
16.	Computer Training Fees			
17.	Other Revenue(s) Testing		360	00
18.	of Sandcrete			
19.	Solid blocks			
20.				
	TOTAL GH¢		360-00	

AMOUNT IN WORDS: Three hundred and Sixty

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CHEQUE No.

FINANCE OFFICER

CONSTRUCTION & WOOD LABs SAFETY ORIENTATION CHECKLIST

User Name: ______________________________ **Date:** ________________

Students Index No. *(if applicable)*: ________________________________

Please tick ☐√ *to indicate your agreement to the safety orientation requirement below*

- ☐ Use PPE (gloves, overcoat, ear plugs, safety boots, etc.), where applicable
- ☐ Seek approval from coordinator before using any tool/equipment/machine
- ☐ Ready to pay for any damage caused at the labs due to my negligence
- ☐ No food and littering in labs
- ☐ Report all emergencies to supervisor/coordinator immediately
- ☐ Always clean your work area after you finish your work
- ☐ Know the location of emergency exits
- ☐ Know the location of assembly point
- ☐ Know the location and use of fire extinguishers
- ☐ Know the location of the washroom
- ☐ Know the location of first aid kit
- ☐ Report all injuries or incidents to supervisor/coordinator immediately
- ☐ Aware of the availability of lab safety manual
- ☐ Aware of the availability of lab security manual
- ☐ Know the location of emergency phone list of lab staff
- ☐ Work only when you have the approval of the supervisor/coordinator
- ☐ Accurate (full description of the content) and complete (name, date, any major risks) labeling of samples must be done at all times, when applicable
- ☐ Aware of the instruction on safe work practices and procedures
- ☐ Be free to ask for help when needed

User Signature: ______________________________

Supervisor/coordinator's Name and Signature: __________________________