UNIVERSITY OF EDUCAT/ION, WINNEBA

COLLEGE OF TECHNOLOGY, KUMASI CAMPUS

INVESTIGATION IN TO THE USE OF CALCIUM CARBIDE WASTE AS A PARTIAL REPLACEMENT OF CEMENT IN SANDCRETE BLOCK

ERIC NARTEH QUARCOO

AUGUST, 2020

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A Dissertation in the Department of CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, submitted to the School of Graduate Studies, University of Education, Winneba, in partial fulfilment of the requirements for award of the Master of Philosophy (Construction Technology) degree

AUGUST, 2020

DECLARATION

STUDENT'S DECLARATION

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

SIGNATURE:…………………………………………………………………………..

DATE:…………………………………………………………..………………

SUPERVISOR'S DECLARATION

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

Dr. Humphrey Danso

SIGNATURE:…………………………………………………………………………..

DATE:…………………………………………………………..………………

DEDICATION

I dedicate this work to God Almighty for his love and protection. It also goes to my beautiful children Pamela, Erica, Ellis and Ella Quarcoo. My lovely mother Grace Martey

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My first and foremost gratitude goes to the Almighty God for seeing me through this programme successfully.

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ABSTRACT

Portland cement production is gradually having an effect on global warming and on the continuous decline of limestone deposits. In order to mitigate the harmful effects of cement processing and recycling of calcium carbide waste, the properties of Calcium Carbide Waste (CCW) replacement of Ordinary Portland Cement (OPC) in sandcrete blocks have been studied. OPC was replaced by CCW at 10, 20,30,40,50 and 90 percent. Mixed ratio 1:6 and a water cement ratio of 0.4 were used. 195 blocks, measuring 100 mm× 100mm × 135 mm, were prepared and tested for compressive strength, tensile strength, water absorption and density after 7, 14, 28 and 56 days of curing. Results of sandcrete block compressive strength, apart from 90% replacement of CCW, the replacement of 10%, 20%, 30%,40% and 50% at age 21 were above the minimum compressive strength of 2.8 N/mm^2 recommended by the Ghana Standard Authority (GS297, 2003). The density of the blocks decreased as the CCW content of the mixture increased. At day 21 average density decreased from 2107.619 kg/m^3, 2083.095 kg/m^3, 2035.238 kg/m^3, 2030.476 kg/m^3, 2005.952 kg/m^{3,} 1982. 857 kg/m^3 and1851.190 kg/m^3 at a placement of CCW at 0%,10%, 20%, 30%, 40%, 50% and 90% respectively. The split tensile strength also decreased as the percentage of CCW increased. At 0.263N/mm^2 strength on day 7, there is an increase difference of 0.009 N/mm^2 strength on day 14 and a decrease at 0.19, 0.005 N/mm^2 and 0.023 N/mm^2 strength on days 21, 28, and 56, respectively. The absorption value increases gradually with the percentage rise in the CCW content However, the best results were obtained at 10% to 40% replacement of the 28-days curing, which met the standard requirementThe study, concluded that the calcium carbide waste is viable as partial replacement of cement in bricks as it gives the satisfactory results at 14 to 28 days of curing

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Across the world and especially in the developing countries, housing remains one of the critical development challenges because of the huge gap between the supply and demand for housing. Consequently, some have described the situation as a global crisis. In broad terms, the housing question is largely a case of housing demand outstripping supply and or the price of housing being over and above the wage of the average worker. In both or either situation, individuals and households resort to officially unapproved means to secure housing leading to the development of slums, especially in large cities and towns.

Many of the challenges faced by the poor can be linked to housing. This is because the housing environment represents an everyday-landscape, which can either support or limit the physical, mental, and social well-being of the residents (Bonnefoy, 2007; Songsore & McGranahan, 1993). Adequate housing can be positively correlated with socio-economic benefits to both the occupants and the larger society (Fergusson, 2008). Despite the universally acknowledged importance of housing for the physical and social well-being of mankind, its provision, affordability and accessibility state that remains a seemly insurmountable problem for the nations in Sub-Saharan Africa. Werna (1998) stated that a full supply of proper decent housing for the low/average-income people is still an unresolved issue in many notable cities throughout the world. According to Werna (1998) housing is one of the three basic needs of mankind, a pre-requisite to survival of man. UN (2003) stated that housing is in short supply or deprived to demand in many countries in the world. It remains the essential element of the physical survival of mankind and contributes to the attainment of physical and moral health of a nation and stimulates the social stability, work efficiency and the development of the individual. It is also one of the best indicators of a person's standard of living and of his place in society. According to Adeniyi (1974), in-spite of the fundamental role of housing in the life of an individual, society or nation and in view of the fact that United Nation 's realization of the need to globally attain adequate shelter/housing for all, the housing situation in the world is at a crisis level and remains one of the global problems. It is a grave and a rising challenge facing urban, peril-urban and rural residents, particularly in most developing economies. Ademiluyi (2009) stated that the situation seems worse than thought given the current trends in population dynamism in major cities in the world especially in developing countries.

Currently, one-sixth of the world's population of one billion people live in urban slums in emerging countries. In addition, virtually all net growth of 2.6 billion in world population between now and 2050 is projected to occur in these cities (Fergusson, 2008).The ever mounting crisis in the housing sector in the world is evident in the fact that there is absolute housing unit shortage, growing emergence and proliferation of slum and squatter settlements, rising cost of housing rent and growing inability of the average citizens to own their own houses or procure decent accommodation of their taste in the housing market (Ademiluyi, 2009). It is estimated that the number of people considered to be homeless are estimated to be in excess of 100 million in the world (UNCHS, 1999). In cities such as Mumbai, Lagos, Accra, Abidjan Shanghai, Mexico City, Moscow, an estimated 40 to 50% of their population live in slums, dilapidated houses and on pavements (Newman 2008). It is projected that the country needs at least 100,000 houses at 35 percent of the total need. Other studies put the country's overall annual deficits between 70,000 and 120,000 housing units with only 30-35 percent of the annual estimated requirement being supplied (ISSER 2013). While there may be disagreements as to the exact estimate of the annual requirement, there is a general consensus of a shortfall in the supply of housing, particularly in urban Ghana. The post-independence era, late 1950s and early 1980s, can be described as the period of active and direct involvement of the state in the provision of public housing, with the establishment of the State Housing Corporation (SHC) and Tema Development Corporation (TDC). In addition, two state-owned financial institutions, the Bank for Housing and Construction (BHC) and the First Ghana Building Society (FGBS) were established to provide financial support for public housing. What was referred to as the 'low-cost houses' in district and regional administrative capitals? Although the state was actively involved in direct housing provision during this period, the bulk of the housing (about 80%) was provided by the private informal sector. Table1.1represent housing demand in Ghana from the year 1970 to 2010 according to GSS 2005, UN -Habitat and 2010 Ghana Population and Housing Census

Table 1.1Housing Demand in Ghana: 1970 to 2010

Year	Housing Demand	Housing Supply (Dwelling units)	Housing Deficit
1970	1,678,296	941,639	736,657
1984	2,410,096	1,184,636	1,184,636
2000	3,708,250	2,181,975	1,526,275
2010	7,417,607	5,817,607	1,600,000

Source: Compiled from GSS 2005, UN -Habitat and 2010 Ghana Population and Housing Census

People desire to be able to meet their basic demands for survival.

In order to fulfil the demand of housing, it has become necessary to search for more materials. Brick is one of the oldest material which is found has been used by human beings in the construction industry. In 14,000 B.C and earlier, bricks were found in Egypt in the form of hand-moulded and sun-dried. The types of bricks are continuing to be varied in most countries and they are being used through ages because of their greater physical and engineering properties. In addition, bricks can be classified into various types and uses such as building brick or common brick, floor brick, paving brick and facing brick.

The earliest use of bricks recorded was in the ancient city of Ur (modern Iraq) that was built with mud bricks around 4,000 BC and the early walls of Jericho around 8,000 BC. Starting from 5,000 BC, the knowledge of preserving clay bricks by firing has been documented. The fired bricks were further developed as archaeological traces discovered in early civilisations, such as the Euphrates, the Tigris and the Indus that used both fired and unfired bricks

Ghana before contact with the European and influence of capitalism, built with locally based materials in the form of thatch, mud, wood, earth and bricks. The paradigm changed when formal trading started under colonization in the 1870s. The trading allowed for the introduction of foreign building materials in the Gold Coast which were later perceived to be better and elitist ‘above the cheaper local materials (Kwofie et al, 2011). As Ghana advanced in age, with trading activities growing above expectation and coupled with certain government policies, the situation grew worse and foreign materials were at all cost preferred above all local materials. This development choked certain housing programmes introduced by certain colonial and successive governments. For example, the rising cost of imported materials such as cement, roofing sheets etc. had to redirect the housing scheme of 1920 by the Guggisberg regime. This trend went on and successive governments did little to control or curtail it. What is witnessed today in the building material industry is an inheritance from the colonial to early independence Ghana (Kwofie et al, 2011; Akuffo, 2007). In the rural Ghana, the local materials constitute about 95% of housing stock whilst foreign materials form about 98% of urban housing stock (Dery, et al). In recent times greater percentage of the national expenditure is on importation of foreign building materials at the expense of cheap local materials. It is estimated that 70% of all building materials in Ghana are imported and more than 180, million dollars are spent on importation of clinker and gypsum. It is also recorded that the construction industry utilizes more than 90% of cement and residential construction account for 75% (Dery, et al, 2014). Table 1.2 shows the relative composition of building material usage in Ghana

Table 1.2 Extent of usage of various building materials for housing in Ghana

Section	Material	Percentage Usage
Floor	Cement/concrete	72.0
	Earth	23.8
	Terrazzo	1.4
	Timber/Wood	1.0
	Stone	0.6
	PVC	0.4

	Ceramic/Marble	0.3
	G	
Roof Carcass	Timber/Wood	97.0
Roof Cover	Metal sheets	60.3
	Thatch/Palm Leaf	18.6
	Slate/Asbestos	12.9
	Cement/Concrete	2.4
	Bamboo	2.1
	Timber/Wood	0.9
	Roofing tiles	0.5

Source: Ghana statistical services, (2005)

This worsening development led to several interventions to remedy the situation but little has been attained. For example, the establishment of Department of Rural Housing (DRH), CSIR/BRRI, KNUST, Brick and Tile Factory. All in an attempt to reduce the component of foreign material in the construction industry and promote the locally made materials through appropriate locally dominated technology and methodology, skill and know-how, research and manufacturing. Unfortunately, little success has been recorded Kwofie et al. (2010) stated that the main set back of the Affordable Housing Scheme in 2006 was rising cost of materials. Cement, alongside a lot of other suggestions for widespread use. Encourage the use of locally produced materials. The local building material industry should be developed and entrenched so as to harness its related benefits.

There are the readily available local materials such as clay, wood, limestone, thatch, bauxite waste, bamboo etc. and as such further studies should be conducted into developing them further to boost the industry as being suggested in many government policies. Bediako and Atiemo (2014). Extensive studies by BRRI, DRH and

Geological Survey indicate that these materials are comparable to cement product and are cheaper in cost.

1.2 Problem Statement

Despite these conveniences and advantages, cement block remains the builders' first choice. This has brought about monopoly in building materials, making cement expensive. All the same, in order to solve Ghana's recurrent housing deficit, it is imperative that the government puts in more effort to emphasize on the use of more local materials. The production of cement is increasing annually by 3% (Olafusi and Olutoge, 2012). it was gathered that the production of every ton of cement emits carbon dioxide to the tune of about one ton. (Rubenstein 2012). Expressing it in another way, it can be said that 7% of the world's carbon dioxide emission is attributable to the Portland cement industry. (Olafusi and Olutoge, 2012). However, the significance of this research is to help reduce the cost of production of sandcrete block from the rising cost of cement, and reduce the volume of solid waste generated from carbide waste.

One such industrial waste whose disposal is a phenomenon that poses a global challenge is calcium carbide. The question then arises whether the calcium carbide waste cannot be put into productive use in construction and civil engineering beside cement?

Several studies were undertaken to find alternative suitable material as a partial replacement for cement of which these materials were agricultural by-products (Oyetola & Abdullahi). Some of the agricultural by-products were Bambara groundnut shell ash mixed with calcium carbide waste and cement in concrete (Alabadan et al 2005), groundnut husk ash mixed with calcium carbide and cement in concrete (Elinwa & Awari 2001) bone powder ash mixed with calcium carbide and cement in concrete (Aribisala & Bamisaye 2006). Calcium Carbide Residue (CCR) blended with pozzolanic materials such as fly ash and rice husk ash used as a cementing agent for manufacturing concrete and masonry units without OPC (Jaturapitakkul & Roongreung, 2003; Horpibulsuk et al., 2014). All these investigations were conducted in an attempt to find solution to the environmental havoc the disposal of the by-products of these crops caused the society.

The waste of interest in this current study is Calcium carbide waste which is produced industrially in an electric arc furnace from a mixture of lime and coke at approximately 2000°C. This method has not changed since its invention in 1888. Calcium carbide waste is produced during the process of reaction between calcium carbide and water in the production of acetylene for welding purposes. The reaction of calcium carbide with water was discovered by Friedrich Wohler in 1962. It is recognized that CCR can be used in various construction applications including soil stabilization, Pozzolana activation, asphaltic paving mixes and concrete. A study conducted by Wang et al. (2013) has confirmed that the main chemical compositions of the calcium carbide slag were basically the same as that of natural limestone. Jaturapitakkul and Roongreung (2003) production also reported that a pozzolanic reaction could occur when calcium carbide residue is mixed with rice husk ash in a mortar and achieved a highest compressive strength of 15.6 MPa at 28 days. Manikandan & Ramamurthy (2007) explored the magnitude of the effects of the continuous usage of constituents of sandcrete and concrete blocks on the environment and recommended the need for alternative materials or reduction in the use of them to safe guard the environment.

Many of the literature reviewed and their findings focused on the combination of rice husk ash with calcium carbide mixed with cement in concrete and groundnut mixed with calcium carbide and cement in concrete. This study is informed by research findings which shows that uncontrolled disposal of calcium carbide waste into the physical environment leads to pollution of surface and underground water. Again the high concentration of calcium carbide was suggested to be responsible for drastic reduction in the growth and yield of Okra plant (Abiya et al 2018).

On the backdrop of the problems stated above, this research is to focus on the effects of calcium carbide waste as partial replacement of sandcrete bricks since earlier studies investigated the use of calcium carbide in partial replacement of cement concrete (Yunusa 2015). The study seeks to contribute to the body of knowledge on calcium carbide waste as partial replacement of cement in sandcrete bricks in the construction industry so that its suitability if proven can lead to putting calcium carbide waste in to productive use to reduce environmental pollution. Particularly the focus of this study is on the compressive, tensile and water absorption properties of calcium carbide waste sandcrete bricks.

1.3 Aim of the study

The aim of the study is to investigate the properties of sandcrete bricks produce with calcium carbide waste as a partial replacement of cement.

1.4 Research Objectives

The specific objectives of the study are as follows

1 To investigate the compressive strength of sandcrete block produced with calcium carbide waste as a partial replacement of cement

1. To investigate tensile strength of sandcrete block produce with calcium carbide waste as a partial replacement of cement
2. To determine the water absorption of sandcrete block produced with calcium carbide waste as a partial replacement of cement
3. To determine the density of sandcrete block produced with calcium carbide waste as a partial replacement of cement

1.5 Research Questions

1. What is the compressive strength of the sandcrete block produced with calcium carbide waste as a partial replacement of cement?
2. What is the tensile strength of the sandcrete block produced with calcium carbide waste as a partial replacement of cement?
3. What is the water absorption of the sandcrete block produced with calcium carbide waste as a partial replacement of cement?
4. What is the density of sandcrete block produced with calcium carbide waste as a partial replacement of cement?

1.6 Significance of Study

This research will focus on calcium carbide waste in to production of brick as partial placement of cement, hence reduce the cost in brick production and also minimize the use of cement.

Besides, this study will become helpful to the government of Ghana especially in the construction industry since green brick is a new trend in Ghana. As the green brick using waste such as carbide waste, the price for buying materials to produce common brick cement and sand can be reduced too.

Furthermore, this study uses wastes such as calcium carbide in order to help providing the people a healthy environment.

Researchers will use the findings of the research as a basis to continue with the investigation as it is the first of its kind to be conducted in Ghana. Second, the practical relevance of this research is based on the fact that the results from this study can be usefully and adequately utilized by society when choosing construction materials to be used on housing projects.

1.7 Scope of the study

Generally, this research is to comprehend the optimum percentage of calcium carbide waste used inside the sandcrete block. The study strictly analyzes calcium carbide waste extracted from Greater Accra in other to compare sandcrete brick of fine aggregate and cement and sandcrete from different sources. There are three parameters outlined for this research which are to find out the compressive strength, tensile strength and water absorption.

In order to get precise results, the research focuses on the varieties of sand particle size analysis of chemical element of calcium carbide, preparation of martials, molding, curing and testing.

Finally, the results of these three tests were compared to the standard control result and the conclusion for this research were established.

1.8 Organization of Thesis/Dissertation

The thesis are six chapters as follows:

Chapter one (1) outlines the background to the study supported by a research problem statement from which the aim and objectives of the study have been derived. Research questions to guide the literature follow next. Significance, the scope of the study and methodology applied in order to achieve the goal of the study are briefly outlined in this chapter. Some expected outcomes of the study capture details of how the entire research may be conducted.

Chapter two (2) present a review of the literature focusing on calcium carbide as partial cement in sandcrete block. The chapter also establishes the varieties of materials available.

Chapter three (3) present the research methodology to be adopted for data collection. The Chapter will also commence with qualitative technique to be used will include a laboratory test in terms of compressive test, tensile test density and water absorption

Chapter four (4) addresses the preliminary analysis of the data collected. This includes results and findings of the study.

Chapter five (5) is devoted to the discussion of the validation process that is undertaken in respect of the study findings.

Chapter six (6) l addresses summary of findings, conclusions and recommendations of the entire study.

1.9 Summary

This chapter consists of brief introduction of the thesis, problem statement, aim, research questions and objectives, significance, scope, summary of the research methodology and design and method used to collect data for the thesis.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this chapter, the literature explored sought to provide background information and discourse awareness within the field of calcium carbide waste as a partial replacement of cement in sandcrete block. Literature was evaluated and categorized according to its relevance to the research problem. Further, the chapter focused on prior studies on materials and their source supported by the mixing methods. Also captured in this chapter are the types of curing used for the manufactured bricks as well as the water used associated by its properties.

2.1 Sand

Sand is a mixture of small grains of rock and granular materials which is mainly defined by size, being finer than gravel and coarser than silt and ranging in size from 0.06 mm to 4 mm. Particles which are larger than 0.0078125 mm but smaller than 0.0625 mm are termed silt.it is made by erosion or broken pebbles and weathering of rocks, which is carried by seas or rivers. Castro (2013) also explains Sand as a loose granular material blanketing the beaches, riverbeds and deserts of the world. Composed of different materials that vary depending on location, sand comes in an array of colors including white, black, green and even pink. The most common component of sand is silicon dioxide in the form of quartz. The earth's landmasses are made up of rocks and minerals, including quartz, feldspar and mica.

2.1.1 Composition of sand

In terms of particle size as used by geologists, sand particles vary in diameter from 0.0625 mm to 4mm. An individual particle in this range size is called a sand grain. Sand grains are between gravel (with particles ranging from 2 mm up to 64 mm in the latter method and 4.75 mm up to 75 mm in the former) and silt (particles smaller than 0.0625 mm down to 0.004 mm) The size specification between sand and gravel has remained constant for more than a century, but particle diameters as small as 0.02 mm were considered sand by the Albert Atterberg standard in use at the beginning of the 20th century. The sand grains in Archimedes' Sand Reckoner, written around 240 BCE, were 0.02 mm in diameter. A 1938 specification of the United States Department of Agriculture was 0.05 mm (Urquhart et al. 1959) The 1953 engineering standard published by the American Association of State Highway and Transport Officials set a minimum sand size of 0.074 mm. Sand feels a little gritty when rubbed between the fingers. Silt, in comparison, feels like flour.

ISO 14688 rates sands as fine, medium and rough with ranges from 0.063 mm to 0.2 mm to 0.63 mm to 2.0 mm. In the United States, sand is generally divided into five subcategories based on size: very fine sand 0,0625 – 0,125 mm in diameter, fine sand 0.125 mm – 0.25 mm, medium sand 0.25 mm – 0.5 mm, coarse sand 0,5 mm – 1 mm and very rough sand 1 mm – 2 mm. The composition of mineral sand varies greatly depending on local rock sources and conditions. The bright white sands found in tropical and subtropical coastal environments are the result of limestone erosion, and may contain coral and shell fragments, as well as other organic or organic fragmented components. Sand production is also influenced by living creatures. The gypsum sand dunes of the White Sands National Park in New Mexico are famous for their bright, white color. Arkose is a sand or sandstone with considerable feldspar content, derived from weathering and erosion of water (usually nearby) granitic rock outcrop. Some of the sands contain magnetite, chlorite, glauconite or gypsum. Sands rich in magnetite are dark to black in color, as are sands derived from volcanic basalts and Chlorite bearing sands are typically green in color, as are sands derived from basaltic lava with a high olivine content Many of the sands, particularly those found extensively in Southern Europe, have iron impurities within the quartz crystals of sand, giving a deep yellow color. Sand deposits in some areas contain explosives and other resistant minerals, including some small gemstones.

2.2 Cement

Cement is one of few modern processed materials known worldwide to layman and expert alike. There are few people in the world who have not watched a block laid, a wall rendered or a fencepost set. (Black, et al. 2010). further explain that Cement, more than any other material defines modern urban life. Annually, 2.7 billion tonnes are manufactured around the world1 which in turn makes 20 billion tonnes of structural concrete, foundations, blocks and paving slabs, mortar and rendering

. According to Somayaji (2001), cement can be defined as any material that unites or binds; essentially as glue. For civil engineering, cement or asphalt materials are always connected to the elements of concrete and mortar. Meanwhile, according to (BS EN197-1:2000), cement is a hydraulic binder; more precisely, an inorganic substance that is finely grounded. After combining with water, it will form a paste that is then set and hardened by hydration reactions and processes. Eventually, it can retain stability and strength even under the surface. Cement combined with fine aggregates creates mortar for masonry or sand and gravel that provides concrete.

According to Mohammad (2019) there are two main types of cement. Hydraulic and non-hydraulic cement. On the other side, the use of non-hydraulic cement is decreasing sharply because it is less effective and feasible compared to hydraulic cement. Mohammad (2019) further claimed the non-hydraulic cement to be made from lime. Lime is formed by calcination of calcium carbonate ($CaCo_3$) at a temperature of more than 825 C. CaCO3 and CaO + CO2 Calcium carbonate combined with water for calcium hydroxide development (Ca(OH)2) Cao + H2O Ca(OH)2-hydraulic cement obtain strength via the carbonation process. Excess water can evaporate completely before carbonation starts.

Hydraulic-cement grouting is a common method of repairing cracks in concrete that is most often used in dormant cracks. This type of grouting tends to be less expensive than chemical grouts, and is well suited for large volume applications. However, the grouting is subject to pressure and may not fill a crack entirely. This is normally the type of grout preferred for sealing cracks in foundations. (Woodson, 2012),The table 2.1 presents the difference between Hydraulic Cement and Non-Hydraulic cement

Table 2.1 difference between Hydraulic Cement and Non-Hydraulic cement

Hydraulic Cement	Non-Hydraulic Cement
Hydraulic Cement is made out of limestone, clay and gypsum	Non Hydraulic Cement is composed of lime, gypsum plaster and oxychloride
Hydraulic Cement hardens when there is a chemical reaction between anhydrous cement powder with water. The hydrates that are formed are not soluble in water. It retains its strength and hardness below	. Non hydraulic Cement hardens when there is a reaction due to carbonation with the carbon di oxide which is naturally present in the air

water	
Hydraulic Cement hardens under water or when in contact with wet weather. Hence it is suitable to work with in any climatic conditions.	Non Hydraulic Cement should be kept dry to attain strength.
Hydraulic cement is used in multiple applications like concrete, mortar in masonry, swimming pools, marine construction, foundations, manholes, reservoirs to name a few	Non hydraulic cement is becoming redundant and obsolete due to the long duration of time taken for setting of cement.

Source McCoy Mart (2019)

2.2.2 Worldwide cement production

China produces the most cement globally by a large margin, at an estimated 2.2 billion metric tons in 2019, followed by India at 320 million metric ton,s in the same year. China currently produces over half of the world's cement. Global cement production is expected to increase from 3.27 billion metric tons in 2010 to 4.83 billion metric tons in 2030. In China, the cement production in 2018 amounted to some 2.17 million metric tons (Garside, 2020)

Table 2.2 presents the trend of worldwide cement production from 2015 to 2019 (in million metric tons). It shows that cement production keeps on increasing

Table 2.2 shows Major countries in worldwide cement production from 2015 to 2019 (in million metric tons)

	2015	2016	2017	2018	2019*
China	2,350	2,410	2,320	2,200	2,200
India	270	290	290	300	320
Vietnam	61	70	78.8	90.2	95
United States	83.4	85.9	86.6	87	89
Egypt	55	55	53	81.2	76
Indonesia	65	63	65	75.2	74
Iran	65	53	54	58	60
Russia	69	56	54.7	53.7	57
Brazil	72	60	53	53	55
South Korea	63	55	56.5	57.5	55
Japan	55	56	55.2	55.3	54
Turkey	77	77	80.6	72.5	51

Source: (Garside, 2020)

2.3 Pozzolana

American society for testing and materials (ASTM) C618 (2001) defines pozzolana as a siliceous aluminum material which, in itself, has little or no cementitious value, but which reacts chemically with lime or calcium hydroxide in solidly divided form and in the presence of water.

Pozzolanas are grouped into two primary classes:

i. Natural Pozzolana: some diatomaceous earths, opalinecherts and shales, tuffs and volcanic ashes or pumicites. Most natural pozzolans are volcanic in origin.

ii. Artificial Pozzolana: fly ash, blast furnace slag, siliceous and opalineshales, spent oil shale (used in Sweden to make "gas concrete"), rice husk ash, burnt banana leaves, burnt sugar cane stalks and bauxite waste.

2.4 .0 Mortar

Mortar is integral to most masonry construction. Its use is widespread in every culture where masonry is constructed. It is present in the majority of the global built cultural heritage, and is therefore a major consideration in building conservation. (Hughes,2012) Mortars of masonry structures may have several roles in the masonry such as bedding mortars, renders, and plasters, bonding of ceramic tiles or pavements and depending on the role, different properties are needed (Hughes et al., 2012). Mortar is spread on the bed and head joint surfaces of masonry units to bond the units together, and, as importantly, to keep them apart. Structurally, mortar distributes gravity loads uniformly from one unit to the next, and increases the shear strength of the assemblage. Mortar also decreases the moisture permeability of the assemblage. Requirements for mortar are specified in ASTM C270 Mortar for Unit Masonry

Adhesion of mortars to concrete and brick walls is a complex mechanism that is affected by several factors. The adhesion loss leads to mortar detachment from the substrate which may cause hazardous situations to passers-by (Kingsley,2003).

Rodriguez(2019) stated that there are four main types of mortar mix: N, O, S, and M. Each type is mixed with a different ratio of cement, lime, and sand to produce specific performance characteristics such as flexibility, bonding properties, and compressive strength.

Type N Mortar Mix

Type N mortar is usually recommended on exterior and above-grade walls that are exposed to severe weather and high heat. it has a medium compressive strength and it is composed of 1 part Portland cement, 1-parrt lime, and 6 parts sand. It is considered to be a general-purpose mix.

Type O Mortar Mix

Type O mortar mix has relatively low compressive strength, at only about2413.25KN/ m^2 It is used primarily interior, above-grade, non-load–bearing walls. Type O can be used as an alternative to Type N for some interior applications, but its exterior use is limited due to its low structural capacity. It is not recommended in areas subjected to high winds.

Type S Mortar Mix

It gives a high compressive strength of over12,411KN/m^2 and a high-tensile bond strength, and is suitable for many projects at or below grade. It performes extremely well to withstand soil pressure and wind. It is preferred for many below-grade applications, thus; masonry foundations, manholes, retaining walls, sewers, and walkways. Although type S mortar must have a minimum compressive strength of12,411KN/m^2, it is often mixed for strengths between15858.5KN/m^2 and 20685KN/m^2.

Type M Mortar Mix

Type M mortar mix has the highest amount of Portland cement and is recommended for heavy loads and below-grade applications, including foundations, retaining walls, and driveways. Provides at least17237.5 of compressive strength, it offers relatively poor adhesion and sealing properties, making it unsuitable for many exposed applications. It is the preferred for use with natural stone because it offers similar strength to that of stone.

2.4.1 Surkhi mortar

Surkhi mortar is a mixture of lime and surkhi and water. It is a lime mortar in which sand has been replaced by surkhi for economic strength. Surkhi is finely powdered burnt clay and is usually made from slightly under burnt bricks. Good surkhi should be perfectly clean and free from any mixture of foreign substances and should not contain particles stored in IS sieve No.9 more than 10% by weight of surkhi as sand is widely used in the preparation of mortar, concrete, plaster, etc. (Sharma, 2017) The table 2.3 and figure1 present the particle size grading of surkhi for use as aggregate in lime mortar in masonry works within the limits specified per I S 3182-1975 and Broking surkhi respectively.

Table 2.3 Particle size grading of surkhi for use as aggregate in lime mortar in masonry works within the limits specified per I S 3182-1975

IS Sieve designation	Percentage passing (By mass
4.75 mm 100	100
2.36 mm 90	90 to 100
1.18mm	70 to100

600 micron	40 to 100
300 micron	5 to 70
150 micron	0 to 15

source: (Sharma, 2017)

Figure 2. 1 Broken surkhi

(Sharma, 2017)

2.5 Sandcrete Blocks

Seeley (1995) defines sandcrete blocks as a walling material made of a rough natural material. Sand or crushed rock dust mixed with cement to a certain extent and with water, and moderately compacted in shapes. Montgomery (2002) defines sandcrete block as blocks made or moulded with sand, water and cements which serves as a binder. Oyetola and Abdullahi (2006) also defined Sandcrete blocks as comprising sand, water and binder, Sandcrete blocks comprise of natural sand, water and binder. Cement, as a binder, is the most expensive input in to the production of sandcrete blocks. This has necessitated producers of sandcrete blocks to produce blocks with low OPC content that will be affordable to people and with much gain. (Aderonmu et al 2015) Sandcrete blocks are composite materials produced from cement, sand and water, moulded into different sizes (Barry, 1999). British Standard (BS6073: 1981 Part 1) defines a block as a heterogeneous building material with a unit of larger size in all dimensions than specified for bricks but no dimension should be more than 650 mm nor should the height be greater than its length or six times its thickness

Concrete (Sandcrete) blocks were first created in the early part of the last century by putting fresh concrete in molds made of steel or wood. The molds were stripped when the concrete was hardened. In order to achieve its construction purpose, the blocks must be shaped in such a way as to support their imposed loads (live and dead) Sandcrete blocks may be hollow or solid, British Standard (B.S) 2028 (1968) offers a specification for precast concrete blocks that define solid, hollow and cell blocks with hollow blocks having an empty hole

2.5.1 Advantages of Concrete Block Homes (Mercado, 2018)

- Concrete homes are common in areas where there is a lot of moisture. Unlike wood, concrete does not attract mildew or rot when it's wet for a long period of time
- It stands termites and other critters that damage homes that are constructed with a lot of wood.
- Concrete homes are great for areas that are prone to high winds, tropical storms and hurricanes.
- They are not easily toppled over during extreme weather and can withstand winds of over 200 miles an hour.
- They tend to last for centuries if well maintained, and are fire resistant because cement is not flammable.
- They are ideal for homeowners who want to lower their energy usage and really value an eco-friendly home.

- The insulation of a concrete home makes it so that warm air from a heater and cold air from central air conditioning do not escape easily.
- They are practically soundproof, which is great for parties or for trying to minimize noise pollution from outside.

2.5.2 Disadvantages of sandcrete block Homes(Mercado, 2018)

- Concrete homes tend to be a little bit more expensive to build than other homes, such as bricks.
- It paid off in energy costs in the long run, but may be out of reach for some potential home owners.
- The price of concrete fluctuates and will also vary depending on the region, so there is not a set price for concrete homes across the country.
- It is best to do research on what prices are like in different areas before setting a specific budget for constructing or buying a concrete home.
- Concrete homes are also often plain and gray unless a homeowner plans to add facing to the walls or add on a layer of cement that can be painted.
- If there are an issue with plumbing in a concrete home and pipes are not in an accessible part of the structure, some of the concrete will have to be cut in order for a plumber to reach the problem.
- It is always best to make sure there is a decent drainage system in the house or near any water pipes to avoid major flooding or plumbing issues.

2.6 Hydraform block

The Hydraform compressed earth block is very popular due to the cost savings that are involved during the construction process, as only around 30% of the structure requires mortar between the blocks. Due to the interlocking nature of the stabilized soil block, unskilled labor can be used in construction to empower rural communities and create jobs. The size of the blocks is 220 mm x 115 mm x 230 mm. It weighs around 12 kilograms. Once the blocks are made, it is "wet cured" for a period of 14–21 days to achieve the desired strength. The technology developed in South Africa but is now used in a number of parts of Africa known as hydraform technology (Oyekan, 2001) The main benefit of using Hydraform Interlocking 'Block for a walling unit is that the interlocking blocks are dry stacked meaning no mortar is required in 70 percent of the structure. Nair et al. (2006) opine that the Hydraform interlocking blocks lock front and back, top and bottom eliminating the need for mortar joints.

the super structures, interlocking refers to the male and female ridges on the top and bottom as well as front and back of the Hydraform blocks. Ganesan et al. (2008) added that these ridges lock into one another to lock the blocks into place The blocks from the first course can be stacked dry. The top 3-4 courses below the roof structure must be lined in mortar (ring beam). It secures the wall to ensure that each block is completely locked and in place. Initial Hydraform Machinery is produced only in South Africa (Abdullahi, 2006; Eze et al, 2005; Thwala et al., 2012; Abdullah, 2006)

2.7 Compressed earth block (CEB)

According to Hub (2009) Compressed Earth Block (CEB) is a kind of construction material created manually or with mechanical machines that forms a mixture of dirt, clay, and an aggregate into a compressed block. Hub (2009) further stated CEBs have lately exhibited exceptional functioning characteristics in areas requiring personnel safety from disasters like earthquakes, tsunamis, and hurricanes. The excellent characteristics of fire, insect, mold, and sound resistance make the CEBs more popular in several applications.

CEB has become a popular form of construction in the majority of the world. It has also gained popularity in the United States, mainly due to the recent focus on sustainability and "green" construction. Benefits of CEB construction include sustainability, insulating properties, local availability, low cost, and aesthetics (Forke, 2017). The Figure 2 shows a typical Compressed earth blocks(CEB) building

2.7.1 Advantages of CEB

The CEB technique has several advantages which deserve mention (Rigassi ,1985)

- The production of the material, using mechanical presses varying in design and operation, marks a real improvement over traditional methods of producing earth blocks, whether adobe or hand-compacted, particularly in the consistency of quality of the products obtained. This quality furthers the social acceptance of a renewal of building with earth.

- Compressed earth block production is generally linked to the setting up of quality control procedures which can meet requirements for building products standards, or even norms, notably for use in urban areas.

- In contexts where the building tradition already relies heavily on the use of small masonry elements (fired bricks, stone, sand-cement blocks), the compressed earth block is very easily assimilated and forms an additional technological resource serving the socioeconomic development of the building sector.

- Policy-makers, investors and entrepreneurs find the flexibility of mode of production of the compressed earth block, whether in the rural or the urban context, small-scale or industrial, a convincing argument.
- Architects and the inhabitants of buildings erected in this material are drawn to the architectural quality of well-designed and well-executed compressed earth block buildings.

Figure 2.2 A typical Compressed earth blocks (CEB) building (Forke, 2017)

2.8 Cinder Block

Cinder blocks are totally different from concrete blocks. Concrete and cinder blocks are made from the same basic components; however, there is a special key component for cinder blocks and created for various functions. Cinder blocks are also made of concrete, however, the mixture includes coal ash. Concrete blocks are lighter than cinder blocks (Rajput, 2020). The Figure 2.3 show How to build with cinder block

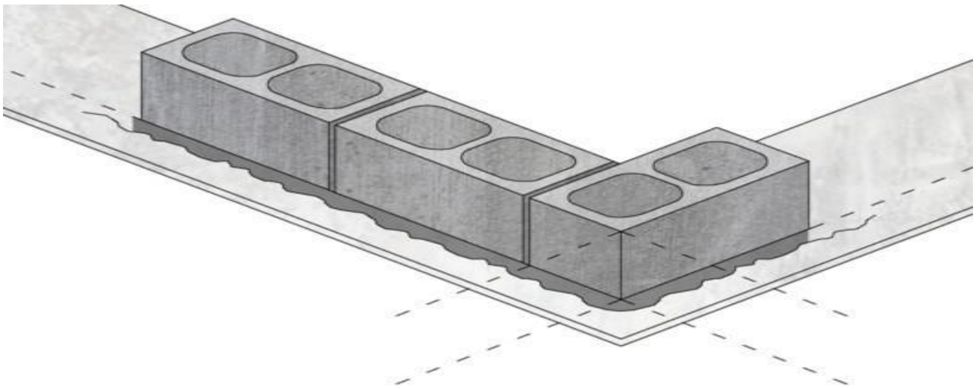

Figure 2.3 building with cinder

(Franco, 2018)

2.8.1 Advantages of Cinder Block Walls (Rajput,2020)

Cinder blocks are an economical material for works. They are used for several reasons and done in different ways:

1. No dressing work.
2. Light in weight.
3. Not much skill required.
4. Structurally stronger than bricks.
5. Thinner walls possible, hence giving more carpet area.
6. Large in size, hence number of joints are less. Saving in mortar.
7. Better insulating against heat, sound & dampness.
8. Need not require plastering.

2.9 Curing

Curing of concrete means maintaining moisture inside the body of concrete during the early ages and beyond in order to develop the desired properties in terms of strength and durability. A good curing practice involves keeping the concrete damp until the concrete is strong enough to do its job (Kulkarni 2006). According to Hamza. (2009) sandcrete blocks should be allowed to mature for at least 28 days. During this period, the blocks are cured to prevent loss of moisture needed for hydration reaction to continue.

Curing helps the mixture to attain about 70% of the strength in 7 days and 85% in 14 days. At 28 days, 99% of the strength is already attained. It is most important that sandcrete blocks are not allowed to dry out within the first seven days (Adenaike, 2015) Curing produces good quality blocks, prevents premature drying out with radiation and wind. Curing could be done by covering the blocks with polythene, by spraying with water and or with hot steam (Yusuf and Hamza, 2011) Curing is necessary because Concrete strength depends on the growth of crystals within the matrix of the concrete. These crystals grow from a reaction between Portland cement and water a reaction known as hydration (Aadithya, 2016) Curing conditions influence drastically the final expansion because water is absolutely necessary to obtain an expansion. Therefore, in order to fully develop the potential of expansion, it is important to provide curing conditions (Gagne,2016).

The only “disadvantage” of curing concrete is that it takes time and effort (and moisture) to cure concrete (Prabhu, 2018) Concrete cures no matter what, but curing can also applied to the concrete. Concrete cures on its own right from the start. Applying a curing method to the concrete can not only increase its strength, but it can reduce cracking (Dietz, 2017)

Methods of curing concrete broadly fall into the following categories

(Kulkarni, 2006):

- Water curing-preventing the moisture loss from the concrete surface by continuously wetting the exposed surface of concrete.
- Membrane curing-minimizing moisture loss from the concrete surface by covering it with an impermeable membrane.

Steam curing-keeping the surface moist and raising the temperature of concrete to accelerate the rate of strength gain.

The length of adequate curing time is dependent on the following factors: (Zemajtis, 2019):

- Mixture proportions
- Specified strength
- Size and shape of concrete member
- Ambient weather conditions
- Future exposure conditions

American Concrete Institute (ACI) recommends the following minimum curing periods (Zemajtis, 2019):

ASTM C 150 Type I cement: seven days

ASTM C 150 Type II cement: ten days

ASTM C 150 Type III cement: three days

ASTM C 150 Type IV or V cement: fourteen days

ASTM C 595, C 845, C 1157 cements: variable

The Ghana Standards Board 1995 specifies a period of 14–21 days of moist conditions and that, immediately after molding, the block should be kept in a shade and protected against the effect of drying winds (Baiden and tuuli 2004).

Curing can be done by sprinkling water on the blocks and covering them with tarpaulin or damp sacks.

Figure 2. 4 : Mist curing of freshly placed concrete

(Kulkarni 2006)

2.10 Bricks

It is a building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of clay, but it is now used to denote rectangular units made of clay-bearing soil, sand, and lime, or concrete materials. Bricks can be joined together using mortar, adhesives or by interlocking them. (CSEB 2019) Bricks are produced in numerous classes, styles, materials, and sizes which vary with region and time period, and are produced in bulk quantities.

Clay bricks were among the first man-made construction materials that proved to be simple to make, resistant and resilient, as attested by the countless examples that can be found all over the world that have survived centuries of harsh climatic conditions and wars (Fernandes et al 2019). Phonphuak .& Chindaprasirt(2005).Also demonstrated that clay brick is one of the oldest building materials and has been used since ancient civilizations. It's a kind of crystalline ceramic, and it is one of the most popular building materials found in the world. (Rodriguez(2019).also stated a number of ways that brick can be categorized :

1. The types used for facing (exposed and visible on the exterior of a structure) and. backing bricks (which are used structurally and are hidden from view).

2. According to how they are manufactured: unfired (brick that is air-cured) and fired (brick that is baked in ovens in order to harden it).

3. According to their typical use: common bricks for purposes of residential construction

4. Engineering bricks are more often used in civil engineering projects, such as road or bridge construction, or in sewers construction

5. According to their shape. Some common shapes include:

   a. Brick veneers: These bricks are thin and used for surface cladding.

   b. Airbricks: these bricks contain large holes to circulate air and lessen weight. They are used in suspended floors and cavity walls.

   c. Perforated bricks: These bricks contain many cylindrical holes drilled throughout the brick. They are very light in weight.

   d. Bullnose brick: These are bricks molded with round angles.

   e. Paving bricks: These bricks contain a good amount of iron. They are used in underfoot paving applications.

   g. Capping bricks: These bricks are used to cap the tops of freestanding walls.

   h. Hollow bricks: About one-third of the weight of the normal bricks, these are used mostly in partition walls where load-bearing is not required.

6. Categorized Bricks by Raw Materials

In modern construction practices, common bricks are categorized according to their component materials and method of manufacture. Under this classification, there are five common types:

a. Burnt clay bricks

b. Sand lime bricks (calcium silicate bricks)

c. Concrete bricks

d. Fly ash clay bricks

e. Fired brick.

(Rodriguez(2019) further claimed that brick is one of the oldest of all building materials. It is also arguably the most durable, since there are brick walls, foundations, pillars, and road surfaces constructed thousands of years ago that are still intact. Today, bricks are most often used for wall construction, especially as an ornamental outer wall surface.

2.10.1 Calcium-silicate bricks

The constituent materials are mixed and left until the lime is completely hydrated; the mixture is then pressed into moulds and cured in an autoclave for three to fourteen hours to speed the chemical hardening. (McArthur & Duncan, 2004) The finished bricks are very accurate and uniform. The bricks can be made in a variety of colours; white, black, buff, and grey-blues are common, and pastel shades can be achieved. This type of brick is common in Sweden, especially in houses built or renovated in the 1970s. In India these are known as fly ash bricks, manufactured using the FaL-G (fly ash, lime, and gypsum) process. Calcium-silicate bricks are also manufactured in Canada and the United States, and meet the criteria set forth in ASTM C73 – 10 Standard Specification for Calcium Silicate Brick (Sand-Lime Brick). The Figure 2.4 presents five common types of classification and uses of brick

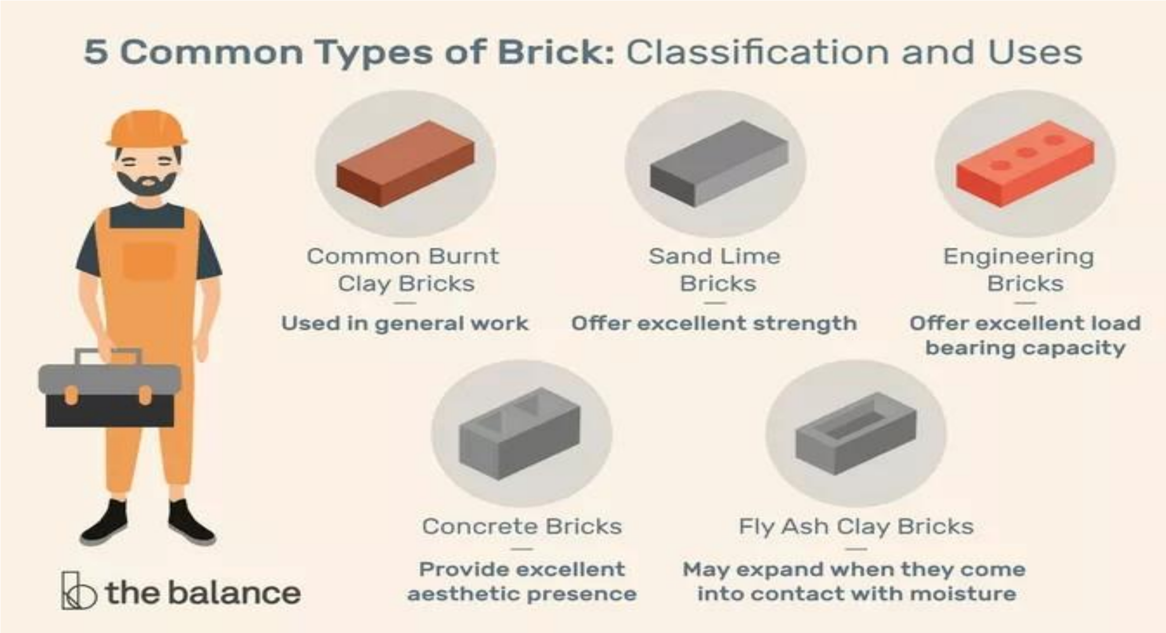

Figure 2.5: Hollow Molded bricks

(Rodriguez, 2019)

2.11 A Wall

Wall is the major component of a building. It is used to divide the space of a building and fulfill all the basic requirements. It has also provided security, privacy and protection against the weathering agencies like sun, rain, snow and water, etc. It is a vertical load bearing member and also provides support to floor and roof. It may be constructed of bricks or stones (Krishna, 2019)

Krishna (2019) also explained wall as a structural element which divides the space (room) into two spaces (rooms) and also provides safety and shelter. Generally, the walls are differentiated into two types outer-walls and inner-walls. Outer-walls give an enclosure to the house for shelter and inner-walls help to partition the enclosure into the required number of rooms. Inner walls are also called as Partition walls or Interior Walls and Outer walls are also called as Exterior walls.

2.11.1 Advantages of walls

Following are some advantages of walls (Krishna, 2019).They are used to provide protection against the weathering agencies.

for the security purposes.

for providing support to floor and roof.

to protect us from heat, cold and other purposes.

for privacy.

to divide the available space of the building to fulfill the basic requirements.

to divide the space as per the requirement

2.11.2 Load Bearing Wall

As the name itself suggests that, the whole building structure is rested on walls instead of columns. In general, loads from slab transfers to beams, from beams to columns and then spread to foundation(Krishna,2019) . The structure has beams and slabs but not columns. the wall which is bearing the whole weight of the structure, including self-weight of structural elements. Strip foundation is adopted for the load-bearing type of wall to support the entire load of the building, including their own are known as load bearing walls. These walls are usually constructed as main walls of the building and may be solid or hollow (Navneet, 2015).

The materials most often used to construct load-bearing walls in large buildings are concrete, block, or brick. By contrast, a curtain wall provides no significant structural support beyond what is necessary to bear its own materials or conduct such loads to a bearing wall (Khalifa, 2018).

2.11.3 Types of non-load bearing wall

This type of wall does not support floor or roof loads above them which means it carries not any of the weight of the structure above it an does not possess any structural integrity. The non-load bearing wall can be removed or shortened without affecting the building structure. Non-Load bearing walls are also called as Drop wall or Filling wall. The thickness of Non Load bearing wall generally lies in between 100mm to 125mm (Navneet, 2015).

2.11.4 Cavity Walls

It is a wall constructed in 2 leaves or skins with a space between them. A type of building wall construction consisting of an outer wall fastened to inner wall separated by an air space. Cavity walls help to prevent the penetration of water to the internal surface of the wall.

2.11.5 Shear Wall

Shear walls are a framed wall designed to resist lateral forces. They are vertical elements that resist horizontal force. They are used to resist wind and earthquake loading on a building. A shear wall may be typically a wood frame stud walls covered with a structural sheathing material like plywood.

2.11.6 Partition Wall

A partition wall is an interior non-load bearing wall to divide the larger space into smaller spaces. The heights of a partition wall depend on the use which may be one storey or part of one storey. These walls are made up of glass, fibre boards or brick masonry.

2.11.7 Panel Wall

A panel wall is generally made of wood and is an exterior non-load bearing wall in framed construction. It is used for aesthetics of the buildings both inside and outside. It remains totally supported at each storey but subjected to lateral loads.

2.11.8 Veneered Walls

A masonry veneer wall is a single non-structural external masonry wall made of brick, stone or manufactured stone. It has an air space behind and is called as anchored veneer.

2.11.9 Faced Wall

Faced walls have the facing and backing of two different materials that are bonded together to ensure common action under load.

2.12 Clay

Clays are layerd silicates that are formed usually as products of chemical weathering of other silicate minerals at the earth's surface which are found most often in shales, the most common type being sedimentary rock (Tong. 2000.) (Hillier(2003) also stated that Clay minerals are the characteristic minerals of the earths near surface environments. They form in soils and sediments, and by diagenetic and hydrothermal alteration of rocks. Water is essential for clay mineral formation and most clay minerals are described as hydrous alumino silicates.

Clays are plastic due to particle size and geometry as well as water content, and become hard, brittle and non–plastic upon drying or firing (Guggenheim & martin 1995). Depending on the soil's content in which it is found, clay can appear in various colours from white to dull grey or brown to deep orange-red.

Although many naturally occurring deposits include both silts and clay, clays are distinguished from other fine-grained soils by differences in size and mineralogy. Silts, which are fine-grained soils that do not include clay minerals, tend to have larger particle sizes than clays. There is, however, some overlap in particle size and other physical properties. The distinction between silt and clay varies by discipline. Geologist sand soil scientists usually consider the separation to occur at a particle size of 2 µm(clays being finer than silts), sedimentologists often use 4–5 µm, and colloid chemists use 1 µm (Guggenheim & Martin 1995).Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins.

2.13 Water

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of most living organisms. It is essential to all recognized life forms, even though it does not have calories or organic nutrients. The chemical formula is H_2O, indicating that each of its molecules contains one oxygen and two hydrogen atoms connected by covalent bonds Water is the name of the liquid state of H_2O at standard ambient temperatures and pressures. Rainfall is produced in the form of rain and aerosols in the form of fog. Clouds are formed by suspended droplets of water and ice, its solid state. When finely divided, crystalline ice can precipitate in the form of snow. Vapor or water vapor is the gaseous state of the atmosphere. Water moves continuously through the water cycle of evaporation, transpiration(evapotranspiration), condensation, precipitation and runoff, usually reaching the shore. Water occupies 71 % of the Earth 's surface, mainly in lakes and oceans (2008 by the CIA). Limited amounts of water exist as groundwater (1.7 per cent), in glaciers and ice caps of Antarctica and Greenland (1.7 per cent), and in the air as vapor, clouds (formed of ice and liquid water suspended in the air) and precipitation (0.001 per cent) (Gleick,1993).

Water plays an important part in the global economy. Approximately 70% of the freshwater used by humans goes to agriculture (Baroni et al., 2007). Fish in salt and freshwater is a significant source of food in many parts of the world. Most of the long-distance trade in materials (such as oil and natural gas) and manufactured goods are carried by ships across the oceans, rivers, lakes and canals. Large amounts of water, ice and steam are used for cooling and heating, in manufacturing and in homes. Water is an excellent solvent for a wide range of mineral and organic substances; as such, it is commonly used in manufacturing processes and in cooking and washing. Water, ice and snow are also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing, sport fishing, diving, ice skating and skiing

.2.13.1 Properties of water

Water (H_2O) is a polar inorganic compound with a tasteless and odorless liquid at room temperature, almost colorless with a touch of violet. This simple hydrogen calcogenide is by far the most studied chemical compound and is known as a "universal solvent" because of its ability to dissolve a variety of substances (Greenwood & Earnshaw 1997). This allows it to be a "production solvent" (Reece, 2013). It is the most natural material to exist as a solid, liquid and gas in normal soil conditions

Definitions of the precise chemical nature of liquid water are not well understood; some theories suggest that the unusual behaviour of water is due to the existence of two liquid states (Kotz et al. 2005; Roberta et al., 2011; Maestro et al., 2016; Mallamace et al., 2012)

2.14 Calcium carbide

Calcium carbide is commercially intended for welding purpose but its use in the artificial ripening of climacteric fruits is rampant in many developing countries. The following is the technique for producing calcium carbide in industries.

1. The mixture used is coke and lime
2. Temperature range is set at approximately 2,200 °C
3. The entire process is carried out in an electric arc furnace (Gandhi et al., 2016)

According to Tuleun and Jimoh. (2018) Pure calcium carbide reacts with water and acetylene gas to form calcium carbide waste. The pure calcium carbide which is colorless and odorless is produced by heating lime with coke and he reaction is as shown in equation 1.

$$2CaO+5C(s)=2CaC_2(s)+CO_2(g) \quad (1)$$

$$CaC_2+2H_2O=C_2H_2+Ca(OH)_2 \quad (2)$$

2.14.1 Uses of Calcium Carbide (CaC_2)

Calcium Carbide (CaC_2) can be used for the following (Tuleun and Jimoh, 2 018):

i. It is used in the production of calcium hydroxide and acetylene

ii. It is used in the production of polyvinyl chloride as acetylene the derivative of calcium carbide can be used as a raw material for the production of PVC.

iii. It is used to produce calcium cyanamide.

iv. It is used in the removal of sulphur from iron. The removal of sulphur from any material is called desulphurization.

v. It is used in lamps such as carbide lamps. In the early days, it was used as headlights of automobiles. Used as a ripening agent like ethylene.

vi. It is used in bamboo cannons as well as big-bang cannons.

vii. It is used as a deoxidizer. It helps in the removal of oxygen during the manufacturing of steel.

According to (Butler and Hewitt, 2006) Calcium carbide, a chemical compound used in the commercial manufacture of acetylene gas, was discovered accidentally during experiments in aluminum processing in Spray (now Eden). (Butler et al, 2006) further stated that in the course of the experimentation, a mixture of lime and coal tar was introduced with calcium for the purpose of producing metallic calciusm as a reduction agent in the aluminum process. Following the routine procedure of quenching the results in water for rapid cooling, a large quantity of gas was observed on 2 May 1892. They identified the new substance as calcium carbide., providing an alternative to coal gas and kerosene.

China is the world's largest producer of calcium carbide. Calcium carbide is produced commercially by the reaction of quicklime and a reducing agent such as coke in an electric furnace. The exothermic reaction of calcium carbide and water produces acetylene, which is the most important use of calcium carbide (Wiley, 2020). Figure 2.5 represents a typical Calcium carbide

2.15 Calcium carbide waste

Calcium carbide residue (CCR) is a by-product obtained from the acetylene gas production process. It is widely used for ripening fruit in agriculture and for welding in industry, while the by-product (CCR) is often discarded as waste in landfills and thus poses a threat to the environment. For example, in China, as much as 2500 tons CCR is generated annually . CCR is mainly composed of calcium hydroxide with a mass fraction of above 92% and is highly alkaline (pH >). It has been found that mixing CCR with certain pozzolans, which have high silicon dioxide (SiO_2) or aluminum oxide content, could yield pozzolanic reactions, resulting in final products that are similar to those obtained from the cement hydration process.

In Ghana, after the use of calcium carbide by arc welders, they leave it to the mercy of the environment. Apart from some low-income homes that use it to scrub their toilets and washrooms there is no other proper use of calcium carbide waste in view of the fact that Ghana has so many artisans practicing arc welding that used calcium carbide. Figure 2.7 and 2.8 show Calcium carbide waste at the collection point and an arc welder in action ,producing Calcium carbide waste in the end respectively.

Figure 2. 7 Calcium carbide waste at the collection point Ofankor Ga North Municipal

Figure 2.8 Arc welder in action and produced Calcium carbide waste at Ofankor Ga North Municipal

2.16 concrete mixer

A concrete mixer (often colloquially called a cement mixer) is a device that homogeneously combines cement, aggregate such as sand or gravel, and water to form concrete. A typical concrete mixer uses a revolving drum to mix the components Henry (2000) and Ferraris, (2001) Stated that in order to determine the mixing method best suited for a specific application, factors to be considered include;

- location of the construction site (distance from the batching plant), The amount of concrete needed,

- The construction schedule (volume of concrete needed per hour), and ‘
- The cost. However, the main consideration is the quality of the concrete produced.

  There are two main categories of mixer (Ferraris2001):

- ➢ Batch mixers

  produce concrete one batch at a time, needs to be emptied completely after each mixing cycle, cleaned (if possible), and reloaded with the materials for the next batch of concrete mixed

- ➢ Continuous mixers

  continuous mixers. as the name indicates, the constituents are continuously entered at one end as the fresh concrete exits the other end. They are usually non-tilting drums with screw-type blades rotating in the middle of the drum. The drum is tilted downward toward the discharge opening

2.17 water–cement ratio

The water–cement ratio is the weight of water in a concrete mix divided by the weight of cement . According to Bentz, et al. (2005) water-to-cement ratio (w/c) is the mass ratio of water to cement in a concrete mixture. It has been used from the first day of concrete production.

Li, et al. (2020) stated that In 1918, Abrams pronounced the water-cement ratio law based on the observation that as the water-cement ratio decreases, the strength of the concrete increases, accordingly. In 1935, Bolomey gave a formula to predict the compressive strength of cement mortar which expresses a linear relationship between the water-cement ratio and compressive strength. Abrams’ law and Bolomey’s formula both indicate that compressive strength of cement-based materials is mainly dependent on the water-cement ratio among all the other factors. The mortar mixed at w/c of 0.5 showed the highest compressive strength while the lowest was observed at 0.6. This reduction of strength is due to the increase of porosity with the increase of w/c ratio, indicating the paste fraction of mortar becomes more porous and the mortar becomes weaker because the pores are interconnected

2.17.1 Advantages of Low Water-Cement Ratio according to (Vicky, 2020):

- It provides increased strength.
- Increased resistance to weathering.
- Reduced drying shrinkage and cracking.
- Less volume changes from wetting and drying.
- Lower permeability.
- Creates better bond between concrete and reinforcement.

2.17.2 Calculate of Water Quantity in Concrete Mix (Vicky, 2020)

The water cement ratio varies from 0.4 to 0.6 as per IS 10262 (2009) for nominal mix (M10, M15…) However the maximum strength of concrete is obtained at a water cement ratio of 0.4, besides we know that for a complete hydration of concrete the water requirement is about 38%.

Generally the formula used to calculate the amount of water is given below :

Required Amount of Water = W/C Ratio x Cement Volume.

Example the volume of cement is 50 kg (1 cement bag) and W/C ratio as 0.4

Required Amount of Water = 50 x 0.4 = 20 liters.

2.18 Batching

Batching is a process in which the quantity or proportion of materials such as cement, aggregates, water, etc. is measured on the basis of either weight or volume for the preparation of a mixture.

According to Malu (2017) there are three modes of batching generally adopted for cement and aggregates. They are follows:

1. Random volumetric batching with absolutely no control over the size and shape of the containers used, resulting in large errors and variations. Cement is packed on the premise that each bag contains 50 kg.

2. Proper volumetric loading of all materials, using measured boxes (forms) and regulating the filling to brim and levelling. Often cement is massed or measured by volumetric scale.

3. Proper weighing of all ingredients is achieved either by using a weighting batch or by using a weighing device in a batching mixing plant.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter focuses on materials, methods and techniques used in the collection of data for this study. The first session deals with the materials used as a partial replacement for cement in different percentages of calcium carbide waste with a quantity of sand and water. The methods and test sessions look at the compressive and tensile strength and water absorption of calcium carbide waste mixed with cement. This is an approach in order to ensure the research achieve the objectives outlined earlier. It will also assure the research to be conducted correctly according to the procedures of the testing

3.1. Research Design

The current study is an experimental research design which employs a quantitative research approach. For such cause and effect investigations, Fellow and Liu (2008) recommend the use of experiment. Thus the current research involved series of laboratory works to measure the strength of sandcrete block produced with calcium carbide waste as a partial replacement of cement.

According to Roger and Revesz (2019), experimental design which is referred to as treatment, determines a causal relationship between the treatment and the outcome.

Again the authors stated that in an exponential design, the variable is influenced in the independent one while the variable is being influenced in the dependent variable (Regers & Revesz 2019). In this study the variable that is being influence is cement and the variable influencer is CCW as treatment group.

3.2 Materials

The material constituents, their mix, presence of admixtures and manufacturing process are important factors that determine the properties of sandcrete blocks. The materials used and method of manufacture employed in this investigation are thus presented.

3.2.1 Calcium Carbide waste (CCW)

Carbide waste (CW) was collected from a welder's shop located at Ofankor, Ga North municipal. It was dried in the open air, and crushed into fine particles with a metal bar (in the absence of a ball mill). The Calcium Carbide waste (C. C. W) sample was sieved through 5mm BS sieve mesh before the laboratory tests were carried out at Ghana Standard Authority. Figures 3.1 and 3.2 show Calcium Carbide waste before and after sieving .

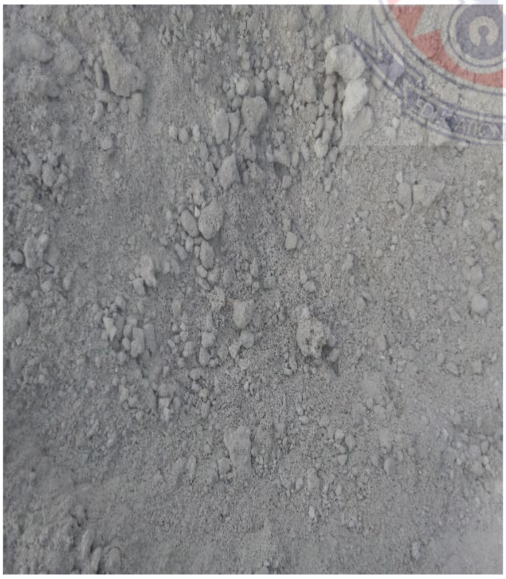

Figure 3.1 Calcium Carbide waste before sieving

Figure 3.2 Calcium Carbide waste after sieving

3.2.2 Fine aggregate (sand)

The sand used was pit sand which was obtained at Tanoso Kumasi, It is free of clay, loam, dirt and any organic and chemical matter. It was sieved to remove larger particles of stone, and other harmful substances like leaves, broken glass and wooden particles to comply with BS 882 (1992). Tests were conducted on samples to further establish the suitability of the sand used for the sandcrete at Ghana Standard Authority

3.2.3 Cement

The cement used for the study was Portland cement Class 32.5R, produced by GHACEM Ltd, Ghana. It was bought from cement depot at Tanoso, in the Kwadaso Municipality. Figure 3.3 shows the Super rapid Ghacem cement used.

Figure 3.3 Super rapid Ghacem cement

3.2.4 Water

Fresh, colourless, odourless and tasteless potable water that is free from organic matter of any kind BS EN 1008; 2002 was used to prepare the specimens.

3.3 Equipment

- Laboratory rotating pan mixer
- hydraulic pressure block making machine digital Vernier calliper
- Universal testing machine
- Tamping rod
- Sieve analysis apparatus
- Digital weighing apparatus.

3.3 Methods

3.3.1 Mix proportions

The term ratio in this content refers to the estimation of different quantities of sand, calcium carbide waste and cement as well as water required for the mix. The weight method of batching was adopted throughout.

A control mix containing cement, pit sand and water was designed for compressive strength, water absorption, abrasive and tensile strength. Cement was partially replaced with calcium carbide waste in the range of 10, 20, 30, 40, 50 and 90%. The mix proportion was 1:6 and the quantities are given in Table 3.1. Size of for the specimen used was 100mm x 100mm x 140mm.

Batching

Batching of the constituent materials was done by weight method of batching using ratio of 1:6. The water cement ratio used in this research was 0.4 for all the blocks made.

3.3.2 Mixing

Seven different types of mixtures were prepared for this experimentation with the aid of laboratory rotating pan mixer. The sand was batched first into the pan, followed by the quantity of cement and calcium carbide waste. As the dry mixture was rotating in the pan, water was added gradually until the water-cement ratio (0.4) of the mixture was attained. The water and sand proportion in the mixes was constant and the cement and calcium carbide waste replacement ratios varies in the seven batches. Figure 3. 4 and Figure 3. 5 show batching of sand and mixing of the mortar for the mould, respectively

Figure 3. 4 Batching sand for moulding

Figure3. 5 mixing of the mortar

3.3.3 Moulding

The machine used was hydraulic pressure block making machine divided with partitioning template to produce six simples at a go of 100mm x 100mm x 140mm size. The wet mixture was placed in the mould to fill it approximately one third and compacted with a tamping rod. The rest was added into the mould and tamped again then compressed with hydraulic pressure of 100 MPa. The excess mixture was scraped off and the top levelled using a straight edge. Before each mould, the partitioning template inside was oiled for easy removal of blocks. In all 195 blocks were produced. Figures 3.6 ,3.7 and 3.8 show hydraulic pressure block machine in action, hydraulic pressure block machine and fresh moulded samples, respectively

Figure 3.6 hydraulic pressure block machine

Figure 3.7 hydraulic pressure block machine

Figure 3. 8 Freshly Moulded samples

3.3.4 Curing

The samples were cured in the laboratory under atmospheric condition with all the doors and windows opened to allow proper circulation of air for 7, 14, 21 28 and 56 days, and sprinkling water twice a day. Care was taken to ensure that the bricks were not disturbed during curing. Figure **3.9** shows Curing of samples.

Figure 3.9. Curing of samples

3.4 TESTING METHOD

3.4.1 Pit sand and Calcium Carbide Waste Sieve Analysis Test

The tests were carried out using the Sieve Analysis Test in accordance with BS 812 Part 103(1990). The experiment was conducted on pit sand and Calcium Carbide Waste. The samples were spread out in the sun to dry for a period of 24 hours before the actual test was carried out. The experiment was carried out using the sieve apparatus for grading. The specimens were weighed using digital weighing apparatus. The sample was poured into the set of sieve apertures and vibrated vigorously with machine for about 5 minutes. The mass of the sample retained in each of the sieves was measured and recorded. Consequently, the percentage mass retained and percentage mass passing the sieve set were obtained by calculation.

3.4.2 Chemical composition of calcium carbide waste

The study, determined the chemical composition of CCW. Atomic absorption spectroscopy (AAS) methods was used, which is a technique for measuring the concentrations of metallic elements in different materials.The standard AAS instrument consists of four components the sample introduction area, the light (radiation) source, the monochromator or polychromator, and the detector.

3.4.3 Compressive Strength

The test was performed to investigate the performance of the sandcrete bricks after the normal curing ages to establish the characteristic strength at the curing ages. Compressive strength is usually measured on a compression testing machine; Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size.

The test was conducted in accordance with BS 1881(1983a) using the compression testing machine. three samples from each of the seven mixes (0%, 10%, 20%, 30%, 40%, 50%, 90%) of the manufactured sandcrete blocks were weighed, and crushed at ages of 7,14,21,28, and 56 days. The values of average compressive strength of the sandcrete bricks were calculated and recorded. Figure3. 10 shows a block under compression testing.

$$CS = F \div A, \qquad (3.1)$$

where CS is the compressive strength,

F is the force or load at point of failure and

A is the initial cross-sectional surface area.

Figure 3.10 Brick under Compressive Test

3.4.4 Tensile Strength

Tensile test applies tensile force to a material and measures the specimen's response to the stress.

The test process involves placing the specimen in the testing machine frame with the split plate at the bottom and the top of the specimen and slowly applying an ever-increasing load to a test sample up to the point of failure. The process creates a stress/strain curve showing how the material reacts throughout the tensile test. The test was conducted in accordance with BS 772-6:2001. Using the compression testing machine, three samples from each of the seven mixes (0%, 10%, 20%, 30%, 40%, 50%, 90%) of the manufactured sandcrete bricks were weighed split as shown in Figure 3.11 at ages of 7, 14, 21, 28 and 56 days. The values of average tensile strength of the sandcrete blocks were calculated and recorded.

The tensile strength, also known as the ultimate tensile strength, the load at failure divided by the original cross sectional area where the ultimate tensile strength (U.T.S.), $\boldsymbol{\sigma_{max} = P_{max} / A_0}$ ———————————————————— 3.2

where P_{max} = maximum load, A_0 = original cross sectional area.

Figure 3. 11 Brick under Split Tensile Test

3.4.5 Water absorption test

An absorption test was carried out on the specimens. The samples were immersed in water to ascertain the rate of absorption of water, this is essential to ascertain the sandcrete blocks behaviour in moist condition.

The test was conducted in accordance with –BS EN 1097-6(2000). Three each of the specimens were placed in a drying oven at 106° C for 24 hours. The specimens were weighed individually after cooling and computed. The dry weighed samples were then immersed in water, at a depth of about 20mm for 20 minutes as shown in Figure3. 12 After that the samples were taken out. Each sample was wiped dry and weighed individually within three minutes after it was taken out from the water.

Absorption value was calculated using the equation:

$$\text{Absorption } \% = w2-w1/w1 \times 100 \qquad 3.2$$

where W1 is dry weight, and W2 is weight after immersion for 20 minutes

Figure 3. 12 specimens in water

3.4.6 Density determination

The bricks were weighed at each test day (7, 14, 21,28 and 56 days), with electronic weighing scale, having accuracy of 0.01 Kg as shown in Figure 3.13,after the specimen was placed in a drying oven at 106° C for 24 hours The three principal dimensions (length, width and height) of the brick were measured with a digital Vernier calliper, having accuracy of 0.01 mm. Then the density of each brick was calculated as the ratio of the weight to the volume (L x W x H) of the block, as shown in equation

$$\rho = \frac{m}{v} \qquad \text{———————————} \qquad 3.3$$

where ρ is the density (kg/m^3);

m is the mass (kg); and

V is the volume (m^3).

Figure 3. 13 Weighing of brick (electronic weighing scale,)

3.5 Analysis of data

The data collected from the laboratory results were analyzed using Microsoft Excel. The data was analyzed using a simple percentage. Discussions of the data obtained from the experiments were analyzed and tables and graphs were used.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the results of the laboratory experiments carried out. The chapter has been organized into different sections in accordance with the objectives of the study. The properties studied were compressive strength, split tensile strength and water absorption.

4.1. Constituent materials

4.1.1 Sieve analysis of aggregate

The purpose of sieve analysis was to determine the relative proportions of different grain sizes as they were distributed among certain size ranges. The aggregates samples were collected and dry under sun for three days, mass of sample was weighed and used for the sieve analysis.

Results of sieve analysis from sand sample are presented in Table 4. 1. Clearly show that, grading curves fall within the BS 410-1:2000 recommended band limit

4.1.2 Sieve analysis of calcium carbide waste

The calcium carbide waste samples were also dried under sun for three days, and the sample was weighed to obtain its mass for sieve analysis.

Results of sieve analysis from calcium carbide waste sample are presented in Table 4.2.

Table 4. 1 Fine Aggregate Grading For M Limits For Pit Sand.

Sieve size	Cumulative % Passing	UPPER LIMIT	LOWER LIMIT
2.36mm	89	100	65
1.18mm	70	100	45
600 µm	50	80	25
300 µm	29	48	5

Sieve size (mm)	Mass of soil Retained (g)	Retained (%)	Passing (%)
3.75	0	0	100
2.36	89	37.4	62.6
1.18	70	29.4	33.2
600 µm	50	21.0	12.2
300 µm	29	12.2	0
Total	238		

Percentage Retained= $\frac{\text{Mass of Soil Retained on Sieve}}{\text{Total Mass of Sample}} \times 100$

Mass of soil retained on the 2.36mm sieve = 89g

Therefore, percentage retained= $\frac{89}{238} \times 100$ =37.4%

Mass of soil retained on the 1.18mm sieve=$\frac{70}{238} \times 100$ = 29.4%

Mass of soil retained on the 600 µm sieve= $\frac{50}{238} \times 100$ = 21.0%

Mass of soil retained on the 300 µm sieve= $\frac{29}{238} \times 100$ = 12.2%

Percentage of soil passing 3.75mm sieve= 100-0 = 100%

Percentage of soil passing 2.36mm sieve= 100-37.4 = 62.6

Percentage of soil passing 1.18mm sieve= 62.6-29.4 = 33.2

Percentage of soil passing 600 µm sieve= 33.2-21.0 = 12.2

Percentage of soil passing 300 µm sieve= 12.2-12.2 = 0

Table 4. 2 Fine Aggregate Grading for F Limits For Carbide Sample.

Sieve size	% Passing	UPPER LIMIT	LOWER LIMIT
2.36mm	93	100	80
1.18mm	86	100	70
600 µm	57	100	55
300 µm	8	70	5

4.1.3 Chemical composition of calcium carbide waste

The study determined the chemical composition of CCW. The results are shown in table 4.3 and reveal that the most dominant chemical is Calcium (56.59%), followed by copper (5.67%), iron (0.058%) and zinc (0.0008%).

Table 4.3 Calcium Carbide waste

Chemical	**%**
Calcium	56.59
Copper (Cu)	5.67
Iron (Fe	0.058
Zinc (Zn	0.0008

4.2 Compressive strength of sandcrete blocks

The study, as one of its main objectives, sought to find out the Compressive Strength The variation of compressive strength of sandcrete block at varying calcium carbide waste for 7days,14days, 21days,28days and 56 days, curing period is show in Table 4.4 and Figure 4.1. The result shows decrease in compressive strength value with increase in the percentage calcium carbide waste of 10.682 N/mm^2 at 10% CCW content and 0.695 N/mm^2 at 90% CCW content at age 21. Beyond 10% there was a sharp decrease in the compressive strength value of the sandcrete block, thus 20% replacement at a value of 4.208 N/mm^2. 20%,30% and 40% CCW replacement decrease small at an average value of 0.027 N/mm^2 at age 14. The strength decreases from a value 10.773 N/mm^2 for control and 9.774 N/mm^2 for10%to a value of 0.298 N/mm^2,for90 and at age21 the value decrease from a value of an 13 at age 21 at the value decrease from a value of control 13.010 N/mm2for the control and 90% at a value of 0.695 N/mm^2.for the 90%

Table 4.4: Average compressive strength of the sandcrete block

Sample Name	Curing day				
	7	**14**	**21**	**28**	**56**
Control	10.773	11.925	13.010	14.299	17.199
10%	9.774	10.324	10.682	11.536	13.975
20%	4.208	7.911	8.126	8.293	10.767
30%	4.279	7.338	7.665	7.758	9.521
40%	4.290	5.077	5.121	5.788	7.532
50%	2.475	3.469	3.955	4.140	4.980
90%	0.298	0.581	0.695	0.885	1.087

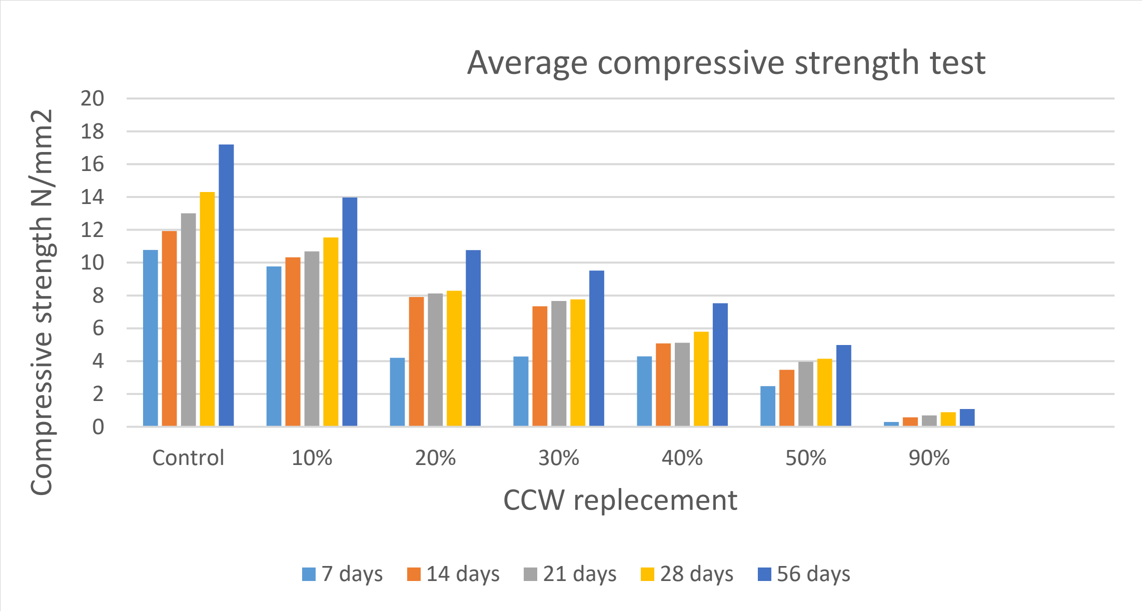

Figure 4.1 Average compressive strength of sandcrete block

4.3 Density of blocks

The result of average density presented in Table 4.5 and Figure 4.2 show that increase in the percentage of CCW in the mix produced sandcrete bricks of lowered density. The implication is that the density of the bricks actually decreased as the CCW content in the mix increased. At day 21 average density decreased from 2107.619 kg/m^3,for the control to 2083.095 kg/m^3, 2035.238 kg/m^3, 2030.476 kg/m^3, 2005.952 kg/m^3 , 1982.857 kg/m^3 and1851.190 kg/m^3 at a placement of CCW at 10%, 20%, 30%, 40%, 50% and 90% respectively

Table 4.5 average density of sandcrete block

	Average Density (kg/m^3)				
	Curing day				
Sample Name	7	14	21	28	56
Control	2058.571	2092.857	2107.619	2108.571	2153.810

10%	2053.810	2052.857	2083.095	2103.095	2038.095
20%	2041.905	2018.095	2035.238	2008.571	1998.333
30%	1992.857	1970.952	2030.476	2000.476	1991.429
40%	2014.762	2019.286	2005.952	2008.095	1961.667
50%	2028.333	2017.857	1982.857	1983.810	1926.905
90%	1919.524	1930.476	1851.190	1814.524	1827.381

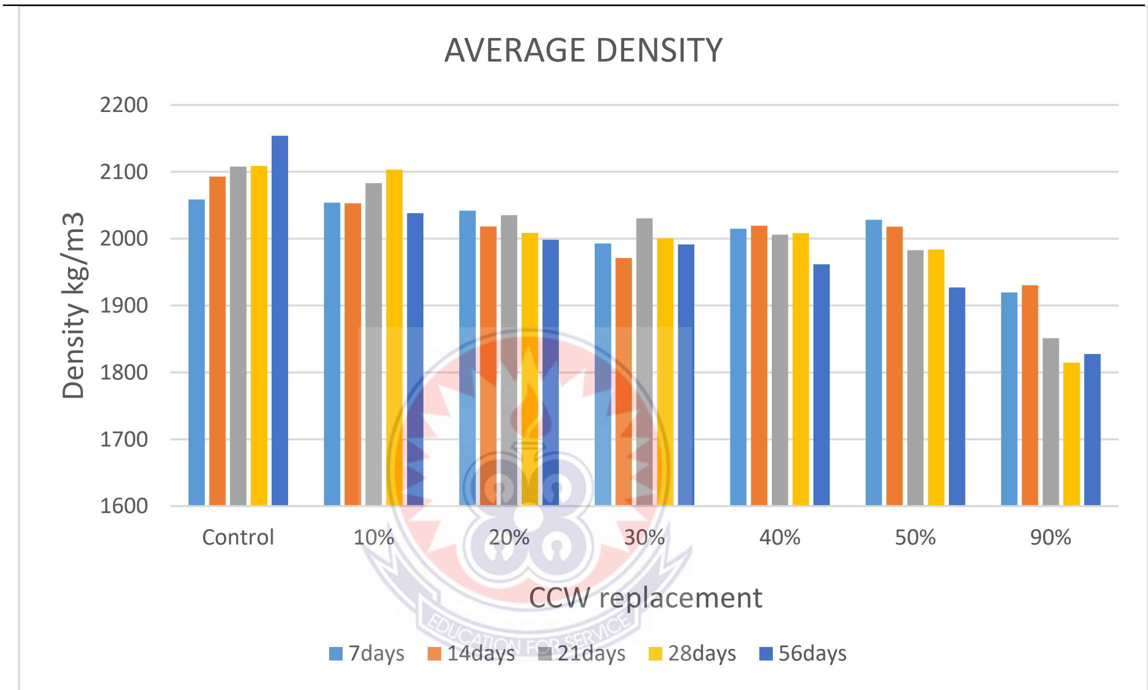

Figure 4.2 Average density of sandcrete block

4.4 Split Tensile Strength

The study also sought to find out the influence of C.C.W. on the tensile strength of sandcrete brick. Table 4.6 and Figure 4.3**.** The results of average Split tensile strength of sandcrete brick using CCW percentage replacement are not different in trend from that of the compressive strength it is found that the split tensile strength decreases as the amount of CCW percentage 90% increases, replacement with CCW, from age 21 days shows decrease in the tensile strength of the sandcrete block strength. At 0.263 strength of day 7 increase difference of 0.009 strength at day 14 and drop at 0.19, 0.005 and 0.023 strength at day 21,28 and 56 strength differences, respectively. The drop in strength is not in the curing days, but rather in the excess percentage (90%) of the CCW added

Table 4.6 average Split tensile strength

Average Split Tensile Strength (N/MM^2)

Curing Days					
Sample Name	**7**	**14**	**21**	**28**	**56**
Control	0.633	0.640	0.901	0.999	1.189
10%	0.524	0.680	0.693	0.773	0.946
20%	0.494	0.464	0.636	0.659	0.936
30%	0.412	0.417	0.423	0.521	0.541
40%	0.343	0.428	0.332	0.417	0.593
50%	0.282	0.297	0.304	0.309	0.446
90%	0.263	0.272	0.082	0.087	0.064

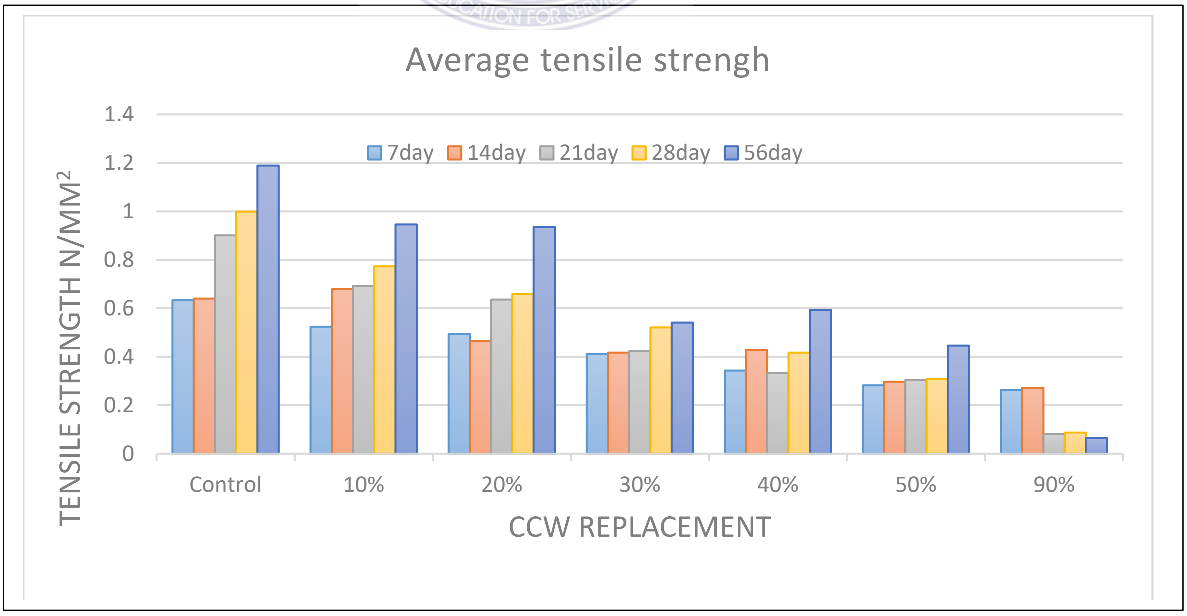

Figure 4.3 Average tensile strength of sandcrete block

4.6 Water Absorption Test

The results of the variation of the water absorption values of sandcrete block at different CCW percentage replacements are shown in Table 4.7 and Figure 4.4 respectively. They represent the variation of water absorption with percentage increase in CCW content. It is observed that partial replacement of cement with CCW increases the water absorption of the sandcrete block. The water absorption values compared with the control were greater by the replacements of 10%, 20%, 30%, 40% and 50% is 0.434%, 1.318%, 1.595%, 1.719%, and 1.961% respectively. The average absorption rate as compared to the control (0%) from 10% to 50% is 1.405%

Table 4.7 Result of Absorption test

Sample	Initial weight 1(kg)	Final weight 2(kg)	percentage
0%	2.907	2.931	0.826%
10%	2.777	2.812	1.260%
20%	2.751	2.810	2.144%
30%	2.726	2.792	2.421%
40%	2.711	2.780	2.545%
50%	2.685	2.762	2.787%
90%	2.498	2.603	4.203%

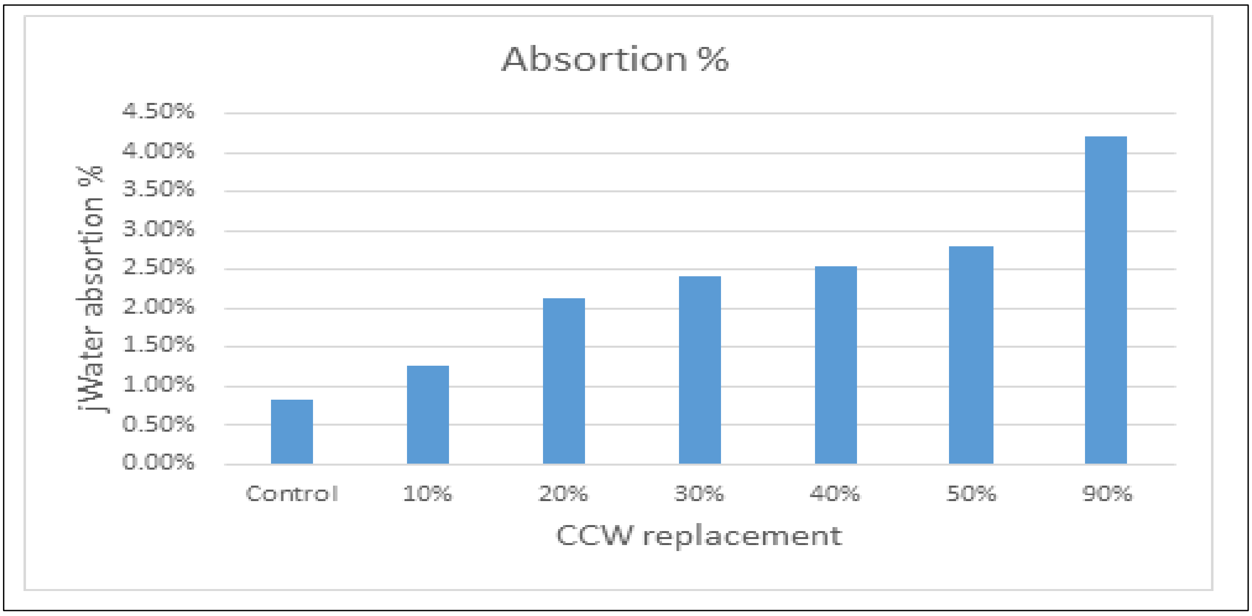

Figure 4.4: Variation of absorption of sandcrete brick for 56 curing days

CHAPTER FIVE

DISCUSSIONS

5.0 Introduction

This chapter provide analysis and discussions of the entire experiment in the context of this study. It also discusses the significance of the results with respect to the suitability of the blended cements for sandcrete brick and general construction using the standard specifications of British, and Ghanaian Standards.

The compressive strength, split tensile strength water absorption, and average density measurements are presented in graphical forms. Also captured in this chapter is the various methods in appraising the specimen brick The chapter ends with summary of what has been captured in the entire chapter.

5.1 Compressive Strength of the bricks

Strength is one of the most important purposes for sandcrete brick. Hence it is very important to ascertain the strength of sandcrete at the different percentage levels and at different ages of curing in order to determine the effect of CCW as strength increase with age. The variation of the compressive strength of sandcrete brick at different CCW replacement and varying curing period is shown in Figures 4.1, the result shows that as the curing periods in days increased there was a corresponding increase in compressive strength value for all treatment this is as a result of strength development with time due to the effort of complete hydration of the constituent of the cement and CCW replaced. Similar trend was recorded by an earlier study by AlKhalaf and Yousif (1984), Oyetola and Abdullahi (2006) and Mahmoud, *e al.,* (2012).

Also Similar results were obtained by Adebakin *et al*. (2012) reported that after 28 curing days, the control (100% sand) sandcrete blocks had compressive strength of 4.26 N/mm^2, while compressive strength of 1.80 N/mm^2 was for sandcrete block made with 40% sawdust content. According to Abdullahi (2005) and Afolayan *et al*. 2008, compressive properties of sandcrete blocks are inconsistent due to the different production methods employed (manual moulding, machine moulding, mixing ratio), the properties of constituent materials, and the level of quality control employed.

Apart from 90% replacement of CCW, the replacement of 10%, 20%, 30%,40% and 50% at age 21 were above the minimum compressive strength of 2.8 N/mm^2 recommended by the Ghana Standard Authority (GS297, 2003).

The Ghana Standards Board ~1995 specifies a period of 14–21 days of moist conditions and that, immediately after molding, the block should be kept under a shade and protected against the effect of drying winds.

5.2 Dry density of the bricks

The result of density variation with the percentage increase in the CCW substitution shown in Figure 4.2. The result shows a decrease in density as the percentage of CCW substitution increases. Thus, at day 21, average density decreased from 2107.619 kg/m^3, 2083.095 kg/m^3, 2035.238 kg/m^3, 2030.476 kg/m^3, 2005.952 kg/m^3, 1982.857 kg/m^3 and 1851.190 kg/m^3 at CCW placements of 10%, 20%, 30%, 40%, 50%, and 90%, respectively. The implication is that the density of the bricks actually decreased as the CCW content in the mix increased. This could be attributed to the fact that the CCW probably consist of particles with lower density in comparison to those of the Portland cement which were replaced partially with the CCW. The fineness of the Portland cement constitutes to the heavy nature of the Portland cement as compared to the calcium carbide waste which is in the granular form or rough in nature.

Boob (2014) reported similar trend for sawdust reinforced sandcrete blocks, where the density decreased from 2400 Kg/m^3 to 1800 Kg/m^3, as the sawdust reinforcement increase from 0% to 20%. On the contrary, Musa and Abubakar (2018), reported an increased in the density of sandcrete block in increased in volume tyre steel fibre reinforcement, which they attributed to the higher density of tyre steel fibres that the sandcrete block were made of. The low density of the CCW replacement in bricks couple with their relative high compressive strength makes

The British standard BS EN 772:11:2011described three types of blocks: Types A, B, and C.

1. Type A: These have a density of not less than 1500Kg/m^3; they are durable even when

exposed to extreme climate.

2. Type B: These are made of light weight aggregates and are load bearing.

They may be used below ground floor damp proof course. Density is less than 1500Kg/m^3 but more than 625Kg/m^3

3. Type C: they are similar to type B blocks except they are non-load bearing and are not suitable to be used below ground floor damp proof course. They are intended for use in non-load bearing walls and partitions

The mean density of sandcrete block for 0%, 10%, 20%, 30%, 40%and 50% at 21days are;2083.093 kg/m^3, 2107.619 kg/m^3, 2035 kg/m^3.2030.476 kg/m^3 and 1982.857kg/m^3 respectively. These values are greater than 1500kg/m^{3}' therefore they could be classified as type A blocks. They are load bearing and may be used as exposed to extreme climate

5.3 Split Tensile Strength of blocks

Figure 4.3 the average Split tensile strength of sandcrete brick using CCW percentage replacement. The tensile strength of the masonry unit is an important factor influencing the ability of concrete brick masonry under different loading conditions. As a result, some measure of the tensile strength of the brick that is both accurate and representative of its strength in the stress field associated with the loading conditions is needed. The tensile strength was found to differ significantly depending on the percentage of the CCW placement.

The outcome is similar to that of the compressive strength test. It was discovered that the split tensile strength decreased as the percentage of CCW increased. At 0.263N/mm^2 strength on day 7, there is an increase deference of 0.009 N/mm^2 strength on day 14 and a decrease at 0.19, 0.005 N/mm^2 and 0.023 N/mm^2 strength on days 21, 28, and 56, respectively

Bazant et al. (1991), Duan et al. (2006), and Rocco et al. (1999) demonstrated that the size of the test specimen has a strong influence on the tensile splitting strength of concrete through experimental research and theoretical analysis.

The average values of test results for the tensile strength ranged from 0.901 N/mm^2,0.693 N/mm^2,0.423 N/mm^2,0.332 N/mm^2 and 0.304 N/mm^2 for the replacement of CCW of 0%, 10%, 20%, 30%, 40%, and 50% at age 21. According to EN 312 – 2 (1996), the minimum tensile strength requirement for general-purpose boards was 0.24 N/mm^2. All of the percentage levels have higher values. As a result, from an engineering standpoint, CCW sandcrete brick will perform satisfactorily.

5.5 Water Absorption of the blocks

The water absorption property of a specimen determines the extent to which the test piece is susceptible to seepage of water through its pores space when immersed in water. This test focused on the change in weight of the specimen that this provided a useful measure of the durability of sandcrete block.

For block to be used as external wall in a humid climate, the water-resistance ability of the brick must be assessed in order to check the ingress of water. The rate of absorption value as compared to the control (0%) from10%, 20%, 30%, 40% and 50% the difference is 0.434%, 1.318%, 1.595%, 1.719%, and 1.961% respectively at the 56 curing days. The average absorption rate as compare to the control (0%) from 10% to 50% is 1.405%. This means that the increase in the percentage of CCW in the mix produced sandcrete bricks, in view of the fact that it opens up the brick in a way that encourages up flow of fluid, the percentage showed that it is not much.

The value for 0%, 10%, 20%,30%,40% and50% satisfies the 12% value recommended by BS EN 1097-6(2000)

These findings are in line with previous observations of Adesanya and Raheem (2010) although different materials were used. In Figure. 5, the water absorption rate is plotted against percentage CCW content. The results show that the addition of the CCW makes the average absorption value to increase than that of the control block. This could be attributed to the lose bond formation resulting from the reaction between the cement and the fine particles of CCW, which improperly sealed the pore space in the sandcrete brick.

Also can be conclude that, the increase of percentage of water absorption with the increment of CCW was due to absorbent characteristic of CCW.

CHAPTER SIX

SUMMARY OF FINDINGS

6.1 Introduction

The thesis was planned to determine the physical properties of calcium carbide waste and the sieve examination, as well as its effect on the compressive strength, split tensile strength, density and absorption of the sandcrete brick.

6 .2 Summary of The Findings

The study was carried out to investigate the use of calcium carbide waste as a partial replacement of cement in sandcrete brick. Based on the results obtained, the study provides the following summary of findings:

Locally accessible CCW was used as a partial replacement of cement, was analyzed in order to assess its effect on the properties of sandcrete bricks. For 195 block that were molded at a percentage of 0, 10,20,30,40,50 and 90, with CCW, the following summary of the findings can be made:

The compressive strength decreases with an increase in the percentage of calcium carbide waste. With replacement of CCW at 10%, 20%, 30%,40% and 50% the specimens produced compressive strength at age 21 that exceeded the minimum of 2.8 N/mm^2 as recommended by the Ghana Standard Authority (GS297, 2003)____

Density of sandcrete bricks decreased progressively with increasing percentage CCW replacement. This means the blocks will contribute to the reduction in weight of structure and reduced crack.

The mean density of sandcrete block for 0%, 10%, 20%, 30%, 40%and 50% replacement of cement with CCW at 21days are 2083.093 kg/m^3, 2107.619 kg/m^3, 2035 kg/m^3. 2030.476 kg/m^3 and 1982.857kg/m^3 respectively. These values are greater than 1500kg/m^3' therefore they could be classified as type A blocks. They are load bearing and may be used as exposed to extreme climate, according to BS EN 772:11:2011

The tensile strength of sandcrete bricks decreased progressively with increasing percentage CCW replacement. The average values of test results for the tensile strength ranged from 0.901 N/mm^2,0.693 N/mm^2, 0.423 N/mm^2, 0.332 N/mm^2 and 0.304 N/mm^2 for the replacement of CCW of 0%, 10%, 20%, 30%, 40%, and 50% at age 21. According to EN 312 – 2 (1996), the minimum tensile strength requirement was 0.24 N/mm^2. All of the percentage levels have higher values. As a result, from an engineering standpoint, CCW sandcrete brick will perform satisfactorily.

Water absorption rate of brick increases as the amount of CCW increases. The water absorption rate of all the replacement levels were within the acceptable value of 12% as stipulated by BS5628: part 1: 2005

Since sufficient capabilities for buildings with less cement content have been attained, it was concluded that this CCW-cement combination is an inexpensive building material, since the cost of bricks depends primarily on the content of cement.

6.3 Conclusion

From the results of the current study, the following conclusions can be drawn:

1. The calcium carbide waste is viable as partial replacement of cement in bricks as it gives
2. satisfactory results at 14 to 28 days of curing respectively.
3. The aggregate grading of the soils used for the manufacture of sandcrete blocks are within the limit specified by BS 882: 1992 and are therefore suitable for block making
4. The density of sandcrete blocks decreases as the CCW increases but increases as the curing days' increases.
5. The compressive strength of sandcrete blocks increases as the curing age increases but decreases as the CCW content increases.
6. Up to 50% CCW replacement is adequate for use in sandcrete brick for walls in buildings.
7. The average density of CCW is found to be greater than 1500kg/m^3. They are load bearing and can be used as exposed to extreme climate, according to BS EN 772:11:2011

6.4 Recommendations

From the results and conclusions drawn it is recommended that;

CCW can be used as partial replacement for cement in normal construction works especially in recent time when the cost of cement is high and waste CCW are readily available. This will help in reducing the threat these waste CCW pose to our environment. In view of the above, there is urgent need to take following measures:

1. A comparative cost-benefit analysis should be evaluated.

2. National level support and research studies on CCW.

3. Preparation of techno-financial regime, financial support for introducing CCW in construction industry.

4. Arc welders should be encouraged in propagating proper storage of CCW for the multiple benefits derived from it.

6.5 Further Studies

It is recommended that further studies should be conducted in the following areas:

1 The properties of CCW in earth block.

2 The type of admixture that can improve the strength of CCW

3 Health hazards associated with the use of CCW

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APPENDIX

The following calculations were carried out for the ratio:

- 1 block weight =2.8kg
- Allowance for waste =0.2kg +1 block weight 2.8kg =3kg

Control

- Number of moulds =56blocks
- Using w/c 0.4
- 3kg weight of 1 block x56 number of blocks =168kg
- Using ratio of 1:6 for moulding blocks
- Cement is 168kg
- 1x168kg/7 =24

Sand

- 6x168kg/7 =144kg

Water

- 24kg x 0.4 =9.6kg

Ii Percentage of calcium carbide waste

- 10% calcium carbide waste
- 10/100 x24kg = 2.4kg

Actual cement used for the mixing for 10% calcium carbide waste

- 24kg – 2.4kg = 21.6kg

The above calculations were repeated for each of the seven mixes.

Table 3.1. Summary of Mix Design for partial placement of calcium carbide waste

	sand(Kg)	water(Kg)	cement(Kg)	calcium carbide waste
Control	144	9.6	24	0
10%	144	9.6	21.6	2.4
20%	144	9.6	19.2	4.8
30%	144	9.6	16.8	7.2
49%	144	9.6	14.6	9.6
50%	144	9.6	12	12
90%	144	9.6	2.4	21.6