UNIVERSITY OF EDUCATION, WINNEBA
KUMASI-COMPUS

DEPARTMENT OF DESIGN AND TECHNOLOGY
MASTER OF TECHNOLOGY EDUCATION IN CONSTRUCTION TECHNOLOGY

INTERLOCKING BLOCKS CONSTRUCTION FOR SUSTAINABLE AFFORDABLE HOUSING IN GHANA – A CASE STUDY OF SUNYANI MUNICIPALITY

BY

ASSIAMAH SAMPSON - 7121190022

AUGUST, 2014

A DISSERTATION SUBMITTED TO THE BUILDING DEPARTMENT OF UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE AWARD OF MASTER OF TECHNOLOGY (MTECH)

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DECLARATION

CANDIDATE'S DECLARATION

I, Sampson Assiamah, declare that this Dissertation, with the exception of quotations and references contained in the 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.

Candidate's 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.

Supervisor:…………………………….

DR. WILLIAM GYADU-ASIEDU

DATE ....

ACKNOWLEDGEMENT

While I give praise, glory and honour to God for His enabling grace, I wish to acknowledge with gratitude and contributions of the following dignataries towards this project:

I owe a deep sense of gratitude and thanks to Dr. William Gyadu-Asiedu whose effort, constructive criticism and corrections have made this work a successful one and to Mrs. Patience Assiamah (wife).

I also wish to thank Mr. Humphrey Danso, a lecturer of UEW, my father, Mr. Osei Afoakwah (Finance Officer, UMAT) Mr. Kwadwo Adinkrah-Appiah (Vice Rector), Mr. Nimo Boakye, Rev. Addy Edward (HOD, BT), Mr. Evans Zoya Kpamma,Phelimon Baah Mr. Michael Kofi Nsiah (my father), Mr,Stephen Okyere-Boateng (Research Dep.) Mr. Anane Augustine (Procurement Office), Adoma Victor (Research Dept.) and all Staff and students of UEW, Kumasi Campus.

May God richly bless them all?

DEDICATION

I dedicate this work to my dear wife, Mrs. Patience Assiamah, whose efforts have made this work a reality and to my daughter, Angel Ampofowaa Assiamah and Phelimon Baah, Sunyani Polytechnic and my entire family.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The building construction industry in Ghana is dominated by the use of conventional sandcrete blocks for wall construction. However, there is challenge of delivering products of maximum value to clients at an affordable cost and on time. Addressing this challenge will require adopting lean construction principles towards minimising waste and maximising value in the building construction process. This study aimed at making a case for the use of interlocking blocks as an alternative building material in Ghana. It investigates into the construction of housing with interlocking blocks as a concept can be successfully incorporated into housing sector of this country as a means of providing an additional support to the affordable housing pursuit in Ghana. A comparative study of constructing a wall using the interlocking block system and sandcrete block system was done. An observation of the processes was also made to identify the extent to which each system contributes to speedy construction. The necessary data were collected using primary sources of data collection. The data were processed, analyzed by SPSS and interpreted using frequencies, percentages and charts. It was revealed from the study that the use of the interlocking block system does not only lead to eliminating a number of non-value adding activities associated with the use of the sandcrete block, but also makes the wall construction process faster and cheaper. It also showed that buildings with interlocking blocks provide a cooler temperature. It was also revealed that the absence of mortar jointing in the interlocking system reduces the quantity of materials, like cement and sand, required in the wall construction process. The study therefore concludes that Hydraform's interlocking block system could therefore be an appropriate tool for implementing Sustainable and Affordable Housing in Ghana.

CHAPTER ONE

INTRODUCTION

1.1 Background

Interlocking compressed earth block (ICEB) masonry has the potential to provide affordable construction around the world. Comprised of basic, inexpensive materials, such as soil, the blocks can provide homes and other facilities at low cost. By creating interlocking joints between layers of blocks, ICEBs allow for the blocks to be dry stacked, without the need for mortar.

While dry stacked ICEBs are currently being used in structures, little is understood about its behaviour during an earthquake. Since there are many different forms of ICEBs, research done for one type is not directly applicable to another. The incomplete understanding of the inelastic performance of ICEB building systems limits the wide spread acceptance of this structural system in earthquake prone areas. The ICEBs used for this thesis are dry- stacked and allow for both transverse and longitudinal reinforcement. The ICEBs used for this thesis are currently being used in Indonesia and Thailand, where earthquakes have the potential to cause significant damage. Out-of-plane forces, created during an earthquake or by wind, can cause significant damage to a structure. However, no out-of-plane experimental research has been completed on reinforced dry stacked ICEB walls. Therefore, it is the intent of this thesis to provide insight into the out-of-plane behaviour of dry stacked, reinforced ICEB walls, constructed according to the current practices found in Indonesia and Thailand.

Soil has been used as a building material for thousands of years. Adobe, rammed earth, and compressed earth masonry are examples of this building tradition in today's world. Using soil as the main material component of a building provides benefits such as the use of local materials, high thermal mass values, and increased workability (Maini, 2010). The soil used in earth buildings is taken from the surrounding areas or the excavation for the foundations (Maini, 2010). In cement stabilized earth construction, cement use is commonly kept to 5-10% by weight (Walker, 1999). In contrast, concrete and concrete masonry construction use anywhere from 10%-15% by volume of cement (Portland Cement Association, 2012). By eliminating the need for heating kilns and reducing the amount of cement, compressed earth blocks are energy efficient. ICEBs require anywhere from 1/5 to 1/15 of energy to make when compared to fired bricks and concrete masonry units (Maini, 2010). All of these facts about earth construction contribute to a decreased cost of construction and an increased availability in developing countries. Dry stacked ICEB construction can lead to a faster construction time when compared to other types of masonry. Dry stacking does not rely on skilled labour such as masons. Instead, dry stacking can be done with little training and in a shorter amount of time than with traditional mortared masonry (Maini, 2010). Some researchers suggest the reduced need for skilled labour and the shorter construction time can reduce the cost of labour by as much as 80% (Anand and Ramamurthy, 2005).

The materials and the forming method used in dry stacked ICEBs can have a very low carbon footprint when compared to traditional masonry, timber, and concrete. Depending on the location of the ICEB building, the importation of construction products is greatly reduced. Since indigenous soil is the main ingredient in ICEBs, a majority of supplies do not have to be shipped to the site (Maini, 2010). This reduction in transportation decreases the fossil fuel use. ICEB structures also use very little to no timber. Timber structures and the wooden forms used in concrete structures can lead to significant deforestation. Even other types of earth structures such as rammed earth and adobe construction require the use of forms during construction, using lots of wood members that eventually go to waste (Wheeler, 2005). Depending on the surrounding areas of the building, the wood products can end up being transported hundreds of miles to reach the site. Without the need for timber or timber forms, compressed earth block construction helps to limit deforestation around the world (Maini, 2010). In developed countries, research, design, and construction improvements of masonry buildings have led to better performance and safety of masonry buildings during an earthquake. However, little structural testing of dry stacked ICEB masonry has been done, leaving the masonry form vulnerable to significant damage or failure during a seismic event. California Polytechnic State University in San Luis Obispo (Cal Poly) has been involved in providing information for the use of ICEB masonry since 2008. The Engineers without Borders chapter of Cal Poly has been working with the Center for Vocational Building Technology (CVBT) in Thailand on improving construction with ICEB technology. Students from the mechanical engineering and civil engineering departments have worked with CVBT to improve the ICEB structural building design. Mechanical engineering students have worked with the Soeng Thai BP6 block press, the Soeng Thai SP3 soil pulverizer, and a pocket penetrometer. All of these items are critical to the creation of ICEB's and in making the blocks uniform in strength. Civil engineering students have begun to provide information on the basic properties of ICEB's as well as the in-plane shear wall capacities. It is the combined goal of the student efforts at Cal Poly to provide the research and evaluation of ICEB's as a structural system and offer insight into a better design manual for all future ICEB buildings.

For several years, the crisis of shelter has been a matter for serious and continuous debate in academic and policy formulation circles. In all these debates, one major solution for the provision of adequate and decent accommodation for all particularly focusing on the poor has been the provision of low cost or affordable housing schemes. Provision of affordable housing throughout the years has been done through two main channels. One is through the encouragement of research into the production and use of local building materials such as bricks and tile, landcrete blocks, adobe bricks, compressed earth blocks, pozolana cement, bamboo, and secondary timber species. The second and most popular means is the construction of affordable or low cost houses by government and private agencies.

Affordable housing in Ghana began in 1939 when as a result of an earthquake in Accra on 22nd June, 1939 and due to the subsequent tremors, a large number of people were rendered homeless. A Rehousing Committee was formed and the government provided funds to build 1000 two-roomed houses at Mamprobi, Chorkor, North West Korle Gonno, Kaneshie and Abossey-Okai. By 1955, 1250 units were completed and up to date still exist, and are inhabited by mostly civil and public servants and members of the Armed Forces. Some of the houses were for rental and others were bought on hire-purchase. The units were all subsidized (CSIR-BRRI, 1970).

In 1952, the Tema Development Corporation (TDC) was established with the objective of housing low income workers in a newly created Tema-Port.

The Schockbeton Housing Scheme was also established which targeted to provide 168 houses in Accra, Kumasi and Secondi-Takoradi. A total of 64 units were built. Policies like the roof loan scheme and the establishment of the State Housing Corporation (SHC) are all examples of policies that were put in place to provide low cost houses during this era (Owusu and Boapeah, 2003).

Soon after taking over the reins of government, the National Redemption Council constituted A National Low Cost Housing Committee in March 1972, under the auspices of the Ministry of Works and Housing. A sum of 10 million old Ghana cedis was allocated for the construction of low cost houses in all the ten regions of Ghana (CSIR-BRRI, 1972).

Interlocking blocks have always been in use to a lesser extent, but extensive studies on this technology only appeared after the first ecological-villages came into being. Dry-stack masonry construction refers to a method of building masonry walls, in which most of the masonry units are laid without mortar in the joints. The units are usually stacked in a stretcher bond. The masonry units may be of bricks or block proportions and may be solid or hollow. The shape of the units usually incorporates geometry that provides an interlock between units when laid in a specified bond. Dry stacking relies on mechanical interlocking features in the units to provide stability and assist alignment and levelling during construction.

Of late, dry stacking or mortarless technology is increasingly becoming popular. A study by Vanderwerf (1999) shows that, conventional masonry is losing grounds to dry-stacking technology. The customers are swayed by the advantages they often perceive in these new systems: lower installed costs, shorter site time and dependence on a small pool of highly skilled labour. Comparatively, conventional masonry requires more labour hours by more highly skilled and highly paid workers. As the history of innovation consistently shows, a successful innovation starts in the market niche. Innovative mortarless systems have improved with time since mid-1980's and are now more competitive in many more market segments than before.

Hydraform is a world leader in masonry construction and the manufacture of hydraulic block machines. Hydraform specializes in using soil cement Compressed Earth Block (CEB) technology to produce interlocking dry Stacked Soil Cement Blocks (SCBs) in over 50 countries worldwide. The company's core business is therefore the manufacture and sale of these Stabilized Soil Block (SSB) machines which is used in creating and utilizing eco-friendly building systems with low embodied energy. These green systems which are cost effective and labour-intensive is equally ideal for both remote rural areas and high-densely urban areas.

1.2 Statement of Problem

The building construction industry in Ghana, particularly the urban housing sector, is dominated by the use of the sandcrete block for wall construction. Various forms of waste in terms of time and financial cost have however been observed to be associated with the process of erecting walls using the sandcrete block. This has led to the need to explore the possibility of adopting other walling systems like interlocking block wall in order to reduce waste and maximise value. More importantly, the present system does a little to support the sustainable construction agenda.

1.3 Aim of the Study

The main aim of this study is to investigate into the interlocking block construction for housing as a means of identifying how the concept can be successfully incorporated into housing sector of this country and to providing an additional support (if not a good alternative) to the affordable housing pursuit in Ghana. The essence is to justify the concept as contributing to the sustainable construction agenda.

1.4 Objectives of the Study

The following objectives shall be pursuits in order to achieve the aim.

1. To compare the speed of construction between the interlocking blocks and sandcrete blocks;
2. To compare the labour cost of construction between the interlocking blocks and sandcrete blocks;
3. To compare the cost of interlocking blocks and sandcrete blocks;
4. To compare compressive strength of interlocking blocks and sandcrete blocks;
5. To determine the thermal conductivity and insulation of the interlocking blocks and sandcrete blocks.

1.5 Research Questions

The study shall be guided by the following research questions:

- What is the difference in speed of construction between interlocking blocks and sandcrete blocks?
- What is the difference in labour cost between constructing interlocking blocks and sandcrete blocks?
- What is the difference in cost between interlocking blocks and sandcrete blocks?
- What is the difference in compressive strength between interlocking blocks and sandcrete blocks?
- What is the difference in thermal ability between interlocking blocks and sandcrete blocks?

1.6. Hypotheses

Hypothesis 1

H0: There is no significant difference between the speed of interlocking block construction technique and conventional sandcrete block construction**.**

H1: There is a significant difference between the speed of interlocking block construction technique and conventional sandcrete block construction**.**

Hypothesis 2

H0: There is no significant difference between the labour cost of constructing interlocking block construction technique and conventional sandcrete block construction**.**

H1: There is a significant difference between the labour cost of constructing interlocking block construction technique and conventional sandcrete block construction**.**

Hypothesis 3

H0: There is no significant difference between the cost of interlocking blocks and conventional sandcrete blocks**.**

H1: There is significant difference between the cost of interlocking blocks and conventional sandcrete blocks**.**

Hypothesis 4

H0: There is no significant difference between the compressive strength of interlocking blocks and conventional sandcrete blocks**.**

H1: There is significant difference between the compressive strength of interlocking blocks and conventional sandcrete blocks**.**

1.7 Justification of the Study

The results of the thesis will add to the body of knowledge of the use of local materials in construction and the provision of affordable housing. In addition, it will also contribute to the construction industry by providing a guide to the use of such technology. Its other contribution to industry shall be in the process of diffusion of the technology. Once the technology becomes accepted, society will benefit in obtaining affordable housing and thereby contribute to the reduction of the housing deficit in the country. It will also contribute to the creation of green environment.

1.8 Scope and Limitation

The scope of this study will be limited to the Sunyani Urban Council due to the following:

- Time factor
- Limited financial resources.
- Reluctance of some of the workers in the consultancy firms to volunteer their full corporation for the necessary assessment.

1.9 Guides to the Report

The study is organized into five chapters. Chapter one introduces the study by giving the background information on the research problem, objectives and scope of the study.

Chapter two deals with the literature review on the research problems and concepts with specific reference to how it applies to interlocking block.

Chapter three discusses the research methodology adopted for the study and relevant justifications. It outlines the methodology for carrying out the secondary and primary data collections and how results were analyzed.

Chapter four presents the results/findings on the use of interlocking blocks as an alternative solution for affordable housing.

Chapter five and six present discussion of the findings, the conclusions drawn from the research findings and recommendations to enhance the use of interlocking blocks.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is devoted to the review of the relevant literature on interlocking blocks and their use in the construction of walls. It starts by discussing issues involved in the use of interlocking by investigating theories propounded by experts in the field as the bases for an elaborate field research. Key highlights include the need for affordable housing, the need for speed of construction, labour output/ productivity.

2.2 The Interlocking Block System

Interlocking blocks are different from conventional bricks since they do not require mortar to be laid. The blocks are just laid dry and locked into place (see Appendix II). As a result of this characteristic, the process of building walls is faster and requires less skilled labour. Laying the first course in the mortar bed requires that care is taken to ensure that blocks are perfectly horizontal and in a straight line or at right angle corners. Once the base is properly laid, the blocks are stacked dry with the help of a wooden rubber hammer to knock the blocks gently in place (Nasly and Yasin, 2009).

The hydraform interlocking block masonry is one building system which almost fulfils all such requirements of sustainability masonry as use of locally available resources (materials and labour), cost-effectiveness, eco-friendly, easy to adopt, faster to build and energy efficient. Hydraform dry stacked interlocking block system enables aesthetic affordable buildings as well

2.3 Compressed Earth Block- Interlocking Block

The interlocking dry-stack block system was tested by Pave (2007). A complete testing program achieved values for compressive strength and flexural strength for the interlocking blocks.

Interlocking blocks are solid, compressed earth blocks that do allow for reinforcement parallel to the bed joint. The blocks form a shape that is pictured in Figure 2.1, where two edges of the blocks are lowered, to form a dry-stacked, interlocking pattern. The tested compressive strength of a single interlocking block, with 5% cement content was found to be 3.0 MPa. The masonry compressive strength, as determined by prism testing was found to be 1.1 MPa for blocks with 5% cement content.

Figure 2.1– Interlocking Blocks (Source: Pave, 2007)

For the flexural strength tests, Pave (2007) decided to use composite beams made of reinforced concrete and dry stacked masonry. Multiple beams with 6 mm steel bar reinforcing were tested with different sizes and cross sections. Each beam was tested with loading perpendicular to the bed joints of the blocks, meaning the beams were tested across their minor axis (see Figure 2.2). The tests showed that the concrete-masonry beams were able to behave with composite action under flexural loading. A beam was tested without concrete, as shown in Figure 2.2, and showed excessive deflections in the masonry. It should be noted that the interlocking block system does not have vertical grout holes or wide horizontal grout channels to resist this out-of-plane loading. Three out of the four beams tested did not meet the theoretical load capacity during experimentation. However, there were instances of shear cracks that could not be investigated completely at that time. The researchers recommended that the shear resistance of the dry-stack system should be extensively investigated.

Figure 2.2 – Example of Cracking Pattern and Loading
(Source: Pave, 2007)

2.4 Benefits of Interlocking Stabilized Soil Blocks

The technology has helped millions of low income earners across the globe to own a decent house (UN-HABITAT, 2009); due to reduced labor costs and construction time. The technology has employed both semi-skilled and unskilled masons, and also supports the local small entrepreneurs. As green construction technology, it saves millions of trees, millions of tonnes of carbon monoxide and reuses waste materials like quarry dust.

The technology has been proven to produce neat, quality and aesthetically attractive block finishes says the UN-HABITAT (2009) report. The blocks are strong and several studies have proved that they are fire and bullet resistant UN-HABITAT (2009).

2.5 Towards Low-cost Housing

Interlocking soil-cement blocks allow for the quick and cost efficient construction of housing units and other buildings. Tucker (2009), international sales manager at interlocking says that using interlocking blocks have numerous benefits, especially for companies operating on the continents. One of the advantages of interlocking blocks is they are low in cost, interlocking block making machines only used three inputs, namely soil that can be sourced on site, a small amount of cement that provides stability to blocks and water. As a result, the machines are ideal for sites where transport costs for cement and sand are high.

2.5.1 Wastes in Construction

A number of non-value adding activities are associated with design and construction processes resulting in waste generation. Majority of these wasteful activities consume time and effort without value generation to clients. As a result of this situation, managers of construction activities at the start of construction projects have to deal with many factors that may negatively affect construction processes producing different types of waste (Serpell et al., 1995). Waste here refers to both the incidence of material losses and the execution of unnecessary work that generates additional costs but does not add value to the construction product (Koskela, 1992).

In the construction and manufacturing industry, waste include among others, delay times, quality costs, lack of safety, rework, unnecessary transportation, long distances, improper choice of management, methods or equipment as well as poor constructability (Alarcon, 1993; Ishiwata ,1997; Koskela, 1992 and Serpell et al., 1995). Formoso et al. (1999) went on to propose their main classification of waste in construction as over production, unwarranted substitution, waiting time, transportation, processing, inventories, movement and defective products.

Ohno (1988), who articulated the lean production philosophy and implemented it in Toyota's production system, classified sources of waste as follows: defects in products, over-production of goods not needed, inventories of goods awaiting further processing or consumption, unnecessary processing, unnecessary movement of people, unnecessary transport of goods, waiting by employees for process equipment to finish its work or for an upstream activity to complete. An eighth category of waste was added by Womack and Jones (1996) as design of goods and services that fail to meet user's needs.

2.5.2 Workflow in Construction

The view of flow in production, proposed by the (Formoso, C.T., Isatto, E.L., and Hirota, E.H. 1999), has in scientific terms, provided the basis for Just in Time (JIT) and lean production. In the concept of flow, production is viewed as a flow whereby in addition to transformation activities, there are non transformation activities like waiting, inspection and movement. Production management therefore involves reducing the share of non-transformation steps of production flow, especially by reducing variability. In this respect the flow model looks beyond transformation activities by taking non-transformation activities into account in order to improve flow efficiency (Formoso, C.T., Isatto, E.L., and Hirota, E.H. 1999).

The concept of lean thinking in construction, apart from focusing on a systematic elimination of waste, also involves the implementation of the concepts of continuous flow and customer pull (Kotelnikov, 2007). Howell (1999) also identifies organising production as a continuous flow as one of the core concepts of lean production. Improving workflow reliability, according to Ballard (1999), is important for productivity of linked production units, and consequently for project cost and duration. Continuous workflow ensures steady production rates that eliminate the chaos of fragmented stop-and-go production processes (Caldeira, 1999).

The nature of production in construction is assembly-type, in which case different material flows are connected to the end product. Koskela (2000) suggested three types of flows in construction. The first type is material flow which involves transportation of components to the site for installation. The second type is location flow whereby one particular trade goes through the different parts of the building or construction site to get work done. The third type is assembly flow involving the sequence of works of assembly and installation.

2.5.3 Speed of Wall Construction

Speedy delivery of value is very important towards ensuring a lean project delivery of construction products. "Lean" is doing more with less: less time among others (Kotelnikov, 2007). The delivery of construction products on time, apart from contributing to a reduction in cost of construction, also enhances value to clients. The results of the study indicate that the pace of wall construction using the interlocking blocks is far more than using the sandcrete block. The elimination of non-value steps like spreading mortar, levelling, vertical mortar jointing and dressing of joints significantly reduces the cycle time of bonding blocks thus increasing the speed of wall construction.

Much time is devoted in the interlocking block system for the construction of the first course to ensure near perfect alignment and proper coordination of block units in subsequent courses. Once the first course is properly laid, the building of the subsequent courses simply involves packing the blocks to interlock. This eliminates the chaos of disjointed stop-and-go production processes associated with the sandcrete blocks and rather focuses on fast cycle times to ensure reliable and continuous workflow. Generally, less than half the time that is used to erect a wall using the sandcrete block is required to erect a similar wall using the interlocking block.

2.5.4 Labour Output / Productivity

According to Womack et el. (1991) "lean production" is "lean" because it uses less of everything including labour. The study showed that greater output of masons was achieved in the use of the interlocking block system compared to the sandcrete block system. The output of masons increased by more than 50% when they used the interlocking blocks instead of the sandcrete blocks. The higher output of the masons resulted from the fact that some steps were eliminated in using the interlocking blocks compared to when laying with the traditional sandcrete blocks. The incidence of "waiting", resulting from the disjointed stop-and-go production processes associated with the sandcrete blocks, was also largely reduced in the case of the interlocking blocks therefore enhancing output.

The idle time of labour in the use of the interlocking block compared to the sandcrete block was also drastically reduced. Unlike the sandcrete block walling system, the continuous workflow nature of the interlocking block walling system took away the intermittent idle times particularly associated with labourers who were engaged to carry blocks and mortar for jointing. The wall construction steps of spreading mortar, vertical jointing, mortar joint dressing and levelling led to the idle time in the use of the sandcrete blocks.

2.6 Reasons for Interlocking Blocks

Hydraform India, (2008), says that using interlocking blocks have numerous benefits, especially for companies operating on the Asia.

- One of the advantages of interlocking blocks is that they can be dry-stacked with no mortar. This greatly increases the speed of construction.

- It has been extensively tested for structural strength and durability, as well as for fire, rain and sound resistance.
- Interlocking block making machines only use three inputs, namely soil that can be sourced on site, a small amount of cement that provides stability to the blocks, and water. As a result, the machines are ideal for sites where transport costs for cement and sand are high. They are also an eco-friendly, cost-saving alternative to conventional vibration machines. Interlocking machines are available in diesel or electrical options. Depending on the model, the machines have the capacity to produce between 1,500 and 3,000 blocks per eight-hour shift.
- The machines are relatively labour intensive, requiring about six operators. For most companies and governments this is an advantage because it creates employment opportunities and allows for skills transfer.
- The company's technology is particularly popular in Africa's mining industry, where entire communities often have to be relocated to make way for new mines.
- Hydraform also provides full training on using its machines as well as building techniques for interlocking blocks. "We offer training programmes both here in South Africa and on-site across the continent. Our technicians would give workers training on operating the machines as well as maintenance. The machines are relatively easy to use and people normally learn quite quickly."
- Tucker notes that although Africa is currently the company's biggest market, its machines are being used extensively throughout the world, including South America, Central America, the US, Eastern Europe and India. Hydraform also has French-speaking sales and training staff.

- Interlocking blocks – a cost effective building solution for Africa
- Interlocking soil-cement blocks allow for the quick and cost efficient construction of housing units and other buildings. South Africa-based interlocking block making Machines are currently being used across Africa by property developers, entrepreneurs, governments and NGOs.
- A building constructed using interlocking blocks.
- One company that is benefitting from interlocking blocks technology is Malawi's Hydra Homes Ltd. Formed in 2009 by a British Chartered Civil Engineer; the company has over 200 employees engaged in construction projects around Malawi.
- An engineering team that can offer simple advice on projects or develop full technical drawings for developments for planning and construction. (Bansal, 2010).

The interlocking building system replaces conventional bricks and mortar through the use of interlocking blocks, which are interlocking and can be dry-stacked. The other components of the conventional building system remain unchanged.

These blocks can be made on construction site or at block yard using interlocking block making machines. Today the interlocking building system and the machines are used in over 50 countries worldwide. These blocks – bricks can be made with local soil and cement or Fly ash (burnt coal ash) and cement. Hydraform has a range of interlocking block making machines and mixers to suit client requirement. Machines can also make conventional brick and other block sizes to suit requirement by changing the moulds. Technical assistance and training is available.

1. High Quality Product

2. Environment Friendly – No burning of bricks required

3. Option to Use Waste materials / Fly Ash / Marble Slurry / Concrete mix with chips up to 6mm

4. Minimum mortar required

5. Independence to make at site of construction

6. Training and technical support

7. International proven product used in more than 50 countries

8. Can be used without plastering

9. Lighter than conventional masonry

10. Suitable for earthquake resistant construction

11. Local / Unskilled labour can be constructed Conduits / Plumbing possible

(Hydraform India, 2008).

2.7 Lean Thinking in Construction

The concept of lean thinking originated from the manufacturing sector and focuses on producing in a manner that eliminates defects while using less input in the form of labour, machinery, space and time by reducing the number of conversion activities and movement flows in making a product (Harris and McCaffer, 2001). Many ideas from the manufacturing industry such as lean thinking have been rejected by the construction industry on the basis that construction is different. Howell (1999) in explaining the peculiarity of the construction industry from the manufacturing sector states that "manufacturers make parts that go into projects, but the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is fundamentally different from making tin cans". According to Koskela (1992), the construction industry as a result of its peculiarities is often seen in a class of its own, different from manufacturing. These peculiarities, Koskela (1992) further explains, are often presented as reasons - or excuses – for failure to implement such well-established and useful concepts as lean production from the manufacturing sector.

While difficult to interpret for construction, the lean thinking concept if adopted as a fundamental concept could be visualised through more accurate pre-planning, an increased use of standard components, prefabrication, modular systems and rigorous attention to resource procurement (Harris and McCaffer, 2001). Koskela (1992) also suggests actions like standardizing components, utilizing modularization and prefabrication as well as using enduring teams, as measures to reduce the uniqueness of construction and bring it closer to manufacturing. Warszawski (1990) has further indicated that industrialized building systems provide solutions to be considered in implementing lean thinking in construction and that construction companies had begun to offer concept buildings (office buildings, schools, day nurseries, etc.), which are pre-engineered solutions that can be adapted to different needs.

The concept of lean thinking in construction project delivery seeks to maximize value delivered to customers while minimizing waste. In its basic form, the practice of lean thinking is the systematic elimination of waste (i.e. overproduction, waiting, transportation, inventory, motion, over-processing, defective units) and the implementation of the concepts of continuous flow and customer pull (Kotelnikov, 2007).

2.8 The Material Composition of Interlocking Blocks

1. Laterite

Different kinds of materials are used for the design and construction of walls in buildings including sand, laterite, timber, glass, plastic etc. in Ghana. Laterite forms a greater percentage of the land surface or soil composition in the country and hence is more available and least expensive than any of the above-mentioned building materials. It is estimated that about seventy percent of the land surface of Ghana is covered by laterite. (Gidigasu; 2005).

Irrespective of this abundance of laterite soil confirms an earlier research by Andam (2004) that 90% of urban housing is built with sandcrete blocks derived mainly from sand and cement. Sand is also used for several other critical activities in the housing construction process including concreting, plastering of walls, laying of blocks in walls and floor screeding, activities which cannot be achieved without the use of sand.

Despite the widespread application of sand in the process of housing construction sandcrete block continues to be the most dominant material used as a building unit for the formation of walls in urban housing delivery in Ghana. The excessive use of sand in the construction industry has led to land degradation in the few areas where sand deposits occur, since identifiable deposits are usually completely exhausted before moving on to new locations. This usually leads to the creation of pools of stagnant water which as bleeding places for mosquitoes and other water-borne diseases. Sand resources in environment therefore face an imminent depletion as a result of over-exploitation in construction activities.

With regard to materials used in producing walling units for buildings, laterite may be more economical and accessible material in Ghana than any other material, yet it has not received the needed attention in the modern building industry. It has generically been applied as a material for hardcore filling for building foundations as well as base and sub base material for road construction due to its good natural cementitious properties which make it set quite naturally (Fales, 1991).

The use of laterite as a material for walling in the building industry has been limited to the production of landcrete blocks (laterite plus cement), adobe blocks, atakpami and wattle-and-danb (earth walls for laterite without cement) technologies, all for rural housing. Landcrete building block, although could be as suitable as sandcrete block if treated professionally, has been relegated to the background since people associate it with rural housing as a result of its reddish colouration which likens it to adobe blocks. Earth walls also exhibit low cohesion with sand-cement plaster, as the plaster usually peels-off from a wall produced from them over a long period as a result of the differential thermal properties of the rather soft material as against the hard sand-cement plaster (Gidigasu, 2005). These perceptions have rendered laterite an unattractive material for walling production.

However, due to its abundance, unique engineering properties and relative low cost compared to sand, the material has a potential of becoming a very significant input in affordable housing delivery for urban dwellers. This potential could be unravelled if further research is carried on it, especially by blending it with sand to produced a hybrid material for building block manufacture.

This prospect is affirmed by the good performance of interlocking blocks, a South-Africa technology that uses a mixture of laterite, marginal amount of sand and cement to produce building block units for affordable and durable housing for both rural and urban dwellers. The technology produces high-strength building block units of compressive strength in the order of 5 to $10N/mm^2$ using 5 to 10% cement content (Hydraform India, 2008) in contrast with the relatively low-compressive-strength sandcrete blocks of the order $0.3\text{-}1N/mm^2$ normally applied in the building industry of Ghana (Andam, 2004). Gidigasu (2005) has also indicated that depending on the plasticity of lateritic soil, an amount of sand stabilization could be done to improve the grading of the soil to achieve high strength blocks with a minimum amount of binder content when producing landcrete blocks for low-cost housing.

The difficulty of transporting sand over long distances for building purposes, the excessive exploitation and depletion of sand deposits in Ghana as well as the exorbitant cost of sandcrete blocks as a result of the relative high cost of sand indicate that lateritic materials should be employed in the building industry to produce affordable and sustainable construction in Ghana.

2. Cement

As a stabilising material cement is well researched, well understood and its properties clearly defined. Portland cement is readily available in most Urban areas, and usually available in semi –urban areas, it is one of the major components for any building construction. Earlier studies have shown that cement is a suitable stabiliser for use with soil in the production of Cement Stabilized Soil Block (CSSB). Cement is mainly composed of Lime (CaO) and Silica (SiO2) which react with each other and the other components in the mix when water is added. This reaction forms combinations of Tri-calcium silicate and Di-calcium silicate referred to as C3S and C2S in the cement literature. The chemical reaction eventually generates a matrix of interlocking crystals that cover any inert filler ie (aggregates) and provide a high compressive strength and stability. The basic mechanism is friction of point contacts between the particles taking place at a microscopic level. The duration time for this reaction to take place is not precisely defined. There is however the definition of the 'critical time'' after which further working of the mix causes breaking of the crystals that have formed but before the total matrix has gained strength.

3. Water

Water must be clean and should not contain any harmful quantities of acid, alkalis, salts, sugar or any other organic or chemical material. Any organic material in water will prevent the cement from setting .Chemicals and impurities could also affect the strength of the end product. Portable water is normally satisfactory.

2.8.1 Material Usage

The description of "lean", according to Kotelnikov (2007), as doing more with fewer inventories, less space, less money and so on, makes the quantity of material usage in the wall construction process important in observing the principles of lean thinking. Apart from the base mortar that is required to link the first course to the floor, no mortar is required for the subsequent courses of the interlocking walling system. The absence of mortar jointing in the interlocking block walling process leads to a significant reduction in the quantity of mortar used compared to the case of the sandcrete block.

The insignificant role of mortar in the interlocking block walling process implies that materials like aggregate and cement are not required in the wall construction process. This ensures that inventory and space associated with the wall construction process are reduced to a significant level. There is also some amount of cost savings arising from the reduced use of materials like cement and aggregate as well as less space required for inventory.

2.9 Challenges with the use of interlocking blocks

- Soil or sand composition may vary considerably even if dug from a single pit.
- Inadequate mixing can produce a highly uneven distribution of cement.
- Mixing too much of a batch of stabilized material at one time can reduce strength due to premature cement hydration.
- Incorrect moisture content at the time of moulding adversely affects the efficiency of compaction.
- Variations in the volume of mix placed in the mould for compaction affects the final density of the block and can seriously damage the machine.
- Inappropriate curing will allow the block, in particular the block surface, to lose the water required for full hydration of the cement, causing low strength blocks with poor surface durability.

2.10 Features of Interlocking Blocks

Interlocking blocks have some basic features and they are as follows:

1. Aesthetics

No doubt, interlocking blocks when used in building are very aesthetically sound and very pleasing to the sight. In most cases there is no need for plastering. They are extremely beautiful if well arranged, it also gives some predetermined shapes and patterns after installation. The Interlocking blocks could also be given different pigmentation to show various glowing colours.

2. Social and Political

Because of the dry stacking nature of the construction, the demand for skilled labour is reduced providing job opportunities to wider range of people in the community particular in the developing countries where specialized skill is scarce.

3. Fire and water resistance

When interlocking block is used for building, it gives a significant level of fire resistance and water resistance. When interlocking polish is applied on the surface blocks, it tends to seal all the pores on the surface which resist the penetration of water in order to destroy the interlocking blocks.

4. Availability

To the layman, laterite means earth or any type of soil but in the sense of it, the analogy demonstrates the ready availability and abundance of laterite. It is found almost everywhere in the Northern part of Ghana, but more commonly found in the savannah, where there is very little amount of rainfall throughout the year. The type available down south is darker than that of the savannah but also very good in building construction. Even much more laterite can be fully exploited for use in building by the south western dwellers of Ghana when it comes to its use in building construction.

5. Cost

Since the raw materials for interlocking are very much readily available in our immediate environment, it is very cheap and requires little skill in manufacture. Where the same size of interlocking blocks and sandcrete blocks are compared, it was discovered from the immediate market survey, that the sandcrete blocks cost more and need to be plastered while interlocking blocks may be left unplastered to showcase the different aesthetic colours.

2.11 Comparisons with Sandcrete Blocks.

Interlocking blocks are different from conventional bricks since they do not require mortar to be laid. The blocks are just laid dry and locked into place. As a result of this characteristic, the process of building walls is faster and requires less skilled labour. Laying the first course in the mortar bed requires that care is taken to ensure that blocks are perfectly horizontal and in a straight line or at right angle corners. Once the base is properly laid, the blocks are stacked dry with the help of a wooden rubber hammer to knock the blocks gently in place (Nasly and Yasin, 2009).

The interlocking block masonry is one building system which almost fulfils all such requirements of sustainability masonry as use of locally available resources (materials and labour), cost-effectiveness, eco-friendly, easy to adopt, faster to build and energy efficient. Interlocking dry stacked interlocking block system enables aesthetic affordable buildings as well as speedy construction of high quality walls in stretcher bond (Bansal, 2010). The interlocking stabilised soil block technology is affordable, environmentally sound, user friendly, versatile in use among others (UN-HABITAT, 2009).

Almost any type of building can be constructed with interlocking blocks. The main design constraints according to Nasly and Yassin (2009) are however that the plan should be rectangular and all wall dimensions and openings must be multiples of the width of the block used. All other principles of design and construction such as dimensioning of foundations, protection against rain and ground moisture, ceiling and roof construction and the like, are the same as for other standard building types.

The concept of inter locking blocks is based on the following principles:

i. The blocks are shaped with protruding parts which fit exactly into recess parts in the blocks placed above such that they are automatically aligned horizontally and vertically (Figures 2.3 and 2.4). This makes brick laying possible without specialised skills.

ii. Since blocks can be laid dry, no mortar is required and considerable amount of cement is saved.

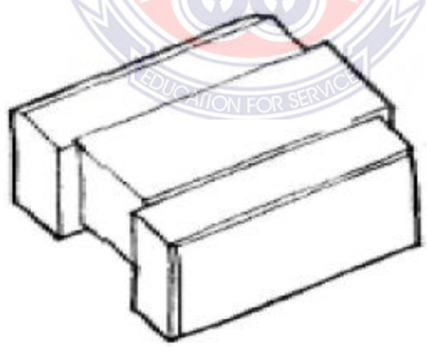


Figure 2.3: Interlocking Block (Bansal, 2010)

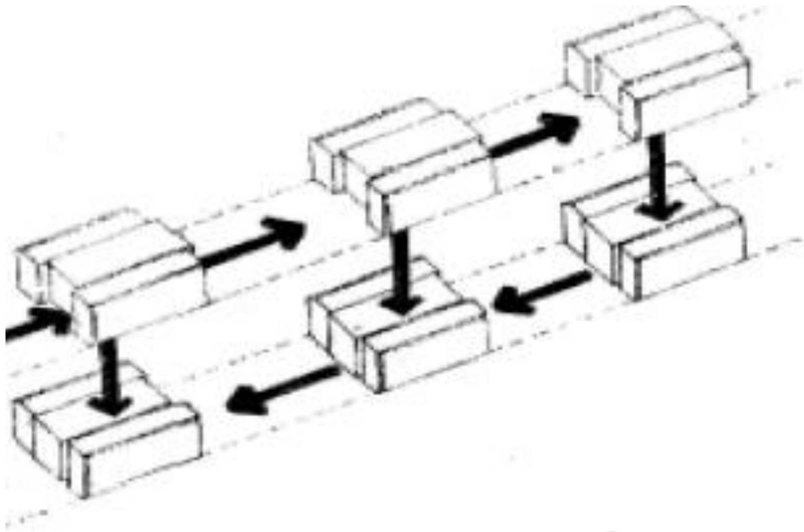


Figure 2.4: Placing of Interlocking Block (Bansal, 2010)

2.12 Wall Construction Process

One of the key concerns of lean thinking is the minimisation of process waste. The core concept behind lean production, according to Caldeira (1999), is to create a flow among value adding work steps while eliminating non-value adding steps. The study revealed that the use of the sandcrete block, which currently dominates walling materials (especially in urban housing) in Ghana, is associated with a number of non-value adding steps compared to the interlocking blocks. The interlocking block walling system is therefore a positive attempt towards a lean process due to the fact that a number of non-value adding steps, like vertical mortar jointing and dressing, are eliminated.

Various forms of waste, manifesting as unnecessary processing, overproduction, waiting, unnecessary movement, inventories and so on, result from the use of the traditional sandcrete block. The use of dry bonding for the interlocking block work leads to a minimisation of these forms of waste. Movement of people and materials related to mortar jointing is, for instance, largely reduced. The use of the interlocking system also minimises unnecessary processing and over production as forms of waste since mortar jointing is eliminated especially after the first course. There is also a reduction in waiting and enhancement of continuous workflow arising from the fact that steps like spreading of mortar, levelling, vertical jointing and dressing of joints are virtually absent in the interlocking walling system. Inventories in the form of materials like sand, cement and water to produce mortar for jointing in the case of the sandcrete block are eliminated in the use of the interlocking block.

The elimination of the various non-value adding steps in the traditional sandcrete wall construction process and the consequent reduction in the various forms of waste, through the use of the interlocking block, has the benefit of cutting down material and labour requirements with an attendant reduction in construction cost. Another impact of the elimination of the non-value steps in the wall construction process is that it ensures fast cycle times thus increasing speed of construction. In line with the description of "lean manufacturing" by Kotelnikov (2007) as a shorthand to commitment to eliminating waste, simplifying procedures and speeding up production, the interlocking block could be seen as a worthy tool towards making wall construction process lean.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The research involved a comparative study of the processes involved in constructing walls using the sandcrete blocks and those involved in using the interlocking dry wall system (interlocking blocks). A critical observation of the various steps involved in using the sandcrete blocks and the interlocking blocks in wall construction was made. This made it possible to make a comparison of the non-value adding steps associated with sandcrete block wall construction to those associated with interlocking block wall construction. The speed of construction, thermal ability, compressive strength and the cost of the walls were also observed and compared.

3.2 Population and Sampling

Kankam and Weiler (2010) state that population refers to all the people the researcher will focus on in the study. Agyedu et al. (2011) also explain population as the complete set of individuals (subjects), objects or events having common observable characteristics in which the researcher is interested in studying. The researcher's population will be finite since the elements can presumably be counted and a finite number obtained. The target population for this study was all workers of P-capital Estate (31 workers), all consultancy firms (10 firms) and private individuals in Sunyani Municipality.

According to Agyedu et al. (2011: 95), a sample is a subset of the population and consists of individuals, objects or events that form part of the population. A sample size of 20 workers of P-Capital Estate housing, 5 personnel from consultancy firms and 20 private individuals were selected for the study with the use of convenience and purposive sampling technique as an approach to sampling. With this sampling technique, the researcher selected the easily accessible population members from whom to obtain information.

3.3 Data Collection Methods

For the purpose of getting valid, reliable, adequate and current information the researcher resorted to the use of primary research. These instruments were used because of the percentage of illiterate and literates within the Sunyani Municipality.

3.4 The Primary Research Methods

The instruments used for collecting the primary data are as follows

- Questionnaires
- Personal interview
- Experiment and observation

A.Questionaires

Three different sets of questionnaire were prepared, each for personnel of consultancy firms, staff of P- A capital estate housing and private individuals (see Appendix III). The researcher administered the questionnaire to the respondents as a tool to collaborate or otherwise of the information gathered through the interview process. The distribution of the questionnaire was done through personal visit to the destination because mailing services was not reliable. Again, it afforded the researcher an opportunity to establish strong rapport with the respondents. The questionnaire items were designed with both close ended questions where the respondent will be required to choose from a list of options or answers provided to respond to a question and open ended items in which the respondent will provided their own response to a question.

B.Personal Interview

The researcher interviewed the respondents namely: 5 personnel's of consultancy firms, 10 staff of P-A capital estate housing and 10 private individuals to compliment that of the questionnaire. The interview process was face-to-face and the researcher allowed the respondents to do most of the talking as this afforded him a unique opportunity to get more information from the primary source. The researcher has to use the interview to ensure that respondents really understood the questions they answered, because of different level of education.

C. Experimental and Observation Procedures

Work study methods were used to provide a ground for comparison between the sandcrete block and the interlocking block dimensions under study to make a case of cost effectiveness, economy and functionality. This method was employed to obtain first hand information on both practices under investigation.

The process involved the manufacturing of solid sandcrete blocks of dimensions 450mm x 100mm x 225mm and 240mm x 230mm x 115mm. Sand was used with Ordinary Portland cement (OPC) with clean, potable water to mix the sandcrete ingredients of ratio of 1 part cement to 9 parts of sand (1:9 cement-sand ratio) and laterite and sand was used with Ordinary Portland cement (OPC) with clean, potable water (water-cement ratio was 0.6) to mix the interlocking ingredients of ratio of 1 head-pan of cement, 2 head-pans of sand and 7 head-pans of laterite (1:2:7 cement- sand and laterite ratio). Sand is added to the cement and the laterite to increase the strength of the interlocking blocks because of its fine particles. Laterite contains rough particles, therefore the sand comes in so that the pores can be filled well for easy compaction to give maximum strength. But cement – sand mix has lower strength than cement-sand-laterite mix because there is no rough particles in it like gravels in the laterite.

The batching was done by volume (of standard head pan of $0.015m^3$). Mixing was done by hand, using shovel, before moulding using hand operated block moulding machine and interlocking block moulding machine. The units were moist cured by wetting after the initial setting until sufficient strength is gained and their compressive strengths determined over a 28 days period. 50 of each set of blocks were weighed and an average of their masses found.

The data for the research was obtained by observing the construction of two sets of walls using sandcrete blocks and interlocking blocks. Each set had two walls joined at 90^o to each other and measuring 3200mm x 1600mm each, as shown in Figures 3.2 and 3.3 below. Two masons (**X** and **Y**, both skilled in sandcrete block wall construction and interlocking block wall construction) were engaged in the process.

The first part involved a simultaneous process whereby mason **X** constructed one set of walls from the sandcrete blocks, while mason **Y** constructed the other set of walls from interlocking blocks. The second part of the experiment was a reverse of the second in which case mason **X** rather constructed the walls with interlocking blocks while mason **Y** constructed the walls with sandcrete blocks.

During each part of the experiment observations were made of the comparative speed of construction between the use of interlocking blocks and sandcrete blocks. Various forms and sources of waste arising from the use of the sandcrete blocks were also observed and compared to those arising from the use of the interlocking blocks.

Individual compressive strength was determined by using a compressive testing machine as shown in figure 3.1. The compression test was done in three (3) batches to determine the compressive strength of both the interlocking blocks and the sandcrete blocks. In the first batch, ten (10) units were also taken from each of the blocks for testing at seven days. In the second batch, another ten (10) samples were taken from each of the blocks for testing at fourteen (14) days. In the last batch, ten (10) units were also taken from each of the blocks for testing at twenty-eight (28) days to determine the compressive strength. The details of test result can be found in Appendix I

One of the key limitations in the data collection procedure was the fact that unlike the interlocking block system, it was not possible to build a continuous height of wall above 1400mm with the sandcrete block without allowing the wall to dry and harden to prevent a collapse. This situation limited the study to a wall height of 1400mm.

Fig 3.1: ***Determination of compressive strength***

Fig 3.2: Sandcrete block wall

Fig 3.3: Interlocking block wall

3.5 Data Analysis

All the 45 respondents completed the questionnaires. The results obtained were analyzed and presented in table form. The percentage scores were calculated for each main item using statistical table and graphs. These were discussed in line with findings of previous researchers. Also, conclusions drawn from these findings and responses to the questionnaires administered could be discussed.

In proving or disproving the hypotheses, the data were analyzed using paired-sample T-test to determine the significance between the interlocking blocks and conventional sandcrete blocks parameters with help of SPSS version 19. The analysis considered a significance level of 0.05.

3.6 Problems Encounted

The problem of not meeting the population concerned in their various homes and offices was encountered as collection of questionnaires was done in person. Some of the workers were always found to be tired even when you met them in their offices. They explain that, they do a lot of work on site, hence their inability to complete questionnaires on time.

CHAPTER FOUR

RESULTS/FINDINGS

The purpose of this chapter is to present and analyse the data obtained using descriptive and inferential statistical analysis. Results are presented graphically and using tables to show and compare the variables.

PART I – EXPERIMENTAL RESULTS

4.1 Speed of Construction Between Interlocking and Sandcrete Block Walls

4.1.1 Steps Involved in Wall Construction

The standard stages and associated activities (steps) involved in the wall construction process in the use of the sandcrete block and those involved in the use of the interlocking block were observed and recorded as shown in Table 1 below. The associated steps were classified as applicable or eliminated/non-value adding steps.

Table 4.1. Steps involved in wall construction

Stage	Description	Activities (Steps)	Sandcrete Block Walling	Interlocking Block Walling
A	General (Preliminary) Preparation	A1. Setting out	●	●
		A2. Preparation of mortar	●	●
B	Laying First Course	B1. Transporting mortar	●	●
		B2. Spreading base mortar	●	●
		B3. Transporting block units	●	●
		B4. Placing block units in first course	●	●
		B5. Plumbing	●	●
		B6. Levelling	●	●
		B7. Filling and dressing vertical mortar joints	●	○
C	Laying Subsequent Courses	C1. Transporting mortar	●	○
		C2. Spreading mortar for the course	●	○
		C3. Transporting block units	●	●
		C4. Placing block units in the course	●	●
		C5. Plumbing	●	●
		C6. Levelling	●	○
		C7. Filling and dressing vertical mortar joint	●	○

Legend

● Applicable step

○ Eliminated / non-value adding step

4.1.2 Speed of Wall Construction

The time that was spent to undertake various activities in the construction of the two walling systems are as follows.

4.1.2.1 Completion of first course

The time that was spent by mason X and mason Y in the construction of the first course of the two walling systems is a shown in Figure 4.1 below.

Figure 4.1 : Time spent to complete first course

During the construction of the first course of the two walling systems it was observed that it took Mason X 21 minutes and 27 minutes respectively to complete the sandcrete block wall and interlocking block wall, while Mason Y used 20 minutes to complete the sandcrete block wall and 28 minutes to complete the interlocking block wall.

4.1.2.2 Completion of second course

Figure 4.2 below contains time spent to complete the second course.

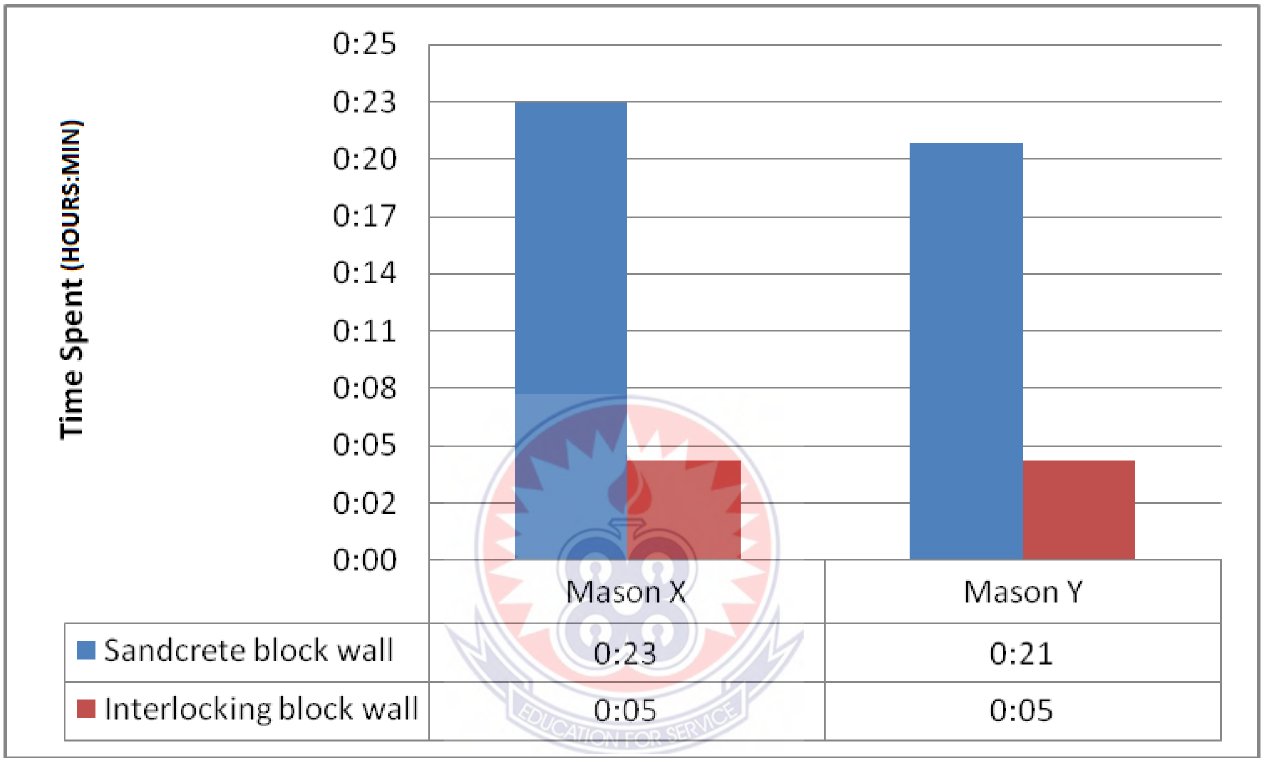


Figure 4.2: Time spent to complete second course

In the construction of the second course it took Mason X 23 minutes and Mason Y 5 minutes to complete the sandcrete block wall and the interlocking block wall respectively, and also Mason Y and Mason X took 21 minutes and 5 minutes respectively to complete the sandcrete block wall and the interlocking block wall.

4.1.2.3 Completion of subsequent courses after first course

The total time spent to complete the rest of the courses of the walls after the first course has been laid is shown in Figure 10. The following completion times were observed. Mason X used a total of 2 hours 38 minutes and 55 minutes for sandcrete block wall and interlocking block wall respectively. Mason Y used a total of 2 hours 40 minutes and 1 hour 2 minutes for sandcrete block wall and interlocking block wall respectively.

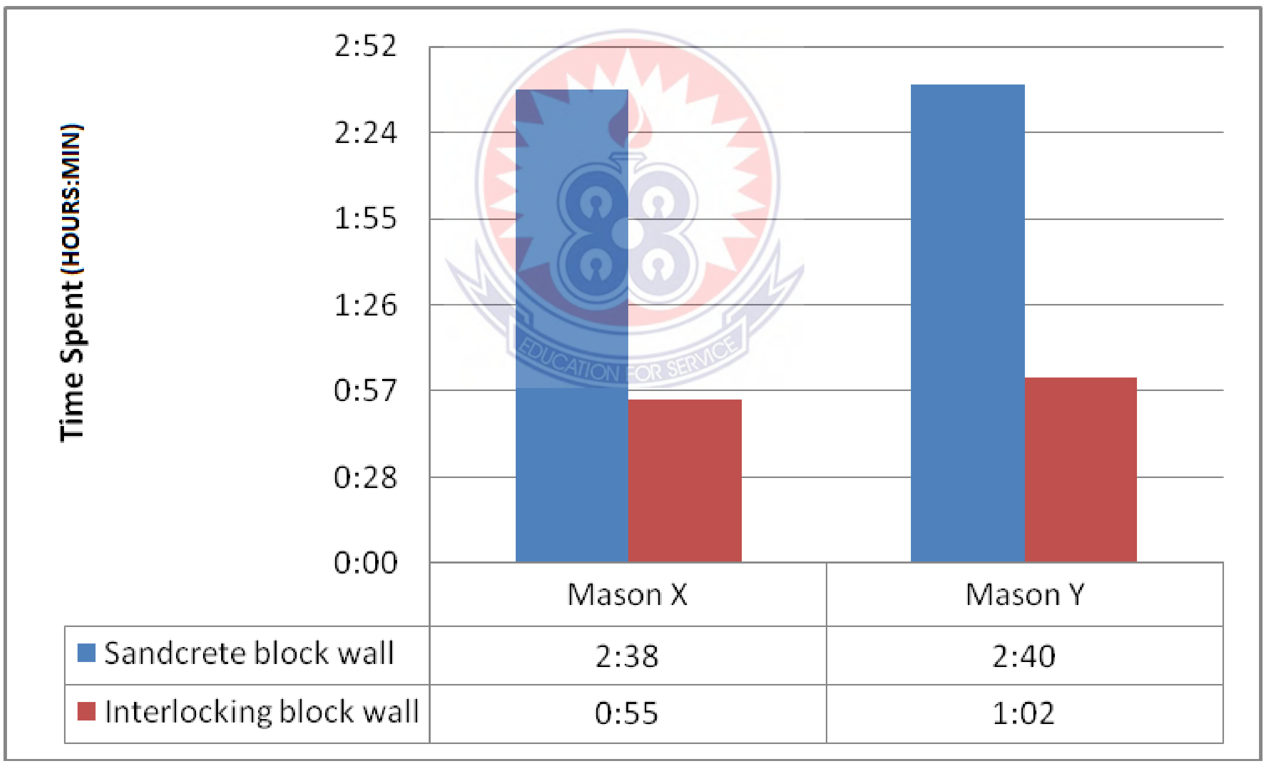


Figure 4.3: Time spent to complete subsequent courses after first course

4.1.3 Completion of the Entire Wall

The duration for the completion of the entire wall using the conventional sandcrete block and the interlocking block is illustrated in Figure 11.

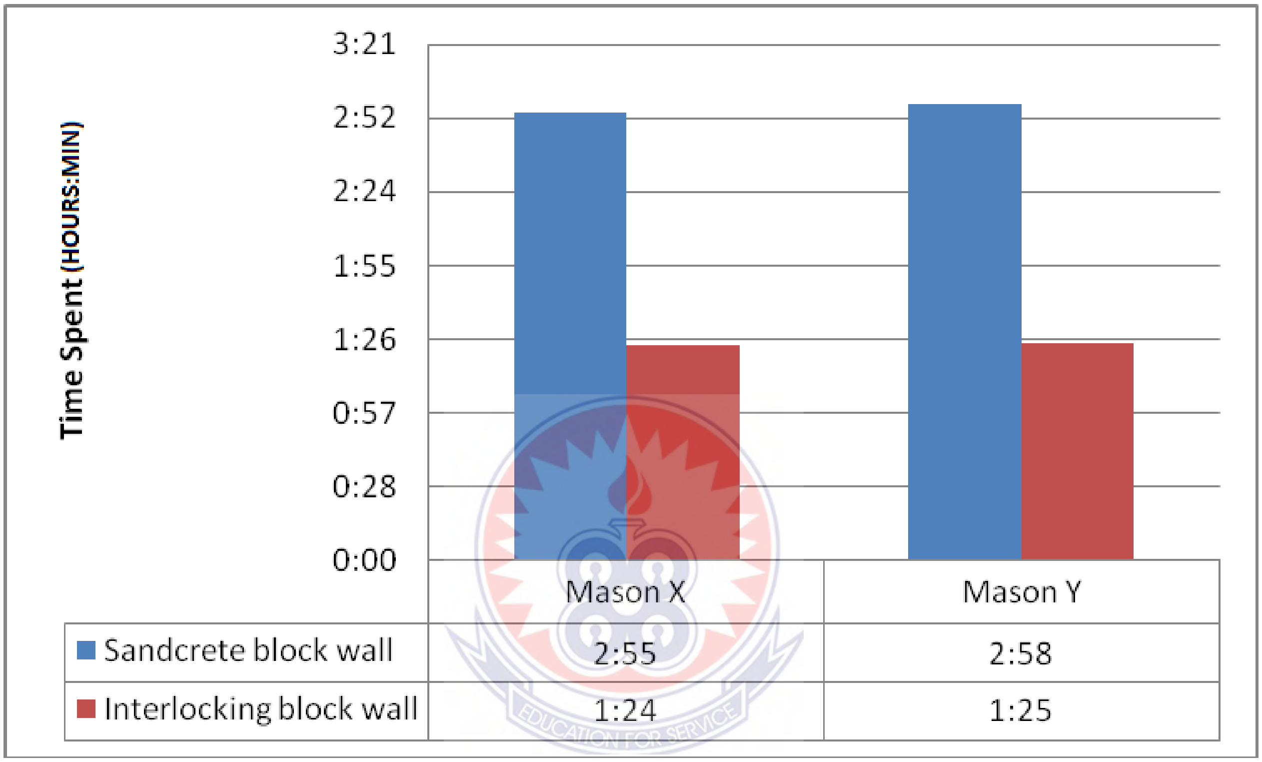


Figure 4.4: Time spent to complete entire wall

In constructing the entire wall, the following completion times were observed respectively for sandcrete block wall and interlocking block wall. Mason X used a total of 2 hours 55 minutes and 1 hour 24 minutes, Mason Y used a total of 2 hours 58 minutes and 1 hour 25 minutes.

Table 4.2: Summary of speed of wall construction results

Technique	Mason	1st Course (min)	2nd Course (min)	Subsequent Courses (min)	Total (min) Individual	Total (min) Average
Sandcrete block	X	21	23	158	202	202
	Y	20	21	160	201	
Interlocking block	X	27	5	55	87	91
	Y	28	5	62	95	

4.2 Labour and Material Cost

The cost of the masons and materials in constructing the walls using the conventional sandcrete block and the interlocking block is shown in Table 4.3.

Table 4.3 below contains the cost associated with the process of constructing a wall with the interlocking block and the conventional sandcrete block. Labour cost was calculated at a rate of Gh¢0.95/hour and material cost at a rate of Gh¢223/m^3 of mortar.

Table 4.3: Cost of Wall Construction

a. Labour Cost

Item	Description	Conventional block		Interlocking block	
		Average Time per mason (hr)	Approximate labour cost @ Gh¢0.95/hr	Average Time per mason (hr)	Approximate labour cost @ Gh¢0.95/hr
1.	Building first course	0.35	0.34	0.49	0.47
2.	Spreading mortar for subsequent courses	0.54	0.52	0.00	0.00
3.	Placing blocks, levelling and plumbing	1.50	1.43	0.95	0.91
4.	Filling and dressing vertical mortar joints	1.16	1.11	0.00	0.00
5.	**Total labour cost**	3.55	**3.40**	1.44	**1.38**

b. Material Cost

Item	Description	Conventional block		Interlocking block	
		Quantity (m^3)	Approximate mortar cost @ Gh¢223/m^3	Quantity (m^3)	Approximate mortar cost @ Gh¢223/m^3
1.	Mortar	0.62	138.26	0.05	11.15
2.	**Total material cost**	0.62	**138.26**	0.05	**11.15**
c.	**Total Cost of Wall Construction**		**141.66**		**12.53**

Table 4.3 indicates that the average time spent per mason for building the first course of sandcrete block wall was 0.35 hour at a cost of Gh¢0.34 and that of the interlocking block wall was 0.49 hour at a cost of Gh¢0.47. The average time spent per mason for spreading mortar of the subsequent courses for sandcrete block wall was 0.54 hour at a cost of Gh¢0.52 and that of the interlocking block wall was 0.00 hour at a cost of Gh¢0.00. The average time spent per mason for placing blocks, levelling and plumbing for sandcrete block wall was 1.50 hours at a cost of Gh¢1.43 and that of the interlocking block wall was 0.95 hour at a cost of Gh¢0.91. The average time spent per mason for filling and dressing the vertical joints for sandcrete block wall was 1.16 hour at a cost of Gh¢1.11 and the interlocking block wall was 0.00 hour at a cost of Gh¢0.00. The total labour cost for the entire sandcrete block wall was GH¢3.40 for a total time of 3.55 hours and that of the interlocking block wall was GH¢1.38 for a total time of 1.44 hours. The total cost of materials for the entire sandcrete block wall was GH¢138.26 for 0.62m^3 mortar and that of the interlocking block wall was GH¢11.15 for 0.05m^3. The overall cost of the wall construction for sandcrete block wall was GH¢141.66 and that of the interlocking block wall was GH¢12.53.

4. 3: Compressive Strength Test Results

Summary statistics of the compressive strengths of the two blocks over a number of days are presented in Table 4.4. Detailed compressive strength test result could be found in Appendix I.

Table 4.4: Compressive strength for sandcrete block and interlocking blocks

Age	100mm Thick Sandcrete Block		115mm Thick Interlocking Block	
	Mean	Standard Deviation	Mean	Standard Deviation
	N/mm^2	N/mm^2	N/mm^2	N/mm^2
7	1.26	0.081	1.30	0.128
14	1.98	0.203	2.02	0.116
28	3.52	0.096	3.56	0.050

For seven days the average strength of 100mm thick sandcrete block was 1.26 N/mm^2 with the standard deviation of 0.081 N/mm^2 and the average strength of 115mm thick interlocking block was 1.30 N/mm^2 with a standard deviation of 0.128N/mm^2. For fourteen days the average strength of 100mm thick sandcrete block was 1.98 N/mm^2 with a standard deviation of 0.203 N/mm^2 and the average strength of 115mm thick interlocking block was 2.02 N/mm^2 with a standard deviation of 0.116 N/mm^2. For twenty-eight days the average strength of 100mm thick sandcrete block was 3.52 N/mm^2 with a standard deviation of 0.096 N/mm^2 and the average strength of 115mm thick interlocking block was 3.56 N/mm^2 with a standard deviation of 0.050 N/mm^2.

4.4 Test of Hypothesis

The study began with a clear hypothesis to be tested:

Hypothesis 1

H0: There is no significant difference between the speed of interlocking block construction technique and conventional sandcrete block construction**.**

H1: There is a significant difference between the speed of interlocking block construction technique and conventional sandcrete block construction**.**

Hypothesis 2

H0: There is no significant difference between the labour cost of constructing interlocking block construction technique and conventional sandcrete block construction**.**

H1: There is a significant difference between the labour cost of constructing interlocking block construction technique and conventional sandcrete block construction**.**

Hypothesis 3

H0: There is no significant difference between the cost of interlocking blocks and conventional sandcrete blocks**.**

H1: There is significant difference between the cost of interlocking blocks and conventional sandcrete blocks**.**

Hypothesis 4

H0: There is no significant difference between the compressive strength of interlocking blocks and conventional sandcrete blocks**.**

H1: There is significant difference between the compressive strength of interlocking blocks and conventional sandcrete blocks**.**

The summary of the results obtained from using paired-sample T-test to determine the significance between the interlocking blocks and conventional sandcrete blocks parameters with help of SPSS version 19 at significance level of 0.05 are presented in Table 4.5. The details of test result can be found in Appendix IV

Table 4.5: Test of significant differences

Test Areas	Sandcrete Block	Interlocking Block	Difference	t-value	T-test for sig. for the differences
Construction Speed					
1 Mason X	202	87	0.14		
2 Mason Y	201	95	0.54		
Total	403	173	1.99	24.6	0.026*
Labour Cost					
1 1st course	0.34	0.47	0.13		
2 spreading mortar	0.52	0.00	0.52		
3 Placing blocks	1.43	0.91	0.11		
4	1.11	0.00	1.11		
Total	3.40	1.76	1.87	1.483	0.235
Material Cost					
Mortar	138.26	11.15	127.11		
Total material	141.66	12.53	129.13		
Total	279.92	23.68	256.24	1.268	0.005*
Compressive Strength Test					
7 days	1.26	1.30	0.04		
14 days	1.98	2.02	0.04		
28 days	3.52	3.56	0.04		
Total	6.76	6.88	0.12	0.380	0.740

*Significant at 0.05 level

PART II - SURVEY

4.5: Gender Category in the Municipality

The Table 5 below contains the gender distribution of employees.

Table 4.6: Gender distribution of employees

Sex	Respondents	Percentages
Males	27	60
Females	18	40
Total	45	100

From Table 4.6, it can be deduced that the sex distribution shows that majority of respondents were males. They constituted (60%) whereas (40%) were females. The difference in the number of respondents for males and females selected at random was as a result of males willing to answer questions put to them but the females were a bit reluctant.

From the statistical board males are more than the females, hence contributing to the fact that more males answered the questionnaires as compared to the females.

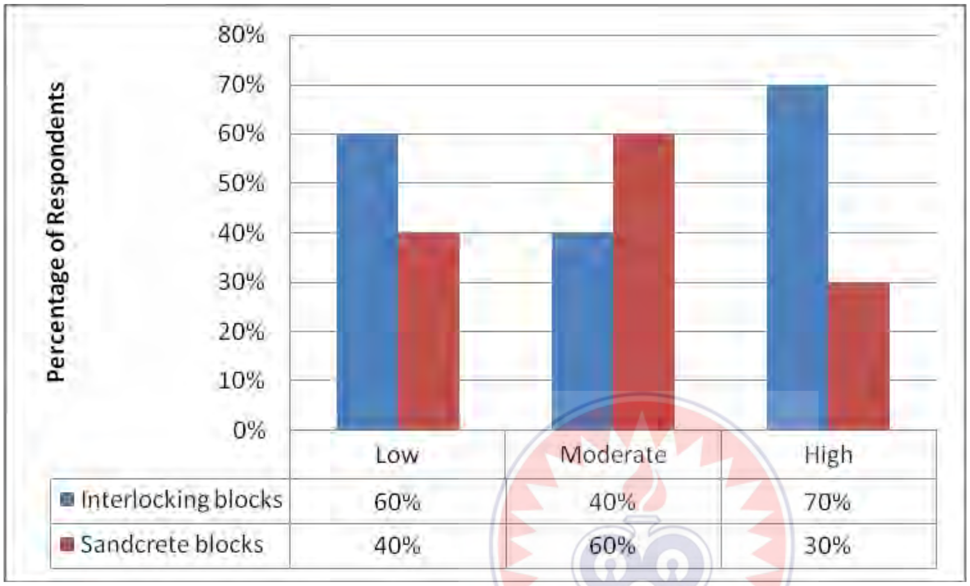
4.6: Rate of Affordability of Blocks

Table 4.7: Rate of Affordability of blocks

BLOCKS	MODERATE (%)	LOW (%)	HIGH (%)
Sandcrate blocks	40	70	30
Interlocking blocks	60	30	70

The Table 4.7 explains the rate of affordability of the blocks. It can be clearly seen that in terms of high rate of affordability, interlocking blocks scored 70% while sandcrete blocks scored 30%. In terms of low rate of affordability, interlocking blocks scored 30% being the lowest scored and 70% for sandcrate blocks. In terms of moderation in rate of affordability, interlocking blocks account for 60% while sandcrete blocks account for 40% respectively. In conclusion, interlocking block is highly affordable and that might account for the high rate of patronage.

4.7: Rate of coolness of blocks



	Low	Moderate	High
Interlocking blocks	60%	40%	70%
Sandcrete blocks	40%	60%	30%

Figure 4.5: Rate of coolness of blocks

Figure 4.5 below contains the Rate of coolness of various kinds of blocks

The chart depicts the rate of respondents of the various blocks according to their ability to make the interior part of the building (room) cool. It can be deduced from the graph that interlocking blocks have high rate of coolness accounting for 70% of the respondent rate while that of sandcrete blocks account for 30% respectively. In terms of low rate of coolness, interlocking blocks scored 60% being the lowest scored and 40% for sandcrate blocks. In terms of moderation in rate of coolness, interlocking blocks account for 40% while sandcrete blocks accounts for 60%. In conclusion, interlocking blocks make the interior part of the building (room) cooler than sandcrete blocks and that might account for the high rate of patronage.

4.8: Speed of construction of blocks

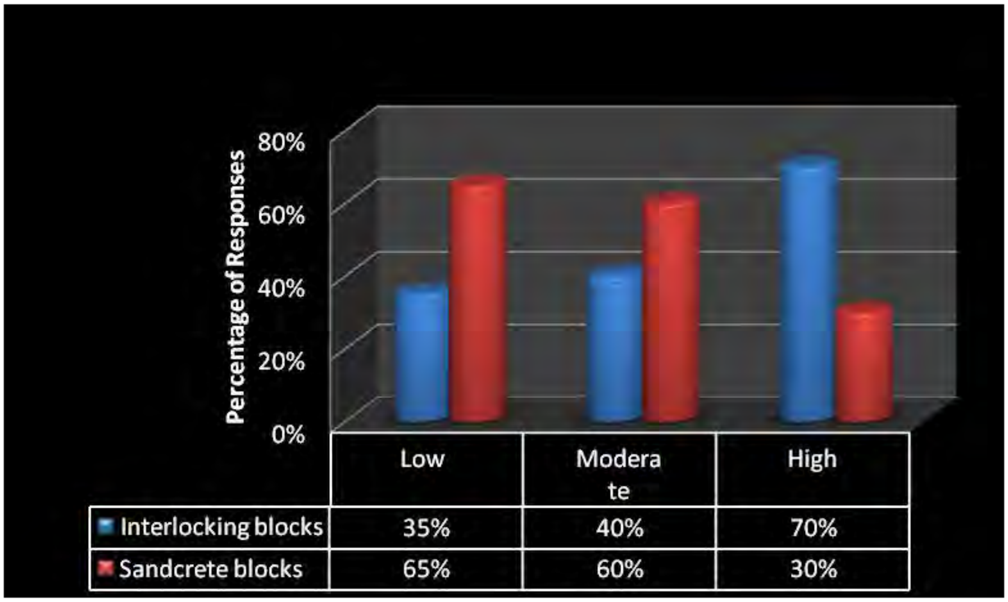


Figure 4.6: Speed of construction of blocks

The Figure 4.6 contains the Speed of construction of blocks.

The chart explains the speed of construction of the various blocks. It can be concluded from the above charts generally explains that interlocking has a high speed of construction which may be due to its interlocking ability which account for 70% of the responding rate, and sandcrete accounting for 30% respectively. In terms of low in rate of speed of construction, interlocking blocks scored 35% responding rate being the lowest scored and 65% for sandcrate blocks. In terms of moderation in rate of speed of construction, interlocking blocks account for 40% responding rate while sandcrete blocks accounts for 60% respectively. In conclusion, interlocking blocks is faster than sandcrete blocks and that might account for the high rate of patronage.

4.9: Comparison of cost difference between two blocks

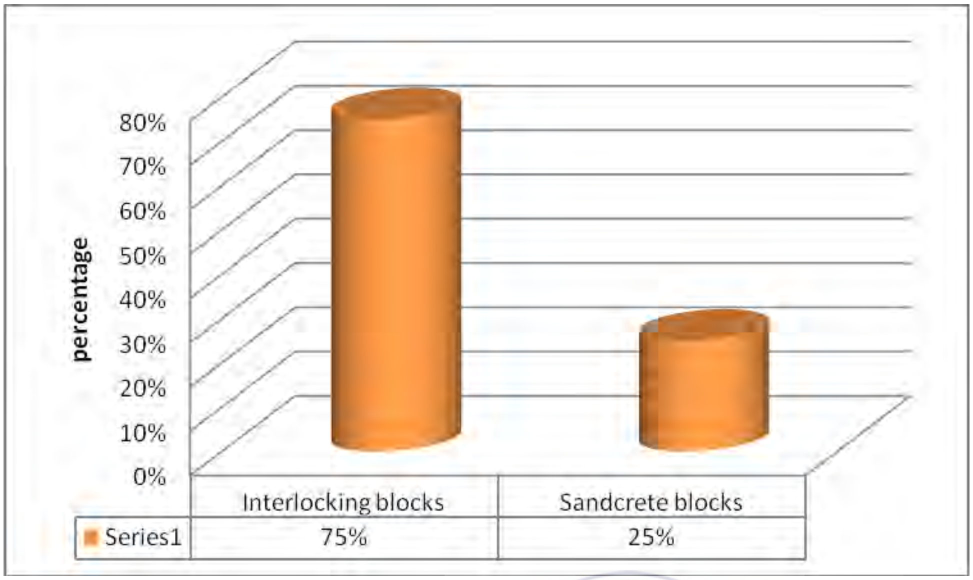


Figure 4.7: Comparison of cost difference between two blocks

Source: Field Survey August, 2012

The Figure 4.7 contains the comparison of cost difference between two blocks.

This chart illustrates how cheaper interlocking block is relatively. From the graph, interlocking block accounts for 75% of the respondents' rate whiles that of sandcrete block accounts for 25%. This shows that interlocking block is cheaper.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter presents the discussions of results and the analysis of the findings.

5.2 Speed of Wall Construction

Speedy delivery is very important to meet the duration of every construction. “Lean” is doing more with less: less time among others (Kotelnikov, 2007). The delivery of construction products on time, apart from contributing to a reduction in cost of construction, also enhances value to clients.

Table 5.1: Time spent in the wall construction process

	Average completion time (minutes)	
Construction Process	Sandcrete block wall	Interlocking block wall
First course	20.5	27.5
Second course	22	5
Subsequent courses from the first	159	58.5
Entire wall	176.5	84.5

The following were noted from the results obtained as presented in subsection 4.1.2 and section 4.9. From the experimental results in subsection 4.1.2, Table 5.1 shows the average time (in minutes) used in the construction process for both masons X and Y. With little computations it can be deduced that for the first course, the sandcrete block wall was constructed at an average speed of 1.34 times faster than the interlocking. For the other courses, interlocking block wall was constructed at an average speed of 4.4 times faster than the sandcrete for the second course, 2.72 faster for the subsequent courses after the first, and 2.09 faster for the completion of the entire wall. The results of both masons show that for the first course sandcrete block wall was construction at a speed of 1.27 times faster than the interlocking block wall. For the other processes, interlocking block wall was constructed at a speed of 4 faster than the sandcrete for the second course, 5.85 faster for the subsequent courses after the first, and 2.24 faster for the completion of the entire wall.

The results of the study indicate that the pace of wall construction using the interlocking blocks is far faster than using the sandcrete block. The elimination of non-value steps like spreading mortar, levelling, and vertical mortar jointing and dressing of joints significantly reduces the cycle time of bonding blocks thus increasing the speed of the wall construction.

5.3 Labour Output / Productivity

According to Womack et al. (1991), "lean production" is "lean" because it uses less of everything including labour. The study showed that greater output of masons was achieved in the use of the interlocking block system compared to the sandcrete block system. The output of masons increased by more than 50% when they used the interlocking blocks than sandcrete blocks. The higher output of the masons resulted from the fact that some steps were eliminated in using the interlocking blocks compared to when laying with the traditional sandcrete blocks. The incidence of "waiting", resulting from the disjointed stop-and-go production processes associated with the sandcrete blocks, was also largely reduced in the case of the interlocking blocks therefore enhancing output.

The idle time of labour in the use of the interlocking block compared to the sandcrete block was also drastically reduced. Unlike the sandcrete block walling system, the continuous workflow nature of the interlocking block walling system took away the intermittent idle times particularly associated with labourers who were engaged to carry blocks and mortar for jointing. The wall construction steps of spreading mortar, vertical jointing, mortar joint dressing and levelling led to the idle time in the use of the sandcrete blocks.

5.4 Material Usage

According to Kotelnikov (2007), as doing more with fewer inventories, less space, less money and so on, makes the quantity of material usage in the wall construction process important in observing the principles of lean thinking. Apart from the base mortar that is required to link the first course to the floor, no mortar is required for the subsequent courses of the interlocking walling system. The absence of mortar jointing in the interlocking block walling process leads to a significant reduction in the quantity of mortar used compared to the case of the sandcrete block. This assertion is confirmed by our results. The results revealed that the average material (mortar) usage per mason and also the mortar usage by both masons were far less for the interlocking block wall than the sandcrete block wall.

The insignificant role of mortar in the interlocking block walling process implies that materials like fine aggregate and cement are not required in the wall construction process. This ensures that inventory and space associated with the wall construction process are reduced to a significant level.

5.5 Compressive Strength Test Results

It was observed that even though the weights of 115mm thick interlocking block units were on the average 60% that of 100mm thick sandcrete units, their compressive strengths taken unit by unit were higher than those of 100mm thick sandcrete units (Andam, 2004). On the average however, there was a difference of 0.04N/mm^2 which means that the mean compressive strength of 100mm sandcrete units was 98% of that of 115mm thick interlocking units. This implies that though there are differences in the weight of the sandcrete blocks and interlocking blocks, the compressive strength was almost the same.

5.6 Cost of Construction

The cost of construction process is mainly influenced by inputs like materials and labour. Any attempt at reducing the cost of these two inputs will go a long way to reduce the overall cost of any construction process. As shown in the discussions above, the use of the interlocking block leads to a significant reduction in the labour and material requirements of the wall construction process compared to the use of the sandcrete block. This situation leads to a far less cost of construction of wall using the interlocking block relative to using the traditional sandcrete block.

Between the two cost parameters of labour and materials, the relatively far less cost of construction of interlocking block walls is driven more by the reduction in the use of materials in the form of mortar. It is the less use mortar for jointing which largely contributes to a reduction in the cost of interlocking block wall construction process by about 90% compared to the sandcrete block.

The time that was spent in the construction of the first course of the interlocking block wall across all the various phases of the study was generally more than the time spent in the construction of the first course of the sandcrete block wall. Averagely about 65% of the time that was used to complete the first course of the interlocking wall was required to complete the first course of the sandcrete block wall. The relatively more time spent in the first course of the interlocking wall results from the fact more time was spent in plumbing and levelling the first course to achieve a near perfect alignment in order to avoid coordination problems during the dry bonding (locking of blocks) for subsequent courses. The unit cost of the interlocking block is GHC1.00 per one while the sandcrete block is GHC 3.00 per one; therefore the interlocking block is cheaper as compare with the sandcrete block.

5.7 Affordability of blocks in Percentage

The results observed form this section can be clearly seen. In terms of high rate of affordability interlocking blocks scored 70% while sandcrete blocks scored 30%. Gidigasu (2005) has also indicated that depending on the plasticity of lateritic soil, an amount of sand stabilization could be done to improve the grading of the soil to achieve high strength blocks with a minimum amount of binder content when producing landcrete blocks for low-cost housing.

The difficulty of transporting sand over long distances for building purposes, the excessive exploitation and depletion of sand deposits in Ghana as well as the exorbitant cost of sandcrete blocks as a result of the relative high cost of sand indicate that lateritic materials should be employed in the building industry to produce affordable and sustainable construction in Ghana.

5.8 Rate of coolness of blocks

Results showed that interlocking blocks have high rate of coolness accounting for 70% of the respondent rate while that of sandcrete blocks account for 30%. This means the interlocking blocks were more effective in thermal resistance than the sandcrete blocks (Oluwole, et al., 2012) this implies that interlocking blocks make the interior part of the building (room) cooler than sandcrete blocks and that might account for the high rate of patronage. According to Danso (2013), houses built with earth tend to be naturally cool in the summer heat and warm in cold weather.

5.9 Test of Hypothesis

Hypothesis 1 – Speed of construction

Table 4.2 presents the results of the test of significance difference between the interlocking blocks and conventional sandcrete blocks. Notwithstanding the closeness of the mean values, it was deemed appropriate to determine whether there were any statistically significant differences between the values using paired-sample T-test at the 0.05 level of significance. With t-value of 24.600 and significance at 0.026, it can be concluded that there is statistically significant difference between the interlocking blocks and conventional sandcrete blocks's speed of construction. The study therefore rejects the null hypothesis (H0) and accepts the alternate hypothesis (H1).

Hypothesis 2 – Labour cost

The results obtained from the paired-sample T-test at the 0.05 level of significance indicate that, the t-value was 1.483 with significance level 0.235. This result implies that there is no statistically significant difference between the interlocking blocks and conventional sandcrete blocks's cost of labour. The study therefore accepts the null hypothesis (H0).

Hypothesis 3 – Material cost

The results from the paired-sample T-test at the 0.05 level of significance show that, the t-value was 1.268 with significance level 0.005. This means that there is statistically significant difference between the cost of interlocking blocks and conventional sandcrete blocks. The study therefore rejects the null hypothesis (H0) and accepts the alternate hypothesis (H1).

Hypothesis 4 – Compressive strength

The results from the paired-sample T-test at the 0.05 level of significance indicate that, the t-value was 0.380 with significance level 0.740. The result means that there is no statistically significant difference between the interlocking blocks and conventional sandcrete blocks's compressive strengths. The study therefore accepts the null hypothesis (H0).

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter concludes the dissertation. It is devoted to summarising the findings, concluding on them (based on the discussions) and recommending on the conclusions provided.

6.2 SUMMARY OF FINDINGS

- The elimination of the various non-value adding steps associated with the conventional sandcrete block wall construction through the use of the interlocking block system reduces the cycle time of block bonding thus increasing the speed of wall construction for interlocking blocks.
- It was also identified that interlocking blocks are affordable in terms of cost compared with sandcrete blocks.
- It was identified that interlocking block has the ability to make the room cooler especially in hot weather conditions.
- There is also a significant reduction in the material requirement for the interlocking block wall construction process due to the absence of mortar jointing. Reduction in the labour and material requirements in the interlocking block wall construction makes the cost associated with the process of building walls using the interlocking blocks far less.
- The study revealed that a number of non-value adding steps like spreading of base mortar for various courses, vertical mortar jointing and levelling, which are associated with the use of sandcrete block, could be eliminated when the interlocking block is used for wall construction.

- The study also revealed that the interlocking blocks have almost the same compressive strength as that of the sandcrete blocks.

6.3 Conclusion

From the aim and objectives of the research and findings, the following main conclusions can be made:

1. There was significant difference between the interlocking blocks and conventional sandcrete blocks's speed of construction. The interlocking blocks construction proved to be faster, thereby ensuring speedy construction.
2. There was no significant difference between the interlocking blocks and conventional sandcrete blocks's cost of labour. This means that in terms of labour cost, the interlocking block wall construction is within the range of the conventional sandcrete block construction.
3. There was significant difference between the cost of interlocking blocks and conventional sandcrete blocks. This implies that interlocking blocks are affordable and can be used to produce low cost buildings, especially at developing countries where building deficits are high.
4. There was no significant difference between the interlocking blocks and conventional sandcrete blocks's compressive strengths. This indicates that the compressive strength of interlocking blocks is comparable to that of the conventional sandcrete blocks.

On the basis of the above, interlocking blocks provide a very good economic alternative to sandcrete blocks. Economically, it provides a cheaper means of construction, low cost resources (materials) and erection process. It therefore has the potential of supporting the affordable housing concept in Ghana. An interlocking block building is also likely to support sustainable construction concept since it uses materials that are abundant and provide cooler environment and will result in less energy use.

6.4 Recommendations

The following recommendations are therefore advanced based on the above conclusions:

- That engineers and architects should recommend interlocking block construction to their clients, especially the Real Estate Developers to gradually introduce interlocking blocks for housing. Private developers should also be encouraged to start using interlocking blocks for buildings.
- The government should set up land banks and encourage estate developers, financial institution and other investors to pursue mass housing programmes using interlocking blocks.
- The government should organise national housing fora to discuss and find workable strategies to address housing challenges using local building material such as interlocking blocks.

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APPENDIX I

Table 4.5: Compressive Strength Results at 7 days for 100mm thick sandcrete block

Sample	Mass of Block (Kg)	Compressive Strength of Block (N/mm^2)
1	20.11	1.4
2	19.29	1.27
3	20.04	1.24
4	20.09	1.31
5	19.17	1.17
6	20.45	1.35
7	19.25	1.14
8	19.08	1.19
9	19.81	1.28
10	19.02	1.26
Mean	19.631	1.261
Standard Deviation	0.52293	0.08062

Table 4.6: Compressive Strength Results at 7 days for 115mm thick interlocking block

Sample	Mass of Block (Kg)	Compressive Strength of Block (N/mm^2)
1	11.1	1.4
2	11.12	1.51
3	11.15	1.4
4	11.19	1.22
5	10.3	1.21
6	10.9	1.31
7	10.01	1.26
8	10.92	1.08
9	11.12	1.2
10	10.19	1.4
Mean	10.8	1.299
Standard Deviation	0.45216	0.12853

Table 4.5: Compressive Strength Results at 14 days for 100mm thick sandcrete block

Sample	Mass of Block (Kg)	Compressive Strength of Block (N/mm^2)
1	20.52	2.16
2	19.83	1.62
3	20.45	2.13
4	20.61	2.2
5	19.67	1.77
6	21	2.13
7	19.94	1.75
8	19.66	2.11
9	20.53	1.99
10	20	1.97
Mean	20.22	1.98
Standard Deviation	0.459	0.203

Table 4.6: Compressive Strength Results at 14 days for 115mm thick interlocking block

Sample	Mass of Block (Kg)	Compressive Strength of Block (N/mm^2)
1	11.14	1.86
2	11.4	2.13
3	11.25	2.11
4	11.35	2.1
5	10.8	1.98
6	11.08	2.15
7	10.5	1.95
8	11.1	1.85
9	11.6	2.12
10	10.49	1.96
Mean	11.07	2.02
Standard Deviation	0.371	0.116

Table 4.5: Compressive Strength Results at 28 days for 100mm thick sandcrete block

Sample	Mass of Block (Kg)	Compressive Strength of Block (N/mm^2)
1	20.61	3.52
2	20.14	3.62
3	20.78	3.54
4	20.81	3.6
5	20.15	3.43
6	21.18	3.63
7	20.12	3.44
8	20.05	3.38
9	20.72	3.62
10	20.18	3.42
Mean	20.474	3.52
Standard Deviation	0.39328	0.09603

Table 4.6: Compressive Strength Results at 28 days for 115mm thick interlocking block

Sample	Mass of Block (Kg)	Compressive Strength of Block (N/mm^2)
1	12.12	3.6
2	12.28	3.49
3	12.13	3.58
4	12.22	3.51
5	11.72	3.5
6	12.04	3.63
7	11.27	3.53
8	12.08	3.61
9	12.31	3.59
10	11.14	3.56
Mean	11.931	3.56
Standard Deviation	0.41707	0.04967

APPENDIX II

Fig 1: Interlocking blocks being arranged by the craftman

Fig: 2 Classroom blocks and Estate housing built with interlocking blocks.

Fig 3: Hydraform's interlocking blockwall

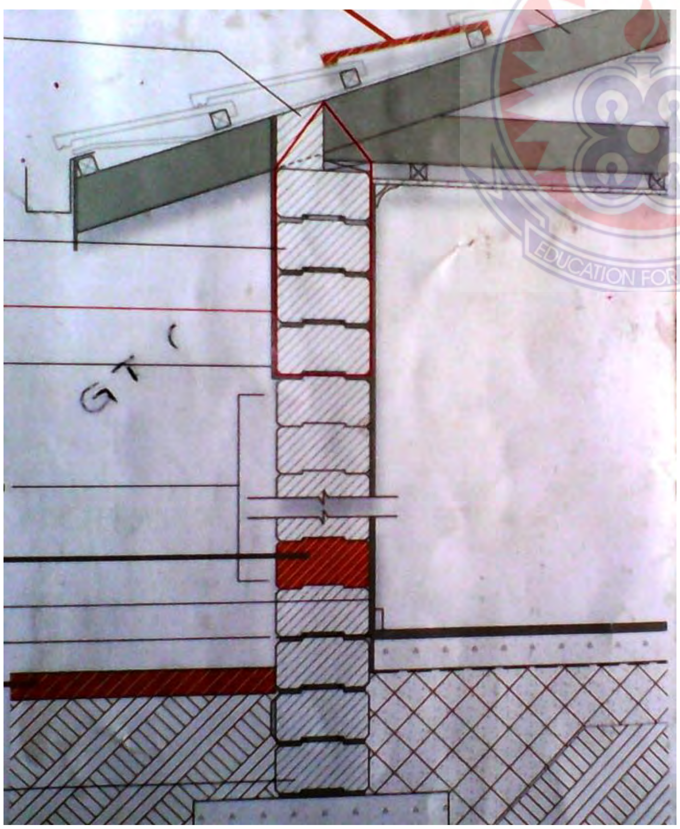

Fig: 4 Interlocking blocks section

Fig: 5 Appearance Structures built with interlocking blocks

APPENDIX III

UNIVERSITY OF EDUCATION, WINNEBA
DEPARTMENT OF DESIGN AND TECHNOLOGY

.

A QUESTIONNAIRE DESIGNED TO WOKERS OF P-A CAPITAL ESTATE LTD

Dear respondent, I am a student at the University of Education, Winneba and currently pursuing M. Tech. Construction at the department of design and technology. I wish to seek your input towards my research work under the topic: **"Interlocking blocks Construction for affordable housing in Ghana' (Case study: Sunyani Municipality)**

'. Kindly respond to the items below as frankly as possible. Every information you provide will be treated with the confidentiality it deserves.

Please respond to the following by ticking [√] where appropriate in the spaces provided.

1. Gender: male [ ] Female [ ]

2. What is your position in the company?

   (a) Production manager ( )

   (b) Production Assistance ( )

   (c) Plant Operator ( )

   (d) Labourer ( )

3. How long have your company been engaged in construction work?

(a) 1 - 5 years ( )

(b) 6 - 10 years ( )

(c) 11 and above ( )

4. When did you start producing interlocking blocks?

   (a) Below 1 month ( )

(b) 1-3 months ( )

(c) 4-12 months ( )

(d) 1year and above ( )

5. Are people patronizing the interlocking blocks?

(a) Yes ( )

(b) No ( )

6. If yes, what is the rate of patronage?

(a) High ( )

(b) Low ( )

7. Do the production of interlocking blocks need any special or trained personnel?

(a) Yes ( )

(b) No ( )

8. Rate the following blocks in terms of speed up construction, using high, moderate or low

BLOCKS	HIGH	MODERATE	LOW
Interlocking blocks			
Sandcrete blocks			

9. What are some of the challenges you are facing in the production of interlocking blocks?

(a) Material acquisition ( )

(b) Financial problem ( )

10. Have you had any complaint on the usage of interlocking blocks?

(a) Yes ( )

(b) No ( )

11. If yes, what are some of the complaint you have been receiving?

(a) Construction problems ( )

(b) Lack of skilled personnel to carry out the construction ( )

(c) Not as durable as sandcrete block ( )

12. What is the compressive strength of one interlocking blocks?

....

....

....

13. Rate the following blocks in terms of affordability using High, moderate and low

(a) Interlocking blocks ( )

(b) Sanlandcrete blocks ( )

(c) Sandcrete blocks ( )

14. Which of the following blocks is strong enough to withstand lateral loadings?

(a) Interlocking blocks ( )

(c) Sandcrete blocks ( )

15. Rate the following blocks in terms of its ability to make the interior part of the building cool?

Please tick.

BLOCKS	HIGH	MODERATE	LOW
Interlocking blocks			
Sandcrete blocks			

APENDIX IV

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF DESIGN AND TECHNOLOGY

.

A QUESTIONNAIRE DESIGNED TO WOKERS OF CONSULTANCY FIRMS

Dear respondent, I am a student at the University of Education, Winneba and currently pursuing M. Tech. Construction at the department of design and technology. I wish to seek your input towards my research work under the topic **'interlocking blocks Construction for sustainable affordable housing in Ghana' (Case study: Sunyani Municipality)**

'. Kindly respond to the items below as frankly as possible. Every information you provide will be treated with the confidentiality it deserves.

Please respond to the following by ticking [√] where appropriate in the spaces provided.

1. Gender: male [ ] Female [ ]

2. What is your position in the company?

(a) Architect [ ]

(b) Quantity Surveyor [ ]

(c)Structural Engineer [ ]

(d) Clerk of work [ ]

3. Have you seen interlocking blocks before?

(a) Yes ( )

(b) No ( )

4. If yes, how long have you seen these blocks?

(a) Below 1 month ( )

(b) 1-3 months ( )

(c) 4-12 months ( )

(d) 1year and above ( )

5. Do you have any knowledge on interlocking blocks construction?

(a) Yes ( )

(b) No ( )

6. If yes, say something about it at the spaces provided.

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7. Have you supervised interlocking blocks construction before?

(a) Yes ( )

(b) No ( )

8. If yes, how long?

(a) Below 1 month ( )

(b) 1-3 months ( )

(c) 4-12 months ( )

(d) 1year and above ( )

9. Do you spend more on interlocking block construction than Sandcrete construction?

(a) Yes ( )

(b) No ( )

10. If yes, at what percentage?

(a) 10-15% ( )

(b) 16-20% ( )

(c) 21 and above ( )

11. Do you recommend the usage of interlocking blocks in residential building?

(a) Yes ( )

(b) No ( )

12. As a Consultant, what can you say about the usage of interlocking blocks construction?

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13. Which of these blocks is likely to fail under lateral loading?

(a) Interlocking blocks ( )

(b) Sandcrete blocks ( )

14. Do the Interlocking blocks make the interior of the room cooler than any other blocks?

(a) Yes ( )

(b) No ( )

15. If yes, then what is the rate of percentage cost?

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UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF DESIGN AND TECHNOLOGY

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A QUESTIONNAIRE DESIGNED TO PRIVATE INDIVIDUALS

Dear respondent, I am a student at the University of Education, Winneba and currently pursuing M. Tech. Construction at the department of design and technology. I wish to seek your input towards my research work under the topic **'interlocking blocks Construction for sustainable affordable housing in Ghana' (Case study: Sunyani Municipality)**

Kindly respond to the items below as frankly as possible. Every information you provide will be treated with the confidentiality it deserves.

Please respond to the following by ticking [√] where appropriate in the spaces provided.

1. Gender: male [ ] Female [ ]

2. Age: i. 20-29[ ] ii. 30-39[ ] iii. 40-49 [ ] iv.41-45 [ ] v. 50-59 [ ] vi. 60yrs and above [ ]

3. Do you have any knowledge on interlocking blocks construction?

(a) Yes ( )

(b) No ( )

4. If yes, say something about it at the spaces provided.

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5. Is interlocking block construction cheaper than any other blocks?

(a) Yes ( )

(b) No ( )

6. Are you planning to use interlocking building in the near future?

(a) Yes ( )

(b) No ( )

7. If no, why?

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8. Which of these blocks is affordable when it comes into construction of building?

(a) Hydraform blocks ( )

(b) Sandcrete blocks ( )

9. Which of these blocks moves faster in construction?

(a) Interlocking blocks ( )

(b) Sandcrete blocks ( )

10. Do you spend more on interlocking block construction than Sandcrete construction?

(a) Yes ( )

(b) No ( )

11. If yes, at what percentage?

(a) 10-15% ( )

(b) 16-20% ( )

(c) 21 and above ( )

APPENDIX IV

Construction Speed

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Ssndcrete Blocks	201.5	2	.70711	0.50000
	Interlocking Blocks	91.0	2	5.65685	4.00000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Ssndcrete Blocks - Interlocking Blocks	110.50	6.36396	4.50000	53.32	167.67	24.6	1	.026

Labour Cost

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Conventional blocks	.8425	4	.49628	.24814
	Interlocking blocks	.4400	4	.60844	.30422

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Conventional blocks - Interlocking blocks	.40250	.54267	.27134	-.46101	1.26601	1.483	3	.235

Material Cost

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Conventional blocks	1.3996E2	2	2.40416	1.70000
	Interlocking blocks	11.8400	2	.97581	.69000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Conventional blocks - Interlocking blocks	1.28120E2	1.42836	1.01000	115.28673	140.95327	126.851	1	.005

Compressive Strength Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Conventional blocks	3	2.2533	1.15453	.66657
Interlocking blocks	3	2.2933	1.15453	.66657

One-Sample Test

	Test Value = 2					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Conventional blocks	.380	2	.740	.25333	-2.6147	3.1213
Interlocking blocks	.440	2	.703	.29333	-2.5747	3.1613