DOWNDRAFT KILN FIRED WITH PALM KERNEL SHELLS

by

Brobbey, Rexford

(BA Industrial Art)

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DECLARATION

I hereby declare that this submission is my own work towards the MA (Art Education) degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

Brobbey Rexford (PG3313009)	…………………………	…………………
Students Name and ID Number	Signature	Date

Certified by

Dr. Rudolf Steiner	……………………………	…………………
Supervisor's Name	Signature	Date

Certified by

Nana Afia Opoku-Asare, Mrs	………………………………	……………………..
Head of Department's Name	Signature	Date

ABSTRACT

This work was carried out to construct a downdraft kiln fired with palm kernel shells as an alternate fuel for firing clay bricks in a more efficient way. The work was a quasi-experimental involving the use of both qualitative and quantitative research methods. Interviews and participatory observation were employed to gather data for the study. Data was selected from a purposeful sample that was relevant to this study especially from heavy clay related areas. The study was in three different phase as part of it objectives. The first was the selection of four local soils which were tested be used for the production of insulating firebrick. They included: Mfensi ball clay, Mankranso ball clay, Tanoso ball clay and Kenyasi fireclay. They were mixed in batches and in ratios. Analysis from samples with code B_3 and B-3 which represents a combination of 70% Mankraso ball clay with 30 % sawdust and 40% Mankraso ball clay, 30% Kenyasi fire clay with 30% sawdust showed a lower percentage with a total fired shrinkage of 1.67% and 1.0% respectively at 1050^oC, compared to other body samples with lower percentage of sawdust which were also fired at the same temperature regime. The following tests showed that, sample with code B-3 with a batch composition of 40% Mankraso plastic clay, 30% Kenyasi fireclay and 30% sawdust which represent a ratio of 4:3:3 was ideal for production of insulating firebricks (IFB) in downdraft kiln linings at lower temperatures of 1050^oC -1200^oC. The second phase of this project was the construction of the downdraft kiln. Finally, test firing at 950^oC showed no deformity in the kiln structure. Sample bricks fired with palm kernel shells showed three different characteristics. They were under-fired (salmon brick as generic word), over-fired brick (clinker brick) and well-fired bricks. These bricks were selected from four different

locations in the kiln: the firebox area, the top (close to roof), middle and bottom areas. These were the results of the physical and mechanical analysis identified from the various test. The side wall brick close to the muffle wall or firebox showed the lowest water of absorption value of 4.5% whiles the brick from the bottom showed the highest water absorption with a value of 16.5%. The bottom brick achieved the lowest compressive strength of 10.0 and 18.0% as the highest value for the top brick which is close to the roof of the kiln. The study indicated that the bricks closer to the muffle wall although showed the lowest water of absorption came out as a defected brick. The bricks were glazed and melting because it had vitrified and almost turning glassy. The defect resulted in cracks and bloating of fired bricks.

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CHAPTER ONE

INTRODUCTION

1.1 Overview

The chapter introduces the main ideas discussed in this thesis. It opened with the background of the study followed by the statement of the problem, objectives and research questions. It is then followed by the delimitation, definition of terms and importance of the study.

1.1 Background of the Study

Fuel availability and energy efficiency is an important requisite that demands constant appraisal in all industries. The emerging market for burnt bricks in Ghana can in one phase be successful only if a cost effective source of fuel and alternate firing methods are developed for the industry. This need necessitated the research into alternate fuel such as an agricultural waste as palm kernel shells an energy saving method of firing bricks a Downdraft firing system instead of the conventional method, by way of Clamp firing. The research sought to compose a body composition from local soils as materials for the construction of the kiln instead on foreign materials which are imported and expensive.

1.3 Statement of the Problem

The major problem facing the brick and tile industry in Ghana today is the unavailability of cheaper and constant supply of fuel which affects the industry negatively by raising the cost of production. This eventually contributes to the high cost of building materials including burnt bricks and tiles, giving the industry limited number of which can collapse the industry if alternate fuel and renewable energy for the brick industry are not found.

The history of brick and tile production in Ghana shows that most of the brick and tile factories established in the 1970's such as Clay Products at Alajo in Accra and Adidome Brick and Tiles in the Volta Region that were collapsed due to lack of access to cheaper fuel beside management problems. Recently, a newly established brick factory - Metalex, also has shut down production because of unavailable and intermittent supply of Gas Oil for firing. Liquefied Petroleum Gas (LPG) cannot be considered as an alternate choice because there has constantly been a shortage of this petroleum product from Tema Oil Refinery.

Obeng, Ocran and Anaba's (1993) study of alternate methods of firing using an agricultural waste product, palm kernel shell, as fuel for firing bricks is explored as a means of reducing environmental degradation and depletion of scarce firewood in Ghana. The fuel is used in a clamp method by stacking together hundred's of bricks to form a kiln. Road Research Institute at Fumesua in Ashanti. The objective was to cut down the Obeng's (1997) comparative study of firewood and palm kernel shells firing which proved that, burnt bricks fired with palm kernel shells are both physically and mechanically stronger than firewood fired bricks. This suggest the possibility of using these products for engineering works as road construction and load bearing walls.

This research therefore focus on the design and construction a downdraft palm kernel shell fired kiln to test the efficiency of the fuel and agricultural waste.

1.4 Objectives

There are three core objectives for this research.

- To construct a downdraft kiln that can be fired using palm kernel shells as fuel.
- To select and test four different soil samples for the production of insulating bricks.
- To determine the efficiency of the kiln by test firing bricks.

1.5 Research Questions

- How will the manufacturers of burnt bricks know the refractoriness of some local soils in kiln construction?
- What are some of the design principles that will be considered in the construction of downdraft kiln?
- How efficient will the Downdraft kiln be over clamp firing method using palm kernel shells as fuel?

1.6 Delimitation

The study is limited to the use of four local soils such as Mfensi clay, Mankraso, Tanoso clay and Kenyasi fireclay. The materials for the construction of the kiln were also limited to sawdust, angle iron, metal plates and Ceramic fiber.

1.7 Definition of Terms

Downdraft Kiln The type of kiln which has a draft movement starting with the inlet flue, circulates in the chamber, passes down through floor exit flues and flows out of the chimney. The downdraft offers inherently even temperature, economical fuel combustion and the ability to expand the kiln to an extremely large size

Clamp kiln A type of kiln constructed by stacking hundreds of bricks together with fireboxes beneath and plastered with a soil to retain temperature.

Refractory Materials, usually non-metallic, that can withstand extreme temperatures.

Insulation To cover a surface with a material that increase heat retention properties of a kiln.

Firebrick Firebrick is a type of brick made from raw clay and powdered fired clay between the temperatures of 1200^oC to 1800^oC.

Skewback A structural member that transmits the stress of the arch of a kiln to the supporting wall and to the framework

1.9 Abbreviations

Mf	Mfensi
Mn	Mankraso
Tn	Tanoso
Kn	Kenyasi
ASTM	American Standard for Testing Materials
BS	British Standard
FD	Force draft
XRF	X-Ray Fluoresce

1.10 Importance of the Study

- The research has provided data on the technical benefits for constructing kilns using local raw materials instead of exchanging huge foreign currencies to import kilns which are very expensive.
- The researcher has added to knowledge on the relevance and advantages of using agricultural waste in the country as an alternate fuel for energy generation in the brick industry.
- The research encourages interested investors to invest in brick and tile manufacturing and in a way create jobs in Ghana.

1.11 Organization of the rest of the Text

Chapter Two provides a review of related literature on Kilns and different types of kilns, materials for kiln construction, both foreign and local. It further reviewed principles of kiln construction and different types of fuel for burnt bricks firing.

Chapter Three deals with the research strategies adopted to gather data which discusses the following: the research design, library research, population, sampling, instrumentation, validity of instruments, administration of instruments, primary and secondary data, practical project which deals with the construction of the Downdraft Palm Kernel Shell Kiln undertaken and data analysis plan.

Chapter Four discusses the data gathered in the study, its analysis and interpretation of test sample insulating firebricks. Chapter Five provides a summary, conclusions drawn and recommendations of the use of alternate fuel in the brick industry. It also gives recommendations based on the adaptability of a downdraft kiln in Ghanaian Brick Industry.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Overview

In this chapter, topics reviewed include kilns, types of kilns, foreign materials for kiln construction as well as selected local raw materials. Other topics also include methods and principles of kiln construction, fuel and fuel efficiency. Journals, internet and books provided the literature were rviewed.

2.2 Kilns

A kiln is a thermally insulated chambers or oven in which controlled temperature regions are produced. They are used to handle harden, burn or dry materials (en.wikipedia.org/wiki/kiln). The concept of kiln design and construction was developed from the early years when pottery was fired in open bon-fires or in shallow pits holding the fire and not in kilns. The process of firing clay to make it hard and durable is of great antiquity. In prehistory, clay objects were first fired before used with different firing methods. Rhodes (1981) states that tests shown by many fragments of pottery are as much as 30,000 years old, much older than that previously been assumed from archeological evidence.

2.3 Types of Kilns

Kilns vary in purpose, construction and the choice of fuel. However, the design principles cut across in almost all kilns. The type of kiln to construct is determined by the type of fuel that is going to be used. For instance, firing a stoneware body at $1150^{o}C – 1200^{o}C$ will require a different kiln from one firing earthenware at $1000^{o}C$. There are different types of kilns used in the ceramic industry. They range from conventional to advance kilns. The conventional method involves the use of Hoffman and clamp. The advance method includes the Continuous (shuttle or tunnel kiln) and the Periodic or Intermittent kiln (Downdraft kiln and Updraft). In most developed countries, the tunnel or shuttle kiln is the commonest under the advanced method of firing in brick and tile industries. These kilns have been designed to fire large quantities of bricks. They are sophisticated and very efficient because they make use of the regenerative principles (Rhodes, 1981). The various kilns are described in the following sections.

2.3.1 Hoffman kiln

According to Rhodes (1981), the "Hoffman kiln is built like a ring made up of several chambers. These chambers may be connected to a central chimney by the use of a movable flue. Each chamber is fired by introducing fuel among the bricks through holes at the tip. Air for combustion is drawn from the neighbouring chamber that is cooling, and exhaust heat is evacuated through the chamber on the other side through the walls of the kiln." (p.80).

In the early 1980's, the Building and Road Research Institute in Ghana, adopted this same principle of firing bricks. However, there was an inconsistency in the supply of gas oil made them halt with the kiln. Okyere (1978) affirmed that "The continuous oil-fired brick kiln (the Hoffman kiln) at the Building and Road Research Institute provides a good alternative firing technique for those part of the country where firewood is in short supply". This suggests that, the gas oil could be the most efficient method of firing bricks.

2.3.2 Clamp kiln

The use of the clamp kiln (plate 2.1) is the oldest and most rudimentary method of firing large quantities of bricks. Clamp is constructed by stacking hundreds of bricks together to form a kiln. The walls are finally plastered with mud to serve as insulation (Jones, 1995). This means the clamp is potentially the most inefficient method of firing because much heat is allowed into the atmosphere during firing and cooling. The fuel is also used uncontrollable and affected by ambient temperature (Jones).

The advantages of using clamp for firing according to http://www2.gtz.de/Basin/gate/brickclamps.htm are as follows.

Advantages:

- They are cheap and straight-forward to build.
- There is no permanent structure to install and maintain.
- A level area of ground and a good supply of fuel is all that is required.

- They can be of any size ranging from 5,000 and above, so they can accommodate fluctuation of brick production.

Plate 2.1 Clamp firing with wood.

The disadvantages are:

- Basic brick clamps are the least energy efficient method of firing with a lot of heat lost by radiation through the walls and conduction from the top of the clamp. The fuel is not consumed efficiently as there is little or no control over it combustion once the clamp is lit.
- They are very labour intensive, being assembled and disassembled by hand and if not built correctly and fired badly, can result in a very high percentage of

incompletely fired bricks up to 20% of the bricks produced. A basic brick clamp can normally be expected to be over or under-fired by this method (plate 2.2).

- They are very slow to fire, taking several days to heat up and cool down, and there is little or no control over the firing once it has started.
- They are highly susceptible to the prevailing weather conditions, especially strong winds will result in a very uneven firing, with many under-fired and over-tired bricks.

Plate 2.2 The labour intensity of clamp firing

2.3.3 Tunnel Kiln

In the brick industry, another efficient method of firing in a continuous process is the use of Car Tunnel Kiln. This is whereby the wares are carried slowly on cars (shelves running on rails into the kiln) through a tunnel. During the heating cycle, the cars approach a hot zone in the middle. They are then drawn out at the cooling end (Olsen, 2001). In Ghana, it is Ceramica Tamakloe located at Dodowa in the Greater Accra Region which uses this type of kiln. The use of this sophisticated kiln is under-utilized in the company because of the constant breakdown due to continuous shortage of liquefied petroleum gas and high cost of maintenance.

2.3.4 Downdraft Kiln

Olsen (2001) defines a Downdraft Kiln as "The type of kiln which has a draft movement starting with the inlet flue, circulates in the chamber, passes down through floor exit flues and flows out of the chimney. The downdraft offers inherently even temperature, economical fuel combustion and the ability to expand the kiln to an extremely large size" (p.95). These features allow the downdraft kiln to be at an advantage over the updraft kiln. The updraft kiln has heat flowing into the chamber from the bottom and finding an easy exit through the top of the arch and openings. The ability to replicate the size of the kiln to an extremely large size suggests the convenience of using this method and principles for firing large quantities of clay bricks. Rhodes (1981) attest that "the downdraft kiln avoids most of the disadvantages of other system and may be considered the ultimate development in fuel burning (p.72). It is, however, noted from this reference that a kiln is effective if it uses less fuel and at the same time fires very efficiently. The construction of fireplace (where fuel is introduced into the kiln) can also be arranged at different areas of the kiln; it can be located at the bottom, front or side depending on the choice of fuel and heat distribution system that one wants to create in the kiln chamber. This also makes it versatile in terms of fuel adaptability including agricultural waste – palm kernel shells, sawdust, rice husk and corn cob.

2.4 Materials for kiln Construction

Materials vary from one kiln to another. In kiln construction, one has to understand what is going to be fired and the insulating materials needed for that work. Material selection for kiln construction is considered of great importance because the core structure is to retain heat in a chamber. The kiln must be constructed of materials which are sufficiently 'refractory'. Olsen (2001) refers to refractory material (refractories) as "materials, usually non-metallic, that can withstand extreme temperatures.", By definition, refractory materials are supposed to be resistant to heat and are exposed to different degrees of mechanical stress and strain, thermal stress and strain, corrosion / erosion from solids, liquids and gases, gas diffusion, and mechanical abrasion at various temperatures without defect (Brosnan, 2004). In other words, the material has the capacity to withstand one or more of the destructive forces of abrasion, which can be pressure, thermal expansion and/or the chemical attacks of either acid or base slag or fluxes at high temperature. The material for the construction, both exterior and interior, must be found neither to melt nor volatize at the working temperature of the kiln. For instance, if the firing temperature of the insulation material is 1050^{o}C, the kiln should always fire below the expected temperature. It will help maintain the durability of the insulating materials. In most developed countries, refractory materials range from a temperature of 1728^{o}C to 3890^{o}C (Olsen, 2001).

2.4.1 Refractory materials for kiln building

Olsen (2001) group refractory materials for kiln building under five categories. They are:

- Firebrick
- Insulating firebrick/Insulating brick
- Castables
- Mortar
- Special materials

These are explanined as follows:

1. **Firebrick**

As part of materials for kiln construction, firebrick is a broad term covering any type of refractory brick, most specifically; brick made of fireclay (Olsen, 2001). Firebricks are made from a mixture of raw clay ad grog. The proportion of clay and grog varies (Rhodes, 1981). The chemical and physical properties of firebrick vary greatly depending upon its intended use and the various materials which may be added to its basic kaolinite composition.

Firebricks are classified according to American Standard for Testing Materials (ASTM) based upon temperature destruction. Brosnan (2004) further states that "Fireclay bricks are classed in standards based on their refractoriness or ability to withstand high temperatures without shrinking and spalling" (p.89). The four classification according to Olsen (2001), are: Super-duty ($1745^{o}C$-$1760^{o}C$), High-duty (17, Intermediate-duty ($1277^{o}C$-$1680^{o}C$), Low-duty ($1615^{o}C$).

2. **Insulating firebrick**

Insulating firebricks (IFB) are the commonest thermal insulating bricks that are used for most kiln linings. The compositions are basically, the introduction of fillers and other diatomaceous earth. This is a natural material from a diatom, a sea animal. The material is soft, porous and contains silicon dioxide. The pores improve greater heat retention. In a more conventional way, porous bricks which serve as insulating bricks are made by mixing clay body with a combustible wood fragments or sawdust (Rhodes, 1981).

3. **Castables**

Krietz (2004) defines refractory castables as premixed combinations of refractory grain, matrix components, bonding agents, and admixtures (p.289). Castables are also composed principally of alumina or aluminum-silica aggregates, using hydraulic-setting cement, so that when tampered with water, they will develop structural strength and retain their cast form (Olsen, 2001). Castables are used for certain parts of a kiln that are difficult to shape with bricks, an example, is the skewback. It is therefore a disadvantage to use this refractory material to cast units that are large. It will eventually crack, spall and disintegrate from continued heating and cooling (Rhodes, 1981).

4. **Mortars**

Materials for kiln construction are bonded by using the right mortar. Refractory Mortars are made from composition of different ceramic raw materials that are heat resistance and facilitate bonding. According to Olsen (2001), “Mortar is a refractory cement which bond small units into a strong, stable and relatively gas-tight structure". Rhodes (1981)also explained further that, refractory mortar is made from a fire clay. Finely crushed grog is added to reduce shrinkage. Air setting mortars contain sodium silicate as the bonding agent. Conventionally, locally prepared mortar is composed from a composition of ordinary ball clay, kaolin, grog and some amount of Portland cement which serves as part of a binder. It is important therefore to do a careful selection of materials for mortar preparation with similar chemical properties to the brick balanced by characteristics and ensuring strong bonding.

5. **Special Materials**

Ceramic fiber is a cotton-like refractory material made from alumina – silica. It is one of the special refractory materials used for kiln construction. Olsen (2001) stated that, "their main purpose is to provide insulation up to 1260^{o}C but with a melting point of 1785^{o}C". Rhodes (1981) also emphasized that "The ceramic fiber materials have the advantage of extremely low thermal conductivity and of being lightweight". Other insulation materials include fiber blankets and boards.

2.4.2 Local raw materials for kiln construction

Clay

The most useful and one of the most available refractory materials is clay. Pure kaolin or kaolinite ($AL_20_3.2SiO_2.2H_2O$) has a melting point of 1785^{o}C (Rhodes, 1981). This implies that clay can be used as a refractory material in the production of insulation bricks for kiln construction. Ghana Geological Survey (1990) defines clay as a rock in which clay mineral dominates. It also states that, “there are many clay minerals with various properties which make them valuable for several purposes”. Clay is also defined as a fine-grained earthenware material which contains clay minerals, and is plastic and cohesive (Obeng & Atiemo, 2005). Clay shrinks when dry and expand when wet and gain strength with retention of shape of firing physically. Clays have particle size ranging from 2μm and below (BS: 1377). They consist of minerals that are tiny crystalline substance and are essentially made of hydrous aluminous silicates, other metallic ions and impurities. The clay mineral is either the two layer type (kaolinite) or the three layer (montmorillonite) in which silicon and aluminum ions have tetrahedral coordination with respect to oxygen while aluminum, magnesium, iron and other ions have octahedral coordination with oxygen in hydroxyl ions (Holtz and Kovacs, 1981) The clay is mixed with a percentage of biomass or sawdust which burns off at 200^{0}C – 400^{o}C leaving pores in-between the structure. Refractory bricks can be produced in Ghana because there are clay deposits all over the country.There are abundant clay deposits in Ghana. Table 2.1 below shows the commercial quantities of clay deposits in Ghana. The subsequent Table 2.2 shows the chemical composition of some clay samples in Ghana and their mineral traces in different percentages.

Table 2.1 Clay deposits in Ghana.

Regions	Tonnage (million)
Central	106
Greater Accra	200
Eastern	90
Ashanti	39
Brong Ahafo	17
Northern	11
Upper East and West	28

Source: Kesse, 1985

Table 2.2 Chemical Composition of Clay Samples

Chemical Compounds	Clay Samples				
	Mfensi	Mankraso	Tanoso	Obuasi Asokwa	Hwereso
SiO_2	69.8	60.3	67.6	69.8	60.3
Al_2O_3	15.7	18.2	16.3	15.7	18.2
Fe_2O_3	4.6	9.1	4.4	4.6	9.1
CaO	0.2	1.2	0.7	0.2	1.2
MgO	0.1	-	0.1	0.1	-
SO	0.02	0.1	0.04	0.02	0.1
LOi	5.3	4.5	4.8	5.3	4.5

Source: Bi-Annual Journal of the Building and Road Research Institute (CSIR), Dec. 2005

2.5 Methods and Principles of Downdraft Kiln Construction

Palissy (as cited in Rhodes, 1981) states:

> …at some time my work was baked in front and not behind; the next time, when I tried to prevent such an accident I would burn it behind and the front would not be baked; sometimes my glazes were put on too thin and sometimes too thick: which caused me heavy losses: sometimes when I had glazes of various colours in the kiln, some were burned before the others had melted. In short, I blundered thus for fifteen or sixteen years: when I have learned to guard against one danger, I encountered another that I would never have thought about. (p.168).

Rhodes in his book on the subject of Kiln Design brings to light that, the efficiency of a kiln goes beyond fuel availability; Most of the time, it is based on the principles applied in the construction. For instance, a downdraft kiln has several parameters that affect its performance.

The Building and Road Research Institute in Ghana has constructed a one thousand capacity downdraft kiln. The researcher has carefully observed the kiln and these are the observations:

- The kiln walls are not properly insulated therefore, most of the heat generated in the kiln is lost through the walls. The walls both external and internal were built with lateritic soil which contains high amount of MnO, FeO and CaO (as fluxing agents) affects the bonding weakening the structure. The insulating bricks has shrunk after few firing cycles and created gaps for heat loss.

- Another observation is the kiln chamber floor. The floor and draft area are just an arrangement of burnt bricks. This method allows water vapour from the ground to enter the kiln and cools the heat generated within the chamber during firing.
- Moreover, flues are created on a kiln to allow smoke escape. However, the BRRI-Downdraft Kiln has several flues on the sides of kiln where the fire area is. This method creates a lot of heat loss during firing because; the heat is located around the area where heat is generated. The principle for the creation of these flues is to allow vapour and smoke escape but it technically does not serve that purpose. A downdraft kiln with all the basic principles of flues construction adhered to, doesn't need flues on the sides of the kiln to allow vapour and smoke escape. It is rather the function of the chimney. The researcher has observed from experience that, even when spy-holes are opened during firing, smoke begins to cease from moving through the chimney and passes through the spy-holes but when it is closed, it finds an exit through the chimney.
- Most chamber kilns that are built without steel frame-work loose their structural position and collapse with the first to second firing. It is necessary therefore to use angle iron at the four corners of the kiln and with a flat iron bar to hold the dome (roof) from expanding and collapse.

  The CSIR-BRRI kiln has bracing only at the shoulders of the kiln given support to the roof from structural collapse. However, it is observed that, the kiln is gradually loosing its original position and may collapse after several firings. It is recommended by the researcher after careful observations that a well-designed kiln should be constructed taken cognizance of the problems identified with the

BRRI kiln. This implies re-designing and construction using palm kernel shells as fuel will be able to fire more bricks and be adopted by most brick and tile factories across the country.

2.5.1 Design principles - Downdraft Kiln Construction

According to Olsen (2001) the critical factors to be considered in that design of a kiln. include:

- The type of kiln to be constructed; it can be an updraft, downdraft, cross-draft or circular dome.
- The type of clay products to be fired in the kiln. For instance, firing a stoneware product will require a kiln that fires above 1200^{o}C whiles a burnt brick kiln will fire at 950^{o}C - 1050^{o}C depending on both physical and chemical characteristics of the soil.
- The choice of fuel is also important to consider, both its availability and efficiency. The efficiency of the fuel will determine the temperature you can achieve.
- The size of the combustion chamber. This will determine the type of fuel and size of inlet flue (firebox) to be constructed. Fuel varies from wood, gas, coal, oil to bio-waste.
- The flue systems must be properly designed. The size and height of chimney will influence the draft and allow the burners or fireboxes to work efficiently.

- The kind of atmosphere one wants to achieve in the kiln. Most manufacturers will want to use the kiln for reduction or oxidation firing.

These basic principles informed the in his design and construction of a downdraft kiln to be fired with palm kernel shells as described in this report.

2.6 Fuel for firing

Access to constant and cheaper source of fuel is a major concern for brick producers all over the world. There are different fuel types for firing clay products; they include, coal, gas, oil, firewood, sawdust and electricity.

Oil

Oil is an excellent fuel for firing bricks. This is because of gas oil of which black oil (dirty-oil) is an example, has a high calorific value of 38,000 kJ/l. Oil burns more easily than wood and coal (Rhodes, 1981). It is therefore not considered economical as of now to be used as fuel in the Ghanaian Brick Industry.

Waste-oil fired kiln

www.cd3wd.com/cd3wd_40/vita/oilkiln2/en/oilkiln2.htm writes that the waste oil removed from automobile normally has no immediate use. It is often discarded in ways that can foul local ground-water or upset waste-water treatment system. The waste oil has been developed to fire kilns using the oil-drip technique. The caution is that waste oil from engine crankcases or gear boxes can be useful as low-cost fuel in certain applications. However, users of waste-oil are warned that oil might contain lead from leaded gasoline. The oil must be tested to find out if it contains Lead.

The article reiterates that, the combustion chamber of the kiln should be sealed and the chimney should be high enough to carry combustion products well away from the work area. The kiln should be operated in a well-ventilated place. Waste-oil from electric transformers contains Poly Chlorinated Bi-phenol (PCB) compound which is highly toxic and should not be burned at all. (www.cd3wd.com/cd3wd_40/vita/oilkiln2/en/oilkiln2.htm). This means that, cleaner oil should rather be used for firing bricks.

Coal

In modern firing system, coal is of little use but from the 1700's, coal was the usual fuel for firing pottery in European factories. Coal has advantages and disadvantages. It has high concentration in British Thermal Units (Btu's) in a given volume. Its steady yet intense combustion has a calorific value between 15,000 – 27,000 kJ/Kg. Rhodes (1981) states one of the negative sides of the use of coal as: it contains sulfur, an element which is often damaging to glazes and on one's health. Hard coal or Anthracite is the best for firing because it burns with less smoke and sulfurous gas than bituminous coal.

Gas

Gas is an ideal fuel for kilns with a calorific value between 18,000 - 133,000 kJ/m^3 from Town Gas to Butane (C_4H_{10}). However, it is expensive to use as fuel in the brick industry. Gas is usually used for tunnel kilns. It gives out clean air with less toxic particulates unto the atmosphere. Gas is rarely used as fuel in developing countries such as Ghana because of constant shortage of gas and the poor safety regulations in the accustomed to working environments in the country.

Firewood

Until relatively recent times, wood was the primary fuel for kiln firing. It has the advantage of being almost universally available and relatively easy to split into desired unit size. Wood has been used as fuel for centuries in the clay industries. However; the global implication on the felling of trees for fuel has been a raised concern for all stakeholders due to excessive increase in environmental pollution and global warming. The Buildingand Road Research Institute has for the past thirty years been operating a brick factory using firewood and quite recently, research works has shown other alternate sources of energy.

Obeng, Ocran and Anaba (1993) reports in Journal of Building Research Information that “the brick industry in Ghana has hitherto depended heavily on firewood as the source of fuel for firing. Obeng (1997) also indicates, “in the mid-eighties, the factory had a problem with the supply of firewood to meet it fuel needs cheaply in sufficient quantities in all part of the country”(p.21). It is very difficult to obtain sufficient firewood to support the brick industry.

Firewood was the primary fuel used for clamp or scove kilns. Rhodes (1981) on kiln design and construction reiterats that “The arrangement for burning of wood in a kiln is actually very simple but some principles can be noted. This is because wood requires a relatively large area for burning because of its bulk and long flames this system therefore allows the clamp method of firing with firewood to be built with larger fireboxes and vent holes from the base of the clamp to the top, to allow escape of water vapour and smoke off the clamp. This serves as a chimney in a clamp. The fireboxes are 635mm wide and 750mm high. This allows in sufficient air to enter the kiln for combustion to be effective. The continuous depletion of wood at an alarming rate also calls for other alternate and cheaper fuel source such as palm kernel shells as renewable energy to sustain the brick industry Ghana

2.7 Palm kernel shells as alternate fuel for firing bricks

As part of the danger of wood consumption as fuel by brick factories with vis-à-vis associated environmental problems, research scientists at the BRRI of CSIR developed a technique using both firewood and palm kernel shells as alternate fuel for firing clay bricks (Obeng, et al., 1993). Palm kernel shell is an agricultural waste. The kernel is obtained from the cracked nut of the palm fruit after the oil and the fiber have been extracted. It has a long historical use as fuel for local blacksmiths. They use the pre-burnt palm kernel shells as the fuel supported by an improvised blower from a bicycle wheel connected to a fan belt. The wheel is turned as it blows air into the ignited shells improving combustion.

In researching alternative energy source from the palm waste industry in Malaysia and Indonesia, discovered that shells and fiber alone can supply more steam and electricity than is required. Mahlia, Abdulmuim, Alamsyah and Mukhlishein, (2001). They however state that it is time to look for alternative sources of energy, such as renewable energy, to replace the rapidly depleting supply of fossil fuel. Table 2.3 shows the chemical constituents in the palm kernel shells. The table indicates the different elements and their percentages present in both the fiber and the shells. The purpose of this chemical analysis is to help the researcher to understand the different reactions that will occur during combustion and their effect on clay product. It will also inform the researcher to give other recommendations in the research of glazes using ash obtained from the different parts of the palm fruit.

Table 2.3 Chemical Composition on dry basis of palm oil wastes

Element	**Empty fruit bunch EFB (%)**	**Fiber (%)**	**Shell (%)**
H	6.3	6.0	6.3
C	48.8	47.2	52.4
S	0.2	0.3	0.2
N	0.2	1.4	0.6
O	36.7	36.7	37.3
Ash	7.3	8.4	3.2

Source: Energy Conservation & Management. Vol. 42, issue 18, Dec, 2001

Table 2.4 indicates that, excess air is necessary because it has much effect on the boiler performance. It suggests that, complete combustion can take place only when there is enough oxygen. The principle is, a shell containing 0.472% of carbon will require oxygen of 2.67kg. it is calculated as 0.472 x 2.67 = 1.39908kg of oxygen to burn the carbon present (Mahlia et al., 2001). to give This system has been proven to be effective by the local blacksmith who uses an improvise blower to introduce secondary air into the shell.

Table 2.4. The amount of oxygen required for complete combustion and products for combustion

Element	**O_2 required for combustion of 1kg substance (Kg)**	**Product of combustion**		
		H_2O (Kg)	**CO_2 (Kg)**	**SO_2 (Kg)**
H_2	8	9	-	-
C	2.67	-	3.67	-
CO	0.57	-	1.67	-
S	1	-	-	2
CH_4	4	2.25	2.27	-

Source: Energy Conservation & Management. Vol. 42, issue 18, Dec, 2001

The gross calorific value of fiber alone (H*uf*) is 17,422 kJ/Kg and the gross calorific value of 35% wet and 65% dry fiber is 11,324 KJ/Kg. However, the gross calorific value of shell (H*us*) is 19,462 kJ/Kg. The actual fuel is comprised of 70% fiber and 30% shell (Mahlia et al., 2001). Wood (dry) has a gross calorific value of 14,400 – 17,400 kJ/Kg (http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html. Dec. 2010, 11:30am)

The calorific value is the measurement of the amount of heat or energy produced, and is measured either as gross calorific value or net calorific value. The difference being the latent heat of condensation of the water vapor produced during the combustion process.

Gross calorific value assumes all water produced during the combustion process is fully condensed (the heat contained in the water vapour are recovered). Net calorific value assumes the water leaves with the combustion products without being fully condensed (the heat contained in the water vapour are not recovered) (http://www.altenergy.com/Technology/LPGProperties.htm).

According to http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html, it explains further that:

> The combustion process generates water vapor and certain techniques may be used to recover the quantity of heat contained in this water vapour by condensing it.
>
> The *Higher Calorific Value* (or Gross Calorific Value - GCV) suppose that the water of combustion is entirely condensed and that the heat contained in the water vapor is recovered.
>
> The *Lower Calorific Value* (or Net Calorific Value - NCV) suppose that the products of combustion contains the water vapor and that the heat in the water vapor is not recovered. (Dec. 2010, 11:16am)

This study therefore provides enough data to substantiate the efficiency of using palm kernel shells as alternate fuel for the brick industry.

2.7.1 Methods of firing bricks in a clamp with palm kernel shells

There are two methods of firing a clamp with palm kernel shells. They include:

- Splints of firewood are placed at the entrance of the fireboxes and then lit with palm kernel fiber (Mmefe). The fireboxes are gradually fed with firewood and palm kernel shells. Firing is completed after 96 hours. The fireboxes are closed with bricks to allow the heat built in the kiln to soak for another 24 hours. It is allowed to cool for another 96 hours before it is opened. On the average, it is estimated that, a clamp takes days from firing to cooling it is ready for use.

- Another method of using the palm kernel shells as fuel is by spreading the shells in-between the bricks during packing. The fireboxes are then fed with splints of firewood till the shells in the packed clamp reaches a flash point of around 150°C. Firewood is fed into the fireboxes to support the palm kernel shells which are already burning.

Obeng's (1997) comparative study on firewood and palm kernel shell clamp method of firing indicates that bricks fired with palm kernel shells have higher compressive strength and low water of absorption than bricks fired with firewood as shown in Table 2.5. Firing with palm kernel shells have better brick yield in terms of well-fired than those fired with firewood as seen from Table 2.6. The study shows that there are promising prospects for using palm kernel shells as alternative fuel for the firing of clay bricks in a clamp kiln.

Table 2.5. Water of Absorption and Compressive Strength of Bricks

Sample	**%Water Absorption (Av)**	**Av. Compressive Strength**
Palm Kernel Shell	1.1	6.9
Firewood	14.6	6.3

Source: Obeng in Bi-annual Journal of the Building and Road Research Institute vol.9. Jan – Dec 1997

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Table 2.6. Statistics of Bricks Fired

Type of fuel	Weight of fuel tonnes	Total No. of Bricks fired	No. of under-Burnt Bricks	% of Burnt Bricks	No. of Well-Burnt Bricks	% of Burnt Bricks	No of Broken Brick	% of Broken Bricks
Palm Kernel Shell + Firewood	4.0 1.0	11,910	580	4.9	11,230	93.4	100	0..8
Firewood	8.0	12,080	838	6.9	11,114	92.0	120	1.1

Source: Obeng in Bi-annual Journal of the Building and Road Research Institute vol.9. Jan – Dec 1997.

This study shows that, Increase utilization of palm kernel shells as fuel for brick production could reduce environmental problems as shells do not compose. This therefore gives the researcher the hope that the construction of a palm kernel shell downdraft kiln will provide an alternate firing method for brick factories in Ghana. The next chapter discusses the methodology adopted for this study.

CHAPTER THREE

METHODOLOGY

3.1 Overview

This Chapter work deals with topics such as the Research Design, Library Research, Population, Sampling and what Purposive Sampling is. Other topics that will be dealt with will include: Instrumentation, Validation of Instruments, Administration of the Instrument, Primary and Secondary Data, Materials Test and Methods, size and dimensions and the construction steps of the downdraft kiln.

3.2 Research Design

The research design used was quasi-experimental with a qualitative research approach. According to Denzin and Lincoln (2000), "qualitative research involves an in-depth understanding of human behavior and the reasons that govern human behaviour." (p.2). It can best be explained as investigating the why and how of decision-making as compared to what, where and when of qualitative research." According to Lofland and Lofland (1984), "The simplest definition for qualitative research is to say, collection and analysis of data that are non-quantitative." In this study the qualitative research involves testing of the efficiency of palm kernel shells as fuel for firing bricks.

Quasi-experimental does not meet all requirements necessary for controlling or influencing extraneous variables as in pure experiment (Leedy and Ormrod, 2005). The research was quasi-experimental because the effect of heat on brick is difficult to determine in the kiln during firing.All the investigation must be done in qualitative terms and there should not be any manipulation of variables to achieve any result. The qualitative research employed in this study required the researcher to stay in the setting for a time and be partially involve in the firing methods in the various industries.

3.2.1 Characteristics of Qualitative Research Method

http://en.wilipedia.org/wiki/qualitativeresearch describes the nature of qualitative research as:

- It implies an on-going analysis of the data.
- Qualitative design incorporates room for description of the role of the researcher as well as description of the researcher's own biases of ideological preference.
- Qualitative design is focused on understanding a given social setting, not necessarily on making prediction about that setting.
- Qualitative design demands that the researcher stays in the setting over time. The reason for using qualitative research to describe the construction of the downdraft kiln is because, the description and construction of a kiln does not need the manipulation of variable and most answers were already inherent in the principles and design of kiln construction. There were some instances where quantitative research was necessary to achieve results of certain tests done at the laboratory.

However, qualitative approach was used in the discussion and analysis of results in a descriptive form.

3.3 Population for the Study

Sidhu (2003) explaines population as the aggregate or totality of objects or individuals regarding which inferences are to be made in a sampling study. For the purpose of this research, the criteria for the selection of the population were based on:

- The respondent should be a Factory manager or Foreman.
- A 'Fireman' with a working experience between 6months to 1year.
- The respondent should be a Ceramic Lecturer, Technologist, Research Scientist or a Technical Staff in the area of study.

3.3.1 Target population

The target population for the study were

- 3 Kiln Experts
- 8 Firemen
- 2 Technicians
- 4 Factory Managers
- 3 Technical Officers

3.3.2 Accessible population

The accessible population were;

- 2 Kiln Experts
- 4 Firemen
- 2 Technicians
- 2 Factory Managers
- 2 Technical Officers

3.3.3 Sampling Technique

The use of purposive sampling technique was employed for the study owing to the fact that, the researcher will like to solicit information from the Manufacturers of Bricks in Kumasi does not necessarily mean that information will be collected from each and every person in the Industry or the Factory visited. Therefore, there was the need to use purposive sampling method to gather those information.

3.3.3.1 Purposive Sampling

Morse (2001) wrote on the nature of qualitative evidence in purposive sampling as:

> Purposive Sampling in qualitative inquiry is the deliberate seeking out of participants with particular characteristics, according to the needs of the developing analysis and emerging theory. Because, at the beginning of the study, the researcher does not know enough about a particular phenomenon, the nature of the sample is not always predetermined. Often, midway through data analysis, the researcher will realize that he or she will need to interview participants who were not envisioned as... (p.192.)

Purposive sampling starts with a purpose in mind and the sample is thus selected to include people of interest and exclude those who do not suit the purpose. This method of sampling is indicative that, those in the selected fields for the study can provide the researcher with the information needed. (Patton, 1990) stated that, purposive sampling method was employed in this research because the various sampling units had something in common. For example, the Managers of selected brick factories had similar experience that those in the Lecturers and Research Scientists in the various institutions such as the Ceramic Department at Kwame Nkrumah University of Science and Technology (KNUST).

3.4 Data Collection Instruments

The research tools that the researcher employed to elucidate relevant information are interviews and observation

3.4.1 Interview

Cohen and Manion (1994) state that, "An interview occurs when a respondent is asked questions that have been designed to elicit a particular type of information." The research interview has been defined as two person conversation initiated by the interviewer for the specific purpose of obtaining research-relevant information. In interview, the investigator gathers data directly from others in face-to-face contact instead of writing the responses; the interviewee gives the needed information in a face-to-face relationship. Interview is unique in that in involves the collection of data through direct verbal interaction between the interviewee and he interviewer McMillan and Schumacher (1993). It requires the actual physical proximity of two or more persons and generally requires that the normal channels of communications be open to them.

3.4.1.1 Importance of Interview

- People are usually willing and less hesitant to talk than to write especially on delicate and confident topics.
- It is particularly appropriate when dealing with infants, young children, illiterates those with language difficulties and those with limited intelligence.
- It permits the investigator to follow up leads and take advantage of small clues in complex material where the development is likely to proceed in any direction.

3.4.1.2 Structured and Unstructured Interview

The structured interview is one in which the content and procedures are organized in advance. This means that the sequence and wordings are determined by means of a schedule and the interviewer is left little freedom to make modification. Non-structured interview is a more causal affair, for in its own way, it also has to be carefully planned. They are flexible, few restrictions are played on the respondent's answer even if pre-planned question are asked; the queries altered to suit the situation and subjects.

3.4.1.3 Conducting an interview

A good interview is more than series of usual question and generalized reply. It is a dynamic interpersonal experience that is carefully planned to accomplish a particular purpose creating a friendly permissive atmosphere. Directing the conversation in the desire channel, encouraging the respondent to reveal information and motivating him to keep presenting useful facts require a high degree of technical shell and competence.

3.4.1.4 Advantages of Interview

- It is especially advantageous over a questionnaire in a sense that percentage of response is likely to be much higher than in the case of questionnaire.
- In interview, the investigation can create a right type of friendly atmosphere which is very conducive for obtaining desired data.
- It permits even change of ideas and information
- It is by far the only method used with some categories of persons like young children, illiterate persons with limited intelligence and those with abnormal state of mind.

In this study the reasons for choosing interview was based on:

- Some of the people interviewed have had no formal education and would find it difficult to read and write.
- They were willing and more prepared to talk while they work because of their limited time at the factories.
- Some of the questions needed to be probed further in order to get the answers.

3.5 Observation

Observation seeks to ascertain what people think and do by watching them in action as they express themselves in various situations and activities. Observation is recognized as the most direct means of studying people when one is interested in their overt behaviouir. It is a natural way of gathering data. Observation is not haphazard or unplanned. On the contrary, observation as research instrument must always be directed to specific purpose, systematic, carefully focused and thoroughly recorded. The researcher had to visit some selected brick industries in Kumasi and observe their method of firing, firing duration, cooling and effect of heat on the bricks after firing.

3.5.2.1 Types of observation

- Structured and unstructured – the observations wide and unstructured in the early stage: it get restricted and structured as the investigation proceeds.
- Participant and Non-participant observation – In participant observation, the observer works his way into the group he is to observe so that as a regular member, he is no longer regarded as an outsider against whom the group needs to guide itself. In non-participant observation, the observer remains aloof from the group.

In this study the researcher visited his employers brick and tile factory at BRRI in Kumasi and participated in the firing process in other to help him prepare his observational guide well. The observational guide employed by the research is shown is appendix two.

Administration of Instruments

Sample interview guide checklists were administered on colleague staff at the Building and Road Research Institute factory at Aprade, Kumasi. Respondents which include two factory managers were asked on their method of firing, the type of fuel used and the quality of bricks after firing.Questions were asked from some selected respondents at Mfensi casually to allow respondents express their unalloyed view about the whole production processes. After the researcher had validated the checklist for the interview based on preliminary interviews, appointment was scheduled with the various respondents. Interviews were expedited with speed since it was basically in a form of discussion.

The use of observation as part of data collection instrument was purely participatory and direct. Firing processes for instance were observed at some factories from start-to-finish to access the various processes and conditions that brick factory workers under-go to achieve a desire results.

3.6 Materials for kiln construction.

Four clay samples were selected from Mfensi, Mankranso, Kenyasi and Tanoso for the study as shown in figure 3.1. The following sections describe the types of clays that were used for the project. These materials were selected for the production of insulating bricks for the interior lining of the kiln. Sieved sawdust of varied sizes was used as the combustible material in the clay to give it pores. Most of the insulating properties in insulating bricks are due to the presence of entrapped voids in the structure.

The equipment employed include jaw crusher, pulverizer, electric kiln, sieve, container, measuring tape, venire caliper, measuring cylinder, weight balance, electric oven and thermocouple. There was no available apparatus to check the thermal conductivity of the material.

3.6.1 Clay

Mfensi clay

The clay sample is grey plastic and is deeply weathered from igneous or metamorphic rocks found in the humid zone of Ghana. Mfensi in the Ashanti Region lies about 24 km west of Kumasi - Sunyani road. The clay deposit, lying along Offin River covers an estimated area of 110,860 m2 with an average thickness of 2km and 0.2 over-burdens.

Mankranso clay

The clay sample was obtained from mankranso in the Ashanti Region; 36 km form Kumasi on the Kumasi-Sunyani road. The clay is derived from the weathering of the lower Birimian (middle Precambrian). Phyllite and is grayish in colour. The deposit area is drained by the Mankran River and has a proven reserve of about 1million m^3 with an overburden thickness of less than 0.2 m

Tanoso Clay

The third clay sample was at Tanoso, a village 19 km east of Sunyani on the Kumasi-Sunyani road in the Brong-Ahafo Region. The rocks in the area belong to the Voltarian Formation. The clay deposit is the residual product of the weathering of siltstone and shale in sandstone. It is brownish red in colour. The area is drained by the Tano River and extends laterally by about 49.053 m^2 with an average thickness of 1.2 m and 0.1m overburden (Kesse, 1985).

Kenyasi Fireclay

This is a white fireclay (Refractory) which runs through the Antoa, Abirim and Busori stretch in Kumasi, Ashanti Region. This site has no data from the Geological Survey Department of Ghana. It is a newly discovered clay deposit. Further works can be carried out to ascertain its commercial quantities for the production of Industrial Ceramic Products. XRF conducted by Geological Survey Department indicated the various elements that makes them refractory and therefore, suitable for use in the firebrick body composition. Among the various clay samples collected, it was Kenyasi fireclay alone that had no data and field work done to verify its chemical composition. Table 3.1 shows the chemical composition of Kenyasi fireclay and their various element constituents.

Table 3.1. Chemical composition of Kenyasi Fireclay conducted at the Geological Survey in Ghana

Kenyasi Fireclay Constituents (%)								
Elements	**SiO_2**	**Al_2O_3**	**FeO_3**	**MgO**	**SO**	**CaO**	**LOi**	**Others**
%	49.57	19.43	2.65	1.30	0.23	2.17	19.00	5.65

Source: Fieldwork at Geological Survey, Accra (2010).

Topographical and Geological Setting of Study Area

This shows the location of the study areas referred to Mn as Mankranso, Mf as Mfensi, Kn as Kenyasi and T as Tanoso.

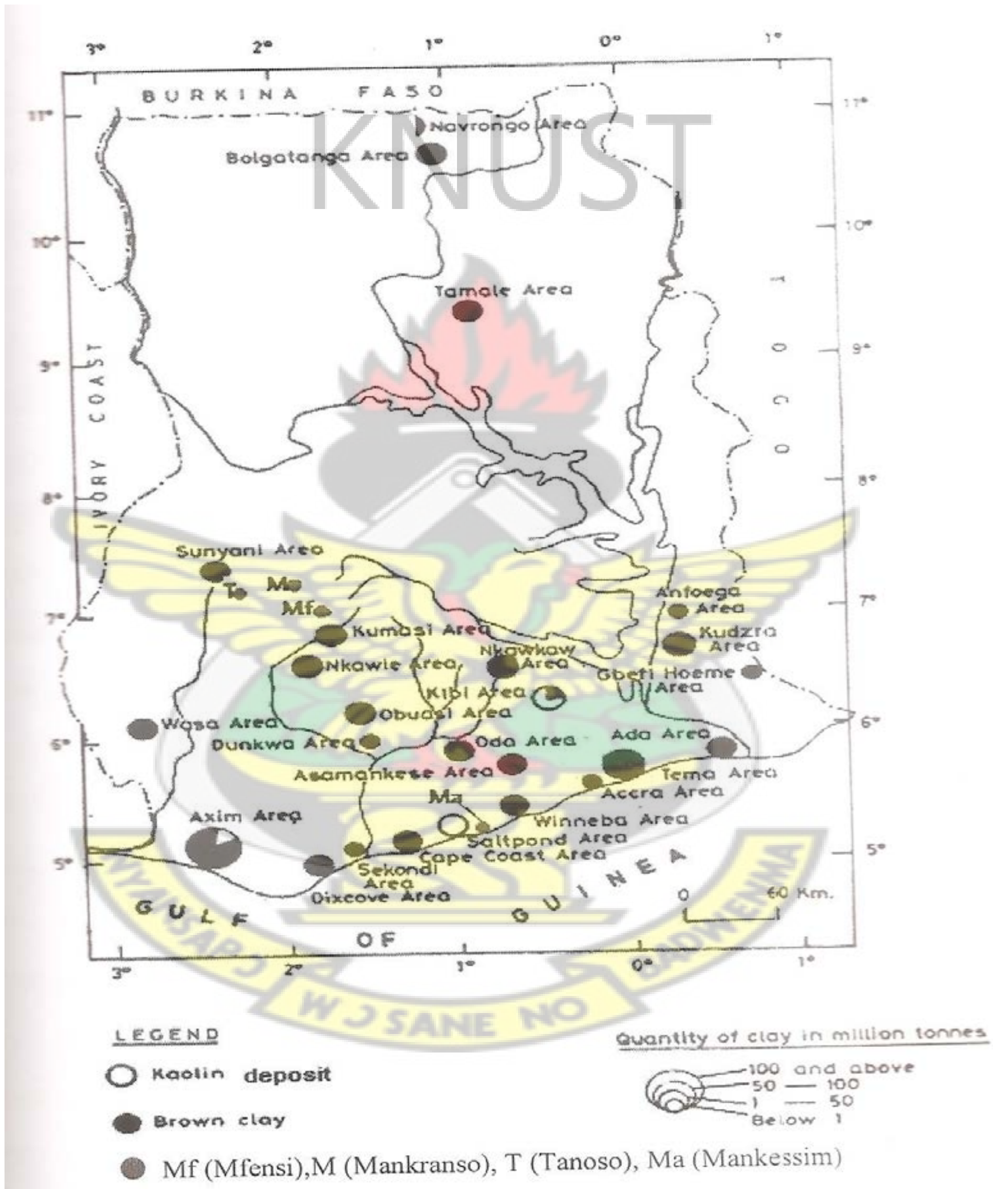

Figure 3.1 Map of Ghana showing clay deposits.

Source: Kesse, (1985).

3.6.2 Other materials used

Sawdust

Sawdust is composed of fine and coarse particles of wood. It is a by-product of cutting lumbers with a saw, hence its name. It can present a hazard in manufacturing industries, especially in terms of its flammability and creating environmental hazards., Sawdust is abundant in every part of the country where there is either a sawmill or a carpentry workshop.

Ceramic Fibre

Ceramic fiber (alumina silica) is one of the special refractory materials used for kiln construction. Olsen (2001) stated that, "their main purpose is to provide insulation up to 1260^{o}C but with a melting point of 1785^{o}C". Rhodes also emphasized that, "the ceramic fiber materials have the advantage of extremely low thermal conductivity and of being lightweight". Other insulation materials include fiber blankets and boards.

Angle iron and Metal plates

An angle iron size of 63.5mm x 63.5mm was used for the kiln frame-work. Galvanized metal plates were also used for the kiln doors which includes other accessories for the door.

3.7 The Production of Insulating Firebricks Test Specimens

Insulating firebrick consisting of Kenyasi fireclay, plastic clay and sawdust, were produced using the following processes:

- Refined fireclay and plastic clays were crushed and ground separately, and stored in respective labeled dry plastic containers. The sawdust was screened and examined to ensure that no other foreign material such as pebbles existed in the mass. It was ground and carefully sieved using a mesh of size 30, and also stored in a labeled dry plastic.
- Three different samples were measured at different percentages and prepared with varying percentage proportions of sawdust. Within each sample, subsequent three different batch compositions were prepared. Eighteen samples were prepared for this sample testing.

Wooden moulds of internal dimensions (75 × 35 × 15) mm were used for hand-moulding of the bricks. Test specimens were formed according to the composition of the mixture. The moulded mixtures were left to dry in the atmosphere, and thereafter, they were dried in an oven at 105°C. Table 3.2 shows the individual clay samples prepared by introducing only sawdust to them. This was to identify their workability when used alone without a mixture of clays.

Table 3.2. Single clays with Sawdust samples (Total weight = 1500g)

Sample Code / Batch No	**Kn (Fireclay)**	**Mf (Plastic clay)**	**Mn (Plastic clay)**	**Tn (plastic clay)**	**Sawdust**
A_1	-	1350	-	-	150
A_2	-	1200	-	-	300
A_3	-	1050	-	-	450
B_1	-	-	1350	-	150
B_2	-	-	1200	-	300
B_3	-	-	1050	-	450
C1	-	-	-	1350	150
C_2	-	-	-	1200	300
C_3	-	-	-	1050	450

Source: Fieldwork at KNUST Ceramics Laboratory, (2010)

The dried bricks were finally fired in an electric kiln at temperatures of 900°C, 950^{o}C and 1050^{o}C. The various firing process were done at the Ceramic Department. The firing process caused the burning out of the sawdust in the finished bricks. The initial, original, fired, dried, and wet lengths and dry weights were noted and recorded. The second table 3.3 shows a body composed by mixing the different soil samples at different percentages.

Table 3.3 Body Composition of Brick samples by weight (Total weight = 1500g)

Sample Code/ Batch No	**Kn (Fireclay)**	**Mf (Plastic clay)**	**Mn (Plastic clay)**	**Tn (plastic clay)**	**Sawdust**
A – 1	450	900			150
A – 2	450	750			300
A – 3	450	600			450
B– 2	450		900	-	150
B – 3	450		750	-	300
C –1	450		600	-	450
	450			900	150
C – 2	450			750	300
C - 3	450			600	450

Source: Fieldwork at Ceramic Laboratory-KNUST, (2010).

3.8 The Downdraft Kiln Design and Dimensions

The size of the downdraft kiln was calculated based on the volume. This was to enable the research the stack area and the volume of products it can take. The volume of the constructed kiln excluded the fireboxes and baffle wall. The kiln volume was calculated as 109.2mm` (length) x 76.2mm (width) x 127mm (height). This is equal to $1.83m^3$ as shown in figure 3.2. There was lack of funding therefore, there was the need to construct a kiln that will suit the budget. The exterior walls are excluded from the calculation because, the walls are constructed with both Red Bricks and insulating bricks which vary in sizes and thickness. Beside this, it does not include the stacking area. The downdraft kiln was constructed in a rectangular structure from angle irons and metal mesh.

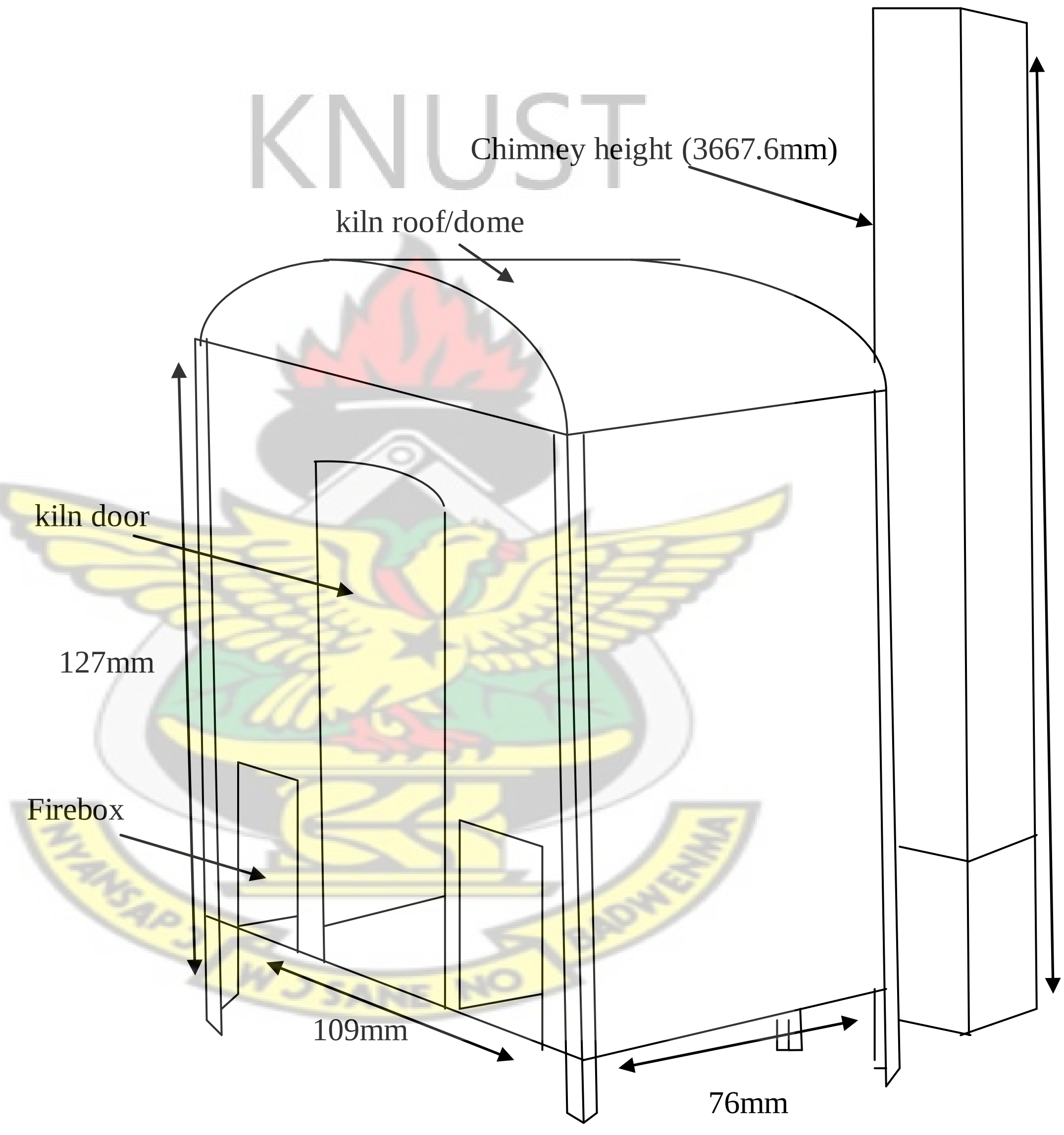

Fig. 3.2 Downdraft kiln design, dimensions and labelling.

Plate 3.3 A view of the kil construction

3.11 Frame and Floor Construction

The frame of the kiln was first constructed by welding together four (4) pieces of 63.5mm "thick angle iron, four (4) piece 0.375mm iron rods and a 0.25mm rod mesh. The four (4) pieces of 63.5mm angle iron were used for the 'legs' of the kiln with the other four pieces of 76.2mm rod were used to brace the shoulders to hold the structure in place from future thermal collapse. The legs were 300mm higher from the concrete floor (see plate 3.3). This was to make it portable. The scrap metal mesh was welded to the legs to serve as the kiln floor or foundation.

Plate 3.4a Arrangement of Kiln foundation on a metal mesh.

Plate 3.4b Arrangement of Kiln foundation on a metal mesh.

3.12 Arrangement of Red Bricks in the Kiln Frame

The red bricks were laid in a stretcher course (plate 3.4). This implies, they are laid lengthwise across the wall with the 63.5mm x 228.6mm surfaces becoming the hot face side as shown in the above plate. Olsen (2001) explained that, “All stretcher walls are not rigid and are not recommended for over 3 feet (914.4mm) in height unless it has other means of support." This is why it was mandatory for the researcher to brace the whole structure and lay the bricks in the metal frame. Four bricks were laid from the metal mesh (base) to serve as the kiln floor (interior) which leads into the draft area which is three (3) bricks from the floor. The purpose of using the red brick for the exterior wall is because of it resistance to the weather and can serve as the kiln was without necessarily covering it with metal sheets.

3.13 Draft and Flue construction

As downdraft kiln that is going to be fired with the aid of a blower as a secondary source of air, it is important to design the flue (or draft) area bigger, not less than the length of a brick. This principle allows in the easy escape of vapour and smoke without been trapped in the chamber. The foundation of the chimney was raised with sandcrete blocks and filled with stones and sand to make it stronger and withstand the weight and height of the chimney from structural collapse which may be affected by storm and excessive heat built-up.Plate 3.7 shows the height of the chimney with the base laid from the ground to support the height.

Plate 3.5 Flue and Draft Construction.

The base of the chimney was constructed with two brick wall thick to improve stability. For the draft to be effective, the base was tapered at an angle of 45^{o} to increase the rate of heat-flow through the chimney. The interior dimension of the chimney was 228.6mm x 228.6 in a cross section with a height of 3667.6mm (12 feet). A damper (plate 3.6) was also created in-between the kiln and the chimney. It helps the control on oxidation and reduction atmosphere in the kiln. Finally, it retains heat in the kiln during soaking of wares (plate 3.7).

Plate 3.6 The damper

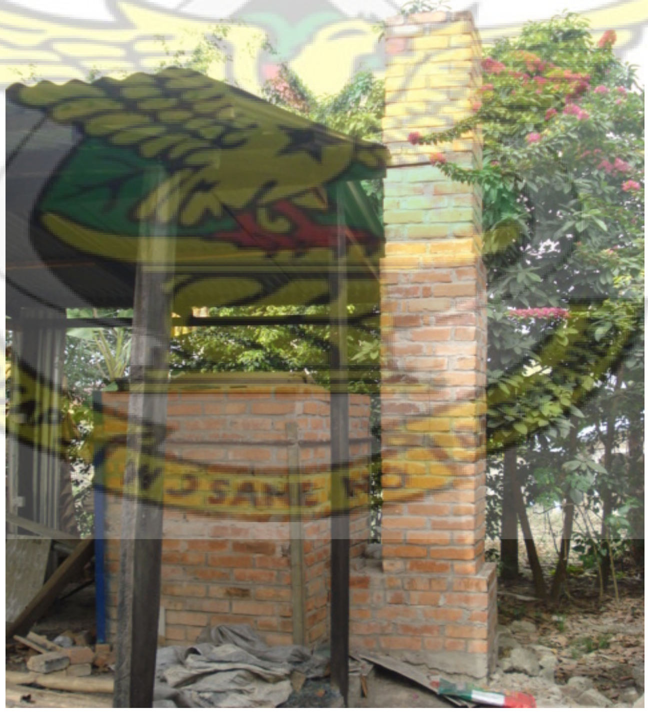

Plate 3.7 Construction of Chimney

One of the purposes of this research was to adopt the use of palm kernel shells as fuel in the heavy clay industry. It was therefore important to take note of the construction of the inlet flue areas (fireboxes) where fuel will be introduced into the kiln.

Plate 3.8: setting out the firebox

Plate 3.9: Construction of firebox (inlet flue)

The fireboxes were laid in header courses with an interior dimension of (228.6 x 228.6 x 127) mm (plate 3.10).

Plate 3.10 Header course

3.14 Insulating the Kiln

The kiln was insulated with three different materials; insulating firebricks, ceramic fiber and fine sand. The insulating materials were used for four important areas, the walls (hot face), the floor, kiln door and the dome (roof). These areas are considered the hot facing areas of the kiln. From the above plate, it can be observed that, the ceramic fiber was used in-between certain parts of the floor and the walls (plate 3.11).

Plate 3.11 Insulating the floor

They were used to create expansion joints. Although, they could be avoided since the kiln was constructed within a metal frame, it was also necessary to avoid the unexpected in the future. The kiln walls were also lined with insulating bricks and were laid in rowlock course, where bricks are laid on their sides (63.5 x 228.6) mm. A space of 0.25mm was left in-between the red brick and the insulating brick. These spaces were filled with fiber and sand to improve insulation.

Plate 3.12a. Insulating the kiln back-up wall

Plate 3.12b. Insulating the kiln back-up wall.

3.15 Construction of the Kiln Roof

The construction of a kiln roof is done in an arch form; either straight or sprung (dome) suspending on a skewback. After the external and the internal walls were laid to the lintel, a skewback (a structural member which is at an angle of 45^o or 105^o where the stress of he arch to the supporting walls and to the framework) was created. It also provides a support for the span of the arch without collapsing.

3.16 Design and construction of the Kiln Door

The door was made from galvanized metal sheet, insulated with firebricks, ceramic fiber and 63.5mm angle irons. The frame was cut according to the size of the door which was 914mm x 1219.2 mm. The angle irons were welded together in a 'U' shape and lined with the ceramic fiber. The insulating bricks were finally laid interlocking within the frame. This is shown in figure 3.2.

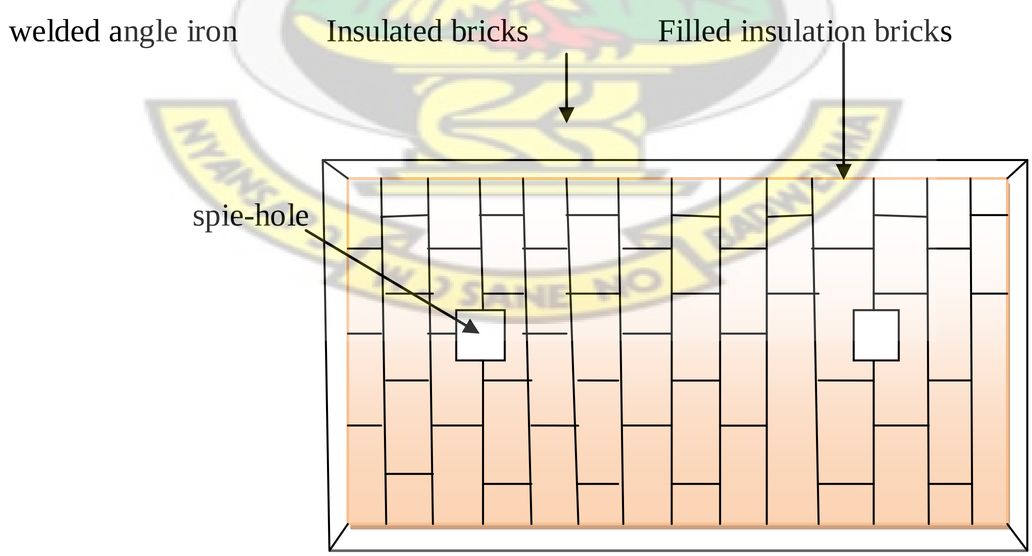

Fig. 3.2 Sketches of kiln door and labelling

Plate 3.13 Kiln Door with Spy holes

The spy-holes were created at the top and the bottom of the door (plate 3.13). The function is to view the interior of the kiln during firing in other to have an idea of what is going on in the kiln. It was difficult to create a spy-hole around either the dome or sides where thermocouple can be inserted. The walls were 304.8 mm thick, almost the length of the K-type thermocouple. It was therefore ideal to create a dent in the spy-hole on the door where the measuring instrument could be slotted in other to read the temperature during firing.

3.17 Data Analysis Plan

In the next chapter, data from the study were assembled, analyzed and interpreted. Conclusions were drawn and recommendations made. The working efficiency of the kiln and fuel were also tested, analyzed, interpreted and described in chapter 4.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF FINDINGS

4.1 Overview

The major problem facing the brick industry in Ghana is the unavailability of cheaper and constant source of fuel. This adversely has affected production cost and raised the cost of burnt clay bricks. Moreover, the firing of large quantity of bricks has also been a problem for most factories. There is a lack of access to cheaper fuel and inefficient methods of firing which allows a lot of heat loss.

The use of the clamp kilns has been the most rudimentary method of firing large quantities of bricks by stacking them in a pyramid structure. As the commonest method of firing bricks in Ghana, it still has several advantages over most of the modern and sophisticated means of firing yet the clamp is potentially the most inefficient method of firing because, much heat is lost through the walls by radiation and conduction. Cooling and fuel combustion is also difficult to control once the clamp is lit.

Brick clamp though can be made moderately efficient but they cannot be compared to a downdraft kiln as far as fuel per brick and brick wastage is concerned. It was deemed necessary to construct a palm kernel shell downdraft kiln to support the brick industry. The objective was to use local raw materials for the construction and employ the use of palm kernel shells as an alternate fuel to firewood and fossil fuel.

This chapter discusses the data collected from the composition of fireclay insulating bricks and the construction of the palm kernel shell downdraft kiln in tables and in descriptive form. It analyses the data, interpret them, draw conclusions and make recommendations.

4.2 Testing methods of the Insulating Firebrick Specimens

Tests were carried out on the bricks samples to determine their shrinkage at certain temperatures. Shrinkage test results calculated for each test specimen using the following formulae are stated below.

$$\%\ \text{Average Drying Shrinkage} = \frac{\text{OriginalLength} - \text{DryLength}}{\text{OriginalLength}} \times 100\%$$

$$\%\ \text{Average Firing Shrinkage} = \frac{\text{DryLength} - \text{FiredLength}}{\text{DryLength}} \times 100\%$$

$$\%\ \text{Total Shrinkage} = \frac{\text{OriginalLength} - \text{FiredLength}}{\text{OriginalLength}} \times 100\%$$

$$\%\ \text{Volume change} = \frac{\text{OriginalVolume} - \text{FinalVolume}}{\text{OriginalVolume}} \times 100\%$$

Source: Ceramics Laboratory

The purpose for testing the shrinkage of the materials was to identify their resistance to thermal expansion at different temperatures. For example, clays with high shrinkage values which are used for kiln construction will cause cracks by expand when fired at high temperatures.

The results obtained from the shrinkage tests are presented in Tables 4.1.

Table 4-1. Shrinkage values at various temperature regimes

Sample code	**Original length (cm)**	**Dry length (cm)**	**Fired length (cm)**	**Dried shrinkage %**	**Fired shrinkage %**	**Total shrinkage %**	**Temperature (°C)**
A_1	6	5.82	5.79	3.0	0.512	3.5	900
A_2	6	5.85	5.80	3.0	0.855	3.33	950
A_3	6	5.88	5.85	2.0	0.510	2.5	1050
B_1	6	5.86	5.74	2.0	2.048	4.3	900
B_2	6	5.88	5.82	2.0	1.020	3.0	950
B_3	6	5.95	5.90	0.83	0.840	1.67	1050
C_1	6	5.82	5.75	3.0	1.202	4.16	900
C_2	6	5.85	5.80	2.5	0.855	3.33	950
C_3	6	5.90	5.82	1.667	1.356	3.0	1050
A-1	6	5.82	5.78	3.0	0.69	3.67	900
A-2	6	5.86	5.82	2.33	0.34	3.0	950
A-3	6	5.90	5.86	1.66	0.678	2.33	1050
B-1	6	5.84	5.82	2.667	0.342	2.67	900
B-2	6	5.90	5.88	1.667	0.34	2.0	950
B-3	6	5.98	5.94	0.33	0.669	1.0	1050
C-1	6	5.83	5.80	2.833	0.515	3.33	900
C-2	6	5.86	5.81	2.33	0.899	3.17	950
C-3	6	5.88	5.83	2.0	0.85	2.5	1050

Source: Fieldwork, 2010.

4.2.1 Interpretation of shrinkage test results

At 900°C, sample C_1 showed the highest shrinkage value of 4.16%, while sample B-1 showed the lowest value of 2.67%. Sample C_2 shows the highest shrinkage value of 3.33% while sample B-2 shows the lowest value of 2.0% at 950 °C. At 1050°C, sample A-3 showed the highest value of 2.33% while B-3 showed the lowest shrinkage value of 1.0% at a temperature of 1050°C. It can be said that the higher the percentages of sawdust and Kenyasi fireclay, the lower the shrinkage results.

The amount of sawdust and Kenyasi fireclay affects the shrinkage of the insulating bricks. The sawdust increases the pores formed within the samples and thereby making it poor heat conductor and ideal for backup insulation (Onche, Ugheoke, Lawal, and Martin-Dickson, 2007).

4.3 Kiln test firing using palm kernel shells as fuel

Test firing was conducted to verify the efficiency of the palm kernel shells in a downdraft kiln with the aid of a 3 horse power (single phase) electric blower to introduce secondary air into the kiln. Two perforated galvanized pipe were connected to the mouth of the blower (FD fan) perforated from one end to the other. The perforations allow air into the kiln chamber to facilitate combustion within the fireboxes.

4.3.1 Test firing

The kiln stacking capacity was 300 pieces of bricks. Firing started at 6:51am with a small amount of charcoal arranged at the entrance to the firebox area. The blower was also started to facilitate combustion. Palm kernel shells were gradually spread over the perforated galvanized pipe which is designed to throw out the air and burn the hot shells.

Pre-heating

Palm kernel shells were spread over the galvanized pipe and pushed gradually into the kiln as the temperature r

rose. At 7:45am, water vapour started coming out through the chimney and areas with openings such as the opened spy holes at a temperature of 95^{o}C. Temperature in the kiln rose steadily as the shells were shoveled into the firebox or flue at increased intervals.

Dehydroxylation and Decomposition

The water vapour ceased coming at 9:05am at a temperature of 400^{o}C with smoke coming out of the chimney instead of vapour. The amount of shells was increased in order to raise the temperature as the firing material goes through decomposition with the release of carbon mono-oxide.

Phase Changes (Quartz inversion and conversion)

There is a phase change in silica which happens to clay during firing at 573^{o}C. The change from alpha (α) quartz or "low" quartz to beta (β) quartz which happened at this temperature, started at 11:00am. Although studies have shown that this temperature is reversible, it was necessary to maintain a steady temperature for a while. There is a separation of silicon and oxygen atoms while maintaining the same spatial arrangement or crystal structure at this temperature called, "inversion" (Brosnan, 2004). At 573^{o}C,the volume of the firing clay product increases by 2% making it very delicate to raise the temperature so fast. The sudden increase in temperature may cause cracks. Temperature at this stage is endothermic; the material absorbs a lot of heat energy.

Temperature at 573^{o}C began to fluctuate at this point as it dropped and rose, a state that is labeled as sluggish inversion. Constant shoveling of shells was necessary to maintain the temperature for a period of 30 minutes and one hour before exothermic (where energy is given out in the form of radiation) was reached at 700^{o}C. Sudden rise in temperature could affect the structural arrangement and cause expansion and cracks. It was necessary therefore to slow down the amount of fuel introduced into the fireboxes.

Full blast and Soaking

At 11:30am when the temperature was approximated 650^{o}C, the atmosphere in the kiln became very dark and gave out obnoxious gas be in the form of carbon mono-oxide.

Exothermic temperature started at 700°C. At this temperature, continuous palm kernel shells were fed into the firebox and the atmosphere began to glow till it became red hot at 950°C. A maximum temperature of 950°C was reached at 12:45pm. Firing was ended at an approximately six hours later.

4.4 Observations during and after firing

Observations were made in and around the kiln to check possible defects in the kiln construction and firing aftermath. They were:

- Bricks packed close to the muffle or bag wall became glazed and showed and cracks (as in plate 4.10).

Plate 4.1 Bricks close to the firebox area

- Three different types of bricks were identified as fired brick, under-fired (salmon brick which are more porous, slightly larger, and lighter colored) as seen in Plate 4.2 and over-fired brick (generic term as clinker brick whose shape is distorted or bloated due to nearly complete vitrification) as seen in Plate 4.3 and well-fired brick (Plate 4.4).

Plate 4.2 Under-fired brick (Salmon brick)

Plate 4.3 Over-fired brick (clinker brick)

Plate 4.4 Well-fired brick

- Excessive carbon was observed emitting from the chimney anytime palm kernel shells were shoveled into the fireboxes. This suggested that, laterite and fibre on the palm kernel shells has to burn-off before the kernel shells began to ignite.

4.5 Physical analysis of Firedbricks

Table 4.2 shows the different water of absorption and compressive strengths test done on the sample bricks fired in the downdraft palm kernel shell kiln. Four different samples were selected and tested as they show different values. Table 4.2 is based on compressive strength and water of absorption test done on bricks selected from four different locations in the kiln. The side wall brick showed the lowest water of absorption with a value of 4.5% whereas the brick from the bottom of the kiln showed the highest water absorption value of 16.5%. This means the bottom brick achieved the lowest compressive strength of 10.0 and 18.0% as the highest value for the top brick close to the roof of the kiln.

Table 4.2 Physical test of sample bricks fired with palm kernel shells

Samples	%Water Absorption (Av)	Av. Compressive Strength
Top	10.6	18.0
Middle	12	13.2
Bottom	16.5	10.0
Side wall	4.5	12.5

Source: Fieldwork , KNUST Engineering Department.

This shows that although firing bricks with palm kernel shells can be effective it is important to incorporate the three mechanisms in heat transfer system. The mechanisms are conduction, convection and radiation.

Conduction involves the transfer of heat through solid therefore, the thickness of the brick affects the transfer of the heat from one end to the other. Convection is simply the transfer of heat through space. The heat introduced into the kiln requires spacing of bricks during packing to allow easy flow of heat around the surface areas of the bricks. Finally, radiation is the transfer of heat through reflective surfaces.

It can be concluded from the findings of both tests conducted on the fire clay insulation brick samples and the downdraft kiln that locally available raw materials can be composed and used as insulating material for the construction of kilns in the Heavy Clay Industries such as burnt bricks factories. Moreover, the use of palm kernel shells has relatively better firing effects on bricks than firewood as indicated in Table 4.2. Comparative studies as shows in Table 2.6 shows that, palm kernel shells firing have increase brick turn out and better mechanical properties than firewood firing. The environmental problem posed by the palm kernel shells provide an alternate and cost effective way of using it to fire clay bricks. The fuel efficiency of the shells has also encourage other industries in foundry applications, soap manufacturing and oil-mill industries (see Plate 4.5).

Plate 4.5 local refinery site, Ejisu (2010)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

In line with the objectives of selecting local raw materials for the preparation of insulation bricks and the use of palm kernel shells as alternate fuel, a suitable soil was selected for the construction of a downdraft palm kernel shell kiln. Tests shows that a composition of 40% Mankraso plastic clay with 30% Kenyasi fireclay and 30% sawdust was ideal for the production of insulating brick which was used for the interior lining of the constructed downdraft kiln. It was also realized that, Mankraso clay was not too plastic as compared to Mfensi and Tanoso clay shown in the shrinkage tests done on the various samples. This means it will not be appropriate to use Mankraso as a plastic clay as a binder in insulation firebrick preparation. This is because, the other raw materials such as Kenyasi clay, and sawdust are both non-plastic materials.

5.2 Conclusions

The quantities of plastic clay and fireclay to sawdust ratio gave different characteristics to the various samples. For instance, the lower the percentage of sawdust added to the clay body affected the total shrinkage of fired sample. A minimum of 10% sawdust has a relatively higher shrinkage as compared to the same body with an increase in 30% sawdust. This also affected the pores structure of the brick therefore making it suitable for use in the production of insulating firebrick for kiln construction and other foundry applications.

Analysis from samples with code B_3 and B-3 which represents a combination of 70% Mankraso ball clay with 30% sawdust and 40% Mankraso ball clay, 30% Kenyasi fire clay with 30% sawdust showed a lower percentage with a total fired shrinkage of 1.67% and 1.0% respectively at 1050^{o}C, compared to other body samples with lower percentage of sawdust. The highly porous structure of the insulating fire brick makes them suitable for both back-up insulation of high temperature furnaces at 1600^{o}C and as hot face linings for low temperature kiln of 1200^{o}C. Air which fills the pores act as insulators. However, sample B-3 gave the best results in terms of strength and thermal conductivity based on physical observation and weight. The mixing ratio is suitable for the production of insulating firebrick (IFB) for kiln lining. It is therefore concluded that, the combination of Kenyasi fireclay with sawdust and Mankraso ball clay improved the few properties that were tested for use as insulating material.

The fibre on the shells (Plate 5.2) burns off during firing process giving out a lot of smoke. The laterite (plate 5.1) on the shells too soils the shells during the process of oil palm extraction by the local producers of palm oil. It produces a lot of smoke when it is initially shoveled into the fireboxes. The laterite lowers the temperature and burns-off with the fibre before the kernel starts to ignite. Test firing of the palm kernel shell downdraft kiln was identified with a lot of smoke from start to finish. This environmental pollution was emanated from Fibre and the laterite on palm kernel shells.

Plate 5.1 Laterite use during the separation of kernel from shells through sedimentation

Plate 5.2 Fibre on palm kernel shell

The fibre on the shells (Plate 5.2) burns off during firing process giving out a lot of smoke. The laterite (plate 5.1) on the shells too soils the shells during the process of oil palm extraction by the local producers of palm oil. It produces a lot of smoke when it is initially shoveled into the fireboxes. The laterite lowers the temperature and burns-off with the fibre before the kernel starts to ignite.

The three types of bricks identified after firing with the palm kernel shell downdraft kiln had some over-fired, under-fired and well-fired. It is generally very difficult to identify an under-fired brick. The sound and colour of a burnt brick have always been the parameter for checking the quality of a well-burnt brick. However, it is not always so since people have different 'ears to sound.' Colour has also been a deviating parameter to verify the quality of a brick since that too is relative because, the colour of a brick is affected by the atmosphere in the kiln chamber during firing, it could be either a reduced or an oxidized atmosphere.

An under-burnt brick which was selected from the bottom of the packed fired brick was pinkish-orange in colour very porous, slightly larger, and lighter coloured than hard-burned brick. The under-fired sample bricks showed the highest water of absorption value of 16.5% and with the lowest compressive strength of 10.0%. The brick after immersed in water for 72 hours (3 days) started getting soaked and weaker with the surface muddy when rubbed. This showed the weak nature of the brick and unsatisfactory for building construction.

Over-fired brick or clinker brick as the generic name implies is a very hard-burned brick. It was selected from the layer of bricks very close to the fireboxes or muffle wall. The brick was glazed with its shape bloated and distorted. Bigger cracks were also identified through the large surface area of the brick. It was recorded with the lowest water absorption value of 4.5% and the second minimum compressive strength of 10.5%. The low water of absorption value was due to the over-fired nature of the brick and its partially glazed surface. However, it was noted to be of low strength. This showed that, the strength of a burnt brick is affected by the amount of heat it has been subjected to. Most clay becomes weaker at near-vitrification temperature. This is due to the different melting point of every clay or soil. Some clay vitrifies at a temperature of $850^{o}C$ and others at $1200^{o}C$ and above. This is due to impurities present in the clay mineral such as K_2O, FeO, Na_2O and so on.

A well-fired brick selected from the top of the stacked bricks showed 10.6% as the water of absorption value and 18.0% as the one with the highest compressive strength. This brick considered ideal for construction. It is hard and the surface is resistant to weathering effect when exposed to water or acid such as sulphate. The use of palm kernel shells for firing was cheaper and cost effective. It was very economical to use a sack of 60Kg of palm kernel shells to fire a kiln with a volume of $1.83m^3$, a monetary value of GH¢ 4.00 (Four Ghana Cedis) to achieve a temperature of $950^{o}C$ in six (6) hours. The kiln has a multi-purpose in that, it was used to fire glass in a process known as "warm glass fusing" and the results was remarkable. A temperature of $1000^{o}C$ was reaches in two hours of continuous firing.

Although the constructed downdraft kiln is smaller in this study yet the advantage of a downdraft kiln is the ability to replicate the smallest design and dimensions into a bigger size when the principles of downdraft kiln construction are adhered to.

5.3 Recommendations

Based on the various findings and conclusions drawn, the following recommendations are made:

1. Firing hours coupled with spacing of bricks in the kiln can be increased so that the bottom bricks will be able to attain the required temperature and quality. The spacing will prevent under-burnt and under-fired bricks.

2. Over-fired bricks can be avoided when the firebox and muffle walls are partially covered with insulating firebricks or increased in height to the middle of the kiln. This will prevent the bricks closer to the firebox from direct heat which may cause cracks and glaze on the surface of the brick.

3. Further tests into the physical, thermal and chemical properties based on ASTM C-583, C-133 and D-20 should be further studied. This will provide data on the thermal conductivity of the insulating brick, thermal shocks, density and porosity, and hot modulus of rupture at different temperatures

4. Excessive carbon which poses environmental threat during firing can be reduced by pre-burning the palm kernel shells. This method burns off the fibre leaving the shells as the major fuel. Since the fuel contains larger percentage of fiber, the amount of palm kernel shells for each firing per kilogram could be increased to substitute the initial pre-burning of the fuel.

5. It is recommended that, further studies should be made into the use of other carbonaceous materials such as rice husk and diatomite besides sawdust into the production of insulating fire bricks.

6. The researcher will organize seminars and training programmes for institutions who use kilns to learn alternate methods of firing and efficient ways of constructing kilns using local soils.

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APPENDIXES

APPENDIX 1 – AN INTERVIEW GUIDE

SECTION A: TYPE OF FACTORY

a. Cottage Brick Factory
b. Small Scale Factory
c. Medium Scale Factory
d. Large Scale Factory

SECTION B: QUALIFICATION OF RESPONDENT

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b. Technician
c. Factory Manager/Foreman
d. Research Scientist
e. Fireman/Labourer

SECTION C: METHOD OF FIRING

a. Kiln firing
b. Clamp firing

SECTION D:

Firing efficiency (based on their personal observations and evaluations)

APPENDIX 2: OBSERVATIONAL GUIDE

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a. Hand moulding

b. Extrusion

c. Parry pressing

d. Hydraulic pressing method

SECTION B: METHOD OF BRICK PACKING

a. Open packing

b. Close packing

SECTION C: INSULATING WALL

a. Insulating bricks

b. Red bricks

SECTION D: STAGES OF FIRING/TIME

a. Pre-heating

b. Full-blast

c. Soaking

d. Cooling

SECTION E: BRICKS CHARACTERISTICS AFTER FIRING.

a. Percentage of fired bricks

b. Percentage of under-fired bricks.

c. Percentage of over-fired bricks.

d. Percentage of broken bricks