HEAT RETENTION BODY FOR KILN CONSTRUCTION: A BLEND OF KENYASE ABREM AND TEPA CLAYS

By

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DECLARATION

I hereby declare that this submission is my own work towards the MPHIL 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 acknowledgement has been made in the text.

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ABSTRACT

Attaining high temperature in locally manufactured kilns for bisque and gloss firing in Ghana has been a major challenge for most potters. Due to this challenge, most refractory materials are imported to build kilns for firing ceramics wares to meet modern demands; in most cases potters import electric kilns to fire their products. The cost of acquiring these kilns and refractory materials are very expensive and leads to high cost of production. Over the years, clay workers in Ghana have tried to compose several bodies made of our local raw materials that could serve this purpose but unfortunately these bodies when used for kiln construction are not able to retain much heat to adequate to fire stoneware, porcelain and high temperature glazes. The researcher adopted the descriptive and experiment research method of the qualitative research design to examine, test and produce low-density refractory brick suitable for the construction of high temperature kilns. It was discovered that, Kenyase Abrem and Tepa clays when composed together into a body produces a refractory material that can fire to a temperature between 1300°C (2372°F) and 1600°C (2912°F). It is therefore recommended that, Kenyase Abrem clay being higher in plasticity than Tepa clay, is appropriate for binding the composed body together for producing low-density refractory bricks for kiln construction. Again, the brick made from the composed body when subjected to open porosity test indicating more air pockets in their internal structure that is suitable for retaining heat in kilns to complete a firing process.

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INTRODUCTION

1.1 Overview

This chapter contains the basic underlying structure of the entire project. It includes the background to the study, the problem statement, research objectives, research questions, delimitations, limitations, and definition of terms, Significance of the study and organization of the text.

1.2 Background to the study

Clay body in a general term is a mixture of two or more clays or clays and organic materials or non-ceramic materials which are intended to achieve a specific purpose. Clay bodies have extensively been made and used to achieve several aims and properties one intends to achieve depending on the kind of ceramic or pottery product to be produced or executed. According to Arbuckle (2013) ”clay bodies are formulations of clays, silica, fluxes, and other components to yield specific properties such as colour, texture, maturing temperature, absorption and shrinkage, plasticity, drying and firing properties etc.”. Arbuckle stipulates that, functional bodies are the best if they are durable in internal structure and much vitrified. She further stated that "sculpture clays should be well scooped to ensure even drying of thick walls, and have limited shrinkage". This implies that, clay bodies are made to suit specific works and specific temperature ranges for firing. Arbuckle further states that, introducing combustible fillers such as straw, sawdust, vermiculite, etc. would minimize shrinkage, promote drying, and reduce the weight after drying, and nylon fibers also introduced to achieve tensile strength in forming and added green strength. Bodies for throwing should also be reasonably plastic. Hand building bodies should also be open enough to aid even drying and reduce shrinkage. In this context, the researcher aims at coming out with a heat retention body by blending two local clays namely Kenyase Abrem clay and Tepa clay together with non-ceramic materials that could be used in the manufacture kilns for firing ceramic wares at high temperatures between 1250°C (2282°F) and 1500°C (2732°F) or higher.

1.3 Problem Statement

Kilns are important devices for the firing of pottery and ceramic products in recent times. Contrary to the indigenous or traditional open-pit firing where a lot of heat is lost to the atmosphere, good kilns retain heat and use relatively little energy to fire the products. Clay has been used to produce bricks for the construction of kilns in recent times but getting the right clays for making clay bodies for making refractory products for kiln construction has become a problem to local pottery workers and ceramists.

The cost of acquiring imported kilns have become a major challenge to most local potters and ceramists since these imported kilns are too expensive to purchase and shipped into the country. Due this this problem, local potters and ceramists have tried to come out with their own kilns built locally but do not meet the standards of the foreign ones. This is because most of the clays do not fire beyond a temperature of 1100°C (2012°F). Due to this, local potters and ceramists are only limited to the firing of biscuit wares and the firing of low temperature glazes. The inability to produce stoneware and porcelain products to meet modern demands are due to the inability of locally manufacture kilns to fire to extreme temperatures. Most clays used in the composition of clay bodies for producing low-density bricks for kiln construction are however single sourced clays. Most of these clays when used are not able to retain much heat in the kilns due to their mineralogical components which reduces their maturing temperatures. In view of this, most clay sourced in Ghana are earthenware clays and they contain some level of Iron (Fe) and Titanium (Ti) which alters the colour of the clays and Lead (Pb) which causes the clays to melt when subjected to extreme heat temperatures.

This therefore triggered the researcher to prospect for locally available clays that could be used to produce heat retention refractory products by composing the clays into a clay body for the manufacture of low-density refractory bricks suitable for kilns construction.

1.4 Research Objectives

The research seeks to

1. identify and describe the properties of Kenyase Abrem and Tepa clays that make them appropriate refractory materials for composing heat retention body
2. compose heat retention clay body from Kenyase Abrem and Tepa clay
3. produce low-density refractory bricks from the composed clay body that is suitable for the construction kilns.

1.5 Research Questions

1. Has the Kenyase Abrem and Tepa clays got the properties that make them appropriate materials for producing refractories?
2. How suitable can Kenyase Abrem and Tepa clays be composed together into a heat retention clay body?
3. Can the low-density refractory bricks be suitable for kiln construction?

1.6 Delimitations

The study is limited to

1. The development of heat retention bodies from Kenyase Abrem and Tepa clays.
2. The production of low-density refractory bricks suitable for constructing kilns.

1.7 Limitations

The researcher did not get access to enough tools, machines and equipment at the department and had to seek assistance from other institutions.

1.8 Definition of terms

To make the understanding of the project much easier, the key terms used in the study are explained as follows.

Clay: The hydrated silicate of Alumina.

Clay body: Clay body refers to the actual clay mixture used in the molding of clay articles. Perhaps it is only a certain kind of clay, but more likely, may consist of a mixture of different types of clay.

Clay mineral: The term "clay mineral" refers to Phyllosilicate minerals and minerals which impart plasticity to clay and which harden upon drying.

Chimney: A channel for the escape of exhaust gases

Conduction: The transmission of heat through the walls of kiln

Damper: A facility for controlling draft system of the kiln

Degradation: Changing something from a higher state to a lower state.

High Density bricks: These are bricks that are less porous and mostly heavy in weight

Insulating bricks: Specially composed low-density bricks used in areas where heat retention is required.

Low-density brick: These are highly porous bricks used for heat retention in kilns.

Phyllosilicate: These are sheet of Silicate minerals, formed by parallel sheets of silicate tetrahedra with Si_2O_5 or 2:5 ratios.

Pottery: These are products made from clay and fired at a high temperature in a kiln.

Retention: the capability to hold something.

Sintering: It is process of compacting and forming a solid mass of material by heat and/or pressure without melting it to the point of liquefaction.

1.9 Significance of the research

1. The research has given insight on which type of clays would be very suitable for constructing good heat retention kilns.
2. It has provided a new clay body for kiln construction.
3. The report of the study will serve as a reference material for future studies.

1.10 Organization of the text

Chapter One entails the introduction containing background to the study, problem statement, research objectives, research questions, delimitations, limitations, definition of terms, Significance of the research and organization of text.

Chapter Two deals with a review of relevant literature related to the topic. These are views of various authors in connection with Clay and Clay Body, Kiln and Kiln construction. Areas considered include; Clay, Physical Properties Of Clay, Clay Bodies, Kenyase Abrem Clay, Tepa Clay, History And Development Of Kilns, Types Of Kilns, Design and Construction, Methods of Kiln Construction, Heat Retention in kilns, High Density bricks.

Chapter Three entails the methodology in relation to the study. It includes the research design, library research, population, data collection instruments, primary and secondary data, data collection procedure, It also deals with the identification, observation, description of the experiments conducted to determine the right clay body composition that is best for making refractory bricks which could be used to manufacture a kiln to attain the results.

Chapter four covers presentation and discussion of findings

Chapter five discusses the summary, conclusions and recommendations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

This chapter discusses pertinent literature related to the study. Literature reviewed in this chapter include; Refractory Products, Properties required in refractories, Refractory brick body, Insulating materials, Clay, Clay minerals, Clays prospected for the study, Clay bodies, Design and construction of Kilns, Methods of Kiln construction, Heat loses in Kilns and Heat retention in Kilns.

2.1 Refractory Products

Refractories are heat-resistant materials that form the linings for kilns and furnaces and high-temperature reactors and other ceramic processing units. Apart from the fact that it is supposed to be resistant to thermal stress and other physical phenomena which is induced by heat, refractories must also be able withstand the physical tear and wear and corrosion cause by chemical agents. Refractory materials are heat resistant than metals and heating are purposely for applications above 800 °C (1472 °F).

Gupta (2014) says refractories are inorganic nonmetallic materials that can withstand high temperatures without suffering physico-chemical changes while remaining in contact with the molten slag, metal and gases. It is necessary to produce range of refractory materials with different properties to suit range of processing conditions. He further claims that "refractory range incorporates fired, chemically and carbon bonded materials that are made in different combinations and shapes for diversified applications".

Although this definition identifies the basic characteristics of refractory accurate, their ability to provide containment of substances at high temperatures are possible. Refractories cover a broad class of materials which have the above characteristics in varying degrees for different time periods, and under different conditions of use. A wide variety of refractory compositions have been produced in a variety of shapes and forms, which have been adapted to a wide range of applications. The common denominator is that when used will be exposed to temperatures above 800 °C (1472 °F) during operation. Refractory products can be divided into two categories: burnt brick or forms, and specialties or monolithic refractories. Linings of refractory products are also made of these forms, and brick, or specialties, such as plastic, concrete, ramming mixes or gunning mixtures, or by a combination of both.

Many refractory products, in final form, are similar to a typical construction bricks. But there are many different shapes and forms. Some refractory elements are small and may have a complex and delicate geometry; others are massive and can weigh several tons, in the form of prefabricated or fusion cast blocks. Refractories are produced from natural and synthetic materials, usually nonmetallic, or combinations of compounds and minerals such as alumina, fireclays, bauxite, chromite, dolomite, magnesite, silicon carbide, zirconia, and others. The researcher found this information very pertinent to the study because the size of the low-density refractory brick to be produced as a final product of this study had to be porous enough to retain much heat in the kiln. The weight and composition of the body, taking into consideration the mineralogical constituents of the Kenyase Abrem and Tepa clays was a key factor to come out with the best of refractory products from the local raw materials that would be viable and suitable for the production of firing equipment such as kilns and furnaces to help reduce the excessive loss of heat through conduction.

Refractories materials are basically made from natural and synthetic materials, usually non-metallic, or combinations of compounds and minerals such as aluminum oxide, fireclays, bauxite, chromite, dolomite, magnesite, silicon carbide, zirconia, and others.

Nandi (1987) says that any substance can be referred to as "refractory" unless measures can withstand high abrasive or corrosive solids, liquids or gases at high temperatures. He further asserts that various combinations of operating conditions in which refractory materials are used make it necessary to manufacture a range of refractory materials with different properties.

The purposes of producing refractories vary in combinations and shapes and are made for specific and variety of applications. Refractory materials are intended to have the following;

- The capability to withstand load conditions.
- Should be able to conserve heat.
- The capability to withstand high temperatures.
- The capability to withstand action of molten metal slag, glass, hot gases, etc.
- The capability to withstand load and abrasive forces.
- Low coefficient of thermal expansion.
- Ability to withstand sudden changes of temperatures.

Nandi (1987) asserts that refractories are used to build structures subjected to high temperatures, ranging from simple to advanced, for example, fire place brick linings reentry heat shields of the space shuttle. He further stated that in industries they are used to line boilers and furnaces of all kinds, reactors, ladles, stills, kilns and so on. Depending on the usage, refractories must be able to resist attacks from chemicals; avoid molten metal and slag erosion, thermal shock, physical impact, thermal and catalytic heat and similar adverse conditions. Because the different ingredients in refractory provide a variety of performance and features, many refractories are developed for specific purposes. The purpose of this study is to come out with a heat retention body which could be used to produce refractory bricks for kiln construction from two local clays from Kenyase Abrem and Tepa. The researcher's target is to reach a temperature ranging between 1250°C (2282°F) and 1700°C (3092°F) when the brick produced from the clay body is used for the construction of a kiln.

2.2 Properties required in a refractory

Nandi (1987) stipulates that, there are vital properties required in every refractory material and this property includes; melting point, size and form, bulk density, porosity, cold crushing strength, pyrometric cone equivalent, refractoriness under load, creep at high temperature, volume stability, expansion, and shrinkage at high temperatures, Reversible Thermal Expansion and thermal conductivity. These properties are further explained below.

2.2.1 Melting point

Nandi (1987) asserts that pure substances become melted sharply at a defined temperature. Most refractory materials consist of particles of high melting point which are bonded together. At high temperature, the glass fuses, and when the temperature rises, it results in the increases of slag amount present in the material by a partial solution of the refractory particles. The temperature at which this action results in a failure of a pyramid test (cone) to support its own weight is called for convenience, the melting point of the refractory material. The melting point of the final products the researcher aims at producing is highly considered since high percentage of some minerals such as Lead (Pb) reduces the maturing temperature of clays. The researcher therefore tested for the clays to make sure such minerals that reduce the maturing temperature of clays when subjected to heat were low in quantity and of low percentages in the general composition of the clays.

2.2.2 Size and form

Nandi (1987) says that the size and shape of the refractory is part of the design elements. Nandi further states that, it is an important design element because it affects the stability of any structure it is used to produce. He further asserts that accuracy and size are extremely important to enable correct assembly of the refractory form and to minimize the thickness and joints in construction. This information was found very important to the study because, when the size and form of the refractory bricks produced are too big and irregular and differs in shapes and form, the firing equipment such as kilns it is used to construct may become too heavy or lack stability due to the irregular shapes. Therefore the research makes a mould to make sure all the bricks produced are of equal sizes and shapes to help align in order the bricks during construction and also stabilize the strength of the firing equipment when constructed.

2.2.3 Bulk density

A useful property of refractories is the bulk density, which defines the material which is present in a given volume. Nandi (1987) says an increase in the density of a given refractory material increases its stability in terms of volume, heat retention capacity, and resistance to slag penetration. Bulk density of bricks was another important factor taken into consideration by the researcher due to the above information Nandi stipulates.

2.2.4 Porosity

Nandi (1987) stipulates that the apparent porosity is a measure of the volume of the open pores, in which liquid may enter, as a percentage of total volume. He continues to buttress the fact that "this is a significant property in the case where the refractory is in contact with the molten charge and slag". Again, he said to activate the apparent porosity is desirable because it would prevent the easy penetration of the refractory size and continuity of the pores will have a major impact on the refractory behavior. A large number of small pores are generally preferable to a corresponding number of large pores. In view of what Nandi (1987) says about porosity, the researcher made sure the introduction of combustible materials such as sawdust was introduce to create multiples of air cell or pockets in the final product after firing to enable the kiln retain much heat. Since heat conductivity in compact refractory bricks is faster and easier than refractory bricks with loosed internal structure, the researcher saw the need to make the final product porous enough to avoid high conductivity of heat which may result in much heat loses.

2.2.5 Cold crushing strength

According to Nandi (1987) the cold crushing strength, which is considered by some to be of doubtful relevance as a useful property, other than that it reveals little more than the ability to withstand the rigors of transport, can be used as a useful indicator to the adequacy of firing and abrasion resistance in consonance with other properties such as bulk density and porosity. Aside Nandi's assertion, the researcher is also of the view that, the cold crushing strength of low-density refractory bricks is considered very important because it shows how the bricks are strong enough to hold the whole structure of the firing equipment together. If the strength of the low-density refractory bricks and not high enough, it may lead to the collapse of these firing equipment when subjected to heavy loads beyond what they can handle.

2.2.6 Refractoriness under load (RUL)

Nandi (1987) says, the refractoriness under load test (RUL test) gives an indication of the temperature at which the bricks will collapse, in service conditions with similar load. To the researcher, refractoriness under load was very important as it revealed the temperature at which the bricks low-density refractory bricks produced from the body composed would melt at extreme temperatures. The refractoriness of the low-density bricks basically is influenced by the minerals present in the clay before composed into a body. The researcher made sure the minerals present in the clay does not affect the targeted temperature at which the final product is to withstand.

2.2.7 Creep at high temperature

Nandi (1987) stipulates that, creep is a time dependent property which determines the deformation in a given time and at a given temperature by a material under stress. Alumina can withstand extreme temperatures whiles silica and Lead oxides at a point may fuse and deform the shape and size of the refractory material or product. Therefore the researcher tested the clays to know their mineralogy to know the percentage of every minerals present to be able to be sure that, minerals that may reduce the maturing temperature of the low-density bricks and deform them are of low quantity and may or may not have any impact of the them when subjected to extreme heat temperatures.

2.2.8 Reversible Thermal Expansion

Nandi (1987) states that, any material such as metals and refractories when heated; they expand and contract when cooled. The reversible thermal expansion is a reflection on the phase transformations that occur during heating and cooling. Some materials affect how refractories expand and contract to temperature extremely higher than their maturing points. This information was very relevant to the study because, how refractories expand and contract at high temperatures without any deformation are mostly influenced by the composition and minerals present in the raw clays.

2.2.9 Thermal Conductivity

Thermal conductivity depends upon the chemical and mineralogical compositions as well as the glassy phase contained in the refractory and the application temperature. The conductivity usually changes with rise in temperature. In cases where heat transfer is required through the brick work, for example in recuperators, regenerators, muffles, etc. the refractory should have high conductivity. Low thermal conductivity is desirable for conservation of heat by providing adequate insulation.

The provisions for back-up insulation, conserves heat but at the same time it increases the hot face temperature and hence the demand on the refractory quality increases. Accordingly, insulation on the roof in open hearth furnaces is normally not provided, otherwise it would cause failure due to severe dripping. Depending on the characteristic of the refractory used in the hot face, such as the high temperature load bearing capacity, it may be required that the quality of the brick be increased to match the rise temperature caused by over insulation.

Light weight refractories of low thermal conductivity find wider applications in the moderately low temperature heat treatment furnaces, where its primary function is usually conservation of energy. It is more so in case of batch type furnaces where the low heat capacity of the refractory structure would minimize the heat storage during the intermittent heating and cooling cycles. In this study, the researcher’s aim is to compose a heat retention body from Kenyase Abrem and Tepa clays that could be used for the production of low-density refractory bricks. Most refractory bricks are composed of several clays or clay minerals to achieve a specific purpose.

2.3 Refractory Brick Body

Clay body or body for refractory bricks can be composed of dense and heavy material which could support heat retention and good insulation properties. These types of bricks are used for fire wood and gas kilns which have harsh firing incidents, unlike the electric kiln. Electric kiln bricks are light softer but very effective in heat absorption and insulation.

A typical composition of refractory brick body composed at the Department of Integrated Rural Art and Industry (IRAI), KNUST, comprised of fifty percent (50%) earthenware clay and Fifty percent (50%) sawdust. Clays used for this operation is mostly mined from Mfensi and has significant percentage of Iron (Fe) and Lead (Pb) in its mineralogical composition. The brick is dense, firm and fired effectively between 800°C and 1150°C.In the body preparation, the mixture was moist with enough water for saturation; it is then left for some days to age before kneading properly and rammed into wooden moulds of 6 x 3 x 4 inches, 6 x 4 x 3.5 inches or 6 x 4 x 4 inches depending on what which part of the kiln it would be used to construct. It is also allowed to sundry gradually and later fired using gas kiln. The insulating materials made into bricks helps the kilns efficiency of retaining heat in the kiln to complete a firing process. Based on these percentages above, the researcher studied and tested the Kenyase Abrem and Tepa clays to know the appropriate percentages that would result in coming out with a heat retention clay body for produce low-density refractory bricks.

2.4 Insulating materials

The role of insulating materials is to minimize heat losses from the high temperature reactors. These materials have low thermal conductivity while their heat capacity depends on the bulk density and specific heat. Insulating materials are porous in structure; excessive heat affects all insulating materials. Choice of insulating materials would depend upon its effectiveness to resist heat conductivity and upon temperature. Nandi (1987) states that, high alumina with thermal conductivity 0.028kcal m℃ and silica with thermal conductivity 0 .04kcal m℃ etc. are amongst others, used as insulating materials. He further states that, ceramic fibres are important insulating materials and are produced from molten silica, Titania, Zirconia etc. in the form of wool, short fibers and long fibres. They have excellent insulation efficiency. They are long weight. Although the researcher aims at producing a refractory material out of the two clays made into a body, the researcher also intends to produce low-density refractory bricks from the composed body that could be used for constructing kilns and other firing equipment. According to Nandi (1987), Insulating materials greatly reduce the heat losses through conduction thus through the walls of kilns and furnaces. Insulation is effected by providing a layer of material having low heat conductivity between the internal hot surface of a furnace and the external surface, thus causing the temperature of the external surface reduced. He further stated that, Structure of air insulating material consists of minute pores filled with air which have in themselves very low thermal conductivity, excessive heat affects all insulation material adversely, but the temperatures to which the various materials can be heated before this adverse effect occurs differ widely. He therefore classified insulating materials into Insulating bricks, Insulating Castables, Ceramic fibre, Calcium silicate, Ceramic coating. To minimize the heat loss in kilns, the researcher found this information very relevant to the study since it gave a clear clarification on how to produce the insulating bricks to help retain heat in firing equipment such as kilns and furnaces.

2.5 Clay

In a simple term clay is hydrated aluminum silicate as described in many written books. This is primarily because it is highly composed of alumina and silica. Folorunso et al., (2014) stipulate that, geological deposits are composed mostly of clay phyllosilicate minerals containing variable amounts of water trapped in the minerals' internal structure. For more insight on the definition of clay, Guggenheim and Martin (1996), state that the definition of "clay" was formalized for the first time in 1546 by Agricola. Although the definition made by Agricola exists, many manufacturers of pottery and ceramics products and pottery and ceramic book writers have revised the definition of clay several times in recent years despite the fundamentals associated with plasticity, particle size, and hardening on firing which have still been retained by most writers. For a clearer and tells the story of the definition from 1546-1963, vision readers are referred to Mackenzie (1993). Definitions and recent developments can also be obtained from Weaver (1989).

Peterson and Peterson (2003: 131), report on clay are ultimately the formation that occurs continually for thousands of years as alter the original igneous rocks such as granite products. The physical and chemical action of the wind, the erosion of the rain, and the gases causes the continual degradation of the rock in the clay. They continue to support the discussion of the fact that as long as the earth remains, clay is formed and it is a gradual process. And it is designated chemically as hydrated aluminum silicate with the formula $Al_2O_3.2SiO_2.2H_2O$. Chappell (1979) discusses this in more scientific terms that, it is a hydrous silicate of alumina; a compound of alumina and silica chemically bonded with water. The formula of this compound formed is represented theoretically as $Al_2O_3.2SiO_2.2H_2O$.

Oteng and Korankye (2008) agreed with Chappell (1979) by saying that the earthy clay is a material substance, composed of a hydrated aluminum silicate, which becomes plastic when wet, hard and rock-like when subjected to heat. This means that, clay in its natural form cannot be made permanent unless it undergoes a chemical change and by heating at an elevated temperature. Rhodes (1957) also says that the clay is a capricious material which can easily be obtained and prepared for use.

In another definition, the researcher defines clay as a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden when dried or fired at a particular temperature range. Although, it is usual that clays may contain certain amount of phyllosilicate materials, it may also contain other important materials which come and form part of it during formation, which may result in adding a certain degree of plasticity and strength to the clay when dried or fired. Associated components in clay may also include materials that do not add plasticity an organic matter. Every clay has its own mineralogical constituents which make them different from each other due to their origin and way of formation.

2.5.1 Clay Minerals

Defining clay brings so many important issues concerning the constituents of clay and implicitly the definition of "clay mineral". Mackenzie (1963) states that, considering any mineral that occurs in clay as a clay mineral amongst other reasons would include many accessories that are not properties and characteristics of clay. According to Bailey (1980), based on the previous definitions of clay minerals, he stated that clay minerals are treated as phyllosilicates, thus endorsing the use of a term without clear justification. However, the term "clay mineral" is very essential when used in connection with clay components or constituents. According to Bailey (1980), the approach to equalizing "clay minerals" to phyllosilicates does not satisfy the relationship between properties of the bulk clay with the properties of the constituents clay consider.

This inconsistency is discussed here in part, without major changes in current use. Weaver (1989, p. 5) noted a further complication: the conceptual problem of combining the particle size requirements of clay with clay mineralogy. Since the term "mineral" has a precise definition which does not include the particle size, the result is that the definition of a non-group mineral may be based on the particle size. Both committees of the nomenclature of AIPEA and CMS began work on the definitions of clay at the same time, and it became clear that a more acceptable result would be obtained if the two committees joined forces.

Norton (1956) states that the clay consists of small crystals; Many are so small they cannot be seen in the greater power of an ordinary microscope. He further contends that the clay is a secondary product in the ground and the result of the dissolution by impairing the oldest stone of the feldspar type. These minerals in clay impact various properties and characteristics to the clays and make them suitable for specific productions.

Clay minerals that are known to exhibit the characteristics of plasticity are known as phyllosilicates. In most cases, the definitions of clay minerals are neither based on their crystallite sizes or nature. The phyllosilicate group of any grain size can be termed as a clay mineral. On the other hand, the definition of clay minerals may not be restricted to only phyllosilicates. If any form of research arrives at a conclusion that, non-Phyllosilicate minerals add certain degree of plasticity to clay and hardens when dried or fired, then that material is termed as a clay mineral. For instance, if clay shows the property of plasticity because it contains an oxy-hydroxide material and hardens when dried or fired, it may then be well referred to as a clay mineral. In view of this, clay is not necessarily required to be most frequently composed of phyllosilicates. Minerals that do add any degree of plasticity to clay and non-crystalline phases may also be termed as associated phases respectively. This definition originates from previous definitions of what clay minerals are and an example could be found in Bailey 1980, where clay minerals were compared and said to be similar to Phyllosilicates.

The latest trend of definitions for clay minerals widens the scope of possible minerals that could also be defined as clay minerals. To add, its distinction from others associates the characteristics of plasticity and hardening upon drying or firing, which is basic to the definition of clay and to the definition of clay minerals. Phyllosilicate minerals of any form and size may be included in the definition of clay minerals as discussed above.

According to Hillier (2003) clay minerals are the characteristic near the earth's surface. They are formed in soils and sediments, and by digenetic and hydrothermal alteration of rocks. He further states that, "water is essential for the formation of clay mineral and most clay minerals are described as hydrated alumino-silicates". Hillier (2003) continued to say that structurally, "the clay minerals are composed of cations planes arranged in layers that can be tetrahedral or octahedral coordinated (with oxygen), which in turn are arranged in layers often referred to as 2: 1 if involve compound units composed of two tetrahedral and one octahedral layer or 1:1 alternating units if they involve tetrahedral and octahedral sheets. Additionally some 2:1 clay minerals have inter-layers sites between successive 2:1 units which may be occupied by interlayer cations, which are often hydrated". He said again that, "the planar structure of clay minerals give rise to characteristic platy habit of many and to perfect cleavage, as seen for example in larger hand specimens of micas". Hillier (2003) further stipulates that classifying the clay minerals of phyllosilicates is based wholly on the characteristics of the layer type (1:1 or 2:1), the dioctahedral or trioctahedral character of the octahedral sheets (i.e., 2 out of 3 or 3 out of 3 occupied sites), the magnitude of any net negative charge layer due to atomic substitutions, and the nature of the interlayer material. The foundation on which the clay minerals are classified according Hillier (2003), shown in the table below;

Table 2.1: Classification of clay Minerals by Hiller S. (2003)

Layer Type	**Layer charge (q)**		**Group**	**Subgroup**	**Species (e.g.)**
1:1	q≈0		Kaolin-Serpentine	Kaolin	Kaolinite
				Serpentine	Berthierine
2:1	q≈0 q≈1	Increasing layer charge	Pyrophyllite-talc	Pyrophyllite	Pyrophyllite
				Talc	Talc
			Smectite (q≈0.2-0.6)	Di-smectite	Montmorillonite
				Tri-smectite	Saponite
			Vermiculite (q≈0.6-0.9)	Di-vermiculite	Di-vermiculite
				Tri-vermiculite	Tri-vermiculite
			Mica (q≈1.0)	Di-mica	Illite, Muscovite
				Tri-mica	Biotite
	q variable		Chlorite	Di-chlorite	Sudoite
				Tri-chlorite	Chamosite
			Sepiolite-Palygorskite	Sepiolite	Sepiolite
				Palygorskite	Palygorskite
Variable	q variable		Mixed-layer	Di-mica-di-smectite	Rectorite
				Tri-chlorite-tri-smectite	Corrensite

Hillier (2003) observed from the above table that, some clay mineral types such as mixed layered clay minerals can only be identified accurately by techniques such as XRD. Although it is not uncommon to have to use a variety of techniques such as XRD, Infrared spectroscopy and electron microscopy to characterize and understand perfectly the types of clay minerals present in a sample. We have extensive experience of the identification of clay minerals in both soils and rocks. Hillier (2003) said "Our XRD work is backed up by our ability to compare clay mineral diffraction data with calculated diffraction data". He continued to say that it is a particularly an important technique for the precise identification of mixed-layer clay minerals. He again stated that "Our track record in the Reynolds Cup round robin on quantitative clay mineral analysis is testimony to the quality of our work on the identification and quantification of clay minerals. We also have wide experience of the use of electron microscopy to study the texture and petrographic relationships of clay minerals".

According Kemp et al., (2014) clay minerals are a group of hydrous aluminum phyllosilicates, which is characterized by two-dimensional sheet structures. Variable cationic substitution in these sheets leads to charge differential layer giving rise to changeable reaction with water and organic compounds with high surface area and cation exchange capacity. Again they said the clay minerals can be divided into four main groups: kaolin, smectite, illite and chlorite. Each of these groups has different characteristics. They further stated that clay minerals are generally of fine grain and constitute about16% by volume of material on the surface of the Earth, and are abundant in soil, sedimentary and metamorphic rocks of low grade and hydrothermal alteration zones. Since characterizing the minerals in clay is very important to know its constituents when it comes to the composition of refractory bodies, the researcher, based on the definition of clay minerals, characterized the Kenyase Abrem and Tepa clays by chemical analysis such as X-Ray Fluorescence (XRF) and Atomic

Absorption Spectroscopy (AAS) which is scientific test for determining the minerals present in a clay, to know the mineralogical constituents that make them viable to achieve the researcher's set aim for the study.

2.5.2 Types of Clay

The types of clays can be categorized into Primary or Residual clay and secondary or Transported or Sedimentary clays.

Primary or residual clay is formed at the location of the bedrock. It is less common than the secondary clay (sedimentary clay), but usually whiter or off white in nature and are pollution-free. Since this clay is decomposed by groundwater etc. and not transported, the particle sizes are mixed (no way to sort or grind) and the clay is generally not very plastic and is highly resistant to high temperatures. Most primary clays are Kaolin.

Secondary clays have been transported by water from multiple sources and wind which sorts out the particle size or by glacier that may grind the clay but has irregular particle sizes. Many secondary types of clay contains organic (carbonaceous) and other impurities like; iron, quartz, mica, etc. which come into contact with the clay during formation etc. Some of the plastic kaolin clay is secondary. Other secondary clays may include ball clay, stoneware clay, fire clay, earthenware clay, volcano clay and slip clay.

Primary clays are highly refractory since they do not contain any impurity. Since they are also low in iron content, their firing temperatures are mostly high and are able to withstand thermal shock. In Ghana, the most common clays that could be found are the earthenware clays. Kaolin is very hard to come by when prospecting for clay in Ghana even though all clay originates from a parent rock. Most clay found in Ghana is very plastic as a result of the gradual breakdown of sedimentary rocks into smaller particle sizes. The researcher, therefore is of the view that, local clays that are primary in nature or possess the qualities of a primary clay could be used and would be suitable to achieve the purpose of this study.

2.5.2 Physical Properties of Clay

The physical properties of clays vary from one to the other depending on their types and their way of formation. The properties of clays include plasticity, firing shrinkage and air drying shrinkage, grain fineness, porosity, colour before and after subjected to heat energy, hardness, cohesiveness and the ability of the surface to accept decoration. Based on such qualities, clays are divided into various classes or groups; products are generally made from mixtures of clay and other substances. The purest clays are the kaolin clays and porcelain. "Ball Clay" is a name for a group of plastic, refractory (high temperature) clay used with other clays to enhance their plasticity and increase strength. Bentonite clays are composed of very fine particles generally derived from volcanic ash. They consist mainly of hydrated magnesium-calcium-aluminum-silicate called montmorillonite. The clay particles are always less than 0.004 mm. Clays often form colloidal suspensions when immersed in water flocculates, and the clay particles settle rapidly in saline. Most clay are easily fashioned into different forms which are able to hold their shapes when dry, and become hard and lose its plasticity when subjected to heat.

Every earth material that is said to be clay is identified by its mineralogical constituent and properties. Clays are said to be a product of weathering and aging, reducing granite, sedimentary and feldspartic rock into an earth material called clay. Speight and Toki (1999), stipulate that, this feldspar has alkaline, silica and alumina as its main components, and these are minimized to alumino-silicates by glacial actions such as rain, wind and sunshine. Once it is abandoned to the mercy of the weather for aging, the alumino-silicates comes into contact with the humidity of the environment brings about the formation of a new material called clay. Home (1953), also buttresses the fact that, the new material formed which is clay differs in mineralogy due to their place of formation. Plasticity of clays is one major property which is very important to ceramic and clay workers. The ability of clays to hold its particles together depends on its plasticity. Most secondary clays are very plastic due to their composition and way of formation while others are less plastic. Home (1953), writes that, almost all clays except kaolin have some level of plasticity, physical property of clay that easily enhances modeling and forming with the clay. Therefore, it is necessary to note that, the plasticity of clay is caused by many factors. According to Rhodes (1968) clay particle sizes are a determining factor of the plasticity of the clay. Finer particle size contributes to high plasticity whereas coarser particles reduce plasticity. Speight and Toki (1999) explained that clays differ in their degree of plasticity. Some are so sticky they are almost impossible to shape. Rhodes (1977) mentioned colour as another physical property of clay that easily affects the clay's thermal responses. He said that there are minerals that show their colour only when the clay mineral has been exposed to heat. He explained these as metallic oxides that in some cases act as fluxes reducing the maturing temperature of the clay. In much scientific terms, clays that have higher percentage Iron (Fe) and Titanium (Ti) alter the colour of the clay material by giving it a reddish colour when it has been subjected to heat while clays with no or little percentage of Iron and Titanium but has high Alumina content fires white or off-white. The colour of clay affects its thermal responses as stipulated by Rhodes (1977). Clays have whitish properties in terms of colour have low conductivity of heat than clays with reddish colour properties. In view of this, the researchers aim was to prospect for clays that have whiter properties after it has been subjected to heat.

The particle size, colour and plasticity of clays were found to be very significant in this study. This is because the nature of the particles of the two clays identified was very coarse and behaved more or less like primary clays. It is believed that clays with coarser particle sizes in nature are good for making refractory products. This is because clays that have coarser particles sizes are mostly primary clays and have high level of Alumina and silica with fewer impurities that may reduce their maturing temperature. The colour of the clay also plays a very important role when it comes to heat conductivity and light transfer. It is believed that, clays which are mostly white in nature are poor conductors of heat therefore when used in the making of a clay body for the manufacture of bricks for kiln construction; the heat conductivity level in the kiln through the walls would be less thereby retaining much heat in the kiln during firing. The plasticity of the clay is also very important since it is the property of the clay that holds and binds it particles together in uniformity, especially in the case where non-plastic materials are introduced in the clay body making. When modeling or forming articles with clay, plasticity is the key property every ceramist or clay worker seeks in the clay before it is fashioned into the piece. In this case, the researcher aims at introducing clay which is plastic enough to bind all the necessary materials used in making the clay body together. Although the plasticity of the base material can be reduced by the introduction of non-plastic material, proper control measures aid in arriving at an expected result. Almost all the clays available in the pottery villages in Ashanti Region and Central Region are comparatively plastic and it is against this backdrop that the Kenyase Abrem clay and Tepa clays are being considered viable for this study. Other factors that were considered for the choice of these clays were transportation, location and accessibility to the materials.

2.5.3 Clays prospected in the course of the study

In all, six (6) Clay samples were taken from Cape Coast and Ashanti Region out of which the ones viable for the study were chosen after testing. The clays tested for this study includes; the Abonko clays (both primary and secondary), the Adankwame clay, the Kenyase Abrem clay and the Tepa clay. Out of these clays tested, the Kenyase Abrem and Tepa clays were found viable by the researcher for this study because they had the qualities necessary for making the heat retention body.

Plate 2.1: Abonko clay in the dry state fetched from the parent rock

Plate 2.2: Abonko clay in the dry state fetched from the deposit near the parent rock

Plate 2.3: Abonko clay sample in the dry state fetched from the secondary clay deposit

Plate 2.4: Adankwame clay sample in the dry state

Plate 2.5: Kenyase Abrem clay sample

Plate 2.6: Tepa clay sample

Plate 2.7: All the clays made wet and rolled into a ball by the researcher

After making all the clays wet by adding water and kneading them into balls, it was found out that the Kenyase Abrem clay in the top middle and the Tepa clay at the bottom left in plate 2.7 look more whitish in nature than the rest of the clays and therefore would be viable in terms of colour for the study. During the kneading process, it was found out that the plasticity of the Tepa clay was very poor but that of the Kenyase Abrem clay was moderate in plasticity. It contained considerable sheets of mica which are good for making refractory products thus products that can withstand a very high temperature of specific degrees.

2.6 Kenyase Abrem Clay

This clay was mined at Kenyase Abrem, a town about twenty (20) kilometers from the Kumasi Airport Runabout. It fires off-white to orange due to the presence of a significant amount of ferrous oxide. It has maturing temperature between 1100°C and 1350°C. This type of clay is used by many locals for the production of crucibles for melting precious metals at metal processing factories due to its ability to withstand high heat temperatures. According to Agya Wusu (2014), a clay worker and a producer of crucibles at Atonsu Bokro in Kumasi in the Ashanti region of Ghana, who mines his clay from Kenyase Abrem for his productions, he say the clay possesses some refractoriness and it is able to withstand a high temperature that is why they use them for the production of the crucibles. He further stated that, they could consider other clays for the production but they have tried and tested and they think the Kenyase Abrem clay is the best so far for their work.

2.7 Tepa Clay

This clay was mined at Tepa, the capital town Ahafo Ano North in the Ashanti Region of Ghana. It covers a distance of 78km drive from Kumasi. This clay fires off-white to buff with little or no reddish colour and possesses more or less the properties of primary clay. The inability for it to fire reddish is because, ferrous oxide and Titanium oxide which alters the colour of clays it of insignificant percentage in it. It has larger particle sizes with large particles sizes of mica in its composition. According to Fadziawu et al., (2014), workers of Tech Ceram company belonging to Professor Kwakume located at Adankwame, a village located about 35kmfrom Kumasi on the Kumasi-Sunyani road, the clay is very refractory and has maturing temperature that could go above thousand four hundred and fifty degrees Celsius. The clay is not mostly used by the locals but rather people from different walks of life go there to mine the clay for their productions.

2.8 Clay Bodies

Clay bodies have been made widely and used to achieve several objectives and properties depending on the type of ceramic or pottery works it is intended for. Clay body in the real sense is the mixture of two or more clays or a mixture of clay and other minerals intended to achieve a particular purpose for which it is to be used for. Clay bodies come in varieties and types depending on the purpose they are to serve. Types include, slip cast bodies, the bodies of hand building and throwing bodies.

Composing clay bodies for the manufacture of refractory bricks began back in ancient times, as potters and ceramists mixed different textures of clay to produce bricks for the construction of buildings and firing equipment such as kilns and furnaces.

Oteng (2011) stipulates that "the adoption and composition of clay materials and other ceramic materials to achieve a specific property in clay is known as Clay Body Composition". Oteng further states that, this is done in most cases to adjust the clay based material to meet the particular thermal response, and the response to heat energy at different temperatures to achieve the properties or characteristics which are not present in the base material". According to Arbuckle (2013), clay bodies are formulations of clays, flux, silica and other minerals to obtain special characteristics like colour, texture, maturing temperature, absorption and shrinkage, plasticity, drying and firing properties. She stipulated that, functional bodies are better if strong and fired to a high temperature. She continued to say that sculpture clays should be open enough for uniform drying of thick walls and have limited shrinkage. She further stated that, combustible fillers (straw, sawdust, vermiculite, etc.) may be added to control shrinkage, aid drying, and reduce fired weight, and nylon fiber added for tensile strength in forming and added green strength. Arbuckle (2013) continued to make it clear that, throwing bodies should be reasonably plastic and hand building bodies should control shrinkage and be open to aid even drying.

Plasticity requirements depend on the method used to form. Slip-cast body does not require plasticity, but must have low shrinkage ability. Rhodes (1968) defines clay body as a mixture of clay or other earthen materials or minerals, which are mixed to achieve a particular purpose in ceramic production. In this establishment, Kwakume (2010), says the researcher, who makes the body must have sufficient knowledge of the materials in the composition, so that adjustments can be made in case of disturbances. This information is considered very important to participate in this study and was the basis for the composition of the heat retention, low-density refractory material to build the kiln. It is very relevant to the researcher that, the properties of the base materials are analyzed as to its behaviour before the composition of the body was made. Therefore the aim of the researcher is to come out with a heat retention body that could be used in the manufacture of low-density refractory bricks for the construction of kilns by mixing two local clays namely from Kenyase Abrem and Tepa.

2.8.1 Clay Body Types

Clay body refers to specific composition of clay types, and preparation to meet required needs for the production and uses of ceramic objects. Kalilu, Akintonde and Ayodele (2006:49-50) observe that the two major types of clay are the foundation of three basic types of clay bodies; earthenware, stoneware and porcelain whose maturing temperature ranges between 750°C (1382°F) and 1150°C (2102°F), 1150°C (2102°F)and 1350°C (2462°F)as well as 1400°C (2552°F)and 1700°C (3092°F)respectively; these clays form the rudiments for other clay bodies. However, clay body formations which vary from place to place have been documented by the likes of Singer and Singer (1963), Cardew (1967), Rothenberg (1972), Daly (1995), Rhodes (1998), Fournier (2000), Petereson (1998), among others. In South-western Nigeria, composition of clay bodies is not also alien to traditional potters as they usually combines two or more clay types to form clay bodies in their various pottery centers according to their understanding of different types of clays that exist in their localities in order to give more strength as well as colour to their pottery wares during firing (Fatunsin, 1992: 17-19 and Abiodun and Akinde, 2013: 699).

In recent time, there is a lot of clay bodies' composition that were developed in various pottery/ceramic workshop and industries as well as art schools. For instance, certain clay body specification may be for strength or aesthetic especially to achieve physical colour effect such as mattness, transparency and translucency. Clay body type may also be selected to appropriately accept a particular glaze batch on a corresponding body to withstand common glaze flaws such as; crazing, dunting, pine-holing, crawling and running. Physical strength of clay during throwing or making of a big hand built ceramic objects; as well as shrinkage degree considerations are also required. Sometimes, ceramic objects required for chemical use must also be composed of non-corrosive or non-absorbent terracotta and glaze bodies. This type of body is also highly essential for ceramic objects in use for mechanical devices or processes. Other considerations for clay bodies for ceramic object used in optics requirement are light reflective, light transmitting in colour wave length as well as transparency and translucency within ceramic material (Daly, 1995, Rhodes, 1998, and Fournier, 2000). The researcher in this study aims at making a clay body with two local clays namely Kenyase Abrem clay and Tepa clays with the addition of an organic material that could be used to produce a high heat retention kiln.

2.9 Design and construction of Kilns

Kilns are equipment with insulating chambers that produces sufficient heat temperatures to complete processes such as drying, hardening and chemical change in ceramic products. All kilns and furnaces are operated by the release of heat energy, and that should be achieved by the combustion of fuels with the exception of electric kilns. Rhodes (1977) says besides the problem of supporting the elements, there is no great difficulty in construction of an electric kiln. Rhodes further that, a kiln is a box built with refractory materials for firing pottery and ceramics. Kilns could be constructed in different shapes as well depending on who constructs it and the fuel they are to be operated with. In Ghana most kilns built locally are operated by the combustion of firewood and gas as the main source of energy for firing. The fuel used for the firing also determines the form, size and shape of the kilns constructed. Aside Rhodes description of kilns as boxes for firing ceramic wares, the researcher also thinks Kilns could be built in different forms and shapes to suit the fuel to be used and purpose.

2.10 Methods of Kiln construction

Olsen (2001) agreed with Rhodes (1977) by stating that, the curved walls are found in doomed, down draft and beehive Kilns. The reason is that using curved walls are much stronger and more durable and stable than straight walls. They explain that the curve produces a wedging effect that continues to hold and prevent the bricks from falling inward within the kiln. Olsen explained that the domes can be cast in order to achieve maximum strength. The researcher is also of the view that, the curved walls also help in easy distribution of heat in the kilns to bring clay wares to their point of maturity. The size, shape, form may affect the kilns efficiency of retaining heat and therefore may increase the fuel used during firing substantially.

2.11 Heat Losses in Kilns

In kilns that are adversely affected by the heat loss through the walls of the Kiln by heat conduction, also affects the fuel consumption considerably. To the researcher, this means that the amount of heat losses that occur through the walls of the kiln during the firing automatically increases fuel consumption since the more heat is lost, the greater amount of fuel is used. The extent to which the kiln walls can lose heat depends on the following factors; Wall emissivity, colour of the bricks, the thickness of the kiln walls, the temperature inside the kiln, the outside air temperature, the outside air velocity, the wall configuration, the conductivity of the refractories in the kilns used and how the kiln is operated continuously or intermittently. Rhodes (1968) stipulates that, colour plays a very important role when it comes to the theory of heat transfer, heat absorption and light transfer. Since white or colours tinted in white has the ability to reflects and transfers heat, bricks that look whitish or off-white in colour are suitable for kiln construction to check heat losses in kilns. According to Nandi and McGraw (1987), different materials have different radiation power (emissivity). The emissivity of walls coated with aluminium paint is lower than that of bricks. The walls of the refractory bricks can be made emissive too by the type of clay used and the kind of body composed for which purpose it is also to serve. Heat loses in kilns can therefore be controlled by increasing the thickness of the kiln walls, the thickness of insulation and checking the thickness and conductivity of kiln walls with kiln fabricators. Based on the factors that affect the heat losses in kiln as stated above, the researcher asserts that, the conductivity of the refractory materials used for the construction of firing equipment such as the kiln is a very important factor to heat loses in Kilns. All the other factors come into play when the refractory material lacks the ability of retaining heat in the kilns. Hence, the researcher’s aim is to come out with a refractory body that can limit the conduction of heat from kilns to the atmosphere and also to retain sufficient heat in the kiln to complete a firing process within a given time range.

2.12 Retaining Heat in Kilns

Rhodes (1968) says insulating bricks are very important when it comes to the housing of the heat energy for firing ceramics. Rhodes (1968) further explains that, the clays are mixed into very thick slips which air bubbles are created in its internal structure by chemical means. If the material is set and dried, it is baked and then cut and formed into sizable bricks. The trapped air bags created then make them lightweight and porous bricks with high insulation properties and this make them have excellent heat resistance properties he said. Steiner et al., (2008) also said porous bricks with insulating properties can be obtained by the introduction of combustible materials such as sawdust in the clay during the production of the bricks, when dried and fired to a high temperature, the sawdust burns leaving air pockets in the fired brick and that makes it light in weight and porous. This results in poor properties of thermal conductivity and the corresponding higher capacity to retain heat when used in the construction of kilns. The focus on the information above is the ability to create multiples of air cells or pockets in bricks to give them porous properties which renders them insulating materials. To achieve the purpose of making the bricks insulating enough to retain heat, the researcher therefore cites with Steiner et al., (2008) on the introduction of sawdust as a combustible material to make the final product porous and insulating.

CHAPTER THREE

METHOLOGY

3.0 Overview

This chapter covers, discusses and explains the process of gathering the data needed for the study, including research design, library research, primary and secondary data sources for the study, population for the study, sampling design, data collection instruments and data collection procedures. Tools and materials are also described. The chapter three (3) considered the general procedures followed chronologically in the project execution.

3.1 Research Design

Research design refers to the entire strategy a researcher chooses to integrate the different components of the study in a coherent and logical way, thereby, ensuring that, the researcher will effectively address the research problem; it constitutes the blueprint for the collection, measurement, and analysis of data. The paradigm of qualitative research was used in this study. The descriptive and experimental research methods of qualitative research design were adopted to collect data for the study.

3.2 Qualitative Research

Qualitative research answers questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participant point of view (Leedy& Ormond: 2005). Shank (2002: 5) also defines qualitative research as “a form of systematic empirical inquiry into meaning”. Denzin and Lincoln (2000: 3) agree that qualitative research involves an *interpretive and naturalistic* approach. “This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them”. A Descriptive and

Experimental research methods of qualitative research design was selected to provide a systematic approach in generating new technique in the formulation of body for the manufacture of low-density refractory bricks suitable for kiln construction. For the purpose of this study, the researcher adopted the qualitative research design because it provided a systematic and scientific approach in unfolding the facts to determine the technique for composing an appropriate heat retention clay body that could be suitable for kiln construction.

3.2.1 Experimental Research Method

The researcher made an attempt to maintain control of all factors that could affect the results of an experiment. In doing so, the researcher tries to determine or predict what might happen in the research (Key, 1997). Experimental research requires different treatments and establishes their effects in the study. The result leads to clarify of interpretations of the effects and results. The general procedure is described step by step, by which the entire project is carried out. The experimental research method of the qualitative research design was adopted by the research to conduct series of tests and experimentations on composing Kenyase Abrem and Tepa clays in varied ratios to know which ratio or composition was much appropriate for producing low-density refractory bricks suitable for kiln construction.

3.2.2 Descriptive Research Method

This method of research, moreover, describes data and characteristics of the population or phenomenon being studied. The idea to choose descriptive research method was that the procedures used to perform the experiment would describe chronologically the processes, to produce a very clear and detailed statement of all events related to the project. Descriptive studies aimed at discovering "what is", so methods of observation and investigation are often used to collect descriptive data (Borg and Gall, 1996). Descriptive research involves the collection of data describing the events and then organizes, tabulates represent and describes the collection of data. The descriptive research method of the qualitative research design was used to describe chronologically the tools, materials and equipment as well as the working procedure and experiments conducted in the study.

3.3 Library Research

The library research is the basis by which a researcher vigorously develops the writing of a scientific article or thesis. Secondary date necessary for the study was provided by the Library research. Libraries that aided the researcher to curl relevant secondary data for the study comprises of: Department of Art Education Library, the College of Art Library, Faculty of Engineering Library and the Faculty of Science Library, the KNUST main library, all in the Kwame Nkrumah University of Science and Technology. Library of the Building and Road Research Institute (BRRI) of the Centre for Scientific and Industrial Research at Fumesua in Kumasi, Books, publications, periodicals, magazines were the sources from which secondary data were collected.

3.4 Population for the Study

According to Fraenkel and Wallen (1996), a population is the group of interest to the researcher, the group to whom the researcher would like to generalize the results of the study. Leedy and Ormrod (2005), also state that qualitative researchers draw their data from many sources – not only from a variety of people, but perhaps also from objects, textual materials, and audio visual and electronic records. The researcher therefore identified the following as the population pertinent to the study:

3.4.1 Target Population

In this study the researcher targeted the senior all clay workers and artisan at Kenyase Abrem in Kumasi and Tepa, a capital of Ahafo Ano north in the Ashanti region of Ghana. The researcher made this a target population because the research was based on the clay deposits available for the locals and workers there.

3.4.2 Accessible Population

A total of seventeen (17) clay artisans were interviewed on how the works they produce are fired and the type of firing equipment used. Out of the 17 clay, 11 were clay artisans from Kenyase Abrem and 6 clay artisans from Tepa. In the cause of eliciting information from the respondents, some agreed on prospecting for the suitable clays that could be used in the making of heat retention bodies from our local raw materials. followed by composition of desirable heat retention body (low density body) for kiln construction using the clays identified as suitable for the study from available local raw materials, and the manufacture of refractory/low density bricks that could be used for kiln construction.

3.4.3 Sampling Techniques

Sample in the context of this study is a portion, piece or segment that is representative of a whole population. Leedy and Ormrod (2005) have the view that, the particular entities a researcher selects is what is termed the sample, whereas the process of the selection is the sampling. After the researcher identified the population, purposive sampling was employed to gather the information because Leedy and Ormrod (2005) continue to explain that, in purposive sampling, people or other units are chosen, as the name implies, for a particular purpose. The researcher therefore relied on purposive sampling technique to elicit information from respondents and also to collect data.

3.4.4 Characteristics for the Population of Study

Population concept is fundamental to both descriptive and mathematical. For this study the researcher considers a population as a group of persons having information on Clays and Clay bodies. Within the context, people working with clay, clay bodies and kilns, teaching about clays bodies and kilns and who manufacture clays bodies in various forms are considered to constitute the population for this study.

A total potential population for this research project was 17 made up clay artisans including technicians from Kenyase Abrem and Tepa all in the Ashanti Region of Ghana.

3.4.5 Justification of Sample Selected

Based upon the above information, the researcher considered a sample of 17 (100%) to be a representation of the total population. The 17 clay artisans also became the accessible population because, they were the only people working with clay combined in the two localities.

3.5 Data Collection Instruments

In conducting a qualitative research, a researcher uses either a single instrument or a triangulation means of collecting data in most cases. Leedy and Ormrod (2005) are of the view that researchers normally make use of multiple forms of data in any single study through observation, interview, objects, written documents, audiovisual materials, electronic documents (e-mail, websites). In this study however, observation and interview were the main instruments employed.

3.5.1 The Observation

Observation philosophically is the process of filtering sensory information through the thought process. Receive input from the hearing, sight, smell, taste or touch and then analyzed by a rational or irrational thinking. Over time, impressions which are stored in the minds of many similar observations together with the resulting relationships and consequence, allow individuals to build or build on the moral implications of behavior.

Oteng (2011) is of the view that, The defining characteristic of observation is that it involves drawing conclusions, as well as building personal views about how to handle similar situations in the future, rather than simply registering that something has happened. However, observation does not necessarily imply drawing conclusions and building personal views instead of the accumulation of knowledge. The researcher observed and studied the different ways of making clay bodies suitable for kiln construction and techniques for making bricks for kiln construction. This helped the researcher to gain much knowledge about making clay bodies and brick making.

3.5.2 The Interview

Interview is defined as putting questions before people with the aim of eliciting for information. Frey and Oishi (1995, 10) define it as a purposeful conversation in which one person asks prepared questions (interviewer) and another answers them (respondent). This is done to gain information on a particular topic or a particular area to be researched. The researcher interviewed a group of clay artisans at Kenyase Abrem and Tepa and clays workers who mine their clays from Kenyase Abrem and Tepa for their productions on their view on clay body formations and brick manufacturing for kiln construction. The researcher used unstructured interview in collecting data needed for the study from respondents.

Unstructured or open-ended interviews are defined by Nichols (1991, 131), as an informal interview, not structured by a standard list of question. For convenience, the researcher chose to use the unstructured interviews in order give room for respondents to express themselves and feel free of tension. By this, other information was tapped unaware. In the unstructured interviews, the researcher just had normal conversation with respondents and jotted down summarized information deduced off the scene of conversation. Because it was not made formal, the respondents talked freely and contributed with ease. This method was used when talking to people with little or no education background because they get scared with book and pen. Interviews were conducted in English, Twi and Ewe dialects and later transcribed the Twi and Ewe into English for analysis

3.6 Types of Data

The types of data accessed for the study were the primary data and secondary data. The primary data were obtained through observations and experiments conducted by the researcher during the execution of the project in the study whiles the secondary data were information elicited from publications, books and the internet.

3.6.1 Primary Data:

This was gathered from the activities performed during the course of the experiment to identify the general compositional methods adopted for the formulation of the heat retention body suitable for producing low-density refractory bricks for kiln construction. This was by critical observation made by the researcher. The data comprise all the interviews, discussions, direct personal observation and the personal communications. The primary data was very essential to the study because the data collected helped the researcher to ascertain information that are close to resolving the problem being studied.

3.6.2Secondary Data:

The secondary data comprised the entire literary materials sought, cited and used from books, articles and published unpublished thesis, internet, journals, magazines and others that were related to this study.

3.7 Data Collection Procedure

Having collected the secondary data from documentary sources (books, publications, periodicals, charts, brochures and thesis) and reviewed the related literature, the researcher built a framework of the study and based upon that, she identified and established the techniques applicable to the study and related requisite tools and materials.

The researcher visited the various sites to see the respondents and introduced himself, the proposed project and the information needed to accomplish the work. The researcher then officially booked suitable appointment dates with the respondents. The researcher adopted the face-to-face unstructured interview to collect data.

3.8 Data Analysis Plan

After obtaining the necessary information, the researcher proceeded preparing the clay body from Kenyase Abrem and Tepa clays in different compositions and percentages to experience the suitability of the various body composition techniques that make them suitable for the construction of the kilns. The result was then analyzed to derive the findings and conclusions, and recommendations were finally drawn.

3.9 General Procedure in Executing the Work

3.9.1 Production Stages

The method used for the composition of the clay body is very simple. It is made simple to enable a lay person read, understand and follow the procedures in the composition of similar clay bodies for the manufacture of low-density refractory bricks that could be used for kiln construction.

During the making of clay bodies for Kiln construction, clays that fire to a high temperature is sought for making the composition of the clay bodies so that, the low-density refractory bricks produced and used for the manufacture of Kilns can retain the maximum degree of heat temperature necessary to bring green wares to their point of maturity and also be able to fuse glazes on biscuit-fired wares, effectively without any defect.

This particular clay body adopts the use of two local clays and sawdust in a deflocculated system to come out with a product that is porous enough thus Low-density which possibly would have a considerable degree of heat retention properties that could be used in the manufacture of bricks for the production of Kilns that can retain certain heat temperatures ranging between 1300°C (2372°F) and 1700°C (3092°F) or more.

In testing the clays, choosing the right clays for the study and composing the heat retention clay body, the researcher considered the entire project in stages; the basic clay testing stage, Choosing the right clays based on their basic properties on test conducted, the composition of the clay body and the manufacture of Low-density refractory bricks from the composed body. These stages were very vital as it guided the researcher to work chronologically based on the objectives of the research for the study and also helped the researcher to point out the vital procedures to follow when making a selection of clays for the making of clay bodies for kiln construction.

3.9.2 Tools, Materials and Equipment

Tools, materials and equipment used in this study have been described. These are any hand or machine-operated devices that are employed in engineering work, brick manufacturing to test and take measurements and wood work to shape wooden products.

The most commonly used tools, materials and equipment used for this study include, mallet, jaw crusher, the carpenter tape measure, a 60meter long ruler, meshes, a wooden brick making mould, bowl, hammer, handsaw, pickaxe, shovel, weighing scale, test kiln, electric kiln, sawdust, clay from Kenyase Abrem and Clay from Tepa. The tools and materials are much described on below;

Mallet

Mallet is a tool with a metallic head and a wooden handle (Plate 3.1). It was used to breakdown lumps of clay.

Plate 3.1: Mallet

Jaw Crusher

This equipment was used to reduce large dried clay lumps into smaller particle sizes for further milling (plate 3.2). It is also used for crushing very hard ceramic material such as feldspartic rocks into smaller particles.

Plate 3.2: jaw crusher

Carpenter's tape

The carpenter's tape was used for taking various measurements when producing works with measurements (Plate 3.3).This tool was used for taking measure of cut wooden boards that were used for making the wooden mould.

Plate 3.3: Carpenter's tape measure

Metal Ruler

This tool was used for measuring the shrinkage of the bricks which were produced at specific stages (Plate 3.4).

Plate 3.4: Metal ruler

Wooden Brick mould

The researcher termed the wooden mould as a tool because it did not form part of the final work produced. It is a constructed hollow rectangular wooden frame (Plate 3.5). The size of the wooden frame was 18.5cm × 11cm × 7.5cm. This tool was used for producing the bricks with the same sizes.

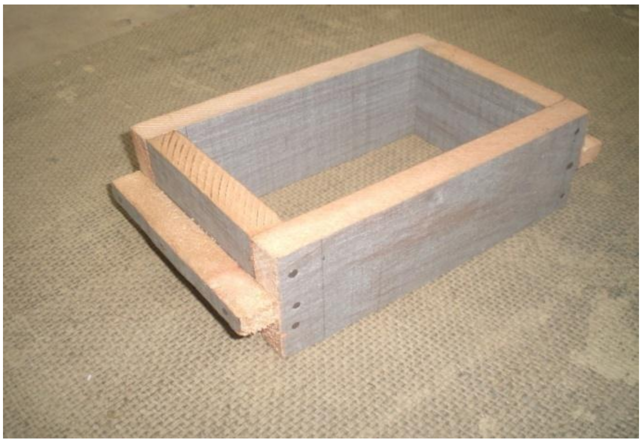


Plate 3.5: Wooden brick mould

Plastic Bowls

More than two Plastic bowls were used by the researcher. Composition of the body was made in the Plastic bowls (Plate 3.6). Bowls of different sizes were used based on the amount of materials mixed.

Plate 3.6: Plastic bowls

Hammer

This is a tool for driving nail into wood. It has a metal head and a wooden handle (Plate3.7). This tool was used during the construction of the wooden mould used for producing the bricks.

Plate 3.7: Hammer

Handsaw

The Handsaw is a tool used for cutting wood of different thicknesses for construction works. This tool has a blade and a wooden hand for easy handling (Plate3.8). It was used for cutting the wooden board for making the wooden mould for the production of the bricks.

Plate 3.8: Handsaw

Vegetable Oil

The vegetable oil is a material which was used for cooking and lubricating rusting parts of metals (Plate 3.9). In this study, the vegetable oil was used for lubricating the inner walls of the brick making mould for easy removal of the bricks after moulding.

Plate 3.9: Vegetable Oil.

Painters Brush

The painters brush is a tool used for spreading paints and other liquid substances on a given surface (Plate 3.10). It was used to spread the vegetable oil on the inner walls of the brick making mould before the composed body was compressed into it for the brick to be moulded.

Plate 3.10: Painters brush.

Pickaxe

A heavy iron tool with a wooden handle and a curved head that is pointed on both ends (Plate3.11). This tool was used for digging the various clays from their deposits.

Plate 3.11: Pickaxe

Shovel

This is a hand tool for lifting loose material; consists of a curved container or scoop and a handle (Plate 3.12). This tool was used for collecting the clay after digging.

Plate 3.12: Shovel

Weighing scale

This was the equipment used for weighing clay and sawdust samples for composing low-density bricks (plate 3.13). It was used for finding the mass of the materials for the composition and the composed bodies.

Plate 3.13: Weighing scale

Test Kiln

This is equipment used for finding the maturing temperature of ceramic materials at specific temperatures (Plate 3.14). The test kiln was used for firing the bricks to know which of the samples made from the experiment would be much suitable for the production of low-density refractory bricks for kiln construction.

Plate 3.14: Test kiln

Sawdust

This material was mixed with the Kenyase Abrem and Tepa clay in different proportions to experiment for the production of low-density bricks (plate 3.15). It was the main component of the clay body used for the production of low-density bricks for construction of the kiln.

Plate 3.15: Sawdust

Electric Kiln

The electric kiln is equipment with metallic elements in its chamber, which heats up the kiln to specific temperatures (Plate 3.16). It was used to fire the bricks in mass quantity.

Plate 3.16: Electric Kiln

Kenyase Abrem Clay

This clay was mined at Kenyase Abrem (plate 3.17), a town about twenty (20) kilometers from the Kumasi Airport Runabout. It fires off-red to orange due to the presence of a significant amount of ferrous oxide present in the mineralogical composition of the clay. It has maturing temperature between thousand degrees Celsius and thousand three hundred and fifty degrees Celsius. This type of clay is used by many locals for the production of crucibles (Plate 3.18) for melting precious metals at metal processing factories due to its ability to withstand high temperatures.

Plate 3.17: Kenyase Abrem clay

Plate 3.18: Crucibles made from Kenyase Abrem Clay because of its refractoriness

This clay was mined at Tepa (Plate 3.19), a capital town of Ahafo Ano North in the Ashanti Region of Ghana. It fires off-white to buff with little or no reddish property and this is because the presence of Ferrous oxide was insignificant of percentage in the mineralogy of the clay and its physical properties are more or less the properties of kaolin. It has larger particle sizes with large particles sizes of mica in its composition. According to Fadziawu et al., (2014) workers of Tech Ceram company located at Adankwame, a village about 35km from Kumasi on the Kumasi - Sunyani road, the clay is very refractory and has maturing temperature that could go above thousand four hundred and fifty degrees Celsius if they were to have a kiln which can fire to extreme heat temperatures. The clay is not mostly used by the locals but rather people from different walks of life go there to mine the clay for their productions.

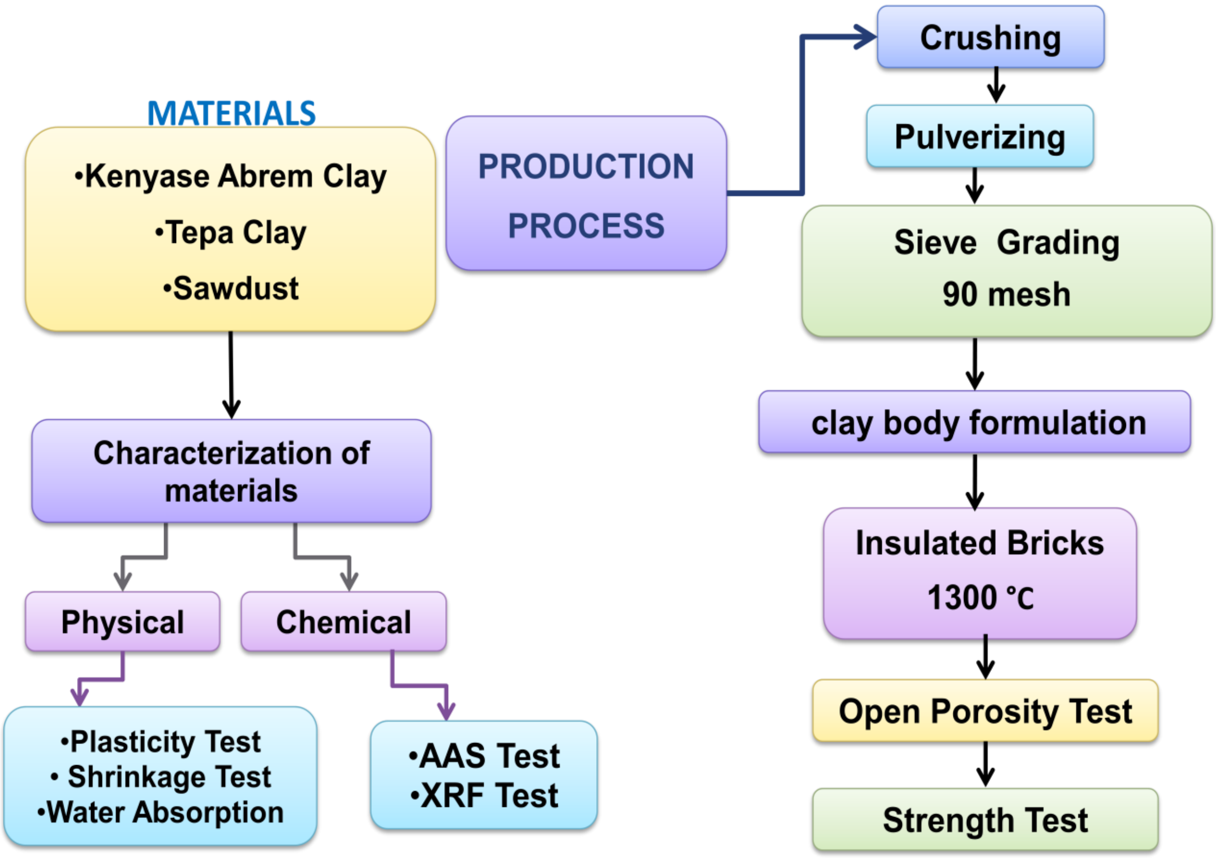
Plate 3.19: Tepa clay

Milling machine

To reduce particle sizes of the feldspartic rocks, clay and other earth minerals into smaller and finer particle size, the milling machine was used (Plate 3.20). It was the main equipment that was used for breaking down the various clays from fetched from the different locations into powder forms which was later sieved with a mesh to get finer particles for the composition of the low-density refractory bricks.

Plate 3.20: Milling machine

A FLOW CHAT SHOWING THE GENERAL WORKING PROCEDURE IN EXECUTING THE PROJECT IN THE STUDY



3.9.3 Research Question (1)

The first objective of this study was to identify and describe Kenyase Abrem and Tepa clays among other local clays as a good ceramic materials heat retention bodies for the manufacture of low-density refractory bricks for kilns construction. The researcher limited his scope to testing six (6) clays of which three (3) were fetched from Abonko in the Nananom district in the Central Region and three (3) fetched from Adankwame, Kenyase Abrem and Tepa all in the Ashanti Region. To identify which clay is best suitable for the production of the heat retention material, a few tests were conducted.

Testing the clays

In identifying the two local clays namely Kenyase Abrem clay and Tepa clay, as viable materials for the study among the six (6) sample clays the researcher prospected and tested for the study, two basic preliminary tests were conducted on each of all the clays of which the two chosen for the study were further tested at Building and Roads Research Institute (BRRI) located at Fumesua in Kumasi-Ghana. Testing for the basic properties in clays before the best ones were selected for this study was very necessary for the researcher. These properties of the clays make them suitable for whatever purpose they are intended to be used for. The researcher adopted two basic tests thus: the plasticity test and the shrinkage test to determine which of the clays would be very viable for the study. All six (6) local clays from different locations were tested, to affirm the selection of Kenyase Abrem and Tepa clay by the researcher. The clays tested include three (3) types of clays all originating from the parent rock from Abonko in the Nananom district in the Central Region and the Adankwame clay, the Kenyase Abrem clay and the Tepa clay all in the Ashanti region of Ghana.

Plasticity test for the clays

Testing for the plasticity of the clays mentioned above, each of the clays was made into coils and looped around the finger to check how elastic it is. Plasticity in ceramics terms is the ability of clay to retain shape after it has been manipulated. In making a clay body, a certain degree of plasticity is needed to bind the components together into one unit and too plastic clays are not recommended in this study. During the plasticity test for the clays, the researcher realized that most of the clays could not withstand elasticity whiles others were very plastic enough to withstand twist and turns. The plates below show the various clays tested and how they all behaved when stretched to test for their elasticity.

Plate 3.21: The researcher checking the plasticity of Abonko Clay fetched from parent rock

The clay in this test (plate 3.21) was fetched from the clay parent rock at Abonko in the Central Region of Ghana by the researcher. It looks very reddish in colour and it is very brittle when missed with water. This type of clay has a very small amount of elasticity and its tendency of cracking is very high when made into a coil. It could not even hold itself together in the wet state and when kneaded.

Plate 3.22: Researcher checking the plasticity of Abonko Clay fetched two (2) meters around parent rock

The clay being worked on (plate 3.22) was also fetched 2 meters away from the parent rock of the Abonko clay in the Central Region of Ghana by the researcher. It looked brownish and a little off-red in colour. It had little plasticity than the one fetched on the parent rock (plate 3.21). It also had the ability to hold itself together when kneaded into a ball and this was because the particles have been broken down into finer particles by the action of rain and wind. When looped around the finger, it developed a huge crack which was a result of its low level of plasticity and also due to the presence of impurities or organic materials that impart plasticity in clays. When clays undergo the process of aging or weathering for a very long time, it becomes very plastic due to the impurities the pick up during their formation and clays with high level of plasticity are mostly secondary clays or transported clays.

Plate 3.23: The researcher checking the plasticity of Abonko Clay from secondary source

The clay in this test (plate 3.23) was also fetched from the secondary clay site about One hundred and twenty (120) meters away from the main parent rock. This clay looked brownish in colour and was very plastic in nature than the clays in Plate 3.21 and Plate 3.22. This was due to its way of formation since it is transported clay. The brownish colour could be as a result of minerals and other organic materials that came into contact with it during its formation. It was able to retain its shape when looped around the finger without developing cracks on its surface. Its ability to retain its shape can be attributed to it plasticity because of the specific number of years it has aged, the impurities that came into contact during transportation form parent rock and the further breakdown of the particles into smaller sizes.

Plate 3.24: The researcher checking the plasticity of Adankwame clay

This type of clay (plate 3.24) is very plastic and has a lower tendency of cracking. Its tensile strength was high enough for it to retain its shape even when looped around the finger. This is due to the fact that it has aged for a number of years and has come into contact with organic materials and minerals that impart plasticity in clay. The Adankwame clay deposit shares boundary with Mfensi clay deposit. They could originate from the same clay but because it is on the land of the locals at Adankwame, it bears the name of the town. People around Adankwame and Mfensi use this clay for making pottery products and bricks for building due to its plastic nature. This clay had so much impurity in it and was concluded by the researcher that it is secondary clay even though the parent rock is unknown but would be sought for future studies.

Plate 3.25: The researcher checking the plasticity of Kenyase Abrem Clay

The clay (plate 3.25) looks off-white in colour and its particle size is a bit coarse in nature and looks more like the builders sand. It contains fewer impurities and had an appreciable level of plasticity needed to bind it particles together. This was because some organic matter and other minerals came into contact with it during its formation has imparted some level of plasticity to it. When organic matter comes into contact with the clay and decay, it imparts plasticity. When made in a coil and looped around the finger, it developed cracks due to the level of plasticity the clay had.

Plate 3.26: The researcher checking the plasticity of Tepa clay

The clay (plate 3.26) is the Tepa clay. It looks whitish in nature and has coarse particles than all the other clays listed above in the study and it also had larger sheets mica in its composition. Mica is a refractory material which can withstand extreme temperatures. This clay when made into a coil and looped around the finger couldn't retain its shape meaning it is not plastic. This was due to its coarser nature in particle size which is a property of primary clays and also had fewer impurities. The cracks were huge to the extent that, the coil broke into pieces.

Linear Shrinkage test on the clays

Shrinkage test was necessary in this study to determine the degree at which each of the clays tested could reduce in size after making them wet and left to dry with time. Shrinkage in ceramics is the reduction in size of ceramic or clay wares after drying or firing. Since moisture is lost in clay while drying or firing, it shrinks in size whiles the particles draw closer to each other as a result of contraction. Even though, most clay would still contain some amount of moisture after drying and firing and this is because, the environmental humidity level is not at 0°C (0°F). Most of the clays tested in this study exhibited a certain degree of shrinkage while others did not. Below is the shrinkage test conducted on each of the clay samples collected and how they behave in size after drying.

BEFORE AFTER TWO HOURS

Plate 3.27 **Plate 3.28**

Plates 3.26, 3.27: Linear Shrinkage Test for Abonko clay fetched on parent rock

The clay above was fetched from the parent rock of the Abonko clay site (Plate 3.27 and Plate 3.28). It was made in a slab form and the measurement taken by the researcher as 8cm×5cm in the wet state. After two (2) hours, the researcher took the measurement again and it read 8cm×5cm, meaning there was no reduction in size and its shrinkage ability is low. Even though, it had lower shrinkage ability, it developed so many cracks (Plate 3.27) and could not retain its shape even in the dry state.

BEFORE AFTER TWO HOURS

Plate 3.29 **Plate 3.30**

Plates 3.28, 3.29: Linear Shrinkage Test for Abonko clay fetched 2 meter way from parent rock

The clay (Plate 3.29 and Plate 3.30) above is the clay fetched two meters away from the parent rock. It was made into a slab and the measurement taken as 8cm×5cm in the wet state. After two hours, it measured 7.75cm×4.75cm showing a slight reduction in size and this is shown in plate 3.29

BEFORE

Plate 3.31

AFTER TWO HOURS

Plate 3.32

In the Plates labeled 3.31 and 3.32 above is clay fetched from the secondary clay source at Abonko. It was made in a slab and measure taken as 8cm×5cm in the wet state. After two hours it reduced 7.5cm×4.5cm showing a drastic reduction in size. This is due to the compatibility of particle size and its plasticity.

BEFORE

Plate 3.33

AFTER TWO HOURS

Plate 3.34

The clay shown in Plate 3.33 and Plate 3.34 is the Adankwame clay. In plate 3, it was rolled into a slab and the measurement taken as 8cm×5cm. After two hours it reduces to 7.5cm×4.5cm. This is because it is plastic in nature and has finer particle sizes.

BEFORE AFTER TWO HOURS

Plate 3.35 **Plate 3.36**

In the plate 3.35 and plate 3.36 above is the Kenyase Abrem clay. The particle size of this clay is more or less like that of the builders stand. Its particles sizes are not two fine in nature. It has a little amount of plasticity in it. It was made in a slab form and the measure taken as 8cm×5cm. After two hours, it reduced to 7.90cm×4.90cm showing a little reduction in plate 3.35.

BEFORE AFTER TWO HOURS

Plate 3.37 **Plate3.38**

The above clays (Plate 3.37 and Plate 3.38) show Tepa clay made in a slab with measurement of 8cm×5cm. It contains much mica and its particle size is very coarse. After two hours, the measurement was still the same showing no reduction in size. This is because its grains are coarser in sizes and has little or no plasticity due to its way of formation.

Based on the tests conducted on each of the following clays above, the researcher selected Kenyase Abrem clay and Tepa clay as materials viable for the study. This is because they possess properties of a refractory material and these are: plasticity, shrinkage, particle sizes and colour by nature. Colour also comes to play a major role in the selection of the clay because it is believed that clays that possess more or less the properties of primary clay can withstand high temperatures. After all the six samples were fired to a temperature of 1300°C (2372°F), Kenyase Abrem clay looked off-white to orange in colour, the Tepa clay looked whitish whiles the remaining clays looked reddish and red-orange in colour.

Plate 3.39: Colour of the tested clay samples fired when fired to 1100°C (2012°F)

Rhodes (1977) mentioned colour as another physical property of clay that easily affects the clay's thermal responses. He said that there are minerals that show their colour right from nature and some which also show their colour only when the clay mineral has been exposed to heat.

The two clays selected by the researcher for the study thus; Kenyase Abrem clay and Tepa clays were then taken to Building and Roads Research Institute (BRRI) at Fumesua for further tests to be conducted. The Atterberg Limit test was used to determine the plastic limit and the liquid limit of the Kenyase Abrem and Tepa clays. The Atterberg Limits are basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. In this study, only the Plastic Limit and the Liquid Limit tests were conducted because, the researcher used the manual way to determine the shrinkage abilities of the clays.

Physical tests performed on the raw clay included Atterberg limit and Particle size Distribution. The chemical composition of the clay was determined.

Atterberg Limit Test on the clays

Atterberg (1911) qualitatively described seven limits that governed the behaviour of cohesive soils like clay at varying water contents. Out of these limit tests, only the liquid and plastic limits, which determine the range of plastic behaviour of the soil, and the shrinkage limit, have remained in common usage. In this study, the plastic limit test and the liquid limit test were employed since the researcher used the manual method of determining the shrinkage ability of the clays.

In this study, the Atterberg limits of the clays were determined according to American Society for Testing and Materials (ASTM) D4318 which is a test code associated with the test for Liquid Limit, Plastic Limit and Shrinkage Limit of soils. This was to determine the basic measure of the critical water content of the sample. The samples were rolled into narrow threads of diameter 3.2mm. The samples were then remoulded and the test repeated. If non-plastic, the thread cannot be rolled down to 3.2mm at any moisture level.

Liquid limit was determined using the Cassagrande apparatus by mixing part of the clay in a round- bottom porcelain bowl. A groove was then made at the centre with a standard tool of 13.5mm and the cup repeatedly dropped at a rate of 120 blows per minute until the groove closed to the moisture content at which it took 25 drops of the cup for the groove to close, was then taken as the liquid limit.

The plasticity index was determined by taking the difference between the liquid limit and the plastic limit (PI=LL-PL).

Plastic Limit

The plastic limit which is also determined by the rolling test has a long history in geotechnics. This is a process of rolling clay wires on paper to determine their tendency of losing moisture and the tendency of breaking. Atterberg (1911) stated that (translated from German): The plastic limit or the lower limit of plasticity is found in the following way: take some of the previous clay paste (it is often advantageous to mix this with some clay powder), and roll into wires with the fingers on a pad of paper. The wires are therefore put together again and are rolled until they develop cracks or break in several pieces or chunks. If the wires break into shorter pieces, this has no meaning, if the pieces, when combined, can be rolled out again. Cassagrande (1932) suggests that the diameter at which the clay thread breaks is important, citing Terzaghi (1926a, 1926b).

Liquid limit

Atterberg (1911) proposed a method for measuring the liquid limit of cohesive soils like clay based on the number of blows required to cause a groove in a clay bed to collapse when the soil container was struck on the hand. As slope stability is a strength-based phenomenon, it would seem rational to assume that soil at the liquid limit exhibits a fixed soil strength that could in principle be measured by more repeatable methods. The fall cone test now used in BS 1377 (BSI, 1990) is a measurement of soil strength, as shown via plasticity analysis by Houlsby (1982).

Particle Size Distribution test

The particle size distribution is determined using the hydrometer method. 50g of clay was weighed and then sieved through 150 inch mesh. 100ml of dispersant solution was added to the sample and was shaken thoroughly into suspension with distilled water not exceeding 500ml. The suspension was transferred to a measuring cylinder where hydrometer reading was taken at the upper rim of the meniscus after periods of 0.5 min, 1 min, 2 min and 4 min. The hydrometer reading was repeated after periods of 8 min, 30 min, 2 h, 8 h, and 24 h from the start of sedimentation. Later, the sample was sieved through 150 inch mesh and oven dried for 24 hours.

Atterberg limit test on Kenyase Abrem clay

Table 3.1: Result on the plastic limit test of Kenyase Abrem clay

PLASTIC LIMIT TEST		
Trial No.	1	2
Container No.	4AB	315
Wt. of wet sample + Cont. (g)	22.8	22.5
Wt. of dry sample + Cont. (g)	19.3	19.7
Wt. of Water (g)	21.1	21.4
Wt. of Container (g)	6.5	6.6
Wt. of dry sample (g)	12.8	13.1
Moisture content (%)	21.1	21.4
Average Plastic Limit	**21.2**	

Table 3.2: Result on the liquid limit test of Kenyase Abrem clay

LIQUID LIMIT TEST				
Trial No.	1	2	3	4
No of Blows	39	28	19	9
Container No.	201	100	KR	41
Wt. of wet sample + Cont. (g)	26.1	34.5	46.5	61.7
Wt. of dry sample + Cont. (g)	21.8	28.3	36.7	48.5
Wt. of Water (g)	4.3	6.2	9.8	13.2
Wt. of Container (g)	6.6	6.5	6.5	6.6
Wt. of dry sample (g)	15.2	21.8	30.2	41.9
Moisture content (%)	28.3	28.4	32.5	31.5
Liquid Limit	**72.5**			

Table 3.3: Result of the plasticity index of Kenyase Abrem clay

Material	Liquid limit	Plastic limit	Plasticity Index
Kenyase Abrem clay	72.5	21.2	51.3

Figure 3.1: Graphical presentation of the liquid limit test for Kenyase Abrem Clay

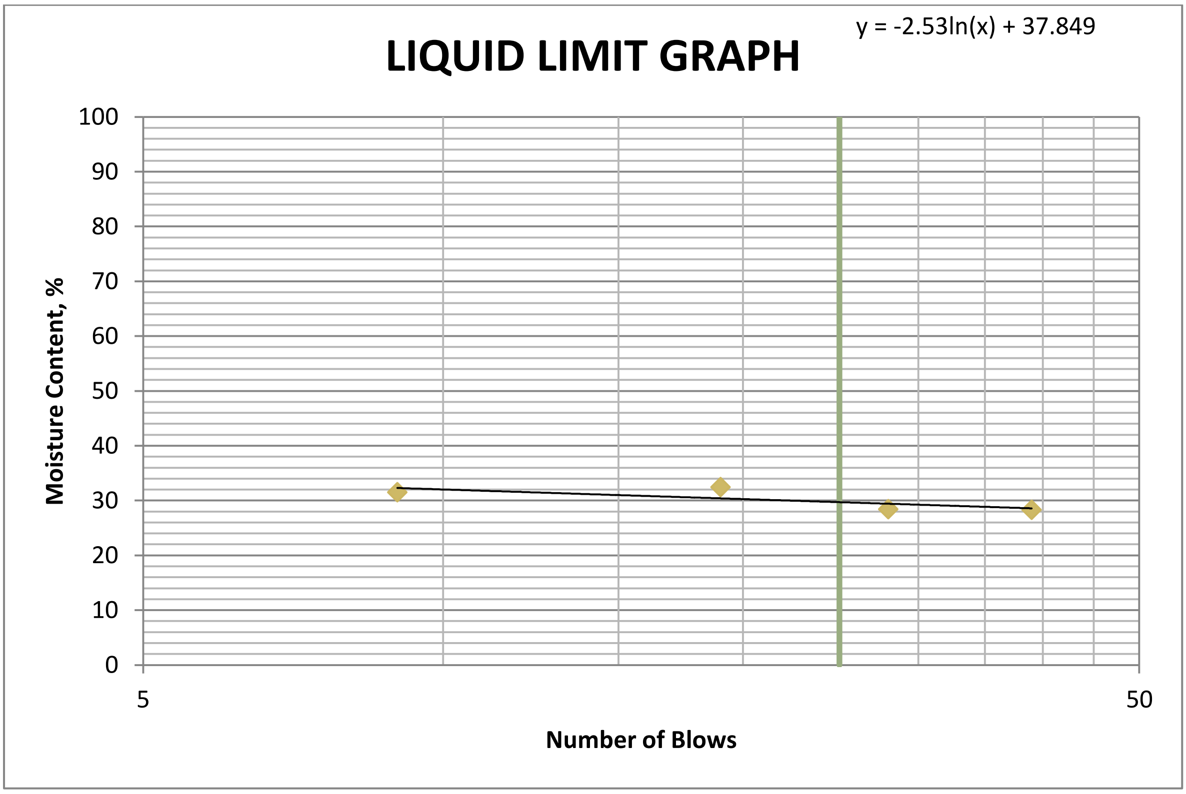


Table 3.4: Result of the plastic limit test of Tepa clay

PLASTIC LIMIT TEST		
Trial No.	1	2
Container No.	288	494
Wt. of wet sample + Cont. (g)	19.3	18.8
Wt. of dry sample + Cont. (g)	16.2	15.6
Wt. of Water (g)	3.1	3.2
Wt. of Container (g)	6.6	6.9
Wt. of dry sample (g)	9.6	8.7
Moisture content (%)	32.3	36.8
Average Plastic Limit	**34.6**	

Table 3.5: Result of the liquid limit test of Tepa clay

LIQUID LIMIT TEST				
Trial No.	1	2	3	4
No of Blows	39	29	19	10
Container No.	278p	284	282	426
Wt. of wet sample + Cont. (g)	24.7	32.6	41.3	51.4
Wt. of dry sample + Cont. (g)	19.3	24.5	30.2	36.4
Wt. of Water (g)	5.4	8.1	11.1	15
Wt. of Container (g)	6.9	6.8	6.7	7.0
Wt. of dry sample (g)	12.4	17.7	23.5	29.4
Moisture content (%)	43.5	45.7	47.2	51
Liquid Limit	**72.5**			

Table 3.6 Result of the plasticity index of Tepa clay

Material	Liquid limit	Plastic limit	Plasticity Index
Kenyase Abrem clay	72.5	34.6	37.9

Figure 3.2: Graphical presentation of the liquid limit test for Tepa Clay

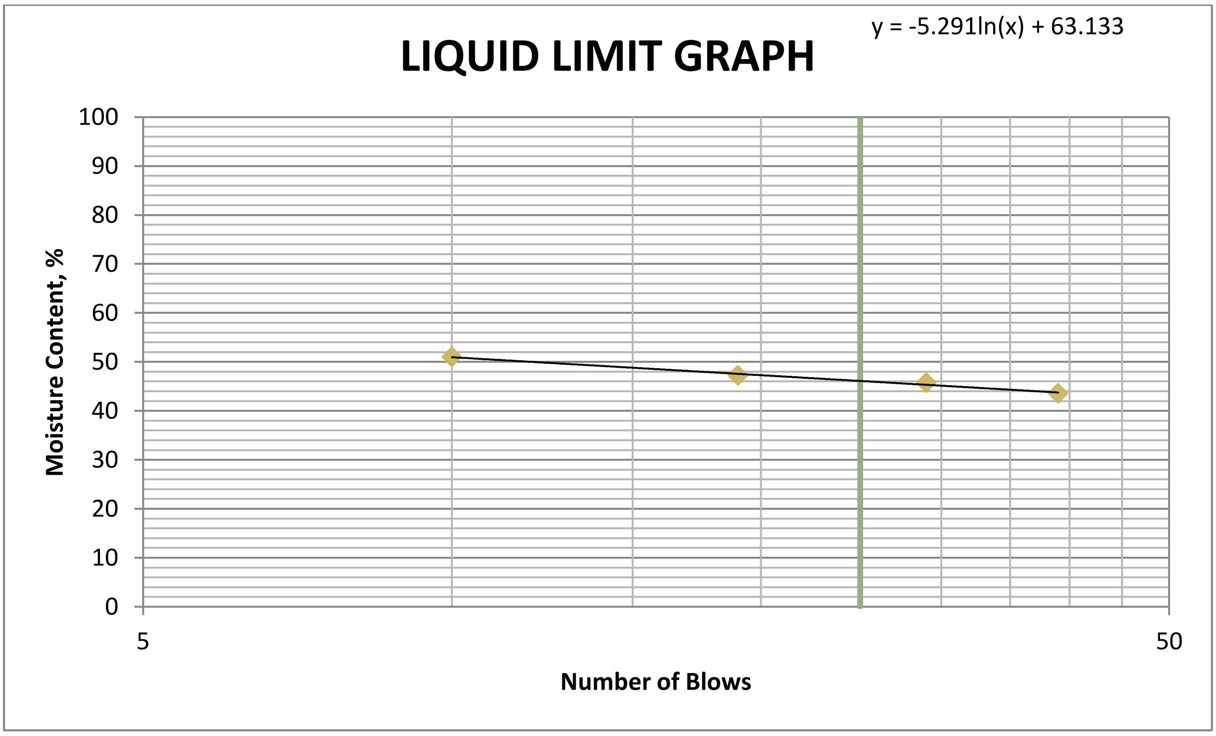


Table 3.7: X-Ray Fluorescence test for Minerals in Kenyase Abrem and Tepa Clays

ELEMENT	KENYASE ABREM CLAY (%)	TEPA CLAY (%)
Na_2O	1.97	0.26
MgO	1.0	0.06
Al_2O_3	31.01	20.40
SiO_2	47.71	70.60
K_2O	1.95	0.76
CaO	0.11	0.13
TiO_2	0.47	0.12
Fe_2O_3	1.90	0.96
LOI	14.00	6.74
TOTAL	100.31	100.03

The X-Ray Fluorescence test (XRF) was very necessary to determine the mineralogy of the clays to see how suitable they would be for the composition of heat retention body for the production of low-density refractory bricks appropriate for kiln construction. The minerals in clay determine how it can respond to thermal energy at certain degrees of heat temperature. The XRF test is a scientific test for clay to identify the oxides that makes up the clay's mineralogical composition. This test was very essential to the researcher because it helped the researcher to identify the basic minerals in the clay at certain percentages which makes the clays suitable and viable for the study.

3.9.4 Research Question Two (2)

The second research question is to compose a heat retention body from the two identified clays namely Kenyase Abrem clay and Tepa clay. Before coming out with the heat retention body, all materials necessary to be used for the composition were gathered for work to be executed. The clays were then crushed in a jaw crusher and later pulverized in a pulverizing machine to further breakdown the clay into fine particles. The researcher therefore needed the two clays in a fine state before they could be composed together into a clay body.

Plate 3.40: Researcher crushing clay into smaller particles in a jaw crusher

Plate 3.41: Researcher pulverizing the clay in a pulverizing machine into a fine state

After the two clays were crushed and pulverized into a fine state, the researcher then did particle size grading using the 90mesh sieve. The meshes of the sieves are calculated by the number of holes that can be found in a scare inch of a net. The higher the number of wholes within a square inch of the meshes, the finer the clay particles when sieved. The researcher used the 9mesh to separate the larger particles from the finer ones.

Plate 3.42: Researcher sieving the pulverized clays into finer particles with a 90mesh sieve

For the researcher to come out with a suitable body composition for the manufacture of low-density refractory bricks that could be used for kiln construction, six (6) experiments were conducted by blending the materials to arrive at the suitable composition for the production of low-density refractory bricks that could be used for Kiln construction. The materials that were used for the experiments include; Kenyase Abrem clay, Tepa clay, sawdust and water. In this composition, it is obvious to expect that, the two clays combined would be the dominating materials and the main components of the composition, the sawdust the second component which is a combustible material and during firing will burn off to create multiples of air cells necessary to retain the heat when used in the manufacture of kilns and furnaces and water as a the main vehicle for mixing the mixture into a wet state for easy manipulation. The researcher did not introduce any deflocculant in all the compositions for all the six (6) experiments. Even though, the deflocculant could have helped check the drying and firing rate of the entire composition when fashioned into bricks but the researcher decided to produce them without adding it to check how long it takes to dry by itself and also to check the strength of the bricks without deflocculant after firing. The weighing scale (Plate 3.13) was also necessary for this study since it was used to weigh the materials required for experiments 1, 2, 3, 4, 5 and 6.

Plate 3.43: Researcher measuring quantity of materials to be used

Measuring the quantity of each material to be used was very necessary for this study. The measurements were taken to aid the researcher to know the exact quantity of materials to be used for each experiment (Plate 3.43). Different measurements were taken in each of the experiment to aid the researcher to arrive at a viable composition for the study.

Plate 3.44: Researcher mixing the two clays homogenously

Plate 3.45: Researcher mixing Kenyase Abrem and Tepa clay together with sawdust, thoroughly with the hand

Plate 3.46: Researcher adding water to the mixture of the two clays and sawdust.

Plate 3.47: Researcher mixing composition into a uniform consistency after adding water

Putting all the materials together and making sure they are mixed well was very necessary for the study (Plate 3.44, Plate 3.45, Plate 3.46 and Plate 3.47). Firstly, the two clays were blended together and stirred with the hand for a uniform mixture (Plate 3.44), followed by the addition of sawdust (Plate 3.45), water was then added (Plate 3.46) and it was further stirred again to get a uniform consistency (Plate 3.47). This procedure was repeated in all the three experiments conducted. It was very necessary for the materials to be mixed and blended together in their dry and powder state before water was added because, working them in their dry and powder state is very easy, fast and also to ensure a thorough mixture. Even though the hand was used for stirring the mixture, the researcher made sure all the mixtures made in each experiment was homogenously mixed into a uniform consistency when water was added.

Experiment One (1)

Table 3.8: Quantity of materials for experimental brick one

MATERIAL	QUANTITY		PERCENTAGE
	LBS	GRAMS	(%)
Kenyase Abrem Clay	1.5	680.389	29.41
Tepa Clay	1.5	680.389	29.41
Sawdust	0.6	272.155	11.77
Water	1.5	680.389	29.41
Total	**5.1**	**2,313.3213**	**100**

In this experiment (Table 3.8), the blending of the materials was done manually with the hand by stirring the composition till a homogenous mixture was attained. 29.41% of Kenyase Abrem and 29.41% of Tepa clays were combined together in this experiment forming 58.82% of the total materials used whiles sawdust and water formed 41.18% of total materials used for the composition. These percentages indicate that, the two clays combined were the dominating materials in this composition.

Experiment Two (2)

Table 3.9: Quantity of materials for experimental brick two

MATERIAL	QUANTITY		PERCENTAGE
	LBS	GRAMS	(%)
Kenyase Abrem Clay	0.75	340.1943	14.70
Tepa Clay	2.25	1020.583	44.12
Sawdust	0.6	272.155	11.77
Water	1.5	680.389	29.41
Total	**5.1**	**2,313.3213**	**100**

In this experiment (Table 3.9), the composition was done manually with the hand for several minutes to ensure a homogenous mixture. 14.70% of Kenyase Abrem and 44.12% of Tepa clays were combined together in this experiment forming 58.82% of the total materials used while sawdust and water formed 41.18% of total materials used for the body composition.

Experiment Three (3)

Table 3.10: Quantity of materials for experimental brick three

MATERIAL	QUANTITY		PERCENTAGE
	LBS	GRAMS	(%)
Kenyase Abrem Clay	2.25	1020.583	44.12
Tepa Clay	0.75	340.1943	14.70
Sawdust	0.6	272.155	11.77
Water	1.5	680.389	29.41
Total	**5.1**	**2,313.3213**	**100**

In this experiment (Table 3.10), the composition was also done manually by stirring the mixture with the hand for several minutes to ensure a homogenous mixture. 44.12% of Kenyase Abrem and 14.70% of Tepa clays were combined together in this experiment forming 58.82% of the total materials used. The remaining materials thus; saw dust and water combined formed 41.18% of the total body composed in this experiment.

Experiment four (4)

Table 3.11: Quantity of materials for experimental brick four

MATERIAL	QUANTITY		PERCENTAGE
	LBS	GRAMS	(%)
Kenyase Abrem Clay	2	907.185	33.33
Tepa Clay	2	907.185	33.33
Sawdust	0.4	181.437	6.67
Water	1.6	725.748	26.66
Total	**6.0**	**2,721.555**	**100**

Blending of the materials was done manually by stirring the composition for several minutes with the hand to ensure homogenous mixture in this experiment (Table 3.11). The constituents of this composition were 33.33% of Kenyase Abrem clay, 33.33% of Tepa clay 6.67% of sawdust and water constituting 26.66 % of the composition.

Experiment five (5)

Table 3.12: Quantity of materials for experimental brick five

MATERIAL	QUANTITY		PERCENTAGE
	LBS	GRAMS	(%)
Kenyase Abrem Clay	3	1360.78	50
Tepa Clay	1	453.592	16.67
Sawdust	0.4	181.437	6.67
Water	1.6	725.748	26.66
Total	**6.0**	**2,721.555**	**100**

In this experiment (Table 3.12), blending of the materials was also done manually with the hand for several minutes to ensure a uniform mixture. Kenyase Abrem clay and Tepa clay combined constituted 56.67% indicating the dominating material in the composition, 6.67% quantity of sawdust was used in this experiment whiles 26.66% of water was added to bring the mixture into a wet state for easy moulding of the bricks.

Experiment Six (6)

Table 3.13: Quantity of materials for experimental brick six

MATERIAL	**QUANTITY**		**PERCENTAGE**
	LBS	**GRAMS**	**(%)**
Kenyase Abrem Clay	1	453.592	16.67
Tepa Clay	3	1360.78	50
Sawdust	0.4	181.437	6.67
Water	1.6	725.748	26.66
Total	**6.0**	**2,721.555**	**100**

In this experiment (Table 3.13), the composition was also done manually by stirring the mixture with the hand for several minutes to ensure a homogenous mixture. 16.67% of Kenyase Abrem Clay and 50% of the Tepa clay were composed together forming the dominating material in this composition. Sawdust constituted 6.67% of the total composition whiles water constituted 26.66% of the total composition.

3.9.5 Research Question Three (3)

The objective three of the research was to use the composed body for the production of low-density refractory bricks that could be used for the manufacture of kilns and furnaces that can fire at extreme temperatures above 1300°C (2372°F) and if possible be able to fire low temperature glazes.

Moulding of the bricks

Plate 3.48: Researcher lubricating the inner walls of the brick making mould with vegetable oil

To make the bricks come out successfully from the brick making mould, the researcher applied cooking oil on the inner walls of the brick making mould (Plate 3.48). This aided in the easy removal of the brick after moulding without any difficulty.

Plate 3.49: Researcher collecting composed body from the bowl into the mould.

Plate 3.50: Researcher pressing the composed body into the mould to make the brick

Plate 3.51: Researcher pushing the molded brick out of the mould

Plate 3.52: Researcher dressing to fix little broken parts of the molded bricks

The size of the bricks produced from experiments 1, 2, 3, 4, 5 and 6 (Tables 3.8, 3.9, 3.10, 3.11, 3.12 and 3.13) were all 18cm×11cm×8cm respectively in sizes in their wet states.

Drying of the bricks

Every ceramic piece after execution needs to undergo both physical and chemical changes by leaving it to the mercy of the weather for some appreciable amount of physical water and water of plasticity to escape from the bricks. This reduces the mass of any ceramic piece when they are in their bone dry state. Almost all ceramic wares can be fired only after they are completely dried. This is to avoid any defect during firing.

Plate 3.53: Drying of the bricks.

During drying of ceramic wares, one can encounter so many defects depending on the nature of the work and how it is dried. Some of these defects may include, warping due to uneven drying and thickness of the ceramic piece, cracking due to quick and uneven drying etc. In this study, the moulded bricks were left to the mercy of the weather to dry (Plate 3.53). The exposure to the weather was controlled by the researcher to avoid any defect before and after drying. The researcher expected that, the rate of drying in the moulded bricks would differ since their compositions vary from one to another. Again the researcher expected that, the combustible material added that is sawdust would aid in the quickness of the drying process.

Plate 3.54: Researching weighing the mass of the dried bricks

Before the drying of the moulded bricks made from Experiment 1, 2, 3, 4, 5 and 6 (Table 3.8, Table 3.9, Table 3.10, Table 3.11, Table 3.12 and Table 3.13), their masses when weighed were 2313.32 grams each for experiment 1, 2 and 3 and the masses for experiment 4, 5 and 6 were 2,721.55 grams each. After drying, the mass of the brick made from Experiment 1 (Table 3.8) was reduced to 1700.97 grams; indicating a decline in mass and this is as a result of shrinkage. The mass of the brick made from experiment 2 (Table 3.9) also reduced to 1723.65 grams, the brick made from Experiment 3 (Table 3.10) had its mass reducing to 1678.29g, the mass of the brick made from experiment 4 (Table 3.11) also reduced to 2025.81 grams the mass of brick made from experiment 5 (Table 3.12) reduced to 2041.17 grams and lastly, the brick made from experiment 6 (Table 3.13) reduced to 2001.17 grams, all showing a decline in the masses of the bricks when they were bone dry. The reason for weight loss was as a result of moisture leaving the bricks when it was exposed to air in a cool dry place to dry. Since the atmosphere is always humid and the bricks can never be devoid of moisture, the researcher made sure the first stage of the firing process for ceramic wares which is pre-heating was highly taking into consideration to make sure moisture has completely left the bricks to prevent any defect during firing. The bricks were pre-heated for almost 3hours to make sure they have totally been devoid of moisture.

Firing of the Bricks

Firing is an essential process of bringing ceramic wares into a stone-like material and also making them permanent to withstand harsh weather conditions. After the bricks made each from the three experiments were bone-dry, they were then fired in a Test Kiln (Plate 3.14) to see their maturing temperatures. In this study, the firing was very necessary to burn off the combustible material that is sawdust (Plate3.15) added to the clays during the composition of the body.

Plate: 3.55: Researcher packing sample bricks into the test kiln

Weighing of Bricks after firing

Once the combustible materials are burnt off, the mass of the moulded brick further reduced there by making them much lighter in weight. When the researcher weighed the six (6) bricks after firing, it was observed that, the brick composed from Experiment 1 (Table 3.8) has further reduced to 1572.45 grams, the brick from Experiment 2 (Table 3.9) has reduced to 1602.59 grams and the brick made from Experiment 3 (Table 3.10) had also further reduced to 1490.64 grams. Experiments 4 (Table 3.11), 5 (Table 3.12) and 6 (Table 3.13) had all further reduced to 1923.57 grams, 1968.33 grams and 1755.86 grams respectively after firing.

Plate 3.56: Researcher weighing the fired bricks to check the reduction in masses

The burning of the sawdust (Plate 3.15; see page 51) which is a combustible introduced in the composition created multiples of air cells in the bricks after they were fired, thereby reducing their masses and making them much lighter in weight and a suitable insulating product for kiln construction. This was determined by comparing the bone dry bricks to the fired bricks and checking the difference in weight after they were fired from the bone dry state to the biscuit state. The air cells are expected to hold heat from escaping the Kiln during firing so that, heat lost through the walls of the Kiln by the process called conduction would be checked and minimized. The bricks from the six (6) experiments were all fired to a temperature 1300°C (2372°F) at the same time. After the bricks were fired, the researcher conducted porosity test on the bricks to know how capable the bricks can hold water to determine the amount of air cells created. The more the air cells in the bricks, the higher its heat holding capability. To check for the open porosity of the bricks and their water absorption rate, water was boiled and poured in a plastic container. The researcher then weighed the masses of each of the fired bricks and their masses were noted down. The researcher then places each of the bricks into the boiled water until they were completely soaked. To make sure the bricks were completely soaked in the water, the researcher made sure no bubbles appeared on the surface of the water from the bricks and that justified that they were completely soaked in the water.

Plate 3.57: Researcher putting fired brick in boiled water to check open porosity and water absorption

Plate 3.58: Water filling air pockets in the fired brick

Plate 3.59: Researcher weighing the mass of bricks right after it has been completely soaked in water

This procedure was repeated for all remaining five bricks and their measurements were recorded for further analysis.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF FINDINGS

4.0 Overview

This chapter examines and presents the results of the blended Kenyase Abrem clay and Tepa clay together in a composition with sawdust as locally obtainable raw materials for the composition of a heat retention body which was further used for the production of low-density refractory bricks, as heat retention material or brick in the construction of Kilns. This chapter continues to discuss and evaluates the suitability of the fired brick made from local raw materials for Kiln construction. Data collection for this chapter was based on experiments and tests conducted in the entire project to confirm the suitability of the new clay body for the manufacture of low-density refractory bricks that could be used for Kiln construction and the manufacture of other refractory products. The discussions and evaluations are presented below.

4.1 Findings on Raw Materials selected for the study

4.1.1 The type of clays selected for the study

Table 4.1: Linear Shrinkage Test on Green Kenyase Abrem and Tepa Clays Samples

MATERIAL	Wet Length (cm)	Dry Length (cm)	Difference (cm)	Difference (%)
Kenyase Abrem Clay	8	7.90	0.10	1.25
Tepa Clay	8	8	0	0

Table 4.2: Linear Shrinkage Test on Fired Kenyase Abrem and Tepa Clay Samples

Material	Dry Length (cm)	Fired length (cm)	Difference (cm)	Difference (%)
Kenyase Abrem Clay	7.90	7.85	0.05	0.63
Tepa Clay	8	7.95	0.05	0.63

In all six clays were tested but only two satisfied the requirements of the researcher for the study. The two clays selected and further tested for were Kenyase Abrem clay and Tepa clays and were used for the composition of the clay body because, Kenyase Abrem clays possess a considerable amount of plasticity and have its properties more or less like those of primary clay. It looked off-white to grey in colour and its particles sizes are a bit coarser in nature. The Kenyase Abrem clay has mica content in its physical composition which by nature makes it a refractory material. Clays and ceramic materials which mostly have mica content in them become refractory when fashioned in products and fired. The researcher observed that, the Kenyase Abrem clay had very low shrinkage percentage (%) when compared to most of the clays tested. Its natural colour was also observed. Because of its whitish or off-white colour in nature, the researcher selected it among the other clays for the study since colour plays a very important role when making refractory product especially for kiln and furnace constructions. The clay from Tepa was selected by the researcher as the topmost material suitable for the study after testing and observing its property and was blended together with the Kenyase Abrem clay for the execution of project. The researcher observed that, the Tepa clay was less plastic when tested as compared to the Kenyase Abrem clay. Its particle sizes were coarser in nature than all the clays tested had larger particles sizes of mica. It also had a less shrinkage rate when compared to the other clays and therefore, based on its properties it possess which are more or less like that of a primary clay. Its colour was also whitish in nature and it was whiter than all the clays tested for the study and therefore, based on these qualities and properties, the researcher made it one of the best options for the study. Their mineralogy contents were also different. The two clays taken to Building and Roads Research Institute indicated that, Kenyase Abrem clay and Tepa clays are all refractory materials but their mineralogical contents were different. The Kenyase Abrem Clay had a high content of Alumina oxide (Al2O3) whiles Tepa clay rather had a high content of Silica oxide (SiO2). The high percentage of these minerals in the clays make them refractory materials which was suitable for the production of the heat retention clay body suitable for kiln construction. The minerals in the clay were determined by a scientific process called the X-Ray Fluorescence test (XRF) which classified all the oxides in Kenyase Abrem and Tepa clays at percentages. All other compounds found in the mineralogical composition of the clays were of low percentage. This low percentage of the other minerals or compounds present in the clays indicated how refractory they are since the other compounds are considered impurities, impurities in the sense that they affect the clays when they have undergone a chemical change during firing. Some of these changes include colour, melting point and refractoriness.

Table 4.3: XRF Classification of Minerals in Kenyase Abrem and Tepa clays

ELEMENT	**KENYASE ABREM CLAY (%)**	**TEPA CLAY (%)**
Na_2O	1.97	0.26
MgO	1.0	0.06
Al_2O_3	31.01	20.40
SiO_2	47.71	70.60
K_2O	1.95	0.76
CaO	0.11	0.13
TiO_2	0.47	0.12
Fe_2O_3	1.90	0.96
LOI	14.00	6.74
TOTAL	**100.31**	**100.03**

The researcher first fired each of the six (6) clay samples in rectangular shapes. After firing, most of the clays thus; all the three clays fetched from Abonko in the Central Region, and Adankwame clay fetched from the Ashanti Region turned reddish, reddish-orange and reddish-brown in colour indicating the high content of Iron (Fe) in the clays. Based on the theory that clays with high iron (Fe) content give a reddish property after they have been subjected to heat, the researcher therefore chose Kenyase Abrem and Tepa clays over the other clays for the study since they had a white looking property after firing. Kenyase Abrem clay looked off-white to orange after firing indicating a very little amount of Iron (Fe) present in it whiles the Tepa clays looked whitish in colour after firing. This aimed at developing a heat retention body that can also be subjected to heat at high temperatures so working with clays with high iron (Fe) contents weren't suitable for this study.

Plate 4.1: Fired clay samples from each of the six (6) clays.

COLOUR TRANSFORMATION OF THE SIX (6) CLAYS

GREEN STATE **AFTER FIRING**

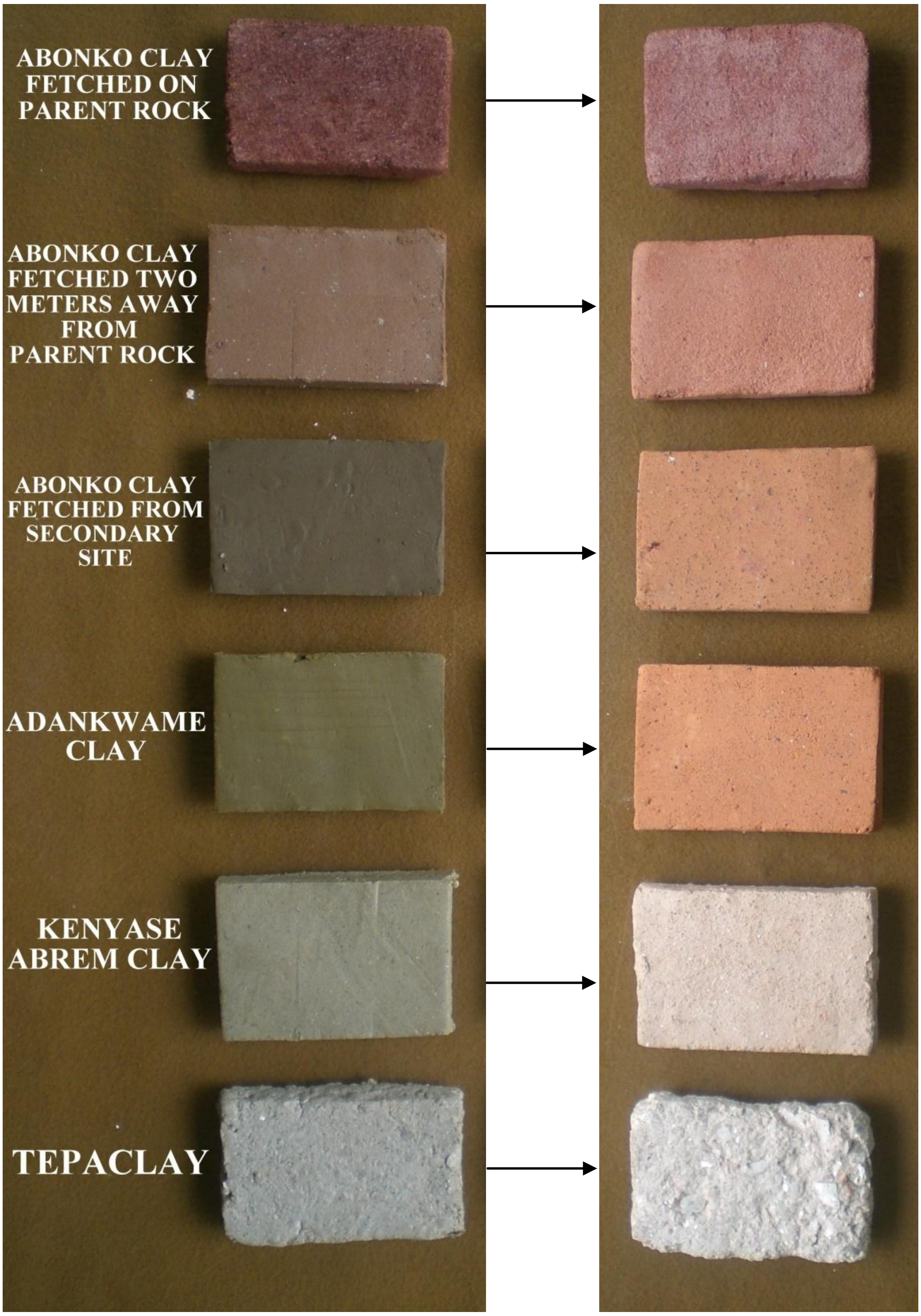


Plate 4.2: Colour transformation in the six (6) clays after they were fired to 1100

4.1.2 The Low-density bricks in their green state

Table 4.4: Mass reduction in bricks from wet state to dry state

EXPERIMENT NUMBER	MASS OF WET BRICK (g)	MASS OF DRIED BRICK (g)	DIFFERENCE IN MASS (g)	PERCENTAGE (%) DIFFERENCE IN MASS
1	2313.32	1700.97	612.35	26.47
2	2313.32	1723.65	589.67	25.49
3	2313.32	1678.29	635.03	27.45
4	2721.55	2025.81	695.74	25.56
5	2721.55	2041.17	680.38	25.00
6	2721.55	2001.17	720.38	26.47

Six (6) experiments were conducted in all for this study. Experiment 3 (Table 3.10) and experiment 4 (Table 3.11) were the only experiments that satisfied the requirements of the study in the green state and they were considered viable for the production of low-density refractory that could be used for the production of high heat retention kilns because they looked much lighter in weight and dried faster as compared to the other bricks made from the Experiment 1, 2, 5 and 6. Based on the experiments conducted, the researcher observed that, the drying rate of the experiments took a longer period because, the oil that was used for lubricating the inter walls of the brick making mould had entered the pores of the brick thereby, reducing the rate at which the moisture content evaporated from the bricks. The researcher again observed that, before the drying the bricks made from Experiment 1, 2 and 3 (Table 3.8, Table 3.9 and Table 3.10 respectively), their masses when weighed were 2313.32 grams each. After drying, the mass of the brick made from Experiment 1 (Table 3.8) was reduced to 1700.97 grams; indicating a decline in mass and this is as a result of shrinkage. The mass of the brick made from experiment 2 (Table 3.9) also reduced to 1723.65 grams and the brick made from Experiment 3 (Table 3.10) had its mass reducing to 1678.29 grams, all showing a decline in the mass of the bricks when they were in the wet state. The masses of experiment 4, 5 and 6 (Tables 4, 5 and 6 respectively) were equally 2721.55 grams in their wet states and after drying their masses had dropped to 2025.81 grams, 2041.17 grams and 2001.17 grams respectively.

4.1.3 The Low-density bricks after firing

Table 4.5: Mass reduction in bricks from dry state to fired state

EXPERIMENT NUMBER	MASS OF DRIED BRICK (g)	MASS OF FIRED BRICK (g)	DIFFERENCE IN MASS (g)	PERCENTAGE (%) DIFFERENCE IN MASS
1	1700.97	1572.45	128.52	7.56
2	1723.65	1602.59	121.06	7.02
3	1678.29	1490.64	187.65	11.18
4	2025.81	1923.57	102.24	5.05
5	2041.17	1968.33	72.84	3.57
6	2001.17	1755.86	245.31	12.26

After the bricks made from each of the experiment were subjected to heat at a temperature of 1300°C (2372°F), some of them became much lighter in weight than others. This is because the sawdust (Plate 3.15) added to the composition in the experiments 1, 2 and 3 (Tables 3.8, 3.9 and 3.10 respectively) were more than the sawdust (Plate 3.15) added to the composition in experiments 4, 5 and 6 (Tables 3.11, 3.12 and 3.13 respectively) and due to high amount of sawdust in experiment 1, 2 and 3 than experiment 4, 5 and 6, the surface of the first three experiment looked rougher than experiment 4, 5 and 6. The colour of each looks whitish when observed.

Plate 4.3: Colour and surface texture brick made from experiment 1, 2 and 3

Plate 3.4: Colour and surface texture brick made from experiment 4, 5 and 6

The researcher after weighing the fired bricks observed that, the brick composed from Experiment one (Table 3.8) has further reduced to 1572.45 grams, the brick from Experiment two (Table 3.9) has reduced to 1602.59 grams and the brick made from Experiment three (Table 3.10) had also further reduced to 1490.64 grams. Experiments four (Table 3.11), five (Table 3.12) and six (Table 3.13) had all further reduced to 1923.57 grams, 1968.33 grams and 1755.86 grams respectively after firing. Based on the mass differences recorded for each brick from the six (6) experiments, the brick from experiment three (Table 3.10) was suitable and could be used in the construction of a kiln or furnace because it was lighter in weight than the other bricks.

4.2 Open Porosity Test on Fired Bricks

Table 4.6: Water absorption test for fired bricks (Open porosity)

State of product	Exp. 1	Exp. 2	Exp. 3	Exp.4	Exp. 5	Exp. 6
Weight of saturated fired bricks in grams (A)	2275.42	2264.62	2252.15	2514.71	2711.32	2632.51
Weight of unsaturated fired brick in grams (B)	1515.42	1505.32	1479.34	1806.54	1911.43	1862.89
Formula = $\frac{A - B}{B} \times 100\%$	**50.15**	**50.44**	**53.10**	**39.20**	**41.85**	**41.31**

The researcher conducted porosity tests on the bricks from all the six (6) experiments to see the rate at which they can absorb water. This was necessary because, it was to check the amount of air cells have been created in each fired brick and the amount of water the brick can absorb. Each brick was placed in water for five (5) minutes to ensure that, they have completely been soaked. The researcher observed that, the mass of the brick after firing from experiment 1 (Table 3.8) was 1515.42 grams. After it was soaked in water and weighed again, the mass had risen to 2275.42grams. The mass of the fired brick of experiment 2 (Table 3.9) was also 1505.32 grams and also rise to 2264.62 grams after soaking it completely in water, the brick from experiment 3 (Table 3.10) also had a rise in mass from 1479.34 grams to 2252.15 grams, experiment 4 (Table 3.11) rising in mass from 1806.54 grams to 2514.71 grams, experiment 5 (Table 3.12) rising in mass from 1911.43 grams to 2711.32 grams and experiment 6 (Table 3.13) had also risen in mass from 1862.89 grams to 2632.51 grams. Out of these, the brick from experiment 3 (Table 3.10) was considered viable because, it was the lightest in weight amongst the other bricks but soaked more water to match the weight of the other bricks. Its ability to hold more water indicated the presence of multiples of air cells to hold heat during firing was more in its internal structure.

Compressive Strength of the Fired Bricks

Table 4.7: Crushing strength test for the fired bricks

EXPERIMENT NUMBER	**SIZE OF FIRED BRICK (cm)**	**CROSS-SECTIONAL AREA OF BRICK**	**LOAD APPLIED**	**CRUSHING STRENGTH**
1	18 × 10 × 7.5	$75cm^2$	500kg	$55kg/cm^2$
2	18 × 9.5 × 7.5	$71.25cm^2$	500kg	$53kg/cm^2$
3	18 × 10 × 7.5	$75cm^2$	500kg	$62kg/cm^2$
4	18 × 9.5 × 7.5	$71.25cm^2$	800kg	$90kg/cm^2$
5	18 × 9.5 × 7.5	$71.25cm^2$	800kg	$87kg/cm^2$
6	18 × 10 × 7.5	$75cm^2$	800kg	$94kg/cm^2$

After the bricks were fired, they were subjected to compressive strength test to check the rate at which the bricks will crush under load. The compressive strength test machine was used. The bricks were placed one after the other in the jaws of the compressive strength machine and a load of 500kg were place on the low-density refractory bricks made from experiment 1, 2 and 3 respectively. The researcher found out that, the brick make from experiment 3 had a high compressive strength than the bricks made from experiment 1 and 2. Because of this, the researcher selected experiment 3 as the appropriate low-density refractory brick suitable for kiln construction due to its ability to within load. The procedure was repeated for experiment 4, 5 and 6. From the table above (table 4.7, see page 99) with a higher load of 800kg applied on the bricks because they were between low-density and high-density. The brick made from experiment 6 was able to withstand heavy load when subjected to compressive strength. The bricks from experiment 6 will be suitable for constructing the corner walls to increase the stability when used in the construction of kilns and the brick from experiment 3 would be suitable for construction the side walls to retain much heat in the kiln when used for the construction a kiln.

4.3 Discussion of General Findings

4.3.1 Firing of the bricks

The entire process of firing the bricks to bring them to their maturing temperature took approximately sixteen (16) hours. The pyrometer of the kiln was then set to 60°C (140°F) per hour to ensure a good preheating of the works to get rid of moisture contents trapped in the bricks after drying. During this period of preheating, there were visible signs of smoke appearing from the chimney of the kiln. This signified the burning of combustible materials added and present in the bricks during the composition of the body. At this stage, the damper was opened to give way to the emerging smoke to escape from the kiln. At 400°C (752°F), the damper was closed and temperature increased to 100°C (212°F) per hours. When the temperature inside the kiln got to 657°C (1214.6°F), an element in the kiln got melted and the kiln was shut down. The researcher waited for the Kiln to cool down and the bricks taken out for the element to be fixed. The breaking down of the element in the kiln was due to inconsistent power supply to the elements in the kiln. When the bricks were taken out, they looked whitish in colour and at that stage they were very brittle and could break easily because they haven't gotten to their maturing point. After the broken element was replaced with a new one, all the bricks were packed again into the kiln. At this stage of the bricks, all combustible materials have been burnt off and all moisture content driven out so the pyrometer was set to 100°C (212°F)per hour to ensure quick firing. After thirteen (13) hours, the temperature was 1300°C (2372°F) and the temperature started dropping downwards.

When it dropped to 300°C (572°F), the damper was opened again to aid in quick cooling down of the kiln. It took about 11 hours for the kiln to eventually cool down before the bricks were unpacked from it.

4.3.2 Evaluation of fired bricks

All the bricks were fired to 1300°C (2372°F) and had all gotten to their point of maturity. Every ceramic piece which gets to its maturing state after bisque fining makes a metallic noise after it has been knocked with the finger or an object. When the bricks were knocked with an object, bricks from experiment 3, 4, 5 and 6 had fused very well and they were solid enough to give out a sound. Experiment 1 and 2 were not too strong enough and the particles wear off when held in the hand. When all the bricks were put in water to check their porosity, the brick from experiment 3 (Table 3.10) was found to be the best since it was lighter in weight but its internal structure was very porous with multiples of air cells which could retain heat when used in the production of a kiln.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The study sought to;

1. Examine Kenyase Abrem and Tepa clays as a good material for composing heat retention bodies suitable for kiln construction.
2. Compose heat retention body from the two identified clays.
3. Produce low-density refractory bricks from the composed body that could be used for kiln construction.

To accomplish these objectives, the researcher visited some brick making sites to observe the methods and procedures adopted for the composition of clay bodies moulding of bricks for kiln construction. The researcher however reviewed the available literature, observed and conducted interview on 17 respondents working with low-density brick in manufacturing and kiln construction, as well as the methods they adopted in the production of clay bodies for brick production and kiln construction. The descriptive and experimental methods of research were adopted for this study. Test results of the experiment and the products indicate that, all the objectives outlined, were achieved thus proving the possibility of the set research questions.

5.2 Conclusions

Positive results were achieved at the end of the project. The ability of the new clay body to withstand a temperature exceeding 1250°C (2282°F), good firing time and evidence of maturity of fired brick were achieved. The firing process faced significant electrical problems due to continual interruption of electrical power supply to the laboratory where the bricks were fired. It took the researcher 5 days to get all the bricks fired to their maturing temperature. The department also lacked many equipment and machines for testing and processing the materials so the researcher sought for assistance from other external sources to get the work done and that made it very tedious. Most of the equipment accessed were not functioning so the researcher had to process some of the materials and experiments manually. Adequate funding for the execution of the project was also another problem and contributed in the delay in testing mineralogy of the clay samples at the laboratory and firing of the bricks. The study makes a clear validity of Kenyase Abrem clay and Tepa clay, when composed together would yield high heat retention material for the manufacture of low-density refractory bricks for kiln construction, since they exceeded a temperature of 1250°C (2282°F) during firing. It has also revealed that, the untapped locally obtainable raw materials must be incorporated in the pottery industry and art education.

5.3 Recommendations

The researcher recommends that;

1. Researchers should be encouraged to study into more clays to ascertain their viability for producing low-density refractory bricks for kiln construction.
2. Clay deposits should be well protected for adequate supply of raw materials for studies and production of ceramic products.
3. Institutional laboratories must be well equipped with tools and machines to make research interesting for researchers in academia.
4. Institutional heads should encourage students and stuff to make studies into clay to ensure adequate information flow for local raw materials in ceramics.

Implication for further studies

1. The bricks produced should be further employed into kiln construction to aid local potters in firing their products.

2. Researchers could make research into more clays across the country to identify the ones that would be appropriate for studies of this nature.

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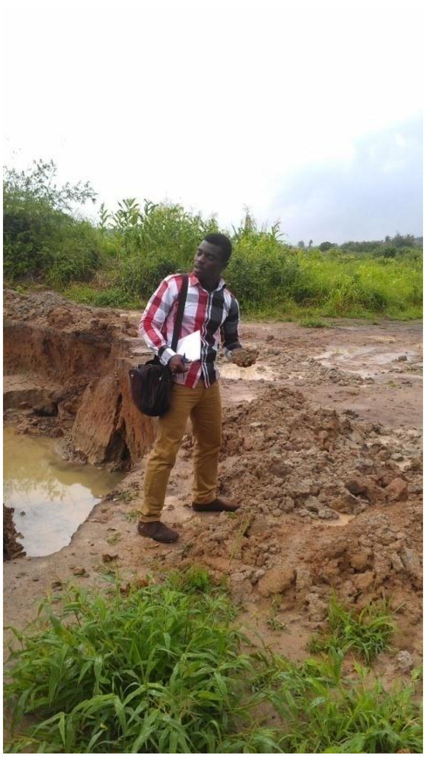
APPENDIX

A: Pictures of the researcher on Clay prospecting for the study



B: Colours of clay samples in the green state and after firing

I. In the green state

II. After firing

C: Pictures of fired bricks

I. Fired bricks from experiment 1, 2 and 3

II. Fired bricks from experiment 4, 5 and 6