ANTHILL AS A RESOURCE FOR CERAMICS

GEORGE ADJEI-HENNE

ANTHILL AS A RESOURCE FOR CERAMICS

By

George Adjei-Henne B.A (Art,)
P.G.D.A.E. M.A. (Art Educ.)

A Dissertation submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
(ART EDUCATION)

Faculty of Fine Art, College of Art and Social Sciences.

JUNE, 2009

DECLARATION

I hereby declare that this submission is my own work towards the Ph.D and that, to the best if my knowledge, it contains no material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

George Adjei-Henne …………………. ………………
20034294 Signature Date Student's name & ID

Certified by:

Dr. E. C. Nyarkoh ……………… ………………
Supervisor Signature Date

Dr. Joe Adu-Agyem ……………… ………………
Supervisor Signature Date

Dr. Joe Adu-Agyem ……………… ………………
Head of Department Signature Date

ABSTRACT

The unavailability of ceramic raw materials and equipment for the firing of ceramic wares coupled with the lack of technical knowhow for the construction of kilns in Junior and Senior high schools have prompted this enquiry into, “Anthill as a resource for Ceramics.”The study has been undertaken to point out the usefulness of anthills in the teaching of ceramics in the Junior High and Senior High Schools. It is to assist the teachers and students to turn to the anthills in their own backyard to source for solutions to the problem of raw material and firing equipment.

A comparative study of anthill materials and soils, have been made to find out the extent to which ants have modified the soils around them. Various tests were conducted to find out how useful anthill materials are so far as ceramic production is concerned. Exploratory study of the anthill structure was also conducted to find out to what extent it could serve as firing chambers and fire ports, flue holes, chimneys and other parts of the kiln. The results of the tests conducted indicated that many clay fabrication methods can be used to shape the soil from anthill. Different forms and wares were fabricated with the clay materials from the anthill. It also unveiled anthill as an insulative structure that retains heat in the semblance of an insulation brick kiln. Three types of anthills were modified to form three kinds of kilns and they were all fired successfully. It was also seen as a stable structure that can withstand a very high temperature without crumbling. Again it was revealed that the fuel consumption rate was comparatively low as only seventeen bundles of firewood were used for a batch whilst about thirty were used for a brick kiln of a similar volume. It was however recommended that further scientific investigations be carried out to find out the physical and chemical properties of the

anthill. The method of construction of the anthill and the thermal regulation strategies used by the ants could also be studied and possibly adopted in the field of architecture.

ACKNOWLEDGEMENTS

I wish to acknowledge with thanks the help I received from many people who in diverse ways made it possible for me to write this dissertation.

First and foremost I would like to thank my supervisors Dr. E. C. Nyarkoh and Dr. Joe Adu-Agyem and Dr. Mariama Ross of the Department of General Art Studies, Faculty of Fine Art and College of Art and Social Sciences; KNUST, whose direction, valuable suggestions and encouragement have yielded this piece. I wish to express my sincere gratitude to all the lecturers of the department for the encouragement and interest they have shown in this study.

My appreciation is also extended to Mr. Opoku George, Madam Agnes Ahenewaa and Joyce Sarpomaa of Berekum Senior High School for their support. I am also indebted to Mr. George Adjei-Hinne Jnr, Miss. Adwoa Afowaa, Mr. & Mrs. Ako Adjei of KNUST, Mr. Leopold Wuni of the ceramic section KNUST, Mr. Amponsah Darko and Miss. Joyce Asamoah-Antwi and all who helped in diverse ways in the writing of this dissertation.

I cannot bring this acknowledgement to an end without the mention of my wife, Susie, for her co-operation, support and motivation. She has been an unfailing source of hope and encouragement. Finally, I thank the Almighty God for His care and guidance throughout this study.

However, I must emphasize that I am solely responsible for any shortcomings, marginal or substantial, which may be found in this dissertation.

June 28, 2009 GA-H

TABLE OF CONTENTS

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF PLATES

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE
INTRODUCTION 1.1

The Statement of the Problem

Ceramics is defined as the art and science of making and using solid articles which have as their essential component, and are composed in large part of inorganic non-metallic materials. (Kingery 1976). It refers to the manufacturing of decorative or useful wares made of clay or other synthetic materials. It ranges from valuable works of art created by artists, to dinnerware, vases, bricks, tiles, glass and porcelain.

The ceramic industry is basic to the successful operation of other industries and their properties are also critical for many applications. For example ceramics such as alumina and boron carbide have been used in ballistic armoured vests to repel large-calibre rifle fire. The origination of novel ceramic material and new methods of manufacture make the subject a very crucial one among other subject areas of study. In Ghana, the industry has the highest potential for resuscitating the economy as there are a lot of ceramic raw material deposits and employable skills under ceramics. The development of the ceramic industry is therefore likely to help ease the massive unemployment problems plaguing the economy. It is therefore not surprising that ceramics has been listed as one of the subjects under the visual arts programme of the Senior High Schools in Ghana. Also in some tertiary institutions such as polytechnics and universities, ceramics is part of the academic programmes leading to the award of diplomas and degrees including Masters.

Despite its enlistment in the school programme it is still unpopular among the Senior High Schools which take visual arts as electives. Many schools 'reject' it on the grounds that there are no materials and equipment for firing.

Some schools still rely on clays which are usually found at the beds and banks of rivers. Such clay beds often become waterlogged. The clay deposits which have extensive non-clay cover also become inaccessible as schools are unable to acquire skimmers, power shovels and bulldozers to strip off the overburden in order to reach the clay. They sometimes resort to the digging of deep pits which also pose very serious safety risks to the students especially during the rainy season. The stones and foreign material that mingle with the raw clay makes its preparation for use burdensome.

Firing of ceramic wares has also been a very big problem in the Senior High Schools and with practitioners of the traditional pottery. They all look up to the use of conventional kilns in their firing. Since these kilns are not readily available in schools, many school authorities do not select ceramics as one of the options of study. Most of them end their ceramics practice at the green ware stage where the wares are left to break apart. At the Serwaa Kesseh Girls Senior High School for instance, the students travel about twenty five kilometres to private potters to fire their examination pieces. (See Plate
1.1)

School authorities usually complain of lack of funds for the purchase of kilns and also the lack of technical know-how needed for the construction of reliable kilns. This situation is impacting negatively on the popularity of the subject and affecting its inclusion in the curricula of Colleges of Education in Ghana. At the traditional setting, the open-firing process and its resultant under fired wares continue to be the practice in the indigenous pottery centres.

Plate 1.1 Students of Serwaa Kesseh S.H.S looking for assistance to fire exams pieces

Despite all these difficulties, most of the schools' environments have many anthills which are common natural landforms, forming part of their landscapes. (See Plate 1.2 and 1.3)

Plate 1.2 Anthill in front of a school in Brong Ahafo Region

Plate 1.3 Anthill in front of a school in the Ashanti Region

These anthills built through the wisdom of the ants, look unique. They are made of neatly sorted out clayey materials which have been mixed with the saliva of the ants.

Whilst some artificial structures tear apart during heavy downpour of rain, most of the anthills have been very stable and resistant to the machinations of the weather. They have also resisted the incessant bushfires which engulf them annually. These structures designed and built by termites have been observed to be very strong and withstand almost all severe weather conditions throughout the year.

Some kiln constructors also claim that they sometimes also rely on anthill soils as mortar for joining the fire bricks they use. It has been reported that the results have been perfect as the clay material from anthills is able to stand the impingement of flames and heat during the firing process without any serious damages.

In spite of these claims, no systematic study has so far been carried out about the properties of these anthills to find out the composition and whether they could be used in solving ceramic problems in Ghana. Not much research has been carried out on anthills in the Ashanti and Brong-Ahafo regions. Not much is written about it and there has not been any known serious study into its value or usefulness as a ceramic material or means of firing ceramic wares.

The successful results of cursory experiment carried out on anthills at Odomaseman Senior High School in Brong Ahafo region some ten years ago, has led to this thesis project. It is aimed at enquiring into the nature of the anthill to unearth the inherent qualities of its structure and clay content and to find out the possibility of using it as a resource material for ceramic production. The study seeks to address the problem of unavailability of ceramic materials and equipment in schools and colleges in the middle belt of Ghana.

1.2 Objectives

1.2.1 To find out the extent to which termites modify the physical and chemical properties of soils to form anthills.

1.2.2 To examine the anthill material to determine its use as a material for ceramic fabrication and production of kiln furniture.

1.2.3 To critically study the anthill structure to ascertain its usefulness as a firing medium by conducting exploratory experiments through the creation of firing ports and other component parts.

1.3 Research Questions

1.3.1 Do the termitaria offer diverse range of physical and chemical environment that differ significantly from those present in general soil mass?

1.3.2 Do anthill soils have multidimensional uses including the manufacturing of ceramic products and kiln furniture?

1.3.3 Can anthills be conveniently converted into workable kilns for firing ceramic wares?

1.4 Assumptions

1.4.1 It is assumed that the teaching of ceramics as a school subject has been adversely affected by the unavailability of materials and equipment for firing works in Ghanaian schools.

1.4.2 Not much exploration has been made into the use of anthill as kiln chambers for firing ceramic wares in Ghana.

1.5 Delimitations

1.5.1 The study will be limited to the production and the firing of test pieces in the bisque form.

1.5.2 The study will be restricted to the study of anthills in Ashanti and Brong Ahafo Regions.

1.5.3 The study restricts itself to experimenting with anthill materials and other materials which are locally available and reporting their results.

1.6 Limitations

1.6.1 The hostile nature of termites impacted negatively on the researcher's access to the anthill materials.

1.6.2 The available source of energy for the firing of the test pieces was a limitation to the required high temperatures desired for the maturing of some products.

1.6.3 The non availability of laboratory ball mill, some X-ray equipment and re-agents limited the parameters determined for the study.

1.7 Importance of the Study

1.7.1 The study will expose researchers and ceramic artists to anthill as a very important source of material for their work.

1.7.2 It will be of benefit to art educators and educational authorities who have 'rejected' ceramics because of the absence of conventional kilns in their schools.

1.7.3 As an exploratory study, it is hoped that it will generate further interest in the investigation of anthills.

1.7.4 The study will offer ceramic students the opportunity to have access to local materials and equipment in their own environment.

1.7.5 It will open up further research into the topicl as a resource for architectural construction in the tropics.

1.8 Definition of Terms

To facilitate understanding of the project, the technical terms used in the text are explained as follows:

Absorption: The taking up of water in the pores of a fired clay piece, the percentage of which indicates hardness and determines the definition of earthenware, stoneware, or porcelain.

Bagwall: A brick structure which prevents the intense heat of the furnace from striking directly unto the wares.

Bisque, Biscuit: Unglazed but fired ware, usually accomplished in a low temperature firing prior to the glaze fire; also applies to unglazed ware fired high.

Bloating: Occurs in clay bodies when they are over fired, or have added bloat ingredients.

Body: A combination of natural clays and non-plastics, especially formulation to have certain workability and firing characteristics.

Centering: Pushing a mass of clay on centre with the centrifugal motion of a potter's wheel.

Coiling: An age-old method of constructing hollow forms by rolling and attaching ropes of soft clay.

Cones: (5cm) pyramids made of clay and glaze constituents that soften and bend at specific temperatures. Cones are placed in the kiln during firing as a guide, and to indicate the final heat; they are classified by numbers coded to their softening point.

Earthenware: All wares with a permeable or porous body after firing; by definition earthenware has 10 to 15 percent absorption.

Firebars: Metal bars arranged in the fire mouth of a kiln for the holding of solid fuel.

Firebox: The chamber of certain kilns into which the combustion takes place.

Fire Clay: Secondary clay that withstands high temperature and has varying amounts if free silica in addition to the clay molecule; prevalent throughout the world.

Flue: The place of escape for the products of combustion from the chamber.

Grog: Course, medium or fine ground bisque clay added to a clay body to reduce warpage, shrinkage and cracking; also used to add texture to a clay surface.

Kiln: Furnace for firing day, slumping glass, or melting enamels; enamel; studio kilns can achieve temperatures up 2500^0F (13710c) depending on their construction materials, they can be fueled carbonaceous, organically, or electrically.

Oxidation Firing: a kiln fired with a full supply of oxygen.

Re-agent: A substance used to detect the presence of other substances by the chemical reaction it causes.

Reduction Firing: A firing in which there is insufficient oxygen available to consume the free carbon emanating from the heated clay.

Shard: A broken piece of pottery.

Shrinkage: Contraction of clays or bodies in drying and firing, caused by the loss of physical and chemical water and the achieving of molecular density.

Skewback: A slanted face of a wall where an arch exerts a thrust.

Slab: Flat piece of clay from which shapes can be fabricated.

Slip: A suspension of ceramic materials in water; generally refers to casting slip for moulds; can mean a liquid clay engobe for decorating or a glaze slip

Soaking: Maintaining a low steady heat in the initial stage of firing to achieve a uniform temperature throughout the kiln.

Spiral Wedging: The act of kneading clay in a pivoting motion to remove air pockets and to make the texture homogeneous.

Stoneware: Hard, dense, and durable ware generally fired to 2150^0F (1176^0c) or above; a body with 0 to 5 percent absorption, regardless of firing temperature.

Sintering: The fusion of particles to form larger masses through pressure.

Termitarium: A structure created by termites as their nest.

Terracotta: Used to describe iron or rust-red colours; an art historian's term for low-fired, unglazed, generally red-coloured ware; a term for pottery or clay.

Throwing: The process of forming pieces on a revolving potter's wheel from solid lumps of clay into hollow forms

1.9 Abbreviations

Al_2O_3	Aluminium Oxide.
B.R.R.I	Building and Road Research Institute.
$CaCO_3$	Calcium Carbonate
CaO	Calcium Oxide
C.S.I.R	Council for Scientific and Industrial Research.
D.D.T	Diclorophenyltricloroethane
L.P.G	Liquefied Petroleum Gas

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Not much information is available on the anthill as there has not been any serious study of the structure in Ghana. However, there is some scanty information available in scattered forms in books, unpublished theses and on the internet which has been relevant to this study. Portions of the limited literature may have been collected and used directly or indirectly as pertinent to the subject and have lent support to their review by the researcher. The following sub-topics were reviewed; anthills and termite control, ceramics, kilns, clay and clay bodies as well as clay products.

2.1. Anthills

According to Stone (1985), “an anthill is a pile of earth, sand, pine needles or clay or a composite of these and other materials that build up at the entrances of the subterranean dwellings of ant colonies.”(p.28) An ant colony is an underground lair where ants live. The queen, the brood and most of the colony’s individuals live in termitaria which are composed of mud that is sometimes as hard as concrete. They consist of series of chambers, connected to each other and the surface of the earth by small tunnels. There are rooms for nurseries, for food storage and for mating. The conditions inside the nest are dark, moist and cool and suit the requirements of the mostly blind unpigmented termites with their cuticles. It is built and maintained by legions of worker ants, which carry tiny bits of dirt in their mandibles and deposit them near the exit of the colony to form an “anthill”. Runways or galleries are built by the workers radially from the nest in all directions and connect the termitarium with sites where the colony gathers food.

A new termitarium begins underground and the mound does not appear until the colony is a year or more old. It grows rapidly and constantly being expanded to, altered or repaired. Inside the mound are the royal chamber and a maze of passages and other chambers which continue below the ground which are linked to a network of tunnels in the soil. The tunnels may extend for up to 100 metres beyond the nest and are used when the workers go in search of food.(Stone and Ndu, 1985)

There are various types of anthills made by different types of ants. Most ant species make their nests underground, carving tunnels and chambers in the soil. Some of these species build large mounds of soil, twigs and pine needles over their underground nests.

Most commonly, ants from different nests exhibit aggression towards each other. However some ants exhibit the phenomenon called unicoloniality where worker ants may freely mix between different nests. An 'organization' where ants do not freely mix is called 'super colony.' Ants from different supercolonies of the same species do exhibit mutual aggression.

Eggs are laid by one or sometimes more queens. Queens are different in structure; they are the largest ones among all ants, especially their abdomen and thorax which are larger than those of most ants. Their tasks are to lay eggs and produce more offspring. Most of the eggs that are laid by the queens grow up to become wingless, sterile females called 'workers'. Periodically, swarms of new queens and males called 'alates' are produced, usually winged, which leave to mate. The males die shortly thereafter, while the surviving queens find new colonies or occasionally return to their old one. The surviving queens can live up to around 15 years. (Hesse, 2007)

Until the year 2000 the largest known ant supercolony was on the Ishikari coast of Hokkaido, Japan. The colony was estimated to comprise 306 million worker ants and 1 million queen ants living in 45,000 nests interconnected by underground passages over an area of $2.7km^2$. (Hesse, 2007)**.**

In 2000, an enormous supercolony of Argentine ants was found in Southern Europe (report published in 2002). Of 33 ant populations tested along the 6004km stretch along the Mediterranean and Atlantic coasts in southern

Europe, 30 belonged to one supercolony with estimated millions of nests and billions of workers, interspersed with three populations of another supercolony.

Ant nests vary greatly in shape and in sizes (see Plates 2.1-2.9). Whiles some may have only one chamber of about the size of a thumb with few ants in them, some tropical ants build huge underground nests that may extend about 12 meters below the surface of the ground, with about ten million ants in it. The termites' road system can be enormous and reach a radius of 50 to 100 metres around the nest.

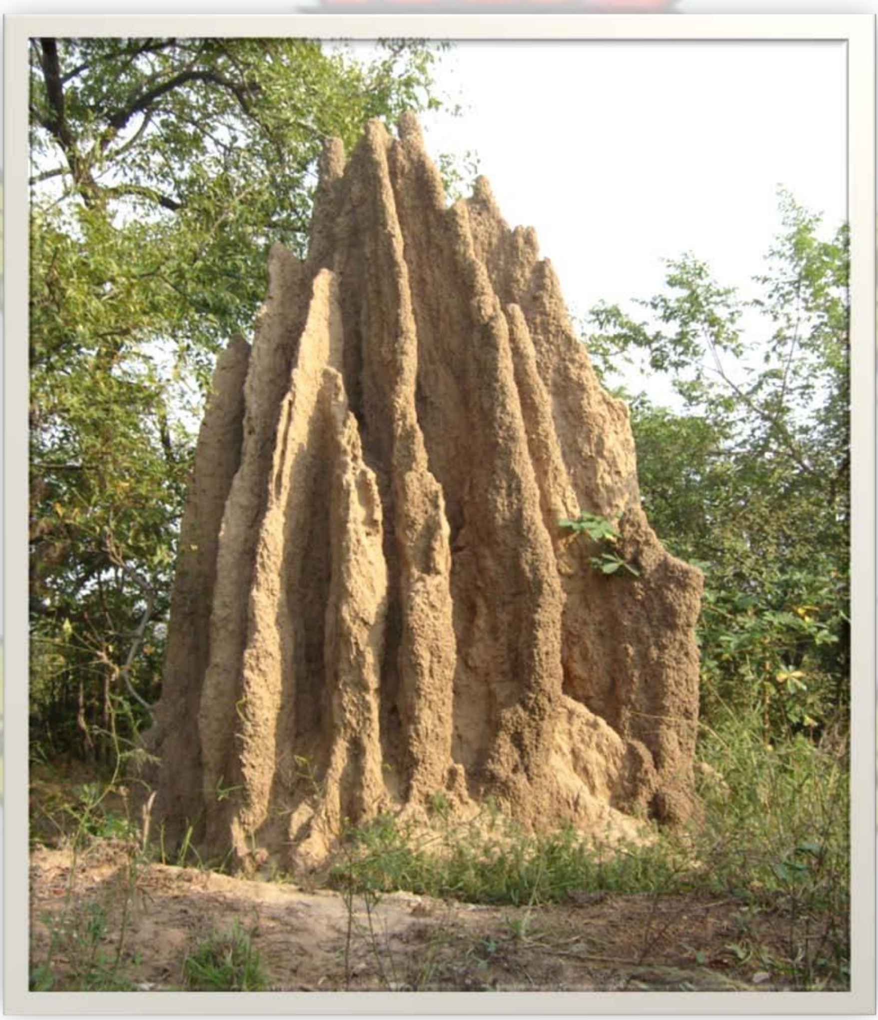


Plate 2.1 A huge anthill

Plates 2.2 A small umbrella shaped anthil

Some huge anthills stand more than 6 metres tall above ground. The huge anthills which are mostly suitable for this research are built by termites. These are small, soft bodied, wingless insects, which are often called “white ants”. Every termite community lives in a nest and different species make different nests. Some chew out tunnels in timber or dead wood. Others are soil dwellers and make themselves one or more underground chambers.

Plate 2.3 A slender anthill

Plate 2.4 A cluster of mushroom shaped anthills

Plate 2.5 An anthill with a tower

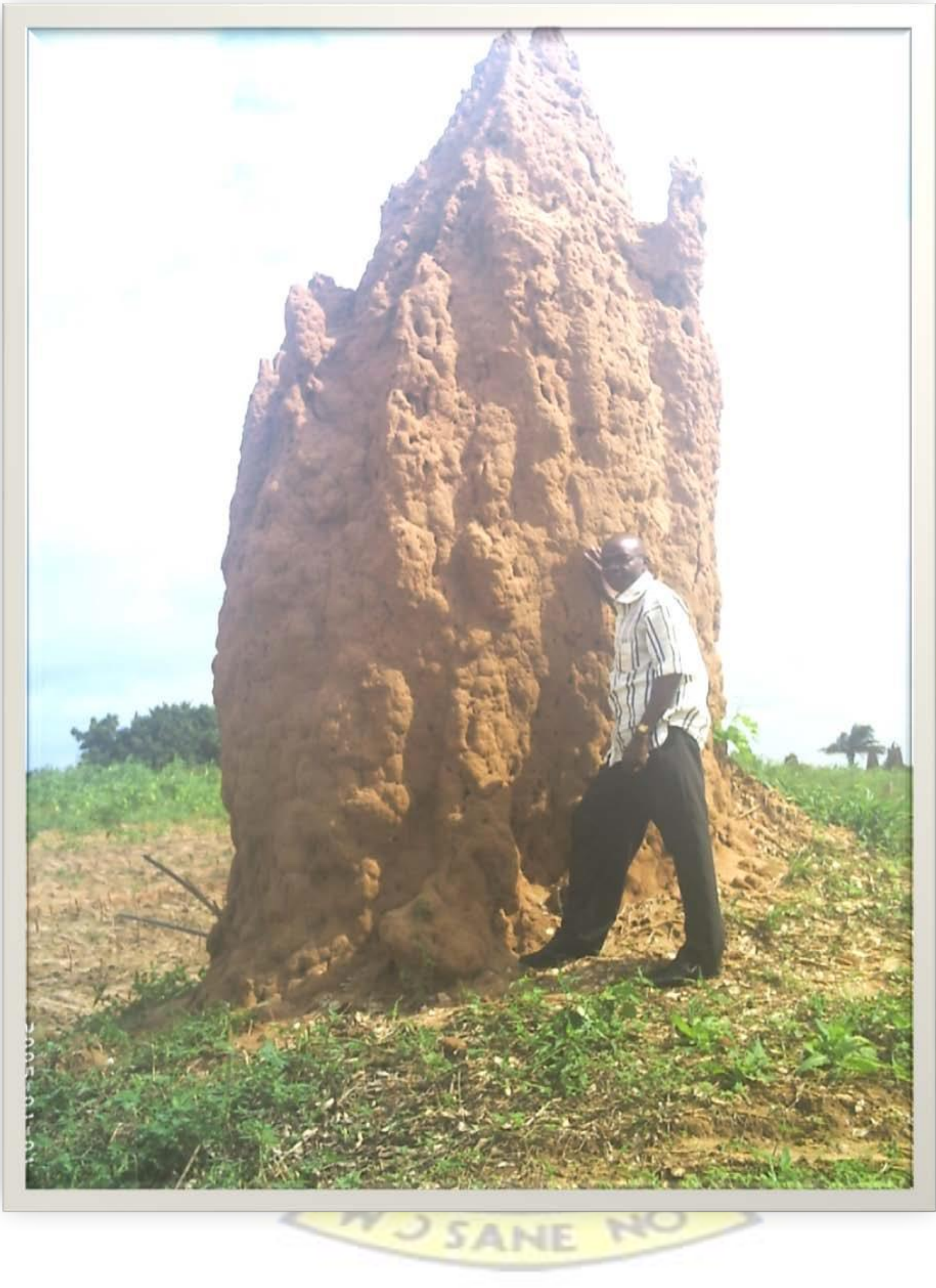


Plate 2.6 An anthill over 12 feet high

Plate2.7 An anthill with some projections

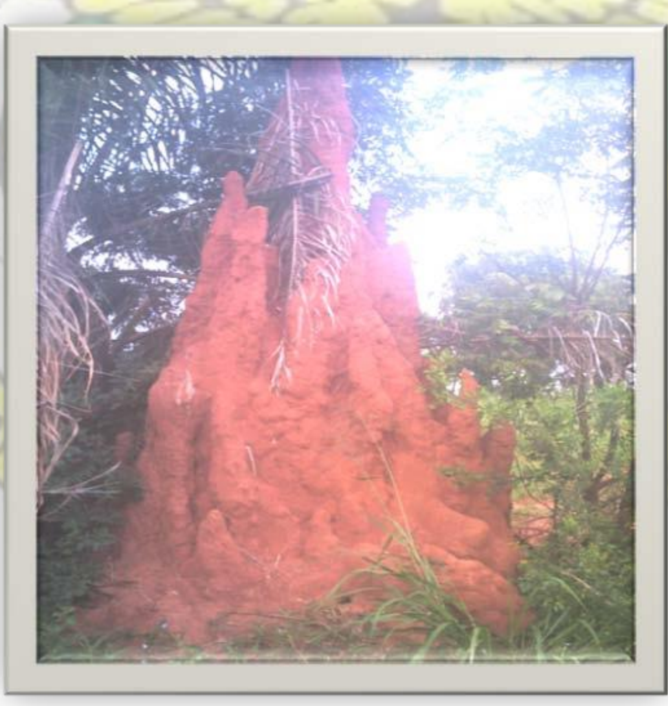


Plate 2.8 An anthill at Botokrom near Japekrom

Plate 2.9 A tilted anthill

Stone (1985) emphasizing how plentiful termites are points out that, "The soil of the savanna is teeming mass of termites and that the weight of termites in savanna soil is probably greater than the weight of animals above ground."(p.28)

The most spectacular termite nests are the large mounds or anthills which are also referred to as termitaria. They can be several times taller than man. (See plate 2.6) In West Africa, they are mostly found in the savanna and the semi deciduous forests and are very common features in the landscape of Brong-Ahafo and Ashanti regions.

They are often built by macrotermes bellicosus, macrotermes goliath, macrotermes nutalansis or related species. The mound is made by the ant workers from particles of sand they carry from the subsoil. These particles are cemented together using a mixture of clay and the workers' own saliva. (Martin 1991)

The shape ranges from somewhat amorphous domes or cones usually covered in grass and/or woody shrubs, to sculptured hard earth mounds, or a mixture of the two. The different species in an area can usually be identified by simply looking at the shape of the mounds.

The sculptured mounds sometimes have elaborate and distinctive forms, such as those of the compass termite (*Amitermes meridionalis* & *A. laurensis*) which build tall wedge-shaped mounds with the long axis oriented approximately north-south. This orientation has been experimentally shown to help in thermoregulation. The column of hot air rising in the above ground mounds helps drive air circulation currents inside the subterranean network. The structure of these mounds can be quite complex. The temperature control is essential for those species that cultivate fungal gardens and even for those that do not. Much effort and energy is spent maintaining the brood within a narrow temperature range, often only plus or minus 1^0C over a day (Eggleton, 2007).

The termitarium of the Australian species ‘anitermes meridonalis’ is flattened and tapered. The tapered sides always orientate towards the north and south. Constructing the nest this way ensures that the inside of the nest is not heated up by the sun since only the narrow sides are exposed to direct sunlight (Hesse, 2007).

In some parts of the African savanna a high density of above-ground mounds dominates the landscape. For instance in some parts of the Busanga Plain area of Zambia, small mounds of about 1m diameter with a density of about 100 per hectare can be seen on grassland between larger tree- and bushcovered mounds about 25m in diameter with a density around 1 per hectare, and both show up well on high-resolution satellite images taken in the wet season (www.wikipedia.com/termite.htm.)

The outside of the mound is dry and hard. The clay and sand cemented with saliva makes it waterproof. The structure is conical and has a round base similar to a round kiln. (Plate 2.10)

Termite mounds have been called marvels of engineering because of their wonderful nature. Their 45centimeter walls baked by the sun are as hard as concrete, and their ventilation system a marvel. A series of chambers and galleries keep the interior of the mound at a constant temperature.

This is so because strategically placed ventilation holes at the bottom of the mound allow fresh air to enter, while hot stale air is forced out through the top. Cooler air then enters the mound from an underground chamber and then circulates through the passages and cells. The termites open and close the holes to adjust the temperature as needed. A constant temperature is therefore maintained to enable them to farm the fungus that is their primary food.

In Zimbabwe for instance the outside temperature can fluctuate from about 2 degrees Celsius at night to over 38 degrees during the day. Yet the temperature inside the mound remains constant at 31 degrees (Awake June 2008)

Plate 2.10 A round shaped shrub covered anthill

The inner part is hollow with a maze of passages made with softer earth. There are ventilation passages which run through the hard outer cover to the hollow inside. (see plate 2.11)

Plate 2.11 The cross section of an anthill with ventilation passages

The shape of the mound is similar to a catenary kiln. In the Northern and Upper Regions of Ghana they are very high and slim with some projections.

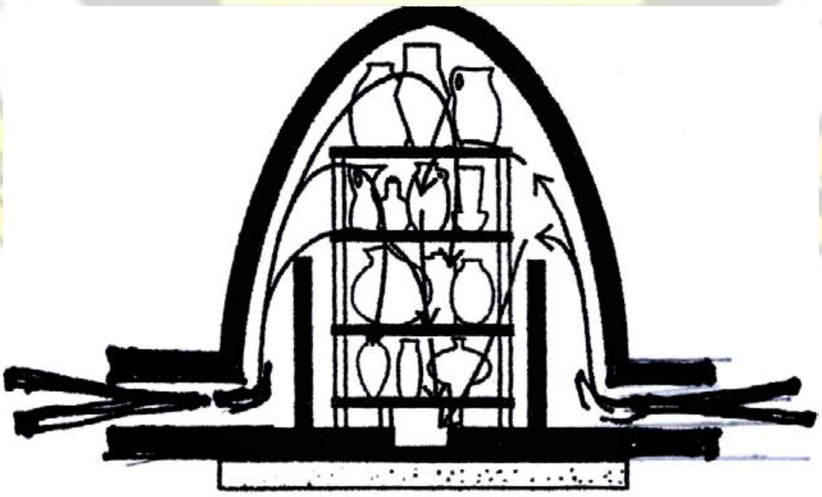


fig. 2.1 The cross section of a catenary kiln

2.1.1 Uses: Ecologically, termites are important in nutrient recycling, habitat creation, soil formation and quality and, particularly the winged reproductives, as food for countless predators. The role of termites in hollowing timbers and thus providing shelter and increased wood surface areas for other creatures is critical for the survival of a large number of timber-inhabiting species.

Larger termite mounds play a role in providing a habitat for plants and animals, especially on plains in Africa which are seasonally inundated by a rainy season, providing a retreat above the water for smaller animals and birds, and a growing medium for woody shrubs with root systems that cannot withstand inundation for several weeks. In addition, scorpions, lizards, snakes, small mammals and birds live in abandoned or weathered mounds, and aardvarks dig substantial caves and burrows in them, which then become homes for larger animals such as hyenas and mongooses.

Termites clear away leaf and woody litter and so reduce the severity of the annual bushfires in African savannas, which are not as destructive as those in Australia and the USA.

For the construction of pit latrines, anthill soil has been used as a substitute for cement in the construction of floors. It has also been used for the construction of shrines in Togo and Benin and some parts of the Volta region. The old Presbyterian church building at Adum constructed over hundred years is said to have been built with anthill soil. (Church records, Kumasi).

Anthill soil mixed with grass and river sand has been used for making fuel saving brick stoves in Mozambique. Anthills soil, river sand and ash have been used to construct similar fuel-saving stoves in Zambia also. This is reputed to be more watertight and stronger than wood.

Anthill soil from termite mounds can be used as a waterproof liner for ponds and dams, as well as being used as an alternative to soap in India, for personal hygiene and also as a shaving cream. Traditional healers in India have used sieved anthill soil as a mudpack to reduce swelling and pain from injuries, as well as a cleanser. (Eggleton. 2007)

Sun dried anthill bricks have been used for housing construction in Zimbabwe, Ant bed soil has been used for constructing traps for coyotes in Kentucky, USA. It has also been used to reduce losses in stored yams in Nigeria. The geochemistry of anthill soils has been used for gold exploration in Africa and or diamond exploration in the Kimberley. (Eggleton, 2007)

Australian indigenous people have traditionally used limonite oxide, obtained from termites' mounds, as an ochre pigment for painting. Termite mound soil has also been traditionally ingested as a medicinal aid in cases of diarrhoea, as well as being used to control bleeding infection.

The practice of eating termite mounds has even been observed among mountain gorillas in Rwanda who were found to suffer from gastrointestinal disturbances.

Anthill soil is used throughout Zimbabwe as a soil amendment, and it has been found to be good for sandy soils and those with high sodium content. Termite soil is believed to contain micro-organisms which suppress or inhibit the growth of fungi which cause plant diseases.

Apart from the life-less ones which are sometimes scooped as materials for the filling of foundation for new building constructions and as mortar by few kiln constructors in Ghana, anthills are almost useless. The destructive nature of termite makes people shun their abode.

Stone and Ndu (1985) agree to this and state further that,

> Unfortunately from mans' point of view they do enormous harm to buildings, furniture, telephone and electrical poles. They may also damage paper, clothes crops etc. It has been estimated that the damage termites do to wooden buildings in West Africa each year is equal to 1/10 of the original cost of buildings. (p. 29)

The live anthills are ignored because of the danger of introducing such destructive creatures into new buildings. They also tend to be hindrances in road construction.

In the Jaman North District of Brong-Ahafo, there is a mythology which affects people's attention and tendency to explore the usefulness of the anthill. They believe in 'Gyina'- a spirit which can sometimes manifest itself in a giant and sometimes in a dwarf. They believe that this creature resides in anthills and sometimes in the buttresses of big trees in the forest. It is invisible to the human eye and possesses powers that can easily destroy the human being.

The mythology claims that 'Gyina' harms individuals who disturb or destroy its abode. The most frequent victims are children who often cause destruction to anthills. Which ever part of the body that causes the damage suffers retaliation. For example, if a person destroyed the home of 'Gyina' by kicking it, the offending foot would swell. If modern medicine is unable to cure such a swelling, an oracle would be consulted to cure such an ailment.

The Philopinoes also have a similar mythology. In their case, the name is called a 'Nuno sa Pun so' which refers to old relatives or great grand parents in Philipino dialect. Whoever destroyed an anthill which is the abode of 'Nuno' suffered an incurable disease.

> In order to cure a victim his /her family needs to provide an offering such as fruit or drinks or a material object to the 'Nuno'. If the victim is still not cured it may be necessary for him to personally ask for 'Nuno's forgiveness. (www.answers.com/topic/anthill).

To avoid the wrath of a "Gyina" people always keep away from the anthill. Also because of the hostile nature of the termites people try to ignore it. This situation might be the cause of man's disinterest in the in-depth study of the structure in Ghana. It also accounts for the widespread existence of anthills in the environments of many African communities. Ecologists and environmentalists are however happy that these natural habitats have been preserved in many parts of the world. It is another area that scientific stance and mythology seem to coalesce.

2.1.2. Termite Control

For easy access to the structure, the termites need to be cleared. The following are methods which have been tried and have proved effective in the elimination of the termites. (www.Drdons.net)

A bait station could be mounted at intervals around the anthill and slow acting chemicals are introduced around the structure. As individual termites feed on the bait and return to the colony, poison is passed onto other members of the colony, killing them in turns. This method although effective, needs some time to work effectively. The amount of chemicals that will be introduced into the bait can also contribute to its effectiveness. The smaller the amount introduced, the bigger the number that would be affected.

Fumigation is by far the quickest way of getting rid of the termites. This is the process of directly introducing chemicals into the colony through the use of pumps. The tent of the anthill could be removed to enable enough fumigants to reach the foundation of the structure.

Stone (1985) remarked that the development of D.D.T (dichlorophenyltrichloroethane) and dieldrin have greatly strengthened man's ability to control termites. These are persistent insecticides. Once sprayed on an area, they retain their insect-killing properties almost indefinitely, yet they are cheap (p.31).

Large propane heating unit could be connected to the tent by a large flexible hose and turned on. Hot air is blown in and around the structure to heat the walls from both the interior and exterior. If this process continues till a temperature of about 50^0 C is attained and the heat inflow is well distributed, the colony will be totally annihilated.

The introduction of pebbles of carbide and water into the inner part of the anthill could also drive away the termites. They are unable to stand the scent and therefore desert it and start a new one elsewhere. A highly concentrated solution of common salt (sodium chloride) has also proved to be very effective in the control of termites.

The leaves of one of the species of cassia from the caesalpiniaceae family, cassia occidentalis also called Negro coffee and locally referred to as 'nkwadaa bɔɔ deɛ ' have also proved to be very effective in termite control. When introduced into the inner part of the termitarium the termites gradually leave to start a new one at another place. This plant has over the years been used by the Dagbani as a wood treatment medium to control the activities of termites.

(Baah, KNUST) As compared to the other termite control methods mentioned this is more environmentally friendly and less destructive to the ecology.

2.2 Ceramics

The complex nature of ceramic works and the problems ceramists faced in connection with the complexity of materials, moulding methods and improvement in quality have prompted scientific enquiry into the subject and have resulted in a lot of breakthroughs that have changed the scope of the ceramics.

The range of ceramic raw materials have widened rapidly. New shaping methods such as dry-pressing and injection moulding which were hitherto unknown have now surfaced.

Works are now developed with materials such as silicon carbide, uranium dioxide, silicon nitrate and carbon, which have very little in common with naturally occurring earths. Hardening by heat which was formerly the last link in the chain of manufacturing processes is no longer very crucial.

After considering these new developments, Chandler, (1968) defined ceramic material as “Materials that lend themselves to manufacture in a certain way, the essential part of which is the application of heat in one form or another to render them hard and resistant to their environment”. (p.11)

Many ceramic materials are hard, porous and brittle. The study and development of ceramics includes methods to mitigate problems associated with these characteristics and to accentuate the strengths of the materials as well as to investigate novel applications. The technology of manufacturing and usage of ceramic materials is part of the field of ceramic engineering.

The four major sectors of ceramics production are; structural ceramic refractory, white wares and technical ceramics. Structural ceramics includes bricks, pipes, floor tiles and roofing tiles. Refractories also include kilns linings, gas fire radiant, steel and glass making crucibles. Tableware, wall tiles, decorative art objects and sanitary wares also come under white-wares and are often made from clay, quartz, kaolin and feldspar. Technical or special ceramics includes tiles used in the space shuttle programme, gas burner nozzles, ballistic protection, nuclear fuel uranium oxide pellets, biomedical implants, jet engine turbine blades and missile nose cones. Technical ceramics can be classified into three distinct material categories which are oxides, nonoxides and composites.

Ceramics can also be classified into two, non-crystalline ceramics and crystalline ceramics. Non-crystalline ceramics, being glasses tend to be formed from melts. The glass is shaped when either fully molten, by casting or when in a state of toffee-like viscosity, by methods such as blowing to a mould. Methods for dealing with crystalline ceramic materials tend to fall into one or two categories. The ceramic is either made in the desired shape, by reaction in situations or by forming powders into the desired shape and then sintering to form a solid body. The forming methods include shaping by hand, slip casting, injection moulding, dry pressing and other variations.

In modern technology, entirely new ceramic materials have been developed and their application is expanding massively to meet the demands of sophisticated modern world. The blade of the ceramic knife will stay sharp for much longer than that of a steel knife, although it is more brittle and can be snapped by dropping it on a hard surface.

Alumina and boron carbide have been used in ballistic armoured vests to repel large-calibre rifle fire. Such plates are known commonly as smallarms protective inserts (SAPI). Similar material is used to protect cockpits of some military airplanes, because of the low weight of the material.

Ceramic balls can be used to replace steel in ball bearings. Their higher hardness means that they are much less susceptible to wear and can often more than triple lifetimes. They also deform less under load meaning they have less contact with the bearing retainer walls and can roll faster. In very high speed applications, heat from friction during rolling can cause problems for metal bearings; problems which are reduced by the use of ceramics. Ceramics are also more chemically resistant and can be used in wet environments where steel bearings would rust. The major drawback to using ceramics is a significantly higher cost. In many cases their electrically insulating properties may also be valuable in bearings.

In the early 1980s, Toyota researched production of an adiabatic ceramic engine which can run at a temperature of over 6000 °F (3300 °C). Ceramic engines do not require a cooling system and hence allow a major weight reduction and therefore greater fuel efficiency. Fuel efficiency of the engine is also higher at high temperature, as shown by Carnot's theorem. In a conventional metallic engine, much of the energy released from the fuel must be dissipated as waste heat in order to prevent a meltdown of the metallic parts.

Work is being done in developing ceramic parts for gas turbine engines. Currently, even blades made of advanced metal alloys used in the engines' hot section require cooling and careful limiting of operating temperatures. Turbine engines made with ceramics could operate more efficiently, giving aircraft greater range and payload for a set amount of fuel.

Recently, there have been advances in ceramics which include bioceramics, such as dental implants and synthetic bones. Hydroxyapatite, the natural mineral component of bone, has been made synthetically from a number of biological and chemical sources and can be formed into ceramic materials. Orthopaedic implants made from these materials bond readily to bone and other tissues in the body without rejection or inflammatory reactions. In view of this, they are of great interest for gene delivery and tissue engineering scaffolds.

Most hydroxyapatite ceramics are very porous and lack mechanical strength and are used to coat metal orthopaedic devices to aid in forming a bond to bone or as bone fillers. They are also used as fillers for orthopaedic plastic screws to aid in reducing the inflammation and increase absorption of these plastic materials.

High-tech ceramic is used in watch making for producing watch cases. The material is valued by watchmakers for its light weight, scratch-resistance, durability and smooth touch. Scientific research has indeed had some remarked effect on ceramic raw materials and processes.

The discussions so far demonstrate the wide scope of ceramics and the new dimensions the subject is taking. It also suggests the extent to which the area can be probed further. The study therefore offers another opportunity perhaps for new discoveries to be made in ceramics.

2.3 Kilns

Although, the skills of shaping, glazing and formulation of materials are very critical in pottery making the process of firing is equally critical and should not be underemphasized. Firing should therefore be considered as an essential aspect of ceramic production. This view is shared by Rhodes (1968) who notes that:

Without knowledge of the action of fire, the potter's craft would not exist. By its action, the soft and formless clay is given hardness and permanence, and a range of colour related to the colours of the primordial igneous landscape. (p. viii)

Rhodes (1968) again asserts that:

Firing is critical and when it is successful, the fruits of all other processes are reaped. But by same token if it fails, all else is cancelled and count for nothing. It is the make or break phase of the process. (p. 100)

The above statement goes to emphasize that, a kiln is an important equipment in the production of ceramics. This is because an unfired clay ware is fragile and has the tendency of breaking easily.

According to Leach (1960), "a kiln may be considered simply as chambers fed with flames by one or more fire places and from which a chimney draws heat and smoke." (p. 178). A kiln may also be described as a box of refractory materials which accumulates and retains heat directed into it.

Since kilns construction forms part of the study, it will be highly appropriate to delve into the history; types, designs and masonry construction of kilns. Such a study will give us some useful hints on kiln construction. The related literature may be a direction for further exploration.

2.3.1 History

The method of firing clay objects or vessels to make them hard, durable and impervious to water was no doubt discovered accidentally. Perhaps the prehistoric men observed that the clay soil beneath the campfire becomes hardened by the heat. Or perhaps mud lined baskets were accidentally burned in fires, leaving the hardened liner in the form of a fired vessel. From such discoveries man started managing fire to gain concentrated heat that was applied to objects fashioned in clay.(Rhodes 1968)

2.3.1.1. Bonfire: The ceramics kiln was therefore one of man's earliest tools which dates back to about 8000 B.C. The exact style of firing used in pre-historic times is conjectural but it is assumed that they are similar to the firing methods practiced by most traditional pottery settings today. There are many local variations of methods used by indigenous potters in Ghana but the essential procedure involves surrounding the pottery with red hot coals and embers, thus raising the temperature of the clay to red heat. This method was a little more than a modified bonfire.(Rhodes 1968)

This view is shared by Norska (1987) who notes that, the oldest type of kiln dating back more than 10,000 years is the bonfire. In some places a shallow pit was dug into the ground, perhaps 28 to 40 centimetres deep and several square meters in area. Twigs, branches and reeds were placed in the pit, lining its sides and bottom. Pots were placed on the lining piled together in a compact mass. Fuel is sometimes stacked in and around the pots and set ablaze. More fuel is added until a bed of red-hot glowing embers surrounds the pottery and the pottery itself reaches red heat.

This method of firing is also referred to as open pit firing which is still practiced in most pottery villages in Ghana. It has the advantage of requiring no fixed structure of any kind, so a firing could be done anywhere and with readily available fuel. The increase of heat is however limited as the open nature of the fire permits heat to rise without obstruction. Firing temperature is insufficient to fire hard impervious pottery or to fuse glazes.

In the pit firing, the wares were often subjected to direct impingement of the flame and so were discoloured by dark and black spots. Careful management of the fire could however produce a clear, smoke–free atmosphere resulting in well oxidized pottery. On the improvement of heat retention and better circulation of heat in the pit firing process, Rhodes (1968) indicates that,

> The first stage in the development of kilns was the improvement of the pit to make it retain the heat better and to introduce the fuel in a way which will promote better heat circulation. A simple but effective improvement of the firing pit was the introduction of holes at the lower part of the pit which could admit air to aid combustion. The introduction of a little air at the bottom of the pit may yield a gain of about 100 degrees Celsius. A further improvement over the dug pit is the use of a low wall of clay or mud which becomes in effect a rudimentary kiln. The wall helps to retain the heat from the embers that accumulate toward the end of the firing. (p. 9)

He maintains that kilns of this sort are still used in Spain and Mexico.

2.3.1.2 Up draught kilns: Kiln technology is very old. The development of the kiln from a simple earthen trench filled with pots and fuel to modern methods happened in stages. The introduction of fuel at the bottom of the pit or chamber to let the flames course upward through the setting rather than relying on a bed of embers to transfer heat to the pottery was a crucial step in kiln development.

The form of the kiln was essentially an opened top cylinder with an entrance tunnel for the fire provided at the bottom. These kilns which are still in operation in Iraq, North Africa and Crete were also developed in Ancient Egypt and Mesopotamia. In Mesopotamia, these circular kilns were developed around 8,000 years ago and variations of these updraught kilns were widely used throughout the ancient world. (Speight & Toki:1999).

The ware to be fired was usually piled into the cylindrical chamber, whilst the fire was built in the entrance and the flame and hot gases from the fire passing through the ware, escaping from the top. The top of the kiln could be partially closed off by a loose thatching of broken pottery or tiles. The kiln walls were made from sandy abode brick, fired brick or from sandstone. The walls were laid up with clay and often earth was piled up around the structure for better heat retention and support. The kilns were often constructed against a hill or bank and become a fixed structure that could withstand numerous firings. This design represents a great advance over the open pit fire.

Rhodes (1968) confirms this,

> It incorporates all the elements of the kiln as we know it today, a fire place or mouth in which fuel could be burnt to generate heat, a chamber to retain heat and a flue or exit from which the hot gases can escape, thus creating a draft that pulls air into the fire mouth and moves the heat upwards through the kiln.(p. 13)

He further claims that the arrangement of elements furnished the prototype for most ceramic kilns used in the Mediterranean area and in Europe down to modern times.

The advantages of a simple updraft kiln of this type are obvious. The fire can be controlled and may vary from a low smouldering fire at the beginning to a fiercely hot blaze at the height of the firing. The hot gases and flame from the fire effectively circulate heat directly to the ware. The walls of the kiln retain the heat and as the surfaces of the walls become red hot they reflect heat back in to the kiln. The top of the kiln can be covered during the firing, to retain heat but allow the escape of sufficient hot gases to create a draft.

It is known from the ceramic ware produced in Egypt, Mesopotamia, Crete and the Aegean area that open topped, updraft kilns reached 900 degrees Celsius and in some cases were fired perhaps as high as 1050 degrees Celsius. This relatively high temperature together with some degrees of control over the advance of heat accounted for the improvement of pottery and the development of ceramic glazes.

No further improvement was made in kiln design until the Greek perfected in the construction of a dome. With this knowledge they built their kilns in the shape of a bee hive. The fire was introduced into a small tunnel leading into the chamber. The draft was controlled by opening and closing a hole at the top. The kiln had a door, a hearth on which the pottery was probably placed and a space below for combustion. (Leach ,1960)

2.3.1.3. Bank kilns: One of the most fascinating aspects of the history of ceramics is the development of kilns in the East and South Eastern part of Asia.

Rhodes (1968) contended that,

> The high achievements of the Oriental potters were made possible to a considerable extent by their possession of well constructed, efficient kilns in which a relatively exacting control of temperatures and atmosphere was attainable. It is certain that by 1000 B C, Chinese potters were making wares that were fired above 1100 degrees Celsius. Such temperatures were possible in the oriental kilns but not in the primitive kilns of the west. (p. 18)

The surviving remains of cave or bank kilns in Japan give a clue to the nature of kilns that were in use in the Orient. Enough archaeological remnants of them still exist to enable us know their original form and method of operation. They were made by digging a cave in a bank. The main chamber was about four or five feet across, three feet high and ten or twelve feet long. The cave sloped at an angle of about 30 degrees. The entrance to the cave was just large enough for a man to crawl through.

This view is further explained by Nelson (2002) who stated that

> In the effort to fire clay at a higher temperature in order to produce a more durable ware, early potters developed the bank kiln. Dug into the side of a bank or hill, it provided a fuel port for the fire at the bottom, an enclosed heat-retaining chamber next to it and a vent-like chimney opening further up the hill. This arrangement created an updraught that contributed to higher temperatures. (p. 338)

Such kilns were located in areas where the soil is sandy with considerable clay in it. Soils containing rock were avoided because of the tendency to be unstable when heated. The fire was built in the entrance and flames travelled upwards through the wares and out the flue. After numerous firing, the inside of the kiln become fired and the hard crust of burned soil formed a tough and relatively permanent lining for the cave. It was observed that, the ceramic industry expanded very fast and stoneware was being fired in workshops by the ninth and the tenth century. This is so because they had developed kilns which were referred to as snake kilns because of their length and form. These kilns were built to climb up a hill in one long tunnel with no interior dividing wall. (Speight and Toki, 1999)

This type of kiln represented an advance in design over the updraft kiln. Since the kiln was completely enclosed and backed up with earth, heat loss was minimal. Furthermore, the heat was forced into a cross draft path through the ware instead of sweeping directly upwards.

2.3.1.4. Cross draught kilns: The cross draught arrangement has the advantage of enabling the thorough transfer of heat to the ware and also the possibility of diverting the hot gases through the ware. However, temperatures are apt to vary from front to back and the position of the fire may cause severe discoloration of wares placed towards the front of the kiln, since the heat is released from one point only.

2.3.1.5. Down draught kilns: The down draught arrangement also surfaced as an improvement of the up draught and the cross draught settings. This arrangement works on the principle that heat is introduced from the fire box and the flames are deflected upwards by a bag wall into the chamber, down through the pots and out through the chimney or into a second chamber before leaving the back of the kiln. It tends to fire more evenly, since the flames are held in the chamber for a greater length of time.

Furthermore, the distribution of heat can be closely controlled if the height and permeability of the bag walls are varied. The flame ways through the setting and the size and the position of the openings into the collecting flue, could also be adjusted to achieve perfect heat distribution. The use of a chimney stack improves the air flow or draw of the kiln, thus burning the fuel more completely. The added control of a damper in the chimney allows for adjustment of chimney pull and therefore of kiln atmosphere. Down draught kilns can be constructed in the round or rectangular shape. Aside the shapes down draught kilns may have many variations. One variation is the use of several chimneys in the walls instead of having one main chimney into which all the flues lead. According to Rhodes (1968), chimneys built into the walls have the advantage of transferring some of the chimney heat back into the ware chamber.

2.3.2. Types of kilns: In the broadest terms there are two types of kilns, intermittent and continuous kilns. Both of them share the same characteristics of being an insulated box with controlled inner temperature and atmosphere. Intermittent kiln is the type in which the ware to be fired is loaded into the kiln. It is sealed and the internal temperature increased according to a scheduled. After the firing process is complete, both the kiln and ware are cooled.

With the continuous kilns, they are long structures in which only the central portion is directly heated. From the cool entrance, the ware is slowly transported through the kiln and its temperature is increased steadily as it approaches the central, hottest part of the kiln. From there its transportation continues and the temperature is reduced until it exits the kiln at near room temperature.

Various types of kilns are available for use in the ceramic industry. Such kilns can be classified into types based on its shape, design and on the fuel used for its firing. On the bases of fuel, there are five major types of kilns which are available. These are coal, oil, gas, electricity and firewood.

2.3.2.1. Coal burning kilns: Coal has been widely used in Europe as a fuel for kilns due to the predominance of the coal industry there. In Ghana, the use of coal as fuel is practically inappropriate since that type of fuel is unavailable. Aside its unavailability, the sulfurous gas emitted by burning coal requires the use of saggars which are not readily available in our schools. Also fire bars made from iron frequently need replacement due to the high ember temperature of coal. This can prove a costly nuisance.

Rhodes, (1968) confirms the idea that, the high ember temperature of coal causes grates to deteriorate rapidly. Comparing coal to other fuels, Gregory, (1977) also notes that, as a fuel for large kilns, its storage space, inevitable dirt and expense, rather puts it to the bottom of the fuel list for practical reasons.

2.3.2.2 Oil fired kilns: Firing with oil requires rather more equipment than other fuels. It requires the use of oil burners which comes in the form of a drip-style a more mechanically complex type which involves the use of air under pressure or a type which uses both air and oil under pressure. There are innumerable types of oil burners on the market. Some are too complex for pottery kilns but some others are very efficient and use air pressure or steam pressure to break the oil into vapour.

In all these variations, the idea is to break up the liquid into vapour, small droplets or mist on a hot surface. Air is brought to the oil so that it may ignite and burn. Oil firing kilns are known to be effective and very cheap. The atmosphere can be easily controlled and every rapid advance of heat is possible if desired. The cost of fuel is not excessive and firing atmosphere can be controlled from oxidation to reduction. Despite these qualities and its availability, oil has not been popular in the ceramic industry in Ghana. This is because its disadvantages far out number the advantages.

Nelson, (1966) indicated that,

> Oil is a satisfactory fuel, cheaper than gas, but it has some draw backs. A separate shed-like installation is desirable, since the fumes that are given off, together with the noisy blowers, make an oil-burning kiln impractical for use inside the potter's studio or the classroom. (p. 344)

These aside, the danger of fire needs to be considered because no matter how careful one may be, oil poses a potential danger. There is also the need for constant watching and adjustment during the firing period. In some cases the smoke that emanates from the chimney in the early hours of firing may be environmentally unfriendly and may disturb the potter and the people in the neighbourhood.

2.3.2.4. Gas kilns: Gas is a very effective energy source for kiln firing. Gas kilns achieve very high temperatures. Rhodes (1968) again contends that in most respects, gas is the ideal fuel for kilns. It is safe, easily burned, very cheap and gives perfect results. Unlike oil burners, gas burners are simple, inexpensive and fool proof.

Norton, (1956) also indicates that gas kilns can achieve very high temperatures. According to him, "Well designed kilns give uniform temperature and may be used up to 1450 degrees Celsius (cone16). They are built both for side and top loading. The latter permits the attainment of uniform temperature with greater ease. (p. 55)

Gas kilns are also reported to produce interesting accidental effects and variation of colours and textures. These effects make the pots fired in them very unique. Also, it is generally clean, efficient and easy to control. (Wikipedia Foundation Inc.)

As part of Ghana's energy policy which aims at easing the pressure on electricity and fuel wood, the government is promoting and encouraging domestic use of Liquid Petroleum Gas. The use of L.P.G. is therefore becoming popular of late for both domestic and industrial use in Ghana. Both the government and private companies are engaged in the distribution of gas to various parts of the country.

One advantage to this policy is that L.P.G. costs are lower than electricity and hence gas is being considered to be a viable choice for firing ceramics in Ghana. A very disturbing factor however, is the intermittent shortages of L.P.G. -a trend which is gradually affecting its popularity. In the rural areas too, gas facilities are non-existent thereby making its use in the rural Senior High Schools almost impossible. Aside these gas kilns have other drawbacks.

Rado, (1988) reiterates that L.P.G. kilns also have their disadvantages too. Using L.P.G. as fuel requires the provision of adequate storage facility, which involves extra cost. There is also the need to have ample reserve which is also at a cost.

Another drawback to the use of gas is the possibility of leakage.

Rhodes (1968) also reveals that L.P.G. does have one bad feature; it is heavier than air and if a leakage occurs, the gas collects along the floor or finds its way into a basement where it can ignite and cause an explosion.

There is also the need for the provision of adequate space and a carefully planned setting. On this Speight and Toki (1999) advised that, if a kiln is being installed inside a room there must be a way to draw excess heat and fumes. An updraught needs a hood whilst downdraught needs a stack. They advise that it is good idea to contact a kiln manufacturer or dealer for information on the latest safety devises and controls for operating the kiln and for the correct type of ventilation system necessary to draw off excess heat and fumes.

2.3.2.5. Electric kilns: The electric kiln works on the principle where electric current is run to resistance elements to generate radiant heat in the kiln. It is relatively a modern invention or development. It was at first unpopular until in the 1930's and 1940's when the development of improved insulating refractories became a reality and practical. The heat is transferred to the inside of the kiln and to the ware by radiation and conduction. The insulation materials used for the walls impede the transfer of heat to the outside and permits the temperature inside the kiln to approach that of the heating elements.

According to free encyclopaedia Wikipedia online, the use of electric kilns in firing ceramics occurred during the 1930's and by about 1940, portable electric kilns were widely used especially in schools, universities and hobby centres.

The advantages of electric kiln over other fuel burning kilns are obvious. The most important is that electric kilns are portable and easy to operate. It does not require the laborious task of continuous stoking, monitoring and high level of technical know how for its management.

Also the atmosphere in most designs is rich in oxygen as there is no open flame to consume oxygen molecules. Rhodes, (1968) rightly remarks that,

> Not only is the electric kiln portable and adaptable for almost any space but it is easy to operate as well. No special skill or knowledge is required to fire, one needs only to turn on the switches at the right time.(p. 141)

Another advantage is that firing tends to be uniform with very little variation in results. The fire itself is clean and uniform with no danger of damage to the pottery by flashing, accidental reduction or uneven atmosphere. It makes its use very convenient for schools and for amateur potters who fear the risk of firing failures.

In addition to these, electric kilns are also very safe to operate. Nelson (2002) articulates that, the change in kiln design in recent times was caused by the development of a new source of power-electricity. He said the electric kiln needs no chimney nor fuel lines and is comparatively portable, simple and safe to operate. According to him the electric kiln has played a large part in the current popularity of ceramics and is especially convenient for the potter whose studio might be relatively temporary or for schools in which there is neither facility for chimney nor for source of fuel.

In spite of the numerous advantages, the electric kilns also have some drawbacks. One major disadvantage of the electric kiln is cost. The cost of electricity is comparatively high in relation to other fuels.

Firing with electricity usually costs about twice as much as firing with gas or oil. The cost of the kiln itself is very high. Rhodes, (1961) confirms this by stating that,

> Large electric kilns are very expensive and the initial cost of even moderate sized ones is high considering their capacity. The cost of refractories, elements, switches and the necessary metal case brings the total up even for a homemade kiln.(p. 142)

Another very serious disadvantage is the size limitation. Electric kilns are generally of a smaller size compared to fuel burning kilns, which can be of varying sizes. Electric kilns do not perform too well if the inside measurement exceeds two and a half feet across. In addition to this, the life expectancy of an electric kiln is rather low. The reason being that the refractory lining which is of the insulating type is subjected to wear and fatigue particularly within the grooves that hold the elements.

In addition to their practical disadvantages electric kilns have a serious limitation in the types of ceramics that can be fired in them. The beautiful accidental effects and variations in colour and texture associated with oil, gas and firewood kilns are absent. Since the atmosphere in the firing chambers is constant and rather neutral, all effects involving reduction or partial reduction are ruled out except when appropriate gas is introduced to induce reduction.

2.3.2.6. Firewood kilns: In Ghana the availability of fuel wood in the past has accounted for the predominant use of wood fired kilns throughout the country. Many traditional potters use twigs of wood for firing. This is probably due to the fact that other fuels are not readily available in most rural areas.

Comparatively, wood is perhaps the cheapest fuel that is available for firing in Ghana. Despite the threat of deforestation and its effect on the ecology, sources of fuel wood in Ghana are many. Sawmill cut offs and twigs of teak trees are left to rot or burn through bush fires. Many schools also have wood lots which could be harvested for use.

A wood fired kiln that is designed to correct specifications and constructed with the right type of materials and has a good operating system, can fire adequately to give very good results. Norton (1956) maintains that, "excellent results can be obtained with a kiln that is well designed. The highest temperature required for firing can be reached in such a kiln. For many years, the porcelain of Copenhagen was wood fired at 1500^{0}C."(p.56)

Norska, (1987) also holds the view that firewood is easily capable of heating kilns beyond 1300^{0}C if desired and it also produces long flames which help to even out temperature inside the kiln.

Rhodes, (1968) also confirms this and further comments that, "Contrary to popular opinion, the use of wood or coal instead of gas or oil does not mean any serious limitation of temperature and with a well-designed kiln temperature in excess of 1300^{0}C can be reached."(p. 63) Firewood is highly ranked as fuel for pottery because of the wonderful surface effects realized in wood fired kilns. The possible textures which result from flashes and ashes that deposit on the wares produce unique results. The minerals in the ashes deposited on their surfaces, may interact with the minerals in the clay, fuse and form a glaze. The ashes may also affect slips or glaze applied to the pots. (p. 63)

Nelson, (2002) confirms this and articulates that,

> Many potters are especially attracted to the accidental glaze effects afforded by wood-fired kilns. These effects result from ashes settling

> on the pots in a random fashion. The increasing cost of electricity, gas and oil fuels has added to the interest in the wood-burning kiln as an alternative source of fuel. (p. 380)

Wood fire produces a long flame which extends through the entire setting to the flues. Therefore clay wares containing iron usually have flashings of brown to reddish brown resulting from the flames that lick the wares. Artificial mottling of colours and texture may be noted on the shoulders of jars and on the horizontal surfaces of plates or lids. Unlike electric kilns it is possible to obtain a clear or oxidizing as well as neutral or reducing atmosphere.

In recent years, the ancient process of wood firing has regained popularity with western ceramics. This assertion is supported by Speight and Toki, (1999) who contended that, wood firing could achieve effects impossible to get in any other way. According to them many ceramists are turning to wood because of the distinctive surface their works are given through that, with wood firing they could achieve effects impossible to get in any other way. (p. 380)

One drawback in the use of firewood is the inevitable production of smoke which can be disturbing to neighbours. Wood fired kilns therefore need to be located in an isolated environment, with a well ventilated shed, standing by itself and with its separate chimney.

Despite this drawback the wood fired kiln is said to be a teacher and a lot of lessons could be learnt from it. This assertion clearly accords well with that of Gregory, (1984)

> Wood firing, although often exhausting, involves the potter with his kilns as no other fuel can do. The continual stoking and the roar of combustion make firing a time of great excitement and even fear! It is a

> very humbling experience to stand beside a reasonable sized wood kiln when it is reaching white heat. The roar of the initial stages of firing settles down to a deep throated rumble with tongues of flame licking from the stoke holes and iridescent heat glowing through the expansion cracks. It's a sight and experience not to be missed on a dark summer's night. (p. 13)

Herman also supports this in his appraisal of an intermittent kiln. He believes also that a kiln is a teacher and a lot of lessons could be learnt from it.(Herman www.greatbasin pottery.com.)

In the school setting and for the purpose of this study, firewood is seen to be the most suitable, affordable and convenient means for firing ceramic products in Senior High Schools and in Colleges. The management of wood burning kilns offers a sense of participation in the firing process. This is so because the students have the opportunity to split the wood, stoke or scoop the kiln.

2.3.3 Firing

Firing simply involves the process of heat generation through the combustion of fuel, the directing of the heat into a chamber and confining it there to bring about elevated temperature.

The advancement of temperature in the kiln is controlled by a few factors most of which are the relation of input to loss and design of the kiln as it affects circulation and heat transfer. Pallissy (1957), remarks that when a kiln fails to perform properly the reasons are seldom hard to find and the difficulty can usually be corrected. He said if a kiln is not reaching the desired temperature the burners may be faulty and may not be generating enough heat.

To achieve elevated temperatures within the kiln, it is necessary to put in more heat than is being lost. Heat generated in the fire box is usually transmitted to the inner chamber of the kiln through convection and radiation. Since gasses must pass through the kiln to bring in the heat, some heat is inevitably lost.

Some escape through the flue and some through the walls, floor and roof. In as much as no insulating material is a perfect heat barrier, some heat is bound to be lost through many routes. An increase in temperature is therefore dependent on the input capacity of the fuel. The fuel must generate and transmit to the kiln more heat than is being stored or lost.

Norton (1952) outlines the heat balance in the most efficient kiln as follows:

Useful heat applied to the ware - 20%

Heat lost through cooling – 18%

Heat lost through the flue – 36%

Heat lost through the walls and crown – 18%

Heat stored in walls and crown – 14%

Heat used in vaporising water – 8%

Incomplete combustion of fuel – 6% (p. 138)

Preparation for successful firing procedures begins from the construction of the wares to be fired. Clay must be wedged thoroughly to remove undesirable air pockets and possible lumpiness. Joints must be well sealed and the wares must be dried completely to avoid trouble in the kiln during firing.

The drying of clay is always accompanied by shrinkage. As the film of water between the clay particles is drawn off by evaporation the particles draw closer together to close up the interstices. The effect of this action is the shrinkage of the entire mass of clay.

The drying shrinkage however, depends on particles size and the amount of water which separates them. Clays with fine particle sizes shrink more than those of large particle sizes. Drying of clay is greatly facilitated by the presence of non-plastics such as sand or grog. They open up the pores or channels through which moisture can escape towards the surface. Apart from the quick drying they promote, the particles serve as skeletons to hold the object in shape during drying and firing. Wares made with clay which contains high percentage of non-clay particles shrink and distort very little when subjected to heat.

Although a clay ware may be well dried, it may contain some amount of moisture absorbed from the atmosphere. Firing completes the drying process in clay ware so it must be brought about slowly otherwise the formation of steam within the clay body may cause it to explode. No matter how dry a clay piece may be the chemically combined water of crystallization ought to be driven off.

This water which constitutes about 14% of the total weight of structure of the clay forms part of the molecular structure of the clay and is unaffected by temperature below 350ºC. Its expulsion causes voids in the structure of the clay and therefore needs to be done slowly and carefully so as to prevent sudden evolution of steam and possible breaking of the object.

Also crystals of quartz which are usually associated with the clay as an accessory material, re-arrange themselves into different order as they are exposed to high temperature. At 573ºC and above quartz crystals undergo a change from alpha to beta quartz. When cooling the beta quartz changes back to alpha. These changes are accompanied by slight changes in volume so in order to avoid damages to clay objects the volume changes must be made to take place slowly. Another form of change that is noticed in clay as it is heated is vitrification. It is the hardening, tightening and partial glassification of clay. It is usually associated with shrinkage, hardness, durability, density and the rocklike properties. This hardness results from fusions or melting of some of the component parts of the clay particularly impurities such as iron oxide.

As the clay is subjected to heat, the more fusible impurities of the clay may melt and soak into the surrounding area, binding the particles together like glue and acting as a solvent in promoting further fusion. Alumina and Silica combine to form interlocking crystals called mullite. Clays vitrify at different temperatures depending on their composition. A common red clay rich in iron and other mineral impurities may fire to hardness at about 1000 ºC and may melt to a liquid at about 1250 ºC.

Ordinarily, ceramics require a rather slow heating schedule. Time is required for the various reactions to occur to change the raw clay into a finished fired piece. Slow cooling is also necessary to prevent damage to the ware from shock and sudden contraction. The kiln must also be heated so that the temperature advances steadily without any erratic gains and losses. Therefore successful firing of clay to high temperature also depends on the understanding of the clay.

The technique of firing with wood can really only be acquired with practice. In order to gain the temperature required, the fire must be fed at a steady rate. Over stoking will fill and choke the fire box and result in heat loss, but a steady and judicious stoking, will bring about a good rise in temperature.

Although hard wood such as Odum, osa, Oak, Birch, have potentially more heat value, soft wood such as Pine, Fir, Framo, Akasaa, Sunuro and Wawa burn faster and will result in a faster heat rise. The resin in soft wood volatilizes and produces a long flame that extends throughout the kiln.

It is also important to know that wood being a solid matter, can only burn on its surface area. It will smoulder and ignite only on the exposed surfaces. Thinner pieces of wood, will therefore burn and release energy faster than large thick logs.

Preparation for successful firing procedures begins from the construction of the wares to be fired. All undesirable elements need to be taken care of and the drying process should be carried through with caution. Initial firing should be done slowly but steadily so as to promote temperature rise. It is necessary to keep the wood very dry and as small as possible for easy handling, stoking and burning. Cooling should also be slow so as to prevent cracking.

2.4. Clay

Clay is a naturally occurring material composed primarily of finegrained minerals, which show plasticity through a variable range of water content, and which can be hardened when dried and/or fired. Clay deposits are mostly composed of clay minerals (phyllosilicate minerals), which impart plasticity and harden when fired and/or dried, and variable amounts of water trapped in the mineral structure by polar attraction. Organic materials which do not impart plasticity may also be a part of clay deposits.

Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks (usually silicate-bearing) by low concentrations of carbonic acid and other diluted solvents. These solvents (usually acidic) migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed by hydrothermal activity.

Clay deposits may be formed in place as residual deposits, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Clay deposits are typically associated with very low energy depositional environments such as large lake and marine deposits.

Chandler, (1967)

Clays are distinguished from other fine-grained soils by various differences in composition. Commercial kaolin, for instance contain up to 90 percent clay substance, whilst others such as certain brick clays, as little as 30 per cent.. Silts, which are fine-grained soils which do not include clay minerals, tend to have larger particle sizes than clays, but there is some overlap in both particle size and other physical properties, and there are many naturally occurring deposits which include both silts and clays.

The word clay is therefore among the more troublesome of the singlesyllable words. It covers a huge range of natural substances differing greatly in appearance, texture, and chemical and physical properties. Chandler (1967) justifies this by commenting that,

> The justification for applying a single generic name to all of them is that they have certain important qualities in common. They are all plastic when wet, when merely dried they are all rigid, but will regain their

plasticity when thoroughly rewetted; when fired they all become permanently non plastic and mechanically stronger. (p. 17)

2.4.1. Clay bodies: Many types of clay found in nature serve very well just as they are. They can be dug out of the ground, kneaded with the right amount of water and made into pottery or bricks without making any additions. In Ghana, the most common clays around are the red clays which are mainly used for the manufacture of brick and tiles as well as tableware.

However, the demands which one makes of clay as a mineral, usually requires the blending of two or more materials in order to achieve the desired results.

A clay body may therefore be defined as a mixture of clays or clays and other earthy mineral substances which are mixed together to achieve a specific ceramic purpose. It is usually necessary to make additions to natural clays in order to have it serve the practical needs of forming and firing. Sometimes, additions are made to improve working properties. For example, some sand might be added to reduce the shrinkage and lessen the tendency of the clay to warp when dried and fired.

Rhodes (1973) listed five ways in which one might wish to change a clay for practical purposes. Thus:

1. Change of colour or texture. It may be desired to alter the fired colour of the clay or to make it either lighter or a darker shade, or to increase or decrease its granular roughness or texture.
2. Changes in plasticity. It may be desired to make clay more plastic or less plastic.

3. Changes to decrease shrinkage or to improve drying and firing with a minimum of warpage or cracking.
4. Changes to lower the maturing temperature. Or stated in another way, changes which will increase or decrease density at a given temperature.
5. Changes to improve the fit of glazes. (p. 22)

From the above, it could be inferred that all adjustments in clays involve either adjustments of the physical properties or adjustments of its reaction to firing. Changes of the physical properties involve adding clays or other materials of more or less plasticity and of varying the particle size. An adjustment of reaction to firing involves adding clays or other materials of more or less fusibility. On the need for clay body formulation, Speight and

Toki, (1999) remarked that,

> One reason for learning to mix at least a few basic clay bodies is to become familiar with the ingredients and how they act in the clay. Even if you do not plan to make your own clay bodies in bulk, some knowledge of formulating, mixing and testing clay bodies will add to your understanding of how the different ingredients affect the body and how a particular clay will respond to your hands on drying or to firing.(p. 181)

It is indeed necessary to have some knowledge of the chemistry and physics involved in the physical and thermal reactions of the clay materials. Such knowledge will enable the researcher to alter the unwelcome behaviour of some clays by making additions of other clays or other materials. It might also help to predict with some accuracy what any combination of clays might do in a body. It may however not be necessary to delve so much into the chemical composition of clays, what is most important is the physical character of the materials. This view is again supported by Rhodes, (1973) who opined that,

> The actual chemical composition of clay bodies is seldom of much interest in the process of formulating mixtures. What is of most interest is the physical character of the ingredients, such as plasticity and grain structure and their thermal behaviour, such as shrinkage and fusibility. (p. 24)

For the sake of convenience, all materials which go into clay body formulation may be plastics, fillers or fluxes. The plastics are usually clay and they lend the necessary workability and plasticity to a clay body. Even clay bodies which are meant for casting or pressing need to have some higher percentage of plasticity.

Non-plastic materials such as flint, grog or calcined clay are the fillers and they enable the clay to dry out safely without undue warping or cracking. They also help decrease the amount of shrinkage considerably. The fluxes such as feldspar or frit in turn control the fusion or hardening point of the clay and make it fire to a satisfactory degree of density at whatever temperature being used.

Peterson (1996) affirms that clay body is thought of in three parts (1) the plastic material–clays chosen for their workability and firing qualities (2) a density controlling material, called a flux, which lowers the melting point of ceramic material, and (3) a filler for lessening the characteristic stickiness and shrinkage of the clay content.

It is essential to know the nature of the body being formulated. Stoneware clay for instance, must be plastic and easily workable but it should not be too plastic to have high drying or firing shrinkage. It must be able to withstand temperature in the region of 1200^0C. For colour and texture, it depends on the potter's choice and the impurities which are present.

Not only are clay bodies formulated for firing temperature desired, texture and colour, they may also be formulated in order to be appropriately shaped. Clay may be shaped into objects either by modelling, throwing, jiggering, pressing, dry pressing or slip casting in moulds. Each of these methods of shaping demands certain physical properties. Whilst for modelling or pressing much less plasticity is required, clays needed for throwing should be of higher plasticity. There are really no fixed rules for formulating clay bodies.

Rhodes (1973) confirms that,

> This process of formulating body compositions is somewhat like cooking, in that the proof of the pudding is in the eating. The recipe is improved over a series of variations until it performs for us, in practice as we want it to. The number of ingredients is usually not great and the individual behaviour of each ingredient may be well known. For this reason, formulating clay bodies is not particularly difficult and may usually be accomplished with fewer tests than are required in the case of originating glazes. (p. 26)

In formulating bodies for earthenware the best plan is to rely on the natural clay. According to Rhodes,(1973) "the vast majority of the world's pottery has been earthenware. This is because of the prevalence of earthenware clays and the relative ease of reaching in the kiln, the temperatures necessary to fire it." (p. 37).

Rothenberg, (1972) also remarked that,

> Earthenware bodies are low firing (from cone 06 to cone 1), suitable for hand building, throwing or modelling. An earthenware body is red, brown or buff according to the amount of iron Oxide in the natural red clay that makes up most of the body, with only enough modification to make it workable and of good firing properties. (p. 4)

Most clays used for the making of bricks, water pots and bowls in the Brong–Ahafo and Ashanti regions are earthenware clays that can be relied upon in the formulation of earthenware bodies.

Once clay has been located, the next step is to test it to find out what its characteristics are. Tests for plasticity, tests for total shrinkage at some specific temperatures should be made. There is the need for some investigation into its green and fired strength and the apparent porosity. It will then be known what adjustments must be made to the clay to make it work well with the intended processes and firing temperature and to arrive at the desired results.

Rhodes (1973) again lists the various forms which the additions are apt to take.

1. If the clay is too refractory – that is if it does not become hard enough at the temperature at which it must be fired – some flux must be added to it. This flux might be iron oxide, talc or a frit.
2. If the clay is too fusible and becomes too dense at the intended firing temperature, refractory materials must be added, such as kaolin, ball clay, stoneware clay, flint, fine grog, or fire clay.
3. If the clay is too sticky and shrinks too much, it will need the additions of more non – plastic materials such as flint, kaolin, grog or fire clay.

4. If the clay is mealy and not sufficiently plastic, it will need the additions of some more plastic materials such as ball clay or bentonite.
5. If the colour of the clay is to be changed, iron or other colouring metallic oxides may be added. (p. 37)

Tests must be made to determine not only the necessity for changes in the clay but also the amount of the additions which will result in the most serviceable body. Some other common clay bodies are porcelain, stoneware, ovenproof bodies, and white ware bodies.

It is usually necessary to make additions to natural clays in order to have it serve the practical needs of forming and firing. Additions could be made to improve working properties of anthill soils so as to meet the objectives of the project

The contributions and different views expressed by various writers on anthills, kilns and clays have opened up new approaches and many areas for critical study. The breakthroughs that have been accomplished in ceramic material science in recent times have also served as an impetus to the author to explore different avenues and strategies towards the achievement of the objectives of the research.

From the review, different shapes and sizes of the anthills, their nature, character and uses surfaced and this stimulated in-depth exploration of the anthill to unearth its usefulness as a ceramic kiln. The literature on kilns also revealed different firing methods, fuels and designs which helped in this same direction.

CHAPTER THREE METHODOLOGY 3.1 Introduction

This chapter outlines the various procedures used in order to ensure the success of the research. The procedures include: the research design, methodology used for the study, description of the population studied and the description of the sampling design used. It also includes library, laboratory and industrial researches conducted, interviews, observations and other survey instruments used and the treatment of the data collected.

3.2 Research Design

The quasi-experimental and descriptive research methods were adopted for the project. Quantitative and qualitative studies were used to observe and examine the phenomena at hand and to describe precisely what the researcher saw so as to discover its meaning.

They were also used to study the data by means of statistical tools to infer from them certain meanings which lay hidden. It also enabled the researcher to discern the presence of potentials and dynamic forces which lay within those data that suggested possibilities for further investigation.

Ex-post-facto experimental research was employed to examine clays and anthill materials to search for the factors that brought about their differences, associations and their meanings. Not true experimental design was used to perform repeated experiments in support of the third hypothesis.

3.3 Library Research Conducted:

Library research was part of the study. The Kwame Nkrumah University of Science and Technology (K.N.U.S.T) main library, the College of Art and

Social Sciences library, Department of Art Education library, Library of Architectural Engineering Faculty and the institute of Renewable Natural Resources library, all at the Kwame Nkrumah University of Science and Technology were visited on many occasions.

Other libraries the researcher visited were the British Council library Accra, Forestry Research Institute of Ghana library at Fumesua, the Ashanti Library at Centre for National Culture and the library at the Institutes of Council for Scientific and Industrial Research Fumesua, all in Kumasi. In the libraries, information on white ants colonies and anthills were sought. Information on the development of kilns, types of kilns and the various fuels used for firing were also sourced. Kiln planning and construction techniques were also sought from books in various libraries.

Some information about clays, clay body formulation, kilns and anthills were also sourced from the internet. Books, publications, journals, magazines, periodicals and theses were the sources from which secondary data were collected.

3.4 Industrial Research Conducted:

The researcher visited six selected pottery and ceramic centres in Brong-Ahafo and Ashanti Regions. He also visited four brick production factories in the Ashanti Region and six in the Brong – Ahafo Region.

Among the centres the researcher visited in Brong Ahafo were Adom clay centre in Biadan, Emmanuel brick works in Wamfie, S.D.A brick and pottery centre, Bossko clay works in Tanoso and Tano clay products in Abesim. In the Ashanti Region, some of the centres the researcher visited were the C.N.C pottery centre, in Kumasi. Di Assempa Brick and tiles, Vicalex brick and tiles, Two Brothers clay works in Mfensi and Aframs clay technology in Asokwa.

At these centres, he interviewed the production managers on the firing processes and the kiln builders on the various stages of construction. This was to enable him get an on the spot information on kiln construction and some techniques in firing.

Another place the researcher visited was the C.S.I.R. at Fumesua in Kumasi. At this institute, the researcher interviewed Dr. J.K. Boadi, the Senior Scientific Officer of the B.R.R.I. on kiln construction, clay bodies' formulation and on anthills. Also at the ceramics section of the Department of Industrial Arts, Faculty of Industrial Arts, the researcher interviewed Mr Leopold Wuni, the Senior Laboratory Technician and Mr Joe Nsiah a lecturer in charge of Ceramic Technology on ceramic raw materials, clay bodies formulation, wood fuel and kiln construction techniques.

Plate 3.1 The researcher interviewing Mr.Leopold Wuni, a laboratory technician

Aside the interviews conducted at Mfensi and the S.D.A brick and tile centres, the researcher engaged in brick moulding process from clay preparation to preparation for drying. (Plate 3.5)

Plate 3.2 The researcher in a brick moulding practice at S.DA brick and pottery centre Tanoso, Sunyani

Plate 3.3 Moulding of bricks

At the Tanoso Brick and Tile Factory the only place with a rectilinear downdraft kiln, the researcher engaged in a five hour fire stoking practice with the fire attendants.

Plate 3.4 Kiln stoking by the researcher

3.5 Laboratory Research

In pursuance of the first and second objectives, anthill materials from Mfensi, Tanoso, Fomena, Wamfie and Biadan were identified and collected for examination. Soils around the anthills of the five selected areas were also collected to make for comparative study. The researcher carried out series of tests on the materials at the laboratories of the Ceramic Section of the Department of Industrial Art KNUST and the Ghana Atomic Energy Commission at Kwabenya.

3.6 Population for the Study

For this study the researcher considers population as anthills located in the Ashanti and Brong Ahafo Regions. This means that all anthills in Brong Ahafo and Ashanti constitute a population. Since anthills are by nature the same and constitute a homogeneous population, geographical location became the highest consideration. Five different locations in Ashanti and Brong Ahafo regions were randomly selected to represent the population.

Population also refers to persons having information on kiln design, construction and operation. Within the context, senior officers of institutions and establishments, ceramic technology lecturers and researchers in brick and tile construction, Technicians at the Ceramic Section of the Department of Industrial Art, Faculty of Industrial Art, Production managers of pottery centres and Brick and Tile Factories in the Ashanti and Brong-Ahafo Regions, kiln constructors and fire attendants and other artisans working in the pottery centres are considered to constitute a population. The total potential population for this research is three hundred and fifty (350).

3.7 Sampling:

Sampling is the operation of securing portions of a system under investigation for subsequent laboratory testing and analysis. In the context of this study sampling is a portion, piece or segment that is representative of a whole population.

By the nature of this research, it was not possible to include all the available population for study so a sample population was studied. They were divided into three categories comprising:

a. Senior officers of institutions and establishments
   (Lecturers and Senior Technicians)

b. Production managers and kiln constructors

c. Fire attendants and other artisans.

In all a sample population of 140 (respondents) representing 40% of the total accessible population was studied. The reason for this choice was that time and resources available could not permit the coverage of the entire population. Besides, Leedy (1974) asserts that for quality research, at least 30% of the accessible population for study is a fair representation for an acceptable accuracy of results. Table 3.1 which follows is a schematic overview of the sampling procedure used.

Even though the sample constitutes a homogenous population, each category is different from the other. The significance of the categorization is that it would help to determine the validity of data collected from the sample selected.

The stratified random sampling technique used by the researcher, sub divides the population into smaller homogenous groups in order to get more accurate representation. This technique was therefore employed to select the sample of 140 (40%) of the entire population. The minimum of 40% was chosen because the researcher considered 40% of the sample as an acceptable figure since the accessible population of this research was about 350

The total population was shared among the three strata (Categories A, B and C) of the population. Each stratum is homogenous. (Table 3.2). The number of subjects needed in the sample was computed according to calculated percentages.

Table 3.1 Schematic overview of stratified random sampling

POPULATION LEVEL	Category A (STRATUM 1) Snr. Officers, Lecturers, Snr. Technicians	15
	Category B (STRATUM 2) Production Managers/ Kiln Constructors	155
	Category C (STRATUM 3) Fire attendants/other artisans	180

EQUALISATION LEVEL	Category A	Category B	Category C
	15	155	180
	STRATUM 1	STRATUM 2	STRATUM 3

RANDOMIZATION LEVEL 40%	6	62	72
	STRATUM 1	STRATUM 2	STRATUM 3

SAMPLE	TOTAL FROM STRATUM 1 + 2 + 3 6 + 62 + 72 = 140

DATA LEVEL	Collection of data from 140 respondents

***Table 3.2**: Selection of sample*

STATUS	NO. IN SAMPLE	PERCENT OF TOTAL
Category A (stratum 1)	6	4.30
Category B (Stratum 2)	62	44.28
Category C (Stratum 3)	72	51.42
Total	140	100.00

Category A (Stratum 1) 6 × 100 ÷140 = 4.3

Category B (Stratum 2) 62 × 100 ÷ 140 = 44.28 Category

C (Stratum 3) 72 × 100 ÷ 140 = 51.42

3.8 The Survey Instruments:

The survey instruments were interview and observation which were used to solicit data from respondents concerning kiln construction and operation, anthill material and brick moulding techniques.

3.8.1 Interviews conducted: Unstructured interviews were conducted. The interviews were relevant to the research because they were the main data gathering device used, apart from observation.(Plates 3.4, 3.8&3.9) All the respondents were willing to talk to the researcher and to give out information relevant to the study. Interviews were conducted at work places of all the respondents. The medium of communication was English for people who fell in category A and mostly Twi for people in category B and category C. A tape recorder was used to record the interviews Notes were additionally taken to record the salient points.

Plate 3.5 The researcher in a pose with Mr. Nsiah, after an interview

3.8.2 Observation: On the spot observation of kiln construction, stoking of kilns and brick making was carried out by the researcher at all the centres visited. (Plates 3.5 3.6&3.7) The researcher had the opportunity of seeing, understanding and photographing some of the processes adopted at the centres. The researcher visited many anthill sites in Brong-Ahafo and Ashanti Regions to observe their shapes, sizes and characteristics. Photographs were taken of some of them. (Plate2.1 to 2.9)

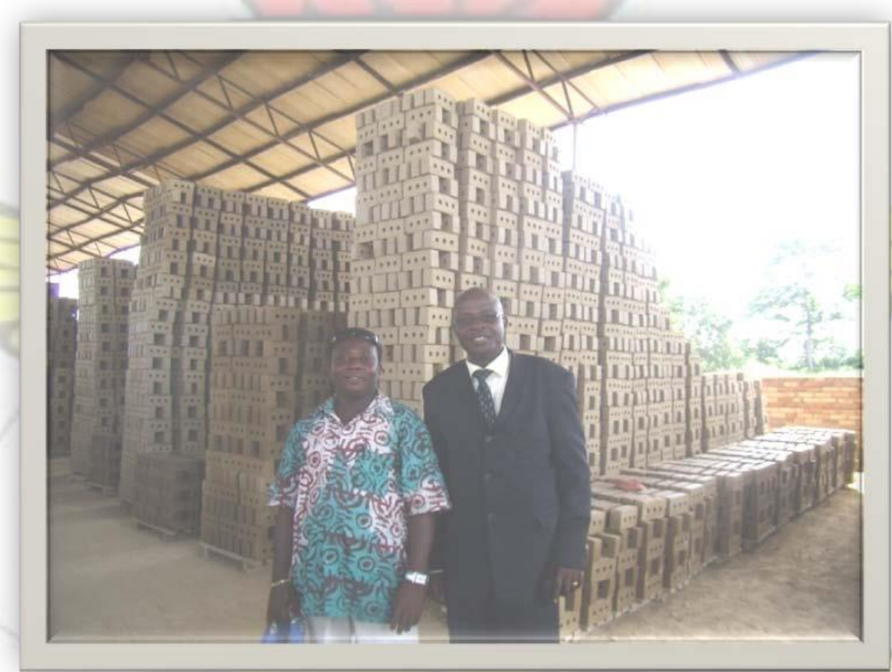


Plate 3.6 The Researcher in a pose with the manager of Vicalex Brick and Tile Mfensi after an interview

3.9 Data Collection

The researcher employed the quasi-experimental and descriptive research methodologies for the research. Some of the primary data were gathered from the field work and others solicited from the senior officers of institutions and other establishments. These include officers at B.R.R.I. Fumesua, lecturers and senior technicians at K.N.U.S.T. and Ghana Atomic Energy Commission.

The secondary data were collected mostly from documentary sources (books, publications, theses and journals.) In all the places visited, efforts were made to get the necessary data. These were later assembled, analyzed, synthesized and used where necessary for the project.

3.10 Data Analysis Plan

The main problem of this study was to find out how anthills could be used as a resource for ceramic production. The objectives of the study were:

i. To find out the extent to which termites modify the physical and chemical properties of anthill materials.

ii. To examine the anthill material to determine its use as a material for ceramic fabrication.

iii To critically study the anthill structure to ascertain its usefulness as a firing medium by conducting exploratory experiments through the creation of firing ports and other component parts.

It was hypothesized that termitaria offer diverse range of physical and chemical environment that differ strongly from those present in general soil mass. It was also hypothesized that anthill materials have multidimensional uses and that anthills could be conveniently converted into workable kilns for firing ceramic wares.

To resolve the first objective, data from the tests conducted were assembled, critically analysed and interpreted. To resolve the second objective the data derived from the series of laboratory tests conducted were assembled, scrutinized and critically analysed to find out how workable the materials were. The third objective was resolved by assembling the data collected from the interviews, industrial research and observation and adopting the applicable ones for experiments.

The results of these enquiries are discussed in the ensuing chapter which covers the tests and experiments carried out in pursuance of the objectives of the project.

CHAPTER FOUR EXPERIMENTAL PROJECT 4.1 Physical and Chemical Examination of Anthills

Anthills were identified at Mfensi and Fomena - in Ashanti Region, Biadan, Tanoso and Wamfie in the Brong Ahafo Region. Soil samples were collected at three different locations (top, middle or bottom) on the identified anthills. Additionally, soil samples around the anthills were taken with hand auger to a depth of about 75 cm below the soil surface. This was done to study the relationship between soil without termite activity and those with termite activity. Such samples were taken at triangles around each termitarium. They were placed in black polythene bags, tightly sealed and labelled and stored in the same condition to serve as a control.

Since the termitaria consist of chemical (composition), physical (strength) and biological (termites and organic matter) contents, physicochemical and biological approach of analysis was adopted for the research. The physico-chemical parameters determined were limited by the availability of equipment, reagents as well as its relevance to the problem on the ground.

On the basis of this, the following parameters were determined: pH, conductivity, resistivity, salinity, resistance, sieve analysis test, moisture content, nutrients (phosphate, nitrate), major ions (sulphate), trace metals (lead). Aside this, the chemical analysis was also carried out to determine the percentage loss on ignition of the clay samples and the percentage of the most important mineral oxides found in the clays.

4.1.1 Moisture content: A crucible was dried in an oven for a while and allowed to cool in desiccators. The mass of crucible, A was determined. The crucible was filled with 20g of soil sample and the mass of the crucible + the soil sample was determined, B. The sample was placed in an oven and dried overnight at about 105 degree Celsius. The sample was removed and cooled in desiccators. The mass of the dried sample plus the crucible was determined, C. The % moisture content, mc% was calculated as

$$\frac{B-C}{C-A} \times 100$$

The moisture content (M) factor, mcf, was calculated as

$$\frac{M + 100}{100}$$

4.1.2 pH, Conductivity, resistivity, salinity and resistance:

About 5g of the soil sample was weighed into an ampoule. 25mg deionized water was added and the cover of the ampoule placed tightly. The mixture was shaken thoroughly with a shaking machine for a while and allowed to settle overnight. The supernatant was carefully poured out into a small conical flask (about 30ml). A multipurpose digital pH meter was used. The probe of the meter was immersed completely into the solution and the pH read.

The conductivity, resistivity, salinity and the resistance were also read in the same manner.

4.1.3 Sieve analysis test: The soil particles were crushed using a pestle and mortar. About 500g of oven dried samples were weighed. The mass of each sample, Wt (g) was determined accurately. A stack of sieves were prepared. Sieves having larger openings were placed above the ones having smaller openings. A pan was placed under the very last sieve to collect the portion of soil passing through the sieve.

The sieves were cleaned and soil particles stuck in the openings were poked out using a brush. The sieves and pan were weighed separately. The weighed samples were poured into the stack of sieves from the top and the cover placed. The stack is placed in the sieve shaker and the clamps fixed. The time was adjusted for about 2 minutes and the shaker started. The shaker was stopped and the mass of each sieve plus the retained soil measured.

4.1.4 Test for turbidity: The standard SO_4 solution for 0.00, 30.00 and 35.00 ppm was prepared. 1ml of acid salt was added to the standards and the samples. 0.5ml of glycerol was also added to the mixtures and finally 0.5g of barium chloride was added to the resulting mixture. The mixture was shaken for 1`minute and allowed to stand for 10 minutes as the sample got turbid.

The absorbance was read at 430nm.

4.1.5 Nutrients: Combine reagent for $P0_4$ (Colour reagent- Yellow) 5ml potassium antimony tartrate solution was added to 50ml 2.5M sulphuric acid, then 15ml ammonium molybdate solution was added and finally 30ml freshly prepared ascorbic acid was added. The mixture was swirled as yellow colour formed to obtain a uniform solution. 0.2, 0.4, 0.6, 0.8 and 1.0 ppm standard solutions of PO_4 were prepared. 2ml of combined reagent was added to all the standards and samples, and shaken thoroughly to mix the resulting mixture. The samples were allowed to stand for about 10 minutes as bluish colour developed. The absorbance was read at 88onm.

4.1.6. Major ions: The standard NO_3solution for 0.00, 0.2, 0.4, 0.8, 104, 3.0 and 7.0 ppm was prepared. 1ml of 30% sodium chloride was *added* to 5ml of standards and samples. The mixture was swirled and 5ml 6.5M sulphuric acid was added to the resulting mixture. 0.5ml Bruccine reagent was added to the mixtures. The samples were heated in a water bath at 95^0C for 25 minutes. The samples were cooled in a water bath to 20^0C. . The absorbance was read at 430nm.

4.1.7. Chemical analysis: The classical method of chemical analysis was used .This method also known as the complexometric method is where ethylene-diamine-tetra-acitic solution is used to titrate against a prepared sample solution of the clay.

The idea here is to systematically attack and eliminate all the other unwanted mineral oxides which are envisaged to be present in the sample. This analysis acts as a check on the uniformity and also gives qualitative ideas on what to expect from the clay. The presence and percentage of certain oxides often determine the fired colour, the plasticity level, maturing temperature and

other qualities. For instance the sum of the Fe_2O_3 and TiO_2 contents affects the fired colour of the samples; if it is less than 2%, the clay
will usually burn white or ivory colour.

Consideration of the silica and alumina content is also worthwhile. Remembering that the ideal clay substance namely $Al_2O_3.2SiO_3.2H_2O$ contains 46.51% of SiO_2, 39.53% of Al_2O_3 and 13.95% water. A high alkaline content generally indicates carbonaceous matter and such clays may be plastic and often deflocculates readily for casting purposes unless soluble salts interfere. A complete chemical analysis is also useful for calculations in rational analysis.

4.2 Workability Examination of Anthill Materials

This part of the project is aimed at investigating some of the physical nature of the clay samples as far as their practical suitability for ceramic fabrication is concerned. Investigations were therefore conducted into the following:

1. The unfired nature of the samples
2. The fired properties of the samples
3. The strength or durability assessment.

Under unfired property test, the percentage moisture content which also is an indication of the plastic index of the clay samples is determined. Also the percentage shrinkage tests are conducted to determine how far the clays shrink when bone dry .This gives an insight into how large moulds for bricks should be in order to arrive at required sizes when dried and fired. Warpage tendencies in the clay during drying could also be found out through this test.

In pursuance of the second objective, the samples were dried in humidifiers for 24 hours at 11^0C. 2kg each of the specimen was taken and soaked overnight. They were reduced to slip and sieved through a 60 mesh sieve after which each was poured into a plaster of Paris mould for one week.

After a week of ageing the clays were thoroughly wedged.

Another batch of the clays was dried in the humidifier and weighed. After soaking they were reduced to slip and poured into a plaster of Paris mould for one week ageing. The clays were wedged and also fabricated into test tablets. (Plate 4.1)

Plate 4.1 The Researcher measuring a test piece

The washed and unwashed clay samples were fabricated into test tablets each measuring 7 centimetres by 4 centimetres. Shrinkage lines of 5 centimetres were drawn on each tablet. On the whole ten tablets each of twenty different specimens with the following labels were made. (Table 4.1) ***TABLE 4.1 LABELS OF SAMPLES***

Mfensi Clay Washed Mfensi Clay Unwashed Mfensi Anthill washed Mfensi Anthill Unwashed	M W M U MAW MAU
Tanoso Clay Washed Tanoso Clay Unwashed Tanoso Anthill Washed Tanoso Anthill Unwashed	TW TU TAW TAU
Biadan Clay Washed Biadan Clay Unwashed Biadan Anthill Washed Biadan Anthill Unwashed	B W B U BAW BAU
Wamfie Clay Washed Wamfie Clay Unwashed Wamfie Anthill Washed Wamfie Anthill Unwashed	W W W U WAW WAU
Fomena Clay Washed Fomena Clay Unwashed Fomena Anthill Washed Fomena Anthill Unwashed	F W F U FAW FAU

The following tests were also conducted on the specimen.

4.2.1 Plasticity test: This involved the feeling of the clays for elasticity.

The clays were rolled into coils bent and pinched into thin pieces to find out if they hold shape. They were flattened to examine stretchiness and built up to see how they support weight. The clays were tempered with to find out if they crumple easily or tear, if they are sluggish or too sticky and refuse to go into shapes easily or if they become dry quickly.

4.2.2 Wet to dry shrinkage: The tablets were left to bone dry. They were dried in a humidifier for 24 hours and put into a desiccator after which the 5 centimetres shrinkage lines were re – measured. The following formula was used to calculate the shrinkage percentage; wet line minus dry line divided by wet line times 100:

$$\frac{\text{wet line} - \text{dry line}}{\text{wet line}} \times \frac{100}{1}$$

4.2.3. Firing shrinkage test: This is to find out the reaction of the samples to temperature changes and to know the extent to which the clay deposits shrink when fired. The specimens were fired in a test kiln at 850, 1000 and 1150 degrees Celsius. The 5 cm. shrinkage lines were measured after each firing.

4.2.4 Dry weight: The specimens were dried in a humidifier for 24 hours and put in a desiccator, weighed and recorded for the dry weight values

4.2.5 Fired weight: This part looks into the fired nature of the clay and the percentage loss of weight on firing. This gives an indication of the amount of chemically combined water in the clay, the amount of vegetable matter that burns off on firing as well as any other volatile elements therein.

The specimens were weighed after each firing. Dry to fired percentage was calculated by subtracting the fired weight value from the dry weight value, dividing it by the dry weight value and multiplying it by 100.

$$\frac{\text{dry wt} - \text{fired wt}}{\text{dry wt}} \times \frac{100}{1}$$

4.2.6. Absorption test: This test looks into the water absorption properties of the samples. It is very necessary because it determines the type of use the clay can be put. For instance, a clay sample that has good resistance to water penetration could be useful for roofing tiles. Clays with high porosity could also be used for water cooler production. Burnt bricks is said to have an advantage over sandcrete because of the low moisture movement of burnt bricks which is averagely 0.02%.This is less than half that of sandcrete blocks which has 0.5% moisture movement (American Journal 1975:16)

The samples were boiled in a basin for one hour. They were allowed to cool, wiped and weighed. The fired weight value was subtracted from the soaked weight and the difference between the two gave the rate of absorption. The percentage absorption is calculated by multiplying the results by 100 and dividing it by the fired weight.

$$\frac{\text{Soaked weight} - \text{fired weight}}{\text{Fired weight}} \times 100$$

The percentage of absorption that a clay body has after a particular firing temperature determines whether it is earthenware, stoneware or porcelain.

Plate 4.2 Test firing in a test kiln

Aside the laboratory test on the selected clay samples, test pieces were also made from them. The test pieces were made to proof the workability or otherwise of the various samples. To give room for comparative study, test pieces were made from all the twenty samples of clay. (table 4.1)

The clays were properly wedged to remove air pockets, lumps and other unwanted materials. Both hands were used to lift and move the clay from the outside of the mass towards the centre. The mass was lifted and rotated slightly then pressed and pushed out and in a circular movement. This was done to make the flat clay particles to lie parallel to one another and to make the clay more plastic, very smooth, uniform, homogeneous and workable.(Plates 4.3&4.4)

Plate 4.3 Kneading of clay

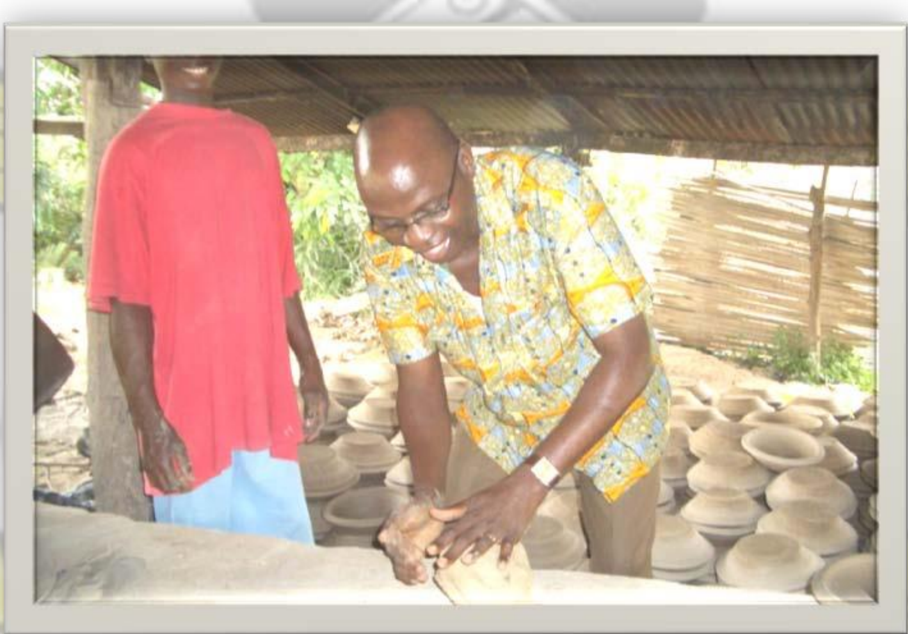


Plate 4.4 Spiral wedging of clay

Four different forming methods were adopted for the construction of the test pieces. They have been presented in a very simple manner to enable any lay person to understand and follow the procedures in the construction. The forming methods are; slab construction, coil work, throwing on the potter's wheel and modelling.

4.2.8. Slab work: Slabs are sections of clay that have been pounded, rolled or cut into flat shapes. Almost any kind of form can be built with these moist clay slabs. Before beginning work on the slab, a large sheet of canvas (jute sack) was laid on the worktable and was securely tacked at the edges. A well kneaded clay lump was set on the canvas and a rolling pin was used to roll out the clay into slabs. In order to make the slabs even, two guide sticks as thick and as long as the planned slabs were placed parallel to each other at the sides of the clay and on the sack board. The clay was rolled slowly and gently until it was fairly spread over the jute sack. Intermittent raising of the spread clay helped to even out the spread.(Plate 4.5)

Plate 4.5 Rolling a clay slab

The rolling pin was rolled back and forth a few times. The partly flattened clay was then turned over and crosswise at different directions until even thickness was obtained. This process was followed for the different clay samples.

To keep them uniformly moist and in very good workable condition, they were covered with polythene bags. The slabs were allowed to dry slightly so as to make them a little stronger as work continued.

4.2.8.1. Rectilinear jewel box Slab works need to be handled carefully at all stages in order to prevent strains that develop into warps or cracks. All slab pieces should be laid on beds of newspapers or any type of towelling that will allow the clay to move and shrink easily during drying.

An initial plan of the jewel box was made. A cardboard pattern with separate patterns for each planned plane of the piece was cut. The patterns were laid out and clay replicas were cut out. When all the flat clay pieces were cut, they were allowed to become slightly firm but not leatherhard.

All the side edges that were to be joined at the seams were bevelled. The edges were scored and moistened with slurry (slip) made from the same clay. The edges were firmly pressed together and sealed carefully so as to prevent cracking during drying and firing. Tiny clay coils were added along the inside of junctures and worked into the seams. All the joined edges were smoothened afterwards.(Plate 4.6)

Plate 4.6 Smoothening the edges of a slab work

The already cut base of the box was scored at the edges with a comb and slip was brushed along the scored edge. The box was positioned on the base and pressed firmly. The edges were pressed together and worked smoothly for a continuous surface.

On the inside of the lid, strips were secured to hold it in position when closed. They were placed in such a way that they could play between the inside of the box and the strips. In all twenty boxes were made from the samples.

4.2.9 Coil work: Interesting forms and exciting surface textures can be built with lengths of clay coils. Although clay coiling is one of the most basic methods of clay construction, beautiful and complex forms can be created from coils.

In the making of the coils for the test pieces, a small lump of clay was placed on an oil cloth spread on the work table and rolled back and forth with both hands. The long lump was rolled from the centre towards the ends until the required size was reached. Several pieces of paper were piled on the work table so as to allow easy turning of the object.

Small, circular flat clay was set as the base. The edges were scored and moistened with water and the first coil was placed. The coil was worked down into the base with a modelling tool and was smoothened with the finger. The top of the coil was scored and a new coil was added. This process continued until the fourth layer was reached, when the clay was allowed to 'set up' for a while. After some time the work continued until the required height was reached.(plate 4.7)

Plate 4.7 Building with coil

4.2.10 Thrown pieces: The different samples of clay were all prepared, weighed and made into lumps. Small cylindrical cups were made on the potter's wheel by centering the lumps on the wheel, opening it, and pulling it up into cups. (plate 4.8) They were allowed to dry slowly for observation.

Plate 4.8 Throwing a test piece

4.2.11 Modelled work: The clay samples were compacted, pounded and shaped into small human (torso) forms. They were left to become firm but not leatherhard. The forms were turned over and cushioned on some dry foam. They were hollowed out with a metal loop tool until all the walls were even. They were finished with the appropriate textures and left to dry slowly.(Plate 4.9)

Plate 4.9 Modelled pieces

4.2.12 Brick making: In addition to the four forming methods, the different clay samples were also moulded into solid bricks measuring 9 inches by 4½ inches by 2½ inches and were labelled. About 40 pieces were made from each sample. These were subjected to thorough observation and care and were dried under shade until they were bone dry. This was to prevent the situation where the outer layer of the brick would dry first and consequently contract leaving the moist interior thereby setting up stresses that could result in cracks. They were arranged and packed into a clamp and fired together with other moulded bricks for 36 hours. (Plates4.10&4.11)

Plate 4.10 Drying bricks for firing

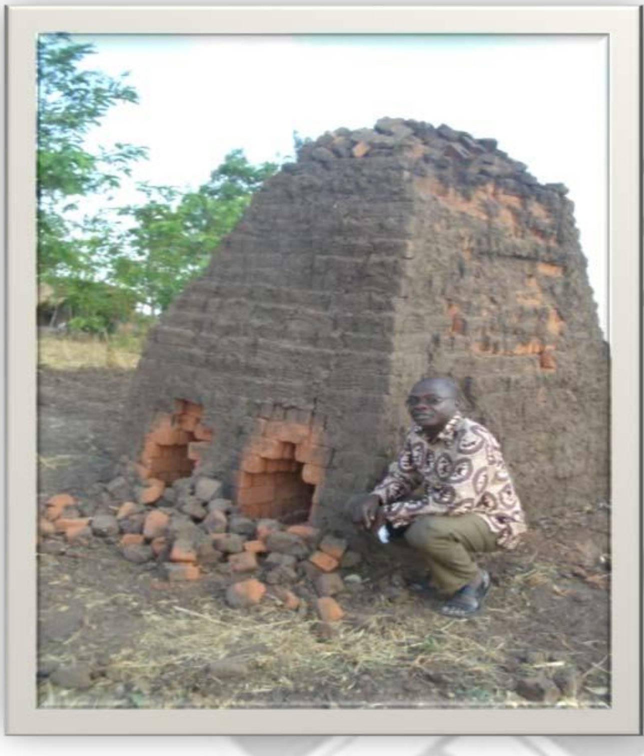


Plate 4.11 Clamp firing of bricks

The setting was done in such a way that the different samples were mixed up. Therefore each of the samples had specimen among the bricks set at the base, the middle and the top of the clamp. The clamp was fired to around 1000^0C. (plate 4.11)

4.2.13 Kiln shelves and props: Anthill materials and well sized grog were mixed into a stiff plastic consistency. This mixture which was in 50-50 proportion was pounded into a wooden mould measuring 30cm x 60cm x 4cm with a mallet. To prevent sticking, the inner part of the mould was bedded with grog. The top was levelled with scraper and trowel and also covered with grog until it became dry. Kiln shelves were made from each of the anthill samples.

The mixture was rolled into heavy snakes and cut into different lengths to serve as props. Both ends were thickened to make them stable in the kiln. The shelves and the props were subjected to thorough observation until they were bone dry and were fired to 1150 degrees Celsius.

4.3. Conversion of anthill into workable kilns

The size and shape of many anthills resemble catenary kilns. They have a round base and taper to the top. The structure has a hard outer cover and hollow inside in the semblance of a round kiln. From afar some look like a kiln with a chimney on it.(Plate 4.12)

The labyrinth of passages in the walls and the ventilation holes are possible insulation vents that are likely to promote heat retention – a very important quality of an efficient kiln.

This impressive design and wonderful technology employed by the ants in the construction of the anthill offer a direction for its adoption as a kiln for firing ceramic wares.

Plate 4.12 An anthill in the semblance of a kiln

Also the best general shape of a kiln is that approaching a cube. The cube encloses more space per area of wall than any other rectilinear shape. A shape of this nature favours the circulation of heat, and the exchange of heat through radiation.

Kilns are built in rectilinear shapes mostly for convenience and mostly because of the awkwardness of building curved structures with rectilinear bricks. The cylindrical shape with a dome is perhaps a better shape for the circulation of heat. This important requirement of a kiln has also been accomplished by the wisdom of ants. The inner chambers of the anthills are cylindrical with a dome top.

Like all building structures the kiln must have a suitable foundation. Kiln builders therefore spend time and resources to provide a solid foundation to prevent cracks and leaning. This duty has also been performed by the ants whose structures have solid foundation and are stable. The above is an indication that only small modification is needed to make an anthill a kiln.

The following observations which were made during the field visit served as a guide in the conversion exercise.

In all the pottery centres visited the kilns were the round downdraft type. They had three or four fire ports which were placed equidistantly from each other. The flames are deflected over perforated bag walls attached to the inner wall of the firing chamber through the packed wares to the flue hole which is in the centre of the chamber and leads out into the chimney. Some of the chimneys stand between 360 centimetres and 500 centimetres high and some as low as 100 centimetres.

Firewood was the only source of energy for all the factories visited. The duration of the firing depended on the size of the kiln and ranges from 18 hours to 48 hours. Almost all the kilns had developed serious cracks, especially in their crowns. Some had wire bracing in place but they were gradually giving way (Plates 4.13& 4.14)

Plate 4.13 Cracks on a kiln despite the wire bracing

Plate 4.14 Cracks on a kiln at Tanoso

At the brick and tile production centres, wood-fired clamp method was mostly used. Clamps are basically not kilns but a method of firing bricks without a kiln. The raw bricks are piled up in a manner that provides fire places at the base of the structure and passageways for flames to the top. Here, fire boxes (where logs of firewood are burnt) were permanently constructed and the clamps were built on top of them. Vent holes from the base of the clamp to its top are used to allow for escape of water vapour and smoke from the clamp. The fire boxes in the clamp are about 630 millimetres wide and 750 millimetres high. (Plate4.15)

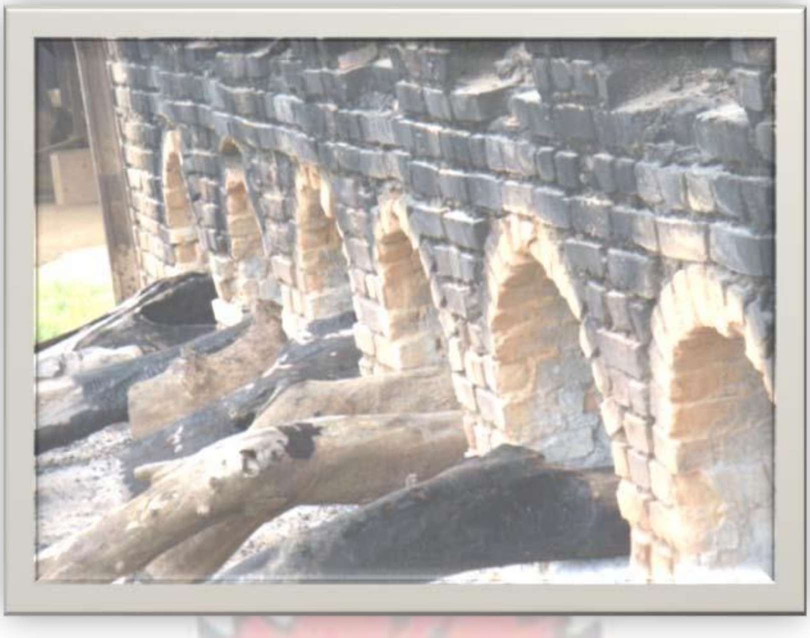


Plate 4.15 Firebox of a clamp kiln

The bricks are packed on edge with a finger thickness of space between them. The fire is started with packed dry logs and dry splints of firewood. The fire is initially kept low to allow moisture from the bricks to be driven off through the vent holes. Dry logs are then added at intervals to keep the fire burning for about 72 hours. The inlet to the fire holes are sealed with bricks to allow the clamp to cool for another 72 hours before unpacking.

At the Centre for National Culture pottery centre in Kumasi, the production manager explained the reason behind the type and sizes of the wood used for firing. He said that wood being a solid matter can only burn on its surface area. Wood will smoulder and ignite only on the exposed surfaces. To get the best heat output, it follows that thinner pieces of wood will burn and release energy faster than large thick logs. Softer wood with air holes also perform better than thick and dense wood.

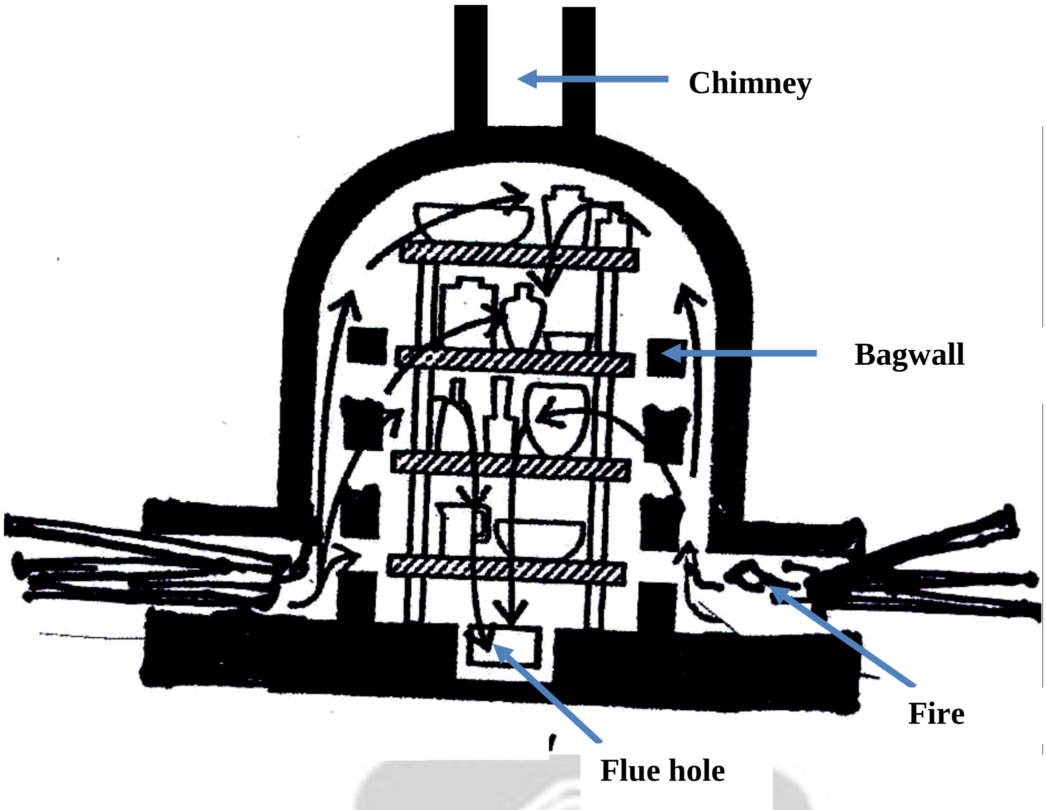
The kiln builders gave reasons for the sizes of the fire ports, the flue holes and the chimneys. They said fire boxes, ash pits and fire bars should be of generous size and free from any area that will cause a build up of ashes, ember or firewood. This is necessary because a build up could cut down access for oxygen from the area of combustion and inhibit the release of the greatest amount of heat.

The lecturer advised that a careful consideration should be given to cost, type of pottery to be fired in the kiln and the size. On the size he said it depends on the user. Whilst professionals require sufficient size to keep their production rate flowing smoothly, a hobbyist needs a smaller one that takes few weeks to fill. With schools and colleges, he advocated for the use of both small and large kilns to cater for testing and firing of larger pieces made by the students.

On the choice of site, he said it should be located at a place where the neighbours will be safe from possible hazard of fire, smoke or fumes.

For the conversion of an anthill into a kiln, there is the need to decide whether downdraught, updraught or crossdraught kiln is required. In converting the anthill the technology approach to problem solving was adopted. This involved the statement of the problem, sourcing of ideas, idea development, the preparation of drawings and the execution of the activity.

4.3.1 Anthill as a downdraught kiln: Fire from a downdraught kiln is usually introduced at its sides and the flames are deflected upwards over a bag wall and then drawn down through the setting and out through a flue hole into



a chimney.(Fig. 4.1)

Fig. 4.1 Downdraught arrangement

In the conversion of an anthill, the researcher considered the entire kiln design in its component parts. The floor of the kiln was also considered since it is necessary to prevent moisture from rising up from the damp ground to the kiln floor. Considerable fuel will be wasted in the drying off of moisture at the commencement of each firing if this is neglected.

In the conversion, the following were considered as component parts: (i) door (ii) fire box (iii) chamber, floor and bag wall, (iv) chimney and the flue hole.

4.3.1.1 The door: There is always the need for an entrance to any kiln. It is through the entrance that loading and offloading is done. It is also through the entrance that inner repairs and other works could be done. A kiln door should therefore be enough for a man to conveniently reach any part of the inner chamber.

The door was dug out through the hard outer cover to the hollow inside and the loose materials were scooped out. The size of the anthill used required a door just enough for a man to crawl into the firing chamber. When the size was attained, an earth chisel was used to shape out the mouth like an arch.(Plate 4.16)

Plate 4.16 Carving through an anthill to create a door

Plate 4.17 The carved- out door of an anthill kiln

To make it a little permanent and presentable, a wooden arch former which is slightly smaller than the entrance was constructed. (plate 4.18) It was erected on a wedge support at the base and the arch was made with burnt bricks fastened together with mortar. (plate 4.19) Wedge shaped bricks were used to strengthen the arch. After about a couple of days when the mortar was set and stiff, the wedge support was removed and the wooden arch former dropped, leaving the brick form hanging.(Plate4.20)

Plate 4.18 Wedge support of the wooden frame

Plate 4.19 Wooden frame in place

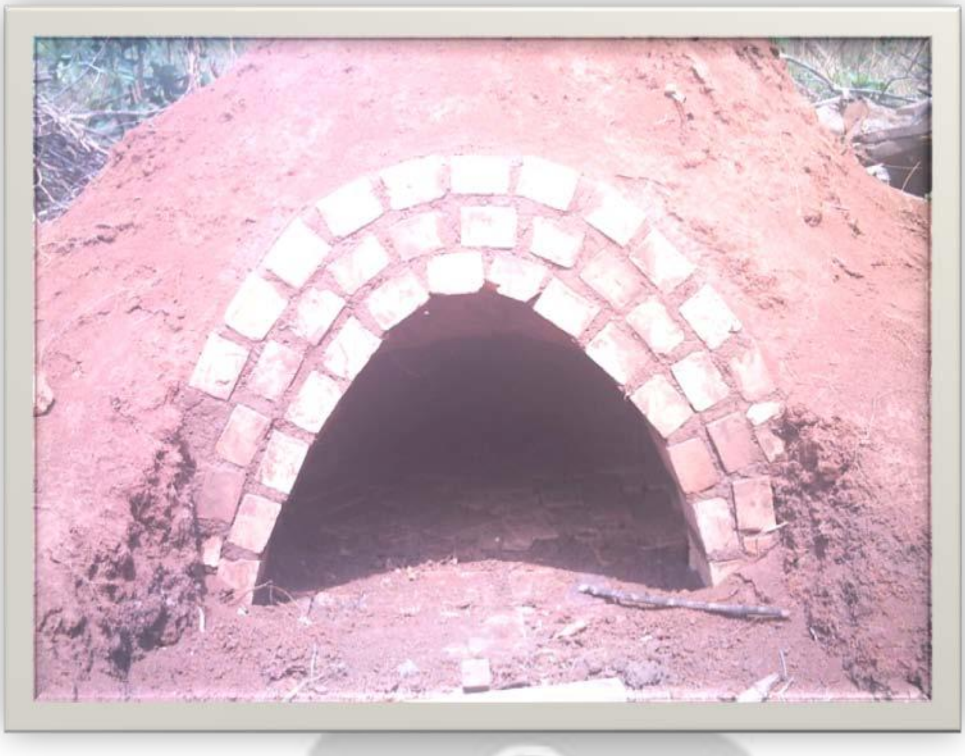


Plate 4.20 Door, after frame has been removed

The entrance is usually closed after packing or setting the kiln and removed when unpacking. There is the need for a spy hole to be left at the entrance when it is being bricked-in. This is to make draw trials and setting of cones possible.

4.3.1.2 The firebox: The firebox is an enclosure where fire is introduced into the firing chamber. For the necessary temperature climb in the kiln, there is the need for the firebox to be quite big to provide adequate heat. A trench measuring 35 centimetres wide and 40 centimetres high was dug from the outskirts of the anthill through the hard, dry outside of the anthill to the hollow inside. (plates 4.21 & 4.22)

Plate 4.21 Carving out a fire port

The inner part which is filled with softer and loose earth was scooped out with a long hoe and a shovel. An earth chisel was later used to straighten out the edges of the dug out trench to the required shape.

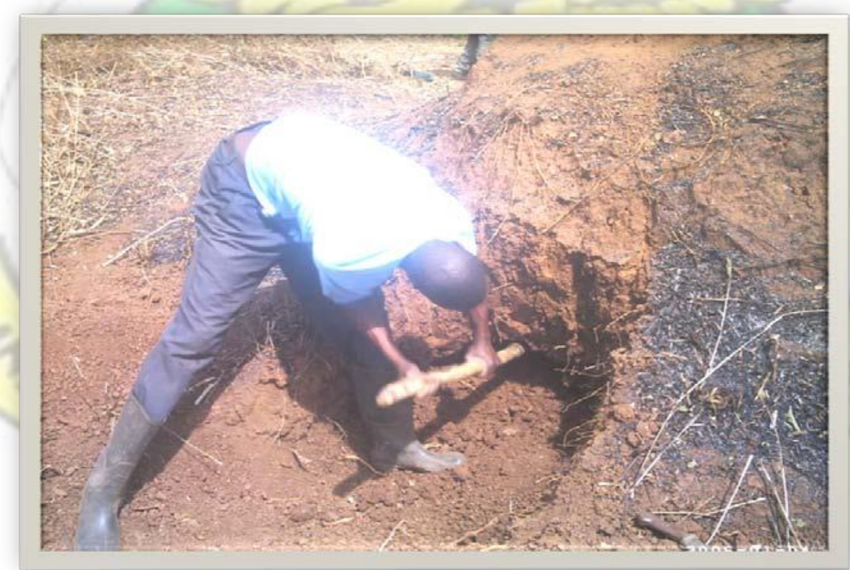


Plate 4.22 Smoothening the rough edges of the tunnel

Two courses of fired solid bricks measuring 22 ½ cm x 11 ½ cm x 6 cm were laid flat at both sides of the trench. The hollow earth scooped from the inside of the mound was soaked and used as mortar. Pieces of steel angle iron were laid about 20centimetres apart, on the laid bricks (Plate 4.23)

Plate 4.23 Erection of fire bars

Two additional courses of bricks were laid on the steel angle iron up to the threshold of the anthill. (Plate 4.23) Bricks were laid to stand edge way to form a bridge over the trench. They were joined to each other with mortar and supported at the base and the top with mortar and broken pieces of bricks which served as skewback - a sloping surface against which the end of the arch rests. The space below the steel grates serve as the ash pit whilst the top serves as the stoking port. (Plates 4.24, 4.25 & 4.26)

Plate 4.24 Two courses of bricks on top of fire bars

Plate 4.25 Bridging the fire port

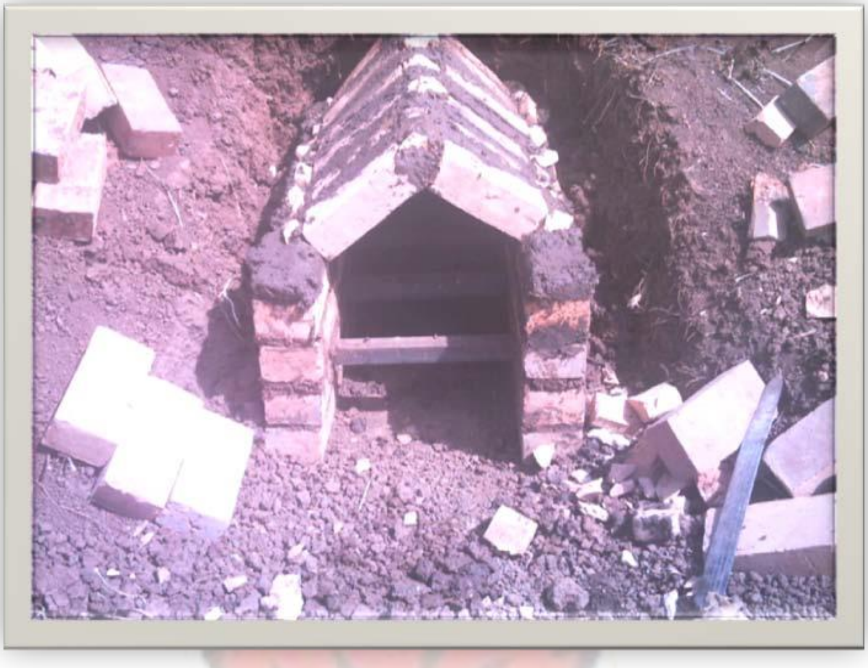


Plate 4.26 Bridge almost complete

To strengthen the bridge, another course of bricks was laid breadth wise over the slanted bricks before earth was piled on it. Grate bars are very necessary in fire box construction because wood is best burnt on it as it holds the fuel up for air to circulate under, around and through the burning mass.(Plate 4.27)

Plate 4.27 Roof of firebox strengthened with bricks.

4.3.1.3 Chamber, floor and bag wall: The loose anthill materials in the inside of the structure were thoroughly removed. The hangings were cleared and the few openings were sutured with mortar. The loose soil from the firebox to the inner chamber was also scooped out.

This made way for the construction of a horse-shoe-like wall about 50 cm high to serve as the baffle wall to prevent the direct impingement of the wares by flames and also to help in the heat distribution in the kiln. Ample chinks were left between the bricks of the bag wall. The proper adjustments of the height and permeability of the bag walls is likely to produce perfect results. ((Plate 4.28)

Plate 4.28 Bagwall.

The inner floor was filled with white coarse sand which was spread neatly to make the floor level and to enable the red bricks to level out to receive the chequer work on which the wares to be fired will be placed.

4.3.1.4. Chimney and flue hole

Flues in kiln help to draw exhaust gases out of the kiln. With wood fired kilns, it is very necessary to have large flues through which smoke and other gases can escape. Like the fire box, the flue hole was dug as a trench from the outer base of the anthill to the firing chamber directly opposite the fire box. According to Gregory (1984), the distance from the flue box through the kiln wall to the chimney should be kept as short as possible so that the efficiency of the chimney is not impaired by excessive horizontal pull. The chimney was therefore constructed very closely to the anthill structure.

A very strong foundation was laid with bricks which were laid flat in the first six courses. The courses were established with utmost care and the builder's line was used to keep the brickwork level and upright. The level was frequently checked as work progressed. (Plate 4.29 & 4.30)

Plate 4.29 Checking the plumb of the chimney

Plate 4.30 Construction of the chimney

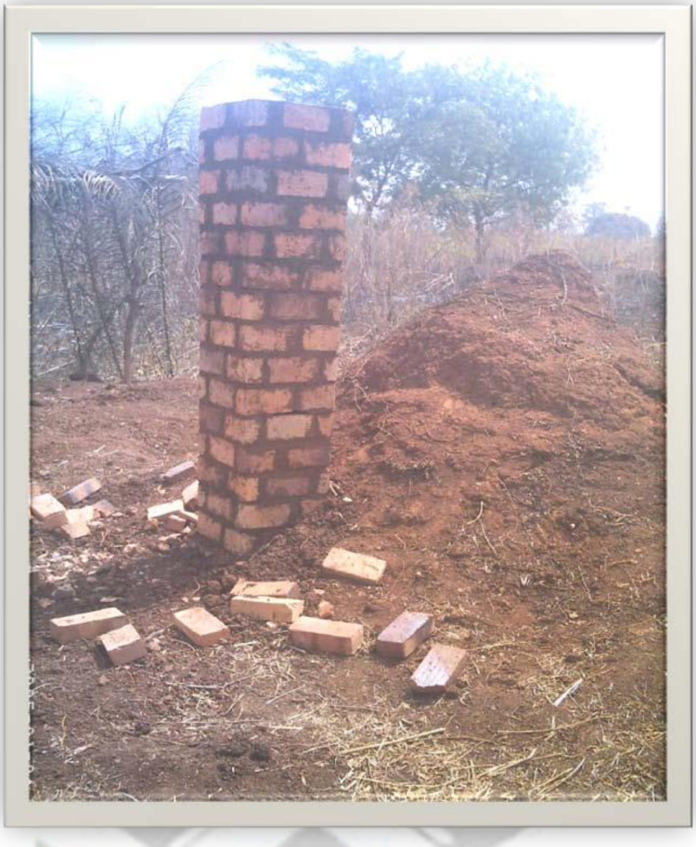


Plate 4.31 Brick chimney of the anthill downdraught kiln

Rhodes (1968) also opines that the dimension of chimney is dependent the size of the kiln and the number of burners. He says kilns up to 40 cubic feet are usually given a 9” x 9” flue but for burning wood a larger flue must be provided. The chimney height may vary from six or eight feet to about 30 feet depending on the size of the kiln, number of burners, horizontal travel of the chimney and degree of draft required. Considering the size of the anthill, the height of the chimney was made to reach 320 cm. (Plate 4.31)

4.3.1.5 Loading of the Downdraught Kiln: Unlike the updraught kiln where loading was done from the top, the loading of the downdraught one was done through the door. Heavier items were first packed followed by the lighter ones as was done in the case of the up draught kiln. The pieces were cautiously packed on top of each other to prevent breakages. (Plate 4.32)

Plate 4.32 Packing the kiln

.

Plate 4.33 Fixing a brick to serve as a spy hole.

Plate 4.34 Bricked in door of the kiln

The door of the kiln was bricked in as the packing proceeded.(Plate 4.33)

A spy hole was created by fitting one of the bricks loosely into the door structure in such a way that it could be removed and fitted back. (Plate 4.34) Three small test pieces were lined very closely to the spy hole for easy drawing. They were hooked out intermittently to check heat treatment in the kiln in course of the firing.

4.3.2 Anthills updraught kilns

An updraught arrangement is where fuel is introduced at the bottom of the packing chamber to let the flames course upward through the setting and escaping from the top.

Before the conversion, a hole was dug through the hardcore of the selected anthill to the inner part. Mashed leaves of a type of cassia locally known as (nkwadaa bɔɔ deɛ) was squeezed through to the inner chamber and was left for a few days unattended to. After some few days the termites deserted the colony thereby making its temperance very easy.

4.3.2.1 Creating the firing chamber: With an earth chisel, mattock and a hoe, the crown of the anthill was removed. The loose material inside it was scooped out leaving a cylindrical wall. The wall was further truncated to make it easier to climb during packing.(Plate 4.35)

Plate 4.35 Truncated anthill showing the hollow inside.

4.3.2.2 Fire port: Like the downdraught type, a trench was dug from the outskirts of the truncated anthill to connect the hollow inside to serve as the fire port. This was also provided with hobs so as to prevent the possible accumulation of partly burnt charcoal in the hearth and also to prevent a situation where the amount of air needed to speed up combustion is reduced.

4.3.3 Compact Mound Updraught

A simple updraught kiln was also constructed using a mound formed from collapsed lifeless anthill which had compacted through the action of weather. Some of these mounds are very huge but one needs a small portion of such a mound to use as a kiln.(Plate 4.36)

Plates 4.36 A section of the mound used as a kiln.

4.3.3.1 Firing Chamber and fire port: A circular hole with a diameter of about 75cm and about 100cm deep was made in a mound. A trench of about 35 centimetres wide and 40cm high was dug from the outskirts of the anthill to the floor of the dug hole. The circular hole served as the firing chamber whilst the trench connects the chamber with the fire box. The inner wall of the chamber was plastered with anthill clay tempered with sand to fill in the voids that were created on the walls in course of the digging. One course of bricks was laid at the top of the dug hole. It was laid to project into the hole in order to close the diameter a little.

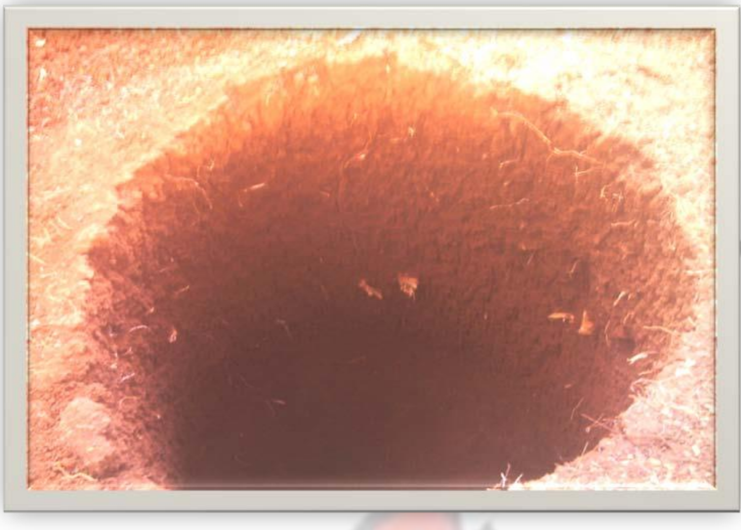


Plate 4.37 Dug out firing chamber of a compact mound kiln

A second course was laid to corbel the first so as to reduce the entrance a little further. (Plate.4.38)

Plate 4.38 Two courses of bricks corbelled to close the mouth

In the first course one of the bricks was left loose and could be pushed in and out so easily. This served as a spy hole to make draw trials and the observation of the pyrometric cones possible. The circular hole served as the firing chamber whilst the trench served as the hearth.(Plate 4.39)

Plate 4.39 Compact mound kiln showing the hearth

Grate bars were erected to divide the fire port into an ash hole and stoke hole. Coarse sand was used to line the base of the firing chamber to serve as a support for bricks that were laid as platform to receive wares in the firing chamber.

4.3.3.2 Setting the updraught kiln: A chequer was built in the firing chamber to serve as a base shelf and help bring about even distribution of heat across the setting. Bricks with straight end faces were used in the three tier arrangement. In the first tier the bricks were stood firmly on their ends in the sandy base and in the two other tiers they were laid out on their edges.

The rows of bricks were placed about 15cm apart so as to create a channel or path between them. On these stretches or bridges of bricks another layer of bricks was laid with ends touching. The third course was laid to stabilize the structure. These bricks bridge alternatively, the spaces between the first two courses. Each brick therefore overlapped the other and locked one another securely. Half bricks were used to fix the structure to the circular wall so that the whole deck becomes securely wedged in position. (Plate4.40)

Plate 4.40 Deck prepared to receive wares

On the deck a layer of broken pots was laid allowing bigger spaces at the back. The space near the throat was slightly blocked to induce the flames to spread out evenly over the floor. (Plate 4.40)

Unlike the downdraught kiln loading was done from the top onto the deck. The heavier items were first packed and the lighter ones were added. Fragile items like lids, saucers, and bowls were laid upside down at the top to form a canopy which tends to regulate and evenly distribute the heat through the kiln.

Plate 4.41 Closing the kiln in with bricks

Plate 4.42 Closing the kiln with bricks

When the kiln was nearly full, three courses of bricks were laid without mortar, each projecting inward to reduce the mouth of the chamber. Broken pots or shards were used to close in the corbelled arrangement leaving a small opening in the centre. (Plate 4.42) Loose soil was used to cover the loose roof. (Plate 4.43)

Plate 4.43 Loose soil piled to back up the roof

The packing was done in such a way that there were no constrictions in the flame ways or in the setting .This was to forestall the inhibition of the flow of heat through the setting. Fire was then built at the entrance of the tunnel to allow the flames and hot gases emitted to flow upwards through the wares and escaping through the top.(Fig.4.1)

In the case of the anthill up draught kiln the closing was done with a loose thatching of broken pottery which was piled on top of each other. Some openings were to serve as a flue or exit from where hot gases could escape. Loose soil was also piled on top of it to reduce the out flow of heat.

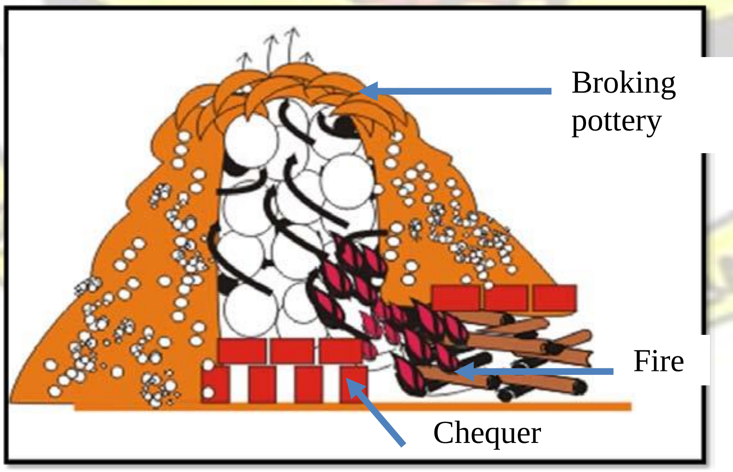


Fig. 4.1 Anthill up draught arrangement

Plate4.44 Students splitting wood into smaller pieces

For a specific firing practice enough firewood should be piled up. They should be left to dry thoroughly in order to get rid of the moisture. If the wood is slightly damp the heat required to volatilize the water as steam will tend to cancel any gain in temperature.

4.3.4.1 Firing schedules: Three different firing schedules were followed: One with the up draught kilns and two with the downdraught kiln.

4.3.4.1.1 Firing the updraught kiln: In the truncated anthill updraught kiln, water cooler pots, fufu bowls and earthenware bowls were fired and the following time table was derived. The fire was started at 1.00 p.m. under the grate bars with three logs of wood. Stoking was done after every ten minutes with fire deliberately kept at a low heat for four hours, as the moisture leaves the ware and the kilns gradually warms up. Relatively large pieces of wood were used in this beginning stage because they burn slowly. At 5.00 p.m. the quantity of the wood was increased to five and was now placed on the grate bars. The stoking time was reduced to six minutes and continued until 8.00 p.m.

After 8.00 p.m. the quantity of the wood was increased and the fire was pushed in. Stoking time was further reduced to only two minutes. At 12.00 a.m. more wood was added, almost filling the stoke holes. At this time fresh wood was tossed in whenever the flames ceased and the stoke holes were closed at 1.00 a.m.

4.3.4.1.2. First firing of downdraught kiln: This firing was carried out with the final year Visual Arts students of Berekum Senior High School basically using their ceramic pieces.(Plate 4.41) In this firing, sculpture pieces in the bust were used. The pieces although dry were very thick and heavy**.** They were packed on top of each other until the kiln was full. It was lit at 6.00 p.m. with three pieces of wood set under the ash pit. To get rid of the moisture, the kiln was steadily stoked with three pieces of wood under the grate for six hours.

At 12.00 am the fire was started from the top of the grate bars and the quantity of wood increased to four. Stoking was done anytime the smoke from the chimney cleared. This pattern continued until 04.00am

Plates 4.45 Students of Berekum senior high school, busily stoking the kiln.

Plates 4.46 Raking out the accumulated ember to aid combustion

After 04.00am the firebox was filled half full. Stoking was around once every 3 minutes until 8.00 am, when the firebox was made virtually full. There was intermittent raking of the ash and the stirring of the wood to increase oxygen flow.(Plate 4.42) This process continued until 10.00 a.m. when stoking stopped and the firebox was damned. The kiln was allowed to gradually cool down.

4.3.4.1.3 Second firing of downdraught kiln: In preparation for the second firing, the bag wall was given more openings and its height was increased with another layer of bricks to help raise the flames to the upper part of the chamber. This time the kiln was filled with pots, bowls and small ceramic pieces. They were handy and could be packed without much stress. In this batch there was availability of cones 012, 06 and 3. The cones were therefore fitted on a plaque and placed strategically at a place where they could be observed from the spy-hole. It is important that the cone pack be placed on a level spot in the kiln, away from immediate contact with flame, so that they can accurately measure the effect of the firing on the ware. The door was bricked in as the packing progressed.

Plate 4.47 Firing in progress as smoke gushes out of chimney

The kiln was lit at 6.00 pm with three pieces of wood fed into the ash pit. The temperature was maintained till 10.00 pm. At 10.00pm, the fire in the ash pit was increased. After about two hours stoking it was started from the top of the grate. At first, fairly light sticks were put in with their ends resting on the grate bars so that the middle part of each stick could be ignited from the heat below.

From 3.00 am onwards, the fire was increased more quickly followed by a clear flame which then died down to ember. This continued until a dark red glow was seen through the spy hole. From this time fresh batch of logs were tossed in whenever the flames ceased. The quantity of wood in the firebox was increased gradually and by 6.00 am, the fire box was almost full.

After 6.00 am the fire was allowed to burn down before replenishing so that the temperature could be maintained as far as possible without increasing and falling. This was to allow time for the heat to become equalized all over the setting chiefly through radiation. At 8.00 am the firebox was damned and the kiln was left to cool gradually till the following morning.

4.3.4.1.4 Firing of compact mound updraught kiln: Fufu bowls were the main items fired in this batch. Although heavy, they were dried very well and adequately stacked in the firing chamber. Three pyrometric cones, 012, 06, and 3 were set on a plaque of clay and placed among the packed bowls at a place where it could be seen from the spy hole.

The firing started at 6.00 a.m. with a couple of pieces of firewood about 5 to 8cm in diameter at a time. This process which was dead slow continued for four hours.

After this stage the number of pieces of wood was increased to 5 and 6 and thinner pieces were selected and crisscrossed to ensure proper combustion. This also continued for 3 hours.

From this stage constant stoking continued. Light pieces of wood were fed into the pit and added to anytime the fire died down. This process continued until 6.00p.m. when soaking started. At 8.00 p.m. firing ended and the fire port was damned. In all four different firing schedules were followed and the results are as shown in the next chapter.

CHAPTER FIVE RESULTS AND DISCUSSION

This chapter deals with the results, analysis and interpretations of data obtained from the laboratory and industrial researches conducted, the field survey and other experiments carried out by the researcher.

5.1 Physical and Chemical Study

5.1.1 Moisture content

The % moisture content values for the termitarium were widely ranged whereas those for the soil around it varied slightly. In all, the results did not show much differentiation in the % moisture content for the termite soil and the soils around it. This is an indication that termite activity did not significantly reduce or increase the moisture content of the soil samples.

(Table 5.1&5.2)

Table 5.1 Results for moisture content of termitarium

Sample	Average (mc%)	Average(mcf)
FA1	36.41564	1.364156
FA2	14.75359	1.147536
FA3	18.80501	1.18805
TA1	8.452179	1.084522
TA2	7.804233	1.078042
TA3	14.00972	1.140097
MA1	7.912187	1.079122
MA2	6.897566	1.068976
MA3	7.238383	1.072384
WA1	13.56193	1.135619
WA2	17.07983	1.170798
WA3	19.22998	1.1923
BA1	4.674231	1.046742
BA2	4.68296	1.010467
BA3	4.396664	1.043967

Table 5.2 Results for moisture content of soil around termitarium

Sample	Average (mc%)	Average(mcf)
FS1	8.333333	1.083333
FS2	9.497207	1.094972
FS3	8.095238	1.080952
TS1	5.913978	1.05914
TS2	7.978723	1.079787
TS3	0.248555	1.092486
MS1	6.25	1.0625
MS2	7.784431	1.077844
MS3	8.176101	1.081761
WS1	25.7485	1.257485
WS2	17.4359	1.174359
WS3	20.33898	1.20339
BS1	14.20455	1.142045
BS2	10.48951	1.104895
BS3	9.090909	1.090909

Table 5.3 Results for physical parameters of termitarium

Sample	pH	Temp.(^{0}C)	Conductivity (μs/cm)	Resistivity (μΩcm)	Resistance (μΩ)	Salinity (ppt)
FA1	7.241	23.4	105.9	0.00944	0.00613	0
FA2	6.742	26.5	108.6	0.00921	0.00598	0
FA3	7.661	26.3	94.8	0.01055	0.00685	0
TA1	7.183	26	104.1	0.00961	0.00624	0
TA2	6.901	23.7	133	0.00752	0.00488	0
TA3	7.186	26.2	52.3	0.01912	0.01242	0
MA1	6.575	25.6	127.8	0.00782	0.00508	0
MA2	6.371	26.6	135.4	0.00739	0.0048	0
MA3	6.261	23.6	319	0.00313	0.00204	0
WA1	5.218	25.8	471	0.00212	0.00136	0.16
WA2	5.728	24.9	482	0.00207	0.00135	0.17
WA3	6.21	25.5	277	0.00361	0.00235	0.06
BA1	6.175	26.2	25.2	0.03968	0.02578	0
BA2	6.203	25.3	70.3	0.01422	0.00924	0
BA3	6.051	26	242	0.00413	0.00268	0.04

Table 5.4 Results for physical parameters of soil around termitarium

Sample	pH	Temp.(^{0}C)	Conductivity (μs/cm)	Resistivity (μΩcm)	Resistance (μΩ)
FS1	7.021	23.9	100.7	0.009930487	0.015284891
FS2	6.358	23.2	66.9	0.014947683	0.023007302
FS3	7.214	25.8	91.5	0.010928962	0.016821732
TS1	6.76	23.6	77.9	0.01283697	0.019758517
TS2	6.968	23.5	157.6	0.006345178	0.009766425
TS3	6.355	23.5	116	0.00862069	0.013268866
MS1	6.792	23.5	251	0.003984064	0.006132225
MS2	6.568	23.1	108.3	0.00923361	0.014212267
MS3	7.246	25.5	118.2	0.008460237	0.013021899
WS1	6.296	24.8	156.2	0.006402049	0.00985396
WS2	6.391	24.1	206	0.004854369	0.007471789
WS3	6.62	24.8	245	0.004081633	0.006282402
BS1	6.628	22.6	60.2	0.016611296	0.025567915
BS2	5.778	22.3	125.9	0.007942812	0.012225485
BS3	6.615	25.2	37.9	0.026385224	0.040611834

5.1.2 Ph, Conductivity, Resistivity, Resistance, Salinity

One of the most enlightening attributes of soil is its Ph. Whether a soil is acidic, basic, or neutral has much to do with the solubility of various compounds, the relative bonding of ions to exchange sites and the activity of various micro organisms. Thomas (1967) noted that three soil pH ranges are particularly informative; a pH less than 4.0 indicates the presence of free acids generally from oxidation of sulphides; a pH below 5.5 suggests the likely occurrence of exchangeable Al; and a pH from 7.8 – 8.2 indicates the presence of $CaCO_3$.

The pH values for both termitarium and soil around termitarium generally ranged between 5.0 and 7.0 (Table 5.4) The least values were recorded at Wamfie for both the termitarium and the soil around it, but none fell below 5.5. The highest values were recorded at Fomena also for both the termitarium and the soil around it, but did not exceed 7.5. In all, there was no significant deviation in the pH values of the termitarium and soil around the termitarium, and the figures did not trigger off any stirring information to suggest the presence of free acids, the occurrence of exchangeable Al or the presence of a $CaCO_3$.

Values for conductivity for both samples were close. The termitarium at Biadan recorded low values and as expected, the soil around it also had low values. The highest values were recorded at Wamfie and the soil around also had high values. Generally, the values were dispersed. There was no marked variation in the results for the resistivity, resistance and salinity for both samples.

The results did not show any significant effect of termites on soil Ph, either directly or indirectly through the creation of the mounds. The nitrogen content did not also vary significantly. (Table 5.5)

5.1.3 Sieve analysis

The results of the particle size analysis show a greater percentage of clay generally in all the samples. (both the termitaria and the soils around them.) Although some of the selected sites are not explored clay sites the analysis revealed high clay content in all the samples.

More than half of the soil mass analysed for each sample, were retained in the sieves with 0.5mm diameter or bigger. Apart from the Mfensi anthill sample which retained 48.98% in the 0.5mm+ sieves, all the other samples had values higher than 50%. (Fig 5.1 - 5.4) Also apart from the Wamfie anthill sample which had a higher percentage in the last two sieves (0.5mm and1.18mm) all the anthill samples had lower values than the soil samples.

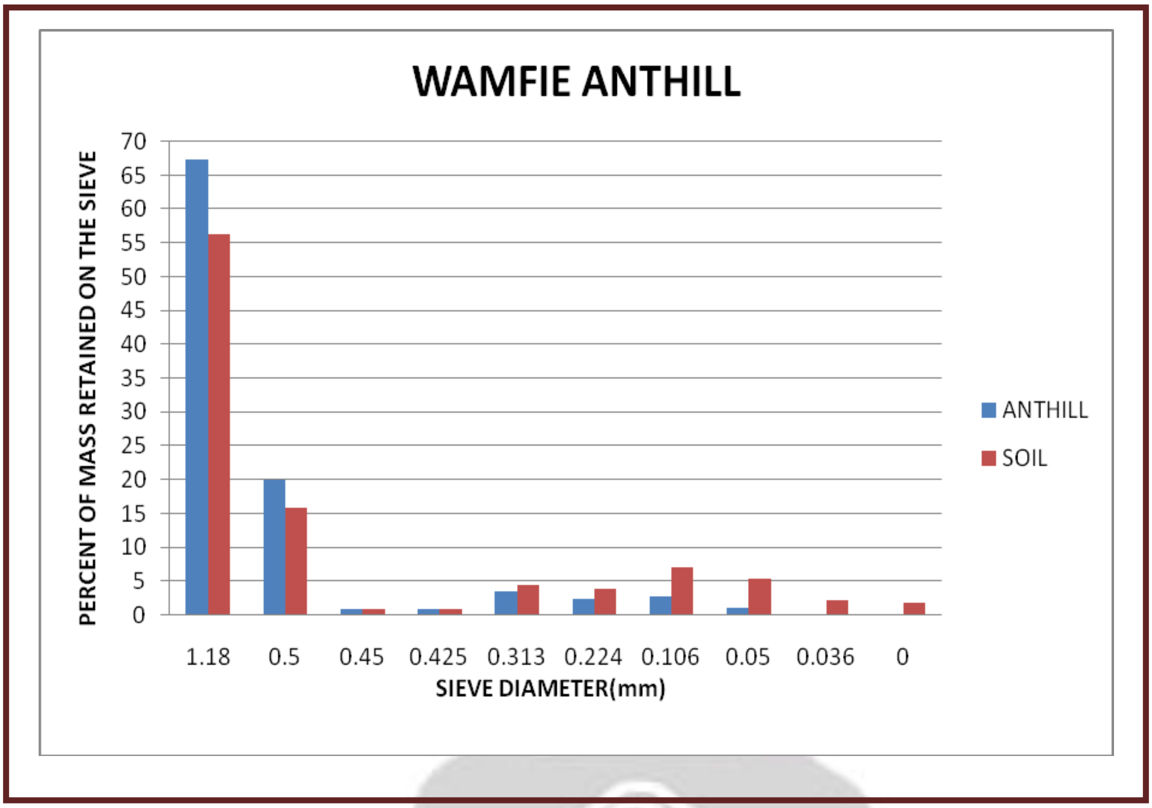


Fig. 5.1 Comparison of sieve analysis report of soil and anthill from Wamfie

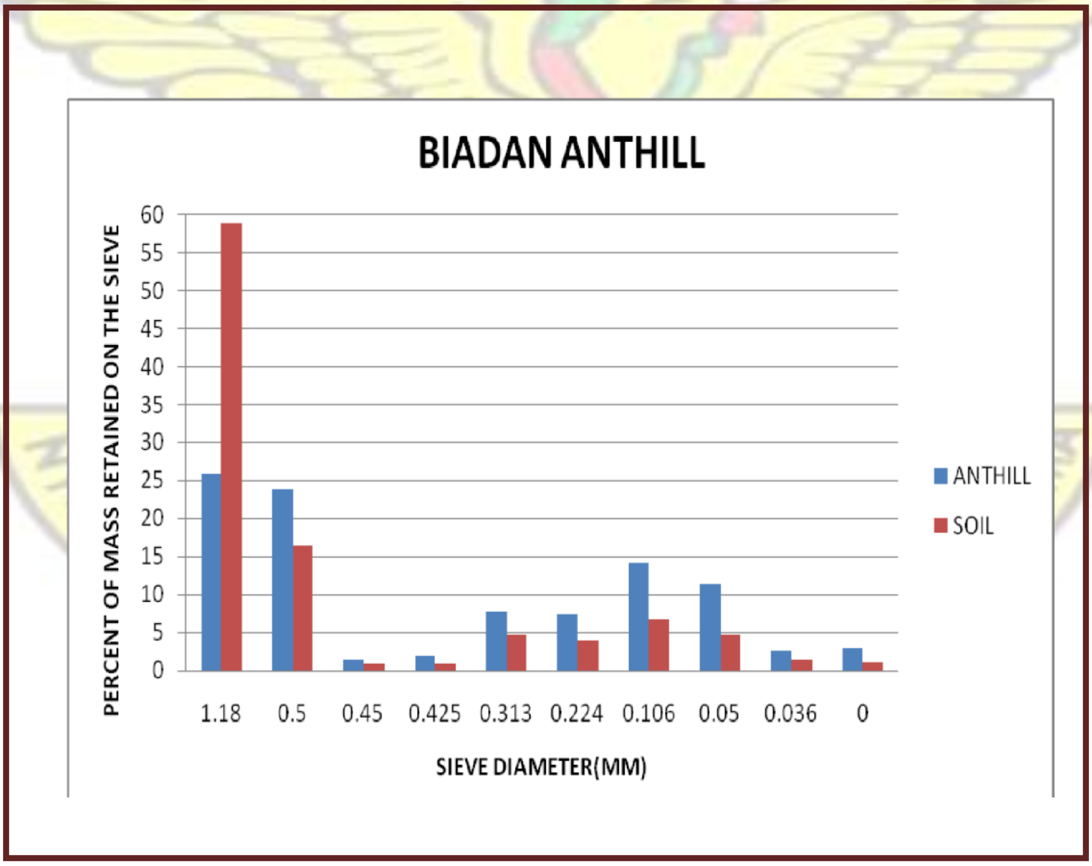


Fig. 5.2 Comparison of sieve analysis report of soil and anthill from Biadan

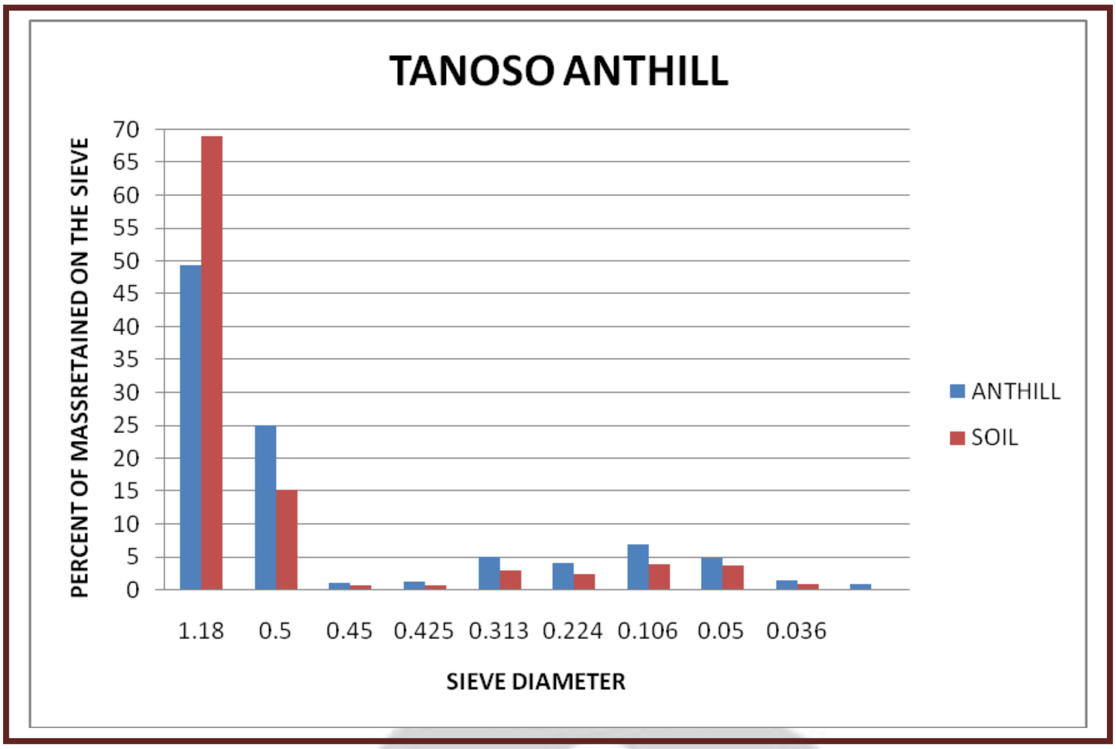


Fig. 5.3 Comparison of sieve analysis report of soil and anthill from Tanoso

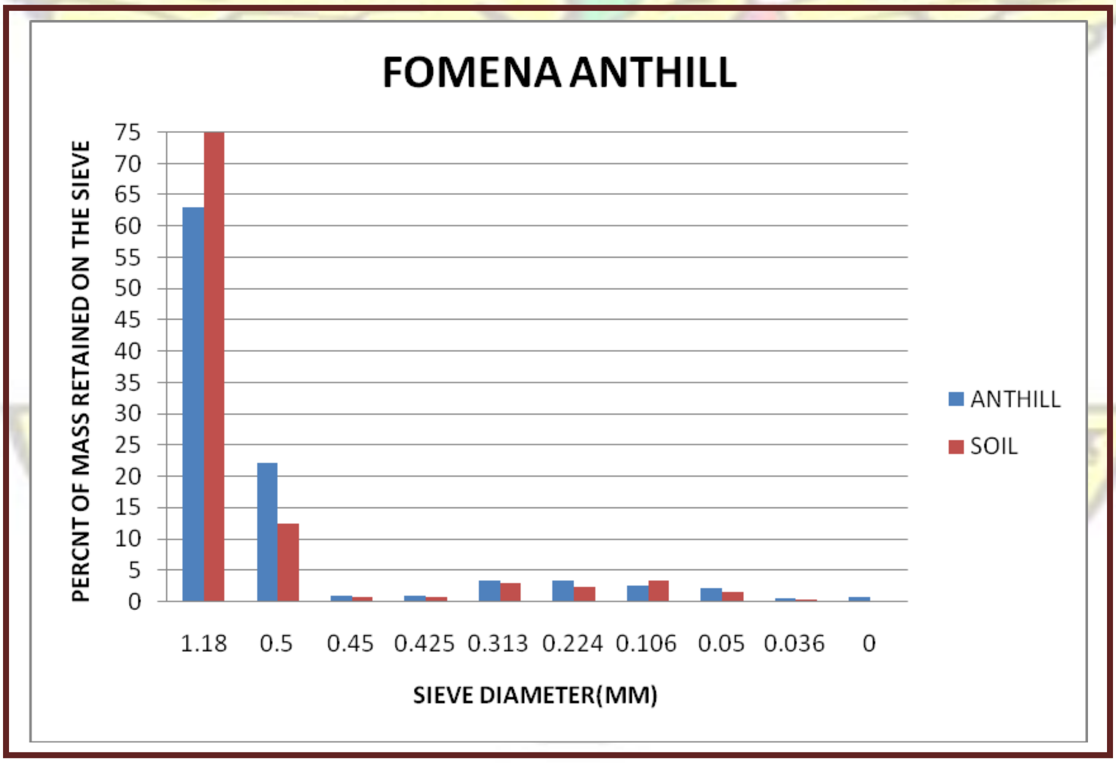


Fig. 5.4 Comparison of sieve analysis report of soil and anthill from Fomena

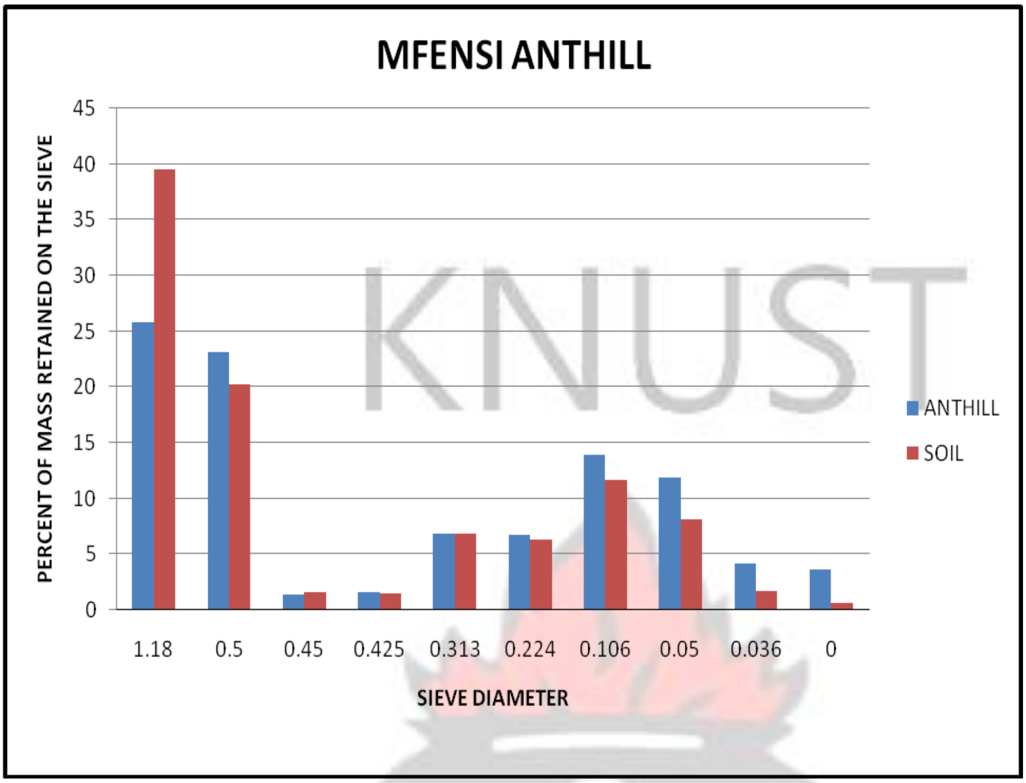


Fig. 5.5 Comparison of sieve analysis report of soil and anthill from Mfensi .

5.1.4 Chemical analysis

It is clear from the results that all the samples have pretty high silica content. (Table 5.5) Every one of them has percentage silica content well above the ideal 46.51% for clay and that should make all the clay samples be able to withstand fairly high temperatures especially the Mfensi samples which have around 76% each. With the exception of Mfensi samples which have Fe_20_3 content below 0.5% all the other samples have a fairly high iron content which should make them fire terracotta red.

The Al_2O_3 content of the samples are not high. In fact every one of them is well below the ideal formula figure of 39.53%. All the figures are below 20%. This situation should influence the maturing temperature.

The analysis further shows that the highest CaO content is 0.52%. This shows a good sign of low carbonaceous content of the clays. A higher content

could have caused black heart, and irregular sizes for fired bricks if firing was not properly controlled. However, high CaO content in any of the samples could have been a very useful asset in so far as glazed tile manufacturing is concerned. This is so because CaO brings about much lower moisture expansion of the body and therefore better crazing resistance.
(Worrall, 1986)

On the relationship between the anthill materials and the surrounding soils, the analysis did not reveal any notable differences. Apart from the Mfensi samples where the silica percentage was 2.71% higher in the soil than in the anthill soil, all the other differences in figures were negligible. However it was also noticed that the silica content of the anthills was lower percentage wise in all the samples than that of the soils around them. (Table 5.5)

Table 5.5 Chemical Analysis

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO	Others

FOMENA SOIL	72.82	17.74	1.55	0.20	0.18	0.2	1.4	1.5	4.41
FOMENA ANTHILL	70.11	19.60	1.68	0.25	0.32	0.18	1.1	1.4	5.36
TANOSO SOIL	69.43	17.33	5.80	0.32	0.31	0.15	1.3	1.2	3.16
TANOSO ANTHILL	69.01	16.94	6.00	0.52	0.70	0.15	1.4	1.2	4.08
MFENSI SOIL	76.1	15.9	0.43	0.35	0.21	0.1	1.7	1.2	4.01
MFENSI ANTHILL	75.77	15.6	0.49	0.34	0.23	0.15	1.67	1.2	4.55
WAMFIE SOIL	70.41	17.30	4.40	0.38	0.70	0.1	1.2	1.2	4.31
WAMFIE ANTHILL	68.43	19.03	3.80	0.41	0.31	0.09	1.1	1.2	5.63
BIADAN SOIL	68.85	18.03	3.20	0.50	0.35	0.2	1.8	1.3	5.77
BIADAN ANTHILL	68.70	18.43	2.36	0.44	0.41	0.2	1.6	1.3	5.56

5.2 Workability Examination

5.2.1 Plasticity test

Plasticity characteristics were found to be of importance to the study. All the samples showed some elasticity. Apart from the Wamfie samples which showed some thin breaks, the rest could be wound round the finger without crumbling or tearing. All the samples except the Biadan ones could hold their shape without losing cohesion when pinched. Although plastic that sample was not very stiff.

An observation of the drying process also showed some cracks in some of the Wamfie anthill samples. This was noticed in both the termitarium material and the surrounding soil. All the other samples dried without blemish. Warping was also detected in few of the samples perhaps because of improper attention during drying. No further warping was detected after firing. Generally, it could be seen from the behaviour of the samples that the termite clays were a shade more plastic than the soils around.

5.2.2 Wet to dry shrinkage

It was observed that the wet to dry shrinkage level was low for all the samples. Apart from the samples from Fomena which recorded the highest for both clay and termitarium (9.0% and 10.0% respectively), the others had values below 7.0%.(Table 5.6) It was also observed that the washed samples had higher percentage shrinkage than the unwashed. The only exception was the Mfensi samples. This is an indication that the coarse materials in the unwashed samples impeded the shrinkage process. The lowest shrinkage was noticed in the Mfensi samples. Surprisingly, shrinkage was higher in the unwashed samples than in the washed.

Comparing the anthill soils and the other soil samples it was observed that generally wet-to-dry shrinkage for the anthill soils was higher than that of the other samples. The only difference was with the Fomena samples where the unwashed sample shrank more than the unwashed anthill sample.

5.2.3 Firing shrinkage

There was a progressive increase in firing shrinkage for all the samples tested. (Table 5.6). As the samples were fired to progressive higher temperatures (850^0C, 1000^0C and 1150^0C) the shrinkage percentage increased.

One would normally expect shrinkage to progressively occur at all time, but this is not the case with the Fomena termitarium and the soil around it. The total shrinkage at 1000^0C and at 1150^0C was the same (16%). However, either samples showed no sign of warping or bloating and the shapes of the tablets were retained as they were.

Table 5.6 Linear firing shrinkage

No	SAMPLE	WET LENGTH	LENGTHAFTER DRYING (CM)	%	LENGTH AT 850^{0}C	%	LENGTH AT 1000^{0}C	%	LENGTH AT 1150^{0}C	%
1	TW	5.00	4.74	5.2	4.73	5.4	4.73	5.4	4.61	7.8
2	TU	5.00	4.81	3.8	4.74	5.2	4.68	6.4	4.51	9.8
3	TAW	5.00	4.74	5.2	4.72	5.6	4.68	6.4	4.64	7.2
4	TAU	5.00	4.80	4.0	4.74	5.2	4.71	5.8	4.64	7.2
5	MW	5.00	4.82	3.6	4.74	5.2	4.74	5.2	4.63	7.4
6	MU	5.00	4.81	3.8	4.79	4.2	4.78	4.4	4.65	7.0
7	MAW	5.00	4.82	3.6	4.81	3.8	4.81	3.8	4.75	5.0
8	MAU	5.00	4.78	4.4	4.77	4.6	4.77	4.6	4.68	6.4
9	BW	5.00	4.78	4.4	4.75	5.0	4.71	5.8	4.65	7.0
10	BU	5.00	4.80	4.0	4.77	4.6	4.75	5.0	4.70	6.0
11	BAW	5.00	4.75	5.0	4.72	5.6	4.69	6.2	4.67	6.6
12	BAU	5.00	4.79	4.2	4.75	5.0	4.70	6.0	4.65	7.0
13	WW	5.00	4.68	6.4	4.66	6.8	4.66	6.8	4.60	8.0
14	WU	5.00	4.70	6.0	4.63	7.4	4.60	8.0	4.60	8.0
15	WAW	5.00	4.66	6.8	4.63	7.4	4.62	7.6	4.59	8.2
16	WAU	5.00	4.69	6.2	4.67	6.6	4.66	6.8	4.64	7.2
17	FW	5.00	4.55	9.0	4.25	15.0	4.20	16.0	4.20	16.0
18	FU	5.00	4.60	8.0	4.55	9.0	4.50	10.0	4.50	10.0
19	FAW	5.00	4.50	10.0	4.46	10.8	4.40	12.0	4.40	12.0
20	FAU	5.00	4.63	7.4	4.60	8.0	4.52	9.6	4.52	9.6

5.2.4. Fired colour

The principal factors affecting fired colour are the proportion of iron oxide, the state of the oxidation of the iron, the degree of the subdivision of the oxide and the extent of vitrification. Calcium oxide and magnesium oxide are said to bleach the reddish colour associated with iron oxide whilst organic matter may lighten the colour. (Worrall 1986).

A close observation of the samples revealed that the colour of the fired samples ranged from light amber to chocolate brown depending on the temperature. The anthill soils fired darker and near chocolate as the temperature increased.

Plate 5.1 Fired colour of the anthill test pieces

5.2.5 Weight loss

There was constant reduction in weight for all the samples with temperature rise. At 850^{o}C the average weight loss was 3.3%. The highest (7.7%) was recorded for the Mfensi unwashed sample. At 1000^{o}C the average weight loss was 6.0% and at 1150^{o}C was 7.8 %. The highest figures of 13.4% and 14.0% respectively were also recorded for the Mfensi unwashed samples. The analysis therefore indicates that the amount of chemically combined water, the amount of vegetable matter and the amount of volatile elements in that sample is higher than in all the samples.

5.2.6 Slab work, coil work, modelling and throwing.

All the clay samples were prepared through wedging. Various items were made using different forming methods i.e. slab work, coil, modelling and throwing. Generally the outcome was satisfactory as almost all the test pieces came out without blemish.

It was only the Biadan samples (both the anthill and other soils) that experienced some sagging and crumbling on the wheel. (Plate 5.2) Although plastic, that sample was not stiff enough to stand the throwing process. It was observed that the use of too much water during the throwing process might have resulted in that. Slight warping was also detected on drying.

All the other samples did not show any appreciable degree of warping even though they were dried under the same conditions (Plates 5.3, 5.4&5.5)

Plate 5.2 Biadan anthill clay crumbling on a wheel.

Plate 5.3 Thrown pieces from anthill clay

Plate 5.4 Slab work made from anthill clay

Plate 5.5 Coil work made from anthill clay.

5.2.7 Brickwork

The examination of the clays revealed that they were plastic and could be moulded without much trouble and also they become very rigid when dry. After firing they were found to be very strong. The temperature achieved was in the region of 1000^0C and hence good enough for brick making.

Plate 5.6 Colour variations in fired bricks

There were some variations in the colour of the fired bricks, perhaps due to their location in the clamp. They were fired in an oxidized atmosphere so most of them were terracotta red in colour. Some were discoloured because they were subjected to the direct impingement and flashes of the flames, and so were discoloured by black or dark areas. (Plate 5.6)

The variations in colour may also be the result of the deposits of carbon that resulted from the smoke from the fire port. Some of the bricks at the base of the clamp also had black heart perhaps due to rapid heating.

5.2.8 Water absorption

A decrease in water absorption with temperature rise was observed in almost all the samples. (Table 5.7) Increasing heat treatment of clay usually lowers the porosity and therefore gives rise to reduction of the amount of water that can be absorbed. However, the Wamfie unwashed sample behaved differently as it recorded increase in percentage absorption at a higher temperature (1150^0C). At 1000^0C the absorption percentage was 12.2 but increased to 15.6 at 1150^0C.

It is unusual to find cases of this nature. Such a situation might suggest that at the higher temperature there was over firing which can result in either bloating or formation of bubbles thereby causing an increase in pore volume. It may also be the result of the formation of micro cracks in the samples due to thermal shock.

Since all the samples were subjected to the same environment and treatment the nature of the clay may be the source of the unusual behaviour.

Table 5.7 WEIGHT (GRAMS) AND ABSORPTION RATE

NO	SAMPLE	DRY	FIRED WGT	% WGT	FIRED WGT	% WGT	FIRED WGT	% WGT	SOAKED WGT	% WGT	SOAKED WGT	% WGT
		WGT	AT 850^0C	LOSS	1000^0C	LOSS	1150^0C	LOSS	1000^0C	GAIN	1150^0C	GAIN
1	TW	53.97	51.80	4.0%	50.19	7.0%	49.82	7.7%	58.52	16.6%	55.24	9.8%
2	TU	52.64	51.46	2.2%	48.01	8.8%	47.19	10.4%	56.51	17.7%	53.48	11.8%
3	TAW	52.52	50.52	3.8%	49.72	5.3%	49.17	6.4%	58.05	16.8%	54.80	10.3%
4	TAU	54.84	52.48	4.3%	50.88	7.2%	49.76	9.3%	57.86	13.7%	54.05	7.9%
5	MW	55.20	52.20	5.4%	51.45	6.8%	51.14	7.4%	61.36	19.3%	58.67	12.8%
6	MU	58.83	54.28	7.7%	50.93	13.4%	50.62	14.0%	60.40	18.6%	58.00	12.7%
7	MAW	68.45	67.90	0.8%	67.65	1.2%	65.76	3.9%	77.63	14.8%	68.20	3.6%
8	MAU	61.98	60.18	2.9%	59.47	4.0%	58.51	5.6%	66.45	11.7%	58.95	0.7%
9	BW	56.45	53.25	5.7%	52.16	7.6%	51.80	8.2%	62.10	19.1%	57.76	10.3%
10	BU	57.30	55.47	3.2%	53.64	6.4%	53.04	7.4%	63.85	19.0%	57.90	8.4%
11	BAW	59.31	57.72	2.7%	55.45	6.5%	55.14	7.0%	65.03	17.3%	63.26	12.8%
12	BAU	58.67	56.69	3.4%	54.45	7.2%	53.16	9.4%	60.77	11.6%	57.43	7.4%
13	WW	59.58	58.02	2.6%	56.60	5.0%	54.61	8.3%	64.70	14.3%	62.60	12.8%
14	WU	61.67	59.07	4.2%	58.08	5.8%	56.45	8.5%	64.31	12.2%	67.15	15.6%
15	WAW	62.40	60.84	2.5%	60.04	3.8%	58.44	6.3%	66.58	10.9%	62.44	6.4%
16	WAU	59.50	58.14	2.3%	55.07	7.4%	53.77	9.6%	60.53	9.9%	58.74	8.5%
17	FW	59.54	58.26	2.1%	56.47	5.2%	55.00	7.6%	61.18	8.3%	58.87	6.6%
18	FU	55.83	53.95	3.4%	51.91	7.0%	50.92	8.8%	63.40	22.1%	60.17	15.4%

19	FAW	58.45	57.13	2.3%	56.71	3.0%	54.75	6.3%	68.50	20.8%	63.00	13.1%
20	FAU	57.31	56.10	2.1%	55.66	2.9%	54.56	4.8%	68.40	22.9%	63.20	13.7%

5.3 Conversion of Anthill into workable kilns

The following were the results and observations made after the conversion process.

5.3.1 Firing the anthill up draught kiln

The packing was very easy as the wares could be easily lowered unto the chequer arrangement. Closing was done with a layer or two of shards which helped to hold the heat in the kiln. Loose soil was piled on the shard as support.

Fire duration was 12 hours and fuel consumption was quite low. Heat circulation in the kiln was averagely uniform. However some over firing was observed at the base whilst under firing was noticed at the top layer. Some of the wares which were near the throat of the fire port had cracks perhaps due to direct impingement of flames on the wares or inadequate pre-heating process due to their nearness to the fire. (Plate 5.7)

Plate 5.7 Cracks resulting from direct impingement of flames

The nature of the kiln structure prevented considerable heat retention as there was the need to allow the escape of sufficient hot gases to create a draft. To reduce excessive inflow of cold air the vent at the top was covered with shards and loose soil to make for gradual cooling.

Apart from few of the wares which were very close to the fire port all the others came out beautiful and strong. It was also observed after scooping, that the inner walls of the firing chamber had become fired thereby making it more permanent as a kiln. The colour inside the kiln during the firing was bright cherry red to orange. This according to Rhode’s colour scale for temperature, was indicating a temperature of between 900^0C and 1000^0C. (Table 5.8)

Table 5.8 Rhode’s colour scale for kiln temperatures

Colour	Degrees Celsius
Lowest visible red	475
lowest visible red to dark red	475 – 650
dark red to cherry red	650 – 750
cherry red to Bright cherry red	750 – 815
Bright cherry red to orange.	815 – 900

Orange to yellow	900 – 1090
Yellow to light yellow	1090 – 1315
light yellow to white	1315 – 1540
white to dazzling white	1540 +

5.3.2. Firing the anthill downdraft kiln

The first firing of the kiln took sixteen hours to complete. Packing was very difficult because the items were very heavy. Raising the heavy items and leaning into the kiln in a sitting position was very tiresome and could result in back injury. As a result of that a couple of the items broke and some got deformed.

The colour inside the kiln as seen from the spy-hole around the 15th hour was red-orange to yellow. Tongues of flames were also spotted intermittently at the top of the chimney, especially shortly after stoking.

Unlike the updraught kiln which cooled rapidly, it was not until the following morning that the items in the kiln could be removed. The wares fired buff and terracotta without so much dark spots as was observed in the updraft kilns.(Plate 5.8)

Plate 5.8 Students admiring their pieces.

Plate 5.9 Scooped out pieces after first firing.

It was noticed after thorough examination of the wares that those at the top and those behind the bag wall were under fired. This was attributed to the low level of the bag wall and insufficient gaps between the bag wall bricks which was to allow passage of flames into the chamber.

After the necessary adjustments had been made in the bagwall, firing started at 6.00 p.m. and ended after 14 hours stoking. In the middle of the 11th hour, cone 012 was down and on the 14th hour cone 06 also followed. The colour inside the kiln was yellow and light yellow. Tongues of flames were once again noticed at the top of the chimney. It was also observed that in the last four hours of firing the use of thin pieces of wood was more effective in promoting temperature gain than the thick ones which needed time to ignite into flames. The wares came out beautifully. (Plates 5.8, 5.9&5.10)

Plate 5.10 Scooping the downdraft kiln

Heat circulation this time improved as almost all the wares had uniform heat treatment. Textures resulting from flashing were also noticed in the wares near the bag wall

Plate 5.11 Some fired wares from the downdraft kiln.

Plate 5.12 Fired wares painted with enamel paint

Plate 5.13 Some fired wares made from Anthill materials and the

flue hole. Overlapping marks were also found on some of the wares

and it made them very beautiful.(Plate 5.8)

No cracks were detected on them except the few broken edges which happened in course of the packing. After the second firing it was detected that

Plate 5.14 The flue hole side of the kiln after firing

Plate 5.15 The bagwall side of the kiln after firing

Plate 5.16 The inner part of the chimney after firing

the walls had also fired red making it stronger (Plates 5.14,5.15&5.16) Cracks were not detected on the walls as was seen with the artificial kilns during the field observation.

In spite of the puncturing the anthill suffered during the modification, it was self supporting after the firing and did not require any external bracing. The nature of the wall also helped to improve heat retention in the oven. When the cone 04 was almost down one could still lean against the structure comfortably. This is an indication that the wall was very insulating and its heat retention properties were effective.

5.3.3. Firing of the compact mound kiln

Packing was done from the top as was done with the anthill updraft kiln. The items fired in this kiln were 'fufu' bowls and 'apotoyewa' and the firing duration was 14 hours. The fuel consumption was quite low as only nineteen bundles of wood were used.

Heat circulation improved drastically as all the wares came out very well without any variation in heat treatment. This might be the loose chequer arrangement and the loose packing which permitted heat circulation in the kiln. Of the three cones (012, 06 &3) which were placed in the kiln, only cone 012 was fully bent. However the wares were dense and came out beautifully. Only few cracks were noticed in the wares which were very close to the throat of the kiln. (Plate 5.17)

Plate 5.17. Fired bowls from the compact mound kiln

Like the anthill updraft kiln the nature of the arrangement prevented considerable heat retention as there was the need to allow the escape of sufficient hot gases to create a draft.

Unlike the updraft anthill where the mouth of the chamber was closed with shards, this was closed with a corbel of bricks. This improved heat retention a little and improved temperature rise in the kiln. Like all the others the inner walls were also fired very well.

CHAPTER SIX SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary:

The non-availability of some ceramic raw materials and the problem of the firing of ceramic wares have affected the teaching of ceramics in junior and senior high schools in Ghana particularly in the rural schools.

This situation is impacting negatively on the popularity of the subject in many schools because at the Senior High School level, authorities select Graphic Design, Textiles and Picture making subject at the neglect of ceramics.

In the midst of this discomforting situation, most of the schools' environments have many anthills which form part of their landscapes. These anthills built through the wisdom of the ants are unique. They are hard, stable and resistant to the machinations of the weather. The annual bushfires that rage through them do not affect their structure. The anthill soils have over the years been used as mortar for joining the firebricks used for kiln construction. They have proved to be perfect as they are able to stand the impingement of flames and heat during the firing process.

In spite of these qualities there has not been any known study into its value or usefulness as a ceramic material or means of firing ceramic wares. It is this concern that prompted the enquiry into the nature of the anthill to find out the possibility of using it to address the problem of non-availability of ceramic materials and firing equipment in schools in Ghana. To achieve this, the following objectives were outlined:

1. To find out the extent to which termites modify the physical and chemical properties of soils to form anthills.
2. To examine the anthill material to determine its use as a material for ceramic fabrication and production of kiln furniture.
3. To critically study the anthill structure to ascertain its usefulness as a firing medium by conducting exploratory experiments through the creation of firing ports and other component parts.

The research questions were also as follows:

1. Do termitaria offer diverse range of physical and chemical environment that differ significantly from those present in general soil mass? 2. Do anthill soils have multidimensional uses including the manufacturing of ceramic products?

3. Can anthills be conveniently converted into workable kilns for firing ceramic wares?

There was scanty information on the topic however the researcher reviewed the available literature and some related ones.

In pursuance of the objectives, the researcher visited many pottery centres, brick and tile factories, anthill sites, research centres, libraries and University departments. He interacted with lecturers, technicians, senior officers, production managers, kiln constructors, fire attendants, farmers and other artisans. The quasi-experimental and descriptive research methods were adopted for the project. Through the visits, the researcher conducted interviews, engaged in on-the-spot observation and also participated in some of the activities relating to the project.

He also carried out laboratory tests on the anthill materials and soils surrounding them to find out the extent of the modification of the soils by the ants. . It also enabled the researcher to have a comparative study of anthills and the soils around them. Tests were also conducted on the anthill materials to find out how they could be used as materials for ceramic fabrication. Ceramic products were therefore manufactured using clay from the anthills. The researcher also conducted exploratory experiments on anthills through the creation of firing chambers and ports to find out their usefulness as a medium for firing.

6.2 Conclusions

The soils around the termitaria analyzed were taken from a depth of 65-75cm, which represent fairly the subsoil. The experiments carried out to establish the relationship between the two samples compared the parameters of the termitaria to those of the soil around it. The parameters analysed showed no remarkable differences in the properties of the termitaria and that of the subsoil. Measurements have confirmed that the main factors affecting the properties of anthills were the nature of nearby subsoil, and the environment of the anthill.

It is therefore concluded that the termitaria are merely heaps of subsoil but with altered soil structure which is due to the method of building. Termites therefore do not directly offer any diverse range of chemical environment that differ strongly from those present in the general soil mass.

The second objective of the research was to examine the anthill material to determine its use as a material for ceramic fabrication. The project therefore sought to look into the physical and chemical nature of the clay samples in so far as their workability, shrinkage, strength, colour and porosity are concerned.

After subjecting the clays to many moulding processes and critically studying the test pieces it can be concluded in precise terms that all the anthill samples are suitable for the manufacture of burnt bricks. At normal brick firing temperature of between 800^0c and 1000^0c, the level of porosity and strength were seen to be generally sufficient for normal building requirement.

All the clays could be used for modelling, coil building and slab construction. Apart from the Wamfie samples which sagged on the wheel, all the other clays were sufficiently plastic when tempered with water and could be thrown on the potters' wheel. Although earthenware temperatures were achieved, it is not certain whether the clays will withstand stoneware temperature since the firing did not go beyond earthenware. Whilst shades of red are characteristic of the fired colours, a few of them burnt buff colour and some were chocolate at higher temperatures.

Firing in all the created anthills kilns were successful as temperatures between 1050^0C and 1150^0C were attained. The examination pieces of the final year ceramic class of Berekum Senior High School were used as test pieces and the outcome was very successful as the students were so delighted.(Plate 6.1)

The wares came out buff and without blemish. The only noticeable shortfalls were the few dents which came in the course of the packing. The enthusiasm with which the students were involved in the project, the experience they had participating in the firing process and the accidental mottling of colours and texture that were noticed on the shoulders of the wares, filled them with great excitement and joy.

Plate 6.1 The students in ecstasy over the outcome of the firing

A remarkable feature of the anthill kiln was its insulatory and heat retention qualities. The tiny vents created in the walls of the anthill by the termites, served as insulation to prevent transfer of heat from the chamber to the outside. Fuel consumption was found to be lower than the other wood fired kilns observed. Higher temperatures could be achieved if other firing procedures are tried. Anthills therefore offer more durable and cheap alternative to the other kilns.

6.3 Problems encountered

Although some positive results were achieved in the project, the experiments were not without problems. The most significant problem was in the use of processing equipment in the laboratories. Most of them were very old and made their use difficult.

For instance, there was the need for X-ray forisis analysis and X–ray defraction which could not be undertaken at the ceramic section of the industrial art department of KNUST, because such equipment were not available. Attempts at having access to such equipment at the Ghana Atomic Energy Commission at Kwabenya also failed.

The non-availability of high firing test kiln made it difficult to fire the test pieces beyond 1150^0c. This situation made it impossible for the testing of the kiln furniture made. Some of the test pieces were fired in commercial wood fired kilns whilst large scale firing was being done. The nonavailability of wares to fill the kilns prevented the variation of firing methods. Not much was therefore known about the performance of the kilns constructed under different firing conditions.

6.4 Recommendations

It is recommended that further scientific research into the physical and chemical properties of the termitaria be conducted to determine what the termites add to it that makes it hard and compact. Also further work could be done to find out the firing characteristics of the anthill kiln as they are affected by size, shape and age.

Also there is the need for architects and building technologists to study further the thermal regulation of the interiors of the anthills and the method of building used by the termites so as to possibly, implement it in the engineering field of building.

To make the venture ecologically friendly, it is suggested that deserted anthills should be sought for the project. However if it becomes necessary for the live ones to be used, the leaves of Cassia occidentalis also called Negro coffee or 'nkwadaa bɔɔ deɛ ' which is milder in effect should be used as a repellent to drive the termites away to enable them relocate to continue their ecological roles.

Recognizing that ceramic technology is an important aspect of vocational and technical education, the Ministry of Education must provide adequate financial support for the supply of ceramic equipment and laboratory materials for the material science laboratories and workshops in the Ceramics section of the department of industrial art, College of Art KNUST and the University of Education, Winneba. This will encourage students to embark on viable projects that can help solve some of the problems that continue to bedevil the nation.

It is recommended that more funds are released to resource the C.S.I.R and B.R.R.I. centres to facilitate the processing of research results for the transfer of technology to business and industry.

Senior high school authorities should encourage the inclusion of ceramics in the visual art programme by recruiting ceramic teachers who are graduates from KNUST and University of Education, Winneba as well as other tertiary institutions where ceramics is offered. Presently there are many teachers of ceramics who are teaching non- ceramic subjects in some Senior High Schools.

Many vocational opportunities are available in the ceramic industry Workshops for ceramic teachers must be organized to up-date them on new techniques for ceramic production, including alternative materials for decorating ceramic works besides imported glazes.

If public funds are available the researcher should be invited to demonstrate the use of anthills as resource for ceramics in schools.

In the new ceramics syllabus for senior high schools, drying and firing, introduction to kilns and kiln construction have been some of the key unit items. Since the study covers most of these topics it is recommended that the project report be made available to schools and colleges as reference document to help solve the firing and materials problems they face.

In Ghana, ceramics materials abound in raw state and have not been exploited to advantage. Even the study, development and production of basic ceramic articles have been a major handicap in the basic and Senior High Schools.

The tests and experiments carried out in the research have opened up opportunities for schools to utilize the materials in their locality especially the anthill soils. The kilns fabricated from the altered anthills also provide an opportunity for the improvement of ceramics teaching and learning. If pursued this technology could expand Ghana’s ability to offer quality ceramic programmes in its schools at minimal cost.

REFERENCES

BEST, J. W. & KANN J. (1998). Research in Education (4th Edition), London: Allyn and Becon.

BOATENG, K. (1983). Wood-ash Glazes and Bodies, Kumasi: U.S.T. Press.

CHANDLER, M. (1968). Ceramics in the Modern World, New York: Doubleday & Company, Inc.

EGGLETON, P.et al (2007). Biological letters, June 7, Dordrecht: Cited in Science News vol.171.

GREGORY, IAN (1984). Kiln Building, London: Adam & Charles Black.

HESSE, P.R. (2000). A Chemical and Physical Study of the Soil Termite Mounds in East Africa, Kenya: Kikuyu.

KENNY, J. B. (1954). The complete Book of Pottery Making, London: Isaac Pitman & Sons.

KINGERY, W. D. (1976). Introduction to Ceramics (2nd Edition), New York: John Willey & Sons. Publishing Company Inc.

LEACH, B. (1960). A Potter's Book, New York: Transatlantic Art.

LEEDY, D.P & ORMROD, J.E. (2005). Practical Research (8th Edition), New Jersey: Pearson Educational International.

MARTIN, A. (1991). Introduction to Soil Microbiology (2nd Edition), Florida: Krieger publishing company.

NELSON, G. C (2002). Ceramics, A Potter's handbook, New York: H, R and Winston.

NORTON, F. H. (1974). Elements of Ceramics (2nd Edition), U.K: Addison Wesley.

NORTON, F. H. (1956). Ceramics for the artist Potter, UK: Addison Wesley Publishing

PETERSON, S. (1996). The Craft and Art of Clay (2nd Edition), New Jersey: Prentice Hall Inc.

RADO, (1988). An introduction to the Technology of Pottery (2nd Edition), New York: Pergamon press.

RHODES, D. (1968). Kilns Design, Construction and Operation. London: Pitman Publishing.

RHODES, D. (1973). Clay and Glazes Pitman Philadelphia: Chilton book Company.

ROTHENBERG, P.(1972). The Complete Book of Ceramic Art, London: George Allen and Unwin Ltd.

SOMKID, K. (1992). Starting, Managing and Reporting Research, Bangkok, Chulalongkorn University Press.

SPEIGHT, C. F (1999) Hands In Clays (4th Edition), New York: Mcgraw – Hill Companies Inc.

STONE & NDU (1985). New Biology for West African Schools, New York: Longmans Group Ltd.

WORAL, W. E. (1964). Raw Materials, London: McClaren & Sons Ltd.

WORAL, W. E. (1986) Clay and Raw Materials, London & New York: (2nd Edition). Elsevier Applied Science Publishers.

APPENDIX

Interview Questions

1. Where do you get clay for your work?
2. How do you mine the clay?
3. What problems do you encounter in the course of mining?
4. How is the quality of your products?
5. What do you do to the clays which are short or sticky? 6. What do you do to the anthills you see at the clay site?
7. What do you use anthill materials for?
8. Why don't you use the anthill materials?
9. How do you prepare the clay for work?
10. How long does it take you to prepare clay enough for 1000bricks or 200 fufu balls?
11. Why didn't you make your kiln angular(square)?
12. Why have you decided to make your kiln round?
13. What usually influence the size of your kiln?
14. What are the functions of the chimney?
15. Why is it that some of the chimneys are short whilst others are tall?
16. What are the functions of the bag walls?

17. What do you do to prevent the occurrence of cracks in the kiln walls?

18. For how long do you fire the wares?

19. How long does the pre-heating take?

20. What proportion of your wares break?

21. What is the best way to reduce breakages?

22. When do you put off your kiln?

23. What do you use to measure the temperature inside the kiln?

24. What quantity of firewood do you use for one firing cycle?

25. What type of firewood do you use and why?

26. What size of wood do you use and why?

27. What problems do you encounter as you fire your works?