Sudan University of Science & Technology
College of Graduate Studies

An Experimental Study on different types of alternative fuels for Production of Bricks on Vertical Shaft Kilns
دراســـــة تجريبية على أنواع مختلفة من الوقود البديل لإنتاج الطوب علي الفرن العمودي

Thesis submitted to the Graduate College, Sudan University of Science & Technology for the degree of Doctor of Philosophy in Mechanical Engineering

By

Abdel-Rahim Mubarak Abu-Sinaina

(B.Sc. M.Sc. Mechanical Engineer)

Supervisor :

Associate. Prof. Dr. Ali Mohamed Hamdan Adam

Co-Supervisor:
Dr. Abdel-Fattah Bilal Abdel-Salam

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بسم الله الرحمن الرحيم

Dedication

To All Who Love

Prophet Mohammed

لكل أحباب المصطفى

صلّ الله عليه وسلم

Acknowledgement

I am fully indebted to my supervisor Ass.Prof. ***Dr. ALi Mohammed Hamdan Adam*** *for his valuable efforts, guidance, helpful, and continuous encouragement during the research period.*

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I would like to express my gratitude to all those who gave me the possibility to complete this thesis.

المستخلص

تركزت الدراسة على كيفية إنتاج الطوب الأحمر بأقل تكلفة ويكون ذلك مصحوباً بإكتساب بيئة صحية صديقة، وذلك عبر إدخال تكنولوجيا جديدة بالسودان ذات كفاءة عالية تتمثل في الفرن ذو العمود الرأسي.

هدفت هذه الدراسة لإنتاج نماذج مختلفة من الطوب الأخضر مضافاً إليه مواد وقود صلب زهيدة في الثمن، وذات قيمة حرارية عالية من المخلفات الزراعية والصناعية كوقود داخلي ثم خلطها مع الطفلة النيلية بنسبة 10% بالوزن وذلك أثناء عملية التصنيع من الفحم البترولي،الزبالة، ونشارة الخشب.

تمت عملية تجفيف هذه النماذج وفق طريقة التجفيف المحددة، ثم تم حرقها وفق طريقة تكنيكية مناسبة ومحددة على مدي درجات حرارة هي، 750م°، 800م°،850م°، 900م°، 950م°، وحتى 1000م°.

تمت عملية كل الاختبارات والقياسات بمعهد بحوث البناء والطرق – جامعة الخرطوم وذلك لتقييم استهلاك الوقود الداخلي والخارجي لهذه العينات وما صاحب ذلك من انبعاثات للغازات الصادرة.

تمت عملية تقييم ورصد ومقارنة لكل المواصفات الهامة للطوب الأحمر من مقاومة للتفتت، النقص في الحريق، ثم الكثافة. تمت عملية مفاضلة بين هذه العينات المختلفة، فكانت عينة الفحم البترولي هي الأفضل حيث كانت أنها الأقل استهلاكاً للوقود وكذلك الوقود النوعي علاوة على إكتسابها أعلي مقاومة للتفتت مع الكثافة.

إستخدام الفحم البترولي لحرق الطوب كان الأفضل إقتصادياً عن إستخدام الفيرنس لحرق نفس الكمية من الطوب الأخضر وذلك بنسبة إنخفاض في التكلفة إمتدت وبلغت 40%.

Abstract

This study is mainly concentrated on how to produce burnt clay bricks with a minimum firing cost and friendly Environmental Impact, through a new implemented energy – efficient technology, ie the Vertical Shaft Brick Kiln (VSBK) in the Sudan.

The study aims to manufacture modeled building green bricks with different cheap solid additives having a high heating values [industrial and agricultural], petro-coke, animal dung, and saw-dust as an internal fuel. Model samples were manufactured, dried according to a predetermined dry process, and then fired through a suitable predetermined firing technique at range of temperature, 750, 800, 850, 900 and 1000C^{o}. The experimental measurements were performed on these samples at Brick and Road Research Institute (BRRI) University of Khartoum, Sudan in order to evaluate internal and external fuel consumption in red brick production and mitigation measures of environmental contamination.

The main bricks properties used for assessment are loss-on-ignition, density and crushing strength that related to the lowest specific fuel consumption and cost. Numerous measurements on samples have been conducted relative to internal and external energy and fuel consumption. The petro-coke sample was found to be the best, with the lowest fuel consumption, higher crushing strength and very good density of clay bricks as well as with the minimum firing cost. Usage of Petrocoke for firing bricks is more economical than Usage of furnace oil, for the same amount of green bricks. The cost reduction is extended to 40%.

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Chapter I

Introduction

1.1 PROBLEM STATEMENT

Now there is a scarcity and a great shortage of furnace oil that used for firing the bricks. It's price had been highly increased from 400 SDG per Ton up to 4000 SDG. Due to that the production cost of the product is increased too much.

1.2 Objectives:

The objective of this research is to study about different alternative fuels, agricultural or industrial, as a cheap source of energy to produce bricks, through a new implemented energy – efficient technology i.e. the Vertical Shaft Brick Kiln according to steps below:

1.2.1 To select suitable alternative fuels as an internal and external fuel according to the availability, calorific values, suitability, …etc.

1.2.2 To Conduct research experimental work at Brick and Road Research Institute (BRRI) University of Khartoum (U of K).

1.2.3 To manufacture four modeled of green bricks samples having 10% of different additives, saw-dust, petrocoke, zibala and clay using a modeling Brick making machine.

1.2.4 To dry and fire these samples through a predetermined program that usually has been applied and used for bricks.

1.2.5 Test and result for brick properties such as, crushing strength, loss - on- ignition, and density.

1.2.6 Recording of these samples specific fuel consumption and fuel consumed.

1.2.7 To make comparison between these samples in order to select the best sample that having the good properties and with low fuel consumption.

1.2.8 To complete Design and shortages of the vertical shaft Brick kiln (VSBK) items.

1.3 Background:

Energy is a back bone of industries and development in all countries. During the energy crisis, in the early 70's. the world began to reconsider its dependence on traditional fuels as a major source of energy.

Both the limited resources of fossil fuel and their un even distribution among all nations together with their rapidly increasing price made most countries try to discover and utilize their local resources of energy.

Transportation, also is becoming expensive as it cost a lot to bring the fuel to the consumers.

Sudan like many other developing countries, has been suffering from acute energy shortage which in many instances threatened its crop, irrigation, harvesting and the everyday needs.

Sudan is rich in most of forms of renewable energy such as wind, Solar, biomass, … etc. the attention is directed now to use the hydraulic energy in the everlasting supplies of water from Blue, and white river Niles.

The clear sky, shining sun and favorable temperatures invite using solar energy. Biomass is now feeding the country with high percent of its needs of energy in the form of wood and charcoal. Conservationists used to object because of the wide ranging deforestation that resulted from the uncontrolled and indiscriminative use of wood for fuel. [5] [43].

Till now there are heaps ofagricultural, animal and industrial residues having a high heating values can be used to reduce energy expenditure.

It is well known that fuel is a great important source of energy being used in the field of Brick Factories. It's almost represented the main production factor that should have to be seriously considered in Brick Factories firing system.

Soba brick factory belonged to the University of Khartoum. The factory machines were manufactured in Yugoslavia by IVOLOLA – RIBAR (ILR). [27]

The factory design capacity is ten million brick per year.

Soba brick pilot plant involved two types of kilns. Both types are related to the branch of a continuous type of kilns, which are represented the most developed ones with a high energy efficient. The first one is an atomized liquid fuel denoted by Hoff–Mann kiln, with a moving – fire and stationary ware system. The second one is denoted by the Vertical Shaft Brick kiln (VSBK), with Stationary fire and a moving ware system. It is worth to mention that VSBK is under construction and it is the first type to be introduced in the Sudan.

Soba Brick Pilot Plant will be the best field to study this research titled An Experimental Study on different types of alternative fuels for Production of Bricks on Vertical Shaft Kilns, since there are the two types of kilns. The atomized liquid Hoff – Mann kiln and the under constructed VSBK for using agricultural, domestic, and industrial residues as a cheapest major source fuel for firing the bricks.

A deeped scientific experimental efforts should have to be attracted to study this research, considering the best facilities of the laboratory center at Brick and Road Research Institute (BRRI) U.of.K. It would be more useful and a good opportunity to deal with the term Firing of Bricks and Heat Energy Management throughout this research process.

Red bricks the most strategic building materials are a widespread use in all building construction such as: the apartments, offices, shops ... etc.

The clay substance is represented by the formula, AL_2O_3, SiO_2, $2H_2O$ when heated at 650 C^o then splits up into separate constituents as silica, alumina and water [6]. This water is known as combined water and considered as a constituent or part of the clay, which is driven off the green bricks as steam. The dry green brick losses the weight when heated to the maximum firing temperature 900C^{o}. This loss is termed as loss-on-ignition of clay that varies in quantities for different types of clay content [7]. The carbonate is a compound often found in clays impurities and in certain cases regarded iron, magnesium, and calcium are also present. These are decomposed by heating into metal oxides and carbon dioxide at high temperature the gas evaporated as black cloud. The iron oxide and magnesium oxide are separated by the temperature in the range of 400–700 C^{o}, while calcium oxide is formed in the temperature from 700 to 900C° 7, [8].

Calcium carbonate, $CaCO_3$ is the common impurity in building brick clay being present as pieces of limestone. This can cause trouble if carbonate is present in large pieces (1/8 inch) of limestone and at that stage carbon dioxide expands through the burning of bricks causing imperfection. The carbonaceous matter is different in nature of different types of clay present normally of about 7% to 8% that a start burning out varies in temperature from 20 C° to 35 C° and then up to 450 C° [9].

Mechanical water is a technique of adding water to the clay mechanically during the manufacturing process, which is driven off in the dryer from the wet brick over the temperature range from 10 to 150 C° [7]. It is usually determined by weighing green bricks before and after drying, which differed for all brick types due to the process of manufacturing. Bricks process depends on the duration of firing and the rate of firing that control relative to the mechanical water, combined water and carbonaceous matter present in the brick [10]. Therefore, the firing is governed by the size of the product and the density in the setting of the bricks. The firing of bricks have to be control during the water smoking period. Mechanical water must be slowly driven off from the bricks set in the kiln. Usually a brick set contains about 5% of mechanical water. Still, the water is moved due to pressure increase and exhausted as vapor through the stack (chimney) during the process. The high percent of moisture in the brick is required slowly firing process to avoid a sudden increase of temperature that can cause cracking of the product [11].

The preheating temperature can be increased at a greater rate once water smoking has been discharged and the temperature is raised to about 650 C°. Therefore, the most important reaction takes place at the 650 C° while the chemically combined water is driven off from the bricks at this stage of the carbonaceous matter oxidized from the bricks [12].

However, there are certain drawbacks associated with the use of rapid temperature range; vapor steam may persist for around the bricks. This excludes air or oxygen that is needed to complete the oxidizing action, which leads to black cored bricks [13]. The good quality of brick production is requires slow heating for a suitable satisfactory time that allows excess air for the oxidation to take place. A soon as all the carbonaceous matter has been burnt the a- temperature can be raised rapidly from 650 C° to the verification temperature. Verification is usually taken to commence at about 900 C° that extended to the highest temperature the brick can withstand without serious distortion [14].

The amount of liquid formed depends on the temperature reached, the duration of heat and the amount of fluxes, soda, potash, magnesia, lime and ferrous oxide present in clay. The highest rates of burning of the fuel are used in the soaking period to reach the maximum temperature, but once this is obtained at the top part of the kiln a slightly lower rate may be employed [15]. Consequently, in order to hold the maximum temperature not to over-fire the bricks at the top of kiln whilst is increasing the temperature at the bottom of the setting [16]. The kiln is allowed to cool gradually after the fires have been burnt down. Crown cooling holes are gradually opened and then the wicked side doors are also gradually broken down. Slowly and gradually cooling is almost well preferred since it will minimize brick cracking [17].

The additive upon fermentation, improve the plasticity of the basic material and act as reinforcing fibbers, thus reducing the cracks. These fibbers ignite thus assisting in even firing of the brick and minimizing the development of high temperature gradients within the brick unit. These fibbers are burnt out and they leave cavities within the brick. The result being a reduction of the unit weight, and improving the thermal characteristics. Cavities on the top and bottom surfaces of the brick increase the bond when brick is built [17].

Sudan standard for common burnt building brick are deemed necessary so that the water absorption not exceeded 35% and crushing strength in the range of 25 kg/cm^2 and dimension (25×12×7 cm, or 23×11×6 cm) is highly required for quality control. The brick kilns in Sudan dependent on traditional fuel as a major source of energy, [18]. This study is aimed to minimize cost of firing as much as possible and improved the quality by using the available agricultural and industrial wastes in the Khartoum province.

These alternative fuel materials are very cheap and having a high heating value, which can be utilized as an internal fuel that to be mixed with the green brick unit by a certain percentage [19].

The source of fuel energy for heating new stack of green bricks in a kiln mainly need huge quantities such as; wood staves and animal dung (Zibala) and industrial petro-coke without estimation of consuming energy request [20]. In order to overcome the bricks production fuel consumption problem an appropriate brick and kiln design were used in this work. Soil, clay and river sand is available at a reasonable cost on the

Blue Nile bank and inexpensive material used as fuels in addition to reduce environmental pollution in site residential area [21].

1.4 Thesis layout

The thesis consists of 6 chapters.

Chapter I:

Presents the problem statement, the objectives and the background, which gives a basic understanding about sources of energy, traditional, renewable and the waste fuels. It also gives a brief overview about brick kilns firing and source of energy.

Chapter II: Presents literature review and the previous studies. This chapter provides a basic understanding of types of kilns as generally and the Vertical Shaft Brick Kiln (VSBK), history, construction, operation and firing. It also gives a brief overview about clay composition, firing of bricks, the effect of heat upon it, and the firing stages, Water Smoking, preheating, full firing& vertification, Soaking & then cooling.

The chapter also provides a brief overview about the previous studies and environmental impact assessments.

Chapter III: This chapter presents the experimental work for the different samples and results.

Chapter IV: This chapter presents the analysis of results.

Chapter V: This chapter presents the design and constructions of the Vertical Shaft Brick Kiln (VSBK)- Soba, the shortages, and design improvement.

Chapter VI: This chapter presents the conclusion of the study and recommendation for future work.

Chapter II

Literature Review

2.1Types of KILNS

A kiln is a thermally insulated oven, in which a controlled temperature regime is produced in order to fire the bricks to a requisite hardness. [31] [51].

Kilns used for firing building bricks may be summarized as follows:

2.1.1 Intermittent Kiln

Intermittent kilns or periodic kilns may be defined as those old primitive kilns in which green bricks, fired according to a definite time – temperature schedule to the required finishing temperature, cooled and then taken out of the kiln. The process is then repeated with another charge of green bricks.

2.1.2 Semi- Continuous Kilns

Semi continuous kilns may be visualized as five or more intermittent kilns or chambers built together within a common structure and so arranged that gases may pass from one to the other. The kiln is lit off at one end, in the first chamber which is fired in the same way as an intermittent kiln, but the kiln gases instead of passing to the chimney, pass through the second chamber before doing so. The bricks in the second chamber are thus preheated to a fairly high temperature before the firing of the first chamber has been completed and it is time to feed fuel to the second: by then gases are passing forward into the third chamber. This process is repeated until the last chamber is fired and from which the flue gases are exhausted direct to the chimney when the firing of the kiln is completed. With kilns of only about five chambers, the fired bricks are then withdrawn from the chambers, green bricks set in them and firing started again at one end of the kiln. As the firing of each chamber is completed air may be allowed to pull through it from the first chamber to assist combustion in the firing chamber. Longer kilns operate like continuous kilns except that periodically the fires have to be restarted at one end of the kiln. [31].

2.1.3 Continuous Kilns

Continuous kilns may be defined as those in which bricks are always being fired [31]. Green bricks being put into one part of the kiln and fired bricks withdrawn continuously from anther. Fuel is fed regularly at more or less constant rate.

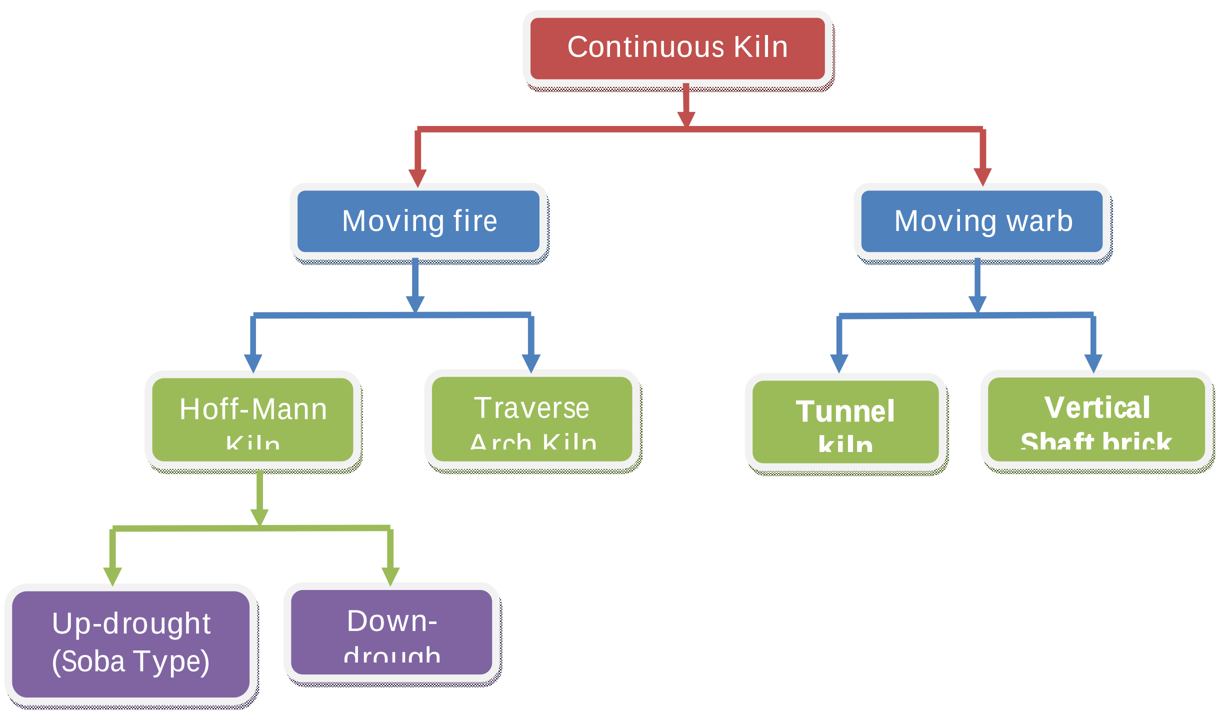


Fig. 2.1. Continuous Kiln[7]

2.2 Vertical Shaft Brick Kiln (VSBK) History

The vertical shaft brick kiln (VSBK) technology evolved in rural china and originated between 1960 to 1973. In 1975 the kiln became popular in several provinces. In 1985, the Chinese government commissioned the Energy Research Institute of the Henoan Academy of Science at Zhengzhou University to study the kiln to improve its energy efficiency. About 50.000 to 60.000 VSBK units were estimated to be operating in China. [38] [5s0]

Usually the kiln productivity vary from 2500 to 20.000 bricks per day. Simple mechanization is used for material handling, transportation and extrusion of green bricks. The time interval between loading of a green bricks and unloading of fired bricks is 20→ 24 hours.

2.2.1 (VSBK) Construction:

The vertical shaft brick kiln consist of one or more shafts located inside rectangular brick structure. The inner side of the shaft surface is often lined with refractory bricks. The gap between the shaft wall and the outer kiln wall is filled with insulating materials (clay, rice husk, ashes …….etc.). Thermocouples are provided along the shaft high to monitor the position of the fire as well as the temperature profile of the kiln.

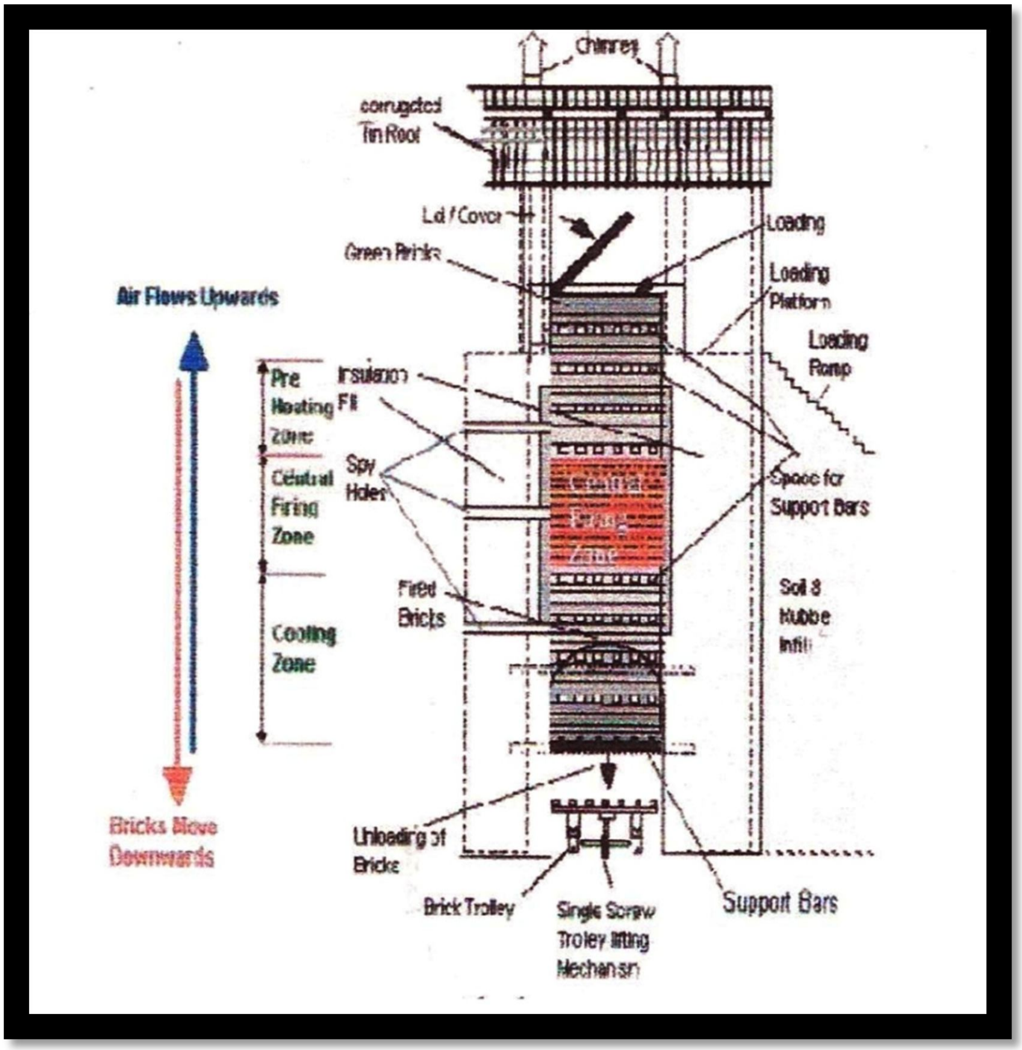


Fig. (2.2) Vertical Shaft Brick Kiln (VSBK)

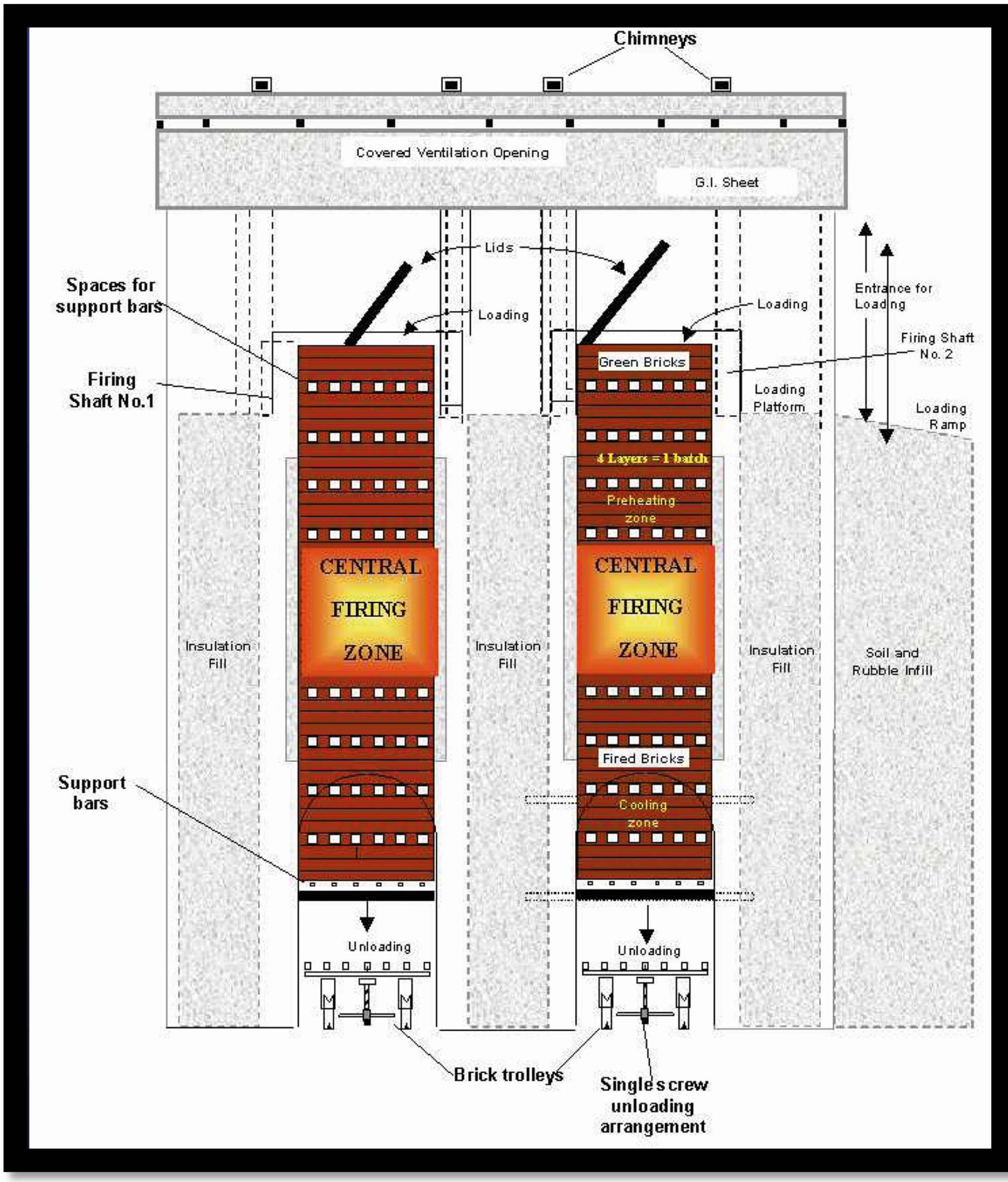


Fig. (2.3) Vertical Shaft Brick Kiln (VSBK) (Two-shaft)

The shafts are open at top and bottom. At the base of each shaft is an arched unloading tunnel, which runs through the centre of the kiln. It allows access to both sides of the base of the firing shaft and contains unloading equipment. At the top of the shaft there is a roofed plate form used for storing and stacking of the dried green bricks being lifted up from the drying area by either of the following means:

a. Use of a ramp structure and bricks are carried manually or by using animals.

b. Use of winch and hoist system.

At the bottom of the kiln unloading trolley which runs in rails along the length of the unloading tunnel been provided. Lifting and lowering of the trolley is done by a single screw unloading mechanism.

The shaft is loaded from the top with a total of 12 batches of green bricks set in a predetermined pattern. The stacks of bricks rest on I-bar (which can be removed or inserted) supported by a pair of horizontal I-beam across the arches in the un loading tunnel.

During continuous operation, one batch, at a time and a sized and weighed quantity of coal is spread uniformly. At the bottom of the shaft, batches of fired bricks are continuously removed using an unloading trolley, which moves on rails along the length of the unloading tunnel.

Lifting and lowering of the trolley is done by using a single screw unloading mechanism. For unloading, the trolley is lifted so that the hole stack of the bricks in the shaft rest on it. The I-bars are taken out, when released, the hole stack is then lowered till the gab in the layer appears through which the I-bar are then reinserted. On further lowering the trolley the load of the stack is then taken by the I-bar except for the batch being in loading, which comes down along with the trolley, which is later pulled out along the rails to the red brick storing area. The next batch is loaded at the top mechanically with the green bricks. Then the process is repeated.

As the procession of batches gradually pass through the shaft, green bricks encounter the preheating firing and cooling zone before reach the shaft exist. The bricks in the preheating zone absorb heat from hot gases coming through the firing zone, which helps in the evaporation of moisture in the green bricks. The temperature in the preheating zone is about 100- 500 C°. After passing through the preheating zone, the bricks enter the firing zone with temperature in area up to 950 C° and then move down to the cooling zone. The unloaded bricks come out of the shaft in a temperature 100- 150 C°.

The draught in the shaft is controlled by variation in the spacing density of the bricks during loading. For evacuation of exhaust gases, typically two metal chimneys are provided at opposite corner of each shaft. A lid cover is provided to cover shaft top, which direct the exhaust gases to the chimney through the flue duct system.

2.2.2 Firing:

For initial firing the shaft is loaded from the bottom with dried green bricks with crushed coal as fuel. Initiating a higher amount of coal is used at the bottom batches, then gradually reduce to the top. While ignition, the wood placed is lightened in the fire box with the help of kerosene at the bottom of the brick setting. Fire wood is continuously stocked till the fire moves along the stacks bricks and starts to ignite the coal. At this time, the fire box is sealed in bricks and mud mortar plastering from both sides to control air passage. After around hour of firing, the sealing is opened for natural draught to proceed when the maximum temperature reaches above the central part of the shaft (firing zone), a first batch is unloaded.[38][50].

2.2.3 Brick Quality:

The quality of fired product mostly depends on the quality of the green bricks being loaded. All the fired bricks can be classified into a single sealable class except breakages appearing sometimes and that due to:

1. In areas with sandy clay with low plasticity, the breakage range can be 5- 6%, while is plastic clay area breakage will be less than 1%.
2. Handling of bricks also causer brick breakage.

3. Every brick in the pattern has to withstand upcoming load from the top and extremely more at the bottom, as the loading of the bricks increases from the upper of the shaft.

2.3 Vertical Shaft Brick Kiln (VSBK) – Sudan (Plate (2.4):

The VSBK was adapted for the use in the Sudan during 1996. A pilot kiln was constructed by the (B.R.R.I) Building and Road Research Institute of the University of Khartoum in corporation with GTZ- GATE; German. Appropriate technology exchange. The shaft still not completed. The proposed fuel to be used was carbonized agricultural waste form cotton stalks, sun flower stalker or bagasse. The carbonized fuel, reduced to a granular size should be dispersed among the green bricks when loading the kiln from the top. [37]

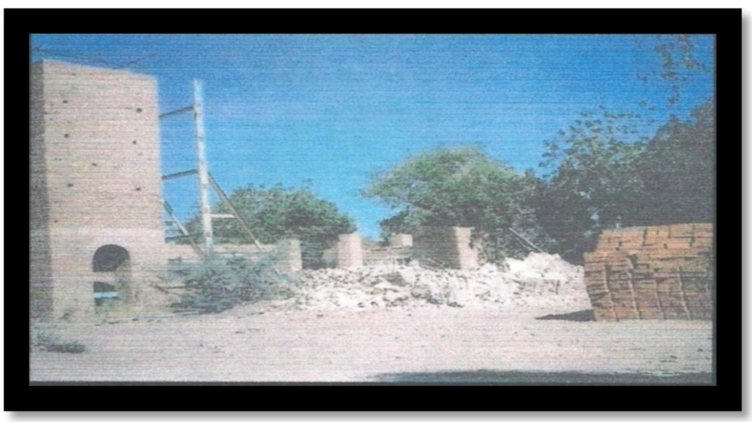


Fig. (2.4) Vertical shaft kiln – Soba- Sudan.

2.4 Composition of Clay and The Effect of Heat Upon it:

A large variety of clays are used for making building bricks. Different processes of manufacture have been developed to suit the different raw materials (e.g. hand-making, wire-cut, stiff-plastic, dry or semidry and soft mud process.). These clays differ in composition and behavior when fired, variations also occur with the same type of clay and with the same clay sample hole at different parts of the hole or clay face. Thus although there are certain characteristic which are similar for all clays, there are others which causes differences in behavior during firing and make it necessary to adjust the firing schedule to suit them. [40]

2.4.1 Mechanical Water:

It is the water which is present in or added to a clay when making the bricks, and which is driven off in the dryer from the wet brick over the temperature range from 10 to 150 C˚. normally it is determined by weighing green bricks before and after drying. The amount of mechanical water is differ for different type of bricks when made with differ process of manufacturing.

2.4.2 Combined Water:

The true clay substance as represented by the formula, AL_2O_3, Sio_2, $2H_2O$. and at 650C˚ splits up into its separate constituents, silica, alumina and water. This water is known as combined water. This combined water is considered as a constituent or part of the clay. This combined water is driven off the green bricks as steam.

2.4.3 Loss-on-ignition:

When dry green brick is heated to the maximum firing temperature 900 C˚, it losses weight. This loss is termed as loss-on-ignition. This loss-on-ignition of clay varies in quantities for different types of clay content. (upon percentage contents of carbonate, carbonaceous matter, and combined water).

2.4.4 Carbonates:

The carbonates, often found in clays and in certain cases regarded as impurities, are those of iron, magnesium, and calcium. These decompose on heating into oxides and carbon dioxide [31]as follows:

Iron carbonate $FeCO_3$	Iron oxide FeO	Carbon dioxide CO_2	Temp. 400 C° 700 C°
Magnesium carbonate $MgCO_3$	Magnesium oxide Mgo	Carbon dioxide CO_2	400 C° 650 C°
Calcium carbonate $CaCO_3$	Calcium oxide CaO	Carbon dioxide CO_2	600 C° 900 C°

Calcium carbonate $CaCO_3$ is the common impurity in building brick clays being present as pieces of limestone. This can cause trouble if carbonate is present in large pieces of limestone. This can cause trouble if carbonate is present in large piece (1/8 inch), and then through burning of bricks carbon dioxide expand and pushing up.

2.4.5 Carbonaceous Matter:

The carbonaceous matter is different in nature in different types of clays present normally of about 7 to 8 percent. Temperature at which the carbonaceous matter starts to burn out varies from 20 C° to 35 C° and then up to 450C°.

2.5 Stage in Firing:

The length of time of firing and the rate of firing depend to a large extent on how much mechanical water; combined water and carbonaceous mater are present in the brick. It also depend on the size of the product and the densely of setting.

The firing of bricks is generally considered in four stages:

a- The water- smoking.

b- The preheating.

c- The full firing or vertification.

d- Cooling.

2.5.1 Water Smoking:

During the water smoking period the mechanical water must be slowly driven off from the bricks set in the kiln. Usually bricks set contain about 5 percent of mechanical water. So this water has got to be moved and exhausted as vapor through the stack (chimney). For brick containing high percent of moisture, care must be taken and the firing should be carried out slowly. Any sudden increase of temperature can cause cracking. This is because for bricks containing a high percentage of moisture, and if drying is carried out rapidly, outer surface of the bricks contract more than the Centre, so cracking will be result.

2.5.2 Preheating:

Once water smoking has been completed, the temperature can be increased at greater rate. During this period the temperature is raised to about 650 co, and two most important reaction take place.

- The carbonaceous matter is oxidized from the bricks.
- The chemical combined water is driven off from the bricks

The removal of chemically combined water from the clay may starts at 400 co, and carry on to 650 C˚. This water maybe driven gradually and smoothly over arrange 450-650C˚. If heating is carried out rapidly through this temperature range, vapour steam may persist on around the bricks. This excludes air or oxygen that is needed to complete the oxidizing action, and can lead to black cored bricks. For the production of good quality bricks therefore slowly heating for a suitable satisfied time is required to allow excess air for the oxidation to take place.

2.5.3 Full firing and vertification:

A soon as all the carbonaceous matter has been burnt and the iron oxidized the temperature, can be raised rapidly from 650 C˚, to the verification temperature. Vertifications usually taken to commence at about 900 C°, and extended to the highest temperature the brick can with stand without serious distortion. The strength of the bricks is developed at this stage.

1. First by centering of particles in close contact with one another.
2. And later, as the temperature increases by more and more melting of the clay mass. The remaining solid particles thus become coated with liquid when the kiln is cooled remains mainly as a glass and binds the particles together. The amount liquid formed depends on the temperature reached, the duration of heat and the amount fluxes, soda, potash, magnesia, lime and ferrous oxide present in clay.

2.5.4 Cooling:

After the finishing of firing, the kiln is allowed to cool gradually after the fires have been burnt down. The crown cooling holes are gradually opened and then the wicket side door are also gradually broken down. Slowly and gradually cooling is almost well preferred since it will minimize brick cracking.

2.5.5 Soaking:

The highest rates of burning of the fuel are used in this period to reach the maximum temperature, but once this is obtained at the top part of kiln a slightly lower rate may be employed in order to hold the maximum temperature not to over-fire the bricks at the top of kiln whilst increasing the temperature at the bottom of the setting

The aim is to fire the bricks satisfactorily at the bottom of the kiln without over firing those at the top. This referred to as the soaking period.

2.6 Fuels Oils:

One could hold the view that any substance which on combining with another substance produces heat is a fuel , but the term is generally restricted to those substance , which contain the element carbon (which will combine with oxygen from the air to produce heat) and exist in large quantities near the earth's surface. This definition covers, wood, peat, coal, petroleum and natural gas, in addition there are the refined fuels such as town gas and cocke.

Many petroleum products can be and have been used as fuels, ranging from crude oil through refinery gases and gasoline-types distillates to the heavies' residual oils and bitumen.

However, it is generally accepted that the term "fuels" refers the range of products which includes the distillate oils known gas oil and diesel fuel and the light, medium and heavy fuel oils. These oils may be either straight-run or cracked or they may be blends of both. Although the nomenclature "light" "medium", and "heavy" refers basically to the specific gravity of these oils, the terms are often used commercially as an indication of the viscosity of the oil.

2.7 Types of Fuel Oils:

Gas oil is a distillate intermediate in character between kerosene and light lubricating oil. being a distillate it is free from residual components, its hard asphalt content is virtually nil and it is low in Sulphur. These properties, together with its low viscosity at ambient temperatures make it ideal fuel for certain industries.

2.7.1 Diesel Fuel:

There are two main groups of diesel fuel, automotive diesel oil and marine diesel oil. Such oils are normally a little more viscous than gas oil, have a slightly higher specific gravity and darker in color.

2.7.2 Light M Medium & Heavy Fuel Oils:

This ranges of fuel oils includes the heavy residual oils and residual oils blended with varying amounts of low viscosity materials in order to obtain the desired viscosity. The specific gravity will be of the order of 0.92 for the light fuel oil up to nearly 1.0 for the heavy residual oils. Commercially, these grades may be marketed according to a maximum viscosity limit, such as 75 centi stockes at 37.8 C^{O} for light fuel, 150 centi stockes medium fuel oil and 225 C^{O}St and over for heavy fuel oil.

2.8 Fuel Oil Characteristics:

2.8.1 Specific Gravity:

Although the specific gravity of an oil has no technical significance from the point of view of quality, it does give an idea of grade of oil,i.e. whether it is a distillate or a residual oil. An increase in specific gravity usually indicates an increase in the viscosity of fuel oils of the same origin. The heavier and more viscous oils generally have a lower calorific value than the lighter blends and distillates, but when sold by volume it may be found that calorific value of the oil per gallon is more for the heavier oil, since the higher specific gravity may compensate for the lower calorific value. Variation in specific gravity with temperature is an important factor in marketing and must also be taken into account when determining the fuel consumption of an appliance.

2.8.2 Viscosity:

Viscosity is a measure of the resistance of a fluid to shear or flow, and can be reported in a number of ways. In the case of oils, it has been commercial practice for many years to quote the viscosity as measured on one of three instruments, the Redwood Viscometer in the UK, the Saybolt viscometer in the USA and the Engler viscometer in some European countries. The principal used is the same, in that the time is measured in seconds, for a given volume of oil at a constant temp. to flow through an orifice of standard size. The temperature used are 100 F^O (37.8 C^o) with the Redwood viscometer, 122 F^O (50 C^o) with the Say bolt viscosity of relatively mobile oils is recorded as many seconds Redwood 100 F^O, or seconds Saybolt Universal 122 F^O but for more viscous oils similar instruments with larger orifices are used, which reduces the time of flow to about $\frac{1}{10}$ of that taken. with the smaller orifice. and the viscosity is then given as seconds Redwood 100 F^O, or seconds Saybolt Furl 122 F^O, when using the Engler viscometer, the result is expressed in terms of Engler degrees (F^O).

A more accurate and scientific method of measuring viscosity is to determine the rate of flow of the oil through a calibrated capillary tabe and to express the viscosity, centipoise for dynamic viscosity.This method of measurement has infact long been used in laboratories in place of the Redwood or Saybolt methods, although results have continued to be reported in terms of Redwood or Saybolt viscosity – obtained from conversion tables – to satisfy conventional practice.

2.8.3 Pour Point:

In the early days of the use of fuel oil was found necessary to have a test that would indicate the lowest temperature at which an oil could be stored or handled without it congealing in tanks or pipelines to meet this requirement the pourpoint test was devised. This test gave the lowest temperature at which the oil would flow under prescribed conditions.

2.8.4 Calorific Value:

The calorific value of a gaseous fuel containing several gases may be calculated from the gas analysis and by summing-up the calorific values of the individual gases. This method, however, can't not be applied to liquid fuels which cannot be readily isolated or identified. For these fuels,a calculation can be made of the theoretical value based on the heat released of the carbon, hydrogen and Sulphur in the fuel.

In practice C.V are always determined experimentally in a "bomb" calorimeter. Since all the moisture liberated during combustion is condensed, the instrument measures a gross calorific value. This is the normal C.V published by the fuel suppliers. The net C.V of the fuel is the gross figure minus the latent heat content of the total moisture in the products of combustion.

2.8.5 Flash Point:

In may countries there is a legal minimum of 150 F^{O} (66 C^{o}) imposed on the flash point of all fuel oils and the same figure is generally applied to commercial bunker fuels. This in the order to provide a sufficient margin of safety from fire risk during storage, handling and transportation. The flash point is an indication of the presence of a certain proportion ignitable vapour in specified set of circumstances.

2.9 Petroleum coke:

Spong coke is a by – product from oil refineries. In petroleum refineries, the useful products, like gasoline, jet fuel, diesel fuel, motor fuel and waxes are separated from crucle petroleum, leaving a heavy tar-like residue. More Products can be obtained by processing it at high temperatures and pressure, to crack large molecules into smaller molecules. It Leaves behind a hard, coal – like substance called petroleum cocke, it consists mostly of carbon, with smaller a mount of hydrocarbons, Sulphur and trace amount of metals.

Petroleum coke is a black solid material, can be categorized generally as either green or calcined coke.

The initial products of the coking process, green coke, is used as a solid fuel, further processing result in calcined coke which is used in the manufacturing of electrodes, in melting application for graphite electrode production, or for minor application such as carbonization of steel which in turn, resembles coke, but contains to many impurities to be useful in metallurgical applications.

Petroleum coke is composed mainly of carbon, thus it also contains high level of Sulphur and metals, such as vanadium and nickel (table) below shows the chemical analysis of petrocoke.

Table (2.1) Analysis of the Sudanese Petrocoke:

Items	**Units**	**Petroleum**
Total moisture	%	5.3
Moisture on air dry basis	%	0.32
Ash content on as received bases	%	4.36
Volatile content on dry and ash-free basis	%	12.21
Carbon content on received bases	%	83.36
Hydrogen content on as received bases	%	3.62
Nitrogen content on as received bases	%	1.58
Total Sulphur	%	0.30
Oxygen content on as received bases	%	1.17
Gross heat value on as received bases	MJ/Kg	32.12
N_{net} heat value on as received bases	μ g/g	62
Flourin on as received bases	%	0.004
Nickel on as received bases	μ g/g	285
Vanadium on as received bases	μ g/g	133

*Analysis done Hyundai University in Southern Korea Polytechnic [58].

Petrocoke is generally significantly cheaper than furnace oil or coal. It is considered as are energy sources of power generation, cement production, the Iron and Steel Production, and also at brick kiln sectors.

2.9.1Petrocoke Production and Availability:

Petrocoke production of the petrocoke grew by 50% from 1987 to 1998. It reached 5 Mt in 1999 and expected to reach 100 Mt by 2010. The USA is the world's largest producer,(Producing three-quarters of the world supplies).

The daily production of petrocoke from Khartoum Refinery between 800 ton to 1000 tons per day till now. It was used by Sudan cement factories and National Electricity Corporation (Garry (4)) Power Station. National Electricity Corporation sign a contract with Khartoum Refinery to supply Garry (4) Power Station by 300,000 ton per year with a fixed price 50 US $ per ton.

2.10 Vertical Shaft Brick Kiln (VSBK)

2.10.1 Previous studies:

- ESMAP-Energy Sector Management Assistance Program- Vertical Shaft Bricks Kilns Development – 2000. Experimental work had been done in VSBK as follows:
  - Coal of a size 50-100 mm was weighed and spread evenly between bricks layers as an external fuel
  - Agricultural, and industrial wastes such as saw-dust, boiler-wastes having high heating values of a size 2mm had been mixed evenly with a clay body in a dry form.
  - This results in a reduction of coal consumption and energy efficient.
- Sameer Maithel – VSBK- Technology, Vietnam- August -2007.
  - Experimental work on VSBK was carried out using coal as an external fuel. A weighed quantity of coal of a size 50 -100 mm is spread evenly between bricks layers.
  - Industrial wastes of a size 2mm was mixed evenly with the clay body in a dry form as an internal fuel.
  - The experimental work results in a low consumption of coal with a high energy efficient as compared with other types of kilns.
  - This Study dealt with the case of the environmental benefits.
- IEE International Environmental Examination VSBK- INDIA - 2003.

- The following consideration had been applied during VSBK operation excrementally to reduce air pollutions
- VSBK is equipped with a laid cover on the shaft top
- VSBK is equipped with a chimney.

❖ Hassan Mohamed Widatal, adaptability of sponge coke usage in Gerry (4) steam Power station, in place of heavy fuel oil – 2012.

❖ In this Study:
- Sudanese sponge coke is petroleum by product of Khartoum refinery.
- Petro coke is used as fuel in Gerry (4) Power station. It has a higher calorific value (35000 kj/kg) more than coal C.V = (27000 kj/kg).
- Petro coke is more economics as compared with fuel oil by one third.

2.10.2 Previous studies for liquid fuel:

❖ Mohamed. A. Mergani, Utilization of Return oil in blend with furnace as fuel.
- Amixture of 30% cleaned filtered return oil with 70% of furnace oil had been achieved.
- It had better characteristic values such as viscosity, C.V, pour point. Flash point…etc., and with a reasonable heating value and energy cost reduction.

2.11 Sudanese standard for common burnt Building brick:

For quality control, the flowing requirements are deemed necessary:

Shape of bricks must be more-on less regular, and homogenous upon breakage,

Dimension 25×12×7 cm, or 23×11×6 cm

Water Absorption not exceeded 35%

Crushing Strength not exceeded 25 kg/cm2.

2.12 Environmental Impact Assessment

- Brick kiln are almost classified as one of the most source of pollutant sectors in the world [59][60]. usually black carbon smokes are emitted and that due to the old traditional technological used and with an adequate supply of air during combustion process.
- Blower are used and added to zigzag kiln type (artificial draft)
- to insure enough air supply to the kiln. The combustion process Improves artificialdraft to created. In VSBK, air flow up ward through natural convection. scrubbers are used to remove the fly ashes and (So_4) in zigzag kilns. In scrubber, flue gas is drawn into underground water visitor to clean solid suspended particulate matter (S.P.M) before being released into the atmosphere through the chimney. Scribing water has to be changed regularly to insure the system works properly. However, brick field owners often don't care as it requires additional workforce unless otherwise monitored by the Government agency.
- For coal based hot – main kiln and VSBK, the flue hot gases are passed through the new stacked green bricks for Preheating. In this case hard particles clean up from the flue gas since it is obstructed into the stacks of the green bricks.
- Moreover, VSBK asmentioned, it requires less fuel per brick, so automatically emits less pollution, Theoretically, there should not be much black smokes from (VSBK) but sometimes happens and that due to unburnt combustion.

- The major designated air pollutant emitted during brick firing Process are oxides of carbon (CO) nitrogen(NO) Sulphur (So)
- Water vapor, suspended particulate matter (S.P.M) Fly ashes ,…etc.
- Carbon dioxide (CO_2), which is not pollutant in the traditional sense, since it is essential to support photosynthesis for all plant life on earth, however carbon dioxide is a greenhouse gas considered to be a contributor to global warning. It's the most abundant an thorogenic (human caused) greenhouse gas in the earth's atmosphere. [58]
- The removal of the suspended particulate matter (S.P.M) the fly ashes from the flue gas is accomplished with electrostatic precipitator or fabric fitters. [58]
- Sulphur dioxide (SO_2) is a pollutant emitted when fuel is containing Sulphur dioxide is one a group of high reactive gases known as oxides of Sulphur. It is a toxic gas with a pungent, irritating smell.
- Nitrogen oxides (NO_2) can also be produced naturally by lightning strikes, and then what we call acid rain is caused by emission of Sulphur dioxides. There are Three technologies known as (De – No_2) Process available for reducing the emission of (NO_2) emission is a Low – No_x, and can achieve up to 50% reduction of No_xemission. [58]
- United states and number of countries, air pollution dispersion modeling [58] studies are required to determine the flue gas stack height needed to comply with the local air pollution regulations. The united states also requires the high of the flue gas stack to comply with what is known as "Good Engineering Practice GEP " stack height [58].

2.12.1 Chimneys: [Stack gas path]

- Effective stack height Equals Actual stack height Plus Velocity and buoyancy factor.
- Chimney Effective height (2.5x) = Physical stack height (x) + height due to velocity and buoyancy of hot smoke (1.5x).

2.12.2 Influence of the emitted carbon price on brick sector:

- Carbon price or the price of each ton of carbon pollution had been implemented by many countries (Australian Government 2011).
- The Australian brick sector put a price for carbon pollution emissions. due to that, carbon price was found to be the most cost-efficient way to cut carbon pollution, since it encourages companies to innovate and invest in new efficient technology with friendly environment.

Chapter III

Influence of Industrial and Agricultural Additives to Clay Mitigates Fuel Consumption on Red Bricks Manufacturing

3.1 Introduction:

The aim of this experimental work is to manufacture modeled green bricks of different cheap solid Alternatives Fuel (Industrial and Agricultural), Such as, saw-dusty animal dung (Zibala), Petrocoke and clay according to these additives availability and a high heating value gained. The samples have to be dried and fired through a suitable predetermined firing techniques, that usually had been applied for common burnt bricks, Experimental measurement has to be performed on these samples at Brick and Road Research Institute (BRRI) of University of Khartoum (U of K) Laboratory, in order to evaluate and compare between these samples of bricks properties such as, Loss-on- ignition, Density, and Crushing Strength. The research has to provide a comparison about fuel consumption between these different samples.

3.1.1 Experimental Work:

Intensive experimental and Laboratory work had been carried out on these different samples, in order to select the best one that having better characteristics, properties and with the lowest specific fuel con sum piton.

3.1.2 Scope of work:

Modeled Brick Making Machine and Brick Manufacturing:

The scope of this experimental Investigation extended to include the flowing:

1. Brick manufacturing process.
2. Brick drying process.
3. Brick firing process.

3.2 Brick manufacturing process

3.2.1 Clay mixing

- The basic raw material, which is the Blue Nile clay deposits is mixed, then water being added to yield a homogeneous mix to achieve about (17) seventeen degree of plasticity index to suite the vertical shaft Brick kiln (VSBK) operation condition.
- The corresponding additives petrocoke, zibala, and saw-dust were about ten percent (10%) by weight for each sample added to the raw material, water being added to these samples and left for a period a week or more for fermentation.

Plate (3.1) Saw-dust

Plate (3.2) Zibala

Plate (3.3) Petrocoke

Table (3.1): Additive sample types

Sample types	Additives	Identification
clay	Nill Additive	Series ……….. 1
clay +zibala	Zibala 10% by weight	Series ……….. 2
clay + petrocoke	Pet rock 10 % byweight	Series …..…… 3
clay +saw-dust	Saw-dust10 % by weight	Series.……… 4

3.2.2 Modeled brick Manufacturing:

Modeling Brick making machine was used to manufacture twenty (20)pieces brick unit for each samples.

Plate (3.4): Modeling Brick Making M/c

3.2.3 Brick drying process:

Green bricks had been dried smoothly and regularly through predetermined program. [49]

Table (3.2): Manufactured and dried bricks

Sample type	Additive	plastically index	Pieces of bricks produced	Wet brick WeightW_W (gr)	Dried brick weight w_d (gr)	Moisture Content m.c %
clay series ……….1	Nil	19	20	201.3	168.4	16.3
clay +zibala series …. 2	10%	19	20	183.13	140.95	23
clay + petrocoke series.3	10%	19	20	170	138	18.8
clay +saw – dust series …..4	10%	19	20	175	111.8	36

3.2.4 Brick firing process

Dried green bricks were subjected to predetermined firing temperature program to eliminate variation in brick quality implanted by burning parameters.e.g. Firingrate, max. temp., soaking time at the max temp and cooling rate [31]. Firing of brick samples and result were shown in Table (3.3) 5 Bricks average.

Plate (3.5) Furnace

Table (3.3): Brick firing result

Sample type	Additive %	Temp range (C^O)	dried brick (W_d)	Fired brick weigh (W_f)
clay Series …………… 1				
	Nil	750	184	164.2
		800	165	148
		850	182	160
		900	176	154.5
		950	173.5	152.7
		1000	172.4	152
Clay + zibal				140
series……… 2	10%	750	160	132.9
		800	158	140
		850	166	126
		900	152	145
		950	173	128
		1000	154	
clay + petrocoke series				
…… 3	10%	750	162	140
		800	178.6	151
		850	164.3	138.3
		900	174.8	146.2
		950	158	130.8
		1000	173	143.9
clay +saw- dust				
Series ………….. 4	10%	750	128.04	105.18
		800	150.4	122.5
		850	141.3	115
		900	155.8	127
		950	131	106
		1000	156	125

Plate (3.6): Samples of Different Additives (Petro-coke, Zibala, Saw-dust & clay)

3.3 Firing of bricks and test results:

To check the quality of the produce red bricks and hence compare the effect of the additives, the flowing parameters have been determined experimentally in the laboratory work as follows:

3.3.1 Loss-on – ignitions:

When dry brick heated to the maximum firing temperature, it losses weight.

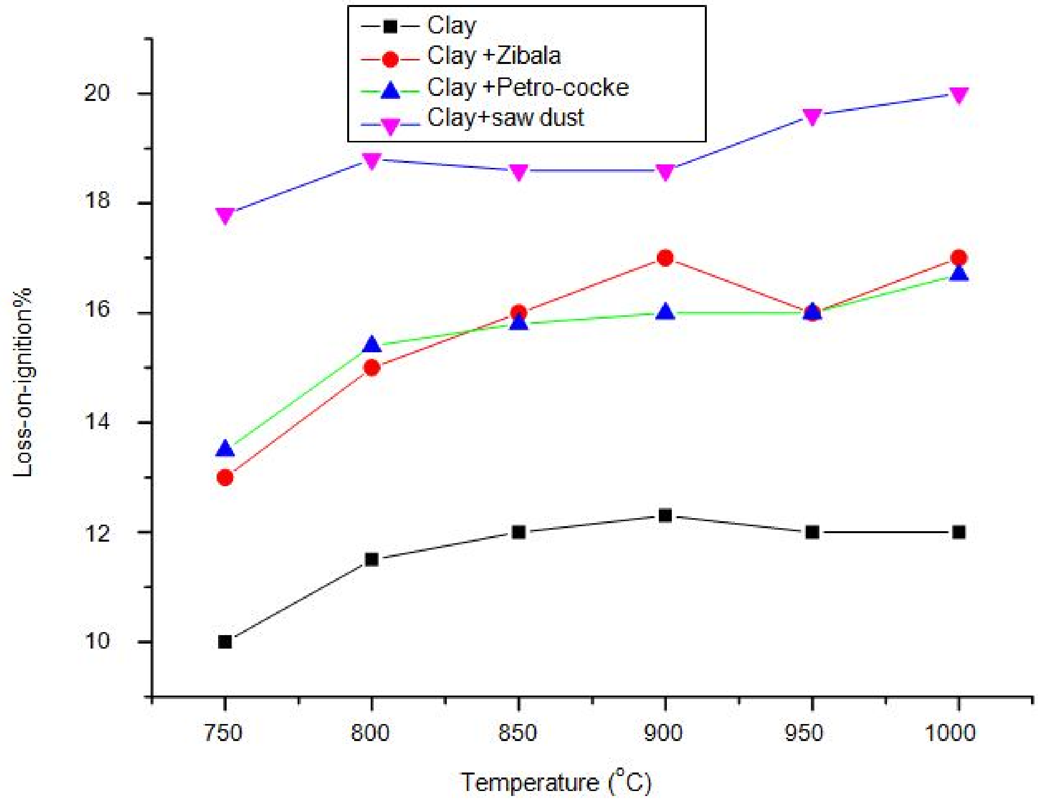
This loss is termed as loss – on – ignition. this loss – on ignition of clay varies in quantities for different types clay content s (upon percentage of additive,carbonate, carbonation material and combined water

$$\text{loss} - \text{ on ignition}$$

$$= \frac{\text{weight of dry brick } (W_d) - \text{ Weight of Fred brick average } (W_F)}{\text{dried brick}(W_d)}$$

Table (3.4): Loss on ignition

Sample type	Additives	Firing temp rang (C^o)	Drybrick average weight (W_D)	Fired brick average weight (W_F)	Loss-on Ignition %
clay series ………. 1	Nile	750	184 (gr)	164.2(gr)	10
		800 850 900 950 1000	165 182 176.5 176.1 172.2	148 160 154.5 152.7 152	11.5 12 12.3 12 12
clay +zibala Series ……….. 2	10%	750 800 850 900 950 1000	146 158 166 152 173 154	140 132.9 140 126 145 128	13 15 16 17 16 17
Clay + petro- cock Series …………… 3	10%	750 800 850 900 950 1000	162 178.6 146.3 173.8 158 173	140 151 138.3 146.4 130 143.9	13.5 15.4 15.8 16 16 16.7
Clay + saw – dust Series ………….. 4	10%	750 800 850 900 950 1000	141.4 150 141.3 155.8 131 15.6	116.2 122.5 115 127 106 125	17.8 18.8 18.6 18.6 19.6 20



Graph (3.1): Loss-on-Ignition

3.3.2 Crushing Strength:

Crushing strength testing machine was used for this test according to the formula.

$$\text{Crushing strength} = \frac{\text{max load at failure (KN)}}{\text{Average area of bed face}(mm^2)} = KN/mm^2$$

Plate(3.7) (Beding and Curing of Samples)

Plate (3.8) Crushing Machine

3.3.3Density:

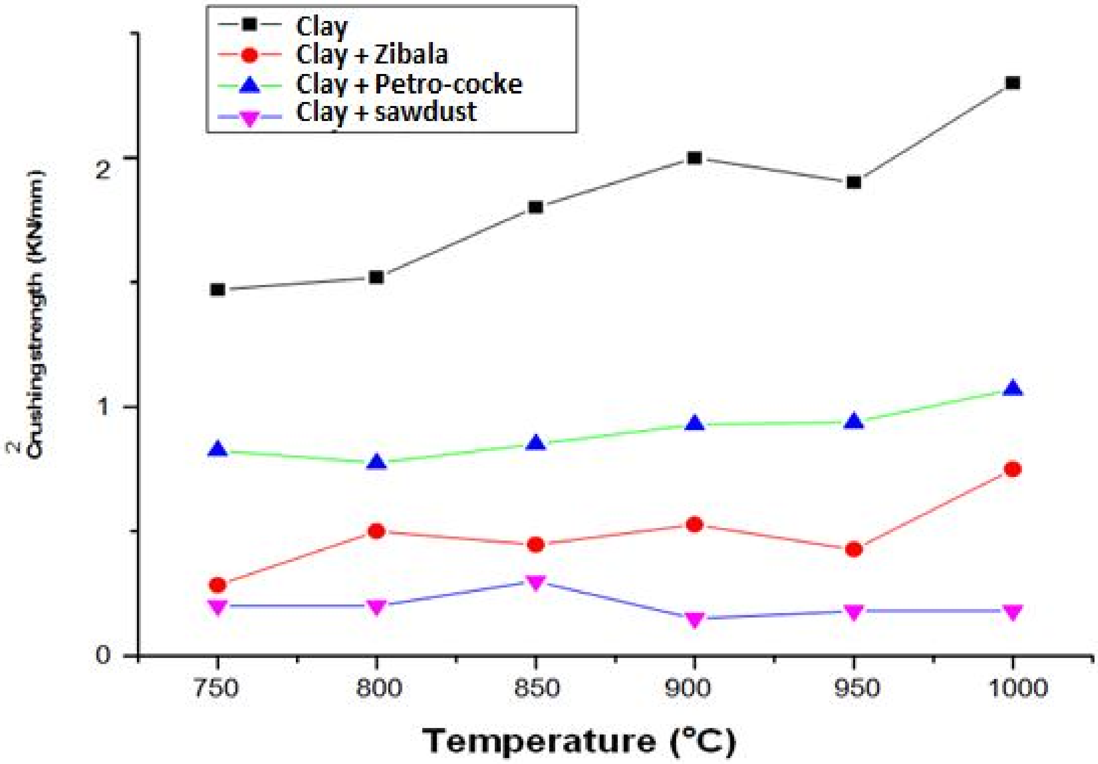
Density test result were as shown at table (3.6)

3.3.4 Visual Test:

Samples of deferent types of fired brick at temp. range of 850 ,900 ad 950 C^{O}.has been selected. Visual test had been conducted out upon unit brick breakage in order to see,to how much degree of quality had been gained. Tests results were as shown in table (3.7).

Table (3.5): Crushing strength Tests Result (5 Bricks average)

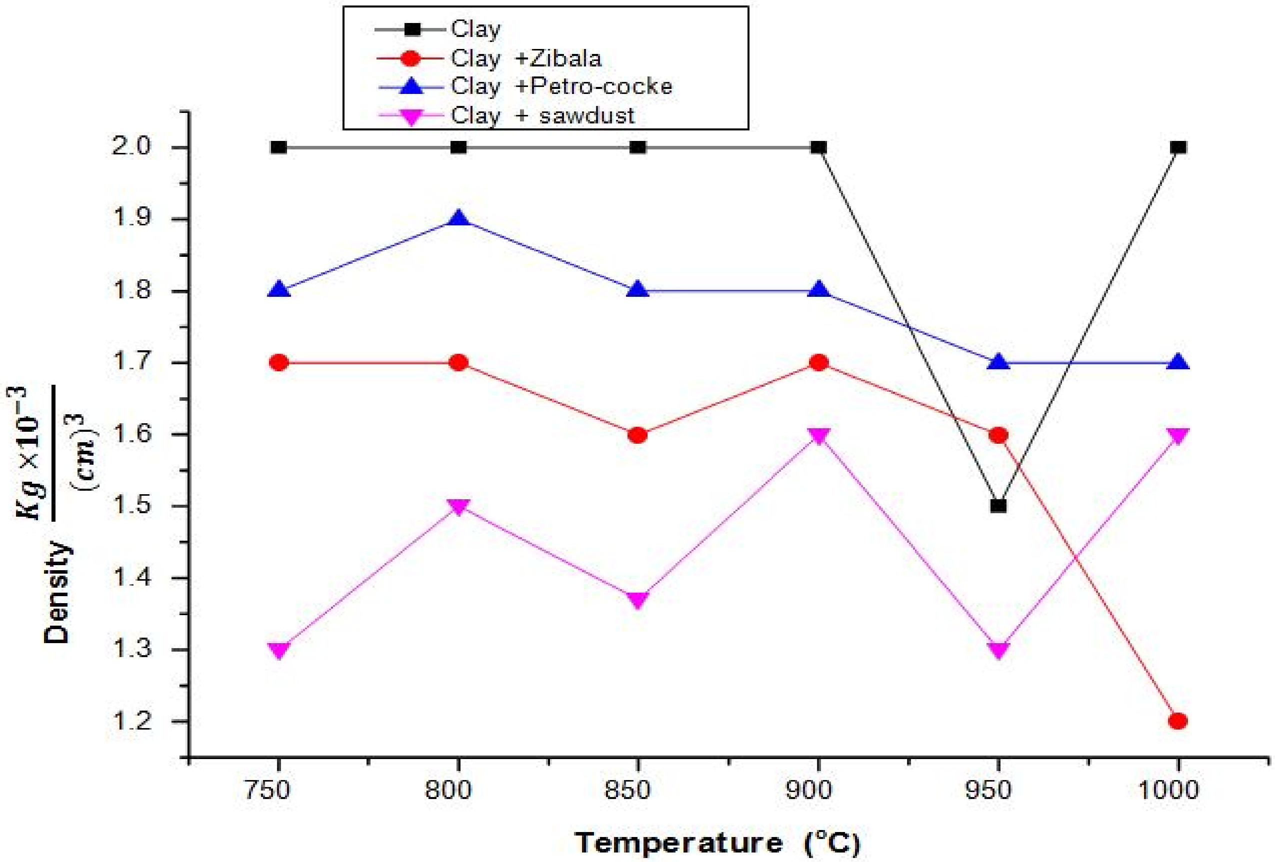
Sample type	Additive	Temp range (c^{o})	Area bed face $(mm)^2$	Max load at failure (KN)	Crushing strength (KN/mm^2)
clay	Nil	750 800 850 900 950 1000	39.13 35.7 38.2 35.3 38.5 37.2	57.5 56.4 71.6 70.6 76.4 86.3	1.469 1.52 1.8 2 1.9 2.3
clay + zibala	10%	750 800 850 900 950 1000	41.1 38.9 42 37.8 42.8 37.7	11.9 19.5 18.5 20 18.3 28.5	0.284 0.5 0.447 0.527 0.427 0.755
clay + petrocoke	10%	750 800 850 900 950 1000	37.5 39 37.5 39.4 36.4 38.3	31 38 32 36.96 32.9 41.8	0.826 0.774 0.85 0.93 0.938 1.07
clay + Saw-dust	10%	750 800 850 900 950 1000	40.6 38.2 41.5 39.2 40 39	8.2 7 12.9 5.7 7.2 6.9	0.201 0.2 0.3 0.15 0.18 0.18



Graph (3.2): Crushing strength

Table (3.6): Density test Results (5 bricks average)

Sample type	Additive	Temp range (c°)	Dry weight w_d (gr)	Volume V (mm^3)	Density $\frac{(kg \times 10^{-3})}{(cm)^3}$
clay	Nill	750 800 850 900 950 1000	168.38 151.26 160.5 152.3 153.4 150	78.2 71.4 76.5 70 77	2.0 2.0 2.0 2.0 1.5 2.0
Clay + zibala	10%	750 800 850 900 950 1000	140 133 142 128 142 90.12	82.25 77.8 84 74 85.2 75	1.7 1.7 1.6 1.7 1.6 1.2
clay + petrocoke	10%	750 800 850 900 950 1000	138 152.9 138 146.9 129.4 140	75 78 75 78.8 72.4 76.6	1.8 1.9 1.8 1.8 1.7 1.7
clay + Saw-dust	10%	750 800 850 900 950 1000	111.8 116.3 116.8 126.26 110.3 127.8	81.21 76.5 83.34 78.4 80 78	1.3 1.5 1.37 1.6 1.3 1.6



Graph (3.3): Density

Table (3.7): Fired brick and visual test Results

Sample type	**Firing temp Range (c°)**	**Brick Quality**		
		Fired	**Well fired**	**Over fired**
clay +10% petrocoke	850 900 950		850 C^O	
clay +zibala	850 900 950		900 C^O	
clay +10% saw-dust	850 900 950		900 C^O	

3.4Firing of Bricks and test Results:

3.4.1 Analysis and Discussion:

As mentioned, dried green bricks were subjected to predetermined firing temperature program, preheating full firing or verification, soaking at maximum temperature, and then cooling gradually. Brick firing process was programmed at ,750C^o, 800 C^o,850 C^o,950C^o and up to 1000 C^o (satisfied firing temp).

Test result and analysis had been carried out deeply for all those different additive samples considering these parameters

1. Loss-on ignition.
2. Density.
3. crushing strength.

and visual test for comparison as flows:

1. Loss- on – ignition:

The reported data table (3.4) showed that loss-on-ignition is increased with respect to the temperature rising. The highest present of loss had been found at saw-dust sample, flowed by zibala, petrocoke and then finally clay sample. carbonates, carbonaceous low material and organic additives were ignited during brick firing process.

The additive upon fermentation, improve the plasticity of the bricks material and act as reinforcing fibers, thus reducing really concentrated cracks leading, even to the break age of the green brick unit, further and up on firing, these fibers ignite thus assisting in even firing of the brick and minimizing the development of high temperature gradients within the brick unit: a phenomenon which may otherwise lead to firing cracks, when these fibers burnt out they leave cavities within the brick: the result being a reeducation of the unit weight and an important of the thermal characteristic, cavities on the top and bottom surfaces of the brick increase the bond when brick are built.

3.4.2 Density:

The reported data showed that the highest density was found at clay, petrocoke, zibala and finally the saw-dust sample. The data of the various samples had been approximated graphically by straight-line density VS temperature range reproduce in Graph (3.3) for comparison.

3.4.3 Crushing strength:

The reported data table (3.5) showed the highest crushing strength that brick will stand before failure was found at petrocoke sample, flowed zibala, and then saw-dust the data of the various types of additives had been plotted graphically giving approximate straight line crushing strength VS temp ranges. Reproduced in Graph (3.2) for comparison.

3.4.4 Visual Test:

Normally and as experienced brick found to be fired at firing temperature range of about 850 C^o, 900C^o and 950C^o, the reported data table [3.3] and the visual test table [3.7] showed that, petrocoke sample type was found being the best one, fired at the lowest temperature range at 850 C^o, and with the lowest fuel consumption.

3.4.5 Specific Fuel Consumption and Fuel Consumed:

Considering the reported data test results, loss-on ignition, density, crushing strength and visual tests, bricks found to be of good quality and well fired at a range of temperature of 850 C$^\circ$, 900C^o, and 950C^o, for the different brick samples, specific fuel consumption and fuel consumed had been calculated for a comparison and the complete calculated Tableas shown in Appendix (A):

3.4.5.1 Fuel Consumption

The same procedure was followed to calculate (a) specific fuel consumption (b) fuel consumed for the other rest different samples, zibala, clay, and saw- dust, at temp – range of 850 C˚, 900 C˚,950 C˚ see appendix(A):

Table (3.8): Different alternative Fuels

Different alternative Fuels	**Calorific Value (KJ/Kg)**
Rice husk	2800 – 2800
Rice husk ash (white)	500
Rice hush ash (black)	1500 – 2000
Coconut shells	4800
Groundnut shells	4800 - 5100
Coconut pith	3000
Bagasse	4500
Charcoal	5000 – 7000
Sewage sludge	2300 - 5400
Sawdust	3800 - 4300
Coal mining waste	800 - 1000
Fly ash	500 - 2700
Paper industry sludge	1600 - 4500
Textile industry waste	1500 – 2500
Coal (used in Dhaka)	3500 – 7000
Boiler ash	700 – 1500
Steel re-rolling waste	2500 - 3500

Brick cost of firing as compared with the different waste additives

Results based on 100,000 brick units:

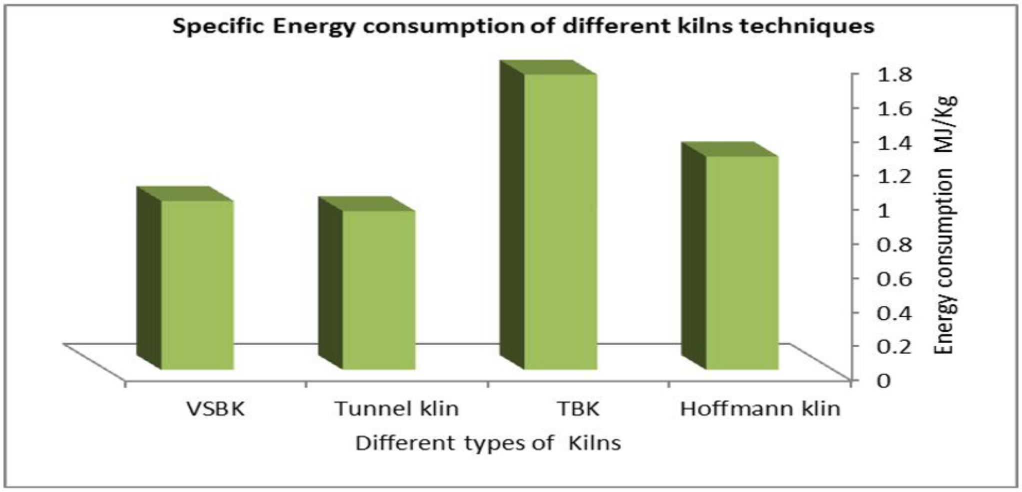


Figure (3.1): Specific Energy Consumption of Different Kilns Techniques

Table (3.9): Equivalent Fuel Consumption

Sample type	Calorific value (C.V) Kj/Kg	Total fuel Consumption (TON)	Specific fuel Consumption	Total fuel consumption equivalent to petrocoke
Petrocoke	35260	6	835.4	6
Zibala	17500	13.3	891	6.6
Saw – Dust	15910	14.4	848	6.5
Clay	-	-	955	7.05

3.5 Result:

- Petrocoke sample was found to be the best one, it showed the lowest fuel consumption and specific fuel consumption.
- zibala and saw-dust found to be huge and bulky, so additional transportation cost is needed as well as, this waste materials should have to be reduced to a form of small cubs for easier operations.
- clay sample found to be of the highest firing cost since it did not convey any type of additives.

Burnt Brick Clay Cost of Firing As Compared Between Petrocoke and Furnace Oil Fuel:

A comparison between using petrocoke and furnace oil for firing building brick:

Experimental work and test result as shown in Appendixes (A) showed that petrocoke specific fuel consumption at 850 C° the satisfied firing temp. was found 835.4 kj/kg of fired brick.

For firing 1000 brick units of weight 2.204 (kg).

Total heat needed = specific fuel consumption total weight brick

= 835.4 * 1000 * 2.204

= 1.841.221.6 kj

Quantity of petrocoke = $\frac{total\ kj}{\text{petro coke calorific value (cv)}} = \frac{1.841.221.6}{35260 * 1000} =$ 0.0502(ton)

petrocoke price /ton = 2000 SDG

total cost for firing 1000 = 2000 * 0.0502 = 104.4 SDG

using furnace oil for firing 1000-unit brick of weight (2.204 kg)

total heat needed for firing 1000 unit bricks = 1.841.221.6 KJ

total ton of furnace oil = $\frac{\text{total heat needed}}{\text{furnace oil (cv)}} = \frac{1.841.221.6}{39800 \ * 1000}$ = 0.046 ton

Furnace of oil price/ton = 4000 SDG

Total cost for firing 1000 unit brick = 0.046 * 4000 = 184 SDG

Cost reduction = $\frac{484 - 104.5 * 1000}{184}$ = 40%.

- Using petrocoke for firing building brick is more better and reduce the cost to 40 %.

3.6 Conclusion:

- Cheap Alternative fuel were used as internal and external fuel to produce bricks. Samples of different types of the additives, petrocoke, animal dung (zibala, saw-dust, and clay, ten percent by weight had been mixed with unit green brick during molding.
- The study perform the sample drying and the effect of a predetermined temperature range at 750, 800, 850, 900C^{o} up to 1000 C^{O}, the satisfied firing temperature. Comparison between brick properties yield that petrocoke sample is the best of all that have a good properties, and low fuel consumption followed by zibala and then saw-dust. This research provide a frame work for the exploration of energy produced from wastes which can be implemented in various industrial applications.

Chapter IV
Discussion & Analysis of The Result

4.1 Introduction:

Extensive laboratory work had been conducted at Brick and Road Research Institute (BRRI) of the University of Khartoum U of K in different four manufactured green brick samples each had been mixed with ten percent by weight of saw-dust , animal dung (Zibala) , petrocoke, and clay.

Test results, data, experimental measurement, graph had been recorded. Deep wide discussion and analysis had been conducted on results to attain more scientific gains.

Discussion of the experimental investigation analysis extended to include the following:

4.2 Raw material, alternative additives mixing and green brick manufacturing:

Basic raw material, the clay was mixed with a weighed ten percent of the alternative additives, saw-dust, animal dung (Zibala) and petrocoke on dry condition for proper mixing.

This mixed was wetted with water for a period of a week or more for fermentation.

The additives upon fermentation is improving the plasticity of the brick material which can be controlled to a mount of 17 plasticity index, in order to suit Vertical Shaft Brick Kiln (VSBK) operation condition.

More over these thin long fibers will act as a reinforcing fiber, thus reducing really concerted cracks leading, even to the breakage of the green brick unit.

4.3 Samples of bricks and drying process:

Gradually, slowly and even drying process through a predetermined controlled program had been applied.

This will prevent a sudden uneven drying of bricks shrinkage to a wide range, and hence stop green brick cracks.

4.4 Samples of dried green brick and firing process:

Experimental predetermined firing program was applied for firing the four dried green bricks samples at a temperature ranges of 750 C^o,800 C^o, 850 C^o, 900 C^o, 950 C^o and 100 $C^{o.}$ This Controlled firing program had been usually applied during brick firing process, since it conveyed all the brick firing zones, water smoking, preheating, full firing and vertification, soaking, and then cooling. During these firing zones process, the bricks were subjected to a very controlled successive firing system, that normally lead to a good brick quality with a high crushing strength.

During full firing zone, or vertification temperature, the strength of the bricks is developed.

a) First by centering of particles in close contact with one another.
b) As the temperature increases then liquid of fluxes , soda , potash , magnesia , lime and ferrous oxides, coated these solid particles , and then after cooling remain as a glass and binds these particles together achieving the bricks hardness.

4.5 Effect of additives on red brick properties:

Experimental measurement, had been carried out on the four different samples of red bricks for brick properties, loss-on-ignition, crushing strength, and density. Reported experimented data of loss-on-ignition table (3.4) and graph (3.1) showed that, sample additives of the saw-dust had lost a high percent as the temperature increases, followed by zibala, petrocoke, and then clay. Crushing strength table (3.5) graph (3.2) showed that clay brick sample had got the highest crushing strength followed by petrocoke zibala and then saw-dust. Density table (3.6) graph (3.3) showed that clay brick samples showed the highest density followed by petrocoke zibala and finally the saw-dust.

4.6 sample of bricks and fuel consumption:

Considering the test data results, loss-on-ignition, crushing strength, and visual test, the four samples of bricks were found beings well fired and with a good quality at a firing temperature range of 850 C^o, 900 C^o, and 950 C^o. Specific fuel consumption, and fuel consumed table (3.9) had been calculated. The results confirm that petrocoke sample is the best of alls and had got the lowest fuel consumption, and that due to the highest calorific value (35260 kj/kg) followed by Zibala with the calorific value (17500 kj/kg), the saw-dust with the least calorific value (15910 kj/kg) and finally the clay without additives had got the highest fuel consumption. There for it can be concluded that, although clay sample had got the highest crushing strength but petrocoke is considered the best of all since it had got the lowest fuel consumption. To fire bricks with petrocoke is more preferred and economical than to fire the same quantity of bricks with furnace oil. The reduction of the firing cost is extended to 40%.

4.7 Conclusion:

Experimental data results, measurement of the four different brick samples of, saw-dust, petrocoke, zibala, and clay had been discussed and analyzed with deep concentration. It was found that petrocoke sample has got the lowest fuel consumption and that due to the highest calorific value gained followed by zibala, the saw-dust sample, and finally the clay sample with no additives of fuels. Although petrocoke sample has got the second crushing strength value after clay samples, but It have been considered the best one, since it has got the lowest fuel consumption. Usage of petrocoke for firing the bricks is more preferred than usage of furnace oil. Since it is cheaper, and the firing cost was reduced to 40% for the same quantity of bricks.

Chapter V

Vertical Shaft Brick Kiln (VSBK) – Design, Construction & Operation

Introduction:5.1

Range of kiln types for bricks production from ancient times till now is very large. If it is investigated more in depth, not only do the kiln type differ, but there are as many variants in each kiln type exit.

Brick kilns should have to be well designed, properly constructed, thermally insulated, energy efficient with friendly environmental impact. Worldwide standard design methods had been created and developed through successive of years depending upon condition and significant situation of a certain region of interest. Almost design aspects depending on technological, geographical, function, machine, and system to perform specified functions with the maximum economy, energy efficient with environmental benefits.

5.2 Vertical Shaft Brick Kiln (VSBK) – Design Soba:

It is very important to declare that VSBK -Soba – Sudan had been constructed by Brick and Road Research Institute (BRRI) of University of Khartoum (U of K), with Corporation of German Appropriate Technology Exchange (GATE) since 1996. Design and Construction work in this kiln had been stopped at the earlier stages of construction.

It is a good opportunity to resume design and construction work of the VSBK at Soba Site. Based on scientific background and experience, this and design should be strickly matching the significant conditions and standard. Based on the above-mentioned design parameters, this work study will expected to serve as a powerful tool for construction engineers, and supervisors to delineate the essential parameters for the construction of a VSBK.

The design constructed out doesn't claim to complete or perfect is in hands of specialist to utilize it fully by using it as a reference guide for further improvements and developments.

5.2.1 What is needed to complete under constructed VSBK -Soba:

1. **Loading plat form**: It's the upper part of VSBK, where the green bricks are stacked before loading inside the kiln.
2. **Flue ducts**: Specially designed structure at the upper most plant of the shaft, through which the flue gases passes to the chimneys.
3. **Chimney**: Two vertical ducts connected diagonally at the shaft top to be used for flue gases.
4. **Screw Jack**: A device connected to the ground, below the shaft used for unloading the fired bricks

4.1 **Screw Jack Foundation Design:**

Suitable Foundation had been designed and completed. Four Concrete bolts had been fixed to the Foundation base in order the screw jack can be rest on.

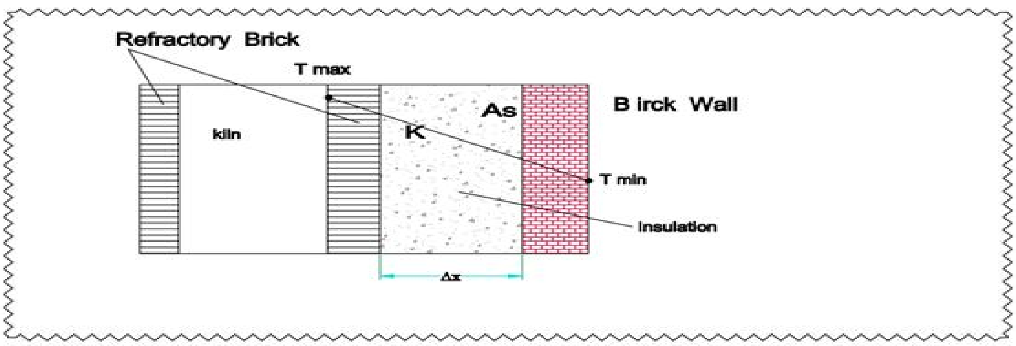
5. **Ladder**: Steel and metal structure used to help works going up and down the shaft top.
6. **Peep – hole pipe**: Fixed in the shaft outer walls. used for monitoring the fire and temp. inside the kiln.
7. **Damper**: Adjustable value connected in the chimney to control the draught and the exist flue gases from the chimney.
8. **Square bars**: Square bars are placed at the bottom of the shaft, on the top of the I-beam, it bears the total load of the bricks in the shaft.
9. **Lid Cover**: Provided at the shaft top the cover the shaft. It Prevents smoke and heat loss from the shaft top

10.**Kiln Insulation**:

Kilninsulation main objective is reduce heat transfer from inside the kiln to the outside. If the thickness of the kiln insulation is increased, and the conductivity of the insulation is decreased, heat losses from kiln will be reduced, as well as the kiln efficiency will be increased.

Kiln Insulation, as shown in Figure (5.1) and equation (5.1)

Kiln Insulation



$$\frac{q}{t} = \frac{KAs\,(Tmax-Tmin)}{\Delta x}$$

$\frac{q}{t}$ = Heat Transfer Rote

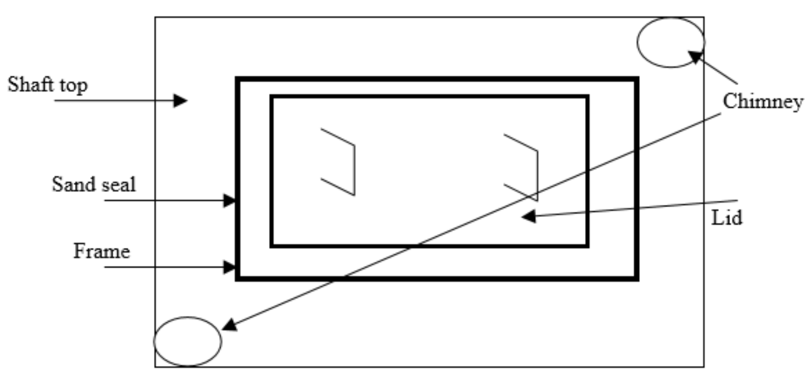
K = insulation conducttivity

Minimum Conductinty will Reduce Heat Transfer Rate

11.**Kiln Roof:** It is used as a shed and Prevent green brick during raining Periods.

Use of shaft lid

- It is recommended to use shaft lid with proper sealing arrangement at the top. This will help in reducing the concentration of pollutant in the loading platform.



Arrangement of Shaft lid

Figure (5.2) Lid Cover

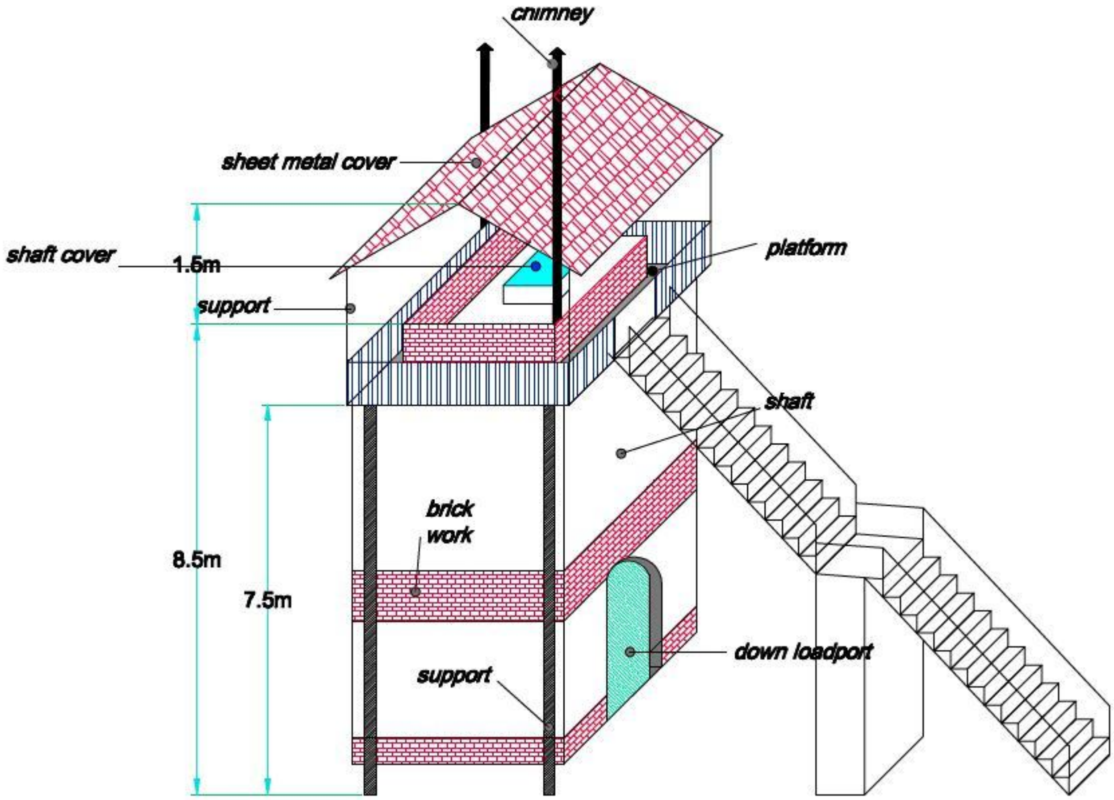
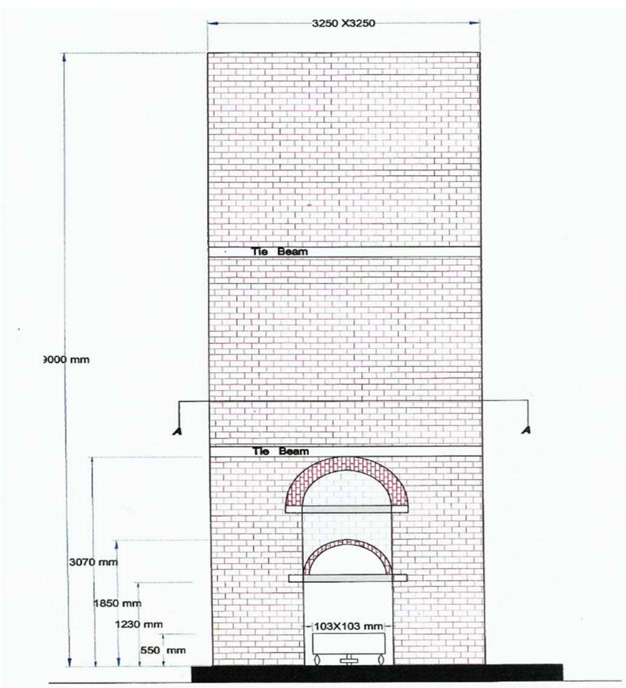


Figure (5.3) a completed constructed of VSBK – Soba



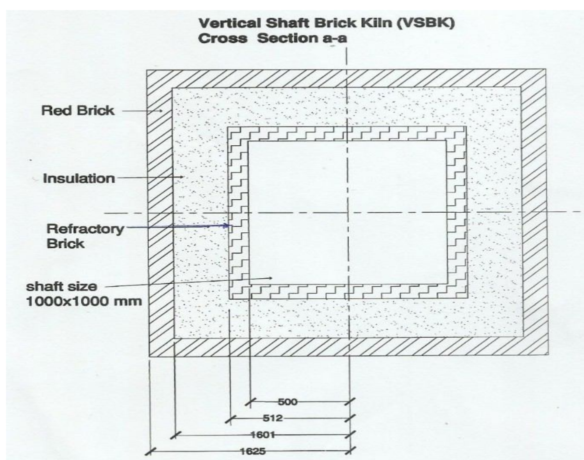


Figure (5.4) the details VSBK – Soba x- Section view

5.3 Ways of Brick Stacking & Effect of Heat Transfer:

There are 3 modes by which heat is to be transferred.

5.3.1 Conduction:

Heat transfer through material due to molecular impact which result from molecular vibration in the case of solid (Bricks).

5.3.2 Convention:

Heat transfer due to movement of the fluid during bricks firing process.

5.3.3 Combined Conduction Convention:

Heat is transferred through a series of brick stacks partly by conduction, through bricks, and partly by convections due to movement of fluid (during brick firing).

5.3.4 Heat Transfer by Radiation:

The kiln is lined with refractory bricks. This refractory bricks used as an insulating material. It has a low thermal conductivity, so its function is to restore the heat within the kiln as more as possible.

During the kiln firing process the refractory bricks absorbed heat and kept it within the kiln crown. When the kiln is loaded by a new cold stacked dried green brick, heat will be transmitted by Radiation from the kiln crown (higher temp.) to the new cold stacked bricks Quantity of Heat radiated from the kiln inner lining of refractory bricks to the new cold dried setting of green bricks.

5.4 Vertical Shaft Brick Kiln (VSBK) Stacking of Brick:

5.4.1 Type (1):

Predetermined type of brick stack with four lays of green brick, had been stacked conveying (32,32,32,32) unit of bricks of a total number of 128 pices . Details were shown below:

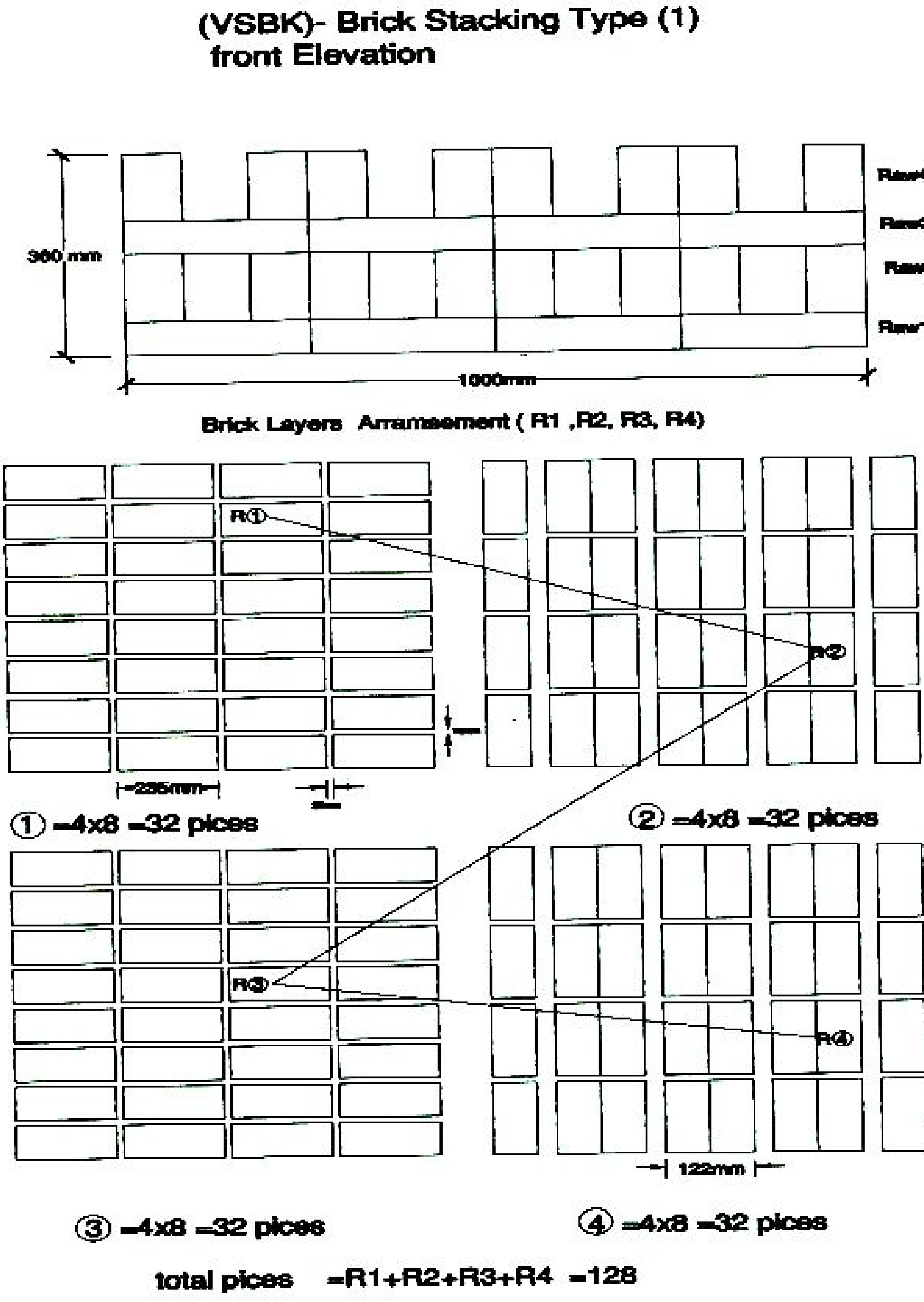


Figure (5.5) Stack Type 1

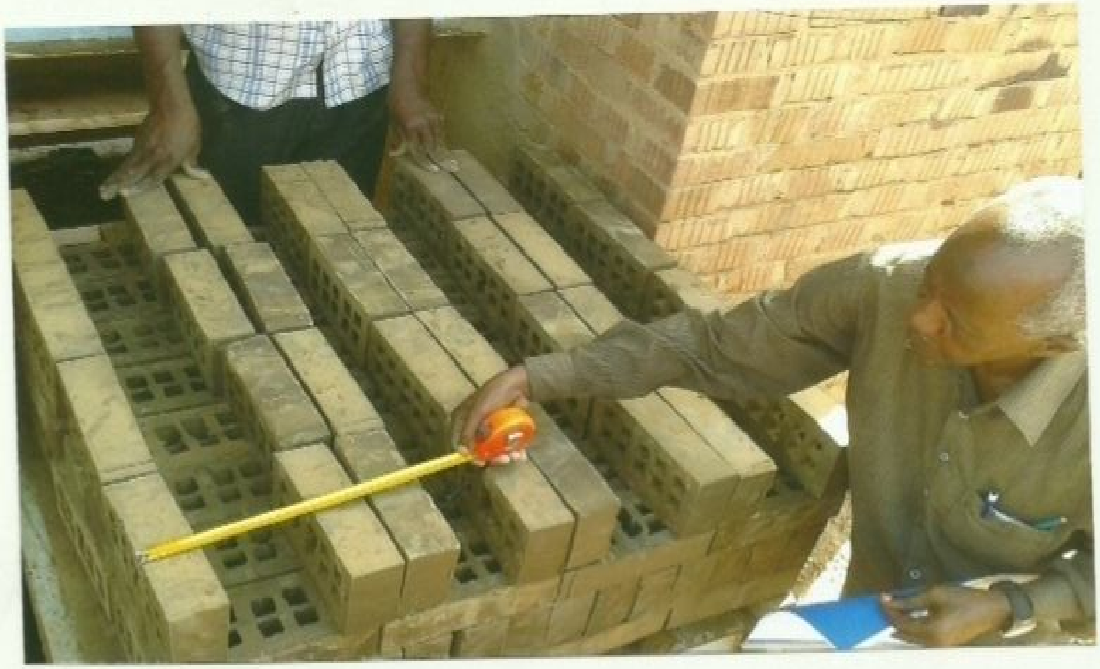


plate (3.9) Stack Type 1

5.4.2 Type (2):

This type of stacking is conveying also four raws of green bricks (32,56,32,32) units of bricks of a total number of 152 pices. Detail were as shown below:

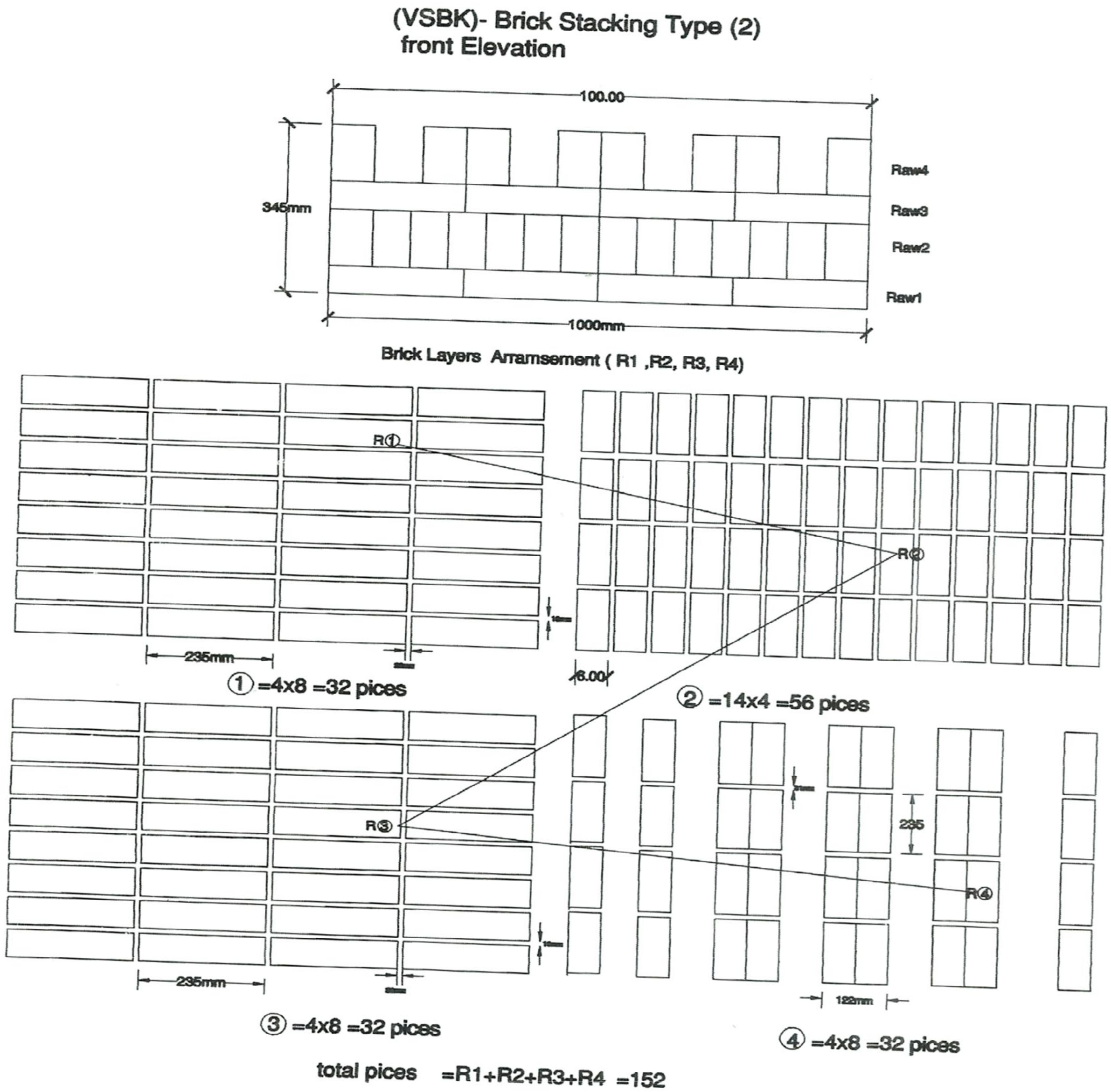


Figure (5.6) Stack Type 2

5.4.3 Firing Box:

As shown below with specified Details:

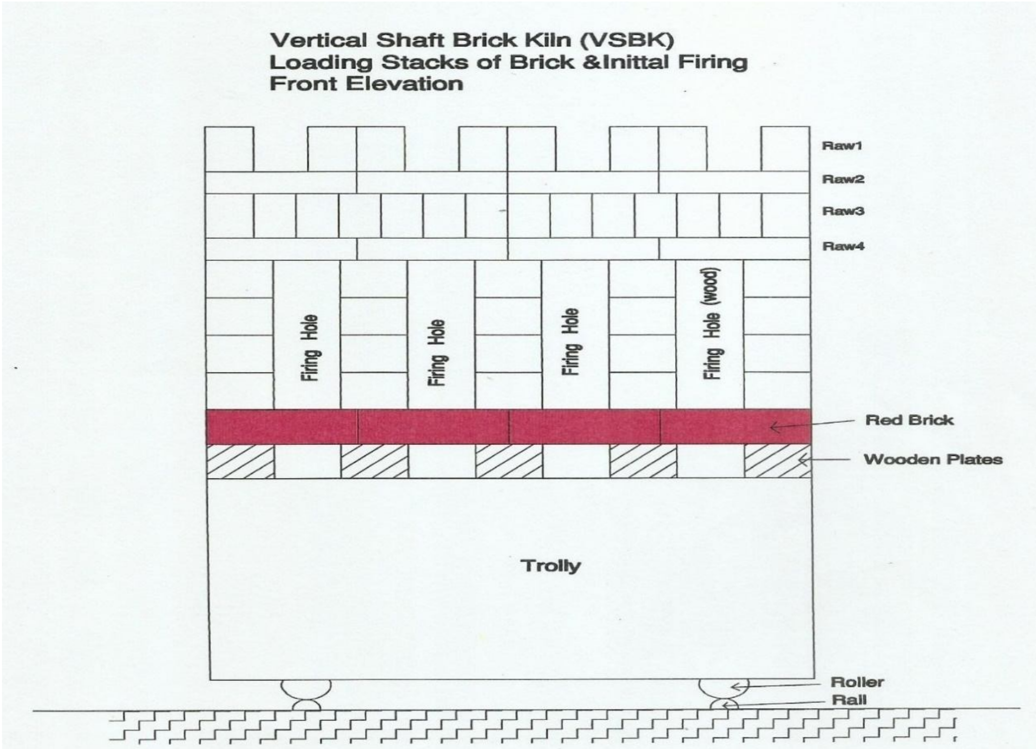


Figure (5.7) Firing Box

5.5Vertical Shaft Brick Kiln (VSBK) Operation:

5.5.1 Steps of Firing Process:

5.5.1.1 Shaft drying:

New constructed Shaft generally gets wet of water and moisture content (m.c). It can be dried naturally by opening the shaft lid cover, and chimneys values for a period between 8 to 10 days.

Forced drying also can be done with the aid of fire created at the shaft bottom , and then the heat was stacked by a fan throughout the entire shaft for drying.[38].

5.5.1.2 Firing box:

It is a Predetermined design of green bricks stacked of four layers with holes in between to convey the chips of wood that needed for the shaft initial firing.

5.5.1.3 Initial Loading:

The Shaft is loaded with dry green bricks (5% m.c) from the bottom of the shaft. The bricks were stacked in a predetermined design pattern consists of four layers, normal layers, Chula layer normal layer and them Chula layer respectively. The Chula layer is designed with a space gab for following roles:

a. To convey external fuel (petrocoke) , needed for this firing process
b. It can be used later on as a gab to insert the square bars to be used during fired bricks unloading process.

Stacking a green brick was being carried out starting just above the firing box and then continued with the same procedure till the shaft top with equally and evenly spreading of external fuel between bricks layers. as shown in figure below (Section A-A).

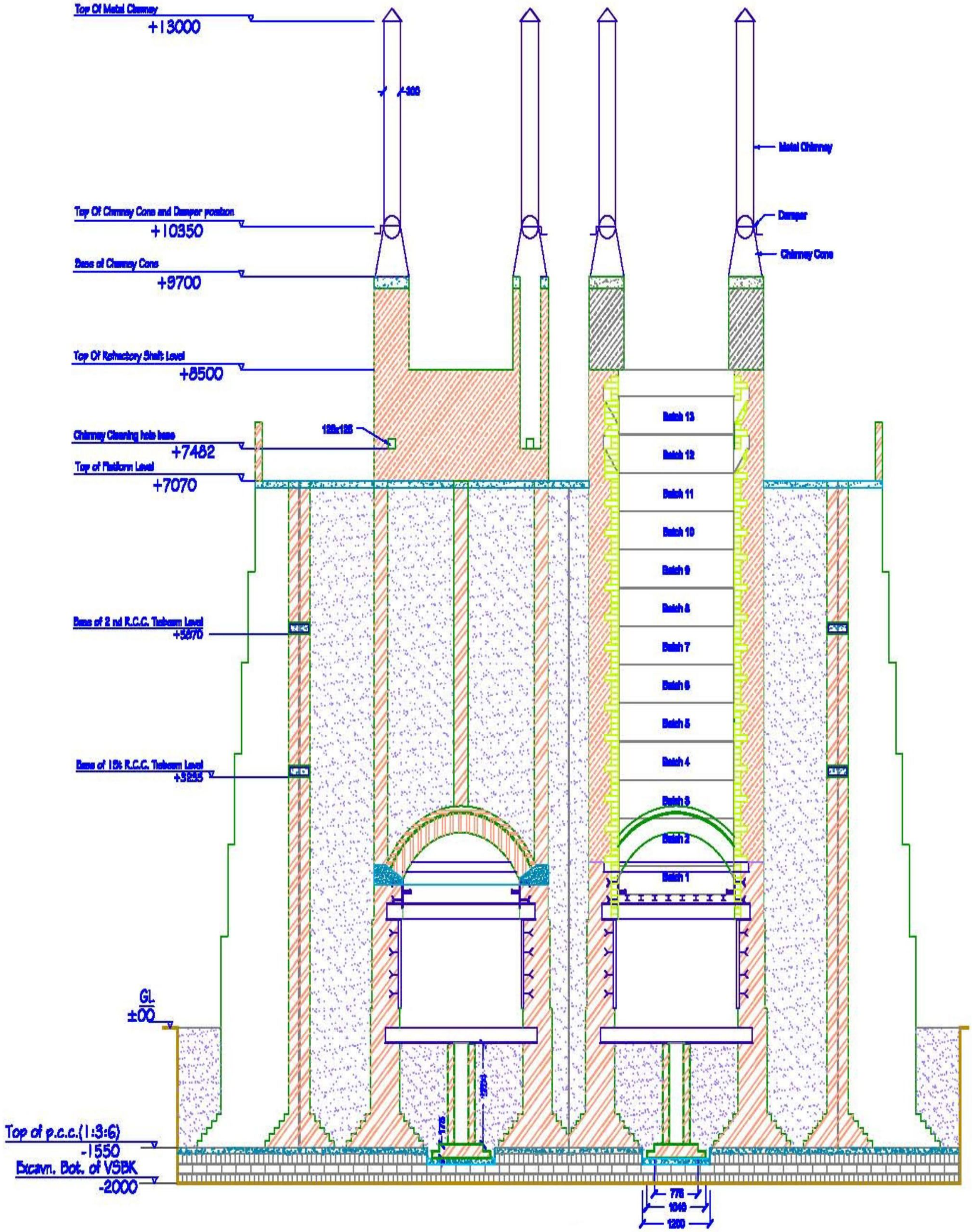
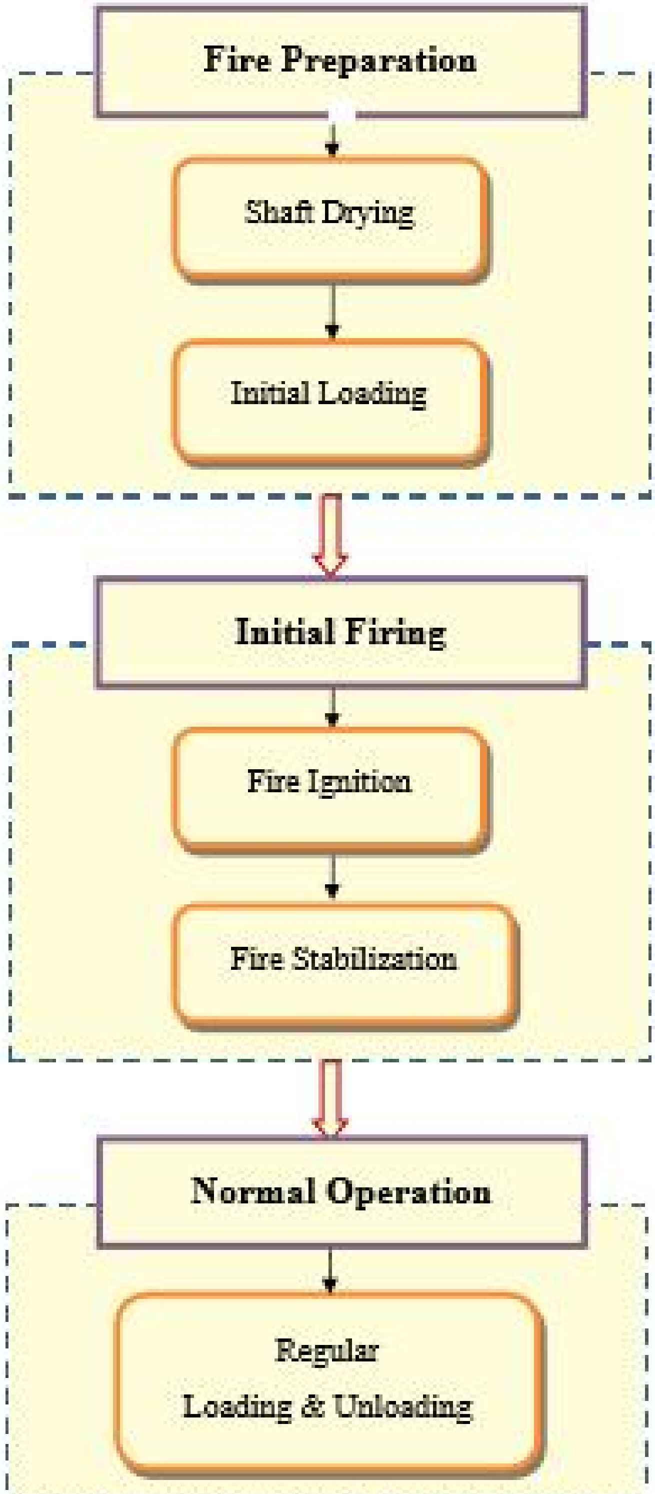


Figure (5.8) VSBK Cross Section A-A

The firing process in VSBK can be visualised in the sequential flowchart given be



Figure(5.9) VSBK Operation Flow chart

5.5.1.4 Initial Firing:

When the shaft was full loaded with stacked green bricks (17 batched), chips of wood in the firing box were ignited. Firing is continued for 3 to four hours till the green bricks of the firing box becomes red.

Big chips of wood, then added through firing box. The firing box port was then sealed with red bricks and plastered with mud.

After 8 to 10 hours, the seal was opened, the cold air then enters from the shaft bottom extracting heat as going up, to start what we call the natural draught to continue the firing process in the kiln.

5.5.1.5 VSBK – Fire Stabilization:

The fire is said to stabilized, when it's position becomes constant at the shaft Centre having the highest temperature with a uniform rate of fuel consumption. Many parameters influences the VSBK fire Stabilization, Such as oil type, VSBK insulations stacks density, green brick moisture content (m.c), type of fuel used …..etc.

5.5.1.6 Temperature Measurement Devices and Control:

Different temperature measuring devices were used during the kiln firing -process, such as thermostats thermocouples, Segercones, …..etc.

Thermostats were used for recording temperature readings during the kiln different firing -zones, such as preheating -zone , full – firing zone , and a cooling -zone . Thermocouples also were used to indicate and controlling the brick finishing temperature (at about 900 C^{o}).

5.6 Segercones:

Segercones are a pyrometric devices used to gauge the temperature rise inside the kiln at any position during the kiln firing – process. Segercones have different code numbers.

Each code number indicates a certain temperature. Usually they are used in three sets. Each set has three ones of different ranges of temperature. The first one was chosen to carry an equivalent temperature above the expected temperature, the second one was chosen to be within the expected temperature, and the last one was chosen to be less than the expected temperature.

Plate (3) showed the three similar sets of segercones groups. They were prepared and fixed up- right on a fired – brick stand.

Each set contained equivalent temperature of 950 C^{o}, 830 C^{o}, 700 C^{o}. These three similar sets should be inserted between green bricks stack before kiln firing – process.

The first set group has to be inserted at of the stack, the second at the middle, and the last one at the far of the stack as shown in plate (2).

After the kiln firing – process had been finished, the three sets were being collected in order to deserve the deformation and the effect of heat on them as shown in plate (4).

A- At the Centre of the Stack:

Segercones carrying an equivalent temperature of 950 C^{o}was found to be a little bit metted, the one carrying 830 C^{o} was found to be metted, and the last one (700 C^{o}) was found totally metted.

B- At the middle of stack:

Segercone carrying an equivalent temperature of 950 C^{o} was found to be as it is, the one carrying 830 C^{o} was found to be metted, and the last one (700 C^{o}) was found totally metted.

C- At the far end of the stack:

Segercone carrying an equivalent temperature of 950 C^{o} was found to be as it is, the one carrying 830 C^{o} was found to be a little bit metted , and the last one (700 C^{o}) was found to be metted .

5.7 Result and Discussion :

The results are given in tables (5.1) below:

Segercone set position	Equivalent temp.	Brick quality
At the Centre of stack	950 C^{o}	Well fired with red colour
At the middle of the stack	830 C^{o}	Fired with red colour
At the Far End of stack	830 C^{o}	Fired with red colour

Tables (5.1) Segercones Test Result

As can be seen from table (5.1)

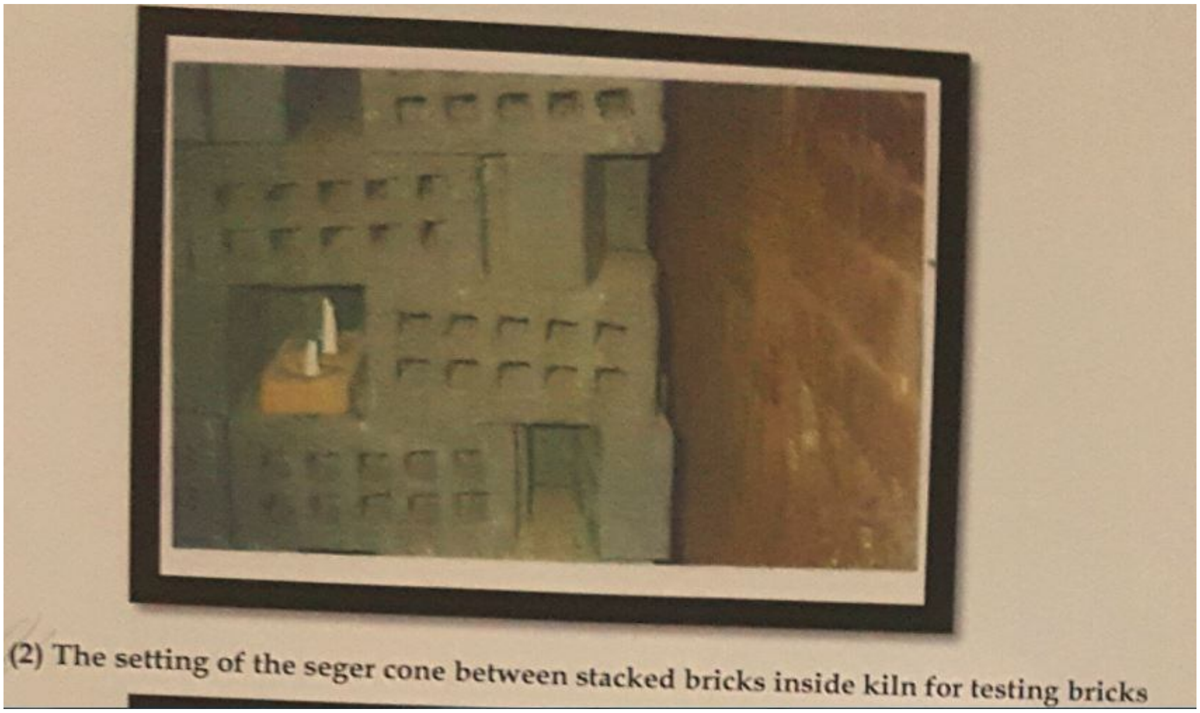
a) There is a small variation in temperature readings at the Centre, middle, and the Far End of the stack.

b) The fired – bricks were found to be well – fired, similar in red colour, with a reduction of bricks cracks (from 5% to 3%).

Important design aspects to be considered during VSBK firing Process:

- Petrocoke should be sprayed equally between brick layers and slightly more at the stacks corner
- (10mm) should be the gabs between the stacks and shaft inner walls
- 3 to 2 (mm) is a gap between bricks during stacking process for the purposed of heat transfer during firing process.
- Stacked green bricks inside the kiln should be with a moisture content not less than 5%
- Thermocouples should be used to control temperature at the shaft different positions, preheating zone, firing zone and the cooling zone.
- 250 cm, 150 cm 250 cm, are the initial gases of the preheating zone, and the cooling zone distances respectively.
- Firing zone should be kept almost at the shaft center.

- Loading and unloading of bricks, should be kept regularly attained within the suitable time of loading and unloading, (about 2 to 2 hours).
- Chimneys control values should be adjusted correctly according to the scheduled process of firing as needed.
- Fuel consumption should be recorded each round of VSBK Firing.
- Fire master and fireman should be well experienced to control the VSBK firing process and then general enhancements can be achieved for the future, utilization.



Figure(5.10) Segercones Group Setting

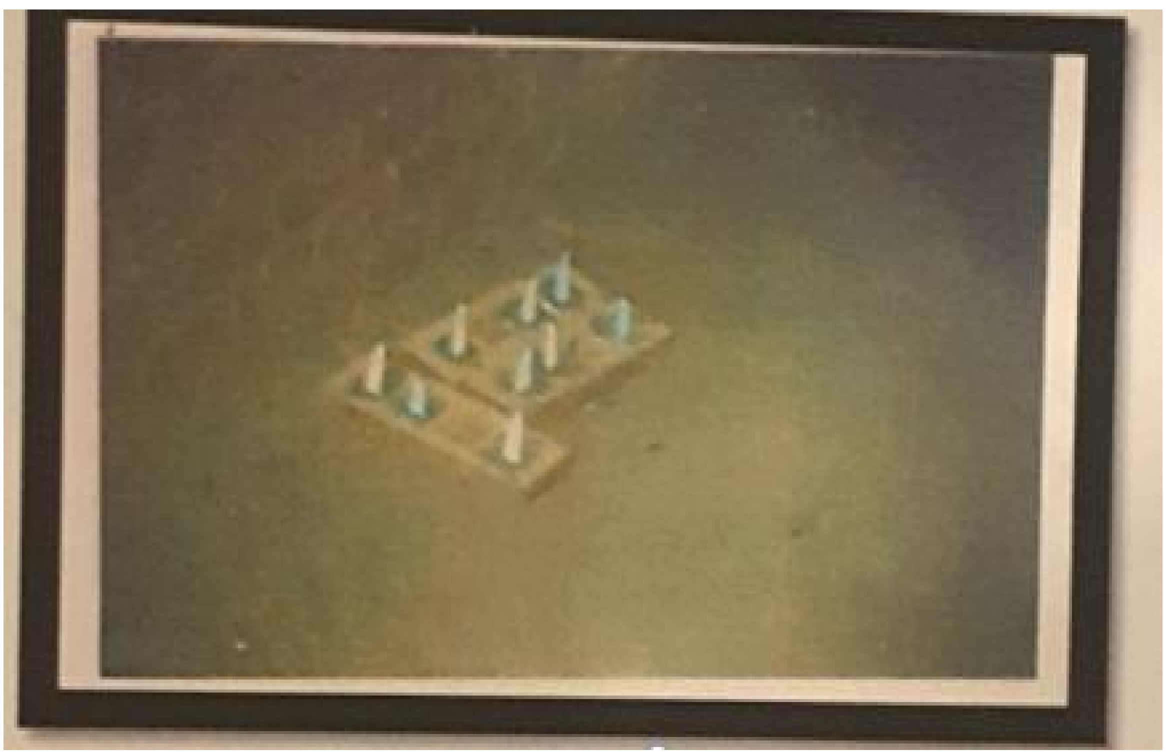
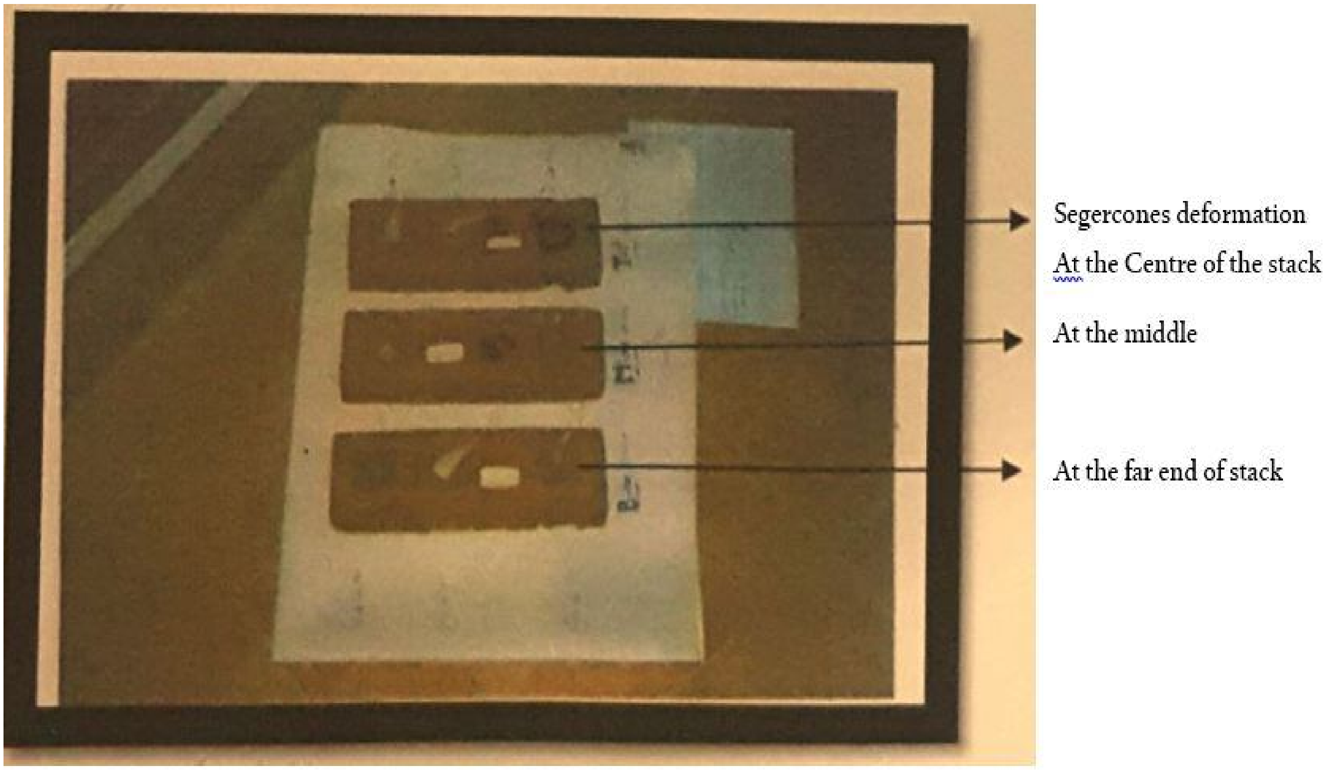


Figure (5.11) Segercones Group Before Firing



Effect of Heat & Deformation

Figure (5.12) Effect of Heat & Deformation

Chapter VI

Conclusion & Recommendation

6.1 Conclusion:

Model different four types of green bricks had been manufactured, each sample was mixed with ten percent by weigh of the alternative fuels, saw-dust, petrocoke, zibala, as internal fuel, and finally the clay without additives. These samples had been subjected to a predetermined controlled drying program, in order to minimize green bricks shrinkage and cracks.

Controlled firing techniques had been applied to fire these samples of greens bricks within the needed firing stages. Water smoking, Preheating, fill firing & vertification, and then cooling, Red bricks Properties to beassessed were loss-on-ignition, crushing strength, and density had been recorded. Investigation showed that Petrocoke sample was found to be the best of alls, having the highest crushing strength and density. Investigation also showed that petrocoke sample has got the lowest fuel consumed, and specific fuel consumption, since it had gained the highest calorific value, followed by zibala, saw-dust, and finally the clay without fuel additive. The study shown that petrocoke as a fuel is cheap, and reduces the firing cost of bricks to 40% as compared with liquid furnace oil.

There for it can be concluded that:

A. Alternative different fuels (Agricultural &Industrial) having a high heating values are considered as a source of fuel.

B. Alternative different fuelsused for firing bricks concluded that petrocoke type found to be the best one since it showed the lowest specific fuel consumption and fuel consumed.

C. Petrocoke type for firing brick reduce the firing cost to 40% as compared with furnace oil fuel.

D. Alternative different fuelused as internal fuel reduces the pollution emission, since it has a clean burning combustion.

E. This research provides a frame work for the exploration of energy produced from wastes that can be implemented in various applications.

F. Additive types were employed as a sources of energy material in tandem with climate change mitigation initiatives among the among the solution strategies

G. Vertical Shaft Brick Kiln (VSBK) will be the best energy-efficient one with friendly environment technology. It can be Implemented to a wide range in the Sudan since it has the following benefits:

- Efficient – energy with friendly environment.
- Having stack (chimney) constructed accordingly to American standard, Good Engineering Practice (G. EP).
- Brick stacks are designed in order to obstruct the fly ashes of burning and suspended particulate matter (S.P.M).
- Electrostatic respirator and fiberfiller are used to reduce emission of fuel gases.
- Low investment capital.
- Easy to operate and low maintenancecost.
- Lille space for errection is needed.

- Productivity can be increased by errection of 2 shaft, 3 or more together.

H. This research will support the idea of brick and road research institute (B.R.R.I) of University of Khartoum to fulfill.

- As a central Consultant research for building materials in the Sudan.
- For technology transfer and contribution between other institutes in the world.

6.2 Recommendation:

- Computational Fluid Dynamics (CFD) can be conducted to Vertical Shaft Brick Kiln (VSBK) to in increase efficiency and thus for optimization of design and reducing of emission from combustion by replacing expensive and time consuming experimentations.
- Implementation of VSBK Technology is very recommended to replace the old traditional inefficient and pollutant technology (the old Kamena) in the Sudan.
- Firing of hollow and perforated bricks through this technology will help in reducing clay consumption and emission.
- VSBK Can be used for lime Production.

REFERENCES

[1] Jensen, R. & PepperedJr, D. M. The traditional brickmaking industry and the rural economy of Vietnam. Journal of Asian and African Studies, 39 (3), 193–207, 2004

[2] Isabel M. Guerrero, et al, 2011, Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh, Environment, Climate Change, and Water Resources Unit, South Asia Region, The World Bank, Report No. 60155-BD, Washington DC, USA.

[3] Ellen Baum , Scientific and Technical Advisory Panel, BLACK CARBON from BRICK KILNS, Clean air task force, 2010, Leaders' Declaration of the G-7 Summit,2015, http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf.

[4] PalashPatra, AvijitGuray, SandipanGanguly, A Study on Brick Kiln Industry in Pursura Block of Hooghly District, WestBengal, International Journal of Applied Research volume1No. (9), pp. 95-99, 2015

[5] Alam, S. A. & Starr, M. Deforestation and greenhouse gas emissions associated with fuel wood consumption of the brick making industry in Sudan. Science of the total environment, 407, p. 847–852, 2009

[6] Badr El-Din E. Hegazy, Hanan A. Fouad and Ahmed M. Hassanain, Brick Manufacturing From Water Treatment Sludge And Rice Husk Ash,Australian Journal of Basic and Applied Sciences, 6(3): 453-461, 2012

[7] A.E. Aldesly(British Development Association)The firing of bricks, Text book,1970

[8] Mahesh V. Iyer, M.S. ChE , High temperature reactive separation process for combined carbon dioxide and Sulfur dioxide capture

from flue gas and enhanced hydrogen production with in-sutu carbon dioxide capture using high reactivity Calcium and bio-mineral sorbents dissertation, PhD Thesis, The Ohio State University 2006

[9] Sedet Karaman Gunal Ersahin, Firing temperature and firing time influence on mechanical and physical properties of clay bricks, Journal of Scientific and Industrial Research, Vol. 65, pp.153-159, 2006

[10] Steve Harrison, An examination of the geological resources of the southern highlands of NSW as raw material for studio ceramics ,PhD, Thesis University of Western Sydney, 2007

[11] G.M. Martinez Gonzalez and H. Jimenez Islas, Experimental study of the firing of red clay brick using liquefied petroleum gas Journal of Scientific and Industrial Research Volume 77 pp 661-666, 2014

[12] Skinder et al., Brick kilns: Cause of Atmospheric Pollution Journal of Pollution Effects & Control - e-Science Central, 20142:2, http://dx.doi.org/10.4172/jpe.1000112

[13] Luis P. Avila, Charles Bruce, Enrique C haves, Antonio S, Lara, and Robert O, A Sustainable solution to the Air Pollution Problem caused by low technology Brick Kilns, https://climate.asu.edu/BorderAirQuality/ASustainableSolutiontotheAirPollutionPro/.

[14] Usha Maskey Manandhar Sanu Babu Dangol , Study on Evaluating Energy Conservation Potential of Brick Production in SAARC Countries A Report on Nepal, SAARC ENERGY CENTRE Islamabad, 2013, www.minergynepal.com/publications/SEC%20Report_MinErgy.pdf

[15] Jesús Chávez-Galán1, Rafael Almanza2 and Neftalí Rodríguez Cuevas2, Convective heat transfer coefficients: experimental

estimation and its impact on thermal building design for walls made of different Mexican building materials, Concreto y Cemento. Investigation Desarrollo, Volume, 5 No. 2, 2014

[16] Le, H. A. &Oanh, N. T. K. Integrated assessment of brick kiln emission impacts on air quality. Environmental monitoring and assessment, 171, pp.381–394, 2010

[17] Hoang Anh Le, Nguyen Thi Kim Oanh , Integrated assessment of brick kiln emission impacts on air quality, Environmental Monitoring and Assessment, 2010, Volume 171, Issue 1, pp 381-394, 2009

[18] Ishtiag Abdalla a, c, Sahar Babiker Abdalla b, d, Kamal El-Siddig d, Detlev Möller a, Andreas Buerkert, (Effects of red brick production on land use, household income, and greenhouse gas emissions in Khartoum, Sudan, Journal of agriculture and rural development in the tropics and sub- tropics, Vol. 113 No. 1, pp. 51–60, 2012

[19] Thompson, J. L., Gebauer, L. &Buerkert, A..Fences in urban and peri-urban gardens of Khartoum, Sudan. Forests, Trees and livelihoods, 19, 379–391, 2010

[20] Omer, A. M. &Fadalla, Y. Biogas energy technology in Sudan. Renewable Energy, 28, 499–507, 2003

[21] Abdalla A. Salam Ahmed, Ahmed Adam Ibrahim, Seif Eldeen Hamed, Samir Ibrahim Saad, Nile basin capacity building network, towards the improvement of the protection methods against bank erosion, NBCBN, river morphology research cluster, group II, 2005

[22] Davies, H. R. J. & Walsh, R. P. D. Historical changes in the flood hazard at Khartoum, Sudan: lessons and warnings for the future.

Singapore Journal of Tropical Geography, volume 18, No.(2), pp.123-140, 1997
[23] NIFES (1993), Evaluation of continuous VSBK in china, overseas development Administration, London.
[24] Mubarak, A. R., Elshami, O. M. E. & Adam, A. E. Short-term effects of tillage on N mineralization from farm yard manure in semi-arid tropical vertisol. Research Journal of Agriculture and Biological Sciences, 6 (2), 157–160, 2010
[25] Sameer Maithel et al, Brick Kilns performance assessment and a roadmap for cleaner brick production in India, A Shakti sustainable energy foundation and climate works Foundation supported initiative, report, 2012
[26] Singh, A. L. & Sarfaraz Asgher, M., Impact of brick kilns on land use/land cover changes around Aligarh city, India, Habitat International, volume 29, pp. 591–602, 2005
[27] IvololaRibar, Mechanical and Technological Documentation 1958.
[28] Dr. Mohamed El-Mustafa Awad, On the Development of fired clay brick 1975. (B.R.R.I). U of K.
[29] Frank P. Incropea, Introduction to heat transfer, 2004.
[30] E. Rowden (B.D.A), Fuel consumption and heat transfer 1970.
[31] A. E Aldersly (B.D.A), The firing of bricks, 1970.
[32] Gordon Roger, Yon Mahew, Engineering thermodynamics, work and transfer 4th edition.
[33] Yunosa, Cegel, Engineering thermodynamics 5th edition.
[34] G.F.C Roger and Y.R Mayhew and Transport properties of Fluid 1995, 3rd edition.
[35] American Society for Testing Petroleum Products, 1970.

[36] Orton Pymrometric Seger Cones http//www.ortonrettrieved 10.2011

[37] Vertical Shaft Brick Kiln (VSBK) Sudan.

[38] Vertical Shaft Brick Kiln (VSBK) India, www.VSBKINDIA.com

[39] Abdel – Rahim Mobarak Abu Sinaina, Improving the performance of Soba Brick Pilot Plant 2012.

[40] Ian Knizek as a Consultant to UNIDO, Brick making plant industry profile, New York 1978.

[41] Research education association, mechanical engineering hand book 1999, discat way, New Jersey.

[42] Mohomed Majzoub, Utilization of Bagasse in brick making practical action Sudan 1999. And has originally published by GTZ for Advisory service and Information net work(Basin).

[43] Syed, Ashraf Alam, Use of Biomas fuel in the brick making industries of Sudan , April 2006.

[44] BS 3921 – 1965 Specification for Brick and Block of Fired Bricks Earth day S.S 19974 “Sudanese Standard for common Burnt Bricks".

[45] Tariq Awan“ occupational Health and safety in Pakistan” Asian labour, update , 2006.

[46] Snjir Pan Dita, “ India Health and safety at work” Asian labour, update , PP 1-6 , 2006.

[47] Kelvin Mason؛Kay Austin PAT Brif, Evolving a standard to compare Energy Efficient of Brick firing process 1998.

[48] Gehad Mersch Merger, GATE Technology.

[49] http:/ www2.gtz-de/ Basin/ gade/ tb12/ clay dring, 1999.

[50] Tim Jones, Vertical Shaft Brick Kilns, GATE , Technical Brief, 1997.

[51] Tim Jones, Gate Technical Brief, Hoff- man kiln,1995.

[52] Gerhard Merschmer ,GATE Technical Brief, Firing of clay Bricks,2000.

[53] http:/ www2.gtz.de/ Basin/ gate/ th13/ clay firing.

[54] Bala. B. K and M.M Hossian, Economics of Biogas Digesters in Bangladish.

[55] GATE/Gtz Question and Answer Reponses, what type of kiln to be chosen fofiring clay bricks,1999.

[56] Henrick NorSker. Energy Saving Brick kiln, swiss development corporation April, 1994.

[57] NIFES, Evaluation of continuous VSBK in china, overseas development Adminstration, London, June 1993.

[58] Hassan M. Widatalla, Adaptability of sponge coke usage in Garry
(4) steam power station, in place of heavy fuel oil, (2012).

[59] Howard E. Hesheth , Understanding and Controlling Air Pollution Ann Arbor , MI: Ann Arbor Science Publishers . Inc. 2002.

[60] World Bank Pollution Prevention Handbook , Thermal Power – Guidelines for New Plants July 1998.

[61] REX W. Grimshaw – The Chemistry of Clays Alled Ceramic Material 4th edition London – 1971

Appendixes (A)

1.Fuel consumed &speciFic Fuel consumption:

$Q = m\, C_P \Delta t$

Where Q = heat for firing (Kj).

m = dried mass of bricks (kg).

C_P = specific heat (Kj/ Kg. K^O).

Δt = change of temperature.

For petro coke at 850 C°.

Q_{850C°petrocoke = m 850 C° cp (850 - 51).

m_{850C°= 0.821 (kg)

C_P = 0.88

850,51 C° = max temp. and initial temp- respectively

Q_{850C°°petrocoke = 0.821×0.88 (850-51) = 577.26 (Kj)

Specific fuel consumption SFC = $\frac{\text{Total heat for firing}}{\text{Total Kgs of fired bricks (0.7kg)}}$

S.F.C $= \frac{577.26}{0.7} = 824.65\frac{\text{Kj}}{\text{Kg.F.B}}$

Total heat needed to fire 100.000 brick unit of weight (2.604 Kg = S.F.C ×total Kgs of fired bricks = 824.65× 100.000 ×2.604 Kj

Total fuel needed= $\frac{\text{Total heat needed to fire 100000 unit bricks}}{\text{calorific value of petrocoke (35260 Kj/Kg)}}$ =

$\frac{824.65\times100000\times2.604}{35260} = \underline{6.090\ \text{Kg}}$

Total fuel needed for fire 100.000 unit of bricks = 6 tons

Total fuel needed = Internal fuel + External fuel = 6 tons

Internal fuel = 10% = $\frac{6\times10}{100}$ = 0.6 ton

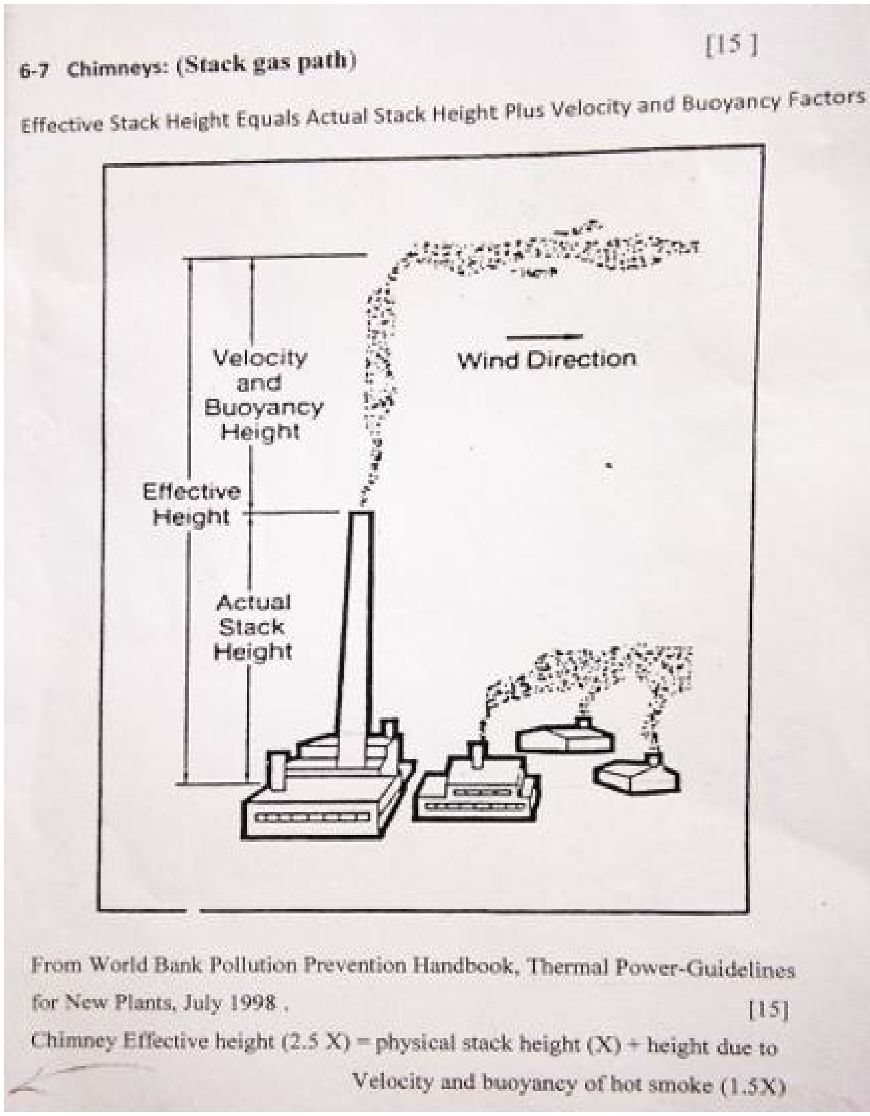
External fuel = 6-0.6 = 5.4 tons.

Fuel consumed and specific fuel consumption Table

Sample Type	Dried brick average weight (Wd)	Fired brick average weight (Wf)	Calorific value (c.v)	Specific fuel Consumption (S.F.C)	Total fuel used	Internal Fuel (Ton)	External Fuel (Ton)
Petrocoke at 850c^{o}	0.821	0.701	35260	835.4	6	0.6	5.4
Zibala at 850c^{o}	0.804	0.7	17500	842.2	12.4	1.2	11.2
Saw dust at 850c^{o}	0.705	0.581	15910	864	14.4	1.4	13
clay at 850c^{o}	0.9	0.7	NILL	904			
Petrocoke at 900c^{o}	0.873	0.732	35260	587	6.55	0.655	5
Zibala at 900c^{o}	0.76	0.634	17500	891	13.3	1.3	12
Saw dust at 900c^{o}	0.7	0.634	15910	848	14.3	1.4	12.9
clay at 900c^{o}	0.86	0.7	NILL	955			
Petrocoke at 950c^{o}	0.789	0.634	35260	586	6.6	0.66	5.94
Zibala at 950c^{o}	0.867	0.591	17500	585.3	16	1.6	14.4
Saw dust at 950c^{o}	0.658	0.447	15910	488.7	17.8	1.78	16.02
clay at 950c^{o}	0.8	0.76	NILL	786.7			

Appendix (b)

Figures


[15]

6-7 Chimneys: (Stack gas path)

Effective Stack Height Equals Actual Stack Height Plus Velocity and Buoyancy Factors

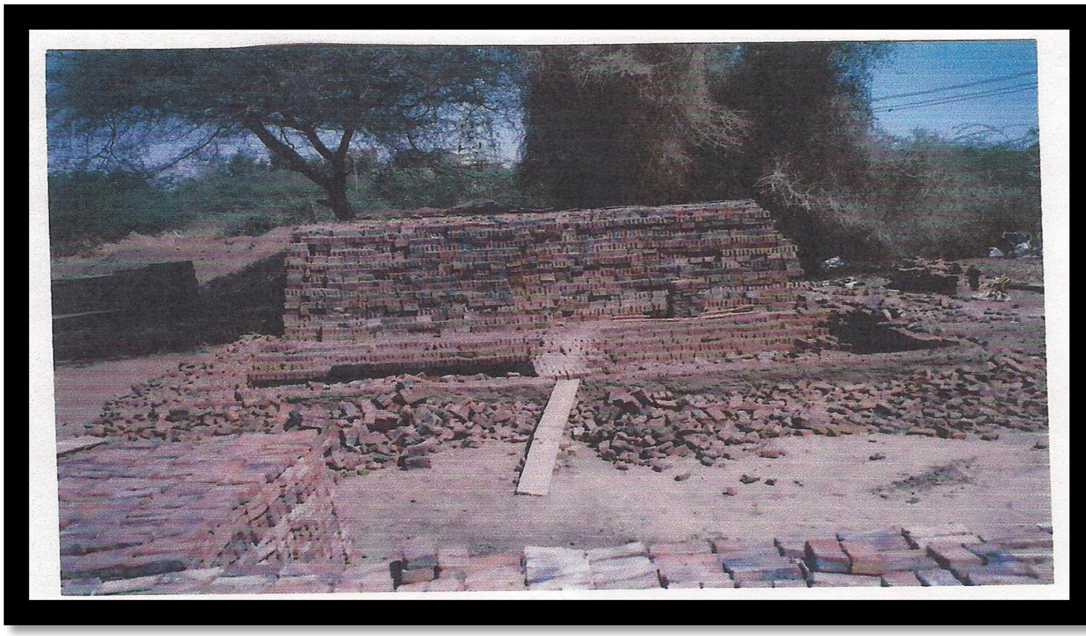
From World Bank Pollution Prevention Handbook, Thermal Power-Guidelines for New Plants, July 1998 . [15]

Chimney Effective height (2.5 X) = physical stack height (X) + height due to Velocity and buoyancy of hot smoke (1.5X)

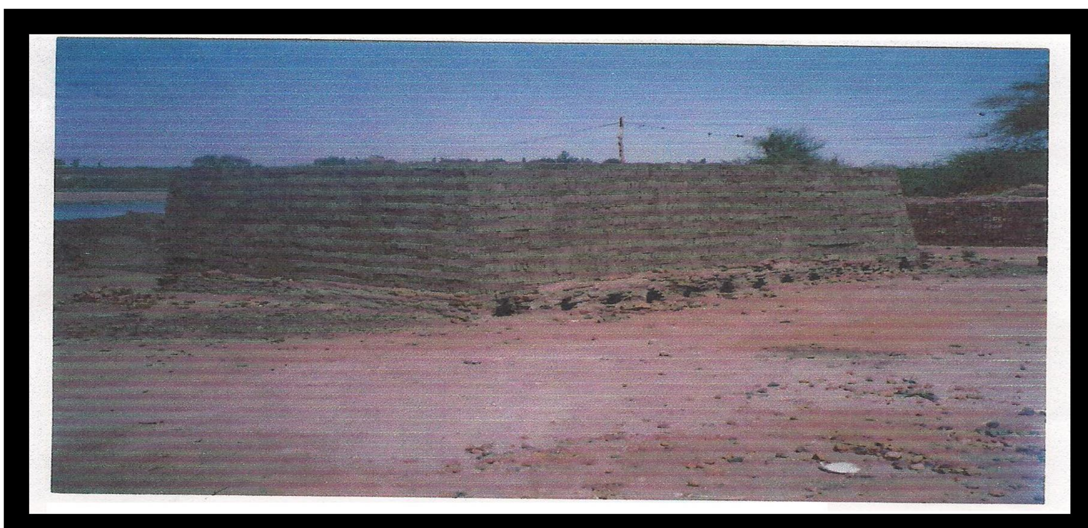
(A-1) Chimney Effective height

Appendix (c)

Plates



Appendix (B-1) Primitive Kiln- Sudanese Kamina



Appendix (B-2) Primitive Kiln- Sudanese Kamina

(B -3) Vertical Shaft Brick Kiln (VSBK) with a Ram .

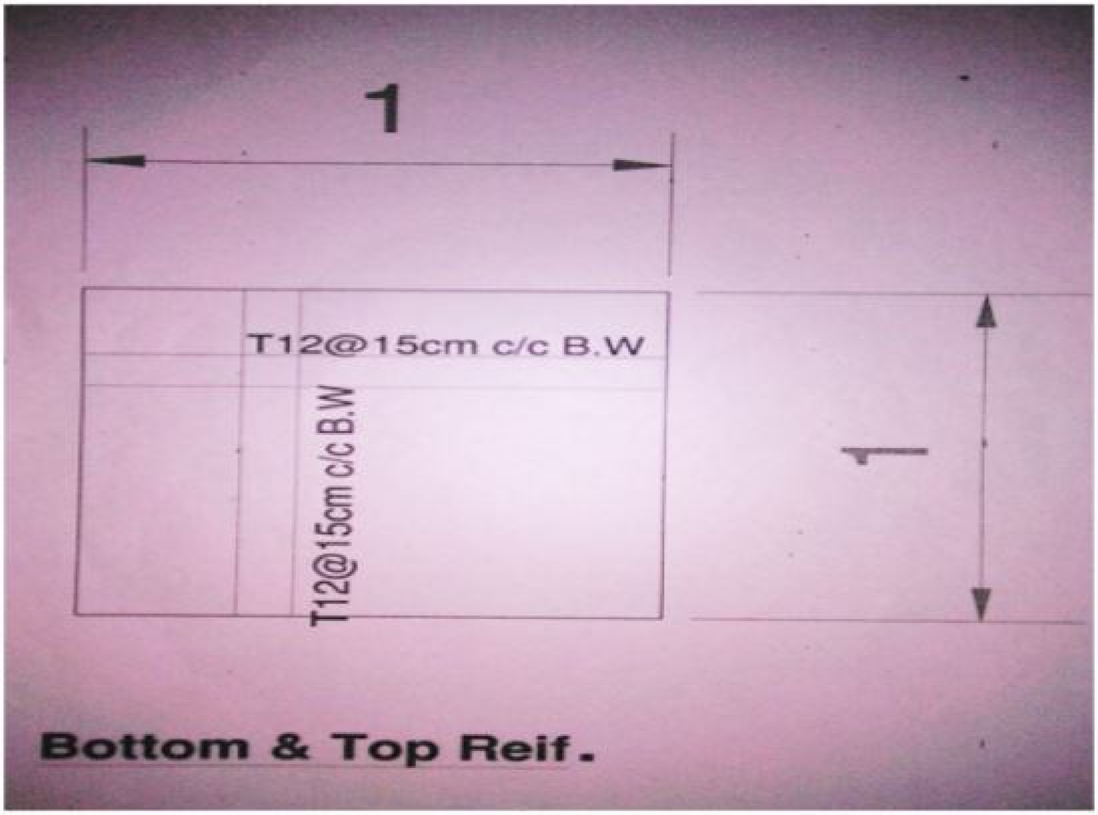
(B- 4) Green Brick Drying

(B- 5) Bricks Firing

(B-6) Crushing Strength Test

(B-7) Multi- Vertical Shaft Brick Kilns

(B- 8) VSBK Ladder (Soba)



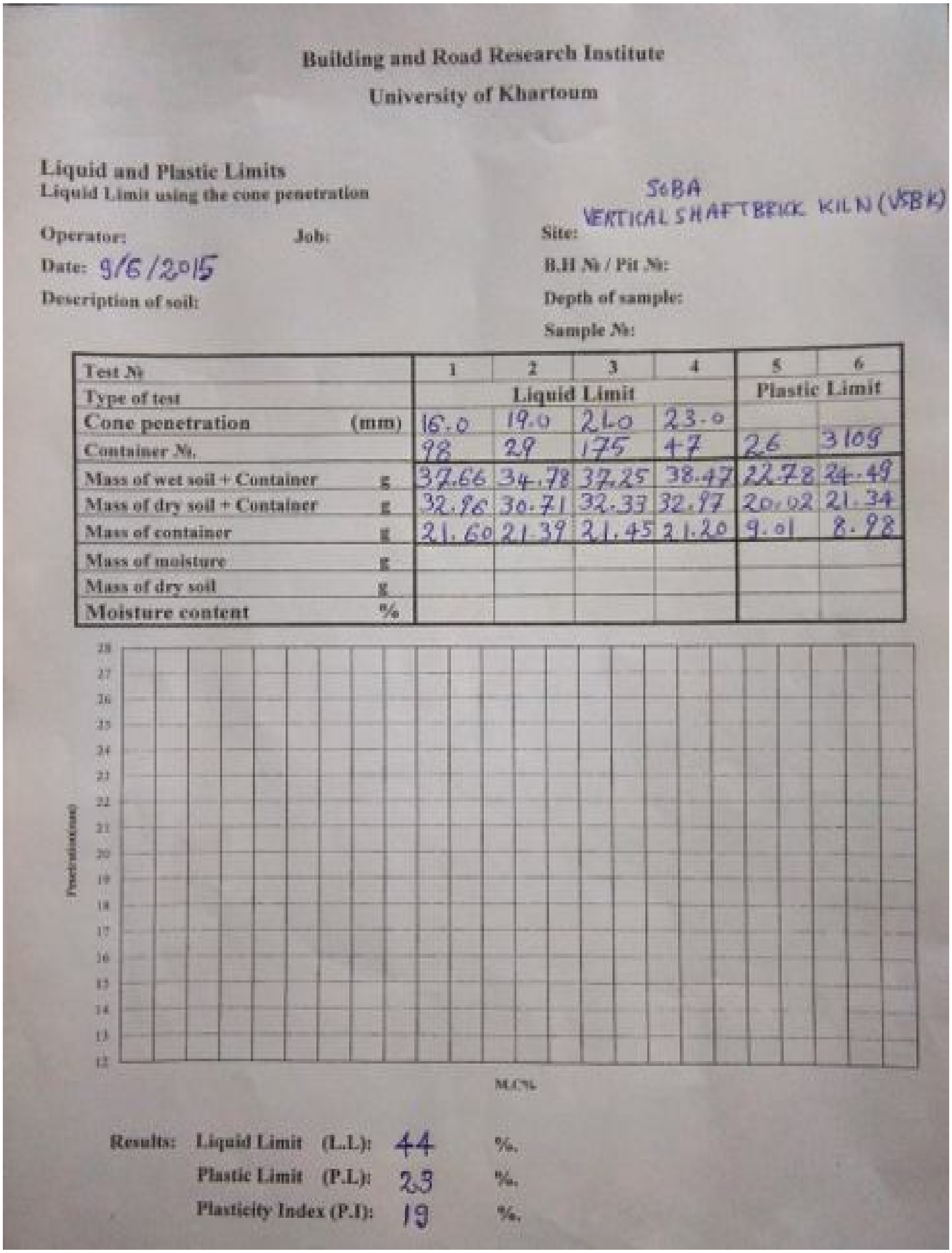
(B-9) Screw Jack Foundation Design

Appendix (d)
Tables

Soba Brick Pilot Plant

Elements	Test 1	Test 2	Test 3
SIO_2	48.53	53.05	62.28
TiO_2	2.03	1.82	1.15
A_2O_3	13.90	13.02	9.51
Fe_2O_3	11.60	10.73	6.55
Mno	0.13	0.13	0.08
Mgo	3.03	2.68	2.73
SiO	6.42	5.85	5.48
Na_2O	1.21	1.29	1.15
K_2O	1.35	1.35	1.23
SO_3	0.15	0.65	1.29
CO_2	1.23	1.01	2.58
Org.mat	1.84	0.95	0.51
H_2O 110C^o	3.18	2.43	2.23
H_2O 1000C^o	6.02	5.36	3.31
Total	**100,65**	**100,52**	**100,26**

Appendix (D-1) Clay- Chemical analysis



Building and Road Research Institute

University of Khartoum

Liquid and Plastic Limits

Liquid Limit using the cone penetration

Operator: Job:

Date: 9/6/2015

Description of soil:

Site: SOBA VERTICAL SHAFT BRICK KILN (VSBK)

B.H № / Pit №:

Depth of sample:

Sample №:

Test №		1	2	3	4	5	6
Type of test		Liquid Limit				Plastic Limit	
Cone penetration	(mm)	16.0	19.0	26.0	23.0		
Container №.		98	29	175	47	26	3109
Mass of wet soil + Container	g	37.66	34.78	37.25	38.47	22.78	24.49
Mass of dry soil + Container	g	32.96	30.71	32.33	32.97	20.02	21.34
Mass of container	g	21.60	21.39	21.45	21.20	9.01	8.98
Mass of moisture	g						
Mass of dry soil	g						
Moisture content	%						

Penetration(mm)

M.C%

Results: Liquid Limit (L.L): 44 %.

Plastic Limit (P.L): 23 %.

Plasticity Index (P.I): 19 %.

(D-2) Plasticity Index Test Result