KILN EFFICIENCY AND INSULATION.

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Introduction

The kiln is an insulating fire chamber that has the ability to retain the heat that is generated into it, and utilizes such heat in baking the clay wares in the chamber to the desired temperature. For effective performance, the materials with which the kiln is built is of utmost importance, hence emphasis is always being laid on the quality of insulating bricks that is used in the building of the kiln. Firing is expensive as it consumes a lot of time, fuel and energy; hence in designing a kiln economy, efficiency is given adequate priority. In recent times, there is renewed emphasis on self-reliance and self-sufficiency, particularly in the manufacturing sectors. The kiln is the most important and most expensive in ceramic manufacturing, whether at the studio level or at the industrial capacity. To sustain the imploding ceramics industry, the urgent need for the kiln by every potter cannot be overemphasized. However due to its expensive financial cost, it becomes very difficult for individuals to purchase it from the market. Improvisation, however, becomes the only way out. In this paper, therefore, attempts are made to seek ways of producing high quality insulating bricks for kiln building that will reduce the cost of firing to the barest minimum. The method will not only reduce the firing time but also fuel consumption and consequently, the energy expended. It is hoped therefore that at the end, potters will take advantage of the findings and equip themselves with the right information about the materials for the insulation of their kilns.

Kilns and Insulation.

A kiln can be defined as an insulating fire chamber, which conserves the heat that is generated or directed into it, in which pottery wares are fired. Fournier (2000) defines it as "essentially a box of refractory bricks, into or around which heat is introduced either by combustion or by radiant heat" (p. 184). Put into perspective, it is the most important and indispensable equipment in the pottery workshop or industry.

The materials with which the kiln is built for effective performance matter and it is of utmost importance. Hence a heat resisting and sufficiently refractory material, that can withstand extreme temperatures which the kiln is exposed to, immediately comes to mind. Kaolin is a very useful and available refractory material. Rhodes, (1981) posits that "The most useful and one of the most available refractory materials is clay. Pure kaolin or kaolinite ($Al_2O_3.2SiO2.2H_2O$) has a melting point of 1785^oC" (p.124). This temperature far exceeds the operating temperature which the kiln and the pottery ware are fired to.

Insulation bricks are specifically designed for greater heat retention and should be made with kaolin and/or fireclay as these are materials that can withstand higher temperatures. The bricks last longer because the operating temperatures of the kiln are usually lower. The common surface red burning clay is still refractory enough to withstand temperatures up to 1100^0C without deforming. Bricks made out of this however, should be confined to the backup layers of the kiln wall only.

A locally made insulating brick could be fashioned out from a combination of kaolin and saw dust. The brick is dried and fired to a reasonably high temperature, (at least to the temperature which the proposed kiln will be operating), and is used for the lining of the kiln chambers. They are very efficient for kiln building and "serve to increase the heat retention properties of kilns when used either as a backup layer behind other refractories or for the entire structure" (Rhodes 1981: 129).

The quality of the insulating bricks to be used in building a kiln that will fire high, last long, stand stress and a test of time is of utmost importance. Hence the use of kaolin and/or fireclay is the best choice of materials as they are sufficiently refractory. These are materials that are very efficient in heat retention such that melting, cracking or slagging will not occur in the kiln built with them. Heat loss will also be minimized, due to its insulating properties.

Rhodes (1981) posits that "insulating bricks are so efficient that a brick which is heated up to red heat on one end can be comfortably picked up in the hand at the other end" (p. 129). Therefore, one can comfortably place his hand on the body of a kiln that has fired to a very high temperature without being hurt, as a result of the insulating quality of the bricks used in lining the chamber. With a good insulating property of the bricks there will be no use making the kiln walls excessively too thick. A wall thickness of fifteen centimetres will serve very efficiently and is more than adequate for a 7cubic metres (20cubic feet) kiln. This is the character of most modern potable studio kilns, which agrees with Norton (1956) as he declares "Modern pottery kilns owe much of their efficiency to the insulating fire bricks with which they are lined. Not only does this refractory cut down heat loss, but it permits fairly rapid heating and cooling" (p. 289). This is why the amount of heat which is absorbed by the wall of the kiln depends on the efficiency of the insulation of the bricks. The only partial remedy to this waste is by using high quality light weight insulating bricks.

It is always better and wiser to use the best material available in building a kiln because it pays. This is the opinion of Gregory (2005) when he states that; "…the most important factor when setting out to build a kiln is to use the best possible materials available as cutting back on quality may in the long term, prove a false saving" (p. 14). Many kilns have been refined and developed after years of experience with a view to both saving labour and fuel consumption by using quality materials, especially the insulating bricks.

Making Insulation Bricks

Insulating bricks are the very essential insulating materials with which the kiln is built, and there are basically two grades of insulating bricks required for the construction of a kiln. They include the low density light weight insulating bricks, and the high density heavy weight refractory bricks. Very efficient insulating bricks can be made with a mixture of kaolin and some combustibles like saw dust at a 50:50 aggregate by volume, with about 10% of ball clay added to it to introduce some plasticity to the mixture.

This is mixed with just enough water to make a stiff mixture to be pressed with a mould. Little sodium silicate is added to the mixture to give it added strength. A wooden mould is constructed for the brick moulding. The standard size for insulation brick for kiln building is 23cm x 11.5cm x 6.5cm, so the mould is constructed to this size. (See figs. i & ii). However, the brick maker or kiln builder may decide to alter the size to suit his design ideas.

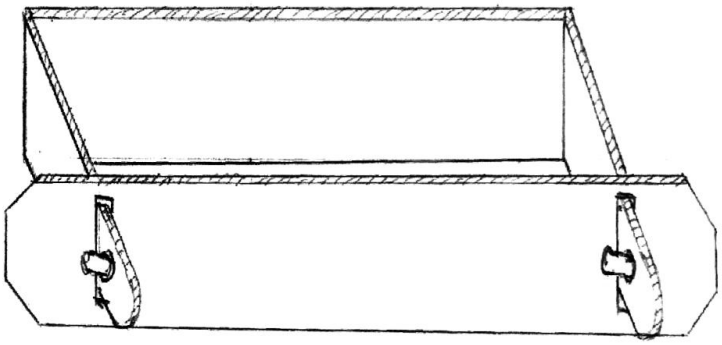


Fig. i. The brick mould.

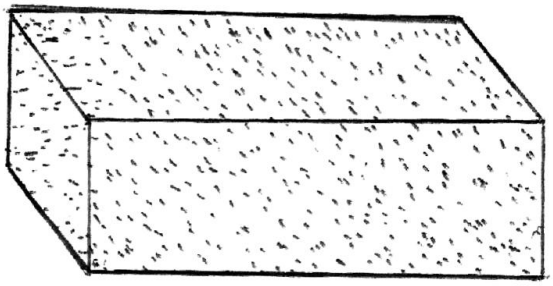


Fig. ii. An Insulating Brick

The bricks mixtures:

1. **The low density light weight Insulating bricks:**

The low density light weight insulating bricks are used for the inside lining of the kiln, this includes the three side walls, the roof arch and the door. It has the following composition:

Kaolin-------50 parts
Ball clay----10 parts
Saw dust---40 parts
Total------100 parts

2. **The high density heavy weight refractory bricks:**

The high density heavy weight refractory bricks are used for the fire chamber, the burner ports, the floor, the flue and the chimney as well as the back-up walls.
The composition for this grade of bricks is as follows:

Kaolin----------50 parts
Ball clay--------20 parts
Quartz ----------20 parts
Saw dust-------10 parts
Total----------100 parts

An addition of 1 to 2% of sodium silicate is added to each of the compositions and enough water to make a stiff mixture. The mixture is allowed to age for at least two days and the brick making can commence. After making the bricks, it is allowed to dry slowly under shelter for some days to leather hard. This is to prevent warping and cracking. It is then spread under the sun to complete the drying sufficiently to bone dry stage, then fire to the highest temperature that the proposed kiln is likely to be operated. Kiln building consumes a lot of bricks; therefore enough of it should be made in readiness for the construction.

Plate 1. Insulator Bricks. These bricks are made and exposed under the shelter to dry slowly for some days to avoid cracking or warping.

Plate 2. Insulator Brick drying under the sun.

Plate 3. The insulation bricks in the kiln after firing to cone 1 (1125 ^{o}C)

The low density light weight insulating bricks are specifically used for the inside lining of the kiln chamber, forming about 10cm thick wall. This is backed up with another wall of at least 5cm thickness of the dense refractory bricks, thereby giving a total wall thickness of about 15cm. In laying the bricks, only a very thin layer of mortar is required in between. (See fig iii).

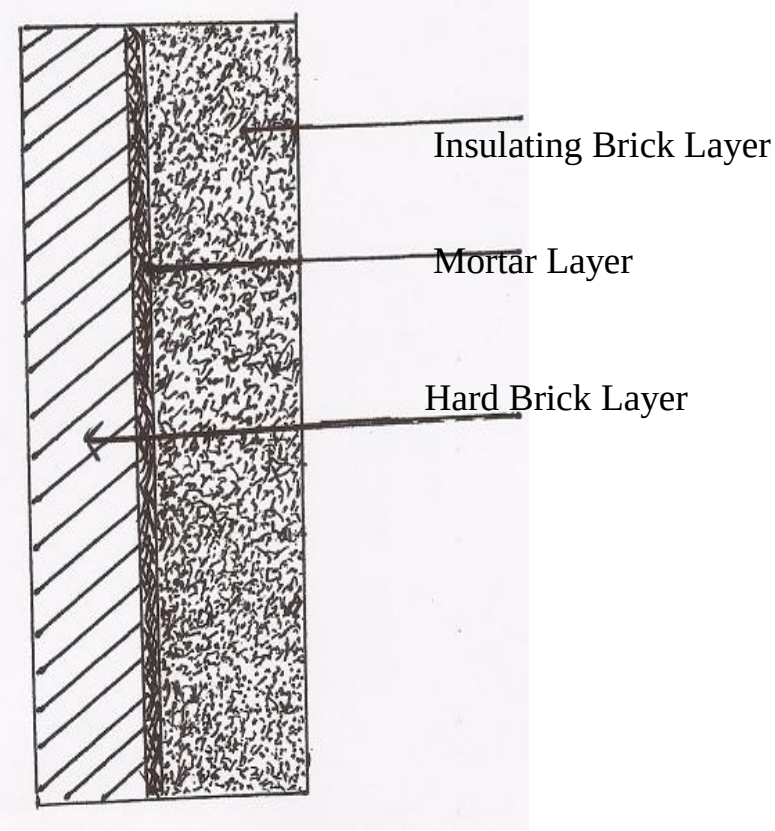


Fig. iii. Showing the insulating brick layer, the mortar and the hard brick layer.

A thick layer of stiff insulating mixture could be used for the backup layer of a kiln. (See plate 4 bellow). The insulator mixture is compounded with the following materials:

Crushed Shards----30 parts
Quartz ---------- 15 parts
Kaolin ----------20 parts

Ball clay----------15 parts
Saw dust----------20 parts
Total----------100 parts.

A little of sodium silicate is added to give the mixture a good bonding strength. This mixture has a shrinkage rate of less than 2%. When used as a backup to the insulating bricks, only very little and negligible cracks will develop as there will be no noticeable shrinkage. This therefore forms a good seal to the inner wall, thereby preventing any heat loss. I have successfully used this method on my 5.5 cubic metre (18 cu. ft.) capacity oil-burning kiln and it has successfully fired to 1160°C in a very short firing circle of about 3hrs 20mins. (See plate 4 bellow).

Plate 4. An oil-burning kiln.

The back-up wall is done with insulation mixture.

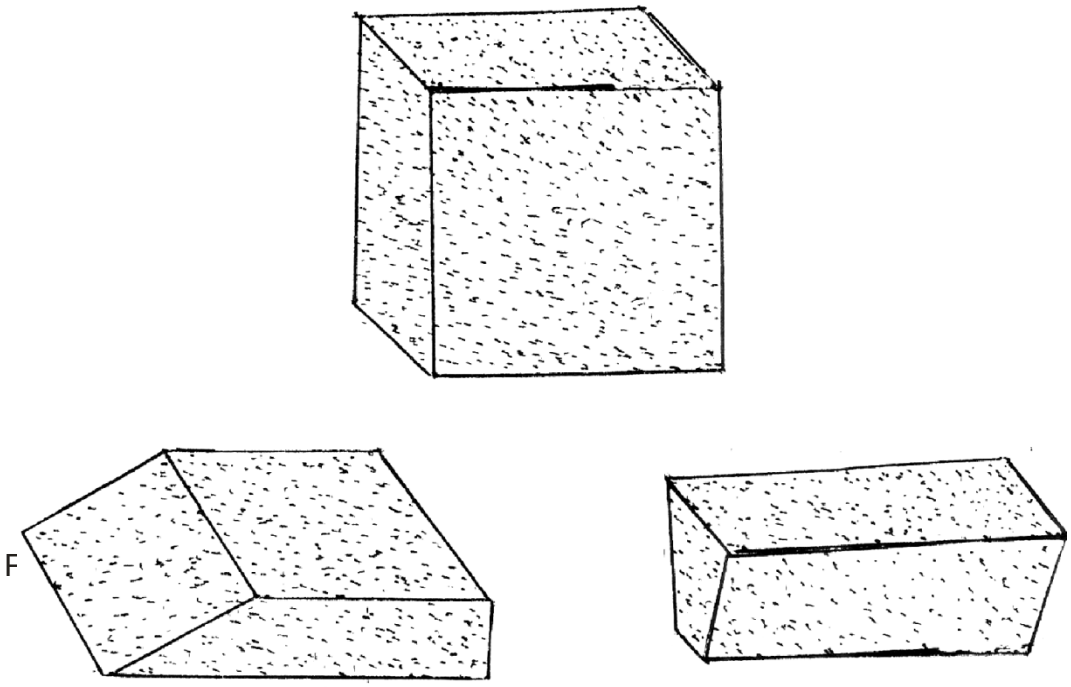
Other grades of bricks could also be made with common red burning clay mixed with fine sand, and a little combustible, like saw dust. This is fired to a fairly high temperature of about cone 1 (1125°C). This grade of bricks is very good for the back-up wall of the kiln. However, the whole kiln structure could be completed entirely with insulation bricks.

Shapes and Types of Bricks.

There are special shapes and types of bricks required for kiln building. These include:

1. Straight brick: This is used for the vertical walls and the door of the kiln. They are rectangular or square in shape (fig. iv a).

2. End skew bricks: This type of brick is used in lining the top of the vertical walls. They are irregular in shape and sizes (fig. iv b).
3. Arch bricks: This brick is specifically for the roof arch or dome. They are also irregular in shape (fig. iv c).



Test for Insulation Property of the Bricks. (Porosity Test).

After firing the two grades of bricks, they are subjected to porosity tests to determine their insulating ability before they are used for the construction of kilns. The tests are conducted as follows:

(i) Percentage Porosity test for insulating bricks-

Weight of fired insulating bricks =10grams

Weight of fired insulating bricks soaked in water =17grams

Percentage Porosity of insulating bricks =

$$\frac{17-10}{10} \times 100 = 70$$

Percentage Porosity of insulating bricks = **70%**

(ii) Percentage Porosity test for dense refractory bricks-

Weight of fired dense bricks =10grams

Weight of fired dense bricks soaked in water =12grams

Percentage Porosity of dense bricks =

$$\frac{12-10}{10} \times 100 = 20$$

Percentage Porosity of dense bricks = **20%**

The Efficiency of the Bricks:

The kiln is potentially a fire box. It is basically a structure designed to retain the heat that is generated into it by combustion. Its ability to accumulate and retain the heat brings about the efficiency which is contributed by the insulation quality of the brickwork and the performance of the burners.

The bricks of the kiln are designed to be insulating enough such that the heat directed into the kiln chamber is not allowed to escape through the walls to the outside; rather, the heat accumulates and results to elevated temperatures. However, a lot of heat is still being lost in heating up the kiln through the flue, walls, floor and roof. As a result, only a fraction of the total heat energy expended is used in heating up the wares contained in the kiln. This notwithstanding, the required high temperature required to heat up the wares in the kiln can still be attained in a very short firing circle if the kiln is well insulated and fitted with good and appropriate burners. This could be achieved before the kiln starts loosing heat from the walls and floor during the firing.

A well designed kiln is expected to fire steadily to attain the desired temperature evenly in all parts of the ware chamber. The kiln bellow was designed entirely with locally made insulation bricks and has fired to cone 4 (1165 ^{o}C) in 3hrs 30mins with as little as 10litres of kerosene. It was designed taking efficiency and economy as first priority hence the use of light weight low density insulation bricks.

Plates 5a & 5b. Kiln under Construction with Insulating Bricks.

Plate 6. The Kiln near Completion.

Plate 7. The Chamber of the Completed and Fired Kiln.

Plate 8. An Oil-Burning Kiln Constructed Entirely with Insulating Bricks, and Installed at the Department of Fine Arts And Design, In the University Of Port Harcourt.

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