American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-6, pp-89-101
www.ajer.org
Research Paper Open Access

Design and Construction of a Prototype Gas Fired Kiln Using Nsu Clay Refractory Bricks

[1,] Oduagwu Ferdinand Azubuike, [2,] Koreyo Victor Dorawa,
[3,] Azubuike Thaddeus Chukwuemeka

Department of Ceramics and Glass Technology
School of Industrial Technology
Akanu Ibiam Federal Polytechnic Unwana Afikpo, Ebonyi State
Nigeria

ABSTRACT: *In the construction of a prototype gas fired kiln, plastic pressing method was used in producing the bricks. The bricks have a specific body composition of 48% of grog and 32% of uncalcined Nsu clay for dense bricks, 16% saw dust and 44% Nsu clay for insulating bricks. Test carried out to ascertain the quality of the bricks include the water absorption test (18.8% for dense bricks and 85% for insulating bricks), apparent porosity test (63.2% for insulating bricks and 23.2% for dense bricks) and crushing strength test (10.2N/mm^2 for dense bricks and 2.5N/mm^2 for insulating bricks). This constructed kiln has a total surface area of 0.54m^2 (54cm^2) with volume of 0.00684m^3 and the kiln can fire up to the temperature of 1200^{0}c it has a high efficiency for firing of ceramic wares and for low melting glasses.*

I. INTRODUCTION

Kiln is any fixed structure of any shape or form built with insulation refractory materials used for the heat treatment of waves making them permanent object of usefulness. It is also used for roasting of ores and in cement production. In the production of ceramic wares, source of firing is the fact to be considered. Any article made with clay is said to be useful only when it undergoes heat treatment. The thermal efficiency of any kiln depends on the refractory wall of the kiln, damper system and heating element. Damper controls firing pressure and heating process of kiln. There is need for technological growth and economic development in our nation. Using our locally sources material kaolin which is available in building kilns, furnace for glass melting and in making ceramic wares. Due to high cost of importation of kiln, inadequate supply of electricity to operate electric kiln and power fluctuation, production of ceramic wares is been hampered. This discourages potters who are in the field. Gas kiln usually has high thermal efficiency which leads to high productivity level and varieties of colours which are absent in electric kiln can be achieved in gas kiln. This varieties of colours make's people to become more excited about ceramic wares since oxidation and reduction (redox reaction) can be done in gas kiln.

The motive behind this research is to embark on construction of prototype gas fired kiln using local material Nsu clay. This is a large clay deposit found in Nsu a town in Imo State, Nigeria. It is hereby imperative to facilitate construction of local kilns to meet increasing demand. Hence, the development of techniques for the construction of high efficiency kilns that are commercially viable and also meet required standard.

A kiln is expected to assume a temperature of not less than 600^{o}c before it can be useful in ceramic. (Rhodes, 1973:16 and Fournier 200:184). The primary determination of use of any bricks, is their ability to withstand high temperature and prevent heat losses to acceptable limit (Fraser, 1979:1). Refractory bricks are made from a mixture of grog and fireclay or kaolin and or a combination of the three materials. According to Cardew (1969:162) this type of brick are heavy, resistant to cracking, wear and abrasion and do not crumble or disintegrate easily.

Insulating refractory brick are heat resistance suitable for inner brickwork of the kiln chamber. There are weak and less resistance to wear and abrasion because of their porous structure cause by the addition of pore creating substance (pore inducer). Searle (1956) say that the commonest among the insulating bricks are these made from refractory fire clays and kaolin with the addition of organic substance such as sawdust, peat, palp, paper, waste flour or grass etc. the use of refractory insulation bricks is “a more recent development, coming into general use during the 1930s and has revolutionized the design of kilns furnaces of all sorts” (Rhodes, 1977:88). The bricks are fitted together to form framework using mortal, usually a heat resisting material of similar composition to the brick themselves. The construction is done to specification making sure that there is a workable relationship between the various parts of the kiln. The size of kiln chamber otherwise draught will be affected. This is necessary if the kiln is to give a maximum efficiency. Other composition of kiln include element, burners and temperature measuring instrument, kiln furniture such as shelves, props etc. used for setting wares inside the kiln. They are made from high firing refractory material that withstand high temperature without warping (Washaw 2006:223). Shelves and props like the bricks are highly refractory and give satisfactory service particularly those made from either high alumina materials such as silimanite, kyanite or silicon carbide, (Rado 1988:104, Cardew p. 158). Heat is introduced into the kiln through heating element for electric kilns or burners for oil, kerosene and gas fired kiln. Most modern kilns are fitted with temperature measurement such as pyrometer, although pyrometric cone can also be used. They are small pyramids made of ceramic materials which will melt and bend when desire temperature is reached and it is seen through spy hole. These materials and equipment are rather two expensive which accounts for the high cost of kilns.

GAS KILN: Gaseous fuel have become highly favoured among contemporary ceramist. This is because they do not require constant stockingand they create no unburned ash as residue that must be periodically removed. These fuels include propane, natural as, kerosene and oil. Modern kilns fired with these fuels greatly give room for ceramist to use a wide variety of glaze types and rich visual textures. A well fired and mature glaze with a reduce lusters can be produce in a gas kilns. Kilns fired with natural gas or propane do not have combustion problems, the burners used to fire these fuel are quit efficient and have only a moderate impact in the environment. When firing with gas it is important to avoid the direct impact of the flame on the ware. Therefore, kiln is constructed in such a way to leads the flame around the interior chamber and generally combustion is created, the wares can be fired in sagars or the kiln can have a full or muffle construction to protect against the direct heat of the flames. Gas kiln has the advantage that temperature can be controlled by reducing or increasing the fuel input.it is suited to reduce stoneware firing as the intake of air into the chamber can be reduced or some form of solid fuel can be introduced to create a reducing atmosphere.It gives a cheap easily burned and gives perfect result. Many gas kilns are downdraft designs which has fire box at the front or by the sides of the firing chamber. These kilns are very similar in design to those meant for firing solid fuel with the exception that since there is no unburned ash residue. Some gas kilns are updraft in design and employ very powerful blower-driven burners; these rely on the efficiency of the fuel and the power of the burners to reach high temperature.

II. MATERIALS AND METHOD

EXPERIMENTAL DETAILS

This chapter focuses on the experimental details of the production process in the construction of a prototype gas fired kiln using Nsu clay insulating and dense refractory bricks. In this study, the percentage composition of Nsu clay to combustible material. (saw dust) which will be used in producing insulation brick is 73.3% Nsu clay and 26.7% sawdust, and 40% unclained Nsu clay against 60% grog of Nsu clay for dense brick. The method selected for the kiln bricks production is pressing method.

MATERIALS FOR THE CONSTRUCTION OF PROTOTYPE GAS-FIRED KILN

Dense brick made from Nsu clay, insulating brick made from Nsu clay, mortar, plume, Angle iron, saw and scraper

METHOD FOR THE KILN’S BRICKS PRODUCTION AND KILN CONSTRUCTION

The procedure for the construction of a prototype gas fired kiln was carried out in different processes.

GROG PREPARATON

Nsu clay is calcined at 1000^0c, crushed and grounded to its finest form and sieved using 30 mesh in a plastic container from which it will be measured out for kiln’s insulating brick production.

PREPARATION OF SAW DUST

The saw dust is sieved using 30 mesh into a plastic container from which it will be measured out for the kiln’s insulating brick production.

III. PREPARATION OF NSU CLAY

NSu clay is crushed and grounded to a fine powder and then sieved using 100 mesh into a plastic container from which it will be weighed out during fabrication of both dense and insulating bricks for the kiln's construction.

3.1 PROCEDURE FORPLASTIC PRESSING METHOD OF KILN'S REFRACTORY BRICKS PRODUCTION

73.3% of Nsu clay is weigh out into a plastic container and the sieved saw dust of 26.7% is also weighted out and mixed with the Nsu clay and water to make the mix. The recipe was thoroughly mixed to obtain a uniform body mixture. It is allowed to age overnight and re-mixed again. The mixed batch is then gradually fed into the wooden mould and pressed to a considerablecompression of uniform application of force using open ended pressing method. The fabricated brick is remolded and allowed to dry evenly by air drying, it is then move into the drying cabinet to dry at the temperature of about 110^0c, it is then removed and into the kiln for firing to obtain the required characteristics such as hardness, toughness, rigid and thermal shock resistance, sharp edges and corners.

The same procedure is equally applied in the dense brick production but excluding saw dust but addition of 60% of grog (calcined Nsu clay) and 40% Nsu clay (uncalcined). Both dense and insulating brick are fired at $1240c^0$.

3.2 GAS – FIRED KILN CONSTRUCTION PROCEDURE

i. the fired bricks (insulating and dense brick) is used in lining the kiln. At the inside of the kiln, dense brick forms the hot face while the insulating brick serve as back up brick to the dense brick, mortar, which is made up of 2% Nsu clay and 1% grog is used to hold the brick one after the other and to level the bricks.

ii. Metal casing is used to encase the kiln against surface abortion and to make the kiln portable and provide a well finished compatibility.

(INSULATING AND DENSE)

i. Test for water of absorption of the bricks

ii. Crushing strength of the bricks

iii. Porosity test of the bricks

3.3 WATER ABSORPTION OF THE BRICKS USED IN KILN CONSTRUCTION

The brick samples (insulating and dense) were boiled at $100c^0$ for five (5) hours to allow the brick samples to absorb water. Water absorption were calculated as a function of the samples weight difference prior to and after water submersion. The water absorption was competed using equation.

$$\text{Water absorption} = \frac{w2-w1}{w1} x\ 100\%$$

Where w_2= boiled weight at $100c^0$ for 5 hours

w_1= dry weight of brick samples.

3.4 APPARENT POROSITY TEST OF THE BRICK SAMPLES

The boiling method were used in which in the samples were weighted dry W_1 and were subjected for boiling of $100c^0$ for five (5) hours and then weighed W_2. The boiled samples were suspended from the beam of a balance in a used of water so arranged that the test piece under consideration was completely immersed in the water without teaching the side of the used. The suspended samples in water were weighed as W_3. Porosity were calculate as a function of the samples weight difference between boiled weight and dry weight to samples against weight difference between boiled weight and suspended immersed weight. The results were abstained by the equation.

$$\text{Apparent Porosity (P)} = \frac{W2-W1}{W2\ \ -W3} x\ 100\%$$

Where W_2= boiled weight

W_1 = dry weight

W_3 = suspended immersed weight

3.5 CRUSHING STRENGHT

The strength of the brick samples was investigated using a universal tensile testing machine in which it was used to carry out the falling load of the samples using formula.

Crushing strength = $\frac{\text{Force (f)}}{\text{Area(A)}}$ N/mm^2

Where f= farce (N)

A= Area (length x width) (m^2)

The crushing strength was determined using a universal tensile testing machine in the civil engineering workshop of Akanu Ibiam Federal polytechnic. Each of the samples was placed one after the other on the bearing edges of the compression machine. Load was then applied at the center of the samples uniformly.

The load at which the sample fails were calculated and recoded in kilo newton (KN). The length and width of the brick sample were measured and multiply by 2 to abstain the final result of the area of the brick samples.

3.6 HEAT PASSING THROUGH THE KILN STRUCTURE

Heat passing through brick structure is proportional to the cross – section area thought the structure from which it passing the temperature difference between the hot face and cold face and it is inversely proportion to the thickness of the brick wall.

$$Q\ \alpha \frac{A\Delta T}{t}$$

$$Q = \frac{KA\Delta T}{t}$$

Where Q= heat passing per unit length (w/m^2)

K = thermal conductivity of the refractory brick (W/mc^0

A = area of the brick (m^2)

Δt = temperature difference between hot face and cold face of the brick (c^0)

T = thickness of the brick wall (m)

3.7 HEAT STORED IN THE KILN STRUCTURE

The quantity of heat stored in a kiln or furnace structure depends on refectory arrangement used in lining the structure. Quantity of heat stare in a brick wall is directly proportional to the muss of the refractory brick, thickness of the brick, and average temperature of the brick

Q α DtT

Q= SDtT (J/m^2)

Where Q = quantity of heat store in the brick (J/M^2)

S =specific heat (KJ/Kg/c^0)

D = Density of the brick (kg/m2)

t = thickness of the brick (m)

T = average temperature of the brick (c^0)

THE INTERFACE TEMPERATURE

This is the temperature between the dense refractory brick wall and insulating refractory brick wall, and which can be calculated as follow.

Heat passing through the structure $\frac{Q}{A} = \frac{\Delta t}{\left(\frac{t1}{k1}\quad\frac{t2}{k2}\right)}$

Where $\frac{Q}{A}$ =heat passing through the structure (w/m^2)

Δt = temperature difference cold face of the brick wall (c^0)

t_1 = thickness of the dense brick wall (m)

t_2 =thickness of the insulating brick wall (m)

k_1 = thermal conductivity of dense brick (W/ m c^0)

K_2 = thermal conductivity of insulating brick (W/ m c^0)

BURNER

The burners used in firing the kiln were locally constructed using 3inch pipe which is connected to a control gas tape. The tape has a nob which is used to control the amount of gas that flows from the tape to the 3inch pipe. The surrounding air entered the pipe through the opening along the side of which will mix with gas (petroleum liquefy gas) which will be ignited at the extreme end of the pip.

BATCH COMPOSITION

(i)DENSE BRICK BATCH COMPOSITION (KG)

TOTAL BATCH WEIGHT (60kg)

MATERIALS (KG)	CALCILATION	% COMPOSITION
NSU GROG FINE = 4.8 COARSE = 24	$\frac{4.8}{60}$ X 100 = 8% $\frac{24}{60}$ X 100 = 40%	8% 40%
UNCALINE NSU CLAY = 19.2	$\frac{19.2}{60}$ X 100 = 32%	32%
WATER = 12	$\frac{12}{60}$ X 100 = 20%	20%
TOTAL = 60 Kg		TOTAL = 100%

(ii)INSULATING BRICK BATCH COMPOSITION (Kg)

TOTAL BATCH WEIGTH (60Kg)

MATERIALS (KG)	CALCILATION	% COMPOSITION
NSU GROG FINE = 26.4 (UNCALINE)	$\frac{26.4}{60}$ X 100 = 44%	44%
SAW DUST = 9.6	$\frac{9.6}{60}$ X 100 = 16%	16%
WATER = 24	$\frac{24}{60}$ X 100 = 40%	40%
TOTAL = 60 Kg		TOTAL = 100%

RESULTS AND DISCUSSION

(i) WATER ABSORPTION TEST OF DENSE REFRACTORY BRICKS

BRICKS SAMPLE	DRY WEIGHT W_1 (kg)	WET WEIGHT W_2 (kg)	CHANGE IN WEIGHT $(W_2 – W_1)$ kg	% WATER OF ABSORPTION $\frac{(W_2 – W_1) \times 100}{W_1}$
A	0.2285	0.2706	(0.2285 – 0.2706) = 0.0421	$\frac{0.0421 \times 100}{0.2285}$ = 18.4
B	0.1166	0.1388	(0.1388 – 0.1166) = 0.0222	$\frac{0.0222 \times 100}{0.1166}$ = 19.0
C	0.102	0.1215	(0.1215 – 0.102) = 0.0195	$\frac{0.0195 \times 100}{0.102}$ = 19.1
TOTAL percentage water of absorption = $\frac{18.4 + 19.0 + 19.1}{3}$ = 18.8% of dense bricks				

(ii) WATER ABSORPTION TEST OF INSULATING BRICKS

BRICKS SAMPLE	DRY WEIGHT W_1 (kg)	WET WEIGHT W_2 (kg)	CHANGE IN WEIGHT $(W_2 – W_1)$ kg	% WATER OF ABSORPTION $\frac{(W_2 – W_1) \times 100}{W_1}$
A	0.1235	0.2287	(0.2287 – 0.1235) = 0.1052	$\frac{0.1052 \times 100}{0.1235}$ = 85.2
B	0.1233	0.2287	(0.2287 – 0.1233) = 0.1036	$\frac{0.1036 \times 100}{0.1233}$ = 84.0
C	0.1225	0.2276	(0.2276 – 0.1225) = 0.1051	$\frac{0.1051 \times 100}{0.1225}$ = 85.8
TOTAL percentage water of absorption = $\frac{85.2 + 84.0 + 85.8}{3}$ = 85.0% of the insulating bricks				

CRUSHING STRENGTH OF THE BRICKS

BRICK SAMPLE	FORCE(F)THAT CRUSH THE BRICK	AREA OF BRICK (L X W) X 2 (MM^2)	CRUSHING STRENGHT = F/A (N/mm^2)
DENSE BRICK	60000	64 X 46 X 2 = 5888	$\frac{60000}{5888}$ = 10.2
INSULATING BRICK	15000	64 X 46 X 2 = 5888	$\frac{15000}{5888}$ = 2.5

4.3 APPARENT POROSITY TEST OF THE BRICKS

Porosity (P) $= \frac{W2-W_1}{W2-W_1}$ X 100%

Where W_1 = dry weight (kg)

W_2 = boiled weight (kg)

W_3 = suspended immersed weight (kg)

INSULATING BRICK

Porosity (P) = W_1 = 0.0593 (kg)

W_2 = 0.1109(kg)

W_3 = 0.1289 (Kg)

INSULATING BRICK

Porosity (P) = W1 = 0.0593(Kg)

W2 = 0.1109 (kg)

W3 = 0.1289(Kg)

P= $\frac{W2-W_1}{W2-W3}$ X 100

= $\frac{0.1109-0.0593}{0.1109-0.0293}$X 100

= $\frac{0.0516}{0.0816}$X 100

= 0.0632 X 100 = 63.2%

P= 63.2%

DENSE BRICK

Porosity (P) = $\frac{W2-W_1}{W2-W3}$ X 100

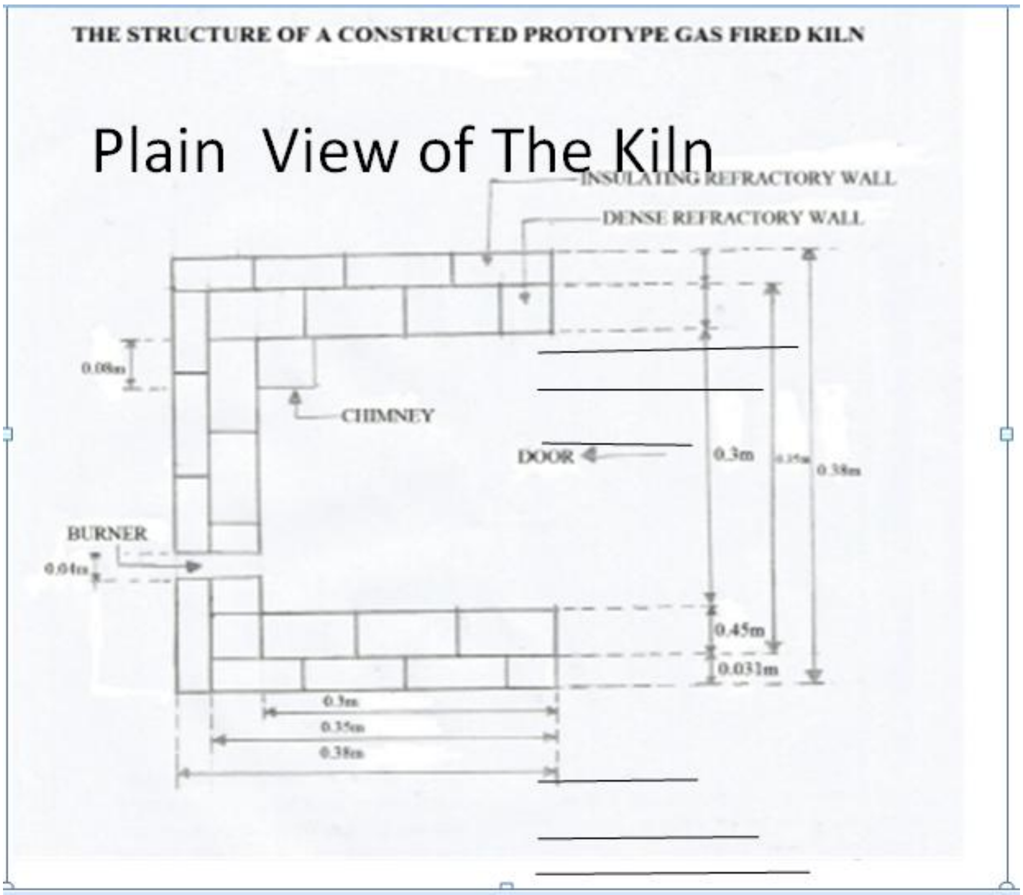
= $\frac{0.0951-0.0814}{0.0951-0.036}$ X 100

= $\frac{0.0137}{0.0591}$ X 100

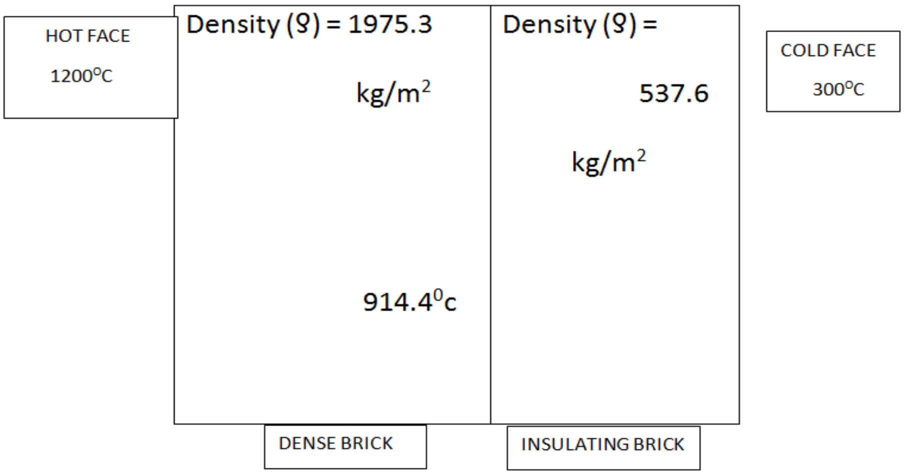
= 0.2318 X 100

= 23.2%

THE STRUCTURE OF A CONSTRUCTED PROTOTYPE GAS FIRED KILN



HEAT STORED IN THE KILN STRUCTURE



HEAT STORED IN THE KILN STRUCTURE

BRICK SAMPLE	DENSITY OF BRICK WALL (kg/m^2)	THICKNESS OF BRICK (m)	AVERAGE TEMPERATURE OF BRICK (^{O}C) $\frac{HOT\ FACE + COLD\ FACE}{2}$	SPECIFIC HEAT OF BRICK (KJ/KG/^{O}C)
DENSE BRICK	1975.3	0.045	$\frac{1200+914.4}{2}$ = 1057.2	1.0
INSULATING BRICK	537.6	0.031	$\frac{914.4+300}{2}$ = 607.2	1.0

Heat stored in the kiln structure Q= D x t x S x T

Where D = Density of brick (kg/m^3)

t = Thickness of brick (m)

s = specific heat of brick (KJ/kg/^{o}c)

T = average temperature of brick (^{o}c)

Heat stored in dense brick wall Q = D x t x S x T

Q = 1975.3 x 0.045 x 1 x 1057.2 = 93972.9

Q = 94KJ/m^2

Heat stored in the insulating brick wall Q = D x t x S x T

Q = 537.6 x 0.031 x 1 x 607.2

Q = 10119.4

Q = 10.1 KJ/m^2

Heat stored in the kiln structure = heat stored in dense wall + heat stored in the insulating brick wall

= 94 + 10.1 =104.2

= 104.2kJ/m$^{2.}$

HEAT PASSING THROUGH THE KILN STRUCTURE

BRICK SAMPLE	AREA OF BRIICK (L X W) (M^2)	RHICKNESS OF BRICKS (M)	TEMPERATURE DIFFERENCE OF BRICKS	THERMAL CONDUCTIVE OF BRICK (W/C)
DENSE BRICK	(0.3 X 0.3) = 0.09	0.45	1200 – 914.4 = 285.6	1.0
INSULATING BRICK	(0.3 X 0.3) = 0.09	0.031	914.4 – 300 = 614.4	0.32

Heat passing through kiln = Q $\alpha\frac{A\Delta T}{t}$

$$Q = \frac{KA\Delta T}{t}$$

Where Q = heat passing per unit length (w/m^2)

A = Area

ΔT = temperature difference between hot face and cold face of brick wall (^oc)

K = Thermal conductivity of the bricks (w/m^2)

Heat passing through the dense wall $= \frac{KA\Delta T}{t}$

$$Q = \frac{1.0 \text{ x } 0.09 \text{ x } 285.56}{0.045}$$

$$= \frac{25.7}{0.045}$$

$$= 571.1$$

$$Q = 571.1 w/m^2$$

Heat passing through the insulating wall $= \frac{KA\Delta T}{t}$

$$Q = \frac{0.32 \text{ x } 0.09 \text{ x } 614.4}{0.031}$$

$$= \frac{17.69}{0.031}$$

$$= 572$$

$$Q = 572 w/m^2$$

Heat passing through the kiln structure during firing = heat passing through the dense wall + heat passing Through the insulating

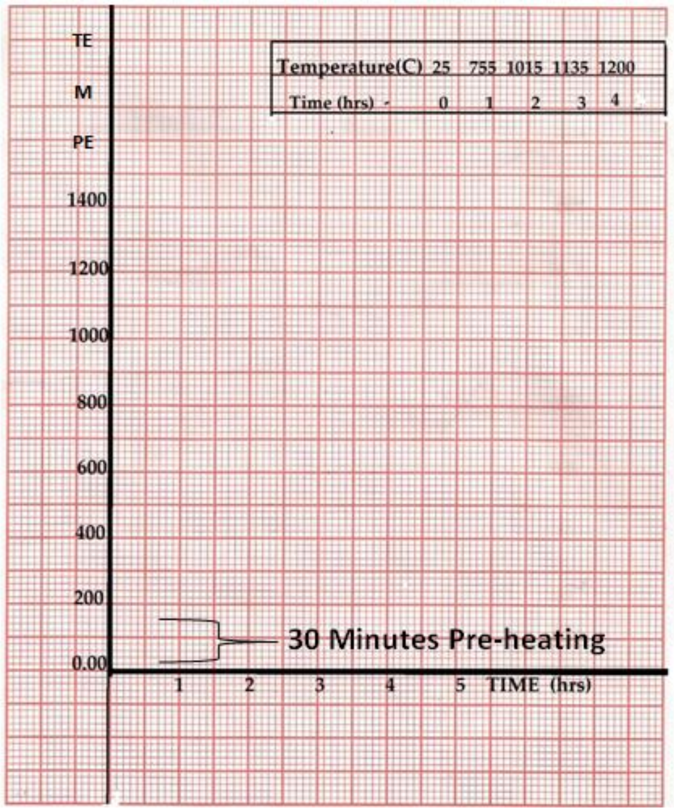
= 571.1 + 572

= 1143.1 W/m^2

FIRING SCHEDULE OF PROTOTYPE GAS FIRED KILN (1200^{0}C)

TEMPERATURE (C^0)	TIME (sec)	REMARK
25	11:53	
74	12: 23	
755	12: 53	
810	12:56	Dark Red Colour
900	1:06	Cherry Red Colour
911	1:13	
942	1:20	
988	1:53	Cherry red-Orange Colour
1000	2:15	
1015	2:53	
1135	3:00	Orange Colour
1200	3:53	Light Orange Colour. Kiln off gas off end firing

THE GRAPH OF FOUR HOURS TESTFIRING OF PROTOTYPE GAS FIRED KILN



V. DISCUSION OF RESULT

The result of this research work shows that insulating bricks absorb more water up to 85% than that of dense brick which is 18.8%. This is because of the presence of large number of very small voids in the insulating which makes it lighter than the dense brick. The crushing strength of the dense brick is 10.2 N/mm^2 and that of insulating is $2.5N/mm^2$. The quantity of heat store in this kiln is $97.5KJ/m^2$, this makes the kiln to fire high up to 1200^0c within four hours with heat loss of $1143.1w/m^2$. However, this kiln can fire at faster rate than the laboratory test electric kiln.

THE BASE OF THE KILN

THE REFRACTORY WALLS OF THE KILN

THE KILN COVERED WITH CRO

THE KILN WITH METAL REINFORCEMENT

FULLY CONSTRUCTED PROTOTYPE GAS FIRED KILN

TESTFIRING OF THE PROTOTYPE GAS FIRED KILN

VI. CONCLUSION

The research work on the design and construction of a prototype gas fired kiln using NSU clay refractory bricks was a success as shown in the result of test that was carried out. A well compatible and high efficiency gas fired kiln was construct having a total surface area of $0.54m^2$ ($54m^2$) and volume of $0.00684m^3$ .This kiln can fire up to the temperature of $1200c^0$ within four hours. The varieties of colours which are absents in electric kiln can be achieved using this kiln.

Base on this result, it shows that local source material (NSU clay refractory brick) can be used for building higher efficient kilns which will reduce the cost of importation of kiln and increase the nationally economic growhence reduce unemployment in this country.This study provide solution to irregular power change which have crippled the use of electric kiln. This local NSU clay bricks has composition of 48% grog (Calcined NSU clay) and 32% uncalcined NSU clay for dense brick.The dense bricks has water absorption of 18:8%, crushing strength of 10.2N/mm.The insulating brick has body composition of 16% saw dust and 44% NSU clay water absorption of 85% and crushing strength of 2.5 N/mm^2.

REFERENCES

[1]. Adegoke, O.S. et al (1987) "Summary of Raw Materials Occurrence" Guid to Non – Metallic Industrial Potentials of Nigeria Vol 1, P. 180-195
[2]. Cardew, M. (1969) Pioneer Potter (P. 162-170).
[3]. Cooper, E. (1982) Electric kiln's Potter (P. 34-36) Echea, C (2001) "Gloss Firing: Beyond Thermosensor", CPAN Journal of Ceramics, Vol. 1,No 1 p,14 -19.
[4]. Fournier, R. (2000) Illustrated Dictionary of Practical Pottery. P.183-190 Fraser, H, (1979) Electric Kilns Firing (P. 84).
[5]. Ossai A. A (2005) Introduction to Alumino-Silicate and Other Refractories (P. 128-134.) Rado, P. (1988). An Introduction to the Technology of Pottery. P 75-88
[6]. Rhodes, D. (1977) Kilns, Design, Construction and Operation (P. 88-90).
[7]. Rhodes, D. (1973) Clay & Glazes for the Potters (P. 16-34).
[8]. kashim, I.B. (1999)" Manufacturing of Electric Kiln from Locally Derived Refractory Materials in Nigeria" Journals of Industrial Design and Technology, Vol.1, No 1., p. 64 – 70.
[9]. "TheJournal of Liberal studies"(2012 - 2014) Improvisation in kiln Construction Materials, an Approach in a Depressed Economy. Vol 15, No. 1. Retrieved from editor @Jls. Online.