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Design, Construction and Performance Evaluation of a Gas Fired Kiln

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A B S T R A C T

Pottery production is one of the ancient crafts in Nigeria that is still being practiced in most parts of the country today. Firing of pottery in Nigeria was usually done in the past using open air firing technique. Due to technological advancement and modernization, a more refined way of firing ceramic wares using kiln has been adopted by a lot of Nigerian Potters. A Kiln is a box or structure of refractory bricks into which heat is introduced and controlled to fire the clay bodies and glazes. Ceramic production is incomplete without subjecting the wares to firing. The Department of Art and Industrial Design, Rufus Giwa Polytechnic, Owo does not have a functional kiln that can be used by students to complete their ceramics production, this necessitated this research. This research adopted a practice-led research approach. The materials used for the production were locally sourced to formulate the bodies for the production of bricks that was used for the construction of the kiln. The efficiency of the kiln was assessed by test-firing wares in the kiln. It was concluded that the materials for the construction of kilns are abundant in Nigeria. The researcher recommended that Art and Industrial Design Departments in higher institutions in Nigeria should endeavour to produce firing kilns using locally sourced materials as this will reduce the cost of importing industrially produced kilns. This will also expose students to the process of kiln design, construction and testing.

Keywords: Design, Construction, kiln, Performance

1. Introduction

Pottery production in Nigeria has been in existence from time immemorial. It is a wide-spread craft which meets the needs of society as cooking utensils, water storage and implements of ritual. Until the present time, not much has been done in the area of kiln construction and performance in the country. Most of the institutions rely on imported kilns from abroad. Saibu (2005) defined kiln as a firing chamber composed of insulating or refractory bricks which are capable of resisting, accumulating, retaining or conserving heat input from heat source. It is a box of refractory bricks into which heat is introduced and controlled to fire the clay bodies and glazes. Rhodes (1981) described kiln as a refractory chamber meant to retain heat which must be constructed with materials which are sufficient refractory so that melting, cracking and slogging will not occur and heat loss would be reduced. The brick kiln was a major advancement on the technology because it provides a stronger brick than primitive sun-dried product. Without kilns the conversion of green ware into hard bisque ware or gloss ware would not be achieved.

A gas kiln is defined by Saibu (2005) as the type of kiln that employs the use of liquidified natural gas or domestic cooking gas as a source of fuel for firing ceramic products. Burners and other accessories that would allow effective firing are used while burning is facilitated as a result of the oxidation taking place during firing. According to Omoraka and Akinbogun (2009) and Fatuyi (2000) it is important to identify the possibility of developing indigenous technology for ceramics product.This research adopted the use of indigenous technology for the design and construction of kiln.

1.1 Problem Statement/Justification

The department of Art and Industrial Design in Nigerian institutions runs programme that are either Industrial or Fine and Applied Art base. Ceramics is one of the specializations in Industrial Arts, saddled with the responsibility of teaching students how to produce fired and glazed clay wares. At present, there is no functional kilns in the Department of Art and Industrial Design, Rufus Giwa Polytechnic, Owo, Ondo State that could be used to bisque or glaze fired student works making the production process of ceramics to be incomplete. Transporting green ware to the neighboring institutions or entrepreneur where this equipment is available is not advisable. This is as a result of the bad nature of our roads that could render the students' effort futile if care is not taken.

Ceramics as a profession has contributed immensely to the technological advancement of the modern world. The field primarily concerned with the treatment of non-metallic and inorganic materials by various processes including heat to produce articles with aesthetic or utilitarian properties. There will not be anything called tiles, sanitary wares, wash hand basin, plates and mugs if not for ceramics. The production of these vessels cannot be completed

without the availability and usage of a kiln. The fact remains that there is no one in urban centres in Nigeria that do not make use of one ceramic product daily; virtually all buildings in the urban centre make use of ceramic products. The clay as one of the main materials used for production is not usable if not subjected to firing. With little drop of water on objects made of clay can easily slake and destroy the creative skills and beauty of the piece.

Presently at the department of Art and Industrial Design, Rufus Giwa Polytechnic, Owo, the kiln which is the most important equipment used for the firing of ceramic products is not available. For a product to be considered as ceramic it has to be fired inside a kiln. There is urgent need for the construction of an effective kiln, as this would not only make teaching and learning easier but would arouse students' interest in the profession. The use of kiln cannot be overemphasizing; it is only when a vessel is fired and probably glazed that could be appreciated by all.In lieu of this, there is need to formulate body for the production of bricks that could be used for the construction of a kiln for effective firing.

2. Methodology

Practice-led research design was adopted for this research because it is a practical research that requires hands-on production. The research was divided into the following phases: design production, sourcing for materials, formation of insulating bricks, firing of insulating bricks, kiln construction and Performance assessment.

The following materials were sourced for the construction of the loom: Kaolin from Akure, Saw dust from Owo and Clay from Sobe in Edo state. AutoCAD software was used to generate the design for the loom. This design served as a guide for the construction process. The performance of the kiln was assessed through double testing firing.

3. Design and Construction of Gas Fired Kiln

Kiln design and construction is not just pilling of refractory or insulating material to house heat directed into it for the firing of ceramic wares. It is a skill that needs to study the technicality of the production for effective and efficient firing of ceramic wares. The present environmental problem of global warming and pollution has made it becoming necessary for environmentally friendly materials and fuels to be used for kiln design and construction. They are three basic design options for kiln construction; updraft, downdraft and cross draft.

The downdraft kiln has burners located on the sides of the kiln. Brodie (1982) sees it as a more complex system of kiln than the updraft kiln in that the exhaust as well as the intake is at the bottom. This causes the heat to affect the wares on both its upward and downward paths. The flame and the heat stay in the kiln for a longer time and more of the heat is utilized before it exits from the kiln. This type of kiln requires a chimney to induce enough draft. This type of kiln provides even distribution of heat when compared to updraft and cross draft kilns. This has made most potters to adopt this design option. This type of kiln design option was used for this study as seen in Fig. 1 and Fig. 2. These designs were produced using AutoCAD software

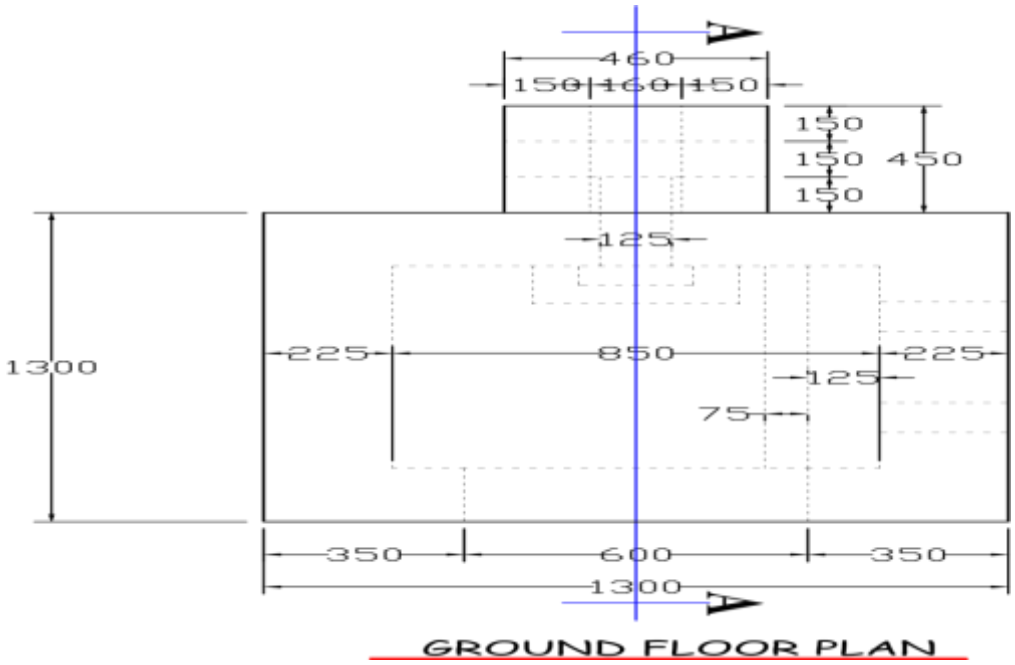

Fig. 1 - Ground Floor Plan of the Kiln

Source: The researcher (2024)

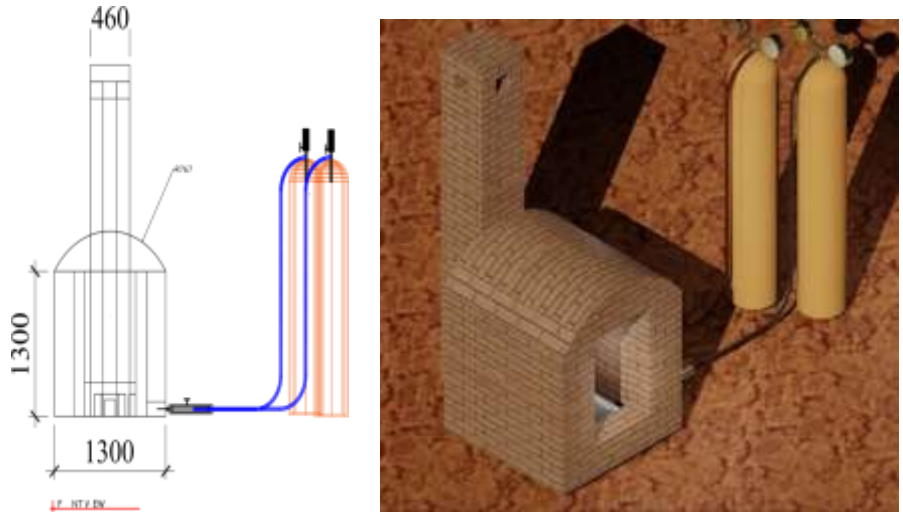

Fig. 2 - Front View of the Kiln; 3D Design of the Proposed Kiln (Side View)

Source: The researcher (2024)

3.1 Composition of Insulating Bricks

Ewule (2003) noted that Nigeria is richly endowed with ceramics mineral resources which include quality kaolin. The use of kaolin would be restricted to the fact that it is the primary material for the production of insulating bricks. Kashim (2000) refers to insulating bricks as bricks designed especially for greater heat retention because they have a multitude of air cells in the materials which is used as effective heat barrier. The kaolin needed for the kiln construction was sourced from a site beside Fiwasaye Girls Grammar school, Akure. The kaolin has been exposed due to ongoing excavation around the school. The saw dust needed was also sourced from a saw mill in Owo while the clay for slip was gotten from Sobe in Edo State. The kaolin collected was carefully sun-dried and prepared to avoid contamination, after which it was crushed into powder. The clay was soaked in water to make it into slurry.

Several experiments were carried out to ascertain the right blend or mix that would be most suitable for the composition of the bricks. It was discovered that the mixture of 50% of kaolin, 40% of sawdust and 10% of clay slip were most suitable for the composition of insulating bricks. The percentage compositions that were used for the composition were measured by volume.

3.2. Moulding of Bricks

This is the process of shaping the bricks into the desired shape. This is done with the use of mould. Two sizes of mould were used for the production of the bricks; big mould size of 34.5cm by 11.5 cm by 8.5 cm while the small mould size of 22.5cm by 11.5cm by 8.5 cm. The mixture of kaolin, sawdust and clay slip was fed into a lubricated mould, pressed and agitated out under a great pressure to release the bricks from the mould.

3.3. Drying of Bricks

This is the process of exposing the bricks to airflow to eliminate the water of plasticity. The bricks were arranged under a shed to be air dried for weeks before they are fully dried. The drying of bricks was gradually carried out and this led to the reduction of the bricks. The reduction in size was noticeable in both the big bricks and the small bricks; the big brick size is 32cm by 10.5 cm by 8cm while the small brick is 21.5cm by 10.5cm by 8cm.

3.4. Firing of Bricks

According to Rhodes (1981) the process of firing clay to make it hard and durable is of great antiquity. The early man's way of firing pottery wares was done in the open air or shallow pit. The bricks were fired using wood in an open air. The firing gives strength and hardness to the composed insulating bricks. This is shown in Fig. 3 below.

Fig 3 - Firing of insulating bricks

Source: The researcher (October, 2024)

4. Construction of the Kiln

4.1. Construction of the Shed

Kiln shed is a protective housing of the kiln in order to protect it from been damaged by weather conditions. The construction of the kiln shed was the first step in any outside kiln construction. The dimension of the kiln shed was 20ft *24ft, it was constructed with cement blocks raised to three couches with the foundation as the fencing, the roofing was built using corrugated zinc roofing sheet supported with galvanize pipe as the pillars at the four corners. In constructing the kiln shed, some factors were put into consideration such as direction of wind, space, size of the kiln, height of the chimney

4.2. Foundation and Floor

A suitable floor made of concrete on a well bedded hard-core base was built. This holds the walls erect and to keep rain water from running under the kiln. The floor concrete was made from the mixture of gravel, sand and cement. After adequate dryness of the cement floor, the construction of the kiln floor began by spreading the mixture of clay slip, grog, kaolin, sawdust and sodium silicate on the cement floor with the use of hand trowel before placing bricks on it as seen in Fig. 4. The bricks were placed at the angles first so as to ensure straightness. Three layers of bricks were laid on the floor bed to minimize heat loss.

Fig. 4 - Making of the foundation.

Source: The researcher (October, 2024)

4.3 The Burner Hole

The burner hole of the kiln was created with ample space necessary for combustion of fuel to take place. Two burner holes of equal dimension were created at the sides of the kilnto make the kiln more efficient. The dimension for each burner pot was 5inches ✕ 4inches as seen in Fig. 5.

Fig. 5 - The construction of the burner hole on the kiln

Source: The researcher (October, 2024)

4.4. The Flue Exit

According to Rhodes (1981) a kiln of about 30 cubic foot should have a flue opening of about 45 square inches, to get this dimension, a flue size of 2inches wide was created for every one feet of the width of the kiln and a flue size of 1.5 inches wide was created for every one feet of the length of the kiln.

4.5 The Wall

The wall of the kiln was constructed using a double wall for adequate heat retaining capability. The bricks for the construction were of good quality with straight edges. Rhodes (1981) pointed out that important thing in the building a brick wall is to keep the structure level and plumb. In order to achieve this, each brick was carefully placed and tapped with the hand or trowel until it lined up perfectly with the rest of the structure as seen in Fig. 6.

Fig. 6 - Building of the Wall; Chimney and Arc in progress

Source: The researcher (October, 2024)

4.6. Door

For the purpose of this study the bricking method was adopted. The door is expected to be bricked in before each firing. The opening would be plumbed with the sides parallel and squared with each other whenever firing is done.

4.7. Chimney and Damper

According to Rhodes (1968), the chimney cross section should be at least equal to that of the flue. And that each of the horizontal flue must be compensated by 2 additional feet of chimney. This rule was strictly adhered to in the building of the chimney. The chimney was built in such a way it exit at the top of the roof to release excess heat and gases to the air in order to avoid fire outbreak during firing. Fig. 7 show the fully constructed kiln with the chimney and damper.

Fig. 7 - Completed Kiln project

Source: The researcher (October, 2024)

5. Performance Evolution

5.1 First Firing

The kiln was subjected to first firing; this was done in order to burn off the wood that was used for the construction of the kiln arc. The kiln door was brick in and the second burner pot was closed. One burner was used for the burning of the wood. The burner was switched on to release hot gas to the kiln chamber. After 30 minutes of firing the heat was increased thereby increasing the rate of combustion. This stage of firing lasted for 1hours. The firing was accompanied with smoke coming out from the chimney and spy hole as the result of the wooden frame used to construct the arc. After this, there was a reduction of the smoke coming out form the kiln opening. It became evident that most of the combustible materials present in the kiln have been burnt out. At this stage the kiln chamber was becoming visible. The firing was continued until the researcher witnessed there was no sign of smoke coming out of the chimney. The gas burner was turned off and left to cool gradually.

5.2. Second Firing

For the purpose of validating the efficiency and performance of the newly constructed kiln, ceramic wares and bricks were produced and fired. The bricks were loaded at the base of the kiln while the wares were stacked at the top of the bricks. The bricks and wares were loaded in such a way there was a gap between the wares for better heat flow; thereby preventing danger in the course of the firing. The wares were fired at bisque temperature ($900^{O}C$). The firing started with preheating by setting the burner pressure low to develop a slow heat. This was also to allow moisture contents within the kiln and wares to escape through the kiln openings. The spy holes were opened for two hours thirty minutes when firing started. The preheating was carefully carried out until the researcher discovered that there was no more moisture coming out of the kiln thereby increasing the gas burners pressure to produce a very high heat for full firing. It was observed after some time that the gas cylinder was freezing making the researcher to heat up the cylinder thereby increasing the pressure of the gas release to the burner for combustion. This process lasted for one hour twenty minutes until one of the burners started malfunctioning. The firing was continued with one burner for additional four hours until the wares are red hot. The temperature was monitored by infrared thermocouple. The kiln was offloaded after 48 hours and wares were sorted. It was observed that bricks were fired fine and the wares came out fine except that four wares were broken and three wares were having network of fine cracks. Fig. 8 shows the process of loading the wares for firing while Fig. 9 shows the firing process.

Fig.8 - Wares ready for firing; Loading of bricks and wares

Source: The researcher (October, 2024)

Fig. 9 - Firing in progress; Offloaded wares

Source: The researcher (October, 2024)

To ascertain the performance of the kiln, one more firing was done. The kiln was loaded with thrown wares and fired to maturity. The entire process of firing the kiln to bring the wares to maturity took about six hours thirty minutes, this involved preheating which took about 2 hours 30 minutes. All the wares were fired to maturity without being broken. See the plate seven below for the pictorial representation of the wares. It was expected that the kiln should be able to fire to gloss temperature (1200ºC-13000ºC) without melting or collapsing of the bricks. Fig. 10 shows the final result of the second firing.

Fig. 10- Firing Result from Second Firing

Source: The researcher (October, 2024)

6. Conclusion

Kiln and firing is the peak of ceramic production processes. Kiln is a compartment that retains the heat energy generated by combustion of fuel. Gas kiln operates through the release of heat energy. The cost of fuel for firing kilns in Nigeria has risen and may continue to rise but the period for firing the newly constructed kiln has made it to be cost effective. The time for firing the kiln is six hours and thirty minutes with an average fuel consumption of 20kg of liquidified natural gas.Nigeria is blessed with mineral resources out of which kaolin is one of them. With this project it was discovered that efficient and reliable gas kiln could be constructed with the use of locally available materials. The mixture of 50% of Akure kaolin, 40% of sawdust and 10% of Sobe clay could be used for the construction of gas kiln. This composition could be fired to gloss temperature without deforming.

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References

Brodie, C. R. (1982). *The Energy Efficient Potter*. New York: Watson Guptil Pub.

Ewule, E. E. (2003). Clay and its many uses. *Ashakwu Journal of Ceramics*. 1 (1), 21-28.

Fatuyi, O.A.(2009). Characterization, property testing and documentation of Afowa and Igarra clay in Edo state. *Ashakwu Journal of Ceramics*. 6, 12-18.

Kashim, I. B. (2000). *Ceramics Materials and the 21st Century Housing Provision in Nigeria: Effective Housing in the 21stCentury in Nigeria*. The publication of Environmental Forum, Federal University of Technology Akure.

Omoraka, A.E. & Akinbogun, T. L. (2009). The evaluation and production of atmospheric gas burners for ceramic firing. *Ashakwu Journal of Ceramics*; 6, 57-65

Rhode, D. (1981). *Kiln building*. Pennsylvania: Chilton book.

Rhodes, D. (1968). *Kiln Design, Construction and Operation*. New York: Pitman Publishing Corporation

Saibu, A. (2005). *Fundamental of Ceramics*. Benin City: Maramon press