SMALL SCALE BRICK PRODUCTION NIGERIA

DOWN DRAFT KILN

DRAWINGS, CONSTRUCTION AND OPERATION INSTRUCTIONS

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

PROJECT NO. 3 - B - 86 - L027/07

PRAIRIE MASONRY RESEARCH INSTITUTE

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INTRODUCTION

This report contains information relating to the construction and operation of a low tech down draft kiln which is to be used for small scale manufacturing of burned clay units. The kiln design is based on available information and knowledge and is intended for usage in remote areas of developing countries.

The materials needed for construction of the kiln can vary to reflect availability of cement, gravel, clay, steel, etc.

The drawings and guidelines provided in this report pertain to a particular kiln to be constructed in Nigeria at a location with road access and access to concrete and reinforcing steel. In addition, some metal parts listed in this report can be replaced or eliminated.

Information relating to the operation of this or similar kilns is also given in this report.

ACKNOWLEDGEMENTS

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DOWN DRAFT KILN

DESCRIPTION

A complete set of drawings for constructing a down draft kiln are attached at the back of this report. In addition, reduced in size drawings are incorporated into the report and referred to throughout the body of the text. These reduced figures are not to scale. Figures 1 to 8 provide an overview of details, with a key to the legend provided in Table 1.

The kiln consists of one chamber and can be constructed in different sizes. The dimensions of the kiln shown in the drawings provide for a capacity of approximately 45 m³, which can produce relatively large quantities of products.

The useful (inside) dimensions of the kiln shown in these drawings are:

3.30 m wide, 6.00 m long and 2.25 m average height (2.60 m at the crown of the vaulted roof.)

The kiln is composed of:

- 2 vertical endwalls (2) 30 cm thick containing one door 90 wide by 1.80 m high made in one of the endwalls to allow the loading and the unloading of the kiln with products.
- 2 vertical side walls 60 mm thick (1). In the lower part of each side wall, there are three fire boxes (4). Each fire box shown in the drawings, which is designed to use coal as fuel, consists of:
  - 1 combustion chamber where fuel is placed (5).
  - 1 grate supporting the coal and allowing the passage of air and evacuation of ashes (6).
  - 1 chamber for ashes (7).
  - Two doors (9) to control the air intake and consequently to regulate the firing temperature.
  - 2 flame bridges (8) (one on each side) to force the flames and the combustion gas upwards in order to avoid direct contact between the fire and the products, which contact will affect the appearance of the fired brick.
- 3 flue gas ducts (10) covered with slotted floor blocks or lines of spaced bricks.
- a 210 mm thick vaulted roof (3) supported by the two 30 cm diameter holes (18) are made. The holes are blocked off during the firing and opened after firing for cooling down the interior of the kiln and the products.
- 1 chimney (15), at least 6.00 m high, made of masonry, connected to the flue gas ducts, which creates sufficient natural draft to evacuate combustion products. The chimney has, at its base, a small opening (17) where a small fire is used to warm the chimney and create a draft, thus establishing a flow of air (combustion air) in the fire boxes.
- 1 damper (16) to control the draft and regulate the firing rate and temperature. Because the thermally induced movements will affect the arched roof of the kiln, it is important that the roof is externally braced. This kiln is braced by means of 2 I Beams placed horizontally at the base of the vault and leaning on vertical I beams (11). The lower extremity of the vertical I beams is fixed in the ground, and the top extremity is anchored to the extremity of the opposite I beam by means of rods. The vault is covered with a filling of earth and waste products, for improved insulation and to stabilize the vault.

In the case of the small size box kiln (5.5 m³ capacity) the stability of the structure is enhanced by buttresses which prevent the vertical sidewalls from moving outward and causing the vault to collapse.

A roof is absolutely necessary to protect this type of kiln from rain. The recommended roof is a metal structure supported by the extended vertical I beams and covered with corrugated iron sheets. Another type of roof (wooden structure + roofing tiles) can also work.
1. Vertical Side Wall (600 mm)
2. Vertical Endwall (300 mm)
3. Arched Roof (270 mm)
4. Fire Box
5. Fuel Chamber (for coal)
6. Grate
7. Place for Ashes
8. Flame Bridge
9. Fire Box Doors
10. Flue Gas Duct
11. U-Channel C75
12. Tie-rod 3/4"
13. Filling up with ground and brick waste
14. Loading and unloading door
15. Chimney (min. 6000 mm high)
16. Valve or damper
17. Opening for preheating the chimney
18. Opening for cooling
19. Bolt 1/2" x 1 1/2"
20. Shelter (steel or wood) (protects the KILN from the rain).

**NOTE:** Dimensions of mortar joints: 2 or 3 mm

Table 1 - Key to the legend
Figure 3. Section BB
Figure 5. Section DD
Figure 6. Fire Box
Figure 7. Chimney Detail

Figure 8. Framing Detail
KILN CONSTRUCTION

1. Foundations
The kiln has to be built in a dry area and where the water table level is very low. The foundation is usually made of concrete (1 part cement, 3 sand, 4 aggregate). The concrete is protected from the heat by masonry or soil to maintain the temperature of the concrete below 200°C. The prepared drawings provide for these guidelines.

2. Type of Bricks to be Used
The brick to be used for making walls and arches are of standard sizes. Arches can also be made of shaped brick the use of which will enhance the quality of the arch, ensuring very small joints and a stronger structure. Such bricks can be shaped with a manual press.

Figure 9. Arch with Standard Size Bricks
Figure 10. Arch with Shaped Brick
Figures 9 and 10 Demonstrate Arch Construction Techniques

It is preferable that surfaces exposed to fire be constructed with refractory brick. In developing countries, such brick are not available most of the time and have to be imported at a very high cost. It is for this reason that standard solid brick are recommended for use.
One alternative solution consists of making the refractory brick on site by utilizing the constructed kiln and extending the height of the chimney to in order to increase temperatures during operation thus producing refractory quality units.

In most cases, kilns (1010°C max.) built in developing countries are entirely built with ordinary red plain brick which are usually available locally at affordable cost. For the present kiln, 5000 refractory units will be provided for the construction of the fire boxes only. The other parts of the kiln will be constructed using available burned clay units.

3. MASONRY MORTARS

Masonry walls are constructed with refractory mortar or clay. These mortars can be produced using the following mix of available materials.

a. Where ordinary red plain brick are used, use clay or fire clay (clay mixed with fired brick crushed into fine particles). Salt can also be added to decrease the melting point and to get a better cohesion between the bricks after the first firing.

b. Where refractory brick are used, joints have to be made of refractory mortar (1 part refractory cement + 2 parts red brick crushed into fine particles.)

c. In places where masonry reaches a temperature less than 400°C, joints can be made of mortar of the following composition:

- 1 part normal portland cement.
- 1 part lime
- 4 parts sand

In order to ensure the shrinkage will be small and cracking minimized, the joints must be very thin (2 or 3 mm).
4. Starting Up

When firing for the first time, the heating-up of the kiln has to be very slow to ensure slow steam migration. Since the walls are very thick, the water transformed into steam must be given enough time to escape without causing damage to the structure. Small cracks will appear in the masonry wall assembly, but they are considered normal and cannot be avoided. After a firing cycle, the joints of the masonry kiln will experience shrinkage; it is recommended to protect the outer side of the kiln from the rain by filling up such shrinkage joints with ordinary Portland cement mortar.

5. Covering

Depending on the weather and the climatic conditions in the area and the kiln location, protection of the kiln from the rain may be necessary. It is highly recommended to provide protection during the construction since a single heavy rain can very seriously damage the partially completed kiln. Protection after the unit is completed will also ensure that the products are not affected by rain prior to firing. A steel structure covered with iron sheets is the easiest solution except if the smoke is evacuated under the roof. In this case, the sulphur containing smoke will condensate on the steel and be transformed into sulfuric acid which will corrode the steel. A wooden structure covered with roofing tiles is also a good solution with the added advantage of not being susceptible to acid.

6. Skills Needed to Operate the Kiln

a. Loading.

The setting of the products is very easy and no experience is needed. See Figure 15 for recommended arrangement of the bricks to be fired.
b. Firing

Some technical background is needed to be able to operate this type of kiln. As with any kiln, the operator needs some practice and experience to obtain a good quality of firing. With this type of kiln, it can be of some benefit to measure and check the temperature inside the kiln with a pyrometric stick.

(For the Nigerian project an individual has been trained for this task in Canada and he will transfer his knowledge to the local groups.)

7. Required Materials (for a kiln of 45 m³ capacity)

All the materials needed to build such a kiln can be locally purchased or manufactured, and no equipment has to be imported. Depending on the type of fuel utilized, some equipment might have to be imported to furnish the fire boxes. If coal is utilized as fuel, grates are necessary. Grates made of normal steel can be made locally, but they will not last very long (less than two years). Ideally, they should be made of cast iron (if it can be obtained locally).

If heavy oil, diesel, gas, etc. are utilized as fuels, special burners are needed together with storage tanks, pipes, pumps, etc.

8. Type of Fuel which can be used.

As the kiln is equipped with fire boxes, different types of fuel can be utilized, namely fire wood, coal, used oil, heavy oil, diesel fuel and gas.

The description of the fire boxes is given in the following sections.

9. Fuel Consumption

The average value of the energy consumption in the case of an intermittent kiln is 1,200 Kcal to fire 1 kg of dry clay (3 times the consumption of a continuous kiln).
10. Quality of Firing

The quality of firing is excellent. The products are never in contact with the fire or flames, as they are fired by the hot gas passing between them. Therefore, a very constant quality of firing is obtained as the kiln is very easy to operate and to regulate.
1. Introduction
The most important operation in fired clay brick and tile production is firing.
The fuel utilized in developing countries is very often fire wood, agricultural waste or coal. Due to the very difficult deforestation problem, many countries are taking measures to reduce or eliminate the use of wood.
In some areas, other solid fuels such as coffee husks, rice husks, or saw dust are available and can be used.
The use of coal can constitute a valuable and economical solution in coal producing countries.
In the urban centres of all African countries, a lot of used lubricating oil is removed from automobiles and electrical transformers. This oil cannot be used for the same lubricating purposes without expensive refining techniques, but it can be used in fire boxes of kilns to fire clay products.
The fire box systems using coal or waste oil is described in the following section, with their application to kilns in the fired clay industry discussed.

2. Use of Oil in Fire Boxes
a. The waste oil can only be collected from gas stations in urban centres. At each of the stations, the oil is either extracted from the gas stations container, or a full barrel is exchanged with an empty one. Occasionally, the waste oil collector offers to leave empty drums at the gas stations which are discarding their oil by pouring the oil over the land in back of the garage or dumping it down drains. The oil, collected once a week from the different gas stations, is brought to the brickyard where it is cleaned before being utilized.
b. Cleaning the Oil
Waste oil requires simple treatment before it can be used as fuel. Drums left at gas stations will often contain metal filings, rocks, sand, water and other debris. All these foreign solids and the water must be removed as illustrated in Figure 10.
The oil is first poured through a screen (60 mesh or finer) into a clean drum that is equipped with a tap located as near to the bottom as possible. The oil is left to stand for a few minutes to allow the water to settle to the bottom of the barrel. The water is removed by opening the tap (which remains open until oil flows from the barrel). The waste oil is then ready for use.

2.2 Functioning Principle of the System.
Waste oil by itself will not burn. However, it can be made to burn under certain conditions. The waste oil is mixed with a small amount of water and dripped onto a hot surface in the fire box chamber. The water vaporizes instantly and the oil becomes a flammable mist. If the chamber has been sufficiently preheated, the oil mist will burst into flame. The heat of the burning oil will then maintain a high enough temperature in the fire box to continue the burning process.
The operation of the waste-oil burner is very simple, but it does require frequent attention and a specially designed fire box. The fire box is fitted with two metal doors. A large upper door allows the loading of the wood or charcoal fuel used to preheat the fire box. A smaller door, positioned below the larger door, permits control (see Figure 11). Inside the fire box, three cast-iron plates are slant-mounted in a stair step fashion (see Figure 12). These plates are called "splash-plates." Separate oil and water containers are positioned above and to the side of the fire box.
Figure 10 Cleaning the Soil

Figure 11 Fire Box Doors

Figure 12 Functioning Principle
Tubes lead from the containers to a short metal trough located on top of the fire box. The oil and water are gravity fed into the trough where the two liquids mix. The mixture then flows through a hole in the top of the fire box and drips onto the splash-plates. The splash-plates are first heated by a charcoal or wood fire beneath them. Gate valves on the oil and water containers are adjusted to permit a flow of four drops of oil to one drop of water. The oil and water mix in the metal trough on the fire box. The mixture then drips onto the hot splash-plates in the fire box. The waste oil ignites after splashing off the iron plates. The heat generated by the burning oil keeps the splash-plates hot and the charcoal or wood fire is allowed to die out. It is important to closely control both the amount of oil and water dripping into the fire box and the draft through the lower fire box door.

The height of the chimney of the kiln, and the incorporated damper will provide additional control of the temperature of the kiln.

2.3 Application of the System to the "Box Kiln"

Figure 13 represents a down draft kiln having two fire boxes on each side. (The detail drawing shows three such boxes on each side because of the size of the kiln). Each fire box contains three cast iron plates measuring 18.00 cm by 13.00 cm slant mounted stair-step fashion. Each fire box has two doors. The larger top door is used for loading the wood or charcoal to preheat the metal plates. The smaller lower door acts as a damper to control the flow of air into the kiln.

A tank of water and a tank of waste oil are located on each side of the kiln. Tubes leading from the tanks have gate valves located above each of the fire boxes.
To start firing, the fire boxes are loaded with fire wood through the larger upper door and fires are started in all the fire boxes. This heats up the iron splash-plates and starts a good draft. Openings at the top of the kiln lets out the smoke and hot air until a sufficient draft is moving into the large chimney. If, due to the design of the kiln a natural draft cannot be created, a small fire may have to be made in the chimney itself so as to preheat the chimney and create a draft. (This aspect is discussed in previous sections of this report).
Both the upper and the lower doors of all the fire boxes are left open during the preheating phase. After about an hour, the iron splash-plates will be hot enough to vaporize the oil and water mixture. The vents on top of the kiln are closed and the oil water firing can start.
The gate valves above each fire box are adjusted so that four drops of oil enter for each drop of water. The oil and water mix in a short metal trough, fall through a hole on the fire box top, and onto the splash-plates. Water is vaporized and oil bursts into flame. Proper adjustment of the oil and water flow requires frequent attention. The draft control doors on the fire boxes may also need to be checked frequently. The burning rate can easily be controlled by regulating the flow of oil and water.

Fig. 13: BOX KILN
3. USE OF COAL AS FUEL

A fire box using coal is shown in Figure 14. The main element of this type of fire box are the fuel damper, the grate usually made of cast iron, the chamber for collecting the ashes and two doors (one for the main fire box and one for the ash dump). Figure 14 shows a coal burning fire box.
The upper door is used to feed the fuel chamber with coal and also to control the air intake. The lower door is used to control the air intake and to remove the ashes after firing. Steel can also be used to manufacture the grates, although they would not last for more than two years. The space between the bars of the grate should be less than 30 cm. Fire boxes working with coal are very easy to operate. To start the firing of clay products in a kiln equipped with this type of fire box, fire is first lit in all the fire boxes with some fire wood. When it is well burning, coal is added. If stone coal is used, the slots in the grates will ensure that the fuel does not fall through. On the other hand, if powder crushed coal is used, some water first has to be added to the coal and well mixed in order to give some cohesion to the coal. The mixture can then be placed on the grates of the fire boxes without falling through. Adjusting of the sizes of the slots may be required in some cases. The draft is created by heating up the kiln and its chimney as mentioned earlier. Initially the firing can be regulated by adjusting the position of the fire boxes to allow more or less combustion air to enter.

4. OPERATING PROCEDURES

The operation of down draft kiln is not continuous, but rather it follows the following cycle.
- loading phase - usually one day is required.
- firing phase -(depends on the products produced) usually one day.
- cooling phase - one day.
- unloading phase - one day.

Under normal conditions a cycle takes four days.
a. Loading Phase

The floor above the flue gas ducts is contracted and maintained level. The setting of the products is thus very easy.
If roofing tiles are to be fired, the tiles are placed vertically, one against another, to reach a density of piling as high as possible. There will always be enough space between the tiles to allow air to pass to have a sufficient draft. When standard bricks are manufactured, gaps have to be left between the bricks to allow the gases to pass to create a draft. Once the loading is completed, the door (4) is closed and sealed with mud.

b. FIRING PHASE
Prior to firing the fire boxes, a draft has to be created. Through the opening provided at the base of the chimney, a small fire is made with fire wood inside the chimney in order to heat it up and create a natural draft. When the chimney is heated up the small opening is closed and the fire is started in the fire boxes. The different types of fire boxes using different fuels are described earlier in this report. Once the draft has been created inside the kiln, fire is lit in all the fire boxes. The combustion air enters through the doors of the fire boxes, and combustion of the fuel occurs in the combustion chamber. The hot combustion gas goes up between the side walls and the flame bridges, and rises to the vaulted roof. It is then fanned out over the entire kiln area and drawn downwards by the chimney draft. The combustion gas is drawn down through the entire kiln setting to the kiln floor, where it is discharged through the slotted floor into the flue gas ducts, and then out through the chimney. The draft, and thus the firing, can be regulated by opening or closing the doors of the fire boxes, and also by lifting or lowering the damper placed before the chimney.
It takes 24 hours to fire the products. After 24 hours, the supply of fuel is stopped and the damper and the doors of the fire boxes are partly closed, to reduce the draft and thus the cooling rate of the products. The firing speed depends on the type of product and the density of the setting and some experience will have to be obtained by trial and error.

c. COOLING DOWN PHASE
The damper and the doors of the fire boxes are kept partly closed for about 12 hours, until the temperature has sufficiently decreased. The doors of the fire boxes are then completely opened, as well as the loading/unloading opening and the two holes in the top part of the vaulted roof, in order to cool down the products at a faster rate.

d. UNLOADING PHASE
The products are removed when they are cool enough to handle. Once the kiln is emptied, a new cycle can start. A team of no more than 40 people is needed for the total operation of pressing the units, loading and unloading the kiln.