PRODUCTION OF REFRACTORY KILN-SHELVES AND PROPS USING LOCAL MATERIALS

BY

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DECLARATION

I, MOLOKWU, GODWIN MADUABUROCHUKWU solemnly declare that this thesis is the report of my own research work on the "Production of Refractory Kiln-shelves and Props Using Local Materials".

It has not been submitted in any previous application for a higher degree.

Signature: _____

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CERTIFICATION

This thesis entitled "Production of Refractory Kiln-shelves and Props Using Local Materials" by Molokwu Godwin Maduaburochukwu, meets the regulation governing the award of the degree of Masters of Arts (Industrial Design) of Ahmadu Bello University, Zaria.

It has this day been approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to my late Mother and Father, Mrs. J.N. Molokwu and Mr. L.W.I. Molokwu.

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ABSTRACT

MOLOKWU, GODWIN MADUABUROCHUKWU

Production of Refractory Kiln-Shelves and Props Using Local Materials

Master of Arts, Industrial Design 1991 33 Pages, 3 tables , 3 Figures, 7 Plates.

The problems of this study is concerned with exploring into the method of making good kiln-shelves and props which could be more reliable and durable using local materials that are easily obtainable. Sabon-Gwaram kaolin from Bauchi State and Bomo secondary clay from Kaduna State were chosen.

Pressing method which was adopted as the technique of production needed the use of press-moulds. Two press-moulds: frame-mould and pipe-mould were designed and constructed using iron pieces bought from Zaria market.

The clays were collected, tested and processed. Grog was made from the primary clay. Following the result of the biaxial blend test for the grog and the clay conducted, and also following the literature review study, the proportions of the materials for the body-composition were determined. The proportions for the shelves were (1) 2 parts clay: 8 parts grog (2) 3 parts clay: 7 parts grog.

The proportion of the grog sizes was coarse grog 5, medium size 1, fine grog 4. But for the prop it was medium size grog 5 and fine grog 5 parts, in the body composition of 3 part clay: 7 parts grog. The proportion of water was 30% of the dry material in all the cases-Measurement was by volume.

A pressing-machine was initially used for the pressing. Due to the problem involved in getting access to the pressing machine, other methods of pressing were introduced, namely: "Ramming with a falling weight" for the shelves and "Poking and ramming" for the props.

The following findings were made from the study:-

(1) Materials for the production of kiln-shelves and props can be easily obtained locally.

(2) Pressing method is a very effective technique of producing kiln-shelves and props.

(3) Production of efficient kiln-shelves and props is possible without the use of a pressing-machine.

(4) High temperature above 1300 ^{o}C is necessary for the initial firing of the shelves and props to make them suitable for use at stone-ware temperature.

In conclusion, production of efficient kiln-shelves and props with easily accessible local materials has been made possible using simple equipments and using simple production process.

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DEFINITION OF TERMS

Andalusite - A hard and refractory mineral occuring in metamorphic rocks.

Batt - A slab or tile of refractory materials used for supporting the wares inside the kiln.

Bentonite - Natural clays derived from weathering volcanic ash very plastic. Some have distinctive swelling property.

Body - Amixture of clays or clays and other materials ready for use in pottery work.

Binder - Plastic materials added to nou-plastic materials in order to hold them together.

Calcine - To disintegrate by heat.

Collar - Connection used at the base of props for greater stability and at the top to give larger area of support for shelves.

Corundum - A very hard alumina compound that can be made by electrical fusion of pure alumina or buxite. It also occurs in nature as expensive gemstones; ruby and sapphire.

Cristobalite - Quartz that has been thoroughly heated to a high temperature and has then increased in volume by 16 or 17%. It occurs in clay between the temperatures of 400 - 1300°C.

Defloculant- Substance added to clay slip to keep the clay in suspension in side the water.

Eutectic mixture - The proportioned mixture of two or more substances which melts at the lowest possible temperature. This temperature is called eutectic point.

Extrusion method - A ceramic production method whereby soft clay is forced through an opening that gives a desired shape.

Fireclay - Refractory clay that reaches the temperature of 1500°C before it starts deformation. It is usually found below coal seams.

Fusion - The softening of solid material by heat alone or by combined action of heat and fluxes.

Green-Stage - The stage of any ceramic product after making, before it is fired

Grog - Non-plastic material usually prefired, added to brick batch or plastic body to reduce shrinkage or to obtain special property as high thermal shock resistance.

Kaolin – The anglicised form of the China word for clay. It is used to mean primary clay. It is also called China clay.

Kiln-Furniture– Refractory shelves, props and other accessories used to support pottery in the kiln.

Kiln-Shelves – Another name for batt as above.

Kyanite – A hard refractory mineral occuring in metamorphic rock of the same class with andalusite but is slightly softer.

Levigation – The method of refining clay by carrying it in a current of water which deposits the finer particles at successive removes from the source Leach (1976).

Mica – A transparent mineral substance easily divided into thin layers.

Mineralizer– A small quantity of flux added to a brick batch or refractory aggregate to promote crystal growth or compound formation.

Mullite – An alumino-silicate compound that is very rare in natural form. It got its name from the Island of Mull off the coast of Scotland, the site of the few known natural deposits Mullite form in clay during firing. It is first observed at 1100°C. It helps the refractoriness in clay.

Pins – A general purpose support for wares in the kiln, triangular in shape with an upward point. It can be set in a set of three.

Plasticity – The property of a material enabling it to be shaped and to hold its shape.

Prop – Refractory posts for supporting kiln-shelves in the kiln.

Refractory – Resistance to heat

Saddle – A triangular bar for supporting glazed wares in the kiln.

Saggar – A refractory box or container used for holding wares in the kiln during firing.

Shelves – Another name for batts above

Spurs – The same as pins above

Stilts – Refractory pieces with three arms, each with a point of contact used for supporting glazed wares in the kiln.

Stoneware – Pottery fired to a temperature of between 1200°C-1280°C at which the body vitrifies.

Temporary binder– The binder that is added to non-plastic materials to hold them together before firing and which burns off during firing.

Thermal Shock – The shock caused due to sudden change in temperature. This shock causes the ware so affected to crack.

Viscosity – The ability of solid or semi-solid to change its shape gradually under stress.

Vitrify – To reach the point of glassification during firing.

CHAPTER 1

1.1. INTRODUCTION

"Machines starve modern man of natural exercises for his hands. Few occupations replace this loss so satisfactorily as the making of pottery" Christy (1969).

Ceramics is becoming more important in Nigeria and more people are showing interest in its products. Many educational institutions are now introducing it in their curriculum as an important part of Creative Art. It is also noticed that more individuals and groups are setting up ceramics studios and workshops. Because of these, the need for kiln accessories is increasing. The kiln accessories include kiln shelves, props, pins, saddles stilts and others.

The traditional potters can do without shelves and saggars for pottery firing because they use the traditional method of stacking the pots one on top of the other. These pots are then covered with grasses and wood, next the firing follows (The bonfire method). They do no grazing rather they do some colour decorations and burnishing. So there is no fear of the pots being stuck together by the glaze.

Kiln-shelves and props are very important materials in the production of pottery in the modern time.

Without the kiln shelves and saggars glazed wares cannot be fired in the kiln. The services they render in pottery work are to support and to seperate the wares so that the glazed wares do not stick during firing.

The importation of these necessary equipments is very difficult now in Nigeria. They are also very expensive to obtain when found. This situation is worsening daily. It is now essential that people struggle and become self sufficient in this aspect by producing these necessities by themselves.

Most of the pottery establishments that have been using kiln shelves in Nigeria have been depending on imported kiln shelves and props manufactured in overseas countries. These potters have not been thinking of how to produce these commodities themselves because they lack the initiative and the push. Also they hope to be getting the best from foreign manufacturers.

Another reason why potters did not consider making the kiln shelves and props was because most of the pottery establishments in the country were using wood firing kilns and thereby preferred using saggars.

Ewule (1988) showed that by 1988 there were twelve pottery establishments in Nigeria.

Seven of them were using wood firing kilns. Three were using wood and gas firing kilns, only two depended wholly on gas. Judging from this fact, it is clear that saggars were needed more and there was not much need for kiln-shelves. So people could not see the need to start producing kiln-shelves and props locally in the past.

The Department of Industrial Design, Ahmadu Bello University , Zaria has been making the kiln-shelves which are used in their kilns for some years now. But their durability is not yet very satisfactory, as they have short life-span. No successful attempt has been made any where in the country to produce standard props.

According to Brodie (1982), some of the problems potters encounter world wide include the rising cost of operating studios and industries. This study is aimed at contributing toward the knowledge of producing good kiln shelves and props locally, which may help in reducing an aspect of the operational cost.

1.2. Statement of Problems

The problem of this study is concerned with exploring into the method of making kiln-shelves and props which could be more reliable and durable using local materials that are easily obtainable in the country.

1.3. Objectives of the Study

The objectives of the study are:-

(1) To use local materials in producing satisfactory kiln-shelves and props that will be strong enough and be able to stand, under load, long firing of pottery wares in the kiln at an operational temperature of 1280 °C (Stone ware temperature limit).

(2) To provide the knowledge that may make potters (especially Students and small scale pottery industries) to be able to acquire good shelves and props that they will need in their studios.

(3) To help reduce dependence on importation of ceramic needs from foreign countries.

(4) To provide an alternative kiln-shelf making method that will be faster and more efficient than that being used in the Department of Industrial Design, Ahmadu Bello University, Zaria.

(5) To contribute towards reducing the operational cost of pottery studios and industries.

1.4. Limitations and Delimitations

(1) Lack of facilities for some test made it impossible to conduct some test. For example the chemical analysis test for the clay used.

(2) Lack of appropriate kilns for high temperature firing. (This could affect some of the results obtained).

(3) This study concerns intself with the production of kiln-shelves and props using the local materials

1. Sabon - Gwaram Clay - Bauchi State
2. Bomo Clay - Kaduna State
3. Grog made from Sabon-Gwaram Clay.

This research will not deal with those very refractory materials such as sillimanite, silicon carbide, magnesite and *others which are difficult to get and process. This is because* the study aims at providing practical knowledge for every potter who wants to produce kiln-shelves he will need to use. For this reason those material that are difficult to obtain and process are not included.

1.5. Basic Assumptions

(1) It is assumed that good refractory kiln-shelves *and props can be made from local materials if the* right materials are used and correct production processes are being followed.

(2) That the knowledge provided by this study will help reduce the operation cost of running studios and industries.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1. Introduction

The purpose of this review is to examine some existing literatures on the following aspect of kiln-shelf making:

(1) Some ceramic refractories

(2) Clay as a refractory material

(3) Use of grog

(4) Choice of materials

(5) Kiln-shelf making methods

2.2. Some Refractory Materials

Kiln furniture need to be able to resist high temperature. Chandler (1967) pointed out that at elevated temperature the rate of chemical reaction for most substances is enormously increased. Refractories must therefore be highly resistant to reaction with substances with which they will come in contact in service.

As Chester (1973) explains, there are many types of refractories that ceramists use today. They include:-

(a) Clay refractories - Fire clay and Kaolin. They normally consist of Kaolinite ($AL_2O_3.2SiO_2.2H_2O$) and 4-5% impurities including oxides and alkalis. Fire clay has alumina content of 25-45%.

(b) Sillimanite refractories. This group includes sillimanite, kyanite and andalusite. They are naturally occurring minerals of general composition $AL_2O_3.SiO_2$ with 45-65% alumina content.

(c) Buxite rock ($AL_2O_3.2H_2O$). This is also a naturally occuring mineral with the allumina content 75-90%; so it is very refractory. It contains, in addition to alumina, some impurities as iron oxide and silica.

(d) Corundum (AL_2O_3), another refractory material, it contains 90-100% alumina. It is also present in natural form. Gem stone such as sapphire and ruby consist chiefly of corundum with traces of other oxides.

(e) Mullite ($3AL_2O_3.\ 2SiO_2$). It contains 65-75% alumina.Natural occuring mullite is not common. According to Worrall (1975) its name is after one of few known deposits on the Island of Mull, off the coast of Scotland. Synthetic mullite is commonly used and can be made by heating a mixture of pure AL_2O_3 or Buxite with clay or Sillimanite. Chandler (1967), pointed out that the importance of mullite in refractories is that, it is the only alumino-silicate compound that remains stable at very high temperature, neither melting nor showing any noticeable reaction until a temperature of 1810 °C is reached.

(f) Silica SiO_2 - Silica is a refractory material that is readily available. It has a melting point of 1712°C Chester (1973) mentioned that silica constitutes not less than 59% of the outer most layer of the earth crust, though much of this is present in combination with other oxides. It is known in the purest form as quartz. Hassan (1990) stated that in refractory production, silica bricks are manufactured from ground ganister rock (quartzite) consisting 98% SiO_2 to which is added 2% CaO as milk of lime. The added lime serves as mineralizer to control the transformation rate of silica during firing.

(g) Magnesite refractories MgO - This belongs to the basic group of refractories. The body consists principally of 'dead burned' magnesium oxide obtained by calcining natural magnesite (magnesium carbonate) rock or from magnesium hydroxide obtained from sea water. Singer and Singer remark that the magnesium content is between 85% and 95%. The most minor content is iron oxide which may range from 8% down to 0.5% or less. Warrall (1975) shows that magnesium oxide in the presence of atmospheric moisture tend to combine with water to form $Mg(OH)_2$ which in refractory is disastrous.

This is reduced if calcining is 1500 °C or higher when the magnesia is said to be 'dead burned'.

(h) Dolomite $CaCO_3.MgCO_3$. This is a mineral with the melting point of about 2300°C. One of the difficulties in using it is that when it is calcine and the CO_2 content driven off, what remains is a mixture of magnesium and lime. Lime very easily hydrates in the presence of atmospheric moisture to disintegrate. This can be prevented by adding some silicious materials to the calcined dolomite.

(i) Silicon carbide SiC. This is a very refractory material but it does not occur in natural form. It is extremely hard. Its refractoriness is high. The thermal expansion and thermal shock resistance are good. Chandler (1967) explained that silicon carbide is made by mixing pure silica sand with high quality coke and saw dust, and heating the mixture to a temperature approaching 2500°C. In the process the silica is reduced to silicon which combines with the carbon to form silicon carbide.

2.3. Clay as a Refractory Material

2.3.1. Refractoriness of Clay:- Chester (1973) speculates that fireclay was probably the first refractory used by man. He also points out that inspite of the development of many other refractories and slag-resistant materials, clay is still widely used. The advantages of clay are that it is a common mineral found everywhere and it is cheap to obtain and easy to process. The refractoriness of fire clay and kaolin is high.

According to Rhodes (1971), "Kaolin is highly refractory and has the melting point above 1800°C and fire-clay resists fussion or deformation up to 1500°C . He also points out that fireclays are useful in a great variety of products including fire bricks and refractory parts of kilns, furnaces, boilers and melting pots.

Fire clays normally consist of Koalinite $AL_2O_3.2SiO_2.2H_2O$ together with free silica and some impurites especially iron oxide and mica. When fired at above 600 degrees centigrade the H_2O and the impurities are driven off and the clay is then a complex of Alumina and Silica, each of which has high melting point: silica 1710°C and alumina 2050°C.
With the mixture of 5.5% alumina and 94.5% silica the melting point drops to 1595°C which is the eutectic point for the two

According to Chandler (1967) kaolin consist of 40% alumina and 54% of silica and the melting point is about 1750°C

2.3.2. Firing of Clay

Chester (1973) discusses the changes that occur in clay during firing as follows.

On firing of clay to above 500°C water is expelled and meta-kaolin is formed.

At 400 - 1300°C quartz in silicious clay begins to convert to cristobalite.

Between 900 - 1000°C Gamma-alumina is present.

At higher temperature, 1300 - 1400°C. cristobalite disappears with the appearance of a difussed reflection, suggesting glass material.

Mullite is first observed at 1100 °C there seem to be no increase in the number with the increase in temperature rather there is increase in size.

The needle-like crystals found in hard-fired clay and porcelain are mullites ($3AL_2O_3.2SiO_2$).

2.4. Use of Grog

Grog which Chester (1967) also calls Chamotte is described by Leach (1977) as powdery burnt fire clay of varying degree of fineness, usually made from old saggar, crusibles etc. Grog is made by crushing such clay waste products, but such products should not contain glaze. Grog can also be made from other materials such as topaz, sillimanite or kyanite.

According to Cardew, Topaz is the only raw materials for making grog that consists entirely of mullite. This quality makes such grog of great attraction. But topaz is scarce so it is uneconomical. He further remarks that the potter's kiln firing to 1280 °C is not suitable for the operation of calcining topaz that needs up to 1480°C.

Grog is needed as an opening material for refractories. Cha..dler (1967) remarks that in general, the more the grog content in the body mixture, the smaller the shrinkage; the larger the particle size, the greater the thermal shock resistance. Kaolin based saggars, shelves and fire-bricks have the great advantage for making grogs; they continue to improve in quality with repeated firing (but not if they contain talc, for talc affects refractoriness). The mullite crystals gradually increase in size with repeated use.

2.5. Choice of Materials

It is not only refractoriness that is required for a good kiln furniture. Good composition of the materials to be used and good production process are also very essential for good kiln furniture. Cardew (1979) gave four reasons why a potter needs the best refractory that he can get.

First, batts and saggars that are very thick are wasteful of kiln space. Second, their refractoriness will be considerably above the operating temperature to be able to stand load put on them.

Third, batts and saggars have to be able to resist a good deal of thermal shock. Fourth the potters mix needs to be plastic if it is to be shaped with hand method, and plasticity is a difficult property to combine with refractoriness.

Some authors have given direction and guidelines on the choice of materials for shelf making. The following is an example by Shaw (1972):

> Fireclay refractories are commonly used, the quality is usually dependent on the alumina content of the raw material,common range containing 35-37% alumina. Sillimanite refractories made from sillimanite minerals such as andalusite and kyanite containing about 60% alumina are exellent materials for batts, slabs and supports for use in kilns and on kiln cars. Silicon carbide bonded with clay or nitride is also an exellent material for kiln furniture because of its high refractoriness under load.

Rhodes (1974) also recommends all the above materials and explains the first one further thus: "Mixture of half fire clay and half well-sized grog mixed to a stiff plastic consistency and is pounded into a wooden mold". He explains that this is best for a potter who wants to make his own shelves. Singer and Singer (1871) suggest two part grog and one part plastic material. This means grog 66.6% clay 33.3%. They go further and explain the degree of suitability and the advantages of different types of clay to be used as binder for the grog.

(1) Kaolin has the advantage of low alkaline content.

(2) Stone ware clay has the advantage of high plasticity.

(3) Bentonite should not be used because of its high flux content which is up to ten percent.

Ewule (1988) shows that he used clay for making the shelves and used the following proportion:-

High fired grog made from kaolin	70%
Levigated kaolin	15%
Levigated secondary clay	15%

The kiln shelves being made and used in the Department of Industrial Design, Ahmadu Bello University, Zaria are made with the same proportion:-

Hard grog	45%
Fine grog	25%
Levigated kaolin	15%
Levigated secondary clay	15%

As referred above, Rhodes (Ibid) gave the proportion as: Half fire clay and half well sized grog. This means - Fire clay 50%, Well sized grog 50%.

Cardew (1979) shows that if only China clay is used as main raw material and the temperature limited to stone ware range, it might be thought that the best mixture is hard grog in a matrix of China clay with just enough plastic clay to bind,for example:

Grog	50%
China	40%
Bond clay	10%

But he explains that the furniture made from this mix is disappointing in two ways:

1. They bend under load. This is because in 1250 - 1300 °C range the mullite has been formed but the crystal are sub-microscopic in size. This has not yet developed the feltted structure which keeps the shelves from bending.

2. They don't have thermal shock resistance. This is due to the matrix for it will consist entirely of free silica left after the formation of the mullite.

To be able to meet the requirements of the firing circle, the fired shelves should have the following properties as pointed out by Singer and Singer (1971):-

1. Very high proportion of the finished material should be crystal held together by minimum of glassy material which should have highest possible viscosity at the temperature of use.

2. The water absorption should be kept between 18-28% except for the small props, etc which may be impervious.

Making the shelves porous assist considerably in lowering proportion of glassy formation required to hold the crystal phase together and so increase the thermal shock resistance.

Kaolin and fire clay are refractory materials good enough for making of potters' kiln-shelves provided enough grog is used.

They are refractory enough and easy to get. High refractory materials are scarce, expensive and inaccessible to a pioneer potter who wants to make the kiln-shelves for himself.

2.6. Kiln-Shelf Making Method

Shaw (1972) mentioned plastic shaping, Casting or pressing to be followed by firing at high temperature. "Ramming with a falling weight" which Parkes (1977) mentioned in his book is a good and effective method of pressing.

According to Rhodes (1974) the potter who is bent towards self sufficiency will mix his materials to a stiff plastic consistency and pound it in a mould with a wooden mallet. This method is the least technical method of making kiln-shelves and it takes much time. Also this method does not produce efficient kiln shelves.

Slip casting is a good kiln-shelf making method for some very refractory materials. Some binding media such as clay or nitride are used with the refractory materials to hold together. Such refractory materials are sillimanite materials, magnesite, sillicon carbide. After casting they are dried and fired to high temperature.

Warrall (1975) expressed that commercial alumina can be shaped by slip-casting or by Electro deposition. When the shapes are fired, at 1700 - 1800 °C, they

become extremely strong though the temperature of firing is below the melting point of 2050°C.

Chester (1967) brings up a method capable of working with 90 percent or over of grogs. This method was developed by two Germans, Sheidhauer and Gressing AG. In this method the surface of the grog grains is covered with defloculated bonding clay slip. This is of the same consistency as that used in dry pressing. This is made to bind together very strongly by pneumatic tamping in a castiron frame-mould. The water needed for this is only 5%. The shrinkage is low.

Jayatilaka(1979) mentions extrusion method which he explains is for producing such components as tubes, rods, and others. But he points out that the components made from this method have low strength.

Pressing method is good for making kiln-furniture and mechanical or hydraulic presses can be used.

The crank and excentric pressing machines are in common use and they can be used for shelf making. According to Mackelt (1961), mechanical presses can generally be differentiated by the shapes of their frame, and they fall into 3 groups:

(a) Front-Back crank-shaft press

(b) Open backed crank-shaft press

(c) Double sided press.

Pressing machines can also be classified according to their capacities:-

(a) Light press - up to 5 tonnes

(b) Medium size press - 50-500 tonnes

(c) Heavy press - with rating over 500 tonnes.

There are also special presses with other mechanical devices such as toggle press friction - screw press, automatic press, hydraulic press.

A pressing machine has some very important functional parts such as the bed, the crank-shaft, the fly wheel, the frame. According to Mackelt (Ibid) "Press-frames are subjected to the total force exerted by the ram and are thus stressed. This necessitates not only careful designing of the frame but also the use of good grade materials".

CHAPTER 3

RESEARCH PROCEEDURE

3.1. Introduction

This is a product development research in which good method of production is applied in the use of locally accessible materials. The project entails double assignment which leads to the achievement of final production. The double assignment is that of producing good moulds (frame mould and pipe-mould) that will facilitate the production of good refractory kiln-shelves and props from local materials, using the moulds.

3.2. Materials

The following materials were chosen for the study:-

1. Sabon-Gwaram clay from Bauchi State
2. Grog made from Sabon-Gwaram primary clay
3. Bomo secondary clay from Kaduna State
4. Pieces of iron from Zaria market
5. Pieces of wood from Zaria market.

3.3. Sampling

Samples were selected from Sabon-Gwaram kaolin in Bauchi State, Bomo clay in Kaduna State, grog made from Sabon-Gwaram kaolin, wood from Zaria market and iron from Zaria market.

3.4. Field Work

3.4.1. Collecting the Clay Samples:

The knowledge of some clay deposits in Bauchi State and the information got from Hassan (1990) helped in locating and collecting some clay samples from which Sabon-Gwaram kaolin was finally chosen for this project, because of its quality, easy accessibility and ease in processing. The Bomo clay which is being used in the ceramic section of the Department of Industrial Design, Ahmadu Bello University, Zaria was chosen as the secondary clay for use in this project.

3.4.2. Collecting the Iron and the Wooden pieces:

It was decided that strong iron pieces will be used for the production of the moulds needed so that the moulds will be strong enough to bear the pressure that will be applied in the process of compression of the body during the production process.

Thick 7.5cm angle-iron was got for the frame of the frame-mould and two flat iron plates, 1.2cm thick were got for the top and the bottom of the frame-mould.

Pipes and rods for the pipe mould, to be used for the production of props, were bought from the Zaria market. The needed pieces of wood were also bought from Zaria market.

3.5. Processing of Materials

3.5.1. Preparation of clay

As explained by Cardew (1979), levigation of clay helps in increasing the refractoriness because by that method the impurities and the free silica are removed. The two clays (primary and the secondary clays) used for this project were levigated. Each of them was soaked seperately for three days and levigated. Levigation is the method of removing impurities from clay by water floating.

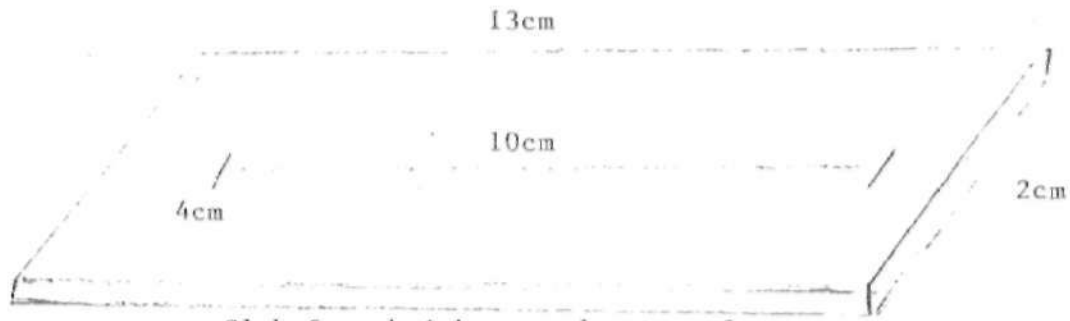
They were dried and put in the condition in which they were used for the project as follows:-

1. Some of the primary clay were pulverised and kept in powder form for easy measurement
2. Some of the dried kaolin was not pulverised, rather the dried pieces were fired to high temperature, 1300°C and crushed into grog.
3. The secondary clay was also pulverised and stored in powder form.

3.5.2. Clay Test

The primary clay and the secondary clay were tested for shrinkage and water of absorption.

(a) Shrinkage Test - Each of the clay samples was mixed into plastic throwing consistency and made into slabs of about 13x4x2cm and a fine line 10cm long was drawn on each. The slabs were kept to dry and the line was measured and the result recorded. Next the slabs were fired to 1300 °C and measured again to know the fired shrinkage.



Slab for shrinkage and water of absorption tests.

(b) Water absorption Test - The clay slabs used for the shrinkage test were used for this. First each was weighed and the weight recorded. They were emersed in water and boiled for one hour. Next they were left in the same water for 24 hours, after which they were brought out of the water, wiped off surface water and weighed. Water absorption was calculated thus:

$$100 \times \frac{\text{Wet} - \text{Dry}}{\text{Dry}} = \text{water of absorption.}$$

The results of the tests are shown in table one.

Table 1: RESULT OF CLAY TEST

CLAY	TEMPERATURE OF FIRING	LENGTH MEASUREMENT			WATER OF ABSORPTION
		Wet	Dry	Fired	
Sabon-Gwaram	1300°C	100mm	95mm	91mm	24.6
Bomo	1300°C	100mm	94mm	91mm	14.6

3.5.3. Preparation of the Grog

The grog got by crushing the fired primary clay pieces was graded for use in the body composition. It was graded into coarse grog, medium size grog and small size grog. All free dust was removed from the fine grog by sieving it with sieves of different mesh sizes. Singer and Singer (1971) recommend that the coarse grog will be up to 5mm grain size. The sizes of the grog were: coarse grog 5mm; medium size 3mm; fire grog 1mm.

3.5.4. Body Composition

Biaxial blend test, shrinkage test, water of absorption test and sagging test were conducted. The biaxial blend test was to determine the ratio of clay to grog that will be most suitable for the shelf making.

The primary clay and the seconday clay were mixed at the ratio of 1:1 for the clay body on one side of the biaxial blend and the grog made from the Sabon-Gwaram kaolin on the other side of the blend. The proportion of the grog sizes was:-

Coarse grog - 5

Medium size - 1

Fine grog - 4

As explained by Cardew (ibid), if the grog is carefully graded, a better packing density can be obtained.

The eleven tiles line blend test

Table 2:

S/No.	0	1	2	3	4	5	6	7	8	9	10	Serial No.
Grog	10	9	8	7	6	5	4	3	2	1	0	Grog
Clay	0	1	2	3	4	5	6	7	8	9	10	Clay

The eleven tiles line blend test

Shrinkage Test and Water of Absorption Test:

Each of the blends was made into two slabs, and ten centimeter line drawn on each slab. They were dried and the line measured to determine the dry shrinkage. Next the slabs were fired to 1300°C after which the lines were measured again and the fired shrinkage noted. The same test slabs were used for the water of absorption test as in the case of the clay test above. The result of the tests are shown in table three.

Table 3:

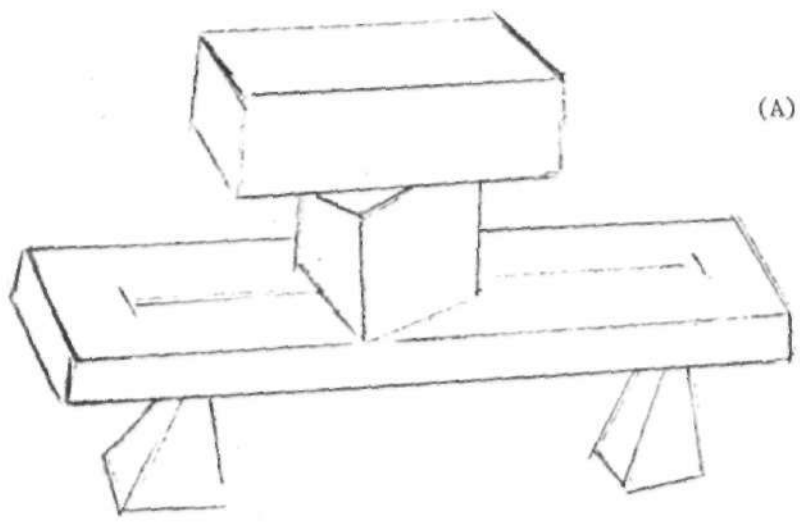
RESULT OF THE TESTS OF THE BODY MIXTURE

CLAY	GROG	TEMP. OF FIRING	LENGTH MEASUREMENT			TOTAL SHRINKAGE	WATER OF ABSOPTION
			WET	DRY	FIRED		
10	0	1300°C	100mm	90	89	11	14.3
9	1	1300°C	100	92	91	9	15
8	2	1300°C	100	93	93	7	22.5
7	3	1300°C	100	95	94	6	21.4
6	4	1300°C	100	97	96	4	28.6
5	5	1300°C	100	98	97	3	26.4
4	6	1300°C	100	98	97	3	26.1
3	7	1300°C	100	98	98	2	31
2	8	1300°C	100	99	99	1	22.6
1	9	1300°C	100	99	99	1	35
0	10	1300°C	100	-	-	-	-

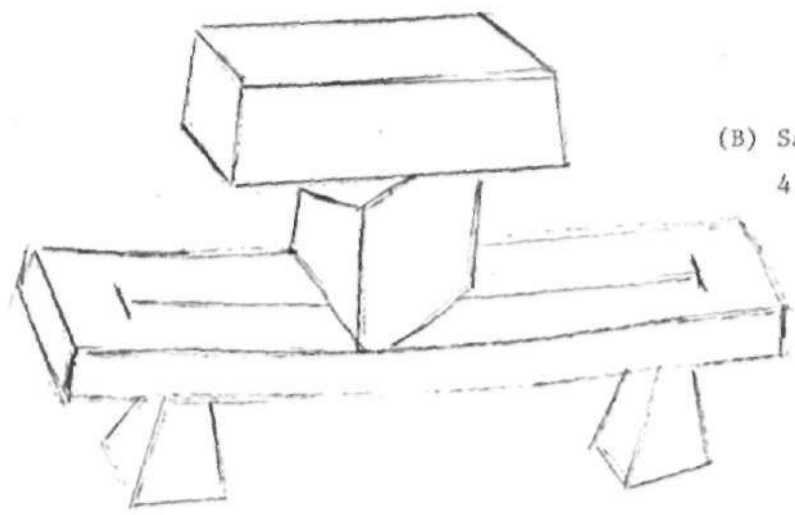
The Sagging Test:

The sagging test was conducted with three of the body mixtures: serial number 2:- 2 clay; 8 grog, serial number 3:- 3 clay; 7 grog and serial number 4:- 4 clay; 6 grog. The biaxial blend slabs were also used for this test. Wedge shaped clay stands were made and used for holding the slabs in the kiln.

Pairs of these wedge shapes were placed in the kiln and each of the slabs was placed on each pair. A weight of 1kg was placed on each slab and the kiln was fired to 1300°C. After the firing, each of the slabs was examined and it was discovered that the mixtures of 2 clay: 8 grog and 3 clay; 7 grog showed no sign of bending, but the mixture 4 clay; 6 grog showed slight bending.



(A) Better proportion:
2 parts clay: 8 parts grog
3 parts clay: 7 parts grog



(B) Sagging sample:
4 parts clay: 6 parts grog

Sagging Test

CHAPTER 4

PRODUCTION

4.1. Mould Construction

4.1.1. Frame Mould for the Shelves

In constructing the frame-mould for the shelves some necessary factors were considered.

(1) Need for strong iron that could bear the pressure of the pressing machine.

(2) Strong angle joining to stand the stress exerted by the press.

(3) Tight fitting of the component parts of the mould to be able to hold the body-mixture intact during the process of pressing.

(4) Effective distribution of pressure on the material during pressing.

(5) Effective method of removing the shelves from the mould after forming in order to maintain them intact.

The following are the component parts of the frame-mould.

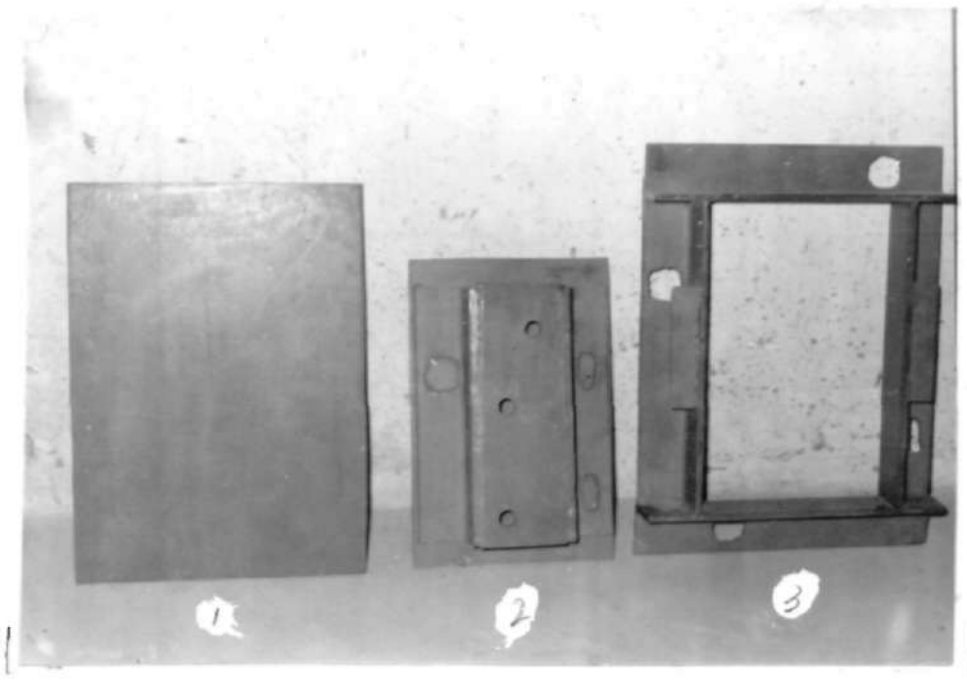
(1) The frame - 7.5cm angle iron was used for the frame which formed the four sides of the mould. The angle iron was 8mm thick. This was cut and the pieces used to form the frame. The internal measurement of the frame was 42.5x27.5x7.5cm.

(2) The base - The base of the frame-mould was made from a strong 1.2cm thick iron-plate and the dimension was 55x38x1.2cm.

(3) The top - The top of the mould is another thick iron-plate with the measurement of 42.5x27.5x1.2cm.

(4) The release frame - Two release frames were made one, made of wood and the other made of iron. The dimension was 48x33x4cm. These were for releasing the new-shelves from the mould.

(5) Removal board - The dimension was 68x52cm. It was a wooden board 1cm thick, onto it the new shelf was released and it was used for carrying the new shelves.



Component parts of the frame-mould 1 The base 2 The top-plate 3 Frame.

4.1.2. Pipe-Mould for the Props:

Pressing method for the production of the prop was considered more appropriate than casting and extrusion methods. As Jayatilaka (1979) points out, all components made by these two methods have low strength. So the mould for pressing method was designed and constructed. Consideration for the strength of this mould was taken into account as in the case of the frame-mould for the shelves.

The component parts of the pipe-mould were:-

(1) The material container: This was a strong 4.5cm iron pipe, 20.5cm long.

(2) The base of the mould: This was an iron disc 1cm thick and 9cm cross section.

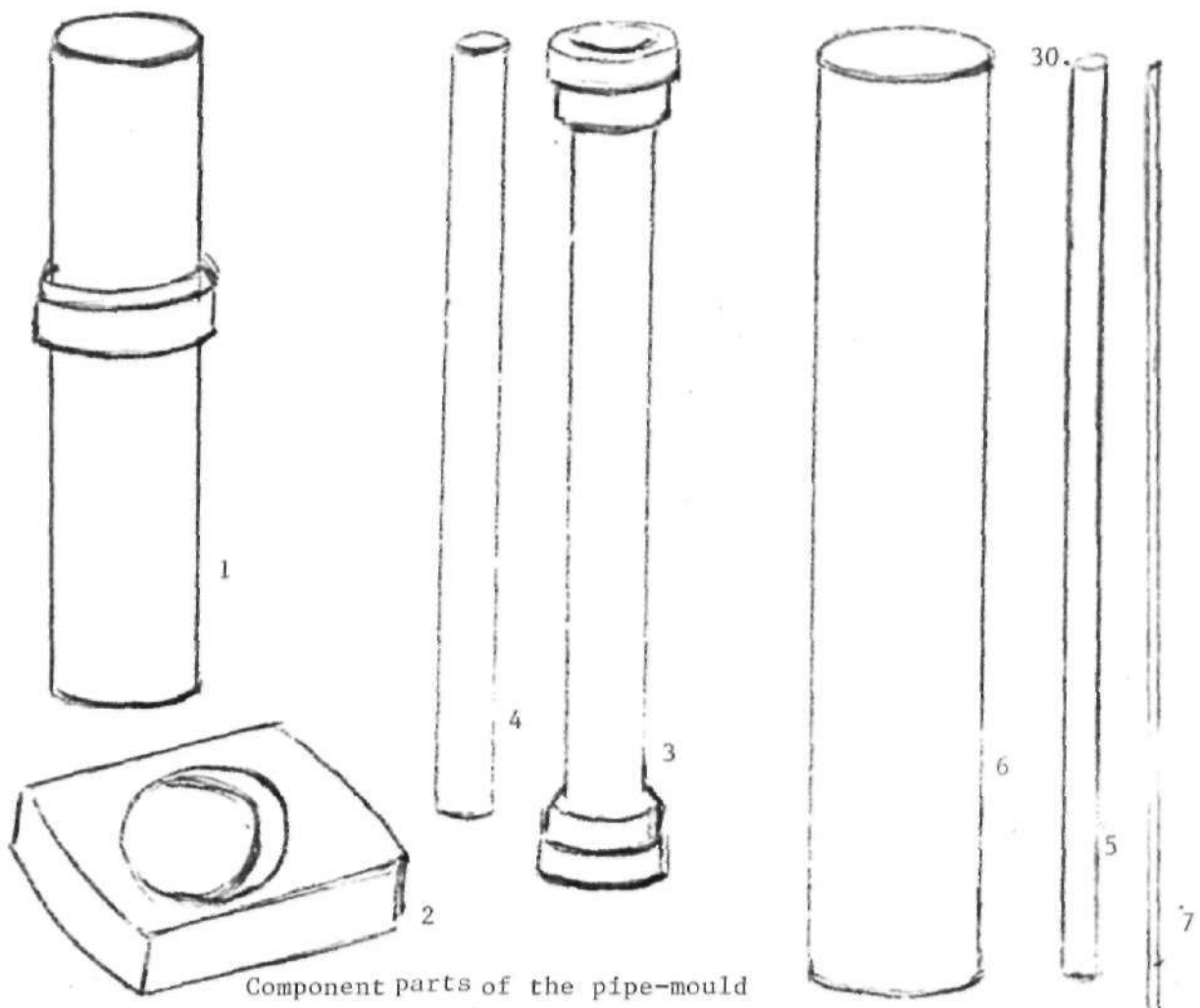
(3) The ram with handle: This was a strong 3cm pipe; 23.5cm long with two ramming heads each about 4.3cm diameter.

(4) The core: This was a 2.5cm rod,23cm long.

(5) Core ejection rod: This was 1.5cm rod, 40cm long.

(6) Material-ejection-pipe: This was a 6cm pipe; 30cm long.

(7) Poking pin: This was a flat iron pin .6cmx.5cmx40cm.



Component parts of the pipe-mould

(1) Material-container (2) Base (3) Ram (4) Core
(5) Core-ejection-rod (6) Material-ejection pipe (7) Poking-pin

4.2. Material Production

4.2.1. Kiln-Shelf Production

In the production of shelves the following were considered:-

(1) Good grading of the materials to be used.

(2) Correct proporiton of water to be used for mixture.

(3) Correct measurement.

(4) Effective mixing of materials

(5) Constancy in the measurement of the materials: clay, grog and water.

(6) Careful pressing and releasing of the shelves from the mould.

(7) Careful handling of the fresh shelves.

(8) Proper drying method

(9) Proper packing and careful firing in the kiln.

From the result of the biaxial blend and the sagging tests, two body mixtures were chosen for the study: 8 grog - 2 clay and 7 grog - 3 clay. These were the ratios that resisted heat and load most at 1300°C (refractoriness underload) and yet fused well. The proportion of the different sizes of grog used was the same in the two bodies:- coarse grog 5, medium size grog 1, fine grog 4.

The materials (clay and grogs) were measured out dry and mixed before water was added. This was to ensure thorough mixing. The water was added gradually during the mixing and it was discovered that the quantity of water that was enough to get the needed consistency was 30% of the dry materials. That was ten measures of dry materials to three measures of water. Measurement was by volume.

Attempt to reduce the quantity of water affected the green strength of the shelf. Addition of extra water to the 30% limit resulted in some quantity of water being pressed

out at the required load of 250 Kilo Newton (KN).

Pressing method was used for the production and Denison Tensil Testing machine was used for the pressing.

First Pressing:

The base-plate of the mould was placed on the bed of the pressing machine. Then the frame of the mould was placed in position on it. The mould was filled with the material to the level of 6.25cm. Next the material was well levelled up. After this the top-plate was placed on top of the materials inside the frame. The pressing machine was operated and the ram came down and pressed, compressing the body mixture untill the load of 200 KN was reached. After this point, the compressing became slower as the material hardened. When 230KN was reached, further pressure started to compress the frame top of the top-plate. So the machine was stopped and the ram of the press raised. The thickness of each shelf after the pressing was about four centimeter.

Removal of the Shelf:

For ejection of the shelf from the mould the release-frame and the removal board were used. First the top-plate was removed, next the frame of the mould was also removed with the new shelf still in it. A removal board was placed on the base-plate of the mould still in position on the bed of the press. Subsequently the release-frame was placed on top of the removal-board.

Then the frame of the mould with the new shelf in it was finally placed in position on the release-frame and the top-plate was put back in position on the new shelf.

The press was operated and the ram came down again and gradually pressed the top-plate. This forced out the shelf from the mould onto the removal board. When the ram went up again, the frame of the mould, the release-frame and the top-plate were removed in this order and the new shelf was carried away on the removal-board and kept for drying.

Second and third shelves:- The pressing and the removal of the second and the third shelves followed the same process as the first, only that the pressing stopped at 200KN.



Pressing machine with Frame-mould in position

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4.2.2. Prop Production:

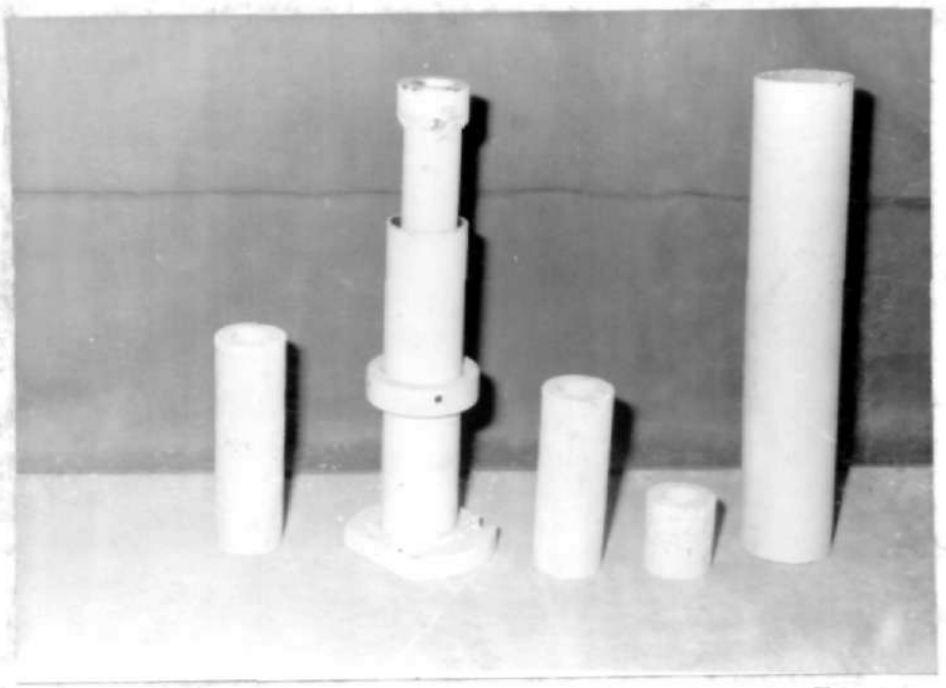
Proportion of Materials:

Only two sizes of grog were used for the body mixture: medium size grog and fine grog. The proportion was medium size 5, fine grog 5. The proportion of grog to clay was 7 grog: 3 clay in all the samples. The above proportions were used because the props has to be dense as Singer and Singer (1971) suggest .

The pipe-mould was used for the production of the prop and the Denison Tensil Testing machine was also used for the pressing.

Production Process:

The core of the mould and the material-container were fixed in position on the base of the mould. Then the container was filled with the material to the required level, and the ram of the mould was put in position in the material container. Finally they were all put in position on the bed of the pressing machine. When the machine was operated, the ram of the machine came down and pressed onto the ram of the mould; the material was gradually pressed down till the load of 200KN was reached. Then the ram of the machine was raised.



The pipe-mould with the ram in ramming position, three prop and ejection pipe.

Ejection of the Prop:

The ejection of the prop from the mould was easy. The ejection process was as follows:-

(1) The material-container and the core of the mould were detached from the base of the mould, with the 'new prop' still in the material-container.

(2) The core-ejection-rod was placed onto the lower end of the core and with some pushing, the core was ejected.

(3) The 'material-container' with the ram of the mould still in the pressing position was turned up-side down and put in position on the bed of the pressing machine. Next the material ejection-pipe was placed on the mould; the material container getting half way into it, stopping at the ring round the middle of the material-container.

(4) The pressing machine was operated and the ram came down and pressed on the ejection-pipe.

This pressure forced the material-container down, thereby the long ram of the mould pushed in, forcing the 'new prop' out of the mould.

Result and Observation:

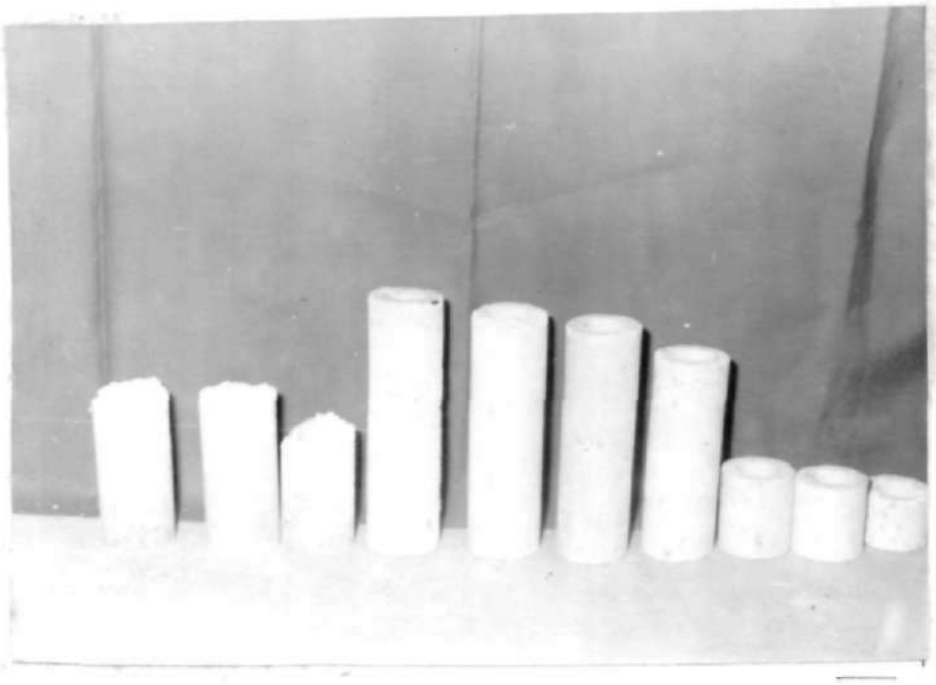
It was discovered that during the pressing, the upper part of the material had enough pressure while the lower half was not compact enough and was weak.

More Attempts for Better Products:

The second attempt to produce good props was made and the pressure reached 250KN. When this was ejected, the lower part was still weak.

Third attempt was made whereby the material was filled into the material-container in three stages. Each stage was pressed to 100KN. In addition, finally they were given together another pressure of 250KN. When ejected, the pressure this time was more uniform. But the resulting prop was in three sections having weak joints.

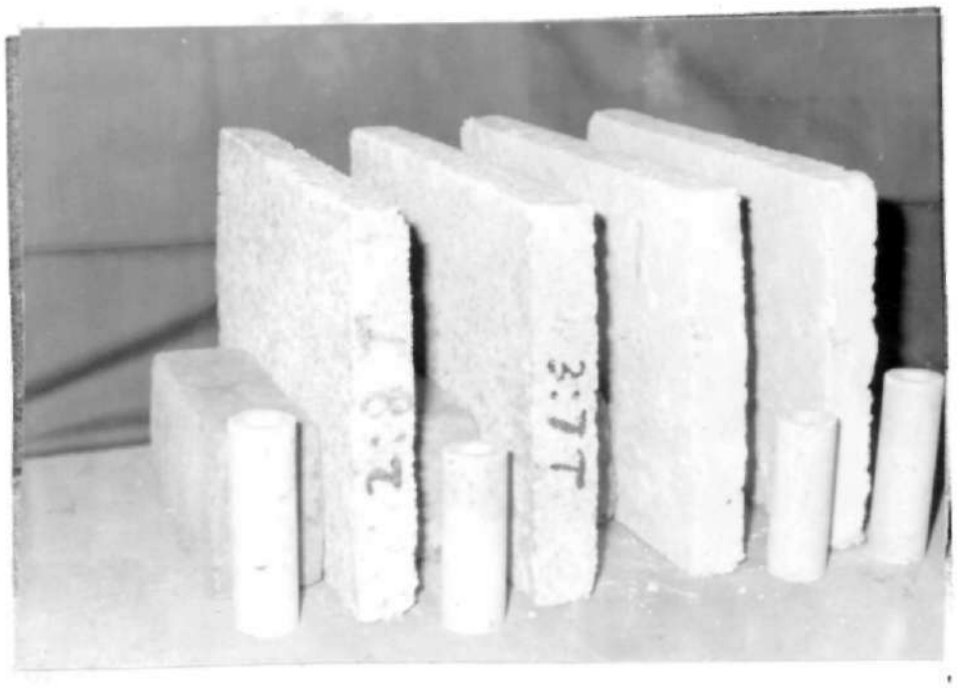
Fourth attempt was made whereby the pressing was done from both ends. One end was pressed first then the mould was turned and the other end pressed. Each pressing reached 230KN. The ejection of the prop this time was very difficult, and by the time that it was forced out, both ends were damaged.



New Prop: 1 Unsuccessful attempts 2 Successful attempts.

4.2.3. Drying the Shelves and the Props:

The new shelves were left on the removal board for one day to allow them to harden. Then they were lifted from the board and laid on their longer edges with some supports on both sides to prevent them from falling. This position was to enable them have free circulation of air around them. This was important to ensure even drying rate. The drying was indoors. After three days their position was changed to make the side touching the ground to come up and have free air. The props were dried together with the shelves indoors.



Drying the shelves and props

4.2.4. Firing the Shelves and the Props:

After drying for one week the shelves and the props were packed into the kiln for firing. The shelves were placed on their shorter edges to allow free circulation of heat.

Chester (1973) recommends that firing below 1000°C will not be rapid so as to avoid 'black-hearting or coring'. He also points out that the final soaking period is generally of greatest importance. So the firing below 1000°C proceeded slowly. After that the firing moved faster till 1300 °C was reached. It is recommended that the shelves will be fired above the operational temperature,

so as the operational temperature for these was 1280°C (stone ware temperature) 1300 °C was considered appropriate. A soaking period of one hour was allowed at the end of the firing. Then the firing stopped and the kiln waa allowed to cool. After cooling the shelves and the props were brought out.

4.2.5. Observation and Report:

(1) It was noticed that 30 percent water was sufficient for mixing the dry materials before pressing as additional water was pressed out during pressing.

(2) After pressing it was discovered that the new shelves were not strong at the angles and the edges especially those with 2:8 mixture. They needed a lot of care in handling during the green stage. One of them broke during packing in the kiln.

(3) After firing it was discovered that the shelves were not quite strong because they did not reach the highest point of fussion needed. But they were strong enough for use and it was hoped that usage in firing will make them stronger.

(4) One end of the prop was strong the other was weak. This called for improvement in the production process.

4.2.6. Second Production:

The Shelves:

Two body mixtures were also used for this second production (1) mixture of 8 parts grog and two parts clay (2) mixture of 7 parts grog and 3 parts clay. The proportion of water was 30% of the dry materials. As before the clay and the grog were mixed dry before water was added and careful mixing was done to avoid the materials forming lumps. After the mixing the material was left for 5 days to absorb water well. This period of aging proved advantageous, for all the grog particles were evenly moistened.

The former process of preparation and pressing was followed. Two of the 3:7 composition were pressed to 200KN, while one of the 3:7 composition and one of 2:8 composition reached 300KN.

The Props

(1) Ramming with mallet: The mixing of the materials was as before but more water was added. Now the pressing was no longer with the pressing machine, rather ordinary hand and a small wooden mallet were used for ramming and hitting the mould-ram in its usual position. When ejected the compression was more evenly distributed through out the length of the prop. But it was not yet satisfactory for the prop was not quite strong.

(2) Ramming and Poking: The 30 percent water was adopted as before. Further improvement was made by filling the material into the container in stages. Then ramming and poking followed each stage.

The process was as follows :-

i. The core and the material-container were put in position on the base-disc of the pipe-mould.

ii. The container was filled in stages. After each stage the material was first poked with the 'poker'. This first pocking levelled out the material in the container and also pressed it down.

iii. The ram was put into the container and was used to ram the material. Next the ram was hit several times to compress the material more. A wooden mallet was used for this purpose.

iv. The ram was removed and a second pocking was done. The purpose of this second pocking was to roughen the top of the rammed material in the material container. This rough top of the rammed material is thus ready to join well with the next stage of the material.

v. The next stage of material was added and another pocking was done. This was a necessary beginning of the next circle, and it made the previous and the succeeding stage of materials to join well. Three stages were used for making a prop of ten centimeter.

4.2.7. Ejecting the Shelves and the Props:

The ejection of the shelves from the mould was done as in the first production. For the ejection of the props, the former process was followed only that every thing was done with out the pressing machine, instead hand was used.

4.2.8. Drying and Firing:

After the ejection from the moulds, the shelves and the props were dried indoors within the room temperature. They were packed into the kiln and fired to 1300°C. The shelves were packed lying on their longer sides and spaces were allowed for free circulation of heat. A set of 4 props was made to carry some load during this first firing and it was able to bear the load and firing.

4.2.9. Observation and Report:

Shelves: With greater care in handling of the green shelves, the falling off of particles at the edges and the angles was reduced in all.

At the fired stage the shelves were strong, and the attempt to chip of particles at the edges with hand was not easy. This showed strong bonding. When struck with a hard object, there was no sharp sound. This showed that fussion was low and that they needed higher temperature.

Props: After drying, the props were strong. After firing all of them were quite sound and were good for continuous packing.

4.2.10. Third Production:

The Shelves:

(a) Ramming with a Falling Weight: The determination to produce very successful kiln shelves met with a very big obstacle. That was great difficulty in getting further access to a pressing machine. Consequently the method of 'Ramming with a falling weight was adopted. Parkes (1971) states that the quickest and most effective method of compacting sand is the use of the method he called 'Ramming with a falling weight. By this method a weight is allowed to fall several times on the material thereby compressing it. To facilitate this, a heavy top-plate was made for the frame-mould. The weight was 21.8 kilograms.

For the production of subsiquent shelves, the former process was followed only that pressing machine was no longer used. The heavy top-plate was allowed to fall several times on the material in the frame mould. This was done manually using hands to lift and drop the weight.

Some shelves were made using exactly the same materials and proportions used for the previous shelves. "Ramming with a falling weight" was used for this and all subsequent productions.

(b) Use of Temporary Binder: Bast (1989) points out some organic additives for dry pressing and he shows that temporary binders which include plant rubber, starch, dextrin

and others could be added for green strength. To increase the green strength of the shelves, temporary binder was added to the mixture of the body used for the body composition of 2 clay to 8 grog. The quantity of water used was still 30% of the dry materials, but half of it was used to mix the dry materials and kept for some days. After 3 days the remaining 15% water was used in preparing the cassava-starch which was used as the temporary binder. This starch was mixed with the body mixture and pressing followed the same day.

(c) Use of 35% Water: Two shelves were made with materials mixed with 35% water instead of 30%. These had more compact pressing but created some problem in ejection from the mould. They could not be lifted together with the frame-mould for ejection, so the ejection frame was not used. Rather the frame and the shelf in it were slid over onto a removal-board and it was ejected onto it without a release frame.

(d) Use of 20% Water: One shelf was made with 20% water and temporary binder. First the body mixture of 2 clay to 8 grog was mixed with 10% water and kept for 5 days. Prepared starch with 10% water was used for mixing the material. After mixing, it was pressed the same day using the method of "Ramming with a falling weight". After which the fresh-shelf was ejected from the mould onto the removal-board as usual.

(e) The Props: More props were made. The method of filling the material-container in stages, pocking and ramming in stages was continued.

(f) Drying and Firing:

Drying - The usual method of drying the shelves and props was followed which involved drying at the room temperature.

Firing:-

All the shelves and the props were fired twice. The first firing reached about 950°C. All of them came out well but the shelves were weak as expected because the temperature was low. After cooling they were packed into a gas kiln and fired to 1300 °C.

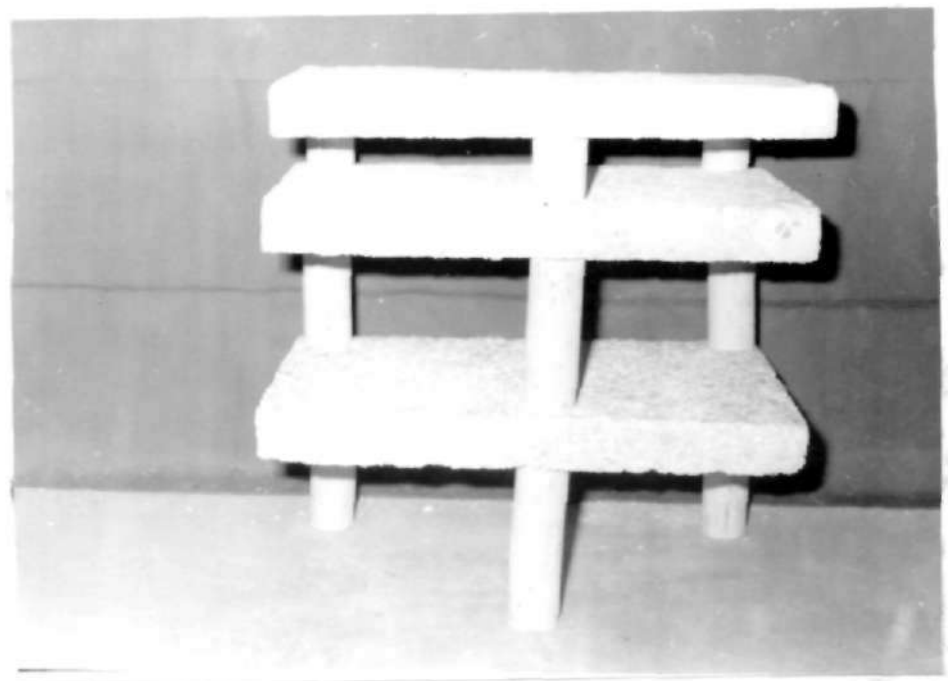
Use of Body Wash:-

Before they were packed into the kiln for the second firing, three of the shelves were washed with 'body-wash'. The body wash was a composition of:

Fine grog	50%
Primary clay	40%
Secondary clay	10%

Rhodes (1974) recommends the use of 50% kaolin and 50% silica as kiln wash for shelves. The body wash used here was a subtitute for 'kiln wash'.

It was felt that being nearer the composition of the materials used for the shelves, applying it after the first firing will be a better coating before the second firing.



Shelves set on props: 1 Shelf coated with body wash
2 Shelves not coated

Observation:

Green Stage - It was discovered that 'Ramming with a falling weight' method was able to press the materials as much as the pressing machine did at 250 Kilo Newton load. This was proved by the degree of hardness of the new shelves when pressed with the finger and also by the thickness of the shelves.

Those made with the 35% water were slightly stronger at green stage, having more intact edges and angles than those made with 30% water.

Those made with the addition of the temporary binder were also stronger at the green stage. That made with 20% water was of lower green strength but yet survived due to careful handling. It dried faster than the rest.

Fired Stage - All the shelves and the props came out well and were strong for kiln firing. Those washed with the 'Body-wash' have stronger and smoother surfaces. This made the angles and the edges more intact.

4.2.11. Test Firing

All were used for packing the kiln for gloss firing and were fired to stone-ware temperature 1280°C. All had load on them. After the firing they were made to cool very fast to test for thermal shock resistance.



Project products after gloss firing

Observation:

1. Those coated with 'Body wash' had cracks and slight bending. This was probably because the coating closed all the pores so the expanding air could not escape freely. Leaving one side uncoated may be a solution to this problem.

2. Those coated with the body wash have strong edges, angles and surfaces.

3. Those made with the 8:2 ratio of grog and clay resisted heat under load more than those with 7:3 ratio.

4. They all stood the test of fast cooling for thermal shock resistance. So they were better product than those being produced in the Department of Industrial Design, Ahmadu Bello University, Zaria which could not stand the test.

5. On the whole it was discovered that the kiln used for the firing and the tests did not give maximum satisfaction for heat needed. There was not even distribution of heat in the kiln, so some shelves received less heat.

   Temperature above 1300°C was not attained. Thereby the shelves could not reach the maximum fussion needed before they were put into test for use. This affected the result.

CHAPTER 5

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1. Findings

The following were the findings made during the course of the study.

1. That using a good production process, the materials obtained locally could be used for the production of reliable and durable kiln-furniture.

2. That the workable mixtures for the body composition for the shelves are :-

   i) 8 parts grog and 2 parts clay

   ii) 7 parts grog and 3 parts clay

   In each of the compositions above,5 parts coarse grog,1 part medium size grog and 4 parts fine grog form a uniform whole of one part grog for the body composition. Also 1 part kaolin and 1 part secondary clay form the clay mixture.

   The first body composition 2(i) is better than the second in heat resistance.

3. That the mixture of 5 parts medium size grog and 5 parts fine grog work out well in the body composition of 3 parts of clay and 7 parts grog for the props.

4. That the addition of a temporary binder was very necessary for the green strength of the shelves.

5. That weak 'removal boards' contributed a lot to the cracking of some fresh-shelves. A stiff board is better used as 'Removal Board'.

6. That the shelves needed initial firing temperature range of above 1300°C to make them fuse well and strong for usage at a lower operational temperature.

7. That the method of 'Ramming with a falling weight' is a good technique and is a better shelf making method than the beating system.

8. That the technique of coating all the sides of the shelves with 'Body-wash' though makes the surfaces and the edges of the shelves stronger, has the disadvantage of blocking the surface pores. This prevents the expanding air from easy escape thereby causing cracks. Thus one side of the shelf is better left uncoated.

5.2. Conclusion

This research which is an exploration into the materials and techniques for making kiln- helves and props in order to improve the quality of those locally made presently, has recorded some achievements in kiln furniture production.

The areas treated are very vast, starting from procurement of materials from different locations, processing them, construction of basic equipments needed for production, namely the frame-mould for the shelves, and the pipe-mould for the props. Finally, kiln-shelves and props were produced with the aid of the equipments.

At the end of the research, the assessment of the products and the production techniques revealed that efficient methods of kiln-furniture production without a pressing machine for pressing have been developed. The methods are "Ramming with a falling weight" for the shelves and "Poking and ramming" for the props. The moulds designed for the production of the kiln-shelves and the props are suitable. The props produced are of good standard. However, the shelves need further standardization through body mixture or heat increase to become as reliable as the props.

It is hoped that the application of the knowledge got from this study will help to reduce the operational cost of running ceramic studios and industries in the country. Also the idea of self-reliance which is necessary for the growth of Nigerian potters in the production of kiln-furniture will remove some obstacles on the way of extensive pottery production. This research work should therefore be seen as a potters' guide in order to achieve the needed self-dependency,

5.3. Recommendations

This research has created the awareness that these ceramic products (shelves and props) formerly imported from abroad can be produced locally using local materials. Market survey should be conducted to maximise the use and the benefit of these materials.

2. A research could be conducted in the use of local materials in the production of other items of kiln-furniture such as spurs, stilts collars and cranks so as to make possible the full use of the shelves and the props. This may reduce drastically the operational cost of running ceramic studios and industries.

3. This study did not go into detailed measurement of quality and the effect of the heat-power of the kiln on the materials produced. This was due to some limitations. Thus more study on these should be conducted to be able to standardize the production.

4. The production methods used here namely "Ramming with a falling weight" for the shelves and "Poking and Ramming" for the props need to be mechanised so as to simplify the production process and make it faster. Further research needs to be conducted in this respect.

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