THE UTILIZATION OF LOCALLY AVAILABLE CERAMIC RAW MATERIALS FOR THE PRODUCTION OF BALUSTERS FOR BALCONIES AND STAIRCASES

BY
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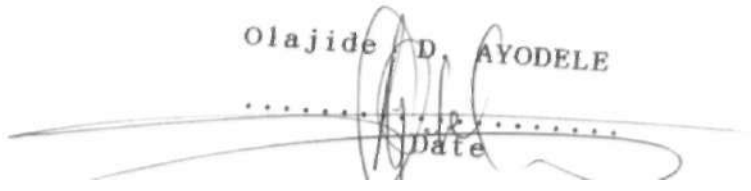
A Thesis Submitted to the Postgraduate School, Ahmadu Bello University, Zaria in Partial Fulfillment of the Requirements for the Degree of Master of Arts Industrial Design

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DECLARATION

I hereby declare that this thesis is an original and true record of my research work. It has not been submitted elsewhere for the application for higher degree. All references are duely acknowledged.



Olajide D. AYODELE

.....

Date

CERTIFICATION

This thesis entitled: "The Utilization of Locally Available Ceramic Raw Materials for The Production of Balusters for Balconies and Staircases" written by Olajide D. Ayodele, meets the regulations governing the award of the degree of Master of Arts (M.A) Industrial Design of Ahmadu Bello University, Zaria, Nigeria and it is this day, approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to my darling wife

Mrs. Morayo A. Ayodele -

Adesewa Ayodele - Daughter

'Juwon Ayodele - Son

and the yet unborn.

ACKNOWLEDGEMENTS

My acknowledgement goes to the Almighty God who has tremendously helped me through this programme.

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ABSTRACT

The Utilization of Locally Available Ceramic Raw Materials for the Production of Balusters for Balconies and Staircases

By

Ayodele David Olajide

The entire thesis is made up of 104 pages, 11 tables, 6 figures, 12 plates and 32 references. The problem of this study is the identification and utilization of the available ceramic raw materials for the production of balusters for balconies and staircases. The purposes of this study are to harness the locally available ceramic materials for the production of balusters as alternative materials to steel, wood and cement. The need for varieties to satisfy client's tastes call for this medium of baluster production for buildings. Raw materials such as quartz, feldspar, kaolin, bentonite and secondary clay were either processed, or obtained and used as body composition for the balusters. A product design was made on paper which was later transferred on wood by a turning machine. This was later used for model casting. The plaster to water ratio of 130:100 was used for casting mould making. Deflocculants of sodium silicate and sodium carbonate in ratio 3:1 respectively were used for the casting slip test. Grease and laundry soap were used as mould separators. Biscuit firing was taken to 1300°C while the gloss firing got to 1200°C in oxidation firing. The researcher employed methods which included seeking alternative medium to the use of cement, wood and metal for

balusters production, testing them to ascertain their strength and functional capabilities. Many studio tests and experiments were conducted and the results of the successful/unsuccessful ones were recorded. Based on the experiments the following results/findings were made: that thick wares of about 1 centimetre does not warp except when too close to the source of heat; that the addition of 1.5 percent bentonite gave a good plasticity; that a cast was only possible per day and per mould in order to avert collapse or sagging; that about 65 percent Kaolin, 13 percent Quartz as well as 20.5 percent of Zaria Feldspar in addition to the use of 1.5 percent bentonite in the clay body composition produced improved stoneware, rather than pure porcelain. This product can therefore, be referred to as being porcelainous, but not true porcelain. Based on the result obtained from this study, it is conclusive that, the materials used in the formulation of the ceramic balusters if utilized in the manner stated by this study will give consistent result; that baluster production using ceramic materials is achievable.

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ABBREVIATION

P.O.P	-	Plaster of Paris
KN	-	Kilonewton
Cm	-	Centimetre
M.O.R	-	Modulus of Rupture
KN/m^2	-	Kilonewton Per Metre Square
^0C	-	Degree Centigrade
%	-	Percentage

DEFINITION OF TERMS

"Afin": King's Palace (in Yoruba Language).

Ball Mill: A drum like pebble grinding mill, used for the grinding of glaze and other ceramic materials.

Balusters: Short props or columns supporting railing at both veranda and stairs.

Balustrade: A long pillar supporting the roof of a building.

Bauhaus: An institute for art, which emerged as the successor to an academy and school of arts and crafts in Dessau, Germany in 1926 Under Walter Gropius.

Biscuit: A porous unglazed fired pottery.

Bisquit Firing: First firing given to "green wares" usually between 900^{0}C - 950^{0}C.

Body: An admixture of clay and other materials producing a workable material suitable for manufacturing process.

Calcined: A method of purifying or softening of some ceramic materials by the action of heat.

Deflocculant: A soluble material which is added to clay slip to increase fluidity and enhance despersion and suspension of clay particles in water.

Earthenware: Low-fired pottery (below 1200^{0}C) usually red or tan in colour with absorbency of between 5 percent to 20 percent.

Flux: An oxide which produces ceramic fusion by interacting with other oxides.

Glaze Firing: Second firing of up to 1300^{0}C and beyond when fusion of minerals take place to produce glass coating on ceramic wares.

Jaw Crusher: A machine used for breaking bulky raw materials into smaller particles after calcination and before milling.

"Ladan": The man that calls for prayer in the Mosque (Hausa/Arabic).

Masallacin Juma'a: Friday Mosque (Hausa/Arabic).

"Obuna Enu": Semi-defensive gate (in Igbo language).

Plasticizer: A plastic material that is added to bodies to improve their workability.

Plasticity: The quality of clay that allows it to be manipulated and still maintain its shape without cracking or sagging.

Porcelain: A vitrified often white and translucent body with a clear ringing note usually fired at 1300^{0}C and above.

Quartz: A mineral rock, used as sources of silica for glazes and bodies (porcelain bodies). They are introduced as powder or as sand.

Slip: A homogeneous mixture of ceramic raw materials and water used for casting.

Spare: An additional part added to the top rim of a model so as to obtain the exact height of model after production.

Three Dimentional Form: That which has length, breadth, and height. And that can be felt round.

Warping: Distortion in the shape of a pot during drying or firing stages.

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CHAPTER ONE

1.1 INTRODUCTION

Every nation, be it developed, developing or underdeveloped is moving with time through one research or the other with the aim of projecting and developing further action on variables needed for new findings. This will in-turn serve as achievement in the bid to attain self reliance, self-sufficiency or supremacy in the world.

Nigeria not left out in this race is gradually getting industrialised with various projects proposed, ongoing or accomplished at different locations for industrial growth through various research institutes. Among these is the Raw Materials Research and Development Council (RMRDC) currently engaged in the development of certain raw materials such as Talc, Kaolin, Feldspar, Soda Ash to mention, but just a few. With this development however, there is much to be done in the field of ceramics.

The use of ceramic related materials such as mud, bricks and flint for architectural finishing is as old as mankind. Architectural design was borne out of the quest

for shelter, creativity and for the satisfaction of human taste. The philosophy behind the establishment of Bauhaus (1926) in Dessau, Germany, was to house a school that brought art and industry together as they were in the past. This was actualised under the great architect Walter Gropius. Eckardt (1967) stated that since we passed the era of living in caves, our communities have grown to consist of dynamic architectural designs. Hence the researcher's effort to expand the frontiers of ceramic products in built environment; such as balusters for our buildings. In addition to the existing ones such as - floor tiles, roofing tiles, wash hand basins, among others stand out as an indication to or of such dynamic ceramic contributions to architectural designs or fittings.

In the traditional architecture of the various cultural groups however, balusters are glaringly absent. A typical example of this in Nigeria is the Katsina Gobarau Minaret (about 6.5 meters in height) built many years back. Story has it that the minaret was for a defensive purpose, used to site invaders in the past. Ironically, this great monument has staircase leading up to the top-most apartment but without balusters or handrails for support, not even of any kind.

The absence of such balusters for stairs could probably be due to the nature of ground buildings for the extended family housing system in the traditional era. This could also be due to lack of necessity for storey buildings that could invariably call for innovations, bringing about balusters for both balconies and stairs. In some cases though, verandas and stairs were at times incorporated with only balustrades as supporting column to the projected roof but without balusters.

This functional baluster is an experimental research product for balconies and staircases which will complement the already existing balusters which are produced either in bricks, cement, iron or wood to now serve as contemporary phenomenon in buildings.

Baluster is alien to Nigerian culture. Wharton and Codman (1978) stated that it was in Italy that stairs first received attention as a feature in the general composition of the house. Cordingley (1951) confirmed this and stated that;

> In later medieval and early Renaissance times in Italy, the parapets often were treated as tiny colonnades, with the panels filled with miniature Doric, ionic or another columns supporting the upper protective rail.
>
> About the year 1476, an important innovation was made in North-west Italy. The shafts of the miniature columns were shaped to a skittle-like profile, in the representative case, slenderly waisted in the upper

> part and bulbous in the lower. Thus was born the true baluster, and the term 'balustrade' henceforward became an apt description of any parapet with this feature.

Glaringly this phenomenon has now been widely accepted in our society today more than ever before. Most modern multi-storey buildings now have balusters. Balusters in buildings serve as aesthetic objects as well as for support and protection of users. Various innovations were carried out using several media like wood, iron, cement, burnt bricks; with varying acceptability. Investors are now engaged in baluster production using the above mentioned media. The non-availability of balusters made of ceramic materials is the concern of this study.

Above all, the successful outcome of this research will obviously add more to the list of contemporary ceramic production, design and development in Nigeria.

1.2 STATEMENT OF THE PROBLEM

The problem of this study is the identification and utilization of the available ceramic raw materials as alternatives for the production of balusters for balconies and staircases.

1.3 PURPOSE OF THE STUDY

The purpose of this study are outlined as follows:

(a) To harness the possibility of using ceramic materials in the production of balusters.

(b) To find alternative materials to steel, wood and cement in the production of balusters.

(c) To help improve the economic condition of Nigeria by finding new uses for ceramic raw materials rather than depending solely on imported materials.

(d) To contribute to the field of knowledge since there is no end to the pursuit of knowledge.

(e) To help serve as complement to the existing balusters made of other media.

(f) To avoid further treatment of balusters by way of painting, as the glazed balusters have once and for ever, brilliant colours and surface textures.

1.4 BASIC ASSUMPTION

The following basic assumptions are made:

(a) that this product will go a long way to meet the consumers taste and need;

(b) that with the aid of brilliant glazes applied, this range of products will add to the glamour of both the interior and exterior harmony needed in the architectural environment;

(c) that the production of balusters will save the nation a lot of foreign exchange if fully developed on a large scale to meet the demand of our housing industry;

(d) that investors will have the accessibility and affordability of various materials and equipment needed for the actualization of this product;

(e) that the choice of these balusters will meet the aesthetic enhancement of any building, its environment as well as the consumers' taste;

(f) that the ceramic baluster will be free from corrosion usually associated with steel balusters;

(g) that it will have the adequate strength comparable to other balusters;

(h) that it will serve both functions of support and guide in any balcony and staircases.

1.5 SIGNIFICANCE OF THE STUDY

One must learn to utilize and appreciate our potentials in both human and natural resources so as to be able to face the challenges ahead.

With the national economic recession, coupled with the high cost of materials which has invariably affected the cost of building construction in Nigeria, there is a need for a continuous search for better, cheaper aesthetic and more widely available alternative, structural and building components to what presently exists.

According to Godfrey (1931), one must search the path of history, and reflect too on the lives of the men and women who were not content to build for utility alone, but consciously or unconsciously adding aesthetics to their handwork which often passes description.

Various media such as wood, metal and cement are currently in use for the making of balusters and are not

resistant to adverse weather conditions. Timber for example, is a versatile and delicate material and requires intensive treatments if it is to last under exposed usage. It is usually affected by the atmospheric condition such as extreme high temperatures, high humidity and moisture which causes the timber to warp, decay and experience deteriorating surface treatment. It is also susceptible to insect and pest attacks. This is not the case with ceramic products that are free from the mentioned defects. The major problem with ceramic products is shrinkage. This can, however, be overcome during firing.

A diversification of local raw materials will be of great significance to the Nigerian economy now that we are clamoring for self reliance, self-sufficiency and generation of employment opportunities for all.

Baluster products using ceramic raw materials as complement to those produced with cement, wood and metal are not found in the Nigerian market. The researcher believes that this is due to inadequate exploration of the use of ceramic raw materials, which this research is set to achieve.

Most of the cottage ceramic industries all over the country including the well established ceramic industries

are engaged in the production of table wares, sanitary wares and other decorative wares. The successful execution of this research will add something new to the product list of the ceramic industry in Nigeria.

1.6 SCOPE AND DELIMITATION

The materials needed for this research are widely spread all over the country, but samples for this research were taken from three States: Kaduna, Katsina and Plateau States, due to the availability and knowledge of the samples as regards their locations and qualities, as well as nearness of these sources of materials.

Casting method was adopted for the production of balusters which are essentially aesthetic and non-structural in function. The products are tested for shrinkage and modulus of rupture in order to determine their suitability.

The design aspect of production was studied rather than an indept research into the geo-chemical properties of the raw materials, or the technical composition of equipment used.

1.7 LIMITATION

The lack of horizontal jigger-jolley machine for polar structures such as balusters of this nature limited the researcher to the use of slip casting method.

Further limitation is the orthodox approach to material characterization, preparation and utilization.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This study is aimed at the use of various ceramic materials for the production of balusters in buildings as complement to the existing ones in cement, wood and iron.

In the scheme of this study, available literature materials were reviewed under the following sub-headings:

1. Origin of staircases and balusters
2. Nigerian Traditional Architecture
3. Available Ceramic Raw Materials
4. Choice of Materials for body Compositions
5. Method of Production
6. Product Design

2.2 ORIGIN OF STAIRCASES AND BALUSTERS

Staircases are comparatively late features in architectural design. According to Mohammed (1987) earlier staircases were structured in stone, spiral or circular newel staircases. Large houses were planned as a series of

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floors of rooms and staircases served as linkages between floors, majorly in storey buildings.

It was in Italy that stairs first received attention as a feature in the general composition of the house. In France it was always preceded by a vestibule, and the upper landing invariably led to an antechamber. In England the relationship between vestibule hall and staircase was never so clearly established (Wharton and Codman 1978). Cordingley (1951) equally noted that at about the year 1476, an important innovation was achieved in north-west Italy when the shafts of the small columns in buildings were shaped to a skittle-like profile, and that this great innovation he said gave birth to the true balusters.

Godfrey (1931) estimated that between 1550-1650 was when the desire for increased comfort and the demand for more convenient and luxurious fittings within the house made for still further progress in England and in this new sphere, the carpenter was raised to a separate trade when objects like chairs and tables too were turned with machines to give further befitting look. The most important structural innovation at this period he noted, was undoubtedly the staircase.

In the middle ages when life was largely lived in the Great Hall, the upper floors did not have the importance they later acquired. Building was approached by a broad stair in one flight. This was a long time when newel stair which was repeated whenever required, was felt to be inconvenient. With this Godfrey (ibid) noted there came the idea of building a self-contained staircase with short flights succeeding one another at a right-angle turn. The only idea that occurred to the builder then was to make the centre in a solid core of masonry and or a square framework. And that when this framework was made in open design, the corner post then became newels, and the open wall being guarded by balustrade. Here he concluded was a new toy for carpenters to manipulate with and they proceeded to expand upon it a wealth of fancy and invention.

This Godfrey (ibid) said led to the true balusters in England which were set close together and were of oak, forming a very serviceable barrier to the stair wall.

During the nineteenth century the art of fabricating objects of iron flourished. South-worth (1978) explained that everything from kitchen equipment and cradles to farm machinery and civic fountains found expression in iron. Among the most enduring works of this period have been

architectural and landscape ornaments - the door grills, balusters, balconies, verandas and many more.

2.2.1 Fundamentals of Staircase

The basic facts of staircase is that it provides access and linkages between floors in storey and multi-storey buildings.

This can conveniently lead to its classifications according to the materials used in construction or according to the geometry of the staircase. Staircase can however be based on materials which include timber stairs, stone stairs, concrete and steel stairs (Mohammed 1987).

2.2.2 Contemporary Balusters

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Saylor (1952) defined it "as a miniature column or other form of upright pillar which in series, supports a handrail, as in a balustrade". Pevsner et al (1975) were not deviating either, a baluster, according to them was defined as "a short post or pillar in a series supporting a rail".

One can therefore, define contemporary balusters as that which is integral to modern building of our time made of wood, cement or metal to serve as props for railings

and also as guide and support on both verandas and staircases.

The contemporary balusters for both balconies and stairs are usually produced in three media namely - cement, iron and wood (see Plates 1, 2, and 3). These have become a conventional appearance of our buildings today.

Cast method is usually the approach in using cement with gravel to cast into various designs, height and sizes. Usually iron can be cast but the method of shaping and sizing are usually being employed by the craftsmen unlike the advanced methods of casting that require moulds.

These days however, iron casting for balusters are uncommon. What is done is to cut and weld iron into various shapes and sizes for balusters. Logs of wood or plank of various thickness are turned with the help of a lathe (machine) to give perfect intricate designs in their different sizes and heights.

2.2.3 Interior Decoration

Records have it that buildings can be grouped into two, the storey and non-storey buildings. The later consists of ground floor solely. Which ever be the case, it



PLATE-1: Balusters Made of Cement



PLATE-2: Balusters Made of Iron



PLATE-3: Balusters Made of Wood

is pertinent in the modern times to have an open place (balcony) usually reserved for relaxation where other sceneries of nature could be viewed. The staircase (within the room) that leads to the upper apartment as in the case of storey buildings or duplexes is regarded as part of interior decoration. The complementary nature of it to the main building makes it inseparable. Salisu (1994) explained that the interior of a building is where all domestic activities take place and that it is automatically related to the outside. He opined that the change between the outside and the inside should not be a drastic difference.

The interior of a building complements the outside. It is a sign of respect that great care be taken in making the interior as nice as the exterior if not better. By the 1660s there was no longer any doubt that it was the French who set the pattern of civilized life indoors. The layout and arrangement of their buildings was widely studied, the details of their interior decoration, balusters inclusive was imitated, and the pattern of life led in such surrounding was copied. Nicodemus Tessin a great Swedish architect was noted in Thornton (1978) as saying, "as far as the interior of grand houses was concerned, there was a field in which the French were continually making admirable refinement". There is little

doubt that Nature's display of colour and form, in the landscape, in animal, birds, trees and flowers, and indeed in all her manifestations, gives to everyone a foundation on which to develop his or her taste; in other words it nourishes the aesthetic faculties (Godfrey 1931).

In the old French stair-rails steel were sometimes combined with gilded iron. It is impossible to keep a steel stair-rail clean and free from rust, except by painting it, this is usually done in black, though a very dark blue is sometimes preferred. According to Wharton and Codman (1978) masses of plain colour are one of the chief means of producing effects in any scheme of decoration.

There are colours that harmonize well with the environment. A good interior designer takes into consideration all these before planning any colour combination. The choice of colours that harmonize well with any interior is what the glaze aspect of this research will address.

Maxwell and Drew (1976) stated that a carpenter makes doors, staircases with lovely curling, polished handrails and which are fitted into the building. And that it is the introduction of new material or some of the older materials that have so changed the character of

architecture. The introduction of large sheets of glass into building was first seen in shop windows. And others thought that the end of architecture had come, but were later shocked. And it was in fact the beginning of a new architecture in which steel, concrete and glass took the place of stone, bricks and timber, and one now enjoys its elegance and lightness. So also is the use of tiles which is a product of ceramics and which cannot be separated from any modern building.

A few decades ago, attempts were made by various researchers in some parts of the world to find a suitable material that will out place steel in the manufacturing industry. To them, the use of ceramics in developing functional products was an alternative approach to solve some of the problems regarding steel processing. According to Alkali (1985) Alumina, Silica and several other ceramic materials in their high hardness, chemical inertness and resistance to degradation would compete favorably and possibly out place steel in various functional capabilities.

In line with this assertion, the use of ceramic materials will go a long way in meeting varieties of uses through innovation and constant research. These innovative ideas are equally and strongly supported by Southworth (1978), that just as iron replaced wood as a material for

balconies and verandas, today other materials: plastics, fiberglass, aluminium and concrete have largely replaced cast and wrought iron. Today's balconies and balusters are typically made of concrete, iron or wood.

2.3 NIGERIAN TRADITIONAL ARCHITECTURE

Traditional architecture as defined by Allsopp (1960) is native, indigenous and characteristic of a locality.

Building is not an end in itself but rather a means to an end, which is to satisfy the material and spiritual needs of the people for which it is created. Dmochiowski (1990) stated that the first impression of Nigerian architecture is its great variety, an obvious consequence of geographical factors and the ethnic diversity of Nigerian population. He further asserts that the characteristics of architectural design were determined by the natural conditions of a given area, most of all by the climate and the building material available.

A brief look at three major groups of the country will give a clue to the traditional architecture of the nation as regards the possible development of balusters.

2.3.1 Northern Nigeria

In the north, the Habe-Hausa method of building dominates. Dmochiowski (ibid) explained that it is best represented by the sophisticated architecture of the mosque and great residences.

However the use of staircases and verandas in Hausa traditional design is not common except in a few cases where stairs give access to the roof space. Examples of such are: "Masallacin Juma'a, built in the early times in Zaria with an external flight of steps for the "Ladan" to call for daily prayers, and also the Katsina Gobarau Minaret situated in Katsina.

No railing was designed with the in-built steps and that confirms that balusters, either using, locally sourced materials or foreign ones were not in existence. Perhaps due to the nature of their architecture or cultural practices.

2.3.2 Western Nigeria

The Yoruba speaking people are one of the largest cultural groups in Western Nigeria. Their architectural prowess can vividly be seen from both the interior and

exterior views. Their veranda roofs were supported on posts (balustrades) usually decoratively carved. The veranda balustrades even in the ordinary houses were generally ornamented.

According to Dmochiowski (1990) the architectural character of much of the palace in Ikere is unique among the other "Afins". It belongs to the style called "Brazilian" which correctly defines it's provenance. Dmochiowski (ibid) explained that it was created by the Yoruba liberated from the slave ship from America in about 1840 who settled in Lagos, Badagry and its environs. These brave people, according to Dmochiowski (ibid) even living in faraway lands for generations, never abandoned their own cultural tradition, at the same time they incorporated the architectural values of colonial masters, mostly Brazilian forms.

Once back in their own country, the liberated slaves introduced into their buildings what they had learned to respect abroad - the colonial; interpretation of Portuguese architecture. The liberated slaves often made these alien patterns into creative Yoruba designs, and "Afin Ikere" is an outstanding example of such an adaptation.

The "Afin" (Palace) is entered through a storey gate house erected in cement. The outer gate with arch

projects from the main building as a sort of porch, and is covered by a balcony. Further description of the house is the other side view that has an outer staircase of two flights of steps with a square landing between them, all decorated with balusters, set closely together in cast cement.

This shows that the Western Nigerian traditional architecture too had no trace of any kind of indigenous balusters; except that which was developed for the "Afin Ikere" (Ikere palace) using the Brazilian style and techniques (see Figure-1).

2.3.3 Eastern Nigeria

The common features of Igbo architecture were massive compound fence, shrine and (nowadays almost non-existent) two or three storey semi-defensive buildings, called "Obuna Enu" Dmochiowski (ibid).

Dmochiowski (ibid) further explained that the majority of houses however, never exceeded ground building, with verandas only supported with balustrades. This further explains why the use of railings or balusters were not commonly developed in the Igbo architecture too. The varandas were only supported with pillars (balustrades)



FIGURE-1: Showing Ikere Afin Residence with Balcony Railing and Balusters

usually made of wood similar to that of the Western Nigerian *architecture.*

Going by the literature review of the three major ethnic groups in Nigeria and the indept search for the possibility of indigenous balusters even of any miniature form among the minority communities, it is obvious that not even a record is found to that effect. The conspicuous absence of baluster in our traditional architecture therefore, confirms it's non existence in the evolution of our traditional architecture.

This further explains too, that places like the Middle Belt-Plateau and Benue and even the down South Cross-River States that had all their traditional architectural structures mostly erected with rafia or grasses had also no trace of balusters in their verandas. Except in some cases where balustrades served as support for the projected roofs.

With this, one can conclusively say that the use of balusters in building is alien in Nigeria.

2.4 AVAILABLE CERAMIC RAW MATERIALS

It is not an over statement that Nigeria is blessed with abundant ceramic raw materials well distributed and in large quantities too. In the Mineral map of Nigeria (1985) as quoted by Sullayman (1995), ceramic related minerals abound in various locations in Nigeria. A few of them according to him are listed as follows:

(a) Kaolin: Available in commercial quantity in Ijebu-Ode, Ayetoro, Bichi, Kankara, River Mimibank, Lokoja etc.

(b) Secondary Clay: Abound in Mararaba-Rido, Katsina, Ilorin, Liruein Kano, Bomo, Garkida, etc.

(c) Quartz: This can be found in commercial quantities in Osara Forest, Okene, etc.

(d) Feldspar: The major source of feldspar in Nigeria is traced to Osara Forest, Others are in Zaria, Okene, etc.

(e) Talc: This is found in Isanlu-Makutu, Iregun, etc.

(f) Fire Clay: Available in Nsude, Enugu, etc.

(g) Lime Stone: Found in Kama, Okene, Odumoke, Yandev, etc.

(h) Zinc: This is obtainable from Liruein Kano West, Zaria Hill, Yelwa-Rishi, Ameri-Amaka, etc.

(i) Gypsum: Obtainable in Gada, Gubio, Auchi, etc.

(j) Zirconium: This is found in Bukuru and Jama'a.

(k) Gold: Deposits abound in Bukuru, Iperindo, Birnin Gwari, Gumi, Malele, Birnin Kebbi, etc.

(l) Iron Ore: Found in Itape, Agbaja, etc.

(m) Silica: This is found in Lagos, Badagri, along Rivers Niger and Benue.

With the abundance of the ceramic raw materials, research of this nature will have no hitch as a result of inadequate raw materials and also for the subsequent investors, especially so, now that government is interested in the development of these gifts of nature for maximum utility and economic development of Nigeria. Baluster development is no exception in the utilization of these materials.

2.5 CHOICE OF MATERIALS FOR BODY COMPOSITIONS

The selection of stoneware and porcelain materials for this research purpose as informed in various literature is due to their strength. Norton (1956) stated that porcelain and stoneware bodies are harder and stronger than earthenware bodies and equally more durable too. The materials used therefore, are: Feldspar, Quartz, Kaolin, Secondary Clay and Bentonite.

2.5.1 Porcelain

The greatest charm of porcelain is its translucency (Norton, ibid). Nelson (1978) also said porcelains are relatively non-plastic and fire between cones 8 and 12, to an extremely hard, viterous state.

Porcelain bodies are compounded principally from Kaolin, feldspar and flint for increased strength resulting in a higher shrinkage rate.

There are two types of porcelain: hard and soft porcelain.

(a) Hard Porcelain ($1300^{0}C$)

The word porcelain has come to cover a wide range of bodies. Primarily it implies a high quality, dense

body. European hard porcelain is composed chiefly of kaolin, potash feldspar and quartz.

Singer and Singer (1963) sub-divided hard porcelain into:

i. Electrical Porcelain
ii. Chemical Porcelain
iii. Mullite Porcelain

Singer and Singer (ibid) further gave a typical example of hard porcelain composition as in Table-2.1:

TABLE-2.1: A Typical Example of Hard Porcelain Composition

	Normal Composition Percentage	Range	Average Percentage
Kaolin	50	42 - 66	54
Potash Feldspar	25	17 - 37	27
Quartz	25	12 - 30	21

SOURCE: Singer and Singer (1963)

(b) Soft Porcelain

The utility value of soft porcelain is limited in that it chips off easily. The vitrification of this body is at lower temperature usually below 1200^0C.

Singer and Singer (1963) gave a typical body composition maturing at 1150^{0}C as:

Ball Clay	25%
Quartz	45%
Feldspar	30%

2.5.2 Feldspar

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The term feldspar according to Singer and Singer (ibid) covers a number of alkali or alkaline earth aluminium silicates. He states that natural feldspars are usually a mixture in varying proportions of the aluminium silicate of sodium, potassium, calcium, lithium and occasionally barium.

These three elements (potassium, sodium and calcium) according to Cardew (1969) are the only common elements capable of making feldspar. It is impossible he noted, to have a lithium, a magnesium or a ferrous (iron) feldspar. Although these elements have the right valencies, they are the wrong "size" (ionic radius).

Nelson (1966) defines feldspar too as a crystalline rock composed of the aluminium silicates of potassium, sodium and calcium. His formula for the types; of feldspars are:

Potash Feldspar (Microline) $K_2O.\ Al_2O_3.\ 6SiO_2$

Soda Feldspar (Albite) $Na_2O.\ Al_2O_3.\ 6SiO_2$

Lime Feldspar (Anorthite) $CaO.\ Al_2O_3.\ 6SiO_2$

2.5.3 Quartz (SiO_2)

Umar (1988) stated that quartz has a reversible expansion of 1 percent at 573^0C and that quartz occurs as quartz sand which is finely granuled quartz found in large deposits.

Quartz sand when added to clay acts as a grog and as non plastic material which opens a body and decrease both plasticity and shrinkage; as well as source of silica for glazes and strength for bodies.

2.5.4 Kaolin ($Al_2O_3.2SiO_2.2H_2O$)

Singer and Singer (1963) said the name "kaolin" is a corruption of the Chinese "kao-liang", meaning "high ridge", a local designation for the area where a white China clay was first found.

Kaolin provides a source of alumina and silica for glazes and is an important ingredient in high fired white wares and porcelain bodies.

Kaolin also called China clay, has been created by the decomposition of feldspar and a pure kaolin will not soften below 1750^{0}c (Nosker, 1987).

Hendsman (1974) as in Gukas (1985) gave the analysis of Kankara kaolin, a primary clay from Katsina state as:

Silica	-	SiO_2	44.55
Alumina	-	Al_2O_3	31.45
Iron Oxide	-	FeO	1.07
Magnesia	-	MgO	0.87
Lime	-	CaO	0.28
Sodium	-	Na_2O	0.17
Potassium	-	K_2O	0.30
Excess Water	-	H_2O^+	12.03
Chemical Water	-	H_2O	9.06
Titanium Oxide	-	TiO_2	0.41
Manganese	-	MnO	0.01
Sulphur	-	SO_4	0.05

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Gukas (ibid) gave the following qualities for Kankara kaolin:

6% Dry Shrinkage

2% Biscuit Shrinkage

6.5% Glaze shrinkage

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14.5% Total Shrinkage

13.5% Biscuit Porosity

12.2% Porosity at 1300^{0}C

2.5.5 Secondary Clay ($Al_2O_3.2SiO_2.2H_2O$)

The colour of this body varies from place to place. However, according to Nelson (ibid) Secondary Clay is usually dark grey due to the presence of organic materials. He stated also that secondary clay increases plasticity and dry strength when used as body component and could also be used as a source of alumina and silica for glazes as well as binding agent.

2.5.6 Bentonite ($Al_2O_3.4SiO_2.9H_2O$)

This is composed largely of silica but used in small amounts as a plasticizer. In the absence of ball clay bentonite can also be used (Nelson, Ibid). But the percentage to be used is grossly far less than ball clay.

Singer and Singer (1963) added that the addition of 1 percent bentonite may improve plasticity more than ten percent (10%) ball clay would, making it particularly useful for moulding sands.

2.6 PLASTER OF PARIS

Plaster is made from gypsum rock, which is composed of $CaSo_4.2H_2O$. The rock is heated so that part of the water is driven off, leaving the heated plaster as follows; $CaSo_4$ $\frac{1}{2}H_2O$.

Singer and Singer (1963) stated that for a typical plaster mix for casting, 90 parts by weight of water to 100 parts plaster be used. He also noted that the optimum plaster to water ratio for any particular plaster for any particular job should be determined in each case by experiment.

Sullayman (1991) gave 100 parts of water to 130 of plaster, while Norton (1956) stated that one hundred pounds of plaster requires about 60 to 75 pounds of water.

Plaster of Paris plays a dual role. Not only does it absorb water and thereby makes the clay stiffer, but the slight solution of the calcium sulphate in water accompanying the clay, furnishes flocculating ions (both calcium and sulphur ions) being efficient flocculants. Therefore, a deflocculated casting slip poured into casting mould is flocculated on the mould surface to give a stiff cast.

2.7 METHOD OF PRODUCTION

As relates to industries, there are different approaches or techniques of producing ceramic wares. These are: Throwing Method, Slip Casting Method, Jiggering and Pressing Techniques Nelson, (ibid).

The best approach of all the mentioned methods as relates to this research is jiggering technique, due to its ability to produce solid wares, diamentional stability and accuracy in the desired design and good surface treatment. Consequently, the lack of horizontal jigger-jolley machine for polar structures such as balusters of this nature will certainly limit the researcher to the use of slip casting method which is considered the next best approach, due to its uniformity in design shapes and sizes.

Most industrial ceramic productions of varied shapes and sizes are done, through casting, using moulds made of Plaster of Paris. There are different methods and approaches to this - Drain and solid cast. Drain cast involves pouring out excess slip in a mould after a relative thickness is attained to create a vacuum. While solid cast is that without a vacuum.

2.7.1 Mould Making

There are different types of moulds - press and cast moulds. A press mould is that which requires a force or pressure either manually or mechanically in order to get the right shape out. Cast mould on the other hand depends on the complexity of the mould. There are one piece mould, two piece moulds, etcetera.

2.7.2 Product Design

Design can be defined as the presentation of a good conceptualized idea on any surface for effective onward utility. It is an inspirational phenomenon that pleases the mind. A good design harmonises with its environment. Ekeada (1988) sees design as that which needs to do with conceptualizing, interpreting on paper, actualizing into solid form and perfecting to finish. Oguntona (1986) stated that design means to make something new, which serves a purpose for which it is made. Design is the intended arrangement of materials to produce a certain result of effect. It plays an important role in the creation of any industrial product. It is the eradication of inconsistency and the establishment of order.

This was ealier asserted by Norton (1956) that the attribute of variety gives richness to the design. And that it leads the eyes about as it continually reveals new relations, new association, and new interest.

Product design is a prototype model through which the right choice of design is reproduced. It can first be sketched on paper for an onward transfer to three dimensional form either with clay thrown on the wheel, carved wood and metal, plasticine and other hard object. The final product coming out of this for the purpose of reproduction is known as the model, which can be expressed in any of the above media.

2.8 CASTING

Norton (1956) classified Ceramic casting into two; namely solid and drain castings. The later is where the mould is completely filled by pouring slip and leaving it there until it has cast solid. Drain casting is by filling the mould with slip which is poured out after a short interval, leaving a thin layer of clay against the mould.

He noted that the level of the slip in the mould must be higher than the required height of the finished piece in

order to allow for drop in the level of the slip during the casting process. This extra height he called "SPARE".

2.8.1 Slip Casting

Slip casting is a method of making ceramics in which liquid clay is poured into a hollowed, absorbent mould (Nelson, 1966).

Umar (1988) listed some requirements of a casting slip.

1. It should contain all the ingredients to form a good pottery body when fired.

2. It must be sufficiently fluid to pour into moulds to fill all the details.

3. That it must be reasonably permeable to allow a layer of clay build up in the mould while more water passes through to increase thickness.

4. It must be capable of an accurate impression of the mould.

5. The newly formed cast although still wet must remain firm until it has hardened sufficiently to keep its form as clay.

To be able to meet the above requirements Hamer (1975) as in Umar (1988) further suggested the following:

(a) More than one clay should be used with feldspatic materials to act as viscous fluxes, flint/Quartz for whiteness and hardness, sand and grog for texture and Crystobalite for the glaze on it.

(b) Fluidity can be achieved by adding more water but best by using deflocculants.

(c) Sieving through 120 mesh.

(d) Clays are naturally permeable but with deflocculants this is lost. So a balance must be sought between natural state and deflocculation to allow permeability.

(e) Suspensions 'set' slightly when allowed to rest. A balance of deflocculants must therefore be used.

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A typical casting slip for porcelain body cone (8-9) according to Nelson (ibid) is:

Porcelain Body (Cone 8 - 9)

Flint	20
Feldspar	36

Kaolin	30
Ball Clay	14

2.8.2 Deflocculants

Deflocculant can be described as anything added to clay slip in order to increase fluidity. There are many kinds of deflocculating agents such as sodium silicate (N Brand), soda ash and Darvan Number-7.

Donald (1975) described Darvan NO. 7 as an excellent deflocculant and that it takes the place of the combined sodium silicate and soda ash. Donald (Ibid) also stated that deflocculation is achieved by adding to the suspension water suitable soluble alkalies called deflocculants. He noted that deflocculants exchange their ions (charged atoms) with those of the clay particles so that the clay particles are all of a similar powerful electrostatic charge. In this state they repel one another and are unable to aggregate. No matter how closely they are packed together they prefer to slide past one another and avoid contact. This repulsion, he said acts as a lubricant.

He further submitted that a pound of plastic clay can be converted into a fluid slip with less than a tenth of a pint of water plus suitable deflocculants. This is

usually 0.5% deflocculant of the total weight of a given composition. Without the deflocculants it would require half a pint of water to reach the same fluidity. He noted that too much soda ash produces a casting that seems never to get hard. Sodium silicate (water glass) on the other hand when left open to the air, turns to a hard glass-like material in a short time. For this reason he suggested their use in ratio 3:1 mixture of sodium silicate (N Brand) and soda ash.

Advantages of using defflocculants as listed by Norton (ibid) are:

(a) a deflocculated slip has little tendency to settle and therefore, the bottom of a cast piece is not thicker than the top, and

(b) a deflocculated slip with a low water content casts a firm wall and the slip drains out clearly.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter basically covers the research design adopted, data collection technique(s), population of the study, beneficiation of materials, processing of raw materials and product design. It also deals with pilot study, sampling, body composition, preparation of moulds, slip test, shrinkage test and modulus of rupture test. Others are method of production, casting, bisquit firing, test for glaze, colour and gloss firing.

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3.2 RESEARCH INSTRUMENT

Adetoro (1986) states that the method of any research depends on the nature of the problem intended to be tackled by the researcher. In this study therefore, the research methodology adopted is basically experimental.

The instrument used were studio and laboratory experiments using the facilities of Industrial Design, Mechanical Engineering and Chemistry Departments, all at the Ahmadu Bello University, Zaria, Nigeria.

3.3 SOURCES OF MATERIALS USED

This study equally entails field study. Several field trips were made to Kankara and Bomo villages where Kaolin and Secondary clay deposits abound respectively in large quantities. The first trip to Kankara village was made during the rainy season but due to the problem of the water-logged terrain, Kaolin could not be collected. A further trip was made in December, 1997; when the whole pits were dried and ready for clay minning. The trips to both Kankara and Bomo villages enabled the researcher to ascertain good Kaolin that has less Silica content through rubbing the clay in between the finger tips. The coarse, clay means there was a lot of Silica in it; but if it was fine and white, it implied good clay. As for the Secondary clay, the researcher made sure it contained less impurities and sand which is usually removed at the top soil layer during minning at the clay deposit. This was done so that proper extraction of the desired workable clay could be made.

Visits were also made to various plank sheds at Sabon-gari market, Zaria in Kaduna State, where the researcher went round to ascertain the best wood to use for the model since not every wood could be suitable for the purpose of this design. The best wood obtained was a Mahogany of 4

inches by 6 inches. However, because of the high cost, the researcher sourced for a tree trunk from the bush that served as an appropriate alternative. It was cut and allowed to season for about three weeks. This was later taken to a wood turner in the same market (Sabon-gari) with a specific design and dimension. The researcher gave the turner, a working drawing for the wood turning, while he observed and guided him. This was because the turners would not allow an outsider to operate their machines for fear of causing damage to it.

Quartz was sourced at Batagarawa, Batagarawa Local Government Area of Katsina State. While Feldspar was obtained in Zaria, Kaduna State.

While Kaolin, Quartz and Feldspar were sourced from the above mentioned places, other materials such as Plaster of Paris, deflocculants, bentonite, laundary soap, grease and glaze materials were obtained through local suppliers (see Table-3.1).

3.4 POPULATION OF THE STUDY

The population of the study comprised; Zaria feldspar, Katsina quartz, Kankara kaolin and Bomo clay. It further

TABLE-3.1: Materials and Sources

Serial Number	Raw Material	Source
1.	Kaolin	Kankara Village in Katsina State
2.	Secondary Clay	Bomo Village, Zaria, Kaduna State
3.	Quartz	Batagarawa Village, Katsina State
4.	Feldspar (Potash)	Zaria, Kaduna State
5.	Bentonite	Purchased
6.	Iron Oxide	Purchased
7.	Tin Oxide	Purchased
8.	Fritted Lead	Purchased
9.	Wood Ash	Purchased
10.	Whitting	Purchased
11.	Magnesium Carbonate	Purchased

comprised; wood, bentonite, Paster of Paris, wood ash, sodium silicate and sodium carbonate. Others are; iron oxide, tin oxide, fritted lead, whiting and magnesium carbonate.

3.5 SAMPLING

The following materials were selected randomly for the pilot studies and eventual body and glaze formulation: kaolin, quartz, bentonite feldspar, iron oxide, tin oxide fritted lead, wood ash, whitting and mangnesium carbonate. Tests for shrinkage, modulus of rupture, firing behaviour, etc., were conducted.

3.6 BENEFICIATION/PROCESSING OF MATERIALS

The raw materials used were thoroughly washed with water in order for the carbonaceous matter to be removed. These raw materials were processed in the Ceramic Studio of the Department of Industrial Design, Ahmadu Bello University, Zaria, Nigeria (see Table-3.2). Plaster of Paris, deflocculants were equally bought already processed.

3.6.1 Quartz (S_iO_2)

The quality of any quartz can first of all, easily be identified by its colour. This material is almost translucent and can as well be described as almost white. The rocks were brought from Batagarawa Village in Katsina State. Obviously they were covered with impurities such as

TABLE-3.2: Procedures for Processing of Raw Materials

Quartz	Feldspar	Kankara Kaolin	Bomo Clay	Wood
Washed	Washed	Soaked	Soaked	Cut from the Bush
Calcined 1000^0C	Calcined 900^0C	Stirred	Stirred	Allowed to Season
Jaw Crushed	Jaw Crushed	Sieved	Sieved	Taken to Turner
Water Milled 10 Hours	Water Milled 8 Hours	Levigated	Levigated	Turned
Dried	Dried	Dried	Dried	Wrapped
Stored	Stored	Stored	Stored	Kept

dust, sand and other organic matter but were later washed with water.

In order to reduce the hardness, they were put in the kiln and calcined to about 1000^0C. And with adequate network of cracks all over the surface, they were soft enough to be broken into chips with a metal hammer (see Plate-4).

The quartz was jaw crushed, put in the ball-mill and milled for ten hours. After this, the ball-mill was emptied, and the material was allowed to settle so as to

remove the excess water off the surface (see Plate-5). The fine quartz, thick, white mass, was dried and stored.

3.6.2 Feldspar ($K_2O.Al_2O_3.6SiO_2$)

Feldspar comes mostly in pink colours. There are other colours however, like pure white (soda feldspar) almost resembling quartz in colour but with its usual characteristic of glass-like nature and strata forms allow for its proper identification. This pink coloured rock was obtained from Zaria and subjected to the same routine in order to remove impurities like sand, dust and other organic matters before calcination in the Kerosine fired Kiln to a temperature of about 900^0C. Found all over its surface were network of cracks. This enables easy disengagement into lumps or flat sheets with hammer, and at times with bare hands.

The Departmental Jaw-Crusher was used to reduce it into smaller chips before ball-milling which took up to eight hours (see Plate-6). It was emptied into a big plastic bin, allowed to settle so as to remove excess water off the surface and finally dried and stored.



PLATE-4: Quartz as seen in the Kiln after calcination



PLATE-5: Milled Quartz Discharched from the Ball-Mill

3.6.3 Kankara Kaolin ($Al_2O_3.2SiO_2.2H_2O$)

Kaolin naturally comes in a fine white grained form. When mixed with impurities, the white nature can be coloured to pink. The clay was obtained from Kankara village, soaked for twenty-four hours. At intervals the soaked clay would be stirred homogeneously in other to enable it desolve completely. This was further sieved through a 60 mesh sieve and levigated by repeatedly allowing the free Silica to settle while draining the clay that is in suspension.

The clay slip was then poured into a plaster mould for the water to be removed and the dried material was then stored.

3.6.4 Bomo Clay

This is a very plastic material and the colour looks gray. The same process of soaking, levigating and sieving were carried out and later dried in a plaster mould before storage (see Table-3.2 above).

3.7 PRODUCT DESIGN

Product design served as a litmus test or as a prelude from which the best was adopted. Since the basic requisite



PLATE-6: Calcined Feldspar Rock been fed into Jaw-Crushing Machine

for effective marketing strategy is to satisfy consumers, the need therefore, for a good product design is always at a focus and as important as the end product itself.

The balusters design, being an industrial product designed for mass production was aimed at attracting investors and consumers alike.

Based on the above factors, various designs were carried out on paper by the researcher as experimental sketches which led to the eventual selection of the most appropriate designs (see Figure-2a-b).

Wood of various sizes were sought for in the bush and taken to a turner for the onward transfer of the design on paper to solid-three dimentional shape, using wood as the medium (see Plate-7). The models were of various heights: 35 centimetre with 16.5 centimetre as diameter, 61 centimetre with 10.5 centimetre as diameter and 67 centimetre with 10 centimetre as diameter, with surface treatment. All in their three dimensional forms (see Plate-8).

3.8 PILOT STUDIES

Pilot study according to Afolabi (1996), can be regarded as a small scale approach of the envisaged study or investigation, whereby a proto-type of the main body is developed. Consequently, this approach avail itself as a means to reduce, to a large extent, the number of treatment errors that would have occured in the main investigation, as most of these errors would have been identified in the pilot study stage.

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Studio experimentation was conducted at Ahmadu Bello University, Zaria for the purpose of ascertaining the suitability and reliability of the chosen materials.

Seven different body compositions comprising three major materials - Feldspar, Quartz and Kaolin were tested and the eventual results which showed some cracks made the researcher to test further additional seven body compositions, this time with binders - Secondary clay and Bentonite. Out of the new seven bodies, the body which had no cracks and also had the highest strength of 1.50 KN/m^2 as revealed from the cast mould tests and modulus of rupture tests respectively was chosen for the final project.

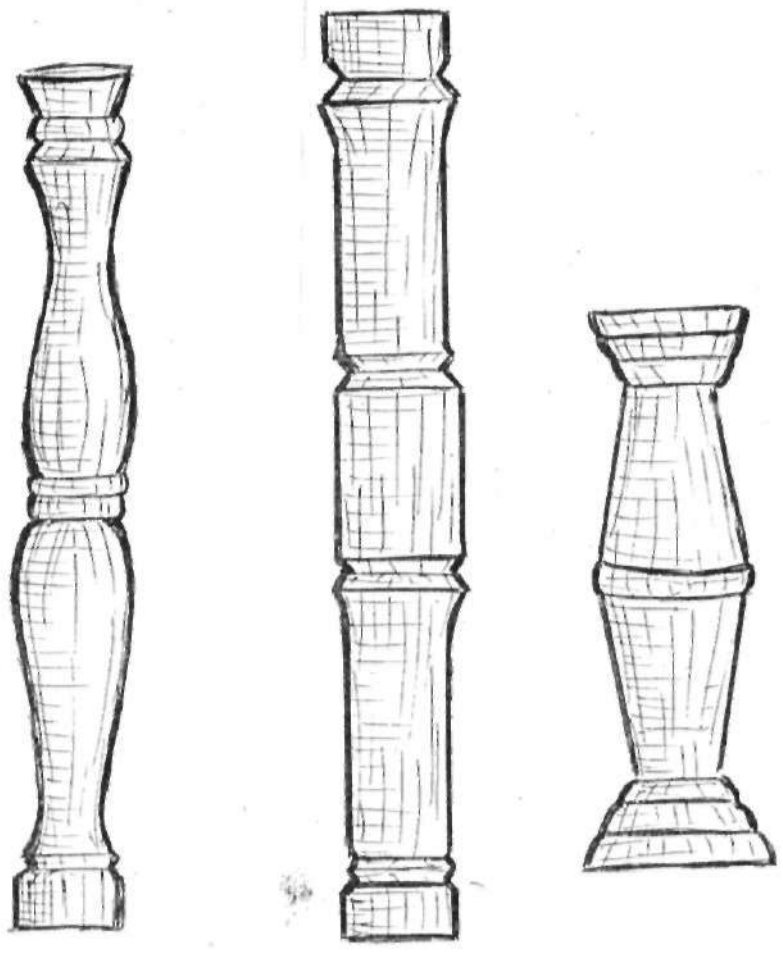


FIGURE-2(a): Product Design

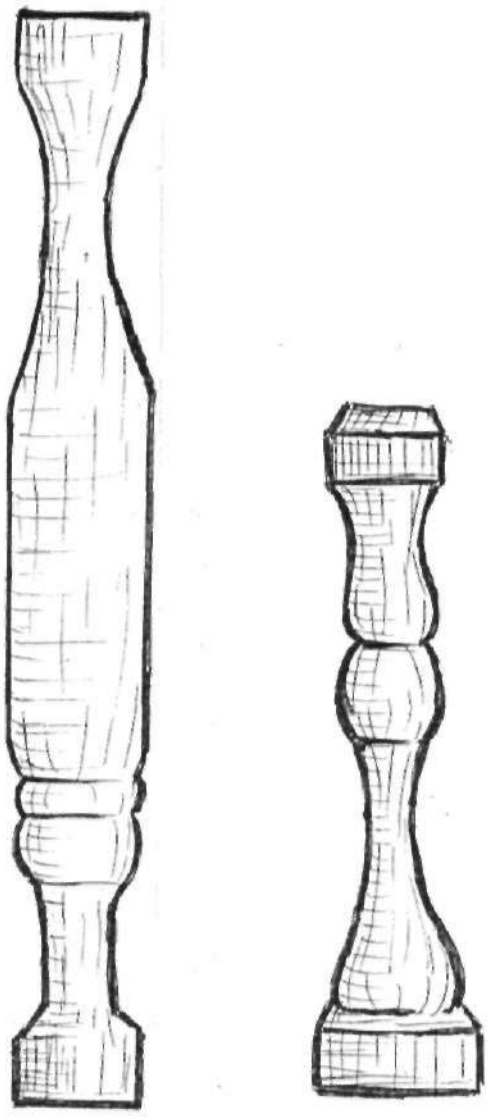


FIGURE-2(b): Product Design

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PLATE-7: The Researcher in a Turning Shed During Wood Turning session.



PLATE-8: Turned Wood in Various Designs and Dimensions (Models)

Through the test conducted under the pilot studies and results obtained, the researcher was able to ascertain the materials and method to use in achieving the stated objectives.

3.9 BODY COMPOSITION

There are two types of Porcelain hard and soft porcelain. With soft porcelain, utility value is limited in that it chips off easily. The vitrification of this body is at lower temperature.

European hard porcelain is composed chiefly of Kaolin, Potash Feldspar and Quartz. Singer and Singer (1963) gave a typical example of hard porcelain composition as in Table-3.3.

TABLE-3.3: Hard Porcelain Composition

	Normal Composition (Percentage)	Range	Average (Percentage)
Kaolin	50	42 - 66	54
Potash Feldspar	25	17 - 37	27
Quartz	25	12 - 30	21

SOURCE: Singer and Singer (1963)

Based on the above composition range seven different bodies were tested (see Table 3.4).

TABLE-3.4: Body Composition - I

Test	1	2	3	4	5	6	7
Kaolin	42	44	47	50	54	56	58
Feldspar	37	30	29	27	25	24	23
Quartz	21	26	24	23	21	20	19

SOURCE: Studio Test (1998)

The results from the seven test bodies, cast from test moulds did not give a suitable outcome, perhaps due to lack of binders in the clay bodies. The behaviours of the test pieces were however, noted. These unfavourable results called for a random adjustment of the percentages in order to accommodate Secondary Clay and Bentonite which now serve two functions - as part of the body composition and as binders; as in the Table-3.5 below.

Therefore, for the purpose of this research which is aimed at high vitreous body formation, measures were taken in order to prevent chipping, to enhance good strength, durability, ability to resist warpage, desired firing temperature and above all, the fusion of the glaze to the body. Hence, the choice of hard porcelain.

Further characteristics that informed the researcher's choice of the selected materials and their compositions were

TABLE-3.5: Body Composition - II

Test	Materials in Grams						
	1	2	3	4	5	6	7
Kaolin	42	44	45	48	60	55	65
Feldspar	28	24	25	25	23	26.5	20.5
Quartz	20	12	14	13	15	17	13
Ball Clay	10	20	16	14	--	--	--
Bentonite	--	--	--	--	2	1.5	1.5
Deflocculants	1gm	1gm	1gm	1gm	1gm	1gm	1gm
Water	50mls	50mls	50mls	50mls	50mls	50mls	50mls

SOURCE: Studio Test (1998)

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suggestions made by various literature, practicing ceramists, professionals on related fields, and as also upheld by Alkali (ibid) that pottery materials are divided into three on the basis of their functional requirements; the first, he stated are the materials that assist in the forming process. The second is the flux and lastly, the filler.

3.10 PREPARATION OF MOULDS

Plaster of Paris was the medium used in this process. Three different moulds were prepared, one after the other since the design of the model varies (see Figures 3a-c). There are different dimensions to casting depending on the complexity of the model. There are single, double and multiple piece moulds. But the mould used for this purpose was the two piece mould.

3.10.1 Procedures

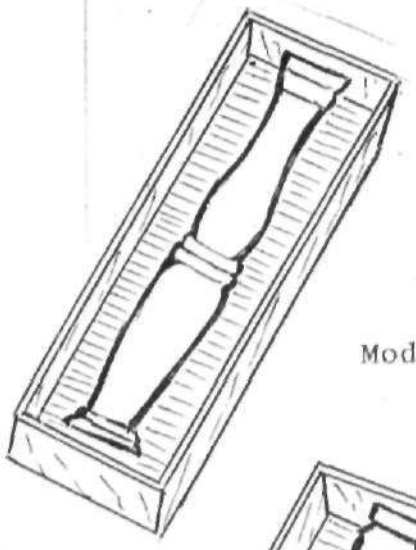
Each model was half way burried into a wet flatened clay surface, well balanced with good support or cottles as elevation or projections above the model. Adequate space was allowed for the plaster to occupy in terms of thickness and also angles of possible spillage of plaster were properly blocked. The thicker a plaster mould is the more water it absorbs. This allows for more cast before the mould gets weak. However, any plaster mould must not be excessively thick. Commercial plaster (chalk grade) of good quality was obtained and in agreement with Sullayman (1991), 130 parts of plaster to 100 parts of water was used. That is, the proportion of the plaster to water used was in ratio 130:100. The plaster was then carefully added to the

water already in a bowl. This was then gently stirred from the bottom and all over to expell air bubbles trapped. The mixture was continuously agitated to avoid setting and thickening of the paste. At this point, it was poured over the model now secured in its box, after coating the surface with laundry soap and grease respectively (see Figure-4).

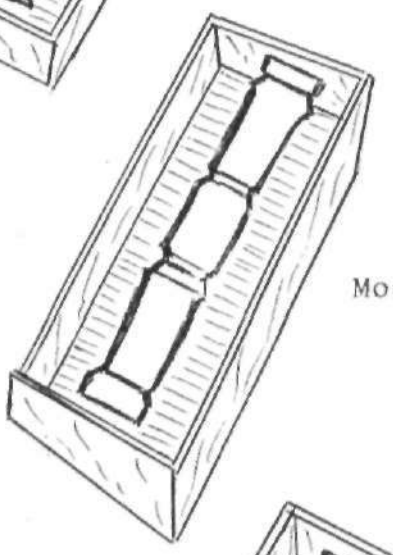
With the help of a flat object the paste was evenly levelled before it solidified. Having ascertained the hardness which took over twenty to twenty-five minutes, what followed was the careful removal of the wooden support (cottle).

Since the model was for a two piece mould, the first successful cast piece was flatened with a ruler and turned upside down for the second piece mould. Four notches were made with a copper coin (₦1) on the first cast, two on each side. These notches later formed the keys for the two piece mould to hold unto each other. The notches also helped in keeping the two halves of the piece mould in position for accurate cast (see same Figure-4).

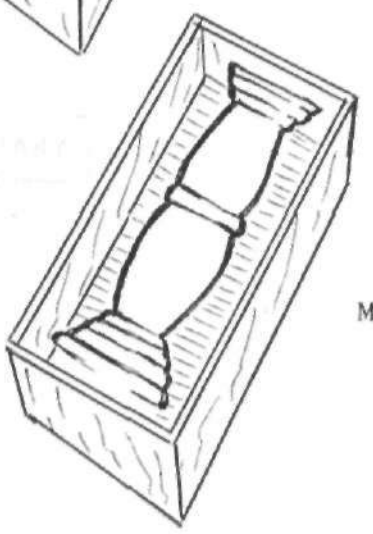
While the model was still intact, the surface of both the model and the plaster were coated with a film of laundry soap paste mixed together with grease and applied to the model and the plaster together with the notches. Both the



Model (a)



Model (b)



Model (c)

FIGURE-3(a-c): Illustration of Models Ready for Casting

soap film mixed together with the grease was to serve as a separator. The mould was again supported with higher walls of planks so as to give an adequate height of about Six centimetres needed for the relative thickness required of the second piece mould. The plaster paste was again poured to cover the part of uncovered model left from the first cast. Before it finally set, the top surface ofthe newly poured plaster paste was smoothened with a flat object. When the plaster hardened it was then disengaged and the model removed by first dipping it in water and gently tapping or hitting with palm.

With the successful casting of the models, the plaster moulds were now ready for slip casting. These procedure were equally applied to the rest of the moulds.

3.10.2 Test Moulds

Two different moulds were cast for both shrinkage and modulus of rupture tests.

3.10.3 Aim

To determine the strength of the materials to use as well as their shrinkage tests through casting since the

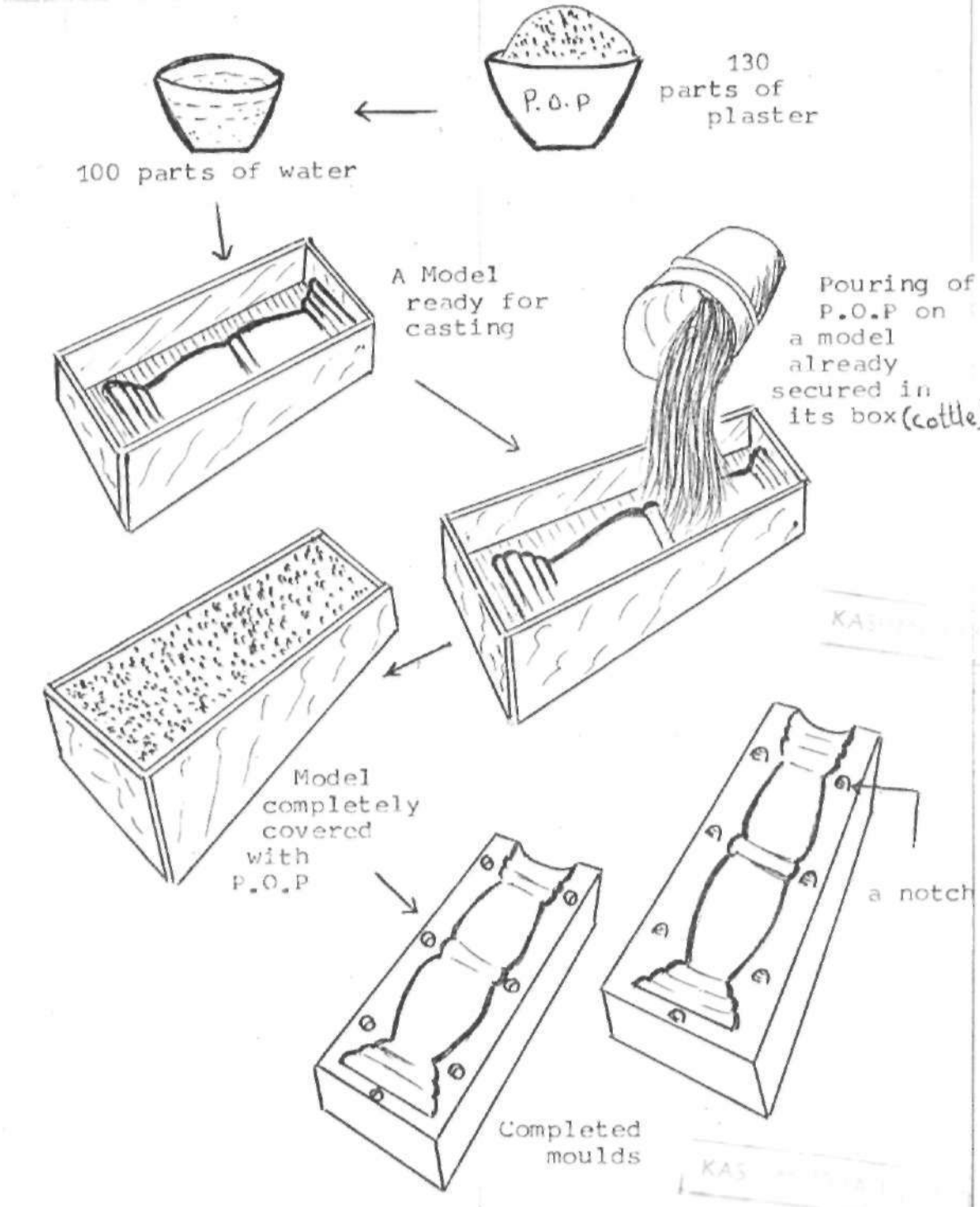


FIGURE-4: Casting Procedures

main project will be achieved by casting. Rather than making compressed slabs that might not give a similar result.

3.11 SLIP TEST

Before the main slip casting was done, the various body compositions were subjected to a simple plaster bat and slip test.

3.11.1 Procedures

Drops of slip from each of the seven bodies were allowed to fall on the plaster bat and with a finger tip attempts were made to dislodge these droplets off the surface. After one minute, suitable drops were expected to move (Umar, ibid).

To test for fluidity, a ruler was dipped in a consistency of slip from each of the bodies. The running behaviour of those slips was noted. Suitable ones were expected to run off the ruler without intermittent stopage.

3.11.2 Aim

To determine the suitability of various slips used as well as to test for fluidity under normal condition.

3.12 SHRINKAGE TEST

This test was first administered through cast method. Straight lines of 15 centimetre were made on each of the seven different bodies of cast tiles from the test mould. Within this 15 centimetre a 10 centimetre mark was further made. Allowed to dry and the lines were measured again. Thus, recording the dry length before further subjecting the tiles to bisque firing at 950^0C and finally to gloss firing temperature at 1300^0C (Cone 10). The percentages of shrinkage was equally recorded using the following formular (Umar, 1988) and (Uduigwome, 1989).

$$DS = \frac{PL - DL}{PL} \times \frac{100}{1}$$

where;

DS = Dry Shrinkage

PL = Plastic Length

DL = Dry Length

and;

$$FS = \frac{PL - FL}{PL} \times \frac{100}{1}$$

where;

FS = Firing Shrinkage

PL = Plastic Length

FL = Fired Length

3.13 MODULUS OF RUPTURE TEST

MOR is the fracture strength of a material under a bending load and the measurement is made on a long bar of either rectangular or circular cross section, supported near its ends, with a load applied at the centre - that is by three-point loading (Ahmed, 1986). Three-point loading of a rectangular bar is illustrated below in Figure-5.

MOR for such bar is given as:

$$MOR = \frac{3PL}{2bd_0^2}; \quad (N/m^2) \qquad \ldots\ldots\ldots (10)$$

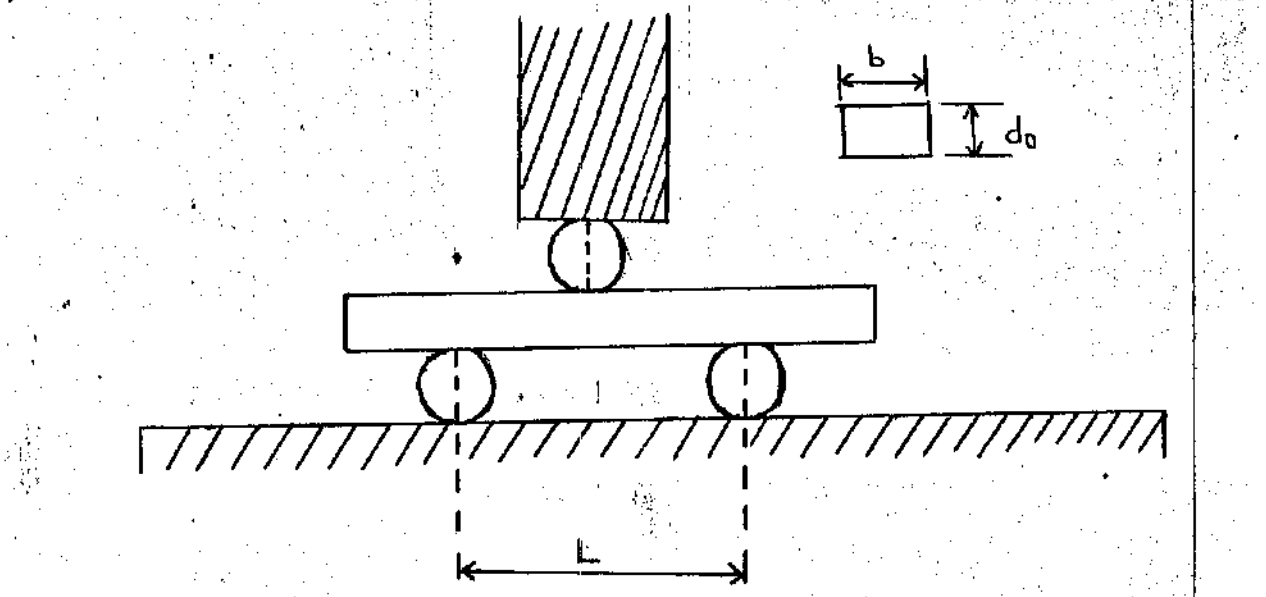
where;

P = Breaking Load in KN

L = Length in Centimetre

B = Breadth in Centimetre

d_0 = Height in Centimetre



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FIGURE-5: Three Point Loading of a Rectangular Bar

3.13.1 Aim

To establish the strength of the various bodies through which the suitable material for reproduction will be chosen.

3.13.2 Procedure

Three tiles were cast from each of the seven bodies, dried, bisque and also taken to gloss firing temperature (1300^{0}C) (see Plate-9).

The fired tiles in their various measurements now are:

i. Tile one measured 15cm x 3.6cm x 1.1cm
ii. Tile two measured 13.6cm x 3.4cm x 1.1cm
iii. Tile three measured 13.7cm x 3.5cm x 1.1cm
iv. Tile four measured 13.7cm x 3.5cm x 1.1cm
v. Tile five measured 13.3cm x 3.2cm x 1.1cm
vi. Tile six measured 13.4cm x 3.3cm x 1.1cm
vii. Tile Seven measured 14.7cm x 3.5cm x 1cm

These tiles were taken to the Department of Mechanical Engineering where a heavy duty machine, very sensitive to reading force applied on any material that could lead to its brakage was used.

Each tile was placed on two parallel bars 10 centimetre apart and the machine was put on. The force at which the tiles broke were recorded as the Force Breaking Load and analysed as already seen in Figure-5 above.

3.14 METHOD OF PRODUCTION

Drain method of production was used. Drain cast is the process of pouring out the excess slip after ascertaining it's relative thickness which is however, to the desire of the researcher, about 1 centimetre thick in about 25 minutes.

3.15 SLIP CASTING PROCESS

The determinant factor for the eventual selection of the body for the main work was the outcome of the results from the seven body compositions already tested.

The chosen body for the final production could be seen from the Table 3.6 below.

It is important to emphasize that deflocculants used here is 1 percent of the weight of total raw materials in ratio 3:1 (Sodium Silicate and Sodium Carbonate), Donald (1976). Also, water which is ½ the weight of the dry



PLATE-9: Fired Tiles Used for Both Shrinkage and Modulus of Rupute Tests

material (Rhodes, 1975) was added to the entire mixture poured into the blunger and blunged for two hours. The purpose of this was for the whole batch to mix homogenously. The batch was then left to settle for some hours. This allowed for the observation of the action of deflocculants.

TABLE-3.6: Final Body Composition Used

Material	Grammage
Kaolin	65.0 Gram
Feldspar	20.5 Gram
Quartz	13.0 Gram
Bentonite	1.5 Gram
Sodium Silicate/Carbonate	1.0 Gram
Water	50 mls

SOURCE: Studio Test (1998)

The moulds were then ready for casting; bound together with both rubber bands at several places so that it could firmly grip the plaster mould together so as not to give way when slip is finally poured (see Figure-6). Also, employed was the use of soft clay to seal up the contact areas where slip might leak out during pouring.

The mixture was stirred poured into moulds and allowed to cast for about 25 minutes, depending on the

humidity of the atmosphere and the saturation level of the moulds. This was to allow for relatively thick wall of cast, about 1 Centimetre due to the need for strength. After 30 minutes the spare edges were trimmed off and the cast ware was left in the mould till the following day before disengagement of the cast from the mould. This was to disallow possible distortion due to their heights. When finally removed they were arranged on the table for gradual drying. When finally dried, they were fettled in readiness for firing.

3.16 BISCUIT FIRING

Cast pieces were arranged on a platform for two weeks for proper drying in readiness for bisque firing.

The normal bisquit firing temperature for clay bodies like stoneware or porcelain is usually around 950^0C - 1000^0C but for the purpose of this research, the wares after drying and in readiness for firing were arranged horizontally in the kerosine fueled kiln and taken to about 1300^0C Cone 10 for approximately four hours.

This was done because the researcher feared if the wares were arranged vertically and subjected to such a high temperature firing, there is the risk of damage from warpage.

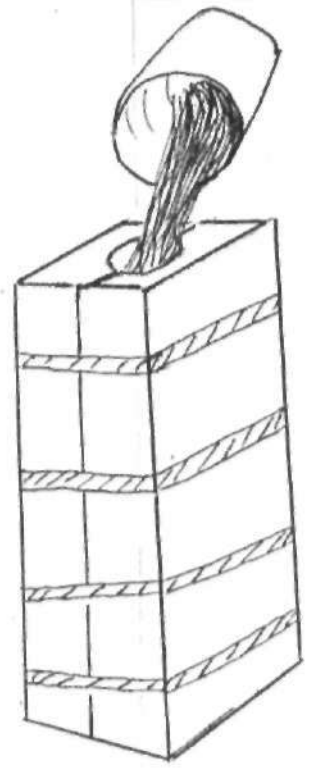


FIGURE-6: Slip Pouring into a Mould

Therefore, the quality or strength that would be attained by the body will now be determined by the 1300^{0}C firing range. Since the gloss firing will be at about 1200^{0}C (Cone-6).

An oxidized atmosphere was used throughout the firing at the Department of Industrial Design, Ahmadu Bello University, Zaria.

The wares were unpacked from the kiln when finally cooled, in readiness for the glaze firing.

3.17 TEST FOR GLAZES

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Glazes behave differently on clay bodies. That of the porcelain body is not an exception, infact special glaze recipes are recommended and tagged porcelain glazes. Rhodes (1957) stated that porcelain glazes can be relatively simple in composition, that feldspar alone melt at around Cone-9 or 10 and little material need to be added to it. He opined that good high-fired glazes can be made from such simple combinations as:

Feldspar	-	85 Parts
Whiting	-	15 Parts

or

Feldspar	-	60 Parts
Flint	-	20 Parts
Whiting	-	20 Parts

However, seven different experimental low and non-low temperature glazes were tested and their outcome were recorded. Those that gave the best results were used on the final products (see Table-3.7).

Due to the nature of this research, high fired glazes for Porcelain or Stoneware as suggested by Rhodes (ibid) could not be used in order to avert excessive warpage. Hence the choice of glazes of 1200^{0}C firing temperature.

3.18 TEST FOR COLOUR

Porcelainous bodies in many cases assume white colour which is one of the main characteristics. Consequently, with the use of binders in form of Secondary Clay and Bentonite the colours after firing were recorded.

It is worth while to note too that the researcher did experiment with other colours such as brown, dark-brown and transparent glaze as test glazes.

3.19 GLOSS FIRING

Having ascertained the glazes to be used from the various glaze tests, two of the already bisque fired works were glazed by dipping and thereafter fired. The results were recorded (see Plate-10). Further experimented upon was the use of spray gun to apply glazes on the works. The result was equally noted.

The firing was achieved at about 1200^0C and 1240^0C using Cone-6 Oxidation firing was used throughout.



PLATE-10: Unsuccessful Glazed Products Using Dipping Method

TABLE-3.7: Glaze Test

Materials	Test-1 Cone 08	Test-2 Cone 012	Test-3 Cone 06-03	Test-4 Cone 06-04	Test-5 Cone 010	Test-6 Cone 6-8	Test-7 Cone 6-8
Wood Ash	--	--	--	--	--	--	30
Fritted White Lead	55	72	62	71	72	--	--
Magnesium Carbonate	--	--	--	--	--	--	10
Flint	17	14	26	16	12	25.2	--
Bentonite	--	--	2	--	--	--	--
Kaolin	2	13	10	2	5	5.0	--
Secondary Clay	--	--	--	--	--	--	20
Tin Oxide	1	1	--	2	4	1.5	--
Potash Feldspar	21	--	--	9	--	62.2	40
Whiting	4	--	--	--	3	7.6	--
Iron Oxide	--	--	--	--	4	--	--
Percentage	100	100	100	100	100	101.5	100

SOURCE: Studio Test (1999)

CHAPTER - FOUR

ANALYSIS OF RESULTS AND FINDINGS

4.1 INTRODUCTION

This chapter deals with the results of various experiments carried out on materials, formulated bodies, slip making and method of production. As such, analysis of results of the various test conducted as well as various findings are documented.

4.2 RESULT OF PRODUCT DESIGN (Model)

The seasoned woods of acacia sought for in the bush in place of the Mahogany sold in the market gave effective result in the Plaster of Paris cast. No warpage. All the intricate grooves on the wood were successfully replicated on the plaster moulds resulting in excellent casts. The wood surfaces gave a good cast on various moulds. They were very fine and smooth. Various lengths of models; 35 centimetre, 61 centimetre and 67 centimetre posed no problem during disengagement of moulds after casting.

4.3 RESULT OF MOULD TEST

The plaster to water ratio of 130:100 used in this study was found to be successful, very strong and cast fine (see Plate-11). Also, the use of grease and laundry soap mixed properly as separator proved effective. It allowed easy disengagement of moulds from the models. The surface of the cast moulds were eventually washed with water and soap.

4.4 RESULT OF SLIP CASTING TEST

Slip suitability as well as test for fluidity proved fine. All the seven drops of slip moved when dislodged with a finger tip, while the viscosity or running behaviour of the slips equally gave an expected result. It runs at a stretch without intermittent stoppage.

4.5 RESULT OF CLAY SLIP BODIES WITHOUT BINDER (Secondary Clay or Bentonite)

The result of this test shows a net work of cracks all over the ware in the mould shortly after pouring out the excess slip.



PLATE-11: Moulds Used for Slip Casting

4.6 RESULT OF CLAY SLIP BODIES WITH BINDER (Secondary Clay or Bentonite)

Here seven compositions are involved, with good casting results highly recorded; using secondary clay or bentonite as plasticizer. Test (T2), T5, and T6 which had 20 percent secondary clay, 2 percent bentonite and 1.5 percent bentonite respectively, recorded small inner cracks that did not show at the outer surface.

Three out of the remaining four tests had secondary clay as plasticizer in these percentages: Test(1) 10 per cent; T3, 16 percent and T4, 14 percent while T7 had 1.5 percent bentonite. These four body slips resulted in good, products that had no cracks. Also, the use of deflocculants such as sodium silicate and carbonate in ratio 3:1 respectively for slip casting proved effective too by deflocculating fine.

4.7 RESULT OF BODY TEST

The bodies used for this study were subjected to various property tests like shrinkage, Modulus of Rupture (M.O.R) and colour test, giving the following results:

(a) Shrinkage Result

All the procedures needed for this results were followed and the results are as follows: Body Test I had 7 Percent; Fired Shrinkage; Test II had 10 Percent; Fired Shrinkage, and Body Test III - 8 Percent Fired Shrinkage. Others are Body Test IV with 8 Percent Fired Shrinkage; Test V - 11 Percent Fired Shrinkage; Test VI and VII had 9 Percent and 10 Percent Fired Shrinkage respectively. As in Table-4.1 below.

TABLE-4.1: Table on Results of Shrinkage Tests

Test	Plastic Length cm	Dry Length cm	Dry Shrinkage Percentage	Fired Length cm	Fired Shrinkage Percentage
T1	10	9.8	2	9.3	7
T2	10	9.7	3	9.0	10
T3	10	9.7	3	9.2	8
T4	10	9.7	3	9.2	8
T5	10	9.5	5	8.9	11
T6	10	9.6	4	9.1	9
T7	10	9.6	4	9.0	10

SOURCE: Studio Test (1998)

(b) Results of Modulus of Rupture (M.O.R) Test

The results for these tests are as follows: MOR Test I: had 1.19 KN/m^2; MOR T2: 1.26 KN/m^2; and MOR T3: had 1.23 KN/m^2. Others are MOR T4: 1.23 KN/m^2; MOR T5: 1.34 KN/m^2;

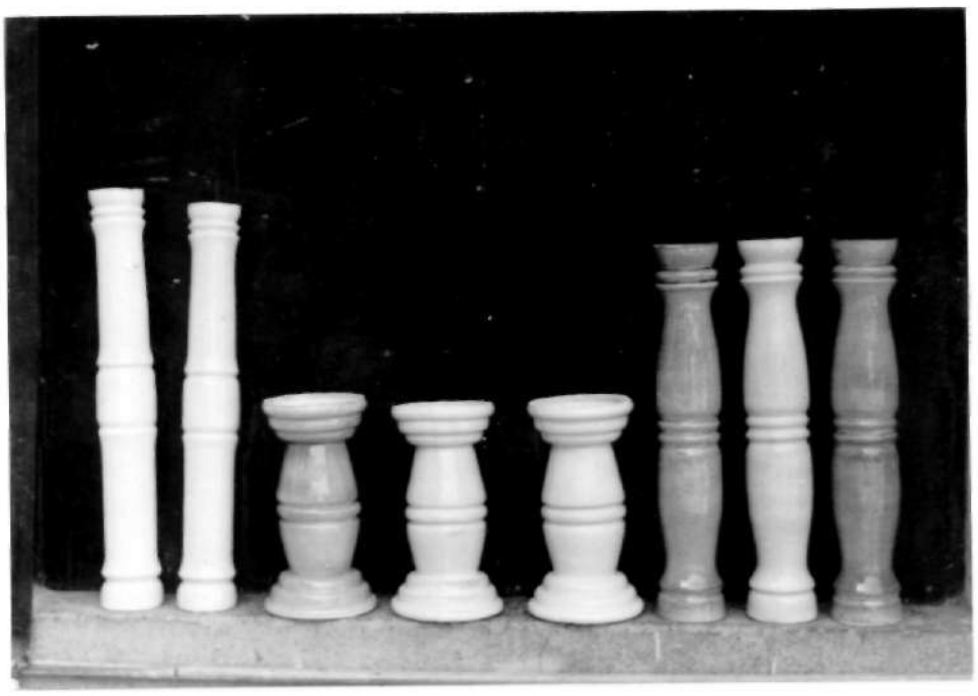


PLATE-12: Successful Glazed Products in Various Colours (Using Spray-Gun).

TABLE-4.3: Glaze Test Result

Material	Test-1 Cone 08	Test-2 Cone 012	Test-3 Cone 06-03	Test-4 Cone 06-04	Test-5 Cone 010	Test-6 Cone 6-8	Test-7 Cone 6-8
Wood Ash	--	--	--	--	--	--	30
Fritted White Lead	55	72	62	71	72	--	--
Magnesium Carbonate	--	--	--	--	--	--	10
Flint	17	14	26	16	--	25.2	--
Bentonite	--	--	2	--	--	--	--
Kaolin							
Secondary Clay	2	13	10	2	5	5.0	--
Tin Oxide	--	--	--	--	--	--	20
Potash Feldspar	1	--	--	2	4	1.5	--
Whiting	21	--	--	9	--	62.2	40
Iron Oxide	4	--	--	--	3	7.6	--
Percentage	--	1	--	--	4	--	--
Result	100	100	100	100	100	101.5	100
	Flaked Off (Bad)	Light Brain Good (Fused Well)	Flaked Off	Air Bubble all over Surface (Bad)	Dark Brown Fused Well (Good)	Clear Transparent Well Fused (Good Used)	Light Brown Well Fused (Good Used)

Specific Study Test 1989

noting too that even the behaviour of dark glaze on the improved stoneware body as was experimented upon gave a different result. This result can be described as translucent dark glaze rather than its being completely opaque as it would have behaved on earthenware and stoneware bodies.

4.12 FINDINGS

(a) In the course of slip casting, it was discovered that bodies without a binder like secondary clay or bentonite cracked.

(b) Thickly cast wares of about 1 centimetre do not warp except when too close to the source of heat. The addition of 1.5 percent bentonite gave a good plasticity.

(c) The horizontal arrangements of cast balusters on each other to the firing range of $1300^{0}C$ reduced the warpage tendency at subsequent gloss firing temperature.

(d) It was further discovered that the balusters closer to the bag-wall warped due to contact with extreme heat.

(e) Almost all the bodies gave similar results in modulus of rupture test, this could be due to the *little or insignificant differences in their* various body formulation and thickness.

(f) Inspite of the general cold weather, once wares were removed off the moulds cast pieces survived even uncovered with cellophene wrappers.

(g) Test Tile number seven with 65 percent Kaolin and being the highest in the composition recorded additional strength under modulus of rupture (MOR) test with 1.50 KN/m^2. This is probably due to higher alumina content injected into the body by this high Kaolin percentage.

(h) It was discovered too that after pouring out the excess slips, the cast piece had to be left in the mould over-night before disengagement. In other words, a cast is only possible per day and per mould in order to avert collapse or sagging.

(i) Two of the bisque fired balusters were glazed by dipping and test fired. Areas where glaze overlapped and with glaze thickening peeled off,

even before firing. When eventually test fired, they crazed producing a rough texture.

(j) The use of spray gun was tried so as to give a uniform glaze application and to reduce excessive thickness. This method gave a good effect both in glaze application and gloss firing. No crazing or dunting, but very glossy and smooth..

(k) The final firing of the glazed balusters gave the desired results or effects, glossy and brilliant.

(L) That about 65 percent of Kaolin, 13 percent of quartz as well as 20.5 percent of Zaria Feldspar in addition to the use of 1.5 percent bentonite in the clay body composition, produced improved stonewares, rather than pure porcelain.

This view is supported by Singer and Singer (1963) who stated that relative translucency in porcelain body decreases with increasing China Clay, and that translucency is equally related to thickness by an exponented law. He concluded that the addition of ball clay also lowers translucency.

CHAPTER - FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The objective of this study is to design and produce balusters using ceramic local raw materials. This chapter enumerates the summary, of research procedures used and result obtained. It also encompases conclusion drawn, and the recommendations made on the basis of the experiments carried out in the course of this study.

5.2 SUMMARY

Persner, et al (1975) defines baluster as; "a short post or pillar in a series supporting a rail".

Various materials needed for processing body formulation, mould making, product design, slip formulation and glazes were obtained and tested to determine their workability, reliability and suitability based on the available literature and studio experiments.

Effective oxidation firing using kerosine as fuel for firing was achieved.

Clear transparent and light brown glazes ranging from Cone: 6-8 of about 1200^{0}C - 1250^{0}C were developed and used. The results were very clear, of good effect, with neither crazing, dunting, nor crawling.

Plaster to water ratio of 130:100 was used in the mould making, this gave efficient result too. Moulds were strong enough, with smooth surfaces, and cast detatched from moulds easily.

The horizontal arrangement of the cast pieces in the Kiln which was fired to about 1300^{0}C as the first firing gave a good result. No warpage, no cracks, excepts in wares on bag wall spots. The second stage, which gloss firing was taken taken to between 1200oC - 1250oC 6-8. The about 1200^{0}C - 1250^{0}C Cone: 6-8. The result was equally good except that wares closer to the source of heat recorded warpage.

5.3 CONCLUSIONS

On the basis of experiments conducted and the result obtained, the following conclusions were drawn:

(a) That the materials used in the formulation of the ceramic balusters if utilized in the manner stated by this study will give consistent results.

(b) That baluster production using ceramic materials is achievable.

(c) That such balusters can withstand the tear and wear of daily use like steel and wooden balusters.

(d) That the warpage of the improved stoneware body used in this study can further be reduced if not overcome by the horizontal arrangement of the balusters on one another, especially at the bisque firing stage.

(e) That there exists in great abundance local raw materials suitable for the production of balusters for our various buildings.

(f) That 1.5 percent addition of Bentonite as Plastizer is adequate for the production of balusters.

(g) That a casting period of 25 minutes is adequate for baluster production of about 1 Centimetre thick.

(h) That due to their various heights; 35 Centimetre, 61 centimetre and 67 centimetre, a cast per mould only is possible daily in other to avert sagging.

5.4 RECOMMENDATION FOR FURTHER RESEARCH

The following areas are recommended for further endeavours in the production of balusters:

i. There is the need to study to overcome completely the warpage of the locally made shelves, which inturn, affect or contribute to the warpage of the balusters.

ii. Further efforts should be made to research into low temperature glazes of about Cones: 015 - 022, using local raw materials. This will enhance baluster production without warpage.

iii. Further efforts should be made into using ceramic materials to produce ceramic features in the house holds such as furniture and other household fittings.

5.5 GENERAL RECOMMENDATION

The following general recommendations are proffered:

i. The utilization of scientific and empirical approach to the analysis of materials for this nature of study is highly recommended.

ii. Also, further research into the facilities that could help in the easier production of balusters should be made.

iii. Although, the researcher employed the use of casting method for the production of ceramic balusters, the use of jigger-jolley for producing polar structures of this nature is further recommended for subsequent producers of ceramic balusters. In other to facilitate quick and large scale production since only a cast was possible per day in casting approach; and in order to stem the problem of warpage due to heat.

iv. That related and relevant elective courses in sister departments such as Engineering, Geology, and Chemistry is highly recommended for students of Ceramics.

v. Equally recommended too is that the Department of Industrial Design Library be built and well equipped with up to date ceramic and science related materials in form of books and journals for update of knowledge.

vi. Obsolete equipment in the department be replaced with modern ones so as to accelerate further development. Furthermore, the need for scientific (Electric) top loading measuring scale, with electric test kilns, and glaze test jar mills be made readily available as a matter of urgency for future researchers and for uptimum efficiency.

vii. Presently the cost per unit of the balusters is high, largely due to cost of fuel. Therefore, it is strongly recommended that the use of cheaper fuel as alternative to the kerosine be looked into in order to reduce cost of production.

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