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Suitability of Some Selected Clays in Ondo and Ekiti States for the Production of Refractory Kiln Furniture

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Abstract
Refractory bats and props are very expensive in Nigeria, as a result of high cost of importation, and in most cases, they are not available. This study is, therefore, aimed at producing refractory bats and props using local ceramics materials that are subjected to adequate quality control processes, not that alone, but also a materials that would guaranty the quality, strength and behavior of the final products in service at high temperature above 1300^0c. To achieve the objectives, field trips were made to different locations of the raw materials to collect samples of kaolin and ball clay in Ondo and Ekiti States based on the existing literatures. The studio chemical analysis of kaolin indicates that, out of the three sourced kaolin from Isan-Ekiti, Ifon and Ikere-Ekiti, Ifon kaolin shows some desirable characteristic and hence more dependable. It has less shrinkage, less porosity, low iron content and high purity level than the other sourced clays. The Alumino-Silicate of the clay is about 70.48% which makes it suitable for refractory production. The workable mixture for the body composition for selves and prop production was given as 2 parts clay and 8 parts grog. It was however, established that both Ifon kaolin and Isan ball clays can be used as substitute for these very important foundry materials which is found abundant in Ondo and Ekiti state. The exploration of these materials will definitely reduced the cost production and also empowered the economics strength of the states.

Keywords: grog, levigation, shelves, refractory, prop, studio

INTRODUCTION

Ceramics can be defined as the art and science of making and clay articles, which have as their essential component, are composed largely of inorganic and non-metallic materials (Kingery, Bowen and Uhmann 1976). Ceramics is becoming increasingly popular in Nigeria in recent times. Ahuwan (2003) and Ozioma (2004) recorded that, contemporary ceramics was fully introduced to Nigeria in 1952 by Micheal Cardew.

The process involved in the production of contemporary ceramic products necessitate various types of equipment such as kiln, glaze and kiln furniture. Kiln, according to Rhodes (1969) is a box of refractory material which accumulates and retains the heat directed into it. Hammer (1975) described kiln furniture as special refractories shaped to hold pots in the kiln either for biscuit or glaze firing. Bats and props which are important kiln accessories in Nigeria are very expensive as a result of high cost of importation and in most cases, they are not available, thus the need for the local production of these items.

It should be noted that in recent times, bats and props are very important for successful pottery production Without these important kiln accessories, it will be difficult to glaze ceramic products since they are to support and separate the glazed ware from getting stuck to one another in the process of firing and cooling. Producers of kiln furniture in advanced countries of the world use alumina and fireclay for the production of these items. Other materials of importance in the making of the refractory furniture accessories are; mullite, zircornia, cordierite and silicon carbide. Since these materials are not readily available in the country, there is need, therefore to look inward for alternatives. The alternatives can be found in local clay deposit in Ondo and Ekiti States, most especially kaolin which is highly refractory and Ball clay which can act as binders to hold the materials together in the process of making. These materials are found in large quantities in both Ondo and Ekiti states of Nigeria. This study is, therefore, aimed at producing refractory bats and props using local ceramic materials that are subjected to adequate quality control processes, not that alone, but also a materials that would guaranty the quality, strength and behavior of the final products in service at high temperature above 1200^oc

LIMITATION OF THE STUDY

This study shall be limited to the use of clays from Ondo and Ekiti States (Nigeria).

IDENTIFICATION AND EXPLOITATION OF KAOLIN AND BALL CLAY

Procedure:
Field trips were made to different locations of raw materials such as kaolin and ball clay in Ondo and Ekiti States based on existing literature. The following samples were collected In-situ.

Kaolin: Isan Ekiti, Ikere Ekiti. (Ekiti state) Ifon (Ondo state)
Ball clay: Isan Ekiti, Ikere Ekiti (Ekiti state)

In order to authenticate the suitability of the samples collected for the production of durable and reliable kiln shelves and props, chemical analysis of kaolin was carried out at the centre for Energy and Research Development O.A.U. Ile Ife. The result of the analysis indicated that Ifon kaolin has refractory constituent similar to the one in Florida U.S.A which is used for the production of refractory furniture. Table (3.3) shows the chemical analysis of kaolin from three selected sites in Ondo and Ekiti State.

The collected kaolin were, however, fired to 1300^0C in order to convert it to mullite which is a high refractory materials as indicated by Irabor (2002).

RECIPE FORMULATION OF THE CLAY MATERIALS

Procedure: In order to forumate suitable recipe, various tests were carried out. However, before the tests could be successfully carried out, the clay materials were processed as follows:

Preparation of clay

Primary clays collected from Isan-Ekiti, Ikere and Ifon as well as the secondary clays collected from Ikere and Isan were levigated. Levigation which is the method of removing impurities from clay by water floating was carried out in the ceramic workshop of Federal Polytechnic, Ado-Ekiti. Cardew (1979) noted that levigation of clay helps to increase the refractoriness since with this method the impurities and free silica are removed. Both the primary and secondary clays given above were soaked separately for four days before levigation.

After levigation, the clays were dried and prepared for the following tests:

a. The primary clay was levigated and dried, secondary clay was pulverized and stored in powdered form.
b. Part of the primary clay were also pulverized and kept in powder form.
c. Another part of the primary clay was not pulverized but was instead fired to a temperature of 1300^0C and crushed into grog.

Clay Test

To formulate suitable recipes that will manifest the characteristics of standard kiln furniture, both the primary and secondary clay were tested for shrinkage and porosity.

a. Shrinkage test on clay sample

The collected clay samples were mixed into plastic state and made into slabs of 140mm x 4mm x 1mm with a line if 100mm long dawn on each slab. The slabs were left to dry and the line was measured and the value recorded. Later, they were fired to 1300^0C and measured the second time to determine the fire shrinkage of the slabs. (fig 1)

b. Porosity test on clay sample: Porosity test was carried out on clay slabs used for shrinkage test. The test was carried out to determine the rate of water absorption. Each of the slabs was weighed and the weight recorded. They were immersed in water to boil for two hours. The slab were left in the water for 24 hours after which they were brought out and the surface water was wipe off and weighed. The porosity was calculated thus:

$$p = \frac{C\ wet - C\ dry}{C\ dry} \times 10 \quad \ldots\ldots. (1)$$

Where:

P = porosity, C wet = wet clay material
C dry = dry clay material

(The result of shrinkage test is shown in the table 3)

In view of the results of porosity tests in table 4, Ifon is found to be more suitable among the three kaolin samples that were used for the tests since it exhibited less shrinkage (4% shrinkage) and less porosity than the others. (Table 3) It should be noted also that the Alumino-silicate content of Ifon kaolin (i.e the refractory content) is 70.48% which makes the clay suitable for refractory production. Although it was observed that the iron content in Ifon kaolin which is a contaminant is 5.07%, the high percentage of alumina and silica reduced the effect to the bearest minimum.

The tests result as well as the analysis shown in figure 2 also indicated that Isan ball clay is the most suitable of the three ball clay samples that were tested. Although, it exhibited a shrinkage rate of about 10% which was slightly higher than the others, the porosity percentage was, however the lowest (8.2%). The two clay samples mentioned above were, therefore recommended, as a substitute for clay material.

Grog Preparation

The primary clay fired to grog was graded into three sizes of coarse grog, medium and small size grog. Alasa (2005) explain that, if the grog is carefully graded, a better packing density can be obtained. Sieves of different mesh sizes were used to remove the free dust from the grog. The sizes of the grog are shown in the table 5.

Body Composition

In order to formulate suitable recipes that will manifest the characteristics of standard kiln furniture, biaxial blend test, as suggested by Singer and Singer (1963). Shrinkage test, modules of rupture test and porosity test were conducted making used of the selected primary and secondary clay.

Biaxial Blend Test

The purpose of conducting the biaxial blend test was to determine the ratio of clay to grog that will be most suitable for props and shelves making. Umar (2003) recommends that line blends are desired when two or three materials are to be used. Ifon kaolin and Isan Ball Clay were mixed at the ratio 1:1 on the clay body on one side of the biaxial blend and grog obtained from Ifon kaolin on the other side of the blend. The proportion of the grog sizes was based on table 5.

The Eleven tiles lime blends are shown in the table 6:

Shrinkage and Porosity Tests Conducted on the Blends

Two slabs with a length of 140mm were made on each of the blends and 100mm line was drawn on each. The slabs were properly dried and the line was measured to ascertain the dry shrinkage. All the slabs were later fired to 1300^0c and the lines were measured again and the fired shrinkage was recorded.

For the porosity test, the fired test slabs weighted to record the dried weight. They were immersed in water and boiled for one hour, left in the same water for 24 hours after which they were brought out.

The surface water was wiped off and weighed again, the shrinkage value were given as

$$ST = \frac{WL - FL}{WL} \times 100$$

Where:

ST is total shrinkage

WL is wet weight,

FL is dry weight

Result of the above tests is shown in the table 7:

From the analysis in table 7, the two body mixtures that are more suitable for the production of kiln furniture are 7 grog: 3 clay and 8 grog: 2 clay. The reason being that, the shrinkage percentage of the two body mixtures were under 5%, and more importantly, the percentage of porosity for each mixture is under 25% as recommended by Singer and Singer (1963). It should be noted that two body mixtures above have a clay to grog compositions recommended by Ewule (1988), Achilam (2000) and Singer and Singer (1963). The two body mixtures were, therefore, adopted for further study.

Compressive Strength Test

Compressive Strength Test was carried out to determine the ability of a material to retain the refractoriness under load. Compressive strength test was conducted with two of the body mixtures, which had a comparative advantage in terms of low shrinkage and porosity as indicated in table 7. The two body mixture are: 7% grog; 3% clay and 8% grog; 2% clay. The biaxial blend slabs were also used for the test. Wedge shaped clay stands were made and used for holding the slabs in the kiln. Pairs of these wedge stands were placed in the kiln and each of the slabs was placed on one pair each.

On each of the slabs was placed a weight of 1kg and the kiln was fired to a temperature of 1300^0C. Each of the slabs was then examined after the firing and it was discovered that the body mixture of 8% grog 2% clay showed no sign of rapture while the body mixture of 7% grog 3% clay indicated a sign of mirror sagging. As a result of this, the body mixture of 8% grog; 2% clay is recommended for the production of refractory kiln furniture.

CONCLUSION AND RECOMMENDATION

From the test conducted, it was revealed that production of standard kiln furniture could be achieved locally by making use of clay in Ondo and Ekiti States. Specially, the studio treatment of kaolin that were experimented for thus study indicates that, out of the three sourced Kaolin from Isan-Ekiti, Ifon and Ikere-Ekiti, Ifon kaolin is the most dependable since it shows less shrinkage and porosity, low iron content and high purity level than the others.

The workable mixture for the body composition for selves and prop production is of 2 parts of the clay and 8 part of kaolin and 1 part of ball clay was used for the clay mixture. In the grog to clay composition above, 5 parts of coarse grog, 1 part medium size grog and 4 parts fine grog forms the whole part of grog.

With the application of knowledge derived from this study, the culture of importation of kiln shelves (Bats) and props might be reduced and this will pave way for local production of these kiln accessories thereby reducing the operational cost of running ceramics studio and industries in Nigeria.

Finally, considering the quality of kaolin available in Ondo and Ekiti State, it is recommended that the studio, industrial potters and tertiary institutions in these areas should make use of this material to produce kiln furniture for their use.

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APPENDIX

Table 1: Location of Clay Samples

NO	LOCATION	MATERIAL	MATERIAL
		Kaolin	Ball clay
1	Isan-Ekiti	”	”
2	Ifon	”	
3	Ikere-Ekiti	”	”

Table 2: Chemical Analysis of Some Kaolin in Ondo and Ekiti States

Element	Isan-Ekiti	Ikere-Ekiti	Ifon
K_20	7.01	3.09	-
Mg0	8.01	5.39	-
Al_20_3	16.40	31.20	14.56
$Si0_2$	46.63	28.17	55.92
Fe0	14.67	-	5.07
Fe_20_3	-	-	3.69
Sr0	0.33	-	-
Ca0	0.02	1.11	2.02
Na_20	0.03	1.42	9.67
Mn0	0.01	3.25	7.48
Zn0	-	5.79	-
B_20_3	-	2.73	-
P_20_5	-	-	-
H_20	5.42	9.9	0.95
$S0_3$	-	7.94	-
F	1.58	-	7.19
0	(0.47)	-	-
CU_20	-	-	-

***Source**: Information as obtained from the chemical analysis of kaolin carried out at Centre for Energy and Research Development O.A.U, ILE-Ife (2007).*

Table 3: Shrinkage Tests on Clay Samples

Types of clay		**Types of firing**	**Measurement**		
Primary Clay	Secondary clay		Wet	Dry	Fired
Isan		1300^0C	10cm	9.5cm	9.2cm
Ifon		1300^0C	10cm	9.6cm	9.3cm
Ikere		1300^0C	10cm	9.5cm	9.1cm
	Isan	1300^0C		9.2cm	8.9cm
	Ikere	1300^0C	10cm	9.3cm	9.0cm
	Ifon	1300^0C	10cm	9.3cm	9.05cm

Table 4: Porosity tests on clay samples

Type of clay		**Porosity (%)**
Primary clay	**Secondary clay**	3
Isan		15
Ifon		14.8
Ikere		17.2
	Isan	8.8
	Ikere	9.2
	Ifon	9.0

Table 5: Grog grades and sizes

Grade of grog	Sizes of grog
Fine grog	1mm
Medium	3mm
Coarse	5mm

Table 6: Tile Line Blend

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

Table 7: Result of the Test to determine the Body Composition

Measurement Length

Grog	**Clay**	**Wet**	**Dry**	**Fired**	**Temp of Firing**	**Total Shrink age**	**Porosity**
10	0	10cm	-	-	-	-	-
9	1	10cm	9.9	9.9	1300^0c	2	34.3
8	2	10cm	9.9	9.8	1300^0c	3	23.5
7	3	10cm	9.7	9.7	1300^0c	6	23.9
6	4	10cm	9.7	9.6	1300^0c	7	25.7
5	5	10cm	9.6	9.6	1300^0c	8	27.1
4	6	10cm	9.4	9.3	1300^0c	1.3	29.8
3	7	10cm	9.4	9.3	1300^0c	1.3	21.8
2	8	10cm	9.3	9.3	1300^0c	1.4	23.3
1	9	10cm	9.3	9.2	1300^0c	1.5	16
0	10	10cm	9.1	9.0	1300^0c	1.9	15.5

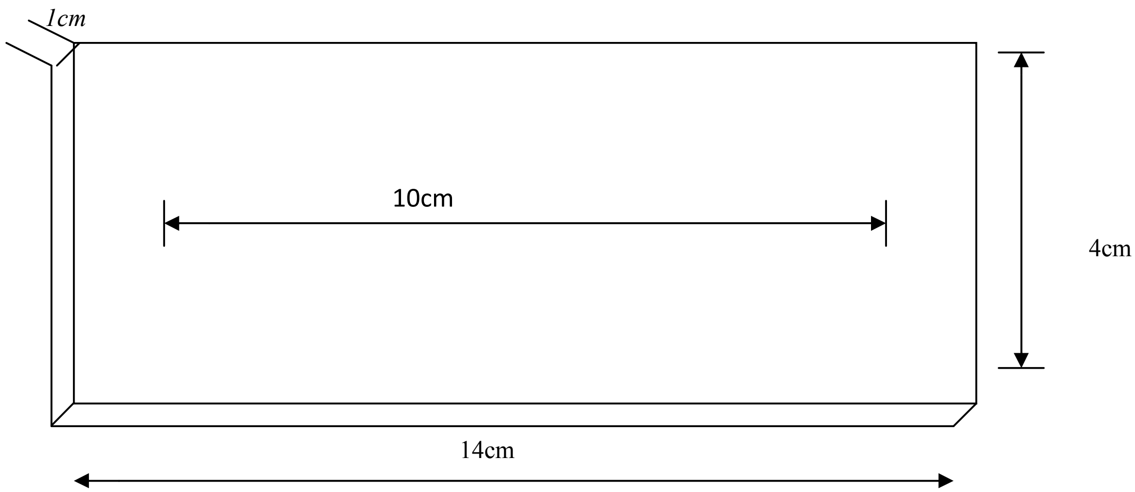

Fig 1: Slab for shrinkage and water of absorption tests

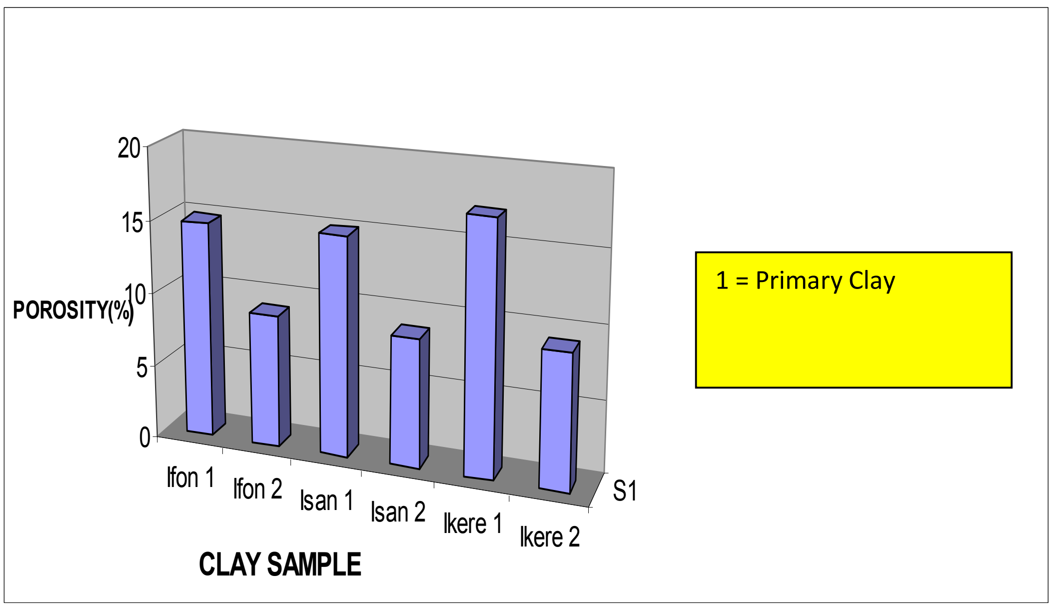

Fig. 2 Porosity of test samples fired at 1300^0C