Production of Studio Kiln Props

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Abstract

This study is on studio design and production of refractory kiln Props. These study addressed the inadequacies found in some kiln furniture produced locally. The statement of the problem shows that most available kiln furniture is imported and some that are produced locally. have some inadequacies to address. In this study, kaolin ("Afowa" Clay) is discovered and used as a matrix material which is mixed with fired clay to produce ceramics composite as refractory materials that fire to 1250^0c. The objectives are set to examine raw material processing, design and fabrication of needed equipment, following the test analysis for strength of materials. This research Ceramic Matrix Composites as guide. The findings show that prop recipe B was used for its structural properties, high thermal shock resistance and good mechanical strength fired at 1250^0c. The combination of hydraulic press machine used for this research has been able to solve the gap identified in the literature reviewed. This study recommends that for exploration of indigenous materials for kiln furniture production, is highly efficient and economical.

Keywords: Afowa clay; Matrix; Production; Studio prop.

Introduction

Prop is made of refractory materials that have high melting point. This can maintain its structural properties, high thermal shock resistance, high creep resistance and good mechanical strength at a very high temperature which are the essential properties for good kiln furniture. Props stilts production are meant for maximum output. Shelves and props are inevitable support or accessories for kiln towards a successful glaze firing. Props supports heavy loads with minimal mass, it is safe and makes it easy for one to stack/ unstack loads. The furniture helps to give wares stability and creates several compartments to stock wares.Kiln props are important pottery equipment which boost pottery production. kiln furniture are materials that contain alumina and silica, and are highly refractory materials used in the kiln to support wares during firing

This research focuses on the production of props, using materials from Afowa, a village near Auchi in Etsako West Local Government Area of Edo State, Nigeria. It is designed as a studio-experimental research undertaken to resolve the yawing gaps that exist between small scale pottery studies and the heavy ceramics industries. The inadequacies in the few local production of kiln furniture such as cracking, wobbling, inability to carry heavy load carry, heavy weights of the furniture and thickness, are gaps this research attempts to fill.

Afowa the village that is adopted in this research, is named after the clay and its sites. Hence, it is reputable for clay that fires to stoneware temperature of about 1250^0c and beyond. In Nigeria, locally-made kiln furniture that fires ceramic wares at high temperature of about 1250^0c are grossly inadequate. Those that are available are mainly imported and very expensive. Agberia, (1998) observes that the declining state of the ceramic industry in Nigeria is as a result of the incremental economic recessions which for the past 20 years have continued unabated. Hence, the turning point was the manifestation in the 2015 up to 2017 budgets of the Federal Government of Nigeria which grossly reduced the Naira value. It thus becomes expedient to engage the production of refractory studio kiln furniture as a means needed to stabilize and sustain the existence of small scale studio potter. The vacuum, therefore is that suitable kiln furniture with no or grossly less inadequacies be produced to meet the firing needs of the potters, who depend mainly on imported kiln shelves and props manufactured in other countries to fire the kiln.

Theoretical / Conceptual Framework

The theoretical framework of this study is based on Design function by Marzano (2009) who assert that: "Design is about creating something that is perceived by people as being ideal and appropriate in all respect; it will be seen as highly relevant and meaningful and will improve people's quality of life".Ceramic matrix composite is used for this research as conceptual framework. Ceramic matrix composite is a material that comprises a strong load carrying materials (known as reinforcement) embedded in weaker materials (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load, while the matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. According to Fredrick (2013) constituents of the composites retain their individual, physical and chemical properties yet together they produce a combination of qualities which individual constituents would be incapable of producing alone.

Review of Empirical Studies

A refractory material which has the ability to withstand high temperature without breaking or deforming was reviewed.Other scholars who have done work onrefractory was reviewed also such: - Chesti (1986), Ruth (2014), Singer and Singer (1977), Leach (1973), Ibude (2012 and 2014), Rhodes(1973) Aither, (2002) Omonmhenle (2006) Egbon (2011) and host of others.

According to Olsen (1973:1) "they are manufactured from ceramic materials designed to withstand much greater temperature than would normally fire (1250^{o}c – 1300^{o}c)." Counts (1973) views kiln as an empty box, and for it to perform to its utmost best, it must contain different accessories like shelves, tripods, stilts and props which formed the kiln furniture. They are made of clay that contains alumina and silica which are highly refractory. In his study potters are advised to produce their shelves from firebricks or from refractory clay materials. However, nothing is said about the processes of manufacturing shelves and props in his research.Chaklader and Linger (1976) develops ceramic/metal composite basing their findings on nickel/alumina and copper/alumina particulate system. The coating with alumina powder makes it able to accomplish uniform distribution of metal phase along with alumina gain boundary by using 68% of weight of nickel and 32% weight of copper. The coated particles were hot-pressed and sintered for densification.

Ewule (1988) writes on the development of a Gas kiln for ceramics production from local resources found in Katsina state. The problem of how to fire the kiln, fabrication of suitable burners and production of kiln furniture using raw materials found in Katsina state were the main focus. Observing the shelves over time showed that the shelves warped after two or three glaze firing. Findings show that the manual technique of production is inadequate. The aspect of kiln furniture in his work which relate to this study still show some lapses in the area of proper production techniques, because he did not avail himself of equipment that are hydraulic-powered to improve on the strength of the outcome of the products.

Methodology

In this study the researcher adopted studio-experimental research. The following are the various modes of data collection for this study: Primary/secondary sources and Laboratory experimentation focusing on the Ceramic MatrixComposition (CMC) The basic material for the production of refractory kiln furniture is Afowa Clay which is from a village near Auchi in Etsako West Local Government Area of Edo State.

Laboratory Experimentation of Ceramic Matrix Composition (CMC)

The following are the materials that constitutes the Ceramic Matrix Composite: -Afowa Primary Clay (kaolin), Afowa Secondary Clay (Black) was used as aluminosilicate, Grog which served as reinforcement andWater was used to mix the materials together.

Processing of Materials

After the collection of clays such as white kaolin and Ball Clay Black, from Afowa village near Auchi in Edo State, Test were carried out to test basic chemical compositions. The percentage and X-ray diffraction analysis were carried out in Nigeria Geological Survey Agency and National Geosciences Research Laboratory (Ngrl), in Kaduna. This is to determine their chemical composition, presence of impurities like iron and alkaline content in the clay.

Table 1: Chemical compositions (%) and x-ray diffraction analysis

Afowa white and Black clay (Laboratory Report No. 3085 Kaduna)

(%) COMPOSITION	SAMPLE A Afowa white	SAMPLE B Afowa Black
SiO_2	51.70	44.00
Al_2O_3	26.60	20.60
Na_2O	0.179	16.93
K_2O	0.80	0.51
CaO	0.03	0.057
MnO	ND	0.031
Fe_2O_3	2.86	2.32
TiO_2	2.78	5.39
CuO	0.10	0.07
NiO	ND	0.013
ZnO	0.035	0.031
V_2O_5	0.14	0.075
Cr_2O_3	0.10	0.049
IrO_2	0.02	0.01
Yb_2O	ND	0.001
Ga_2O_3	0.035	0.015
As_2O_3	0.01	0.004
SrO	0.13	0.057
Y_2O_3	0.13	0.034
ZrO_2	0.44	0.257
BaO	0.76	0.37
PbO	0.053	0.028
L.O.I.	13.04	9.12

* ND = Not Detected

Analyst: P.B. OTIONO (NGRL/OP/5334/3085 © Uzzi, F. (6th Sept., 2016)

Physical property test

Visual inspection was done using British Standard Specification for bucks and ceramics clays. The clay materials used for analysis were obtained randomly at the site of collection and the following physical property test of Afowa white clay bodies was conducted as follows:

1. Drying shrinkage test; (British standard specification formula was adopted)
2. Fired shrinkage test;
3. Water absorption test;

Construction and Production of Kiln Props

construction of props frame: The cylinder of about 600mm x 225mm x 300mm was used with inlet cover of 224mm x 5mm with a stainless steel rod of 700mm x 10mm used along with 35 tones hydraulic pressing machine.While props measurement sizes are (1) 600mm x 225mm and 300mm x 225mm

Firing of the levigated clay:

Each of the Levigated clay is dried and treated as follows:

All the secondary clays were pulverized and stored dry for easy measurement.

Some of the primary clays was pulverized and stored dry for easy measurement. The rest of the primary clay, which has been in dry pieces, is fired to 1250C and crushed to grog.

The grog is graded for use in the body composition, coarse medium and fine grog. The grog has all the dust particles removed from it.

Plate 1: Firing of levigated kaolin using kerosene kiln

Plate 2: Fired levigated kaolin

The kiln was fired to cone 01 (1160^{o}C)

Mixture of materials

A wide strong platform of tarpaulin sheet was used, spread on the floor to prevent the earth surface from absolving the mixture of materials. This prevents variation in the mixtures, moisture content, and the picking up of extraneous material.Ceramics matrix formula was used, that is 70% of grog (comprising of 20% large, 30% middle and 20% small) plus 30% of Levigated kaolin and clay after measuring 70% of the total materials, the mixed Levigated clay discharged into the grog (20% kaolin and 10% clay) and mixed thoroughly with a shovel. The material was covered with plastic paper (polythene sheet) and left for about three days for aging. This enables the mixture to become plastic and workable.

Sieving of grog into large, medium and small.

Plate 3: Sieving grog using 80, 100 and 120 mesh

Plate 4: Coarse, medium and fine grog

Plate 5: Mixing of Materials Grog and Kaolin)

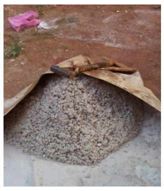


Plate 6: Aging of Materials

Production of Prop

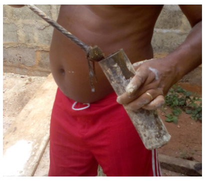


Plate 7: Oiling of Prop Pipe with clay recipe

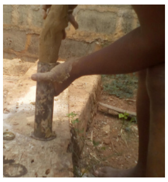


Plate 8 : Filling pipe-

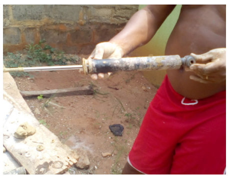
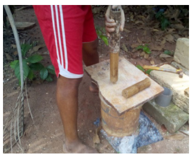
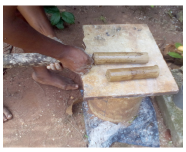


Plate 9 : Extruding pipe © Uzzi,

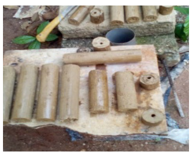
Plate 10 : Prop Reaming



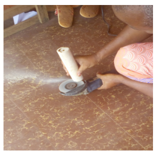
Plaste 11: Extruding the Prop



Plaste 12: Extruded Prop



Plaste 13: Drying of Moulded Props



Plaste 14: Dressing Moulded Shelf

Loading and Firing of Props

The firing of props is the final stage in props production. It is the firing that makes the wares functional to be called a kiln prop or kiln furniture. The shelves were loaded into the kiln in a special arrangement of two layers. The first is the ground floor horizontal arrangement with space in between each shelf, while 4 shelves were loaded on the floor inside the kiln.

The second layer (on top of the first) is laid vertically, for example, placing them on opposite side of the first layer with space in between. This system of shelves laying enables the free flow of heat energy to circulate properly from top to bottom of the kiln. It should be noted that proper arrangement of kiln furniture, as well as the wares in the kiln chamber boosts a successful firing aside from using good quality kiln shelves.The kiln was fired to cone 7 (1250^{o}C) and the changes in temperature were recorded at every 30 minutes to show the rise in temperature scheme. Below is the table (3.3) for the firing procedure and appendices:

Table 2: Record of Prop Firing

Time (Hrs.)	Activity	Kiln Atmosphere	Temp. (^{0}C)	Kiln Condition	No. of Hrs.
2.30pm	Kiln swished on with one burner at low pressure (pre heating)	Oxidizing	0	Damp	0hrs.
3pm	Heating Continues	Oxidizing	148		0.3hrs.
3.30pm	Heating Continues	Oxidizing	228	Dry Hot Air	1hr.
4pm	Introduction of Second Burner	Oxidizing	400		1.3hrs.
4.30pm	Full Pressure(heating)	Oxidizing	593	Dull Red colour (Alpha beta quartz) most organic materials carbonized	2hrs.
5pm	Full Pressure	Oxidizing	895	Orange-Red contraction starts to form	2.3hrs.
5.30pm	Full Pressure Continues	Oxidizing	920		3hrs.
6pm	Full Pressure Continues	Oxidizing	975		3.3hrs.
6.30pm	Full Pressure Continues		1014	Cone 05.5 Falls (most carbonites dissociate at this port)	4hrs.
6.46pm	Full Pressure/Problem with One Burner	Cone 04 Bend	1050	Cone 05 Falls	4.16hrs.
7pm	Full Pressure/Shocking	Cone 03 Bend	1072	Cone 04 Falls (formation of mullite and cristobalite takes place in molten point of soft glazes)	4.30hrs.
7.17pm	Stop Firing	Cone 7 Bend	1238	Cone 7 Falls (molten of stone ware glazes at 125^{0}C)	4.47hrs.

A firing graph showing the projections (dotted line indicating the commencement and finishing of the firing) of the kiln performance. It can be seen that the firing continued at a steady rate until 400^{0}c when the second burner was introduced. At this point most organic materials carbonized between 400^{0}c - 573^{0}c (the kiln atmosphere is dull red)

Quartz inversion takes place at 593^0c, contraction starts to form at 895^0c, cone 05 falls at 1014^0c, most carbonites dissociate at this point. Formation of mullite and cristobalite takes place in melting point of soft glazes between 1100^0c and 1200^0c. Vitrification of clay and increase in viscosity takes place between 1238^0c to 1250^0c. Molten of stone ware glazes at 1250^0c (cone 07). This is the point shelves and props are fired to stoneware temperature. (Below is the Engineering test result/appendix for firing chart):

Results and Discussion

Presentation of Results(Equipment and Tools Used for the Research)The equipment used for this study includes the following: -Soil test machine, Universal testing machine, Hydraulic pressure machine, extruding machine, Caliper, Kiln, Weighing scale and other tools.

Different experiments engaged in the study

Experiments were carried out using the following composition of three batches of recipes:

Tab 3: Props Recipe credit Uzzi

PROPS RECIPES			
	A	B	C
Kaolin	70	65	40
Ball clay	15	20	20
Fine grog	15	15	40

Props Recipes Calculation For A

(1) Prop1 Kaolin – 70%

Ball clay – 15%

Fine grog - 15%

Plate 15 : Result of fired Props Recipe A

Kaolin calculation = Total weight of kaolin – 70%

Therefore 70% of total weight = $\frac{70}{100} \times \frac{15kg}{1} = 10.5(Kaolin = 10.5\%)$

Ball clay calculation = Total weight of Ball clay – 15%

Therefore 15% of total weight = $\frac{15}{100} \times \frac{15}{1} = 2.25(BallClay = 2.25\%)$

Fine grog calculation = Total weight of Fine grog = 15%

Therefore 15% of total weight = $\frac{15}{100} \times \frac{15kg}{1} = 2.25(\text{Fine grog} = 2.25\%)$

Props Recipes Calculation For B

(2) Prop2 Kaolin – 65%

Ball clay – 20%

Fine grog - 15%

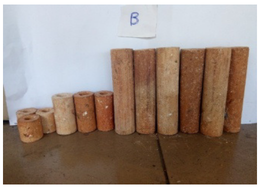


Plate 16: Result of fired Props Recipe B

Kaolin calculation = Total weight of kaolin – 65%

Therefore 65% of total weight = $\frac{65}{100} \times \frac{15kg}{1} = 9.75(\text{Kaolin} = 9.75\%)$

Ball clay calculation = Total weight of Ball clay – 20%

Therefore 20% of total weight = $\frac{20}{100} \times \frac{15}{1} = 3(\text{Ball clay} = 3\%)$

Fine grog calculation = Total weight of Fine grog = 15%

Therefore 15% of total weight = $\frac{15}{100} \times \frac{15kg}{1} = 2.25(\text{Fine grog} = 2.25\%)$

Props Recipes Calculation For C

(3) Prop 3 Kaolin – 40%

Ball clay – 20%

Fine grog - 40%

Plate 17: Result of fired Props Recipe C

Kaolin calculation = Total weight of kaolin – 40%

Therefore 40% of total weight = $\frac{40}{100} \times \frac{15kg}{1} = 6(\text{Kaolin} = 6\%)$

Ball clay calculation = Total weight of Ball clay – 20%

Therefore 20% of total weight = $\frac{20}{100} \times \frac{15}{1} = 2.25(\text{Ball clay} = 2.25\%)$

Fine grog calculation = Total weight of Fine grog = 10%

Therefore 10% of total weight = $\frac{15}{100} \times \frac{15kg}{1} = 2.25(\text{Fine grog} = 2.25\%)$

This was done also, in order to guide the researcher on which range of composition to focus on. The three refractory materials (grog, kaolin and clay) were sourced from Afowa. These materials were prepared and blended in three different batches and proportions. The variations are necessary so as to have different mixtures or recipes that can be best used for refractory furniture production. The under listed are adopted for this research:

Production of Props

The props recipe is 65% Kaolin, 20% clay, 15% fine grog, Engine oil (as lubricant) and Extruding kit (made up of ramming upright pipe and base stand. The production was carried out using the above recipe after the study of three blended recipes. All the recipes for props are used in this study, although recipe 'B' shows greater strength than others. The mixed materials were left to age. The pipe and the barrel were mounted on the base while the pipe was oiled and the clay body fed into it. (see plate: 3.33)

The clay body is compressed within the pipe by the use of hydraulic press. The rammed clay in the pipe is removed from the base stand. The barrel is pushed downward as the extruded prop is exposed and allowed to dry. This process was repeated to get the desired numbers of props. After the production the props were kept in room temperature to dry completely before the wares were packed into the kiln for firing. They were fired to a temperature of 1250^{o}c and made ready for use.

Analysis of Result

Results of props Composition Blend

The props are of three different sizes as follows:

1. The longer props measuring 26cm in height, a top width of 4.5cm and bottom width of 10cm,
2. 16cm in height, 4.5cm top width and a bottom width of 10cm
3. 6cm in height, 4.5 cm top width and 10cm.

The crushing strength of the developed composite material was calculated using Schmidt hammer for QA/QC Crushing strength of concrete/ sand Crete test and the result obtained are presented in the

Prop Recipe A

The result obtained from sample A shows that the introduction of Fine grog 70%, Clay 15%, kaolin 15% and 5cm extruding rod increased the hardness of the composite when extruding it. Result shows weakness in prop with rough body and lacks enough binding materials

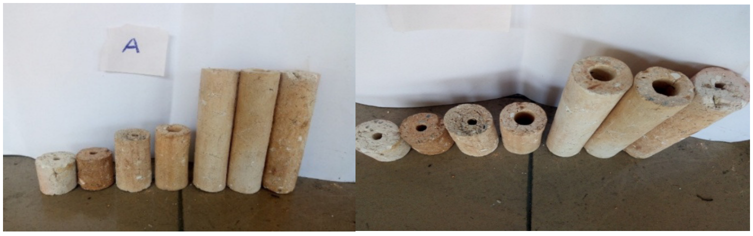


Plate 18: Result of fired Props Recipe A

Prop Recipe B

The result obtained from sample B shows that the introduction of Fine grog 15%, Clay 20%, kaolin 65% and 2.5cm extruding rod increased the hardness of the composite. The strength of the recipe B is higher, recipe B is adopted for this study

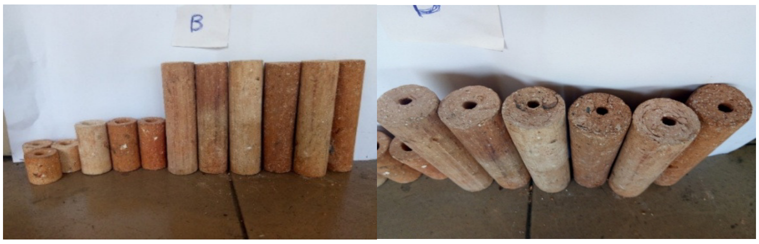


Plate 19: Result of fired Props Recipe B

Prop Recipe C

The result obtained from sample C shows that the introduction of fine grog 40%, clay 20%, kaolin 40% and 5cm extruding rod increased the hardness of the composite when extruding it. Result shows weakness in prop with rough body.

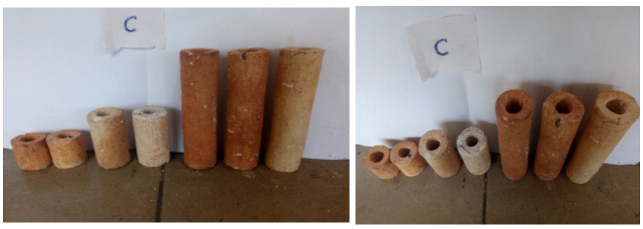


Plate 20: Result of fired Props Recipe C

Results of Compressive strength test of Props using QA/QC Crushing strength of concrete / Sand Crete test

This test was carried out in the soil laboratory, Department of Civil Engineering. University of Port Harcourt with Ref. BS 1881: part 116. Hammer reading Strike through highest and lower reading using British standard formula. Sum of remaining reading 89.2 vertical down (N/mm^2) Average – 12.74 while compressive strength (from chart) is 14.19.

Good result considering the materials used for the study in relation to crushing strength of concreated sand Crete

Note – Compress strength in N/mm^2 = load cross section area which is the effective area UTS

$$= \frac{\text{maximum compressive load (N)}}{\text{Area (N)}}$$

Nondestructive compressive strength test using Schmidt (Rebound) hammer conducted on the samples. The average R-index value obtained from the rebound hammer test is converted to the strength value using rebound hammer chart.

The first test was to fire shelves and props (Bisque wares) using kerosene kiln. A test firing was conducted on completion of the shelves and props moulding. Some of the shelves were arranged and used to fire bisque wares in the process.

High Temperature Firing for prop Efficiency

The firing was very successful; the shelves and props were able to carry the total load of glaze ware. The firing props load varied from different sizes and weight of wares. These facilitate testing the strength of the props. There was no bend on the shelves as the shelves were arranged with three supportive props supports for the firing. These were credited to high quality of materials used Afowa Clay with-stood high temperature firing, using ceramics matrix composition for the production of studio kiln furniture.

Plate 21:
Offloaded glazed wares, shelves and props

Plate 22:
Fired Kiln Props

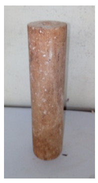


Plate 23:
Fired Kiln Prop

Discussion of Findings

The study proves that the Ceramic matrix composite (CMC) is appropriate forprocessing the raw materials to solve the inadequacies found in the previous works on kiln furniture production.It was discovered that using indigenous or local clay materials for the production of refractory kiln furniture, Recipes A, Band C are suitablefor solving the encountered problem as the props maintain their structural properties, high thermal shock resistance, high creep resistance and good mechanical strength fired at a veryhigh temperature of 1250^{o}c, which are essential properties for studio kiln furniture.

The props were used to stack glaze wares and it was successful.Looking inward for the utilization of indigenous or local materials, props production can save foreign exchange spent on such products, and this in turn can also generate income.

Summary

The influx of plastic and metal utensils in our market poses a great challenge to local potter/ceramic production in general. Due to the existing threat of extinction posed by scientific and technological development of locally-made pottery, this study focuses on how locally-available raw materials can be transformed into new standard kiln furniture for ceramic production.The solution was sought by focusing on the usage of Afowa clay for the production of props. Afowa Clay is found or it is reputed to have large deposit of clay that fires to stoneware temperature of about 1250^{0}C and beyond.

The extant literature reviewed shows that there is an existing gap in studio props production. This include the technique of producing them, strength of the wares thickness and the engineering test as well as load-carrying strength. Consequently, the researcher sourced for three refractory materials such as kaolin, grog and clay from Afowa. He prepared and blended these materials in four different batches and equal proportions. The variations shown in this exercise led to different mixtures or recipes that were used to envisage refractory furniture production.

In chapter four, the results were presented and elaborately discussed. It was found that the shelves and props maintain their structural properties, high thermal shock resistance, high creep resistance and good mechanical strength fired at a very high temperature of 1250^{0}C. These properties are essential for studio kiln furniture production.The study concludes that the results from the studio experiments showed that the refractory materials from Afowa can be used successfully in production of studio kiln furniture.

The study then recommends the utilization of indigenous or local materials (Afowa Clay) for the production of studio kiln furniture.

Conclusion

The role of ceramics in the present day technological advancement cannot be over emphasized when considering the totality of human comfort that circles round ceramic products. The skill and ability to create and please consumers are all assets to the technological era, because the bedrock of any economy is its manufacturing ability to turn what might be considered worthless to finished useful goods.

Researchers are to be encouraged to carry out research on studio equipment for manufacturing ceramics. The successes of such equipment production can create wealth and boost manufacturing in any economy.

In the course of this research, it is established that the production of kiln furniture using Afowa Clay could reduce the cost of importing such kiln furniture from other countries. The combination of hydraulic press machine with Afowa Clay used for the research has been able to fill the gaps identified in the literature reviewed.

It was also established that the success of pottery industries or ceramics studio is the ability for their Kilns to fire bisque or glaze wares successfully. These can be achieved by following the various methods recommended above for kiln shelves and props production. Any Potter who wants to make a good living from glaze wares, must look inward by learning how to manage his kiln and kiln furniture.Other researchers in future should collaborate with Department of Mechanical Engineering to explore ceramics equipment fabrication researches also, in order to cut down the large amount of money lost through foreign exchange, it is recommended that the abundant ceramic raw materials be tapped, and utilized to produce ceramics wares for export.

Work Cited

Agberia, J. T. (1998). The ceramics industry in Nigeria: Problem and prospects Uso. *Nigerian Journal of Arts 2, (1 & 2)*. P. 123-30.

Alther, G.R. 2002. Using organic clays to enhance carbon filtration, waste management. 22, 507 – 513

Chesti, A.R 1986. Refractory manufacture, properties and application. London: Prentice Hall of Private Ltd., 1-140Edo State map Google. Retrieved 19th 0ctorber 2015.

Chaklader, A.C. and Linger, D. K.R. (1976). Ceramic/metal composites using metal-coated alumina powder composites, 7(4), p.239-243

Counts, C. (1973). *Pottery workshop: A study in the making of pottery from idea to finish*. London: Collier Macmillan Publisher's Ltd.

Edo State map Google. Retrieved 19th 0ctorber 2015.

Egbon, E.E, Ebhoaye, J.E, Asia, I.O, Ize-lyamu, O.K, Egbon, I.E and Ehigbor, MJ 2011. Treatment of waste-water from food Industry using native clay. *Chemtech Journal*.7(1), 19-23.

Ewule, J.O. (1988). *Development of gas kiln for ceramics production from local resources*. M. A. dissertation, ABU, Zaria.