THE FEASIBILITY OF UTILIZING CAST IRON FILINGS IN CLAY BODY FOR THE PRODUCTION OF DECORATIVE CERAMICS

By

OKEWU Ebute Jonathan, B.A CREATIVE ARTS (MAIDUGURI) 2007
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DECLARATION

I hereby declare that the work in the thesis titled, "The Feasibility of Utilizing Cast Iron Filings Into Clay Body for the Production of Decorative Ceramics" was performed by me in the Ceramics Section, Department of Industrial Design, Ahmadu Bello University, Zaria, under the supervision of Dr.Tukur D.M. Zauro and Dr. A.D. Garkida. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

_____ _____

OKEWU Ebute Jonathan Date

CERTIFICATION

This thesis titled: THE FEASIBILITY OF UTILIZING CAST IRON FILINGS IN CLAY BODY FOR THE PRODUCTION OF DECORATIVE CERAMICS, meets the regulations governing the award of degree of Masters of Arts Industrial Design of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation

Dr. Tukur D.M. Zauro Chairman, Supervisory Committee	_____ (Signature)	_____ Date
Dr. A.D. Garkida Member, Supervisory Committee	_____ (Signature)	_____ Date
Dr. Salihu Maiwada Head of Department	_____ (Signature)	_____ Date
Professor A.Z. Hassan Dean of Post Graduate School	_____ (Signature)	_____ Date

DEDICATION

This study is dedicated to Brother Emmanuel Okewu for his unrelenting efforts towards my education and Sister Martha Benjamin for both financial and motherly role towards my stay in Zaria.

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ABSTRACT

This research was experimental in approach. It went through the process of gathering of materials from different locations, iron filings from Buniyaminu Engineering workshop at "Randa Kano" area in Zaria, Kaduna State, Kankara kaolin from Kankara in Katsina State while ball clay was obtained from Bomo village in Zaria, Kaduna State. The materials were processed for workability, iron filings were subjected to sieve analyses into three aggregate sizes of 1.18mm, 600µm, and 300µm. Kaolin and ball clay were soaked in 50/50 percentage in water for two weeks after which they were blunged together and sieved. Iron filings of the three aggregate sizes and the un-sieved were blended into clay in varying percentages in form of test slabs, while four other slabs without iron filings were made to serve as control. Throwing test was carried out to check the throwing ability of the clay with iron filings. Test Firing was carried out between $800^{o}C$ - $1100^{o}C$ to determine the suitable temperature that enhanced favourably on speckle effects of iron filings on clay body. The results showed that it was possible to throw wares from clay containing iron filings. The body with iron filings shrank less as compares to the body without iron filings. The firing temperature of 1000 was found most suitable for achieving the most speckle effects of iron filings in clay body.

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DEFINITION OF OPERATIONAL TERMS

Clay body: A mixture of clays with other earthy mineral substances blended together to achieve a specific ceramic purpose.

Cast iron**:** Iron with a high carbon content, so that it is hard but brittle, and must be shaped by casting, rather than by hammering or beating

Filings: Tiny particle or shaving of metal

Throwing: Producing a ceramic object by turning clay on a potter's wheel

Speckle: With a pattern of many small spots or small irregular patches, often of a contrasting color

Blunging: Mixing clay with water to generate slip or the mixing of glazes.

Levigate: To form a smooth uniform liquid mixture such as a paste or gel, or make something do this

ABREVIATIONS;

ASTM = American Society for Testing and Materials

µm = micron

mm = millimeter

cm = centimeter

g = grams

Ppn = parts-per notation

Conc. = concentration

SIGNS / CHEMICAL SYMBOLS

^{o}C = degree centigrade

% = percentage

Al = Aluminum

Ba = Barium

Ca = Calcium

Ce = Cerium

Cr =Chromium

Co =Cobalt

Cs = Cesium

Dy = Dysprosium

Eu = Europium

Fe = Iron

Hf = Hafnium

K = Potassium

La = Lanthanum

Lu =Lutetium

Mg = Magnesium

Mn = Manganese

Na = Sodium

Pa = Protactinium

Rb = Rubidium

Sc = Scandium

Sb = Antimony

Sm = Samarium

Ta = Tantalum

Ti = Titanium

U = Uranium

V = Vanadium

CHAPTER ONE

1.0 INTRODUCTION

The concept of design seems to have found its way into the making of ceramics for daily use and it is necessary as well as consistent with the aesthetic needs of today's society. It represents a thought-shift of modern society and is consistent with the developmental speed of modern society. In the design and decoration of ceramics for daily use, the decorative pattern design should be achieved using a number of design techniques. Not only do these designs arouse visual impressions, they also impart emotional responses to their consumers.

According to Freebies (2013), decorating ceramics is one of the most rewarding aspects of working in clay. It is the time when you can add colour and life to a bare clay surface that can show off your creative talents. There are scores of decorating techniques available and here are five successful techniques that are sure to add that extra flair to your work that will make it a masterpiece. Five Great Pottery Decorating Techniques: A how-to guide for decorating ceramics with slip transfers, Chinese brush techniques, ceramic slip, sgraffito, and more explains the ins and outs of these ever-popular ceramic decorating techniques!

The first use of platinum for the decoration of ceramics was as a so-called silver lustre over a brown earthenware body. Although it was only discovered in the middle of the eighteenth century, sufficient was already known about the properties of platinum for it to come into commercial use as a ceramic decorating medium by the end of that century. This took place in the English Potteries of Staffordshire. (Wynn, 1959).

The idea of decorative ceramics is one that has taken a large portion of productions in the specialization, whether tableware or decorative, all have elements of aesthetics depending on how it is put into use. Decorative ceramics which are of different shapes and styles includes ; vases, jars, planters, storage jars, tiles of different types to mention but a few. To make decorative wares, one has to decide on the suitable body and decorative technique that will suit one's purpose.

1.1 Background of the Study

The world is changing, as the human race advances and as a result, the urge and tastes for improved ways of life keep emerging. This has brought about innovations and improvements in ideas which cover the entire spheres of the human life. According to Webster (2011) “innovation is an improvement to something already existing”. The idea of innovation is important in whatever field including ceramics for the advancement of the specialization. A ceramist is at liberty to manipulate clay bodies to suit his purpose for either aesthetics or function or both. The driving force behind this research is predicated on the above purpose engaging iron filings as the motivator.

Peterson (2011) views clay body as the actual clay mixture that is used in forming objects. It may have one specific type of clay in it, but it is more likely to consist of a mixture of different types of clay. Other additives may also be introduced into the mixture and each specific material used is included to give the clay a particular attribute. For example, materials may be added to aid plasticity, to lower or raise the clay body's maturing temperature, or change its fired coloration. Iron filings was used here as an experimental additive to explore the possibilities of achieving both decorative and functional vessels. Iron filings was anticipated to give a unique outcome on clay body for decorative effects when fired to suitable temperature. The need for

advancement becomes important especially when there are locally sourced materials that could possibly be incorporated into the clay body for decorative effects.

1.2 Statement of the Problem

Iron filings which are a by-product in the Engineering field, is got as a result of grinding, filing and reconditioning of problematic motor engine blocks in order to make them work well. The material comes in different aggregate sizes in semi-powdered form and it is grey in colour. It is sometimes used in glaze formulation as flux which lowers the glaze maturing temperature. It was perceived that iron filings when mixed into clay body should have a unique effect on the body.

The problem of this study is that iron filings has not been exhaustively used in ceramics for decorative effects in clay bodies aside the use in glazes as oxide and flux. This leaves a gap of decorative possibility of these filings. The feasibility of utilizing cast iron filings in clay body for the production of decorative ceramics should fill the gap.

1.3 Aim of the Study

The aim of the study is to utilize cast iron filings from in clay body for the production of decorative ceramics in order to create a unique decorative technique different from those been used frequently by potters and ceramists in Nigeria

1.4 Objectives of the Study

In actualizing the aim of this study, the following objectives were pursued:

1. Sieve iron filings into different aggregate sizes
2. Blend iron filings into varying proportion with clay body in form of test slabs

3. Fire at a temperature of 800^{o}C - 1100^{o}C so as to determine suitable temperature to enhance speckle effects
4. Conduct shrinkage test on the test slabs
5. Produce decorative wares through throwing method of production from compositions with best result

1.5 Research Questions

1. What sizes of Tyler meshes will be suitable for screening the iron filings ?
2. In what proportion and clay body is Iron filing intended to be blended with?
3. To what temperature ranges will samples be fired ?
4. In what way will the shrinkage of clay and iron filings be ascertained ?
5. What method of production will be suitable for the wares?

1.6 Delimitation of the Study

This study is delimited to incorporating iron filings from Buniyaminu Engineering workshop, Randa Kano area Zaria, Kaduna State, ball clay from Bomo-Zaria, Kaduna State and kaolin from Kankara, Katsina State into a clay body for possible production of decorative ceramics.

1.7 Limitation of the Study

This study had its limitation in the area of compositions for production on the potter's wheel. The compositions that had 15% and 20% iron fillings in clay body for throwing on the wheel became injurious to the hands as a result of the high amount and coarseness of the aggregate size of iron filings, in addition to the extra pressure that was needed to be inserted before such compositions could be centered on the wheel. This therefore is not advisable to be used on the wheel.

1.8 Justification of the Study

"Decorative ceramics wares are items that appeal to the human sense when viewed. This is as a result of the decorative content and technique employed in the making of such wares. When one thinks of finished pots, one tends to think first of pots covered in richly colored, shiny glazes. But is that the only possibility?" (About. com pottery 2014).

In ceramics, there are several ways of decorating the pieces to appeal to the ever-increasing human aesthetic senses. In other to sustain the interest generated by decorative ceramic wares and probably increase it, there is need for more innovations to decorative techniques. It is from this frame of mind that the thought of this research work came about, so as to be able to try a different material and approach that based on existing literatures, have not been used for decorative technique of this nature.

According to lake side pottery (2014), clay shrinks both in drying and in firing. Different clay bodies shrink at different rates which can be as little as 4%, or as much as 15%. Even one percentage point can make a difference in the final product depending on the need for precision. While Aluwong (1988) reveals that Kankara kaolin has shrinkage rate of 14.5%, Bomo clay has 11% shrinkage. The presence of iron filings in the adopted clay body should serve as remedy (opener) to the high shrinkage rate of the body.

1.9 Basic Assumptions

The research is based on the following assumptions:

1. That iron filings will have decorative effect on ceramic wares (speckle)
2. That iron filings will reduce the shrinkage rate of the existing clay body

1.10 Significance of the Study

This research is significant in the areas of education, economic, technological, and aesthetic developments of ceramics. Educationally, the uniqueness of blending clay and iron fillings will serve as reference material for ceramic artists in an attempt to develop more aesthetic clay bodies. Aesthetically, the speckle effects of iron filings on clay body further enhances the beauty of ceramic products in a unique way to satisfy higher emotions. Technologically, possibilities of incorporating iron filings in clay body formulation for the production of decorative ceramics will be converting a bi-product (waste) in the engineering field into a useful material in the ceramic specialization area.

While economically, the introduction of a foreign material (iron filings) and its unique effect is expected to create a new outlook in terms of its finishing and beauty. Perhaps this new outlook will be an added advantage that will promote marketability of ceramic products.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In order to properly situate decorative innovations and effects on clay bodies and wares, it will be pertinent to review related literatures that will provide good theoretical background of the state of the subject in terms of knowing what areas have been covered, what is left to be covered, and the techniques to employ in achieving those effects.

"The earliest type of decorative art was pottery, notably the Jomon style Japanese ceramics pioneered from about 14,500 BCE (Before Common Era). Potters produced a wide range of pots in all shapes and sizes, and decorated them with abstract, historical and mythological designs, in a variety of styles which developed throughout the period 3,000 - 300 BCE". (Encyclopedia of Art, 2012)

2.2 Clay

Zauro (2007) asserts that clay is characterized as a heavy, damp, plastic material and it becomes hardened if dried. While Leach (1975) views clay as an astonishingly simple four-letter word that describes the most complex and significant material known to humans, it is an essential mineral for use in ceramics, refractory, petroleum, paper, adhesives, radioactive waste disposal, and cement industries. Clay is also important in fabrics, fertilizer, food, wine, beer, soil, medicine, pharmaceuticals and cosmetics, paint, leather, plastics as well as rubber, soap, polishing compounds, and water purification industries.

In Gukas and Datiri (2001) clay is defined as earthy malleable substance. It is soft when wet but hard and rocklike when fired to high temperatures. Peterson (2011) has it that clay differs from

the inelastic earths and fine sand because of its ability, when wet with the proper amount of water, to form a cohesive mass and to retain its shape when moulded. This quality is known as plasticity of clay. When heated to high temperatures, clay also partially melts, resulting in the tight, hard rock-like substance known as ceramic material. Gukas and Datiri (ibid) further stress that clay has some very tiny particles sizes, yet it is sometimes referred to as a rock. People refer to clay as a rock because of the simple fact that it consists of some naturally formed aggregates of earth. Geologists have grouped the entire earth crust into three convenient groups namely: igneous or granite rocks, sedimentary rocks, and metamorphic rocks. Out of these three, the principal clay forming rock is the igneous or granite rock.

Clay has been described as an earthy plastic material that is different from the inelastic earth. The capability of clay to be shaped into different forms of clay makes it important not only in the field of ceramics but also in the entire human life. The nature of clay has made it possible for it to be explored in diverse ways to meet the needs of industries as well as the studio ceramist.

There are three basic types of clay: earthenware which are natural clay body, stoneware which can be natural or formulated and porcelain. Earthenware is porous; Stoneware comes in several colours, textures and it will hold water all by itself when fired to the maturing temperature. Porcelain is the closest to glass and will vitrify (hold water) and display some translusency when held to a bright light (Winokur, 2006).

2.3 Clay Body

At this point, it will be necessary to make a distinction between the terms ‘clay' and 'clay body'. The term "clay" refers to those earthy materials of a plastic quality which are formed by natural forces and which are to be found in nature. The term ‘clay body’ will be used to indicate a mixture of clay-like materials with other inclusions for a specific ceramic purpose. In other words, a 'clay body' may have several different kinds of clay, fluxes, silica, grog, and other ingredients for colour, plasticity, warping, cracking, shrinkage, porosity, firing temperature, and texture. (Fromme, 1994)

Peterson (2011) stated that clay bodies used for throwing must be plastic and yet strong enough to hold up under the rigors of being thrown on the potter's wheel. He went further to give some guidelines for developing throwing clay body from the scratch. In the following ways: Use not more than 30% ball clay in your clay recipe (some potters say no more than 25%). Use not more than 8 - 10% grog or sand to add strength. The best grog or sand to use should be able to pass through 30 / 80 mesh; particles should not be larger than 30 mesh or smaller than 80 mesh. When adding bentonite for plasticity, use very low amounts (some potters say less than 2%, while some potters use up to 3%). For darker clay bodies, use dry clays that already contain iron to add color and aid fluxing.

This shows that clay bodies could be formulated or developed to meet the taste or desire of a ceramist. It is clear that this could be achieved by blending together clay and other materials to furnish some other characteristics. Cast Iron filings in clay body may possibly reduce shrinkage rate of clay, serve as flux in a body and possibly have deferent effects on the clay body.

Leach (1975) notes that the classification of clay minerals is impressive in its awesome complexity and yet, for a potter, it is more important to know how a particular clay will behave

in a glaze or clay body. Thus, the only meaningful classification of clay minerals for a potter is one based on the working properties of the clays. Each clay contributes one or more of the following qualities needed to make up a good clay body as outlined by Leach;

l. Plasticity: How does the clay hand-build and throw on the wheel?

2. Wet strength: Does the clay slump when it takes on water?

3. Dry strength: Does the clay crack during the handling or drying process?

4. Firing strength: Does the clay shrink excessively, slump, or crack when subjected to the heat of the fire?

5. Firing range: Is the clay mature or immature at the desired firing temperature? Will water seep through its pores? Can the clay tolerate a range of firing temperatures?

6. Colour/Texture: How does the clay contribute to the desired color and texture of a glazed or unglazed piece after firing?

7. Thermal shock: Does the clay crack or dent during the firing or cooling cycle?

8. Glaze fit: Does the glaze crack or shiver off the fired clay form?

It is important that in the attempt to innovate or formulate a clay body, the above working properties of an ideal clay body be put into consideration. Mixing an existing clay body with iron filings calls for experimental approach to be able to arrive at an acceptable proportional mixture that could stand the test of time

Singer and Singer (1963) notes that the term ‘body’ covers both the mixture of raw materials prepared for making any one product, and also the main part of that product as opposed to the glaze. They further reiterate that the traditional bodies have distinctive names which have come to mean particular features of colour, texture and shapability. These bodies according to Singer

and Singer are largely based on clay, or on the triaxial diagram of clay-feldspar-flint but that modern bodies based on better knowledge of the composition, structure and reaction of materials are described either by the specialized use to which they can be put, or by chief raw material or by the chief compound formed in the body.

The composition of traditional ceramics bodies as described by Singer and Singer lie within certain limits which are governed by a number of factors. Firstly, the shaping of the ware which necessitates the inclusion of sufficient plastic materials, after the shaping, the clay also holds the ware together as it dries. Secondly, the drying and firing of the ware, without cracking, which calls for the incorporation of non-clay materials that do not shrink during the drying and firing. These are flint, quartz, and for large bodies grog, which is essentially a ground up fired clay, or ceramic body.

Frank and Hamer (2004) opined that body is clay for a special purpose which is created by blending different clays or by adding to clays other minerals, such as feldspar and flint, in order to produce a desired workability (for the furnished result). Fromme (1994) reveales that the principles of forming a body are the same regardless of whether it is earthenware, stoneware, or porcelain.

Peterson (2011) confirms that the most commonly used clay bodies are earthenware clay bodies, mid-fire stoneware clay bodies, and high-fire stoneware clay bodies. Clay bodies can also be produced by mixing dry clays and additives with water to create one's own desired clay body.

2.3.1 Earthenware Clays

Traditionally, earthenware clays have been natural clays (buff, red, and terra-cotta) which mature at firings under 1100ºC. For the most part, earthenware used for cooking and serving as tableware, cereal storage, liquid storage, and so forth by cultures since Neolithic times rarely fire over 900ºC. (Willis, 2008)

2.3.2 Stoneware Clays

"Natural stoneware clays are finely and uniformly grained fabric (not rarely of the “300 mesh” variety) comprised mainly of pegmatite. The material is such that when kneaded and sun-baked it has a sedimentary stone-like hardness, and when fired to maturity the hardness and aspect becomes granite-like" (Willis, 2008).

2.3.3 Kaolin

Also known as china clay, by itself, kaolin has a melting point of around 3275^{o}C, and is difficult to form because of low plasticity. To achieve the dense, hard, white, translucent clay body known as porcelain, kaolin is mixed with other clays to achieve a high degree of workability and to lower the firing temperature. However, it is difficult to work with during the throwing stage because of its low plasticity. (Zauro, 2007)

There are known deposits of kaolin in various parts of the world and in Nigeria, there are deposits in Katsina, Kebbi, Edo, Kwara, Bauchi and Sokoto states. Kankara Kaolin has the following analyses as recorded in table 2.1:

Table 2.1 Analysis of Kankara Kaolin

Compound	Formula	Percent

Silica	$Si0_2$	44.55%
Alumina	AL_20_3	31.45%
Iron Oxide	Fe0	1.07%
Magnesia	Mg0	0.87%
Lime	Ca0	0.28%
Sodium Oxide	Na_20	0.17%
Potassium Oxide	K_20	0.03%
Excess water	H_20+	12.03%
Chemical water	H_20	9.06%
Titanium Oxide	$Ti0_2$	0.41%
Manganese	Mn0	0.01%
Sulphur	$S0_4$	0.05%

Source; Umar and Hendsman in Garkida (1998)

Kankara kaolin according to Gukas (1985) has been found to have the following qualities as shown in Table 2.2;

Table 2.2 some other properties of Kankara Kaolin

Property	Measured Value
Plasticity	low
Dry shrinkage	6%
Bisque shrinkage	2%
Glaze shrinkage	6.5%
Total shrinkage	14.5%
Adsorption at Biscuit	13.5%
Adsorption at 1300^oC	12.5%

Source; Gukas (1985)

The importance of kaolin in formulation of clay body cannot be over emphasized. It has proved, over time, to be the strength of many clay bodies to withstand the rigours of heat to a desired temperature without deforming.

2.3.4 Secondary Clay

A secondary clay is a clay that has been transported by agent of weathering from its original site to other locations. It can be moulded, pounded, pinched, flattened, rolled, coiled, thrown on wheel or cast into moulds. The clay responds to shaping, bending, smoothing, drying, firing and glazing (Manzuche, 1991).Considering the fundamental characteristic and qualities of ball clay, it is indispensable in ceramics and body formulation because of its high degree of plasticity with corresponding bonding power and dry strength.

The following data on ball clay found at Bomo-Zaria, Kaduna state is given by Aluwong(1988).

Plasticity medium

Shrinkage 11%

Fusibility Vitrifiable

Using the instrumental Neutron Activation Analysis (NAA) 26 elements were reportedly determined in Bomo ball clay by Oladipo and Akomolafe in Garkida(1998)

Table 2.3 Results of NAA reported for Bomo Ball clay

Elements	Conc. (ppm)	Element	Conc. (ppm)	Element	Conc. (ppm)
Na	3499	Sb	0.03	Cr	188
M	5059	Cs	0.75	Mn	336
Al	7.47%	Ba	75.4	Fe	0.91
K	1.50%	La	92.0	Co	4.29
Ca	3932	Ce	170	Rb	6.07
Sc	15.5	Sm	15.1	Lu	9.07
Ti	3516	Eu	1.64	Ta	5.33
V	51.4	Dy	5.76	Pa (Th)	21.2
U	10.3	Hf	9.07		

Source;Oladipo and Akomolafe in Garkida (1998)

2.3.5 Fire Clay

This is clay that has a high degree of resistance to heat. By the best standards it should have a fusion point higher than 1600°C. The term “fire clay” is commonly held to exclude kaolin and other refractory clays. Fire clay should contain high percentages of silica and alumina, with little of such impurities as lime, magnesia, soda, and potash, which lower the fusion point of the clay. The principal uses of fire clay are in the manufacture of firebrick and of various accessory utensils, such as crucibles, saggers, retorts, and glass pots, used in the metalworking industries (Encyclopedia, 2007).

The classification of clays shows that different bodies mature at different temperatures due to the unique compositions of each body. These bodies are invariably designed for specific ware types.

2.4 The Nature of Iron

Iron is a chemical element with the symbol Fe and atomic number 26. It is the most common element in the whole planet, forming much of earth's outer and inner core and it is the fourth most common element in the earth's crust. It is produced in abundance as a result of fusion in high-mass stars where the production of nickel-56 (which decays to iron) is the last nuclear fusion reaction that is exothermic, becoming the last element to be produced before collapse of a supernova leads to events that scatter the precursor radio nuclides of iron into space. Iron is a common silver-coloured metal element which is magnetic. (Cambridge Dictionary online, 2011).

2.4.1 Cast Iron

Cast iron which has melting temperatures closely relating usually ranging from 1150 to 1200 °C (2102 to 2192 °F), which is about 300 °C (572 °F) lower than the melting point of pure iron, is used widely in the automotive and heavy equipment industries for structural components such as engine, brake, suspension, and steering parts. Cast iron is formed by adding carbon (graphite) to steel. The characteristics of cast iron are formed during solidification and once solid cannot be changed through further heating (Nikon, 2011).

The chemical composition of cast iron alloys shall be determined accurately in order to ensure the desired metallurgical properties. This procedure is suitable for manufacturing control and inspection testing. Analysis by (ASTM E1999, 2011), as indicated in table 2.4:

Table 2.4 Cast iron analysis

Concentration Ranges, %

Elements,	Applicable Range, %,	Quantitative Range, %[A]
Carbon,	1.9 to 3.8,	1.90 to 3.8
Chromium	0 to 2.0	0.025 to 2.0
Copper	0 to 0.75	0.015 to 0.75
Manganese	0 to 1.8	0.03 to 1.8
Molybdenum	0 to 1.2	0.01 to 1.2
Nickel	0 to 2.0	0.02 to 2.0
Phosphorus	0 to 0.4	0.005 to 0.4
Silicon	0 to 2.5	0.15 to 2.5
Sulfur	0 to 0.08	0.01 to 0.08
Tin	0 to 0.14	0.004 to 0.14
Titanium	0 to 0.12	0.003 to 0.12
Vanadium,	0 to 0.22,	0.008 to 0.22,

Source; ASTM E1999 (2011)

Possibly due to the presence of some toxic elements in cast iron especially when used in the production of tableware, this study is of the opinion that decorative wares will be more appropriate as the products will not be used for drinking or eating.

2.4.2 Iron as Additive

Malvern (2011) revealed that Metal powders are made either by gas atomization or grinding, and are then classified using dynamic classifiers or cyclones to obtain the precise particle size distribution to form the final end-user product, the metal powders are then used in various consolidation processes;

- Extrusion
- Injection molding
- Blending
- Compaction
- Sintering

Line blending is a systematic way of finding out the reactions of two different materials or mixtures of materials (Henrik and James, 1993) see table 2.5.

Table 2.5 Line blend 10 steps

MATERIAL	**PARTS BY VOLUME**
material A	0 1 2 3 4 5 6 7 8 9 10
material B	10 9 8 7 6 5 4 3 2 1 0

An example of a line blend in ten steps, which gives the full range of combinations of two materials

Cast iron filings could also be referred to as iron powder due to the ground state of both, while metal filings are more coarse and particles more visible. It has shown that the more finely the particle size of iron powder, the more effective in the production of items. This is made possible by particle size distribution analyses. Blending of iron and stoneware clay which are two different materials will be blended using the line blend theory as recommended by Henrik and James, 1993

2.5 Particle Distribution Analyses

In Particle Technology Lab P.T.L (2011) a sieve analysis is described as the use of a single or set of screens (typically woven wire mesh), decreasing in opening size, to separate or classify a sample. Several mechanisms are used to disperse the sample and transport it through the screens (vibration, air entrainment or flowing liquid). While considered relatively low resolution, sieving practical application lend itself well to quality control specifications.

ASTM establishes accepted criteria for the woven wire mesh opening tolerances of standard sieve sizes. For optimal quality control, PTL verifies its in-house sieves with an external vendor for compliance with the ASTM.A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sand, crushed rock, clay, granite, feldspar, coal, and soil, a wide range of manufactured powder, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

Grading of grains for analyses and experiment becomes important as it provides the avenue to determine the best particle size that will be best for a desired outcome. This is made possible by the use of sieves of different hole sizes which produce finer particles as the grains pass through.

2.6 DECORATIVE ART

Saliu (2005) discloses that decorative art is an activity which arises from complex requirement in which scale and quality vary according to how strongly a cultural group feels the need to express the requirements. Decorative art, usually, but not always non- representational, is for design reasons and enhancement of a given surface and space.

Jefferson (1974) views decorative art as the end result from the simple urge to improve the appearance of things, to achieve designs that are pleasing to the eye, to enrich both utilitarian and religious objects with familiar patterns and symbols which are meaningful to the artist and his people. Decorative ceramics ranges from tiles to ornaments and vases. Pottery and ceramics have been decorated in a large variety of ways. The use of glazes, slips, and impressed surface details are only a few of the options available to the ceramic artist. Pottery surfaces can run the gamut from glossy, silky smooth, sandpaper roughness, to complete cragginess. Decorative techniques in pottery are grouped under four main categories as follows:

- Surface treatments
- Glazes
- Under glaze
- Over glazes

2.6.1 Burnishing

"Burnishing is the technique of polishing clay to a beautiful sheen without the use of glaze. Ancient potters used these techniques to produce their wares before glazes and kilns were

developed. Today, modern potters use burnishing to create works of great beauty". (Dassow, 2011), see figure 2.1:



Figure. 2.1 Burnished and carved pieces
Source; anonymous

2.6.2 Screen Printing

Ceramic oxides are mixed with a medium into a smooth paste, which is printed onto a transfer paper (usually a gelatin coated paper) with traditional screen printing techniques. When the transfer paper has dried, the decal is ready for use or can be stored indefinitely. The decal is applied by softening in warm water. The gelatinous skin with the embed image releases from the base paper and can be applied to the ceramic ware. It is then fired to 700-750o C (1300-1380o F), at which temperature the glaze softens just enough to embed the oxides (VisGirda, 1998), see figure 2.2:



Figure. 2.2: screen print on pottery
Source; Susan Kotulak (2011)

2.6.3 Agateware

Agateware is a type of pottery that is made from a prepared mixture of various colored clays and mimics the variegated appearance of agate stone. It originated in the late seventeenth century in England, and is one of the many great techniques that utilize coloured clays to create interesting surface features. There are two types of agateware, one is wheel thrown and the other is made using hand building techniques, and is classified as laid agateware. (Erickson and Hunter 2012), see figure 2.3:



Figure. 2.3: Agate ware, Josiah Wedgwood (1768)
Source; http://www.pottery-magic.com/pottery/topics/pottery_types.htm

2.6.4 Magnificent Marbling

Using coloured slips to create marbled patterning on pottery slip. This versatile liquid form of clay can be used in a multitude of different ways to create and embellish ceramic art. One such method involves using coloured slips to create marble effect on pottery, which is reminiscent of Staffordshire-style English marbled slipware. Gravity and centrifugal force are key elements for inducing the movement or flow of slips during the marbleizing process. The term “joggling” is used to describe the physical act of controlling this movement which requires very specific and

somewhat awkward looking body and arm movements. The degree of aesthetic success is directly linked to the skill of the potter in controlling the flow of the slips. (Harnetty, 2011), see figure 2.4:



Figure. 2.4: Marble Ware Shallow Dish
Tang Dynasty (AD 618 - 907)
Source; http://www.albertomanuelcheung.com/Tang%20marble%20dish.htm

2.6.5 Terra Sigillata

The term terra sigillata, which means ‘sealed earth’, comes from the name of a type of Roman pottery mass-produced around the first century AD. This pottery was decorated with impressed or stamped decoration which is what the word ‘sigillata’ refers to. These pots were coated with the same kind of very fine slip which Greek potters had been using for hundreds of years to create their famous black and red pottery. Terra sigillata is an ultra refined clay slip that can give a soft sheen when applied to bone-dry wares and if polished or burnished while still damp may give a high gloss. The ancient Greeks and Romans used this technique in lieu of glaze. (Dassow, 2011), see figure 2.5:



Figure. 2.5:Terra Sigillata decorated
Source; anonymous

2.6.6 Under Glaze

Under glaze as a term can mean any decoration that is applied almost always in a fluid form on the pottery surface before any glaze is applied. Under glazes are used in pottery to create designs and patterns that will come up through the glaze covering them which can give the surface more visual depth and character. Although they are often used under clear glazes, they can also be used under other generally light coloured transparent glazes.(Peterson, 2008), as shown in figure 2.6:



Figure. 2.6; Hu Jar with Cover
Han Dynasty (AD 25 - 220)
Source; Anonimous

2.6.7 Glaze

Glaze is a layer of glass which is fused into place on pottery because it is smoother than the body it covers and it is non-porous. It is also decorative, providing colour, shine and textural contrast with the body; and it increases the strength of the ware by the creation of a body-glaze layer. The glaze is first attached to the pottery body in form of a layer of powder. This powder is composed of glass forming materials, fluxes and stabilizers. During the firing, they all fuse together to form

a compact layer of molten material. On cooling, this layer does not separate into its former constituent but remains as the new material, glass. (Frank and Hamer, 2004), see figure 2.7:



Figure 2.7; Karatsu Pottery,
Source; Microsoft Encarta

Decorative Ceramics are produced in a varieties of unique methods which add to the aesthetics and market value of the wares. These methods of decoration on ceramics range from screen printing, agate wares, burnishing, glazing, under -glazing and over-glazing, terra sigillata, marble ware and a host of others that are not captured. The introduction of iron filings into clay body will, no doubt, be an indigenous addition to the decorative methods already existing.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

The research methodology is adopted for this study is experimental. This chapter systematically enumerates procedures, materials and components on the possibilities of incorporating iron filings into clay body for the production of decorative effects on ceramic wares.

3.2 Population of the Study

Population of this study is comprised of kaolin, secondary clay and iron filings. The choices of these materials were guided by their known physical, chemical and thermodynamic properties as obtained from available literature.

3.3 Sampling

Locations of samples were guided by information obtained from professionals in related fields and residents in the areas. Kaolin was procured from Kankara, Katsina State; secondary clay was procured from Bomo-Zaria, Kaduna State while iron filings were procured from Randa Kano area Zaria, Kaduna State.

3.4 Chemical Analysis

Kaolin, secondary clay and iron filings that were used in this study had already been analyzed, and the results are stated in the previous chapter (chapter two). The analysis of Kankara Kaolin

and Bomo clay was carried out by Hendsman (1979) and Oladipo (1989) respectively as sited by (Garkida, 1998) while the analyses of iron were carried out by ASTM (2011).

3.5 Treatment and Processing of Raw Materials

3.5.1 Kankara kaolin and Bomo clay

Kankara kaolin and Bomo clay were obtained in the form of fine grain materials with some lumps. The kaolin and clay were soaked in different bins but in the same proportion of 50/50 for some days and this was followed by blunging the secondary clay and kaolin together to form a homogenous mixture which was sieved to improve the clays plasticity resulting in the formation of the clay body. This was an adopted body from the ceramics section, Department of Industrial Design, Ahmadu Bello University, Zaria.

3.5.2 Iron Filings

Iron filings were obtained in the form of semi powder in different particle sizes. It was subjected to analyses by sieving with graduated mesh of three hole sizes of 1.18 millimeter, 600 micron, and 300 micron. The largest aggregate size of 1.18mm took 60% of the whole constituent, 600µm became the second largest aggregate size with 24% of the constituent, and 300µm took 16%.

The 16% of the 300µm aggregate size was inadequate for the test, for that reason some percentage of the largest aggregate size of 1.18mm was further broken down by pounding in a mortar and then re-sieved to give more of the 300µm aggregate sizes to be adequate for the test. See plate I - III d:



Plate I: Soaked Secondary Clay and Kaolin in Bins



Plate II: Analyzing Iron Filings by Sieving



Plate III a: 1.18mm Aggregate Sizes of Iron Filings



Plate III b: 600µm Aggregate Sizes of Iron Filings



Plate III c: Un- sieved Aggregate of Iron Filings



Plate III d: 300µm Aggregate Sizes of Iron filings

3.6 Ratio of Clay and Iron filings in Grams/ Size of Slabs

Irrespective of the aggregate sizes, 1000g of clay body and iron filings was decided at any point of measuring constituent for the slabs so as to be able to divide the weight of clay and iron filings in each slab with ease. This is laid out in table 3.1, slab size of 7cm by 5cm was also chosen for all the slabs.

3.6.1 Composition of Test Slabs

Clay body and iron filings were blended in different percentages using the line blend method; they were made into slabs according to the different aggregate sizes of iron filings. See plate IV - VI below. Four slabs were made from each aggregate size, the slabs were further reproduced into four places to give a total of sixteen slabs from each aggregate size of iron filings as shown in table 3.2, 3.3, 3.4 and 3.5 respectively, while four slabs free of iron filings were made to serve as control. In all, sixty eight slabs were produced so that each aggregate was represented in each test firing. This process is to determine the temperature most suitable for effective speckle effects to be employed in making the actual decorative wares. The composition of test slabs and throwing tests were blended in both dried and wet states. While iron filing was in its dried state, the clay body was in its wet state so that iron filings were easily blended into it by kneading. The test slabs were dried in room temperature for three days and later exposed to the sun for final drying.

Table 3.1; Ratio of clay and iron filings in grams

	Clay	Iron Filings

A	950g	:	50g
B	900g	:	100g
C	850g	:	150g
D	800g	:	200g

Letters A – B represent the slabs while ratio 950g : 50g – 800g : 200g represents clay body and iron filings as they were weighed on scale.

Table 3.2; Compositions containing clay and iron fillings in different percentages for un-sieved Iron Filings

Samples	A	B	C	D
Stoneware Clay / Iron Filings	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20

Letter A – B represent the different aggregate sizes, percentages 95/5 – 80/20 is for the ratio of clay body and iron filings.

Table 3.3; Compositions containing clay and iron fillings in different percentages for 300µm aggregate size of Iron Filings

Samples	A	B	C	D
Stoneware Clay / Iron Filings	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20

Letters A – B represent the different aggregate sizes, percentages 95/5 – 80/20 is for the ratio of clay body and iron filings.

Table 3.4; Compositions containing clay and iron fillings in different percentages for 600µm aggregate size of iron filings

Samples	A	B	C	D

Stoneware Clay / Iron Filings	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20

Letters A – B represent the different aggregate sizes, percentages 95/5 – 80/20 is for the ratio of clay body and iron filings.

Table 3.5; Compositions containing clay and iron fillings in different percentages for 1.18mm aggregate size of iron filings

Samples	A	B	C	D
Stoneware Clay / Iron Filings	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20
	95/5	90/10	85/15	80/20

Letters A – B represent the different aggregate sizes, percentages 95/5 – 80/20 is for the ratio of clay body and iron filings.



Plate IV: 1000g of Clay Body and Iron Filings on the Scale



Plate V: Blending Clay Body and Iron Filings Together by Kneading



Plate VI: Measuring and Cutting off of 7cm by 5cm slabs

3.6.2 Firing of the Test Slabs

The tests were fired using different temperatures starting from 800^{o}C up to 1100^{o}C of melting point of the iron filings, therefore the firing range was 800^{o}C, 900^{o}C, 1000^{o}C and 1100^{o}C respectively. The firing was carried out in an electric kiln for accuracy in temperature measurement in order to ascertain the extent to which the temperatures affected the speckled effects most in the slabs. The sixty eight test slabs made from the four aggregate sizes were equally shared into the four firing temperatures such that each group of test slabs was represented in all the firing.

3.6.3 Shrinkage Test at Fired Stage of Test Slabs

The various test slabs produced were subjected to shrinkage tests at the fired stage, this was to determine the level at which iron filings was able to reduce the shrinkage level of the clay body. This was conducted by taking the measurements of the test slabs before they were dried, and after firing.

Table 3.6; Even Distribution of Test Slabs to the Four Firing Temperatures

Firing Temperatures	Group of 'A'	Group of 'B'	Group of 'C'	Group of 'D'
800^{o}C	1a, 2a, 3a, 4a	1b, 2b, 3b, 4b	1c, 2c, 3c, 4c	1d, 2d, 3d, 4d
900^{o}C	1a, 2a, 3a, 4a	1b, 2b, 3b, 4b	1c, 2c, 3c, 4c	1d, 2d, 3d, 4d
1000^{o}C	1a, 2a, 3a, 4a	1b, 2b, 3b, 4b	1c, 2c, 3c, 4c	1d, 2d, 3d, 4d
1100^{o}C	1a, 2a, 3a, 4a	1b, 2b, 3b, 4b	1c, 2c, 3c, 4c	1d, 2d, 3d, 4d

Numbers 1-4 represent the various compositions of clay/iron fillings as thus 1= 95/5, 2= 90/10, 3= 85/15 and 4= 80/20 respectively. While a-d represent the aggregate sizes of the iron fillings as thus a = 1.18mm, b = 600microns, c= 300 microns and d = not sieved iron fillings.



Plate VII: Measuring Shrinkage Extent of Test Slabs

3.7 Throwing Test

Throwing test was carried out and this was targeted at knowing how iron filings and clay at different proportions would react to centering, pulling and shaping on the potter's wheel.

3.8 Choice of Blend and Firing Temperature Employed in Making Decorative Wares

Choice of composition and temperature that were employed in making the decorative wares were based on different outcomes of the experimentation. The following were the considerations made before concluding on the particular compositions and firing temperature that were employed;

- Percentage of clay body and iron filings as it affected plasticity during throwing considering the fact that there should be appropriate plastic quality of the clay body for the throwing method of production that was adopted.
- Visibility of aggregate size; since the speckled effects of iron filing were ultimately sorted after in this study. It became imperative to look out for the largest aggregate size of iron filings that could produce very clear speckled effects.
- Firing temperature; the essence of firing is to make the wares more durable and to further enhance the speckled decorative effects of iron filings on the wares.

3.9 Design and Production

Throwing method of production was adopted in producing the actual decorative wares. The stone ware clay was further moistened to be a little softer than the usual throwing hardness. As is the custom, the thrown wares were allowed to get dried to leather hard stage before trimming, joining and attachment of appendages were carried out. Some parts of the wares were thrown half way with iron filings while the other half of the same wares were free of iron filings. In other wares the appendages were free of iron filings while the main body of the wares had iron

filings; this was done repeatedly before allowing the wares to dry. The following sketches were computer aided designs of the proposed decorative wares before they were actually produced. The designs show different decorative pieces and the effects iron filings had on the body, see plates IXa to XVIIIb:



Plate VIII a: Ware with iron filings all over the body



Plate VIII b: ware without iron fillings



Plate IX a: Ware with iron filings all over



Plate IX b: Ware without iron fillings at the top and ring appendage

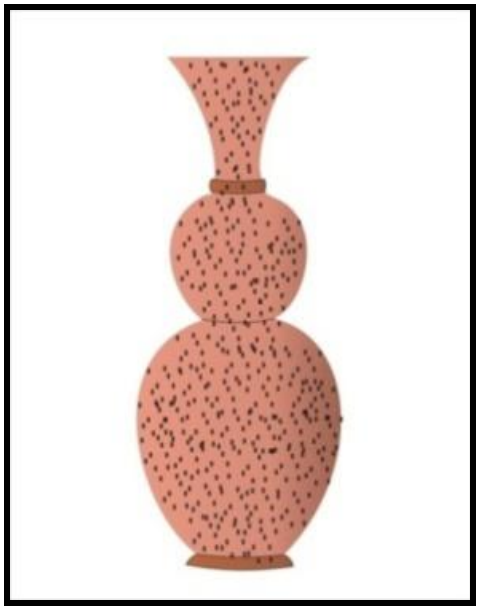


Plate X a: Ware without iron filings

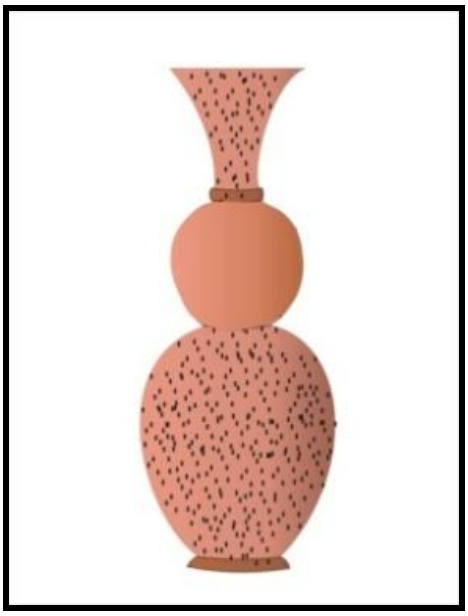


Plate X b: Ware without iron fillings at the shoulder

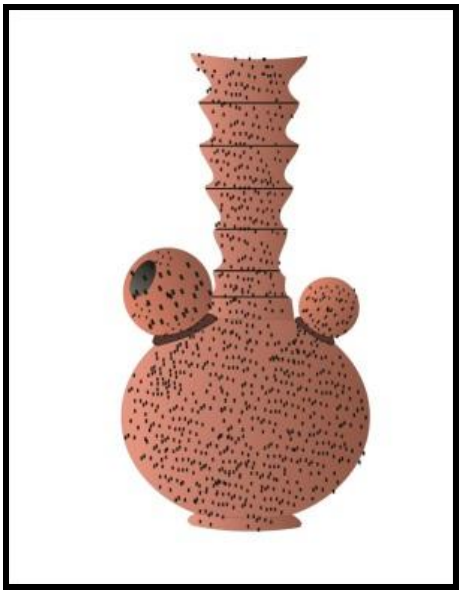


Plate XI a: Ware without iron filings



Plate XI b: Ware without iron fillings at the appendages



Plate XII a: Ware without iron filings at the top half

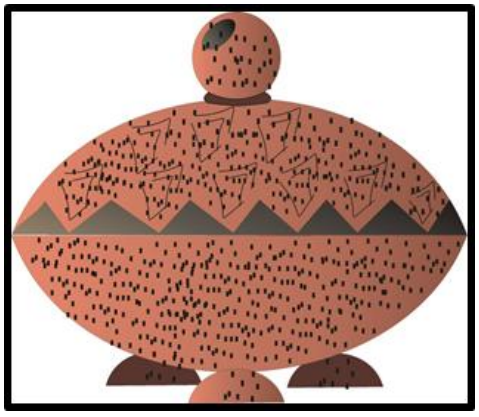


Plate XII b: Ware with iron filings all over



Plate XIII a: Ware with iron fillings all over



Plate XIII b:Ware without iron filings at the top appendage

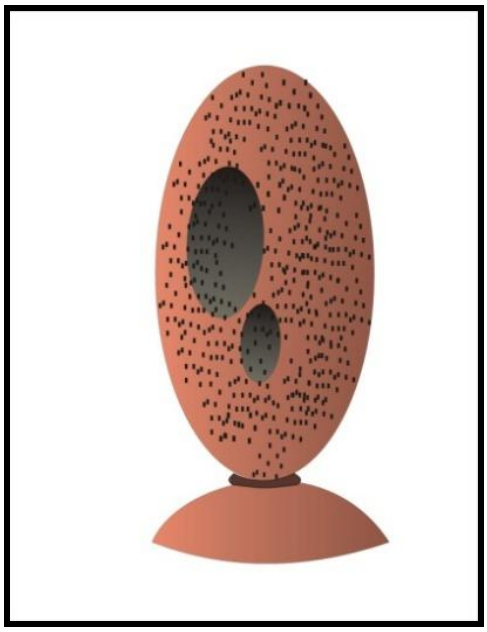


Plate XIV a: Ware without Iron Filings at the base



Plate XIV b: Ware with iron fillings all over

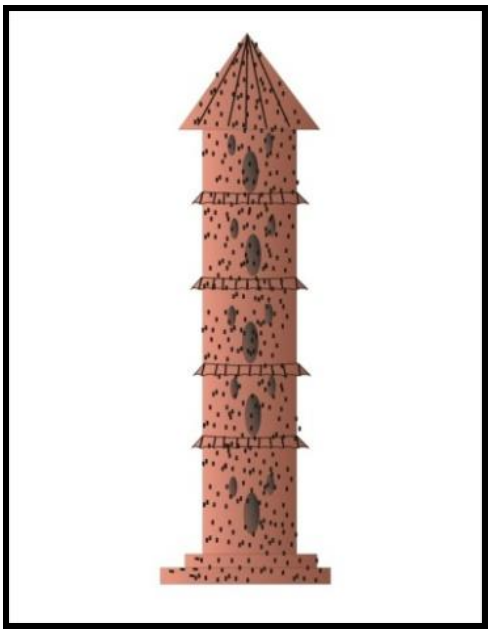


Plate XV b: Ware with iron fillings all over

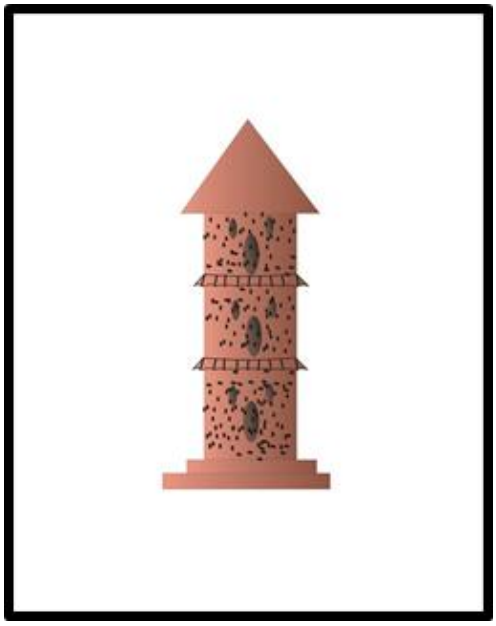


Plate XV b: Wares without iron filings at the top and base

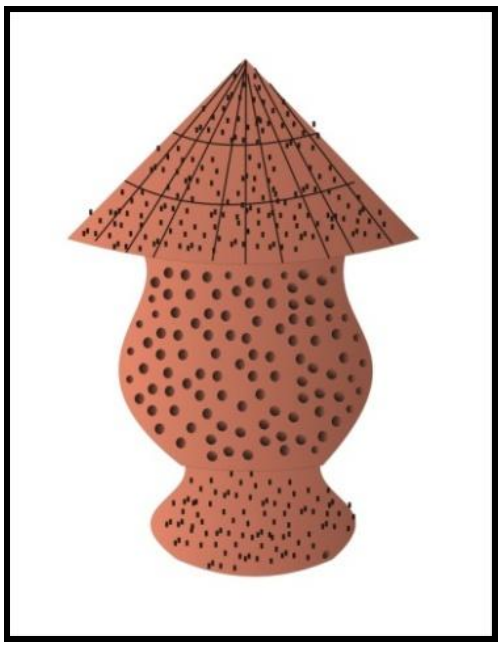


Plate XVI a: Ware without iron filings on belly



Plate XVI b: Ware with iron fillings all over at the body

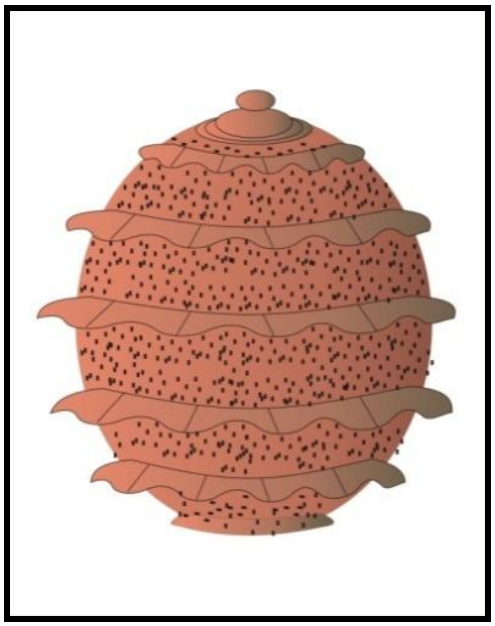


Plate XVII a:Ware without iron filings at the appendages

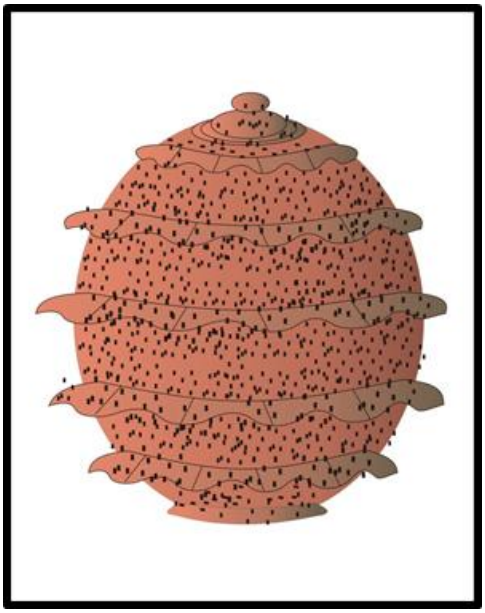


Plate XVII b: Ware with iron fillings all over

3.10 Drying and Firing of Decorative Wares

Drying was carried out in room atmosphere and was kept at a minimum to avoid crack development. The wares were loaded into the kiln, gradually pre-heated and finally fired to 1000^{o}C with the aid of a pyrometric cone which was placed at the spy hole of the kiln to be able to monitor the firing temperature. The decorative wares were fired with kerosene kiln because it is spacious and able to accommodate the sizes and the number of wares as shown on plates XIX to XXI below:



Plate XVIII: Drying of decorative wares before loading into the kiln



Plate XIX: Loading kerosene kiln with the decorative wares for firing



Plate XX: Cone for 1000^{o}C at the position of the spy hole

CHAPTER FOUR

4.0 RESULTS AND FINDINGS

4.1 INTRODUCTION

The objectives of this study are actualized as a result of the manipulation of iron filings and clay body as experimented, results and discussions based on the research work are hereby explained for better understanding

4.2 Forming of Test Slabs

Clay body and iron filings of 1000g weight was decided for producing all the test slabs for convenience and easy measurement, this resulted in even sizes of test slabs. While the test slabs free of iron filing served as control, it showed clearly the difference between clay body with and without iron filings. Corrosion was prevented as a result of blending in both wet and dry stages of clay body and iron filings as production was done immediately before corrosion could set in. Further softening of the blend made working on the potter's wheel easier without the difficulty of excessive pressing.

Test slabs that is 7cm by 5cm size was employed for the test because of uniformity. The sixty-eight test slabs made had even representation in the four different firing temperatures and this aided proper analyses.

4.2.1 Drying of Test Slabs

As was mentioned earlier, drying of the slabs guarded against cracking or deformation that could occur if hastily dried. The slabs mixed with iron filings showed rusted speckled effect.

4.2.2 Effect of Experimental Sample Slabs Fired at 800^{o}c

Very little impact of this temperature could be seen on the iron filings. However, 1.18mm aggregate size was little outstanding in the slabs because of the large size of iron filings.

4.2.3 Effect of Experimental Sample Slabs Fired at 900^{o}c

At this temperature, speckled effects were not as vibrant compared to 1100^{o}C and 1000^{o}C; this was because the temperature was not high enough to cause a chemical reaction on the iron filings. 1.18mm was better under this temperature because the size of aggregate were larger naturally.

4.2.4 Effects of Experimental Sample Slabs Fired at 1000^{o}c

There were no much differences in the speckled effect as compared to 1100^{o}C. The major difference was that the temperature of 1100^{o}C was able to cause a melt of iron filings and burst out on the composition of 80/20% and 85/15% while the temperature of 1000^{o}C was not up to that. 10% and 5% iron in clay remains the most favorable under this temperature as the speckled effects were reasonably distributed with spaces in between. The un- sieved aggregate created a mix feeling of homogenously mixing with the body as it composed of very tiny sizes of iron while the large sizes give the effects.

4.2.5 Effect of Experimental Sample Slabs Fired at 1100^{o}c

At 1100^{o}C, iron filings started melting and blotting out of the clay body. The speckled effects were enhanced and had semi-fused effects. Aggregate size of 1.18mm had the most conspicuous speckled effect. This is because originally the size of the aggregate was big and further made larger by the temperature of 1000^{o}C. The blend with 20% of 1.18mm iron filings looked and felt too much in the body thereby having overcrowded speckled effects. Fifteen percent (15%) of the same aggregate size though not as much as 20% iron filings but also crowded in the body. Ten percent (10%) iron filings in the clay body looked suitable and moderate as these were sparsely distributed iron filings with meaningful spaces in between to allow for much appreciation of

speckled effects on the body. A 5% iron filing in stoneware clay under this temperature was also reasonable on the body but a bit fewer than 10% iron filings.

At 600µm the speckled effect as affected by 1100^{o}C looked smaller but also interesting. Due to the small nature of the particles, 20% iron in the clay body at 1100^{o}C melted and created a burst effect that came out of the slab. Just like the foregoing, 20% and 15% iron filings in the slabs were much and created over crowded speckled effects, while 10% and 5% iron filings and their speckled effects under 1100^{o}C looked more interesting and more appealing.

The basic difference between 300µm aggregate size under the temperature of 1100^{o}C is the fact that the speckled effects were tinier because of the size. 20% and 15% iron in clay body under this temperature created a burst effect out of the body as iron filings melted out causing a swellings on the body (see appendix 7.1). While 10% and 5% iron in the body were more desirable, the speckled effects could be seen, though tiny.

The effect of 1100^{o}C on the mixed aggregate sizes was that both tiny and large aggregate in their speckled effects could be seen like the rest. The more the percentage of iron in the body, the more crowded it became but the fewer the clearer the speckled effect is seen and more desirous. Plate XXII are samples of the effects of the four temperatures on the different aggregate sizes of iron filings, while more can be seen in appendices 5, 6 and 6.1









Plate XXII: Samples of test slabs of the different firing temperatures and their effects

4.3 Result of Throwing Test

Just as the percentages of clay and iron filings differ in each test, so their behaviour in the throwing tests. Breakage occured according to the amount of iron filings in the body during shaping. Each aggregate size of iron filings had peculiar textural feel when it was thrown and plasticity was affected as the quantity of iron filings changed in each body.

- Throwing test with 1.18mm aggregate. This aggregate size was varied from 95/5% up to 80/20% clay and iron filings. At 95% clay and 5% iron filings, there was enough plasticity to work with as there was no difficulty centering the clay, pulling, and shaping as the clay was still obedient to instructions on the wheel. The composition of 90% clay and 10% iron filings in this aggregate size proved little different from the 95/5% composition, the reduction in plasticity could be felt, the coarseness and quantity of iron could also be felt. Reasonable amount of plasticity still abound for reasonable centering, pulling and shaping of clay on the wheel.

  Unlike the two foregoing compositions, 85% clay and 15% iron filings proved difficult as the clay became heavy, had little plasticity to work with, and entails great skill to be able to manipulate it on the wheel. Cylinders can only be conveniently made out of this composition as there were breakages on the body in attempts to shape the clay, which is as a result of much iron filings in the body.

  Composition of 80% clay and 20% iron filings became the most difficult of them all. The clay became very heavy, very insignificant plasticity to work with and left with no option

other than managing to make a cylinder and little shaping ability. The coarseness of the aggregate size of iron filings could be injuriously felt.

- Throwing test with 600µm aggregate size; the basic difference between the throwing test of compositions from this aggregate size of iron filings and the foregoing lies with the coarseness of the aggregate size. While the former is very coarse to the touch especially when it is much in the body, 600µm size is less coarse to the touch and allows for more blending into the clay body.

  Like the other, the less the iron filing in the body, the more the plasticity to work with and the more the iron filings in the body, the less the plasticity to work with. 85/15% clay and iron with 80/20% clay and iron throwing test from this aggregate size all showed breakages during shaping due to reduced plasticity as a result of overwhelming iron filings in the clay bodies.

- Throwing test with 300µm aggregate size; this is the finest size of aggregate of iron filings, this felt and showed almost homogenous mix with clay during throwing. Every other attributes was the same during throwing as the preceding two.

- Throwing test with mixed aggregate sizes; the iron filings here were not sieved and had the combination of all the aggregate sizes. Both homogeneity and coarseness of the composition could be felt and seen during throwing. The quantity of iron filings in clay had a lot of influence in testing the workability of composition of clay and iron filings as

far as throwing method of production is concerned. The throwing tests were majorly to determine the suitability of iron filings and clay for throwing production as shown in plates XXIII and XXIV below:



Plate XXIII; Throwing test of clay and iron filings on the potter's wheel



Plate XXIV: Throwing and fired test pieces

4.4 Result of Shrinkage Test

The test slabs showed varied degrees of shrinkage rate as iron filings varied in the body but a remarkable difference was observed between slabs with iron filings and the ones without. The results show that slabs without iron filings shrank more than those without. The graphs below shows differences between slab without iron filings and the once with iron filings at fired stage. Throughout the different chats, stoneware clay had flat rate average shrinkage of 0.7cm while clay body and iron filings varied in all the charts.

The graph in Figure 4a shows an average difference of 0.4cm between slabs with iron filings and those without. Figure 4b has an average difference of 0.4cm between slabs with iron filings and slabs without iron filings. Figure 4c shows average difference of 0.5cm between clay body with iron filings and clay body without. Figure 4d also has a difference of 0.5cm between clay with iron filings and clay without. Figure 5a has a difference of 0.4cm between clay with iron filings and clay without. Difference of 0.3cm was recorded between clay with iron filings and clay without iron filing in figure 5b. Figure 5c also has a difference of 0.3cm. Figure 5d followed with 0.3cm differences between clay with iron filings and clay without. Figure 6a shows that difference of 0.4cm existed between clay with iron filings and clay without. The difference of 0.4cm also existed in figure 6b. Figure 6c has 0.4cm as difference between clay with iron filings and clay without. Figure 6d differed with 0.3cm. Figure 7a has difference of 0.4cm between clay with iron filings and clay without iron filings. A difference of 0.3cm was observed in figure 7b. The difference of 0.3cm also exists in figure 7c. While figure 7d has a difference of 0.4cm between clay with iron filings and clay without.

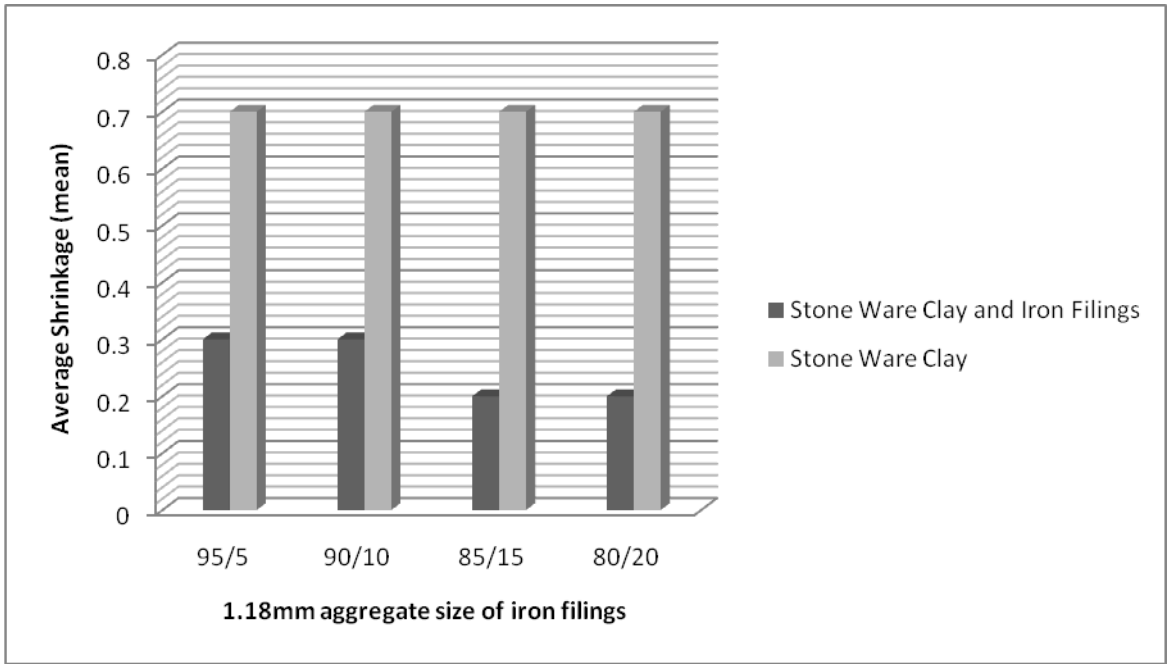


Figure 4a ; Variation of Shrinkage with iron filing content Fired at 800°C

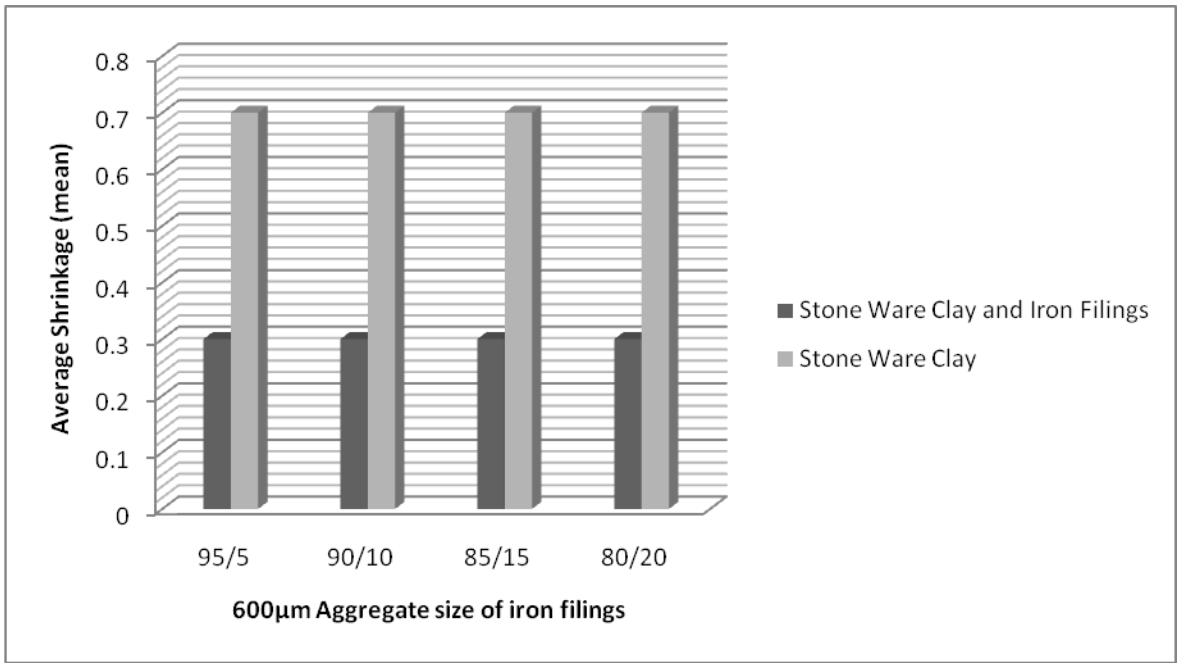


Figure 4b ; Variation of Shrinkage with iron filing content Fired at 800°C

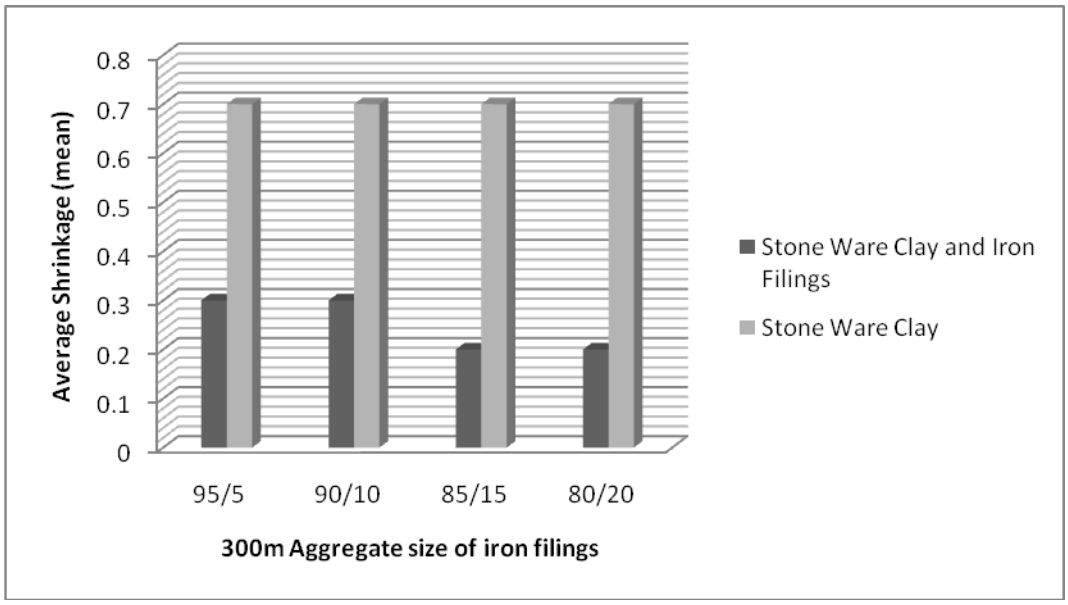


Figure 4c ; Variation of Shrinkage with iron filing content Fired at 800°C

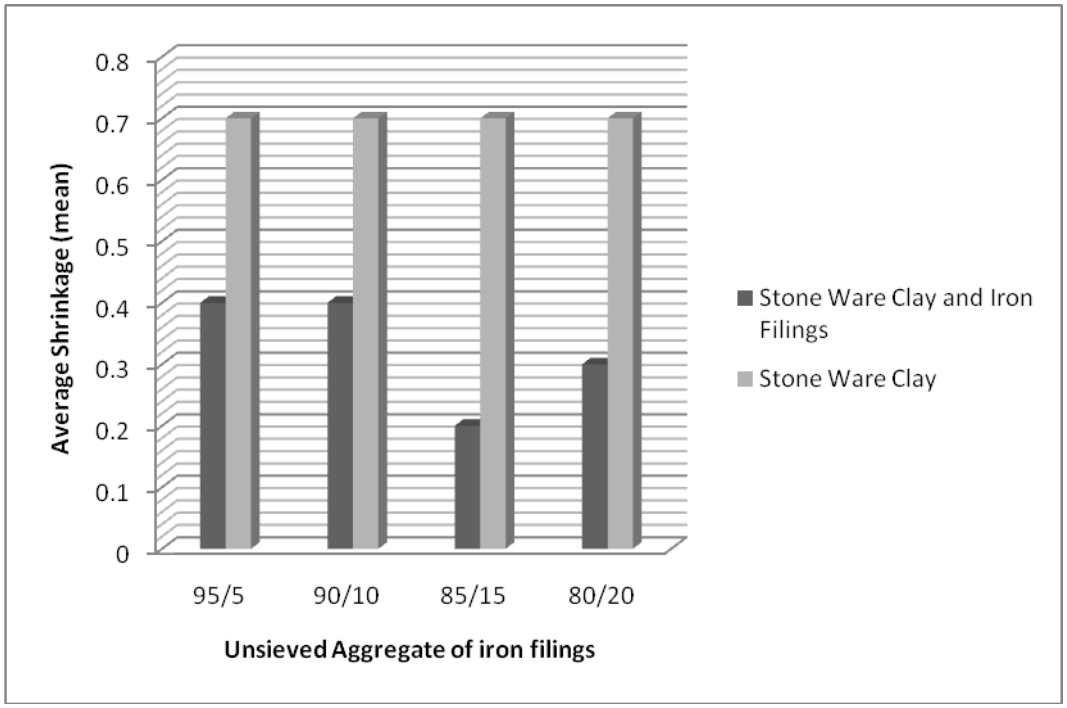


Figure 4d ; Variation of Shrinkage with iron filing content Fired at 800°C

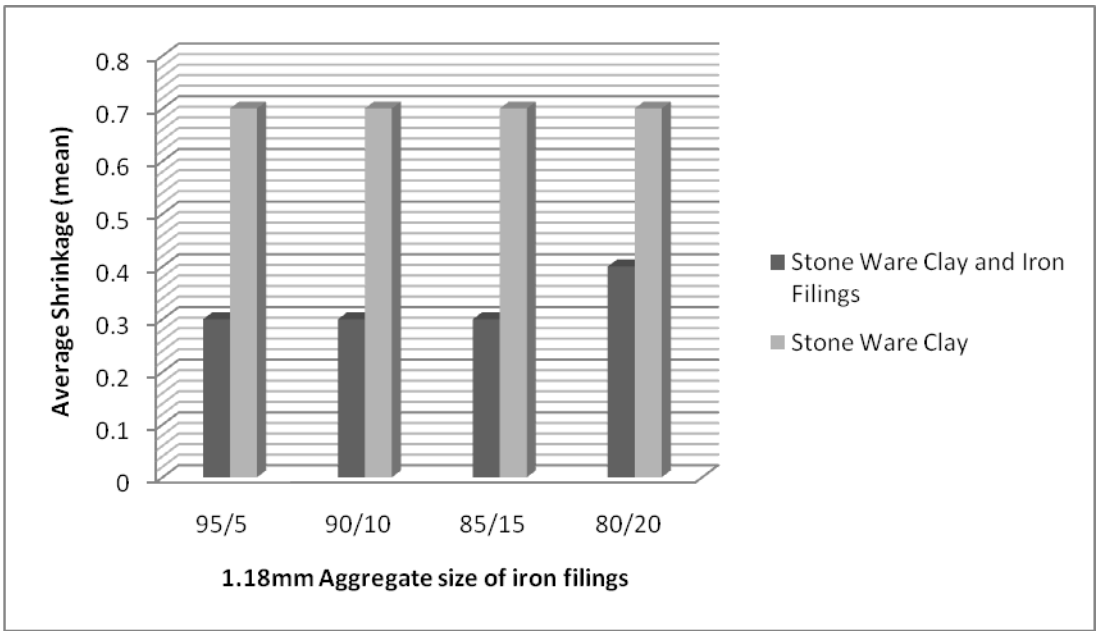


Figure 5a ; Variation of Shrinkage with iron filing content Fired at 900°C

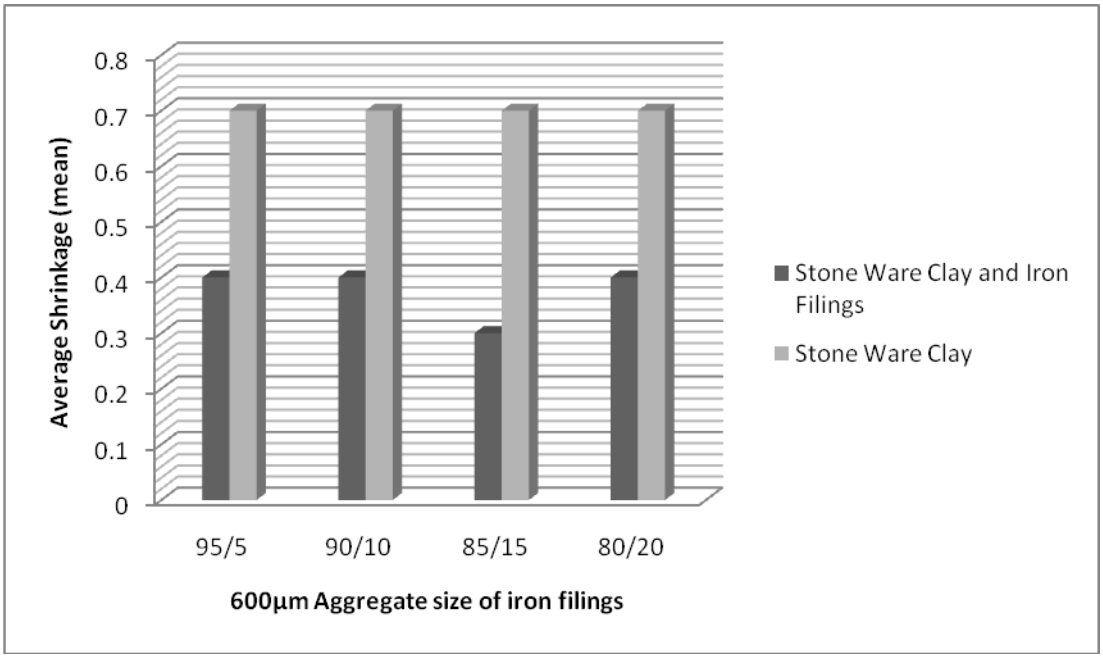


Figure 5b ; Variation of Shrinkage with iron filing content Fired at 900°C

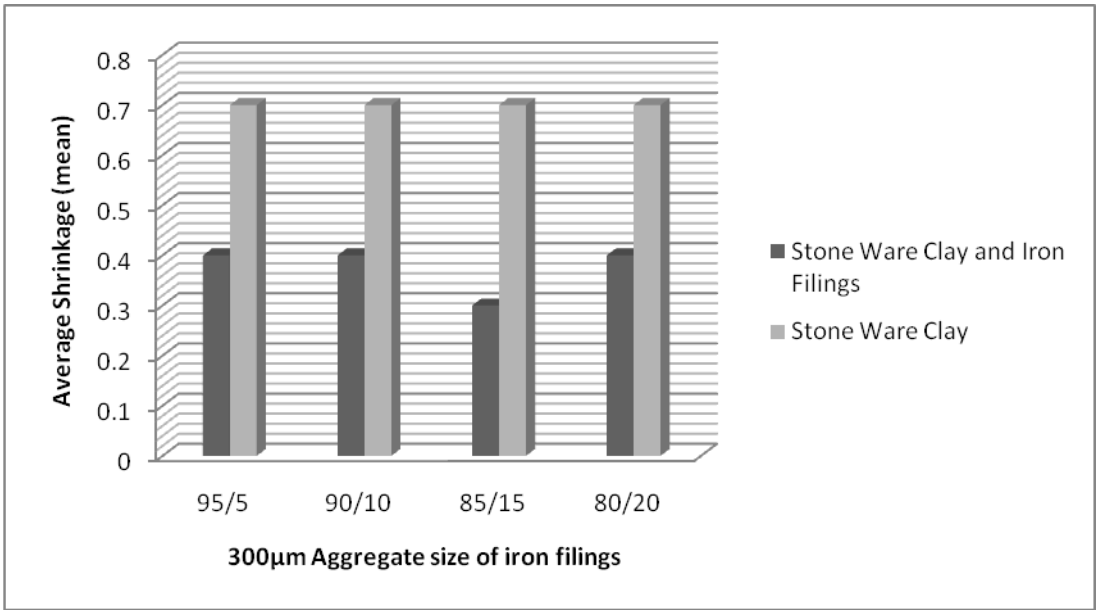


Figure 5c ; Variation of Shrinkage with iron filing content Fired at 900°C

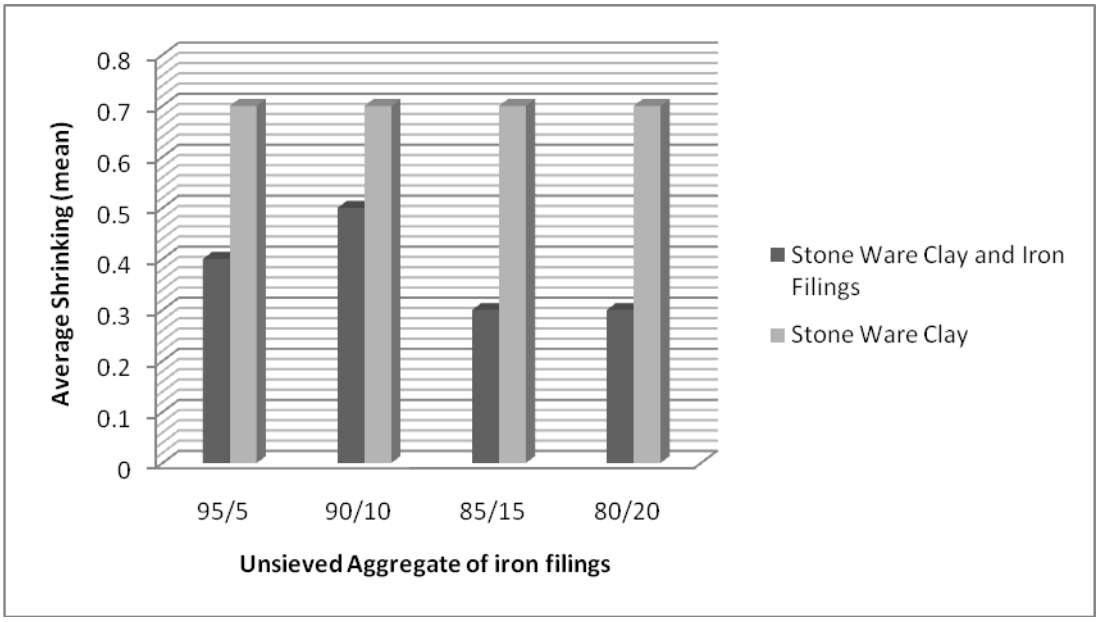


Figure 5d ; Variation of Shrinkage with iron filing content Fired at 900°C

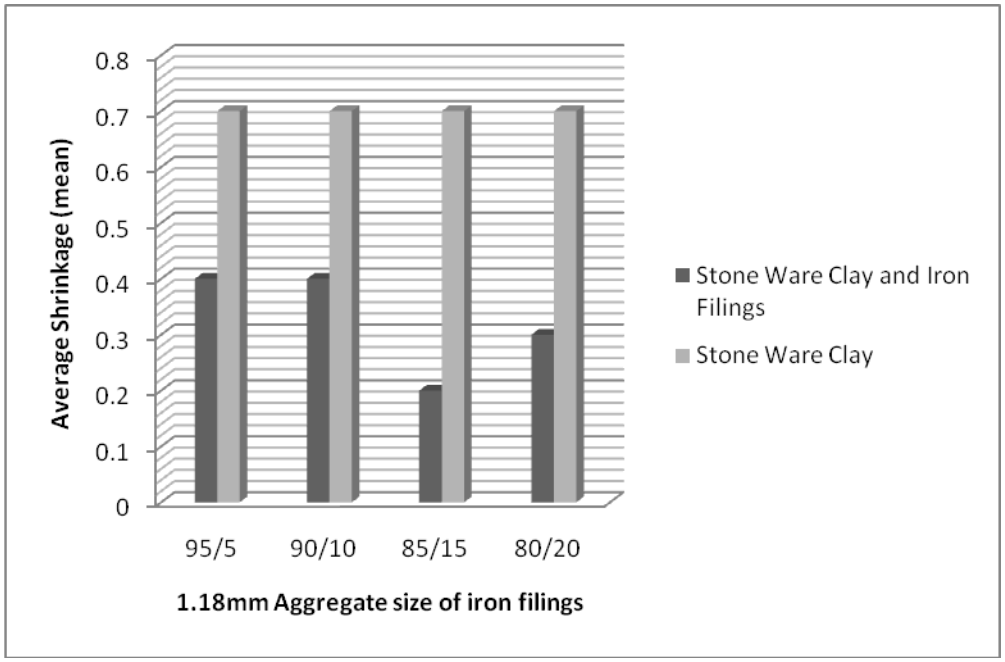


Figure 6a ; Variation of Shrinkage with iron filing content Fired at 1000°C

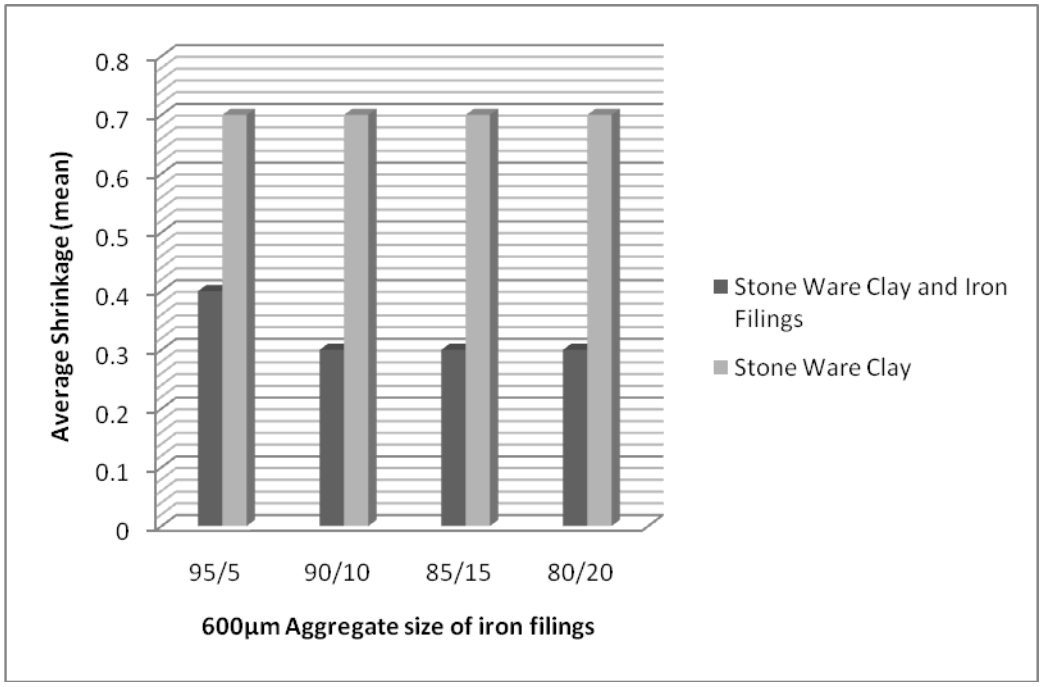


Figure 6b ; Variation of Shrinkage with iron filing content Fired at 1000°C

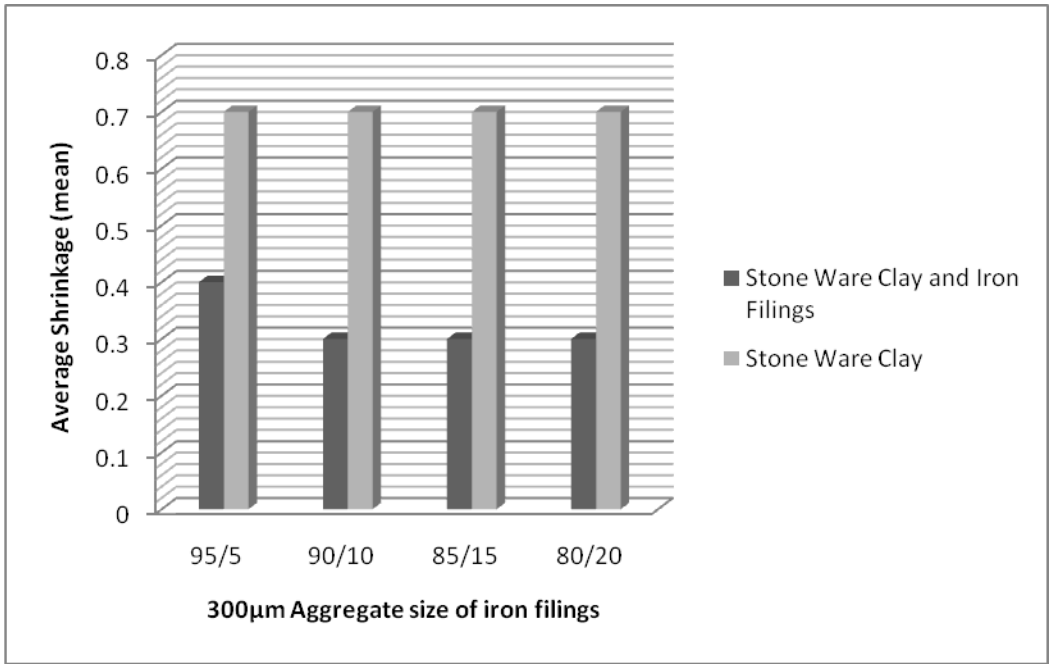


Figure 6c ; Variation of Shrinkage with iron filing content Fired at 1000°C

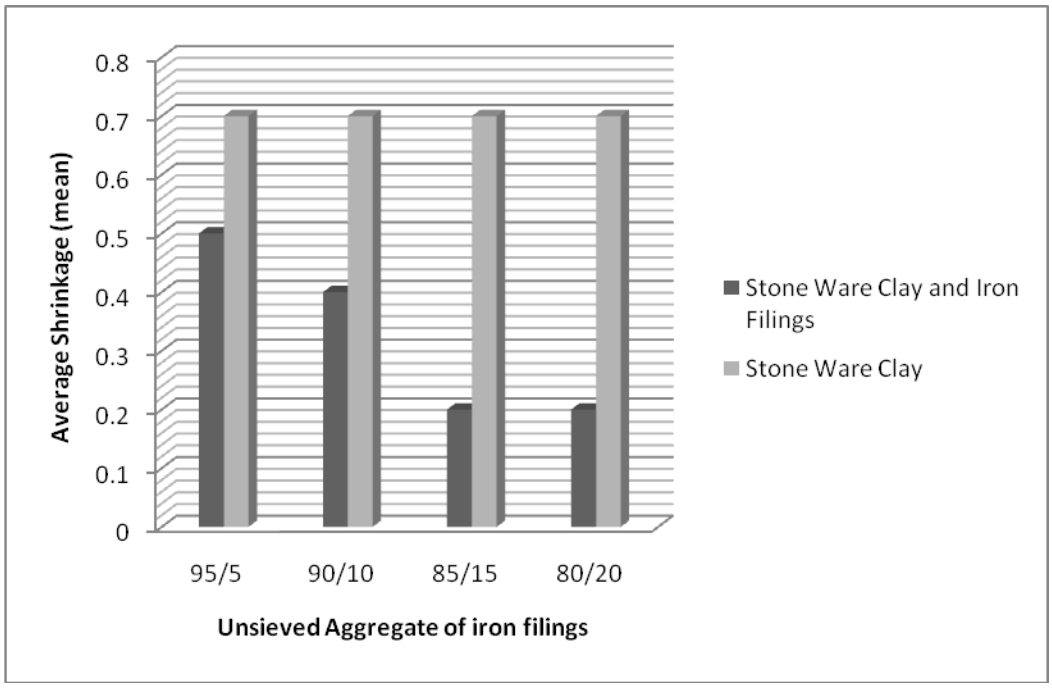


Figure 6d ; Variation of Shrinkage with iron filing content Fired at 1000°C

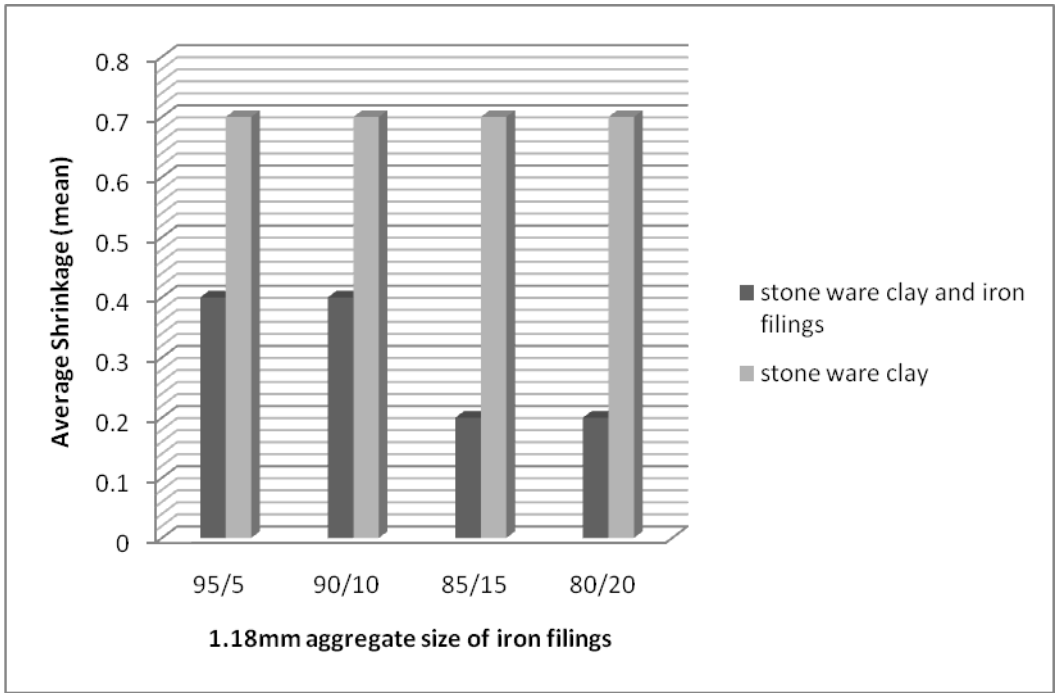


Figure 7a ; Variation of Shrinkage with iron filing content Fired at 1100°C

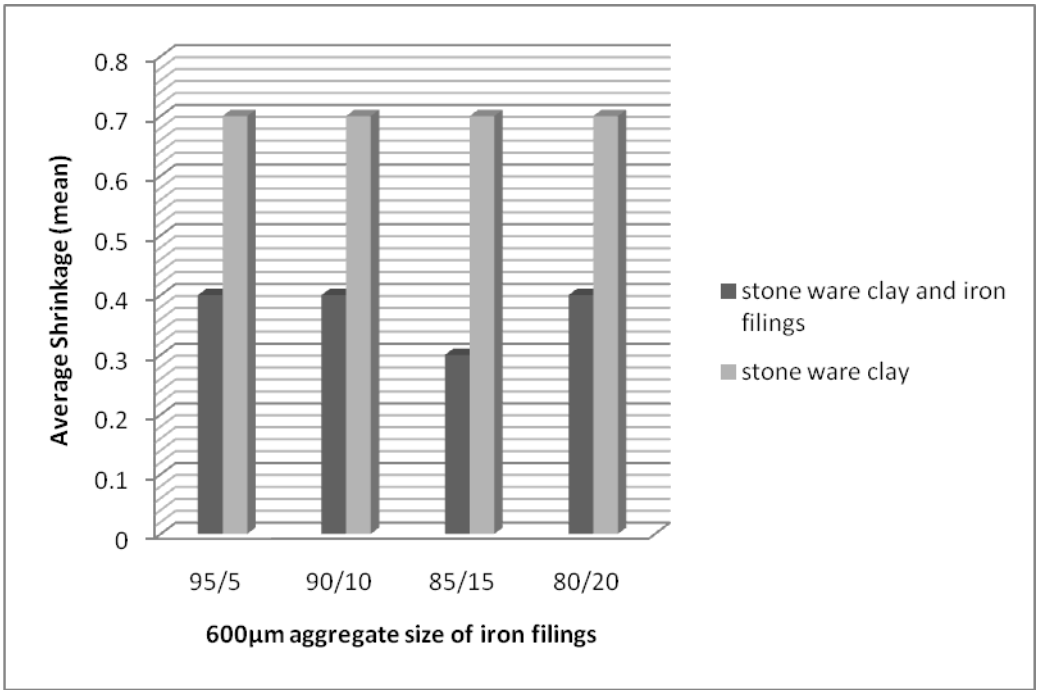


Figure 7b ; Variation of Shrinkage with iron filing content Fired at 1100°C

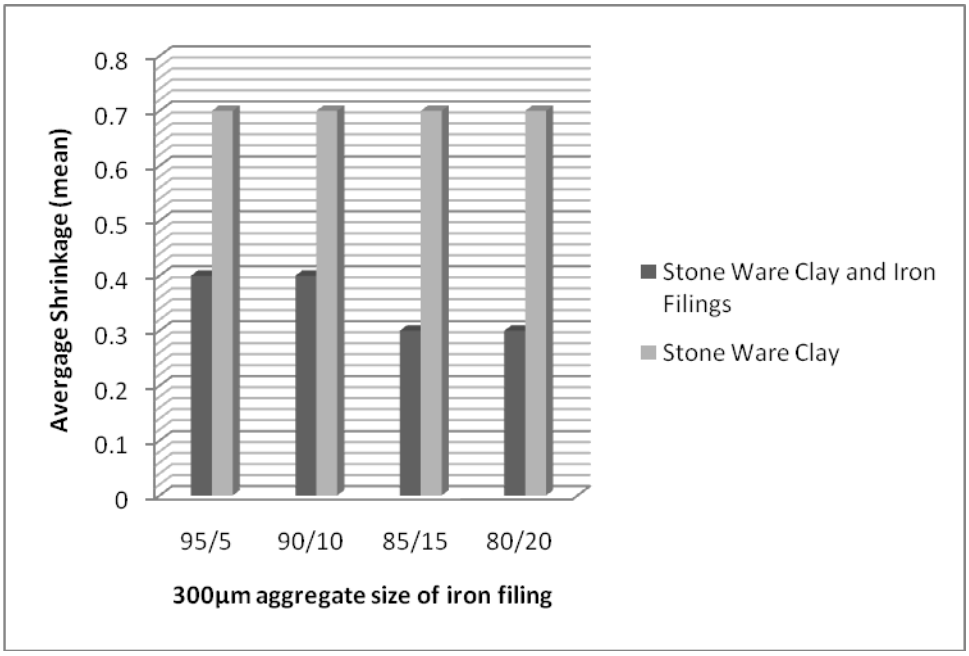


Figure 7c ; Variation of Shrinkage with iron filing content Fired at 1100°C

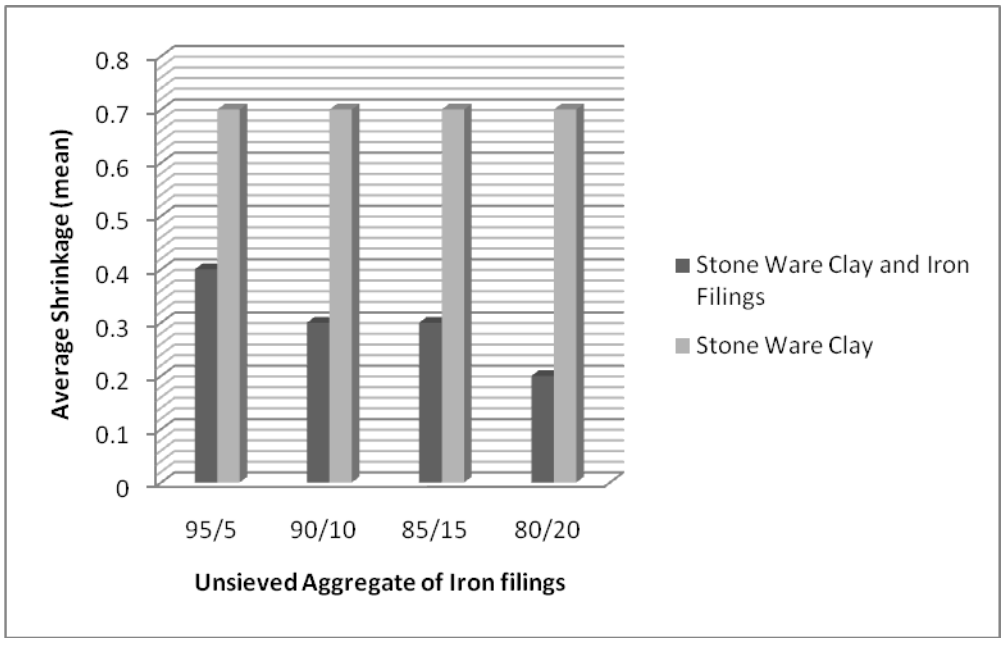


Figure 7d ; Variation of Shrinkage with iron filing content Fired at 1100°C

4.5 Result of Choice of Blend and Firing Temperature Employed in Making Decorative Wares

- Out of the four different mixtures of 95/5, 90/10, 85/15 and 80/20 of clay body and iron filings, 95/5 and 90/10 composition were more appropriate as they allowed for reasonable plasticity and reasonable amount of iron filings to be appreciated.

- The aggregate size of 1.18mm became the biggest and fortunately the largest in quantity of the entire iron filings with 60% after the sieve analyses and this was considered.

- After carrying out four different firing temperature tests, 1100^{o}C, 1000^{o}C and 900^{o}C had their peculiar effects on iron filings and are suitable as they all amplified the speckled effects of iron filings on the test slabs on different degrees. Notwithstanding, 1000^{o}C was adopted in firing the wares because there was no defect of any sort and the speckled effects were reasonably enhanced.

4.6 Result of Production of Decorative Wares

Throwing method of production employed was convenient and stress- free though with good amount of skill to be able to handle the mixture of stoneware clay and iron filings on the wheel. The technique of moistening the stoneware clay and making it softer than the normal throwing clay before throwing proved effective as it prevented breakage of the body that could have occurred on the wheel if the blend was not properly moistened. The immediate throwing of the blend guarded against rust of the iron filings. Fixing of appendages and manipulation at leather-hard stages were effective and productive as the wares were desirously finished. Drying the decorative wares in a gradual room atmosphere forestalled the incidents of cracking that would have occurred as a result of accelerated drying.

The kerosene kiln was able to carry all the decorative wares produced due to the large space it has. The heat of the firing was monitored effectively with a cone that was put at the spy hole for

1000^{o}C. Enhanced speckled effects were achieved as a result of the 1000^{o}C temperature the wares were fired to.

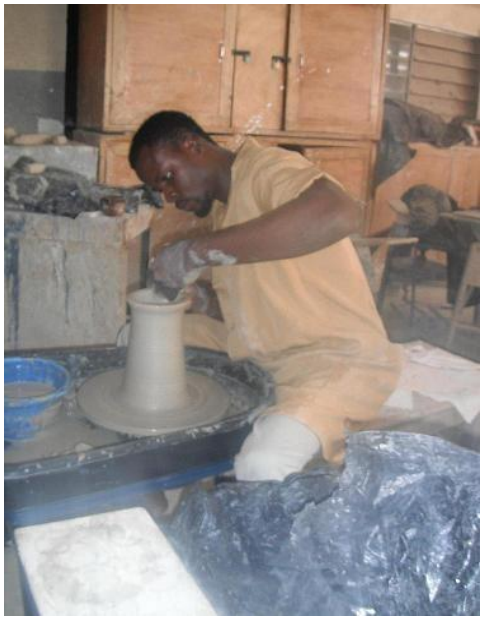


Plate XXV: Throwing clay body mixed with iron filings on an electric potter's wheel

Plate XXVI

Slim vases: One is completely covered with iron filings; the speckled effects could be seen all over the body of the ware while the other is totally free of iron filings and was used as a control to determine the clear difference between the two vases.

Plate XXVII

The satellite vases: One is completely covered with speckled effects while the other has the top and the ring appendages around the ware without speckled effects, the variation is to create more interest. This was achieved at leather hard stage of the wares.

Plate XXVIII

The double bellied decorative ware: One has the lower part of it free of speckled effects and the upper part with speckle effects, the other is completely covered with speckled effects.

Plate XXIX

Semi traditional decorative ware with stepped long neck and two smaller pots attached: One is completely covered with speckled effects while the other has the smaller pot appendages free of speckled effects. This further shows that the presence of iron filings does not hinder the joining at leather hard stage.

Plate XXX

The tripod: The three stands and the small pot on one are free of speckled effects while the ware is covered with speckled effects in the other.

Plate XXXI

Carrying calabash: One is free of speckled effects on the body with speckled effects on the calabash while the other is complete with speckled effects.

Plate XXXII

The hollow decorative ware in ‘A’ has no speckled effect at the base but on the body, ‘B’ is covered with speckled effects

Plate XXXIII

The decorative storey hut: One possesses speckled effects on the main body but not on the roof and ring wavy appendages, while the other is completely covered with speckled effects.

Plate XXXIV

lamp shades, ‘A’ is covered with speckled effects totally while ‘B’ has no speckled effects on the body.

Plate XXXV

Decorative storage jar, ‘A’ has no speckled effects on the cover and on the wavy appendages but on the body, ‘B’ storage jar is adorned completely with speckled effects. This shows that iron filings can be added to any part of a ware as desired.



Plate XXVI a: Slim vase with iron filings



Plate XXVI b: Slim vase without iron filings



Plate XXVII a: Satellite Vase with iron filings all over



Plate XXVII b: Satellite Vase with restricted areas of iron filings



Plate XXVIII a: Twin bellied vase with restricted area of iron filings



Plate XXVIII b: Twin bellied vase with restricted area of iron filings



Plate XXIX a: Stepped traditional vase with iron filings all round



Plate XXIX b: Stepped traditional vase with restricted areas of iron filings



Plate XXX a: The tripod with restricted area of iron filings



Plate XXX b: The tripod with iron filings all round



Plate XXXI a: Carrying calabash with restricted areas of iron filings



Plate XXXI b: Carrying calabash with iron filings all round



Plate XXXII a: The hollow ware with restricted areas of iron filings



Plate XXXII b: The hollow ware with iron filings all over



Plate XXXIII a: Decorative storey thatch hose with restricted areas of iron filings



Plate XXXIII b: Decorative storey thatch hose with iron filings all over



Plate XXXIV a: Lamp shade with iron filings all over



Plate XXXIV b: Lamp shade with restricted areas of iron filings



Plate XXXV: Decorative storage Jar with restricted areas of iron filings



Plate XXXV: Decorative storage Jar with iron filings all over

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMENDATIONS

5.1 INTRODUCTION

The possibilities of incorporating iron filings into clay body for the production of decorative ceramics points to a research that brings together two different materials from two different specialization area. The aim of the study is to incorporate iron filings into a clay body for the production of decorative Ceramics. The summary of findings from this study is based on the unique decorative effects of iron filings on clay body based on a temperature that was not necessary a stoneware temperature.

5.2 Findings

At a higher temperature than 1000^{o}C, iron filings started melting and blotting out (see Appendices 7 and 7.1) which is not a desired outcome for the study. Temperature of 1000^{o}C was maintained in firing the wares and this gave the desired result to meet with the objective of the study.

This study has shown that innovative possibilities abound in inculcating iron filings into clay for the production of decorative wares as a result of speckled effects of iron. Mixing iron filings with clay proved that decorative ceramics can be produced not only by glazing, burnishing, or over glaze decorations but also in the body decoration.

Analyzing iron filings by sieving before blending into clay body gave the opportunity for variety of aggregate sizes which could be used at any point depending on the kind of outcome needed. Iron filings has proven to be able to come in convenience with clay body if properly manipulated and utilized.

Throwing method of production as applied in the research gave a good opportunity to really feel the effect of iron on the body as it affected plasticity which ultimately is needed for pulling and shaping of wares on the wheel.

The use of 20% coarse aggregate size of iron filings with 80% clay on the wheel is injurious in an attempt to force the centering of the clay body on the wheel.

Iron filings with fine aggregate size is not encouraged to be utilized as it does not show reasonable effects and a high temperature of 1100^{o}C can melt and deform the outcome, or it might be utilized but not fired beyond 1000^{o}C.

Iron filings being used in this study, though not in abundance as compared to kaolin and secondary clay, but are always available when needed, this can be got from Engineering workshops where block engines from cars are being reconditioned in Zaria.

From the entire different shrinkage tests between clay with iron filings and clay alone, an average difference in shrinkage of 0.4cm was recorded. This means that iron filings has a meaningful impact in the reduction of shrinkage of the clay body.

The uniqueness of the speckled effects on decorative ceramics is an additional aesthetic value which is capable of increasing marketability of ceramic wares.

The study has introduced a different approach in producing decorative wares in the ceramic specialization and this will serve as a reference point to other attempts of this kind.

This study has shown that the interaction of two different materials from two different fields can evolve an acceptable product that can further promote technology for sustainable development.

The usefulness of iron filings for the production of ceramic wares can only be applied to decorative pieces since the material contains chemicals that might not be healthy for it to be employed in the production of table wares.

5.3 Summary and Conclusion

The Feasibility Of Utilizing Cast Iron Filings Into Clay Body For The Production Of Decorative Ceramics was achieved by scientifically and artistically carrying out the objectives that were outlined. This started with the collection of cast iron fillings from its location and sieving it into different aggregate sizes for experimentation. Primary and secondary clays were also processed into a body in which the iron fillings were blended into. Experimentations were carried out with iron fillings and clay in the form of test slabs, throwing tests and firing tests. The different experiments were targeted at: (i) The most conspicuous speckle effects of iron fillings on the clay body,(ii) The composition that allows for reasonable plasticity for throwing on the wheel, and (iii) The temperature that enhanced more on the iron fillings for speckle effects. These culminated in the composition of clay and iron fillings that was arrived at for production of the decorative wares. Greater skill than the normal was also vital in the throwing method of production that was employed in making the decorative wares.

In conclusion, iron filings in clay body reacted in a thermal environment according to the degree of temperature it was fired. There was a visual difference between clay with iron fillings and clay without due to speckle effects of iron fillings. At 1000^{o}C, the best speckle effects were achieved. Throwing iron fillings with clay on the wheel was possible though with extra skill to control it on the potter's wheel. Introducing cast iron fillings into clay body was able to serve as opener to the clay body as against the clay's normal shrinkage rate which is an additional advantage of iron

fillings in the clay body. This study has evolved additional unique decorative technique into the ceramic specialization which can be adopted by ceramists.

5.4 General Recommendations

Innovating ways of indigenously producing ceramic wares especially with waste materials is very important and cannot be overemphasized. This will help in curtailing the growing urge for foreign products which are expensive and sometimes beyond reach.

Iron filings though not in abundance as compared to Kaolin and secondary clay, but are always available when needed, this can be gotten from Engineering workshops where block engines from cars are being reconditioned in Zaria. Ceramists should take advantage of this fact to further maximize the availability of iron filings.

Test slabs and throwing tests wares were fired at the Industrial Development Center Zaria. This does not give a good opportunity for total supervision of a research work. This calls for urgent upgrading of facilities and equipments in the ceramics section.

5.5 Recommendation for Further Studies

It will be important to experiment on how iron filings in clay body will affect glazes at different levels and also to develop glazes that can conveniently go with iron – clay.

Further research effort should be geared towards innovating more indigenous decorative clay body with the use of wastes from bronze iron or aluminum iron that can stand the test of time as this study will serve as a guide and working tool for such research.

The decorative wares produced in this study can be improved upon by researching Further into ways of polishing or burnishing the wares for better finishing and outcome.

REFERENCES

About.com.pottery (2014), *Decorating Techniques,* retrieved 1st April, 2014 http://pottery.about.com/od/decoratingtechniques/

Agate ware (image) retrieved February 30, 2012, from http://www.pottery-magic.com/pottery/topics/pottery_types.htm

Alewai, M.J. (2011), Development of Glazes using Local Raw Materials from North Eastern Nigeria. Unpublished Ph.D. Proposal. Ahmadu Bello University, Zaria

Aluwong, M.S. (1988) Developing slip glazes from selected clay materials in Kaduna State.

Unpublished M.A. thesis, Ahmadu Bello University, Zaria, Nigeria

ASTM E1999 (2011), *Analysis of Cast Iron by Spark Atomic Emission Spectrometry,* retrieved 15 November, 2011. http://www.astm.org/Standards/E1999.htm

Burnished and carved pieces (image) retrieved August 12, 2012, from http://www.msu.edu/~bonnersh/Blackware.html

Cambridge (2011), *Dictionary online*, retrieved 5 September, 2011 http://dictionary.cambridge.org/dictionary/british/iron_1

Chun ware, moon-white and purple-spotted glaze jar with two handles (image) retrieved August 5, 2012, from http://japan.park.org/Taiwan/Culture/museum/npmtr/B1104/B110414/npml.jpg

Clay Times (2002), retrieved August 10, 2011. http://www.claytimes.com/reference-guide/clay-basics.html

Dassow, S.V. (2011), *a step by step guide to burnishing pottery*, retrieved 3 February 2012. http://ceramicartsdaily.org/pottery-making-techniques/ceramic-decorating-techniques/going-low-tech-a-step-by-step-guide-to-burnishing-pottery

Dassow, S.V. (2011a), *Terra Sigillata 101,* retrieved 15 February 2012 Error! Hyperlink reference not valid.

Dassow, S.V. (2011b), *A Step by Step Guide to Burnishing Pottery*, retrieved 23 February 2012. http://ceramicartsdaily.org/pottery-making-techniques/ceramic-decorating-techniques/going-low-tech-a-step-by-step-guide-to-burnishing-pottery/

Eastern Han Dynasty Glaze Stoneware "Hu" Jar with Cover (image) retrieved March 3, 2012, from http://www.albertomanuelcheung.com/Eastern%20Han%20Jar%20with%20cover.htm

Encyclopedia of Art, (2011) retrieved 19 September, 2012 http://www.visual-arts-cork.com/definitions/decorative-art.htm

Encyclopedia (2007), *fire clay*, retrieved 12 April, 2012.The Columbia Electronic Encyclopedia, 6th edition,http://www.factmonster.com/ce6/sci/A0818730.html

Erickson, .M and Hunter .R (2012), *How to Make Agateware Vessels on the Pottery Wheel,* Retrieved 3 February 2012, http://ceramicartsdaily.org/pottery-makingtechniques/wheelthrowing- techniques/how-to-make-agateware-vessels-on-the-pottery-wheel/

Freebies (2013), *Pottery Decorating Techniques, retrieved 31 March, 2014* http://ceramicartsdaily.org/free-gifts/three-great-pottery-decorating-techniques-a-how-to-guide-for-decorating-ceramics-with-slip-transfers-chinese-brush-techniques-

ceramic-slip-sgraffito-and-more-2/

Fromme, R. (1994), retrieved August 9, 2011
http://www.cavemanchemistry.com/oldcave/projects/pottery/basic_clays.html

Garkida, A.D (1998), Local Raw Material Exploration for the Production of Refractory Pots for MeltingGlass. Unpublished M.A Thesis, Ahmadu Bello University, Zaria

Gukas, H.J. and Datiri Y.C. (2001), *The Art of Pottery*, published by C.C. communications, Jos. P. 9

Gukas, H.J. (1985), A feasibility Study for Formulating Some Porcelain Bodies from Local RawMaterials in Kaduna State. Unpublished M.A. Thesis, Ahmadu Bello University, Zaria,Nigeria

Harnetty,.J (2011) *Magnificent Marbling*, retrieved 15 February 2012
http://ceramicartsdaily.org/pottery-making-techniques/ceramic-decorating-techniques/magnificent-marbling-using-colored-slips-to-create-marbled-patterning-on-pottery/

Hamer, F. and Hamer J. (2004a), *The potter's Dictionary of Materials and Techniques,* Fifth Edition, A&C. London, University of Pennsylvania Press, Philadelphia P.31.

Hamer, F. and Hamer J. (2004b), *The potter's Dictionary of Materials and Techniques,* Fifth Edition, A&C. London, University of Pennsylvania Press, Philadelphia P. 163

Henrik, N. and James D. (1993), *glazes – for the self-reliant potter*, retrieved 15 May, 2013
http://www.gate-international.org/documents/publications/webdocs/pdfs/g17gle.pdf. p. 86

Jefferson, L.E. (1974), *the Decorative Arts of Africa*. London: Collins St. James Place. P

Karatsu Pottery (image) from Microsoft Encarta

Leach (1975), *Out of Earth Excerpt*. Retrieved 17 August, 2011
http://www.ceramicartdaily.net/booksales/outofearthexcerpt.pdf . P. 95

Malvern (2011), *Metal Powders Industry Overview*, retrieved 25 August, 2011
http://www.malvern.com/ProcessEng/industries/metalpowders/overview.htm

Manzuche, S.M.A (1991), Formulation of some High-fired Porcelanous Throwing Bodies and GlazeFit, Unpublished M.A Thesis, Ahmadu University, Zaria, Nigeria.

Merriam Webster Incorporated, (2011), retrieved July 25, 2011 http://www.merriamwebster.com/concise/innovation?show=0&t=1311935487

Molokwu, G.M (1991), Production of refractory kiln-shelves and props using local materials. Unpublished M.A. Thesis, Ahmadu Bello University, Zaria, Nigeria

Nikon (2011), *Cast iron nodularity and flake analysis*, retrieved 15 November, 2011. http://www.nikoninstruments.com/Applications/Industrial/Material-Analysis/Cast-iron-nodularity-and-flake-analysis

Nugz, S (2012), *Production of Iron (III) Oxide*, retrieved 5 April, 2012 http://skratenugz.hubpages.com/hub/Production-of-IronIII-Oxide

Particle Technology Lab (2011), *particle size distribution Analyses*, retrieved 22 September 2011. http://www.particletechlabs.com/particle-size/sieve-analyses

Peterson, B. (2011), Retrieved August 5 2011 http://pottery.about.com/od/potterygloassary/g/claybod.htm

Peterson, .B (2012), *Decorative Techniques*, retrieved February 1, 2012 http://pottery.about.com/od/surfacetreatments/tp/burnish.htm

Peterson, .B (2008) *What Are Under glazes?* Retrieved 15 February 2012 http://pottery.about.com/od/slipsengobes/tp/underglaze.htm

Saliu, R.O.A (2005), *Decorative Arts of the Ebira*, published by Ahmadu Bello University Press limited, Zaria, Kaduna State, Nigeria

Screen printing on clay (image) retrieved January 1, 2013 from http://ceramicartsdaily.org/clay-tools/decorating-tools/from-flat-to-round-screen-printing-glaze-patterns-onto-pottery/

Singer, F. and Singer S.S (1963a), *Industrial Ceramics*. London,Chapman and Hall Ltd. PP. 393-395

Singer, F. and Singer S.S (1963b), *Industrial Ceramics*, London ,Chapman and Hall Ltd. PP. 1075-1077, 1089-1095.

Suncheng (2011), *What are the design principles of design and decoration of ceramics for daily use?* Retrieved 31 March, 2014. http://www.hnsc-ceramicmug.com/xinwendongtai1/2012-07-30/82.html

Tang Dynasty Marble Ware Shallow Dish (image) retrieved march 3, 2013, from http://www.albertomanuelcheung.com/Tang%20marble%20dish.htm

Terra Sigillata (image) retrieved March 3, 2013, from http://www.zum.de/zum/Faecher/G/BW/Landeskunde/rhein/kultur/museen/speyer/roemer/tsig4.htm

VisGirda. R (1998) *Printing Ceramics*, retrieved 16 April, 2012 http://www.ceramicstoday.com/articles/090798.htm

Willis, R (2008a) *Earthenware Clay*, retrieved 10 April, 2012 http://digitalfire.com/4sight/material/earthenware_clay_1858.html

Willis, R (2008b) *Stoneware Clay*, retrieved 12 April, 2012 http://digitalfire.com/4sight/material/stoneware_clay_2068.html

Winokur, C (2006) *Overview of types of clay*, retrieved 26 April, 2012 http://en.allexperts.com/q/Pottery-2316/Overview-types-clay.htm

Wynn, N. (1959), *Platinum in the Decoration of Ceramic Wares*, retrieved 31 March 2014 http://www.platinummetalsreview.com/pdf/pmr-v3-i2-060-065.pdf

Zauro, T.D.M (2007), An Evaluation of the Suitability of Ceramic Raw Materials in Kebbi State for the Production of Tableware for Small Scale Industry. Unpublished PhD Dissertation. Ahmadu Bello University, Zaria

APPENDIX I

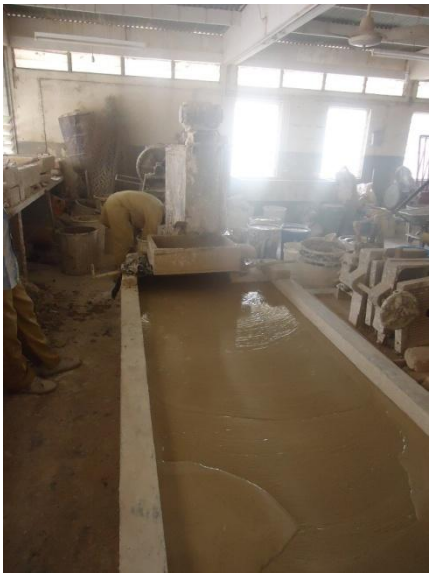


Plate. XXXVI: Blunging and Sieving of Kaolin and Secondary Clay



Plate. XXXVII: Pounding Iron Filings Into Smaller Aggregate Size

APPENDIX II



Plate XXXVIII: Studio Setting for Production of Test Slabs

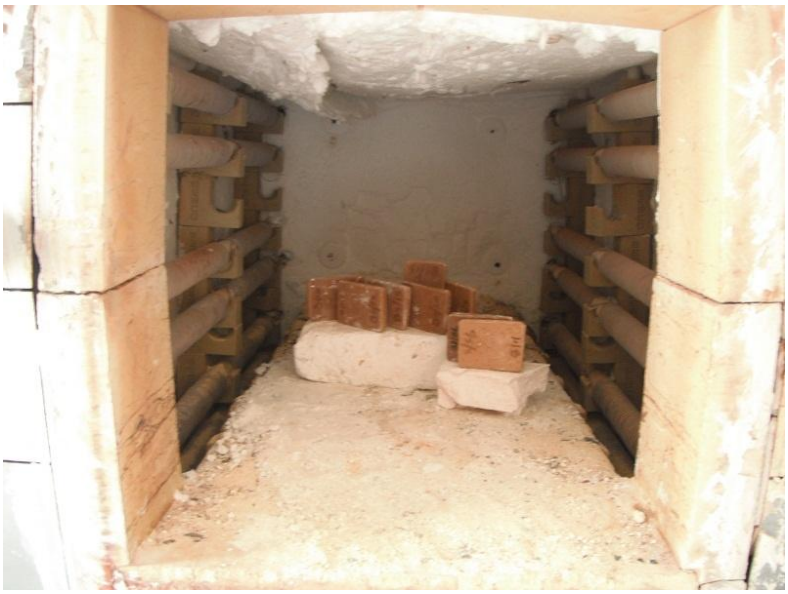


Plate XXXIX: Test Slabs in an Electric Kiln for Heating

APPENDIX III

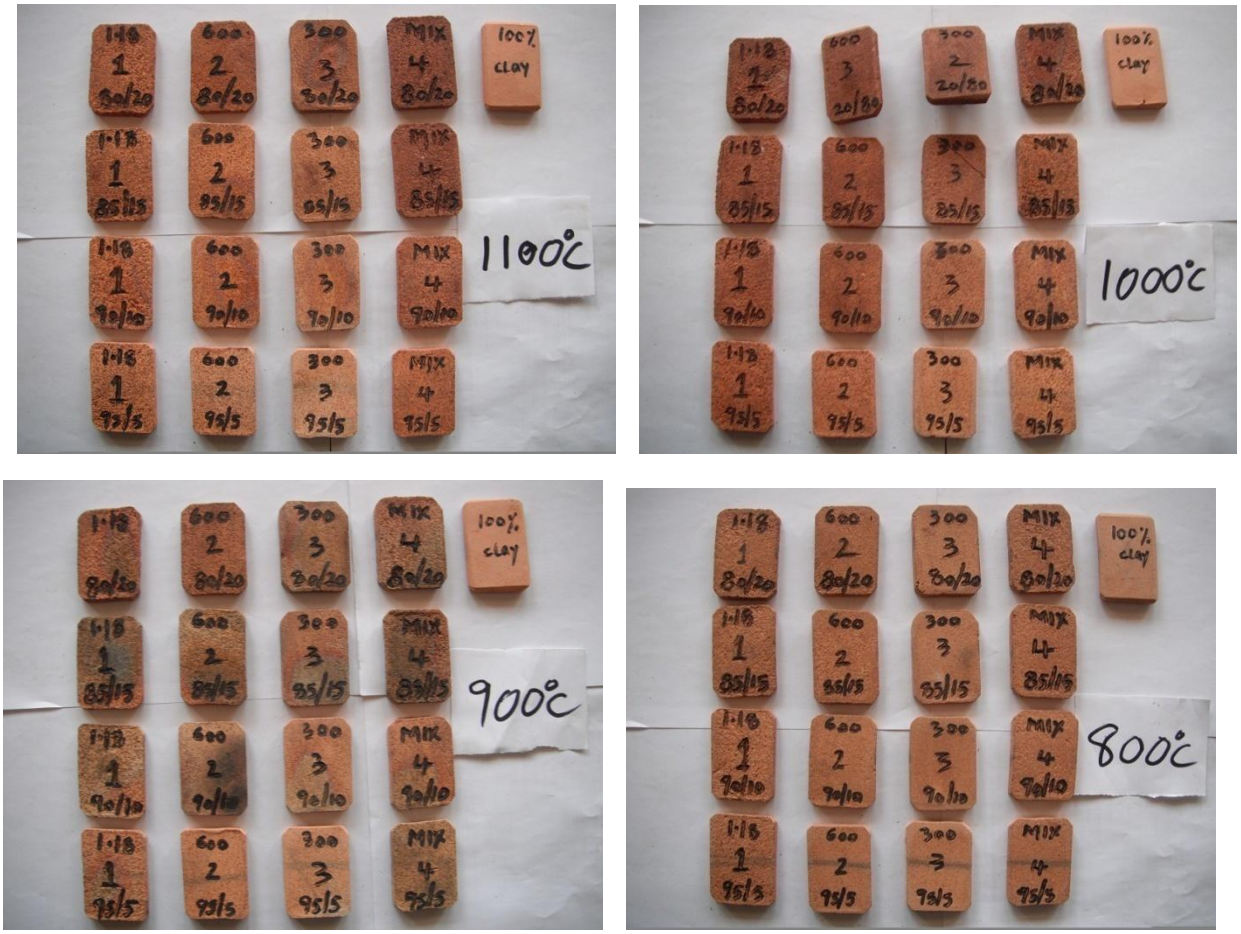


Plate XL: The Entire Sixty Eight (68) Fired Test Slabs and Temperatures at Which they were Fired

APPENDIX IV

Table 1: Shrinkage Values of Samples Fired at 800^{o}C

1.18mm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
A 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
A 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.5	4.7	0.8	0.5	0.3	0.2	0.3
A 90/10	7	5	1	6.7	4.7	0.9	0.3	0.3	0.1	0.2	6.6	4.6	0.8	0.4	0.4	0.2	0.3
A 85/15	7	5	1	6.8	4.8	0.9	0.2	0.2	0.1	0.1	6.6	4.6	0.8	0.4	0.4	0.2	0.2
A 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.8	4.6	0.8	0.2	0.4	0.2	0.2

600µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
A 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
A 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.5	4.7	0.8	0.5	0.3	0.2	0.3
A 90/10	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.5	4.6	0.8	0.5	0.4	0.2	0.3
A 85/15	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.6	4.6	0.8	0.4	0.4	0.2	0.3
A 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.6	4.6	0.8	0.4	0.4	0.2	0.3

300µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
A 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
A 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.5	4.6	0.8	0.5	0.4	0.2	0.3
A 90/10	7	5	1	6.7	4.5	0.9	0.3	0.5	0.1	0.3	6.6	4.6	0.8	0.4	0.4	0.2	0.3
A 85/15	7	5	1	6.7	4.6	0.9	0.3	0.4	0.1	0.2	6.7	4.7	0.8	0.3	0.3	0.2	0.2
A 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.8	4.7	0.8	0.2	0.3	0.2	0.2

un sieved aggregate samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
A 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
A 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.4	4.5	0.8	0.6	0.5	0.2	0.4
A 90/10	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.4	4.6	0.8	0.6	0.4	0.2	0.4
A 85/15	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.7	4.7	0.8	0.3	0.3	0.2	0.2
A 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.7	4.6	0.8	0.3	0.4	0.2	0.3

Table 2: Shrinkage Values of Samples Fired at 900^{o}C

1.18mm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
B 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
B 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.6	4.6	0.8	0.4	0.4	0.2	0.3
B 90/10	7	5	1	6.7	4.7	0.9	0.3	0.3	0.1	0.2	6.5	4.6	0.8	0.5	0.4	0.2	0.3
B 85/15	7	5	1	6.8	4.8	0.9	0.2	0.2	0.1	0.1	6.5	4.6	0.8	0.5	0.4	0.2	0.3
B 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.6	4.4	0.8	0.4	0.6	0.2	0.4

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600µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
B 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
B 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.5	4.5	0.8	0.5	0.5	0.2	0.4
B 90/10	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.5	4.5	0.8	0.5	0.5	0.2	0.4
B 85/15	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.6	4.5	0.8	0.4	0.5	0.2	0.3
B 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.5	4.5	0.8	0.5	0.5	0.2	0.4

300µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
B 100%	7	5	1	6	4.5	0.6	1	0	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
B 95/5	7	5	1	6.5	4.5	0.9	0.5	0	0.1	0.3	6.5	4.5	0.8	0.5	0.5	0.2	0.4
B 90/10	7	5	1	6.7	4.5	0.9	0.3	0.5	0.1	0.3	6.5	4.5	0.8	0.5	0.5	0.2	0.4
B 85/15	7	5	1	6.7	4.6	0.9	0.3	0.4	0.1	0.2	6.6	4.5	0.8	0.4	0.5	0.2	0.3
B 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.5	4.5	0.8	0.5	0.5	0.2	0.4

un sieved aggregate samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
B100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7

B 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.3	4.5	0.8	0.7	0.5	0.2	0.4
B 90/10	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.3	4.4	0.8	0.7	0.6	0.2	0.5
B 85/15	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.6	4.7	0.8	0.4	0.3	0.2	0.3
B 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.6	4.7	0.8	0.4	0.3	0.2	0.3

Table 3: Shrinkage Values of Samples Fired at 1000^{o}C

1.18mm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
C 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
C 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.5	4.5	0.8	0.5	0.5	0.2	0.4
C 90/10	7	5	1	6.7	4.7	0.9	0.3	0.3	0.1	0.2	6.5	4.5	0.8	0.5	0.5	0.2	0.4
C 85/15	7	5	1	6.8	4.8	0.9	0.2	0.2	0.1	0.1	6.8	4.8	0.8	0.2	0.2	0.2	0.2
C 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.5	4.7	0.8	0.5	0.3	0.2	0.3

600µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shri	hrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
C 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
C 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.4	4.5	0.8	0.6	0.6	0.2	0.4
C 90/10	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.5	4.6	0.8	0.5	0.4	0.2	0.3
C 85/15	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.6	4.6	0.8	0.4	0.4	0.2	0.3
C 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.6	4.6	0.8	0.4	0.4	0.2	0.3

84

300µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
C 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
C 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.4	4.5	0.8	0.6	0.5	0.2	0.4
C 90/10	7	5	1	6.7	4.5	0.9	0.3	0.5	0.1	0.3	6.6	4.6	0.8	0.4	0.4	0.2	0.3
C 85/15	7	5	1	6.7	4.6	0.9	0.3	0.4	0.1	0.2	6.6	4.7	0.8	0.4	0.3	0.2	0.3
C 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.6	4.7	0.8	0.4	0.3	0.2	0.3

un sieved aggregate samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
C 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
C 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.2	4.5	0.8	0.8	0.5	0.2	0.5
C 90/10	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.5	4.5	0.8	0.5	0.5	0.2	0.4
C 85/15	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.8	4.8	0.8	0.2	0.2	0.2	0.2
C 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.5	4.8	0.8	0.5	0.2	0.2	0.2

APPENDIX VII

Table 4: Shrinkage Values of Samples Fired at 1100^{o}C

1.18mm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
D 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
D 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.5	4.5	0.8	0.5	0.5	0.2	0.4
D 90/10	7	5	1	6.7	4.7	0.9	0.3	0.3	0.1	0.2	6.4	4.5	0.8	0.6	0.5	0.2	0.4
D 85/15	7	5	1	6.8	4.8	0.9	0.2	0.2	0.1	0.1	6.7	4.8	0.8	0.3	0.2	0.2	0.2
D 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.8	4.7	0.8	0.2	0.3	0.2	0.2

600µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
D 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
D 95/5	7	5	1	6.4	4.5	0.9	0.6	0.5	0.1	0.4	6.3	4.5	0.8	0.7	0.5	0.2	0.4
D 90/10	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.5	4.4	0.8	0.5	0.6	0.2	0.4
D 85/15	7	5	1	6.6	4.6	0.9	0.4	0.4	0.1	0.3	6.6	4.5	0.8	0.4	0.5	0.2	0.3
D 80/20	7	5	1	6.6	4.7	0.9	0.4	0.3	0.1	0.2	6.4	4.6	0.8	0.6	0.4	0.2	0.4

300µm aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrinkage	T shrinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
D 100%	7	5	1	6	4.5	0.6	1	0.5	0.4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
D 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.5	4.4	0.8	0.5	0.6	0.2	0.4
D 90/10	7	5	1	6.7	4.5	0.9	0.3	0.5	0.1	0.3	6.4	4.5	0.8	0.6	0.5	0.2	0.4
D 85/15	7	5	1	6.7	4.6	0.9	0.3	0.4	0.1	0.2	6.6	4.5	0.5	0.4	0.5	0.2	0.3
D 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.6	4.5	0.8	0.4	0.5	0.2	0.3

un sieved aggregate size samples

Sample	Initial L	Initial B	Initial T	Dry L	Dry B	Dry T	L shrinkage	B shrin	rinkage	M shrinkage	Firing L	firing B	firing T	L shrinkage	B shrinkage	T shrinkage	M shrinkage
D 100%	7	5	1	6	4.5	0.6	1	0.5	4	0.6	6.2	4.2	0.5	0.8	0.8	0.5	0.7
D 95/5	7	5	1	6.5	4.5	0.9	0.5	0.5	1	0.3	6.4	4.5	0.8	0.6	0.5	0.2	0.4
D 90/10	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.5	4.6	0.8	0.5	0.4	0.2	0.3
D 85/15	7	5	1	6.5	4.5	0.9	0.5	0.5	0.1	0.3	6.7	4.6	0.8	0.3	0.4	0.2	0.3
D 80/20	7	5	1	6.8	4.7	0.9	0.2	0.3	0.1	0.2	6.8	4.7	0.8	0.2	0.3	0.2	0.2

APPENDIX VI



Plate. XLI: Bulged Out 300µm Iron Filings out of the Test Slab At 1100^{o}c



Plate. XLII: Swollen 600µm Iron Filings out of Test Slab At 1100^{o}c



Plate. XLIII: Throwing Test Outcome of 1.18mm Aggregate Size of Iron in a Body Of 80% Clay and 20% Iron Filings



Plate. XLIV: Throwing Test Outcome of 600m Aggregate Size of Iron in a Body Of 85% Clay and 15% Iron Filings

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Plate. XLV: Throwing Test Outcome Of 1.18mm Aggregate Size of Iron, in a Body of 95% Clay and 5% Iron Filings



Plate. XLVI: Throwing Test Outcome Of 1.18mm Aggregate Size of Iron, in a Body of 90% Clay and 10% Iron Filings

APPENDIX IX

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Plate XLVII: Outcomes of Throwing Test of Clay and Iron Filings at Green Ware Stage

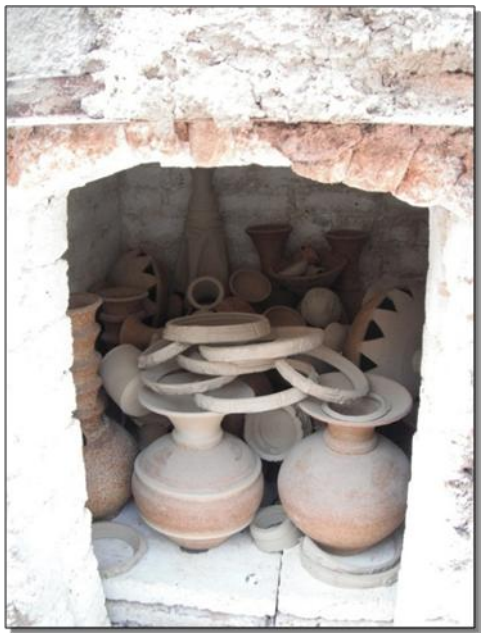


App. XLVIII: Centering of Iron Filings Blended Into Clay Body for Production

APP 91 X X



App. XLIX: Opening and Pulling Clay Body with Iron Filings



App. L: Loaded Kiln for Firing

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