FABRICATION OF TERRACOTTA FLOOR-TILES USING LOCAL RAW MATERIALS

by

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A Thesis submitted to the School of Graduate Studies,

Kwame Nkrumah University of Science and Technology

in partial fulfillment of the requirements for the degree of

MASTER OF ARTS (ART EDUCATION)

Faculty of Fine Art, College of Art and Social Sciences, Kumasi

MAY 2008

DECLARATION

I hereby declare that this submission is my own work towards the Master of Arts in Art Education and that, to the best of my knowledge it contains been made in the text no material previously published by another person or material which has been accepted for the award of any other degree of the university, except where acknowledgement has

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ABSTRACT

The production of floor tiles has been a very lucrative venture and a major foreign exchange earner to countries like China, Spain, Italy, Mexico etc. The cost of floor tiles as at 2005 was between $150 and $200 per square metre. It therefore baffles the researcher why the production of the ware in the region and for that matter Ghana seems a hidden venture. The West African examination council has not for a long time set questions on tiles although the curriculum and syllabus makes provision for tile production. Organisations and researchers throughout the region have turned their attention to the production of bricks and sparsely roofing tiles ignoring the most lucrative venture of the Brick and tile industry which are floor and wall tiles. The teaching of the topic in question has also been ignored by teacher in the second cycle and tertiary institutions. Since it is a lucrative venture the promotion of the industry is very eminent for the economic and the social development of a country like Ghana especially the Apinkra community where there is no means of income except farming but have the request raw material base (clay deposite) for the production of floor tiles. The industry when given the needed attention will afford school dropouts a meaningful source of income and expand the scoop of studio production. The survey carried out experiments on Apinkra and Mfensi together others like Fomena, Afari Dekyemso clay etc, with the objective of exploring the factors will enhance the production floor tiles. The researcher finally settled at Apinkra and Mfensi clays. The project was completed with the construction of a tile pressing mechanism all aiming at enhancing and promoting the production of terracotta tile manufacturing in Ghana the study recommends the government as well as other allied institutions should help in the promotion of floor tiles

in the region with reference to Apinkra community The Ministry of Education should help facilitate the teaching and learning tile production in the country. This can be done by given in-service training to teachers, regularly setting question on the topic, making strong emphasis in the syllabi and providing facilities for the production of the ware, By the end of the project it is hope that the study will rouse the interest of tile producers in Ghana and thereby seek to the local industry. Finally, it must be re-emphasis that the production of floor tiles has a great economic significance. This will resuscitate employment which should not be down played by developing countries like Ghana.

ACKNOWLEDGEMENTS

I would like to acknowledge God who is the most high, for keeping me healthy and happy throughout the study period. I would also like to acknowledge the

Kwame Nkrumah, University of Science and Technology (K.N.U.S.T) and the Department of Art Education (K.N.U.S.T) for providing me with an academic atmosphere that made it possible for me to successfully complete my master's program without any stress. Special thanks go to the Ghana Government for giving me the scholarship grant to study. Further thanks go to the authorities at the ceramics section (K.N.U.S.T) and special thanks also go to Dr.AduAgyem who tirelessly gave me the support and guidance right from the commencement of the study to the end. This study would not have been straightforwardly done without such a professional and academic input.

I would also like to further acknowledge Dr E.D. Darkwa (Lecturer, Chemical Engineering), Dr A.B.C Dadson and Dr. E. K Addison (Both Lecturers of Department of Physics K.N.U.S.T) who supported and guided me during the writing of the thesis.

Furthermore, I would like to give exceptionally special thanks to staff of B.R.R.I especially Vincent Ekow-Baiden (Technician, Geotech, Department) and Musah Seidu for the help they offered me during the commencement of the project.

Last but not the least, I would like to give further thanks to the staff of the Department of Agricultural Engineering K.N.U.S.T especially Mr. Emmanuel Seidu and Mr. D.O. Boamah, (Both technicians of the said Department) for their technical support during the commencement of the project.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The production of tile is a major foreign exchange earner for many countries including China, Spain, Italy, Mexico etc. Ghana abounds in clays of different charactures (colour, temperature). The cost of the ware is "between" $150-$200 in the U.S making it very attractive one for its producers. With this no company as at the year 2005 had gone into the production of this ware.

1.2 Statement of the Problem

1. Production units in the country appears to have ignored terra-cotta floor tiles although it is a very lucrative venture and cheap to the consumer.
2. It is alleged that most of the wares that are imported into the country are factory rejects and are therefore substandard. Most entrepreneurs believe that the industry should always be large-scale industry, but can also be small scale one.
3. The production of terra-cotta floor tiles is seemingly a missing concept in the production industries despite the abundance of clay in the country. (G.O Kesse Rocks & Minerals resources in Ghana,)
4. Tillers use ceramic tiles not meant for floor tiles for flooring e.g., people use wall-tiles as floor tiles.
5. Tillers use slippery tiles for floors. This is a very dangerous and unprofessional practice, if water is poured on any floor tile should not cause slippage.

1.3 Objectives of Study

1. Trace the development of ceramic tiles and their various uses in the development of the industry in Ghana.
2. Discuss the problems in tile production in Ghana.
3. To design and construct a machine for pressing tiles.
4. Carry to fabricate floor-tiles using the constructed machine and local raw material.
5. Assess the quality of the tile and the machine.

1.4 Hypothesis: Production of terracotta floor tiles using local raw materials and the development of a tile-press mechanism will enhance the work of local artisans to revive the tile industry in Ghana.

1.5 Delimitation: The study is limited to the use of Mfansi and Apinkra clays for the production of the terracotta floor tiles

1.6 Definition of Terms

Bisque or biscuit: Fired but unglazed ware, sufficient to harden but not matured.

Green Ware: Unfired ware.

Terracotta: Italian word for baked earth (clay).

Refractory: A material ability to resist heat.

Plasticity: The ability for clay to be manipulated or moulded.

Ware: Pottery or ceramic product.

Trivial Diagram: A diagram used to determine the proportions of materials in a body.

Pulverize: To press or crush a material until it becomes powder.

Mesh: A net-like material (sieve) for sieving materials.

Pressing: A process of compacting or compressing a clay mass or body to from a ware usually tiles.

Grog: Crushed fired clay.

Kiln: Furnace or oven used for firing or baking clay.

Firing: Act of baking clay.

Fuse: Melt within a body or clay mass during firing.

Glass Former: Material that melts and hardens during firing and cooling to give a glassy nature within and on the surface of a ware.

Flux: Materials that aid melting of other materials at lower temperatures during firing.

Abrasion resistance: Ability of a surface to resist being worn away by rubbing and friction

Accelerator: A substance which, when added to concrete, mortar, or grout, increases the rate of hydration of the hydraulic cement, shortens the time of setting, or increases the rate of hardening of strength development, or both.

Aggregate: Granular material, such as sand, gravel, crushed stone, and iron blast-furnace slag, used with a cementing medium to form a hydraulic-cement, concrete or mortar.

Backing: Any material used as a base over which a finished material is to be installed.

Bisque cracks: Any fractures in the body of a tile visible both on the face and back.

Dutchman: A cut tile used as filler in the run of a wall or floor area.

Epoxy grout: A two-part grout system consisting of epoxy resin and epoxy hardener, especially formulated to have impervious qualities, stain, and chemical resistance, used to fill joints between tile units.

Epoxy mortar: A two-part mortar system consisting of epoxy resin and epoxy hardener used to bond tile to back-up material where chemical resistance of high bond strength is a consideration.

Efflorescence: The residue deposited on the surface of a material by the crystallization of soluble salts.

Encaustic: Tile decorated with colored clays inlaid and fired. Also colored tile laid in a wall or floor to form a pattern.

Extruded tile: A tile or trim unit that is formed when plastic clay mixtures are forced through a pug mill opening (die) of suitable configuration, resulting in a continuous ribbon of formed clay. A wire cutter or similar cut-off device is then used to cut the ribbon into appropriate lengths and widths of tile.

Field tile: An area of tile covering a wall or floor. The field is bordered by tile trim.

Tile cutter: It is one of the most efficient and economic tools in the tile setting trade. A popular model is the hand-drawn tile cutting board that is adjustable.

Tile nipper: Special pliers that nibble away little bites of ceramic tile to create small, irregular or curved cuts.

Underlayment: An application of a relatively thin layer of mortar primarily used to level out-of-plane surfaces such as concrete slab

1.7 Abbreviations

M.O.R. Modulus of Rupture

Hp. Horse Powers

P.I. Plastic Index

T.S. Tensile Strength

T.S.B Tensile Strength Bar

M.O.H.S Modulus of hardness of surface

1.8 Importance of the Study

The study will:

1. promote floor-tiles production in Ghana, through National Board of the small-scale industries (NBSSI).
2. help create employment in the ceramic industry for school leavers and drop-outs in Ghana.
3. enhance the work of the artisans who are involved in ceramic production.
4. serves as a guide and instructional material for ceramic students and researchers.
5. to promote studio based tile production.
6. introduce ceramic students to innovative floor-tiles production techniques.
7. expand scope of ceramic floor-tile production in Ghana.
8. aim at fostering creativity in ceramic students towards tile production.

1.9 Arrangement of text

The thesis began with the abstract of the study and acknowledgements given to those due who assisted the author. Chapter one was an introduction to the study, which include a background of the study a statement of the problem that necessitated this writing. Objectives were drawn and hypothesis focussed. Delimitation was made on the topic and finally terms associated with the topic were delimited. Chapter two reviewed related literature. Chapter three described and discussed some of the tools, material and equipment used in the execution of the project. Chapter four describes the methods used in the study. Chapter five discusses the results. Chapter six was the final part of study where the summary, conclusions and recommendations of the study were made.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

The tile industry is an ancient phenomenon and therefore has much literature written about it. Very important to the researcher is its background history that combs to the fact that the production for the ware has been artisanal since it began 4000 years ago till the late 70"s when large scale industrial production begun in the U.S.A and Germany (Refer David Hamilton 1978). This has prompted a review of some related literature on the topic.

The related literature review covers on the following subsections.

2.2 Background History

Most books including the website www.johnbrigdge.com peg the use of tile to the 12th and 13th century. But the web-site www.designboom.com/history/tiles_
History.html states with the researcher that historically, ceramic tile has been made by man over 4000 years. Man has desired to create living spaces with beautiful, durable, and user-friendly artifacts. It is this that the website gives an account of beautiful tiled surfaces as being found in the oldest pyramids, the ruins of Babylon, and ancient ruins of Greek cities. Decorative tile work was invented in the near east, where it has enjoyed a longer popularity and assumed a greater variety of design than anywhere in the world. During the Islamic period, all methods of tile decoration were brought to perfection in Persia. In Europe decorated tiles did not come into general use outside Moorish in Spain until the second half of the 12th century. The tile mosaics of Spain and Portugal, the majolica floor tiles of renaissance Italy, the faiences of Antwerp, the development of tile iconography in England

and in the Netherlands, and the ceramic tiles of Germany are all prominent landmarks in the history of ceramic tile.

The use of tiles dates as far back in the time of Moses in the bible where God wrote the Ten Commandments on tiles. (Some bibles refer to these tiles as slabs whilst others refer to these tiles as tablets, which are all the same tiles.) These tiles according to the bible were made from stone. This period was before the Birth of Christ.

According to the web-site www.JohnPBridge.com (2005) the first clay tiles were produced seven to eight thousand years ago in the area now known as the Holy Land. And since that time little has changed fundamentally in the tile setting trade. The most of the historic event that comes to mind is the invention of cement mortar by the Romans. But the web-site: www.diydoctor.org.uk is of a similar view, it attributes to the Persians saying, "The first samples of glazed ceramic tiles used in architecture dates back to the end of the 12th Century".

Bridge(2005) further supports this by saying, new methods and materials have, of course, been introduced, but tile setting (despite modern efforts to mechanize it) remains a hand-operated, labor-intensive process, and it's not likely to change soon. In an age when "downsizing" and mass layoffs are commonplace, tile setters have achieved true job security, working their tails off in the process.

Bridge (2005) and the web-site www.diydoctor.org.uk are of the same idea with Norton (1970) and Hamilton (1978), that glazed decorative tiles are first known to have been produced in Egypt, and from there the tile making art spread to Persia and across North Africa. The Low Countries of Northern Europe somehow acquired the technology from Persia, while the Moors brought African tiles with them when they invaded Iberia (Spain).

It was aboard the ships of Spanish conquistadors that decorative clay tiles found their way to the New World, where they were used primarily to decorate the churches of newly built missions. A form of tile making had also evolved among the natives of North and South America at some point.

2.3 Definition of Tiles and Terracotta

[Most textbooks do not actually define tiles, perhaps it may be because authors feel it is a common ware and it will be too elementary defining the ware.] The web-site www.encarta.com (2003) defines the ware as a thin flat slab of glazed or unglazed fired clay used structurally or decoratively on floor, walls and roofs, sometimes used as extension, thin slab of glass, plastic, stone, asphalt or acoustically sound absorbent materials such as asbestos, as well as hollow ceramic blocks used structurally (as in drains or partitions). Tiles are mostly defined in terms of their physical, or their constructional purposes, as building accessories and components and also for their decorative and functional purposes.

Therefore the thickness of a tile should be 25% or less the total area in question. This means that drainage cover slabs and pavement bricks can qualify to be a tile.

On terracotta the Encyclopaedia Britannica (15th edition) (1988) claims that it is an Italian word meaning baked earth and it goes on to say that it is literally any kind of fired clay in general usage, kinds of objects e.g. vessels, figures of structural forms made from fairly course porous clay that when fired assumes a colour from dull ochre to red and usually left unglazed. [Here the researcher would like to differ from the statement about its colour, which is not the factual truth,] the colour will depend on the fired colour of the clay or body being used. Traditionally, tiles are ceramic i.e. fired clay (either glazed or unglazed) but some modern tiles are made of plastic, glass, asphalt or asbestos cement.

2.4 Type and Usage of Tiles

The web-site www.wikipedea.com describes tiles as being interior or exterior, component or accessory.

2.4.1 Interior tiles: These are tiles which are used in-doors e.g. bathroom, kitchen, ceiling, interior floor and wall tiles, etc.

2.4.2 Exterior tiles: They are tiles which are used out-doors e.g. pavement, roofing, exterior floor and wall tiles, etc

Every tile belongs to two of the mentioned groups but not three or all of the four.

According to the web-site www.designboom.com/history/tiles_ tile are classified into the following types

2.4.3 Terracotta Tile: Terracotta tiles have a rustic charm that derives from being made of natural clays, and which is accentuated by variations in tones, textures, and size. The variations and imperfections are considered a desirable feature of terracotta tile. Terra cotta tiles are usually highly water absorbent, which makes them unsuitable for most outdoor applications. When used indoors, terra cotta tiles are often given a sealer coat to improve their stain resistance. Terra cotta tiles are often used in flooring applications because of their size and thick body. (Also see www.johnbridge.com , www.tile.org.uk)

2.4.4 Ceramic Mosaic Tile: Unlike pictorial mosaics that are composed of thousands of tiny irregular tesserae, ceramic mosaics use small regular tiles to make geometric patterns of varying complexity. Some tile studios provide individual tiles that are assembled on site to create custom geometric designs. At the lower end, geometric mosaics can also be factory-mounted on a sheet backing in one- or two-foot squares so they can be installed quickly. Ceramic mosaics come glazed and unglazed, and in a variety of shapes including squares, rectangles, and hexagons. Unglazed ceramic mosaics are often used in flooring applications. Refer Norton F.H and www.johnbridge.com

2.4.5 Quarry Tile: Quarry tile refers to tile produced by extrusion method; clay or shale dough is forced through a die in a continuous ribbon, then cut into tiles and fired.

Paradoxically, this mechanical extrusion process can give quarry tile a "natural" look. Quarry tile are normally left unglazed, but occasionally glazes are used.

The extrusion process produces a dense skin on quarry tile that is quite resistant to water absorption. Unglazed quarry tile provides an economical, stain- and slip-resistant floor. In commercial applications where additional slip-resistance might be needed, some quarry tile is given surface with tiny abrasive particles added. Some quarry tiles are sufficiently water-resistant to be used outside in freeze-thaw zones, other quarry tiles are not. It is necessary to consult manufacturers' application data before using quarry tiles for exterior paving. Also see www.floorguide.com/howto/

ceramic001.php, ezinearticles.com/?Ceramic-Floor-Tile---5-Types&id=3666422

2.4.6 Pavement Tile: Pavement-tiles are often confused with quarry tiles because they are similar in size and weight and both are used primarily in flooring applications. Produced by the pressed-dust method, pavement tiles differ from quarry tiles because of the larger range of colors and finish available. Pavement-tiles can come glazed or unglazed, and have very low water absorption usually in the "vitreous" or "impervious" range. Like unglazed ceramic mosaics, Pavement tiles find wide use in flooring applications. The two tile types share similar physical characteristics; the major difference is that Pavement tile come in larger sizes and have a greater variety of textures. Refer ezinearticles.com/?Ceramic-Floor-Tile---5-Types&id=3666422

2.4.7 Handmade tiles: They often have slight irregularities in the surface that, when taken together in a group, create a subtle texture. Visual textures can also be created with glazes, where variations in light and dark tones, or flecks of color in the glaze, can create the visual impression of textures. In general, textured tiles tends to create less formal appearance, but looks more rustic and suitable for such styles as Arts & Crafts in Southwest Spanish Mission. Refer to www.gustinceramics.com

2.4.8 Honed and matt tiles**:** Have a uniform slightly roughened surface that imparts a subtle texture. Honed tiles are unglazed tile that are ground to a smooth dull surface during manufacture. Matt finish tiles have glaze that creates a dull, low-luster surface. The slight roughness of honed and matt tiles makes them slip-resistant and thus more suitable than glossy tile for floor installations.

2.4.9 Glossy Smooth Tiles: In contrast to textured tiles, smooth glossy tile create a better finish and a more formal look. Also, smooth glossy tiles resist dirt and stains and are easy to clean. As a result, smooth glossy tiles work well in high-maintenance areas that require frequent cleaning, such as kitchens, bathrooms, and entry halls. But they are slippery, and should not be used for floors.

2.4.10 Encaustic Tiles: These are patterned tile that combines two different clays within a single tile and the tile's main clay body. The pattern in encaustic tiles is extremely durable in high-traffic. This is because the pattern is created by a 0.3175cm thick colored clay slip that contrasts with areas. Consequently, encaustic tiles are very popular in the late Victorian era for floors in both homes and public buildings. With the popularity of the Victorian Revival today, people who want can get true encaustic tiles made just like they were in the 1880s or more-economical "faux" encaustics, where the pattern is silk-screened onto the glaze and then fired. The "faux" encaustics are quite adequate for residential installations. Refer www.nps.gov/history/hps/ tps/ briefs/brief40.htm

2.4.11 Saltillo tiles: These are Mexican terracotta tiles, produced from a Mexican traditional handicraft method, they are rustic and bear imprints of dog paw, chicken claws and some other animals that might have strayed across the tile surface when they are sun dried.

2.4.12 Ceramic Murals: Ceramic tile murals are made by combining a number of smaller tiles together to create a larger scene or picture. Some murals use a relatively small number of large tiles; each with a significant portion of the picture silk-screened or hand-painted on it. Other murals use the standard 10.16x10.16cm tile as the basic pictorial unit. In either case, and no matter if it is a stock or custom design, the tiles have to be site-assembled in the proper order.

In any case tiles are hand moulded or machine pressed. In the case of pressing, two or more methods are adopted. The producer may also create his own method of fabrication according to his desire and specification. Ceramic materials available are a determinable variable in choosing the method and mode of fabrication. Refer ezinearticles.com/?Ceramic-Floor-Tile---5-Types&id=3666422

The most important usage of tiles stands in its definition that a tile is the cover of an unsightly surface. Other uses include souvenir, antique and gift tile and as a communication medium.

2.5 Characteristics of Tiles

On the characteristics of tiles www.designboom.com/history/lites/history.html and www.nps.gov/history/hps/tps/briefs/brief40.htm sees as texture and colour are important characteristics in ceramic tile.

2.5.1 Texture: There are two basic types of textures used in making ceramic tiles, these are tactile and visual. Also see www.wikipedia.org/Elementsofart

Tactile textures can be felt, and convey the look of the natural product and the visual textures actually have a flat, smooth surface, but give the impression of texture through.
2.5.2 Colour: Probably the most powerful of the design elements is colour. From calm to bold, and cool to warm, ceramic tile offers an abundance of such choices. One facet of colour, called shade variation, deals with one of the most popular looks today - stone tiles. It is also the most dramatic. Today's stone products are designed with shade variation to provide a more natural look. www.wikipedia.org/Elementsofart

2.5.3 Effect of temperature on tiles: It is a good conductor of heat, therefore during at a hot day it hot or warm to walk on. It becomes very cold during very cold days. However, like bricks it gives off heat at a very slow pace, therefore in the night when the weather is cold one will feel warm and cool during the day when warm. This is rather for a short while because of its thickness. The combination of brick and tiles in construction give the total effect of the said thermal exponential.

Sharp thermal differentials cause cracks and rupture in extreme cases.

2.6 Classification of tiles

According to these web-sites www.geoffering-ceramic.com/china-ceramic-tiles-classification.htm,www.johnbridge.com and www.infotile.com to them tiles are classified according to its traffic density. Most countries have their own classification. They quote the Chinese classification of floor tiles under the following class.

Class O - Decorative use only, not recommended for use on floors

Class I - Light Traffic, for residential bathroom floors, no direct outside access

Class II-Medium Light Traffic: Residential interiors with the exception of kitchens, stairs, landings and areas near external entries.

Class III - Medium / Heavy Traffic: All residential applications, Commercial applications which are similar in traffic to residential applications. Specific exceptions are areas of prevalent circulation or turning points

Class IV - Heavy Traffic, all residential and most commercial applications such as the public areas of exhibition halls, hotels, restaurants, supermarkets, shops and schools

Class V - Extra heavy traffic, all residential and commercial applications similar to extra durability

Class IV -Extra durability may be required, suitable for commercial usage and industrial applications.

2.7 Methods of Fabrication

On the making of floor-tiles, Hamilton (1978) and the web-sites www.ceramics.com (27/10/2005) agrees with each other that there are many ways of making tiles. They may be made from plastic clay slip or dry clay and in theory be of any size. However the larger a tile the more difficult it is to produce, i.e., its flatness and its dimensional accuracy.

Tiles may be hand moulded, pressed, extruded or cast. The producer may also create his own method of fabrication according to his desire and specification. In the case of pressing, two or more methods are adopted. Ceramic materials available are a determinable variable in choosing the method and mode of fabrication.

2.7.1 Extrusion**:** In recent years the technique of extruding developed for brick production has been modified for the production of extruded tiles. Hamilton (1978) accounts for the extrusion process of Floor tiles.

2.7.2 Cast Tiles: On Cast tiles Norton (1972) and Hamilton (1978) describes how casting can be used for the production of tiles. They opine that they are produced by casting larger tiles in the bank of moulds where the pouring holes are interconnected; there are risers which allow air trapped to escape. (Risers are introduced on lesser commercial scale, but on the mega scale vibrators may be introduced to hasten settlement of clay material and escape of air.) Otherwise slip casting will be used to produce those surfaces, which will be unobtainable in any other way (i.e. accidentals.)

The tile should be produced with a clay or plaster model and from that model a mould made. The moulds are made from Plaster of Paris, usually two pieces which separate along the back edge of the tile. The top of the mould, which is the back of the tile, contains two or more holes according to the relief on the surface of the tile. The top of the mould, which is the back of the tile, contains one or more pouring holes according to the relief on the surface of the tile. To produce a mould the model is placed uppermost on a glass and cottles are placed 50-75mm away from the edge of the model.

The plaster is mixed in correct proportions with water, blend to ensure that there are no lumps and pour on to the model, casting around and over it to produce of plaster above the model about 50mm thick. If the model itself is plastic it must be sized or impregnated with resin to prevent the plaster from sticking. The modelling of the surface must be such that, it does not key with any the plaster mould otherwise the mould would be impossible to remove. When the top and the side surfaces are cast and the mould is turned and the side of the mould, which have just been cast, so opted and clay or resin impregnated plaster plug placed in the centre of the back of the tile fresh plaster is mixed and poured onto the back of the model to the main dimension as the first part of the mould. When the plaster is set the mould is separated and the model is removed.

Notches must be cut into the mould to allow the second piece as it is poured to run into it, to allow a registration device allowing the mould be assembled correctly. When the plaster has dried, it is filled with a deflocculated slip and cast up to the correct thickness to produce either a hollow cast or a solid cast. When the slip is cast to the correct thickness the mould is drained and left to dry until the cast tile is in a state where it may be removed without damage. Any seam on the new tile is fettled off and the piece left to dry. After which it is bisque fired.

2.8 Tile Pressing

Tile pressing is a mechanical method of tile fabrication whereby they are physically pressed by a direct or pre-force. This force is usually downwardly delivered and received on top of the ware.

Classification of Tile-Pressing

According to Waye (1964) pressing material could be classified into four main groups, wet, semi-wet, dust and dry, depending on the moisture percentage of the material being pressed. Waye (1964) presents the classification tile-Pressing in table 2.1 (also see www.Tilepress.com, (29/03/06)

Table 2.1 Classification tile-Pressing

Type of pressing	Percentage moisture content	Type of die	Condition of material	Application
Wet	18-22	Reinforced plaster	plastic	Simple box shape
Semi-wet (added oil)	15-17	steel	Plastic and granular	LT porcelain & complex shapes
Dust	6-10	steel	powder	Tiles
Dry	0-5	steel	granular	LT porcelain, steatite electro-ceramic

2.8.1 Wet Press: The materials used for wet press mostly contain 18-20 % moisture. The piece must be pugged, de-aired and pressed in a perforce-plastic mould (dye). The material used in this type of press is plastic. The dyes used for this type of press could be any box-like shape mould. In fact, the mould here is known as dye. These could be done by simply kneading or plunging through pug mill. (De-airing pug mill). It could also be done with hot pressing to evaporate the moisture within it.

2.8.2 Semi-wet pressing: Semi-wet pressing of materials with moisture content of 8-16% and constancy used here could partially granular. The press incase here are light complex shapes wares.

2.8.3 Dust pressing: Could be used to press tiles and have the moisture content of 6-10% and are pressed in powder form.

2.8.4 Dry press: It is used to press electro-ceramic ware such as insulator, capacitors etc. and its moisture content is from 0% to 5%. Lubricants are sometimes added to facilitate a discharge. The replacement of water partially or entirely, with organic binders makes it entirely different from other pressing methods.

2.8.5 Difference between a Die and a Mould: potters and artists often use the words interchangeably, but there is a difference. Here are over-simplified but workable definitions as they apply to the tile press.

According to the web-site www.ceramic.com a mould is made of soft plaster, such as Potter Plaster. The inside of the mold is usually shaped like the outside of the piece to be made. Moulds are absorbent and designed to "pull" water from the clay. It is usually used only once before it must be allowed to dry, so a great many molds are required for production. Moulds are mostly temporal.

To the same web-site www.ceramic.com A die, on the other hand, is made from gypsum cement (often called "hard plaster") and it uses clay of throwing consistency which is not further wetted. The die forms the clay in exactly the same way as a sheet of steel is stamped into an automobile fender. Dies have two halves, one to form the bottom of, say, a saucer and one to form the top. These two halves are brought together with a ball of clay between them. Within each half there is buried a porous tube. When air is sent into it, the air escapes and pushes water, which is resident in the "plaster" toward the clay, releasing it from the die. The bottom usually released first, the upper half of the die is then raised with the formed piece clinging to it. A bat or other material is held under the upper half of the die and the tube in that part is pressurized. The formed clay is released and caught very gently with the bat. Dies are usually permanent.

2.9 Firing

Conditions within the diocese of the kiln follow a specific nomenclature i.e. water smoking, endothermic and exothermic, heating and cooling although some of the mentioned processes are dodged during some firing process like continuous firing. It is also realized that within the firing area certain physical and chemical processes have their adverse effect on the ware being fired. Norton F.H (1970) and the web-site www.evenheat.com aggress "says that; It has been recognized that the composition of the combustion gases influence the maturing of ceramic bodies. Trixal bodies are almost always fired in an oxidizing atmosphere. Hard porcelain is fired for a portion of the cycle in an atmosphere containing some carbon in order to the ferric oxides to ferrous compounds and thus gives a better fired colour".

2.9.1 Fire treatment: This is done with all tenacity to avoid firing accidents such as rapture and warpage. Firing nomenclature is therefore gradual and steadily. Cardew (1983) classifies the nomenclature under the following stage.

Stage 1: Preheating 20-200^oC for 6 hrs. Average temperature rise (ATR) 30^oC/hour also known in the brick industry as water-smoke mechanically or physically waters are expelled. Stage 2: 200^oC to 600^oC for 6 hours ATR 67^oC/hr at this stage there is an adiabatic rise of temperature. This stage is half way and known as fire to the holes. Here fire can rise sharply to compensate for the endothermic effect from any raw clay. The dehydroxylised dull red glow fire begins to show loss in hydroxylsis.

Stage 3: 600^oC to 1000^oC (Full firing) oxidation for 6hours ATR 67^oC/hr primary air and secondary air are partly closedown. Melting of metallic ore and oxides are reduced. Stage 4: 1250 to 1280^oC for 2hours ATR. 15^oC/hr (ALR) at cone 8 where the prism is bent further no reduction is needed glaze liquids are melt (i.e. iron dioxides in glazes and bodies.) If reduced to Fe_2O_3 the irons i.e. Fe_2O will be affected by the oxidizing conditions. Stage 5: Soaking fire where cone 8b or 9 has bent (1250 to 1280^oC) between 30min.to 1hr.

At this stage secondary air is kept half open, pressure holes are usually closed.

It must be specified that tiles must be packed standing to prevent warpage.

2.10 Tessellation

In Latin, tessella was a small cubical piece of clay, stone or glass used to make mosaics. The word "tessella" means "small square" (from "tessera", square, which in its turn is from the Greek word for "four").

According to Hamilton (1978), Penrose (2004) and web sites like www.ogre3d. org/wiki/index /php/tessellation (04/08/06), a tessellation is a repetitive pattern of polygons that fit together with no gaps or overlaps. A tessellation of the plane is a collection of plane figures that fill the plane with no overlaps and no gaps. One may also speak of tessellations of parts of the plane or of other surfaces. Tessellation is an expression of the size and number of triangles in a polygon mesh.

2.10.1 Classification of tessellation: Tessellation could be classified as high or low. High tessellation means lots of small triangles and low tessellation means a smaller number of large triangles. It can also be said to be simple or complex.

Simple tessellations**:** are those in which only the translation operation is used.

Complex tessellations: are those in which one or both of the rotation and reflection operations is used with the translation operation.

2.10.2 Types of Tessellation: Tessellation is classified into three main categories; these are regular, Semi-regular tessellations and Non -regular irregular tessellations. regular tessellation is a highly symmetric tessellation made up of congruent regular polygons. There are only three regular tessellations that exist: those made up of equilateral triangles, squares, or hexagons.

It involves a regular polygon, which has 3, 4, 5 or more sides and angles, all equal. A regular tessellation means a tessellation made up of congruent regular polygons. Regular means that the sides of the polygon are all the same length. Congruent means that the polygons, which are put together are, all of the same size and shape. Regular tessellations are made up entirely of congruent regular polygons all meeting vertex to vertex.

Those using triangles and hexagons comprise semi-regular tessellations non-regular or irregular tessellations and origami tessellation:

Semi-regular tessellations are made up of two or more types of regular polygon, which are fitted together in such a way, that the same polygons in the same cyclic order surround every vertex. There are eight semi-regular tessellations, which comprise different combinations of equilateral triangles, squares, hexagons, octagons and dodecagons.

Non-regular or irregular Tessellations: Non-regular tessellations are those in which there is no restriction on the order of the polygons around vertices. There are an infinite number of such tessellations.

Origami tessellation is where the crease patterns and folded objects look like mosaic tiling.

A single or multiple of a polyiamond may be combined to form a figure, which is capable of tessellating the plane using only the translation operation. This figure will be called the unit cell.

2.11 Difference between Tiling and Tessellation

Definitions of most books and web-sites give the impression that tessellation and tiling are the same. The web-site http://en.wikipedia.org/wiki/Tessellation says, A tessellation or tiling of the plane is a collection of plane figures that fills the plane with no overlaps and no gaps. Tessellation is the planning of tiling, whilst tiling is putting tessellation into practice. Tessellation can be done on paper by drawing shapes and painting them or cut and paste.

Designing, Decoration, Finishing and Maintenance

Designers see the floor tile as the fifth wall; meaning their treatment should be the same or below. This could be true for aesthetics but not function. Owing to its traffic requirements, the floor tile should be made more durable than its neighbouring tiles.

2.12 Designing

The web-site www.diydoctor.org.uk states that designing, is the planning and patterning of any act towards foreseeable course constitute designing it further states that, should be meaningful in its form, it should follow functions, while aesthetic values should also be seen as an inherent part of its functions.

To design is to make partial and workable decisions, which influence size, geometry and material of finished items and will amongst other things be the product of mathematical method of analysis.

Hence the design of floor-tiles must conform to shapes and aesthetic values of the structure in question, for example tiles for corners oval rooms should be made to fix accurately in the said positions. This has not usually been the case because of the commercial dimensions the ware has taken currently.

Large tiles make the work of a designer easier but create problems during drying and firing.

Traditionally tiles were limited in size so that they could be handled easily. In any small malformation of a tile would not entail the remaking the whole design.

2.13 Decoration

The floor being the most dense traffic area in the house needs material and treatments that can withstand such work load. www.tiledecorative.com and www.designboom.com/history/lites/history.html treats decoration of tiles under the following headings

2.13.1 Unglazed: The colour range in unglazed tiles is limited to the natural colours of the clay, ranging from light sand to a red brick.

2.13.2 Plain Glazes: White lead, flint, china stone and china clay were ground to form a glaze. A clear glaze brought out the natural body colour and might be applied over any coloured decoration. Glazed tiles are decorated with natural and artificial colours. Palette of colors consists of glaze and under-glaze colours. The first glazes were blue in color and were made from copper. Also turquoise and light green glaze were popular colors. Ground metal oxides could be added to give different colours.

2.13.3 Encaustic or Inlaid: This method was to fill the matrix of a stamped tile with white pipe clay before it was glazed and fired. The two sections fuse together during firing.

2.13.4 Mosaic: Tiles in such colors as yellow, blue, brown, black, turquoise, green and white were cut and carved into small pieces according to a previously prepared pattern. These pieces were placed close together and liquid plaster pored over to fill in all the opening and gaps. After the plaster dried and hardened, a large single piece tile panel had been created, which was then plastered onto the required wall of the building.

2.13.5 Hand painting: Painting is done freely onto a plain surface tile; glaze is about one centimeter thick, with hand-painted decorations of flowers, plants, geometric designs, birds and human beings. A design could also be copied from an original sketch by 'pouncing'. Alternatively a tile could be transfer printed and coloured by hand.

2.13.6 Carved and Modelled Tiles: Each piece is individually carved in relief or modelled in clay, the pattern could be engraved in outline on the surface of the tile or the design carved in relief or counter-relief on a wood-block which was then pressed into the tile sometimes painted to emphasise the three-dimensional appearance of the work.

2.13.7 Sgraffito: An early form of decoration, the tile body is covered with coats of slip that is scratched off to produce the design.

2.13.8 Lustre Painting: The metallic lustre of glazed ceramics is a very special type of decoration. It can be red, brown, yellow-ochre, yellow or green in scattered light and shows, in specula reflection, coloured metallic reflections (blue, yellow, orange, rose). Metallic copper and silver colloids are suspended in glazes provides a lustre decoration.

2.13.9 Tube Lining: Slip is trailed onto the surface of the tile to make raised lines separating the areas where different colour is wanted. Coloured glazes were then applied. This technique was used for art nouveau tiles.

2.13.10 Transfer Printing

A copper plate was engraved with a design, this would be covered in colour and the excess removed leaving the colour only in the engraved parts. A transfer paper was pressed onto the plate, and placed colour side down onto the tile. Then removed, and the colour transferred to the tile. This method was quicker, and therefore cheaper than hand painting.

2.13.11 Scheme of Decoration

This involves the format at which a pattern or design may take on a tile or group of tiles the web-sites www.tiledecorative.comwww.designboom.com/history/lites/history.html and www.johnbridge.com under the following headings

2.13.12 Tile Pictures: Square tiles were placed together and necessary design was painted in glazed colours on them. They were placed next to each other to create the main large illustration. Also see enwikipedia.org/design and www.penrose.com

2.13. 13 Patterns: Mathematically minded people elaborated geometric designs, providing a continuous decoration. Most designs required four tiles to complete a pattern, some required as many as sixteen. See enwikipediia.org/design and www.penrose.com

2. 13.14 ‘Wallpaper’ Pattern: It is one that has translation symmetry in two directions (such as left/right and up /down). www.wikipedia.org/

2.13.15 Frieze pattern: It is one that has translation symmetry in one direction.

2.13.16 Rosette Pattern**:** This is one that has no translation symmetry, just reflection and or rotation symmetry. However, decoration of floor-tiles the colour of the clay should be appropriate for the decorative process involved. (refer www.tiledoctor.co.uk/tiledecorating.html)

2.14 Finishing

Terracotta floor-tiles are finished by using natural sealants such as boiled linseed oil, wax or artificial sealants like lacquer, Stonefix etc. With maintenance it is only necessary to clean with only water but not with soap. (See www.tiledoctor.co.uk/Tilecleaning.html)

2.15 Maintenance

Using strong detergents can cause a reduction in blatancy or its luster. Use clean water only. (Refer the web-site www.tiledoctor.co.uk. /TileCleaning.html.) The ware should be submitted to its specifications e.g. a class 1 tile must not be used in of a class II area because it will not be able to withstand the corresponding traffic. Interior tiles should not be used for outdoor architecture, otherwise will not be able to withstand the adverse weather conditions. Refer installingceramictileflooring.com/

CHAPTER THREE

TOOLS, MATERIALS AND EQUIPMENT

Tools, equipment and material for the construction of tile-press

Introduction

This chapter is in two parts i.e. construction of a tile-press and the fabrication of terracotta floor-tiles. The fabrication of the tile led the researcher to the search for suitable material for the said purpose and hence various experiments were performed to check the authenticity and potency of the would-be material to be used. Therefore tools and equipment were focused on precision on the fabrication and experimentation of the mentioned objective.

3.1 Tools: These included, saw, hacksaw, hand file, spanner, tap and dies, etc.

The carpenter's saw was used to cut plywood for the edge of the piston and the pallets. (See plate 3.1)

Plate 3.1 Carpenter's saw

The hacksaw was used to cut various types of metal to shape. (See plate 3.2)

The hand file was used in filing off weedy metals. (Also see plate 3.2)

Plate 3.2 The Hacksaw, Hand file, Screwdriver

The screwdriver was used in tightening some of the nuts, (plate 3.2).

The spanner was used to screw together the part of the pressing machine (plate 3.3).

Plate 3.3 Spanner

The tap and dies were used in reverting screw holes. (See plate 3.4)

Plate 3.4 Tap and dies

3.2 Equipment:

Oxy-Acetone Welding Machine, Electric Welding Machine, Bench-vice, Lathe-Turning Machine, Drilling Machine, Electric Motor, Filing Machine etc.

The bench vice

The bench vice was used to hold the various metals in stationary position when cutting (as shown in plate 3.5)

Plate 3.5 Bench –vice

The oxy-acetone welding machine was used to cut the thick metal plates to size, (as shown in plate 3.6)

Plate 3.6 Oxy-acetone welding machine

The electric welding machine was used to weld the permanent parts of the machine together (as shown in plate 3.7)

Plate 3.7Electric welding machine

The lathe-turning machine was used for grinding the bars of the shaft to the required size (see plate 3.8).

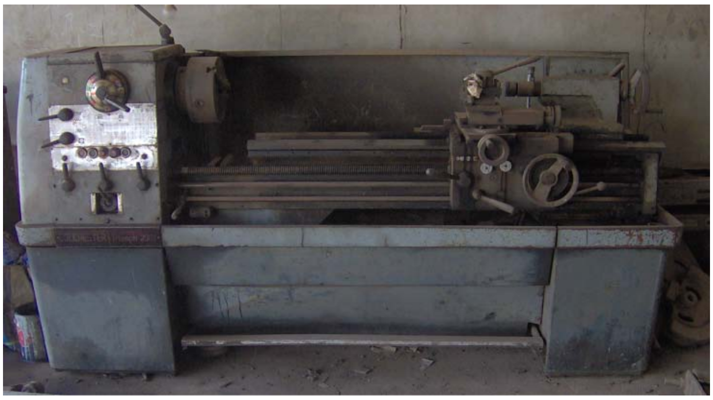


Plate 3.8 Lathe-turning machine

The drilling machine was used to bore or drill holes in the metals such as the angle iron, the base etc. (shown in plate.3.9)

Plate.3.9 Drilling machine

3.3 Materials

Materials used for the construction of the tile press includes, Metal plates, angle iron, plywood, a metal ball, engine oil, metal rods bolts and nuts etc.

Metal plates with the thickness of 2.54cm (1") were used to construct the body of the press and 0.3175cm (1/8") for the shatters of the hopper, (see plate.3.10)

Plate.3.10 Metal plates of various thicknesses

Plywood 1.27cm (½") thick was used on the tip of the piston which did the pressing. Plywood 0.3175cm (1/8") was used as pallets on which the tiles were pressed, (see plate.3.11)

Plate.3.11 Plywood of various thicknesses

A metal ball was placed in a case at the edge of the piston to allow the edge to be easily turned at all direction, (see plate.3.12)

Plate.3.12 Metal ball

Pictures of the sample clay are shown in Plate.3.13 and 3.14

Plate.3.13 Apinkra

Plate.3.14 Mfensi

Tools, Equipment and Materials for Test of Terracotta Floor-Tiles

Introduction

Before the fabrication of terracotta floor-tiles, some experiments were performed, this necessitated the use of some tools, equipment and materials which are discussed subsequently. The tools used are Kidney, spatula, cutting knife, rolling board, rolling pin, P.O.P moulds, lawn etc. The equipments used are Rapture machine, Electric stove, Electronic-weighing-scale, Test kiln, etc.

Materials: the Basic clay were clays from Apinkra and Mfensi

3.4 Tools

Rolling Pin and Board: They were used for rolling the slab, with which the samples were made, (as shown in plate 3.13)

Plate 3.15 Rolling Pin and Board

Lawn: The lawn were used in sieving the materials to the required particle size (see plate 3.14)

Plate 3.16 Lawn of different mesh

Pair of Dividers, Ruler, and Cutting Knife are represented in plate 3.15 were used for measuring and cutting samples to size.

Plate 3.17 Pair of Dividers, Ruler, and Cutting Knife

Pair of Dividers: It was used for the exact measurement during the linear shrinkage test. (See plate 3.15)

Ruler: It was used in the measuring during the various tests (see plate 3.15)

Cutting Knife: It was used for cutting samples to various sizes and shapes during the various tests (see plate 3.15)

A Pair of Dividers: This was used for accurate measurements (also see plate 3.15).

Equipment

Electric drier: The electric drier was used on drying the clay, (as shown in plate 3.16)

Plate 3.18 electric drier

The Rapture Scale: Rapture Scale was used in finding the tensile strength of the various clay and bodies formulated, (see plate 3.17).

Plate 3.19 Rapture Scale

Electronic Weighing Scale: It was used to find the weights of the samples used for the water absorption test represented in plate 3.18

Plate 3.20 Electronic Weighing Scale

Jaw crusher: This was used for breaking size of the clays used for the preparation of the samples into smaller lambs, (as shown in plate 3.19).

Plate 3.21 Jaw crusher

The vibrating ball mill: It was used for the milling of the clay (as shown in plate 3.20)

Plate 3.22 Vibrating ball mill

The Casablanca machine: The Casablanca machine was used in finding the plastic index during the plastic test, (see plate 3.2)

Plate 3.23 Casablanca machine

CHAPTER FOUR

METHODOLOGY

4.1 Research Design

The chapter describes the research design and the general procedure that was used in the execution of the project.

The research design was based on both Descriptive and Quasi-Experimental methods of research. These research methodologies were adopted to facilitate collection and detailed analysis of data, which were, used in the fabrication to meet international standards.

The data gathered by the researcher were mostly from the primary source as the he gathered materials from deposits in the locality and performed the required experiments to ascertain their quality and properties all for the production of terracotta floor tiles.

The researcher visited some laboratories such as the Ceramic Department laboratory at the College of Art, the Chemistry laboratory and the Material Science laboratory, all at KNUST and the Geological Survey Department laboratory in Accra.

Some libraries were also visited to gather relevant information pertaining to the project. These include: The British Council Library, Kumasi, KNUST libraries, Building and Road Research Institute (BRRI) library in Kumasi. Various websites were also visited in the search for information.

4.1.1 Research Instruments

The study made use of observation and interview for data collection. Observation is either an activity of a living being (such as a human), consisting of receiving knowledge of the outside world through the senses, or the recording of data using scientific instrument. An observation can also be the way one looks at things or when one looks at something. An observation may be classified into many types including; direct observation, indirect observation, covert observation, participant and non-participant observation. (www.asiamarketresearch.com/glossaryobservational-research.htm).

As the main research data collection instrument, observation was used significantly to collect relevant data for the study. The researcher, prior to the study, embarked on a preliminary survey to observe the state of the local tile industry at Apinkra and Mfensi communities to establish firm grounds for the project. Direct observations were made by the researcher to ascertain the type of materials, equipment and processes used by the tile manufacturers in the area. During the project, tests were done by critical observation through reading of experimental instruments and equipment and raw data recorded. After the observations and subsequent readings of the instruments and equipment, the results were obtained using their respective formulae. The observation helped the researcher to obtain first-hand information on the industry to draw conclusion and recommendations.

Aside the observation, the researcher also interviewed resource personnel in the industry such as Kwansosem and Kwasi Addai at Mfensi Brick factory and selected personnel at B.R.R.I., Kumasi and Tamakloe Ceramics, Accra.

The research is in two parts. These are: the construction of a simple tile press in part one and the fabrication of terracotta floor-tiles in part two. This fabrication however led to the investigation into some “clays” and for that matter, clay bodies that will be suitable for the fabrication of the tiles.

Tests Prior to the Fabrication of the Tile

The investigation involved two main types of experiments i.e. chemical test and physical test.

4.2 Chemical Test

According to Clyness, Williams and Clarke (1983) chemical changes involves the breaking up and the rearrangement of the atoms into new molecules. To the ceramist a chemical test is to check the extent at which a chemical (elements or compounds) may cause disintegration or decomposition on matter.

4.2.1 Corrosive test: It is a Chemical test which seeks to assess the extent to which a chemical will disintegrate a matter. This was performed by weighing some of the ruptured bars.

Test procedure: This was done by weighing some of the ruptured bars and then boiling for 3 hours in salt solution, placed in a desiccator to cool and then reweighed. The raw data is computed in appendix x. (Corrosive test only the only chemical test performed.)

4.3 Physical Test

This is based on physical changes, Clyness, et al (1983) argue that when physical changes occurs, the particles in the original arrangement move to an arrangement which can easily be changed back to its origin. The physical tests performed included plasticity, shrinkage, water absorption and tensile strength.

4.3.1 Plasticity test (Material Analysis)**:** This was necessary because when clay is too coarse (non-plastic) it usually cracks, either hair line or ducting and when too plastic it usually wraps. Before the test was conducted the following had to be carried out.

4.3.1.1 Moisture Content Determination**:** This is a test used to determine the amount of moisture (water) in a particular clay. It is the ratio of the weight of water to the weight of clay solids.

4.3.1.2 Liquid Limit Determination**:** A soil's liquid limit is the moisture content at which the soil passes from a plastic to a liquid state. This is useful in describing clay's reaction with water.

Test procedure: A clay samples (Mfensi and Apinkra) passing the No.36 B.S sieve was selected and 100g of which was taken. The sample was placed on a mixing board and distilled water was added to it. It was then mixed thoroughly by stirring, kneading and chopping with a flat spatula. Sufficient distilled water was added to the sample to form a uniform mass of clay with a stiff consistency. Some of the mixed sample was placed into a liquid limit device and the spatula used to squeeze and spread the sample in the liquid limit device to expel the entrapped air bubbles within the mass.

The clay on the Casagrindle machine was then divided into two equal parts with the grooving tool. The Casagrindle machine has a cup on which the clay was placed. This cup was dropped from a determined height onto a metal base by turning the crank at a rate of approximately two revolutions per second until the two halves of the clay parted came together along a distance of about 13mm. The number of blows required to close the groove was recorded, sample of the soil in the cup was taken, placed in a container, oven dried, and its moisture content determined. The procedure was repeated and in each case the water content was increased with reducing number of blows. A semi-log graph was drawn with moisture content values on the x-axis and the number of blows on the y-axis. The liquid limit was given as the moisture content at the 25^{th} blow

4.3.1.3 Plastic Limit Determination**:** This is the lowest water content at which a clay remains plastic.

Test procedure: the clay samples (Apinkra and Mfensi) passing the No.36 B.S sieve was taken, mixed and rolled on a rolling board to form a coil of uniform diameter (usually 3mm) throughout the length. This rolling was continued until the coil crumbled. The disintegrated clays were gathered and placed in a container, the weight was determined and the sample was oven dried. The dried sample was weighed and the difference in weight between the wet and dry samples gave the moisture content.

The plastic limit was given as the moisture content in percentage was determined.

4.3.1.4 Plasticity index**:** It is the water content range within which "a clay" will be in a plastic state. It is the numerical difference between the liquid limit and the plastic limit. That is;

PI=LL-PL Where PI=Plasticity Index

LL=Liquid limit

PL=Plastic Limit

The raw data is computed in appendices vii, viii and ix. The results are discussed in chapter five.

4.3.1.5 Particle Size Analysis, (Sieve Grading or Analysis): The particle size analysis was performed to determine the mesh size suitable for the clays i.e. to maintain the maximum clay ingredients within the material. This was done by sieve analyses, which are of two types, the dry and wet sieving.

Wet Sieving: This analysis was carried out to determine the particle size distribution of granular materials, which is a major factor determining density.

Sieve analysis is the percentages of the dry weight of the sample remain in the sieve. 300g of clay was added to 900ml of water and the resultant was mixed to form slip and left for 3mins to let the particle settle.

The slip was transferred to the coarsest of the series of sieve and washed by means of a jet of water until the emerging liquid is quite clean.

The residue that collected in the series of sieve were dried to constant weight at 110^0C for 24hrs and weighed. The sample that passed through the smallest sieve was allowed to settle and dried at 110^oC for 24hrs. This was also weighed and calculated for the difference.

Dry Sieving: This was done by sieving the clay through mesh from larger to smaller mesh and the residue (i.e. trapped clay) were collected. This was done till the last of the clay mineral is sieved, leaving the residue. The last mesh to be worked becomes the right mesh for the operation. Another method for particle size is by using the travelling microscope. Here, the clay samples are placed under a travelling microscope and viewed through its graded lens to determine the particle size.

4.3.2 Shrinkage test**:** The next physical test that was performed was the shrinkage test. This was necessary to determine the rate of shrinkage after firing so as to maintain the international standards.

Procedure: This was done by rolling slabs and waiting until leather hard and then cutting to the size 6cm x 3cm. A line of 5cm was scratched in the middle as shown in fig. 4.1

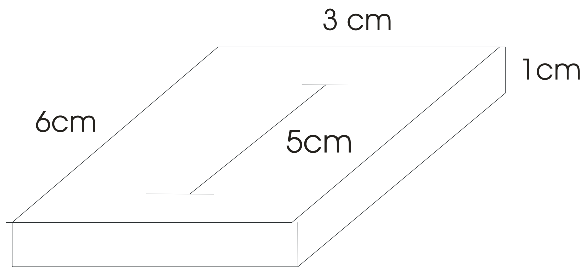


Fig. 4.1 Shrinkage tablet used for shrinkage test

They were then dried at the temperature of 110°C for 24hours. The shrinkage lines were then measured and its data recorded and the percentage shrinkage calculated with the formula.

$$\frac{L_1 - L_2}{L_1} \times 100$$

Where L_1 = plastic length

L_2 = dry length

The pieces were dried in an electric dryer at the temperature of 110°C for 24 hours and then fired to 1000°C.

The samples were placed in a desiccator to cool and after the shrinkage lines measured and recorded in appendix 1. The average percentage shrinkages were calculated with the formula

$$\frac{L_1 - L_3}{L_1} \times 100$$

The pieces were again dried in an electric drier at the temperature of 110°C for 24 hours and then fired to 1150°C.

The samples were again placed in a desiccator to cool and the shrinkage lines measured and recorded after which the average percentage shrinkage was calculated using the formula

$$\frac{L_1 - L_3}{L_1} \times 100$$

The raw data is computed in appendices I and II.

4.3.3 Water Absorption**:** This physical test was done hand in hand with the shrinkage since the same test piece was used for both. Green absorption could not be performed because the vacuum pump was out of order at the time of the project.

The shrinkage test pieces were fired to 1000^{o}c and 1150^{o}c which was kept in a desiccator to cool and was weighed, boiled for 3hrs, kept in a desiccator to cool again and weighed. The data was recorded and the water absorption calculated with the formula

$$\frac{W_2 - W_1}{W_1} x\ 100$$

Where W_1 = dried weight

W_2 = boiled weight.

The raw data is computed in appendices iii and iv

This is further discussed in chapter five being results.

4.3.4 Tensile strength**:** After the shrinkage and water absorption tests were performed, it was now proper to perform the tensile strength another physical test, since the length at which the rupture bars were to be made could now be determined. A slab was rolled and cut to size at leather-hard. The dimensions were as follows 1.5/1.5/17 cm and is shown in figure 4.2

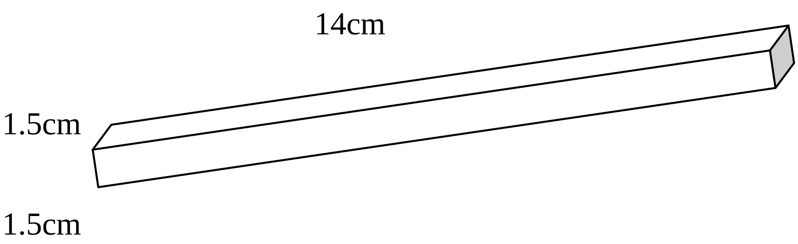


Figure 4.2 A Rapture Bar

They were fired to the temperature of 1000^oc and ruptured. The dimensions of the ruptured portions were taken and the results computed in a table in appendix v

Tensile Strength at 1150^oC: Another set of bars were fabricated also at 1.5cm/1.5cm/14cm fired at 1150^oc and ruptured. The ruptured areas were measured and the results (the raw data) presented in appendix vi

This is further discussed in chapter five being results.

Designing, Construction, Manufacturing and Operation of Tile-Press

Here the fabrication processes and techniques used in the construction of a tile-press were addressed. These involved the planning, designing and Construction of the press.
The need to press a tile became eminent. To make it authentic the researcher sought a formula that will help determine the force needed to press a tile. This is presented as follows;

The researcher was assisted by Mr.Musah of BRRI and Mr.Boamah, chief technical at the Agricultural Engineering department, KNUST in the actual fabrication of the tile press. An oxy-acetone welding machine was used to cut the thick metal pieces used for the Hooper. An electric motor was borrowed from Mr. Adjei of the Electrical Engineering department which was used to power the tile pressing machine.

4.4 Design

This was in three parts the hopper (Die), the bench and the paddle

4.4.1 The Hopper (Die)**:** A metal plate with the thickness of 2.54cm (1”) was cut to size. Two paired screw holes were drilled through the plate at calculated intervals. This plate was named plate A and was the base of the hopper (or vacuum) as shown in fig.4.3

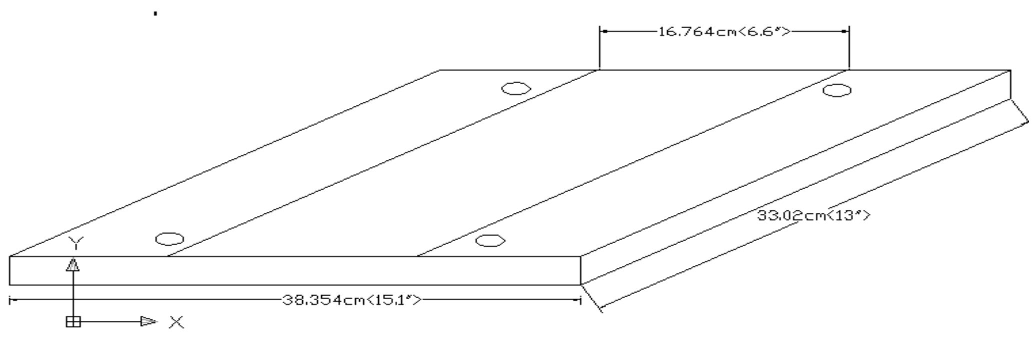


Figure 4.3 Base of hopper (Die)

Pair holes were drilled on top of the plate A and reverted. Also represented in fig.4.4

The paired holes were meant to be the place where an angle will hold sides of the hopper, to the base and also the bench.

Size of plate = 35.56/35.35cm (14/14")

Intervals of screwed holes = 16.51 and 30.98546cm (12 1/6"and 6 ½")

Hole size =0.3175cm (1/8") diameter

Two metal sheets with the sizes of 38.354cm (15.1") and thickness of 2.54cm (1") were used for the sides of the hopper by drilling slots on it. (See fig. 17)

Size of plate =38.354cm (15.1/15.1")

Intervals of screwed holes =33.274 and 16.764cm (13.1and 6.6")

Hole size =0.3175cm (1/8")

At the top of the two plates two holes were drilled and reverted, for the position of the pivot. Two blots screwed in them as shown in fig.4.4

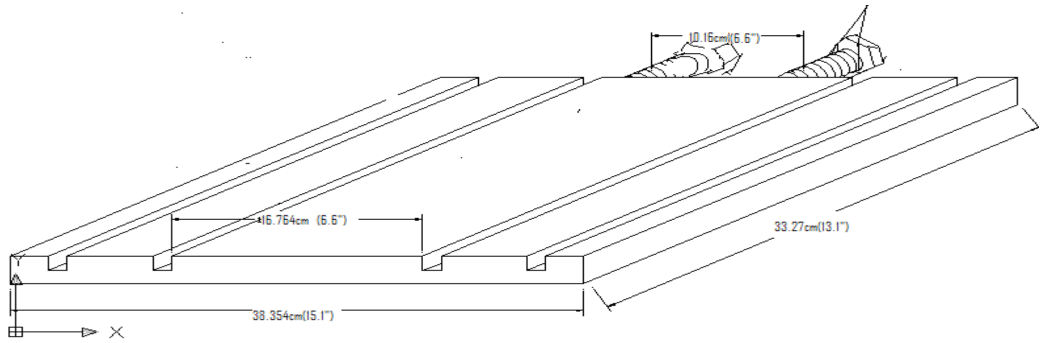


Figure 4.4 Side of Hopper. (Die)

At the back of the two plates, two holes were drilled on each and reverted. As shown in fig. 4.5

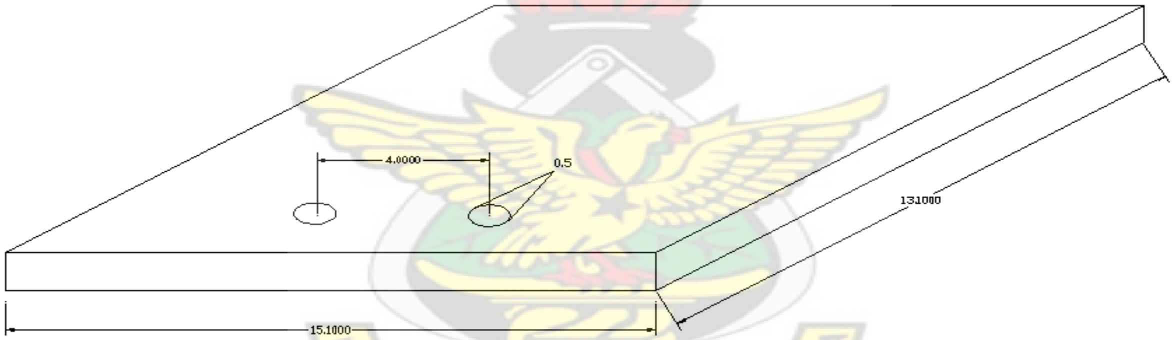


Figure 4.5 Back of sheet for the side of the hopper (Die)

A pair of angle iron was cut to size. Holes were drilled through them with the diameter of 0.635cm, as shown in fig. 4.6, these were to correspond with those at the back of the sheets for the sides, those at the base and the screws of the bench.

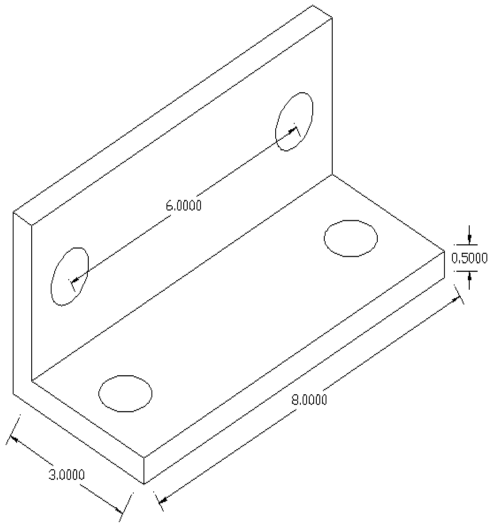


Figure 4.6 Angle iron

Angle iron that holds the parts of the machine together i.e. sides, base and bench

Thickness of Angle iron = 0.313 75cm

Length of Angle iron =15.24cm

Interval between screwed holes =7.62cm

Twin-reverted holes in the paired plates were to correspond with the holes drilled in the angle iron and also the screws of the bench. (The machine was to sit on a bench, which is the same height of the machine, which will power it.)

Thickness of metal plates =1.27cm

Size of metal plates =35.56/ 17.78cm

Intervals of holes and slots= 32.4cm and 16. 2cm

Screw hole size =1.27cm decimeter

An angle iron bigger than figure 4.19 was cut, holes of 2.54cm from the edge were drilled through it on each side of the L shape and was named angle iron B

Thickness of Angle iron =0.635cm

Length of Angle iron =12.7cm

Interval of hole on iron =15.24cm

Two pairs of plates were cut to size, one pair bigger than the other. The bigger one was for the big tiles and the smaller ones for the small tiles.

One of each of the pairs of plate C was fixed with handles to enable easy removal, during the discharge of fabricated floor-tile. The plate was named plate C as shown in figure. 4.7 (One for 15.24/15.24cm and another for 30.48/ 30.48cm) and was meant to be the doors of the hopper.

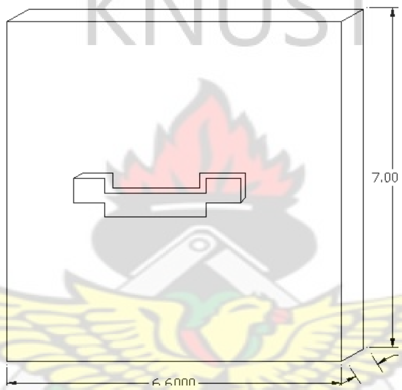


Figure 4.7 “Slot door” for the front of hopper (Die).

4.4.2 The lever (shaft): A shaft of a motorbike was modified by removing the rod of the loop and replaced with another rod of 2.54cm in diameter. This was used as the lever or shaft (see Figure 4. 8)

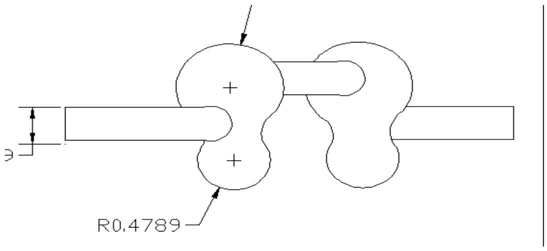


Figure 4.8 Shaft of motorbike

The modification of the Shaft of the motorbike was done by hammering an iron into the ridges of the shaft as shown in fig 4.9

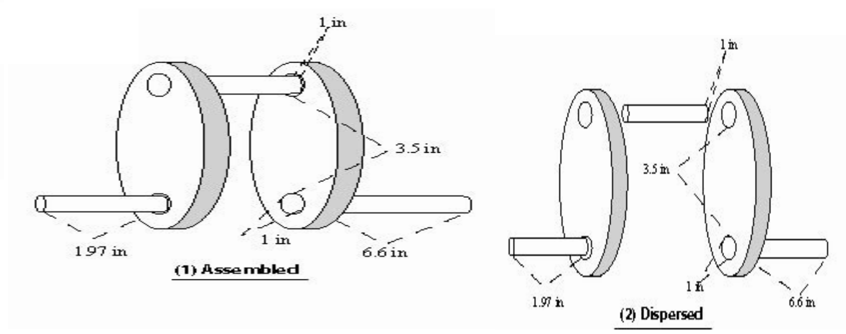


Fig 4.9 Modified motor-bike shaft

The rod 0.635cm was hammered into the lever (see figure 4.10)

4.4.3 Ball-Ring Case**:** A ball-ring case was made for the shaft using the middle part of a grinding stone. A flat bar of a 0.3175 cm was welded to it, as shown in figure 4. 1

Fig.4.10 Ball-ring case

4.4.4 The Spindle**:** The rim of a bicycle tyre was used for a spindle for the press to reduce since there was no reduction gear available. It was made by welding two flat bars across the diameter of the rim as indicated in figure 4.11

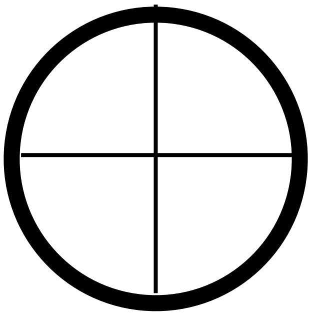
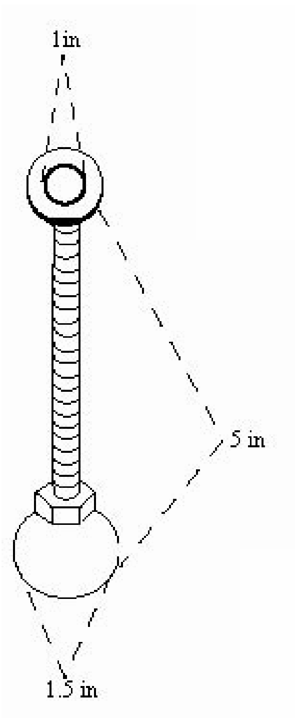


Fig. 4.11Spindle to be attached to the shaft of the press

4.4.5 The Piston (Various Parts): A piston was made for the press. This was meant to press the feed. Parts of the piston are drawn and labelled figures 4.12 to 4.15 and discussed as follows:



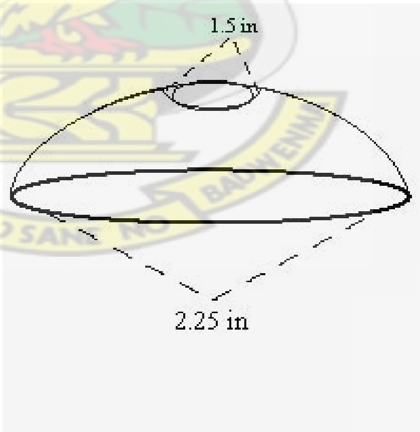


Figure 4.12 The inner piston

Figure 4.13 Top of case

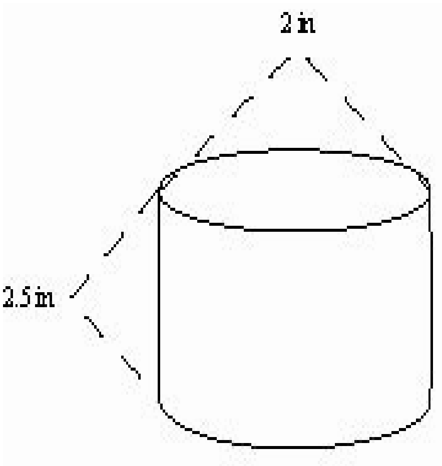


Figure 4.14 case for ball

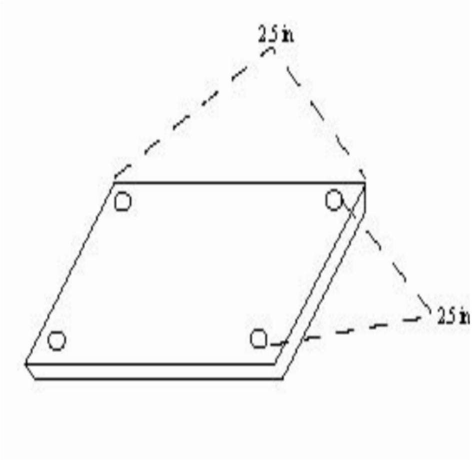


Figure 4.15 Base of piston case

The Inner Piston: The inner part of a piston was made by welding a nut onto a metal ball. A "beheaded" bolt measuring 10.16cm was screwed into the nut. A metal pole 3.81 cm in diameter was cut to the length of 5.08 cm; smaller poles were welded in the 3.81 cm pole a 5.08 cm diameter was attained in the middle of the larger pole. This was welded on the top of the bolt as shown in fig.4.12

Top of case: A washer of 10.16cm was placed on a smaller but thick pole and hammered till it assumed the shape of a hut. This was used for the top of the case as shown in fig 4.13

Case for Ball of Piston: A metal pole of 7.62cm was cut also to the length of 7.62cm and was used for the pistons ball case as shown in fig 4.14

Base of Piston: A 0.635 metal was cut to the size of 10.16cm/10.16cm and four holes were drilled at its corners presented in fig. 4.15

The Piston: These parts (4.12 to 4.15) were assembled to give the whole piston as presented in fig. 4.16

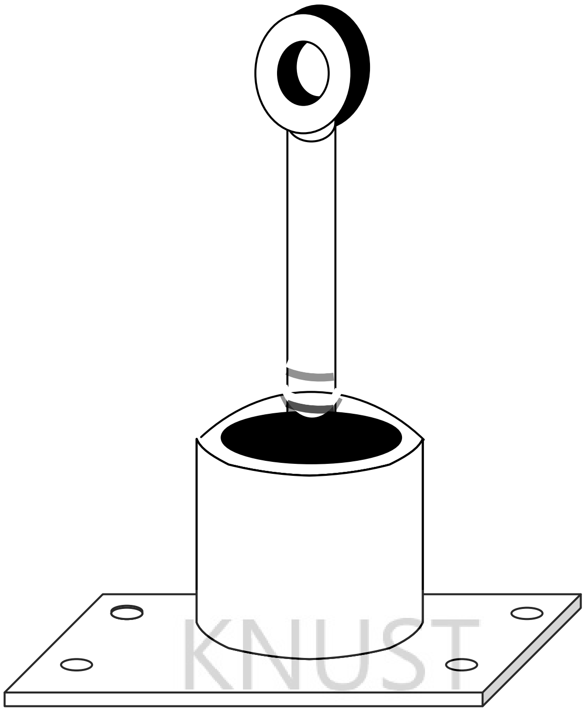


Fig 4.16 The piston

4.4.6 Bench A bench was made for the machine. This was made by welding angle irons and iron rod together, (see figure 4.17)

Figure 4.17 Machine bench

4.4.7 Paddle: A paddle was made by welding 504/2.54cm rectangular metal bars and a 0.635cm iron rods (smooth) as shown in figure 4.18

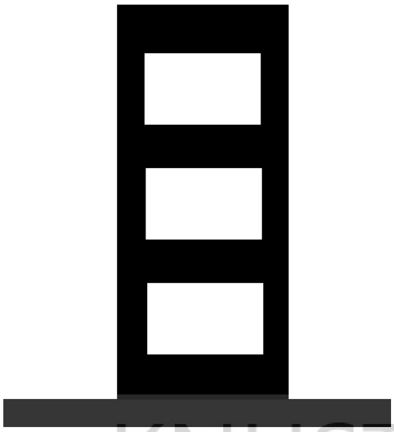


Figure 4.18 Paddle for tile press

A 0.635cm by 2.54cm bar was cut to 1’ and placed at the ends, meant to be the hinges. The paddle was fixed on the stand of the bench such that it will be above the belt when hanged on the spindle on the hopper

A stand was made for the paddle by welding an iron rod in the right angle of an angle iron and a pair of metal spring, welded on the angle iron, and shown in figure 4.19.

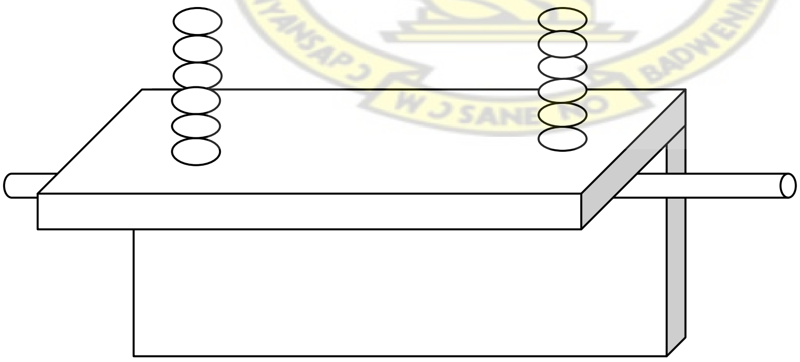


Fig. 4.19 Paddle stand

Paired holes were drilled on the stands (legs) of the bench. The paddle stand was flipped into the hole on the stand and the paddles placed on them

4.4.8 Placing of Electric Motor**:** An electric motor was placed on top of the paddle on the bench and connected to the spindle as shown in figure 4.21 this was meant to turn the shaft

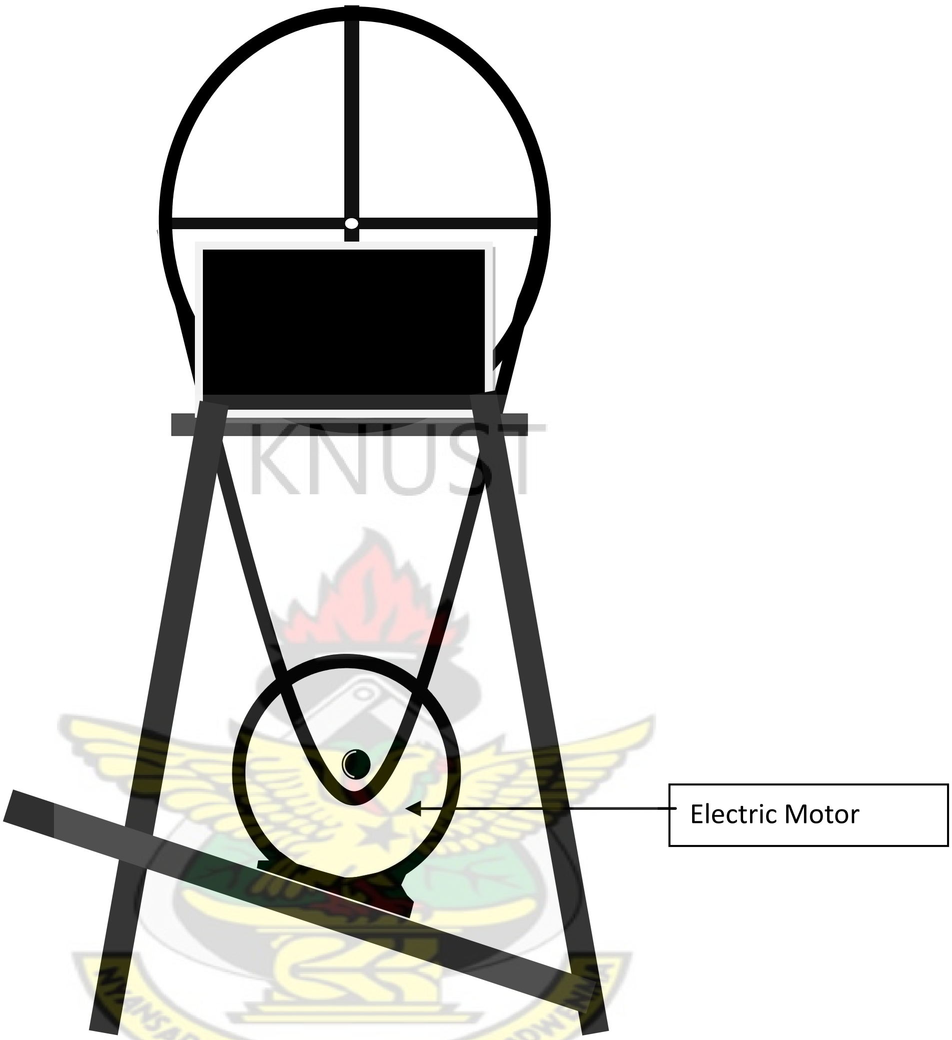


Figure 4.20 Side view of the machine

Assembly and Operation of Tile-Press

4.5 Assembly

The base, which was named plate 'A', was laid flat with screw holes facing upward and screwed to the bench. (See plate. 4.5)

Plate 4.1Base of the press screwed on the bench

The two metal plates, plate B's being the sides, were screwed unto sheet A together with angle iron, angle iron A. as shown in plate 4.6

Plate 4.2 Base and the sides of the press on the bench

The shaft with the piston was screwed on the two plate B's at the sides of the ball-ring case as shown in picture 4.7

Plate 4.3 Shaft and piston screwed on the two plate B's

One of the C's, was slotted at the back of the two sheet B's and the other with the handle slotted in front as shown plate 4.8

Plate 4.4 Artisan slotting one of the plate C's

The spindle was screwed to the long side of the shaft and a belt connected to a pulley on the motor, as shown in plate 4.9

Plate 4.5 completely assembled tile-press

4.6 Operation

The operation involved the Loading and Off-loading of feeder

4.6.1 Loading: The operation of the press also presents the researcher with the feeding and management habits of the t-press, refer B.E Waye (1964) provided in table 2.1

A Slab of plywood was placed at the base of the hopper and the required amount of feeder, (clay) was weighed and poured on the top of the wooden slab in the hooper(see Plate 4.10.)

Plate 4.6 Die fed with feeder

The piston was placed on top of the feeder, piston flipping it on top of the feeder. (See plate 4.11)

Plate 4.7 Piston being flipped to cover feeder in the hopper

The motor was started and the paddle stepped on to press the required tile. The motor revolved twice or more to permit a proper press. At the end of the press, the piston was gradually regulated. Here the ball and socket joint was pushed to the topmost end, (see plate 4.12)

Plate 4.8 A fully pressed tile with the piston opened

4.6.2 Off-loading: When the tile was fully pressed, the machine was put off and the sheet C removed by it pushing upwards. The fabricated tile was removed by pushing the piston upwards (plate 4.13)

Plate 4.9 A fully pressed tile with one of the sheet C removed.

They were removed when the piston was in an upward position. The pressing process was restarted when the piston was replaced and plate C also replaced.

A pressed tile (green) is shown in Plate 4.10 and a pile of fired tiles are shown Plate 4.11.

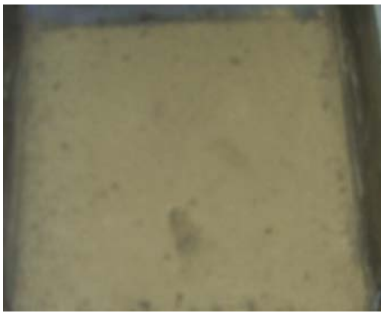


Plate 4.

Plate 4.11

CHAPTER FIVE

PRESENTATION AND DISCUSSION OF RESULTS

In this chapter the results of the study were described and the analyses of the data presented. The results described information on the step by step procedures of experiments which were basically physical and chemical tests.

In addition, the analysis indicated the relationships between variables provided from the tests performed. These tests were basically shrinkage, water absorption, tensile strength and plasticity test for physical test and corrosive test for chemical test.

The experiments performed, gave very fascinating results, which eventually led to an assertion of the potency of the ware to be produced.

5.1 Chemical Test

5.1.1 Corrosive Test: After the corrosive test it was realised that there was no significant change in weight, showing that all the bodies were resistant to salt corrosion and therefore can be used in the kitchen.

5.2 Physical Test

5.2.1 Water Absorption Tests**:** At the end of the water absorption tests at 1000^{o}C the raw data was plotted in a table appendix iii and used to calculate result as plotted in figure 5.1

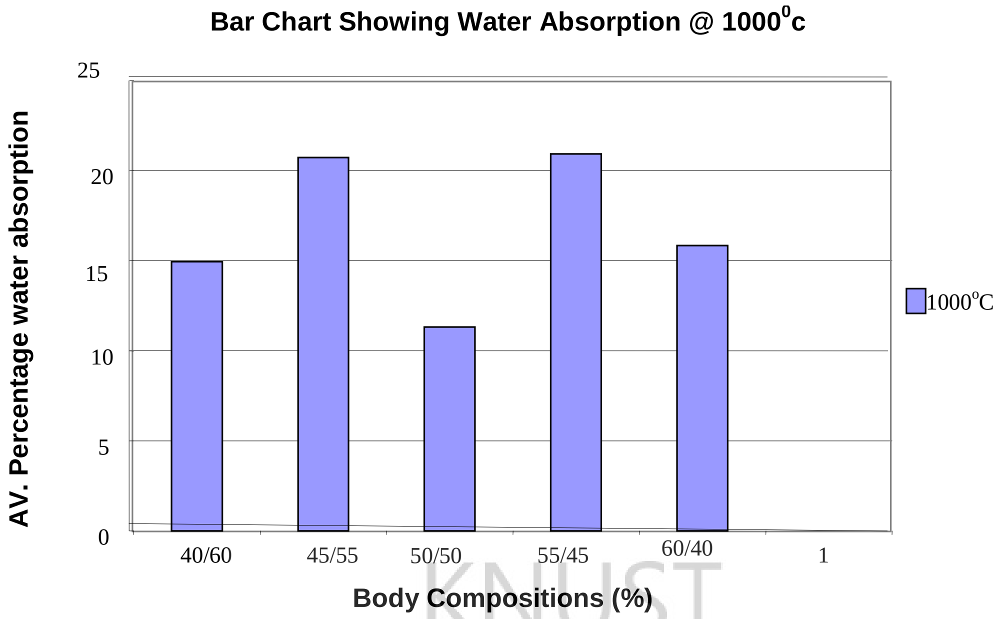


Figure 5.1 Water Absorption at1000°C

At the end of water absorption tests at 1150°C the raw data was plotted in a table and used to calculate the W.A. the results was used to plot a bar chart as shown in figure 5.2

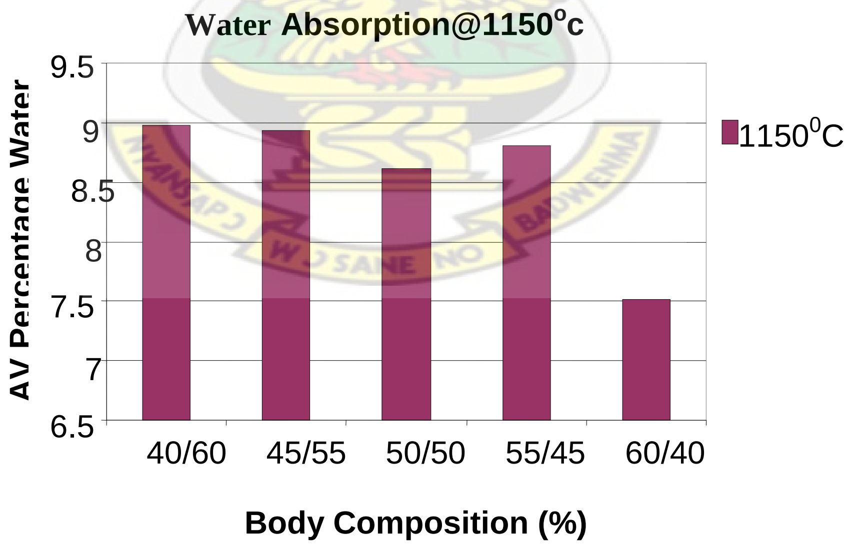


Figure 5.2 Water Absorption at 1150°C

The results of the two charts were merged to give a group bar chart which enabled a feasible analysis, and a sound discussion of findings, as shown in figure 5.3

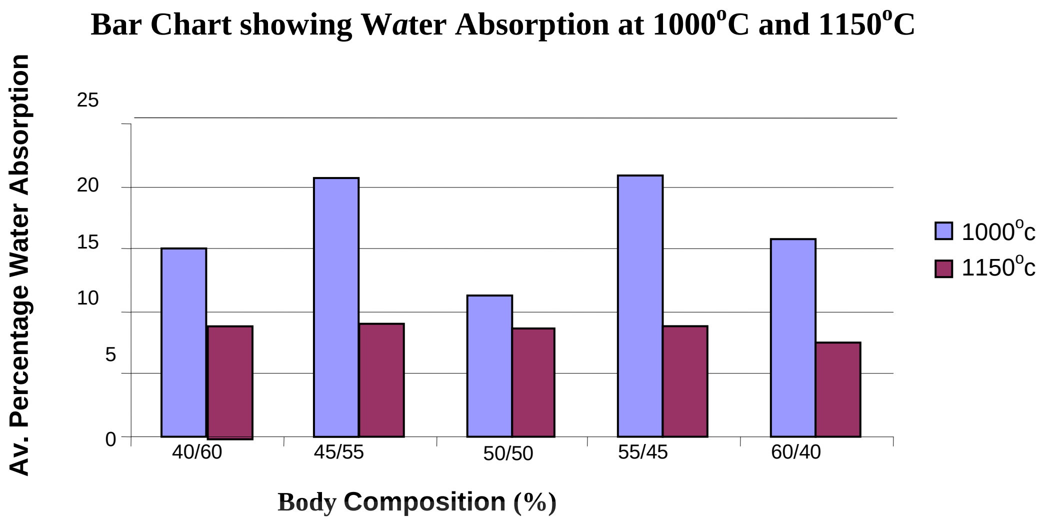


Figure 5.3 Water Absorption at 1000°C and1150°C

The end of the test for tensile strength at 1000°C and 1150°C also showed interesting results which were computed into a table and plotted in a bar chart

5.2.2 Tests for Tensile Strength: At the end of tensile strength tests at 1000°C the raw data was computed and used to calculate the T.S (formula presented in chapter 4) as shown in appendix iii and plotted in a bar chart and presented in figure 5.4

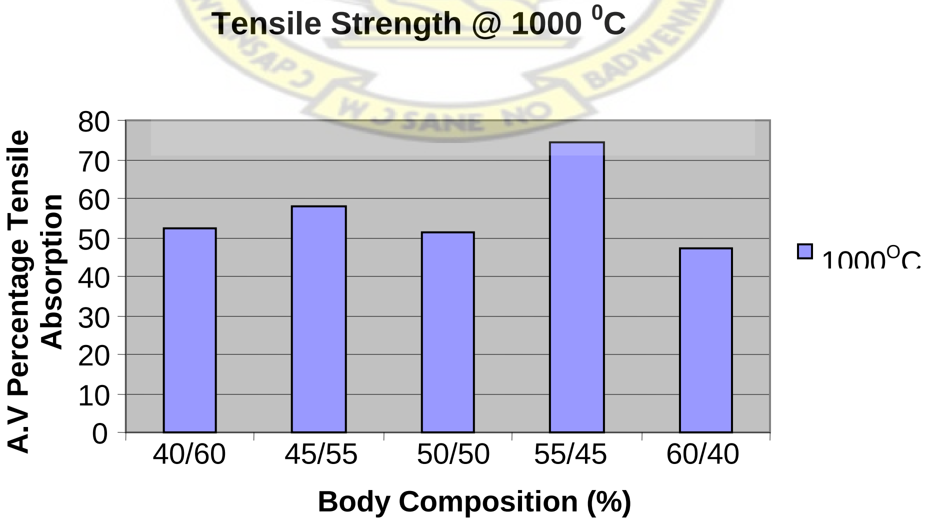


Figure 5.4 Tensile Strength Tests at 1000°C

At the end of tensile strength tests at 1150^{o}C the raw data was computed and used to calculate the T.S (formula presented in chapter 4) as shown in appendix iii and plotted in a bar chart which is presented in figure 5.5

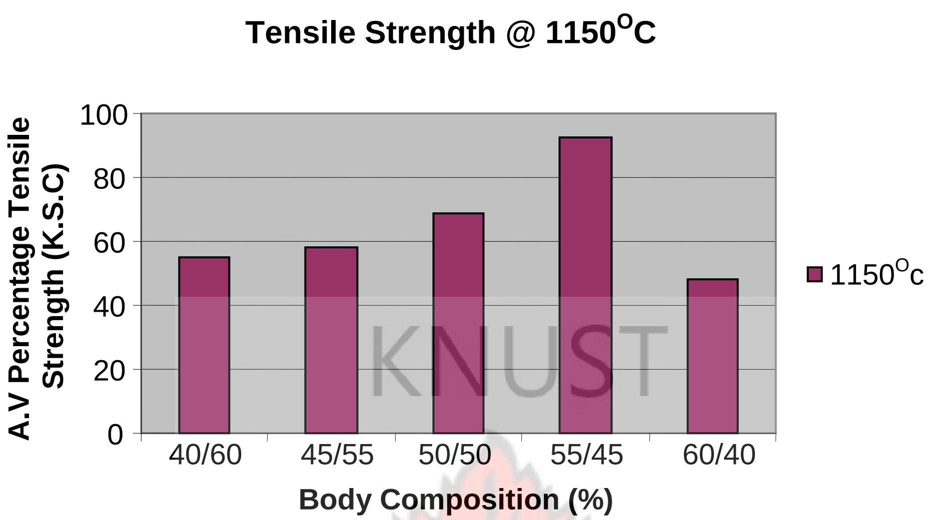


Figure 5.5 Tensile Strength Tests at 1150^{o}C

The results of the two charts were merged to enable a feasible analysis, and sound discussion of the findings, as shown in figure 5.6

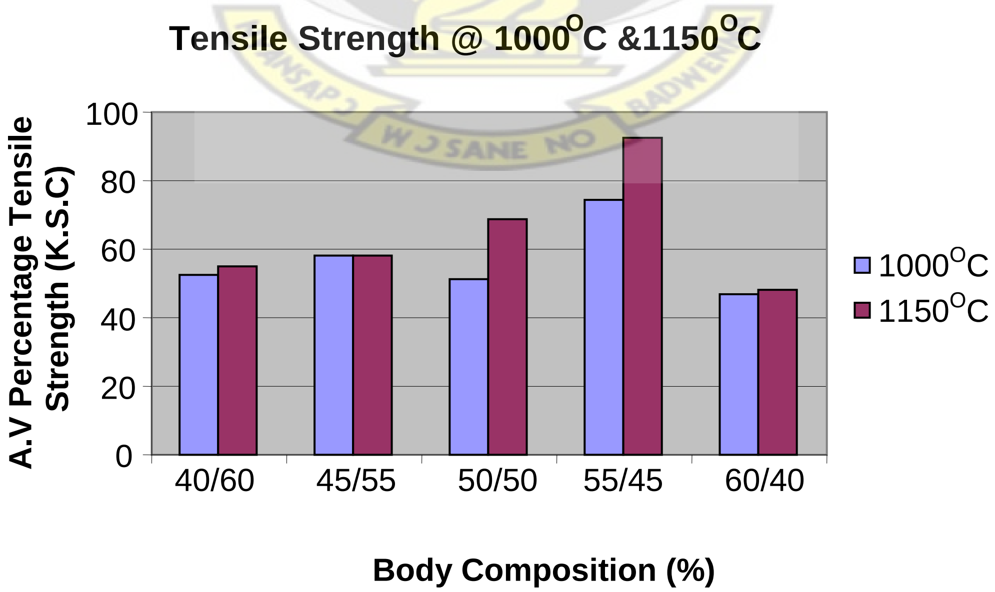


Figure 5.6 Tensile Strength Tests at 1000^{o}C and1150^{o}C

The results of the plasticity test were plotted in a graph and named plasticity chart as shown in fig. 5.7 whilst the raw data were sent to the appendix vi,viii,and viii respectively

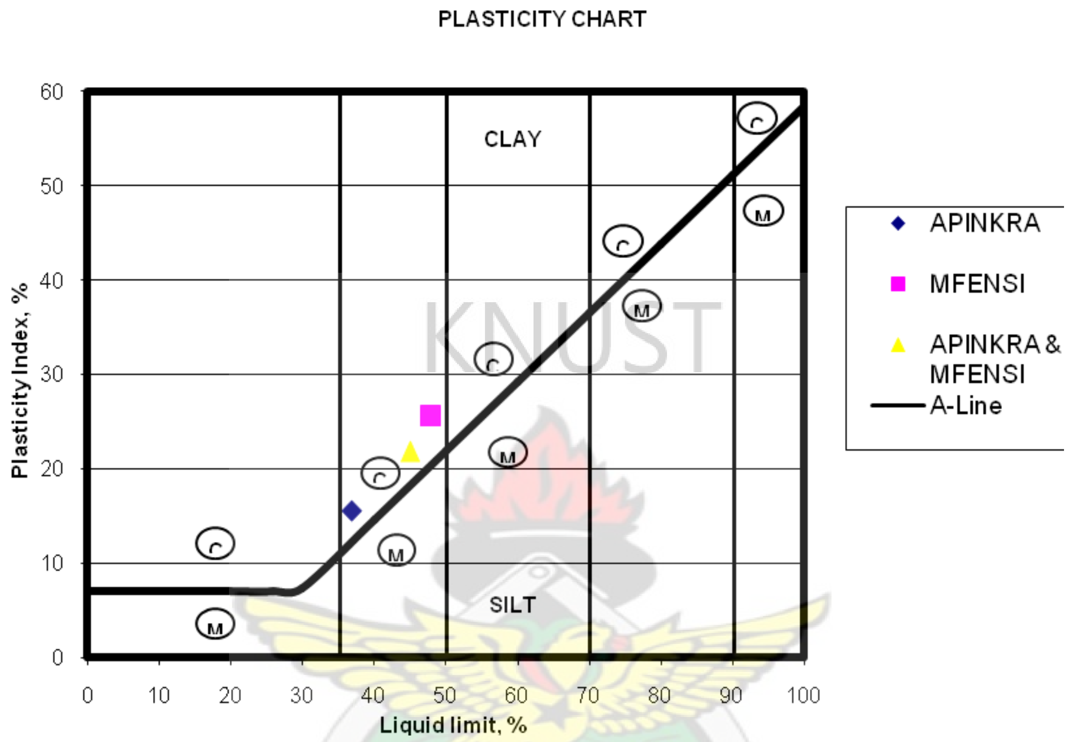


Figure 5.7 Plastic index

5.3 Tile Pressing

Force on tile= ρg Δh*A =2*9.8*6*144 =282.9J+hp (of electric motor)

Force needed to a tile = ρ*m = 0.365*144*2.15

Discussion of Results

This chapter discusses the results and findings of the study through analyses of the results.

5.4 Corrosive Test

Corrosive test using salt was performed and it showed no lost in weight indicating that the bodies were all suitable for kitchen. Since no chemical substance is used in the sitting room, the clay bodies can be used for floor tiles for the kitchen, dinning hall etc.

5.5 Water Absorption:

From the table and graph 5.4, at 1150^{O}C, all the bodies had qualified at the class of BIII which is E > 10 (it must be noted that at our part of the world, high water absorption to resist frost action is not necessary). However 60/40% gave a fascinating low absorbency.

5.6 Tensile Strength

The temperature that could be reached was only 1150^{O}C which was below the traditional stoneware temperatures which is between 1200^{O}C and 1250^{O}C. (Norton, 1974)

Owing to this limitation, 55/45 was close to the I.S.O strengths, of BIII by 1250^{O}C all the composition would have reached the required strength of class BIII and above.

5.7 Plasticity

Plasticity is rated (low; 0% – 30%, medium; 30% - 70% and high; > 70%) by the website www.patentonline.com/4253636.htm. The plasticity test performed showed that Apinkra clay which was 25.3 in the low plasticity range (non plastic) whilst Mfensi was 48.8 which was of medium plasticity. The use of Mfensi alone which is plastic could have caused the tiles to warp while the use of Apinkra alone which is coarse could have caused the tiles to crack. This is not to say that these faults should occur in any case. There are many variables that can cause faulting in tiles. But the mixture of the two clays made the bodies suitable for tile production. (Mfensi clay is above medium plastic levels and Apinkra is of low plasticity).

Capacity of usage: During operation it was realized that a team of two or more (the operator and his assistant) should operate the machine for it maximum production and efficiency.

5.8 Summary of Test Results

At the end of the various tests, their results were assembled and combined with the I.S.O. 91:100:25 standards as shown in table 5.1

I.S.O Standard

Classification / test type	**B1a**	**B1$_b$**	**BIIa**	**B11$_b$**	**B111**
Water Absorption	E ≤ 0.5% Maxi 0.6	0.5<E≤ 3% Maxi 3.3%	3< E≤6% Maxi 6.5%	6<E≤10% Maxi 11%	E>10%
Tensile Strength (M.O.R in N/mm^2)	Maxi 35 Mini 32	Maxi 30 Mini 27	Maxi 22 Mini 20	Maxi 18 Mini 16	Maxi 15 Mini 12

Table 5.1 I.S.O Standard

The data for the said results were analysed to check their potency, thus their submission to the standard (I.S.O) provided and through the analysis, deciphers those which qualify under the said standard, shown in table 5.2 and table 5.3, being water absorption and tensile strength respectively.

Table 5.2 Results of Water Absorption

	40/60	**45/55**	**50/50**	**55/45**	**60/40**	
1000^{O}C	14.946	20.73191	11.33	20.93	15.84	
1150^{O}C	8.9737	8.934322	8.618	8.8087	7.514	B111 E>10%

Table 5.3 Results of tensile Strength

	40/60	45/55	50/50	45/55	60/40	I.S.O BIII
1000^{O}C K.S.C	52.4	57.84	51.08	74.434	47.11	shall not be less than 12N/mm^2 or
1150^{O}C K.S.C	54.8	58.06 54.8	68.7154.8	92.69654 .8	48.19	122.4 K.S.C

After the assembly of the results and that of the I.S.O. as shown in tables 5.2 and 5.3 It was realised that all the bodies qualified under the class BIII which is E<10 W.A. After the assembly of the ISO and that test results of the project, it was realised that although the temperature recorded could not reach the traditional stoneware temperatures of 1200^{o}C to 1250^{0}C (Norton, 1974), the body 55/45 would reach the standard under the ISO requirement of BIII which is 12N/mm^2 equivalent to 122.4 K.S.C. at 1150^{O}C, it is 92.696 K.S.C. More of the Bodies may reach or near the required standard at the mentioned temperature.

The plastic index of the Mfensi 48.8 is medium (plastic), Apinkra 25.3 (low) non plastic and 50% / 50% was 32.8%.

5.9 Tile pressing machine

The number of tiles that can be pressed in a hopper will depend on the horsepower of the motor at work i.e. 1 horsepower may press one tone which is equivalent to 746 lbs. The web-site www.bizrate.com/powertools/products_keyword--floor+drill+press-html says that 1hp presses a tile. The amount of material to be pressed is between 2.15 to 2.17g per centimeter cube (ref. www.patent.com/638704.html) therefore, the 30cm/30cm/1cm tile (12” /12”/ 3/4”) will be equal to 1955g and then a 1.5 horse power motor should press a 30/30 cm tile. However, for a motor to last long a two-horse power motor can be used to press the tile.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In the quest to look for suitable material for the fabrication of floor tiles and the construction of a tile press to press tiles the researcher had to battle many odds to achieve the said objective.

6.1 Summary

With the objectives, to design and construct a machine for pressing tiles and to use specific local raw materials some experimental tests were conducted.

The project involved the use of a combination of the two clays i.e. Apinkra and Mfensi bodies for the manufacture of terracotta floor tiles. It became necessary that for the researcher to perform a number of experiment, which would lead to a durability and potency of the ware. It was therefore necessary to perform tests like tensile strength, water absorption, plasticity and corrosive tests to determine the durability and potency of the tile. The tensile strength gave various results with the 60/40% body being the most fascinating. Since water absorption has a wide range of values all the clay bodies qualified for group BII_2.

During its execution the project associated with some problems which include

1. Lack of equipment; the first problem that comes to mind is the availability of equipment. Some equipment and apparatus needed to conduct some of the experiments were not available; therefore tests of less important had to be ignored. Example of such equipment was the America slip scale for performing the slip test

2. At the time the only available test kiln at the Chemical Engineering Department was operating at 1000^{o}C. There was no test-kiln at the time of the project that could reach

1200^{o}C at the time of the-research. Temperatures between 1200^{o}C and 1250^{o}C are most desirable (Stoneware temperature).

3. Most of the equipments used were old and obsolete. The mettler's suspension balance for the Ceramic laboratory at the time was out of order; therefore, the porosity test could not be performed.

4. Kilns at the Ceramic section were all very old. The Art Education has no laboratory or studio of its own. Because the department does not have its own ceramic laboratory and studio, the researcher had to rely on studio and laboratories of other departments and institutions e.g. B.R.R.I, Agricultural Engineering Department etc before the project could be completed.

5. The workers of these places had their own timetables while the researcher had his own schedules. The time tables of the other different institutions and the schedule of the researcher t created great conflict of time. The researcher in the long run suffered because the laboratory assistance and technicians would not leave their busy schedules to attend to him. .

6. Lack of standards; Ghana does not have its own standard on ceramic floor tiles and so the researcher had to look for other standards before finally settling on the British standards.

7. Difficulty in obtaining International Standards; There was also a difficulty in obtaining the mentioned standards. This was because the Ghana Standard board could not give the researcher the entire requirement needed and the K.N.U.S.T Library could not also give all the requirements. The website has also restricted viewing of some of the requirements.

8. Need for Ghanaian standards; Since Ghana does not have its own standards, the researcher had to battle in other standards before finally settling with I.S.O Standards.

9. Difficulty in obtaining appropriate Literature; There were limited publications in the Libraries but the researcher had to fall on information from web-site and also moved from library to library for information.

10. Problems on the construction of Tile Press; the researcher encounted difficulties in working with technicians and artisans

11. Since the department does not have its own workshop, the researcher had to rely on other workshops of other institutions. Here also the workers of these workshops seem too busy most of the time that they would not have enough time for the researcher and his “project”.

12. Technicians and artisans inability to make a straight shaft; The researcher had a difficulty in getting an artisan who could make a straight and uniform shaft from a rod. The one made was so bad that the researcher had to make modifications on the shaft of a motor-bicycle.

13. The researcher’s work slowed down due to the then power cuts; there were times when there was power failure for three months at the place (B.R.R.I) where the tile press was undergoing construction. These and others caused the delay in the execution of the project.

6.2 Conclusions

Clay deposits in the Ashanti region with much emphasis with those of Apinkra and Mfensi communities went through a series of studio experiments and clay body preparation. After a number of tests two of the bodies were selected from the mentioned deposits. These bodies were selected for the study due to certain qualities found in them. In order to reach appreciable results all aiming at the production of the production of the actual floor tile, a tile pressing machine was designed and constructed which proved to be an ideal mechanism for tile production on the small-scale induction, basic school and freelance ceramic studio artist. The study provides a good platform for the development of tile production in the nation using purely local materials and equipment.

6.3 Recommendations

After the various test and the construction of the tile press it researcher has the following recommendations:

The temperature the researcher could reach was 1150^{o}C. If a researcher wants to pursue this project further at least 1250^{o}C should be reached. These temperatures many more of bodies would reach the required the ISO standard.

Water absorption at 7.5% (60/40%) may also come back to 6% or below at 1250^{o}C, the body and some other bodies will reach the tensile strength of BII_b of the I.S.O. 91:100:25

The recommended body here will be 55%/ Apinkra 45% Mfensi and Apinkra 60% / Mfensi 40% in the order to arrive are the required ISO standard.

The reasons are as follows;

The main experiments performed show that all the values for water absorption passed for the groups AII_b and BIII which are = $6\% < E \leq 10\%$ and BIII =E > 10%. On tensile strength though most of the bodies could not reach the required standards, it is recommended that most of the bodies should reach the I.S.O standard of BIII i.e. 12N/mm^2 or higher at 1150/1250^{0}C

6.3.1 Corrosion Test: A corrosion test on salt was performed on the body and no lost of weight was realized. The tile can be used in the kitchen and dinning hall, sitting room etc. therefore it is recommended that further chemical test on the fired body should be performed e.g. Ammonia test, tests with other Acids etc. A Modulus of surface hardness (MOHS) test should also be performed to ascertain the ware resistance of the body. There should be further test for bodies below and above the already experimented bodies.

6.3.2 Further Experiment: Further experiment up to 1250^0C should be performed to ascertain the potency clay bodies. The Art Education Department should be equipped with modern studios, workshops and laboratories.

The KNUST Library should purchase up to date standard. Ghana standard board should also prepare standards on floor tiles and other ceramic wares. The Library should again purchase up-to-date books ceramics.

6.3.3 Number of workers at the Hooper: During operation, it was realized that it would be appropriate that two workers work on a hopper. If there is an extension then the ratio may differ since one person may be able to assist two workers may be desirable. An appreciable amount feeder should be prepared in advance before production proceeds.

6.3.4 Number of Dies or hoppers: More than one hopper can be powered with one motor, depending on power of the motor. As shown in Figure 6.1

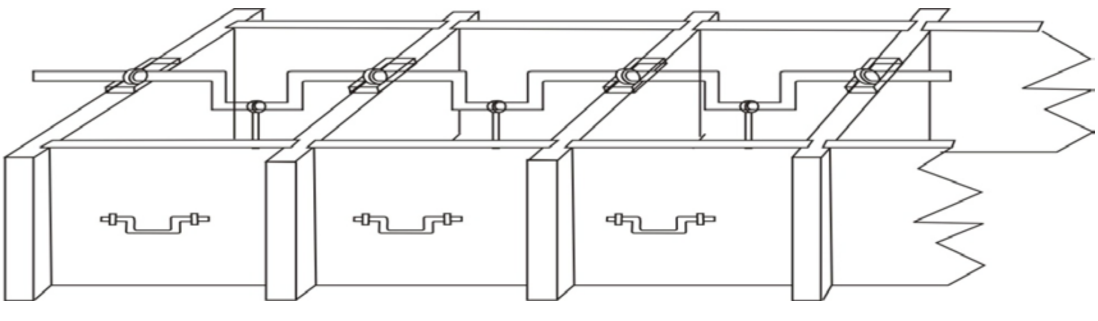


Figure 6.1 tile press made with series of hoppers

6.3.5 Capacity of usage: This machine is recommended for small-scale industries. An operator and assistant (team of 2) must operate the machine. The press can also be used in pressing other tiles e.g. Roofing tiles provided suitable moulds be fixed unto it.

6.3.6 Modification of parts: A better shaft can be made from the one-inch rod. However, it should be straight and uniform.

6.3.7 A vibrator disc: Due to financial difficulties the researcher could not make a vibrator. A vibrator disc can be made underneath to create a vibro-mechanical effect. This can be made by welding four iron rods on a flat metal sheet and passing them through holes made in the base. Strips of gears can be welded on the tips in such a way that it corresponds to a geared pulley on the electric motor as shown in Figure 6.2. This is the researchers own invention.

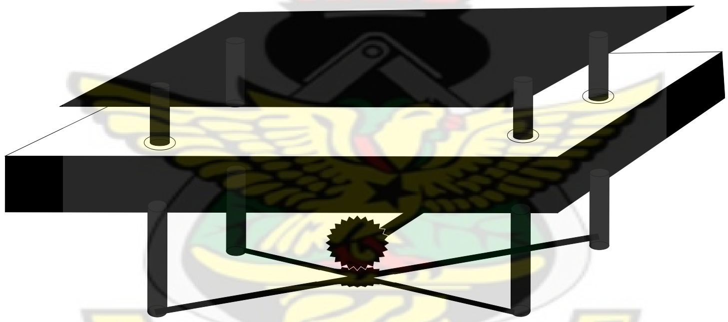


Figure 6.2 Recommended vibro-mechanical devices

6.3.8 Further research: It is finally recommended that further research should be carried out to improve upon the invented tile press and the clay bodies.

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APPENDIX I

		40			45			50			55			60	
	L_1	L_3		L_1	L_3		L_1	L_3		L_1	L_3		L_1	L_3	
i	4.6	4.5	2.17	4.7	4.5	4.26	4.9	4.8	2.04	4.8	4.5	6.25	4.7	4.5	4.255
ii	4.6	4.5	2.17	4.7	4.5	4.26	4.8	4.6	4.17	4.7	4.6	2.13	4.7	4.6	2.128
iii	4.6	4.5	2.17	4.6	4.6	0	4.9	4.9	0	4.7	4.5	4.26	4.75	4.6	3.158
iv	4.7	4.6	2.13	4.8	4.6	4.17	4.8	4.5	6.25	4.7	4.5	4.26	4.6	4.5	2.174
v	4.7	4.6	2.13	4.8	4.5	6.25	4.8	4.7	2.08	4.9	4.8	2.04	4.65	4.6	1.075
vi	4.6	4.5	2.17	4.6	4.4	4.35	4.8	4.7	2.08	4.8	4.5	6.25	4.6	4.4	4.348
vii	4.7	4.6	2.13	4.8	4.6	4.17	4.8	4.6	4.17	4.6	4.5	2.17	4.7	4.6	2.128
viii	4.6	4.5	2.17	4.6	4.6	0	4.8	4.8	0	4.8	4.6	4.17	4.75	4.6	3.158
ix	4.6	4.5	2.17	4.8	4.6	4.17	4.8	4.5	6.25	4.7	4.5	4.26	4.5	4.4	2.222
x	4.7	4.6	2.13	4.8	4.5	6.25	4.8	4.7	2.08	4.9	4.8	2.04	4.65	4.6	1.075
			2.16			3.79			2.91			3.78			2.572

Raw data of Shrinkage at 1000^{0}C

APPENDIX II

		40			45			50			55			60		
	L1	L_2		L_1	L_2		L_1	L_2		L_1	L_2		L_1	L_2		
i	4.6	4.4	4.35	4.7	4.4	6.38	4.9	4.6	6.12	4.8	4.4	8.33	4.7	4.4	6.383	4.348
ii	4.6	4.5	2.17	4.7	4.3	8.51	4.8	4.6	4.17	4.7	4.5	4.26	4.7	4.5	4.255	4.167
iii	4.6	4.4	4.35	4.6	4.3	6.52	4.9	4.7	4.08	4.7	4.4	6.38	4.75	4.4	7.368	4.348
iv	4.7	4.5	4.26	4.8	4.5	6.25	4.8	4.6	4.17	4.7	4.4	6.38	4.6	4.4	4.348	4.255
v	4.7	4.5	4.26	4.8	4.6	4.17	4.8	4.6	4.17	4.9	4.7	4.08	4.7	4.65	1.064	4.255
vi	4.6	4.4	4.35	4.6	4.4	4.35	5	4.8	4	4.9	4.6	6.12	4.6	4.4	4.348	4.167
vii	4.7	4.5	4.26	4.8	4.4	8.33	4.7	4.5	4.26	4.5	4.3	4.44	4.5	4.3	4.444	4.255
viii	4.6	4.4	4.35	4.7	4.5	6.83	4.7	4.6	2.13	4.65	4.5	3.23	4.8	4.5	6.25	4.167
ix	4.7	4.5	4.26	4.7	4.5	4.26	5	4.8	4	4.7	4.4	6.38	4.5	4.4	2.222	4.255
x	4.7	4.6	2.13	4.8	4.4	8.33	4.8	4.6	4.17	4.7	4.5	4.26	4.6	4.5	2.174	4.082
			3.87			6.39			4.13			5.39			4.286	4.23

Raw data of Shrinkage at 1150^{0}C

APPENDIX III

	40			45			50			55			60		
	W_2	W_1		W_2	W_1		W_2	W_1		W_2	W_1		W_2	W_1	
I	44	38	15.8	38	32	18.8	50.7	44.6	12.42	49	42	16.667	39	33	18.18
ii	46	39	17.9	42. 9	36.5	17,53	52.4	46.1	14.82	47	39	20.513	40	34	17.65
iii	35	34	2.94	43	37	16.2	51	45.1	11.71	56	47	19.149	40	37	8.108
iv	52	44	18.2	43	42	2.38	45.4	39.9	13.65	48. 2	40.5	19,91	41	35	17.14
v	44	37	18.9	52	35	48.6	48.5	42.8	11.61	51	43	18.605	46	39	17.95
vi	43	37	16.2	37	31	19.4	51	45.1	11.71	48	43	11.628	40	32	25
vii	45	39	15.4	39	33	18.2	45.2	39.7	13.85	48	38	26.316	39	35	11.43
viii	45	38	18.4	38	31.9	19.1	50.6	44.7	13.2	56	48	16.667	39	36	8.333
ix	47	40	17.5	36	33	9.09	48.5	44.6	8.744	47. 2	41.5	13,73	42	36	16.67
x	40	39	2.56	45.5	35	30	46.1	45.4	1.542	52	43	20.93	46	39	17.95
		=	14.4			20.4			11.33			20.93			15.84

Raw data of Water absorption at 1000°c

APPENDIX I

		40			45			50			55			60	
	W2	W1		W2	W1		W2	W1		W2	W1		W2	W1	
i	40	37	8.11	34	31	9.677	20	17.8	11	45	41	9.76	35	33	6.06
ii	42	38	10.5	39	36	8.333	26.3	24.4	7.22	43	39	10.3	36	33	9.09
iii	37	34	8.82	39	36	8.333	30.2	29	3.97	51	47	8.51	39	36	8.33
iv	47	43	9.3	38	35	8.571	24.4	22.7	6.97	44	40	10	37	34	8.82
v	40	37	8.11	47	41	14.63	20.7	18.6	10.1	47	43	9.3	40	38	5.26
vi	42	38	10.5	34	31	9.677	19.6	17.8	9.18	45	41	9.76	35	33	6.06
vii	40	37	8.11	39	36	8.333	19.6	17.8	9.18	43	39	10.3	36	33	9.09
viii	37	34	8.82	38	35	8.571	20.7	18.8	9.18	51	47	8.51	39	36	8.33
ix	47	43	9.3	39	36	8.333	20.7	18.6	10.1	44	40	10	37	34	8.82
x	40	37	8.11	47	41	14.63	19.6	17.8	9.18	47	43	9.3	40	38	5.26
			8.97			9.91			8.62			9.57			7.51

Raw data of Water absorption of various bodies @ 1150°C

APPENDIX V

		A 40	40		=	A 45	45			A 50	50		S	A55	55			A 60	60	
i	1.2	1.3	2.1	44	1.3	1	2.5	57.04	1	1.3	1.7	54.3	1	1.3	5.3	110.96	1.1	1.2	2.5	47.64
ii	1.2	1.3	2.6	54.4	1.2	1	3	62.81	1.1	1.3	1.7	49.36	1	1.3	3.9	95.823	1.2	1.3	2.1	43.96
iii	1.3	1.3	2.5	61.4	1	1	3.5	47.25	1	1.1	1.8	41.16	1	1.3	2.7	56.526	1.1	1.2	2.3	43.83
iv	1.2	1.3	2.7	56.5	1.3	1	2.6	59.32	1	1.3	1.5	47.91	1	1.3	2.6	54.432	1.3	1.3	2.2	54.05
v	1.1	1.5	3	45.7	1.2	1	3	62.81	1	1.3	1.7	54.3	1	1.3	2.6	54.432	1.2	1.3	2.2	45.01
vi	1.2	1.3	2.1	44	1.3	1	2.5	57.04	1	1.3	1.7	54.3	1	1.3	5.3	110.96	1.1	1.2	2.5	47.64
vii	1.2	1.3	2.6	54.4	1.2	1	3	62.81	1.1	1.2	1.7	42.06	1	1.3	3.9	95.823	1.2	1.3	2.1	43.96
viii	1.3	1.3	2.5	61.4	1	1	3.5	47.25	1	1.3	1.8	57.49	1	1.3	2.7	56.526	1.1	1.2	2.3	43.83
ix	1.2	1.3	2.7	56.5	1.3	1	2.6	59.32	1	1.4	1.5	55.57	1	1.3	2.6	54.432	1.3	1.3	2.2	54.05
x	1.1	1.5	3	45.7	1.2	1	3	62.81	1	1.3	1.7	54.3	1	1.3	2.6	54.432	1.2	1.3	2.3	47.1
AVERAGE				52.4				57.84				51.08				74.434				47.11

Raw data of tensile strength at 1000^0c

APPENDIX VI

		40				45				50				55				60		
i	1	1.3	4.5	65.4	0.9	1.3	4.25	50.05	0.9	1.3	4.25	50.05	1.2	1.3	9.7	203.7	1.1	1.2	2.5	47.64
ii	0.9	1.1	3	41.8	1	1.2	3.4	53.55	1.1	1.3	3.54	62.27	1	1.4	5	67.5	1.1	1.2	3	57.17
iii	1	1.2	2.5	39.4	0.9	1.2	4.5	57.41	1	1.2	2.5	39.38	1.1	1.3	4	70.366	1.1	1.4	4	65.34
iv	1.1	1.2	5	95.3	1.2	1.3	2.7	56.53	1	1.2	4.5	70.88	1	1.1	3	51.545	1	1.2	2.5	39.38
v	0.8	1.2	2.7	27.2	1	1.3	4.6	66.88	1.1	1.3	4	70.37	1.1	1.3	4	70.366	1.2	1.3	1.5	31.4
vi	1	1.3	4.5	65.4	1	1.3	4.25	61.79	1	1.2	2.5	39.38	1.2	1.3	9.7	203.7	1.1	1.2	2.5	47.64
vii	1	1.1	3	51.5	1	1.2	3.4	53.55	1.1	1.3	3.54	62.27	1	1.4	5	67.5	1.1	1.2	3	57.17
viii	1	1.2	2.5	39.4	0.9	1.2	4.5	57.41	1.1	1.3	8.6	151.3	1.1	1.3	4	70.366	1.1	1.4	4	65.34
ix	1.1	1.2	5	95.3	1.2	1.3	2.7	56.53	1	1.2	4.5	70.88	1	1.1	3	51.545	1	1.2	2.5	39.38
x	0.8	1.2	2.7	27.2	1	1.3	4.6	66.88	1.1	1.3	4	70.37	1.1	1.3	4	70.366	1.2	1.3	1.5	31.4
AVERAGE				54.8				58.06				68.71				92.696				48.19

Raw data of tensile strength at 1150^{o}c

APPENDIX VII

Plasticity Test (Mfensi)

RAW DATA LIQUID LIMIT DETERMINATION **ATTERBERG LIMITS** **LOCATION MFENSI**

TRIAL NO			1	2	3	4	
NO. OF BLOWS			42.0	28.0	16.0	7.0	
CONTAINER NO.							
Wt OF WET SAMLPE + CONTAINER			24.5	28.4	31.3	34.1	
Wt OF DRY SAMLPE + CONTAINER			19.9	22.3	24.1	25.6	
Wt OF WATER			4.6	6.1	7.2	8.5	
Wt OF CONTAINER			9.5	9.5	9.9	10.1	
Wt OF DRY SOIL			10.4	12.8	14.2	15.5	
MOISTURE CONTENT			**44.23**	**47.66**	**50.70**	**54.84**	**LL** **48.0**

RAW DATA PLASTIC LIMIT DETERMINATION

TRIAL NO		1	2				
CONTAINER NO.							
Wt OF WET SAMLPE + CONTAINER		18.2	18.8				
Wt OF DRY SAMLPE + CONTAINER		16.1	16.5				
Wt OF WATER		2.1	2.3				
Wt OF CONTAINER		6.7	6.4				
Wt OF DRY SOIL		9.4	10.1				
MOISTURE CONTENT		22.3	22.8	**PL=**	**22.6**	**PI**	**25.4**

APPENDIX VIII

Plasticity Test (Apinkra)

RAW DATA LIQUID LIMIT DETERMINATION **ATTERBERG LIMITS** **LOCATION APINKRA**

TRIAL NO	1	2	3	4		
NO. OF BLOWS	38.0	22.0	14.0	6.0		
CONTAINER NO.	A1	A2	A3	A4		
Wt OF WET SAMLPE + CONTAINER	23.5	26.4	29.1	30.8		
Wt OF DRY SAMLPE + CONTAINER	19.9	21.8	23.7	24.6		
Wt OF WATER	3.6	4.6	5.4	6.2		
Wt OF CONTAINER	9.8	9.6	9.9	10.0		
Wt OF DRY SOIL	10.1	12.2	13.8	14.6		
MOISTURE CONTENT	**35.64**	**37.70**	**39.13**	**42.47**	**LL**	**37.0**

RAW DATA PLASTIC LIMIT DETERMINATION

TRIAL NO	1	2				
CONTAINER NO.	A1	A2				
Wt OF WET SAMLPE + CONTAINER	18.0	18.3				
Wt OF DRY SAMLPE + CONTAINER	16.0	16.2				
Wt OF WATER	2.0	2.1				
Wt OF CONTAINER	6.7	6.4				
Wt OF DRY SOIL	9.3	9.8				
MOISTURE CONTENT	21.5	21.4	**PL =**	**21.5**	**PI**	**15.5**

APPENDIX IX

Plasticity Test (Mfensi and Apinkra)

RAW DATA LIQUID LIMIT DETERMINATION **ATTERBERG LIMITS** **LOCATION** APINKRA & MFENSI

TRIAL NO	1	2	3	4	
NO. OF BLOWS	43.0	31.0	19.0	7.0	
CONTAINER NO.					
Wt OF WET SAMLPE + CONTAINER	24	27.9	30.1	38.6	
Wt OF DRY SAMLPE + CONTAINER	19.7	22.1	23.7	29.2	
Wt OF WATER	4.3	5.8	6.4	9.4	
Wt OF CONTAINER	9.5	9.5	9.7	10.0	
Wt OF DRY SOIL	10.2	12.6	14.0	19.2	
MOISTURE CONTENT	**42.2**	**46.0**	**45.7**	**49.0**	**LL** 45.0

RAW DATA PLASTIC LIMIT DETERMINATION

TRIAL NO	1	2			
CONTAINER NO.					
Wt OF WET SAMLPE + CONTAINER	18.4	18.7			
Wt OF DRY SAMLPE + CONTAINER	16.2	16.4			
Wt OF WATER	2.2	2.3			
Wt OF CONTAINER	6.6	6.6			
Wt OF DRY SOIL	9.6	9.8			
MOISTURE CONTENT	22.9	23.5	**PL =**	23.2	**PI** 21.8

APPENDIX X

Raw Data Corrosive test at 1150^{0}C

	40			45			50			55		60			
	w1	w2		w1	w2		w2	w1		w2	w1		w2	w1	
I	37	41.44	36.98	31	34.72	31	17.8	19.936	17.8	41	45.92	41	33	36.96	33
ii	38	42.56	38	36	40.32	36	24.4	27.328	24.4	39	43.68	39	33	36.96	33
iii	34	38.08	34	36	40.32	36	29	32.48	29	47	52.64	47	36	40.32	36
iv	43	48.16	42.99	35	39.2	34.99	22.7	25.424	22.6	40	44.8	40	34	38.08	34
v	37	41.44	37	41	45.92	41	18.6	20.832	18.6	43	48.16	43	38	42.56	38
vi	38	42.56	38	31	34.72	30.89	17.8	19.936	17.8	41	45.92	41	33	36.96	33
vii	37	41.44	37	36	40.32	36	17.8	19.936	17.8	39	43.68	39	33	36.96	33
viii	34	38.08	34	35	39.2	35	18.8	21.056	18.8	47	52.64	47	36	40.32	36
ix	43	48.16	43	36	40.32	36	18.6	20.832	18.6	40	44.8	40	34	38.08	34
x	37	41.44	37	41	45.92	41	17.8	19.936	17.8	43	48.16	43	38	42.56	38
	37.8		37.797	35.8		35.788	20.33		20.32	42		42	34.8		34.8