THE DESIGN AND FABRICATION OF TILE MAKING MACHINE

BY

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DECLARATION

I hereby declare that the work in this thesis titled "The Design and Fabrication of Tile Making Machine" was performed by me in the Department of Industrial Design, Ahmadu Bello University, Zaria under the supervision of Prof. U. A. A. Sullayman and Dr. D. S. Yawas.

All information derived from other literatures have been duly acknowledged in the text and in the list of references provided. No part of this work has been presented for another degree or diploma at any institution.

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CERTIFICATION

This thesis titled "THE DESIGN AND FABRICATION OF TILE MAKING MACHINE" by *MORAKINYO, Abraham David* (MA/ENV – DESIGN/12853/2007-2008) meets the regulations governing the award of degree of Masters of Arts (MA) in Industrial Design, Department of Industrial Design Ahmadu Bello University, Zaria, Nigeria and it is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is specifically dedicated to God Almighty who for His mercy, affection and destiny gave me the strength to undertake this research. I give glory and unequivocal encomium to his name. I also dedicate this work to my lovely wife, Mrs. Chizoba Maryann Morakinyo, our children Oluwaramipada (late), Ajinde and my son Mercy (late) who endured the period of my absence, through the thin and thick.

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ABSTRACT

This study is centre on the design and construction of an extrusion tile-making machine, following specific design standards, design considerations, design theories and calculations, to improve the level of efficiency of production in ceramic industries and institutions of higher learning in Nigeria. Mild steel, stainless steel, cast iron and wood were the materials utilized in the fabrication of this machine. A mathematical modelling was first produced of the entire machine. Each component of the designed machine was drawn with AutoCAD, sketch up and pen. The various forces acting on the machine and other relevant mechanics were calculated before the physical fabrication. The machine is about 450cm long with three important sections: the processing, stamping and cutting, and the receiving section, powered by an electric gear motor of 3hp. Two major bodies were compounded from clay, feldspar, silica and kaolin and the second was of kaolin and clay in different percentages. After beneficiation they were lined and quaixially blended. Performance and capacity tests were employed to check the effectiveness of the machine and extrusion of sample tiles. Sample tiles of 30by30cm, 20by20cm, 15 by 15cm and 10 by 10cm in thickness of 20, 15, 12 and 10mm respectively were extruded and fired to a high bisque temperature of 1100 ^{0}C. An average of 48 of 20 x 20 cm^2 and 72 of 15 x 15 cm^2 pieces of tiles were extruded in an hour, 384 and 576 pieces of tiles in a day and 10,752 and 16,128 pieces of tiles in a month respectively. The following Mechanical tests were carried out on the tiles produced: Hardness Test, Impact Test and Tensile Strength tests. These tests results were compared with the mechanical properties of existing China Tiles. The work gave encouraging results because at least the mechanism that was proposed worked and produced usable samples of tiles in different proportion and thickness. This is stimulus for evolving more enduring researches to upgrade our indigenous technology using available local materials.

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LIST OF ABBREVATIONS

PEI: Porcelain Enamel Institute

GGI: Green Guard Institute

DSAN: Department of Statistical Analysis

AC: Alternating Current

DC: Direct Current

CAD: Computer Aided Design

IEA: International Ergonomics Association

IWM: In Weight of Material

RSI: Repetitive Stress Injuries

EMHBCGV4: Engineering Handbook Ceramic and Glass Volume 4

Uni. University

EN: European Standard

ANIA: American National Standards Institute

ASTM: American Standard of Testing Materials

E: Water absorption

TMM: Tile Moulding Machine

Auto CAD: Automatic Computer Aided Design

ABU: Ahmadu Bello University

FUTY: Federal University of Technology Yola

ATBU: Abubakar Tafawa Balewa University

Vol: Volume

H: Heightion factor

SOH: Sin, Opposite, Hypotenuse

CAH: Cosine, Adjacent, Hypotenuse

TOA: Tangent, opposite, Adjacent

ASM: American Society for Metals

Fig: Figure

VPW: Vacuum power wedger

R & D: Research and Development

Ca: Calcium

K: Potassium

N_a: Sodium

L: length

B: Breath

IDC: Industrial Development Centre

POP: Plaster of Paris

MST: Moulded sample tiles

TB: Test bars

Etc: Etcetera

C.I.: Cast Iron

US: United States

S/N: Serial Number

LIST OF NOTATIONS AND SYMBOLS

L: load

E: effort

f: fulcrum

Ø: diameter

k_f: the fatigue-concentration factors

n: constant for the type of column end support

S_e: endurance strength

M_a: bending moment for alternating stress

T_a: torque for alternating stress

α: Alpha

μ: coefficient of friction

≈ : Approximately

θ: Theta

σ: Sigma

γ : Gamma

δ: Delta

∴ : Therefore

$\sqrt[3]{}$: Cube root

π: PI

σ_o: allowable static stress

°F : Degree Fahrenheit

°C: Degree Celsius

∵: Because

r: Radius

h.p.: Horse Power

k: Constant

kg/mm^2: kilogramme per millilitre square

E_P: Young's modulus for pinion

E_g: Young's modulus for gear

V.R.: Velocity Ratio

W_w: Maximum or limiting load for wear in Newton

F_S: Safe shear stress in shaft material

f: Permissible stress in arms material

m: Bending moment

α: Major axis of elliptical section

g: Acceleration due to gravity

v: velocity

б: maximum shear stress of the material (480 mpa)

I: Moment of inertia

%: Percentage

MPa: Mega Pascal

psi: Pounds Square inch

C_V: Velocity ratio

W_T: Tangential tooth load

W_N: Normal load acting between the tooth surfaces

W_R: Resultant load acting on gear

τ: Tau

σ_c: Circulating stress

Z: Section modulus

(a): Abrasion Resistance

≤: Less-than or equal to

≥: Greater-than or equal to

H_2O: Water

HB: Hardness Scale (B)

HRF: Hardness Rockwell Scale (F)

wt%: Percentage

mm^2: Millimetres square

cm^3: Centimetre cubic

Nm: Newton metre

rpm: Revolution per minute

T: Torque

TS: Tensile Strength

T_e: Equivalent twisting moment

N/mm^2: Newton per millimetre square

N: Newton

h.p: Horse Power

kw: Kilo watts

mm: Millimetre

K.g.: kilograms

mhp: Mili Horse Power

w: Watts

ft: foot

Ib: pounds

METRIC CONVERSION TABLE

To Convert By	Multiply By	To Convert	Multiply
Length			
inches to millimeters	25.4	millimeters to inches	0.0393701
feet to meters	0.3048	meters to feet	3.28084
Centimeters to inches	0.3940	Inches to centimeters	2.54
yards to meters	0.9144	meters to yards	1.09361
Area			
square inches to square centimeters	6.4516	square centimeters to square inches	0.1550
square feet to square meters	0.092903	square meters to square feet	10.7639
square yards to square meters	0.836127	square meters to square yards	1.19599
square miles to square kilometers	2.589988	square kilometers to square miles	0.386102
Volume/Capacity			
cubic inches to cubic centimeters	16.387064	cubic centimeters to cubic inches	0.061024
cubic feet to cubic meters	0.028317	cubic meters to cubic feet	35.3147
cubic yards to cubic meters	0.764555	cubic meters to cubic yards	1.30795
cubic miles to cubic kilometers	4.1682	cubic kilometers to cubic miles	0.239912

Source:- Encarta (2009)

Mass/Weight			
ounces to grams	28.349523	grams to ounces	0.035274
pounds to kilograms	0.453592	kilograms to pounds	2.20462
stone (14 lb) to kilograms	6.350293	kilograms to stone (14 lb)	0.157473
tons (U.S.) to kilograms	907.18474	kilograms to tons (U.S.)	0.001102
tons (imperial) to kilograms	1016.046909	kilograms to tons (imperial)	0.000984
tons (U.S.) to metric tons	0.907185	metric tons to tons (U.S.)	1.10231
tons (imperial) to metric tons	1.016047	metric tons to tons (imperial)	0.984207

Source:- Encarta (2009)

Mass

S/No	When you know	Multiply by	To find
1.	Ounces (oz)	28.349	Milliliters (ml)
2.	Pounds (Ib)	0.454	Liters (l)
3.	Long Tons (2,240 Ib)	1.016	Liters (l)
4.	Grams (g)	0.035	Liters (l)
5.	Kilograms (kg)	2,205	Liters (l)
6.	Tones (t)	0.984	Liters (l)

Source:- Sullayman (2005)

Selected Conversions

S/No		
1.	1 in = 1 inch	25.4×10^{-3} m (= 25.4 mm)
2.	1 ft = 1 foot	0.3048m
3.	$1 in^2 = 1 inch^2$	0.64516×10^{-3} m^2 ($6.452 cm^2$)
4.	$1 ft^2 = 1 foot^2$	$0.0929 m^2$

Source:- Sullayman (2005)

Volume and Capacity

S/No	Derived Measurement	Unit	Symbol
1.	Force	Newton	N = kg. m/s^2
2.	Pressure	Pascal	Pa = N/m^2
3.	Electrical Power	Watt	W = /s

Source:- Sullayman (2005)

Temperature

S/No	Derived Measurement	Unit	Symbol
1.	Degree Fahrenheit (^{0}F)	5/9 after subtracting 32	Degree Celsius (^{0}C)
2.	Degree Celsius (^{0}C)	5/9 (then add 32)	Degree Fahrenheit (^{0}F)

Source:- Sullayman (2005)

DEFINITION OF TERMS

1. **Aluminosilicate**: - A class of ceramic materials whose major constituents are alumina and silica, e.g. fireclay, ball clay, kyanite, kaolin, sillimanite, montmorillnite etc.

2. **Anthropometry**: - Is the science of human movements.

3. **Biomechanics**: - Is the study of muscular activities.

4. **Broaching**: A process of using any of the various pointed or tapered tools, implements, or parts as a cutting tool for removing material from metal or plastic to shape an outside surface or a hole. Is a process of sharpening or enlarging (a hole) with a broach**.**

5. **Cam**: - A machine part that transfers motion. It is an irregularly shaped projection on a rotating shaft that changes rotary motion into a reciprocating up-and-down motion.

6. **Clamp**: - A mechanical device with movable jaws, Used to hold two things firmly together or one objects firmly in position.

7. **Cognitive (information Design)**: - Also known as engineering psychology, is concerned with mental processes such as perception, attention, cognition, motor control, and memory storage and retrieval as they affect interactions among humans and other elements of a system. Such information helps employers to asses both individual tasks necessary to perform a particular job and skills needed to accomplish each task.

8. **Cottorforte**: - Glazed semi-vitreous products for internal applications and can all be used for floor because of its low porosity.

9. **Dead welded**: - Is a joining of metal together through arch welding or other means of joining that are permanent, the joining does not permit ease in separation except by cutting, sawing using mechanical or manual means that deforms the metal.

10. **Exterior wall tiles**: - Are glazed tiles that are thicker and larger than interior tiles, with a vitreous or semi-vitreous body that resists frost action.

11. **Extrudate**: - A product extruded from an orifice or outlet.

12. **Facing**: - The trimmings of metals, it is one of the machining operations.

13. **Faience tiles**: - Decorative tiles produced in different shapes with relief designs and in different sizes-glazed opaque.

14. **Gear electric motor**: - Any of a class of devices that a gear box of a desired speed is attached, that convert electrical energy to mechanical energy, usually by employing electromagnetic phenomena. Most electric motors develop their mechanical torque by the interaction of conductors carrying current in a direction at right angles to a magnetic field.

15. **H-link**: - is a link between the compressing lever and the compressing pipe, with a H form.

16. **Inert materials**: - inactive materials or secondary materials.

17. **Isometric projection**: - A method of graphic representation of three-dimensional objects used by engineers, technical illustrators, and

occasionally, architects The technique is intended to combine the illusion of depth, as in a perspective rendering, with the undistorted presentation of the object's principal dimensions. That is, those parallel to a chosen set of three mutually perpendicular coordinate axes.

18. **Jaw joint**: - Rigid and rugged metal plate in form of a jaw, a link between the second and the third sections.

19. **Klinker tile***:* - These are sintered products with uniform microstructure with low porosity, resistance to chemical and atmospheric agents, high resistance to compression, abrasion and frost. These are produced by extrusion and are widely used for paving sidewalks, workshops and floors subjected to high wear and chemical agents.

20. **L-cap**: - An overlay metal in the symbol of L indicating the intersection and links the first and the second sections. It is made of an angle iron. This serves as a link between the two sections.

21. **Mandrels**: - Tapered or cylindrical axles, spindles, inserted into a hole in a piece of work to support it during machining.

22. **Mathematical modelling**: - Is a model that provides quick and cheap means to establish volume, strength, or weight of components (entire object). This facilitates feedback from variety of sources such as users, manufacturers, or other members of a design team. This model can be in form of drawings or constructions, which allows problem to be explored, ideas to be visualized, and intentions to be communicated.

23. **Cone Nose**: - Also called orifice is a predetermined outlet of conical form where the slab of clay is rolled out or extruded unto the conveyor belt.

24. **Orthographic projection**: - Common method of representing three-dimensional objects, usually by two-dimensional drawings, in each of which the object is viewed along parallel lines that are perpendicular to the plane of the drawing. For example, an orthographic projection of a house typically consists of a top view, or plan, and a front view and one side view (front and side elevations).

25. **Palletized**: - To place on, transport or store by means of pallets.

26. **Pegmatite**: - Something fastened together: to fasten together — more at a coarse variety of granite occurring in dikes or veins.

27. **Porous single fired ("Monoporosa tiles")***:* - These are used for coverage of interiors and are suitable substitutes for classifying faience majolica tiles. These find application at a medium-high aesthetic level, with relatively contained cost.

28. **Progressive assembly**: - Is a continuance or advancing in fitting together of manufactured parts or component into a complete machine, as they are machined and formed one after the other. It is a collection of parts so assembled in sequence as they are formed with machine or modelled.

29. **Pulverized**: - To crush or break up into powder or mill materials.

30. **Quarry tiles***:* - Are tiles made by extrusion from natural clay or shale, with a 39cm^2(6 in^2) or more facial area, it is either glazed or unglazed. These are thick and larger than other floor tiles they have coarse texture. They

are used in kitchen, dairies, slaughterhouses, public buildings, balconies, terraces, porches, yards and sills and also wall lining. The shapes are always precise.

31. **Rheology**: - Science that deals with the deformation and flow of matter**:** the ability to flow or be deformed.

32. **Stone tiles***:* - Glazed or unglazed products used for exterior application and interior of cold rooms (frost-resistant structure) some varieties are classical stoneware floor tiles, chemical stoneware (chemical resistant tile) and fine stoneware (glazed high-quality tiles).

33. **Stove tile (majolica earthen ware)**: - Large and thick decorated tile of considerable porosity that possesses good thermal shock resistance and thermal efficiency. They are made of inexpensive raw materials like clay.

34 **Tap**: - A tool for screw threads: it is used to make an internal screw thread

34. **Telescope mechanism**: - A piece of apparatus or tubular instrument with a shape of a telescope that regulates the upward and downward movement of the template tray and likewise affords easy adjustment of the entire mechanism through the clamp. (item 5 above)

35. **Template tray**: - A predetermined formed stainless steel that houses the template (impression of a design) on tile which helps to cut the tile to size and shape.

36. **Thawing**: - To go from a frozen to a liquid state. Defrosting situation.

37. **Torque**: - A turning or twisting force. A force that produces or tends to produce rotation or torsion e.g. an automobile engine delivers ~ to the drive shaft. It is a measure of the effectiveness of such a force that consists of the product of the force and the perpendicular distance from the line of action of the force to the axis 0f rotation.

38. **Turning**: - Forming of a metal into a shape by use of a lathe. Turning operations involve cutting excess metal, in the form of chips, from the external diameter of a work piece and include turning straight or tapered cylindrical shapes, grooves, shoulders, and screw threads and facing flat surfaces on the ends of cylindrical parts. Internal cylindrical operations include most of the common hole-machining operations, such as drilling, boring, reaming, counter boring, countersinking, and threading with a single-point tool or tap.

39. **Plaster of Paris**: - Semi-hydrated calcium sulphate. (2 $CaSO4\ H_2O$)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The aesthetic, decorative decency and excellent treatments of modern architectural designed walls, floors, roofs, ceilings, tables, slabs and pathways, and even nose cones of space shuttle orbiters with tiles are premised on the availability of ceramic materials and the technology of their manufacture. They possess health advantages, comfort value, architectural durability and even provide resistance to adverse chemical reactions, frost, impact and some other natural tendencies. The qualities of tiles make them so compelling and significant, that they are used in the design of floors, roofs, walls, tables and walkways. Mostly, porcelain tiles amongst others are used to achieve some of the functions above. The aesthetic and technical characteristics of tile materials determine to a great extent, how they may be functionally classified (Ruini and Arnal, 1990).

Sullayman (2008) said tiles, as product type of structural ceramics, are manufactured using the industrial ceramic process-a controlled process of ceramic manufacturing in which mass production of identical wares can be achieved. Industrial ceramics is also the science and technology of designing, formulating and manufacturing ceramic products that have industrial and technical utilities. Tiles are pressed, extruded or cast. These range from wall tiles (decorated wall tiles, faience tiles, stove tiles, cottoforte tile, porous single-fired tiles, and exterior wall tiles), floor tiles (quarry tiles, stone tiles, klinker tiles and mosaic tiles) and porcelain tiles (ceramics tiles). Tiles are most often made from ceramic, with a hard glaze finish, but other materials are also commonly used, such as glass, marble, wood, granite, slate, and, kaolin and reformed ceramic slurry, which is cast in a mould and fired.

The hardness of the tile is rated from zero to five according to the Porcelain Enamel Institute (PEI) scale. This rating, called the PEI rating (http://www.porcelainenamel.com/about.htm, 2008) and (Matteucci, et al 2002 in Luz and Ribeiro (2006) determines that tiles' suitability for various surfaces a rating of zero indicating a tile not suitable for use on walls. Such tiles protect building walls and floors and retain their shapes, aesthetic quality and give durability to any surface where they are used. Tiles are also used for prolonged existence and aesthetic improvement of surfaces and for antiseptic environments where hygiene is paramount, as they combine sufficient cleanliness with suitable electrical properties. Ceiling tiles are placed on a steel grid and, depending on the tile selected, may provide thermal insulation, sound absorption, enhanced fire protection, and improved indoor air quality. Some are approved for use in food preparation areas, and some are certified for indoor air quality by the Green Guard Institute (GGI). There are also tiles that are resistant to mould and moisture damage that have enhanced acoustical properties (American Society for Metal (ASM) 1992).

In the last two decades, the technology of producing porcelain and glass tiles has become more efficient, allowing more mass production. Because of the invention of automated tile lines that use diamonds to cut and finish stone slabs into tiles, it has made stone tiles more available. This has allowed tiles to move from being small business into broader markets (www.infotile.com/publications, 2009) and (**http://www.encyclopedia.com/doc/ceramictile**1G2-2896500032.html). Records from the Department of Statistical Analysis (DSAN) U.S. show that there is an increase of 55% annually in demand of tiles from 2000-2005, the growth in the U.S. market which amounts to over $3 billion.

There has been shift in the world ceramic tile industry with a complementary growth in the supply of tiles. For example, Europe in 1990 accounted for 54% but in 2002 was

down to 25% of world ceramic tile production. David, (2009) on tile production reported that in 2009 the world ceramic tile production was about 8.5 billion sq. metres, of which Asia with china on the lead accounted for 65.1% , Other Europe (Turkey included) 4.6%, North America (Mexico included) 2 3.0 %, Central South America 10.5%, Africa 4.1% and Oceania 0.1%. The reason why Asia has now taken on the lead is that they have state of the art equipment in its ceramic tile plants, which means low cost. The U.S. is the world's largest market for ceramic tiles. A number of European (mostly Italian) ceramic tile manufacturers have built or expanded their U.S. plants, or bought out domestic ceramic tile firms. The European tile firms have benefited from lower manufacturing costs and this resulted into both faster production and sale of tiles.

From all the statistics above and in appendices IX to XII, the account for Africa percentile in tiles production and export is infinitesimally low. Nevertheless, one thing that is clear with most African countries like Nigeria, as consumer nation that cannot manufacture most of her goods but depend largely on imports. Economically, Africans are enriching nations that produce these goods, at the expense of their economies.

It is worthy to note that, apart from the cement concrete tiles (inter-locking tiles), drainage concrete tiles/slabs and roof tiles designed mainly to keep out rain water, most of the other ranges of tiles produced are imported from abroad into the country or produce with imported machines. An assessment of most of the buildings in Nigeria with aesthetic, decorative decency and excellent treatments in modern architectural designs (walls, floors, roofs, ceilings, slabs and pathway flood with tiles) indicates that most are all imported. Indeed, our markets have virtually no Nigerian made tiles, except for the imported tiles. The firms that claim to manufacture tiles only import and impress the company’s emblem.

Another form of tile products in the country is the granite or marble tiles from some available stones. These are expensive and are affordable only by the well-to-do in the society and organizations with an advantaged financial base. Consequently, even if firms want to produce made in Nigeria tiles suitable for the modern architectural design, the machineries for producing them are not even available in such local industries. If it was, there could have been indigenously designed tiles that reflect our true identity as a people in our local markets. This will in turn enhance our technology and economy, and we would have been able to export and earn foreign exchange for our nation through this sector. All the machines available are imported, very expensive and this phenomenon affects the cost of production and sales.

The nation lags behind in our institutions of learning in regards to the production of industrial ceramic wares - like tile production. This is because most of the productions are done manually due to lack of requisite machines and equipment. However, there seems to be a promotion of the traditional aspects of ceramics more than the contemporary industrial ceramics. Conversely, products of traditional ceramics or pottery are limited in many ways due to materials used, process controls of material, scope of products made, techniques of production and the technologies adopted (Sullayman, 2008).

The availability of contemporary industrial ceramic-making machines will increase the scope of functions in industrial ceramics and make production easier. Institutions could now in turn design and construct with standard specifications, industrial ceramic machines and products such as the tile-making machine for the production of world class tiles which can be used by both institutions of learning and industries. Many industries in the world are affiliated to institutions of higher learning in order to support and tap from the discoveries brought to bear through research activities. These discoveries are gleaned

to improve a nation's status, productivity, economy and other sectors that affect its populace. This is because every nation can only develop with the available local technology, well harnessed using international specifications and standards; brought about by the nation's professionals.

1.2 STATEMENT OF THE PROBLEM

There is a prevalent lack of indigenous and foreign training equipment and machines to produce standard tiles in the departments of Industrial Design in schools of higher learning, and ceramic industries in Nigeria. In this present age of machine-assisted mass production, tiles are still being produced using the manual process. However, in the past twenty years, the technology surrounding porcelain and glass tiles manufacture has become more efficient, allowing for multiple reproductions. Similarly, the invention of automated tile lines has made porcelain tiles more easily produced and accessible (www.infotile.com/publications, 2009) and (Paolo, 2001). There is a need to upgrade the state of industrial ceramic facilities like the tile making machine, by utilizing modern technology to make it more viable and enhancing. One cannot continue to favour traditional ceramic practices since it will not enhance applied research or reproduction, and can scarcely advance the course of science, technology and intensive economic development (Sullayman, 2008). Thus, the problem of this study is the design and construction of an indigenous tile making machine using available mild steel and other relevant materials. It will serve as a simple design and a means for the preservation of foreign exchange.

1.3 AIM OF THE STUDY

The aim of this study is to design and construct a tile-making machine following standard in design, design considerations, design theories and calculations to improve the

level of efficiency of production in ceramic industries and institutions of higher learning in Nigeria.

1.4 OBJECTIVES OF THE STUDY

The objectives of this study are to:

a. Design and fabricate a tile-making machine;
b. Develop an adaptable prototype design of tile-making machine, with standard specifications; which institutions of learning and ceramic industries in Nigeria can use in making tiles and teaching of the tile making process;
c. Reduce the stress associated with manual tiles production by substituting it with a much easier and stress-less method, thereby reducing the man hour on tile production;
d. Develop a machine that is durable, that can be assembled/disassembled and not dead welded; and maintained with ease, within the technical capability of our local artisans;
e. Test the machine and the number of tiles it can produce in an hour.
f. Carry out performance evaluation test.

1.5 JUSTIFICATION FOR THE STUDY

This machine is a contribution to technology. The ceramic institution of learning in Nigeria and ceramic industries are in dire need of technological equipment. The availability of this tile-making machine will to a large extent boost industrial ceramic institutions of higher learning and ceramic industry in the country; which has little impact within the country at the moment due to lack of the needed equipment to prove its worth and contribute its quota.

All the needed materials (mild steel, stainless steel, rubber, fibre etc) for the production of this machine are all available within this nation but are not directed toward such production. So, with the production it will prove the possibilities in the abundant material resources we have in Nigeria lying fallow that can generate wealth.

This is a significant contribution to knowledge because from available literature, no such machine was made in Nigeria prior to now. For example, after fabrication the individual institution or industries could build up the same machine following the standard design consideration. From this knowledge, several other designs could come up for positive modification.

This technology will boost the building industries. Likewise, institutions of learning will be able to have internally generated revenue to take care of some basic departmental needs and reduce dependence on the authority in supplying or providing all her needed equipment. This will bring about the employment of labour (skilled and unskilled).

This machine cannot be localized because the parameters that are used are of international standards. This gives the machine a favourable disposition to compete with other tile-making machines in the world; like that of Peter Pugger tile-moulding machine, extruders etc.

The financial implication is reduced because most of the costs for other miscellaneous expenses have been taken care of with this first fabrication. So, in the subsequent one the machine will cost less. This is expected to be far cheaper compared to the imported ones.

1.6 SIGNIFICANCE OF THE STUDY

The availability of locally constructed tile-making machines will give rise to increased level of ceramic tile production in Nigeria. Educationally, this research could be adopted

as a model design. Institutions of learning can develop and use following the standard specifications in the designed machine. This will enhance teaching and learning, encourage more creative tile design with the availability of a much simpler and less stressful means of production by both staff and students.

Economically, our industries can adopt it for tile production, if it is replicated at an industrial scale. It can also reduce the importation of tile-making machines into the nation, thereby boosting locally made ceramic tile as an export article of trade to some of the African countries. It is also expected that the fabrication of this machine will lead to mass production of tiles, thereby adding to our export value and reduce importation to some reasonable extent in foreign tile. This development will give an opportunity to the businessmen, who cannot afford imported machines to have one of its kinds made in Nigeria. If this happens, the demand for imported tiles from outside the country will become reduced. Conversely, export of tiles from Nigeria will be increased, and Nigeria will be enlisted as a contributory nation to tiles export in the world economy. Within the country, cheaper tiles will be made available, so that both the rich and the poor can afford and exploit functional capabilities of tiles.

Technologically, it is an original concept locally made/fabricated with available materials, and it is functional within our immediate environment. This can replace manual labour currently used in tile production and make work a lot easier and faster. It will enlist Nigeria as a nation contributing towards technological advancement not only in Africa but also in the world.

Another imperative significance is the ease it affords in tile reproducibility. Within an hour, the machine is expected to produce about 48 of 20 x 20 cm and 72 of 15 x 15 cm pieces of tiles. And this means that the machine can produce about 384 and 576 pieces of

tiles in a day working in projection of 8 hours, 2,688 and 4,032 pieces of tiles in a week and 10,752 and 16,128 pieces of tiles respectively in a month. This is expected to meet the need in production target and the costumer's demand as it may be required.

Finally, it is hoped that this research contributes to knowledge, and would be of assistance to future researchers who will identify other areas for further studies and at the same time improve on the practice of industrial ceramics among students, thereby promoting national productivity.

1.7 SCOPE OF THE STUDY

(a) This research covers the design and fabrication of a tile-making machine, using mainly mild steel and other relevant available materials.
(b) It utilizes generally established parameters in Mechanical Engineering, as applied in machine design and product design.

1.8 DELIMITATION OF THE STUDY

This study is delimited to:
The fabrication of the machine, not production of tiles. On this note, available tile bodies or compositions are to be used to test-run or produce sample tiles; that is to say, no new tile-making body is compounded.

(a) The construction of all components of the machine, except the electric motor, switch, bearings, V-belt, belt conveyor, electric control box, chain and sprocket, bolts and nuts, contactors, etc., that were purchased from the stock shop.
(b) Tile production to a size from a minimum of 2" x 2" (5 x 5 cm) and a maximum of 12" x 12" (30 x 30 cm).

1.9 LIMITATION OF THE STUDY

Due to paucity of time and finance this study is limited to the design and construction of a Tile Making Machine only, and will not involve formulation of clay body for the production of tiles. However established compositions will be adopted to test run the machine.

The general properties of the parts of the type of metals used were not determined.

CHAPTER TWO

LITREATURE REVIEW

2.0 INTRODUCTION

Indigenous technology is such a technology that enhances a nation's development and reduces its dependence on importation of equipment and machineries. It addresses the local need and to an extent, meets international standards. This section basically examines literatures that are relevant to design and fabrication of the machine.

Therefore, literature review for this study is centred on the following key aspects:

a. Machine design:- design process, drawing preparation, design procedure, and computer aided design
b. Design theory and considerations of major component parts: - such as bearing, pin, gear, conveyor belt, shaft, rollers, lever, the hopper, spring, machine frame etc.
c. Fabrication:- fabrication and production processes
d. Motor/Power transmission
e. Product design/development:-ergonomics
f. Materials such as mild steel, materials for tile production; mould making, template, production processes of tiles, extrusion and rheology (ability to flow or be deformed i.e. flow under pressure) of mixed substance
g. Example of tile making machine.

2.1 MACHINE DESIGN

Mechanical engineers have decision making process with which plans for physical realization of machines, devices and systems are arrived at. This decision making makes machine design and manufacture or production possible. This is in other word machine design. According to Khurmi & Gupta (2004) machine design is the process of creating new and better machines, and improving the existing ones. A new or better machine is one which is more economical in the overall cost of production and operation. Nagpal (2002) said machine design is being acquainted with the fundamentals of designing the most commonly used parts, elements and units of various machines. This may lead to an entirely new machine or an improvement of the existing machine. The objective here he said, is to produce machine which is sufficiently rugged to function a reasonable life and also cheap enough. The processing of a design is long and time consuming. From the study of the existing idea, a new idea has to be conceived. This study is done keeping in mind it's commercial success, and given shape and form in the form of drawing. Khurmi and Nagpal agree that in designing a machine or its components the knowledge of the following courses are necessary to the designer: mathematics, engineering mechanism (mechanics of materials), strength of materials, and theory of machines (mechanism), workshop processes, workshop organisation, metallurgy and engineering drawing. In addition to these, it is required to have the knowledge of the principles of the following apart from the subjects mentioned above;

I. CAD (computer Aided Design)
II. CAM (Computer Aided Manufacture)
III. Concurrent engineering
IV. Design for Manufacture (DFM)
V. Design for Assembly (DFA)

VI. Group Technology

VII. Value engineering etc.

All these are to enhance creative activity, originality and excellence in design. This is because the designer or engineer should be of sound judgement and experience. This is important because in design, there are layouts which require both empirical and scientific design; as no design is possible without the use of tables, charts and formulas established from experimental studies and scientific computations.

2.1.1 Classification of Machine Design

Khurmi and Gupta (2004) and Nagpal (2002) believed that machine designs are/can be classified as follows:

1. Adaptive design: - This means adaptation of existing design, which is adopted and utilized. This needs no special training or skills. The designer only makes minor alteration or modification in the existing designs of the product.
2. Development design: - This needs scientific training and design ability in order to modify existing designs into new ideas by adopting new materials or new method(s) of manufacture. The final product after completion differs from the original product.
3. New design: - This needs a high professional personal research skills, technical ability and creative thinking as qualities to take up a new design.

Depending on the methods used above Khurmi and Gupta, and Nagpal further classified these as:

I. Rational Design:-This depends on mathematical formulation or principles of mechanics

II. Empirical Design: - This depends on empirical formula based on the principles and past experience.

III. Design by experience

IV. Combined rational and empirical design

V. Industrial designing:- This is the production aspect of manufacturing any machine component in the industry

VI. Design optimization:- It is the best design for the given objective to function under the specified constructs; achieved by minimizing undesirable effects.

VII. System design:- Is the design of any complex mechanical system like piston, crank shaft; connecting rod etc.

VIII. Computer aided designed:- This depends on the use of computer to assist in creation, modification, analysis and optimization of design.

After the above, the design of machine could proceed along the following lines:

i. Machine should satisfy the functional requirements once visualized.

ii. Preliminary analyses of forces that will act on the parts.

iii. Determine the general properties of the parts

iv. Selection of materials in respect to parts

v. To decide the manufacturing processes

vi. Preparation of production drawings

Modification based on (a.) Practical experience, (b.) Cost, (c.) Requirement for quality production in designing the machine should be cheaper.

Khurmi and Gupta (2004) gave some factors which make a product cheaper, which are as listed below:

a. Use of casting in place of forgings and machined parts.
b. Adoption of fabrication by welding
c. Incorporation of standard parts
d. Reduction of the usage of costly materials
e. Allowing proper tolerance on the various dimensions.

In view of the above, the method adopted is "the developmental design method". The empirical and rational design combined was used in line with the other processes like, fabrication by wielding.

2.1.2 Final Drawings

Nagpal (2002), Khurmi and Gupta (2004) suggested that the assembly drawing should constitute all the component parts drawn separately, and then assembled to form the complete design. They added that the working drawing should possess the following information:

I. It should be clear, concise and complete. All dimensions that are needed for manufacturing or assembling equipment should be mentioned clearly.
II. Type of finish to be used should be given
III. Standard symbols should be used
IV. Bill of materials should be prepared in tabular form.
V. If the manufacturing process involves any special method such as lapping, heat treatment etc. then such process should be indicated in a footnote.

2.1.3 Standardized Codes

Apart from the above, the machine must comply with codes and standard in design. A standard is a set of specifications in parts, materials or process intended to achieve

uniformity, efficiency and a specified quality (Nagpal, 2002). This places a limitation on the number of items on the specification, so as to provide a reasonable catalogue of tooling sizes, shapes and varieties.

Standardization is defined as the adoption of prescribed regulations and specifications as they pertain to materials, methods and equipment. This helps in reducing cost, simplicity replacement and elimination of unnecessary variation in sizes (Ibid, 2002).

Advantages of standardization it reduces cost, simplifies replacement and reduces the quantities of materials in stock. Patterns and dies are available instead of making new designs which serve purpose better.

A code is a set of specifications for the analysis, design, manufacture and construction of something. The purpose of code is to achieve a specified degree of safety, efficiency and performance or quality (Shirgley, 2004). He further suggested that it is important to observe that safety code do not imply absolute safety. Absolute safety according to him is impossible to obtain, because the unexpected happens sometimes.

2.2 DESIGN CONSIDERATIONS, THEORIES AND CALCULATIONS

2.2.1 Design Considerations

Nagpal (2002) and Khurmi & Gupta (2004a) gave the following as necessary considerations in designing a new machine or component. These are in line with the point mentioned on machine design earlier.

i. To state the problem completely and accurately, and

ii. To decide the kinematic arrangement of parts of the machine and to carry out definite analysis of their motions.

iii. To determine the nature of the forces and their magnitude acting on different elements of the machine.

iv. To select proper materials for each elements of the machine and to determine the allowable stresses in the different materials—as a result thorough knowledge is vital of the properties of the materials, there behaviours and some of the load. Characteristics like: strength, durability, flexibility, weight resistance to heat and corrosion, ability to cast, welded or hardened, machinability, electrical conductivity etc.

v. To determine the size of each element

vi. To prepare detailed drawings of the various elements of the machine designed

vii. To select the economical manufacturing processes by which various elements are to be manufactured.

viii. To fabricate prototypes and to test the prototypes for performance. Any flaws revealed during testing should be removed by making alterations in the preliminary design of the component. The design should be such that: (a). It is easier to manufacture the various parts, (b). It is easier to assemble the various parts, (c), as far as possible standards parts should be used and (d). There should be safety of operation and adjustment for wear. Any moving part of the machine which is within the zone of a worker is consider accident—hazard and may be the cause of injury. Safety device and operation must be provided. Khurmi and Gupta added apart from the above there is need to consider the:

ix. Frictional resistance and lubrication:- There is always a loss power due to frictional resistance and it should be noted that the friction of starting is higher than that of running friction. So, careful attention must be given to lubrication of

all movable surfaces that have contact with each other –in rotating, sliding or rolling bearing.

x. Used of standard parts:- The use of standard part is closely related to cost, since stock parts are only a fraction of the cost of similar parts made. Parts which patterns are already in existence such as gear, pulley and bearings and parts which may be selected from regular shop stock such as screws, nuts and pins. Bolts and studs be minimized to avoid delay caused by changing drills, reamers and taps and also to decrease the numbers of variables required. The entire point of consideration can be summarized thus:

    a. Specification quality:- This should comply with basic design specifications
    b. Functional quality:- Functioning of component parts
    c. Aesthetic quality:- Provide aesthetic value demanded by users
    d. Usage quality: - It should be simple, economic and higher trouble free working life of the components.

2.2.2 Bearing

Bearings are mechanical devices for decreasing frictions in a machine in which a moving part bears or rolls while exerting force on another part (Bearing in Encarta, 2008). While Bearing in Britannica (2009) sees bearing as a machine (usually a support) that permits the connected members to rotate or move in a straight line relative to one another. Often, one of the members is fixed, and the bearing acts as a support for the moving member. The commonest bearings are found at the rigid support of rotating shaft, where friction is the greatest. The support is either transverse (radial) or thrust (axial) loads. The connecting surfaces in a bearing may be separated completely or partially by a film of

liquid (usually oil) or gas. These are sliding bearings and the put-off the shaft that turns in the bearing, which is the journal.

Bearings have been basically classified into two

a. Friction bearings comprises of sleeve or journal bearings. Friction bearings are simpler than antifriction bearings in construction but more complex in theory and operation. The shaft supported by the bearings is called the journal, and the outer portion the sleeve.

> *The sleeves of most bearings therefore are lined with brass, bronze or Babbitt metal in order to avoid grab or pick up. Sleeve bearings are generally pressure-lubricated through a hole in the journal or from the housing, which contains the bearings. The sleeve is often grooved this distribute the oil evenly over the bearing surface. The journal is thus supported on an extremely with the film of oil and the two parts have no actual contact. As the rotational speed increases, other variables remaining constant, the oil film become thicker so that the friction increases in less than a direct proportion to the speed. Conversely at lower speeds the oil film in thinner if other factors are changed. Therefore, friction is high when the machine is started in motion and the bearing may fail if high stresses are put on it during starting. Antifriction bearing on the other hand has low starting friction* (Britannica ibid).

b. Anti friction bearings (rolling contact bearing) - comprises of ball and roller bearings. In a ball bearing, a number of balls rotate freely between an inner ring, which is rigidly fixed to a rotating shaft, and on outer ring, which is rigidly fixed to a support.

> *Both balls and rings are made of hardened alloy steel, usually finished to extremely fine tolerance. The balls are generally held in position by a cage or separator that keeps them evenly spaced and prevents them from rubbing against each other. The bearing is lubricated with grease or oil. A roller bearing is similar to a ball bearing, except that small steel cylinders, or rollers, are substituted for the balls. A needle bearing is a roller bearing in which the rollers are extremely long and thin. An ordinary roller bearing may have 20 rollers, each twice as long as it is wide; whereas a needle bearing may have 100 needles, each 10 times, as long as it is wide. Needle bearings are particularly useful when space is limited, (Britannica Op cit)*

The rolling contact bearing will serve a better function in the fabrication of tile-moulding machine, specifically the ball bearings.

There are some considerations or factors that determine the selection of bearing to support shaft, as a standard part to be purchased in the market these are given by Nagpal (2002) as:

I. Mechanical strength requirements
    - Load
    - Speed
    - Starting friction
    - Space requirements
    - Type of lubrication
    - Power consumption

II. Environmental conditions

III. Economics
    - life
    - maintenance
    - cost

The table for the selection of bearings can be obtain in (Nagpal, 2002)

2.2.3 Lever

Lever is one of the four classes of simple machines used to work. The other three are the pulley, the wheel and axel, and the inclined plane). Levers make work easier by reducing the force needed to move a load or object (Griffin, 2008). A lever has been defined as a simple machine consisting of a rigid bar that rotates about a fixed point, called a fulcrum. Levers affect the effort or force needed to do a certain amount of work (Kurmi & Gupta,

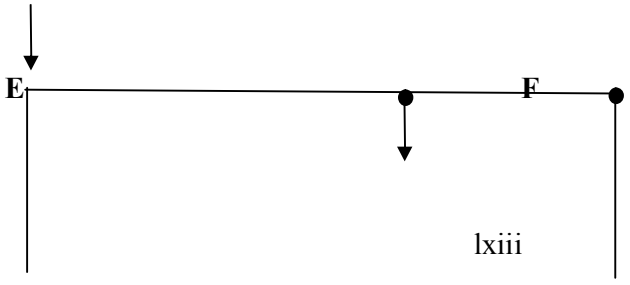
2004b) and (Nagpal, 2002). The ratio of load lifted to the effort applied is called mechanical advantage. A lever is used to facilitate the application of force in a desired direction.

Levers are classified into three (3) depending on the arrangement of the force, the load and the fulcrum along the lever bar. Each of these affects force in a different way, and each class has its different application. The class of lever that fits the tile-moulding machine is class 1 type of lever; where the fulcrum is between the effort and the load. The lever actually comes in during compression of tile mix and stamping of tile.

Class 1 levers: - this has the fulcrum between the force (effort) and the load, as in a seesaw. A lever may be straight or curved and the forces applied on a lever (or by the lever) may be parallel or inclined to one another (Griffin, ibid).

Design of a lever determines the physical dimensions of a lever when forces acting on the lever are given. The forces that act on a lever are load (w), effort (p), and reaction at the fulcrum F (R_f). The load and the effort cause moments (movement i.e measure of tendency to produce motion especially about a point or axis) in opposite directions about the fulcrum (Khurmi and Gupta, 2004). Basically, in designing, there is no single formula, but it goes along with the class of lever to be used.

The design consideration for the levers is to find the length of the lever arm from the fulcrum position. This can be found by taking moment about the fulcrum position, (Malachy, 2009).



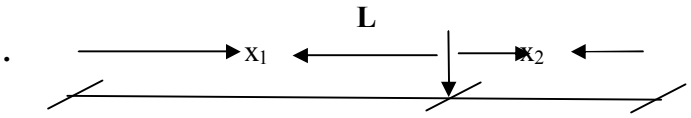


Figure 1 Lever Calculation

Where L = load

E = Effort

$L x_2 + E (x_1 + x_2) = 0$

$L x_2 = - E (x_1 + x_2)$

$= - E x_1 . E x_2$

$(L - E) x_2 = - E x_1$

$$x_1 = \left(\frac{L-E}{E}\right) x2 \quad \text{.....1}$$

2.2.4 Shaft

Nagpal (2002) and Shirgley (2004) define shaft as a rotating or stationary member usually of circular cross section. Shafts can be solid or hollow. Shaft provides the axis of rotation or used for transmission of power of elements such as gears, pulley, fly wheels, cranks, sprockets, and other power transmission elements and controls the geometry of their motion. A short rotating shaft is known as a spindle. In shafts design they can be subjected to bending tension, compression, or torsional loads acting singly or in combination with one another; these, engineer, must put in mind when designing and positioning a shaft.

The major consideration in the shaft design is for combined bending and torsion stress, and the diameter is given by (Shirley, ibid).

$$d = \left\{\frac{16n}{\pi}\left[4\left(\frac{KfMa}{Se}\right) + 3\left(\frac{BfsTa}{Se}\right)^2\right]\right\} \quad \text{.....2}$$

where d = diameter of shaft

.

$\mathbf{K}_f$ = the fatigue stress-concentration factors

$\mathbf{K}_{fs}$ =

n = constant for the type of column end support

$\mathbf{S}_e$ = endurance strength

$\mathbf{M}_a$ = bending moment for alternating stress

$\mathbf{T}_a$ = torque for alternating stress

2.2.5 Belt

Belts are used for power transmission from one shaft to another shaft. There are four types of belts: flat belt, V –belt, ribbed belt and toothed belt. The features that will be considered in the selection of belt are:

i. Power to be transmitted

ii. Centre distance

iii. Speed of driver and driven shafts

iv. Space available

v. Reduction ratio

vi. Positive drive requirements

vii. Service conditions.

Belt drives are classified into six. One of such is the open belt drive system. The specific belt to be used in this research is the V-belt.

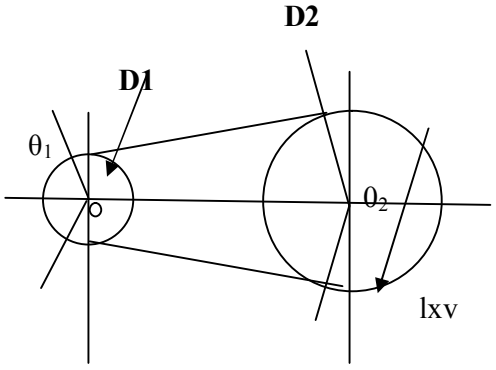




Figure 2 Open Belt System

D1 = diameter of driving pulley
D2 = diameter of driven pulley

In this system, a belt passes over two pulleys rotating in the same direction.

(i) The **length of belt** is given by (Nagpal, 2002)

L = Length of belt

$$= \pi(R_1 + R_2) + 2c + \frac{(R1-R2)^2}{C} \quad \text{.....3}$$

Where C = Distance between centres of pulleys

R_1 = Radius of driven pulley

$$= \frac{D1}{2}$$

R_2 = Radius of driven pulley

$$= \frac{D2}{2}$$

θ_1 = Angle of contact on smaller pulley

$$= 180 - 2 \sin^{-1} \frac{D2-D1}{2C} \text{ degrees} \quad \text{.....4}$$

θ_2 = Angle of contact for larger pulley

$$= 180 - 2 \sin^{-1} \frac{D2-D1}{2C} \quad \text{.....5}$$

Where angle $\alpha = \sin^{-1} \frac{D2-D1}{2C}$

(ii) (a) **Ratio of Driving Tension and Power Transmitted**

The horse power transmitted by belt drive depends upon tensions in the belt coefficient of friction between belt and pulleys and linear speed of belt.

T1 – Tension in tight side of belt in kg

T2 – Tension in slack side of belt and pulley

μ = coefficient of friction between belt and pulley

θ = Angle of lap on smaller pulley in radians

H.P = Horse Power transmitted

$$= \frac{(T1-T2}{4500} = \frac{T1\,(1-\frac{T2}{T2})V}{4500}$$

$$= \frac{T1(1-\frac{1}{e^{\mu\theta}})V}{4500} \quad \text{.....6}$$

Where V = speed of belt is metre/min

$$\frac{T1}{T2} = e^{\mu\theta}$$

(b) The centrifugal tension in the belt becomes of consequence at high speeds, and should be taken into account while calculating width of belt.

T_c = centrifugal tension in kg

$$= \frac{w.v^2}{g} \quad \text{.....7}$$

Where w = Weight per metre length of belt in kg

V = Linear speed of belt in metre per second

Tension on tight side of belt = T_1+T_c

Tension on slack side of belt = T_2+T_c

(c) When the effect of centrifugal tension is considered the horse power transmitted is given by the relation, (Nagpal, 2002).

$$\text{H.P} = \frac{(T-Tc)\left(1-\frac{1}{e^{\mu\theta}}\right)x\,V}{4500} \quad \text{.....8}$$

T = Maximum permissible tension in belt

$= T_1 + T_c$ 9

Where V = Linear speed of belt in metre per minute

Design H.P. = H.P. to be transmitted x Service factor

Service factor = 1.4 for shock and reversed loads.

(iii). Maximum Permissible Velocity of Belt

The maximum Permissible velocity of belt at which maximum H.P. that can be transmitted is calculated as follows:

$$V_m = \text{Maximum permissible velocity} = \sqrt{\frac{T \times g}{3w}} \quad \text{.....10}$$

Where T = Maximum permissible tension in belt

(iv). Initial Tension in Belt

It is calculated as follows:

$$T = T_0 = \frac{T_1 + T_2}{2} \quad \text{.....11}$$

T_0 = Initial tension

2.2.6 Gears

Gear is defined by Kurmi (2006b) is a friction wheel with the teeth cut on. It is also known as toothed wheel. This is a position drive that is also provided, when the distance between the driver and the follower is very small. Nagpal (2002) according to him they are medium means to transmit power, positively without slip and at a constant velocity ratio. He opined that they are useful for high torque transmissions. It has high efficiency, reliable service and simple operation. Gears also help to control speed either on the faster or slower note. Most gears are circular. To transmit motion smoothly and with a non varying speed ratio at every instance, the contacting surfaces of gear teeth must be carefully sloped to a specific profile. If the smaller of a gear pair (pinion) on the driving

shaft, the pair acts to reduce speed and the amplify torque; if the pinion is on the driven shaft the pair acts as a speed increaser and torque (moment of a force i.e. the tendency of a force to rotate the body to which it is applied) reducer. If the driven gear has twice as many teeth as the pinion for example, the torque of the driven gear is twice the pinion torque, where as the pinion speed is twice the speed of the driven gear.

. Some of the considerations are to determine the horse power (h.p.) to be transmitted, the centre distance between gear 1 and 2, the number of teeth on the driving and the driven pulley this will give the → Velocity ratio:

(i) $\frac{N_1}{N_2} = \frac{T_2}{T_1}$ 12

Where N_1 = rmp of gear (G1)

N_2 = rmp of gear (G2)

T_1 = no. of Teeth in G1

T_2 = no. of Teeth in G**2**

(ii) Diagram of Flank

Flank is the part of tooth surface lying below the pitch surface.

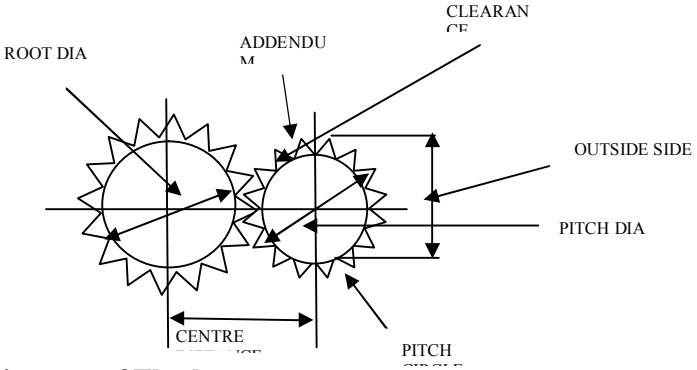


Figure 3 Diagram of Flank

SOURCE: Nagpal (2002)

(iii). Centre Distance: It ıs the dıstance between the centres of two mating gears, (**fig. 3**).

C = centre distance

$$= \frac{D1}{2} + \frac{D2}{2} \quad \text{.....13}$$

Where D_1 = Pitch circle diameter (P.C.D.) of gear 1

D_2 = P.C.D. of gear 2

(iv). Velocity Ratio: This is defined as the number of revolutions of the driver dear to the number of revolution of driven gear. Given by, (Nagpal, 2002).

Velocity ratio:- $= V.R. = Vel.\ Ratio = \frac{N_1}{N_2} = \frac{D_2}{D_1} = \frac{T_2}{T_1}$ 14

Where N_1 = Revolution Per Minute (rpm) of driving gear

D_1 = P.C.D. of driving gear

T_1 = Number of teeth on driving gear

N_2 = rpm of driven gear

D_2 = P.C.D. of driven gear.

T_2 = Number of teeth in driven gear.

Likewise the strength of gear teeth: - $F = \theta \cos \Psi$ 15

(v) Service Factor $\frac{F-H.P.\times 4500}{V \times C_s}$ 16

The value of service factor is indicated in (Nagpal, 2002)

(vi) Permissible Working Stress for Gear Teeth in the Lewis Equation

The equation is given by Khurmi, and Gupta, (2004b) as:

$\sigma_w = \sigma_0 \times c_v$ 17

Where σ_0 = Allowable static stress

C_v = Velocity factor.

$(C_v) = \frac{4.5}{4.5+V}$, for carefully cut gears operating at velocities up to 12.m/s

(vii) Dynamic Load on Gear Teeth

is given by Nagpal (2002) as:

$$F_d = F + F_v = F + \frac{0.112v(b \times c_1 + F)}{0.112v + \sqrt{bc_1 + F}}$$ 18

Where F_d = dynamic load

F_v = Variable load

V = Pitch line velocity in m/min

b = Face width in cm

C_1 = Factor depending upon machinery errors

$= \frac{k.e}{\frac{1}{E_p} + \frac{1}{E_g}}$ 19

where k = a constant depending upon tooth form

= 0.107 for 14 $\frac{1}{2}$ Tooth

= 0.111 for 20^0 full depth tooth

= 0.115 for 20^0 stub tooth

E_p = Young's modulus for pinion

E_g = Young's modulus for gear (kg/cm^2)

e = Tooth action error in cm.

(viii) Wear Tooth Load-

The maximum load that gear teeth can carry, without premature wear, depends upon the radii of the curvature of the teeth profiles and the elasticity and surface fatigue limits of the materials.

The maximum load for satisfactory wear of gear teeth is given by (Khurmi and Gupta, 2004) using Buckingham equation as:

$W_w = D_p.b.Q.K$ 20

Where W_w = Maximum or limiting load for wear in newtons,

D_p = Pitch circle diameter of the pinion in mm,

b = face width of pinion in mm,

Q = Ratio factor

$= \frac{2 \times V.R.}{V.R. + 1} = \frac{2T_G}{T_G + T_P}$, for external gears

$= \frac{2 \times V.R.}{V.R. - 1} = \frac{2T_G}{T_G + T_P}$, for internal gears

V.R. = Velocity ratio = T_G/T_P,

K = load-stress factor (also known as material combination factor) in N/mm^2

2.2.7 Pulley

Pulley by Encyclopaedia of Britannica (2009) and Griffin (2009) is define as a wheel that carries a flexible rope, chord, cable, chain or belt on its rim. They are used singly or in combination to transmit energy and motion. Belt and pulleys arrangement are used basically to transmit power from shaft to driven (follower) shaft. One or more independently rotating pulley can be used to gain mechanical advantage, for lifting weights. Nagpal (2002) said pulleys are made of cast iron, pressed steel, welded steel and wood in standard sizes. Cast iron steel pulleys are the most used in transmitting power.

Pulleys are in different sizes and types. These consist of Flat belt, V- belt, and Rope pulleys.

The various considerations in the design of pulleys are as follows:

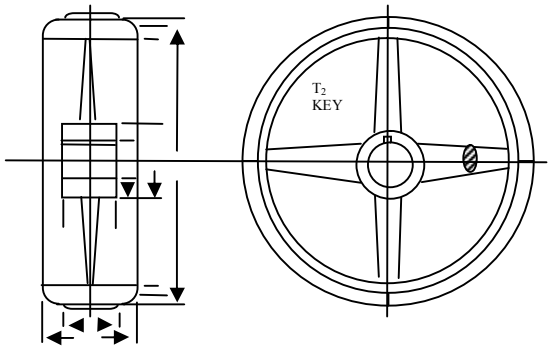


Figure 4 Cast Iron pulley with straight arms

Source (Nagpal, 2004)

(i) **Design of Cast Iron Pulley**

The various parts of cast iron pulley are designed as follows

a). To calculate shaft diameter

d = shaft diameter

N = R.P.M. of shaft

F_s = safe shear stress in shaft material

r = shaft radius = $\frac{d}{2}$ 21

H.P. = $2\pi \frac{NT}{4500}$ where T = Torque (kgm)

$\frac{T}{\frac{\pi}{16}d^4} = \frac{f_s}{r}$

T = Torque = $\frac{\pi}{16} f_s d^3$

(b) **Hub**

d^1 = outer diameter of hub = 2d

Length of hub (L) = 1.5d to 2d

or L = $\frac{2}{3}$ B to B 22

where

B = width of pulley rim

(c) Key

A rectangular parallel sunk key way may be used.

Thickness of key = d/4

Width of key = d/6

Length = length of hub + 6mm

(d) Arms

The numbers of arms (spokes) in a pulley depend upon the pulley diameter

D = diameter of pulley

n = number of arms

= 4 when D = 20 t0 6mm

= 6 when D = 61 to 150 cm

= 8 when D is more than 150 cm

Or $n = 1.7\sqrt{\frac{D}{100}}$ 23

where D is in millimetres.

For elliptical section of arms

Let α = Major axis of elliptical section

b = Minor axis of elliptical section

Assuming that only half the number of arms is effective as the belt wraps itself around the pulley through 180 supo. Assuming that the arms act as cantilevers and that arms extend up to centre of pulley then,

M = Bending moment on each arm = $\frac{T}{n_1}$

Where $n_1 = \frac{n}{2}$

f = permissible stress in arms material

$M = f \times z$

Where z = section modulus of an eclipse = $\frac{\pi}{64} a^3$

Where $a = 2b$

$M = f \times \frac{\pi}{64}$ 24

From the equation the value of major axis (a) is found

$b = \frac{a}{2}$

Major axis is placed in the plane of rotation. These dimensions are at the hub.

The taper terms is usually $\frac{1}{48}$ to $\frac{1}{32}$

Arm taper from hub to rim small pulleys are provided with web or web with holes

D = 20cm use web

Since the arms are subjected to complete reserved of stress a factor of safety of about 8 should be used

f = safe stress for C.I. arms

$= 140 \text{ to } 210 \text{ kg/cm}^2$

For pulleys above 450mm diameter, use 6 arms. The cross-section of arms is generally ellipticed with minor axis half of the major axis.

Major axis of arm near boss is given by (Nagpal, 2002)

$b = 2.943 \sqrt{\frac{a_1 D}{4n}}$ for single belt.

The cross-section of arm near the rim may be taken as 2/3rd of that near the boss or a taper of 4mm per 100 mm may be provided.

Radius of the cross-section of arms = $\frac{3}{4}$ b

Radius, $r_1 = r_2$ near rim = b/2

(e) Rim

t = thickness of pulley rim

$= \frac{D}{300} + 2\text{mm to } \frac{D}{300} + 3\text{mm}$

Where D = Diameter of pulley in mm

Width of rim (B) is about 25% more than width (B_1) of belt

h = crowning in rim

The permissible speed can be obtained in the table below.

Table 2.1: Types of Pulley and Rim Speed

Types of Pulley	Rim Speed m/min
(i) Mild steel pulleys sold or split with flat or crown face and mild steel speaks.	1500
(ii) Cast iron pulleys	
(a) Solid with flat or crown face	1500
(b) Split with flat or crown face	1000

Source: (Nagpal 2002)

(f) Centrifugal Stress in the Rim

(f_s) = induced in the rim is given by

$$f_s = p \frac{V^2}{g}$$

where p = Density of material of pulley

V = velocity of rim in m/sec

g = Acceleration due to gravity.

(g) Width of Belt

To find width of belt and width of pulley

Let T_1 = Tension on tight side of belt (kg)

M = Coefficient of friction between belt and pulley

T_2 = Tension in loose side (kg)

θ = Angle of lap

R = pulley radius

$\frac{T_1}{T_2} = e^{m\theta}$ .....a

$(T_1 - T_2) \times R$ = Torque .....b

From (a) and (b) value of T_1 & T_2 can be found

Let F = permissible tension in belt (kg/cm) s

B_1= width of pulley = 1.2 B_1 (say)

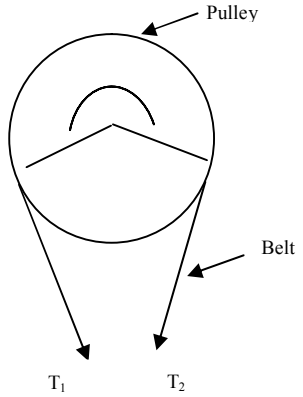


Figure 5: Belt on Pulley

The table that contain pulley width as in (Nagpal, 2002)

(ii) **Coefficient of Friction**

The coefficient of friction between belt and pulley depends on

1. Material of belt

2. Material of pulley

3. Belt speed

4. Belt slip

For C.I. and steel pulleys for leather oak formed belt

$\mu = 0.25$—Dry = 0.2 – wet = 0.15 – Greasy

2.2.8 Hopper

Hopper can be small or big, depending on the use. In order to determine the size standard parameters in design of hopper are implore. e.g.

$V = abc + 2\ [(1/2)\ dbc]$ 25

Where

V = volume of hopper m^3

a = base width of hopper m

b = height of hopper m

c = length of hopper m

d= base width of triangle.

In the design of a hopper the weight is also, considered using some design parameters. Once it comes to any form of design, if these parameters in design are utilized throughout, the needed product would be achieved without much difficulty (Gonah, 2001).

2.2.9 Machine Frame

Machine frame is a supporting structure- an underlying structure that consists of solid parts such as struts (bar) with spaces between them and carries the weight of what is built around or on top of it (Encarta, 2009). In designing of machine frame, the most important consideration is the thickness of the material or mild steel bar that will carry the desired load. In order to get that done the following formula below is used, given by (Malachy, 2002)

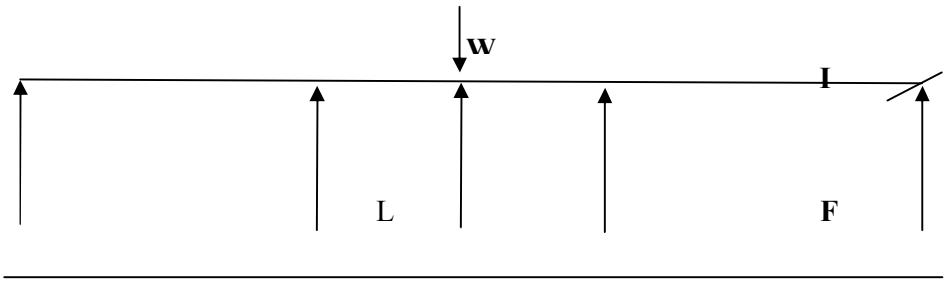


Figure 6: Machine Frame

Max Bm = $\frac{WL}{2}$

Where M = Maximum Bending moment

I = Moment of Inertia

σ = Maximum shear stress of the material (480 mpa)

z = Section modulus

$= \frac{bd^3}{12}$

Max Bm = $\frac{WL}{2}$

$\frac{M}{I} = \frac{\sigma}{Z}$

$z = \frac{bd^3}{12}$

$$bd^3 = 12z$$

$$d = \sqrt[3]{\frac{12}{b}}$$

2.3 THE CONCEPT OF FABRICATION

According to **http://www.thefreedictionary.com/** fabrication (2008) fabrication, as an industrial term, applies to the building of machines, structures, or process equipment for the chemical or fertilizer sector, by cutting, shaping and assembling components made from raw materials. This source describes steel fabrication generally concentrating on the metal preparation, welding and assembly aspect while the machine workshop is more concerned with the machining of parts.

ASM (2003) describes fabrication as an act of manufacturing which, is from Latin word Manu- factura, "meaning making by hand". It is the use of materials, tools and labour to make things for use or sale. The term may refer to a vast range of human activity, from handicraft to high technology, but it is most commonly applied to industrial production, in which raw materials are transformed into finished products of choice, and that which are in turn used for producing goods on a large scale.

Fabrication is usually directed toward the mass production of machine that produces products for sale to consumers at a profit. Fabrication has made available today several machines that have been assisting man in the production of goods without much stress. ASM (ibid), stated further that, with the advent of the industrial revolution, many machines are now fabricated to enhance production of goods and reduce human labour.

2.3.1 The Procedure in Fabrication

Metal fabrication is a value added process that involves the construction of machines and structures from various raw materials. Fabrication is usually based on engineering drawings, in building product. Fabrication involves the manufacture of individual components that make up larger assemblies or end products. This activity encompasses the working of metals and the incorporation of electrical and electronic devices into processors, circuit boards, and subassemblies. (**http://www.britannica.com/EBchecked/topic/199795/fabrication** Retrieved 17-07-2012).

Groover and Mikell (2007) gave the under-listed as the procedures or steps involved in successful fabrication of any sorts.

2.3.2 Engineering Drawing

Engineering drawing is the rendering of the various component parts of a machine constructed/fabricated with computer software or manually.

An engineering drawing is a type of drawing that is technical in nature, used to fully and clearly define requirements for engineered items, and is usually created in accordance with standardized conventions for layout, nomenclature, interpretation, appearance (such as typefaces and line styles), size, etc (Erik, 2000). Its purpose is to accurately and unambiguously capture all the geometric features of a product or a component. The end goal of an engineering drawing is to convey all the required information that will allow a manufacturer to produce that component. The drawing is mostly rendered in isometric and orthographic projections.

Engineering drawings are often referred to as "blueprints" or "blue-lines". The process of producing engineering drawings, and the skill of producing them, is often referred to as technical drawing, (Erik, ibid).

2.3.3 Purchase of Raw Material

Once the drawings, are set, the next thing is to purchase or order all materials, specialized fabrication equipment and others, like those with material standard (engineering standards). Standard raw materials used by metal fabricators are; plate metal, formed and expanded metal, tube stock, square stock, sectional metals (I beams, W beams, C-channel), welding wire, hardware, castings, fittings.

2.3.4 Cutting and Burning

The various raw materials are cut to size. Variety of tools; as Special band saws designed for cutting metal have hardened blades and a feed mechanism for even cutting are used. Abrasive cut-off saws, also known as chop saws, are similar to mitre saws, but with a steel cutting abrasive disk. Cutting torches can cut very large sections of steel with little effort. Plate steel is loaded on a table and the parts are cut out as programmed.

2.3.5 Forming

Most of the parts cut are formed into various shapes and forms using hydraulic brakes with v-dies, and these are the most common methods of forming metal. The cut plate is placed in the press and pressed in a predetermined distance to bend the plate to the desired angle. Wing brakes and hand-powered brakes are also used.

Tube bending machines have specially shaped dies and mandrels to bend tubular sections without kinking (disfiguring or dis-shapening) them. Rolling/folding machines are used to form plate steel into a round section.

2.3.6 Machining

After forming, the next stage is machining with capability tools including; metal lathes, mills, magnetic based drills along with other portable metal working tools. According to Groover and Mikell (2007) conventional machining, is a collection of material-working processes in which power-driven machine tools, such as lathes, milling machines, and drill presses are used with a sharp cutting tool. These are used to mechanically cut the material to achieve the desired geometry. Machining is a part of the manufacture of almost all metal products.

Groover and Mikell, further expounded that, there are three principal machining processes, classified as turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planning, boring, broaching and sawing.

2.3.7 Welding

According to American Society for Metals (ASM) International (2003) welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence (fuse/melt together). This is often done by melting the work-pieces and adding a filler material to form a pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. Welding is the focus of steel fabrication. The formed and machined parts are assembled and tack-welded into place, and are then re-checked for accuracy. A fixture may be used to locate parts for welding if multiple weldments have been ordered. The welder then completes welding per (in line with) the engineering drawings, with details provided. And he leaves it to cool.

2.3.8 Final Assembly

After the weldment has cooled, it is generally sand blasted, primed and painted. Other additional requirements like the electrical wiring and fittings of the various electrical components will then be completed. The finished products are then inspected and tested.

2.4 MOTOR

A motor is any device for converting chemical energy or electrical energy into mechanical energy. This employs electromagnetic phenomena such as the coupling between the electrical and mechanical systems. Most motors develop their torque by the interaction of conductors carrying current in a direction at right angle to a magnetic field (Gordon, 2009). Robert *et al*. (1992) said electric motor is very widely used for providing the prime power to industrial machinery, consumer products and business equipment. Motors classification by size is used to group motors of similar design. The horse power (hp) is currently most frequently used, with the meter unit of watts or kilo watts (kw).

- The conversion is given by 1.0 hp = 0.746 kW =746W…..
- The classifications are as follows:

    I. Sub-fractional hp: 1 to 40 milli-horse power (mhp) where 1 to 40 mhp = 0.001to 0.040 (horse) hp (0.75 W to 30 W, approximately).

    II. Fractional hp: 1.0 hp (0.75 watts (W) to 746 W, approximately).

    III. Internal hp: 1.0hp (0.75kW and larger).

Robert *et al.* (ibid) noted that motors are generally categorised into two. These are the Alternating current (AC) and the Direct Current (DC); further categorised into single-phase, two phase and three phase. He opined that in selecting a motor that will fit the service requirements of a machine, the followings are put into consideration:

- Motor type
- Power rating and speed
- Operating voltage and frequency
- Frame size
- Mounting details
- Type of enclosure
- Operating torque
- Current limitations during the running and starting phases of operation.
- Starting torque
- Load variations expected and corresponding speed variations that can be tolerated.
- Environmental factors: temperature, presence of corrosive or explosive atmosphere, exposure to weather or liquids, availability of cooling air, etc.
- Duty circle: how frequently the motor is to be started and stopped.
- Shaft loading: particularly side loads and thrust loads that can affect the life shaft bearings, etc.

2.5 PRODUCT DESIGN

Product design is an idea generation, concept development, testing and manufacturing or implementation of a physical object or service. Designers make product tangible through systematic approach (Ivar, 2006). He said that the designer also does the work of marketing, management, industrial designer and design engineer. Most ideas, he said arise from a need and have a use in structures that serve intended purpose. A designer designs by creating an object or form and functions of product, machines. In designing a product, a designer is also concerned with aesthetic, safety, technology, ergonomics, usability, and material technology. The idea is made visible by drawing with hand and machine (computer) aided drawing.

2.5.1 Ergonomics

Ergonomics is defined by the http://www.thefreedictionary.com/ergonomic (2009) as the application of scientific information concerning humans to the design of objects, systems and environment for human use. It deals with how tasks and work areas or space are designed, organized for efficiency and quality of their employees' work. Hedge (2009) said ergonomics is the science of designing machines, products, and systems to maximize the safety, comfort, and efficiency of the people who use them. Ergonomists draw on the principles of industrial engineering, psychology, anthropometry (the science of human measurement), and biomechanics (the study of muscular activity). These are applied by Ergonomists to adapt the design of products and workplaces to people's sizes and shapes and their physical strength and limitations.

Ergonomic design blends both the best abilities of people and machine in order to maximize efficiency of both.

The international Ergonomics Association (IEA, 2000) divides ergonomics into three main domains:

I. Physical (work place) ergonomics: - deals with the human body's responses to physical and physiological stress. In this illness and accident, prevention is the main concern. Because many of these occur as a result of performing tasks associated with repetition—repetitive stress injuries (RSI). Works like screwing, twisting, typing, unassisted lifting, extreme noise, bending, eyes strain, tripling knobs and levers. etc. this continuous processes bring about work related injuries—caused by improper or poor work place and machineries design. To eliminate these in work places, offices or assembly lines are designed with injury prevention in mind. Tools and machineries are also positioned to be accessible without twisting, reaching or bending.

II. Cognitive (information Design) ergonomics : - also known as engineering psychology, concerns mental processes such as perception, attention, cognition, motor control, and memory storage and retrieval as they affect interactions among humans and other elements of a system. Here Hedge (ibid) said that ergonomic help employers to asses both individual tasks necessary to perform a particular job and skills needed to accomplish each task. Tasks and skills are grouped and job redesigned for maximum efficiency.

III. Organizational (maximizing job performance and efficiency) ergonomics or macro-ergonomics: - is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes. Hedge (Op cit) also added here that professional according to some studies, gather, how

human process and respond to information. Instructional manuals for designed products are made available for easy usage with simple but clear instructions.

2.6 MATERIALS

Majorly in machine design, one of the paramount points is the material selection for the various component parts. Previous to discussion further, on material selection Khurmi and Gupta (2004) and Nagpal (2002) advanced the following as needed considerations in selection of materials.

(a) Availability of the materials

(b) The cost (economy)

(c) The suitability of the materials for the working conditions in service. That is:

(i) Ability of the material to be machined shaped, joined, hardened etc.

(ii) Strength

(iii) Durability and

(iv) Corrosion resistance

They further opined that the important properties of these materials need to be considered which are:

1) Physical properties: - density, porosity, structure, feasibility, lustre, colour, shape, size, electric and thermal conductivity.

2) Mechanical properties: - strength, stiffness, elasticity, plasticity toughness, hardness, brittleness, and creep.

3) Magnetic properties: - permeability and hysteresis.

4) Thermal properties: - thermal conductivity, specific heat, latent heat and thermal stress.

5) Electrical properties: - dielectric strength conductivity and resistivity.

6) Chemical: - chemical composition, corrosion resistance, acidity and alkalinity.

2.6.1 Classification of Materials

Materials are generally classified into two. They are:

(a) Metals and other alloys such as iron, steel, copper, aluminium etc.

(b) Non-metals such as glass, rubber, plastic etc.

The metals are further divided into ferrous and non-ferrous.

- Ferrous have iron as their main constituent such as cast iron, wrought iron and steel(plain carbon steel and alloy steel)

- Non-ferrous (this have a metal other than iron as their main constituent) copper, aluminium. Brass, tin, brass etc.

2.7 TILE

Tile is defined as a covering for floors, roofs; or walls: a thin flat or curved piece of baked sometimes glazed, clay or synthetic materials used to cover roofs, floors and walls or for decoration (Tiles in Encarta, 2009). Ceramics article in Encyclopaedia Britannica (2009), defines tile, as thin, flat slab or block used structurally or decoratively in building or an open earth ware or concrete piece used in constructions. Encarta added that they are thin slabs of glazed or unglazed fired clay used structurally or decoratively on floors,

walls, and roofs. It is recorded that, tiles are formed by pressing moist clay into a mould; modern floor tiles are often machine pressed from fine-grained clay. They can also be slip cast, or formed by pouring slip (liquid clay) into a porous mould and allowing it to stiffen.

The Engineering Materials Hand Book of Glass & Ceramics Vol. 4 (EMHBCGV4), (1991) defines tiles according to their types. Drews, (1983) in EMHBGCV4, (1991) stated that ceramic floor and wall tiles include all ceramics products used as wall and floor covering, tiles and components for swimming pools, as well as relevant accessories.

Ceramic Wall and Floor Files:- Uni, (1985) in EMHBGCV4, (1991) says the European standard EN87, approved in Nov. 1981 specifies that "ceramic wall and floor tiles are building materials that are generally designed for use for floor and wall. These are coverings, for both indoors and outdoors. Regardless of their shapes and sizes, these are manufactured by standard ceramic processes and prepared from mixture of ball clays, sand, fluxes, colouring agents and other mineral raw materials. The tiles are processed by milling, screening, blending and wetting. The shaping of tiles is carried out either by pressing, extrusion, casting or other processes normally at room temperature. After shaping, tiles are subsequently dried and fired at high temperature by single or two stage firing- glazed which are unglazed or engobed.

The definitions below are given in EMHBGCV4, by American National Standard Institute Specification for ceramic Tile (ANSIA137.1)

I. ***Ceramic Mosaic Tile*:--** Is formed by either the dust-pressed or plastic method with 6.4 to 9.5 mm(1/4 to 1/8 in) thick with a facial area of less than 39cm^2(6 in^2). Its composition is either porcelain or natural clay with either plain or abrasive mixture.

II. ***Decorative Wall Tile: --*** Is a glazed tile with a thin body, non vitreous it is also suitable for interior or residential decorative us where breaking strength is not a requirement.

III. ***Paver Tile: --*** Is a glazed or unglazed porcelain or natural clay tile formed by dust pressed method with $39cm^2$(6 in^2) or more facial area.

IV. ***Porcelain Tile: --*** Is a ceramic mosaic or paver tile made by dust-press method. Its composition is dense, impervious, fine-grained and smooth sharp form.

V. ***Quarry Tile: --*** Is a tile made by extrusion from natural clay or shale, with a $39cm^2$(6 cm^2) or more facial area, it is either glazed or unglazed.

VI. ***Wall Tile: --*** Is a glazed tile from a body suitable for interior use. It is non vitreous and does not require to withstand excessive impact or to be subjected to freezing and thawing (liquefying) conditions.

VII. ***Individual Tile White Ware Grades: --***These includes unglazed tiles (ceramic mosaic tile, quarry tile, paver tile), and glazed tiles (glazed wall tile, glazed ceramic mosaic tile, glazed quarry tile, glazed paver tile).

2.7.1. Classification of Ceramic Tiles

It is on record that many classifications have been proposed to define tiles. Some are classifications of usage or based on the characteristics of the starting materials or firing cycle. EMHBGCV4, (1991) recorded that, it is difficult to give exhaustive classification owing to the extreme heterogeneity of tile products, yet they are still categorized thus:

1. ***Red Ware and White Ware*** — Red and white tiles are different based on the amount of iron content. The iron reacts with other body's components which gives more or less colouration and modify the behaviour of the body in firing. (Nassetti 1985) in EMHBGCV4, (1991).

2. European (EN) and America Society of Testing and Materials (ASTM) standards, classify ceramic tiles base on the function of water absorption and shaping method.

i. ***Shaping process***: (a). (extruded floor tile) this process includes split tiles and individual extruded tiles.

(b). dry-pressed floor and wall tiles.

(c). cast floor and wall tiles

ii. ***Water (H_2O) absorption:*** (is directly related to porosity) this is represented with E, expressed as a mass fraction given as a percentage:

- Group I (low H_2O absorption) where $E \leq 3\%$
- Group II (medium H_2O absorption) where $3\% < E \leq 6\%$ (Group IIa) or where $6\% < E \leq 10\%$ (Group IIb)
- Group III (high H_2O absorption) where $E > 10\%$.

iii. ***Shaping process and water absorption as*** in Table 2.2. These parameters are directly related to the physical, chemical, mechanical and micro-structural properties such as:

- Modulus of rupture of fired tiles;
- Abrasion resistance;
- Chemical resistance;
- Frost resistance.

Table 2.2 Classification of Ceramic Tiles in Compliance with EN 87

Tile classification/water (H_2O) absorption. E, wt%				
Tile type	$E \leq 3$ (Group I)	$3 < E \leq 6$ (Group IIa)	$6 < E \leq 10\%$ 9Group IIb)	$E > 10$ (Group III)
Extruded tiles (a)	AI	AIIa	AIIb	AIII
Pressed tiles (b)	BI (d)	BIIa	BIIb	BIII
Cast tiles (c)	CI	CIIa	CIIb	CIII
(a) Includes split tiles and individually extruded tiles. (b) Includes dry-pressed floor and wall tiles. (c) Includes cast floor and wall tiles (d) water absorption for BI unglazed tiles is <1.5 wt%. For unglazed and very vitrified tiles. $E < 0.5$. Source Drews (1983)				

Source: EMHBGCV4 (1991)

2.7.2 Characteristics of Ceramic Tile

Ceramic tile according to Benlloch *et al* (1981) in EMHBGCV4 (1991) is a stable inexpensive building material of 5 to 15 mm (0.2 to 0.6 in) thickness and a wide range of dimensions Table 2.3

Table 2.3 Common shapes and sizes of ceramic floor and wall tiles. Their dimensions are given in cm 1 cm = 0.4 in.

Square		Rectangle	
Floor tiles	Wall tiles	Floor tiles	Wall tiles
10 x 10	5 x 5	7.5 x 13.3	7.5 x 15
15 x 15	10 x 10	7.5 x 15	10 x 20
20 x 20	15 x 15	10 x 20	10 x 15
21.6b x 21.6	20 x20	15 x 20	20 x 30
25 x 25		16.5 x 33	20 x 25
30 x 30		15 x 30	30 x 40
31.6 x 31.6		20 x 25	
33 x 33		20 x 30	
40 x 40		20 x 33.3	
50 x 50		30 x 40	
60 x 60		30 x 40	

Source: EMHBGCV4 (1991)

Benlloch *et al* (1981) further deduced that most of the tiles available in the market are single fired or twice-fired. Such tiles are made up of the basic components below;

- Clay minerals
- Inert materials, such as feldspars, and pegmatite
- Others (calcite dolomite & other oxides)

However, some specialized bodies for specific applications contain other components, such as alumina, in certain porcelains and bone ash in bone china. Cubbon and Till (1983) in EMHBGCV4 said most tiles and floor white ware bodies are prepared by single firing technology, which steps were specify by Dardi and Bresciani (1990) as follows;

Batching

Grinding

Spray-drying

Pressing

Dying

Glazing and

Firing

With the following steps above varieties of tile, types can be produced with diverse applications.

2.7.3 Tile Type/Application (function)

The technical and aesthetic characteristics of tile material determine to a large extent how they may be functionally classified (Ruini and Arnal, 1991).

A. ***Wall Tiles (both medium and high porosity)*** -- Are classified as decorated wall tiles, faience tiles, stove tiles, cottoforte tiles, porous single-fired *("Monoporosa")* tiles and exterior wall tiles. According to Singer and Singer (1963), wall tiles are mass-produced thin tiles with a porous body, and finished with a white coloured glossy or matte glaze. These are in wide varieties of shapes and sizes, some in square and rectangle shapes. They are used in domestic and institutional kitchens, bathrooms, and washroom and swimming pools and as well as in decorative work such as table tops and fire place surrounds. Wall tiles are not used in places exposed to frost attack or abrasion. He singer & singer (ibid) further advanced that a good wall tile should possess the following technical characteristics:

(i) Excellent dimensional stability in the manufacturing process usually obtained using body composition with low firing shrinkage (less than 0.5%).

(ii) Very narrow dimensional range to ensure easy setting and vertical applications.

(iii)The glaze must be easy to clean with no dust retention, because one of the requirements in bathrooms or kitchen application is hygiene.

B. ***Floor Tiles:-*** are low porosity materials which include quarry tiles, stoneware tiles, klinker and mosaic tiles. Floor tiles apart from being strong and attractive need to possess the following technical characteristics:

(i) High mechanical strength (breaking resistance):- This is referred to as the modulus of rupture.

(ii) High abrasion resistance:- This addresses the hardness and gloss of the surface; also the presence of cavities. A shiny product is intrinsically less resistance than a matted product with the same surface hardness.

(iii) High impact resistance:- Is related to the strength of the body and the thickness of the glaze. Unglazed porcelain tiles with thick dense glaze made by hot glazing display optimum properties.

(iv) Frost resistance: - This is more important for floor tiles than for wall tile in exterior application.

(v) Weathering and stoning resistance.

C. ***Porcelain Tiles:-*** These are very low-porosity materials. They were prepared using kaolin or pure kaolinitic clays, quartz and high amounts of feldspars as fluxing agents to increase sintering. The raw materials are highly milled than other types of tile product and fired at about 1200^{o}C (2190^{o}F), Nasseti (1985) in EMHBGCV4. Below are data provided on the classification and property values associated with porcelain tile products:

D. Table 2.4 Selected Properties of Porcelain Tile

Standard Property	Value prescribed by the standards	Real value of the products
EN 99	Water absorption, E, wt%	≤0.5
<0.2		
EN 100	Bending strength, Mpa (ksi)	≥27 (≥ 3.9)
≥20 (≥7.25)		
EN 101	Scratch hardness (Mohs scale)	≥6
7/8		
EN 102	Abrasion resistance (a)	≤205 mm^3
<130 mm^3		
EN 103	Coefficient of thermal expansion at	
	20--100 ^oC	≤ 9 x 10^{-6} K^{-1}
<7 x 10^{-6} K^{-1}		

(a) Unglazed tile requirement.

Source EMHBGCV4 (1991)

These tiles are mostly used for antiseptic environments where hygiene is paramount. This is because; they combine sufficient cleanliness with suitable electrical properties.

2.7.4 Tiles' Recipe

Kenneth (2002) advanced that in making tiles one does not need to stress himself in preparing tile body or recipe; if the tile is not meant for special orders. He said one can get ready-made good commercial clay bodies for making tiles. Both Kenneth and Pozo (2005) as specialists in tile making gave some recipes for tiles. This suggests that tile recipe can be adopted either for fabrication or for test running of machines. Example of such recipes by Pozo are listed in Appendices V

2.7.5.0 Mould/Template

2.7.5.1 Template

Template is a master pattern. Encarta, (2009), Murphy In Encarta (2009) and Giorgini (1994) all concur that, a template is that, that serves as a master or pattern from where other similar things can be made (master stencil, model etc). Murphy added that each reproduction serves as the template for the next copy. In marking a template Giorgini (ibid), said it should be cut to the size and shape of the tile—this can be from ply wood, Masonite or cardboard. In using template, he said that it should be place on the clay slabs and inscribes or cut around it with a pin tool. Before cutting the templates to size, shrinkage should be put into consideration.

2.7.5.2 Mould/Mold

Mould s a frame in which something is constructed or shaped—is a container that gives a shape to a molten or liquid substance poured into it to harden. Gukas and Datiri (2001), Encarta (2009), and French (1972) a mould, they said is a frame that retains or holds the exact outer surface of a design, model or shape of an object (pot, tile, image etc.) through casting or other means. Mould are made from plaster semi-hydrated calcium sulphate

($2CaSO_4H_2O$), got primarily from gypsum. Mould can be one piece, two pieces, and three pieces or more; depending on the shape or design or protrusions on an image and the purpose it is meant to serve. Mould can be in form of a block mould, master or case mould, working or casting mould. Usually mould is got from a model. It is a copy of an original object made in a smaller or larger size. The essence of a mould is for continuous reproduction of an object on a larger scale, mass or industrial-scale, Gukas and Datiri (ibid) and Industrial Ceramic lecture notes (2001-2).

2.7.5.3 Steps in Mould Preparation

Gukas and Datiri (Op cit) and Pozo (2005) said in mould making, the first important thing to do is to produce a model, made from a material that can retain its shape when the plaster mix is poured on it. Next, ascertain if the model is to be casted in one piece or multiple pieces. For example, a model of a one piece mould should be placed on the centre of a slab of clay or cut wood ensuring that it extends beyond all the edges of the model of about 5cm to 6cm. A retention wall or cottle should be created with a cardboard paper using rubber band to hold it up; supported with plastic clay from outside to avoid the plaster from escaping or running out. The model should be creamed or rub with a plaster separator or oil. Once this is done, the plaster is mix with equivalent water for that mould size and poured on the model. This is left for 10 to 15 minutes to settle before the model is separated from the mould. This is now washed and dried before is put to use. The multiple moulds follows the same pattern, only that it is cast part by part depending on the number of the parts, up till the final cast. Pozo (ibid) added that, in making a mould the designer should ensure that all the necessary design is completed, smoothen and without any undercut. Instead of using clay, she suggested that wood should serve as the cottle held firm together with two clamps. She also advanced that, the base of the mould frame where the original model (tile or object) sits, should be a slick

resistant surface or an old glass window or a piece of wood with a laminated plastic coating. This surface will enhance easy removal after casting. She gave the following as guide in the mixture of water to plaster for an effective result.

> *Plaster volume guide*
>
> *Determine the cubic dimension of a mould by multiplying its height, length and width. Use approximately 1 pound (.9kg) of water and 11/2 pounds (1,4kg) of No.1 pottery plaster for every 45 cubic inches. Weight the water rather than measure its volume. Other types of plasters use different water-to-plaster ratio.*

On other hand, Frank and Hamer (1991) gave the ratio of water-to-plaster for other types of plaster as specified by Pozo.

Table 2.5 CHARTS OF PLASTER MIXES

Parts by weight		Minutes	Further		
Water	plaster	Pouring Time	Minutes Setting	% Absorbency	Use
100	110	6	13	50	patching moulds
91	100				
100	120	51/2	18	45	absorbent bats; hump moulds
83	100				
100	130	5	20	40	Casting moulds rolling mould blocks
77	100				
100	140	3	18	35	cases
71	100				

SOURCE Frank and Hamer (1991)

In producing tiles, Giorgini (1994) gave the following plaster mixing.

Table 2.6 Plaster Mixing

SIZE OF MOULD-FORM INTERIOR	POUNDS (Kg) OF WATER	POUNDS (Kg) OF PLASTER
8’ X 8” X 3’ (20.3cm x 20.3 cm x 7.6cm)	4.5 (2.0 kg)	7 (3.2 kg)
9’ X 9” X 3’ (22.9cm x 22.9cm x 7.6cm)	6 (2.7 kg)	9 (4.1 kg)
10’ X 10” X 3’ (25.4cm x 25.4cm x 7.6cm)	7 (3.2 kg)	11 (5.0 kg)
11’ X 11” X 3’ (27.9cm x 27.9cm x 7.6cm)	9 (4.1 kg)	13.5 (6.1 kg)
12’ X 12” X 3’ (30.5cm x 30.5cm x 7.6cm)	10.5 (4.8 kg)	16 (7.3 kg)
13’ X 13” X 3’ (33.0cm x 33.0cm x 7..6cm)	13 (5.9 kg)	19.5 (8.6 kg)
14’ X 14” X 3’ (35,6cm x 35.6cm x 7.6cm)	17 (6.4 kg)	21 (9.5 kg)
15’ X 15” X 3’ (38.1cm x 8.1cm x 7.6cm)	7.7 (7.7 kg)	26 (11.8 kg)
16’ X 16” X 3’ (40.6cm x 40.6cm x 7.6cm)	20 (9.1 kg)	30 (13.6 kg)

Source : (Giorgini, 1994).

2.8. REVIEW OF PAST WORKS ON TILE EXTRUSION

2.8.1 Extrusion

One of the methods used in most machines for tile production and making is extrusion. 'Extrusion' in Encarta (2009) and EMHBGCV4 (1991) defines extrusion as a process or an instance of making something by forcing semi-soft material through a specially shaped mould or nozzle. The duo said, this, is a very effective and efficient method as a continuous or semi-continuous process in which ceramic powder is heated in a long barrel. A rotating screw then forces the heated material through an opening of the desired shape. As the continuous form emerges from the die opening, the form cools, solidifies, and is cut to the desired length. EMHBGCV4 (ibid) added that simple equipment can be used in this forming process, which helps in energy and material conservation. Though extrusion has some limitations, it can be used to form all products but is best suited to fabricate shapes that are of constant cross section and linearly formed. Extrusion principle is used to make products such as:

Ceramic pipe or tubes, with open or closed ends

Tiles

Bricks

Profiles of numerous shapes

Rods

Honeycombs

Plates; solid, hollow or ribbed

Films

EMHBGCV4 (Op cit) stated that there are three basic extruders used in ceramic processes, advanced by Benbow, *et al* (1989), Schweigner and Burnfield (1989),

Mckelvey (Washington University), Reed (New York State College of Ceramics, Alfred University) and Reed (1987) which are:

Ram or piston

Pug mill-auger and

Screw-fed plasticator

a). ***The Ram or Piston Extruder: -*** This has a capability to reach very high pressure. It is powered by hydraulic pumps, which makes it easy to maintain.

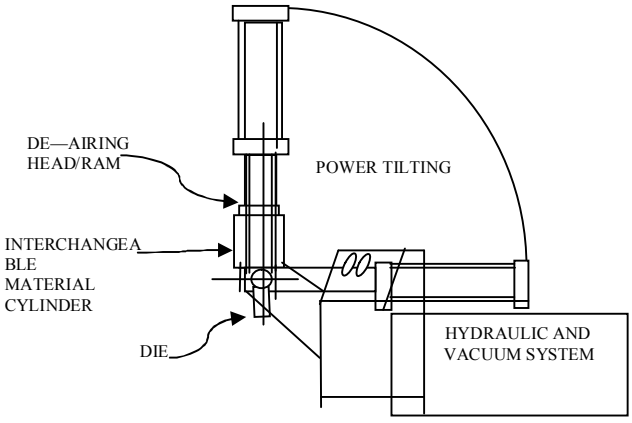


Figure 7: Hydraulic (RAM) Piston Extruder

Source: EMHBGCV4 (1991)

The piston extruder has a disadvantage being a batch machine that holds limited amount of material. Secondly, it has incremental recording (layer of mix) in the mix; cylinder can cause disruptions in the flow pattern of the cylinder/die. This, as well trapped air, which can result in changes in extrusion behaviour and flaws in the green parts.

b). A ***Pug Mill-Auger: -*** This serves as a mixer and extruder in one unit. The material used is pre-blended before feeding into the machine mixing section. Materials, like large pebbles or augers are shredded and drop into a vacuum chamber and de-aired. This is

now transported and consolidated by an auger screw which forces the material out through a trapped die/nozzle. It has an advantage because of the continuous mixing; de-airing, consolidation and extrusion are done inside a single equipment. However, the shredders and turning augers can wear out and even contaminate the mixed extruded parts. The pug mill works well with material that slide, the screw can moved and be consolidated. Below is an example of a pug-mill extruder frame.

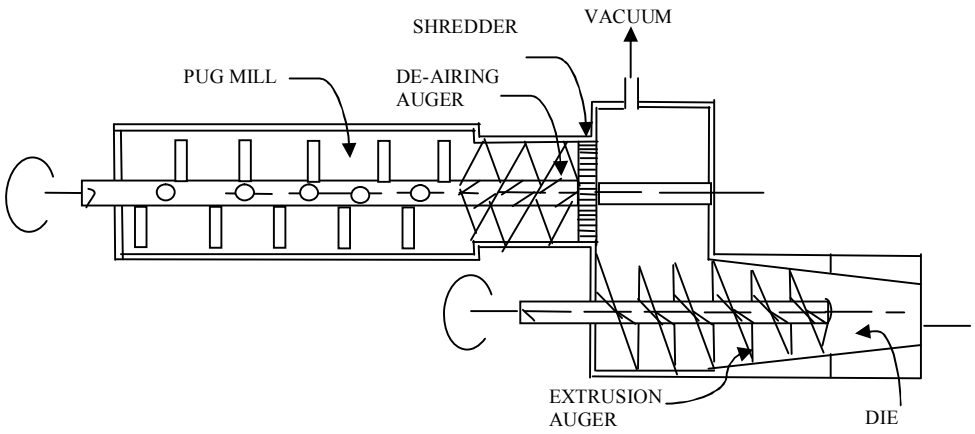


Figure 8: **Pug mill with de-airing chamber and extrusion auger**
Source*: EMHBGCV4 (1991)*

c). **Screw-fed Plasticator:-** Is design to extrude plastic. It has a single or twin screw inside a barrel formed at variable rev/min. The barrel is heated extremely. The dies can be heated and/ or cooled. The barrel/screw assembly is broken into three sections as shown below.

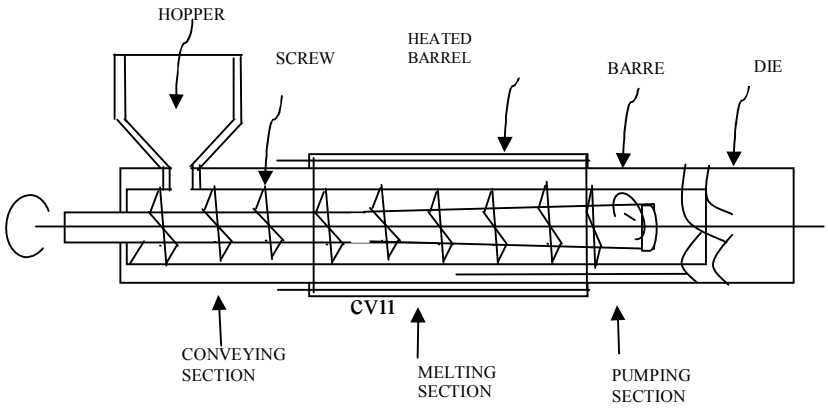


Figure 9: Single-Screw Plasticating Extruder

Source: EMHBGCV4 (1991)

A palletized ceramics powder and plastic binder is fed into the first sector, conveying to the melting section, when heat is applied to soften and meet the binder. It is then move into mixing/pumping section, for further mixing and the formation of a relatively fluid mixture. The mixture is then transported into the primary section where the material is pressurized and delivered with the desired rheology to the die. This also offers continues operation and improved mix homogeneity like the pug mill. It is however high in maintenance cost and also contaminates mix through the screw and barrel wear. But its problem can be contained by the type of binder and screw used.

This type of extruder design was adopted in the fabrication of the tile making machine; with few modifications to accommodate cold extrusion.

Table 2.7 Advantages and disadvantages of vertical and horizontal extrusion

Orientation	Advantages	Disadvantages
Vertical	Assistance of gravity to take up material; no friction on extrudate	Gravity can stress material as extrudate mass approaches or exceeds green strength; dimensional changes/flaws can result
	Reduction of surface flaws related to take-up fixture	Extrudate length limited, such as from die to bottom of pit or floor
	Tilting unnecessary	Handling of extruded part after being cut at die
	Minimal floor space required	
	Safer if die assembly fails at high pressure	
	Multiple (turret-type) mix cylinders possible	
Horizontal	Extrudate length virtually unlimited	Reloading mix cylinder on piston extruders may require cessation of extrusion and tilting to reload
	Take-up equipment/mixtures can help maintain size/tolerances	Equipment/fixtures may be required to take up extruded part to maintain size and reduce effects of gravity and friction

Source: (EMHBGCV4, 1991).

2.8.2 Example of Tile Making Machine using Pug mill-auger

The tile making machines are operated manually, while some are operated semi-automatic, others are automatically powered and some are completely produced using just hand rolled clay slab and plaster mould. Peter pugger, 2007 htt://www.peterpugger.com/pugmill-extruder/tilepugger-mixer.html has produced three of such tile extruders and pug-mills made of stainless still. He called them generation powered extruders; ram press and tile making equipment. These, he developed in line with pottery ideas from studio and engineering ideas of his set up tile production, creating various forming techniques, custom built machines and process brain efficiency and artistic method to large scale manufacturer.

M 1700 Dearing Pugmill

TM 1700 de-airing pug-mill with specifications

- Pug Diameter: 5”
- Maximum output: 2,204 Ibs (pound)/hr.
- Weight: 1,708 Ibs.
- Length: 105”
- Width: 29:
- Height: 77”
- Maximum extrusion capacity: 13 3/8” wide



Plate I: M 1700 Dearing Pugmill
Source: Peter (2007)

TM 2700 Deairing Pugmill

TM 2700 de-airing pug-mill with specifications

- Pug Diameter: 7”
- Maximum output: 5,511 Ibs (pound)/hr.
- Weight: 3,791 Ibs.
- Length: 122”
- Width: 37”
- Height: 98”
- Maximum extrusion capacity: 13 3/8” wide



Plate II: TM 2700 Deairing Pugmill

Source: Peter (2007**)**

VPM—60 Vacuum Power Wedger “the Vacuum Dearing Pugger-mixer”.

VPM—60 vacuum power wedger (140 ib) mix batch size with specifications

- Maximum batch capacity: 140 Ibs
- Pugging rate: 1500 Ibs/hr
- Mixing rate: 500 Ibs/hr
- Crated weight: 520 Ibs.
- Hopper size: 9" x 9"
- Motor: 2 HP Iph, 12 amps at 240V
- Vacuum pump: ½ HP, 3.8 amps at 120 volts
- Length: 58"
- Width: 24"
- Height: 31"
- Tile extruder (variable speed).



Plate III: VPM—60 Vacuum Power Wedger "the Vacuum Dearing Pugger-mixer".

Source: Peter (2007)

The three machines work alike with similar features. There are virtually no significant differences, except for their shapes, sizes and capacities.

2.8.3. How The Peter Pugger Works

Diagram in the working of vpm—60 vacuum power wedger (140 ib) in batch size "the vacuum Dearing pugger-mixer".

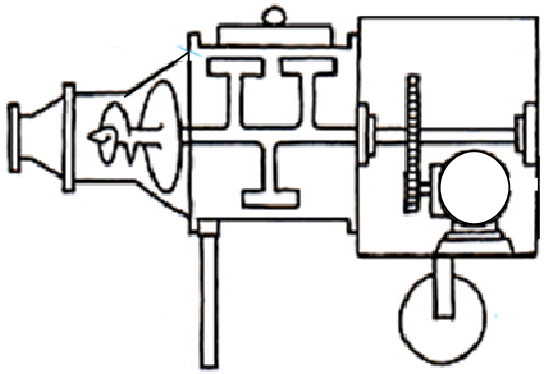


Figure 10: Vacuum Dearing Pugger-mixer

Source Peter: (2007**)**

CHAPTER THREE

METHODOLOGY

3.0 INTRODUCTION

This section seeks to highlight the usefulness of information acquired from the review literature into a practical solution. This will give the details of what materials to source for, where it was got and prepared, how to use it and what aid was used. It also gives an insight into the procedure used in analysing the various tests carried out.

3.1 RESEARCH DESIGN

As the name implies, this section shows the step by step approach in realizing this project from beginning to the end. It shows the order of progression on how this project was accomplished. This progression includes; the methodology, pilot study, materials, design theories, design considerations and calculations, approaches in production, production site, equipment/tools and facilities implored, assembling of parts made, tile production etc.

3.2 METHODOLOGY

The research methodology chosen for this study is research and development (R&D) or product development procedure as suggested by Kurmi (2004), Nagpal (2002) and Adetoro (1997). The research methodology adopted for this study is an experimental method towards the development of a product. The end result is expected to produce what is known in research cycle as “research and development (R&D)” as suggested by the three authors mentioned above. This was done in line with item 2.2 – 2.6 machine design considerations, theories and calculations mentioned in chapter two, alongside the fabrication processes, product development, materials etc.

3.3 PILOT STUDIES

Prior to the fabrication of the equipment, preliminary drawings right from the conception of the idea to the end product were made. This led to various gradations of drawings of the entire machine from manual to computer aided design (CAD) with software like AutoCAD and Sketchup. The drawings were broken into various component parts to ease fabrication of parts. From these sketch diagrams, workable designs were selected to work on. Below are some of these drawings:

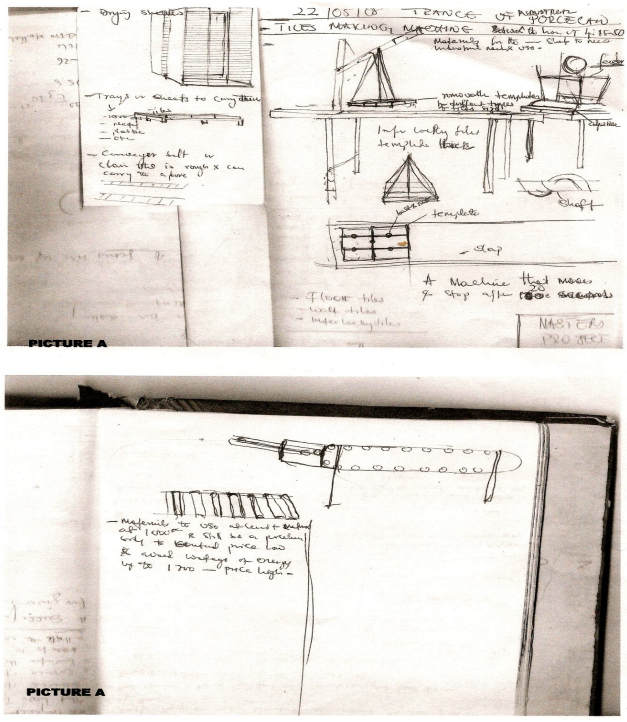


Figure 11:- *First Drawing of Idea (TMM) Developed into a Sketch*

Source: Researcher's computer (scanned drawing), (2008)

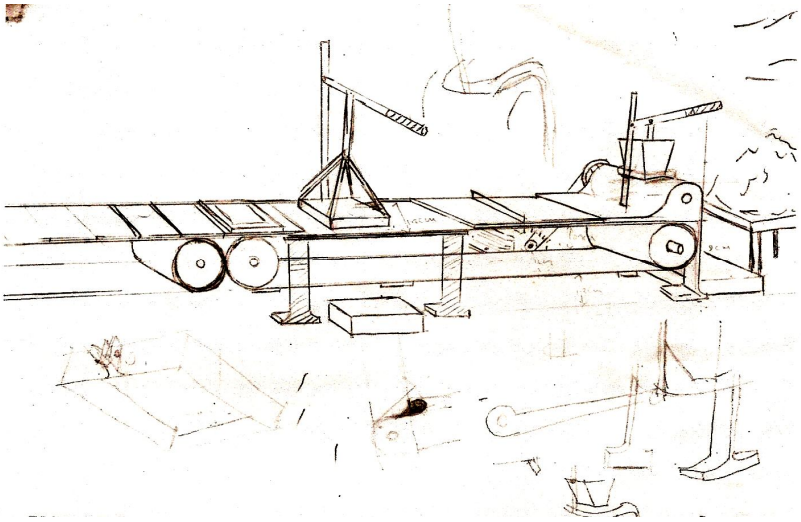


Figure 12:- *Second Drawing of Idea (TMM) with Pencil and Pen Developed Further*
Source: Researcher's scanned drawing, (2009)

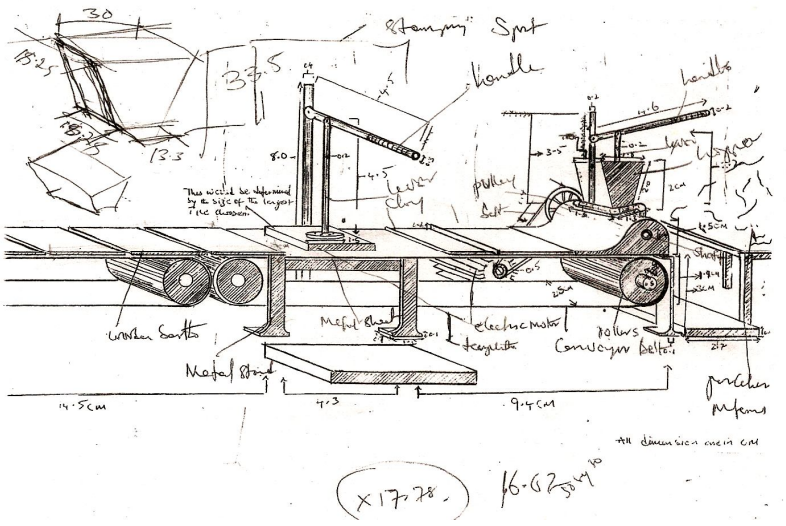


Figure 13:- *Third Drawing of Idea (TMM) with Pencil and Pen Modified, Refined and Dimensioned*

Source: Researcher's scanned drawing, (2009)

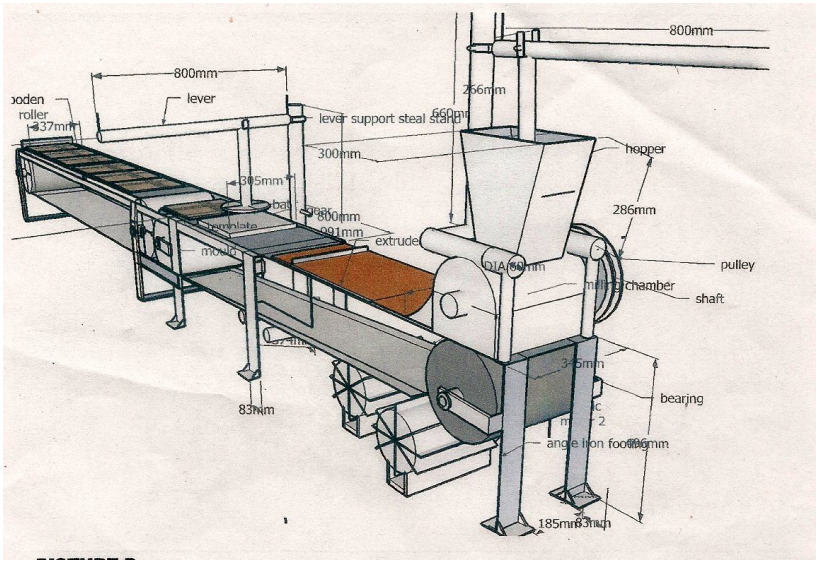


***Figure 14**:- Fourth Drawing of Idea (TMM) Developed on CAD with Sketch-up Dimensioned.*

Source: Researcher's scanned drawing, (2009)

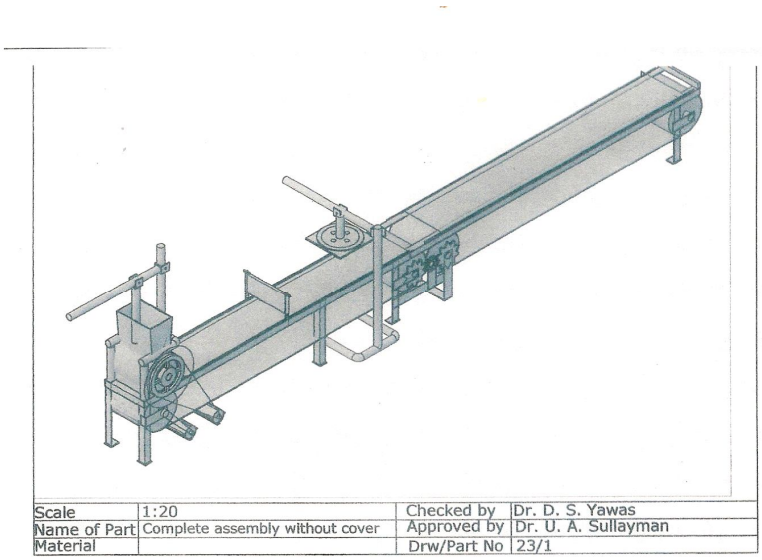


***Figure 15**:- Fifth Drawing of Idea (TMM Developed on AutoCAD)*
Source: Researcher's scanned drawing, (2009)

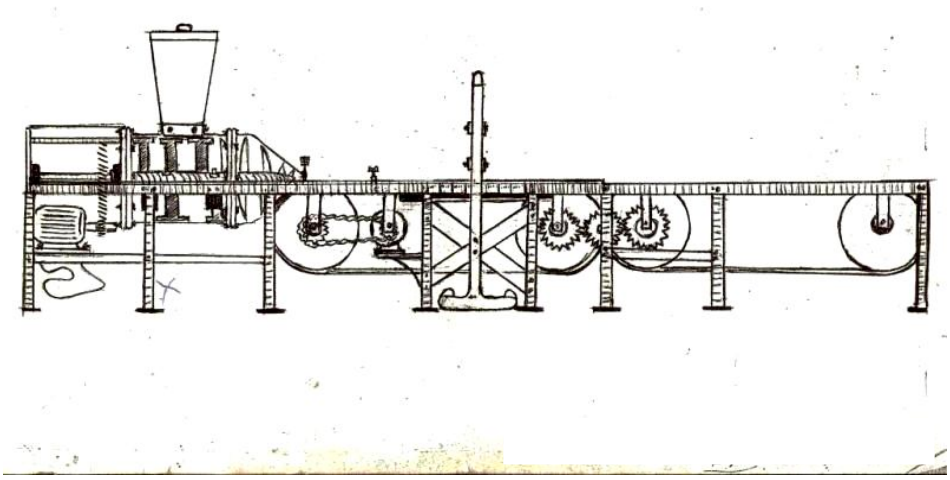


Figure 16:- *Sixth Drawing of Idea at the Nib of Fabrication (Side View of TMM Developed with Pen) with some modifications.*

Source: Researcher's scanned drawing, (2010)

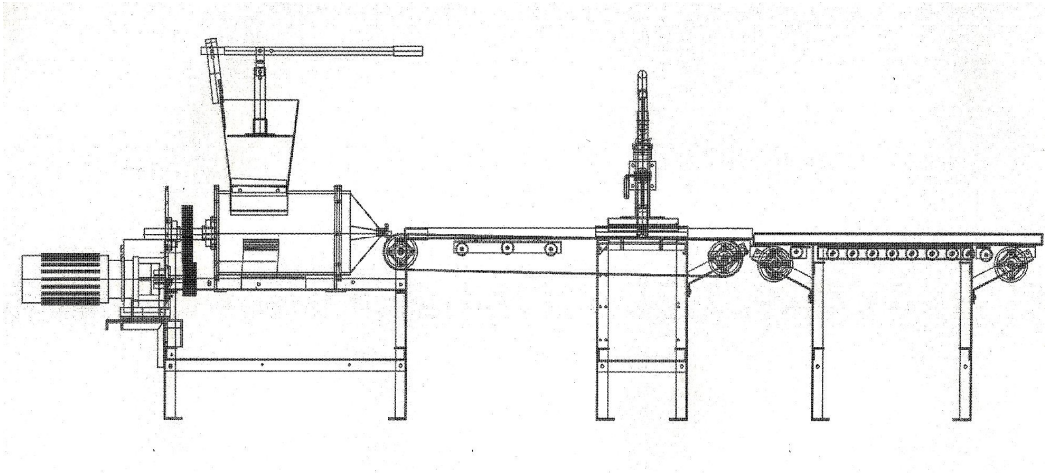


Figure 17:- *Seventh and Final Drawing of Machine after Fabrication (Side View of TMM Developed with AutoCAD)*

Source: Researcher's scanned drawing, (2011)

Morakinyo *et al* (2011) are of the view that drawing for a creative worker is a dynamic conversation with the plan and the other stakeholders. The drawing talks to the designers and the designers respond to the drawing by producing alterations or modifications until

the best possible outcome is realized. In mechanical engineering in the same vein prior to the design of products, machines or components, meaningful/creative ideas are first drawn (sketched), further developed and eventually drafted with a software subsequently. Such dimensioned, becomes a blue print from which dependable and realistic machines/components are realized. This drawing is called "*Mathematical modelling*". It provides quick and cheap means to establish volume, strength, or weight of components. It further facilitates feedback from variety of sources such as users, manufacturers or other members of a design team. This model can be in form of drawings or constructions which allow problems to be explored, ideas to be visualized and intentions to be communicated.

The drawings above are arranged according to order of development, modification and refinement base on careful observation. Eventually, a decision was made on one of the drawings which were used in the fabrication of the machine. The various materials used in developing every part of the machine are visible from figures 15. But at the point of actual production, a sixth drawing figure 16 was produced as a result of some lapses seen in the fifth drawing on figure 15. The best of the model drawing actually served as the working drawing or the blue print chosen for the fabrication of the TMM as suggested by Nagpal (2002) and Khurmi and Gupta (2004). The last drawing is the final and complete drawing with AutoCAD, figure 17.

3.3.1 3D Modelling of Parts

In the preliminary pilot study, 3D models of some component parts became imperative. Apart from the engineering drawing that serves as a blue print, the 3D modelling is a mathematical model used to view a project prospect; this is in form of a physical model

produced. In the case of this research, only the complicated and nerve-racking geometric shapes of the major component parts were produced using cardboard paper and strawboard which helped in obtaining triangulation of shapes feedback and decision making. This paper models were later transferred or copied unto the key steel materials. This helped to achieve:

a. Accuracy of shape and dimension.

b. Prevent wastage of material and time.

c. Failure of component function.

d. Possibility of component parts as designed.

e. Ease in cutting and forming out shapes.

Some of the parts that were modelled on paper Plate IV to VI include the top of the chamber i.e. the gallery (hopper seating), the cone-nose or the orifice as well as the outlet, roller inner four arms support and cylinder shaft to determine the paddles location.

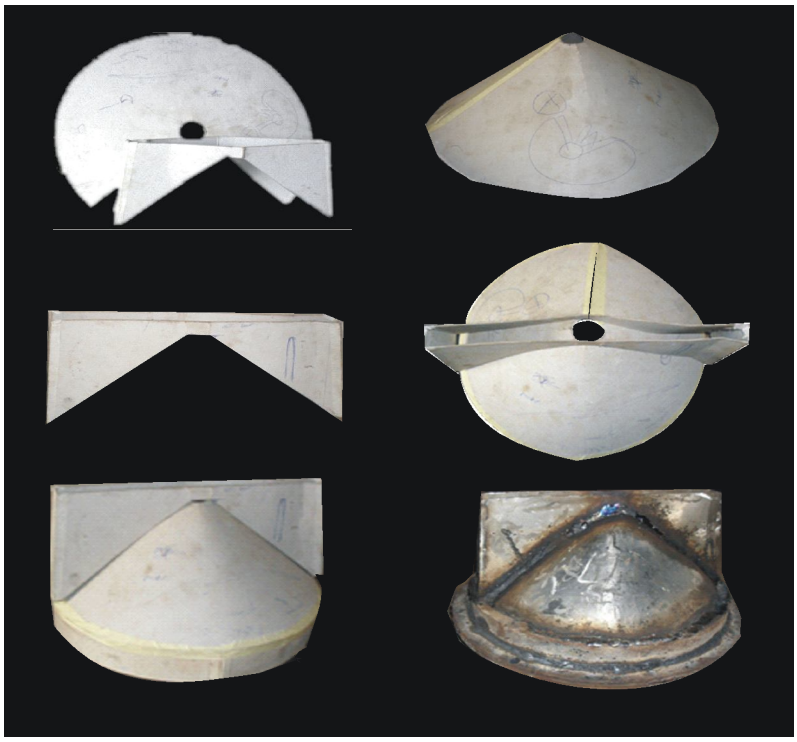
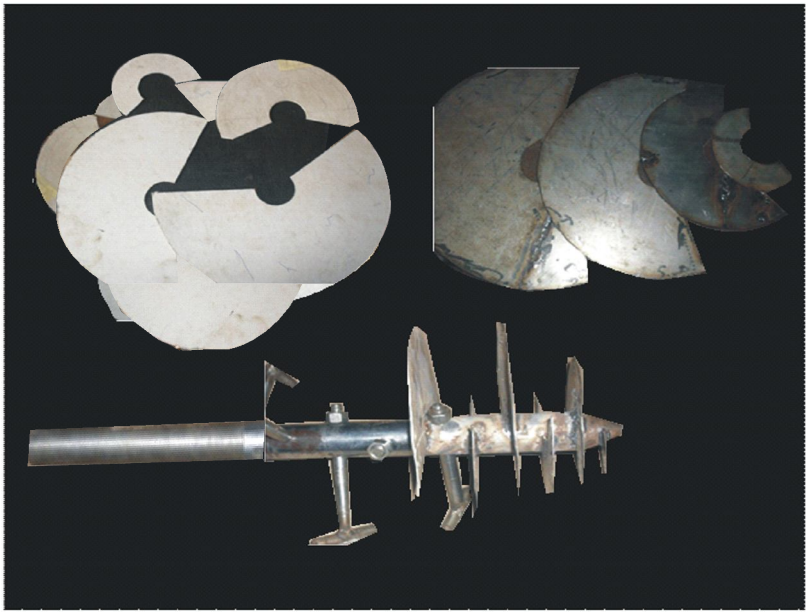
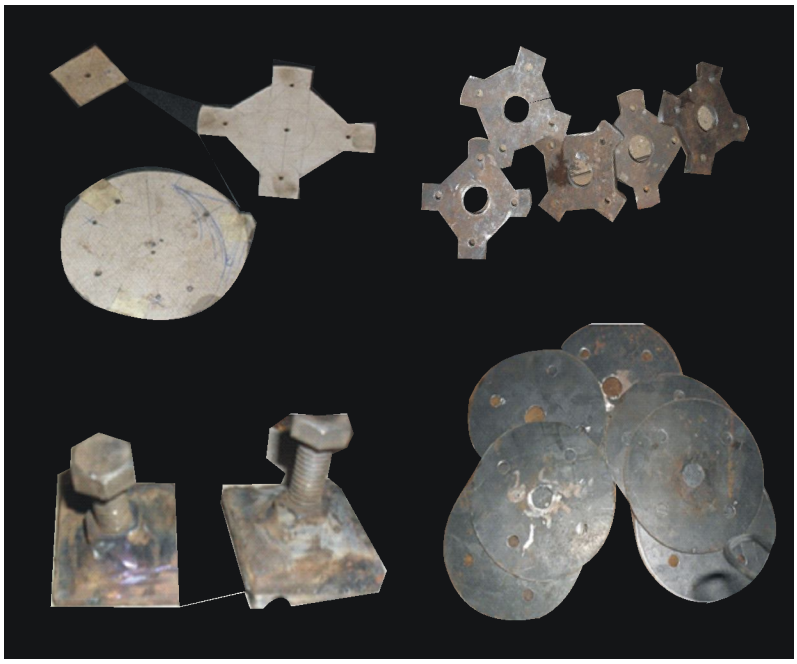


Plate IV*: - Stages in the development of the Cone-nose or Orifice from straw board to the original produce with Stainless and Mild Steel.*
Source: Source: Original Research Photograph Morakinyo, (2010)



*Plates V****: - Stages in the development of the initial auger plate/blade from straw board to the original produce with stainless steel welded on a chromed mild steel shaft.***
Source: Original Research Photograph Morakinyo, (2010)



Plates VI: - Stages of development of roller hanger footing, roller internal support, and the roller cover patterns from straw board to the original, produce with mild steel.

Source: Original Research Photograph Morakinyo, (2010)

3.4 MATERIALS

In the fabrication of the major component parts of the machine various materials were used such as mild steel, stainless steel and cast iron. These were used for components like the pulleys, sprockets, pins, keys, bolts and nuts, shaft, auger blade, gears, spring, the lever steel stand, angular metal footings, milling chamber, plates, cone nose end, rollers big and small, flange, blind flange, clamp, motor bed and connecting plate etc.

Mild steel has been the best and most widely used, in building the world's infrastructure and industries (Britannica, 2009). Mild steel is available, cheaper and easy to machine and it possesses all the properties of metals - physical, mechanical, magnetic, thermal, electrical and chemical which makes it usable as mentioned by Khurmi and Gupta (2004 and Nagpal (2002).

Stainless steel was used for the lever, hopper, chamber lining, thickness regulating bar, hopper regulation plate, template's casing (tray) etc. Stainless steel increases corrosion resistance to specific environments, enhances oxidation resistance and imparts special characteristics (Britannica, 2011).

Plastic material was implored for the lever's handles. Wood was also incorporated for the production of wooden baths and a wooden base at the stamping point. This is to support the belt conveyor for swift cutting of tile without strain or distortion. For other major components with materials standards these were purchased; the electric motor, bearings, switches, contactors, chain, pins, belt conveyor and V-belt. The belt conveyor was cut to the operational size of the machine rollers.

All the materials discussed above were purchased from market in Kaduna i.e. metal and scrap markets (Kakuri, Panteka, and Angwan Ma'azu Kaduna-Abuja Expressway).

The major material used for the tile production is clay. There was no new formulation of tile mix. Instead an existing tile recipe was adopted to make the machine relevant; not localized to a particular environment but to be of international value and usage. On this note, the recipe proposed by Pozo (2005) and Kenneth (2002) as earlier stated was used, but it was later substituted with Tony Hassen's recipe.

3.4.1 Tile Material

Tile is made up of different materials composition call a body. A body for tile has different compositions depending on the type of tile to be moulded. The body used for this research comprised three major materials namely clay, silica, feldspar and kaolin or clay in different composition to determine a suitable and workable body. The above materials with the exception of silica were obtained from the Department of Industrial Design, Ceramics section, Ahmadu Bello University (ABU) Zaria. Raw silica was obtained from the Department of Industrial Design, Ceramics section, Abubakar Tafawa Balewa University (ATBU), Bauchi. All these are conventional materials previously analyzed and used by previous researchers. So, there was no need going into individual analysis of these. This is to allow for focus on the fabrication of the tile moulding machine devoid of digression or distraction.

CLAY

Basically, clay can be classified into two types: primary/residual clay and secondary/sedimentary clay. That is Kaolin/china clay and ball clay respectively. Kaolin is less plastic and contains larger particle size. It is white in nature and fires at an extremely high temperature. Monteiro *et al.* (2003) in Alkali (2009) said the kaolinitic nature and the presence of aluminium hydroxide confers a refractory behaviour which impairs sintering during firing in some cases. This he said result in the greater porosity associated with elevated values of water absorption of primary clay, reduces the mechanical strength of forms at green ware stage.

FELDSPAR

Grema (2004) in Morakinyo *et al.* (2010) and Britannica on Material Science (2011) defines feldspar as a crystalline rock composed of alumina silicates of potassium (K), sodium(Na), and calcium (Ca) (orthoclase), (albite) and (anothite). It is the most important flux in bodies and glazes. It acts as fluxing agents to reduce the melting temperatures of the aluminosilicate phases. Feldspar covers a number of alkali and alkaline earth aluminium silicate. It contains the entire active minerals essential for making glaze. Feldspars are a group of minerals that come from crushed rocks and can supply up to 25 per cent of fluxes in a body, and varying proportions in a glaze (Kenneth, 2002 in Morakinyo *et al.* 2010).

SILICA

Silica is a major ingredient in refractorys and white-wares. It is usually added as quartz sand, sandstone or flint pebbles (Britannica, 2011). The role of silica is that of a filler used to impart “green” (that is, unfired) strength to the shape of an object and to maintain that shape during firing. It also improves its final properties.

In summary, the two clays (primary and secondary clay) serves as binders. Where silica produces strength the feldspar reasonably reduces the melting time of the tile body.

3.5 EQUIPMENT/TOOLS AND FACILITIES

In executing this study, the under-listed equipment/tools and facilities were used: the angle and bench grinders, industrial cutting machine, the hand and industrial drilling machine, industrial folding machine, the milling and lathe machine and a hack saw. Others are measuring tape, square, vernier and normal calliper, oxyacetylene (oxygen and gas) cylinder and nozzle, slotting/shaping machine, chain pulley machine, hammer,

grip pliers, vice, welding machines, spray gun, spanners, and screw drivers. All these with the exception of some few were available for use at Delmat fabrication and machining workshop Kakuri, Artillery, Kaduna, Kaduna State. Other equipment required were ball mill, test kiln, weighing machine, modelling tools, plunger, etc. These were available in the Ceramics section, Department of Industrial Design, Ahmadu Bello University, Zaria; Ceramics section, Industrial Programme and Ceramics section, Department of Industrial Design, Federal University of Technology Yola. The laptop, internet modem, cameras, drawing sets etc. were provided by the researcher.

3.6 DESIGN THEORIES, CONSIDERATIONS AND CALCULATIONS

The design theory, consideration and calculation in chapter two item 2.2 – 2.6 for the major component parts were assiduously utilized and followed to the latter in this section, except otherwise stated. Other conditions necessary in determining other factors were also spelt out clearly.

3.6.1 Conditions and Consideration before Construction and Calculation

The following parameters were first determined:

I. The material to be used

II. Determine the bulk density of the material

III. Shear stress value

IV. Coefficient of friction of the material to the wall of the chamber

V. The batch in feeding the hopper chamber in an hour to produce 40 tiles fig. 18

VI. Selection of bearings to used.

VII. Classes of lever to be adopted

VIII. Flow direction of the tile material

IX. Type of gear or reduction motor and the h.p.

X. Type and thickness of the metal or materials for each elements to be used

XI. Determine sizes of each elements

3.6.2 Volume of Hopper

The hopper design: It is expected that in a single batch 40 tiles would be produced per hour

∴ the volume (vol) of a single tile was required in order to determine the volume of the entire material to be poured into the hopper to produce 40 tiles within an hour.

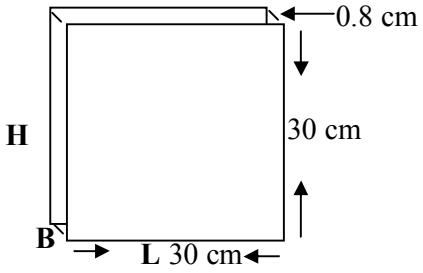


Figure 18 Tile Sample

Vol. of 1 tile = L x B x H

= 30 x 30 x 0.8

= $\underline{720cm^3}$

Vol. of 40 tiles = 40 x 720 cm^3

= $\underline{28800\ cm^3}$

To cater for clay that will stick to the chamber wall 5% of needed quantity was added.

= 28,800 x.0.5 (28800 + 1440)

= <u>30,240 cm^3</u>

In a further calculation of the volume of the hopper, the dimension of sides were fixed base on the following:

- Aesthetic
- Strength of the material
- Batch requirement
- Flow direction
- Desired shape of the chamber, hopper and the entire machine e.t.c

Similarly, some of the dimensions were pegged i.e.

The top length was pegged as - 35 cm

The top breath was pegged as – 35 cm

The base length was pegged as – 25 cm

The base breath was pegged as – 30 cm but the height was yet to be determined

The height is =?

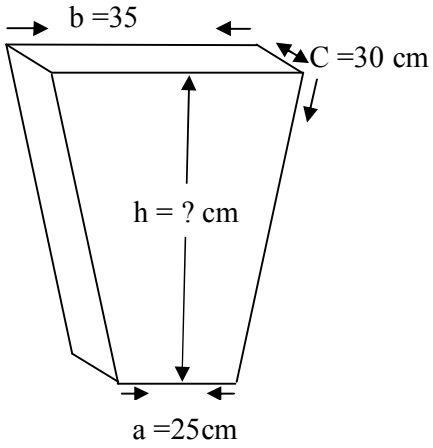


Figure 19 The Hopper

The height of the hopper was determined using the formula below by making **h** the subject of the formula…

Vol. of hopper as given in 2.2.8 as ½ (a + b) x h x c

½ (25 + 35) + h x 30 = 30240 cm^3

½ (60) x h x 30 = 30240 cm^3

h = $\frac{30420 \times 2}{30 \times 60}$ = 33.6 cm

For allowance of work, 10% was add

=33.6 x 0.10 = 3.36

33.6 + 3.36 = 37 cm

h = 37 cm

V = ½ (25 + 35) x 33.6 x 30

V = $\frac{1 \times 60480}{2}$ = 30240 cm^3 (volume as per the material to pour or that it can contained)

But the entire V = $\frac{60 \times 37 \times 30}{2}$ = 33,300 cm^3

∴ 1 cm^3 = $\frac{1000kg}{1000000}$ = $\frac{1}{1000}$ kg

30240 x 0.001 = <u>30.24 kg</u> in weight of material

3.6.3. The Volume of Chamber

The volume of chamber was determined by fixing some dimensions and using the same method of calculating the volume as above to determine the height; to be 38 cm volume.

I. **Shape of Chamber**

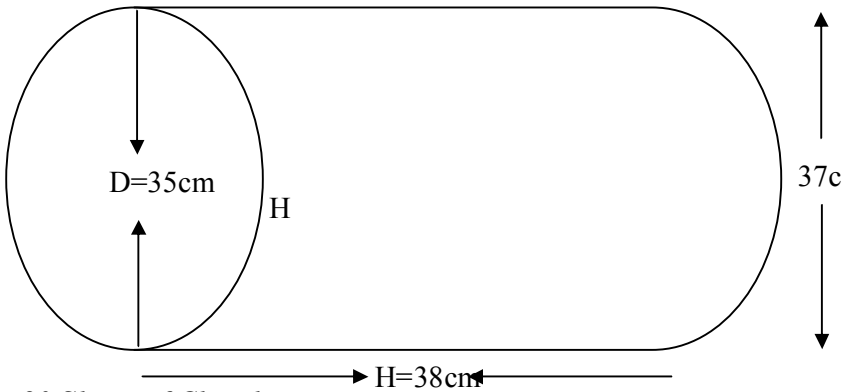


Figure 20 Shape of Chamber

From the original drawing of the cylinder D = 35cm, H = 38 cm, r = D/2 = 17.5

The chamber is a combination of a cylinder and frustum (a cone without the top or arch). Each was calculated separately and the result added.

In the same vein, the shaft, blades or auger diameter, they require weight and space occupied by all of these would be calculated and added to the volume of the chamber in order to ascertain the entire/actual volume of the chamber and likewise for consideration of safety.

II. **Volume of Cylinder (Main Chamber)**

The volume of the cylindrical part of the chamber is given as; $V = \pi r^2 h$

$V = 3.142 \times 17.5^2 \times 38 = \underline{36565\ cm^3} \times 0.001 = 36.6$ kg.

III. **Volume of Frustum**

The height of the frustum need to be determined before calculating the Volume

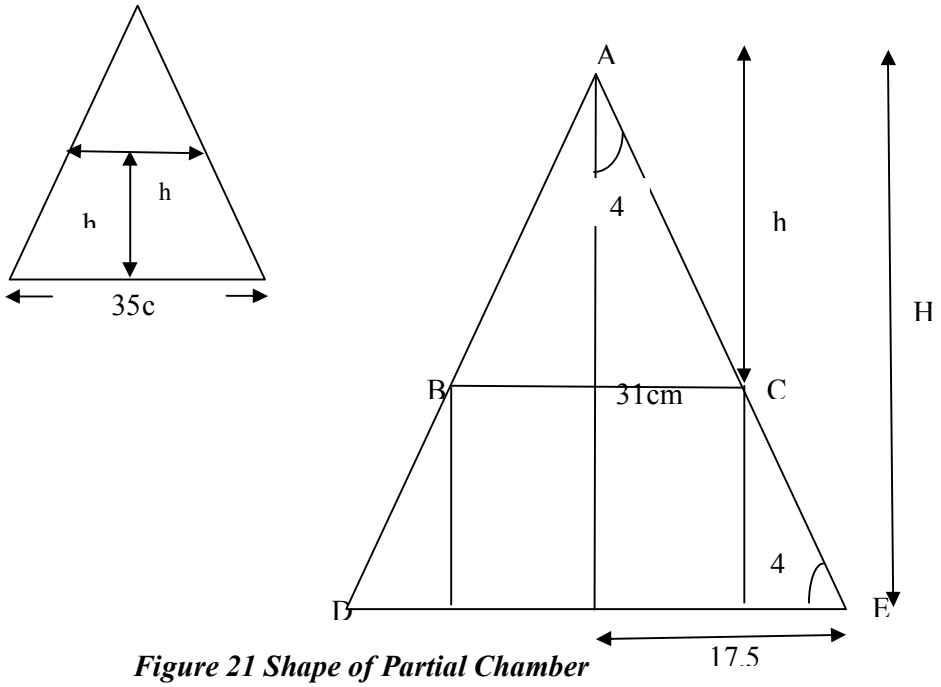


Figure 21 Shape of Partial Chamber

Considering the big triangle ADE, using SOH, CAH, TOA

Where:-

S = sin
O = Opposite
H = Hypotenuse
C = Cosine
A = Adjacent and
T = Tangent

Tan 45 = $\frac{17.5}{H}$

H = $\frac{17.5}{Tan\ 45}$ = 17.5 cm

Using the law of similarities section $\triangle ABC$ and $\triangle ADE$

$\frac{h}{31} = \frac{H}{35}$

$h = \frac{31\ H}{35} = \frac{31 \times 17.5}{35} = \frac{31}{2} = 15.5$ cm

∴ , height of the frustum = H – h

= 17.5 – 15.5 = 2cm

IV. **The Volume of Frustum (Partial Chamber)**

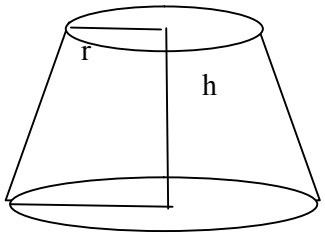


Figure 22: Volume of Frustum (Partial Chamber)

Is given as $V = \frac{\pi h}{3}(R^2 + Rr + r^2)$

Where:- R is the radius of the lower base

r is the radius of the upper base

h is the height of the frustum

r = D/2 = 31/2 = 15.5

R = D/2 = 35/2 = 17.5

h = 2 cm

$V = \frac{3.142 \times 2}{3}(17.5^2 + 17.5 \times 15.5 + 15.5^2)$

$V = \frac{6.284}{3}$ x 323.75 + 255.75

V = 2.09 x 82799.06

V = 1211.155 = 1211 cm^3

∴ The entire volume of chamber is volume of cylinder + volume of frustum

= 36,565 + 1,211 cm^3 = 37,776 cm^3

37776 x 0.001 = **37.8 kg (in weight)**

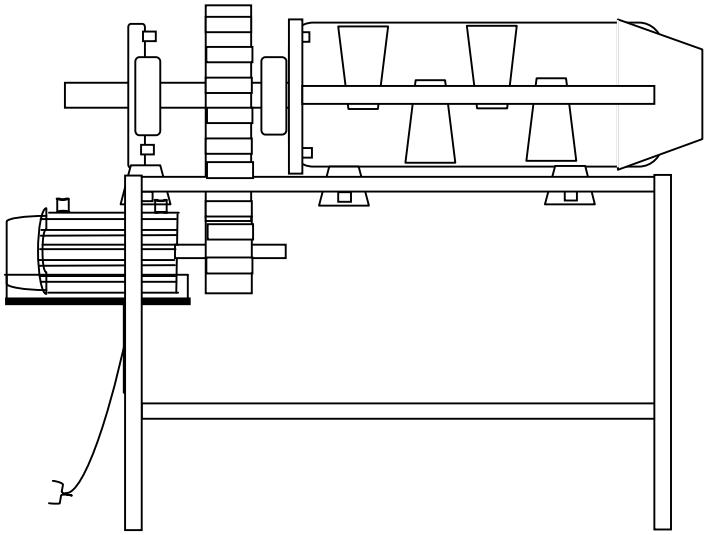


Figure 23: The Mixer Drive or processing Section Drive

3.6.4 Design of a Mixer Drive

Problem – Design a drive to mix clay of bulk density 2050 kg/m^3

Volume of clay to be mixed ≡ volume of mixer chamber = 36,565 ~ 36,600cm^3 = 36,600 x $10^{-6}m^3$ this and not 3, 7776 was used for allowance inside the chamber.

Components selected/chosen from market based on design are:

Electric motor

Bearings

Components fabricated or selected:

Mixer shaft

Gear

I. Calculations

From the information above, mass of clay in the chamber was calculated as

Mass of clay = bulk density x volume of clay

= 2050 kg/m^3 x 36,600 x 10^{-6} = 75.03 kg.

∴ Dead weight of clay in chamber (w) = m_{clay} x g (g = 10mls^2

= 75.03 x 10 =

= 750.03 N

Known diameter of mixer chamber in which mixer shaft blades rotated was 35cm = 0.35m.

The arm of twist of the shaft or the radius of the chamber determined the torque required to turn the clay.

∴ Arm of twist = 0.35/2 = 0.175.

Then torque = W x (arm of twist) = 750.03 x 0.175

= 133.26 say 132Nm

Therefore, the minimum torque required for mixting of clay = 132Nm

Note: some dimensions must be wisely chosen and comparisms made to arrive at the desired result.

3.6.5 Design of a Gear Drive

The available data for the gear drive design (spur gear) are:

Motor power = 1.865 say 1.87 kw (2.5hp)

Speed of motor gear N_1 = 920 rpm (speed of motor)

Speed of mixer shaft gear N_2 =?

Centre distance between gears (approximate) L = 200mm

Overload service/factors C_s = 1.25

Static stress for mixer shaft gear material (steel) 6_{01} = 105 MPa

Static stress for motor gear material (steel) 6_{01} = 105 MPa

Pressure angle of gears $\theta = 20^o$ for stub involute system.

To get the value of N_2 the formula for power will be used,

$$P = \frac{2\pi NT}{60}$$

Where P = power of motor

N = Speed of mixer shaft gear

T = Torque

π = 3.142

$\therefore$ N = $\frac{60 \times 1.87 \times 10^3}{2 \times 3.142 \times 132} = \frac{112200}{926.949}$ = 135.7 say 135

N_2 = **135**

I. Design Calculations

LET T_1 = Number of teeth on motor gears.

T_2 = Number of teeth on mixer shaft gear.

M = Module of gear in mm

D_1 = Pitch circle diameter of motor gear

D_2 = Pitch circle diameter of mixer shaft gear

Center distance L = $\frac{D_1}{2} + \frac{D_2}{2}$ Note, V.R = $\frac{D_2}{D_1} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$

From data above, velocity ratio V.R = $\frac{N_1}{N_2} = \frac{920}{135}$ = 6.8

$\therefore$ L = 200 = $\frac{D_1}{2} + \frac{6.8D_1}{2} = \frac{7.8D_1}{2}$

$D_1 = \frac{400}{7.8}$ = **51.28mm** = **0.05128m**

Also D_2 = V.R x D_1 = 6.8 x 51.28 = **348.70mm** =**0.034870m**

For the design,

Design tangential tooth load, $W_T = \frac{P}{V} = C_s$

Since mixer shaft gear material is weaker, design will be based on that.

Linear speed = V = $\frac{\pi D_2 N_2}{60} = \frac{\pi \times 0.34870 \times 135}{60}$ = 2.465 say **2.5m/s**

Since V is less 12/ms, therefore velocity factor (C_V) is

$C_V = \frac{3}{3+V} = \frac{3}{3+2.5}$ = 0.55

Also, we know that the number of teeth on mixer shaft gear is T_2

$T_2 = \frac{D_2}{m} = \frac{349}{m}$

∴ Tooth form factor for the mixer shaft gear was calculated as:

$Y_2 = 0.175 - \frac{0.841}{T_2} = 0.175 - -\frac{0.841m}{349}$ (for 20^o stub system)

$= 0.175 - 0.00241$ m

∴ $W_T = \frac{1.87 \times 10^3 \times 1.25}{2.5} = 935$N

Also, tangential tooth load is

$W_T = 6_{w2}.b.\pi m.y_2 = (6_{02} \times C_y)\ b.\ \pi m.y_2$

$935 = (105 \times 0.55) \times 10m \times \pi m\ (0.175 - 0.00241m)$ note (b = 10m)

$935 = 317.54m^2 - 4.373m^3$

Solving the cubic equation by iteration we have

M = 1.73 say 3mm

Face width b = 10m = 10 x 3 = 30mm

$T_1 = \frac{D_2}{m} \frac{51.28}{3} = 17.09$

$T_2 = \frac{D_2}{m} = \frac{340.70}{3} = 116.23$

Taking $T_1 = 18$ in order to get exact V.R of 6.8

$T_2 = 6.8 \times 18 = 122.4$ say 122

∴ $T_1 =$ **18**, $T_2 =$ **122**

$D_1 = MT_1 = 3 \times 18 = 54$mm

$D_2 = MT_2 = 3 \times 122 = 366$mm.

From table 28.1 Khurmi and Gupta's (2004) other proportions for the motor gear and mixer shaft gear having 20^o stub involute teeth can be determined.

Addendum = 0.8 x m = 0.8 x 3 = 2.4mm

Dedendum = 1 x m = 1 x 3 = 3mm

Working depth 1.6 x m = 1.6 x 3 = 4.8mm

Minimum total depth = 1.8 x m = 1.8 x 3 = 5.4mm

Tooth thickness = 1.5708 x m = 1.5708 x 3 = 4.7125

Minimum clearance = 0.2 x m = 0.2 x 3 = 0.6

3.6.6 Design for Motor Gear Shaft

Normal load acting between the tooth surfaces is given by

$W_N = \frac{W_T}{Cos\theta} = \frac{935}{Cos20}$ = **995.01N**

Weight of the gear is given by

$M_1 = 0.00118T_1bM^2 = 0.00118 \times 10 \times 3^2$ = **5.735 N**

∴ Resultant load acting on the gear

$W_R = \sqrt{(W_N)^2 + (M_1)^2 + 2W_N.M_1Cos\theta}$

$= \sqrt{995.01^2 + 5.735^2 + 2\ (995.01)(5.735)x\ Cos20}$

= **1000.40N**

The gear was over loaded on the shaft by 25mm.

Bending moment on the shaft due to resultant load is

$M = W_{R1} \times 25 = 1000.40 \text{ X } 25 = 25010$ N mm

Twisting moment on shaft is

T = W_T x $\frac{D_1}{2} = \frac{935 \times 54}{2}$ = 25245 Nmm,

∴ Equivalent twisting moment is

Te = $\sqrt{M^2 + T^2} = \sqrt{25010^2 + 2545^2}$ = **35536.04 Nmm**

Let d_1 = diameter of motor gear shaft

Te = $\frac{\pi}{16}$ x $\tau(d1)^3$ τ (Tau) = 42Mpa for mild steel

$d_1 = \sqrt[3]{\frac{16 \times 35536.04}{\pi \times 42}}$ = 16.27

d_1 = **16mm**

Diameter of the gear hub = 1.8d_1 = 1.8 x 16 = **28.8mm**

Length of hub = 1.25d_1 = 1.25 x 16 = **20mm**

∴ Length of hub should not be less than face width is the length of hub = 3**0mm**

3.6.7 Design of Mixer Shaft

Already we know, W_N = 995.01

Weight of mixer gear = M_2 = 0.00118 x T_2 x bm^2

= 0.00118 x 122 x 30 x 3^2 = **116.608N**

Resultant loading acting on the gear

$W_{R2} = \sqrt{{W_N}^2 + {M_2}^2 + 2W_N \times M_2 Cos\theta}$

$= \sqrt{995.01^2 + 116.608^2 + 2\,(995.01) \times (116.08) \times Cos20}$

= **1105.31N**

The gear is between two bearings where center distance is 200mm apart.

∴ Bending moment on the shaft due to resultant force is

$M_2 = \frac{W_{R2} \times L}{4} = \frac{1105.31 \times 200}{4} = 55{,}265.5N$

Twisting moment on the shaft is

$$T = W_T = x \frac{D_2}{2} = \frac{935 \times 366}{2} = \mathbf{171{,}105N}$$

∴ Equivalent twisting moment is

$Te = \sqrt{M^2 + T^2} = \sqrt{55265.5^2 + 171105^2} = \mathbf{179{,}808.793Nmm}$

Let d_2 = diameter of mixer shaft

Also, $Te = \frac{\pi}{16} \times \tau(d1)^3$ τ = 42Mpa for mild steel

$d_2 = \sqrt[3]{\frac{16 \times 179808.793}{\pi \times 42}} = \mathbf{27.94}$

d_2 = 27.94 say **30mm**

Diameter of the gear hub = $1.8d_2$, = 1.8 x 30 = **54mm**

Length of hub = $1.25d_2$ = 1.25 x 30 = **37.5mm**

3.6.8 Design of Key

The standard dimensions of key for shaft of 35mm are

Width of key 12mm

Thickness of key = 8mm according to Gupta … (2006)

If the key materials is also mild steel

shearing stress = 42 Mpa

circulating stress (σ_c) = 70Mpa

Note the length of key is equivalent to the length of the pulley or gear hub.

Density of steel = 7,850kg/m^3

Volume of stamp = (31 x 31 x 3) + π x 25^2 x 34.7

= 3,564.33cm^3

= 3,504.33 x 10^{-6} m^3

3.6.9. Design of Frame

Angle bar was used as supporting frame work for the entire machine.

Dimensions of the angle bar used

Thickness (t) – 5mm

Breath (b) – 51mm

Height (d) – 51mm

A cross-section of the angle bar looks like this

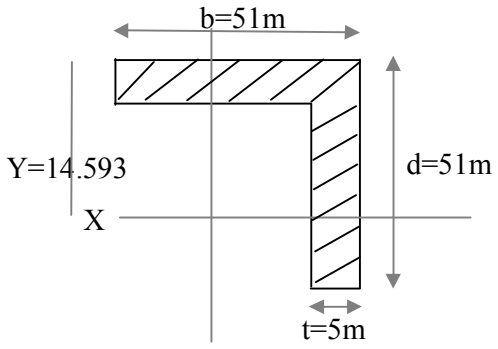


Figure 24 Cross-section of Angle Bar

Material of the angle bar is mild steel.

Max. Permissible shear stress of mild steel = 400 mpa (mega Pascal)

Max. Permissible stress of mild steel = 80 mpa (mega Pascal)

Area of the cross section = (51 x 51) + (46 x 5) = 485mm^2 = 485 x 10^{-6}m^2.

The major part of the machine is at the point (Section) where the mixing takes place i.e., the processing section-where the hopper, mixer and motor are. The length of the angle bar that support or carry's these components is 1080mm (108 cm) long. The mixing chamber was bolted to the centre of the angle bars which is the point of the load as shown below

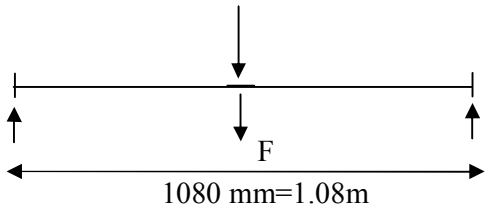


Figure 25 point of load on the mixing chamber

Approximate mass of the mixing chamber = P

Direct stress on the chamber $б_0 = \frac{P}{A}$

Bending moment due to mixer load on member (M) $= \frac{PL}{2}$

Bending stress induced by this bending moment

$б_o = \frac{M}{Z}$

But Z = section modulus is given by

$\frac{I}{y}$ Where I = moment of inertia of section

y = distance of neutral axis of section from top of the flange.

$$y = \frac{51x5x\frac{5}{2} + 46x5x(5+\frac{46}{2})}{(51x5)+(46x5)}$$

$$= \frac{637.5+6,440}{485} = 14.593mm$$

Moment of inertia about xx

$$I = \left[\frac{51x5^3}{12} + 255(14.593-2.5)^2\right] + \left[\frac{5x46^3}{12} + 230(28-14.593)^2\right]$$

$$= [531.25 + 37,291.37] + [40,556.7 + 41,341.96]$$

$=119,721.28mm^{4'}$

Therefore, section modulus

$Z = \frac{I}{y} = \frac{119,721.28}{14.593} = 8,204.02mm^3$

To get the P, we need the weight of the mixer on the frame.

Volume of material of cylinder = $\pi(R^2 - r^2)h$

$$\pi(18.5^2 - 17.5^2)x53$$

$= 5{,}994.16\text{cm}^3$

Volume of material of blade (2 in number) = 2xLxbxt

$= 2\text{x}41\text{x}41\text{x}1 = 3{,}362\text{cm}^3$

Volume of material of mixer shaft = $\frac{\pi d^2 L}{4} = \frac{\pi x 5.5^2 103}{4} =$

$= 2{,}447.104\text{cm}^3$

Volume of hopper material = $4\left[\frac{1}{2}(35+30)x33.6\right]$x0.2 = 873.6cm^3

Total volume of mild steel material is 5,994.16+3,362+2,447.104 = $11{,}803.264\text{cm}^3$

Mass of mild steel material = Density of mild steel x volume

$7850 \text{ x } 11{,}803.264\text{x}10^{-6} = 92.65\text{kg}$

Mass of hopper (stainless steel) = $8000\text{x}873.6\text{x}10^{-6} = 6.98\text{kg}$.

Total mass of weight on frame =92.65 +6.98 = 99.63kg

Weight = mass x g = 99.63x9.81 = 977.37N

Therefore, bending moment (M) = $\frac{PL}{2} = \frac{977.37x1080}{2} = 527{,}779.96\text{Nmm}$

Bending stress is, therefore, $б_b = \frac{M}{Z} = \frac{527{,}779.96}{3{,}204.02} = 64.33\text{N/mm}^2$

Total stress on the member is = 6

$б_o + б_y = \frac{977.39}{485} + 64.33 = 2.02 + 64.33 = 66.35\text{N/mm}^2$

This is less than the maximum permissible stress of 80N/mm^2. Therefore, the choice of angle bar dimensions is safe.

3.7 APPROACH IN PRODUCTION AND THE SITE

In machine design, there are various manufacturing processes used in producing machines and their component parts. The manufacturing process adopted for this particular project is fabrication by welding as suggested by (Khurmi and Gupta, 2004) and (Nagpal, 2002) to enhance cost reduction. During the welding exercise of the component parts, there were some of the components that were not welded. These shapes were formed and most of the parts were joined with bolts and nuts to achieve one of the major objectives of this project: to make available a machine that is durable, that can be assembled/disassembled (not dead welded) and maintained with ease.

The site used in the fabrication of the machine is Delmat fabrication and machining workshop Kakuri, Artillery, Kaduna, Kaduna State.

The preparation of the tile mix, the templates, specimens for testing some parameters, and firing of the tiles produced were done in the following institution; Ceramics section department of Industrial Design and metallurgical department, Ahmadu Bello University Zaria, Industrial Design programme, School of Environmental Technology, Bauchi (ATBU), Ceramics section department of Industrial Design Federal University of Technology Yola (FUTY) and Industrial Development Centre (IDC).

Generally, the approach took the following steps as proffered by (Groover, *et al* 2007) and (ASM 2003) etc:

3.7.1 Fabrication Processes

According to ("fabrication". *Encyclopædia Britannica*. *Encyclopædia Britannica Online.*Encyclopædia Britannica Inc., 2012. Web. 17 Jul. 2012), fabrication as an industrial term, applies to the building of machines, structures, by cutting, shaping and assembling components made from raw materials. On the other hand, Groover et al (2007) describes fabrication as an act of manufacturing (from Latin word Manu- factura, "making by hand"), which is the use of materials, tools and labour to make things for use or sale.

Metal fabrication is a value added process based on engineering drawings in building products. This is usually directed toward the mass production of equipment. Fabrication has made available today several machines that have been assisting humans in the production of goods without much tension.

The steps in fabrication adopted for this machine tracked the format below:

3.7.1.1 Engineering Drawing

Information from the pilot study of item 3.3, figure 15 and 16 (pages 74 & 75) were used at this stage with the dimensions and the drawing of the various component. These serve as a blue print/a road map, though it was not followed verbatim because of modification that refines such components. This is in consonant with fabrication or construction generally. The drawings were produced with AutoCAD and pen, as used by mechanical engineers and other professionals to visualize their work or have their work visualized. At the point of construction, the drawing was modified to figure 16 which was eventually used for the fabrication. Materials were purchased to fabricate according to the drawing.

3.7.1.2 Purchase of Materials

Different materials were purchased before the fabrication began. Some were also purchased as the construction progressed. This occurred because better materials were discovered and considered inexpensive, while others where changed due some factors considered in their functions. Another factor that brought about changes in the purchase of such materials was the modifications that occurred on the drawings. These include the raw materials and those with standardised materials. This equally brought about alterations that led to purchase of other materials not earlier stated. Tables of materials purchased were divided into three; these are attached in appendix I, II, and III.

Paint and thinner were purchased after the whole fabrication process was over; to give the work good finish with paint (car paint).

3.7.1.7 Cutting, Drilling, Forming and Machining

The machine (TMM) is divided into 3 sections. Cuttings were done based on sections. At the point of sections linkage, it was done simultaneously and the parts were eventually formed and machined before welding. These processes were in strict adherence to the drawing of some the component parts because they contain the accurate dimensions of each part. Various machines were utilized at this stage.

The grinding and cutting machine, industrial cutting machine, hack saw and oxyacetylene cylinder and nozzle were the equipment/tools basically used for cutting the mild steel/plates and all other materials to their accurate shapes and sizes. However, the lathe was used for phasing, stepping, turning, reducing excesses, marking, shaping, etc of steel materials. The milling machine was used to cut gears, providing key ways on shafts, grooving and drilling or boring holes on metal etc. The industrial folding machine was used in folding plates into the desire diameter and lengths before welding. The slotting/shaping machine was used for creating grooves inside cylindrical shapes. The

vernier and normal calliper, the square and the measuring tape were basically used for securing accuracy in length, diameter, accurate markings, and sizes of metals. Drilling work was done with both hand and electric industrial drilling machine using different drill sizes to bore holes. The chain pulley was used to pull component that needed to be stretched beyond its normal length to a desired length or size. The hammer was for beating, bending, hitting and separating simple joints. The metals were held down tight, for some of the processes above with grip pliers and the vice. The same machines above were used for multipurpose beyond the listed functions above.

3.7.1.8 Cutting, Forming, Drilling and Machining of the First or Processing Section:

This section has the electric box (wiring), electric motor, chamber (barrel), two sprockets and chain, hopper, tile mix regulating plate and compressor plate with lever and its stand. Further we have the extruding or cone nose nozzle (orifice or outlet), auger shaft, motion transmitting shaft, two shaft angle iron footed base, pulley, two blind flanges, two flanges, four footed angle iron base for the entire section, six brazing angle iron and bedding or seating of electric motor.

3.7.1.5 Cutting, Forming, Drilling and Machining of the Second or Conveying and Stamping Section: This section is the conveying section linked with an L-cap (a joint between the first and the second section) joint to the major processing section. This section has the conveyor belt, two long angle iron metal frame, four angle iron footed base, four brazing angle iron, two small rollers rail, the telescope mechanism stand and block (the stamping stand, base and its stamping plate, pipe and a clamp, the template tray), two conveyor hanger support and adjustment fittings, two big conveyor rollers and three small rollers supporting the conveyor belt.

3.7.1.6 Cutting, Forming, Drilling and Machining of the Third or Receiving Section:

This section is the receiving section which is linked or joined to the second section with a jaw joint. This section has many things similar to the conveying section. It contains the two long angle iron metal frame, four angle iron footed base, four brazing angle iron, four small rollers rail, two roller hanger supports, two big conveyor rollers and fourteen small rollers.

3.8 CONSTRUCTION PROCESSES OF MAJOR COMPONENTS

This section entails components construction, material requirement and sequence in operation. The entire processes of fabricating the components were carried out in Delmat Technical works No. M30E Old Artillery Barrack, Off Textile Road, behind Army Children School, P.O. Box 2215 Kakuri, Kaduna, Nigeria.

Simple machining operations such as: boring, turning, drilling, grinding, broaching, bending or pressing, chamfering, etc; were implored The Fabrication operations implored include welding (gas and arch), joining by means of bolt and nut (mechanical fastening) so as to attain one of the major objectives of this project in item1.3 (d). The principal machines/tools utilized were as stated in section 3.5 and 3.7.1.

3.8.1 Cylindrical Chamber (Barrel) Construction:

This is one of the most vital components of the tile making machine. Its capacity, efficiency and performance in depend on this.

3.8.1.1 Material Requirements:-

A mild steel pipe or a cylinder of internal diameter of ø350 and ø370, external diameter, 10mm thick, with length of 530mm is required. Three square plates of 10mm thickness, 420x420mm square was acquired for the two flanges and one blind flange. Two plates 410x110mm and 10mm thick for chamber flange concave footing, two plates of 300x200mm and 10mm thick for the middle chamber footing. A stainless plate of 2mm in thickness and 1,060 x 540mm in size, meant for the lining of the chamber. Lastly, two stainless plates of 320x150mm and 2mm thickness were used for the chamber hopper gallery (seating).

3.8.1.2 Operational Sequence

One end of the cylinder was held and centred on a four-jaw chuck lathe machine and the other end faced (machined) to ensure straightness and accuracy. After that, the other end was also faced to required length of 530mm. Further, on the top of the chamber barrel, a side selected as the top measuring 230x310mm was cut out. The inner and outer diameter of the flanges was drawn on the square plate of 410x410mm with an industrial compass and a calliper. The square plate was held on the lathe machine and with the aid of a parting tool; the inner diameter was cut through. Subsequently, for efficient and fast cutting, a gas flame was later used to cut out the inner diameter. The flanges where then held on the four-jaw chuck lathe machine one after the other, faced and smoothened both ways to the required diameter of ø370 and ø410mm.

From this point, the flanges were tagged welded and divided into eight equal parts. From the middle, of each divided part 8 holes were marked with a centre punch and drilled with 13mm drill (M12). The footing plates were cut to ø410mm diameter and an external square of 410x110x10x2.5mm. The plates for the chamber footing were cut to

an L-shape of 190(H) x290(L) x90x200mm and bored mid way of 290mm, with a 13mm drill. From the top, 30mm was measured to the other end. From the bottom, 50mm was measured to the other end. These were cut out to a depth of 6mm and bend to the opposite direction to the required shape. Subsequently, the grooves were sealed with molten metal using electrode using arc welding.

The length of the stainless plate required to line the inner part of the chamber was derived from this equation;

πD

Where π = 3.142 (known standard)

D = 340mm inner diameter of the chamber

$\therefore$ 3.142 x 340 = 1,068.28 say 1,068mm

8mm was removed for clearance, i.e. 1,068 – 8 = 1,060mm

With this diameter above and the length of the chamber 520mm, the stainless plate was measured and cut to this dimension. It was then folded into a form of pipe/cylinder with an industrial folding machine and welded at the seam line or dividing line. The next to the last operation was cutting of the two stainless plates to a dimensions of 310 x 100mm, with one end of both chamfered to fit the outer diameter of the chamber from the hopper gallery. Two holes each were bored with a 13mm drill on both plates.

The folded stainless plate was forced into the cylinder as a lining to avoid wear. At the top portion where the cylinder was cut out, the lining was also cut and pulled outward and joined to form the hopper gallery by arc welding.

The two flanges were fitted and welded, one to each end of the barrel. Equally, the chamber footings were midway welded to both flanges downward. Subsequently, they were ground to ensure smoothness of surface.

3.8.2 Hopper Construction:

This is one of the major parts of the machine that made possible the pouring and holding of material into the chamber for onward processing. The other name for a hopper is a funnel. This allows the passage of material into the chamber.

3.8.2.1 Material Requirements:-

Stainless plates: two of 370 x 300mm, two of 370(H) x 350(L) x 250(B)mm, 250 x 310mm, 259 x 100 and two of 290 x 50mm; all of 2mm thickness.

3.8.2.2 Operational Sequence

The calculation involved in the forming of the hopper is on item 3.6.2 considering the condition stated in designing a hopper. These plates were cut to the required dimensions above, folded, welded and grounded to form the hopper. The material for regulating plate, the regulating support and the two rails were also cut.

3.8.3 Screw Auger Construction:

The screw auger is the heart of the chamber and the machine. This is because the processing and extrusion of the material (tile mix) into slab and subsequently into tiles is dependent on this. This also works to provide the required torque alongside the electric motor, chain and sprocket. So without the screw auger tile extrusion and the possibility of the machine is not feasible.

3.8.3.1 Material Requirements:-

A chromed shaft of mild steel 1050mm in length, four plates of ø55mm in diameter 410 x 410mm^{2-} and 4mm thick.

3.8.3.2 *Operational Sequence:*

The mathematical modelled of this component was produced on straw board and later transferred onto the mild steel as in 3.3.1. The shaft was tightened to a four-jaw chuck lathe machine and one of its ends turned into a cone like shape. The other end was faced and stepped down to a diameter of ø50mm and of length 350mm. The shaft was held down on the milling machine with a vice and a key way grooved of length 65x13 (w) x10 mm breaths according to the calculation in 3.6.8. The plates were cut to an outer diameter of ø400mm and internal diameter of ø105mm with a gas flame. They were tightened on the lathe machine to desired dimension and smoothness. The plates were cut through from one side, bended and the three were welded together in form of a spring or screw like shape. One end of this was tagged to the base end of the shaft at the point where it was step turned and then the two ends of the shaft were partially welded to a metal frame. The other end of the plate not welded was supported with a short cylinder. From that point, it was pulled with a jack pulley to take a form of a spring. It was concurrently beaten with a hammer while pulling until it reached the desired point and shape. Further, at every point the plate had contact with the shaft it was welded permanently to the shaft to form a screw auger shaft.

3.8.4 Cone-nose (Orifice) Construction:

This is a very vital component of the machine. It determines the flat shape, thickness, width and surface quality of the slab and consequently tile extruded. This particular component was hard-hitting to realised, but after several trials and consultations with engineers, books and internet sources on triangulation it was successful.

3.8.4.1 Material Requirements:-

A mild steel plate 420 x 420mm 10mm thick, stainless plate of 1060 x 150mm of a thickness of 2mm; two stainless plates of 380 x 250mm, stainless plate of 1060 x 50mm and another two of 80 x 25mm and 2mm thick. A ring pipe of mild steel 50mm long, ø350 and ø370 in diameter; with two cubes like shape of mild steel 40 x 30 x 12mm^3.

3.8.4.2 *Operational Sequence:*

The mathematical modelling of this component was first produced on a straw board before it was transfer onto the metal plates as in 3.3.1. The stainless plate of 360 x 150mm was cut and folded into a cone of ø350 diameter at the base and height of 180mm. A diameter ø20mm was cut out from the top to form a frustum. The other plate of 1060 x 50mm was folded into a ring and welded to the base of the frustum. Consequently, 20mm from the top and 50mm at the base were cut out from two opposite sides of the frustum. The other plate was cut to 350 x 150 (H) x 310mm; as an inverted shape with base 20mm top and 350mm base by 130 (H). Two other plates were cut to 600mm base x 150mm (H) x 20mm (B). These four were welded to form a pyramid with a void invert in form of V shape in the middle. This shape was welded to the frustum to form a frustum/cone with a pyramid sides. A frustum is a cone with and open end. The flange of ø370 x ø410mm was cut out from the mild steel plate of 410 x 410mm. Eight holes of equal distance and diameter with a 13mm drill were bore on the drilling machine. This was fitted into one end of the pipe rim. The cone shape with the pyramid side was welded to the other end of the pipe rim to form what is now called the cone-nose (orifice) where the extrudate comes out.

The two cubes shape of dimension 40 x 30 x 12mm were bore with 5mm drill and tapped with a 6mm tap from the side with 30 x 12mm and welded to the tope side of the cone

nose. This is used to hold down the regulating bar support with the aid of 7mm flat head screw. The entire component was grounded, sandpapered and smoothened.

3.8.5 Regulating Bar Support and Thickness Regulating Bar Construction:

This particular part determines the thickness of the tile to a large extent.

3.8.5.1 Material Requirements:-

A mild steel plate of 10mm thick, 375(L) x 60mm (B) and 5mm thick and a stainless bar of 375x50mm are required.

5.8.5.2 Operational Sequence:

The mild steel plate was measured 315 x 20mm and was cut out, bored with a 10mm and 7mm drill. The stainless was marked and four holes were milled out with 10mm drill. With these two above, the stainless and mild steel plates were ground and smoothened as required.

3.8.6 Rollers Construction:

The rollers were essentially for motion transmission and load carrying through the belt conveyor. Similarly, the rollers serve as a belt conveyor support and conveying of tile after stamping and cutting to size.

3.8.6.1 Material Requirements:-

A hollow and padded cylindrical pipe mild steel of inter and external diameter ø130 x ø150mm, 1,640mm length and 10mm thick. Eight mild steel plates of 10mm thick, 130 x 130mm square, eight 3mm plates ø130 diameter, eight shafts of 555mm and ø27mm diameter are needed with eight bearings of size F204.

3.8.6.2 *Operational Sequence:*

Four short cylinders of 310mm length were cut out from the long padded mild steel cylindrical pipe; both ends were faced on the three chuck lathe machine to the required sizes. The four 10mm plates of 130x130mm square were bored in the centre with a 30mm drills. Before this a model of the plates was first produced in 3.3.1. These were arranged in two sets on a mandrel and faced to a diameter of ø130mm. Four arms of equal length and breadth of 50 x 30mm was cut out and bored with a 9mm drill at the centre of each arm. Two of these plates were fitted one to each side of the padded pipe ø130mm diameter with 10mm gap between the plates and edges of the padded pipe. It was tagged and welded. The other four 3mm thick plates of ø130mm diameter were modelled as in 3.3.1 and held unto the three-jaw chuck lathe machine and bored with a 25mm drill from the centre. Four holes were also bored on each of the plates in consonant with those plates arms welded inside the padded pipe.

The eight shafts were annealed because of the toughness of the shaft material in a black Smiths furnace and step turned to ø20mm from both ends, 14.25mm long and bore with a drill of 3.4mm on each end.

3.8.7 Electric Motor Bed/Seating Construction:

This is where the electric motor sits; it is a relevant component without which no motion can be transmitted.

3.8.7.1 Material Requirements:-

A U-channel mild steel of 1,360x75 x 50mm, 5mm thick; a plate of 280 x 275mm, 6mm thick and an angle iron of 2 x 2” and 5mm thick are required.

3.8.7.2 Operational Sequence

The U-channel was marked and cut into required dimensions bored with a 13mm and 15mm drill, it was milled-to extend the drilled hole and then welded. The angle iron was cut to 510mm x 2" it was also bored and milled with 13mm drill and 15M mill respectively. The 6mm plate of 280 x 275mm was curved in form of a semicircle and chamfered at one end, bored and milled: likewise the angle iron. These were then ground and smoothened.

3.8.8 Template Tray and Holder and Plate Construction:

The template tray is a predetermined formed stainless steel that houses the template (impression of a design) and holds the template intact; it helps to cut the tile to size and shape.

3.8.8.1 Material Requirements:-

A stainless plate of 2mm thickness 3 x 1.5ft, a mild steel plate 200 x 200mm square and short pipe 8mm thick of ø6.6x ø40mm diameter and 35mm long.

3.8.8.2 *Operational Sequence:*

From the stainless plate of 3 x 1.5ft x 2mm, two stainless plates of 310mm^2 and 210mm^2 were cut out. And, six set each of 310 x 50mm and 210 x 50mm from the same stainless plate. Tray boxes of 310 x 50mm (H) and 210 x 50mm (H) square were constructed, bored and welded. The mild steel plate was cut opened in the centre with a drill to a diameter ø66mm and machined on a lathe machine. Eight holes were bored

from the two diagonal cardinals of the mild steel plate. Each of the diagonals cardinals has four holes.

The short pipe was mounted on the lathe machine. Its sides were both faced; and the inner diameter was treaded to an inches pitch. This was fitted on the centre of the plate, welded and smoothened.

3.8.9 Blind Flange Construction:

Collar for attaching or strengthening i.e., the rim, or rib on an object for fixing it to another object, holding it in place, or strengthening it.

3.8.9.1 Material Requirements:

Two plates 10mm thick, 410x410mm square and a stainless plate 2mm thick, 410x410mm.

3.8.9.2 *Operational Sequence:*

The stainless and the mild steel plates were cut to required sizes; one side on each of the three plates was chamfered. One stainless plate was welded unto one side on one of the mild steel plates. The plates were tagged welded and a cycle of ø340mm drawn to serve as the inner diameter. The ring cycle was equally divided into eight. From the centre of the division, eight holes were bored with a 13mm drill on the drilling machine. These holes were in consonance with the holes on the chamber flanges. The blind flanges were tightened on the four-jaw chuck lathe machine and a hole bored from the centre with a 51mm drill to create an opening for the shaft. They were later separated, grounded and smoothened.

3.8.10 Stamping Mechanism and Stand (Telescope Stand) Construction:

This is a crucial component of the machine because it enhances the upward and downward movement of the templates to impress design and cut tiles to the required size. This mechanism also holds the template-plate tray holder, the tray, and the template. It comprises of a lever, clamp, clamp pipe, piston and cylinder and the pipe-angle iron footing.

3.8.10.1 Material Requirements:-

Hollow mild steel pipe of ø48mm diameter, 4mm thick, 405mm long; ø48mm diameter and 4mm thick, 535mm long are required. Two pipes of ø48mm, 4mm thick 185mm long, ø48mm and 4mm thick, 35mm long, and ø48mm, 4mm thick and 95mm long are estimated.

Three hollow pipes of the same diameter of ø66mm and 8mm thick with diverse length of 295mm, 120mm and 135mm. Two mild steel plates, 6mm thick of 120 x 120mm and one of 55 x 55mm square. A hollow pipe of ø23mm diameter, 3mm thick 70mm long. Two small pipes of ø20mm diameter, 3.25mm thick 30mm long. Two washers of ø35mm outer diameter, ø20mm inner diameter and 3mm thick are required. A rod of ø20mm and 112mm long are required. A 13mm long free treaded bolt of 300mm and a spring of 120mm height with a pitch of 22mm and inner diameter ø49mm.

3.8.10.2 *Operational Sequence:*

The hollow pipes of length 535mm and 405mm were tightened on the lathe machine and faced one after the other. The 535mm was treaded inside to a length of 70mm and the 405mm treaded outside to a length of 35mm long on one end and treaded inside to a length of 40mm all with inches pitch. The two other smaller hollow pipes of 95mm and 35mm lengths were faced and turned on the lathe machine, subsequently treaded all through on the outside. The hollow pipes of ø66mm and 8mm thick, length of 295mm,

135mm and 120mm were cut, faced and turned on the lathe machine to their required sizes.

A space (void) of 23mm (H) and 70mm (L) was cut out from the middle of the 120mm long pipe. The 135mm pipe was chamfered on one of the hollowed sides to fit the outer diameter of the 120mm pipe.

The 295mm long was sharpened or grooved inside of 11.2mm (L) x 12mm (W) x 4mm (H) and a hole bored half way from the top of the groove this serves as the key way from the inside.

The smaller hollow pipes of ø23mm were cut through midway and chamfered to conform to the diameter of the 120mm long pipe above. One out of the two smaller pipes of ø20mm was tapped (treaded) with a 13mm tap and the other end left free. The rod of ø20mm was bored with a 12mm drill, 80mm long and tapped with 13mm tap. The two metal plates were tightened to the lathe machine and bored at the centre with a drill of 67mm and four other holes bored at each of the diagonal ends. All these were ground, welded and smoothened as required to form a complete mechanism.

3.8.11 Roller Hanger and Rails Constructions:

This holds the rollers in place on both sides of the shafts to afford continuous motion as required.

3.8.11.1 Material Requirements:-

Mild steel angle iron 2 x 2", six each of 308mm and 90mm. Six sets each of a mild steel flat bar of 50 x 40mm^2, 50 x 50mm^2 square and 12 sets of 50 x 5mm and two sets of 50 x 20mm all of the same thickness of 5mm. Twenty four cubes of 10 x10 x 10 x 10mm^3

mild steel and two plates of 120 x 45mm; two angle iron 2 x 2" of 685mm and two of 600mm.

3.8.11.2 *Operational Sequence:*

The entire materials were cut to required sizes, bored with 13 and 21mm drill after which they were welded and ground component by component. These produce eight sets of hangers and 6 sets of roller rails.

3.8.12 Frame Construction:

The frame is very important, as it provides the mounting parts for all other components of the machine and its rigidity determines the rigidity of the entire machine complex. Therefore, care was taken in ensuring proper alignment and sequences of joints for the three various sections.

3.8.12.1 Material Requirements:-

Eight lengths of 2 x 2", 5mm thick 18ft long mild steel angle iron. Twelve mild steel plates of 80 x 80mm square, 5mm thickness.

3.8.11.2 Operational Sequence:

The calculation in 3.6.9 was considered assiduously in line with the construction. The various dimensions were marked out with measuring tape. The hacksaw and a milling machine were used to cut these into required lengths and sizes. These were subsequently joined by welding and bolt and nuts as shown in the drawing of tile machine. Lastly, the

required holes were bored with different drills at each point in the various parts of the frames with the aid of drilling machines.

3.9 WELDING

According to ASM International (2003), welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence (fuse/melt together). This is often done by melting the work-pieces and adding a filler material to form a pool of molten material that cools to become a strong joint to produce the weld. Welding is the focus of steel fabrication.

The formed and machined parts are assembled and tack welded into place then re-checked for accuracy. The welder then completes welding per the engineering drawings with the details provided. The steel will have a net contraction upon cooling in the direction of the sweep.

The same method as explained above was used to join the cut, formed, drilled and machined parts. Tacking of parts before welding is very important because it helps to check mistakes, visualize the weld and make necessary adjustment before the major welding. In the welding, different kind of electrodes were utilized due to the varieties of steel used. Stainless, carbon and cast electrodes were used in the welding, based on the type of steel.

The welding was done in line with the different sections.

3.9.1 First Grinding/Sanding

After the welding, the next stage was the grinding and sanding. This was done before and after painting. The welded parts, drilled holes, cut parts and other formed components were grinded or sanded with the aid of a grinding disk attached onto a grinding machine,

hand file and sandpaper. However, some of these activities were done on the lathe machine. The weld or formed steel, were sharpen, chamfered, smoothened, cleaned, polished, dulled (makes the steel hazard free) to remove chips and excess welds. This make the steel fit well into each other and looks neat and cleaned, free from molten dust, stains, and body rust.

3.10 ASSEMBLY

This section deals with assembling of the entire machine component by component. Assembling is a process that involves the fitting together or the collection of manufactured parts into a complete machine, structure, or unit of a machine. This usually after welding and after this follows the finishing--painting or final external treatment (aesthetic outlook). The tile making machine was assembled in two phases the progressive assembly and immediately after the finishing. The assembling was done pedestal on the sections of the machine—from the first section, the second and then the last section.

3.10.1 Progressive Assembly:-

In the first instance, the sub-units of the machine were assembled individually and according to the three sections. The frame of the first section (processing section) was positioned, tightened with M12 bolt and nuts and the major components were mounted and tightened. These include: the milling chamber, screw auger shaft, electric motor, hopper, sprocket and chain, electric (Power) box with its components, the cone-nose (orifice), the roller and other necessary parts.

The standard bolt and nut selected for tightening the entire machine is M12. At some points, there are some exceptions, because of size, function and standard of a particular

part; these make few bolts and nuts different from others. Examples of such parts were the shaft bearing, machine covers and the rollers hanger bearing.

The second (conveying stamping and cutting) section was connected to the top of the first section with an L-cap. The other footings and brazes were fixed and tighten with M12 bolts and nuts. Other parts of this section like the roller hangers and the stamping mechanism with its base tightened were fastened to the frame. The belt conveyor was also fixed, fastened and adjusted to the requisite tension.

The next and the last (receiving) section's frame was also mounted on its footing with M12 bolts and nuts. Other components like the roller rails, roller hanger and the rollers were mounted and tightened. The machine was tested after the first assembly before final finishing (painting).

3.10.2 Assembly after Finishing:-

This was done after the whole system was dismantled, re-ground and sandpapered to secure a very smooth surface painted by spraying with the spray nozzle attached to a compressor and a cylinder. The compounded tile body recipe was used to test-run the machine and all the necessary assessment taken. Before the machine was operated the entire parts were well tightened and ensured.

3.11 WIRING

Wiring: - is line of wires for conducting electric current (Merriam Webster' dictionary, 2010). These wires were run within the machine to the motor that receives the current from the power source. In the wiring, a professional was employed because it is an aspect that makes the machine functional by connecting it to power. It needs a technical knowhow of a practicing professional. An electric motor, two contactors, wiring box, 3-

phase and 2-phase wires, two two-way switch, two indicators, clips and links were used. The electric motor is the primary source of motion. It can move in any direction but contactors were connected to aid the forward and backward movement. The first two-way switch is to aid in the off & on and in the selection of motion's direction. The two indicators used work alongside the two direction of the motion once it is on. The second two-way switch was used to control the stoppage and onward motion at the point of stamping and cutting of the tile to size. The switch is an automatic switch attached to the lever of the template carrier so as to automatically stop the machine when one is about to stamp. Once the lever is released, it continued in motion for the next point of action.

3.12 PAINTING AND SECOND GRINDING/SANDING

This is the final stage in production, after which the machine is test-run following appropriate finishing i.e. painting. Painting of a fabricated machine can be done in parts or in whole. In the case of this machine, it was done part by part so the paint can saturate every corner/aspect of the fabricated components.

Before the final painting, the complete fabricated parts were grinded-polished, planed, smoothened and washed to remove greasy or oily contaminants. This is to enable the paint adhere to the steel surface. The spraying/painting was done with the aid of a spray gun, vacuum tank and hose. Two colours of paints were used, sky blue and ash. After this, comes the assembling of the machine.

3.13 MOULD/TEMPLATE PRODUCTION IN DIFFERENT SIZES

In the production of the templates, some parameters were considered before the productions which are size, the impact/weight, material, design/impression and thickness/depth of template:

a. The size of the template:- This has to go along with the template housing or tray

b. The impact/weight of the template: - It is of utmost importance that this is not heavy due to the place it will be functioning. This will enhance easy upward and downward movement as required.

c. Material for the template: - It should be such that will impress design without sticking or holding onto the tile surface.

d. Design/impression (Motif):- The impression should be such that can be easily produced without stress which also depicts the cultural value being portrayed or designed objectives.

e. Thickness/depth of template: - This determines how deep the impression will be. It is required that the impression should not be more than 2 to 3mm deep.

Five clay slabs measuring 20mm in thickness and 425cmx46cm each were prepared. The tiles clay body was made up of 50% Kaolin (primary clay) and 50% Bomo clay (secondary clay). Rough sketches of several African motifs were made from which four motifs comprise of a talking drum, horn, gauge and a shield were chosen. The drawings were later drawn with the aid of a computer (Microsoft word and Corel draw). They were repeated as simple repeat patterns; to visualize the result before enlarging them onto a drawing sheet as designs for to onward transfer on the clay slabs to serve as decorations..

Each of the four designs was produced in two different sizes of 31cmx31cm and 21cmx21cm. The slabs were left to become leather hard before the designs were traced on individual slabs. Turning tools, knife and spatulas were used to subtract the unwanted parts. This was left with a simple low relief not less than 2 to 3mm in depth. The template sizes of 31x31 cm and 21x21 cm were cut out from the larger slab set for casting with plaster of Paris (pop) which is the main template.

Each design plate LXVII to LVIII was place on a clean flat surface (table) and Cottles prepared from ply wood and ceiling board for each relief (design). Engine oil was used as plaster separator. Before casting, the altitude of the cast was determined in consonant with the height or thickness of the tile and the template housing (tray). The cast (POP) of 31/2cm in height is equivalent to 1.5cm thickness of a tile. The cast (POP) of 4cm in height is equivalent to 1.cm thickness of a tile.

Giorgini (1994) and Frank and Hammer (1991) in item 2.7.5.3 gave the mixture of plaster to part of water for tiles and other wares. For the purpose of this work, a dense plaster was prepared from a mixture of 150 part of (POP) to 100 parts of water. This is required because of the pressure that will be exacted on it. From the measurement scale 1kg = 100% and 1.5kg = 150% were used respectively. After mixing, the mixture was subsequently poured onto the cottled relief and allowed to set before removing the Cottles to reveal the cast. A graphic illustration of all the processes is given in chapter five.

Following the templates' removal; grooves were created by the sides round of depth1cm =10mm. This grooves allowed the template to be slotted into the try without stress. Equally, some cleaning and dressing was done on the templates which has need of correction. Two of the templates (one 31 x 31cm and one 21 x 21cm) were to be divided

into four equal squares each of which produces a particular size of tile. From the division 31cm x 31cm, we had duet of 31cm x 15.5cm and quadruped of 15.5cm x 15.5cm. And 21cm x 21cm gave pair of 21cmx10.5cm and four of 10.5cm x 10.5cm. The templates were slotted in turns while those divided where collectively inserted into the tray or template holder. Thus, the machine was test run to have the effect of the impression from the individual templates.

3.13.1 Preparation of Adopted Tile Mixed

Pozo tile mixed or recipe would have been perfect in adoption, but several materials in appendix V that made up the body are foreign to our environment, Nigeria to be particular. It was on this note that a new body was prepared as suggested by Hansen [2011], who said, a combination can be tried depending on tile body recipes and type of moulding process.```

> *The composition of the tile body should start with 25% ball clay, silica, feldspar and kaolin. If it is too plastic change some ball clay for kaolin. If it is too short, do the opposite. If it is too vitreous, reduce the feldspar for silica. If it is too refractory, do the opposite. If glazes craze, you need more silica.*

Despite this, he further suggested that enough clay be used to get the plasticity required, enough feldspar to get the maturity necessary, enough grog to get the drying performance essential and enough silica to get the glaze to fit without crazing. On the other hand, Tony said the grog can be left out at the start. Thus, he suggested 50% clay, 25% feldspar and 25% silica for high temperature, or 40% clay, 40% feldspar, 20% silica for medium temperature. Of course, if the tile is not to be vitrified, then less feldspar should be used.

From the information advanced, four of these materials were compounded in different proportion just to have a body that can be suitable for tile production.

In preparing the tile, material empirical method was employed, beginning with locating, identifying and charting of local deposits, exploration, procurement, transportation, beneficiation or treatment (calcinations, crushing, ball milling/grinding, drying, sieving and measuring), compounding/mixing of ceramic materials, aging, application/production of the prepared recipes, drying and firing which mark the final stage Fig.26 :

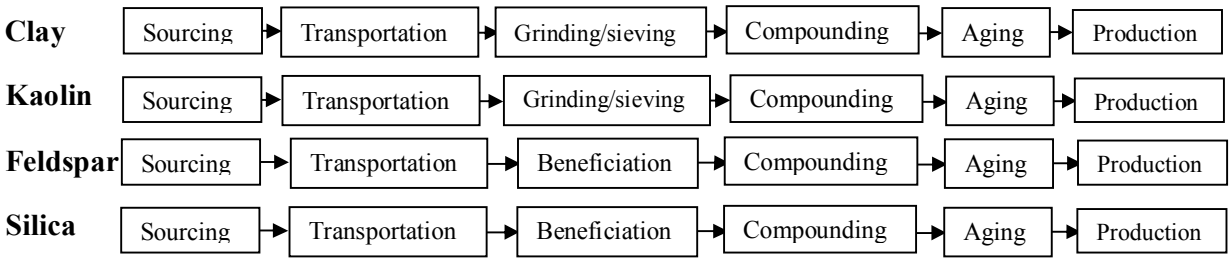


Figure 26: Beneficiation of the Materials: Clay, Kaolin, Feldspar and Silica

Table 3.1 Volumetric Composition of Ball clay, Feldspar, Silica and Kaolin

S/N	MATERIALS	A	B	C	D	E
1	Ball clay	25	25	25	30	30
2	Kaolin	25	30	25	20	30
3	Silica/Quartz	25	20	20	20	30
4	Feldspar	25	25	30	30	10
	Total	**100**	**100**	**100**	**100**	**100**

From each of these tile bodies, five test bars and five sample tiles of 10cm x 10cm were moulded and fired to between 850^{o}C--852^{o}C and then to glazed temperature of 1150^{o}C--1200^{o}C to observe the behaviour of the bodies to determine body appropriateness which include:

1. Plasticity and consistency (cohesion) of bodies
2. Shrinkage rate
3. Porosity
4. Firing temperature
5. Surface quality
6. Strength
7. Moulding qualities
8. Glaze adhesion
9. Colour etc

Here is a visual image of the tiles and test bars produced.

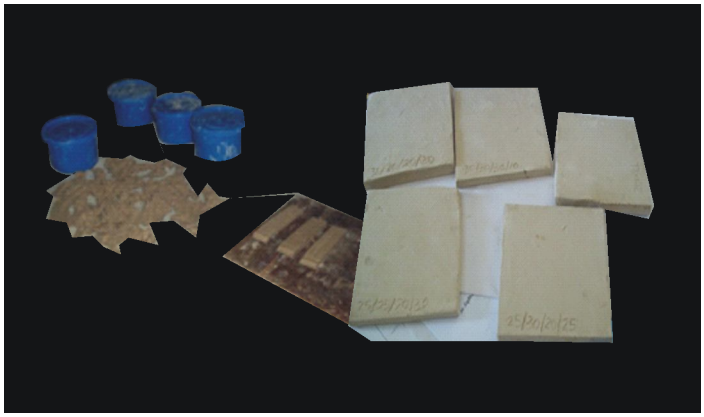


***Plate* VII:-** *Initial preparation of Test Bar and Sample Tiles with some Tiles at Green stage*



PlateVIII:- Bisque Sample of Test Bars and Tiles

CHAPTER FOUR

TESTING OF THE MACHINE

4.0 INTRODUCTION:

In fabrication, test running is very important. This is done to visualize what has been fabricated, the effective working of parts, workability of machine/design-function, surety of forces acting, safety of parts, etc. and at most, make necessary corrections.

After these tests, the machine was dismantled for onward and final grinding/sanding and painting.

4.2 TESTING OF THE MACHINE:

It is an excellent and normal practice to subject engineering products to test after manufacture or fabrication. This is a significant step in manufacturing processes. Under test, the product is checked to see if the functional requirements are satisfied, or to identify manufacturing problems, and to ascertain the economic viability, if the design considerations were satisfied etc. (Amalu, 1994 in Malachy, 2002). This was in agreement with what Khurmi and Gupta (2004a) and Napgal, (2002) earlier suggested that, a prototype (machine) should be subjected to performance test, flaws revealed while testing should be removed by making alterations in the preliminary design of the component.

Testing was therefore, employed to prove the effectiveness of the machine's major components, and to check the major forces acting on the machine. The product, and extrusion test, was the most significant test. The Testing of the machine was done base on the following sub-headings and substantiated.

4.3 Performance Test:

The following performance tests were conducted:

4.3.1 Testing of Machine Under no Load Condition:-

At this point, the machine was tested under no load condition with a gear, belt and pulley, and chain and sprocket drive and the two-way switch at the stamping point. Similarly, at the stamping point the two way switch was tested to stop the machine while in motion at the point of stamping and release after stamping and cutting of the tile. This went on for about 20 minutes with a 2hp electric motor and other electric motors ranging from 2-7hp were also used. Another important aspect of this test was to check if any part within or outside the milling chamber was having an unwanted rubbing contact while in motion.

Test to Milling Tile Mix: The material was poured and the machine was put (powered) in forward and backward motion to mill the tile mix for some minutes. The rheology, the yield stress and contactors were also assessed at this point.

4.3.2 Efficiency Test of Some Major Components/Parts:-

The machine was tested by pouring the tile mixed into the machine through the hopper. Up to seven diverse electric motors of different horse power (hp) were used in testing to transmit motion. This test was done to check the efficiency of the electric motor in generating the required torque (productive or enhancing force), screw auger shaft, the nose-cone, rollers, vibration and stability of the frame under load condition. The components tested are very vital to the efficiency of the machine. It was observed that the major factor for these to function is associated to the electric motor in transmitting and supplying the functional and required torque.

4.3.3 Extrusion Test:-

The machine was powered; the material poured into the hopper to see if it can generate the required torque and pressure to push or extrude the material through the orifice in different sizes and thickness.

4.3.4 Testing to Extrude Sample Tiles:-

The machine was powered with material inside and more added to ascertain its capacity to extrude the tile mixed. This was achieved with the conveyor belt conveying the slab extruded to the stamping and cutting section and conveyed to the receiving end where it slides on the wooden bath as a product.

4.4 Capacity Test:

The following capacity tests were conducted:

4.4.1 Testing the Quantity of Tile Mix the Milling Chamber and The Hopper can Contain:-

The already mixed material was poured into the chamber through the hopper and more added to observe quantum of mixed that the chamber and the hopper can contain at a time and if the machine can take the load (move when powered).

4.4.2 Testing to Extrude tile:-

After the second or final assembly, the machine was tested to extrude tiles with the adopted compounded tile mix and conveyed on the belt conveyor.

4.4.3 Template Testing:-

The four templates were in turns, slotted into the tray, to stamped and cut tile to shape. This was done to have a feel of what such impression could present and the tiles sizes from the various templates.

4.4.4 Quantity/output Testing within an hour:-

The machine was operated, the slab extruded, cut to sizes with four different templates and finally removed as a tiles. This was a kind of continuous operation to afford production capacity. It was done twice for 15 minutes each to determine what number of tiles it can produce within a given time so that such can be multiply by 4 to assume the number of tiles it will produce in an hour.

4.5 ERGONOMIC ASSESSMENT:-

This is an assessment that basically deals with the relationship of the machine parts, working environment and postures it affords to the human body. Especially, those in constant use: the hopper, hopper lever, stamping lever, the frames height and others used frequently as compared to the body frame regarding to comfort and convenience. This was to determine whether the parts or machine is convenient to operate comfortable and safe without side effects and unwarranted stress.

4.6 OTHER TESTS:-

These tests encompass the tile body recipe, tensile test, impact test, hardness test and the test bars.

4.6.4 **Aims and Objectives Assessment**

The assessment of the aims and objectives of this project were done base on the entire work done, by using some tests carried out and results obtained. This is to ascertain the level of attainment in the objectives proposed from the onset. The result is presented in chapter five.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.0 INTRODUCTION

For every test carried out, fabrication work or any mechanical exercise there are anticipations or results expected. This section/chapter presents the various results and discussed adjustments, changes, modification and refinement and introductions to bring the machine to this present state. The objectives of this research work are here by evaluated to the extent of their realisation or failure and the assessment of the objectives and mechanism put forward.

5.1 RESULTS OF SOME OF THE PARTS FABRICATED:

Outcome of the various constructed components and processes are given below in plates. This is a medium used to assess the structural integrity and performance cycle of the level of involvement and results of the fabrication processes. In other words, it gives a feel of the work done in form of first-hand information. Numerous of these parts constructed were altered, adjusted, improved, and new ones introduced. Some have to be mocked-up on paper, before they were transferred onto the metal plates. This kind of occurrence is actually an aspect of the chain processes involved in fabrication of machines. Thus, the machine might not be exactly as designed but would definitely function as it is required. Subsequently, there might sometimes be an introduction of new features which can alter design. This is acceptable in product development (machine design) or fabrication.

A number of difficulties were encountered at the course of fabrication but most were surmounted following a line of investigations of books, internet, brainstorming,

consultations with the M.D. and Chief Technical staff of Delmat Technical workshop, my supervisors and other Engineers who where available to proffer supportive and prolific suggestions. In view of the fact that the machine is divided into 3 sections, the results of these processes will be given in accordance to the sections.

5.1.1 The Result of The First (Processing) Section: This is the result of the first section from the foundation of the fabrication, comprising the components before painting.



***Plate IX**:- Researcher welding some Component*

Source: Original Research Photograph Morakinyo, (2010)



Plate X:- *Frame of Processing Section and Hopper within*

Source: Original Research Photograph Morakinyo, (2010)



Plate XI:- *The First Fabricated Milling Chamber before expansion and correction*

Source: Original Research Photograph Morakinyo, (2010)



Plate XII:- *Corrected and expanded Milling Chamber.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XIII:- *First Alternated Auger Shaft with Milling and Mixing Paddles.*
Source: Original Research Photograph Morakinyo, (2010)



Plate XIV:- *Second formed Screw auger Shaft, on grinding by the Researcher.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XV:- *Cut And bended Auger Plates*

Source: Original Research Photograph Morakinyo, (2010)



***Plate XVI:-**. Screw Auger Shaft forming process*

Source: Original Research Photograph Morakinyo, (2010)



***Plate XVII:-** Formed and welded Hopper.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XVIII:- *Cone-nose.*
Source: Original Research Photograph Morakinyo, (2010)

5.1.2 The Result of the Second (Stamping and Cutting) Section: This is the result of the second comprising the various components that made up this section before painting.



Plate XIX:- *Roller Hanger and the Stopper.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XX:- *L-cap Joint (link of the First and Second Section)*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXI:- *Four cut Padded Cylindrical Pipes for the big conveyor rollers.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXII:- *Roller's Plates Sides' covers and Formed Roller's Internal Four Arms Plate*
Source: Original Research Photograph Morakinyo, (2010)

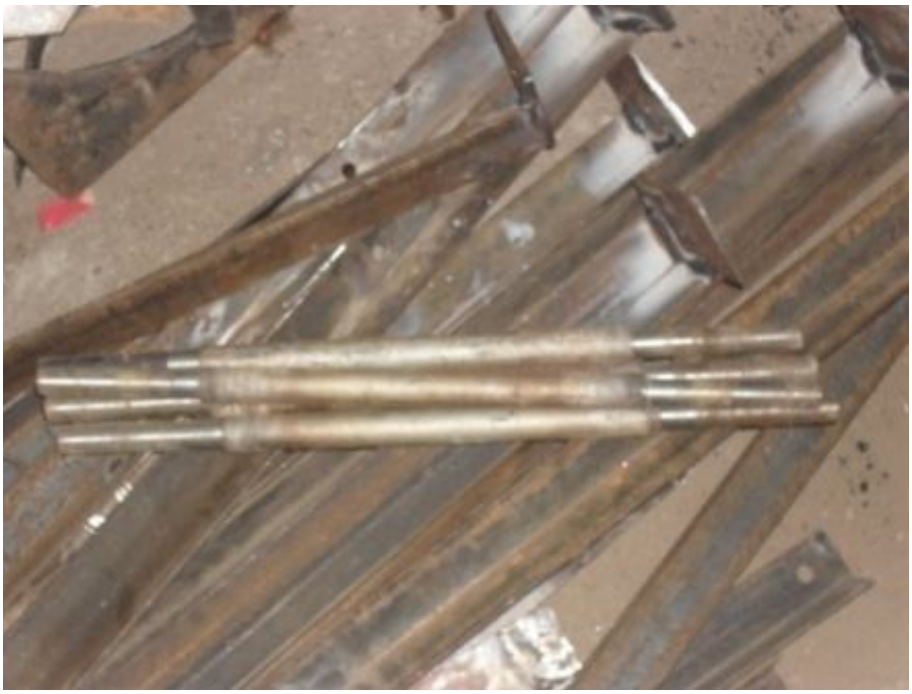


Plate XXIII:- *Four stepped Roller's Shafts and Footings.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXIV:- *Two Templates' Tray*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXV:- *Researcher Grinding Component.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXVI:- *Stamping and Cutting Mechanism.*
Source: Original Research Photograph Morakinyo, (2010)

5.1.3. The Result of the Third (Receiving) Section: This is the result of the third section comprising mainly of rollers for receiving the cut tile on a wooden bath before painting.



Plate XXVII*: - Complete view of the Receiving Section, comprising of the Rollers, Rollers' Rail, roller Hanger and the Jaw Joint Connector (link of the Second and the Third Sections).*
Source: Original Research Photograph Morakinyo, (2010)

The detailed drawing of the entire machine and the various components labelled and dimensioned individually is attached to this project (as in appendix XV).

5.2 ASSEMBLY RESULT:

5.2.1 Result of the Progressive Assembly:-

As the name implies progressive assembly *Plates XXVIII–XXXIII* show the first assembly before the entire machine was painted. It is termed progressive for the reason that, as the parts are machined, cut, drilled, formed, chamfered, adjusted, corrected, transformed, added etc in this progression, they are coupled and finally test-runed. In addition, plate XXX shows the Researcher's two supervisors during the first test-running (test of the proposed mechanism for the Tile Making Machine) without load in the machine.



Plate XXVIII*: Skeletal Assembly in Progressive with the Chamber and the link to the Second Section*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXIX:- *Progressive Assembly in Progressive with the First Section near Completion, Skeletal Second and Third Section*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXX:- *Researcher's Supervisors during the First Test Running of the TMM*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXXI:- *The processing Section with a Pulley and Belt Drive with the Sixth Electric gear motor*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXXII :- *The Conveying section with Belt Conveyor, StampingMechanism and The Third Section*

Source: Original Research Photograph Morakinyo, (2010)



***Plate XXXIII**:- Progressive Assembly as the Fabrication Progressed and The Entire Machine Coupled.*

Source: Original Research Photograph Morakinyo, (2010)

5.2.2 The Result of Assembly after Finishing:-

As the name implies, assembly after finishing Plates XXXIV–XXXIX shows the second assembly after the machine was dismantled, regrind, body filled, smoothened and painted with car paint and the assemblage in progress by the Researcher. That is a stage by stage assembly after finishing. After this coupling, the machine was test-run with the templates and the new tile recipe compounded.



Plate XXXIV *:- Frame of the Processing Section In Place*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXXV*:- Researcher Coupling the Machine*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXXVI *:- Researcher Coupling the Machine at the Point Of the Telescope Mechanism.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XXXVII*:- Researcher Coupling the Machine by fixing one of the Bigger Roller at the end of the Machine.*
Source: Original Research Photograph Morakinyo, (2010)



***Plate XXXVIII**:- A complete Assembly from the End-side view*
Source: Original Research Photograph Morakinyo, (2010)



***Plate XXXIX**:- A Complete Assembly from the Back-side view*

Source: Original Research Photograph Morakinyo, (2010)

5.3 THE RESULT OF PERFORMANCE TEST: -

The tile mix of 50% : 50% = 100%, of Kaolin and Secondary clay, was used to carry out the performance test, largely done before painting of the machine.

5.3.1 The Result of Testing of the Machine Under no Load Condition after First Assembly:-

Under no load condition, with the gear, belt and pulley, and the chain and sprocket drives, the machine was observed and the processing components, these worked well in the directions required. The seven different motor used transmitted the necessary speed and motion at every point as required, it was effective- from the gear, belt and pulley and the chain and sprocket drives, to the driven gear, pulley and sprocket shafts. The noise produced is consequent to the type of drive used. The vibration was not injurious as expected. The stamping switch worked as expected without any disappointment. Unwanted rubbing contact between the chamber inner wall and the blade of the shaft auger was observed though ignorable, but this was eliminated by grinding further the auger's plates. This indicates that the machine performed very well under no load condition.

5.3.2 Results of Testing in Mixing Tile Body Composition:-

The following result was observed with the three different auger shafts. First alternated auger shaft with milling and mixing paddles (Plate XIII), the second formed screw auger shaft with milling and mixing paddles (Plate XIV*)* and the final Screw auger shaft (Plate XVI). These were able to mix the tile mix while the machine was operated in clock and anti-clock wise motion. In the mixing, the forward and backward switch nub was operated intermittently within short seconds. It was observed that, while moving forward it goes freely due to the large space available within the milling chamber, but while

going backward at some points, the machine stopped on its own. This was because the space backward within the chamber was not sufficient to afford such motion as wanted but only for brief seconds. This shows that more space is required. It can be incorporated into subsequent design of same or similar machine in the future because with or without it the machine efficiency or productivity was not affected. With these results it is noticed that the contactors are working effectively except for space within the chamber backward that is not sufficient.

Similarly, the material yield stress was positive because it was allowing free movement of the augers between the material and the wall of the milling chamber. This is very vital to successful extrusion and efficiency of the machine.

5.3.3 Result of Efficiency Test:-

The components tested were very vital to the efficiency of the machine. It was observed that among the seven electric motors used only one supplied the required torque. That is the 2.5 to 3hp gear electric motor. The screw auger shaft, the cone- nose and the rollers also worked well with all the other electric motors. The stability of the frame and vibration can further be assessed once load is involved in a machine. The major anchor or operational determinants of the machine when it is in motion is linked to the screw auger shaft. The vibration was normal and the frame was stabled. The chamber was moving in a left to right form under load condition. This was adjusted by adding packing to the footing of the milling chamber. Apart from that, the vibration was normal as expected.

5.3.4 Result of Extrusion Test:-

The test above and this one go hand in hand. Before the 2.5 to 3hp electric motor Plate XXXIII worked, 5 electric motors with diverse speed were first used ranging: two of

2hp, a 3hp, 5hp and 7hp, and none of these could extrude the material. It was at this point that the chamber was extended in length from 380mm to 530mm Plate XI and XII. This consequently affected the lengths of the screw auger shaft from 880mm to 1,003mm Plates XIV and XVI and the frame of the processing section lengthwise from 930mm to 1008mm plate I*X*. This affected the volume of the entire chamber from 37800cm^3 to 51340cm^3 (37.8kg to 51.34kg in weight of material (IWM)). Therefore, the volume of chamber and hopper is no longer 68080cm^3 but 81530cm^3 (68.08 kg but 81.53kg IWM). Consequently, a 1 hp gear electric motor was used to test run the machine, changing the gear drive to belt and pulley drive and to the chain and sprocket gear which is now working with the 2.5 to 3hp gear electric motor Plate XXXIII. The change to the two order drive incurred more financial obligation/involvement. The mathematical equation for the chain and sprocket drive is given in appendix VI

Changing of the entire electric motors one after the other at each point affected the bedding/seating of the electric motor. This is because their footings were all different. On that note, there was always an adjustment/modification or an addition to the bedding each time any one is changed so that the motor can fit into the seating. It was a very monotonous, hectic and time consuming adventure.

Correction of any sort in fabrication is very expensive, laborious, time consuming and discouraging. Because this is quite difficult, it is better to produce a new and neat component afresh than correcting another.

It is worthy to note that, at this particular point the screw auger shaft was also changed, from Plate XIII to Plate XIV and finally Plate XVI. The first auger shaft in Plate XIII was change to the one on Plate XIV due to its lack of strength to withstand and support the pressure that provides the required torque. The change of shaft from Plate XIV - XVI

was necessary because the screw auger plate were too close and consequently trapping of the material within its pitch. Though this was made of stainless plate, as the best to prevent wear and contamination, but due to the joints and patches on the plates these were weakened. On that note, a thicker plate of 4mm thickness of mild steel was sort for because of the cost of stainless plate of that size.

It was also discovered that the major problem which results in the change in drives was related to the choice of the electric motor rather than on a fault with the drives.

After all said and done, with the 2.5 to 3hp gear motor and the necessary adjustment, the motor was able to generate the required torque while the screw auger shaft milled and extruded the tile mix without any difficulty. At that point, it was another "**Eureka"**. Obviously it was a great relieve and ecstasy in the entire workshop; Plates XL - XLIV are examples of long slabs extruded in the workshop:



Plate XL:- *One of the First Extruded Slabs with the Orifice at 310x20mm*

Source: Original Research Photograph Morakinyo, (2010)



Plate XLI:- *Further Extruded Slab when the Orifice was Adjusted to 310x10mm.*

Source: Original Research Photograph Morakinyo, (2010)



Plate XLII:- *Extruded Slab Conveyed on the Belt Conveyor up to the Stamping and Cutting Mechanism.*
Source: Original Research Photograph Morakinyo, (2010)



Plate XLIII:- *The Orifice of the Cone-nose with the Adjusting Bar and its Support at its First Position with a Slab Extruded Slab.*
Source: Original Research Photograph Morakinyo, (2010)



Plate XLIV:- *The Position of the Regulating Bar and its Supporting Bar adjusted with a slab about to extrude through the Orifice or Extruded through the Orifice*

Source: Original Research Photograph Morakinyo, (2010)

5.3.5 Result of Testing to Produce Sample Tile:-

The machine was able to generate the required torque as mentioned above and extruded the tile mix into a long slab as shown above while in the workshop. The orifice of the Cone- Nose was set at 310 x 20mm, and when it was adjusted to 310 x 15mm and 310 x 10mm in thickness, it extruded to some measure. However, there were many wrinkles on the surface of the slab. Also, the slab was breaking and sticking. When it was further adjusted to the 310 x 8mm, there was much tear and breakage. This resulted to the cutting of slab at the orifice with more vibration noticed. The result was not too comfortable; it affected the surface quality, the length of the slab and eventually the tile.

There was a lot of cutting and realignment of the extended orifice of the Cone-nose component. The position of the regulating bar support and the regulating bar was

affected by shifting the position of the bar and its support and altering the entire support for a better option. After the correction, the machine was able to extrude the slab in different thickness; the tile produced was cut with just the template tray without the template (impression) at this point. Though the vibration and wrinkles were still noticed, they were much fairer than the first experienced. After testing, the orifice was further improved upon before the final painting of the work—for better output. The tile size cut was 310 x 310mm square. 10mm was added to the 300 x 300mm to take care of shrinkage.

A compressing stand, lever, plate and handle were introduced to the machine on the hopper. This is to help compress tile mix, thereby improving the extrusion surface quality of the tile, extrusion speed, reduce cutting and gumming of the slab to the orifice and save manual compression Plates XLV:



Plate XLV:- *Introduced Compressing Stand, Lever, Plate and Handle to the Machine on the Hopper to help Compress the Tile Mix; in 3 phases*
Source: Original Research Photograph Morakinyo, (2010)

The machine was successful because, the mechanism that was proposed worked out and ultimately functions to carry out the required task. This is another innovation like many

discoveries in the world today that were later enhanced, like the first aeroplane, automobile, bicycle, bulb discovery, computer, train to mentioned a few.

> *(1867–1912 and 1871–1948, res). Two young American brothers, Wilbur and Orville Wright, made the dream of flying a reality when they built and flew the first motor-driven airplane in 1903. The technology and design that they used in the original 1903 model is still the basis for modern airplanes today. The Wright brothers' airplane made many other achievements possible as well, including commercial air travel.*
>
> *The powered plane had twin propellers and, like the brothers' third glider, could be controlled by the pilot. In Kill Devil Hills at about 10:35 on the morning of December 17, 1903, Orville made the first successful powered flight. Although the airplane wobbled quite a bit, it flew a distance of 120 feet (37 meters) in 12 seconds. As the day went on Wilbur and Orville became better at controlling the airplane. During the fourth and final flight of the day, Wilbur flew 852 feet (260 meters) in 59 seconds. For the first time in history, a heavier-than-air machine that was completely controlled by the pilot flew above the ground.* (Bell, 2011)

In a research, an objective put forth attained up to 50% is actually successful. But for this work, it is above that percentage; so, it can be considered successful. This can be a model that will serve as a platform for other enduring achievement with an African touch. Below are sample of the tile extruded while still at the workshop:



Plate XLVI :- *A Cut Tile and the Extruded Slab on the Receiving end where the Tile was Cut.*
Source: Original Research Photograph Morakinyo, (2010)



Plate XLVII:- *A Sample of Tile Cut to Size*
Source: Original Research Photograph Morakinyo, (2010).



Plate XLVIII:- *A Cross Section of the Extruded Slab, on the Belt Conveyor*

Source: Original Research Photograph Morakinyo, (2010).



Plate XLIX:- *A Sample of Tile Cut to Size.*
Source: Original Research Photograph Morakinyo, (2010)

5.4 CAPACITY TESTS RESULTS:

This test deals with the volume an maximum productivity or output of the machine, it is also in line with one of the test a machine must be subjected to after fabrication. The results of these tests are listed under the sub headings below:

5.4.1 Results of the Quantity of Tile Mix Milling Chamber and Hopper can contain:

The chamber and hopper was able to contain 80000cm^3(80kg IWM) tile mix. The chamber alone contained 500cm^3(50kg IWM) tile mix while the hopper contained 30,000cm^3(30kg IWM) of the same material. With the quantum of this material, the machine was set in motion and worked appropriately when powered. This suggested that this test was successful. The material was left inside the barrel for 3-4 days and when powered it functioned.

5.4.2 Result of Extrusion Test with The Second Body Composition:

After the second or final assembly, the machine was tested to extrude tiles with the new compounded material and conveyed on the belt conveyor. The tile mix lacks cohesion, plasticity and bond. Because of this, while extruding the slab, the extrudate was breaking at the edges Plate L & LI. The particles were not bonded together like the first material used in test running the machine initially. On this note, the first material used was reverted to of 50% clay and 50% kaolin in composition; to produce the final numbers of tiles required (Plate LII to LVII).

This shows that any tile mix that would be used must be plastic for it to extrude successfully from this machine. Before reverting to the first tile body, the second body was allowed to age or mature for more than a month and pug milled, yet it remained as it were.

In the bid to produce the required number of tiles serious problems were encountered. The duplex chain broke several times which was repaired, but later changed to a new one. The gear drive Plates LVIII to LXII were reverted to as the chain drive kept skipping. This took several corrections and milling of entirely new once before the reduction of the gear system which eventually cooperated in producing the final tiles as required. But the financial implication incurred was very expensive.

A new cone-nose was fabricate Plate LXIII to LXV and tested, yet there was no significant change before reverting to the gear drive. On a final note, it was discovered that the tile material was too hard and not plastic as required. The material was then pug milled to a consistency of hand building clay with about 30% to 40% of water content. As a result the end or tip plate of the shaft auger was further extended. This responded well in extruding and producing the required number of tiles and carried out the major tests that were requisite.



Plate L: *Sample of Extruded Slab with the New Compounded Tile Body*
Source: Original Research Photograph Morakinyo, (2010)



Plate LI:- *Sample of Extruded Slab with the New Compounded Tile Body at the Orifice.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LII:- *A phases in Tile Production, in order to determine the number of Tiles the Machine can Produce in an Hour. The Machine was run for 15 and 20 minutes to determine this, while the Researcher and a Research Student operate the machine.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LIII:- *Another phases in Tile Production, in order to determine the number of Tiles the Machine can produce in an Hour. The Machine was run for 15 and 20 minutes to determine this, while the Researcher and a Research Student operate the Machine.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LIV:- *Different Sizes of Tiles Extruded and Arranged on a Table before Firing.*
Source: Original Research Photograph Morakinyo, (2010)



Plate LV:- *Tiles arranged inside the Kiln while open after Firing respectively.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LVI:- *15 x15 cm of Fired Tiles up to a Temperature of 1100^{o}C Arranged on a Table.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LVII *:- Different sizes of fired tiles up to a temperature of 1100^{o}C arranged on a table.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LVIII:- F*irst Cut Gear of Cast Iron reverted to which has an initial teeth of 122 and change to 64 teeth as a Driven and Transmission Gear.*
Source: Original Research Photograph Morakinyo, (2010)



Plate LIX: - *The pinion of the cast iron gear with 36 teeth initially and change to 18, which is the driver.*
Source: Original Research Photograph Morakinyo, (2010)



Plate LX : - *The third Gear used, both for the Transmission and the Pinion-with 41 an 23 teeth respectively, a ration of 1:1.8. this work but the speed was much resulting to less torque.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LXI: - *The pinion with 23 teeth was furtheer reduced to 18 teeth mating with the 41 teeth. This resulted in low speed and a high toque as reqiured*

Source: Original Research Photograph Morakinyo, (2010).



Plate LXII:- *The Angle Bar Footing holding the Motor Bed or Seating at the First Section being ajusted to accommodate the Changes, Correction and Modification for the Gears introduced.*

Source: Original Research Photograph Morakinyo, (2010)



Plate LXIII:- *A part of the Second Fabricated* ***Cone-nose*** *in/with the various stages involved in the Fabrication.*

Source: Original Research Photograph Morakinyo, (2010)



***Plate LXIV**:- The Second Fabricated **cone-nose** in/with the various stages involved in the Fabrication, while the Researcher was welding the bits together.*

Source: Original Research Photograph Morakinyo, (2010)



***Plate LXV: - T**he Second Fabricated C**one-nose** after Fabrication.*
Source: Original Research Photograph Morakinyo, (2010)

5.5 RESULTS OF TEMPLATES PRODUCED:

The production of the four templates were successful because they design were as expected. Below are the graphic results processes of templates production.



Plate LXVI:- Step by Step Preparation of the Templates from Slab of clay
Source: Original Research Photograph Morakinyo, (2010)



Plate LXVII:- *Step by Step Drawing and Computer Development of Drawings of patterns.*
Source: Original Research Photograph Morakinyo, (2010)



Plate LVIII:- *Cottled, Lubricated, Measured, Mixed and Pouring of Plaster*
Source: Original Research Photograph Morakinyo, (2010)



Plate LXIX:-*Templates made ready of POP.*
Source: Original Research Photograph Morakinyo, (2010)

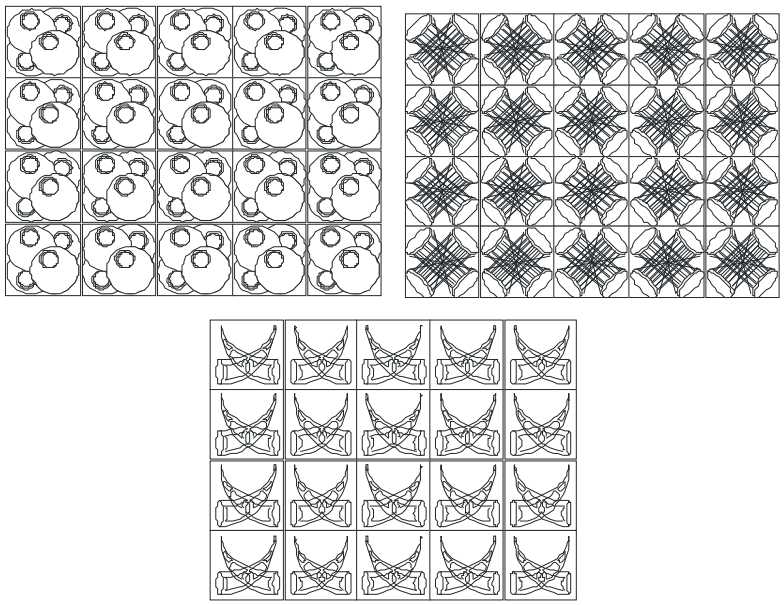


Figure 27 *Repeat Patterns of the Templates*
Source: Original Research Drawing Morakinyo, (2010)

5.5.1 The Results Of Templates Testing:-

The four templates in *Plate LXIX* were slotted sequentially to stamp and cut tile to shape. This was done to have a feel of what such impression could present and the size tiles from the various templates.

The result was not satisfactory as the templates were all cracked by the edges due to pressure. This is for a singular reason that they were made of Plaster of Paris (POP) even though denser and harder. This suggests that POP cannot work here. On that note, a design *Plate LXX* to LXXIII was adopted from plastic material; these were cut out and fastened to a wooden surface and it worked to an extent. Several sizes of tiles were produced with this and it yielded some result (*Plate LII to LVII*). It was later discovered that linoleum, wood or fired templates (gloss stage) can be tried and it might work better, but with precision in design.

The tiles produced were eventually fired to 1100^{o}C though some of the tiles in the ranges of 15x15mm and 20x20mm cracked; while the 10x10mm was successful. A second set of tiles 15x15mm and 20x20mm was re-produced and fired (appendices XIII and XIV);

this was successful without any crack. This was successful because the tiles were preheated before the actual firing. In the first firing there was no preheating and this was the reason for the cracked experienced in the first set of tiles that were fired.



Plate LXX: - *A 15 x 15cm Template Size Nail to Wooden Base*
Source: Original Research Photograph Morakinyo, (2010)



Plate LXXI: - The 10 x 10cm Template Fasten to a Wooden Base
Source: Original Research Photograph Morakinyo, (2010)

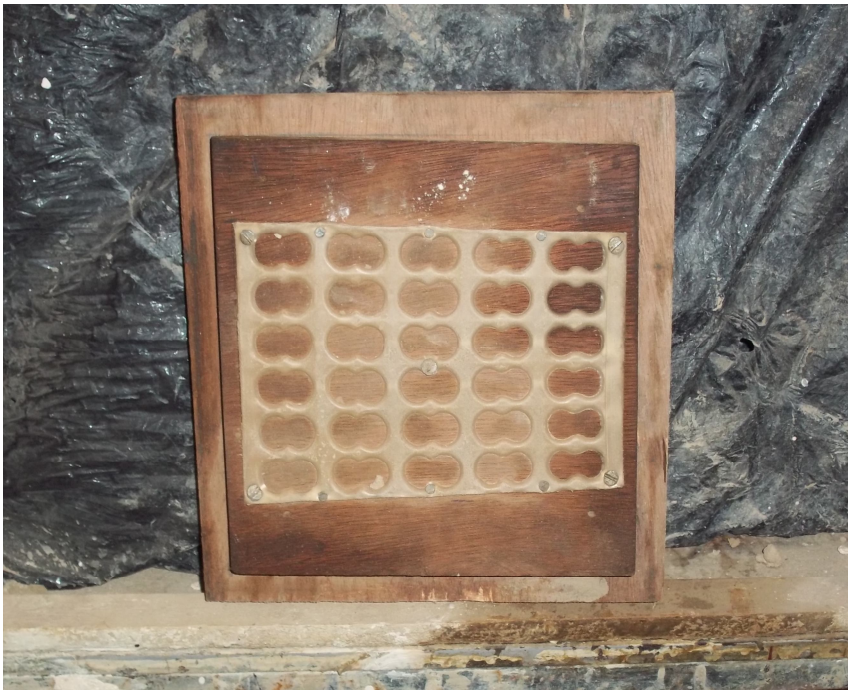


Plate LXXII: - *The the 20 x20cm Template Stamp Nail on a Wood.*
Source: Original Research Photograph Morakinyo, (2010)



Plate LXXIII: - The fourth template fastened to a wooden base of 30 x 30 cm in size
Source: Original Research Photograph Morakinyo, (2010).



Plate LXXIV: - *The big Basket as the source of the Template.*
Source: Original Research Photograph Morakinyo, (2010)



Plate LXXV: - *The Second Basket also a source of the Plastic Template.*
Source: Original Research Photograph Morakinyo, (2010)

5.6 QUANTITY /OUTPUT TEST RESULT:

After the final assembly, the machine was operated to extrude the slab, cut to size, and further received or removed. This was a kind of continuous operation to afford production capacity. It was done for 15 minutes to determine what number of tiles it can produce. Such can be multiplied by 4 to assume the number of tiles it will produce in an hour; with this equation

- 15 minutes if it produced 18 tiles = 18 x 4 = 72 in 60 minutes.
- 72 tiles in an hour; if operated for 8 hours in a day = 72 x 8 hours = 576 tiles per day**.**
- In a week it will be 576 x 7 = 4032.
- **The average in a Month =** 4032 x 4 = 16128 tiles.

The tiles were produced in different sizes of 30x30, 20 x20, 15x15 and 10x10 with thickness of 2, 1.5, 1.2 and 1.0 all in cm. These were dried, fired and used later to determine some properties and behaviour of the material

.

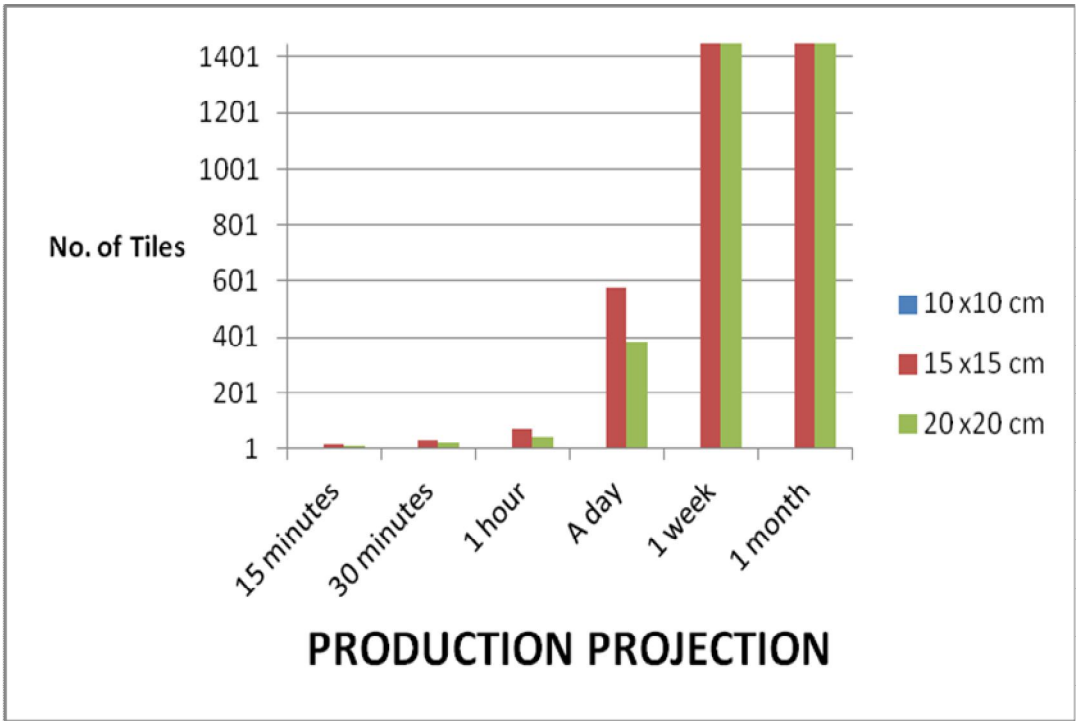


Figure 28 A Graph Showing the Production projection of Tiles

Source: Original Research Figure Morakinyo, (2012)

5.7 ERGONOMIC ASSESSMENT RESULT:

The machine was user friendly. The relationship of the body with some components check was convenient and comfortable as the environment is quite freer for work. On safety, many of the noticed sharp and injurious edges were chamfered and dulled. The entire machine was covered with a 1.5mm plates to also enhance the safety of the exposed parts. Persons of normal height and above can use the machine without any side effect. And those below average can use a stool as an adjustment of their height deficiency.

5.8 RESULTS OF OTHER TESTS:

The testss results encompassed the adopted tile body recipe, Mechanical Properties Tests (impact test, hardness test, tensile test), made sample tiles (M.S.T.) and test bars (T.B.).

5.8.1 Results of Mechanical Properties Tests

5.8.1.1 Results of Impact, Tensile and Hardness Test

Many materials when in service are subjected to forces or loads. It is necessary to know the characteristics of the material and to design the member from which it is made such that any resulting deformation will not be excessive and fracture will not occur. The mechanical behaviour of a material reflects the relationship between its response and deformation to an applied load or force. (William 1996). Important mechanical properties are strength, hardness, ductility, and stiffness.

Mechanical properties of materials are ascertained by performing carefully designed laboratory experiments that replicate as nearly as possible the service conditions. Mechanical properties are of concern to a variety of parties like the producers, consumers, research organisation, government agencies and many more.

Materials are frequently chosen for structural applications because they have desirable combinations of mechanical characteristics. This helps to understand the material, its mechanical behaviours, relationship with others and its service requirement.

Three tests were carried out on the tile material; these are tensile strength, impact and hardness test.

i. Impact test

Three tests were carried out in accordance with the thickness of the tiles, each of the samples was tested in triplicates and the average result presented.

Chappy Impact Testing Machine was implored for the tests. The results are given according to the thickness of the tiles:

a. 20mm thickness = 5.5J

b. 15mm thickness = 2.13J

c. 10mm thickness = 0.63J

ii. Hardness Test

For the hardess test the "Indentec Universal Hardness Test Machine" was used to perform the task. The Rockwell test was performed on F scale with a minimal load of 10kg and total of 60kg. The Rockwell Hardness Scales are given in appendix VII. The averages of the three tests carried out for each thickness are given below:

a. 20mm thickness = 40.2 HRF

b. 15mm thickness = 29.7 HRF

c. 10mm thickness = 18.7 HRF

Where H- hardness

R- Rockwell

F- Scale used

iii. Tensile Strength

The result of this was deduced using the correlation between Hardness and Tensile Strength. This is given as:

*TS (*MPa) = 3.35 x HB Note: 1MPa = 0.102 kg/mm^2

TS (psi) = 500 x HB 1 kg/mm^2 = 9.806 MPa

From the relationship between tensile and hardness test appendix VIII the following values were obtained for:

a. 40.2 HRF = 380

b. 29.7 HRF = 278

c. 18.7 HRF = 215

a) 20mm thickness $\therefore$ = 380 x 3.45 = Tensile Strength (Ts)

= 1311(MPa)

= 1311 x 0.102 = 133.7kg mm^2

= 133.7x 9.806 = **1311.06 N/ mm^2**

For the other two values using the same formula above we have

b) 15mm = **951.78 N/ mm^2**

c) 10mm = **741.47 N/ mm^2**

The Tensile Strength of the material for each of the thicknesses are as given above and as express on a graph below.

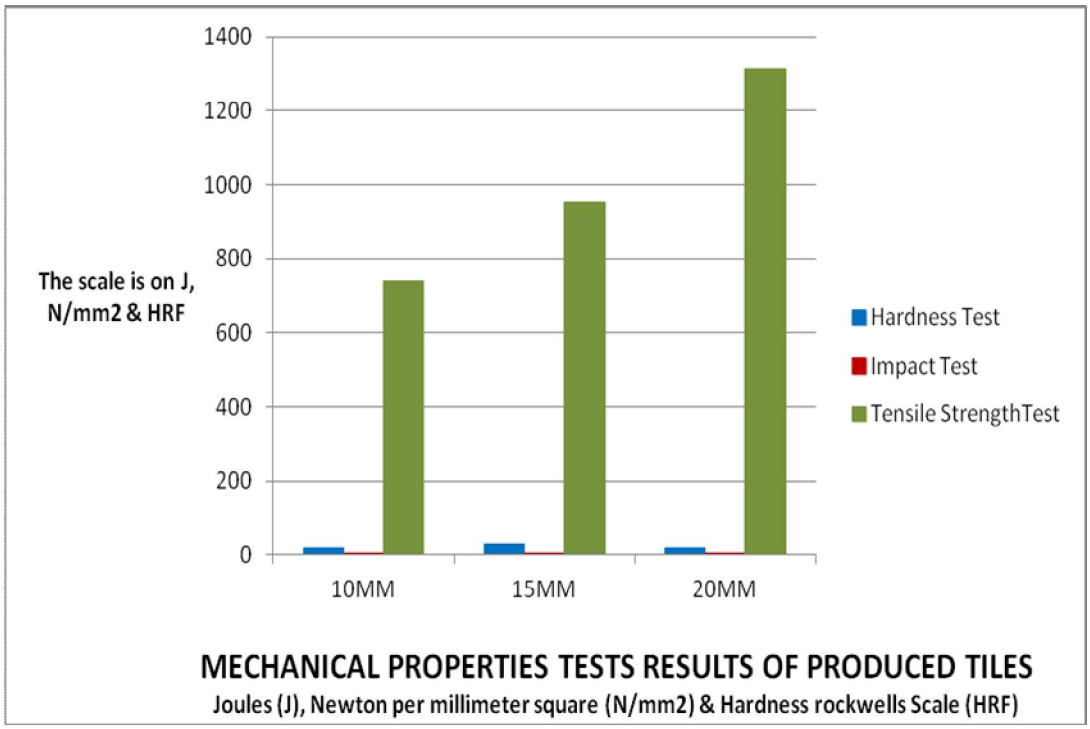


Figure 29 :- A Graph on the Results of the Mechanical Properties tests of the Tiles Produced

Source: Original Research Figure Morakinyo, (2012)

5.8.1.2 Results of Impact, Tensile and Hardness Test of China Tiles

Three tests were also carried out on two glazed China tiles using the same format in calculation just like the one above. These makes it easy to compare the results of the produced tiles with the foreign tiles which has established international standards; the tests carried out are tensile strength, impact and hardness test.

i. **Impact test**

a. Sample A 7.5mm thickness = 2.12 J

b. Sample B 7.2mm thickness = 3.25 J

iv. Hardness test

a. Sample A 7.5mm thickness = 46.3 HRF

b. Sample B 7.2mm thickness = 53.4 HRF

ii. **Tensile test**

a. Sample A 7.5mm thickness =**1552.83 N/mm^2**

b. Sample B 7.2mm thickness = **1725.36 N/mm^2**

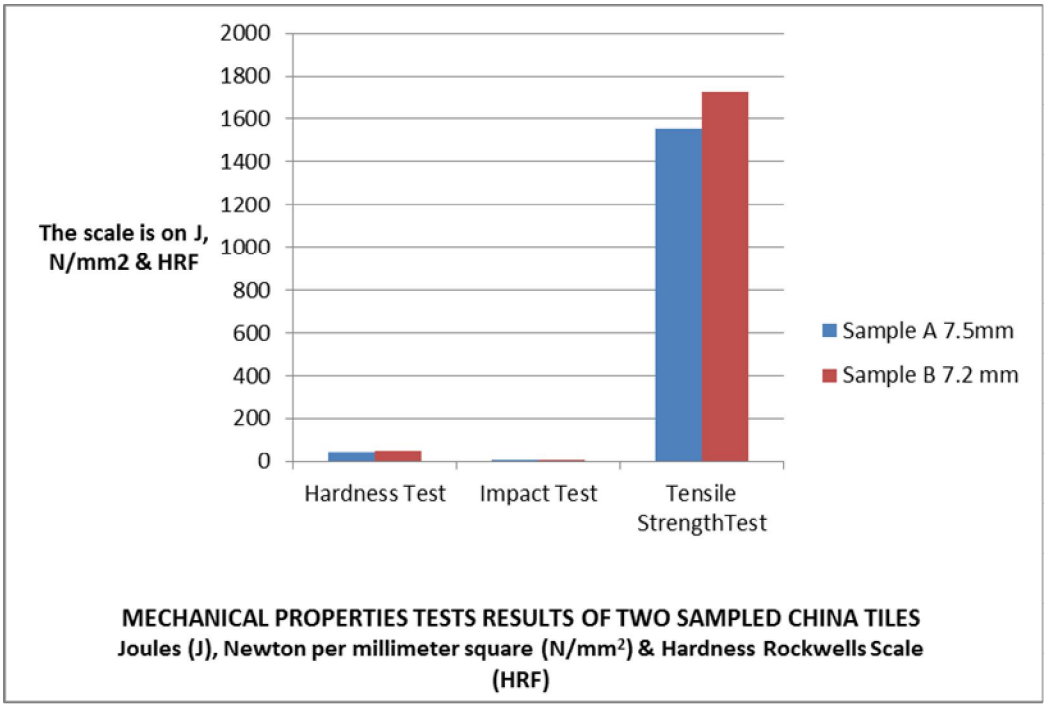


Figure 30 :- A Graph on the Results of the Mechanical Properties Tests for The Two Sampled China Tiles

Source: Original Research Photograph Morakinyo, (2012)

The two tests carried out on the tiles produced with the TMM and the glazed China tiles shows significant relationship in the parameters measure. Even though one tiles produced from the TMM machine were not glazed but the met the standard stipulated for unglazed tiles on the three tests carried out.

5.9 RESULT OF ADOPTED TILE MIX

Table *5.1* Bisque results of moulded tiles sample (MTS) and the test bars (T.B) 10x10cm square and 10cm long bars. The results are the same because they were compounded from the same materials and same percentage.

S/N	MATERIALS	A	B	C	D	E
1.	Ball clay	25	25	25	30	30
2.	Kaolin	25	30	25	20	30
3.	Silica/Quartz	25	20	20	20	30
4.	Feldspar	25	25	30	30	10
	Total	**100**	**100**	**100**	**100**	**100**
	Initial sizes in cm	**10**	**10**	**10**	**10**	**10**
RESULTS						
T.B.	**First drying** (Leather hard)	**9.5**	**9.45**	**9.7**	**9,7**	**9.5**
M.S.T		**9.5**	**9.8**	**9.8**	**9.7**	**9.8**
T.B.	**Bisque firing 852^{o}c 1:22 min**	**9.5**	**9.5**	**9.7**	**9.6**	**9.5**
M.S.T		**9.5**	**9.5**	**9.7**	**9.6**	**9.5**
T.B.	**Gloss firing 1200^{o}c 4:30 min**	**There were no significant differences in size**				
M.S.T		**There were no significant differences in size**				

From each of these tile bodies, five test bars and five sample tiles of 10cmx10cm were made and fired to 850^{o}C to 852^{o}C up to glazed temperature of 1250^{o}C to 1260^{o}C to observe the behaviour of the bodies and determine some parameters used in ceramics; measuring a body appropriateness such as:

1. Plasticity and consistency (cohesion) of bodies
2. Shrinkage rate
3. Porosity

3 Firing temperature

4 Surface quality

5 Strength

6 Moulding qualities

7 Glaze adhesion

8 Colour, to mention but few.

The gloss firing melted and volatilised, because of the high firing temperature. This led to the second samples of the same composition, size and number. This was also successful.

5.10 LINING OF THE CHAMBER/CONE-NOSE/THE HOPPER/BLIND FLANGE AND TEMPLATE TRAY:

The components parts above were lined with stainless steel to prevent contamination of mix, corrosion of parts and to enhance the free flow of the tile mixture. This is an advantage; in salvaging of the problem stated by (EMHBGCV4) 1991 that most barrels contaminate mixed especially the screw fed plasticator type of chamber. It is apparent that the used of stainless as lining curbs contamination and gives a clean product. This also allow much time for mix inside the barrel without any fear of contamination and rust or wear of parts.

5.11 ASSESSMENT OF RESEARCH OBJECTIVES:

5.11.1 Research Objectives 1: Design and fabricate a tile-making machine;

Plates XXXIII, XXXVIII and *XXXIX* revealed an assembled fabricated Tile Making Machine. *Plates XLVI – XLIX and LII – LVII* demonstrated extrusion on slabs in progress from the same machine. Plate's *XLIV, XLVII, LIV, LVI* and LVII confirmed tiles produced from the same machine mentioned. The results above show a greater relationship with the first objective. On this assessment, the first objective to a large extend has been attained.

5.11.2 Research Objectives 2: Develop an adaptable prototype design of tile-making machine, with standard specifications; which institutions of learning and ceramic industries in Nigeria can use in making tiles. and teaching of the tile making process;

The methodology used from beginning to the end of the project is such that is used in fabricating world industrial machines. Item 3.6 to 3.6.9 in its entirety dealt with basic and relevant standards, in fabrication of the machine; and shows design considerations, theory and calculations of the major components. Item 3.7.1.1 dealt with engineering drawing as one of the basic preliminaries before the commencement of fabrication. Item

3.5 highlighted issues on equipment/tools and facilities used as vital requirement and item 3.3.1 modeling of some of components to visualized the parts of the machine. The first part of chapter four enumerates the construction processes of the machine. More to these are the procedures of testing the machine which were subjected to various aspects and consequent results. All these afforded this objective a high level of attainment. Records on items mentioned above and the methodology used with a competent but creative heart, has made this prototype a reality. Thus, this can be fabricated by any institution or small scale industry for maximum utilization.

5.11.3 Research Objectives 3: To reduce the stress associated with manual tiles production by substituting it with a much easier and stress-less method thereby reducing the man hour on the tile production.

With the overall result achieved, so far, this objective has been attained. The machine can produce an average of 48 and 72 tiles per hour of 20 x 20cm and 15 x 15 cm respectively. This cannot be produced manually in one hour or a day by a person except with multiple moulds. For a whole day, we have about 384 and 576 tiles within 8 hours and an average of 2304 and 16128 tiles in a week respectively.

Technologically it has actually substituted hand or reduces manual labour involved in the production of a product, a tile technology has evolved. And knowledge added to the existing ceramic equipment fabrication.

5.11.4 Research Objectives 4: Develop a machine that is durable, that can be assembled/disassembled and not dead welded; and maintained with ease within the technical capability of our local technicians.

The machine has but few welding and largely parts were joint with bolt and nuts a mechanical form of fastening. It can be dismantled and packaged to make it portable. See

P*lates XXVIII - XXXIII & XXXIV - XXXIX* the assembly processes. Several times when there was a technical or partial fault this was easily managed by the researcher. Changing of the drives from gear to pulley, chain and sprocket and later on to a gear drive was done by the researcher without aid of any technical assistant. The corrections that were done after finishing that brought the machine to a stable state was carried out by the researcher P*lates LXIII—LXX*.

Plate's LXXVI - LXXVII, shows the entire machine dismantled and arranged before painting.



Plate LXXVI:- *The Tile Making Machine dismantled and arranged, before Painting. Source: Original Research Photograph Morakinyo, (2010)*



Plate LXXVII:- *The Tile Making Machine from a rear view dismantled and arranged, before Painting.*
Source: Original Research Photograph Morakinyo, (2010)

5.11.5 Research Objectives 5: Test the machine and the number of tiles it can produce in an hour.

The machine went through series of tests and the number of tiles it can produce in an hour was also ascertained. In section 5.7 it was ascertained that wthin an hour, the machine is expected to produce about 48 of 20 x 20 cm and 72 of 15 x 15 cm pieces of tiles.

The first sample tiles produced at the progressive assembly stage can be seen in Plates XLIX and XLVII. Though the surface quality was not as desired, but is a step further, the mechanism proposed has worked. Alterations and corrections were made to improve the output. After the final assembly, the tiles produced can be seen in Plates CIV to CVII and appendices XII and XIV. The challenge of surface quality, the few dimensional instability and other minor issues can be taken care of in subsequent project.

The crack of some of the lager tiles after the first firing was due to lack of preheating of the tiles. The second set of tiles produced in appendices XIII and XIV recorded no cracks after the second firing because, the tiles were preheated before the actual firing. These were even fired a little above the first temperature.

5.11.6 Research Objectives 6: Carry out performance evaluation test.

This objective was attained to a large extent; several tests were carried out in order to evaluate the performance of the machine. Subsequently, three tests were carried out to evaluate the eventual performance of the tiles. The tests above were significant to the realisation of this objective; even though there are still more tests in terms of the technical and mechanical properties of the tile.

Subsequent research can take care of some the qualities like: the tiles surfaces, improve the design of the templates, tile size, better body technology, more technical characteristics of tiles etc. since research is a process that is continuous. The Wright Brother's first flight on the plane they invented flied for only 12 seconds of a distance of 120 ft and they continued working on it up till the stage that made the work better. After their dead, more researches were carried out to improve the airplane to its present state. The same went with automobile, before the final success and up till-date research on improving such are still on. Thomas Edison who discovered the bulb learnt hundreds of ways that are not congruent with bulb production, and one that is possible. For the tile making machine because of the limitation in time and finance for study, it is equally recommendable that further research be carried on (or pursued) by other researchers to improve the machine and the product.

5.12 COST ANALYSIS

Engineering product cost is in terms of direct or indirect cost. The former are costs, which are as a result of direct production of a commodity; in form of direct material and labour cost. (Malachy, 2002).

Labour cost, according to Malachy is the product of time spent in manufacturing a product by the direct shop floor workers and the wage rate.

Direct material cost is the cost of all material that becomes part of the product. It means/entails a measurable material changed directly into the cost of the product.

Indirect costs are the costs of those factors which can simply be directly credited to the manufacture of specific product. Examples are rents, indirect labour, power, security, consumables in the store and all forms of direct materials.

5.12.1 Cost Analysis of Tile Making Machine:

i. **Material Cost:** The cost incurred as a consequence of direct material of the tile moulding machine represents the material cost. This is the actual material costs as purchased in the market. It is shown in appendixes I, II and IV.

ii. **Labour Costs:** These are costs consequent upon direct man power input into the production of a commodity. This includes workmen wages as effort applied to a product during its journey through the factory.

The labour of personnel engaged in the activities of inspection, testing, moving the product from machine to machine.

Factory over head cost Malachy (ibid) described as shop expense, indirect costs and on-cost. Factory overhead costs embrace all expenses incurred in the factory

production, which are directly charged to products as direct materials or labour. They are costs of labour or material not charged to product and fixed cost. Fixed charges include insurance, taxes and interest, rent and depreciation charges.

Administrative cost is another form of cost incurred from expenditure on salaries of executives, clerical personnel and depreciation of office equipment, etc.

The production of the tile moulding machine took about thirteen (13) months. The wage bill of a junior staff in the workshop is here assumed to ₦22,000.00 (junior staff on GL 06) per month. Let us also assume that the total overhead cost is 40% of the Labour cost.

Labour Cost = 22,000 x 13 = ₦ 286,000.00

∴ Overhead cost = 40% of Labour cost

= 0.4 x 286,000.00 or 286,000/100 x 40%

= ₦114,400.00

Total Cost = Material Cost + Labour Cost + Overhead Cost.

= 432,471 + 286,000 + 114,000

= **₦ 832,471.00**

NB: The sum of **appendixes I, II and IV is the Material cost**; while **appendixes I**, **II**, and **III** gives a summary of the entire amount spent, besides other things.

5.13 MANUFACTURING DIFFICULTIES:

Some of the major difficulties encountered during the manufacture of the machine were as follows:

i. Power supply was a major setback experienced at the course of manufacture of this machine. This alone caused a major setback in meeting up with time and getting results recorded as required. The machines used in the workshop are all powered. So, without electricity supply there is no how any of them can function, thereby causing delay. The giant generator used for power supplement must be fuelled before usage. Every attempt at using it had incurred personal bill on fuelling. However, on occasions where there are lesser work on ground, the generating set would not be switched on as a matter of principle.

More so, difficult moments were encountered in the course of firing the sample tiles made from the adopted tile mixed. That is, the means of securing power to fire the works using the electric muffle (test) kiln was hellish. This delayed the results for more than three months. Also it was almost impossible to compound the main material for the final test run of the machine, before presenting the work to the public. Power supply equally hindered the typing and entries of data on the laptop as that is what it depend upon largely. Most times, after the day's job in the workshop, there is usually no power supply at the researcher's residence. Consequently, much delay on the theoretical aspect of this project was experienced.

ii. Another major difficulty was funds. As a salary earner, the researcher had to wait till month end when salaries are paid to purchase materials, pay for services or embark on journeys that had significant impact on the project. It was not palatable

as meals are some-times forfeited for the progress of this work and family welfare-even though time spent on the work was most often than not at the expense of the researcher's family. Though it hits them badly. More to these, three research grants were applied for, but none was realised up-to the period the project was completed. Notwithstanding the school study grant which was reluctantly reapplied for, ₦ 40,000.00 was released in two instalments. Sourcing of material from the internet was very expensive because all the money expended was from the researcher's personal savings for project. Also, loading of the Zain modem (used for the research) was cumbersome as several attempts would be made before accessing the internet eventually.

iii. Obviously, the lathe machines, milling machine, other equipment and tools used in the workshop are old. Although they can still be put to proper form but they generally needed to be replaced. The working surfaces of the machines are worn-out; as such, there are clearances between the working members. This affected stability and promoted vibration during machining which led not only to poor surface finish, but also to inaccurate dimensions. At a point, the welding machine, milling machine and both the hand and industrial drilling machine stopped working. It was a terrible experience because it took some time before they were repaired. This was another major setback to the research/work.

iv. Poor storing and retrieving of tools in the workshop coupled with the nonchalant attitude of some workshop staff is a great impediment to the progress of works in the workshop. Tools are littered about the workshop. Consequently, getting a particular tool was usually not easy because they were not properly kept/stored. This also resulted in the wastages of valuable and job scheduled with completion dates not easily met (or meeting up with record time).

v. Attitudes of the workshop staff towards an individual job is very discouraging, especially when one is directly involved in his work and will only need their services in machining or milling some parts on machines restricted to their staff. Many parts they were given stayed for one month, six weeks and so on before they were attended to. This resulted to delay in fabrication, the entire process involved and incurred more cost and time wastage.

vi. Another challenge was that of physical fitness. Several times, one experienced health hazards which usually hampered as suspended the work until strength is regained. On occasions when the work was given out for health reasons and journeys embarked upon for short break and rest, one still returned to find the work undone.

vii. Accessing material and persons to assist on some core engineering values or issues was tough. Particularly, while fabricating the Cone-nose which involves triangulation. At such points, the advice of an expert in engineering sorted for, even though, assistance was not forthcoming. On that note, the internet service is resorted to several times to gather information and later employ personal discretion after meeting several dead ends going through thick thin. This further delayed the work for nearly two months.

viii. Another difficult encounter happened in the process of locating a workshop to use in fabricating the machine. In the first workshop consulted posed a delay of about one month without active engagement. This happened because the man managing the workshop was money conscious and desired that the work be contracted to him for economic value without the researcher's personal involvement. About the end of June 2010, another workshop was secured in kakuri, Kaduna where the

fabrication of the machine eventually was realised. This caused frustration of some sort. The man's interest in the machine was not hidden with the working drawing given to him. He can later become a household name in producing similar machine (product). On noticing his intensions, the deal with him was cancelled.

ix. There was a serious challenge in getting a test kiln to fire the sample tiles. This took more than 3 months before the means to fire the works was secured. After this, the required sample that better serve the intended purpose was realised.

The elements one of the first test kiln used got burnt and up till date it has not been replaced.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.0 INTRODUCTION

It has been a very tasking, inquisitive, informing, suggestive, and fruitful expedition, from the beginning to the standing point of this project. The present chapter is of immense value for a note worthy conclusions. Therefore, conclusions based on the objectives of the project, discoveries and useful notes are crucial in this chapter. General and further recommendations on progressive and functional studies will be presented here.

6.1 SUMMARY

The design and fabrication of a tile making machine was the main aim of this work. The study dealt with design and construction of tile making machine specific attention to design considerations, theory and calculations. Materials for the machine and tiles were both locally sourced. The machine has three major sections; the first section is processing, the second section is conveying and stamping and the third section is receiving. The machine went through two major tests after completion-performance test and capacity test to produce sample tiles.

6.2. CONCLUSIONS

From the research carried out and the results obtained, it is hereby, concluded that the fabrication of tile making machine from locally available scrap metals in Nigeria is a clear possibility. Indigenous technology alone has the capacity to bring forth advancement expected in the nation. The potential in producing model equipment in Nigeria are underutilized.

The outcome of this research established standards, guidelines or principles for the production of standard tile making machine. These, to a greater extent, have added knowledge and removed fears and difficulties associated with mechanical and practical research of this nature. It is without doubt that a new knowledge has been contributed to the body of existing knowledge in ceramic equipment fabrication in Nigeria.

Further, from the assessment of the research objectives spelled out it is evident that these objectives have been released. The results of the work and tests carried out shows form the assessment of such objectives in section 5.6 that the project is a success to a greater extent.

Consequently, the main setback of this research amongst other things is in securing financial support or grant. Lack of grant limits the scope of a research and relevant addendums that would have been part of it.

The scrap market is such that has much potential in aiding fruitful research. Most materials that were difficult to come by, especially those with material standard were secured from the scrap market.

It is not possible to finish everything in a single research. As the name implies, 'research' connotes 'search again, inquire again' or it can be better again for every viable research gives room for more enduring ones. As such, a number of related departments can secure needed and necessary equipment. This suggests that research is one of the many tools and easiest means to procure such departmental equipment, thereby making teaching and learning more interestingly productive and interactive for both staff and students.

6.3 GENERAL RECOMMENDATIONS:

a. Based on the findings on this project it is of uttermost significance for the Government to always look inward on the available human and local resources that

can develop the technological sector of our nation, just like China and other nations did.

b. The Department should deliberately go out in order to relate to the industries. This will go a long way to erase the existing prejudice that institutions are not realistic about their research. Or Industries should be deliberately linked to Industrial Design Department and other productive department, for an effective and enduring collaboration in the area of research.

c. There should be a forum in such a way that a conference is organised by the ministry of science and technology or by the university in order to display, educated, harness and collect/collate discoveries; for consequential national development. This will go a long way to improve indigenous inventions and inventors.

6.4. RECOMMENDATIONS FOR FURTHER RESEARCH:

1. The design and fabrication of tile making machine with the principles or procedural order can be used to fabricate other useful machines like the pug-mill, insulating and refractory bricks making machine, roofing tiles machine etc.

2. The drive arrangement should not be a strait arrangement but a chain arrangement to the driving shaft. This will save the electric motor from overheating, the drive from damage and remove unnecessary bending and twisting of the processing frame and the motor bed. In the end, there will be generation of more torque and motion transmission.

3. A cam (a component that rotates or moves back and front) can be introduced at the point of cutting and stamping of tiles instead of manual cutting, it will be an automatic cutting and stamping by the machine itself. This will be synchronised with the speed of the delivery of the slab.

4. A sensor can be introduced at the end of the second section where the tile is cut to automatically the machine once the tile reached its maximum length as required.

5. The entire machine footings can be made as an adjustable footing to save the problem of height for short persons (under average height) and gives it a convenient height as deemed fit by user.

6. The chamber can be increased in length **Fig 6.1**. This will help in building more pressure and required torque to extrude the tiles easily. The opening on top of the chamber should be like the illustration below instead of what it is now. This will provide more pressure-space and also complete clearing of mix once poured in the chamber.

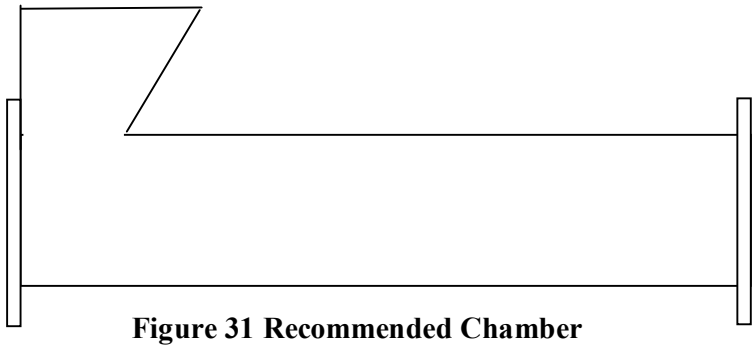


Figure 31 Recommended Chamber

Source: Researcher's recommendation

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7. A stopper can also be introduced to hold the wooden bath in place instead of hand. After the tile slide's on the bath, it can then be release or made in an automatic manner to release the bath with the tile on it.

8. To completely address the issue of wear, rust and contamination of mix the chamber should be completely lined with stainless plate of about 3mm, the screw auger and the shaft made of stainless.

9. The frame of the processing or first section should be made from an angle iron of 7-10mm thick instead of the 5mm used. On the other hand, a U-channel of same thickness should be used. This will add more strength, firmness and eliminate unnecessary twisting.

10. The Cone-nose (orifice can be made in such a way that it can be of multiple opening thereby producing two to more tiles at a time. This will lead to having multiple belt conveyors.

11. A motor of 3-4 hp and of 100 rpm should be used i.e. gear motor. This will increase speed in tile extrusion and more comfort in operation.

12. The fabrication of machine and materials for testing should not be in a single research but separated because such make research over bearing on the researcher. This causes unnecessary time delays, over spending, ignoring of little details, focus diversion and several difficulties.

13. There should be a scientific analysis on the material that made up the tile body. Instead of the five blend sample tested, more blends should be included to have possible tile mix that might be better than the one at present. A suggested blend to employ is the quadrilateral blend.

14. The cutting and stamping (second) section can be reduced in length; it will not affect the performance and efficiency of the machine. More to this, the telescope mechanism can be made in such a way that it can be adjustable. That is, the entire mechanism can be shifted from one point to another.

The department and possibly the school should make provision to support students on this kind of research; since such study constitutes productive additions to the department.

The financial implication should be supplemented after fabrication or all paid back to the researcher since the machine will remain in the department.

This is a product in a product that serves its purpose and produces another product to the benefit of the community.

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APPENDICES

Appendix I

Materials bought and processed for the major components

S/N	Materials	Component parts the materials where used for	Size	Description of materials	Quantity	Unit price ₦	Actual cost in ₦
1	Big Pipe 10mm	Chamber and cone nose	3ft	Mild steel	1	5,250	5,250
2	Medium padded pipe 10mm	Conveyor rollers	6.4ft	mild steel and rubber	1	2,500	2,500
3	Small pipe	Small rollers, clam, clam stand, stamping stand, compressing pipe and stand.		Mild steel	1	2,000	2,000
4	Smaller pipes 2mm	Compressing and stamping levers		Stainless steel	1	600	600
5	Big shaft	Auger shaft	3.2ft	Chrome mild steel	1	2,520	2,520
6	Medium shaft 25mm	Motion transmitting shaft, conveyor rollers shaft		Hardened mild steel		2,000	2,000
7	Medium Rollers	Receiving and conveyor belt support rollers				3,500	3,500
8	Small shaft 16mm	Rollers shaft				500	500
9	Plate 2mm	Chamber lining, hopper, hopper flow regulator, cone nose, template casing (tray), auger plate and hopper base(gallery) link to the chamber.	4ftx6ft	Stainless steel	2	8,000	16,000
10	Plate 6mm	Footing base, template holder, compressing plate motor bed and key		Mild steel	4	2,000	8,000

11	Plate 10mm	Flanges, blind flange, regulating, bar, chamber side support, key and section connecting plate		Mild steel	1		17,300
12	Angle iron 2”x2”x5 mm	All footing, machine frame, stands, rollers hanger	18ft	Mild steel	8	4,500	36,000
13	Disk 60mm	Major driven shaft gear	410mm in dia	Cast	1	4,300	4,300
14	Disk 50mm	Motor driver shaft gear	70mm in dia	Cast	2	500	1,000
15	Disk 200mm	Major driven shaft pulley	150 mm in dia	Mild steel	2	600	1,200
16	Disk 80mm	Bearing housing	200mm in dia	Mild steel	2	500	1,000
17	Pulley				1	600	600
18	Adjuster				2	90	180
19	U channel 5mm	Motor bedding	10 ft	Mild Steel	1	2,000	2,000
Total							**₦106,450**

Appendix II

Materials with Material Standard for the Major Component Parts and others.

S/N	Component parts	Size	Description of materials	Quantity	Unit price (₦)	Actual cost in (₦)
1	Duplex tooth large sprocket	200mmx50mm dia.	Mild steel	1	700	700
2	Duplex tooth medium sprocket		Mild steel	1	600	600
3	Duplex tooth small sprocket	60x30.5mm dia	Mild steel	1	400	400
4	Duplex tooth small sprocket	60.5mm dia. x 30mm	Mild steel	2	300	600
5	Duplex Chain	½"	Steel	2	1,750	3,500
6	Big bearing	F 210	Steel	3	2,500	7,500
7	Medium bearing	F 204	Steel	8	750	6,000
8	Small bearing	6203	Steel	6	200	1,200
9	Conveyor belt	40mmx 5mm	Treaded rubber	4yds	1,500	6,000
10	V belt (A)	32 and 33		3	200	600
11	Gear electric motors and repairs	1hp & 2.5-3hp		2 by exchange in succession	25,000 & 4,00	29,000
12	Bevel gear		Mild steel	3	500	1,500
13	Wire	3 phase	Rubber and bronze	10yds	200	2,000
14	Wire	2 phase	Rubber and bronze	6yds	150	900
15	Bolt and nuts	Different Sizes m13, m10, 19, m24, m6,	Mild steel and stainless	Bulk		5,320
16	Pins	3mm & 4mm	Mild steel and stainless	36 and 10	50	2,300
17	Contactors	3 phase		2	1,500	3,000
18	Switches	Different sizes		3	500	1,500
19	Washers	Different sizes	Mild steel and stainless	Bulk	1,200	1,200
20	Springs		Mild steel	2	200	400
21	Belt fastener	Set	Mild steel	1	2,500	2,500

22	Limit switch			1	1,500	1,500
23	Paddle shaft	Set	Stainless	6	300	1,800
Total						**(₦)80,020**
Sub-Total						**(₦)186,470**

Appendix III

Other materials purchased as well.

S/N	Component parts	Size	Description of materials	Quantity	Unit price (₦)	Actual cost in (₦)
1	Grinding stone	9" and 7"		17	250	4,250
2	Cutting stone	7"		20	200	4,000
3	Electrode	Gauge 8	For mild steel	1 packet	2,500	2,500
4	Electrode	Gauge 10	For mild steel	3 packet	1,100	3,300
5	Electrode	Gauge 12	For mild steel	1 packet	1,000	1,000
6	Electrode	Gauge 10	Stainless	2 packet	6,000	12,000
7	Electrode	Gauge 10	Cast	½ packet	1,000	1,000
8	Bulb	Small indicators		2	200	400
9	Control box		Mild steel	1	1,000	1,000
10	Sand paper			8	100	800
11	Spanners	Sets	Mild steel	1	2,500	2,500
12	Spanners	Sets and others	Mild steel		1,000	1,000
13	Car paint	Medium sizes		5	1,000	5,000
14	Plate 1.5mm	12 x 4ft	Mild steel	1	4,500	4,500

15	Wood		Wood		1,000	1,000
16	Receiving bath	2”	Ply wood	20	300	6,000
17	Straw board		Paper	4	200	800
18	Card board		Paper	24	25	600
19	Thinner	Gallon	Thinner	1	1,500	1,500
20	Oxyacetylene gas and oxygen			1	4,500	4,500
21	Pop	Bag	Pop	1	3,000	3,000
22	Tile material	Bag	Kaolin	1	1,000	1,000
23	Tile material	Quantum	Quartz /silica	Quantum	10,000	10,000
24	Tile material	Quantum	Feldspar	Quantum	5,000	5,000
25	Tile material	Quantum	Clay (secondary)	Quantum	250	250
26	Photo records	Digital Kodak camera	Kodak company	1	50,000	50,000
27	For reading dimensions	Vanier caliper	Stainless	1	700	700
28	Measurement of components	5mTape	Plate and plastic	2	300	600
29	Measurement of components	30cm square	Stainless and cast steel	2	300	600
30	Firing calcinations of raw quartz and	Quantum	Quartz and	2	3,000	6,000

	feldspar		feldspar			
31	Payment for used of workshop and personnel				30,000	30,000
32	Payment for turning, cutting of gears and sprocket				10,000	10,000
33	Payment for folding of Plates to cone shape	Cone shape			1,500	1,500
34	Payment to research assistants in the workshop and the department			4	10,000 at the moment	40,000
35	Transportation within Kaduna					25,000
36	Transportation within Zaria					20,000
37	Transportation within states					93,169
38	Internet expenses					35,210
39	Printing, typing and binding				42,600	42,600
40	Purchase of card for communication					30,500
41	Masking tape			2	300	600
42	Saw blade			8	180	1,440
43	Hand gloves				680	680

44	File			2	300	600
45	Drills				150	150
46	Drawing and printing of the machine with CAD				20,000	20,000
47	Miscellaneous					123,461
Total					**(₦) 597,970**	
Grand Total				**(₦)780,573**		

Appendix IV

Extract from Appendix III above to have the total figures spent on materials apart from some other items, though relevant.

S/N	Component parts	Size	Description of materials	Quantity	Unit price (₦)	Actual cost in (₦)
1	Grinding stone	9" and 7"		17	250	4,250
2	Cutting stone	7"		20	200	4,000
3	Electrode	Gauge 8	For mild steel	1 packet	2,500	2,500
4	Electrode	Gauge 10	For mild steel	3 packet	1,100	3,300
5	Electrode	Gauge 12	For mild steel	1 packet	1,000	1,000
6	Electrode	Gauge 10	Stainless	2 packet	6,000	12,000
7	Electrode	Gauge 10	Cast	½ packet	1,000	1,000
8	Bulb	Small indicators		2	200	400
9	Electric box		Mild steel	1	1,000	1,000
10	Sand paper			8	100	800
11	Spanners	Sets	Mild steel	1	2,500	2,500
12	Spanners	Sets and others	Mild steel		1,000	1,000
13	Car paint	Medium sizes		5	1,000	5,000
14	Plate 1.5mm	12 x 4ft	Mild steel	1	4,500	4,500
15	Wood		Wood		1,000	1,000
16	Receiving bath	2"	Ply wood	20	300	6,000
17	Straw board		Paper	4	200	800
18	Card board		Paper	24	25	600
19	Thinner	Gallon	Thinner	1	1,500	1,500

20	Oxyacetylene gas and oxygen			1	4,500	4,500
41	Masking tape			2	300	600
42	Saw blade			8	180	1,440
43	Hand gloves				680	680
44	Printing, typing and binding				42,600	42,600
45	File			2	300	600
46	Drills				150	150
47	Drawing of the machine with CAD				20,000	20,000
48	Miscellaneous					123,461
Total						**(₦) 245,981**
Grand Total of Appendix I,II and IV						**(₦) 432,471**

Appendix V

Pozo and Kenneth tile Recipe

△03 Terra Cotta Tile Clay	
Shrinkage:	8%
Absorption:	4.4%
C/B ratio:	0.6
Red art clay	62.5
Tennessee #5 ball clay	12.5
Hawthorne fire clay	12.5
Gold art stoneware clay	6.25
Wollastonite	6.5
Total	100.0

△01 Terra Cotta Tile Clay	
Shrinkage:	10%
Absorption:	4.7%
C/B ratio:	0.6
Red art clay	46.3
Hawthorne fire clay	29.3
Gold art stoneware clay	17.1
Talc	7.3
Total	100.0

Fine grog	12.5	Medium grog	10.0
Medium grog	25.0	Silica sand	10.0
Bentonite	2.5	Barium carbonate	0.6 L (1/3
cup) Barium carbonate	0.6 L (1/3 cup)		

Barium carbonate is very toxic there is need for extreme caution by wearing a dust mask and gloves she added.

Source Pozo (2005)

Appendix VI

Design of chain drive

Rated power of motor = 3 hp =2.24 kw

Small sprocket on motor or pinion has (T_1) = 15 teeth

Larger (bigger) sprocket has (T_2) = 36 teeth

∴ Velocity ratio = $\frac{T_2}{T_1} = \frac{36}{15} = 2.4 \approx 3$

Design power = rated power x service factor (k_s)

Service factor = k_1 x k_2 x k_3

Where = k_1 = load factor = 1.25 for variable load with mild shock

K_2 = lubrication factor = 1 for drop lubrication

K_3 = rating factor = 1 for 8 hours per day operation

∴ Design power = 2.24 kw x (1.25 x 1 x 1)

= 2.8 kw

From the table 21.4 (page 694) of R.S. Khurmi, corresponding to a speed of 300 rpm, the power transmitted by chain No. 08 is 1, kw per stand. Therefore, a chain No. with two stands can be used to transmit the required power from table 21.1, we find that

Pitch, P = 12.70 mm

Roller diameter (d) = 8.51 mm

Minimum width of roller (w) = 7.75 mm

Breaking load, (W_B) = 31.1 KN

The pitch circle diameter of the smaller sprocket or pinion is given by

D = P Cosec ($\frac{180}{T_1}$)

= 12.70 Cosec ($\frac{180}{15}$)

= 12.70 x 4.81

= 61.1 mm = 0.0611 m

Pitch circle diameter of larger sprocket is

$D_2 = P \text{ Cosec } (\frac{180}{T_2})$

$= 12.70 \text{ Cosec } (\frac{180}{36})$

$= 12.70 \times 11.474$

= 146 mm = 0.146 m

Pitch line velocity of smaller sprocket

$V_1 = \frac{\pi d_1 N_1}{60}$

$= \frac{\pi \times 0.0611 \times 300}{60}$

$= 0.959 \approx 1$ m/s.

$\therefore$ Load on chain (W) $= \frac{rated\ power}{pitch\ line\ velocity} = \frac{2.24}{1} = 2.24$ kw

Factor of safety $= \frac{W_B}{W} = \frac{31.1 \times 10^3}{2.24 \times 10^3} = 13.89 \approx 14$

The value for factor of safety prescribed in table 21.2, of page 693 of R.S. Khurmi, given pitch of chain and speed of the sprocket pinion is about 10.

The calculated value is 14; therefore, design is within well above safety.

Appendix VII

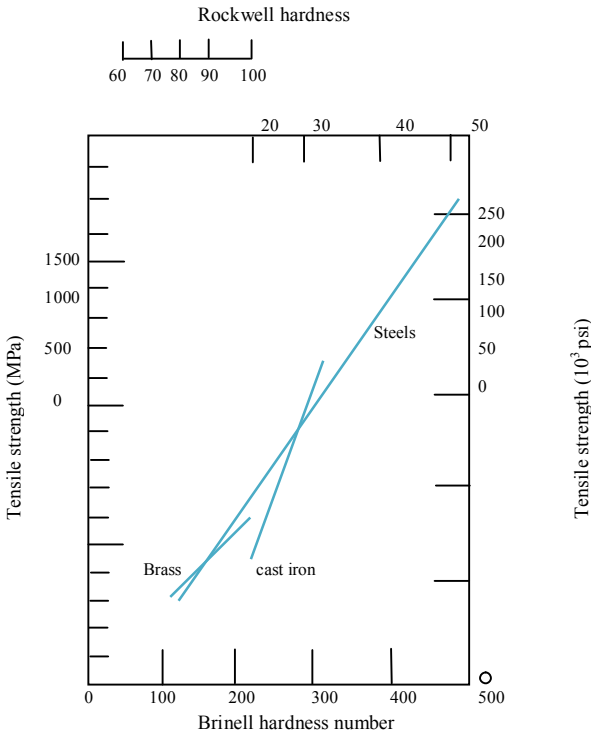
ROCKWELL Hardness Scales

Scale Symbol	Indenter	Major Load *(kg)*
A	Daimond	60
B	1/16 in. ball	100
C	Daimond	150
D	Daimond	100
E	1/8 in. ball	100
F	1/16 in. ball	60
G	1/16 in. ball	150
H	1/8 in. ball	60
K	1/8 in. Ball	150

Source: William (1996)

APPENDIX VIII

Relationship between Hardness and Tensile Strength



Source: William (1996)

Relationship between hardness and tensile strength for steel, brass, and cast iron. (Data taken from Metals Handbook: Properties and selection: Irons and Steels, Vol. 1.9th edition, B. Barnardes, Editor, American Society for Metals, 1978, pp. 36 and 461; and Metals Handbook: Properties and Selection: Nonferrous Alloys and pure Metals, Vol. 2, 9th edition, H. Baker, Managing Editor American Society for Metals, 1979, p. 327.)

APPENDIX IX

Tile world production in 2009

TOP MANUFACTURING COUNTRIES								
	COUNTRY	2005 (Sq.m Mill.)	2006 (Sq.m Mill.)	2007 (Sq.m Mill.)	2008 (Sq.m Mill.)	2009 (Sq.m Mill.)	% on 2009 world production	% var. 09/08
1	CHINA	2,500	3,000	3,200	3,400	3,600	42.3	5.9
2	BRAZIL	568	594	637	713	715	8.4	0.2
3	INDIA	298	340	385	390	490	5.8	25.6
4	ITALY	570	569	559	513	368	4.3	-28.2
5.	IRAN	190	210	250	320	350	4.1	9.4
6.	SPAIN	609	608	585	495	324	3.8	-34.5
7	VIETNAM	176	199	254	270	295	3.5	9.3
8.	INDONESIA	175	170	235	275	278	3.3	1.2
9.	TURKEY	261	265	260	225	205	2.4	8.9
10.	EGYPT	112	122	140	160	200	2.3	25.0
11	MEXICO	196	210	215	205	200	2.3	-2.4
12.	THAILAND	138	139	130	130	128	1.5	-1.5
13	RUSSIA	100	115	135	147	117	1.4	-20.4
14.	POLAND	108	110	112	118	112	1.3	3 -5
15.	MALAYSIA	71	75	75	85	90	1.1	5.9
16.	UAE	68	75	76	77	77	0.9	0.0
17	PORTUGAL	72	74	74	74	70	0.8	-5.1
18.	ARGENTINA	48	54	60	60	56	0.7	-6.7
19.	SAUDI ARABIA	20	22	34	40	55	0.6	37.5
20.	MOROCCO	44	47	50	51	54	0.6	4.9
21.	GERMANY	62	64	67	59	51	0.6	-13.6
22.	COLOMBIA	40	44	48	50	50	0.6	0.0
23.	USA	61	58	51	45	50	0.6	10.4
24.	UKRAINE	20	21	27	39	44	0.5	12.8
25.	SOUTH KOREA	46	44	42	39	42	0.5	9.6
26.	SOUTH AFRICA	33	37	38	38	32	0.4	-15.8
27	TAIWAN	53	53	50	40	32	0.4	-20.0
28	SYRIA	19	19	19	28	31	0.4	10.7
29	ALGERIA	28	28	28	28	30	0.4	7.1
30.	VENEZUELA	26	28	30	32	30	0.4	-6.3
	TOTAL	6,713	7,395	7,866	8,145	8,176	96.0	0.4
	WORLD TOTAL	7,077	7,760	8,252	8,495	8,515	100.0	-0.1

In 2009, the 30 major manufacturing countries covered 96.0% of world production

Source: **www.infotile.com/publications** (2009)

APPENDIX X

Tile world consumption in 2009

TOP CONSUMPTION COUNTRIES								
	COUNTRY	2005 (Sq.m Mill.)	2006 (Sq.m Mill.)	2007 (Sq.m Mill.)	2008 (Sq.m Mill.)	2009 (Sq.m Mill.)	% on 2009 world consupmtion	% var. 09/08
1	CHINA	2,050	2,450	2,700	2,830	3,030	35.8	7.1
2	BRAZIL	443	484	535	605	645	7.6	6.5
3	INDIA	303	350	397	403	494	5.8	22.6
4	INDONESIA	155	148	178	262	297	3.5	13.4
5.	IRAN	153	182	236	265	295	3.5	11.3
6.	VIETNAM	120	145	210	220	240	2.8	9.1
7	EGYPT	93	103	105	140	180	2.1	28.6
8.	USA	303	308	249	197	169	2.0	-14.2
9.	SAUDI ARABIA	90	100	110	136	166	2.0	22.1
10.	MEXICO	161	164	173	176	163	1.9	-7.2
11.	SPAIN	303	319	314	240	156	1.8	-34.9
12.	ITALY	192	199	199	176	146	1.7	-16.8
13	RUSSIA	131	151	176	191	139	1.6	-27.3
14.	TURKEY	169	179	161	129	138	1.6	6.5
15.	THAILAND	120	121	120	120	117	1.4	-2.5
16.	FRANCE	130	120	129	128	113	1.3	-11.5
17	GERMANY	132	128	124	112	106	1.3	-4.8
18.	SOUTH KOREA	94	99	110	99	99	1.2	0.5
19.	POLAND	101	102	100	103	93	1.1	-10.1
20.	UAE	70	80	81	96	77	0.9	-19.8
21.	MALAYSIA	52	45	53	50	69	0.8	38.0
22.	MOROCCO	49	52	56	60	66	0.8	9.2
23.	ARGENTINA	44	48	55	59	55	0.7	-6.8
24.	COLOMBIA	44	48	53	54	53	0.6	-1.9
25.	GREAT BRITAIN	72	75	75	66	50	0.6	-23.7
26.	PORTUGAL	51	47	48	50	48	0.6	-2.8
27	UKRAINE	29	33	47	59	48	0.6	-18.6
28	SOUTH AFRICA	44	48	50	50	43	0.5	-14.0
29	ALGERIA	33	34	35	37	40	0.5	8.1
30.	PHILIPPINES	30	33	37	38	40	0.5	5.3
	TOTAL	**5,762**	**6,456**	**6,914**	**7,150**	**7,374**	**87.2**	**3.1**
	WORLD TOTAL	**6,750**	**7,420**	**8,060**	**8,350**	**8,460**	**100.0**	**1.3**

In 2009, the 30 major consuming countries covered 87.2% of world consumption

Source: **www.infotile.com/publications** (2009)

APPENDIX XI

Tile total world export in 2009

	TOP EXPORTING COUNTRIES								
	COUNTRY	2005 (Sq.m Mill.)	2006 (Sq.m Mill.)	2007 (Sq.m Mill.)	2008 (Sq.m Mill.)	2009 (Sq.m Mill.)	% on 2009 world consumption	% on 2009 world exports	% var. 09/08
1	CHINA	342	450	500	570	584	6.9	33.7	2.5
2	ITALY	390	396	379	355	281	3.3	16.2	-20.9
3	SPAIN	341	336	333	306	235	2.8	13.6	-23.0
4	TURKEY	97	93	104	92	67	0.8	3.9	-26.8
5	BRAZIL	114	115	102	81	61	0.7	3.5	-25.4
6	MEXICO	46	55	56	62	51	0.6	2.9	-18.3
7	IRAN	14	19	17	27	40	0.5	2.3	48.9
8	THAILAND	25	27	25	25	36	0.4	2.1	44.0
9	POLAND	19	21	30	34	35	0.4	2.0	3.2
10	PORTUGAL	34	36	37	37	32	0.4	1.9	-12.1
11	UAE	25	32	38	34	31	0.4	1.8	-8.8
12	VIETNAM	12	15	25	25	28	0.3	1.6	12.0
13	EGYPT	16	17	22	23	23	0.3	1.3	0.0
14	MALAYSIA	18	22	18	23	23	0.3	1.3	0.0
15	GERMANY	21	24	26	28	23	0.3	1.3	-17.1
	TOTAL	**1,514**	**1,657**	**1,712**	**1,722**	**1,550**	**18.3**	**89.4**	**-9.9**
WORLD TOTAL		**1,715**	**1,865**	**1,910**	**1,919**	**1,735**	**20.5**	**100.0**	**-9.6**

In 2009 the 15 major exporting countries represented 89.9% of total exports and 18.3% of total world consumption.
Source: **www.infotile.com/publications** (2009)

APPENDIX XII

2009 Tile Imports of the 20 major importing countries

	TOP IMPORTING COUNTRIES								
	COUNTRY	2005 (Sq. m Mill.)	2006 (Sq.m Mill.)	2007 (Sq.m Mill.)	2008 (Sq.m Mill.)	2009 (Sq.m Mill.)	% on 2009 national consumption	% on 2009 world imports	% var. 09/08
1.	USA	245	254	202	157	124	73.3	7.1	-20.9
2.	SAUDI ARABIA	80	89	77	99	116	69.7	6.7	17.2
3.	FRANCE	110	110	110	112	101	89.0	5.8	-10.2
4	GERMANY	90	87	83	80	78	73.4	4.5	-2.5
5	SOUTH KOREA	51	54	66	59	55	55.1	3.2	-7.8
6.	UAE	35	51	43	55	45	58.4	2.6	-17.4
7	GREAT BRITAIN	64	66	67	58	43	86.0	2.5	-25.9
8	IRAQ	2	3	10	23	40	100.0	2.3	76.0
9	ISRAEL	29	26	30	30	30	90.9	1.7	0.0
10	RUSSIA	35	42	47	54	30	21.5	1.7	-44.8
11	GREECE	42p	43	51	44	30	79.7	1.7	-33.0
12	NIGERIA	19	27	22	30	29	100.0	1.7	-3.3
13	THAILAND	22	20	22	25	28	23.9	1.6	12.0
14	AUSTRALIA	32	31	34	33	28	79.7	1.7	-15.9
15	CANADA	32	33	35	30	27	97.8	1.6	-10.0
16	BELGIUM + LUX	22	23	28	26	25	97.3	1.5	-3.1
17	ROMANIA	27	28	33	35	22	62.9	1,3	-36.4
18	PHILIPPINES	9	15	15	16	21	52.5	1.2	35.5
19	KUWAIT	19	18	16	23	19	96.5	1.1	-16.1
20	ITALY	22	28	31	25	19	13.0	1.1	-23.4
	TOTAL	**985**	**1,043**	**1,020**	**1,012**	**910**	**60.5**	**52.4**	**-9.5**
WORLD TOTAL		**1,715**	**1,855**	**1,910**	**1,919**	**1,735**	**20.5**	**100.0**	**-9.6**

In 2009 Imports of the 20 major importing countries represented 52.4% of total imports and 10.8% of total world consumption.

Source: **www.infotile.com/publications** (2009)

APPENDIX XIII

Second sets of Tiles Fired Above 1100^0c of 20x20mm



20 x20 cm of Fired Tiles up to a Temperature of 1100^oC Arranged on a Table after Second Firing..

Source: Original Research Photograph Morakinyo, (2010)

APPENDIX XIV

Second sets of Tiles Fired Above 1100^0c of 15x15mm



15 x15 cm of Fired Tiles up to a Temperature of 1100^oC Arranged on a Table after Second Firing.

Source: Original Research Photograph Morakinyo, (2010)

APPENDIX XV

ATTACHED COMPLETE DRAWINGS OF VARIOUS PARTS AND

COMPLETE MACHINE ASSEMBLY