The Design and Development of Tile Making Machine

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Abstract

Research and development was adopted as a methodology, as well as standard design analysis and processes used by Engineers to fabricate a tile making machine. Mild steel and other steels were the materials utilized in the fabrication of this machine. A mathematical modelling was first produced for the entire machine. The machine is about 450cm long with three important sections: the processing, stamping & cutting, and the receiving section all powered by an electric gear motor of 2.5hp. Performance and capacity tests were employed to check the efficiency of the machine and extrusion of sample tiles. An average of 48 tiles of 20 x 20 cm^2 and 72 tiles of 15 x 15 cm^2 pieces 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 performance of the machine and the products were satisfactory.

Key words: Design; Extrusion; 3-D Modelling; Screw –Auger; Processing Chamber; Assembly;

1. Introduction

The aesthetic, decorative decency and excellent treatments of modern architectural designed walls, floors, roofs, ceilings, 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. These products possess health advantages, comfort, durability in architectural use 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, [1].

There has been shift in the world ceramic tile industry with a complementary growth in the supply of tiles from the statistic given by [2], in 2009. For example, Europe in 1990 accounted for 54% but in 2002 was down to 25% of world ceramic tile production. [2], 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 parts of Europe (Turkey included) 4.6%, North America (Mexico included) 2 3.0 %, Central and 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 in production and sells of tiles. 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 the data of [3], the account for Africa percentile in tiles production and export is infinitesimally low. The African percentile in production shows: Egypt 2.3%, Morocco 0.6% South Africa 0.4% and Algeria 0.4% totalling 3.7%. While in export Egypt represented Africa with only Egypt 1.3%. 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 African economies. It is worthy to note that from the researcher's findings, apart from the cement concrete tiles (inter-locking tiles) and drainage concrete tiles/slabs most of the other ranges of tiles produced are imported from overseas into the country or are produced with imported machines. An assessment of most of the buildings in Nigeria with aesthetic, decorative features and excellent treatments in modern architectural designs (walls, floors, roofs, ceilings, slabs and pathway tiles) indicates that most of the tile coverings are imported. Indeed, our markets have virtually no Nigerian made tiles, except for the imported tiles.

The availability of requisite machines will increase the scope of functions in industrial ceramics and make production easier. Many industries in the world are affiliated to institutions of higher learning in order to support and tap from the discoveries brought to bear with their research activities. These discoveries are geared to improve a nation's status, productivity, economy and other sectors that affect its populace. This factor informs the design and development of the tle-making machine as presented in this paper.

2. Extrusion

Extrusion is one of the production methods used in tile production or making is extrusion. [4] and [5] define 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. [6] 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.

There are three basic extruders used in ceramic processes, advanced by [6]], [7], [8], [9] and [5] which are:

2.1. The Ram or Piston Extruder

Ram or piston extruder has a capability to reach very high pressures. It is powered by hydraulic pumps, which makes it easy to maintain. 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 traps air, which can result in changes in extrusion behaviour and flaws in the green parts.

2.2. A **Pug Mill-Auger**

Pug mill-Auger 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 dropped 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 that extrusions are done inside single equipment. However, the shredders and turning augers can wear out and even contaminate the mixed extruded parts. The pug mill works well with materials that slide, the screw can be moved and be consolidated.

2.3. Screw-fed Plasticator

Screw-fed plasticator is designed to extrude plastic bodies. 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.

A palletized ceramic 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 moved 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 continuous 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.

The type of extruder design under consideration uses the screw-fed plasticator with modifications or improvement to give it an edge over other extruders.

3. The Working Principles of The Tile Making Machine

The designed Tile Making Machine is powered by a gear electric motor, transmitting motion from the electric motor to the gear drive See Fig. 10-12. The motion is transferred to the larger driven gear connected to the shaft enclosed in the milling chamber. At the hopper, the mix is poured, mixed and milled as the screw augers turn clock wise for onward extrusion at the orifice. At this point the mix comes out in form of a slab and slides over the belt conveyor. The extruded slab motion on the belt affords the first two rollers motion carrying the conveyor. The extruded mix is conveyed to the stamping or designing section; where a mould as a template is attached to a lever on a metal steel stand. The stamped/pressed tile is moved to the receiving conveyor on a wooden bath moving into the tile carriage or crate. This is repeated continuously until the desired numbers of tiles in a batch are made.

4. Methodology

The research methodology used for this study is experimental, using product development procedures as suggested by [10], [11] and [12]. This was done in line with machine design considerations, theories and calculations as suggested by [10] and a modified fabrication processes by [13] to achieve the machine.

4.1. Design Theories, Considerations and Calculations of Some Major Components

4.1.1. Conditions before Construction and Calculation.

The following parameters were first determined:

i. Rational analysis to determine the choice of the material need
ii. Determination of the bulk density of the material
iii. Determination shear stress value
iv. Coefficient of friction of the material to the wall of the chamber
v. The batch in feeding the hopper chamber to produce 40 tiles Fig. 1

4.2. 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, plastic, wood, etc. 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, nose cone 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 [14]. 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 [10] and [11].

4.3. Design Theory

4.3.1 The Hopper Design.

The hopper is that part of the machine where the materials for tile production are fed through. [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. According to [15]

4.3.2. Tile Dimension for Single Tile.

Vol. of 1 tile = L x B x H
= 30 x 30 x 0.8
= $\underline{720\text{cm}^3}$

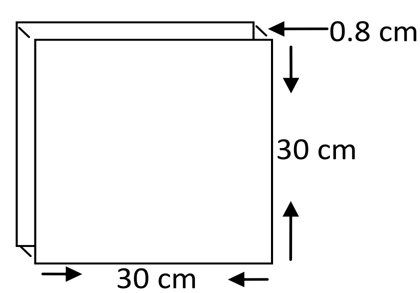

Fig. 1 Tile Sample

Vol. of 40 tiles = 40 x 720 cm^3
= $\underline{28800\ \text{cm}^3}$

To cater for clay that will stick to the chamber wall 5% of needed quantity was added
= 28,800 x.0.5 (28800 + 1440)
= $\underline{30{,}240\ \text{cm}^3}$

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/fixed i.e.
The top length is peg as - 35 cm
The top breath is peg as – 35 cm
The base length is peg as – 25 cm
The base breath is peg as – 30 cm
The height is =?
From Fig. 2 the height of the hopper is given as:
$\frac{1}{2}(25 + 35) + h \times 30 = 30240\ cm^3$
$\frac{1}{2}(60) \times h \times 30 = 30240\ cm^3$
$h = \frac{30420 \times 2}{30 \times 60} = 33.6$ cm

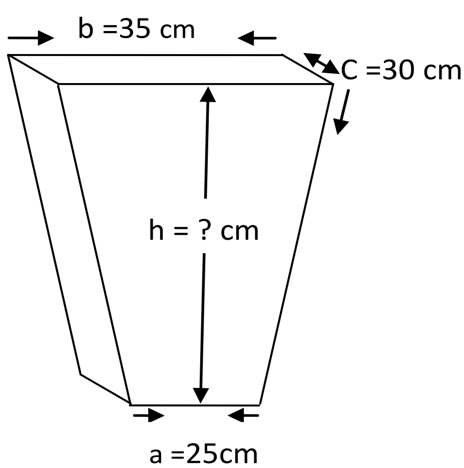

Fig 2: The Hopper

For allowance of work, 10% of the entire vol. of the hopper was added
=33.6 x 0.10 = 3.36
33.6 + 3.36 = 37 cm
h = 37 cm
$V = \frac{1}{2}(25 + 35) \times 33.6 \times 30$
$V = \frac{1 \times 60480}{2} = 30240\ cm^3$ (volume as per the material to pour or that it can contained)
But the entire $V = \frac{60 \times 37 \times 30}{2} = 33{,}300\ cm^3$
$\therefore 1\ cm^3 = \frac{1000\,kg}{1000000} = \frac{1}{1000}$ kg
30240 x 0.001 = 30.24 kg in weight of material.

4.4. Processing Chamber Design

The chamber is a combination of a cylinder and frustum (a cone without the top or arch), it is the point where the material is processed before extrusion. For a compact design the dimensions are given Fig. 3.

4.4.1. The Volume of Chamber.

The volume of chamber was determined by fixing some dimensions and using the same volume. Some parameters like the height etc. were equally determined.

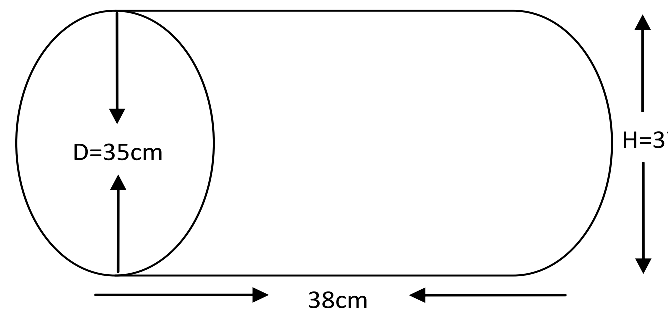

Fig. 3: 4.4.2. Processing or Cylindrical Chamber

4.4.2 Volume of Cylinder (Main Chamber).

The volume of the cylindrical part of the chamber is given as; $V = \pi r^2 h$
6 kg. $V = 3.142 \times 17.5^2 \times 38 = \underline{36565\ cm^3} \times 0.001 = 36$

4.4.3. Volume of Frustum

The height of the frustum was determined before calculating the volume.

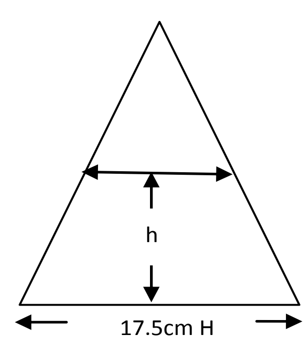

Fig. 4a: Determining The Height of The Frustum from The Bigger Triangle ADE

Considering the big triangle ADE, using SOH, CAH, TOA
Where:-
S = sin
O = Opposite
H = Hypotenuse

C = Cosine
A = Adjacent and
T = Tangent

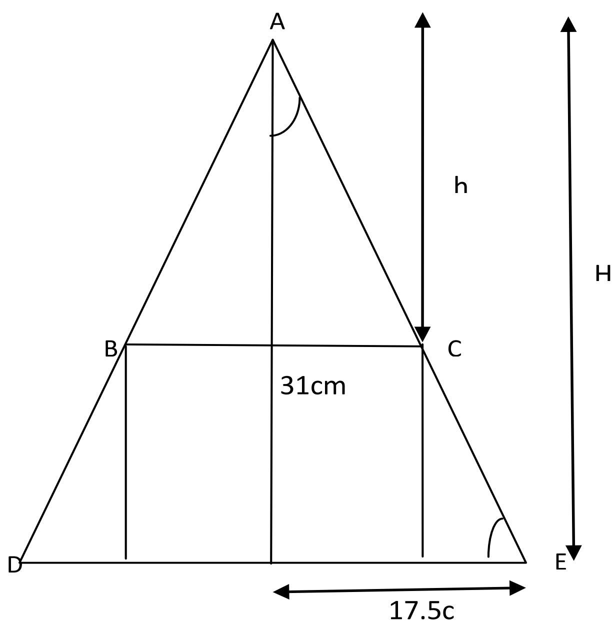

Fig 4b: Shape of the Partial Chamber

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

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

Using the law of similarities section △ABC and △ 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
∴ = 2cm or 20mm

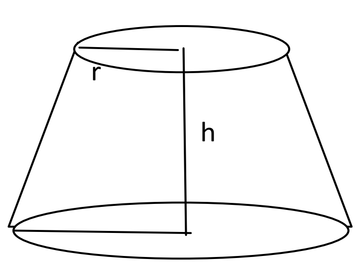

Fig. 5: Volume of Frustum (Partial Chamber)

From fig. 5, the volume of the frustum 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)**

4.5. Design of a Mixer Drive

Volume of clay to be mixed ≡ volume of mixer chamber = 36,565 ~ 36,600cm^3 = 36,600 x $10^{-6}m^3$

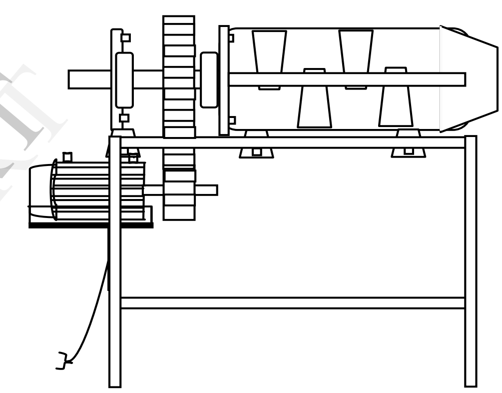

Fig. 6: The Mixer Driver or Processing Section Drive

4.5.1. Calculations.

The mass of clay in the chamber is as follows:
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

∴ Arm of twist = 0.35/2 = 0.175.

Hence the torque = W x (arm of twist) = 750.03 x 0.175 = 133.26 say 132Nm
Therefore, the minimum torque required for mixture of clay = 132Nm

4.6. 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.
The value of N_2 was determined with the formula for power.
From the power relationship, the speed of mixer shaft gear can be obtained as follows:

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

Where P = power of motor
N = Speed of mixer shaft gear
T = Torque
π = 3.142
∴ $N = \frac{60 \; x \; 1.87 \; x \; 10^3}{2 \; x \; 3.142 \; x 132} = \frac{112200}{826.848}$ = 135.7 say 135
N_2 = **135**

4.6.1. 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
The Center distance is given as: L, = $\frac{D_1}{2} + \frac{D_2}{2}$
but, 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
∴ 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**.

A gear (reduced speed) motor of 2.5hp, 80 rpm was selected for this work.

4.7. Design for Motor Gear Shaft

Normal load acting between the tooth surfaces is given by
$W_N = \frac{W_r}{Cos\theta} = \frac{935}{Cos20}$ = **995.01N**
Weight of the gear is given by
$M_1 = 0.00118T_1bM^2 = 0.00118 \; x \; 10 \; x \; 3^2$ = **5.735 N**
∴ **Resultant load acting on the gear**

$W_R = \sqrt{(W_N)^2 + (M_1)^2 + 2W_N.M_1 Cos\theta}$
= $\sqrt{995.01^2 + 5.735^2 + 2\,(995.01)(5.735) x \; Cos20}$
= **1000.40N**
The gear is over loading on the shaft by 25mm.
Bending moment on the shaft due to resultant load is
M = W_{R1} x 25 = 1000.40 X 25 = 25010 N mm
Twisting moment on shaft is
T = W_T x $\frac{D_1}{2} = \frac{935 \; x \; 54}{2}$ = 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
$d_1 = \sqrt[3]{\frac{16 \; x \; 35536.04}{\pi \; x \; 42}}$ = 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**

4.8. Design of Mixer Shaft

This shaft is the mechanism that turns anti-clock wise blending, compressing and pushing out the tile material through the orifice.
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
$W_{R2} = \sqrt{W_N{}^2 + M_2{}^2 + 2W_N \; x \; M_2 Cos\theta}$
= $\sqrt{995.01^2 + 116.608^2 + 2\,(995.01) x \,(116.08) x \; Cos20}$
= **1105.31N**
The gear is between two bearings where centre distance is 200mm apart.
∴ **Bending moment on the shaft due to resultant force** is
$M_2 = \frac{W_{R2} \; x \; L}{4} = \frac{1105.31 \; x \; 200}{4}$ = 55,265.5N
Twisting moment on the shaft is
T = W_T = x $\frac{D_2}{2} = \frac{935 \; x \; 366}{2}$ = **171,105N**
∴ **Equivalent twisting moment is**
Te = $\sqrt{M^2 + T^2}$ = $\sqrt{55265.5^2 + 171105^2}$ = **179,808.793Nmm**
Let d_2 = diameter of mixer shaft
Also, Te = $\frac{\pi}{16}$ x $\tau(d1)^3$
τ = 42Mpa for mild steel
$d_2 = \sqrt[3]{\frac{16 \; x 179808.793}{\pi \; x \; 42}}$ = **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**

4.9. Design of Key

The key is a mechanical device that holds the gears in place onto the shaft. The standard dimensions of shaft key of 35mm are:
Width of key 12mm
Thickness of key = 8mm according to [15].

If the key materials is also mild steel, shearing stress = 42 Mpa
Circulating stress (σ_c) = 70Mpa
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

4.10. 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

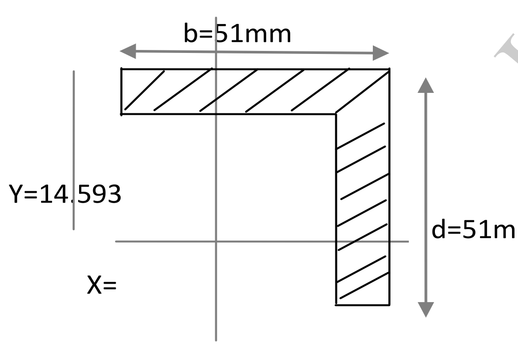

Fig. 7: Cross Section of Angle Bar Point of Load on The Mixing Chamber

The material used for 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 is bolted to the centre of the angle bars which is the point of the load as shown in Fig 8

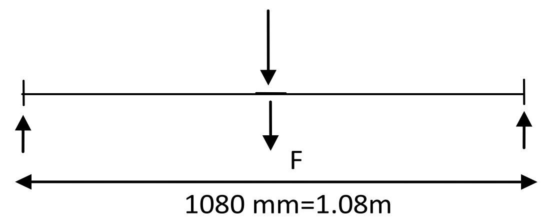

Fig. 8: Point of Load on the Mixing Chamber

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 x
$I = \left[\frac{51x5^3}{12} + 255(14.593-2.5)^2\right] + \left[\frac{5x46^3}{12} + 230(28-14.593)^2\right]$
$= [531.25 + 37{,}291.37] + [40{,}556.7 + 41{,}341.96]$
=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 = $\pi(R^2 - r^2)h$
$\pi(18.5^2 - 17.5^2)x53$
= 5,994.16cm^3
Volume of material of blade (2 in number) = 2xLxbxt
= 2x41x41x1=3,362cm^3
Volume of material of mixer shaft = $\frac{\pi d^2 L}{4}$ = $\frac{\pi x\, 5.5^2 103}{4}$ = 2,447.104cm^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 $5,994.16+3,362+2,447.104 = 11,803.264cm^3$
Mass of mild steel material = Density of mild steel x volume
$7850 \times 11,803.264 \times 10^{-6} = 92.65kg$
Mass of hopper (stainless steel) = $8000 \times 873.6 \times 10^{-6} = 6.98kg$.
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) = $\frac{PL}{2} = \frac{977.37x1080}{2}$ = 527,779.96Nmm

Bending stress is, therefore, $\sigma_b = \frac{M}{Z} = \frac{527,779.96}{8,204.02} = 64.33N/mm^2$
Total stress on the member is = б
$\sigma_o+\sigma_y = \frac{977.39}{485} + 64.33 = 2.02 + 64.33 = 66.35N/mm^2$

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

5. Fabrication Processes

The fabrication process was listed in Fig 9. After the fabrication the parts were assembled and the machine tested in producing tiles using a compounded tile body for extrusion.

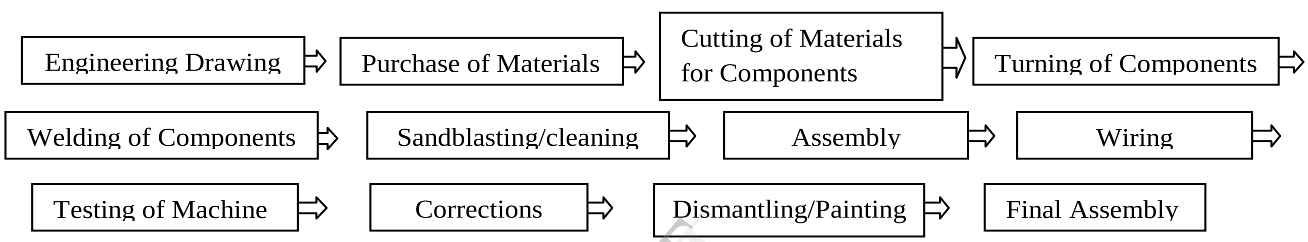

Fig. 9: Fabrication Procedure
Source: Morakinyo (2012)

6. Assembly

The assembly was done in two folds; first, as the fabrication progressed (progressive assembly) and later, after the final finishing (Painting) - assembly after finishing.

6.1. 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 nose-cone (orifice), the roller and other necessary parts.

The standard bolt and nut selected for tightening the entire machine was M12. At some points, there were some exceptions, because of size, function and standard of a particular part. These made 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 tightened 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).

6.2. Assembly After Finishing

This was done after the whole system was dismantled, re-ground and sandpapered to secure a very smooth surface. It was 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 assessments taken. Before the machine was operated the entire parts were well tightened and ensured.

7. Test Procedure

The testing of the machine took the following direction: testing the machine on performance, under no load condition, testing to mill tile mix, efficiency test of some major component parts, extrusion test to extrude sample tiles; capacity test: testing the quantity of tile mix the milling chamber and the hopper can contain testing to extrude tile, template test, quantity/output test within an hour, ergonomic assessment, evaluation test of the tiles produced, impact test, tensile strength test, hardness test, etc.

8. Test Results and Discussion

Under no load condition, the first two drives with the final gear drive were observed and the processing components, these worked well in the directions required. The 3hp gear electric motor used transmitted the necessary speed and motion at every point as required; the noise produced is consequent to the type of drive used. Unwanted rubbing contact between the chamber's inner wall and the blade of the shaft auger was eliminated by grinding further the auger's plates.

Among the three different screw auger shafts used, one was efficient in the end. The final Screw auger shaft was able to mix the tile-mix while the machine was operated in clock and anti-clock wise motion. Similarly, the material yield stress was positive because it allowed free movement of the screw augers between the material and the wall of the milling chamber. This was very vital to successful extrusion and efficiency of the machine. It was observed that among the seven electric motors used only one supplied the required torque. That is the 2.5hp gear electric motor because it has a reduced speed of about 80rpm. 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 machine was able to generate the required torque as mentioned above and extruded the tile mix into a long slab. The orifice of the Nose-Cone 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 into the cutting of slab at the orifice with more vibration. The result was not too comfortable; it affected the surface quality, the length of the slab and eventually the tile.

The extended orifice of the Cone-nose component was cut and realigned; the position of the regulating bar support and the regulating bar was shifted for a better option. After the correction, the machine was able to extrude the slab in different thicknesses. The tiles produced were cut into different sizes. After testing, the orifice was further improved before the final painting of the work—for better output. The tile size cut were 310 x 310mm square, 20 x 20 cm, 15 x15cm and 10 x10cm.

At the hopper the tile-mix is compressed by a lever improving the extrusion surface quality of the tile, extrusion speed; reduce cutting and gumming of the slab to the orifice. This aided in fine extrusion of slabs eventually cut into tiles of different sizes by using different templates.

After the final assembly, the machine was operated in a continuous operation to ascertain production capacity. It was done for 15 minutes to determine what number of tiles it can produce. Such was multiplied by 4 to assess the number of tiles it will produce in an hour; with this equation: In 15 minutes if it produced 18 tiles = 18 x 4 = 72 in 60 minutes. Then 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 = 3456 and **the average in a Month =** 3456 x 4 = 13824 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. The tiles produced were compared with china tiles in the Nigerian market in terms of their mechanical properties test: tensile, hardness and impact tests.

9. Ergonomic Assessment

The machine was user friendly. The relationship of the body with some components check was convenient and comfortable as the environment is quite free for work. On safety, many of the noticed sharp and injurious edges were chamfered and dulled. The entire machine is covered with 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.

10. Conclusion

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 needed equipment in Nigeria are underutilized.

The outcome of this research has to a greater extent established that available local materials can be used to build machines as an aspect of indigenous technology. Standards in mechanical engineering are actually universal; because these guidelines or principles were used for the production of 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.

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 in higher education in Nigeria.

This is a product in a product that serves its purpose and produces another product to the benefit of the community.

11. Acknowledgement

The authors would like to recognise the supplementary financial support extended by the Educational Trust Fund (ETF) Nigeria, through the Department of Research and Development FUT-Yola. Engr. Ibrahim Iliyasu, Engr. Yetu Babazhitsu Kolo and Mr. S. Malachy are all appreciated for their invaluable contribution in the AutoCAD drawings, checking and corrections of the calculations towards the success design and fabrication of the TMM. We also appreciate Engr. Saidu Triumph, Engr. Mathew Oladele and the entire staff of Delmat Technical works No. M30E old Artillery Barracks, off Textile Road, Behind Army Children School, Kakuri Kaduna, Nigeria; for the use of your workshop.

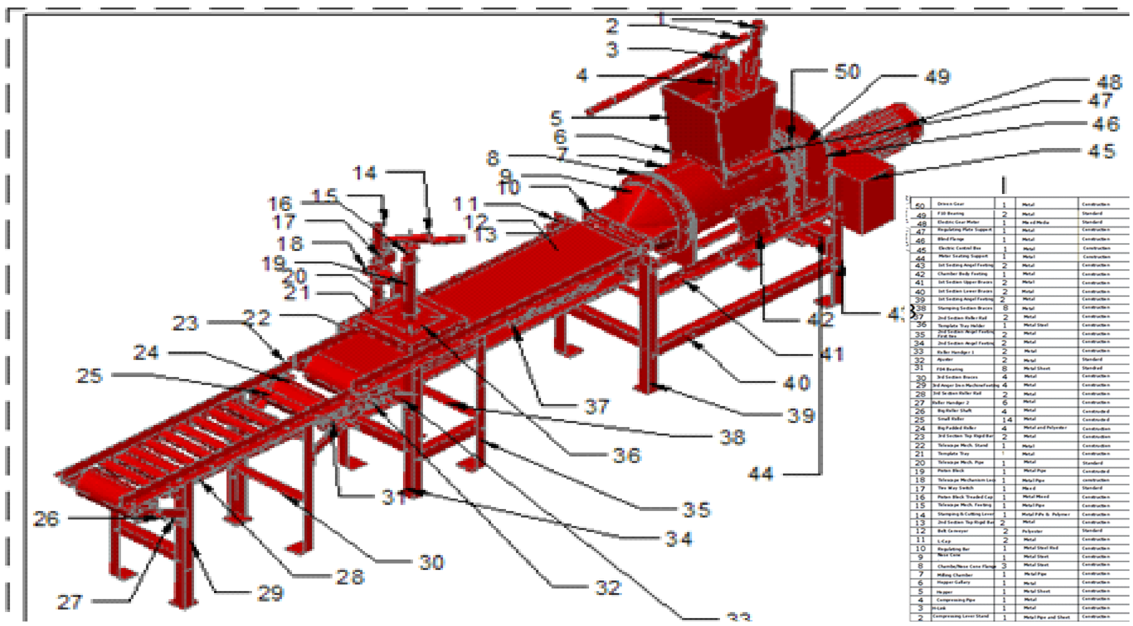

Figure. 10: 3-D Model (Isometric View) of the Tile Making Machine

Table 1: Machine Components List

ITEM NO	DESCRIPTION	ITEM NO	DESCRIPTION
1	Compressing Rod	26	Big Roller Shaft
2	Compressing ever Stand	27	Roller Hanger 2
3	H – Link	28	3rd Section Roller Rail
4	Compressing Pipe	29	3rd Angle Iron Machine Footing
5	Hopper	30	3rd Section Braces
6	Hopper Gallery	31	F04 Bearing
7	Milling machine	32	Adjuster
8	Chamber/Nose cone Flange	33	Roller Hanger 1
9	Nose Cone	34	2nd Section Angle Footing
10	Regulating Bar	35	2nd Section Angle Footing First Two
11	L – Cap	36	Template Tray Holder
12	Belt Conveyor	37	2nd Section Roller Rail
13	2nd Section Top Rigid Bar	38	Stamping Section Braces
14	Stamping & Cutting Lever	39	1st Section Angle Footing
15	Telescope Mech. Footing	40	1st Section Lower Braces
16	Piston Block Treaded Cap	41	1st Section Upper Braces
17	Two Way Switch	42	Small pulley
18	Telescope Mechanism Lock	43	1st Section Angle Footing
19	Piston Block	44	Motor Seating Support
20	Telescope Mechanism Pipe	45	Electric Control Box
21	Template Tray	46	Blind Flange
22	Telescope Mechanism Stand	47	Regulating Plate Support
23	3rd Section Top Rigid Bar	48	Electric Gear Motor
24	Big Padded Roller	49	F 10 Bearing
25	Small Roller	50	Driven Gear

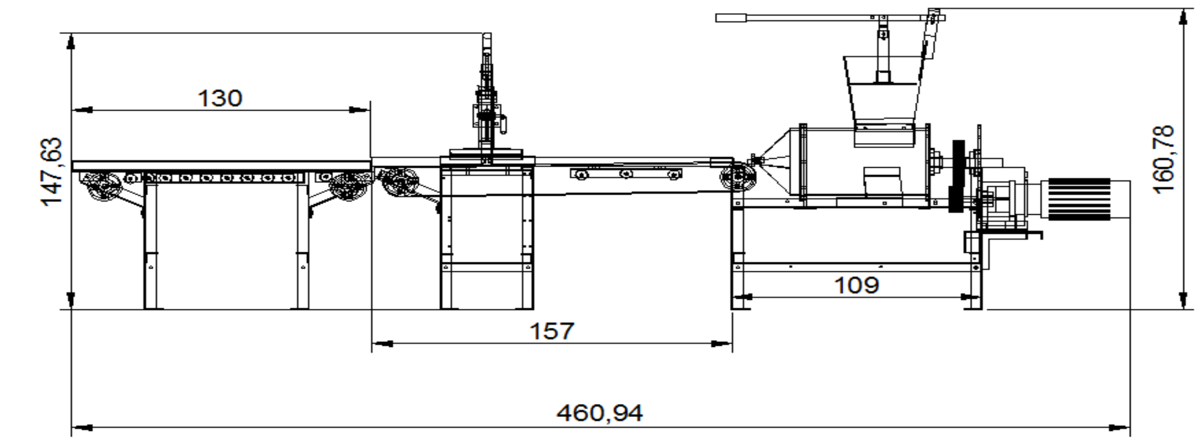

Fig. 11: Front View of the Tile Making Machine
Source: Morakinyo (2012)

Fig. 12: The Developed Tile Making Machine

Source: Morakinyo (2012)

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