Umudike Journal of Engineering and Technology (UJET); Vol. 8, No. 2, December 2022, pp. 20 – 30; Michael Okpara University of Agriculture, Umudike, Print ISSN: 2536-7404, Electronic ISSN:2545-5257; http://ujetmouau.net; https://doi.org/10.33922/j.ujet_v8i2_3

DESIGN AND CONSTRUCTION OF A HYDRAULIC PARTICLEBOARD COMPACTION MACHINE

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ABSTRACT

The study was on the design and construction of a cold press hydraulic particle-board compaction machine. The developed machine comprises of the frame, fixed platen, movable platen, premix mat platter, and the prime mover (1.0-tonne hydraulic cylinder). The framework of the machine presented a respective permissible force, working stress, bending stress, operational deformation, and platen thickness of 10,362.303N, 103.005 N/mm^2, 2,302.7Nmm^2, 0.3605mm, and 15mm.The machine was evaluated by using it to compact admixtures of rice husk and sawdust from 51mm mat thickness to 25mm. Finished particleboards of relative dimensions of 1000mm $\times$ 500mm $\times$ 25mm were produced from the differently constituted base and adhesive materials. The compaction result showed that the machine was effective in the consolidation of the admixture mat into boards of consistent dimensions and optimized base-material and binder blend. The results show that the different categories of particleboards maintained evident variations in their physical characteristics. After drying the produced boards, it was observed that the "S+RP board" reduced most with a final length of 0.970m and the "S+RS board" reduced least with a final length of 0.990m. The "RP board" reduced most in width to 0.485m while "SS board" reduced least to 0.492m. The "S+RP board" reduced most in thickness to 0.015m and the "SS board" reduced least to 0.025m. The "S+RP board" has the least volume of 0.071m^3 and the "SS board" has the highest volume of 0.21m^3. "The S+RP board" has the least weight of 1.400Kg while the "RS board" has the highest weight of 3.100Kg. The "RS board" is the highest dense board by 28.181 Kg/m^{3}and the "SP board" is the least dense board by 12.000Kg/m^3. The "Saw dust plus Rice husk (S+R) category of board presented a more strong and stable characteristics which could be attributed to the blend of the properties of two different base materials. Moreover, the study ventured into bridging the gap of little or no indigenously produced technologies used in waste handling and processing, especially as it concerns rural and urban generated agricultural and lignocellulose materials conversion to useful engineering structural products like panel boards. *It is imperative to recommend that automation and hot surface finishing principles should be adapted to the machine to ensure the production of structurally standardized particleboards.*

Keywords: *Particleboard, compaction machine, hydraulic compaction, premixed material, lignocellulose*

1.0 INTRODUCTION

The borne of technology and the advancement in scientific revolutions have continued to promote mechanization in agro-products handling and engineering, diversification, and extensive value addition to raw agricultural products. It facilitates recycling and re-utilization of agricultural unit operation generated by-products, effective agro-based forecasting and propositions, and reliable agro-allied services rendering and consultations. Excessive increase in population and the consequent need to adequately provide a complementary quantity of food for the teeming population continues to promote present-day technological development. In recent times, advancements in technology have produced mechanized means for agricultural productions that have in turn improved agricultural production and foster food security in many parts of the world (Paul and Anna, 2015; Abdul *et al*., 2016; Desalegn, 2021). Engineering mechanics, hydraulics, aerodynamics, and so many other scientific and engineering-related principles are applied to modern technological artifacts so that they can be suitably adopted in diverse disciplines, especially in agriculture, to reduce drudgery, optimize operation efficiency, improve timeliness in operation, and maximize production in the embodying operations and practices (Shubhankar and Ramesh, 2015).

The concept of hydraulics is based upon the essence of fluid power which according to Durfee *et al*. (2015) is the transmission of forces and motions using a confined, pressurized fluid. Hydraulic technology is fast replacing other environmental threatening and hazard-prone power transmission options (Snap-on, 2019). It is usually simple and compact in configuration but highly power-yielding. The development of modern hydraulic components is principally aimed at increasing the transmitted power, reducing the energy intensity, minimizing environmental pollution, and increasing the technical life and machine reliability (Tóth *et al*., 2014; Asaff *et al*., 2014). Hydraulic components are widely used in powerful mechanisms of feudal agricultural and forest machines as well as in modern agricultural resource handling and processing unit operations and processes. Specifically, hydraulic technologies have been applied to such agricultural subdivisions as irrigation and control, drainage direction and control, agrochemical spraying, material pressing and extractions, material compaction and consolidation, and material impact and crushing (Nash, 2014; Roy and Ansari, 2014; Tkac *et al*., 2018; Metro Hydraulic, 2019). Hydraulically powered devices have a wide application in powerful mechanisms of agricultural and forest machines as well as in many other areas (TLC, 2018). Recent improvements on them are aimed at increasing transferred power, decreasing energy severity, minimizing environmental pollution, and increasing technical durability and machine reliability. This equipment has been utilized in many agricultural resource handling and processing unit operations and processes (Asaf *et al*., 2014; Mohammed *et al*., 2020).

Agricultural post-harvest and processing operations generate a huge amount of waste (Madurwar *et al*., 2013; Muruganandam *et al*., 2016) which have continued to pose a serious environmental pollution menace due to the lack of formidable waste disposal and recycling scheme.post-harvest byproducts that have continued to constitute serious environmental nuisance and pollution across Nigeria. Although the lignocellulose agricultural wastes are potential raw materials for particleboard production (Mohamed, 2011), they have not gained optimized applications, especially at the grass-root level. There is therefore a need to focus attention on the development of such technologies that will aid the conversion and secondary utilization of wastes generated from agricultural products post-harvest operations.

Particleboards are produced from materials that are usually of plant and crop post-harvest by-products origin (César *et al.,* 2017). It is a composite and woody material that is adhesive-bonded (Sotande *et al.,* 2012). Structurally, particleboard consists of two main components usually referred to as 'filler' and 'fibrous' material. Like other composite wood products, particleboard is extensively utilized in structural applications like load-bearing support structures, sub-flooring layers, furniture and upholstery frameworks. It also finds application in non-structural applications like interior covering panels. GAPS (2015) observed the term 'pressboard' as a generic term for any board made from woody pieces that are glued together and pressed and it encompassed plywood, chipboard, particleboard, and fiberboard. The invention of hydraulic cylinder aided technological improvisations in agricultural material pressing, crushing, compression, and compaction unit operations. Hydraulic cylinder actuating presses and compactors are usually portable, easy to operate and control.

Hydraulic compaction technologies are principally made up of a static platform for placing particleboard premixed material, a movable superimposing platform for surface pressure engagement, hydraulic cylinder that primes the compaction operation (Kumar and Prashant, 2017), and the frame that provides structural supports to the entire constituting parts. After mixing the base material and adhesive to a specified mix ratio, the compactor tends to consolidate the pre-mixed material into structurally firm and rigid boards (Kollmann *et al*., 2012).

The need to eradicate the full dependence on alien and foreign technologies and products juxtapose the essence of indigenous technologies in a nation's strives for technological emancipation. If developing countries like Nigeria can strategize on measures to effectively promote their indigenous machine development and simulations, their dependence on imported machinery ought to be minimized for their indigenous technologies to gain due attention, concern, and patronage. With this, material and waste handling technologies will be available even at the grass root level as rural farmers will be able to afford to procure such technologies against their very expensive foreign options.

With highly efficient indigenously or locally fabricated compaction machines, the most suitable, and reliable compaction methods will be those based on available waste as raw materials. Low-cost and low-pressure techniques are presently advocated for harnessing agricultural process residues to useful engineering construction finished products like particleboards and briquettes. In order to optimize the cost of production, the manufacturing process should be carried out using simple manual compactors and locally sourced adhesive materials. This study is therefore focused on the design and construction of a hydraulic particleboard compaction machine.

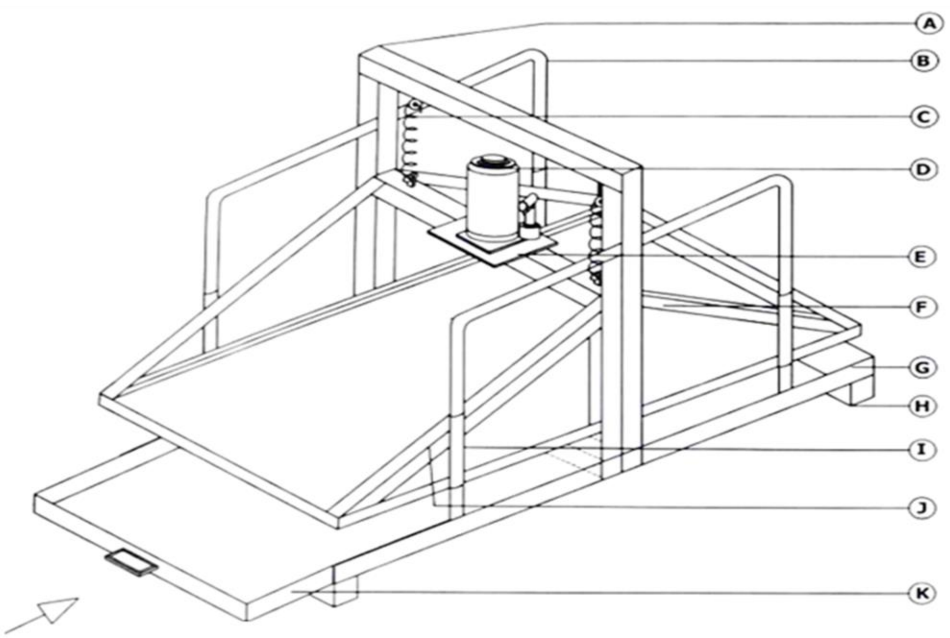
2.0 MATERIALS AND METHODS

2.1 Materials

The materials that are used for the construction work include mild steel angular iron, channel iron, steel plates and mild steel pipes. The performance evaluation test, rice husk and sawdust lignocellulose material were respectively sourced from Omogho rice processing mill in Omogho Town, Orumba North Local Government Area, and Ekwulobia wood processing market in Aguata Local Government Area, Anambra State. The materials were sorted to remove impurities after which they were dried using the open sun method. After drying the materials for 4 days, they were gathered and ground to a homogenous particle sizes of between 0.5-0.1mm. Using weigh balance, the milled materials were measured, formulated and constituted into different admixtures that were processed (pressed and compacted) into particleboards. *Heveabra siliensis* (para rubber wood) sap and starch were used as the binding agents.

2.1.1 Description of the machine

The machine is made up of parts like the frame, a fixed platen, a movable platen, mat platter, and a hydraulic cylinder (Fig. 2.1). It operates basically on Pascal's principle of hydraulics and pressure multiplications as adopted by Mohammed *et al.* (2020). Mat of properly constituted particleboard admixture is formed on the mat platter and placed onto the fixed platen. On actuation of the hydraulic cylinder lever, pressure is applied to the admixture mat for it to be compacted to the designed dimensions (length, width, and thickness). After the compaction process, pressure is released by loosening the relieve valve on the hydraulic cylinder. The movable platen is retracted from the fixed platen, and the resulting finished particleboard board is removed for another batch process to be re-initiated.



Legend

Label	Part
A	Frame
B	Fixed platen liner
C	Movable platen suspension springs
D	Hydraulic cylinder
E	Cylinder base
F	Movable platen
G	Fixed platen
H	Stand
I	Movable platen liner
J	Bracing
K	Mat platter

Fig.2.1: Isometric Presentation of the Developed Hydraulic Particleboard Compaction

2.2 Methods

2.2.1 Design considerations

The factors considered in the design included:

i. the engineering properties of the materials to be handled,
ii. the properties of the hydraulic fluid,
iii. strength,
iv. portability, and
v. Affordability.

On the other hand, the material used was mild steel due to reasons like:

i. availability,
ii. cost, and
iii. Machinability.

The factor of safety (FOS) of "4" was chosen because in hydraulic compaction machines, loading is uncertain in design application. The high FOS was to check for the pressure relief valve.

2.2.2 Fundamental design assumptions

The assumptions made in the execution of this study are:

i. The size of the panel board for this project is 1000mm x 500mm x 25.4mm for efficient compaction.
ii. The total load acting on the frame is equally distributed in the hitch points.
iii. The internal pressure/stress of the machine is assumed to be evenly distributed.
iv. The hydraulic fluid is oil.

2.3 Basic Design Equations

The working principle of trusses is that they will slightly deflect under a vertical load. The upper chord will be under compression while the lower chord is under tension. Diagonals can either be compression or tension members depending on their inclination.

The bracings of the movable platen are constituted into metal trusses for even distribution of the pressure produced by the hydraulic cylinder across the compacted admixture mat. The assumptions that guided the researcher in considering a bracing pattern are:

i. The distance between trusses is relatively 0.75m – 1.25m
ii. The slope of bracing is 35^{o} – 60^{o}
iii. Typical weight of steel truss is $0.10 kN/m^2$

The frame provides mounting points and maintains proper relative positions of the units and parts mounted on it throughout service under all specified working conditions. It also provides general rigidity of the compactor. The design consideration is that of direct tension imposed on the pillars. Other frame members such as the platens (as in our case) are subjected to simple bending stresses. The main frame of the compactor is characterized by:

i. Material used – Mild steel
ii. Density – 7.84kg/m^3

The capacity of the compaction machine determines the forces acting on the compactor frame structure.

hydraulic compactor tensile stress $(\sigma_t) = \frac{\text{Tensile strength}}{\text{Factor of Safety}}$ (1)

$\sigma_t = \frac{F}{A}$ (2)

Where; σ_t = hydraulic compactor tensile stress, N/mm^2
F = force, N
A = area, mm^2

Stress acting on the pillar = $\frac{\text{Force}}{\text{area}}$ (3)

Deformation of pillar, $\delta = \frac{FL}{AE}$ (4)

Where; F = force acting on pillar, N
L = Length of pillar, mm
A = Cross-sectional area of pillar, mm^2
E = Young modulus (200GPa)

$t_1 = K_3 x \sqrt{\frac{a \times b \times F}{\sigma_t(a^2+b^2)}}$ (5)

Where; t_1 = movable platen frame thickness, mm
a = platen length, mm
b = platen width, mm
K= coefficient of material (3 for steel)
F = Total force acting on the compactor, N

$\sigma_b = \frac{M \times y}{I}$ (6)

$I = \frac{bd^3}{12}$ (7)

$M = \frac{Wb}{4}$ (8)

$y = \frac{b}{2}$ (9)

Where; σ_b = bending stress acting on the platen, Nmm^2
I = Inertia, mm^3
M = moment, Nmm
d = thickness of framework, mm
b = width of the compactor, mm
W = F = force acting on the compactor, N
y = distance from neutral axis, mm

Wahl's stress factor (K) = $\frac{4C-1}{4C-4} + \frac{0.615}{C}$ (10)

Maximum shear stress $(\tau) = \frac{K \times 8W \times C}{\pi d^2}$ (11)

Mean diameter of the spring coil (D) = C.d (12)

Outer diameter of the spring coil (D_o) = D + d (13)

Where; W = load pose by the movable platen, N
δ = assumed deflection, mm
C = assumed spring index
τ = maximum permissible stress for spring wire, MPa
G = modulus of rigidity, N/mm^2

2.3.1 Hydraulic compactor tensile stress (σ_t)

According to the bought-out hydraulic cylinder manual, the specifications are indicated thus:
Material for tube: St-42 Structural steel hollow tube
Tensile strength: 42 kgf/mm^2 = 412.02 N/mm^2

Hydraulic compactor tensile stress $(\sigma_t) = \frac{412.02}{4}$ = 103.005 N/mm^2

From the equation, $\sigma_t = \frac{F}{A}$;
F = σ_t x A
= σ_t x [(length of horizontal rectangle x width) + (length of vertical rectangle x width)]
= 103.005 [(50.8 x 1) + (49.8 x 1)]
= 103.005 (100.6)
= 10,362.303N

2.3.2 Design of column

Material: Angular steel bar (St. 42)
Cylinder capacity = 1000 kg = 1.0tonnes
Hydraulic pressure = 350 bar = 350 $\times$0.1 = 35N/mm^2.
The assumed factor of safety (FOS) = 4

Force acting on each pillar = $\frac{10,362.303}{2}$ = 5,181.15N

Stress acting on pillar = $\frac{10,362.303}{100.6}$ = 103.005N/mm^2

Deformation of pillar, $\delta = \frac{10,362.303 \times 700}{100.6 \times 200000}$ = 0.3605mm

2.3.3 Design of movable platen

Material: Steel
Tensile strength = 800 N/mm^2
Working stress = σ_t = 800/4 = 200N/mm^2
According to Khurmi and Gupta (2018), the thickness of platen is expressed as:

$t_1 = 3 \text{ x } \sqrt{\frac{1000 \times 500 \times 10,362.303}{200(1000^2+500^2)}} = 3 \text{ x } \sqrt{\frac{5,181,151,500}{250000000}} = 3 \text{ x } \sqrt{20.72}$ = 3 x 4.55 =13.65mm

The chosen standard thickness is 15mm.

2.3.4 Bending stresses acting on the platen

Recall; $\sigma_b = \frac{M \times y}{I}$

$I = \frac{500 \times 15^3}{12} = \frac{1,687,500}{12}$ =140,625mm^4

$M = \frac{10,362.303 \times 500}{4} = \frac{5,181,151.5}{4}$ = 1,295,287.875Nmm

$y = \frac{500}{2}$ =250mm

$\therefore \sigma_b = \frac{M \times y}{I} = \frac{1,295,287.875 \times 250}{140,625} = \frac{323,821,968.8}{140,625} =$ 2,302.7Nmm^2

2.3.5 Design of movable platen suspension spring

Helical spring is selected as it is the category of spring that is usually intended for compressive or tensile loads.

Data:

Weight of movable platen (m) = 19.8kg

Load pose by the movable platen (W) = 194.24N

Assumed deflection (δ) = 40mm

Assumed spring index (C) = 5

Maximum permissible stress for spring wire (τ) = 420MPa/420N/mm^2

Modulus of rigidity (G) = 84×10^{3}N/mm^2

Wahl's stress factor (K) = $\frac{(4\times5)-1}{(4\times5)-4} + \frac{0.615}{5} = \frac{19}{16} + 0.123 =$ 1.1875 + 0.123 = 1.31

Maximum shear stress (τ), 420 = $\frac{1.31 \times 8(194.24)\times5}{(3.142)d^2} = \frac{10,178.18}{(3.142)d^2}$ $= \frac{3239.39}{d^2}$

$d^2 = \frac{3239.39}{420} = 7.71$

$d = \sqrt{7.71} = 2.78$mm

A standard wire of size SWG2 having a diameter (d) = 4.401mm.

Mean diameter of the spring coil (D) = 5 × 4.401 = 22.005mm

Outer diameter of the spring coil (D_o) = 22.005 + 4.401 = 26.406mm

Having got the mean outer diameters of the spring coil to be 22.005mm and 26.406mm respectively, two SWG1 springs were selected for the effective suspension of the movable platen.

2.3.6 Shear force and bending moment diagrams

The total load = (weight of movable platen + weight of the hydraulic cylinder) × 9.81 = (19.8 + 0.2) × 9.81 = 196.2N = 0.1962kN

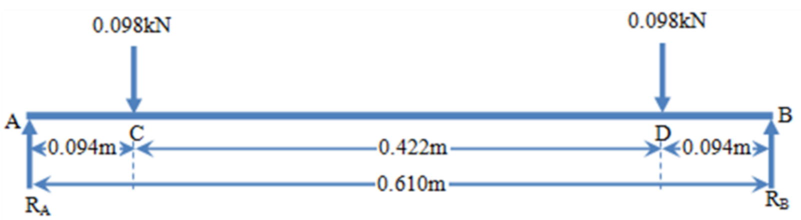


Fig. 2.2: Force Diagram

$\sum F_y = 0\ (\uparrow +\text{ve}, \downarrow -\text{ve})$

S.F Calculations: S_{B-D}= +0.00077kN

S_{D-C} = 0.00077 – 0 .098 = – 0.09723kN

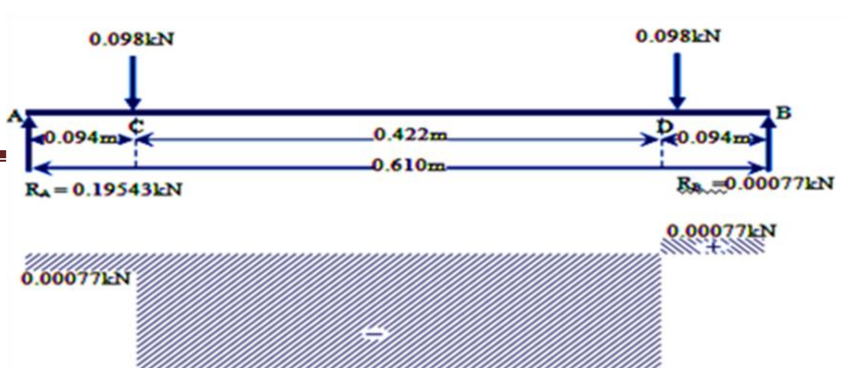
S_{C-A} = – 0.09723 – 0.098 = – 0.00077kN

B.M calculations: M_B = 0

M_D = 0.00077 × 0.094 = 0.000072kNm

M_C = 0.00077(0.094+0.422) – 0.098(0.422) = 0.04kNm

M_A = 0.00077(0.610)– 0.098(0.094+0.422) – 0.098(0.094) = -0.06kNm



2.4 Bill of Engineering Measurements and Evaluations

The materials that are used for the construction and their respective cost implications are presented in the table below.

Table 2.1: Bill of Engineering Measurements and Evaluation

S/N	Items	Quantity	Unit price (₦)	Amount (₦)
1	50.8mm by 50.8mm angular iron	1½ length	1450	2175
2	101.6mm by 50.8mm channel iron	1/4 length	3600	900
3	1.0-tonne hydraulic cylinder	1	6500	6500
4	15mm thick plate	1 full sheet	15000	15000
5	Ø28mm pipe	½ length	1050	525
6	Ø26mm pipe	½ length	970	485
7	Labour	-	-	10500
Total				**36085**

2.5 Performance Evaluation Procedure

Various proportions of the sourced base materials (sawdust and rice husk) and the binding materials ("para rubber tree" sap and starch) were constituted prior to the compaction machine test run. The debris, dried leaves and tree bark particles that are in the sap were manually removed. Known amount of water was added to the harvested "para rubber tree sap" and the starch to produce the solutions that served as the binding agent for performance evaluation of the machine. After the constitution, the compaction of each batch of "SP – sawdust + para rubber sap solution"; "SS – sawdust + Starch solution"; "S+RP – sawdust (50%): Rice-husk (50%) + para rubber sap solution"; "S+RS – sawdust (50%): Rice-husk (50%) + Starch solution"; "RP – Rice-husk + para rubber sap solution"; and "RS – Rice-husk + Starch solution", was carried out. The table below outlined the various proportions of materials for the production of particleboard.

Table 3.2: Particleboard Material Constitution

Particleboard Category	Material		
	Rice husk (Kg)	Sawdust (Kg)	Binding materials

SP	0.00	5.00	3.00 litre of "para tree sap" + 15 litre of water
SS	0.00	5.00	100.00 gram of starch + 15 litre of water
S+RP	2.50	2.50	3.00 litre of "para tree sap" + 15 litre of water
S+RS	2.50	2.50	50.00 gram of starch + 15 litre of water
RP	5.00	0.00	3.00 litre of "para tree sap" + 15 litre of water
RS	5.00	0.00	50.00 gram of starch + 15 litre of water

With proportions presented in the above table, admixtures of rice husk, sawdust materials, freshly harvested "para" rubber wood sap and starch solutions were produced, thorough mixed by manual method, laid on the mat platter and placed on the developed compaction machine. On actuating the hydraulic cylinder, the constituted particleboard material was compacted from a loosely laid height of approximately 51mm to 25mm.

3.0 RESULTS

3.1 Design Computations

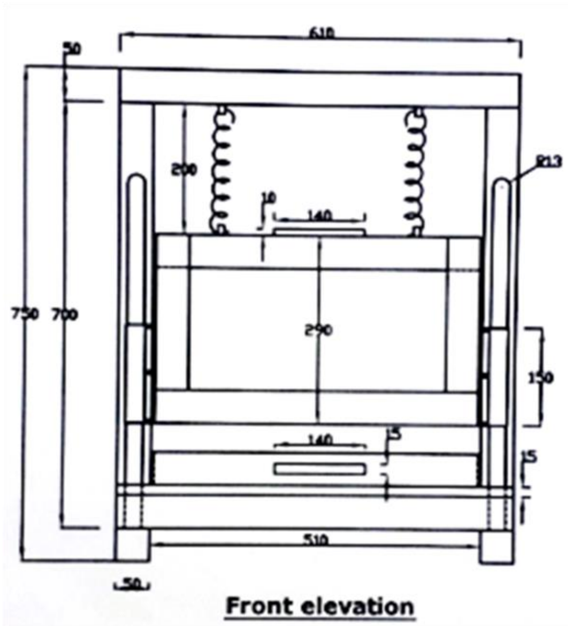
The results from the design computations are outlined in table 3.1.

Table 3.1: Summary of Design Computations

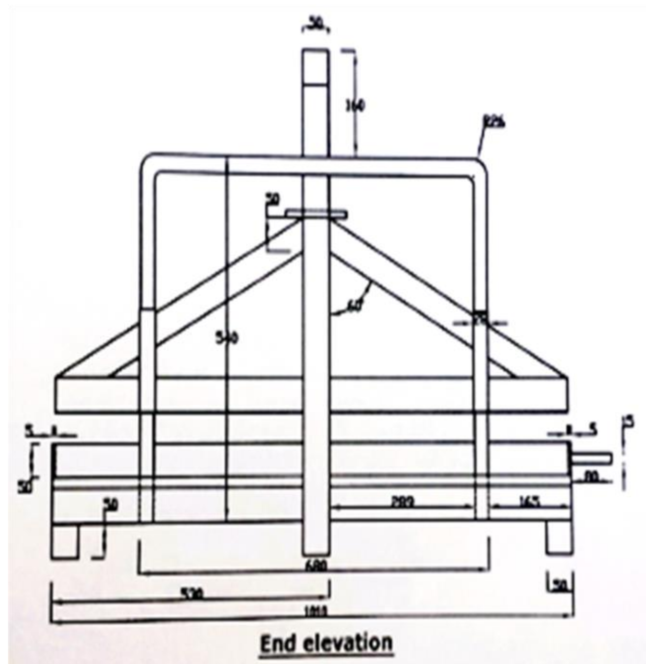
Design feature	Specifications
A. **The framework**	
Density	7.84kg/m^3
Factor of Safety	4
Working stress (σ_t)	103.005 N/mm^2
Maximum force	10,362.303N
B. **Columns**	
Force acting on each pillar	5,181.15N
Stress acting on the pillar	103.005N/mm^2
Deformation of the pillar, δ	0.3605mm
C. **Hydraulic Cylinder**	
Cylinder capacity	1000kg
Hydraulic pressure	35N/mm^2
D. **Moving Platen**	
Working stress, σ_t	200N/mm^2
Bending stresses	2,302.7Nmm^2
E. **Suspension spring**	
Spring type	Helical
Diameter	4.401mm (SWG2)
F. **Bracing**	
Distance between trusses	0.75m – 1.25m
Slope of bracing	35^o – 60^o
Weight of steel truss	0.10kN/m^2

The developed machine has overall dimensions of 1010mm by 610mm by 750mm. It is portable, effective in particleboard compaction operation, and required little or no maintenance hassles. Lubrication is required in the liners to facilitate easy sliding and returning actions of the movable platen during operation.

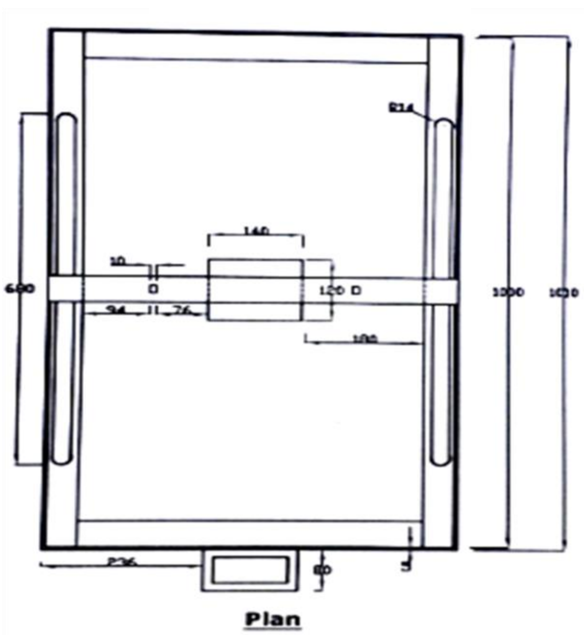
3.2 The Developed Hydraulic Particleboard Machine



FRONT VIEW



SIDE VIEW



PLAN

Fig. 3.2: Orthographic Presentation of the Developed Hydraulic Particleboard Compaction Machine

3.3 Performance Evaluation Results

On completion of the compaction, drying and cooling operations, the resulting boards were measured and their respective characteristics are presented as follows.

3.3.1 Rice husk particleboard

The characteristics of the produced rice husk particleboards are outlined as contained in the table below.

Table 3.1: Characteristics of the Rice Husk Particleboard

Particleboard Category	Final board dimensions (m)			Volume (m^3)	Weight (Kg)	Density (Kg/m^3)
	Length	Width	Thickness			
RP	0.984	0.485	0.0230	0.110	2.400	21.818
RS	0.985	0.487	0.0230	0.110	3.100	28.181
Initial board dimension: 1m by 0.5m by ≈0.0255m						

From Table 4.1, the results show that there are variations in the characteristics of the produced particleboards. After drying, both boards showed a noticeable variation in length, width, thickness, volume, weight and density. The "RP board" featured0.984mm, 0.485mm, 0.0230mm, 0.110m^3, 2.4kg and 21.818kg/m^3 for length, width, thickness, volume, weight and density respectively while the "RS board" featured 0.985mm, 0.487mm, 0.0230mm, 0.110m^3, 3.1kg and 28.181kg/m^3 for length, width, thickness, volume, weight and density respectively. There are relatively small variations in the characteristics of the boards except for the weight and density where there is a relatively large variation. The RS board showed higher weight and density but the two board categories maintained same volume after the drying operation.

3.3.2 Saw dust particleboard

The characteristics of the produced saw dust particleboards are outlined as contained in the table below.

Table 3.2: Physical Characteristics of the Saw Dust Particleboard

Particleboard Category	Final board dimensions (m)			Volume (m^3)	Weight (Kg)	Density (Kg/m^3)
	Length	Width	Thickness			
SP	0.980	0.490	0.0210	0.100	1.200	12.000
SS	0.987	0.492	0.0250	0.121	1.700	14.050
Initial board dimension: 1m by 0.5m by ≈0.0255m						

From Table 4.2, the results show that there are variations in the characteristics of the produced particleboards. The "SP board" featured 0.980mm, 0.490mm, 0.0210mm, 0.100m^3, 1.200kg and 12.000kg/m^3 for length, width, thickness, volume, weight and density respectively while the "SS board" featured 0.987mm, 0.492mm, 0.0250mm, 0.121m^3, 1.7kg and 14.050kg/m^3 for length, width, thickness, volume, weight and density respectively. There are noticeable variations in all the characteristics of the boards with the "SS board featuring higher values than the "SP board".

3.3.3 Saw dust plus rice husk particleboard

The characteristics of the produced "saw dust plus rice husk" particleboards are outlined as contained in the table below.

Table 3.3: Physical Characteristics of the Saw Dustplus Rice Husk Particleboard

Particleboard Category	Final board dimensions (m)			Volume (m^3)	Weight (Kg)	Density (Kg/m^3)
	Length	Width	Thickness			
S+RP	0.970	0.487	0.0150	0.071	1.400	19.718
S+RS	0.990	0.489	0.0170	0.082	2.100	25.610
Initial board dimension: 1m by 0.5m by ≈0.0255m						

From Table 3.3, the results show that there are variations in the characteristics of the produced particleboards. The "S+RP board" featured 0.970mm, 0.487mm, 0.0150mm, 0.071m^3, 1.400kg and 19.718kg/m^3 for length, width, thickness, volume, weight and density respectively while the "S+RS board" featured 0.990mm, 0.489mm, 0.0170mm, 0.082m^3, 2.100kg and 25.610kg/m^3 for length, width, thickness, volume, weight and density respectively. There are variations in all the characteristics of the boards with the "S+RS board featuring higher values than the "S+RP board".

Comparatively, the "S+RP board" reduced most with a final length of 0.970m and the "S+RS board" reduced least with a final length of 0.990m. The "RP board" reduced most in width to 0.485m while "SS board" reduced least to 0.492m. The "S+RP board" reduced most in thickness to 0.015m and the "SS board" reduced least to 0.025m. The "S+RP board" has the least volume of 0.071m^3 and the "SS board" has the highest volume of 0.21m^3. "The S+RP board" has the least weight of 1.400Kg while the "RS board" has the highest weight of 3.100Kg. The "RS board" is the highest dense board by 28.181 Kg/m^{3}and the "SP board" is the least dense board by 12.000Kg/m^3.

At the course of the study, some subjective observations were made. The starch bound boards maintained higher characteristics when compared to their respective "para tree sap" bound counterparts, except for RP and RS boards that have the same volume. The based materials (rice husk and sawdust) gave the individual board pairs their respective colour variations. All the starch bound boards produced cracks during their drying period and none of the "para rubber sap" bound boards showed this feature. On further subjection of heat, the "para tree sap" bound boards tends to become unstable and on cooling down it becomes stiffened. The surface finishing of the S+RP and S+RS boards are the best when compared to the other pairs.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

A hydraulic particleboard compaction machine for value addition of the ever-abounding agricultural rice and wood processing wastes was designed and constructed to add to the wealth of indigenously constructed machines. This cold press compaction machine consists of such parts as frame and fixed platen, movable platen, premix mat platter, and the prime mover (1.0-tonne hydraulic cylinder). The framework featured a working stress of 103.005 N/mm^2, a possible deformation of 0.3605mm during operation, and platen thickness of relatively 15mm. The machine was able to compact laid admixtures of rice, sawdust, and naturally sourced binding materials from a mat thickness of approximately 51mm to approximately 25mm, and for each batch of compaction, finished particleboards of relative dimensions of 1000mm $\times$ 500mm $\times$ 25mm was produced The developed machine goes a long way to bridge the gap of little or no indigenously produced technologies used in waste material handling and processing, especially as it concern rural and urban generated agricultural and lignocellulose waste materials conversion to useful structural products. The results from the machine test run showed that the constitution of rice husk and sawdust gave a well surfaced finished and more stable particleboards as it fosters the blending of the properties of two distinct agricultural waste materials.

4.2 Recommendations

Sequel to the technological relevance of this study, it is recommended that:

i. Research should be concentrated on value addition to agricultural waste materials to help government in curbing the ever-growing problems associated with them.

ii. Due and concerted attention should be paid to the emancipation criteria for indigenous technology, by both government and technological research institutes, so that our finished indigenous technologies will be standardized for easy adoption and utilization.

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