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DESIGN, FABRICATION AND TESTING OF MANUALLY OPERATED DOUBLE COMPARTMENT BLOCK MOULDING MACHINE

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ABSTRACT

This work focuses on the design, fabrication and testing of a manually operated double compartment block moulding machine. It cost less compared to the mechanically powered block moulding machine in existence. The double compartment makes it time saving and also reduces the energy input. All the materials used were obtained locally therefore the objective of this work which is producing a relatively cheap, strong, portable, time and energy saving block moulding machine was achieved.

***Keywords:** Fabrication, Double compartment, Block moulding, Energy saving.*

INTRODUCTION

Sheltering and housing has been a major problem to man since the earliest day of human existence. In order to escape from harsh climatic condition and vulnerability to wild animal attack, the early men resolved to seek refuge in caves, which is the reason why they are sometimes referred to as cave men. As protective as these caves seem to be to the early men, they still have their limitations like poor or no ventilation, erosion incursion and only one entrance and no exit in case of emergency. These limitations necessitated the research into building of artificial houses since caves are considered to be natural. The artificial buildings are meant to correct or eradicate the limitations of the natural house (cave) thus that marked the beginning of house building and construction in human life (Hodge, 1972). Since that decision was made tremendous improvement has been recorded in house building and material used. The discovery of Portland cement led to the development of concrete block (Watson, 1986). Block may be classified among the most durable building material. Indeed throughout the world we have many excellent example of block building, which has survived hundreds of years. The Romans were excellent builders and the structures that can be seen in many parts of Britain Isles are testimonies of their skill (Obande, 1989). The earliest blocks were made in moulds such as wooden boxes; they were solid, very bulky and heavy making it very difficult for the masonry to lay (Hendry, 1981). Hand operated block moulding machine is one of the oldest conventional block moulding machine and it can either be single or twin mould type. With such design, the mould is fixed to the base or stand while the plates carrying the palette on which the cement block is produced is directly below the mould. The plate moves vertically upward to discharge the block after it has been rammed manually. It was later discovered that the blocks produced by this method lacks proper bonding of the cement block aggregate, it has low production output, clumsy design and there were difficulty in carrying the block after it has been discharged (Ivor, 1995).

DESIGN ANALYSIS

Rectangular Compartment

This is a rectangular plate with all the edges fixed and carrying uniformly distributed load over its surface. The maximum tensile stress of the plate is given by

$$S = \frac{0.5W}{t^2}\left[\frac{L}{l} + \frac{(0.623l^5)}{L^5}\right]$$

Where, W = total load on the plate (N)
t = thickness of the plate (m)
L = long side of the plate (m)
l = short side of the plate (m)

Determination of Shear Stress and Bending Moment on the Front Plate

At the front plate only the weight of block (W) was considered. At the longitudinal sections, the load is uniformly distributed.

wl = point load

Summation of vertical forces

$$R_A + R_B - wl = 0$$

Taking the moment about point B

$$R_A \times l - Wl \times \frac{l}{2} = 0$$

$$\therefore R_A = \frac{Wl}{2}$$

Shear stress along longitudinal section taking section along 0<x<l

$$\sum F_V = 0$$

$$R_A - Wx - V = 0$$

$$V = R_A - Wx$$

For bending moment 0<x<1

$$R_A x - Wx \times \frac{x}{2} - M_b = 0$$

$$M_b = R_A x - W x^2/2$$

Determination of Shear Stress and Bending Moment of Side Plate

In this case, the weight (W) of two blocks is acting on the plate. This is represented with W acting as uniformly distributed load.

To determine the reaction on the plate

$$\sum F_V = 0$$

$$R_C + R_D - Wl = 0$$

$$R_D = Wl - R_C$$

Taking moment about point D

$$R_C l - Wl\left(\frac{l}{2}\right) = 0$$

$$R_C = \frac{Wl}{2} \qquad \text{(Ryder, 1988)}$$

To determine the shear stress alone 0 < x <l

$$R_C - Wx - V = 0$$

$$V = R_C - Wx$$

For bending moment 0<x<1

$$R_C x - Wx \times \frac{x}{2} - M_b = 0$$

$$M_b = R_C x - W x^2/2$$

Determination of Bending Moment and Shear Stress on the Base Plate

This was considered as a single load acting as uniformly distributed load at the centre of the plate.

Reaction can be determined as

$$\sum F_V = 0$$

$$R_E + R_F - Wl = 0$$

Taking moment about R_F,

$$\sum M_{R_F} = 0$$

$$R_E l - Wl\left(\frac{l}{2}\right) = 0$$

$$R_E = \frac{Wl}{2}$$

Shear stress 0<x<l

$$R_E - Wx - V = 0$$

$$V = R_E - Wx$$

For bending moment 0<x<1

$$R_E x - Wx \times \frac{x}{2} - M_b = 0$$

$$M_b = R_E x - W\,{x^2}/{2}$$

Determination of Deflection on the Plate

Since the same material is used for the plates the maximum bending moment M_{max} would be used to determine deflection for the plates.

Bending moment about principal axis can be obtained from this expression

$$\frac{M}{EI} = \frac{1}{R}$$

$$\frac{1}{R} = \pm \frac{{d^2y}/{dx^2}}{\left[1 + \left({dy}/{dx}\right)^2\right]^{\frac{2}{3}}}$$

For beams in engineering practice the slope dy/dx is every where small, and may be negligible.

$$\therefore \quad \frac{1}{R} = \frac{d^2y}{dx^2}$$

$$\frac{d^2y}{dx^2} = \frac{M}{EI}$$

Where, M = Bending moment
E = Young modulus
y = Deflection

$$I = \frac{bd^4}{64}$$

Where, I = Moment of inertia m^4
b = length of the plate mm
d = breath of the plate in m

Determination of thickness of the Plate to be used

The maximum deflection on the plate is related to the thickness by the formula

$$\delta = \frac{0.0284W}{Et^3}\left[\frac{L}{l^3} + \left(\frac{1.056l^2}{L^4}\right)\right]$$

Making t the subject of the formula, it becomes

$$t = \sqrt[3]{\frac{0.0284W}{E\delta}\left[\frac{L}{l^3} + \left(\frac{1.056l^2}{L^4}\right)\right]}$$

From the above expression the thickness of the plate which can withstand the deflection and the bending moment can be determined.

Where, t = Thickness in mm
L = length of the plate (mm)
l = Breadth of the plate (mm)
δ = Deflection on the plate
W = Weight of the plate

Analysis of Structural Support (Angle Bar)
The area of an angle bar can be obtained from the expression

$$A = t(2a - t)$$

Where, t = thickness of the angle bar
a = actual width of the bar
The thickness of the angle bar can be determined from the expression

$$t = \tfrac{3}{8} a^1 \quad \text{(Ryder, 1988)}$$

Also the distance from the neutral axis of the bar can be determined from the expression

$$y = a - \frac{a^2 + (at - t^2)}{2(2a - t)}$$

The moment of inertia I of an angle bar can be obtained from the expression

$$I = \tfrac{1}{3}\left[ty^3 + a(a-y)^3 - (a-t)(a-y-y-t)^3\right]$$

$$\textit{Section Modulus } Z = \frac{I}{y}$$

Where, I = moment of Inertia
y = Distance from the neutral axis

Determination of the Critical Load Length of the Angle Bar That Can Withstand The Load.
Yield stress can be determined from the relationship.

$$\sigma_y = \frac{P_{Cr}}{A}$$

Where, σ_y = yield stress
P_{cr} = Critical load
A = Area
Making critical load the subject of the formula we have

$$P_{Cr} = \sigma_y \times A$$

This could be related to the length of the angle bar by the expression

$$P_{Cr} = \frac{\pi^2 EI}{l^2}$$

Where, E = Young Modulus
I = Moment of inertia
l = required length of the bar
Making l the subject of the formula from the expression above, we obtained

$$l = \sqrt{\frac{\pi^2 EI}{P_{Cr}}}$$

Determination of the Diameter of the Metal Rod which can Raise the Block
The rod in this case is considered to be under the action of bending forces only. ASME code stipulated that in finding the diameter of shaft (d) the following relationship can be used

$$\sigma = \frac{M}{Z_P}$$

$$Z_P = \frac{M}{\sigma}$$

Where, M = Bending moment
Z_p = sectional modulus
σ = allowable stress

$$Z_P = \frac{\pi d^3}{16}$$

Making d the subject of the formula we obtain

$$d = \sqrt[3]{\frac{16Z_P}{\pi}}$$

Determination of Force to Compress the Block

The force to compress the block could be obtain using the relation given below

$$F = \frac{Mgh}{V} \times A_T$$

Where, A_T = total area of the compressed regions of the two blocks
M = mass of the two blocks (kg)
H = height of the block (m)
g = acceleration due to gravity (m/s^2)
V = volume of the block (m^3)

Determination of Lifting Force

The lifting force is the force applied to the lifting rod to raise the block from the block compartment after it has been compressed with upper region. The force must be considerably minimum so that little effort can be applied to raise the block. To obtain considerable minimum force, the position in which the force is applied to the position in which the force is applied to the weight of the block has to be considered, this could be determined by taking the moment along the position of weigh and the force.

Taking moment about B

$$Wx - F(l - x) = 0$$

$$F = \frac{Wx}{(l - x)}$$

$$where \quad W = 2mg \quad for\ two\ blocks$$

$$Volume = length \times breadth \times height$$

$$V = lbh$$

The hollow space occupied 20% of total volume of each block

The solid part = Total volume - Volume of hollow

$$Mass = density \times Volume$$

Analysis of Welding

The part analyzed on this machine is the handle which is used to raise the block, because it is the part of the machine that is under the action of shear and bending forces.

$$A_w = \pi d$$

$$F_R = \sqrt{F_b^2 + F_S^2}$$

Where, F_R = resultant force
F_b = Bending force
F_s = shear force (vertical)

$$F_b = \frac{M}{Z_W}$$

$$F_S = \frac{P}{Aw}$$

$$A = \frac{F_R}{\sigma_T}$$

Where, σ_T = tensile stress of mild steel = 345N/mm^2
w = depth of the weld

DESIGN CALCULATION AND RESULTS

e following results were obtained from calculation:
Maximum Bending Moment of side plate = 8.25Nm
Maximum Bending Moment of Base Plate = 4.56Nm
Compaction Box Thickness = 4mm
Thickness of the angle bar = 9.525mm
Critical Load That Support Can Withstand = 285KN (on each Angle Bar)
Length of bar which can withstand the load = 1.20m
Force to Compress the Blocks in the Moulding Compartment = 215N
Force to Raise the Blocks F = 218N
Diameter of the Rod to Raise the Blocks = 30mm
Welding Size w = 2mm
Efficiency = 68%

CONCLUSION

This work presents the Design, Fabrication, and Testing of a Manually Operated Double Compartment Block Moulding Machine. It cost less compared to the mechanically powered block moulding machine in existence. The double compartment makes it time saving and also reduces the energy input. The problem of hike in fuel price and availability of fuel is also overcome and due to method of joining certain part of the machine it is flexible, some part of it are bolted instead of welding which makes it possible for a single compartment to be functional if the need arises detachability also leads to portability which is part of the problem facing the cumbersome mechanically powered machine.

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