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Original Research Article

Development of Broken Building Blocks Pulverizer for Recycling Process and Waste Control In Blocks Moulding Industries

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Abstract: A moulded broken blocks pulverizer of 0.5 tonne per hour was designed, fabricated, tested and evaluated for pulverizing moulded broken blocks for recycling process. The pulverizer was developed to pulverized both cement and clay moulded broken blocks having a power rating of 2 HP and its motor speed of 1420 rpm stepped down to 828 rpm. The sieve mesh used was 5 mm. this machine will assist in controlling and recycling broken blocks in block moulding industries. The design was made simple and cost of production cheap to be affordable by small, medium and large scale block molding industries. Its performance efficiency is 85 %.
Keywords: Building blocks, Pulverizer, Recycling, Industries, Waste, Broken, Crusher

INTRODUCTION

One of the major problems the block moulding industries are facing is block wastage in the form of broken blocks. The major causes of broken blocks in block moulding industries includes; inappropriate proportioning of the raw materials (cement, water and mineral aggregate) used, usage of low-grade raw materials (sand). Also if the cement-water paste does not completely cover the whole aggregate, the blocks produce will be substandard, presence of impurities, improper curing, drying and handling. Due to these occurrences, the wastage in the industries is always high when compared to productivity as the effects are loss of time, effort and resources which reduce the cash inflow of the industry. In most block moulding industries, the labourers normally use hammer to crush the broken blocks to fine aggregate again but this manual process is laborious, time and power consuming and also highly ineffective because most of the broken blocks won't be crushed. For efficient crushing of broken blocks, the horizontal shaft impactor crusher was designed and fabricated as a better alternative to this method.

A crusher is a device that is designed to reduce large solid chunks of raw material into smaller ones. Crushers may be used to reduce the size or change the form of a material so they can be more easily disposed or recycled, or to reduce the size of a solid mixture of raw material so that pieces of different composition can be differentiated (Jarmo, E.2006). A crusher can be considered as primary, secondary or fine crusher depending on the size reduction factor (Khurmi, R.S. and Gupta 2005).

This study aims at developing, testing and evaluating recycling machine for broken mould block.The simplest tool for crushing appeared two thousand years before Christ in china, the Chinese name is chjiu, it was called "ball and socket". The further evolution of the ball and socket is foot pestle from 200 to 100 years BC (www.google.com). These tools use the leverage, but the action was still intermittent grinding. The earliest use of continuous crushing action of the crusher machine is chulimo called mill in the fourth century BC invented by shuban gong. The other crusher machine with continuous grinding action is the roller grinding machinery; it appeared later than the mill in that period. Two hundred years AD later, Du Yu and other Chinese researched out a machine named shuizhui forced by water power on the basis of the foot pestle and mill to improve production efficiency.

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Crushing machineries in the modern times were created after the improvement and promotion of the steam engine, electric motor and other power machinery. In 1806 a steam engine-driven roll crusher appeared. The jaw crusher was invented by Blake from United States for crushing rock in 1858. With the development in United States in 1878 of continuous gyratory crusher crushing action, the production efficiency was higher than for the intermittent crushing action of the jaw crusher. Until now many domestic manufacturers of crusher name their crushers "crushers". To the 1970s, along with the development of technology, automatic controller has been developed to be used to control the hydraulic cone. Several researches have been carried out on the utilization of the manufacturing Wastes in construction. Examination of the possibility of using crushed clay bricks as coarse and fine aggregate for a new concrete was done by (Kenai, S. and Debieb, F. 2008). It was found that with the percentage of recycled aggregates limited to 25% and 50% for the coarse and fine aggregates respectively, produced concrete with similar characteristics to those of natural aggregates concrete. A substitution of coarse aggregate with crushed fine clay brick up to 40% in Concrete at 28 days curing had a higher mechanical strength compared to the natural aggregate concrete. The application of recycled aggregate as partial replacement of coarse aggregate in the range of 20 to 40% has been reported to be successful. A study by (Nagabhushana, and Sharada bai, H. 2011) concluded that up to 50% of natural aggregate could be replaced by recycled aggregate without seriously affecting the properties of the concrete, both in the fresh and hardened states. Investigated of the use of waste sandcrete blocks collected from block moulding yards as partial replacement of fine aggregate in medium concrete was carried out by (Umoh, A. A and Kamang E. E. J.2005).Utilization of waste concrete for new construction has long been proposed by (Ravindrarajah, R. S. 1987). Attempts have been made to recycle demolished concrete and masonry (Hansen, 1992). To promote the recycling of concrete (Shima, H. *et al.,* 2005) have developed a technology to produce high-quality recycled aggregate. As technology to recycle the waste concrete had been improved, it was possible to evaluate the fundamental characteristics of concrete using RCA for structural concrete members, such as pavement structures (Park, C. and Sim, J.2006). More researches on Compound Performance of Waste Concrete Pulverized Admixture and Slag Powder have also been experimented by (Li,S. U. N & Da-xing, Q. I. A. N, 2009). Cost of evaluation guideline on using crushed concrete as coarse aggregate for concrete was given by (Seangatith, S. 2011). Only cost of the material, cost of installation, and maintenance cost were considered. It was also emphasized that recycled concrete with good gradation can be used in concrete while proper mechanical properties can be maintained in terms of compressive strength, modulus of elasticity, and creep. This RCA concrete is equivalent to normal concrete. Aggregate as stated in ACI E1-07 is granular material such as sand, gravel, crushed stone, blast-furnace slag, and light weight aggregates that usually occupy approximately 60 to 75% of the volume of concrete. Aggregates can be processed from wastes that abound in the construction and other industries for use in mortar and concrete.

Design Analysis, Construction and Material Selection

In machine design and construction, special considerations are being made as well as assumptions. These considerations are in area of the choice of design, material selection with respect to its mechanical properties; load to be overcome by the machine, safety of operation, cost of construction friction resistance, aesthetics and lubrication required, etc. However, in this design, the machine fabrication, its operation, material selection were carefully done bearing in mind the operation condition of the machine. Also, the conditions considered in this regards were the tendency of the selected material to fracture under fatigue, resistance to wear during operation, corrosion when in contact with moisture and ability to dissipate heat to the environment to avoid overheating.

Machine Components

These are unit components of the machine that are assembled together to form the entire machine. The machine components include; frame, housing, hammer mill, hammer shaft, mounted shaft, feed inlet, outlet, perforated screen, machine base, electric motor base, bearings, shaft pulley, v- belt and the electric motor which was selected.

Material Selection

Material selection is of paramount importance demanding understanding of each of the functional requirements for the individual machine components as there are greater than ever varieties of materials presently available and the development of new materials with distinctive properties and applications (Budynas, and Nisbett, 2008). If the selection process is done arbitrarily, the risk of overlooking a possible attractive alternate material may occur. To circumvent this, there is a need for analysis of the material performance requirement. However, the material performance requirement was well thought-out in the following perspectives (Kalpakjian, S. and Schmid, S. 2006).

Design Factor

This refers to some characteristics which influence the design of the machine or some of its components functionality. However, out of the numerous factors that affected the design, only few will turn out to be the major factors and the minors ones ignored as they produce little effect on the design.

These considerations are in terms of;

- Strength of the materials used

- Overall weight of the machine in order to achieve its portability and machine size
- Ease of maintenance
- Noise and vibration
- Resistance to wear and corrosion attack
- Finishing

Design Analysis for the Crusher

In designing a horizontal shaft impact crusher for materials like the broken blocks and dry sand, density, ρ = 1600 Kg/m^3) with a feed rate of 0.1 TPH and the top feed size is 50 mm.

Design Analysis for Hammer/Blow Bars

The hammers or the blow bars are subject to shear force at the point of fixation, centrifugal force due to rotation, bending force due to striking of the material.

When a sudden impact is observed by the blow bars due to input feed striking over, it experiences an impact load. The effect of impact loads differs appreciably from that of the static loads as with a suddenly applied load, both the magnitude of the stresses produced and resistance properties of materials are affected.

With a hammer or the blow bar made of Manganese steel and having a rectangular cross section.

Length of bar = 100 mm; Width of bar = 50 mm; Thickness of bar = 5 mm
Material = High carbon steel; Density, ρ = 7.85 g/cm3
Young's Modulus E= 210 GPa $= 210 \times 10^3$ N/mm^2;
Yield Stress σ_{ys} = 370 MPa = 370 N/mm^2
Height of fall of material h = 240mm
Weight of each hammer/blow bar = 200 g

The hammer is considered to act like a cantilevered beam with 1/3 of its width inserted in to rotor plate slots for the fixation purpose.

Impact Bending Stress (Static)

(a) When the cantilever is subjected to a concentrated load at the mid of its span.

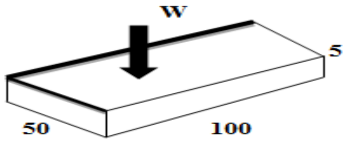

Fig.-1 cantilever subjected to concentrated load at the mid of span

Total open screen area per hammer = 67% of area of the hammer plate
= $3.35 \times 10^3 mm^2$

Now from a feed rate of 10 TPH and a revolution of 497 RPM of the rotor we have 2 impacts in one second.
Tonnage / impact W = 13.61N

Let y be the bending

Applying impact equation [2]

$$W\,(h + y) = \frac{py}{2} \qquad (1)$$

Where P is the equivalent static force
y = the deflection of the hammer
W = tonnage impact
h = height of fall
L = length of hammer

Also for a cantilever beam subjected to a load the deflection [2] is given as

$$Y = Pl^3 \times \frac{1}{3EI} \quad (2)$$

Where I is the moment of inertia

$$\text{Here} I = \frac{bd^3}{12} \quad (3)$$

$$= 1.1 \times 10^3 mm^4$$

$$\therefore \text{ EI}= 2.31 \times 10^8 Nmm^2$$

$$y = 3.1\text{mm}$$

$$P = 2148.3\text{N}$$

Maximum moment, $M_{max} = 5.3 \times 10^4 Nmm$

Now we have allowable stress
σ_{ys} = 500 MPa = 500 N/mm^2

Maximum allowable moment

$$M_{all} = \sigma ys * z \quad (4)$$

$$= \sigma \times \frac{I}{d/2} \quad (5)$$

$$= 2.08 \times 10^5 Nmm$$

Since Mall > M_{max}. The design is safe for this condition.

(b) When the cantilever blow bar is subjected to a concentrated load at the tip of the cantilever.

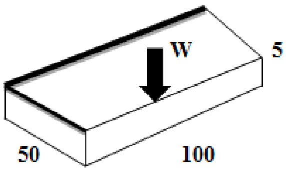

Fig.-2 Cantilever beam subjected to load at the tip of the cantilever

We have
From equation (1) and (3),
Y = 3.1 mm (Deflection)

$$P = 2148.3 \text{ N}$$

$$\text{Max. Moment, } M_{max} = P \times l \quad (6)$$

$$= 2.1 \times 10^4 Nmm$$

Maximum Allowable moment $M_{all} = \sigma Z$ (7)
$= 2.08 \times 10^5 Nmm$
Since $M_{max} < M_{all}$ hence the design is safe.

(c) Impact bending stress due to cantilever beam subjected to uniformly distributed
Load.

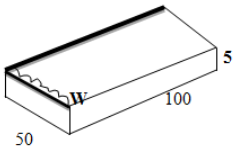

Fig.-3 cantilever beam subjected to uniformly distributed load

Since the weight is distributed uniformly over the length *l* = 33.3mm

We have from equation (1)

$$W(h + y) = \frac{py}{2}$$

The Bending moment at any section X from the fixed end is given as [2]

$$M = EI \times \frac{d^{2}y}{dx^{2}} = -\frac{W}{2}(l-x)^{2} \quad (8)$$

Integrating we get

$$EI \times y = -\frac{W}{24}(l-x)^{4} - \frac{wl^{3x}}{6} + c1 \quad (9)$$

At x=0, y=0 C1 = *wl*2/24

$$:y = -\frac{W}{24EI}(L-x)^{4} - \frac{Wl^{3}}{6EI} + \frac{Wl^{4}}{24EI} \quad (10)$$

Small work done due to impact distributed load

$$W\,(h+y)/l\,dx \quad (11)$$

The total work done becomes

$$= \int_{0}^{t} \frac{w(h+y)}{l}\,dx \quad (12)$$

$$= \frac{w}{l}\int_{0}^{l}\left(h - \frac{W(l-x)^{4}}{24EI} - \frac{Wl^{3x}}{6EI} + \frac{Wl^{4}}{24EI}\right)dx$$

$$= \frac{W}{l}\left(hl + \left[\frac{W(l-x)^{5}}{120EI}\right] - \left[\frac{Wl^{3x^{2}}}{12EI}\right]_{0}^{L} + \left[\frac{W(l)^{4}x}{24EI}\right]_{0}^{l} \right) = \frac{W}{L}\left(hl - \frac{Wl^{5}}{20EI}\right) \quad (13)$$

$$= \frac{13.6}{33.3}(240 \times 33.3 - (13.6 \times 33.3^{5})/\,(20 \times 2.31 \times 10^{8}) \quad = 7991.8\text{Nmm}$$

Also

$$\text{Static Work done} = \int \frac{py}{2}\,dx \quad (14)$$

$$= \int_{0}^{L} \frac{P}{2}\left[-\frac{W(\,l-x)^{4}}{24EI} - W\left(\frac{l^{3}x}{6EI} + \frac{Wl^{4}}{24EI}\right]dx \quad (15)$$

$$= \frac{p}{2}\left\{[W(l-x)^{5}/120EI]_{0}^{l} - \left[\frac{Wl^{3}x^{2}}{12EI}\right]_{o}^{l} + \left[\frac{Wl^{4}x}{24EI}\right]_{0}^{L}\right\} = \left(-\frac{P}{40}wl^{5}/EI\right)(3.17) \quad (16)$$

We have

$$\int \frac{W}{l}(h+y)dx = \int \frac{py}{2}dx \quad (17)$$

Therefore, P = 13276.8 N

Max Moment, M_{max} = *Pl/2* (18)

$= 2.2 \times 10^{5}Nmm$

Max Stress Induced

$$\Sigma\text{b} = \frac{\text{M}}{\text{Z}} = \frac{2\text{M}}{\text{Id}} \quad (19)$$

$= 350Nmm^{2}$

But max allowable stress Mallowable = 500 N/mm2
The design is safe in accordance to this condition.

Static Load Shearing

By using strain energy method and approximating the loading to be a static one,
Shear stress produced due to force F at any distance y is

$$\tau = \frac{FAy}{Ib} = f * \frac{b}{l*b} * \left(\frac{d}{2} - y\right)\left(\frac{d}{4} + \frac{y}{2}\right) \quad (20)$$

$$\tau = \frac{6F}{bd^{3}}\left(\frac{d^{2}}{4} - y^{2}\right) \quad (21)$$

Shear strain energy for the small volume

$$dv = \frac{\tau^{2}}{2G}\,(Volume)$$

$$= \frac{1}{2G}\left[\frac{6F}{bd^3}\left(\frac{d^2}{4} - y^2\right]^2 \times (bdy \times dx) \quad (22)$$

So the total strain energy $= \int_0^l \int_0^{\frac{d}{2}} [dv] = \frac{1}{2G}\int_0^l \int_0^{\frac{d}{2}} \left[\frac{6F}{bd^3}\left(\frac{d^2}{4} - y^2\right]^2 * bdy * dx$

$$= \frac{1}{2G} * \left(\frac{6F}{bd^2}\right)^2 b * \int_0^l \left[\frac{d^4}{16} + \frac{y^5}{5} - \frac{d^2y^2}{6}\right]^{d/2} dx = \frac{3F^2 l}{10bGd} \quad (23)$$

$$\text{Work done } W = F * \frac{Ys}{2} \quad (24)$$

Where ys = displacement

$$y_{s=}\frac{6PL}{10bGd} \quad (25)$$

Here P = 13,6*N;* G= bulk modulus = 140 GPa = $140 \text{ X } 10^3 \text{ N/mm}^2$

$y_s =$ 0.00000388mm

Design of V-Belt Drive

A V- belt drive mechanism drives the rotor.

Power to be transmitted = 2Hp = 1.5 KW (calculated from the crushing and its drive power required)

Minimum pitch dia. D of pulley = 75 mm

Pulley dia. at sheave d_2 = 100 mm

Top width of v belt, b = 13 mm

Thickness of v - belt, t = 8 mm

2β = 34°

For pulley

Since the power to be transmitted is 1.5kw, type A v belt was used.

w = 11mm; d = 12 mm; a=3.3 mm

c = 8.7 mm; f= 10 mm; e = 15mm; No. of sheave grooves (n) = 26

N2 = 480 rpm

For belt:

Coefficient of friction μ = 0.25 (leather) ; σ all = 7 N/mm2 ; ρ $= 1.2\, x\, 10^3 \text{Kg/m}^3$

To get the speed of the driven pulley,

N_1= 1420rpm, D_1=35mm, N_2= 828 rpm

Where D_1 = Diameter of the driver pulley

D_2 = Diameter of the driven pulley

N_1 = Speed in rpm of the driver pulley

N_2 = Speed in rpm of the driven pulley

D_2 = 60mm

The peripheral velocity:

$$V = \frac{\pi D_1 N_1}{60} \quad (26)$$

= 2.60 m/s

Determination of the Length of Belt

The Centre distance between the two pulleys is assumed to be 200mm using the formula

Let the overhang be, x = 0.2m

$$L = \left[\frac{\pi}{2}(D_1 + D_2) + 2x + (D_1 - D_{2)}^2 / \, 4x\right] \quad (27)$$

L = 0.55m

Also to get the angle of contact between the belt and the pulley

$$\sin\alpha = \frac{r_2 - r_1}{x} \quad (28)$$

Where r_1= radius of the driver pulley and

r_2= radius of the driven pulley

$$r_{1=}0.0175m$$

$r_{2=}0.03m \sin\alpha = \frac{0.03-0.0175}{0.2}$= 0.062

$$\alpha = \sin^{-1} 0.062$$
$$\alpha = 3.5^{\circ}$$

Angle of Contact Θ

θ = 180 - 2α (29)

θ = $172.6°$

θ = 3.01 rad

Power Transmitted By the Belt

The power transmitted by the belt is given as

$P = (T_1 - T_{2)}V)$ (30)

Where

P = power in watts

T_1 = tension on the tight side of the belt

T_2 = tension on the slack side of the belt

V = peripheral velocity

Therefore, taking the power as 1.5kW

1500 = $(T_1 \ - T_2)$ 2.60

$(T_1 - T_2) = 576.9$ N

And since $2.30 \log \frac{T_1}{T_2} = \mu\theta$

$$\log \frac{T_1}{T_2} = 0.306$$
$$T_2 = 565\ N$$
$$T_1 = 2.02\ T_2$$
$$T_1 = 1100\ N$$

Determination of Weight of Driver Pulley

Driver pulley diameter D_p = 35mm =0.035m

Thickness of pulley t = 30mm =0.003m

Density 0f mild steel = 7800kg/m^3

Therefore volume of pulley =$\frac{\pi}{4} \times D_p^2 \times t$ (31)

= $2.86 \times 10^{-5} m^3$

Weight of pulley = Mg (32)

= 21.5 N

The assumed input feed for the screen, feed rate = 0.1 Tph

Solid density = $1.6\ \text{t/m}^3$

Max feed size = 50 mm

Moisture content = 3%

Particle shape = circular; Screening process = dry

Desired products = Not larger than 5 mm

Screen Selection:-

85% of the passing material is collected in the first deck of the screen. The circular material shape leads to the choice of square opening screen.

Assume the use of steel screening mesh (Eloranta, J., & Chart, B.,2006).

Dimensioning

At the screen, particles with size greater than 5 mm would be retained and the rest would be passed to the conveyor. To obtain 5mm separation the square opening screen was 5.5 mm and with an opening of 73% [1].

Manufacturing Process

All parts of the horizontal shaft impactor crusher were machined and produced to specification. The manufacturing process takes into account all processes from assembly of parts to surface finishing of the crusher.

Assembling of Machine Components

- The horizontal shaft impactor crusher was assembled in the following order;
- The machine frame was welded to give the rectangular machine frame.
- The cylindrical housing of the hammer mill was then placed inside the support and welded
- The mounting shaft was then fixed inside the housing through the holes that was drilled on the housing and fixed using bearing that was attached to the frame.
- The hammers were then arranged on the three hammer mill shafts and clipped with anvils at both ends and then attached to the mounting shaft with clips to ensure rigidity.
- The perforated net was then attached inside the housing
- The outlet was then welded to the cylindrical housing at the bottom Plate.

Fig.-4 Manufactured horizontal shaft impactor crusher

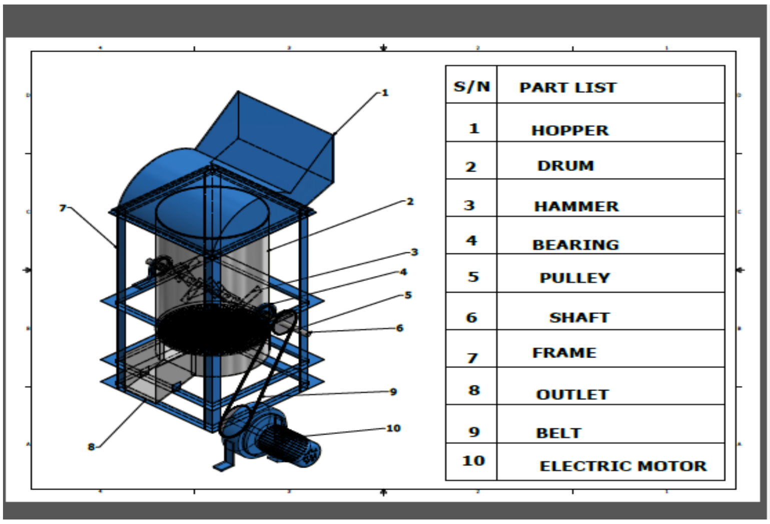

Fig.-4.1: The Fabricated broken blocks pulverizing Machine

RESULT AND DISCUSION

From the result gotten from the testing of the crusher, it was found that the crushing efficiency of the machine is 85%. Some of the blocks were not crushed to the desired grain size because of some factors which include the particle of the blocks getting attached to the locker pin used in fixing the hammers to the shaft and some of the grain size which are not up to the desired diameter not been crushed further by the hammers.

CONCLUSION

From the result, it can be seen that the machine can crush 0.5 tons of broken blocks within an hour at a very high efficiency therefore it can be concluded that the HSI crusher will do a lot of good to blocks manufacturers and also builders, because it would save the time and energy which might be expended on the breaking the blocks manually.

RECOMMENDATION

This project could be adopted in various ways in order to improve its efficiency. To this end, the following recommendations are made:

Decrease heat generation from the electric motor by using fan and vents instead of using pulley system in the crusher, the hydraulic system of crushing should be incorporated into subsequent designs as this will improve the performance of the crusher.

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