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Calculation of capacity reduced to create directed movement of slant materials in press roll unit

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Abstract. The article presents analytical studies on the calculation of the power spent on grinding shale materials in a press roll machine in order to obtain cube-shaped rubble.

1. Introduction.

In the development of rocks in order to obtain an enriched product in the dump, a huge amount of material is used, which accumulates in dumps. Most of such materials consist of shale rocks, which have an elongated shape and a layered structure. The growing requirement for crushed stone materials has led to an expansion of the resource base in road construction and the use of shale materials. However, grinding of shale rocks in existing crushing units does not allow us to obtain cube-shaped crushed stone. The use of crushed stone with dimensions significantly different from the cuboidal form reduces the service life of the roadway 2-2.5 times and increases the consumption of binding materials - cement and bitumen. The strength of concrete structures in this case is reduced by 10-15% with a simultaneous increase in cement consumption by 7-12% and by 3-5% of the water requirement of the concrete mix [1]. All this requires the creation of new or upgrading of existing equipment that will allow for the directional supply of shale materials to the working parts of the unit and create a force action in the given direction.

2. Methodology.

A rational solution of this problem is to develop and create an aggregate that combines the processes of directed feeding of rock pieces to the working bodies and the force action with a certain step in the direction of the largest axis of a rock slice.

3. Main part.

Taking into account the obtained results of the research, we developed an experimental design of a press roller machine with a device for directing shale pieces along their major axis to the working parts of the unit, which makes it possible to effect a force action and to obtain cube-shaped crushed stone (Figure 1).

A roller press unit with a device for directional feeding includes hopper 1, located above toothed rollers 2, mounted on the frame of the unit [1,2].





Figure 1. Experimental installation of a press roller machine with a device for directing anisotropic materials

To create a directed movement of slate pieces of material having an elongated shape (Figure 2), guide rollers 3 are movably fixed in the hopper. The toothed rollers rotate to a meeting and have gear set on their surface with a certain pitch.



Figure 2. Starting material



Figure 3. Form of cube-shaped crushed stone

The machine for grinding materials works as follows. The initial shale material is fed into hopper 2, which is grasped by the rollers, between which it is rotated in the direction of its greatest axis and feed to the toothed rollers. In the space between rollers, pieces of material are captured and destroyed between the gear set at a certain step on the working surface of the rolls. As a result, crushed stone have a cuboidal shape (Figure 3) [3].

However, the creation of a directed supply of shale materials to the working elements of the unit consumes power, and the lack of a methodology for calculating its value hinders the introduction of this design in production. The value of the pre-compacting force exerts a significant influence not only on the energy parameters of the grinding process, but also on the structural design of the unit and this is largely determined by the position of the roller in the hopper [3,4,5]. Therefore, in order to determine the rational effort, required to uniformly distribute the width and compact the shale materials in the roller arrangement, let us consider the design scheme shown in Figure 4.

The position of the roller in unit 1 of radius r in relation to the hopper 2 is set by shifting its center horizontally - L and vertically - l . The angle of inclination a of the hopper wall will be denoted by the angle at which the compaction of the material begins – through β

Thus, the intensity q can be written as follows:

$$q = \mu \Delta \rho, \tag{7}$$

where μ - coefficient of proportionality, depending on the characteristics of the material to be compacted (particle size distribution, shape and deformability of particles, etc.), the dimension of this coefficient is N/m^3 . The physical interpretation of the coefficient μ is as follows: this is the magnitude of the force that must be applied to reduce per unit volume of material.

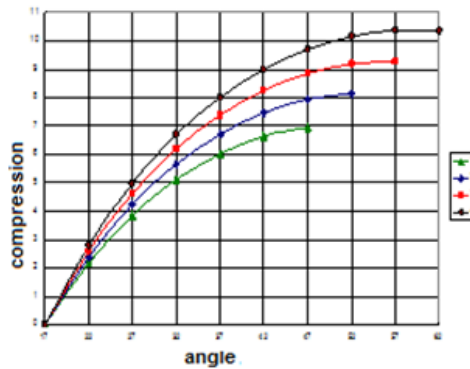


Figure 5. The amount of material compression depending on angle φ : 1 – $l=10$ cm; 2 – $l=13$ cm; 3 – $l=16$ cm; 4 – $l=19$ cm

Thus, considering the distributed load uniformly distributed along the roll axis, we obtain:

$$dF = \mu \Delta \rho ds \tag{8}$$

where ds - the surface element of the roll, determined by the formula $ds = r d\varphi db$; db - a linear length element along the generator of the roll surface.

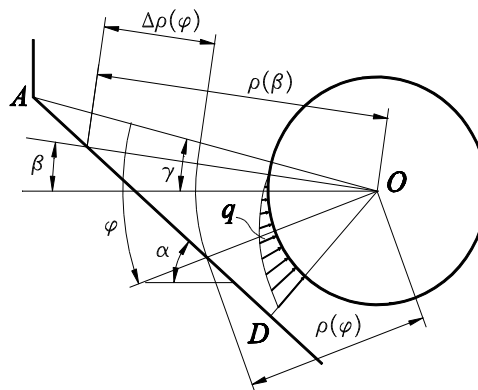


Figure 6. A scheme for calculating the intensity of a distributed load q

Thus, the formula for calculating the force of impact of a roll on a material is determined by the formula:

$$F = \iint_{(S)} \mu \Delta \rho r d\varphi db = \mu r b (h+r) \int_{\beta}^{\varphi_{max}} \left(\frac{h+r}{\sin(\alpha-\gamma+\beta)} - \frac{h+r}{\sin(\alpha-\gamma+\varphi)} \right) d\varphi, \tag{9}$$

where b – roll width; φ_{max} – maximum value of the angle φ .

As it follows from figure 2, $\varphi_{max} = \angle AOD = \frac{\pi}{2} - \alpha + \gamma$.

To calculate the integral (9), we make the substitution $\xi = \alpha - \gamma + \varphi$, then:

$$F = \mu r b (h+r) \left(\frac{\pi/2 - \psi}{\sin(\psi)} + \ln \operatorname{tg} \frac{\psi}{2} \right), \tag{10}$$

where $\psi = \alpha - \gamma + \beta$.

As it is noticed, the value of the parameter μ depends on the properties of the material to be compacted, its value was determined experimentally.

Figure 7 shows the experimentally obtained dependence of the compaction coefficient k on the value of the specific load q , for two materials - limestone and clinker.

To use the results of experimental studies for the purpose of determining the parameter μ , the formula for k is as follows:

$$k = \frac{\rho(\beta) - r}{\rho(\varphi) - r} \tag{11}$$

or

$$k - 1 = \frac{\Delta\rho}{\rho(\varphi) - r} \tag{12}$$

We convert the results of the experimental data, presented in Figure 5, to the form when the parameter k is an argument and the specific load q is a function (Figure 7).

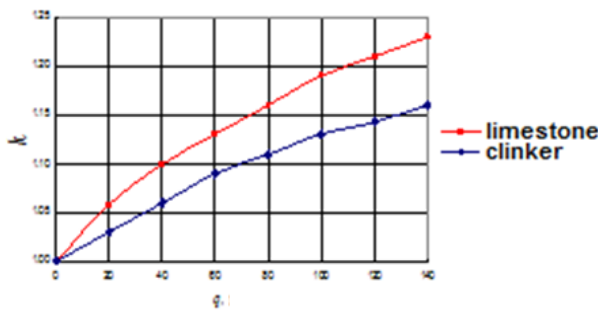


Figure 7. Dependence of strength F on angle a for different values r

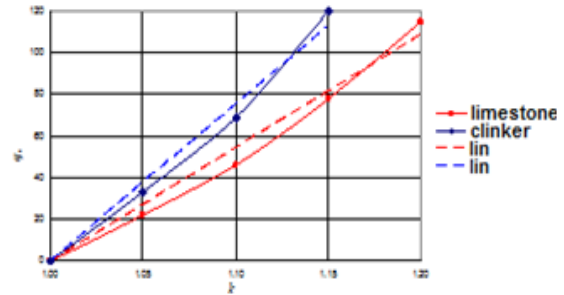


Figure 8. Dependence of strength F on angle a for different values l

Having approximated the obtained dependency curves q against linear curves k (shown in dashed lines in Figure 8), we obtain the dependence of the following form:

$$q = a(k - 1), \tag{13}$$

where $a_{\text{lime}} = 545 \text{ N/m}$, $a_{\text{clinker}} = 754 \text{ N/cm}^2$.

Finally for q and μ :

$$q = \frac{a}{\rho(\varphi) - r} \Delta\rho, \tag{14}$$

$$\mu = \frac{a}{\rho(\varphi) - r} \tag{15}$$

In the derivation of formula (10), parameter μ was assumed as constant. Given that change ρ when the angle φ is ranging from $\varphi = \beta$ to $\varphi = \varphi_{\text{ia}\bar{0}}$, μ can be calculated from formula:

$$\mu = \frac{a}{\rho_{\bar{n}\bar{0}} - r}, \tag{16}$$

where $\rho_{\bar{n}\bar{0}} = \frac{\rho(\beta) - (h+r)}{2}$. (17)

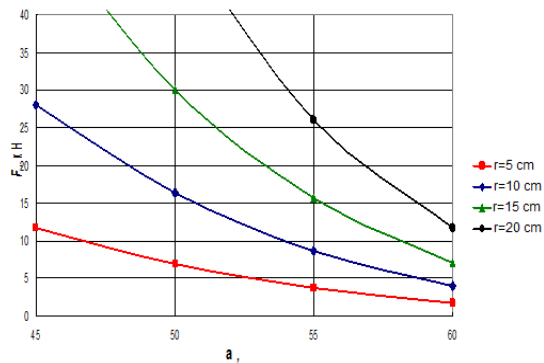


Figure 9. Dependence of strength F on angle a for different values r

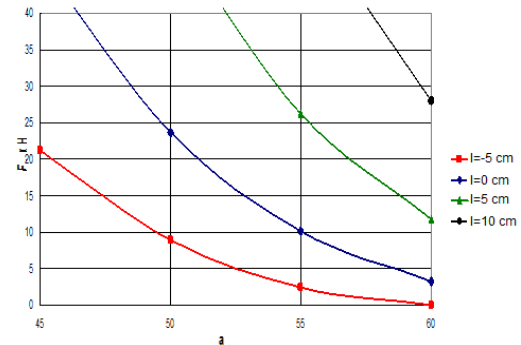


Figure 10. Dependence of strength F on angle a for different values l

In Figures 9,10, as an illustration, we presented the results of the calculation according to equation (10) of the force of action of the roller on the sealable material with a change in the angle of inclination of the hopper wall a radius of felling r and displacement of the center of the roller vertically l at $\beta=17^\circ$, $l=5$ cm, $l=50$ cm, $r=20$ cm, $b=50$ cm, $a=545$ N/cm² (limestone).

4. Conclusion.

Thus, the theoretical studies allowed obtaining an analytical expression for calculating the force created by the rollers necessary for pre-packing and creating a directed supply of shale materials to the gear rolls of the unit. Knowing the required efforts to carry out pre-packing for creating a directed supply of shale materials using known equations, we can determine the required power.

The use of the roller device before feeding the materials to the rolls of the press roll unit allows one to create a directional supply of shale materials, and to pre-compact and evenly distribute them along the width of the working elements of the unit, which leads to a more uniform wear and hence longevity.

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