DOI: 10.2478/rjti-2018-0008
ROMANIAN JOURNAL
OF TRANSPORT INFRASTRUCTURE

INNOVATIVE CALCULATION METHOD OF THE PRODUCTIVITY OF VIBRATING SCREENS USED IN MINERAL AGGREGATES SORTING

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Rezumat

În procesul tehnologic de preparare a betoanelor din ciment sau a betoanelor asfaltice – frecvent utilizate la construcţia de drumuri, şosele, căi de acces, este necesară sortarea unor amestecuri granulare polidisperse provenite din zăcământuri de balastieră sau din carierele de piatră. Clasarea mecanică realizează separarea granulelor pe sorturi dimensionale (dimensiunea granulelor clasate poate fi de 1…70 mm) cu ajutorul unor maşini numite ciururi. În cazul ciururilor vibratoare, organul de lucru (sita) prezintă o mişcare vibratorie, cu avantajul asigurării unei productivităţi ridicate a utilajului de cernere şi a unei calităţi foarte bune a produselor finale obţinute. Articolul tratează asupra studiului productivităţii ciurului vibrator pentru sortarea agregatelor minerale prin diferite metode. În acest sens, se propune o formulă pragmatică simplificată, numită convenţional Pragma, verificată cu bune rezultate prin experimentări în situ pe un ciur vibrator bimasic, într-o staţie pilot.

Cuvinte-cheie: ciur vibrator, agregate minerale, productivitate, metoda Pragma

Abstract

In the process of preparing cement or asphalt concrete – frequently used in ways, roads and access road construction, it is necessary to sort out poly-dispersed granular mixtures from bilge deposits or quarries. The mechanical sieving performs the separation of the granules on dimensional sorts (the size of graded grains can be 1 ... 70 mm) by means of machines called screeners. In the case of vibrating screeners, the working body (the sieve) presents a vibratory movement that ensures a high productivity of the screening machine and a very good quality of the final products obtained. The article studies the productivity of the vibrating screen used in mineral aggregates sorting process obtained by different methods. In this regard, a pragmatic simplified formula called Pragma is proposed, a formula which was tested with good results in situ experiments done on a bi-mass vibrating screen in a pilot station.

Keywords: vibrating screen, mineral aggregates, productivity, Pragma method

1. GENERAL CONTEXT

In the process of preparing cement or asphalt concrete – frequently used in ways, roads and access road construction - it is necessary to sort out poly-dispersed granular mixtures from bilge deposits or quarries.

The source of origin as well as the granule size of granular mixtures lead to their classification into basic components – sand, gravel, ballast.

Polydisperse mixtures can be mechanically, pneumatically and hydraulically classified. The mechanical classification is based on the size of the granules (dimensional classification) and the pneumatic and hydraulic classification is realized based on the falling velocity limit of the granules entrained in a fluid stream. Thus, in the case of technological processes of concrete preparation, a mechanical classification is required.

The mechanical sieving performs the separation of the granules on dimensional sorts (the size of graded grains can be 1 ... 70 mm) by means of machines called SCREENS (screeners). Their working tool is a sieve of metal wire mesh, sheet metal, perforated rubber carpet or plastics material, provided with square, rectangular or circular holes.

In the case of vibrating screens, the working body (the sieve) presents a vibratory movement that ensures a high productivity of the screening machine and a very good quality of the final products obtained.

For the natural aggregates sorting, a wide range of vibratory, horizontal or inclined screens are produced, equipped with one or more sieves (maximum 4), having surfaces ranging from 2 to 12 m^2.

An important weight in assuring the quality of cement concretes and mortars is represented by the heavy natural aggregates.

2. PRODUCTIVITY OF VIBRATING SCREENERS/SCREENS

The main technological elements influencing the sifting process are the productivity of the vibrating screens and the quality of the products obtained by sieving.

The high complexity of the sifting process imposes for the calculation of the productivity of the vibrating screen the use of statistical methods and empirical formulas, with good results in practice.

2.1. The analysis of the vibrating screen's productivity presented by various authors

Factors involved in productivity computing relationships can be structured into three main groups, determined by the construction of the screen, the sorting material and the technological flow the vibrating screen is integrated into.

The comparative analysis performed on the screen's productivity calculations presented by 20 authors leads to relations that can be structured on/into? two main groups of factors:

- ✓ A first group, mainly develops on the specific productivity ***q***, in m^3 / h - analyzed at 16 authors;
- ✓ A second group, which develops mainly on the speed of movement of the material along the site, v, in m/s – analyzed by 4 authors.

Studying the vibrating screen productivity expressions, in the specialized literature, at/in the works of 16 authors, has shown that most of the forms of the proposed calculus relations are close, the only differences being the number and values of the component/constituting factors.

2.2. General Computing Relationship

Analyzing the physical definitions of the component factors resulted in a total of 16 common factors, out of which 13 were retained as significant. Thus, the general expression of the screen productivity can be expressed as the following relation:

$$Q = f\,(k \cdot A, q, a, b, c, d, e, f, g, \; h, \; i, \; j, \; k', \; l, \; m) \qquad (1)$$

The meanings of each factor are as follows:

k- calculation coefficient-of the screen's active surface;

A- the screen's geometric surface area in m^2, that some authors present as an active/effective surface;

q- screen's specific productivity in m^3/m^2 screen and hour (some authors give it in t/m^2, h);

a- influence coefficient of the material's content percentage having granules smaller than the mesh hole of the lower screening sieve, also referred to as the part passing through the sieve.

Some authors give/designate it as "the part not passing through the sieve", meaning the upper class fractions:

b- influence coefficient of the material's content percentage having granules smaller than the mesh's half hole of the screening sieve (lower class fractions). Factors a and b are rapidly deducted from the material's granulometric curve subjected to the sifting or from the flow diagram;
c- influence coefficient of the sifting process (wet or dry screening);
d- influence coefficient of the granules' shape: rounded shape in case of river or lake material (sand, gravel, ballast), or square(d) in case of crushed material;
e- influence coefficient of the prescribed sifting capability (efficiency, quality);
f - influence coefficient of the material's humidity subjected to sifting;
g- influence coefficient of the sieve's inclination angle;
h- influence coefficient of the sieve's? serial number in the package on the vibrating screen frame (I, II, III or IV sieve);
i- coefficient taking into account the screen's construction type (gyrational, inertial, with circular or unidirectional vibrations);
j- spraying coefficient – water scrubbing the screening surface;
k'- coefficient taking into account the possible unevenness of the feeding material on the screen;
l- coefficient taking into account simultaneously the screen's constructive type, inclination and the granule's shape;
m- influence coefficient of the material's density.

3. THE "PRAGMA" METHOD FOR CALCULATING THE VIBRATING SCREEN'S PRODUCTIVITY BASED ON THE SPECIFIC PRODUCTIVITY "q" - PROPOSED BY THE AUTHOR [1]

Analyzing the expressions found in the specialized literature in the works of 16 authors and following the graphs plotted on groups of common factors, average values are indicated. Thus, a pragmatic calculation method for the vibrating screen's productivity is proposed, conventionally called the "pragma" method, formula considering 11 factors:

$$Q = f(\overset{(0)}{k}, \overset{(1)}{A}, \overset{(2)}{q}, \overset{(3)}{a}, \overset{(4)}{b}, \overset{(5)}{c}, \overset{(6)}{d}, \overset{(7)}{e}, \overset{(8)}{f}, \overset{(9)}{g}, \overset{(10)}{h}) \qquad (2)$$

Only 11 component coefficients of the previous formula will be studied and plotted as variation graphs considering their values.

3.1. The active surface of the screen (A_a)

The manufacturing documentation and standards for wire mesh and perforated sheet sieves show that the active sieving surface depends on the size of the mesh holes, construction type and shape.

The "pragma" method proposes the determination of the sieve's active surface as total sieve surface multiplied by a coefficient "*k*" depending on the size of mesh holes, construction type and shape.

$$A_a = A \cdot k \tag{3}$$

where:

A_a – the active surface of the sieve, in m^2;

A – the total surface of the sieve, in m^2;

k – calculation coefficient of the active surface.

The variation of the "*k*" coefficient for sieve's wire mesh – square holes and perforated metallic sheet – square and round holes, is shown in Figure 1.

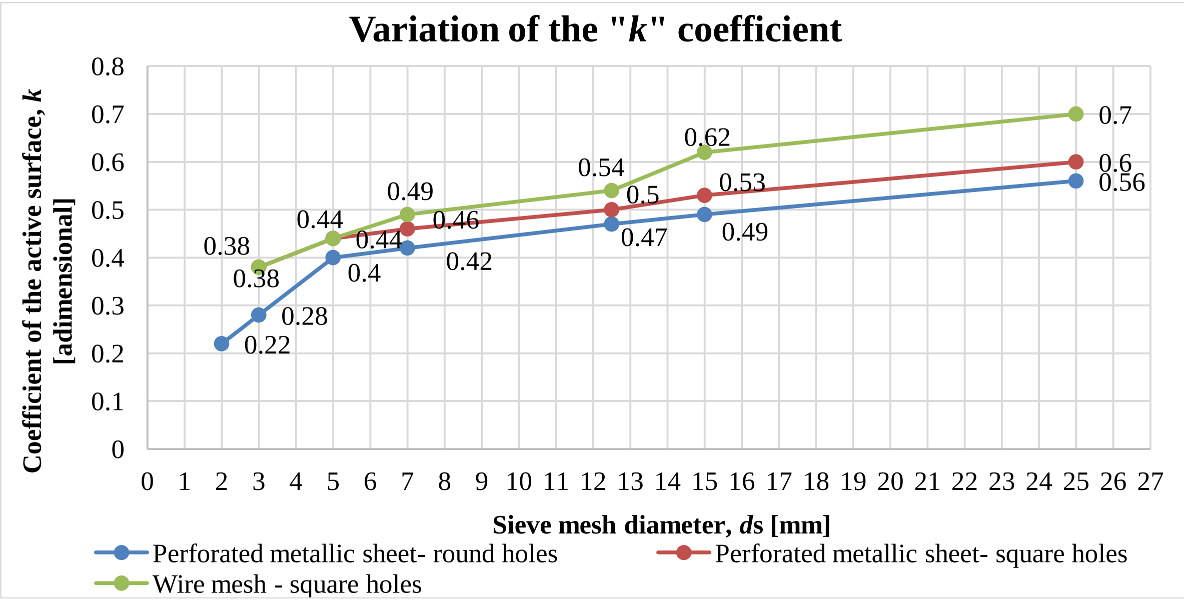

Figure 1. "*k*" coefficient variation diagram for wire mesh sieve and perforated metallic sheet - "pragma" method

3.2. Sieve specific productivity (q)

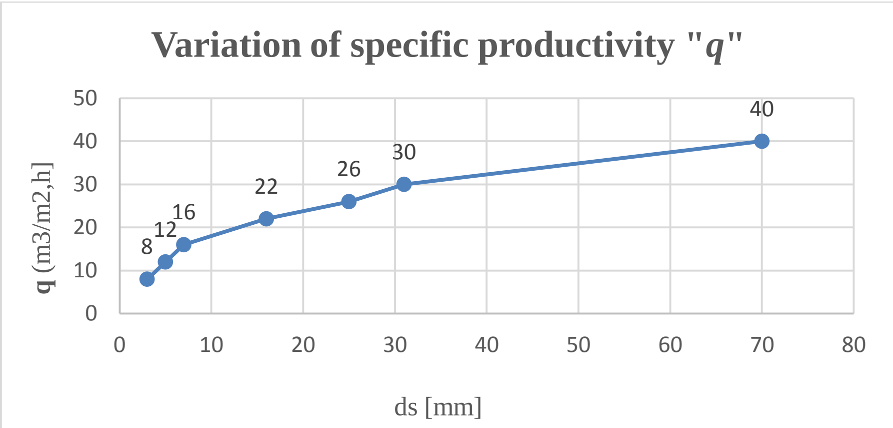

Figure 2. Variation curve of specific productivity *q*, depending on the mesh holes' size d_s – "pragma" method

3.3. The coefficient "a" taking into account the "passing part" (d <d_s) contained in the feeding material

The Rexnord and Blanc [1] curves, being closed to each other, were taken as ~~a~~ basis in plotting the medium values of "*a*" coefficient (figure 3) proposed by "pragma" method.

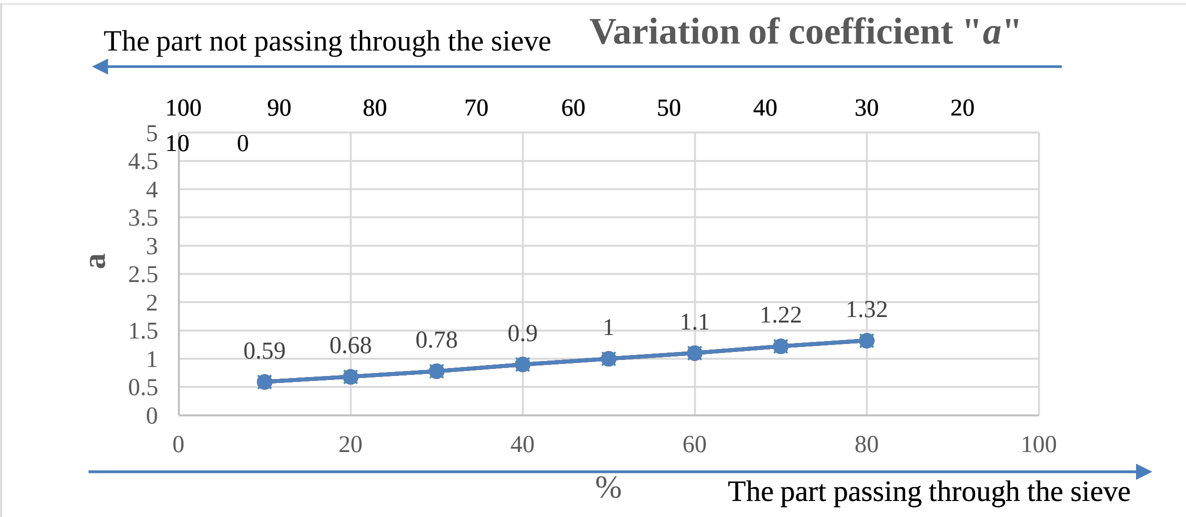

Figure 3. The variation curve of the "*a*" influence coefficient of the material percentage content with $d < d_s$ - "pragma" method

To notice that the standard value a = 1,00 corresponds to the content of "part passing through the sieve" material, respectively "part not passing through the sieve" at p_1 = 50%.

3.4. The coefficient "b" taking into account the part "passing through the sieve" with d <1/2 d_s of the feeding material

The average values of the "*b*" coefficient, proposed to be used use in the sieve productivity calculus according to "pragma" method, are shown in figure 4.

To be noticed that the standard value b = 1,0 corresponds to the content of "passing through" material at p_2 = 40% for d <1/2 d_s.

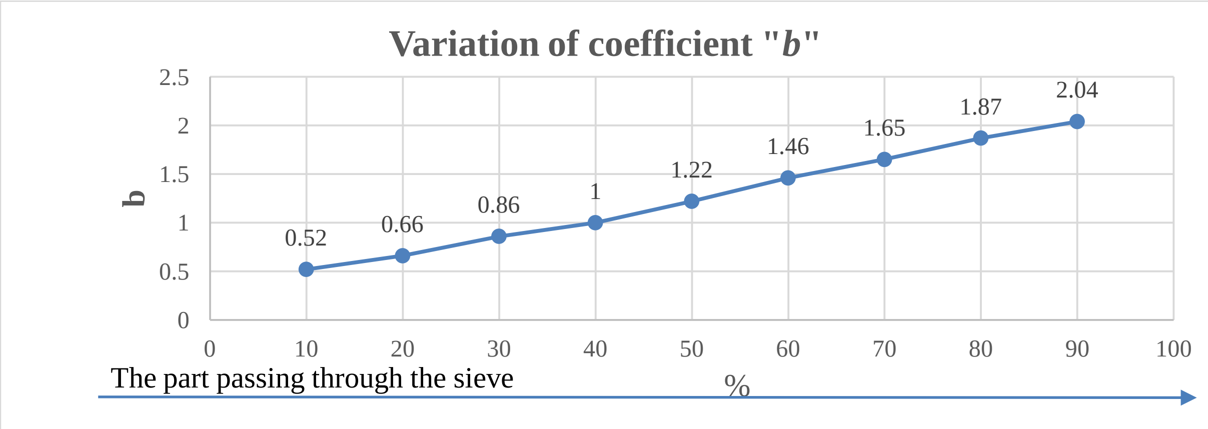

Figure 4. The variation curve of the influence coefficient "*b*" of the material percentage content with d < 1/2 d_s – "pragma" method

3.5. The influence coefficient "c" of dry or wet screening process

In order to calculate the screen's productivity, the author recommends the diagram of figure 5, built mainly according to Rexnord USA data [4], [8], [9].

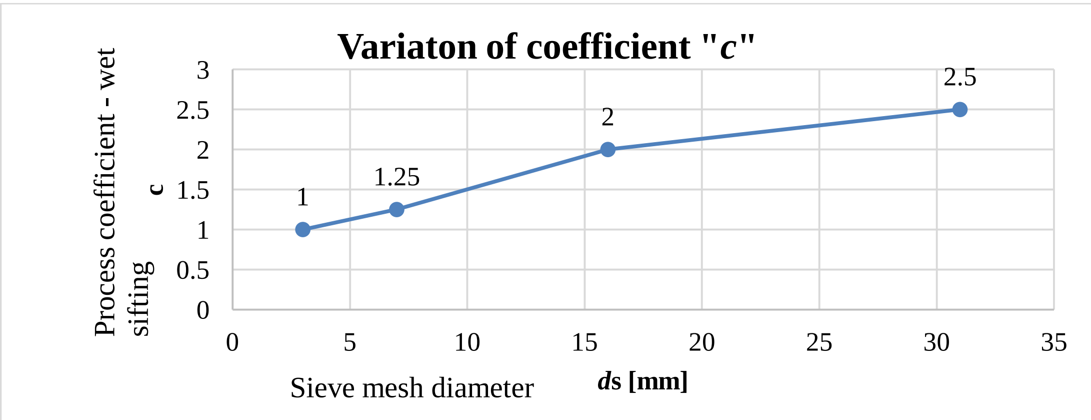

Figure 5. Influence coefficient diagram "*c*" of the wet sieving process– "pragma" method

It results that screening granular material larger than 31 mm using the wet process does not influence the amount of the sieve's productivity.

3.6. The influence coefficient "d" of granule's shape

Figure 6 shows the values of the influence coefficient "*d*" of granule's shape.

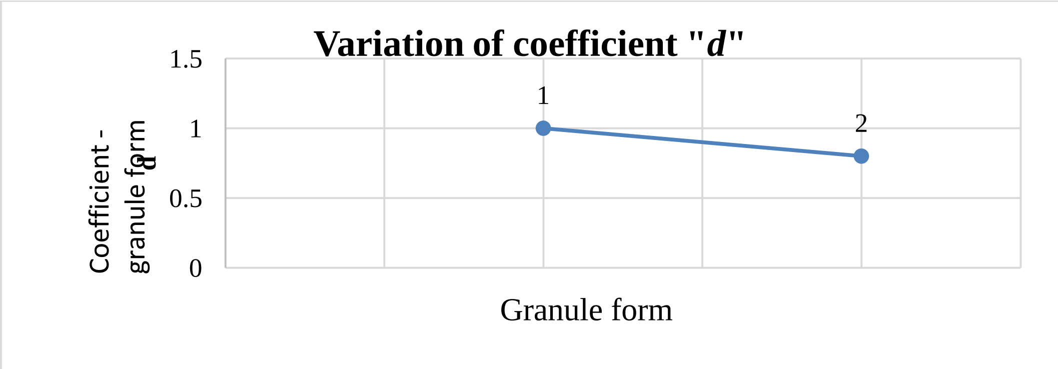

Figure 6. Influence coefficient "*d*" diagram of granule's shape – "pragma" method

It results that sieving productivity in the case of cornering stones (position 2 on the graph) is 20% lower than in the case of rounded stone (position 1 of the graph). The chart was based on Bauman, Polkin, Blanc, Ilievici's data [1].

3.7. The influence coefficient "e" of the sifting efficiency

When preparing high quality concrete, the standards require a 95% screening efficiency.

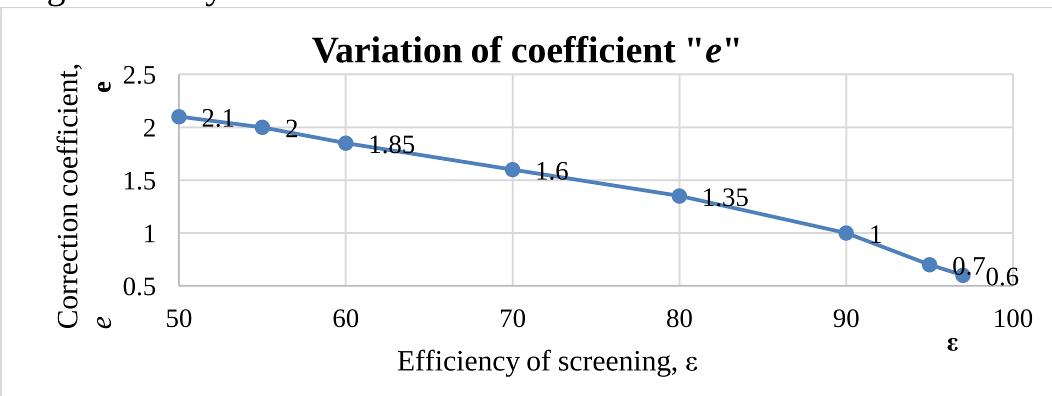

Figure 7. The variation curve of the influence coefficient "*e*" of the sieving efficiency – "pragma" method

3.8. The influence coefficient "f" of material's humidity

The values proposed for calculating productivity using "pragma" method are those indicated by Blanc (Figure 8).

The material's free humidity, ranging between 5 to 30%, causes agglomeration of small granules and their sticking to the sieve's surface leading to clogging of the mesh.

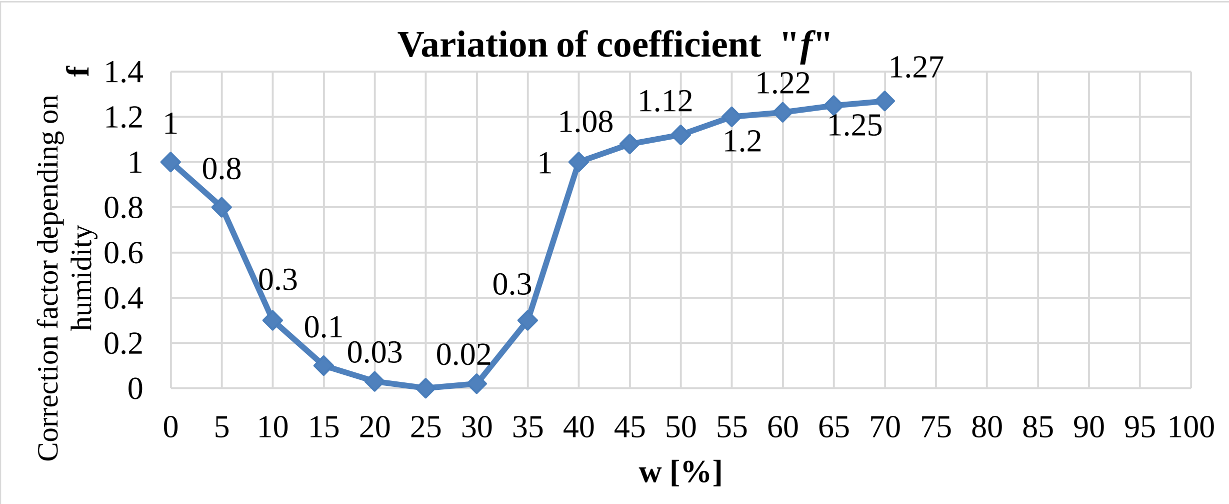

Figure 8. The variation curve of the influence factor "*f*" of material's moisture for meshes' small holes– "pragma" method

At 30…70% humidity, the mobility of particles increases again and the screening conditions improve significantly.

3.9. The influence coefficient "*g*" of the sieve's inclination angle

To calculate the screen's productivity –"pragma" method, the values of the influence coefficient "g" of the sieve's inclination angle are proposed, according to curve in figure 9. [1], [7]

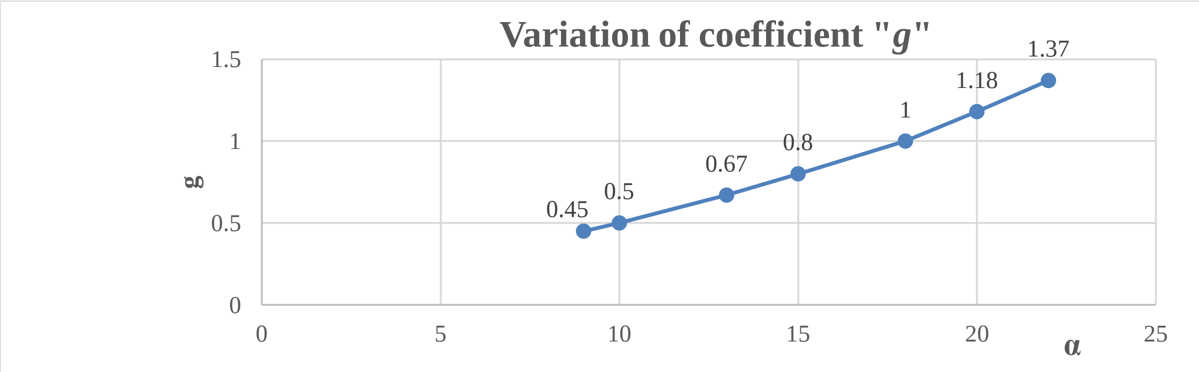

Figure 9. The variation curve of the influence coefficient "g" of the sieve's inclination angle *α*

3.10. The influence coefficient "h" of the sieve's serial order number in the vibrating screen's mobile frame package

To calculate the screen's productivity "pragma" method, the variation curve of coefficient "h" is proposed in figure 10.

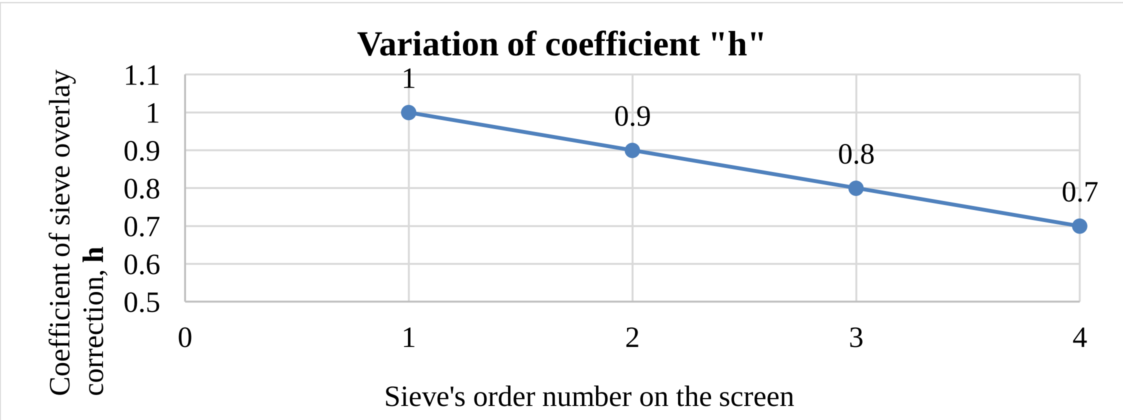

Figure 10. The variation curve of the sieve's order number coefficient "*h*" – "pragma" method

The curve is based on Rexnord data [4] for all four sieves.

In case of a two sieve screen, Blanc shows the same values for the correction coefficient.

To calculate the vibrating screen's productivity, relationship (4), determined by the "pragma" method, is recommended.

$$Q = k \cdot A \cdot q \cdot a \cdot b \cdot c \cdot d \cdot e \cdot f \cdot g \cdot h \quad (4)$$

Major advantages in using "pragma" method to determine the vibrating screen's productivity: unification of the calculation methodology and the significance of the coefficients which were used; ordering the factors framing in the computing product according to the sieving physical phenomenon; graphical presentation of all coefficients allowing fast and accurate reading.

4. PRAGMA METHOD – EXPERIMENTAL MEASUREMENTS PERFORMED ON A 7.5 M² BIMASS VIBRATING SCREEN, MOUNTED IN A PILOT STATION – PĂTROAIA GRAVEL PIT ON ARGEŞ RIVER

The feeding material used was 0 ... 70 mm fraction from the main gravel pit station.

The screen, having the total surface A=7,5 m^2, was provided with two sieves: 7 mm and 16 mm, thus obtaining three types of sorts: 0.2 ... 7 mm; 7…16 mm; 16 ... 70 mm.

Three methods were used to determine the hourly productivity of vibrating screens:

- Pragma method-based on the screen’s specific productivity;
- method of measuring in time the feeding material deposits and screened aggregates;
- method based on the displacement velocity of the material granules on the screen’s surface.

In the case of the Pragma method, the numerical data extracted from the variation graphs of the component factors of the formula were chosen (table 1) by taking into account the concrete functioning conditions of the bi-mass horizontal vibrating screen operating in resonance and the screened aggregate grading – percentage of part passing or not through each sieve apart/independently.

Table 1. Component factors of the formula

Sieve	k	$(A_a)^*$	q	a	b	c	d	e	f	g	h	Q (m^3/h)
16 mm	0.65	6.375	22	0.98	0.88	1.25	1.0	0.7	0.6	1.3	1.0	80.5
7 mm	0.5	5.625	16	0.88	0.76	2	1.0	0.7	0.8	1.3	0.9	78.6

A_a – the active surface of the sieve, in m^2; $A_a = A \cdot k$

The comparative analysis of the results obtained by the three methods is presented in the table below.

Table 2. Analysis of results obtained by the three methods

Crt. No.	Type of sort	Measurement method		
		Deposits (m^3/h)	The material displacement velocity (m^3/h)	Specific productivity - Pragma method (m^3/h)
1	16-70	44.34	40.44	42.90
2	7-16	9.26	13.73	14.65
3	0.2-7	25.00	23.59	22.85
Total on the screen		78.60	77.67	80.40

The calculation of Q in table 2 was experimentally done based on the oversize reject on each sieve apart taking into account the passing through probability, resulting thus the quantity passed through the respective sieve. To mind/note that a 5,3% percentage, representing the weight fraction 0…0,2, is lost being taken away due to washing water flow.

According to the data presented in the table, the results obtained are approximate and justified by the variation of some factors even during the measurements done. Variations in total on the sieve and in sorts are due to wrong fractions in the material.

In the passage and refusal calculation, the theoretical weight of different fractions was used towards the total quantity of feeding material.

The hourly productivity of the screen by Pragma method proves to be closed to the real sieving values, being more simplistic and easy to apply.

The differences resulted can be explained by the material's large fraction (16…70) contamination with about 4 m^3 fine material.

5. CONCLUSIONS

The article focuses on the productivity study of vibrating screens used in sorting mineral aggregates, turned to account in roads, highways or access ways construction hereby:

- *theoretically* – according to relations in the specialized literature dedicated to the field;
- *theoretically* – according to the original Pragma relationship proposed by the author;
- *experimentally* – according to experimental measurements done in a pilot station, using three different methods.

The study and results obtained by experimental determinations done in situ confirm the validity and the correctness of Pragma's simplified pragmatic formula proposed. The formula is the calculation basis in determining the equipment profitability from the productivity and production costs points of view. It is everywhere used in any type of gravel pit.

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