ANALYSIS OF THE OBTAINED STATISTICAL MEASUREMENT VALUES OF SEISMICAL BLASTING TREMORS

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Abstract

The paper provided some measurements carried out by seismic shocks caused when carrying out primary mining and appropriate parameters in terms of safety of the surrounding buildings. In this paper one of the goals is to analyze and define the criteria for assessment of shocks in terms of appropriate application for methods of mining, safety distances, especially for different mining conditions.

With statistical analyses of the values we can determine the criteria for soil oscillation law depending on reduced distance, seismic intensity of the protected facilities etc.

This gets a final conclusion on the assessment of shocks depending of the parameters of mining, safety distances when performing the various methods of blasting and the formation of tabular presentation of evaluation criteria for the shocks and safety distances.

The calculation or dimensioning of parameters blasting are the step in setting the technique of drilling and blasting which later, in local conditions, can be modified and yield the best possible results.

KEYWORDS: *Seismic tremors, Criterion, Blasting, Safe distance*

1. INTRODUCTION

With the tightening of environmental requirements for environmental protection and respect for private property, the application of blasting is limited in the strict framework of regulations. Therefore there is a need for control, measurement and regulation (as possible) the oscillations of the ground and seismic shocks caused by these oscillations occurred as the effect of sapping the blast.

In order to evaluate and control the effects of seismic blasting, it is necessary to determine the soil oscillation law in direction and ground distance to the appropriate place or object that are to be protected.

One of the most commonly used theories and equations given by Professor Sadovski that define the law to change the speed of soil particles, depending on distance, quantity and tipe of explosives, blasting conditions and structural - geological characteristics of the surrounding rocks.

While determining the soil oscillation law depending on reduced distance, it is necessary, previously, to establish to what level of seismic intensity the protected facilities can be exposed, taking into account their dimensions and quality of material, construction value, the level of resistance to seismic shock wave effects etc. to prevent their damaging on that occasion.

Seismic and other effects that are caused by the detonation of a quantity of explosives are dependent on many factors, of which the most important among them are: the method of blasting, the distance from the place, the quantity of explosives, the type of explosives, the method of initiating of series, explosives construction in the drillholes, physical-mechanical characteristics of rocks, structural features of rocks etc.

2.0 ANALYSIS CRITERIA

2.1 Law oscillation of the ground

The analysis and correlation between the size of the seismic tremors i.e. the speed of oscillation and the basic parameters that have the greatest impact on the effects of seismic tremors. In the world are used and developed several mathematical models.

The most commonly used model is the theory of prof. Sadovski which is expressed through a mathematical formula (1) that reflects the speed of oscillation depending on the distance, the amount of explosives and the manner of execution of blasting.

The dependence of the speed of oscillation of the ground is obtained based on the calculated peak velocities of oscillations of the particles of soil (Vmax), distance from the blasting location of the measuring instrument (r), and the amount of explosive that is used in blasting series. This speed is expressed in the following form:

$$V = K_v \cdot R^{-n} \quad , \quad [\text{mm/s}] \qquad [1]$$

where is:

V – speed of oscillation of the ground , [mm/s],

K_v – coefficient which is dependent of the characteristics of the rocks and blasting conditions and are determined by field measurements,

n – exponent which is dependent on the characteristics of the rocks and mining conditions and are determined by field measurements

R – reduced distance, $R = \frac{r}{\sqrt[3]{Q}}$, [m]

Where is:

r - distance from the blasting site to the site of measurement, [m]

Q - amount of explosives used, [kg]

In the equation (1) appear two parameters (Kv) and (n), which should determine the specific work environment and conditions of blasting. For their definition are used method of least squares which equation (1) gets the following form:(with logarithm)

$$\log v = \log K_v - n\log R \quad [2]$$

With the introduction of substitute: v = y; K_v = **a**; R = x; n = **b**;

gets:

$$\log a - b\log x = \log y \quad [3]$$

The system of equations for the parameters (a) and (b) in this case is:

$$\begin{aligned} &n\log a - b\sum_{i=1}^{N}\log x_i = \sum_{i=1}^{N}\log y_i \\ &(\log a)\sum_{i=1}^{N}\log x_i - b\sum_{i=1}^{N}(\log x_i)^2 = \sum_{i=1}^{N}\log x_i \cdot \log y_i \end{aligned} \quad [4]$$

каде: N – number of measurement (measuring points).

Important properties of the law of oscillation of the ground depending on **Reduced slow distance** that the change of reduced distance (R), with reducing or by its increase by only 1%, the value for the speed of oscillation in proportion to the ground opposite applies i.e. increases or decreases by n%.

In brief, the aforementioned formula prof. Sadovski means the total amount of explosive that is used in the blasting series.

The analysis of this parameter used provisions of the "Law for the Protection of blastings substances" (Official Gazette br.4/78) and "Regulation of technical norms for handling explosives and blasting in mining" (Official Gazette of SFRY no. 26/88).

In this regulation in Article 110 stated that under both individually considered initiating ignition of a quantity of explosives which initiated simultaneously or during deceleration (retardation detonation) between intervals starting at millisecond initiation is no greater than 100ms (milliseconds).

In measuring these oscillations (in such initiation) the appropriate measurement points, the obtained velosigrams (curves) of instruments, it is impossible to determine which pick the curve that shows the components of the oscillation corresponds to some interval or slowing in the certain amount of explosives given slowing because existing modern instruments those individual pulses (for now) cannot separate.

For these reasons the calculations of oscillations and distances sapping adopted as values total quantity of explosives as it is initiated simultaneously.

This calculation method however keep in mind that the amount of explosives is separated by intervals and the values obtained are quite reliable and strict with the possibility of their (unintentionally) and increase reliability in terms of security and safety distances to surrounding objects.

2.2 Defining the statistical criteria

Assessment and definition of criteria for the level of security when establishing correlation equations and ratios are used mathematical- statistical methods. The assessment of the degree of reliability of these relations are calculated based on the results obtained by examining i.e. practical field measurements of certain blasting series. These mathematical methods for processing the results depending on the data, the method of interpretation and the required accuracy and reliability, allow defining the changes induced in the ground and the general law of behavior change investigated.

Some of the basic statistical parameters used to analyze and define the individual criteria are:

- Arithmetic mean $(\bar{x})$

which is expressed as:

$$\bar{x} = \frac{x_1 + x_2 + x_3 + ... + x_N}{N} = \frac{\sum x_i}{N} \quad [5]$$

Where is: x_1, x_2...x_N - values of the results of certain measurements (trials)

N - number of results (sample)

- Intermediate arithmetic deviation (σ_0)

$$\sigma_0 = \frac{\sum |x_i - \bar{x}|}{N} \quad [6]$$

Where is:

$|x_i - \bar{x}|$ - absolute magnitude of the deviation

- Variance (σ^2)

$$\sigma^2 = \frac{\sum (x_i - \bar{x})^2}{N} = \frac{1}{N}\Sigma x_i^2 - \bar{x}^2 \quad [7]$$

2.2.1 Criteria for checking mathematical dependencies

To eliminate subjective decisions and impacts analysis of the dependencies and the resulting mathematical shape of the curve y = y (x), which is approximated values obtained in the survey, use the linear correlation coefficient:

$$k = \frac{\mu_{11}}{\sigma_x \cdot \sigma_y} = \frac{\Sigma(x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\Sigma(x_i - \bar{x})^2 \cdot \Sigma(y_i - \bar{y})^2}}, \quad [8]$$

This route is used if the question assumed a linear functional relationship between $\mathbf{x_i}$ and $\mathbf{y_i}$, as assessment of the degree of linear relationship between two dependencies.
If dependence between $\mathbf{x_i}$ and $\mathbf{y_i}$, is with curves are used relation for the index of this curve line dependence:

$$\rho = \sqrt{1 - \frac{\Sigma(y_i - y(x_i))^2}{\Sigma(y_i - \bar{y})^2}} \qquad [9]$$

The assessment of the degree of association between two variables is given by the following relations given descriptive:

0,0 <ρ <0,2, no connection or very weak
0,2 <ρ <0,4, weak links,
0,4 <ρ <0,7, significant connection,
0,7 <ρ <1,0, strong or very strong interconnection,

These relations also apply to the absolute value of the coefficient of linear correlation **k.**

To assess the degree of certainty (reliability) of the selected curve in mathematical statistics are used criterion called **„3S"** :

$$S = \sqrt{\frac{\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2 + \ldots + \varepsilon_N^2}{N}} \qquad [10]$$

Where is:

$\mathbf{e_1}, \mathbf{e_2}, \ldots$.. squares of the difference between the measurement results and calculated by the method of least squares to established addictions $\mathbf{x_i}$ и $\mathbf{y_i}$.

According to this criterion for assessing the degree of certainty or reliability of the resulting functional dependency, use and apply the following ratios:

- **if** $|\varepsilon_{max}| > 3S$, the resulting functional dependency is rejected as unfavorable
- **if** $|\varepsilon_{max}| < 3S$, functional dependency (connection) is accepted as good.

This criterion is used in cases when the number of measurements is $N \geq 10^{th}$

2.3 Results of measurement

Measurements of ground oscillations are performed on Open Pit Bucim, the mine accident defense series, preparation and blasted by standard procedures. When it is used 7 measuring instruments placed at different distances from Blasting series S-35. Values read the parameters and derived values are presented in Table 1 and it is used in the form [1].

Table 1. Calculated values of maximum speeds of oscillation ground and reduced distances for separate measuring points

Blasting series	Measuring points, MM / elevation of the ground	Distance from blasting series to measuring point , m	Maximum speed of the oscillation components, mm/s			Maximum resultant speed of oscillation, mm/s	Calculated reduced distance, R, m
			V_V	V_L	V_T		
S-35	MM-1/ 659,43	95	27,66	19,37	8,414	***34,809***	***5,63***
	MM-2/ 660,42	165	10,06	12,23	9,465	***18,455***	***9,78***
	MM-3/ 659,71	245	5,026	5,576	3,070	***8,110***	***14,52***
	MM-4/ 659,30	297	2,778	2,403	2,088	***4,225***	***17,6***
	MM-5/ 658,88	452	1,178	1,956	2,277	***3,224***	***26,80***
	MM-6/ 641,05	637	0,539	1,251	1,230	***1,835***	***37,76***
	MM-7/ 640,25	665	0,503	0,709	1,244	***1,517***	***39,42***

2.4 Statistical analysis of the obtained values

The processing of the data obtained through field trials are used methods of mathematical statistics.
Their application and calculation allows defining the changes and laws - relations that are used in the calculations and their behavior in terms of theoretical parameters.

Table 2. Parameters obtained from measurements and calculated derived values

Number of the measuring point	Reduced distance R, (m)	Registered speeds of oscillations, V_r, (cm/s)	Calculated speed of oscillations, V_{pr}, (cm/s)	$V_r - V_{pr}$	$(V_r - V_{pr})^2$
1	5,63	28,57	34,8	-6,23	38,81
2	9,78	13,32	18,45	-5,13	26,32
3	14,52	6,7	8,1	-1,4	1,96
4	17,6	3,2	4,2	-1	1
5	26,8	2,8	3,2	-0,4	0,16
6	37,76	1,69	1,8	-0,11	0,0121
7	39,42	1,33	1,5	-0,17	0,0289
	R_{sr}=21,64	Σ=57,61	$\bar{y}$ = 10,29	$\lvert 14,44 \rvert_{sr}$	

In Table 2 are obtained the following values for the parameters which are analyzed statistically:

- - Arithmetic mean $\left(\bar{x}\right)$:

$$\bar{x} = \frac{x_1 + x_2 + x_3 + ... + x_N}{N} = \frac{\sum x_i}{N} = \frac{57,61}{7} = 8,23 \qquad [11]$$

- Intermediate arithmetic deviation**:** $\left(\sigma_0\right)$

$$\sigma_0 = \frac{\sum\left|x_i - \bar{x}\right|}{N} = \frac{345,66}{7} = 49,38 \qquad [12]$$

- variance **:**

$$\sigma^2 = \frac{\sum\left(x_i - \bar{x}\right)^2}{N} = \frac{1}{N}\Sigma x_i^2 - \bar{x}^2 = 17067,7 \qquad [13]$$

- Criterion "3S":

$$S = \sqrt{\frac{\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2 + ... + \varepsilon_N^2}{N}} = \sqrt{\frac{38,81^2 + 26,32^2 + 1,96 \ + 1^2 + 0,16^2 + 0,0121^2 + 0,0289^2}{7}}$$

S = 17,74 $\Rightarrow$ 3S = 3 · 17,74 = **53,23** [14]

|εmax| = 38,81

In this case are given relation:

38,81 < 53,23

The resulting relationship that reflects the functional relationship between the dependent - changing can be accepted **as good.**

- Index of curve line dependence:

$$\rho = \sqrt{1 - \frac{\Sigma\left(y_i - y\left(x_i\right)\right)^2}{\Sigma\left(y_i - \bar{y}\right)^2}} = \rho \ \mathbf{= 0,\ 875} \qquad [15]$$

Based on the obtained value can be concluded that the two variables, reduced distance and speed of the oscillations of the ground, there is a very close relationship and strong relationship and this value has a high practical relevance (according to the empirical rule to evaluate the strength of ties, **0, 7 <ρ <1,0,** which means strong or very strong interconnection).

Also, analyzing the criteria for blasting with statistical analysis, derived values are express level of connections and correlations between predefined parameters which are analyzed and their interdependencies.

CONCLUSION

Based on these practical and scientific research and calculations derived directly or combined, it can be concluded
that the performance of massive blasting of any surface blasting, the application of the oscillation of the ground, and application interdependencies and correlations obtained, practically allows the derivation of mass blasting reduce negative effects primarily in terms of seismic impacts.

In this way you can increase the efficiency of blasting, to protect the surrounding accompanying buildings from these impacts and in particular, to predict and pre-ensure all the surrounding buildings, machinery and people with regard to the action of seismic waves and tremors caused from blasting.

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