



## SEISMIC EFFECTS ON THE ENVIRONMENT RELATED TO BLASTING SERIES

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### ABSTRACT

Blasted series performed on surface and underground mines, cause different effects on the environment in terms of intensity of the shocks, air shocks and pieces of blasted rock mass.

These negative effects can cause harmful effects on humans and buildings. For protection from the harmful effects introduced standards, criteria and restrictions on the intensity of these effects, especially the allowable intensity of tremors on the ground to some distance from the blasting series.

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

**Keywords:** blasting, oscillations, seismic effects, safety distance

### 1. INTRODUCTION

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 drill holes, physical-mechanical characteristics of rocks, structural features of rocks etc.

The energy generated by the explosion of some quantity of explosives, have broken and breaking rocks, cracks form and various deformations in the surrounding rocks. Around of blasting place and outlying areas the generate detonated wave, causing elastic deformation, concentrically arranged around the mining area.

These (seismic) waves passing through a rocky massif cause oscillations of the particles from the ground and surrounding buildings. Blasted series performed on surface and underground mines, cause different effects on the environment in terms of intensity of the shocks, air shocks and pieces of blasted rock mass.

### 2.0 THEORETICAL ANALYSIS OF CRITERIA

When analyzing and we make correlation between the magnitude of seismic shocks, i.e. the speed of oscillation we have on regard the basic parameters that have the greatest impact on the effects of seismic tremors which are: quantity of explosives, physical - mechanical characteristics of the rock, and the distance from the Blasting series to the appropriate measurement point, In the world is used and developed several mathematical models.

One of the most commonly used model is the theory of prof. Sadovski which is expressed through mathematical form (1) that reflects the speed of oscillation depending on the distance, amount of explosives and the manner of execution of mining. Thus defined law, gives us the opportunity to determine seismic effects of mining in the direction of an object or township, and the use and analyze the relationships between criteria and the speed of oscillation of the ground and the consequences that may reflect the appropriate facilities and certainly depending on the reduced distance.

The dependence of the speed of oscillation of the ground is obtained based on the calculated values of maximum speeds of oscillations of the particles of soil ( $V_{max}$ ), the distance from the blasting site to the located measuring instrument ( $r$ ), and the amount of explosive that is used in blasting series. This speed is expressed in the following form:

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



where:

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

Kv - coefficient which is dependent on the characteristics of the rocks and mining conditions are determined by field measurements

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

R - reduced distance, [m]

where:

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

Q - quantity 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.

The important feature of the law of oscillation of the ground depending on the distance is reduced as the change of the reduced distance (R), or by reducing its increase by only 1%, the value for the speed of oscillation of the ground inversely relates, i.e. increases or decreases by n%.

The value of the quantity of explosives is also for additional analyzes that could exceed the volume of this paper.

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

Under individually initiating ignition of a quantity of explosives which initiated simultaneously or during deceleration (retardation detonation) between intervals of initiating ignition in milliseconds is non greater than 100ms (milliseconds).

Where are initiated by detonating fuse without applying entertainers of detonation are considered simultaneously initiating the incremental blast charges. By applying Nonel-initiating systems it is possible to obtain larger intervals of initiating 100ms in the third or fourth row of ignition.

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

In Western countries and the United States in connection with this methodology is applied following form to calculate the reduced distance:

$$R = \frac{r}{\sqrt{Q_i}}, [m] \quad (2)$$

where:  $Q_i$  - the maximum amount of explosives which simultaneously initiate in the 1 (one) interval [kg]

According to this relation (definition) means simultaneously initiating amount of explosive charge with between two successive intervals (initiate) a sufficient interval that prevents overlapping, colliding and overrunning of the detonation waves of different intervals of initiating.

The U.S. regulations that define this matter for minimum interval between two separate initiation of 8ms.

Based on the law of oscillation of the ground, the calculations made by the presented methodology can construct approximate curve that will correlate the results depending on the amount of explosives, the distance, the working environment and conditions of blasting. Values thus obtained (graphical and analytical) allow to predict in advance of any blasting speeds and oscillation of the ground and from there to the extent of the seismic intensity of the shocks that will be caused from blasting series. In this way, in terms of blasting seismically action, is brought under control, it also means and giving opportunities to shocks caused not only to control, but also to plan ahead and take it and appropriate protective measures.

### 3.0 ANALYSIS OF THE RESULTS

Seismic effects of blasting can be measured in different ways and at different stages of exploration and exploitation of the mine.



These measurements presented in this paper were conducted in the regular phase - normal operation and may be of interest because rare of the mine near present settlements around the surface mine and near important buildings such as stationary primary crushing plant, mechanical workshop, gas pump etc..

Measurement points for the individual series are set according to location of blast series and objects that are located around and in the surface mine.

In view of the results obtained from measurements and analysis and processing equations are derived under the oscillation of the ground and working environment and methods of blasting. According to these relations are set correlations of functional dependency degree of connectivity and interdependence as well as safety distances in terms of seismic tremors, detonation weave etc.

### 3.1 Analysis of Blasting series

The blasting some of series is performed on floor 660/675 (gneiss) with the following drilling - blasting parameters (Fig. 1):

**Number of drill holes. . . 16 (arranged in three rows)**

**Drilling diameter 250 mm**

**Quantity of explosives in drill hole. . . . 300 kg**

**Type of explosives. . . . . AN – FO (Detonit, Radovis, Trayal – corporation, Serbia)**

Trigger explosives of drill holes performed with percussion patrons of amoneks F70 and depth Nonel - detonator U - 500 with length of Nonel U<sub>500</sub> with 21m length.

For this series of blast spent the next explosive devices to connect, charge and initiating:

AN-FO explosives. . . . . 4800 kg

Explosive Amoneks 1. . . . . 30 kg

U -500 (nonel). . . . . 16 numbers

SL 67 (nonel). . . . . 8 numbers

SI 0 (nonel). . . . . number 1

K.. no. 8th . . . . . number 1

Fuse . . . . . 1 Number (1,5 m length)

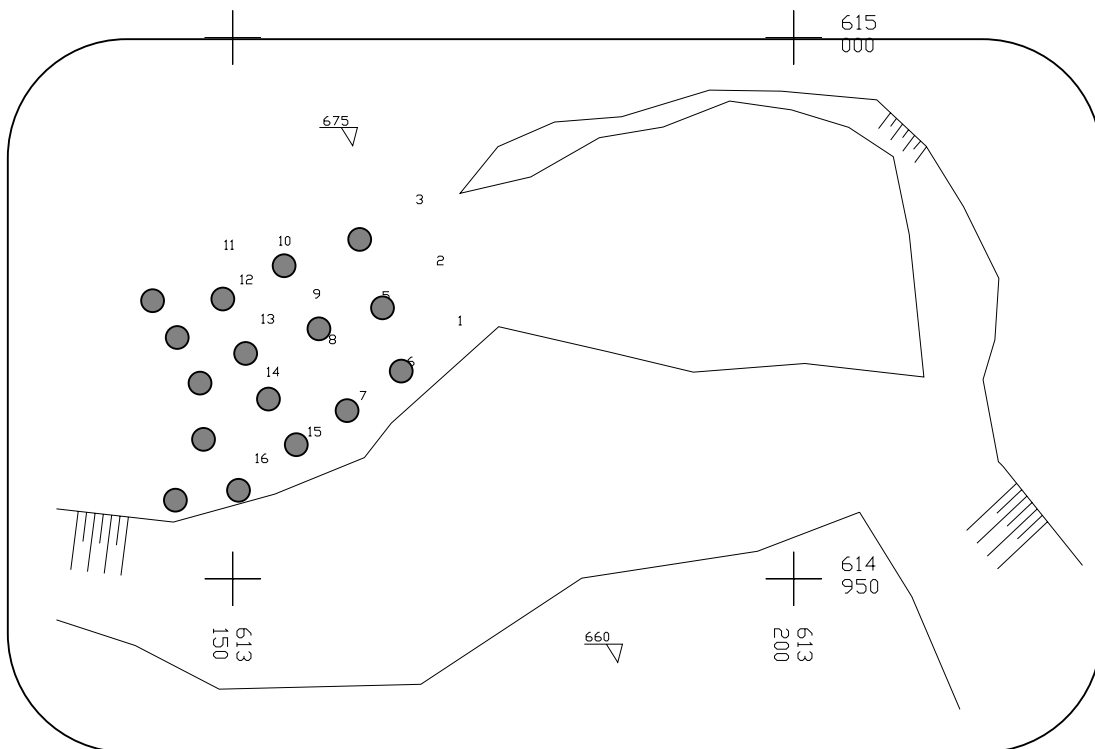


Figure 1. Scheme of blasting series with a design on holes



Registering seismic tremors is made in 7 (seven) measuring points (MM-1, MM-2, MM-3, MM-4 ....) with seven instruments "Vibrlok", from Sweden, which were located at appropriate places in the open pit and object - primary crushing near blasting series.

Blasting plan and schedule a series of blast with drill holes are given in the fig. 1.

### 3.2 Obtained results of measurements and analysis

Because our regulations and standards such matters and professional issues not regulated, assessing the intensity of the tremors caused by blasting solid rock masses and their impact on buildings and facilities of the trench (in this case - primary crushing) is performed according to criteria are selected from the global classification chosen by the authors. These criteria were selected:

- Criteria on a scale IFZ Academy of Sciences, Russia
- Criterion on DIN 4150 (Germany)
- Criterion according to Russian norms for mining and construction sites

According to the value and scale of IFZ Academy of Sciences of Russia, the object belongs to class III of industrial facilities with relatively small size, the amount of which does not pass three floors. The building is partly AB and construction steel structure.

According to the measured results of MM -1 have speed oscillations of 34,8 mm / s which means that if the object is the distance where the MM-1 would be the VI degree damage (according to the criterion of IFZA , 30 to 60 mm / s), i.e. would have been fine cracks in plaster, damage to places that previously had no initial deformations in concrete and partition walls. According to this criterion permissible speed oscillations of the ground is not satisfactory and above the limit of allowable values. For this type of objects at a distance from the blasting site (MM -1), the permissible speed oscillations of the ground equals 20mm/s. According to the criterion DIN (Germany), the object is in the second category and ensuing speed oscillations of the ground for this measuring point MM-1 is not satisfactory and above the limit of allowable values.

According to Russian norms for assessment of damages object is classified as first-class objects that are placed in machines and plants with larger dimensions and weight control - measuring devices and present static and dynamic shots. According to this criterion in terms of MM-1, the speed and frequency of oscillations of the measuring point, does not meet these measured values are above permissible. According to these standards the maximum permissible speed of oscillations in any direction shall not exceed 1 mm/s. In this case measured in max 27,66 mm/s and min 8,4 mm/s.

The definition of law oscillation of the ground used the values of Table 1 and the form (1). Using the theory of least squares are form a table number 1<sup>th</sup>.

From the values in Table 1 and based on the theory of least squares, can be expressed law oscillation of particles of soil in function of reduced distance and the conditions under which blasting is carried out.

According to the form (1) and the values of tables is obtained:

$$\log v = \log K_v - n \log R$$

With the introduction of substitute:  $v = y$ ;  $K_v = a$ ;  $R = x$ ;  $n = b$ ;  
is obtained:  $\log a - b \log x = \log y$

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

$$n \log a - b \sum_{i=1}^N \log x_i = \sum_{i=1}^N \log y_i$$

$$(\log a) \sum_{i=1}^N \log x_i - b \sum_{i=1}^N (\log x_i)^2 = \sum_{i=1}^N \log x_i \cdot \log y_i$$



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

Blast series	Measuring place, MM / Elevation of the ground	Distance from blast series to MM - ., m	Max. speed of oscillation with components, mm/s			Resultant of maximum speed of oscillation, mm/s	Calculated reduced distance, R, m
			$V_V$	$V_L$	$V_T$		
<b>S-35</b>	MM-1/ 659,43	<b>95</b>	27,666	19,375	8,414	<b>34,809</b>	<b>5,63</b>
	MM-2/ 660,42	<b>165</b>	10,067	12,233	9,465	<b>18,455</b>	<b>9,78</b>
	MM-3/ 659,71	<b>245</b>	5,026	5,576	3,070	<b>8,110</b>	<b>14,52</b>
	MM-4/ 659,30	<b>297</b>	2,778	2,403	2,088	<b>4,225</b>	<b>17,6</b>
	MM-5/ 658,88	<b>452</b>	1,178	1,956	2,277	<b>3,224</b>	<b>26,80</b>
	MM-6/ 641,05	<b>637</b>	0,539	1,251	1,230	<b>1,835</b>	<b>37,76</b>
	MM-7/ 640,25	<b>665</b>	0,503	0,709	1,244	<b>1,517</b>	<b>39,42</b>

Tab. 2 Calculated values with the theory of least squares

MM - No..	$R_i$	$\log R_i$	$(\log R_i)^2$	$V_{i(max)}$ (cm/s)	$\log V_i$	$\log R_i \log V_i$
MM - 1	<b>5,63</b>	0,75	0,56	<b>3,4809</b>	0,54	0,405
MM - 2	<b>9,78</b>	0,99	0,98	<b>1,8455</b>	0,266	0,263
MM - 3	<b>14,52</b>	1,16	1,35	<b>0,8110</b>	-0,091	0,106
MM - 4	<b>17,6</b>	1,25	1,56	<b>0,4225</b>	-0,374	-0,468
MM - 5	<b>26,80</b>	1,43	2,01	<b>0,3224</b>	-0,492	-0,704
MM - 6	<b>37,76</b>	1,58	2,50	<b>0,1835</b>	-0,736	-1,163
MM - 7	<b>39,42</b>	1,60	2,56	<b>0,1517</b>	-0,819	-1,310
$\Sigma$		<b>8,76</b>	<b>11,52</b>	<b>7,215</b>	<b>-1,7</b>	<b>-2,871</b>



Solving this system we get:

$$n \log a - b \cdot 8,76 = -1,7$$

$$(\log a) \cdot 8,76 - b \cdot 11,52 = -2,871$$

$$\log a = -1,7 + 8,76 b / n$$

$$\log a \cdot 8,76 = 11,52 b - 2,871$$

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$$b = 1,335 ; a = 26,789$$

With the return of replacements are finally gets:

$$V = 26,789 R^{-1,335}, (\text{cm / s}) \quad (3)$$

By getting this exponential relationship between speed oscillations and reduced distance can construct approximate curve that correlates the results and presents the law to change the speed of oscillations depending on the amount of explosives, the distance to the measurement site, the working environment and conditions of blasting. This dependence is presented in graph in Figure 2.

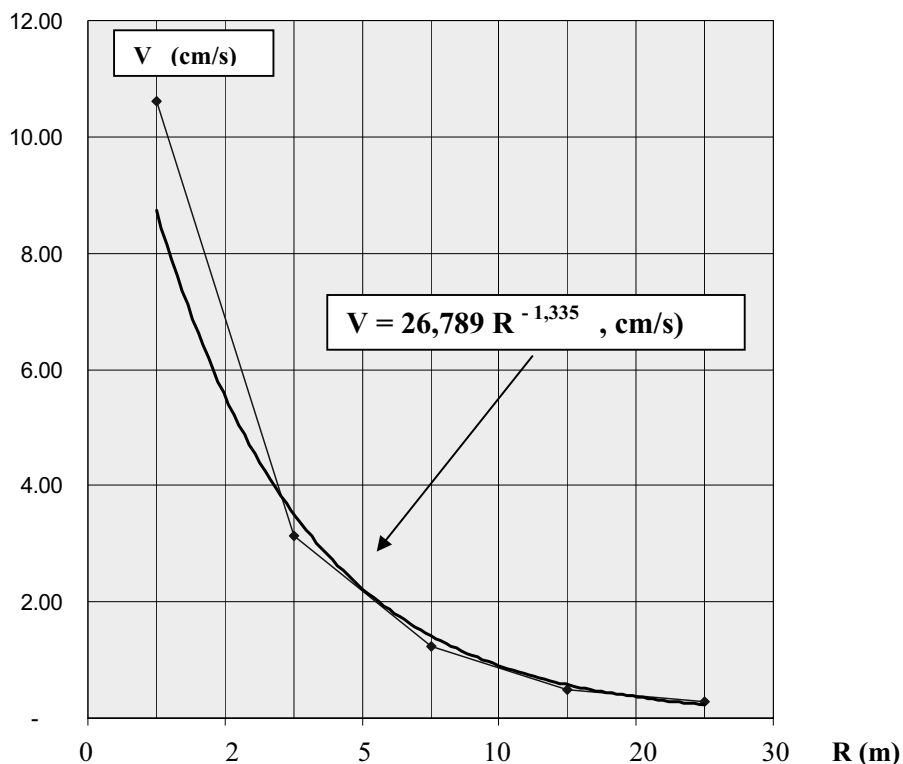


Fig. 2 Graph of exponential (approximate) curve for speed of oscillation of the ground

On both the abscise are given distances R according to Table 2 and in the ordinate values are obtained for the velocity oscillations V. These values are given in Table 3 and are obtained under the form (1) by substituting arbitrary values of the distance R.

#### 4. CONCLUSION

Within the scope of this paper carried out analyzes, calculations and measurements i.e. capture Minsk series with the most advanced instruments for registering oscillations of the ground. In addition to the previously used parameters derived from the same surface mine and used the classical



forms of analysis and presentation of results through analytical and graphical displays. From the measurements and analyzes received more functional dependencies, in terms of the criteria for blasting as follows:

- Speed fluctuations and reduced ground distance, (V - R)

$$V = 26,789 R - 1,335, (\text{cm} / \text{s})$$

Based on these dependencies defined curves are constructed by hands that can be read directly mentioned parameters. These interdependencies obtained can be used practically for every surface mine with similar physical characteristics of rocks and technological and can be used for comparing and analyzing some previously obtained results from other quarries.

This from a scientific point of view as an incentive for research on these seismic effects in laboratory conditions, different models, different rocks with its specifics and also the volume of scientific research can be conducted in terms of the impact of initiation, the method front and Blasting, types of explosives, the depth of the surface mine, explosive charging schedule, the drilling geometry etc.

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