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The assessment of the seismic effect produced by the blasting works in the Măgura Sârbi Brănișca Quarry

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Abstract. In addition to the technical and economic advantages of blasting rocks from open-pit mining, this method of extraction can produce effects with a direct impact in the area near the quarry. Blasting works generates effects such as seismic waves that cause vibrations, rock throws, noise and toxic gases. When their intensity and scope are not systematically evaluated and analysed, blasting works can cause serious consequences for people, civil / industrial buildings, the environment, thus affecting the health of the population and the stability / integrity of the buildings / slopes in the vicinity of the mining operations. The paper presents design / determination methods of areas where explosives may / may not be used in conditions of maximum safety in terms of seismic intensity, thus protecting the population and the civil / industrial objectives in the area of the mining work.

1 Introduction

Methods for assessing the seismic effect are found in the literature and include mathematical expressions that refer to the parameters that characterize seismic waves, such as particle displacement, u (mm); particle velocity, V (cm/s), particle motion acceleration, a (m/s^2), frecvency (Hz) [1].

Also, an immediate and objective assessment can be made by analyzing the measured values of the parameters that characterize the seismic waves, which are designed and classified in different standardized charts, adopted in different countries [2].

Several evaluation standards were applied in the research study, in this paper, the assessment of the seismic effect according to the German Standard DIN4150 and the assessment of the seismic effect according to the Technical Regulations for the Storage, Transport and Use of Explosive Materials, ed. 1997 (currently repealed) were retained for presentation.

The Technical Prescriptions presented the correlation between the degree of seismic intensity according to STAS 3684/71, the velosity of the oscillations of the soil particles and the effects on the structures, in the case of vibration produced by the blasting works [3].

The correlation between the velocity of the oscillations of the soil particles, the degree of seismic intensity and the possible effects on the structures are presented in table 1 [4].

- the allowed oscillation speed is the speed at which it is guaranteed that the previously accepted effects on the construction structures are not exceeded;

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- when performing repeated shooting works, the oscillation speed of the soil particles must be within the values of the allowed speed. Oscillation speeds between the allowed and the limit can be accepted only by specialists, in special situations;
- the limit oscillation velocity will be accepted only in special situations, with a single shot when the technological conditions require shooting with larger quantities of explosives;

Table 1. Correlation between velocity of oscillation of the soil particles and their effects on structures

Seismic intensity categories	Effects induced on the structures	particle velocity v* (cm/s)	
		allowed	limit
IV	Possible damages for village-type buildings, under pressure pipes, gas and petrol wells, mine shaft, and very fragile structures.	0.5	1.0
V	The painting is falling down, small and thin cracks appear in par get in rural and urban buildings. possible minor damages for industrial constructions.	1.1	2.0
VI	Cracks in par get on the walls and pieces of par get start to fall down in rural and urban buildings. also minor damage for industrial constructions.	2.1	4.0
VII	Significant fractures are occurring in the basic elements of the rural buildings, great pieces of parget are falling down in urban buildings and cracks are appearing in industrial constructions. possible damage for pipes jointing system and fixed - mounted equipment.	4.1	8.0
VIII	Major factures occur in the resistance elements of rural and urban buildings. cracks are produced in the resistance elements of industrial constructions.	8.1	16.0
IX	Crumbing (collapse, falling down) of some joint elements of rural and urban buildings can occur. fractures can take place in industrial structures. dams and underground pipes can be damaged.	16.1	32.0
X	Rural buildings are destroyed, urban constructions are seriously damaged and industrial structures are affected seriously by fracturing and dislocation of resistance elements.	32.1	64.0

The evaluation of the seismic effect according to the German Standard DIN4150 is carried out by analyzing the design of the values recorded by the seismographs in the specific graph. Such an example can be seen in Fig. 1, which represent values of the velosity recorded on the three components in the frequency intervals in the graph, are below the level considered non-dangerous for the types of buildings: L1- Office building or factory, L2- Residential building with plastered walls, L3- Historic buildings or other buildings that require special attention [5].

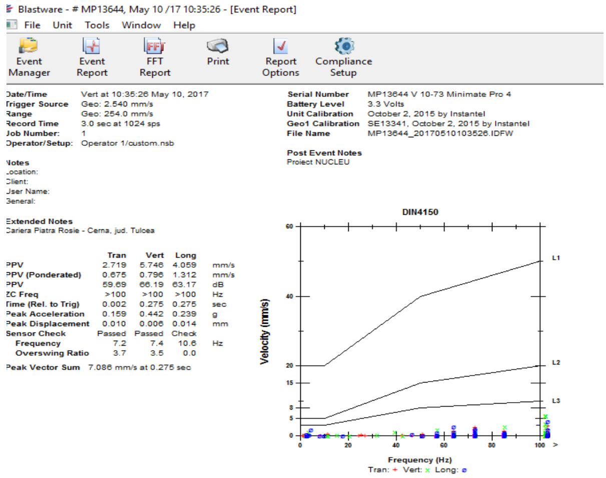

Fig. 1. Graphic representation of the values according to the German standard DIN4150

2 METHODS OF EVALUATION

This paper presents the results obtained in the process of evaluating the seismic effect generated by the blasting works carried out in the Măgura Sârbi-Brănișca Quarry. The main objective is to identify possible risk situations following the process of evaluating the seismic effect generated by the blasting works carried out in the Măgura Sârbi-Brănișca Quarry. By risk situations we mean inadequate values of the parameters that characterize the seismic waves, which would highlight the negative impact of the blasting works carried out in the Măgura Sârbi-Brănișca Quarry on the surrounding area.

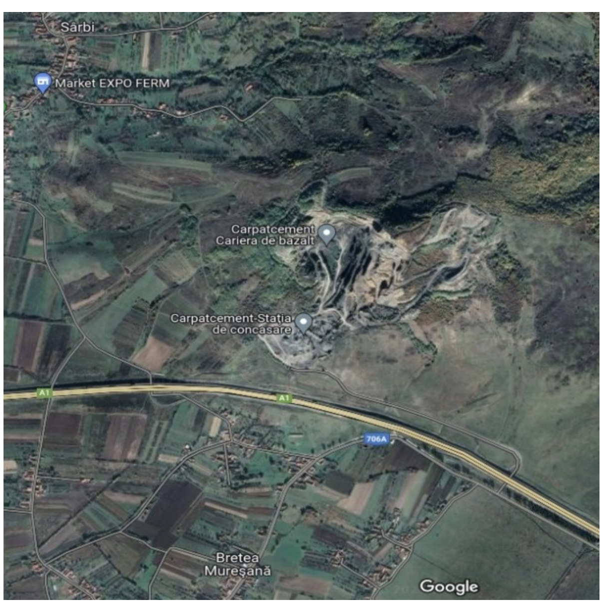

Fig. 2. Măgura Sârbi Brănișca Quarry

The Măgura Sârbi quarry is open on the south-western coast of the Măgura Sârbi hill, being located in the outskirts of the villages of Bretea Muresană and Sârbi, Ilia commune, at a distance of approx. 3 km from the Bretea Muresană railway station and 8 km from the railway station Brănişca railway, on the Deva-Arad railway line. Fig. 2

In the southern part of the exploitation perimeter, approximately 250m away from the crushing station related to the Măgura Sârbi Brănișca Quarry, the A1 Arad-Deva Highway is being built

In the Măgura Sârbi-Brănişca Quarry, basalt is mined from the deposit of the same name, a deposit currently exploited by the HeidelbergCement company.

In order to evaluate the seismic effect generated in the near area by blasting from the Măgura Sârbi – Brănişca Quarry, 3 blasting works (I1, I2, I3) were seismically monitored.

The blasting fronts were located in the center of the quarry, on the VIII stage of exploitation, placed longitudinally on the N-S axis of the Măgura Sârbi – Brănișca quarry;

The monitoring was done by placing equipment for measuring the parameters that characterize seismic waves (seismographs), in locations located at different distances from the blasting front [6].

The locations where the seismographs were placed were established by mutual agreement with the representative of HeidelbergCement România SA.

In the following, are presented the conditions for carrying out the monitored blasting works in terms of the geometric and quantitative parameters used:

- stepped height: I1,I2-10m, I3-13m;
- inclination blasting holes: I1,I2,I3- 85°;
- number of blasting holes: I1-58, I2-61, I3-74;
- number of rows: I1,I2,I3- 4;
- diameter blasting holes: I1,I2,I3-89mm;
- burden (w): I1-4 m, I2,I3- 3m;
- distance between holes placed on the same row (a): I1,I2,I3- 3,5m;
- distance between rows (b): I1,I2,I3-3,5 m;
- the length of the deepening ($L_{sub.}$): I1,I2,I3- 0m;
- length of blasting holes (L_g): I1,I2 -10m, I3- 13m;
- length of stemming (L_b): I1- 2,5m, I2- 2m, I3- 2,5m;
- length of explosives column: I1- 7,5m, I2- 8m, I3- 10,5m;
- explosives used:
    - basic explosive charge, explosive ANFODET;
    - initiation explosive charge, explosives Riogel XE Ø65 mm și Riogel HE Ø60 mm;
- means of initiation: nonelectric initiation system intiatied to electrical detonator;
- the amount of explosive / blasting hole: I1- 31,78 kg ETNT (eqhivalent trotil), consist of explosive ANFODET and initiation explosive charge: Riogel XE Ø65 mm și Riogel HE Ø60 mm, I2- 35,14 kg ETNT (eqhivalent trotil), consist of explosive ANFODET and initiation explosive charge: Riogel XE Ø65 mm și Riogel HE Ø60 mm, Riogel XE Ø65 mm și Riogel HE Ø60 mm, I3- 42,04 kg ETNT (eqhivalent trotil), consist of explosive ANFODET and initiation explosive charge: Riogel XE Ø65 mm și Riogel HE Ø60 mm, Riogel XE Ø65 mm și Riogel HE Ø60 mm;
- the maximum amount of explosive / delay stage: I1- 63,56 kg ETNT (2 blasting hole / delay stage), I2- 70,28 kg ETNT (2 blasting hole / delay stage), I3- 84,08 kg ETNT (2 blasting hole / delay stage).

The sequential moves of the rock from the massif will be performed using a network of delayed surface connectors for the initiation of the shock tubes of the primers that transmit the detonation in the blasting holes [7].

The design and coordination of blasting work must include [8]:

- the moves from the massif of the necessary rock volume, at a granulation corresponding to the technological requirements;
- the protection of civil and industrial objectives in the area against the effects of blasting works (shock wave, throwing pieces of rock and seismic effect).

The seismic effect generated by the blasting works in the quarries is determined by a series of natural and technological factors, which must be taken into account when studying the influence of environmental vibrations on the objectives in the area close to the perimeters where the explosions occur [8].

3. Results

In order to carry out the proposed evaluation, 3 blasting works carried out in the quarry were monitored from a seismic point of view.
Seismic monitoring consisted of placing specific measuring devices (seismographs) in accessible locations, distributed around the quarry, at different distances from the sources generating seismic waves, respectively the detonated blasting fronts [9].
In the monitoring process, the recording of the "soil oscillation velosity" parameter was considered, which characterizes the seismic waves transmitted by the generating source (blast) in the surrounding environment, producing vibrations of a certain intensity.
The evaluation of the obtained results was carried out by analyzing the design of the values recorded by the seismographs, in the graph of the German standard DIN 4150-3.
Also, the measured oscillation velosity values were compared with the velosity values (admitted/limit) corresponding to some degrees of seismic seismicity (STAS 3684-71) which are associated with possible effects on the structures, according to the specifications in the Technical Prescriptions for Storage, Transport and Use of Explosive Materials, code 71, ed.1997.
In the following, the results of the measurements and their evaluation are presented.

3.1. Blasting no. 1 din October 11, 2022 (I1)

The measurement locations and the blasting front are shown schematically in figure 3.

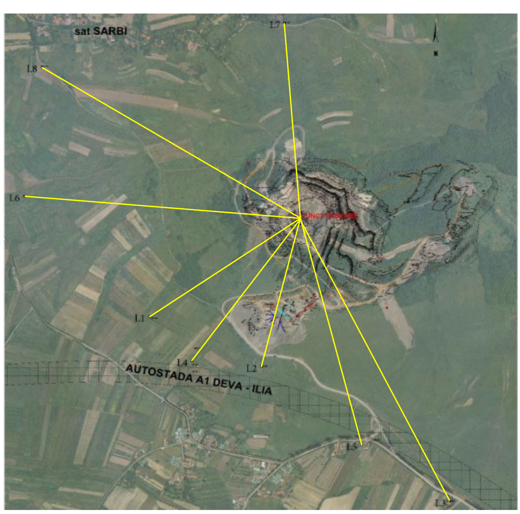

Fig. 3. Blasting 1 – The measurement locations

To monitor seismic waves, a number of 8 seismographs (L1÷L8) were placed in the near area

The results of the measurements are presented in table 2.

Table 2. The results of the measurements [10]

No. crt.	Measurement locations	Particle oscillation velocity measured on the three components (radial -V_R, transverse -V_T, vertical -V_V)				Distance from blasting point [m]
		V_R [mm/s]	V_T [mm/s]	V_V [mm/s]	Vector sum [mm/s]	
0.	1.	2.	3.	4.	5.	6.
1	L1	0,635	0,635	0,508	0,72	581,65
2	L2	0,445	0,635	0,508	0,72	506,55
3	L3	0,318	0,254	0,191	0,38	1052,22
4	L4	0,504	0,631	1,198	1,28	771,90
5	L5	0,349	0,476	0,191	0,58	616,83
6	L6	0,254	0,191	0,349	0,36	983,68
7	L7	0,794	0,413	0,825	0,87	953,96
8	L8	0,286	0,191	0,381	0,39	970,53

Analyzing the data in the table, it can be seen that the highest value of particle oscillation velosity parameter (1.198 mm/s), measured on the vertical component VT, was recorded from location L4, located at a distance of 771.9 m from the blasting point.
From location L2, located at a distance of 506.55m, being the smallest compared to the blasting front, the values recorded on the three components of the velosity, radial, transverse and vertical, were VR=0.445mm/s, VT=0.635mm/s and VV=0.508mm/s.
For the evaluation of the intensity of the seismic waves, the measured values of the oscillation velosity were projected in the standardized DIN4150-3.
All the values measured and projected in the graph are below the admissible levels drawn according to the type of objectives to be protected.
Also, according to table 1, taken from the Technical Regulations for the Storage, Transport and Use of Explosive Materials, code 71, ed.1997, all the values of the velosity measured on the three components, between 0.191-1.198 mm/s, as well as the vector the amount generated by the specialized software, for each measurement/location, falls well below the IV degree of seismic intensity, where the effect on the structures is described as "Possible damage to rural constructions, pressure pipes, oil and gas wells, mining wells, very fragile structures", when the value of the oscillation speed is between 0.5 ÷ 1.0 cm/s.

3.2. Blasting no. 2 from November 08, 2022 (I2)

In order to monitor the seismic waves, a number of 7 seismographs were placed in the bordering area. The measurement locations (L1÷L7) and the blasting front are similar to those shown schematically in figure 3.
The results of the measurements carried out at blasting no. 2 are presented in table 3.

Table 3. The results of the measurements [11]

No. crt.	Measurement locations	Particle oscillation velocity measured on the three components (radial - V_R, transverse - V_T, vertical - V_V)				Distance from blasting point [m]
		V_R [mm/s]	V_T [mm/s]	V_V [mm/s]	Vector sum [mm/s]	
0.	2.	4.	5.	6.	7.	8.
1	L1	0,826	1,207	1,080	1,43	573
2	L2	0,953	0,699	0,508	0,99	484
3	L3	0,445	0,318	0,381	0,48	1092
4	L4	0,434	1,048	0,946	1,17	599
5	L5	0,381	0,317	0,667	0,70	989
6	L6	0,762	1,048	1,27	1,30	678
7	L7	0,476	0,349	0,381	0,54	984

Analyzing the data in the table, it can be seen that the highest value of the particle oscillation velocity parameter (1.27 mm/s), measured on the vertical component VT, was recorded from location L6, located at a distance of 678.0 m from the blasting front.
From location L1, from the distance of 573m, being the smallest compared to the blasting front, the values recorded on the three components of the velocity, radial, transverse and vertical, were VR=0.826mm/s, VT=1.207mm/s and VV =1.080mm/s.
For the evaluation of the intensity of the seismic waves, the measured values of the oscillation velocity were projected in the standardized DIN4150-3 graphs.
All the values measured and projected in the graph are below the admissible levels drawn according to the type of objectives to be protected. At the same time, in accordance with table 1, taken from the Technical Regulations for the Storage, Transport and Use of Explosive Materials, code 71, ed.1997, all the values of the velosity measured on the three components, between 0.317-1.27 mm/s, as well as the sum vector generated by the specialized software, for each measurement/location, falls under the IV degree of seismic intensity, where the effect on the structures is described as "Possible damage to rural constructions, pressure pipes, oil and gas wells, mining wells , very fragile structures", when the value of the oscillation speed is between 0.5 ÷ 1.0 cm/s.

3.1. Blasting no. 3 din December 07, 2022 (I3)

To monitor the seismic waves, a number of 10 seismographs (L1÷L10) were placed in the bordering area.The measurement locations and the blasting front are shown schematically in figure 4.

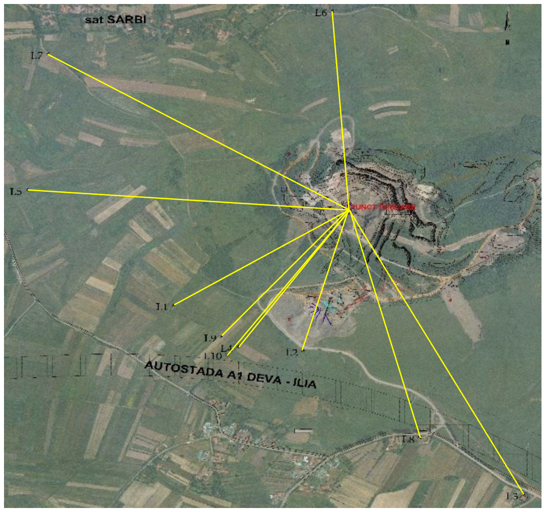

Fig.4 Blasting 3 – The measurement locations

The results of the measurements carried out at blasting no. 3 are presented in table 4.

Table 4. The results of the measurements [12]

No. crt.	Measurement locations	Particle oscillation velocity measured on the three components (radial -V_R, transverse -V_T, vertical -V_V)				Distance from blasting point [m]
		V_R [mm/s]	V_T [mm/s]	V_V [mm/s]	Vector sum [mm/s]	
0.	2.	4.	5.	6.	7.	8.
1	L1	0,572	0,889	1,080	1,11	573
2	L2	0,508	0,508	0,508	0,72	484
3	L3	0,318	0,254	0,254	0,43	1092
4	L4	0,402	1,498	0,828	1,572	599
5	L5	0,254	0,254	0,413	0,41	989
6	L6	0,222	0,286	0,159	0,33	984
7	L7	0,349	0,381	0,444	0,46	678
8	L8	0,317	0,190	0,254	0,38	748
9	L9	0,762	0,635	0,508	0,889	533
10	L10	0,859	0,300	2,097	2,157	580

The data in the table indicate that the highest value of the particle oscillation velosity parameter (2.097mm/s), also measured this time on the vertical component VT, was recorded from location L10, located at a distance of 580m from the blasting front.

From location L2, located at a distance of 484m, being the smallest compared to the blasting front (I3), the values recorded on the three components of the velosity, radial, transverse and vertical, were VR=0.508mm/s, VT=0.508mm /s and VV=0.508mm/s.
For the evaluation of the intensity of the seismic waves, the measured values of the oscillation velosity were projected in the standardized DIN4150-3 graphs.
All the values measured and projected in the graph are below the admissible levels drawn, depending on the type of objectives to be protected.
At the same time, in accordance with table 1 taken from the Technical Regulations for the Storage, Transport and Use of Explosive Materials, code 71, ed.1997, all the values of the speeds measured on the three components, between 0.159-2.097 mm/s, as well as the sum vector generated by the specialized software, for each measurement/location, falls below the IV degree of seismic intensity, where the effect on the structures is described as "Possible damage to rural constructions, pipelines under pressure, oil and gas wells, mining wells, very structures fragile", when the value of the oscillation speed is between 0.5 ÷ 1.0 cm/s.

3. Conlusion

In the monitoring process, the recording of the "soil oscillation velosity" parameter was considered, which characterizes the seismic waves transmitted by the generating source (shot) in the surrounding environment, producing vibrations of a certain intensity.
The evaluation of the obtained results was carried out by analyzing the design of the values recorded by the seismographs, in the graph of the German standard DIN 4150-3. The projection in the standardized graph places all the values of the oscillation speed (75 values in total), measured on three axes (radial, vertical, transverse), which are between 0.191mm/s and 2.097mm/s, below the levels considered non-dangerous as follows: the measured values are below the levels considered non-dangerous, as specified by the norm, for the types of buildings, L1- Office or factory building, L2- Residential building with plastered walls, L 3- Historic buildings or other buildings that require special attention .
Also, the measured oscillation velosity values were compared with the velosity values (admitted/limit) corresponding to some degrees of seismic seismicity (STAS 3684-71) which are associated with possible effects on the structures, according to the specifications in the Technical Prescriptions for Storage, Transport and Use of Explosive Materials, code 71, ed.1997. The velocity values measured on the three components, VR, VT, VV (75 values) as well as the values of the vector sum of the three components, generated for each measurement, fall below the IV degree of seismic intensity corresponding to oscillation velosity between 0.5 - 1 cm/s, values at which the effects that can occur on structures are described as "Possible damage to rural constructions, pipelines under pressure, oil and gas wells, mining wells, very fragile structures."
The evaluation of the results obtained during the measurements does not highlight a risk situation that presents a possible danger for the integrity of the objectives located in the near area of the Măgura Sârbi Brănișca Quarry.
The values of the ground oscillation velosity, the parameter through which the results were interpreted, had values that are within acceptable limits, compared to the conditions in which the seismic measurements were made.
Even if the number of blasting works in the Măgura Sârbi Brănișca Quarry is small (10-15 / year), variable factors such as terrain morphology, atmospheric conditions, physical-mechanical characteristics of the rocks, etc., can change the existing situation at the time of the evaluation.
In this sense and considering the objectives in the bordering area, the blasting works must be kept under control, permanently monitored to ascertain compliance with the adopted seismic requirements.

In the situation where the values of the parameters measured during the blasting work exceed the safety thresholds regarding the seismic protection, technical solutions must be identified and applied that lead to the reduction of the seismic effect, until the activities with a minimal impact on the neighborhoods are carried out.

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