Acoustic zoning for the safe use of explosives in the open pit

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Abstract. Rockfall in open pit mining using explosives is the most method of operation. Also, in addition to the technical and economic advantages, this method of extraction produces effects that can have a negative impact in the area near the quarry. The effects of the blasting are such as seismic waves that produce vibrations, air overpressure (noise), rock throws and toxic gases. If the intensity and extent of these effects are not properly anticipated and assessed, serious consequences can occur to people, civil / industrial buildings, the environment, thus affecting the health of the population and the stability / integrity of buildings / slopes in the vicinity of mining operations. The paper describes methods to assess the noise produced by the detonation of explosives for civilian use when removing rocks in the quarry, with the aim of ensuring a degree of disturbance acceptable to the population as well as for the protection of civil / industrial objectives in the area of mining. The obtained results are extracted from a research study carried out for the opening in operation of a new mining deposit, applying calculations and theoretical interpretations having as reference the conditions established for the development of the blasting works.

1 Description of the analyzed objectives

This paper presents a way to forecast the acoustic effect generated by the blasting works that will be carried out in the Colnic Quarry and the Remetea Quarry in the Rovina mining perimeter [1].

The purpose of the evaluation was to determine the intensity of the overpressure in the shock wave front, which can have an effect on the comfort of the population in the area as well as on the integrity and stability of the civilian objectives in the neighborhood.

The Rovina perimeter is located in the southern part of the Apuseni Mountains, in the north of the Southern Carpathians and in the west of the Transylvanian Plateau, in the area of the gold quadrilateral near Criscior locality, Hunedoara county. (Fig.1)

The locality of Rovina, Merişor and Bucharest, Crişcior and Zdrapţi are partially included in the exploitation perimeter. For the exploitation of porphyry bodies with cupro-

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gold mineralization from the Rovina-Remetea and Colnic area, the method of exploitation through up-to-date mining works will be applied, in the quarry respectively the method with descending steps and the transport of sterile rocks to the outer (Halda Rovina) and inner dumps. the remaining goal of the Colnic quarry).

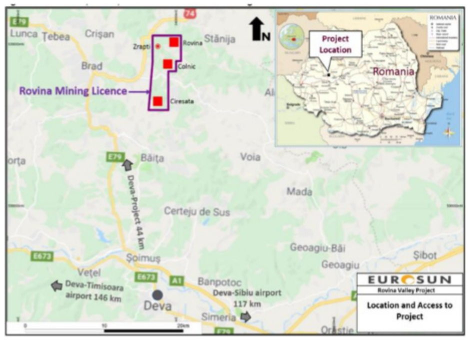

Fig. 1. The Rovina perimeter.

The development program of the exploitation in the Rovina perimeter, foresees the opening of two big quarries, respectively the Rovina-Remetea quarry located on the slope of the Baroque valley, and the Colnic quarry located on the Rovina valley, with hearths located at +264 m (Rovina) and +76 m (Colnic). For the exploitation of the copper deposit with gold content from the Rovina perimeter, the exploitation method adequate to the geological-technical conditions is the exploitation method through open mining works, in quarry, in steps with a height of 12 m - Rovina Remetea and Colnic quarries and through works underground mines - Cireşata V. Gârzii mine. The rock removal will be done with explosives placed in boreholes.

The following are the geometric and quantitative parameters, under the conditions of using the technique of blasting with well holes, with continuous explosive charges [1]:

- stepped height: 12 m;
- inclination blasting holes: 75 ÷ 90°;
- number of blasting holes: 15;
- number of rows: 2;
- diameter blasting holes: 200 mm;
- burden (w); 4 m;
- distance between holes placed on the same row (a): 5,3 m;
- distance between rows (b): 4,8 m;
- the length of the deepening ($L_{sub.}$): 1,2 m;
- length of blasting holes (L_g): 13,2 m;
- length of stemming (L_b): 5 m;
- length of explosives column: 8,2 m;
- explosives used:
    - basic explosive charge, explosive Blendex emultion;
    - initiation explosive charge, Booster;
- means of initiation: nonelectric initiation sistem;
- the amount of explosive / blasting hole: 297 kg E TNT (eqhivalent trotil), consist of explosive Blendex emultion and initiation explosive charge, Booster;
- the maximum amount of explosive / delay stage: 297 kg E TNT (1 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.

The initiation of the deployment of the blasting will be done from one of the side (left / right) or frontally depending on the conditions in the working stopped. The design and coordination of blasting work must include [2]:

- 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).

2 Methods of evaluation

A distribution in the air surrounding a blasting works is created by a premature release of explosive gases from the blast hole, this can happen through drilling, pre-existing cracks or those caused by massive blasting work and movement the mass of rock in front [3].

The air distribution is propagated by a series of overpressures that decrease in intensity with the distance from the blasting hole [4].

The following are some possible sources of air waves [5]:

a) Pulse of air pressure - due to the piston effect as the air is moved by the direct movement of the rock;

b) The pressure pulse of the rock - due to the vertical component of the ground vibration moving along the surface. This impulse is the first signal to reach the air transducer;

c) The explosion gas release pulse - results from "blown" blasting holes (blown face and craters);

d) The stemming release pulse - due to detonation of the explosive in the blasting holes (the trow of the stemming);

e) The Aerial waves formed due to the means of initiation (using the system detonating cords);

The sound noise is in the range of air vibration spectrum, from 20 to 20,000 Hz. Air waves include perceptible noise plus frequencies below 20 Hz. Noise and air waves decrease as the distance from the generating source increases. As the low frequencies attenuate more slowly, it is possible to maintain a significant air wave with minimal noise at considerable distances from the area of the blasting.

Silent air waves will cause buildings to vibrate and may cause vibration complaints at km away from the blasting front [6, 7].

The overpressure is usually recorded in dB (which measures all frequency components) so that:

$$dB = 20 \log_{10} (P/P_0) \tag{1}$$

where:

P = measured overpressure;

P_0 = reference pressure (2×10^{-8} kPa)

The significant factors of the blasting works that influence the production of air waves are [8]:

- the controllable variables, of which the amount of explosive detonated / delay stage, the total amount of explosive detonated, the duration of the delay, the anticipation and the distance between the holes, the length of the borehole, the direction of initiation, the initiation system used;

- the uncontrollable variables, general topography and atmospheric conditions.

Even after extensive site characterization, air wave estimates can vary widely from actual values.

This is mainly due to the complexity of atmospheric propagation, which far exceeds that of propagation in soil.

In order to estimate the level of the air wave at different distances from a quarry blasting front, the following formulas may be adopted [9]:
Air wave level:

$$dB = 20 \log [(PA + PB) / P_0] \quad (2)$$

$$PA = 185(R / W^{1/3})^{-1.2} \quad (3)$$

$$PB = 3.3(R / W^{1/3})^{-1.2} \quad (4)$$

where:
- PA, overpressure for unconfined charges (contact to air) [kPa]
- PB, overpressure for confined charges [kPa]
- P_o, reference pressure (2 x 10^{-8} kPa)
- R, distance from charge [m]
- W, maximum charge explosive / delay stage [kg]

When fully using electric detonators or a non-electric initiation system, an evaluation is recommended using the formula [9]:

$$dB = 165 - 24 \log_{10} (R / W^{1/3}) \quad (5)$$

In some situations, air waves can directly damage structures, but more often they are recorded as higher frequency vibrations that manifest as noise from windows, doors, etc.

The value of 133 dB can be adopted as the maximum permissible safety limit [10]

In most cases no recognized standard or recommendation is applied taking into account a level of overpressure according to purely perceptual criteria [10]:

100 dB (2 Pa) – barely noticeable
110 dB (6 Pa) - readily acceptable
128 dB (5 Pa) – will not occur below this level.

The applications selected as appropriate for the process of assessing the intensity of the overpressure in the shock wave front, are those that refer to known data, extracted from the information provided by the applicant.

Thus, in this stage the values of the parameters determined by the applicant were taken into account depending on the field conditions, which consisted mainly of:
- Quantity of explosive / delay stage: 297 kg explosive E TNT (trotyl equivalent)
- Reference distances, respectively:
  - 515 m the distance between the nearest objective (building in Rovina locality) and the exploitation limit in the southern part of the Rovina-Remetea Quarry;
  - 840 m the distance between the nearest objective to be protected (building in Rovina) and the opening area of the Rovina-Remetea Quarry, where the first blasting works will be carried out;
  - 640 m distance between the nearest objective (the building in Merișor) and the exploitation limit in the eastern part of the Colnic Quarry;
  - 875 m distance between the nearest objective (the building in Rovina) and the opening area in the northern part of the Colnic Quarry, where the first blasting works will be carried out.

3 Results and discussions

For the assessment of the air wave produced by the detonation of the explosive in blast holes, the calculation relation (5) was applied resulting from the values in the table 1.

Table 1. The reults of air overpressure at different distances.

Distance from blasting point [m]	The amount of explosive ETNT / Delay stage [kg]	Air overpressure [dB]
200	297	130
300		125
400		122
515		120
640		117
840		115
875		114

The table shows the values of the overpressure in the front of the shock wave, produced at the blasting works performed in the adjacent exploitation areas located at the smallest distances from the objectives to be protected. The obtained results are represented in fig. 2, 3 and 4.

The figure 2 shows two circles. Circle 1, has a radius of 515 m which is the distance between the southern limit of exploitation of the Remetea-Rovina Quarry and the nearest objective (Rovina building).

The circumference of circle 1 marks the distance to which the execution of the blasting works in the southern limit of operation generates an overpressure in the front of the shock wave with a value of 120 dB.

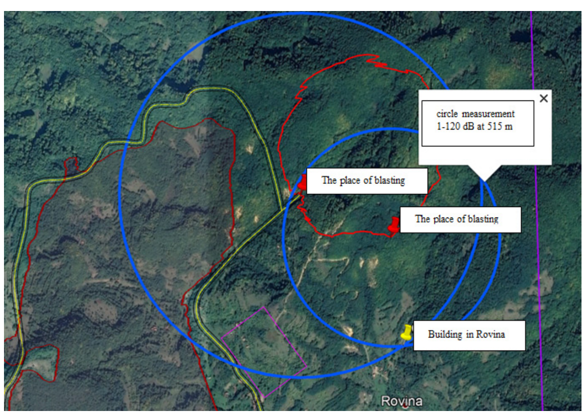

Fig. 2. Air overpressure determined for the Rovina-Remetea Quarry, (Google Earth Pro).

The circle 2, has a radius of 840 m which is the distance between the area where the Remetea-Rovina Quarry will open and the nearest objective (Rovina building).
The circumference of circle 2 marks the distance to which the performance of the first blasting works generates an overpressure in the front of the shock wave with a value of 115 dB.

It is noted that in the area delimited by circle 2, there are only the objectives that are on the land to be purchased by SAMAX.

In figure 3 the drawn circle has a radius of 640 m which is the distance between the eastern limit of exploitation of the Colnic Quarry and the nearest objective (building from Merişor).

The circumference of the circle marks the distance to which, performing the blasting works in the eastern limit of operation, generates an overpressure in the front of the shock wave with a value of 117 dB. It should be noted that in the area delimited by the circle, there are no other objectives.

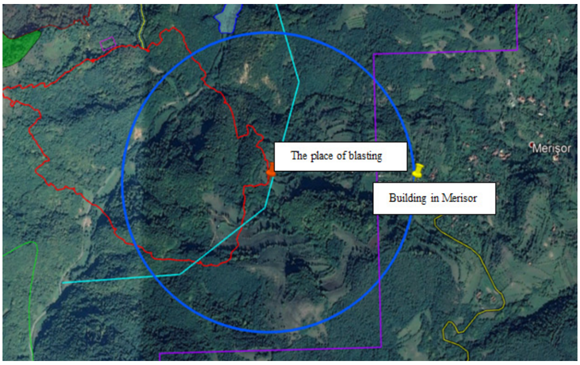

Fig. 3. Air overpressure, determined for the Colnic Quarry (at the eastern limit of operation) (Google Earth Pro).

In figure 4, the drawn circle has a radius of 875 m which is the distance between the area where the Colnic Quarry will open and the nearest objective (building in Rovina).

The circumference of the circle marks the distance to which, performing the first blasting works for the opening of the Colnic quarry, generates an overpressure in the front of the shock wave with a value of 114 dB. It should also be mentioned in this case that there are no other objectives in the area delimited by the circle.

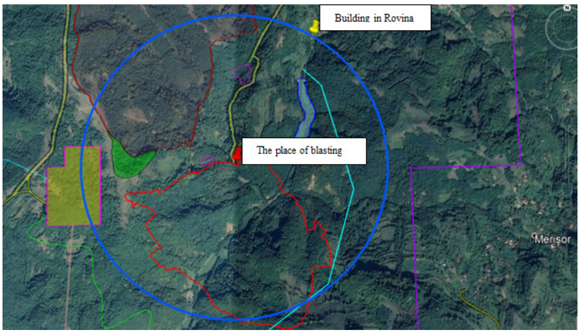

Fig. 4 Air overpressure, determined for Colnic Quarry (quarry opening area) (Google Earth Pro).

4 Conclusions

All values resulting from the calculations fall below the level of 133 dB which can be adopted as the maximum allowable.

The determined overpressure level is considerably lower than the perceptual criterion, respectively 128 dB (5 Pa) level at which it is considered that no damage will occur.

The preliminary information obtained as a result of the work was obtained by applying empirical mathematical relations that must be confirmed by air wave monitoring generated by the blasting works performed in the Colnic Quarry and the Remetea Quarry.

The results of the evaluation of the air wave intensity that was the object of a theoretical study, applying analytical methods, for the conditions designed by the applicant, do not highlight a risk situation that does not allow the start of operation in Colnic Quarry and Remetea Quarry.

However, variable factors such as terrain morphology, atmospheric conditions, physical and mechanical characteristics, etc., can influence the appearance of differences between the results obtained by calculations and the results that will be obtained by concrete measurements "in situ".

In this regard, it is recommended that in the first stage an experiment be carried out in the opening areas of the quarry, by carrying out control blasting in which to use minimum quantities of explosive per stage of delay, which may be even smaller for the beginning than those designed.

In order to open the database with concrete results obtained in real conditions, the control blasting will be monitored by placing specific measuring equipment (seismographs with microphones) in the locations in the area adjacent to the quarry and at the objectives to be protected at different distances from the site production of the explosion.

In case the values of the parameters measured at the blasting works exceed the safety thresholds regarding the noise protection, the operator of the blasting works will identify and apply technical solutions leading to the reduction of the air wave effect, until the activities are carried out in maximum safety conditions a minimal impact on neighborhoods.

The final of the blasting conditions should be updated after evaluating the results of the "in situ" measurements carried out in a certification process, using the test infrastructure of an accredited laboratory with competent personnel and having a sufficient number of high-performance equipment, specific to this activity.

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