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OPTIMALIZATION BLASTING OPERATIONS IN THE QUARRY SEDLICE IN TERMS OF MEETING QUALITY AND SAFETY REQUIREMENTS

OPTIMALIZÁCIA TRHACÍCH PRÁC V LOME SEDLICE Z HĽADISKA SPLNENIA KVALITATÍVNYCH A BEZPEČNOSTNÝCH POŽIADAVIEK

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Abstract

Blasting operations in the quarry represent one of the basic technological processes, the aim of which is to obtain a span of timber of suitable fragmentation. When doing blasting, it is important to ensure that these blasting operations do not adversely affect the safety of the environment (due to seismic effects, excessive take-off, etc.). For this reason, it is necessary to constantly address the optimization of blasting operations, both in terms of their parameters, but also ingested explosives and blasting aids. The paper presents solutions to optimize blasting operations in the quarry Sedlice in terms of meeting quality and safety requirements.

Abstrakt

Trhacie práce v lome predstavujú jeden zo základných technologických procesov, ktorého cieľom je získanie rozvalu rúbaniny o vhodnej fragmentácii. Pri realizácii odstrelov je pritom dôležité zabezpečiť, aby tieto trhacie práce negatívne neovplyvňovali bezpečnosť okolia (pôsobením seizmických účinkov, nadmerného rozletu a pod.). Z tohto dôvodu je potrebné sa neustále zaoberať optimalizáciou trhacích prác jednak z hľadiska ich parametrov, ale aj používaných trhavín a pomôcok trhacej techniky. V príspevku sú uvedené riešenia optimalizácie trhacích prác v lome Sedlice z hľadiska splnenia kvalitatívnych a bezpečnostných požiadaviek.

Keywords

blasting works, seismic effects, fragmentation

Klíčová slova

trhacie práce, seizmické účinky, fragmentácia

1. Introduction

Blasting technics since Alfred Nobel's invention of dynamite (1867) reached a massive development and blasting works are still the most effective and economically best methods to break the rock massif environment. Blasting works have and in history had the main task in the minerals extraction process.

On the other side rock massif breaking outcome is the energy of the explosion, which is transformed into the energy of seismic waves, which causes many problems related to noise and vibrations. Mainly vibrations of blasting works can exceed tolerable - safe limit when they become damaged and can massively damage to surrounding buildings and discomfort for residents. An increasing amount of explosives is increasing the intensity of seismic waves, propagating into the rock massif, and causes oscillation of rock environment sections. [1, 2]

Reduction or regulation of the seismic effects of vibrations is therefore a major problem for most quarry operations. Bench blasts are known to be an effective way to reduce shocks. In this method, the individual bores are fired one after the other with a certain time delay. The vibrational waves generated during blasting work from boreholes cancel each other out and the oscillation speed can be reduced by suitable time intervals. Despite the theoretical simplicity, it is usually difficult to predict the oscillation rate with sufficient accuracy due to the error in the timing of the delay and the inhomogeneity of the rock massif environment. [3, 4]

An extremely important and current problem is the definition of side effects and the determination of seismic safety. It is desirable to develop an economically and economically beneficial method which would, from one point of view, ensure the certainty of the failure of the object and, from the other point of view, the most economical blasting technology for rock fragmentation. [5, 6]

At present, the study of seismic effects is an integral part of blasting work. The blasting works are planning with depending on the applied measurements. Using the measured data, the parameters of the next shot are adjusted. Modified parameters include, for example, the angle, spacing of boreholes and, last but not least, the timing of blasting in individual boreholes to meet rock fragmentation and protection of objects that are close to the blasting. [7,8]

Vibrations caused by blasting works are one of the main problems in mining in surface mines, and intense vibrations can cause great damage to structures and plants near surface mines. It is very important to study how to regulate the vibrations caused by blasting works while mitigating the negative effects of these works in quarries. This study aims to investigate the propagation of ground vibrations caused by blasting operations and to find possible approaches to reduce the harmful effects of vibrations caused by blasting operations on the environment. To this end, a series of field experiments were performed at Xin Qiao Mining Co. Ltd. The parameters of these blasting operations were carefully recorded. A total of sixtysix shots were fired. In the statistical analysis of the data collected, a predictor equation proposed by the United States Mining Authority (USBM) was used to establish a relationship between the maximum particle vibration velocity (PPV) and the minimum distance factor (SD). The relationship between PPV and SD has been determined and proposed for use in quarries. In practice, the control of the maximum amount of charge per timing stage and the selection of the optimal delay between the individual timing stages were used to reduce the intensity of vibrations by seismic wave interference. Based on field experiments, it was possible to determine the optimal value of the delay of 15 ms, and a reduction of vibrations of 24.5 % was achieved. [9]

2. Geological structure of the rock environment around the Sedlice quarry

Fig. 1 Aerial shot of EUROVIA - Kameňolomy, s.r.o., Quarry SEDLICE

Mining area EUROVIA - Kameňolomy, s.r.o., SEDLICE quarry is located in the Čierna hora mountain range, about 1 km southeast of the village of Sedlice and about 1 km southwest of the village of Suchá Dolina belonging to the Prešov region. It is accessible by a 1 km long panel road, which is connected to the state road 3. class before the village Sucha Dolina in the direction from the village Ľubovec. Overall, this area has highland character, mostly forested with beech hornbeam forest and fir-spruce forest on brown forest soils, rendzina and carbonate soils. The highlands consist of Mesolithic crystalline and flysch rocks.

The mined mineral in this quarry is exclusively dolomite of the middle and upper Triassic of the envelope Mesozoic. The most common type of dolomites in the quarry are dark grey solid to fine-grained dolomites, which have a very fine-grained structure and their texture is omnidirectional, rarely banded. The second most common petrographic type is brecciated and organodetritic dolomites, as well as light crystalline medium-grained dolomites and coarse-grained dolomites. [10]

3. Positions of measurement and apparatus used in the technical seismicity measurement

The assessment of the dynamic effects of blasting depends very much on the measurement technique used to obtain the results. For accurate and objective measurement results, it is important to know the measuring instruments and measurement procedures. The placement and number of sensors are important, which has a significant effect on the accuracy of the measurement. The sensors can be mounted without additional anchoring or with. When choosing a suitable sensor, its weight is decisive. If the weight of the device is lower than the force acting by the oscillating movement, a thorough connection to the measuring point is necessary. If the weight of the device is higher, such a measure is not necessary. Undoubtedly, the correct orientation of the sensor to the centre of the planned blasting also plays a large part in the accuracy of the measurement. The following digital seismic instruments were used at measuring positions to measure and graphically record the seismic effects of blasting:

Minimate Pro 6 - Instantel (Fig. 2),

Svantek 958 A - Class 1 (Fig. 3).

Fig. 2 Minimate Pro 6 - Instantel

Fig. 3 Svantek 958 A - Class

The positions of measurement were present at the nearest buildings to a house in the village of Miklušovce (S1) and a house in the village of Sedlice (S2). At the position S1, was placed a vibrograph Svantek 958A at the foundations at the entrance to the residential building, and at position S2, a Minimate Pro 6 vibrograph was placed at the entrance to the residential buildings. Vibrography recorded the effects of seismic waves on the monitored objects. The positions of the apparatus and the devices with sensors are drawn in fig. 4 and 5. Vibrographic possibilities of the digital and graphic recording of three-speed options, horizontal longitudinal - vx, horizontal - vy, vertical - vz. Vibrographs are working autonomously, they automatically perform a channel test without the intervention and influence of the operator on the measured and registered vibration characteristics.

4. Parameters of the bench blast in Sedlice quarry

The source of seismic waves was bench blast EUROVIA-Kameňolomy s.r.o., Quarry Sedlice. GDPR we cannot publish information about blasting works as: drilling distance, borehole diameter, borehole inclination, borehole depth, name of used explosives, weight of explosives in borehole, total amount of explosives and timing. [11]

Fig. 4 ***Position and distance between bench blasting in Sedlice quarry and position of measurement at house in Miklušovce village.***

Fig. 5 ***Position and distance between bench blasting in Sedlice quarry and position of measurement at house in Sedlice village.***

5. Methodology of measurement and evaluation of measured data

In March 2020, the technical seismicity of the aperture blast was measured at the above-mentioned positions. From the measured values, we evaluated the effects of aperture blasting on an individual residential building in Sedlice and Miklušovce. The measuring apparatuses were placed on the stands to register the course of the waves in the vicinity of the blasting works to the nearest residential houses, where the objects could be damaged by the effects of the blasting works. Apparatus stored on the stands were calibrated before measurement and their sensitivity was checked. The graphical course of individual components of seismic waves during blasting works was recorded at the measuring stations. The vibrographs were placed on the measuring stations so that it was possible to assess the influence of the excited technical seismicity on the assessed objects.

Based on the measured values of velocities and frequencies of individual components of waves during bench blasting, we were able to evaluate according to STN EN 1998-1 / NA / Z1 (Seismic loading of building structures) the effects of individual blasting on housing development in Sedlice and Miklušovce.

Tab. 1 Measured values of vibration velocity during blasting works

Position	Distance	Amount of explosive	V_x [mm. s^{-1}]	V_y [mm. s^{-1}]	V_z [mm. s^{-1}]
House in village Miklušovce (S1)	1 060 m	150 kg	1,78	1,16	0,94
House in village Sedlice (S2)	1 100 m	150 kg	1,65	1,21	0,85

6. Analysis and evaluation of measured data

Based on the recommendations of STN EN 1998-1 / NA / Z1 Seismic loading of building structures, about charges used for bench blasting, which are tens of kilograms, where the oscillation frequencies are usually $f < 10$ Hz and based on the resistance of buildings to technical seismicity it is possible to classify buildings in the villages of Sedlice and Miklušovce into resistance class B (see Tab. No. 2).

As for the type and category of foundation soil of protected objects, due to the absence of more specific characteristics and data, we can classify it into category b, which is closest to reality (groundwater level is more than 3 m below the surface level).

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Tab. 2 Dependence of damage level on maximum vibration speed, type of object, and foundation soils according to STN EN 1998-1 / NA / Z1

Maximal velocity for frequency interval			**Destruction level**	**Class of building resistance**	**Class of soil**
$f_k < 10$ Hz	**10 Hz $< f_k < 50$ Hz**	**$f_k > 50$ Hz**			
to 3	3 to 6	6 to 5	0	A	a
3 to 6	6 to 12	12 to 20	0	A	b, c
				B	a
6 to 10	10 to 20	15 to 30	0	B	b, c
				C	a
			1	A	a
8 to 15	15 to 30	20 to 30	0	C	b
				B	c
			1	A	b, c
				B	a

***Legend class of building resistance**: **A** - Old buildings not conforming with regulations, ruins, historical buildings from unworked stone or bricks with arches cross-beams, girders and flat arches above the premise of the ground floor and basement : stone and brick monuments and fountains, buildings with extensive moulding decorations, buildings with special preservation and conservation status. **B** - Conventional brick buildings detached or terraced houses with ground area up to 200m three storeys at the most. **C** - Big buildings from bricks and shaped bricks, well-reinforced panel buildings built from reinforced concrete components, masonry binder in cement mortar.*

***Legend class of soil: Category a** - Includes rocks of all classes with the design strength $R_{dt} \leq 0,15$ Mpa, underground water level at the constant depth of 1,0 to 3,0 m below the footing bottom. **Category b** - Includes rocks of all classes with design strength $R_{dt} \leq 0,15$ Mpa, underground water level at the constant depth of more than 3,0 m. This category also includes rocks of all classes with design strength $R_{dt} \leq 0,15$ Mpa if the underground water level is constantly at the depth of 1,0 to 3,0 m below the footing bottom, **Category c** - includes rocks of all classes with the design strength Rdt ≥ 0,15 Mpa, underground water level at the constant depth of more than 3,0 m below the footing bottom. This category also includes rocks of all classes with design strength Rdt ≤ 0,6 Mpa if the underground water level is constantly at the depth of more than 1,0 m.*

In addition to the measured values of the oscillation frequency ($f < 10$ Hz), it is necessary to take into account the longer-term nature of blasting at the dolomite deposit and also the higher age of residential buildings (positions of measurement) on which were found small cracks. For these reasons, the maximum permissible oscillation speed (speed element) can be determined:

$v_d \leq 3\ mm.s^{-1}$.

Based on the measured data, we can calculate the weight of explosives, while not exceeding the allowed maximum oscillation speed. If according to STN EN 1998-1 / NA / Z1 the following applies [12, 13]:

$$v = K.\frac{\sqrt{Q_{ev}}}{L},$$

(v - the maximum oscillation velocity (a maximum component of the oscillation velocity) generated by blasting is measured, [mm.s^{-1}])

then from the given relation, the coefficient of the transmission environment K for the near surroundings in the Sedlice quarry has the value: $K_1 = v.\ L / \sqrt{Q_{ev}} = 1,78\ .\ 1060 / \sqrt{150} = 1886,6/12,24 = 154,1$

$K_2 = v.\ L / \sqrt{Q_{ev}} = 1,65\ .\ 1100 / \sqrt{150} = 1815/12,24 = 148,3$.

Mining at the Sedlice locality is carried out by bench blasting. Based on the measured and calculated values in the case of bench blasting in the Sedlice quarry, in the case of repeated bench blasting in the Sedlice quarry, it is possible to use the maximum allowed charge per timing step depending on the distance as follows:

For distance 1000 m $Q_{vmax} = v^2 \quad L^2/K^2 = 3^2 \quad 1000^2/154^2 = 379,5$ kg,

For distance 1500 m $Q_{vmax} = v^2 \quad L^2/K^2 = 3^2 \quad 1500^2/154^2 = 854,0$ kg,

At the same time, we will achieve better fragmentation of crushed rock.

7. Conclusion

The values of technical seismicity, measured during blasting works, did not exceed the lowest permissible values set by the valid Slovak technical standard STN EN 1998-1 / NA / Z1 Seismic loading of buildings $v_d = 3\ mm.s^{-1}$ for frequencies less than 10 Hz and foundation soil type "b". These values are safe for seismical safety for buildings and residents.

Based on the measured values, we can tell that the impact of seismic effect of blasting on people in residential buildings in the villages of Sedlice and Miklušovce, a bench blasting performed in the Sedlice quarry are safe.

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