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Research on the milisecond delay blasting impact in order to minimize seismic effects in Kučín quarry surrounding

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Abstract: *The intensity of seismic waves' vibrations is proportional to the weight of the applied explosive. If the vibrations are sufficientin energy, surrounding buildings can be damaged or destroyed. Evaluating the negative effects of the blasting operations and quantification of the seismic safety is nowadays very actual and a challenging problem. The article presents the results of the analysis as well as an evaluation on seismic safety of the objects during blasting in the quarry Kučín. The results the evaluation seismic effects blasting verified in a Kučín quarry are the methodological base for evaluating the seismic effects of blasting in all quarries in Slovakia.*

Keywords: *blasting operations, seismic effect, particle velocity, seismic safety*

1. Introduction

In blasting operation, even with the most sophisticated procedures can not count on using the energy released by an absolute explosion of an explosive charge only to perform the intended work. It is necessary to keep that part of the energy reflected in the form they consider adversely.

When blasting, now caried everywhere, can find many different objects, underground wiring, respectively. above ground, fauna, flora, that we have to think to protect, for us to use energy explosion, did not cause more damage than useful work.

The seismic effects of the expected blast can be substantially reduced by dividing the total charges to several partial charges. Can be very effective in reducing the seismic effect by milisecond timing blast, in which the delay of the charges creates interference of seismic waves such that their side effects cancel each other out. The result is lower seismic activity.

According to timing the blasting can be divided into [1-10]:

- instantaneous (simultaneous initiation of a group of explosive charges),
- timed (the partial blasts explode in different time sequences).

More charges can explode simultaneously in one time stage which are considered one partial charge.

In timed blasting there are two time sequences taken into consideration Δt:

- **Δt ≥ 250 ms** (there is a seismic waves attenuation before explosion of the next charge component),
- **Δt < 250 ms** (occurrence of effects interference of charge components).

The required length of boundary sequence timing depends on rock environment and it can decrease from value 250 ms up to Δt = 10 ms [2, 4, 8, 10, 11].

2. Quick geological structure Kučín quarry (Transmission medium)

From geological point of view it constitutes that the bearing zone between the zeolite tuff Kučín and Pusté Čemerne one unit. The influence of surface erosion and segmentation modeling but its continuous progress is interrupted either sediments quaternary cover (in the valley Hrabovecký stream), or cross–disruptive disorders and thus divided into individual parts.

Fig. 1. Position Kučín quarry (left) and residential property in the village Kučín (right).

Part Kučín – below this is described in the bearing zone between Kučín and Pusté Čemerné (Fig. 1), which builds morphologically protruding mound Red Stone (232.0 m). The length of this part of the surface is 1250 m, width 150–200 m (175 m diameter). The power of the body, there is 106.93 m and bow is approximately 56° to the southwest [10].

3. Using the apparatus and measurement methodology

For the measurement of seismic effects were used four channel digital seismographs:

- Vibraloc ABEM, from the Swedish company ABEM (Fig. 2a),
- VMS 2000 MP, from the American company Thomas Instruments Inc. (Geospace) (Fig. 2b),
- UVS 1504, from the Swedish company Nitro Consult (Fig. 2c).

Seismometers provide digital and graphic record of the three components of particle velocity rate environment, horizontal longitudinal – vx, horizontal cross – vy, vertical – vz. Seismographs ABEM Vibraloc, VMS 2000 MP and 1504 UVS operate autonomously, automatically run the test channel without operator intervention and influence in the measured and registered vibration characteristics.

a) b)

c)

Fig. 2. The measuring instruments: a) Vibraloc ABEM; b) VMS 2000; c) UVS 1504.

Fig. 3. Measuring position 1− residential house No. 44 in the Kučín village; three−component seismometers from the American company Geospace at the entrance of a residential building.

Fig. 4. Measuring position 2 − prior to entry into a house in the Kučín village; seismometer was placed on a foundation wall in front of the house.

4. Source of seismic effects

The source of seismic waves were bench blasting in the Kučín quarry the deposit of zeolite tuff, before entering the Kučín village (Fig. 5).

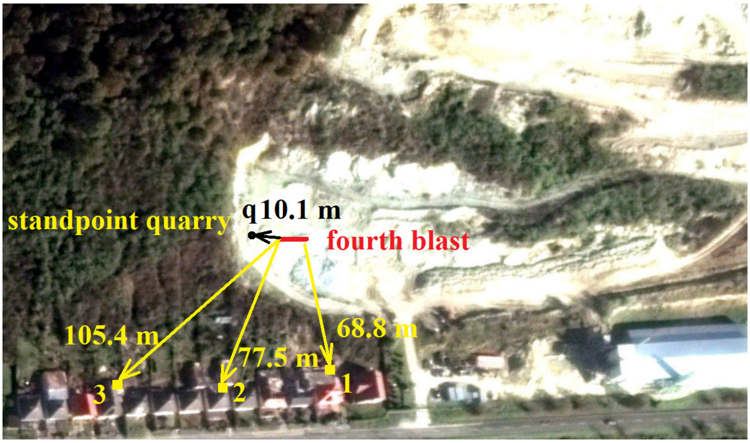


Fig 5. Distance positions by blasting operation in a Kučín quarry.

4.1. Parameters of blasting operations

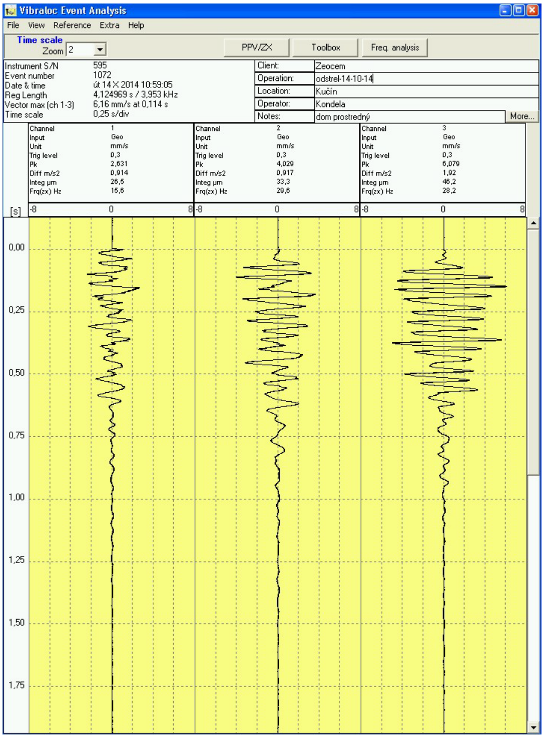
Explosives and charging into wells are shown in Fig. 6.

Fig. 6. EURODYN explosives and borehole charge.

The total charge of the first blast was 105 kg, of which explosive EXAN G 85.5 kg, 12 kg of the SENATEL and 7.5 kg of explosives EURODYN. On disconnection of 3 wells were used. Non-electric ignitor, timing 42 ms.
The total charge second blast was 113 kg, of which explosive EXAN G 58.5 kg, 12 kg of the SENATEL and 17.5 kg of explosives EURODYN. Dissociating the 8 boreholes were used, including 3 heeled boreholes. Non-electric ignitor, timing 42 ms.
To optimize the timing of blasting operations was done the third line blast in the quarry Kučín. The total charge of the third blast was 25 kg of explosives EURODYN 2000. The disengagement was used 10 heeled boreholes. In one borehole was 2.5 kg explosives EURODYN 2000. The depth of the hole was 3.5 meters. Seal 3 m. Non-electric ignitor, timing 42 ms.
Due to the further optimization of the parameters was carried out by the fourth line blast. The total charge of the fourth blast was 25 kg of explosives EURODYN 2000. The disengagement was used 10 heeled wells. In one borehole was 2.5 kg explosives EURODYN 2000. The depth of the borehole was 3.5 m. Seal 3 m. Non-electric ignitor, timing 9 ms.

5. Measured seismic effect of blasting operations and analysis

At the measuring standpoints there was recorded the graphical process of individual components of seismic vibration at bench blastings. Example the measured values and frequency analysis of the vibration record presented in Figs. 7 and 8. Measured maximum values of particle velocity in the quarry Kučín are shown in Table 1.



Zoom 2

Instrument S/N 595
Event number 1072
Date & time út 14 X 2014 10:59:05
Reg Length 4,124969 s / 3,953 kHz
Vector max (ch 1-3) 6,16 mm/s at 0,114 s
Time scale 0,25 s/div

Client: Zeocem
Operation: odstrel-14-10-14
Location: Kučín
Operator: Kondela
Notes: dom prostredný

Channel	1	Channel	2	Channel	3
Input	Geo	Input	Geo	Input	Geo
Unit	mm/s	Unit	mm/s	Unit	mm/s
Trig level	0,3	Trig level	0,3	Trig level	0,3
Pk	2,631	Pk	4,029	Pk	6,079
Diff m/s2	0,914	Diff m/s2	0,917	Diff m/s2	1,92
Integ µm	26,5	Integ µm	33,3	Integ µm	46,2
Frq(zx) Hz	15,6	Frq(zx) Hz	29,6	Frq(zx) Hz	28,2

Fig. 7. The resulting record the particle velocity of the components (in the longitudinal, transverse and vertical directions) on the measuring position 2 (residential building), on the third blast.

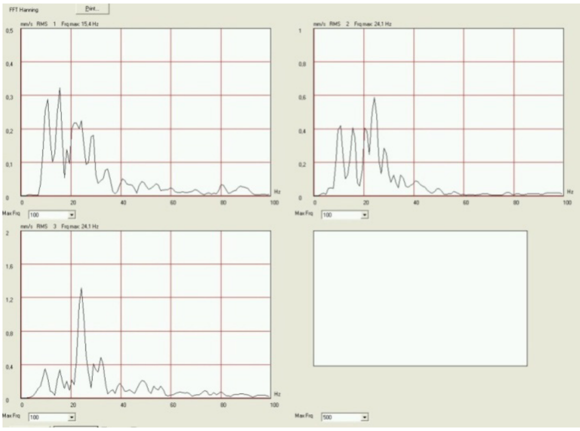


Fig. 8. Frequency analysis of the vibration record of the individual components (in the longitudinal, transverse and vertical directions) measured on the measuring position 2 (residential building), on the third blast.

Tab. 1. Measured particle velocities, frequencies and air pressure of individual components in the Kučín quarry

Measuring position	x [mm/s]	y [mm/s]	z [mm/s]	Air [Pa]	x [Hz]	y [Hz]	z [Hz]	Air [Pa]
Kučín quarry blast one:	-	-	-	-	-	-	-	-
– position 1	8.83	8.39	11.93	61.35	28.4	10.7	11.4	19.7
– position 2	1.75	1.4	0.95	6.5	7.6	7.4	4.5	0.9
Kučín quarry blast two:	-	-	-	-	-	-	-	-
– position 1	4.2	3.98	8.17	43.51	26.9	13.1	10.2	19
– position 2	1.7	1.4	1.3	11	10	7.2	10	1.3
Kučín quarry blast three:	26.39	12.81	32.36	-	20.5	8.4	36.6	-
– position 1	2.3	3.65	4.8	28	20	40	16	29
– position 2	4.029	6.079	2.631	-	29.6	28.2	15.6	-
– position 3	1.361	1.417	0.863	-	25.3	25	22.2	-
Kučín quarry blast four:	40.97	5.19	20.54	-	19.0	46.5	20.5	-
– position 1	1.739	1.621	2.631	-	40.9	56.1	12.3	-
– position 2	2.039	1.957	2.006	-	42.1	35.9	14.1	-
– position 3	0.7	1.25	1	0.9	3.6	7.2	6.1	6.3

According to long-term experiences obtained during measuring of seismic effects of bench blasting, it was determined that even in the case of measuring of the same rock blast in the same standpoint by a couple of identical equipment sets it is possible to obtain three times bigger and also higher variable of measured speed characteristics. Therefore the measurement, analysis and assessment of seismic effects require mathematical and statistical approach [2-4, 10, 12]. The theory and experiments in several quarries showed that speed of vibration is well governed by semi-empirical law of seismic waves` attenuation which is given by relation (1):

$$\mathbf{v} = \mathbf{K}\left(\frac{\mathbf{L}}{\mathbf{Q}^{0,5}}\right)^{-\mathbf{n}} = \mathbf{K}\left(\frac{\mathbf{Q}^{0,5}}{\mathbf{L}}\right)^{\mathbf{n}} \text{[mm/s]} \tag{1}$$

where: **K** and **n** are determined in experimental measurement; **Q** – weight of the charge, [kg]; **L** – the shorted distance blast from measuring position, [m].

There is a theoretical relation of the effect and causality between **v** and $\mathbf{L_R}$ (resp. $\mathbf{Q_R}$) variables. Because of high variability of recorded values of **v** between different rock blasts, and at different locations the particle velocity is considered as dependent variable and the reduced distance $\mathbf{L_R = (L/Q^{0.5})}$ as independent variable.

Both values are stochastically jointed (not functionally). Therefore, the law of seismic waves` attenuation of investigated area is studied by statistical methods based on trial rock blasts.

By taking a logarithm of relation (1) we have relation:

$$\mathbf{logv = logK - n \cdot log\left(\frac{L}{Q^{0,5}}\right)} \tag{2}$$

which is represented by line inclined by an angle **β** at logaritmical scale. Parameters **n** and **K** of this regression line are determined statistically.

If according to equation [13]:

$$v = K \cdot \frac{\sqrt{Q_{ev}}}{L} \tag{3}$$

where: **v** – the measured maximum particle velocity activated by blast, [mm/s]; **K** – coefficient of dependent on conditions of blast, properties of transmission rock environment, type of explosion and so on; $\mathbf{Q}_{ev}$ – maximum charge of time stage; is true then coefficient **K** for the vicinity of the Kučín quarry is worth, from that relationship (3):

$K_0 = v \cdot L/\sqrt{Q_{ev}} = 40.97 \cdot 10.1/\sqrt{2.5} = 261.7$
$K_1 = v \cdot L/\sqrt{Q_{ev}} = 2.631 \cdot 68.8/\ \sqrt{2.5} = 114.48$
$K_2 = v \cdot L/\sqrt{Q_{ev}} = 2.039 \cdot 77.5/\sqrt{2.5} = 99.94$
$K_3 = v \cdot L/\sqrt{Q_{ev}} = 1.25 \cdot 105.4/\sqrt{2.5} = 83.32$
where: $\mathbf{K_0}$, $\mathbf{K_1}$, $\mathbf{K_2}$ and $\mathbf{K_3}$ – values of the coefficient **K** for measuring positions 0, 1, 2 and 3, respectively.

Tab. 2. Parameters source and receptor and the measured maximum value of the components particle velocity monitored blasting operation

L [m]	Q [kg]	$L_R = L/Q^{0.5}$[m/kg$^{0.5}$]	v_x [mm/s]	v_y [mm/s]	v_z [mm/s]
62.11	35	10.5	8.83	8.39	11.93
150.25		25.4	1.75	1.4	0.95
70.05	21.5	15.1	4.2	3.98	8.17
147.43		31.79	1.7	1.4	1.3
13.2	2.5	8.35	26.39	12.81	32.36
50.7		32.06	2.3	3.65	4.8
71.6		45.28	4.029	6.079	2.631
125.8		79.56	1.361	1.417	0.863
10.1		6.39	40.97	5.19	20.54
68.8		43.51	1.739	1.621	2.631
77.5		49.01	2.039	1.957	2.006
105.4		66.66	0.7	1.25	1

Based on the collected data graphic relation of maximum components of particle velocity on reduced distance during bench blasting a quarry Kučín was created. Graph in Fig. 9 shows, so called principles of seismic waves attenuation for Kučín quarry.

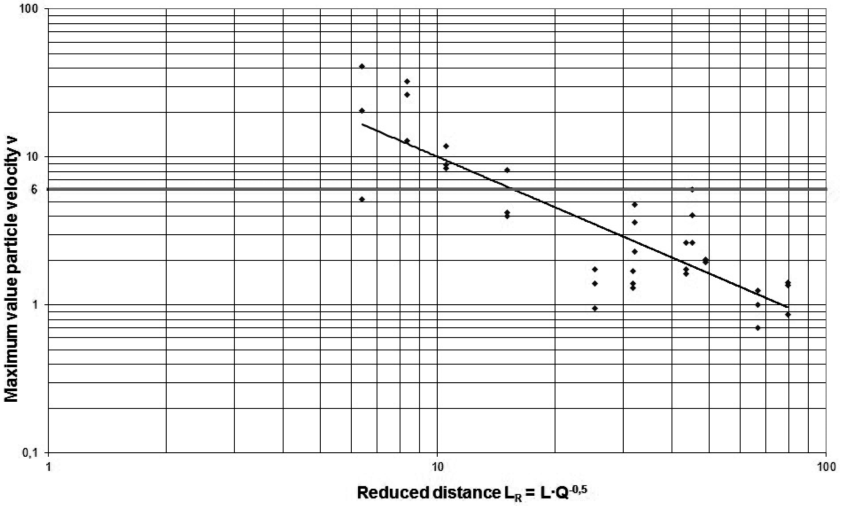


Fig. 9. Graphical dependence of maximum component particle velocity components on reduced distance for bench blastings in Kučín quarry – the seismic waves´ attenuation law.

From the seismic waves` attenuation law (1) it is possible to determine the amount of explosive charge and to determine (preliminarily) expected speed of vibration generated at protected object by rock blast for minimum distance of rock blast from object under consideration **L**.

Another, more important way of usage of attenuation law is following: for the allowed particle velocity $\mathbf{v_d}$ of the protected object determined in advance, in the graph (Fig. 9) we determine the maximum allowed reduced distance $\mathbf{L_{Rd}}$, from which, using known distance **L**, we calculate the maximum allowed reduced weight of explosive charge for rock blast:

$$\mathbf{Q_{cd}} = \left(\frac{\mathbf{L}}{\mathbf{L_{RQd}}}\right)^{2} \text{ [kg]} \tag{4}$$

For the monitoring object, where $v_d \leq 6$ mm/s (grey line), we can read from the graph in Fig. 9 that $L_{Rd} = 16$ m·kg$^{0.5}$, we obtain:

$Q_{cd} = (1/16)^2 L^2$ [kg]

For rock blasts done in the closest distance L = 68.8 m from the transmitter object under consideration, the maximum allowed total explosive charge for rock blast will be:

$Q_{cd} = 18.5$ kg.

From the graphical view of the seismic waves` attenuation law for Kučín quarry (Fig. 9) it was possible to determine the allowed particle velocity of 6 mm/s for frequencies below 50 Hz and higher than 10 Hz, at maximum allowed explosive charge of 18.5 kg for one time stage that would not be exceeded distance up to 68.8 m from the protected object-transmitter.

6. Conclusions

Mining in the quarry Kučín is performed in bench blasting operations. This technology quarrying maximum charge batting in one time stage does not exceed 35 kg. Corresponding to this is that, depending on the distance of the source – receptor and intensity of seismic effects.

Optimizing the timing of blasting operations that were made in the Kučín quarry been achieved, that the measured values do not exceed the values laid down by applicable Slovak technical standard STN EN 1998-1/NA/Z1 Seismic structures $v_d < 6$ mm/s and cause no harm monitored residential buildings in the village Kučín. Given that the measured particle velocity at the objects were well below 6 mm/s, the maximum size load one time stage to 5 kg of explosives was set correctly. Used timing 9 ms significantly contribute to reducing the seismic effects of blast in the Kučín quarry.

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