RESEARCH ON THE INFLUENCE OF BLASTING ON ENVIRONMENT IN THE QUARRY VČELÁRE

VÝSKUM VPLYVU TRHACÍCH PRÁC NA ŽIVOTNÉ PROSTREDIE V LOME VČELÁRE

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Abstract

Blasting has always been playing a decisive role for human's in extraction mineral resources. Depending on the conditions and parameters blasting can exceed the bearable limits for safety and in this case it becomes harmful and can cause serious damages. Due to increasing weight of explosive charge there can be observed an increasing seismic vibration spreading through the rock environment and consequently it causes vibration of individual components of this environment. If the intensity of the vibration is large enough, there may be a violation of the environment, or even to its destruction. Research on the effects of blasting on the environment has long been realized during mining works in limestone quarry Včeláre. Its results are used in the projection of blasting with respect to environmental impacts. This paper presents the methodology for measuring and evaluating the possible impact of blasting in the quarry Včeláre on residential property in the village Včeláre.

Abstrakt

Trhacie práce majú a oddávna mali rozhodujúcu úlohu pre človeka pri získavaní nerastných surovín. V závislosti od podmienok a parametrov rozpojovania, môžu prekročiť únosné – bezpečné hranice kedy sa stávajú škodlivými a môžu zapríčiniť veľké škody. S rastúcou hmotnosťou nálože trhaviny rastie aj intenzita vlnenia seizmických vĺn, ktoré sa šíria v horninovom prostredí a spôsobujú kmitanie jednotlivých časti tohto prostredia. Ak je intenzita kmitania dostatočne veľká, môže dôjsť k porušeniu prostredia, prípadne aj k jeho deštrukcii. Výskum vplyvov trhacích prác na environment je dlhodobo realizovaný počas ťažobných prác vo vápencovom lome Včeláre. Jeho výsledky sú využívané pri projektovaní trhacích prác s ohľadom na dopady na životné prostredie. V článku je prezentovaná metodika merania a vyhodnocovania možného vplyvu trhacích prác v lome Včeláre na obytné objekty v obci Včeláre.

Keywords

blasting, Včeláre quarry, particle velocity, seismic safety, law of attenuation seismic waves

Kľúčové slová

trhacie práce, lom Včeláre, rýchlosť kmitania, seizmická bezpečnosť, zákon útlmu seizmických vĺn

1 Introduction

Parallel with the development of blasting techniques there can be observed the technical development of measures on minimizing damages to avoid harmful effects of blasting and mainly of the seismic effects. Due to the Slovak Technical Standards STN 73 0036 (STN EN 1998-1/NA/Z1) on Seismic Loading of Buildings there exists a given standard for general assessment of seismic effects of blasting on buildings. Our criteria on building damages caused by blasting belong to the most rigorous ones in the world. The introduced values of the vibration velocity present an important issue mainly for the project engineers, technical shot firers and mining engineers whose responsibility is to prepare the new areas for quarrying. The more precise definition of the limiting vibration values can lead to enrichment of existing know-how and it can support further research in this field focused mainly on further measurements of technical blasting and consequently on seismic effects and moreover it can highlight their impact on the environment.

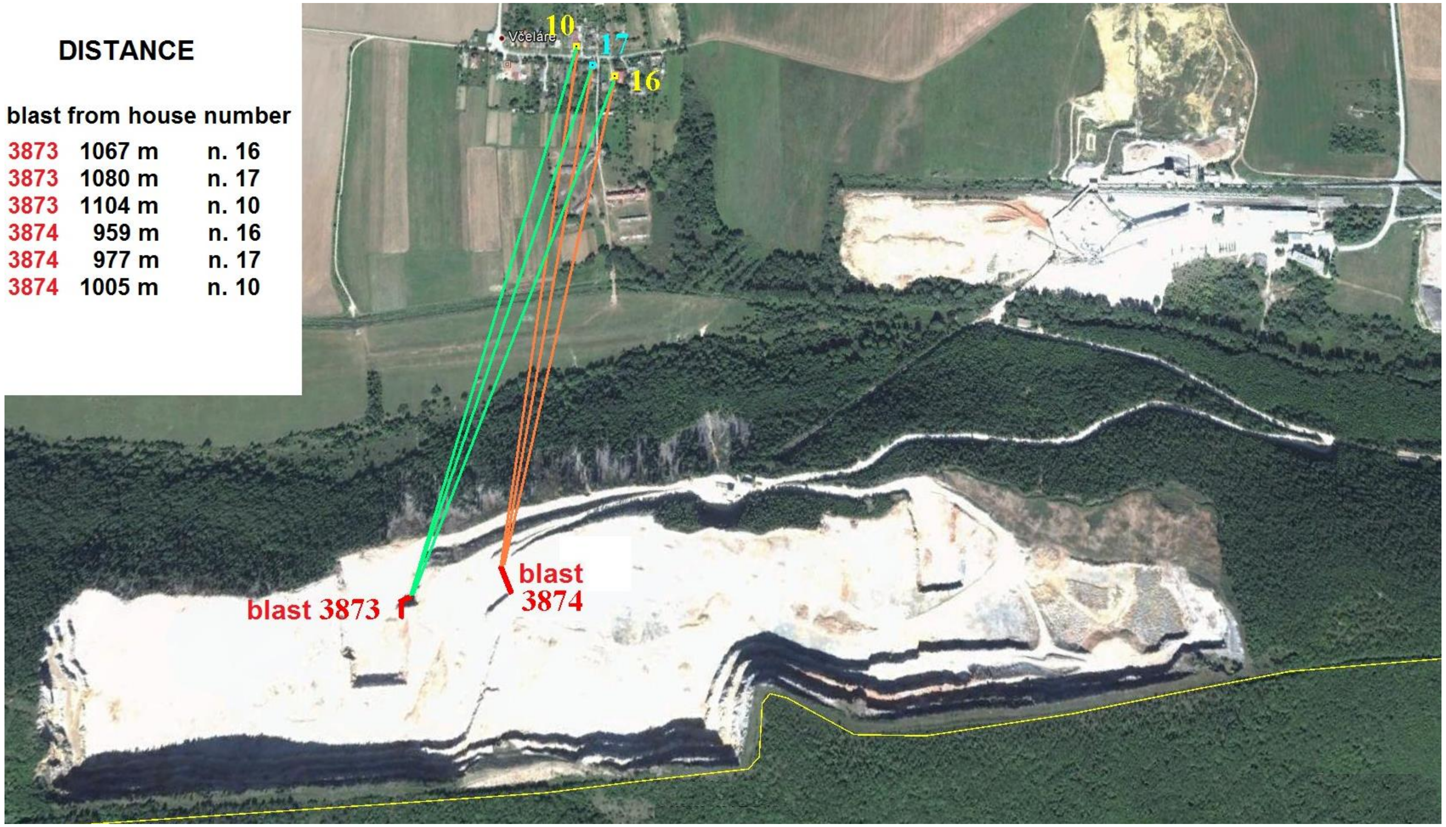

Fig. 2 Position and distance blast point No. 3873 and blast point No. 3874 in the quarry Včeláre in relation to the measuring standpoints in the village Včeláre

The aim of the research was to reduce seismic effects of blasting on environment. The final seismic impact can be efficiently reduced by charge per millisecond time stage in which then the retarded explosion causes interference of seismic waves and as a result their ineligible effects are reciprocally disturbed.

It is well-known that the smaller the vibration the charge lighter overcomes the resistance of the enclosing body and therefore in some cases it is advisable to overdesign the charge capacity by 30 – 40%.

On the one hand the amplitude increases but on the other hand the vibration velocity decreases and moreover the gripping of blasted material decreases.

As a result there is a smaller seismic effect at the cost of the diffusion increase and the projection of blasted material.

In the presented paper there are demonstrated measurements and assessment of seismic effects of blasting in the quarry Včeláre with the aim to decrease the seismic effects of bench blasting in the quarry Včeláre on the buildings in the village Včeláre and in the nearby environment of the quarry Včeláre. There was achieved an optimization of parameters of individual blastings thoroughly applying the latest research results about seismic effects of blasting on the environment. The blastings in the quarry Včeláre were single-row and oriented from the receptor – the village Včeláre. Timing between individual time stages was determined so that to achieve the maximum attenuation of charge in the next time stage. The composition of the charge was modified to divide the total charge in the borehole into more time stages and consequently the maximum charge capacity decreased at one time stage. All these modifications of parameters were carried out due to the methodology of seismic effects of blasting and the result was a maximum reduction of seismic effects of blasting in the quarry Včeláre on the environment. (Dojčár and Pandula, 1998; Viskup and Pandula, 2008; Pandula and Kondela, 2010; Viskup et al., 2010, 2011)

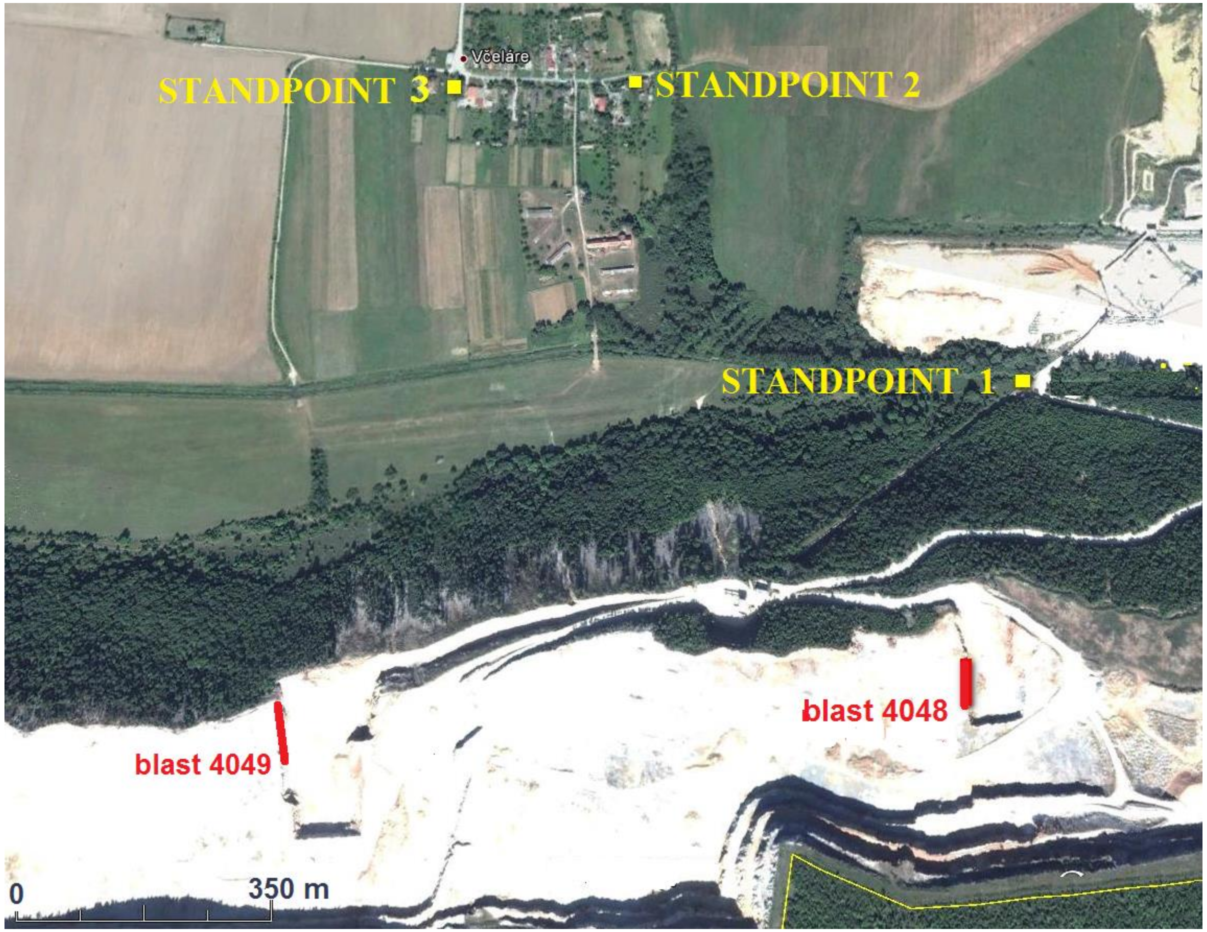

***Fig. 3** Position and distance blast point No. 4048 and blast point No. 4049 in the quarry Včeláre in relation to the measuring standpoints in the village Včeláre*

2 Shortened geological structure of the Včeláre quarries (transmitting medium)

Včeláre surface quarry is situated in the rock environment of weterstein limestones of the Silica Nappe (Fig. 1). Silica Nappe is a horizontally and subhorizontally situated body in which there are mainly present middle and dominantly Lower-Triassic carbonate sediments. The wetterstein limestones are mined raw materials which are used predominantly in the steel and cement industry. The village Včeláre lies on the post-tertiary diluvial eolic loess and loess loams which are in overlying limestones. Unlike the limestones loess they are characterized by a higher attenuation of seismic waves as limestones.

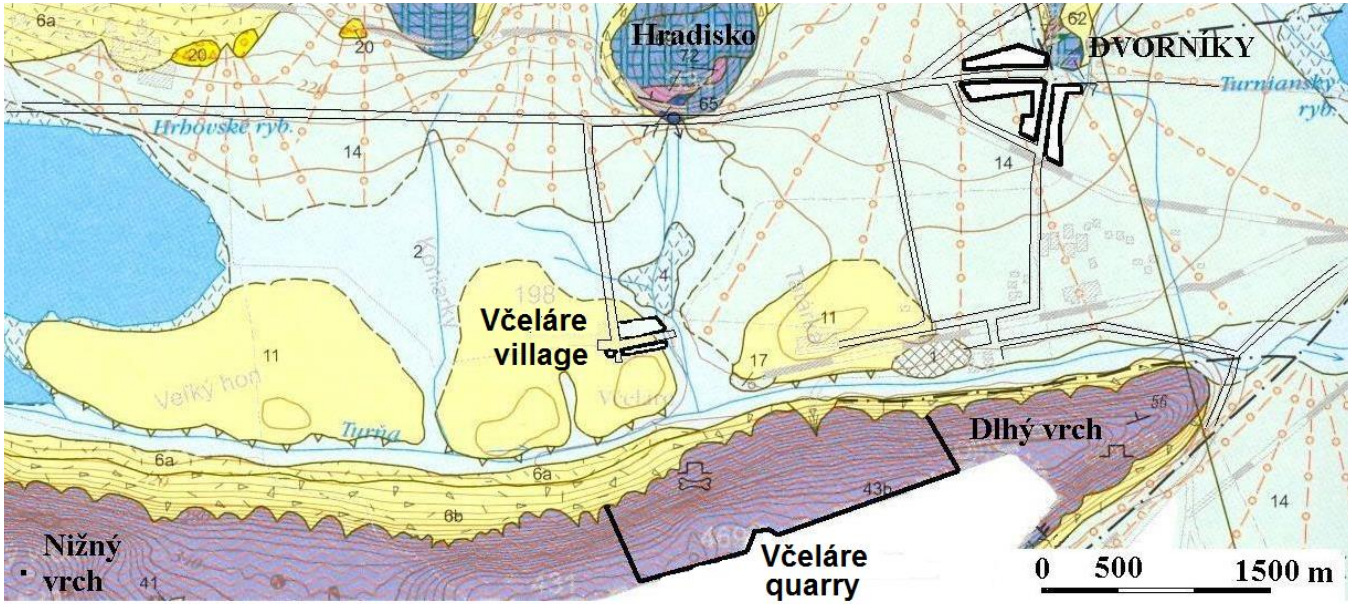

Fig. 1 The geological map of the environment of the quarry Včeláre with the nearest marked villages (Mello et al., 1996) – modified.

Description: The POST-TERTIARY PERIOD: 1 – anthropogenic sediments, 2 – fluvial sediments: bottomland of rivers – loamy-sandy and gravelly-sandy, 4 – organic sediments: moorlands (sphagnum bogs), 6a and 6b – diluvial sediments (a-clayey with fragments of rocks, b-clayey stoney and sandy stony), 8 – diluvial-proluvial sediments: detrial cones, 11 – diluvial-eolic sediments: loamy clay and loams, 14 – proluvial sediments: gravel and clayey sandy gravels, 17 – fluvial sediments: gravels, sandy gravels and sand of terraces, 20 – diluvial sediments: compacted hillwash, breccias and conglomerates, sporadically gravels. The MESOZOIC PERIOD: Triassic of the Silicky overthrust 41 – Leckogel limestones (oncolytic, pisolitic), 43 (a, b) – Wetterstein limestones (a-reef, b-lagoon), Triassic of Turniansky overthrust, 62 – dark foliaceous limestones and sandy calcareous clays, 65 – Dvornícke layers: shales and phyllites with sandstone components, 72 – Gutenstein dolomites, 77 – Bodvasilašsky sandstones and shales.

3 Measurement Methodology and applied instrument at bench blasting measurement

The measuring standpoints were situated in the village Včeláre according to the requirement of the submitter (Pandula and Kondela, 2014) see Fig 5a, Fig.6a, Fig 7a. Data about the position of the recording instrument and distance between the recorders and blastings are depicted in Table 1. The position of the blastings and the measuring standpoints in the village Včeláre are demonstrated in Fig. 2 and Fig. 3.

Table 1. Data about blast point positions and distance of the standpoint (family house) from the blasts

Standpoint	Bench blasting	Co-ordinates of geophones and blast			Distance from blast to standpoint		Note
		x	y	z	slant	horizontal [m]	
quarry Včeláre	No. 3873	1253654.964	296727.229	366.080	-	171.38	
1	No. 3873	1252592.099	296576.194	194.773	-	1067.19	
2	No. 3873	1252544.900	296650.549	198.472	-	1104.11	
3	No. 3873	1252588.628	296612.296	196.026	-	1080.71	
quarry Včeláre	No. 3874	1253592.944	296546.720	380.568	-	7.50	
1	No. 3874	1252592.099	296576.194	194.773	-	959.60	
2	No. 3874	1252544.900	296650.549	198.472	-	1005.22	
3	No. 3874	1252588.628	296612.296	196.026	-	977.87	
quarry Včeláre	No. 4048	-	-	-	-	-	
1	No. 4048	-	-	-	-	546.80	
2	No. 4048	-	-	-	-	1085.59	
3	No. 4048	-	-	-	-	1024.06	
quarry Včeláre	No. 4049	-	-	-	-	11.87	
1	No. 4049	-	-	-	-	1309.25	
2	No. 4049	-	-	-	-	1165.00	
3	No. 4049	-	-	-	-	961.13	

The following digital seismic instruments were applied for measuring and graphical recording of the seismic effects of the blasts:

- seismic instrument VMS 2000 MP of the American company Thomas Instruments and geophone of the American company Geospace Technologies (Fig. 4a);
- seismograph UVS 1504 and geophone of the Swedish company Nitro Consult (Fig. 5b, Fig. 7b);
- seismograph ABEM Vibraloc and geophone of the Swedish company ABEM (Fig. 4b , Fig. 6b).

The seismograph provides digital and graphical records of all three vibration velocity components of the transmitting medium, horizontal longitudinal [v_x], horizontal lateral [v_y], vertical [v_z]. The seismographs UVS 1504 and ABEM Vibraloc work autonomously, they test the channels automatically without any intervention and influence of the operators on the measured and registered vibration characteristics.

Fig. 4a The position of the measuring standpoint in the quarry Včeláre near to the blast point. The instrument VMS 2000 MP in distance of 11.87 m from the boreholes of the bench blasting No. 4049

Fig. 4b Position of the measuring instrument ABEM Vibraloc at the standpoint 1 in the quarry Včeláre

Fig. 5a Measuring standpoint 1 at blast point No. 3873 and blast point No. 3874

Fig. 5b Position of the seismograph UVS 1504 at the entrance of the family house No. 16 in the village Včeláre

The seismographs VMS 2000 MP, UVS 1504 and ABEM Vibraloc have an AD conventor with automatic 14 bit dynamic range of 0.05/250 $mm.s^{-1}$. For these measurements there was used the electrodynamic geophone NitroConsult with frequency range of 1/1000 Hz and responsiveness of 20 $mV/mm.s^{-1}$. Further the three component geophone of the company GeoSpace and the three component geophone of the company ABEM with frequency range of 1/1000 Hz and responsiveness of 10 $mV/mm.s^{-1}$ were applied in the measurements. The geophones were set on a special support with sharp steel spikes which assured continual contact with the foot (Fig. 4a).

4 Source of vibrations

The source of seismic effects was created by bench blasts No. 3873, blast point No. 3874 (Fig. 2) blast point No. 4048 and blast point No. 4049 at the limestone bed situated approx. 1 km in the south from the village Včeláre. The blasts were carried out in the western part of the IV. etage at the northern part of the quarry Včeláre (Fig. 3).

Bench blasting No. 3873: There were 6 boreholes drilled at hole diameter 105, 115 a 130 mm and under the angle 65°. The length was 31 m, with the shot from 4.2 up to 4.7 m and with the span 5.3 m + 17 bottom charge boreholes. The total charge of blast was 903.6 kg explosive and the total charge at one time stage was 260.2 kg (Fig 8a).

Fig. 6a Measuring standpoint 2 – the church in the village Včeláre

Fig. 6b The measuring instrument ABEM Vibraloc set on the concrete basis at the entrance of the church

Fig. 7a Measuring standpoint 3 – the family house No. 10 in the village Včeláre

Fig. 7b The measuring instrument UVS 1504 set on the concrete basis at the entrance of the house

Bench blasting No. 3874: There were 14 boreholes drilled (with length from 12 to 15.5 m) + 12 bottom charge boreholes (with length 4 m at hole diameter 105 mm) and under the angle of 10°, with shot from 4.2 to 4.7 m and span from 5.2 to 5.3 m (Fig. 9). The total charge of the blasting was 953.4 kg explosives and 139.7 kg charge at one time stage. Distribution of bottom charge boreholes is in Fig. 8b and the applied explosives are presented in Fig. 10.

Bench blasting No. 4048: There were 6 boreholes drilled at hole diameter 105, 115 and 130 mm and under the angle of 65°. The length was 31 m, with shot from 4.2 up to 4.7 m and with span 5.3 m + 17 bottom charge boreholes. The total charge of blasting was 903.6 kg explosives and the maximum charge at one time stage was 260.2 kg.

Bench blasting No. 4049: There were 14 boreholes drilled (with length from 12 to 15.5 m) + 12 bottom charge boreholes (with length 4 m at hole diameter 105 mm) and under the angle of 10°, with shot from 4.2 up to 4.7 m and with span from 5.2 to 5.3 m (Fig. 13). The total charge of blasting was 953.4 kg explosives and 139.7 kg was the total charge at one time stage. Distribution of bottom charge boreholes is in Fig. 9a, Fig. 9b, and the applied explosives are presented in Fig. 10.

Fig. 8a Charging and feeding of individual boreholes for the bench blasting No. 3873

Fig. 8b Position of boreholes for the bench blasting No. 3874

Fig. 9a Charging and feeding of individual boreholes for the bench blasting No. 4049

Fig. 9b The realized bench blasting No. 4049 at the IV. etage in the northern part of the quarry Včeláre

5 Measured values

Before measurements the instruments positioned at individual standpoints were calibrated and their responsiveness was checked. At the measuring standpoints there was recorded the graphical process of individual components of seismic vibration at bench blastings (Fig. 11, Fig. 12a, Fig. 12b).

Fig. 10 Applied explosives in blasting Polonit E, Infernit and Dapmon

In the case of blasts No. 4048 and No. 4049, at the measuring standpoints No. 1 and 2 – (instrument ABEM Vibraloc) channel No. 1 – component **z**, channel No. 2 – component **x**, channel No. 3 – component **y** there were recorded the seismic effects. (Fig. 3). The individual graphical records last four seconds. The particular measuring instruments were positioned at the measuring standpoints enabling assessment of impact of generated technical seismicity on the surveyed objects. During these measurements the measuring instrument VMS 2000 MP was also set in the quarry Včeláre in a nearby distance to the boreholes (Fig. 4) and it enabled to achieve values of particle velocity for the very strict determination of the seismic waves attenuation law from the blastings to the receptors, i.e. to the surveyed objects in the village Včeláre (Pandula and Kondela, 2010).

All measured values at the individual measuring standpoints are illustrated in Table 2.

According to the measured values of particle velocity and frequency of individual vibration components at all blasts we could have been evaluated – due to the Slovak Technical Standard STN EN 1998-1/NA/Z1 (Seismic Loading of Building Structures) – the seismic effects of individual blasting concerning the objects in the quarry Včeláre and in the housing area of the village Včeláre.

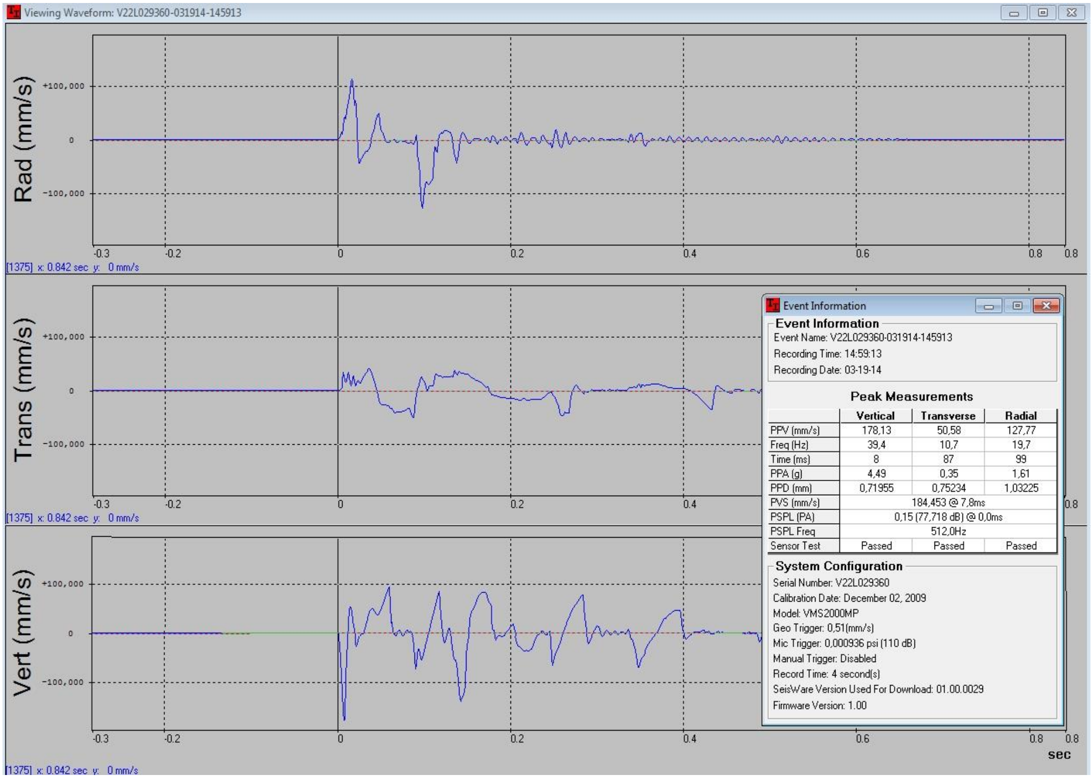

Fig. 11 Seismic record of particular vibration components vertical-z, transversal-y, longitudinal-x at blast point No. 4049 at the distance of 11.87 m from the first initiated borehole of bench blasting No. 4049 in the quarry Včeláre

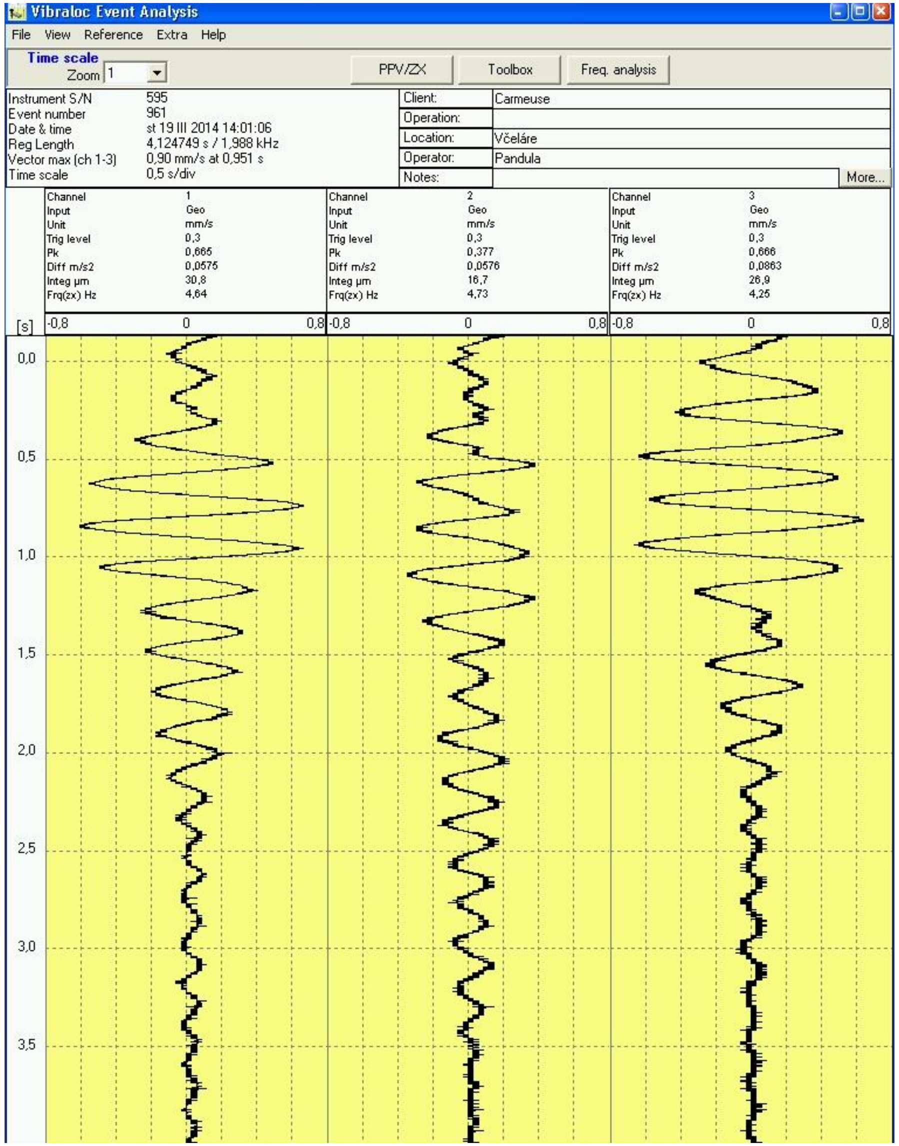

Fig. 12a Seismic four-second record of particular vibration components measured at the church in the village Včeláre. The first channel-z, the second channel-x, the third channel-y at the blast point No. 4049

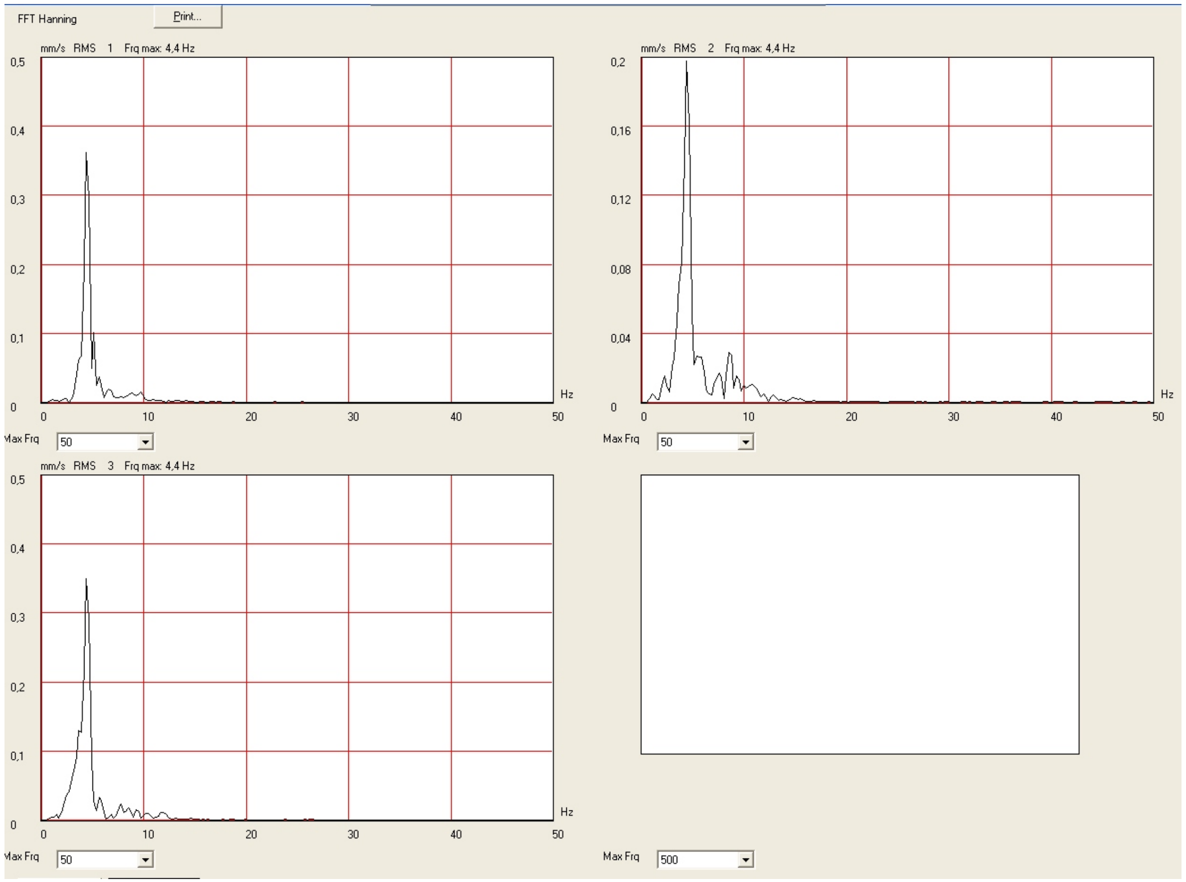

Fig. 12b Fourier amplitudes of individual vibration components measured at the church in the village Včeláre. The first channel-z, the second channel-x, the third channel-y at blast point No. 4049

6 Vibration velocity limitation for the protected objects in the housing area in the village Včeláre

Table 2 Measured values of frequency and velocity at blastings in the quarry Včeláre

Standpoint	f_x [Hz]	f_y [Hz]	f_z [Hz]	v_x [mm. s^{-1}]	v_y [mm. s^{-1}]	v_z [mm. s^{-1}]	Blast point No.
quarry Včeláre							3873
quarry	13.1	11.1	20.5	6.52	6.52	5,74	-
1	2.8	2.5	2.0	3.2	0.65	0.8	-
2	4.65	7.84	5.28	0.175	0.484	0.515	-
3	3.72	7.52	5.13	0,522	0.522	0.483	-
quarry Včeláre							3874
quarry	10.7	42.7	85.3	178.35	85.15	82.27	-
1	2.7	3.0	2.6	3.6	0.8	1.05	-
2	4.23	6.82	5.12	0.196	0.637	0.644	-
3	3.83	7.43	4.88	0.812	0. 560	0,318	-
quarry Včeláre							4048
quarry	-	-	-	-	-	-	-
1	8.01	9.24	2.5	1.55	1.906	1.183	-
2	4.73	4.25	0.64	0.377	0.606	0.665	-
3	0.3	1.3	0.9	0.4	0.6	0.4	-
quarry Včeláre							4049
quarry	28.4	0.7	9.7	178.13	50.58	127.77	-
1	6.75	5.86	7.43	0.816	0.818	0.305	-
2	3.43	4.25	4.9	0.609	1.158	1.185	-
3	4.5	4.0	4.5	0.75	1.35	0.8	-

Due to the recommendations of the Slovak Technical Standard STN EN 1998-1/NA/Z1 on Seismic Loading of Buildings, with respect to the charge used at bench blasting presenting tens of kilograms, where the particle velocity usually can be f > 10 Hz and according to the building objects resistance against the technical seismicity it is possible to categorize the building objects in the village Včeláre as resistance class B.

Concerning the type and category of foundation soil of the protected objects with regard to missing particular characteristics and data, they can be ranked to the category B, which is nearest to the reality (level of groundwater is more than 3 m under the surface level).

According to the measured values at blastings in the quarry Včeláre, where the particle velocity was f < 10 Hz and with regard to longer-term character of blastings on limestone bed of the quarry Včeláre and taking into consideration the mostly higher age of building

structures proving some cracks as well, for the blasting by bench blasting the maximum particle velocity limit (velocity component) for both the quarry Včeláre and building objects in the village Včeláre can be determined by the following value: $v_d \leq 3$ mm/s.

7 Measured seismic effects of bench blastings and their analysis

According to timing blastings can be divided as follows:

- instantaneous – simultaneous initiation of a group of charges,
- timed – partial charges explode in different time sequences.

At one time stage more charges can explode simultaneously which are considered one partial charge.

Seismic effects of the intended blasting can be substantially reduced: by distribution of total charge into more

Table 3 Measured maximum values of vibration velocity components of bench blasting in the quarry Včeláre

L [m]	Q [kg]	$L_R = L.Q^{-0.5}$ [m.kg$^{-0.5}$]	v_x [mm.s^{-1}]	v_y [mm.s^{-1}]	v_z [mm.s^{-1}]
1165	2535	23.14	1.10	1.45	1.60
1312	10486.4	12.81	2.15	3.20	3.35
1496	1271.6	41.95	0.95	0.75	0.60
1210	540	52.07	0.55	0.55	0.75
1081	115.6	100.54	1.30	1.00	1.00
992.6	336	54.15	0.75	0.9	0.4
1072.3	336	58.50	0.55	0.75	0.5
1010.7	514.2	44.57	0.484	0.515	0.25
1060.8	514.2	46.78	0.484	0.464	0.25
1067.19	260.2	66.16	0.65	0.8	0.55
1104.11	260.2	68.45	0.484	0.515	0.330
1080.71	260.2	67.00	0.522	0.483	0.260
959.6	139.7	81.19	0.8	1.05	0.55
1085.22	139.7	91.82	0.637	0.644	0.432
977.7	139.7	82.72	0.812	0. 560	0.318
12.5	139.7	1.06	85.15	82.27	178.35
546.8	140.2	46.18	0.377	0.606	0.665
1085.59	140.2	91.68	1.55	1.906	1.183
1024.06	140.2	86.49	0.4	0.6	1.3
28.58	226.2	1.90	178.13	50.58	127.77
1309.05	226.2	87.04	4.67	1.158	1.185
1165	226.2	77.46	0.816	0.818	0.305
961.13	226.2	63.91	0.75	1.35	0.8

partial charges. A very efficient way of reducing the final seismic effects is to apply the millisecond blasting timing in which the retarding of individual charges causes interference of seismic waves so that their eligible effects are reciprocally disturbed.

In timed blasting there are two time sequences taken into consideration Δt (Pandula and Kondela, 2010):

$\Delta t \geq 250$ ms (there is a seismic waves attenuation before the explosion of the next partial charge),

$\Delta t < 250$ ms (occurrence of effects interference of partial charges).

Then required length of boundary sequence timing depends on the rock environment and it can decrease from the value of 250 ms up to $\Delta t = 7$ ms.

The maximum reduction of the vibration velocity can be achieved at the initiation sequence of the charge:

$\tau = 10^5/c_p$ [ms]

where c_p = transition velocity of longitudinal seismic waves in the rock environment between the blast and the protected object [m/s].

In accordance with chosen value $\boldsymbol{\tau}$, the total charge capacity of the blast Q_c can be:

$Q_c = Q_č \,.\, N^{\tau}$ [kg]

where $Q_č$ = the admissible charge of timed blasting (charge per millisecond time stage) [kg],

N = the number of charges, respectively a group of charges with capacity blasted at the time stage $\boldsymbol{\tau}$, is the exponent dependent on the solid mass characteristics.

The measured maximum values of seismic effects generated by bench blasting which were carried out in previous period and currently in the quarry Včeláre are presented in Table 3. According to these values there was determined the seismic waves attenuation law in the quarry Včeláre. (Dojčár and Pandula, 1998)

Due to the data in Table 3 the graphical dependence of maximum vibration velocity components was completed at the reduced distance at bench blasting. The graph in Fig. 13 demonstrates the application of the seismic waves attenuation law for the quarry Včeláre completed by the values from Table 3 in which the value Q was expressed as follows:

$$v = \left(\frac{L}{Q^{0,5}}\right) = K\left[\frac{L}{Q^{0,5}}\right]^n$$

where v = the maximum vibration velocity (maximum component of vibration velocity) generated by blasting, [$mm.s^{-1}$],

$L/Q^{0,5}$ = the so-called reduced distance, [$m.kg^{-0,5}$],

L = the shortest vibration source – receptor distance, [m],

Q = the charge capacity of the time stage, [kg],

K = the coefficient dependent on the conditions of blasting, properties of transmitting medium, type of explosive etc.,

n = the index of the seismic waves attenuation.

According to the seismic waves attenuation law it is possible for a particular receptor to assess the charge size at a given distance so that the maximum values of the individual particle velocity components will not exceed the determined maximum particle velocity.

In the graph (Fig. 13) there are marked by blue points the measured values of the vibration velocity for the surveyed object in the village Včeláre at blasting in the quarry Včeláre. The points on the left side of the figure mark the measured values of particle velocity at the source of vibration, i.e. near by the blasting in the quarry Včeláre. The red line stands for the boundary of the maximum limit of the vibration velocity for the foundation soil type "B" (level of ground water is higher than 3 m under the surface level).

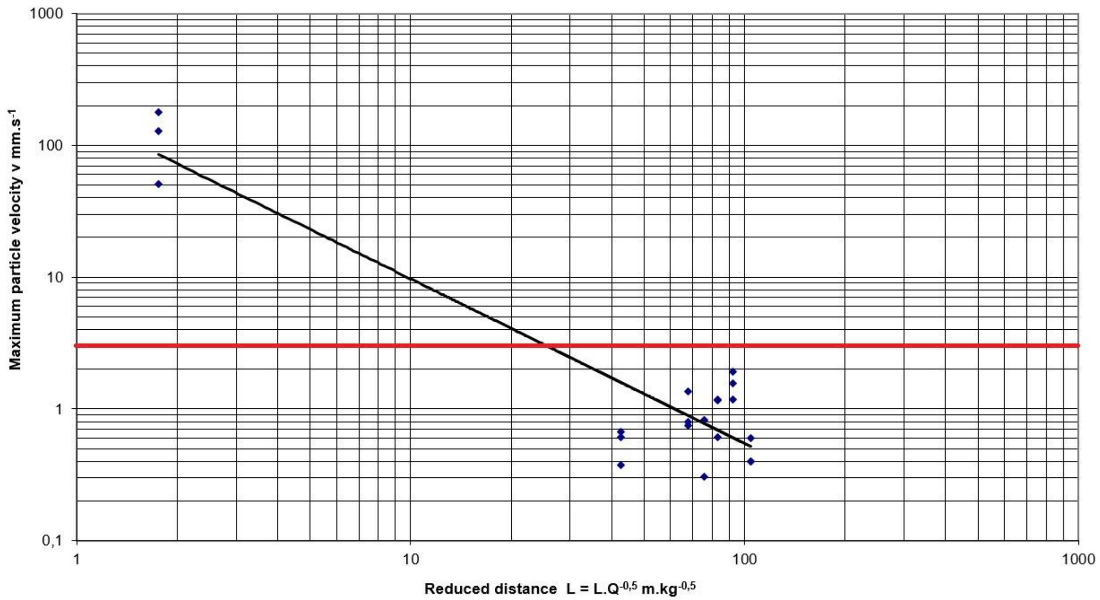

***Fig. 13** Graphical dependence of maximum particle velocity components at the reduced distance at bench blastings in the quarry Včeláre – seismic waves attenuation law. The lateral red line marks the maximum limit for safety of particle velocity for the building structures. The points demonstrate the measured values of particle velocity at the individual measuring standpoints of bench blasting in the quarry Včeláre. The highest points depict the measured values of particle velocity near the blast point in the quarry Včeláre*

8 Conclusion

Quarrying in the area Včeláre is carried out by bench blasting. According to the measured and calculated values at the operating blastings in the quarry Včeláre there was appointed the maximum limit of charge capacity for the repeated bench blastings in the quarry Včeláre at one time stage depending on the following distances (Pandula and Jelšovská, 2008, Pandula and Kondela, 2010):

For the distance 500 m $Q_{vmax} = L^2/L_R^2 = 500^2 / 50^2 = 100$ kg,

For the distance 1000 m $Q_{vmax} = L^2/L_R^2 = 1000^2 /50^2 = 400$ kg,

For the distance 1100 m $Q_{vmax} = L^2/L_R^2 = 1100^2 /50^2 = 484$ kg,

For the distance 1200 m $Q_{vmax} = L^2/L_R^2 = 1200^2 /50^2 = 576$ kg,

For the distance 1250 m $Q_{vmax} = L^2/L_R^2 = 1250^2 /50^2 = 625$ kg.

The measurement results of seismic effects of blasting, which were carried out in the quarry Včeláre, proved that due to the previous measurements the seismic waves attenuation law was correctly applied for the quarry Včeláre. During the inspection of the housing area before the blastings there were identified cracks in both the external and internal walls of the buildings. After the monitored blastings in the quarry Včeláre there was no evidence found about the further cracks. The measured values did not exceed those values which are specified in the valid Slovak Technical Standard STN EN 1998-1/NA/Z1 Seismic Loading of Building Structures $v_d < 3$ mm/s for the frequencies lower than 10 Hz and for the foundation soil type “B“. The research on blasting in the quarry Včeláre confirmed that the seismic effects of blastings on the environment can be reduced due to the projecting of blasting and applying the appropriate methodology of blasting.

To achieve the maximum reduction of seismic effects in millisecond timing it is necessary to focus on the following issues:

- distribute the total charge of blasting into maximum number of time stages;
- the bigger the number of time stages , the lower the seismic effect of the blasting;
- distribute the total charge capacity equally into time stages so that the differences in charge capacity at one time stage would not exceed 10÷15%;
- orientate the direction of the blasting away from the protected objects and pay big attention to the determination of the blasting scheme.

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