SEISMIC MEASUREMENTS AND ANALYSIS OF VIBRATION INTENSITY CAUSED BY BLASTING IN "GOVRLEVO" MINEFIELD, MACEDONIA

SEIZMIČKA MJERENJA I ANALIZA INTENZITETA VIBRACIJA IZAZVANIH MINIRANJEM U RUDNIKU „GOVRLEVO“, MAKEDONIJA

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Abstract: *The performed investigations involved measurement of seismic impacts induced by blasting (an explosion) in a minefield located within the concession borders of the limestone mine "Govrlevo"; processing, analysis and interpretation of the records, determination of vibration intensities and evaluation of their potential harmful effects upon people and material property in accordance with the current legal regulations and standards. Since the normative framework of Macedonia inadequately cover the considered field, measurements and their interpretation were done in compliance with DIN 4150-3: 1993 and BS 6472-2: 2006 standards, and WAC 296-52-67065, USBM: RI 8507 and OSMRE: CFR Part 816.67 (D) Rules and Recommendations.*

Keywords: *Seismic measurements, vibrations, minefield, blasting, damage, discomfort, Govrlevo, Macedonia*

Sažetak: *Izvršena istraživanja obuhvaćaju instrumentalna mjerenja oscilacija seizmičkih udara prouzrokovanih eksplozijom minskog polja lociranog u krugu površinskog rudnika krečnjaka „Govrlevo“, obradu i analizu izmjerenih oscilacija seizmičkih udara, određivanje intenziteta vibracija i ocjenu, suglasno aktualnoj zakonskoj regulativi i standardima, njihovih potencijalno štetnih utjecaja na ljude i materijalna dobra. Obzirom da nacionalna regulativa Makedonije neadekvatno pokriva predmetno područje, mjerenja i njihova interpretacija su izvršena suglasno DIN 4150-3:1993 i BS 6472-2:2006 standardima, odnosno pravilnicima i preporukama WAC 296-52-67065, USBM:RI 8507 i OSMRE:CFR Deo 816.67(D).*

Ključne riječi: *Seizmička mjerenja, vibracija, rudnik, miniranje, oštećenje, neugodnost, Govrlevo, Makedonija*

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1. INTRODUCTION

The seismic measurements at Govrlevo mine, i.e., definition of vibration intensity and evaluation of its potentially harmful effect upon people and material property were performed in accordance with the requirements arising from the Integrated Environmental Permit “B”. At the request of the joint stock company TITAN, cement factory “Usje”, the Institute of Earthquake Engineering and Engineering Seismology, Ss. Cyril and Methodius University, Skopje (UKIM-IZIIS, Skopje) performed:

- Seismic measurements of seismic effects caused by blasting in the minefield located within the surface limestone mine Govrlevo (2.07.2014);
- Processing and analysis of the records obtained; and,
- Definition of intensity of vibrations for evaluating their potential adverse effects upon people and material property in compliance with the currently valid legal regulations and standards.

Since the national regulations very inappropriately cover the subject area, the quantification and evaluation of the effect of the vibrations induced by explosions upon people and material property, the measurements and their interpretation were done in conformity with the DIN 4150-3:1993 and BS 6472-2:2006 standards, i.e., the WAC 296-52-67065, USBM: RI 8507 and OSMRE: CFR Part 816.67(D) rulebooks and recommendations.

2. REGULATORY FRAMEWORK FOR EVALUATING EFFECTS OF EXPLOSION INDUCED VIBRATIONS

2.1. National Normative Framework

The minimum requirements for protection of employees against risks related to their health and safety which are possible to occur due to exposure to mechanical vibrations and are exclusively applied for activities during which employees are exposed or are potentially exposed to risks related to mechanical vibrations during their work are defined in the “Rulebook on Safety and Health at Work of Employees Exposed to Risks Related to Mechanical Vibrations” (Official Gazette of RM no. 26/2008), based on Article 47 of the Law on Safety and Health at Work (Official Gazette of RM no. 92/07).

The Rulebook (Official Gazette of RM no. 26/2008) is focused on two specific risks related to health and safety of employees, namely:

- "Hand - arm vibration": mechanical vibration which, when transferred through the human hand – arm system, causes risks related to health and safety of employees, particularly vascular, bone or joint, neurological or muscular disorders;
- "Vibrations of the entire body": mechanical vibration which, when transferred through the entire body, causes risks related to health and safety of employees, particularly numbness of the lower back and spine damage.

Appendix A to the Rulebook (Official Gazette of RM no. 26/2008) regulates to details the evaluation of the exposure, the procedure of measurement of vibrations and the methodological aspects of evaluation of the stated risks related to health and safety of employees. The adopted criteria on the level of exposure and risk level in the Rulebook are taken from:

- ISO 5349-1:2001 (chapters 4 and 5 and Appendix A) on hand-arm vibrations, and,
- ISO 2631–1:1997 (chapters 5, 6 and 7, Appendices A and B) on vibration of the entire body.

The exposure to explosions and related phenomena (vibration and impact wave) are instant (impact) phenomena and last up to several seconds at the most.

The discussed current national regulations in this field are not relevant for evaluation of the level of exposure and risk related to vibrations and impact wave caused by explosions taking into account that:

- The Rulebook (Official Gazette of RM no. 26/2008) that regulates safety and health at work contextually does not correspond and cannot be applied in the field of evaluation of the level of exposure and risk due to vibrations and impact wave caused by explosions;
- The character, the time duration (maximum several seconds) and the frequency content of the vibrations caused by explosion radically deviate from the characteristics of vibrations and noise to which employees are exposed during the 8 hour working day; and,
- ISO and BS criteria defined for another field are not adequate to be applied in the field of evaluation of the level of exposure and risk due to vibrations and impact wave (air overpressure) caused by explosion.

The Law on Environment (Official Gazette of RM no. 53/2005, 81/2005 and 24/2007) based on the provisions of the 96/61 EU Directive on Integrated Pollution Prevention and Control also treats vibrations as polluters in addition to processes connected with emission of chemical agents and noise, but there is not a single bylaw act that prescribes a methodology for their analysis and necessary benchmarks.

2.2. International Normative Framework

For relevant qualitative and quantitative interpretation of the measured vibrations and their effect upon people and structures, ample analysis and synthesis of international standards (ISO) and relevant national rulebooks and instructions regulating the considered field and defining quantitative criteria were performed to evaluate:

- Damage to structures; and,
- Human sensitivity to and perception of different kinds of long- and short- term vibrations and vibrations caused by explosions.

Irrespective of the type, the character and the time duration of the vibrations (long term /vibrations due to activities on construction sites/, short term /passing of vehicles on tracks and alike/, instant /explosion/), the quantitative criteria of the standards are based on:

- maximum (ppD, ppV), i.e., mean square (rmsD, rmsV) values of displacement (D) and velocity(V), respectively; and,
- Amplitude frequency spectra of the vibration velocity of the soil particles.

The stated physical quantities were identified, adopted and quantitatively expressed as parameters that have an exclusive control over the processes of damage to structures and human sensitivity to and perception of vibrations.

2.2.1. Risk Related to Damage of Structures due to Vibrations

DIN 4150-3:1999 and BS 7385-2:1995 also include vibrations due to explosions. The dominant part of the empirical basis of the defined criteria (benchmarks) are the effects of short term vibrations upon the potential for damage to structures as well as human sensitivity to and perception of these vibrations.

Competent standards for evaluation of the effect of vibrations due to explosions are incorporated in WAC (Washington Administrative Code) 296-52-67065, Chapter 296-52: Safety Standards for Possession, Handling, and Use of Explosives, Part: 67065. The bases of WAC 296-52-67065 are the investigations published in the following reports: USBM: RI 8507 (U.S. Bureau of Mines, Report: RI 8507, "Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting" 1980) and OSMRE (U.S. Office of Surface Mining and Reclamation Enforcement) normative: CFR (Code of Federal Regulations), Part 816.67(D) 1983).

3. MEASUREMENT AND ANALYSIS OF SEISMIC EFFECTS CAUSED BY EXPLOSION IN A MINE FIELD

Modern practice of measurement of vibrations due to explosions anticipates measurement of ppV by seismometers, i.e., velocity transducers – sensors for measurement of vibration velocity. The minimal requirements that the equipment for measurement of explosion vibrations (BS 6472-2:2008) should satisfy are:

an amplitude range of 0.0001 m/s (0.1 mm/s) to 0.1 m/s (100 mm/s) in the entire frequency range of 4.5–250 Hz. While seismometers are the most frequently used instruments since they directly measure the necessary parameter (velocity), BS 6472-2:2008 also allows application of other types of instruments (accelerometers) provided that velocities with stable and reliable characteristics in the necessary frequency range are obtained with the processing of the data from the measurements.

The preferred technique of measurement is that with which reliable unfiltered (raw) time histories of acceleration are obtained to evaluate the human exposure, i.e., velocity and acceleration for evaluation of exposure of structures from which the necessary physical quantities are analytically obtained (ISO 2631-2:1989 Part 3.5).

The length (time duration) of the measurement of vibrations, the dynamic range of the instrument and the frequency (or the velocity) of sampling (sampling frequency – number of readings in a unit of time) should provide a satisfying statistic preciseness and enable that the sample (the time history of the necessary parameter) be "typical" for the type of exposure (of people or structures) for which the evaluation is performed (ISO 2631-1:1997(E) parts 5.4 and 5.5).

3.1. Geotechnical Medium of Surface Excavation

The blasting of the limestone in Govrlevo mine was done in three lithophysical media (surface cracked rocks /Mp/, more compact cracked rocks /Mi/ and relatively compact rocks /Mr/) with the following interval seismic velocities (Mirakovski & Aleksovski 2002), **Table 1**:

Table 1. Lithophysical media of Govrlevo mine

Limestone medium	Density *ρv (kNs/m⁴)*	Seismic velocities	
		Vp (m/s)	*Vs (m/s)*
Mp	20.0 - 22.0	750 - 1 350	400 - 750
Mi	22.0 - 24.0	1 350 - 2 400	450 - 1 350
Mr	24.0 - 26.5	2 950 - 4 150	1 150 - 2 150

Source: Mirakovski & Aleksovski (2002)

Figure 1. Disposition of the minefield

3.2. Main Parameters of Minefield and Blasting

The main blasting parameters are presented in **Table 2.** The general disposition of the minefield is depicted in **Figure 1**.

Table 2. Main Blasting Parameters

Blasting parameter	Value
Number of boreholes:	39
Number of rows:	5
Charges per borehole Qm (kg):	73
Total charge Q (kg):	2,850
Mode of activation:	NON-EL system with millisecond (ms) delay 36 pcs. (17, 25, 42 ms)

3.3. Disposition of Measuring Points, Measurement and Recording of Seismic Vibrations

The disposition of the seismic measuring points (SMP) and the disposition of the shallow refraction geophysical profile (PT-KT) are shown in **Figure 2**.

3.4. Disposition of Measuring Points, Measurement and Recording of Seismic Vibrations

The disposition of the seismic measuring points (SMP) and the disposition of the shallow refraction geophysical profile (GPSP-GPEP) are shown in **Figure 2**.

3.5. Processing and Analysis of Records

The processing of the recorded time histories of the vibration velocity of soil particles was carried out in accordance with DIN 44150 3:1990-2:

- Definition of the maximum (peak) velocity [*ppV = maxVr*] of the recorded time history of velocity [*vr(t)*] and the time at which it occurs [*TmaxVr*];
- Extraction of the signal segment with a length To that contains the vibrations due to the explosion [*ve(t)*] and is symmetrically centred around the time of the peak [*TmaxVr-To/2, TmaxVr+To/2*];
- Multiplication of the extracted signal by the time displaced Hanning window with a length To, centered around the peak time *TmaxVr*:

$$h_w(t) = \begin{cases} \dfrac{\left(1 - \cos\left[\frac{2\pi(t-t_0)}{T_0}\right]\right)}{2} & for\ t_0 \le T_0 \le T_0 + t_0 \\ 0 & for\ t_0 \le T_0 \le T_0 + t_0 \end{cases}$$

- Computation of the velocity amplitude spectra over the frequency range characteristic for the type of exposure for which the evaluation is made (human perception and reaction, i.e., risk related to damage to structures) were computed;

- Integration of *ve(t)* signal (velocities) for obtaining the *de(t)* (displacement) signal and calculation of the maximum (peak) displacements [*ppD = maxDe*];
- To the *de(t)* amplitude spectra is not given importance considering that it not anticipated by the requirements contained in the standards for evaluation of risk related to damage to structures exposed to the effect of transient vibrations and vibrations caused by explosions.

All processing and analyses are made by inhaus developed Matlab software package (MilutinoviĆ & Šalić 2014).

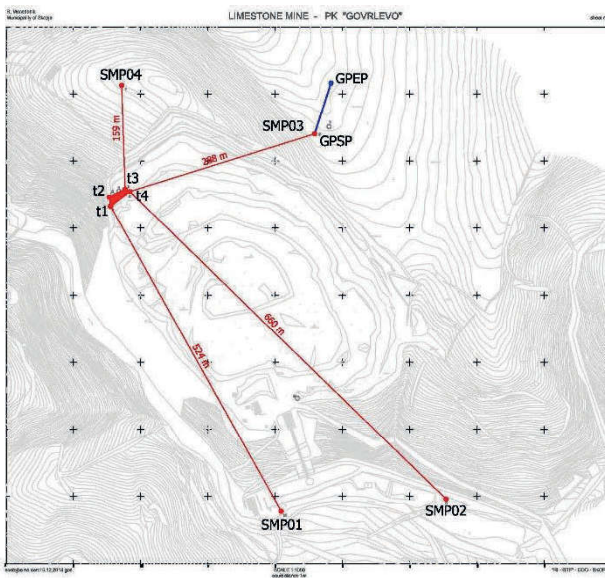

Figure 2. Disposition of seismic measuring points (SMP01-04) and geophysical profile GFSP-GFEP in respect to the minefield.

Table 3. **Seismogeological and stratigraphic characteristics of the investigated geophysical profile**					
Lithophysical media	**Vp [m/s]**	**Vs [m/s]**	**γ* (kN/m3)**	Depth **H[m]**	**Period T[s]**
D – Quaternary cover with admixtures of crushed bedrock at the base	400-600	150-240	17.0	4-8	0.07-0.08
Mi – Cracked limestone	1,550-2,000	700-1,000	20.0-22.0	4-15	0.12-0.17
Mr – Relatively compact limestone	2,500-2,800	1,400-1,500	24.0-26.5	15+	~ 0.2
**Source:* Mirakovski & Aleksovski (2002)					

The blasting vibrations in Govrlevo mine were measured by:

- a set of 4 ultramobile triaxial TROMINO^{TM}, MICROMED, Italy, seismometers,
- one uniaxial SS-1 Ranger (Kinemetrics, Pasadena, USA) seismometer, and
- a set of 4 Guralp CMG-5DT (Guralp Systems Ltd., Reading, UK) accelerometers.
- SoilSpy Rosina^{TM}, MICROMED, Italy, 16 channel digital seismograph was used for shallow refraction geophysical prospection.

The equipment used fulfils the BS 6472-2:2008 requirements.

4. RESULTS

4.1. Seismogeological Characteristics of Measuring Point SMP03

Shallow seismic refraction was performed along a seismic refraction profile with a length of 80 metres, in the direction of the Govrlevo surface excavation - Structures in the village of Dolno Sonje. Geophysical prospection were performed for getting a general insight into the characteristics of the potential amplitude-frequency modification and amplification potential of seismic vibrations due to blasting in relation to the local seismogeological characteristics of the terrain.

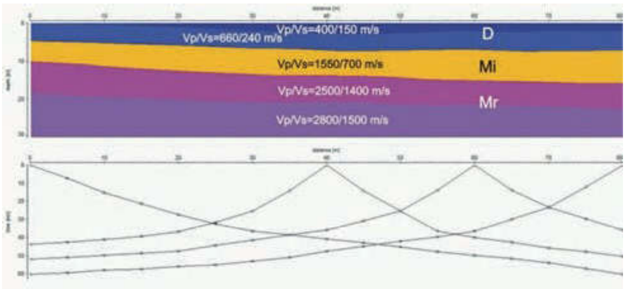

Figure 3. Lithostratigraphic/lithophysical characteristics of the researched geophysical profile

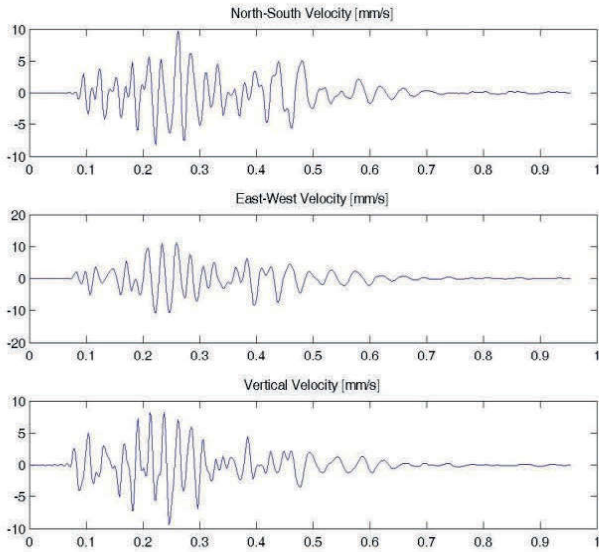

Figure 4. Measuring point SMP03: Time history of velocity[ve(t)]

The lithophysical and lithostratigraphic structure of the terrain along the investigated profile is presented in **Figure 3**. The obtained results fit well with the results from the investigations performed in 2002 and 2003 (Mirakovski & Aleksovski 2002, 2003), **Table 3.**

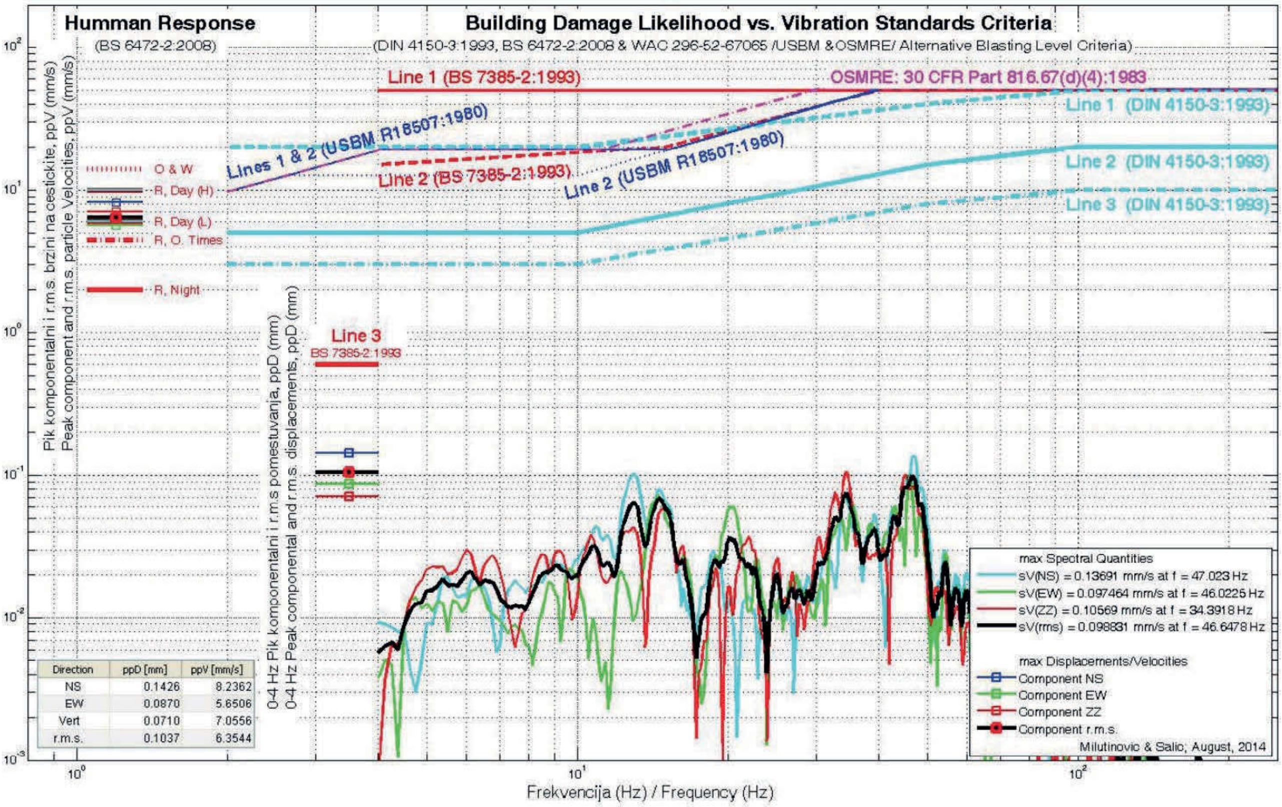

Figure 5. Comparative frequency graph, measurement point SMP02 (660m from the minefield)

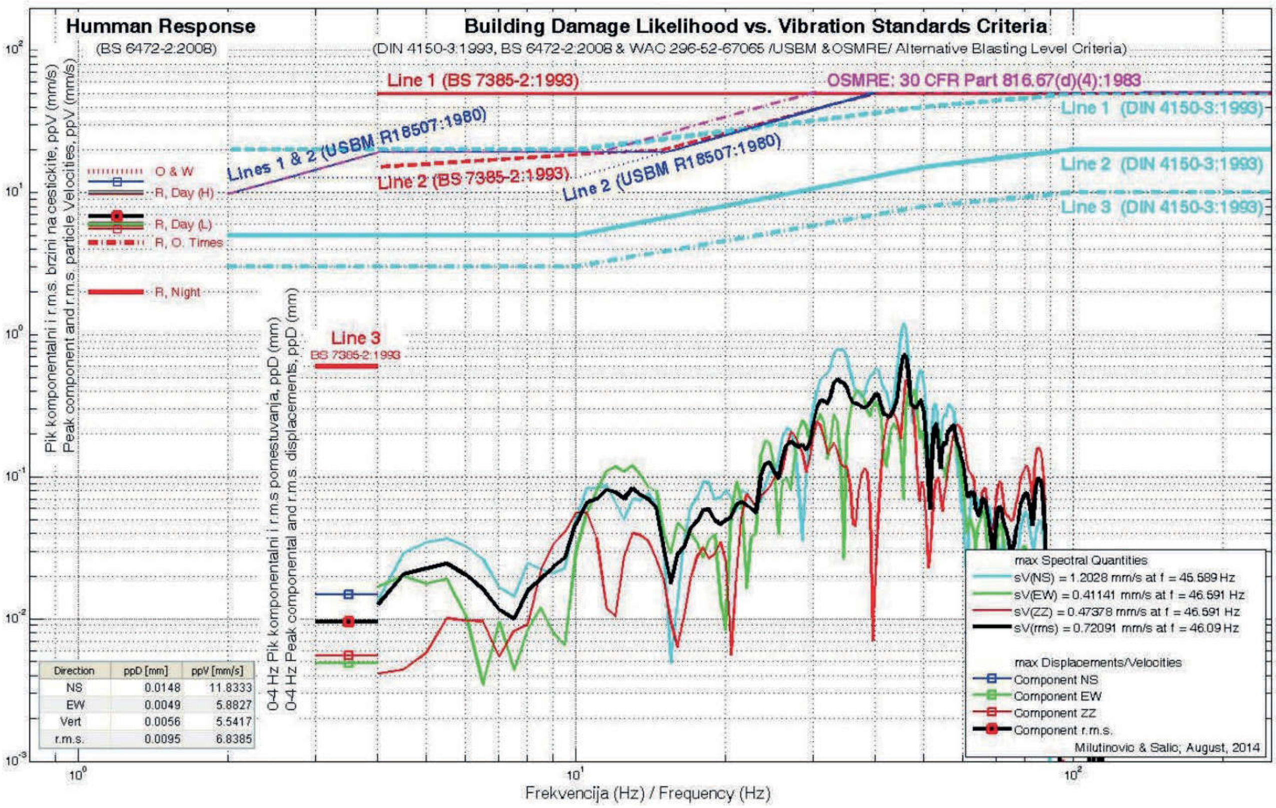

Figure 5. Comparative frequency graph, measurement point SMP04 (159m from the minefield)

The seismogeological characteristics of the other seismic measuring points were not defined considering that these are located on a rock outcrop as well as that they are within the limits of Govrlevo mine concession area.

For the measuring points SMP02 and SMP03, topographically located on a thin quaternary diluvium in the transit zone between the exploited rock massif and a valley, there is an indication for development of a secondary seismic wave (**Figure 4**) due to:

- the complex geometry of the geological structure, and,
- presence of a relatively thin quaternary layer.

Due to the closeness of the measuring points to the hilly massif, the secondary wave could not develop completely so that its amplitudes were smaller than the amplitudes of the primary wave. However, at greater distances from the hilly massif and in conditions of a thicker quaternary layer, it can be amplified and exceed the amplitudes of the primary wave.

To understand and interpret this effect completely, during the next blasting, particularly if blasting with a total charge weight greater than 2,850 kg is planned, at least one measuring point should be established in the direction leading to v. Dolno Sonje, at minimum 500-800 m from the measuring point SMP03. For this, it is necessary to define the seismogeological and stratigraphic characteristics by shallow refraction geophysical prospecting.

4.2. Risk Related to Damage to Structures and Human Discomfort

The level of risk related to occurrence of cosmetic damage to structures and human discomfort causing complaints by the population, the measured (BS 6472-2:2008, ISO 2631-1:1997) and analytically processed (DIN 44150 3:1990-2) time histories of velocity were compared with the benchmark values prescribed by the DIN 4150-3:1999, BS 7385-2:1995 and OSMRE CFR Part 816.67(D) standards and the USBM: RI 8507 (WAC 296-52-67065) instructions.

Comparative summary graphs and synthesis of fulfilment/unfulfilment of the criteria for the four measuring points (SMP01, SMP02, SMP03 and SMP04) were elaborated and presented in details (Milutinović & Šalić 2014).

A typical comparative spectral graphs for SMP02 (thin diluvium, 660m from the minefield) and SMP04 (rockoutcrop, 159m from the minefield) are shown in Figs. 5 and 6 respectively. Both graphs, as well as other two not presented, show that, in addition to the fulfilment of the relevant standards and recommendations of BS 7385-2:1995 and OSMRE CFR Part 816.67(D) and USBM: RI 8507 (WAC 296-52-67065) instructions [norms relevant for vibrations due to explosions], there is also fulfilment of the DIN 4150-3:1999 standard, which is most frequently used in the EU and, at the same time, is the most conservative standard being based on empirical data from "transient" vibrations.

5. CONCLUSIONS

Based on the comprehensive investigations that arose from the considered analyses and investigations in the domain of legal regulatory framework, the following conclusions are drawn:

1. The national regulatory framework of the Republic of Macedonia inappropriately covers the considered field – in particular the quantification and evaluation of effects of vibrations caused by explosions upon people and man-made property;
2. The measurements, the analysis of data and the interpretation of the obtained results were done according to the following valid international standards and norms: DIN 4150 3:1993, BS 6472-2:2006, BS 5228-2:2009 и BS 7385-2:1993 standards, i.e., rulebooks and norms WAC 296-52-6706, USBM:RI 8507 and OSMRE:CFR Part 816.67(D);
3. Based on the results from the measurements and analysis of the level of vibrations emitted by blasting at the Govrlevo mine done on 2.07.2014 with an explosive charge of 2,850 kg, (Table 4), it is concluded that:
   - The intensity of vibrations emitted from the blasting at all measuring points (SMP01, SMP02, SMP03 and SMP04) was considerably below the benchmark values that may cause cosmetic damage to structures, cf: DIN 4150 3:1993, BS 7385-2:1993, WAC 296-52-67065, USBM:RI 8507 and OSMRE:CFR Part 816.67(D);
   - The intensity of vibrations emitted from blasting at all measuring points (SMP01, SMP02, SMP03 and SMP04) were below the level of perception that may cause complaints by the users of administrative and industrial structures, cf: BS6472-2:2008, BS 5228-2:2009, J&S 02-039;
   - The intensity of vibrations measured at measuring points SMP03 and SMP04 was greater than the benchmark values that may cause human discomfort – a level that will cause complaints by the users of residential structures. The unfulfilment of this criterion should be neglected considering that there are no residential structures within the concession limits of Govrlevo mine, cf: BS 6472-2:2008, BS 5228-2:2009, J&S 02-039;
   - The blast wave and the accompanying sound effects were not felt and should be treated as atypical for explosive charges of up to 2,850 kg.
4. The measured and interpreted effects of vibrations due to blasting within the limits of the concession area were considerably below the ultimate (allowed) values and other benchmark indicators prescribed by the implemented standards;
5. The blasting carried out on 02.07.2014 12h35 with an explosive charge of 2,850 kg, within the concession area of Govrlevo mine did not cause vibration and/or accompanying effects that would have any effect upon the environment and the structures and would not cause any human discomfort (**Table 4**);

6. Within the limits of the concession area of Govrlevo mine, the vibrations due to production blasting with explosive charges of up to 2,850 kg., activated by a NON-EL system with millisecond delay, at distances of 150+ metres do not pose any risk related to damage to structures or causing human discomfort.

Table 4. Risk related to damage to structures and human discomfort (Govrlevo, 02.07.2014)

Measured parameters/criteria for risk related to damage to structures and human discomfort	Seismic measuring point			
	SMP 01	**SMP 02**	**SMP 03**	**SMP 04**
A. Measured quantities				
Distance to the mine field [m]	**523.64**	**659.65**	**288.03**	**158.99**
$_{max}ppD_{[NS, EW, ZZ, rms]}$ (1-4 Hz) [mm]	**0.0098**	**0.1426**	**0.0151**	**0.0148**
$_{max}ppV_{[NS, EW, ZZ, rms]}$	**1.9609**	**8.2362**	**11.3355**	**11.8333**
B. Risk related to occurrence of cosmetic damage				
OSMRE CFR part 816.67(D),1983 **ppV = 25.4[mm/s]**for distances: 91.5 – 1,525 m	√	√	√	√
BS 7585-2:1993 (BS 5228-2:2009) **Line 3:** **$_{max}$ppD(1-4 Hz) = 0.6 [mm]**	√	√	√	√
1-100 (250) Hz ppV amplitude spectra				
USBM:RI 8507: RI 8507, 1980; **Line 1 and Line 2**	√	√	√	√
OSMRE CFR part 816.67(D),1983	√	√	√	√
BS 7385-2:1993 (ISO 4866:1990); **Line 1 and Line 2**	√	√	√	√
DIN 4150-3:1999; **Line 1, Line 2 and Line 3**	√	√	√	√
C. Risk related to human discomfort				
BS 6472-2:2008, *Administration, workshops, industry* **At any time:** **ppV = 14.0[mm/s]**	√	√	√	√
BS 6472-2:2008,*Housing*; **Day:ppV = 6-10[mm/s]**[1]	√	√	**No**	**No**
BS 5228-2:2009, *Sensitivity to vibrations*	**Level 4**	**Level 4**	**Level 4**	**Level 4**

√ *- Criteria satisfied,* ***No*** *– DOES NOT satisfied*

6. RECOMMENDATIONS

6.1. Specific

1. The measurements at measuring points SMP02 and SMP03, both located on a thin quaternary diluvium, topographically situated in the transit zone between the rock massif that is exploited and a valley, point to a potential of development of a secondary seismic wave (**Figure 4**).
2. The measured amplitudes of the secondary wave are smaller than the amplitudes of the primary wave since it could not develop considering that both measuring points are located at the contact zone between the hilly massif and the valley. At greater distances from the hilly massif, in conditions of thicker quaternary deposit and under the effect of blasting with heavier charges, these can be amplified and exceed the amplitudes of the primary wave.
3. To completely clarify this effect, during next blasts, in particular if blasting with charges heavier than 2,850 kg is planned, there should be at least one measuring point at min. 500-800 m from the measuring point SMP03, in the direction of the village of Dolno Sonje. For this, it is necessary to define the seismogeological and lithostratigraphic characteristics by shallow geophysical refraction prospection.

6.2. Strategic

1. The current national regulatory framework of Macedonia exclusively treat the work-place exposure and the minimal requirements for protection of employees against work-place risks related to their health and safety that are incurred or are possible to be incurred due to exposure to mechanical vibrations emitted during activities in which the employees are exposed or there is a possibility to be exposed to risks due to mechanical vibrations.
2. These are defined in the "Rulebook on Safety and Health at Work of Employees Exposed to Risk Related to Mechanical Vibrations" (Official Gazette of RM no. 26/2008) prepared as a by-law act of the "Law on Safety and Health at Work" (Article 47, Official Gazette of RM no. 92/07). The Rulebook is exclusively focused on two specific risks related to health and safety of employees: (1)"hand – arm vibration", and (2) "vibrations of the entire body".
3. The national regulations based on the ISO 2631 set of standards, ISO 5349 and ISO 8041 standards and IEC 61260:1995 filtering techniques are not relevant for evaluation of the level of exposure and risk related to long term (vibrations due to activities on construction sites), short term (passing of vehicles on tracks and alike) and instant (explosion and impact wave) vibrations.
4. In accordance with the above, the studies in the field of evaluation of the level of exposure and risk related to vibrations and air blow caused by explosions that have been done so far and have been reported to have been performed in accordance with the recommendations and the criteria pertaining to ISO 2631, ISO 5349 and ISO 8041 standards should be treated as contextually

[1]According to the Minerals Planning Guidance Note MPG 9 and the memorandum of the Scottish Government no. 26/1992, the measured ppV values should be within the frames of the statistically obtained ultimate values, but should not exceed the value of 12 mm/s. Accordingly, the level of risk related to human discomfort that could lead to complaints of the population evaluated by NO (unacceptable) could be reduced to an acceptable (√) level.

inadequate, while the presented defined estimates of the risk should be treated as irrelevant.

5. The previous conclusion also holds for all other types of investigations that are not based upon relevant standards in the field considering that they are based on parameters that are not correlated with the statistically quantified and internationally accepted criteria related to risk (benchmark values of velocity and displacement and spectral frequency content at certain levels of damage to structures, i.e., human sensitivity and perception). This is particularly true when the risks from blast induced vibrations are evaluated based on criteria developed for macroseismic estimation of seismic intensity (S.V Medvedev, 1962, MSK 1976 scale, similar).
6. Economic entities, i.e., operators of installations that perform activities contained in Appendix 1 of the Ordinance on Definition of Activities within Installations for Which Integrated Environmental Permit is issued and connected with emission of long term, short term and instant vibrations, in cooperation with and under the auspices of competent ministries and professional associations, should launch a coordinated initiative for establishment of a national normative framework and corresponding by-law acts regulating and prescribing:
   - Technology and instruments' characteristics for measurement of long, short and instant vibrations;
   - Measurement data processing and related analytical techniques;
   - Techniques and procedures for quantification and interpretation of potential effects as well as definition of the risk benchmarks related to the damages of the environment, structures and human discomfort.

   Postulates, prescriptions and benchmarks of the recommended regulatory framework shall be based on a multi-faceted analysis and synthesis of existing international standards and national rulebooks in the field (of the countries where this field is normatively regulated), national experience and blasts' (and other vibrations) data available in the Republic of Macedonia and internationally.
7. Until the national normative framework is developed and enforced, authors suggest implementation of DIN4150-3:1999-2 criteria. As the most conservative standard in the field it is most frequently used in the region (for example, Strelec et al. 2012), and worldwide.

7. ACKNOWLEDGEMENTS

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