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EVALUATION OF LOAD ON STRUCTURES CAUSED BY MINING SEISMICITY FOR MAPS OF CLASH OF OPINIONS – FIRST RESULTS

Summary. This contribution presents first results of usage of the methodology presented in Kaláb 2007. The methodology dissert on mining induced seismicity load evaluation of structures for the maps of clash of opinions. Karviná region is the area selected for the methodology presentation (Kaláb, in this issue), so the input data of performed measurement in Karviná region were used for the first assessment.

OKREŚLANIE OBCIĄŻEŃ OBIEKTÓW BUDOWLANYCH PODDANYCH WPŁYWOM SEJSMIKI GÓRNICZEJ W CELU BUDOWY MAP ZAGROŻEŃ – WYNIKI WSTĘPNE

Streszczenie. Niniejszy artykuł prezentuje pierwsze wyniki prac nad tworzeniem map zagrożeń obiektów budowlanych z tytułu wstrząsów górniczych (tzw. map konfliktów opinii). W ramach przeprowadzonych prac wykorzystano wyniki badań Z. Kalaba, które są również prezentowane w ramach tejże konferencji.

1. Introduction

The main aim of the methodology is to take into account an amount of the mining induced seismic events, especially number of the intensive ones. High number of seismic events is typical also for mining induced seismicity in the Karviná region; about 40 thousand or more seismic events are recorded annually – according to the sensitiveness of seismic apparatus (Kaláb, Knejzlík, 2002). This seismic load affects many buildings and structures, because this region is densely populated. Especially old and weak structures need special assessment of this long-term dynamic load.

At this time, mining induced seismic activity of the region is continuously monitored by the seismic stations of mining network (administered by the OKD, DPB Paskov). On the basis of this monitoring we can determine the number of mining induced seismic events during the evaluated periods and subsequently energy-frequency distribution of this seismicity. In tab.1 a number of events recorded during the period 2000 – 2006 is presented in dependence on their seismic energy classes. Solitary seismic stations at the surface operated by Institute of Geonics are used to detect macroseismic effect of this seismicity on surface; these stations are situated in surface objects, especially in cellars.

The number of mining induced seismic events and their energy – frequency distribution depend on the intensity of mining activities in individual coalfaces. From the long-term point of view, there is not adequate decrease of number and radiated seismic energy of mining induced seismic events, although the production of coal in OKR is decreasing (Konečný et al. 2003). Moreover, seismic activity can last many months, even years, after the closure of coal mines in the future, before a balance of the rock mass conditions is achieved.

Table 1

Number of events recorded by mining network stations during the period 2000 – 2006 (according to annual reports of OKD, DPB Paskov)

Number of seismic events								
year		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Energy class (J)	**10^4**	186	178	282	294	330	312	278
	10^5	5	18	38	38	31	39	42
	10^6	3	1	4	2	2	5	6
	10^7	0	0	0	0	0	0	0
	10^8	0	0	1	0	0	0	0

2. Input data for load evaluation

There are several accesses to obtain input data for methodology, which is in detail described in contribution presented by Kaláb (in this issue). Set of maximum velocity amplitudes (Czech Technical Standard 73 0040) at given point at the surface in the period of 12 months composes the input data. Input data set relates to the place, where a specific building is situated, or to the place, where new structure is being engineered, so characteristics of seismic load relates closely to the structures.

Type of input data is as follows:

1 - Maximum amplitudes of oscillation velocity taken from the special maps of oscillation velocity isolines of mining induced seismic events (data from OKD, DPB Paskov, Fig.1)

2 - Maximum amplitudes of oscillation velocity derived from seismic event characteristics (location, seismic energy, distance, attenuation ...)

3 - Maximum amplitudes of oscillation velocity measured at the given point

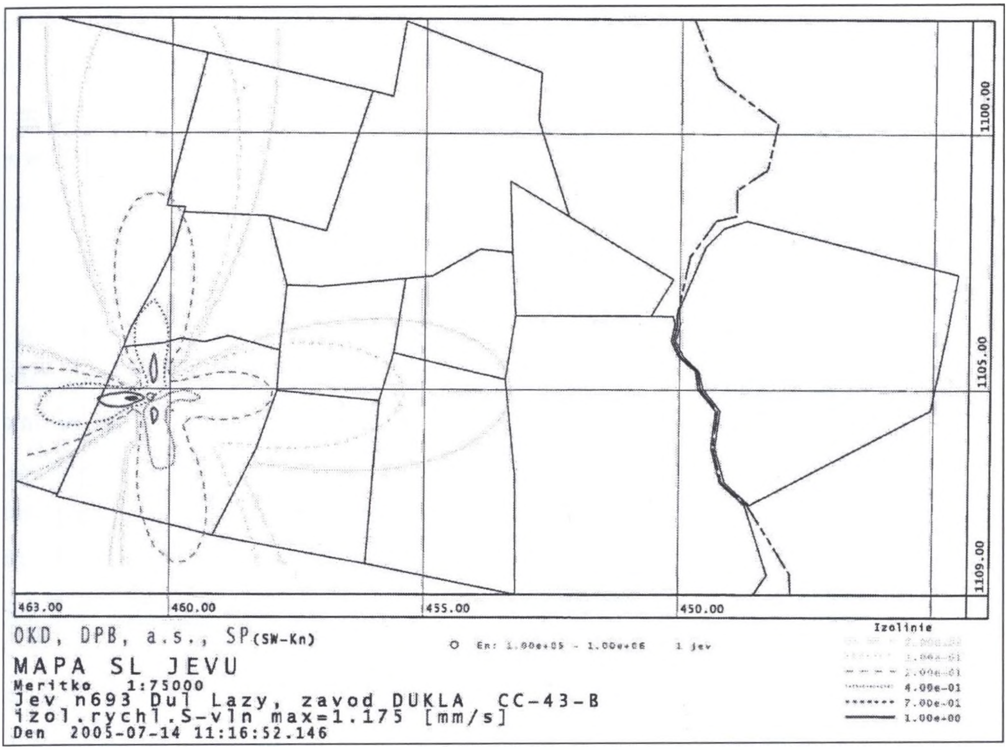

Fig. 1. Map of oscillation velocity isolines of mining induced seismic event from 14.7.2005 (data from OKD, DPB Paskov). The colours of the isolines represent various oscillation velocities at the surface

Rys. 1. Mapa izolinii prędkości drgań wstrząsów wywołanych działalnością górniczą z dnia 14.07.2005. Poszczególne kolory oznaczają zróżnicowanie prędkości drgań na powierzchni

The first type of input data seems to be the best and the fastest for the maps of clash of opinions in terms of elaboration. Special maps of isolines of maximum oscillation velocity for mining induced seismic events enable to take the value of oscillation velocity amplitude at any place of the affected point. These maps usually display oscillation velocity isolines only for the events with energy class higher than 10^5 J. These isolines are calculated from measured values on selected stations in Karvina region (see Holečko et al. 2006).

The second input data type is based on calculation from parameters of given seismic event and characteristics of geological medium. All the data about given seismic event characteristics must be ascertained, so it seems to be more complicated and time consuming in terms of elaboration. Moreover, the calculation contains information from one seismic event only and so the result will not be so precise due to complicated geological pattern.

The third input data type – measured oscillation velocity values at the surface – is the truest information about seismic manifestations at selected point. The disadvantage of this input data type for the methodology mentioned above is, that its usage is possible only at the place, where the apparatus was installed, and also relatively short period of measurement is at disposal for elaboration.

3. Input data used for load evaluation

The third input data type is applied for the first presentation of this load evaluation. Data set includes maximum values of oscillation velocity measured at the surface by the seismic station in Stonava. Sensors and recording apparatus are situated in the Municipal building. This seismic station (signed as STO1) was put into operation on 6 January, 2000 and it is still operated. Seismometers are fixed at the concrete slab in the boiler-room in the cellar. Digital three-component instrument PCM3-EPC2 is used for the measurement (Knejzlík, Kaláb 2002). Two of the seismometers are oriented to geographic directions and the third component is vertical. Data from the station are recorded in a trigger mode after exceeding the pre-set level of the oscillation velocity. This pre-set level is not the same during the whole monitoring time, because of increase of seismic noise caused by technical vibrations or other activities in the vicinity of the station (reconstruction works in building, road repair, ...). Therefore the total number of recorded seismic events depends on this trigger level but it is sufficient for input data set selection, especially for set of more intensive events.

As is described in Kaláb (this issue), input data set includes only those seismic events that exceed the value of 0.5 $mm.s^{-1}$ at least on one measured component. Analyzed period is 12 months. Tab. 2 contains summary of used input data – numbers of recorded seismic events from station STO1 for selected periods (2002 – 2006) and values of maximum velocity amplitudes. Example of input data set (i.e. maximum oscillation velocity values measured at station STO 1 in the year 2006) is presented at figure 1. Here we can see that the frequency of seismic events is not the same during the whole period of 12 months. In the first and second third of the year, number of seismic events is prevailing.

Table 2

Summary of input data sets; **N** – total number of recorded seismic events with value of minimally one component higher than 0.5 mm.s^{-1} in given period T(one year), $\mathbf{x_{max.}}$ – maximum calculated absolute value of space component in given period T (mm.s^{-1}), $\mathbf{u_{max.}}$, $\mathbf{v_{max.}}$, $\mathbf{w_{max.}}$ – maximum component values in given period T(mm.s^{-1})

STO 1						
year		**2002**	**2003**	**2004**	**2005**	**2006**
N		*17*	*21*	*52*	*88*	*129*
$\mathbf{x_{max.}}$	mm.s^{-1}	7.60	4.97	4.47	9.37	8.47
$\mathbf{u_{max.}}$		6.12	1.81	4.09	7.50	7.61
$\mathbf{v_{max.}}$		4.29	4.68	3.12	3.52	4.39
$\mathbf{w_{max.}}$		1.39	0.825	1.37	4.37	3.02

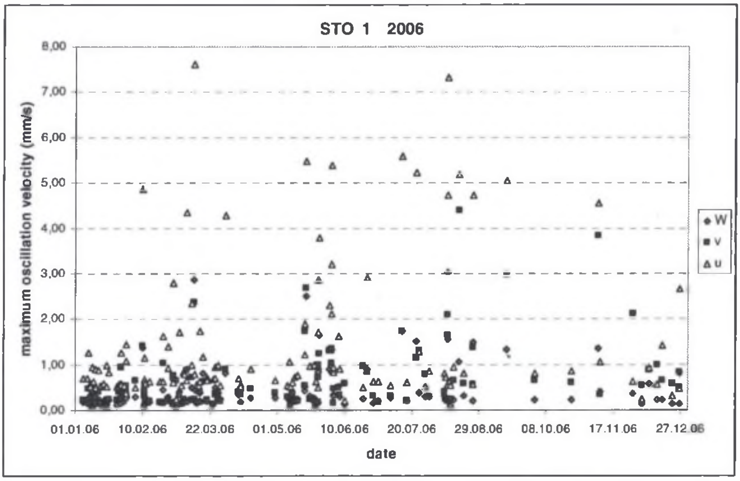

Fig. 2. Maximum oscillation velocity values measured at station STO 1 in 2006
Rys. 2. Maksymalne prędkości drgań zmierzone przez stację pomiarową STO 1 w 2006 roku

4. Calculation of total value of velocity

Resultant value of the calculation is so called *total value of velocity in given point for analyzed period* $\mathbf{x_T}$ (and/or components $\mathbf{u_T}$, $\mathbf{v_T}$, $\mathbf{w_T}$) where $\mathbf{x_T}$ is result for input data set containing absolute values of space component; $\mathbf{u_T}$, $\mathbf{v_T}$, $\mathbf{w_T}$ are results for input data set containing individual components.

Analysed period T is **12 months**. Basic equations are as follows:

$x_T = x_{max.} * C_N * C_M$

$u_T = u_{max.} * C_N * C_M$

$v_T = v_{max.} * C_N * C_M$

$w_T = w_{max.} * C_N * C_M$

$x_{max.}$ ... maximum calculated absolute value of space component in given period T

$u_{max.}$, $v_{max.}$, $w_{max.}$ ... maximum component value in given period T

C_N ... coefficient that takes into account the number of recorded seismic events in given period T

C_M ... coefficient that takes into account the number of recorded intensive seismic events in given period T

The coefficients are calculated using equations:

$$C_N = \frac{1}{11} arctg \left(\frac{N - 200}{100} \right) + 1.1005$$

$$C_M = C_{M0} * C_{M1} * C_{M2}$$

N ... total number of recorded seismic events with value of minimally one component higher than 0,5 mm.s^{-1} in given period T

C_{M0} ... partial coefficient that takes into account number of recorded seismic events in given period T with maximum value in range 3 – 6 mm.s^{-1}

C_{M1} ... partial coefficient that takes into account number of recorded seismic events in given period T with maximum value in range 6 – 10 mm.s^{-1}

C_{M2} ... partial coefficient that takes into account number of recorded seismic events in given period T with maximum value above 10 mm.s^{-1}

The partial coefficients are defined using equations:

$$C_{M0} = 0.0204 * ln (N_0) + 1.0126$$

$$C_{M1} = 0.0254 * ln (N_1) + 1.0361$$

$$C_{M2} = 0.039 * ln (N_2) + 1.071$$

Numbers in individual data sub-sets are defined:

N_0 … number of recorded seismic events in given period T with maximum value in range 3 – 6 mm.s^{-1}

N_1 … number of recorded seismic events in given period T with maximum value in range 6 – 10 mm.s^{-1}

N_2 … number of recorded seismic events in given period T with maximum value above 10 mm.s^{-1}

Detailed explanation of described procedure is stated in tab. 3, where results of two year work are presented.

Table 3

Example of velocity total value calculation for year 2005 and 2006

STO1 2005					
		w	v	u	x
N_0		1	1	2	4
N_1		0	0	2	2
N_2		0	0	0	0
C_{M0}		1.0126	1.0126	1.0267	1.0409
C_{M1}		1	1	1.0537	1.0537
C_{M2}		1	1	1	1
C_M		1.0126	1.0126	1.0819	1.0968
N		88			
C_N		1.0240			
$w_{max.}$	mm.s^{-1}	4.37			
w_T		**4.53**			
$v_{max.}$			3.52		
v_T			**3.65**		
$u_{max.}$				7.50	
u_T				**8.31**	
$x_{max.}$					9.37
x_T					**10.52**

STO1 2006					
		w	v	u	X
N_0		1	2	14	11
N_1		0	0	2	7
N_2		0	0	0	0
C_{M0}		1.0126	1.0267	1.0664	1.0615
C_{M1}		1	1	1.0537	1.0855
C_{M2}		1	1	1	1
C_M		1.0126	1.0267	1.1237	1.1523
N		129			
C_N		1.0444			
$w_{max.}$	mm.s^{-1}	3.02			
w_T		**3.20**			
$v_{max.}$			4.39		
v_T			**4.71**		
$u_{max.}$				7.61	
u_T				**8.93**	
$x_{max.}$					8.47
x_T					**10.19**

5. Evaluation of obtained results

Total values of velocity in given point (STO 1) for analyzed periods (2002 – 2006) are presented in tab.4.Values of C_N*C_M present how often the total values of velocity are higher than the maximum measured values. It depends on the number of seismic events and number of intensive seismic events. In time period 2002, 2003 and 2004, values of C_N*C_M were almost equal to 1, this means that total values of velocity are almost the same as the measured values. In these time periods there were not many seismic events; in 2002 and 2003 maximally 2 intensive seismic events were recorded. In time periods 2005 and 2006, there is an apparent difference between the total values of velocity and the maximum measured values – mainly at the components **u** and **x**. Maximal difference is **1.7 mm.s^{-1}** and maximal value of C_N*C_M is **1.2**. That is a consequence of more number of seismic events and more number of intensive seismic events (18 and 16 intensive seismic events at space component **x** respectively component **u** in the year 2006).

The difference between the total value of velocity and the maximum measured value can change the classification of structure damage degree due to exceeding the limit values for individual degrees of damage. For example, in case of an old and weak building with geological conditions of type **a,** the maximum measured velocity in given time period is **8.5 mm.s^{-1}** - see tab. 4 for component **x** in the year 2006 (measured values from station STO1 are used only for demonstration). Due to the classification according to Czech Technical Standard 73 0040 the degree of damage is 0, that means vibrations do not cause damage but influence technical conditions of the structure. According to the presented methodology, the total value of velocity calculated from data set in given time period is **10.2 mm.s^{-1}** (see tab. 4 for component **x** in 2006). In this case, degree of damage is 1 due to the classification. That means that fissures and cracks up to 1 mm occur.

Due to classification according to total value of velocity, the determination of the degree of damage according 73 0040 can be higher value than by classification according to maximum measured value. It is likeliest where maximum measured value approximate limit value for crossing lower and subsequent higher degree of damage and where amount of seismic events are recorded in given period.

Table 4

Total values of velocity in given point for analyzed periods

		2002	**2003**	**2004**	**2005**	**2006**
$w_{max.}$	$mm.s^{-1}$	*1.39*	*0.83*	*1.37*	*4.37*	*3.02*
w_T		**1.39**	**0.83**	**1.39**	**4.53**	**3.20**
C_N*C_M		1.003	1.004	1.012	1.037	1.058
$v_{max.}$	$mm.s^{-1}$	*4.29*	*4.68*	*3.12*	*3.52*	*4.39*
v_T		**4.36**	**4.82**	**3.20**	**3.65**	**4.71**
C_N*C_M		1.016	1.031	1.024	1.037	1.072
$u_{max.}$	$mm.s^{-1}$	*6.12*	*1.81*	*4.09*	*7.5*	*7.61*
u_T		**6.36**	**1.82**	**4.31**	**8.31**	**8.93**
C_N*C_M		1.039	1.004	1.053	1.108	1.174
$x_{max.}$	$mm.s^{-1}$	*7.60*	*4.97*	*4.47*	*9.37*	*8.47*
x_T		**7.90**	**5.13**	**4.73**	**10.52**	**10.19**
C_N*C_M		1.039	1.031	1.058	1.123	1.203

6. Conclusion

High number of seismic events is typical for the area where mining induced seismicity exists. Now it is topical problem, especially in densely populated regions, where this seismic load affects many buildings and structures (e.g. Wodyński, Lasocki, 2004). Problem of high number of seismic events is very important also in areas where natural earthquakes occur and where designing of seismic resistant structures is typical (Wasti S.T. and Ozcebe G. 2003).

This contribution presents an example of load evaluation of old masonry building (situated in Stonava - Karviná region) according to the methodology presented by Kaláb in this issue. This methodology takes into account not only measured maximum amplitude value but also number of the mining induced seismic events, especially number of the intensive ones. The first obtained results from the data set of measured maximum velocity values were presented.

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Omówienie

Niniejszy artykuł przedstawia pierwsze wyniki badań nad wykorzystaniem metodologii, opracowanej przez Z. Kalaba i zaprezentowanej również w ramach tejże konferencji. Przedmiotowa metodologia dotyczy określania wpływu wstrząsów górniczych na obiekty w celu opracowania tzw. map konfliktów opinii. Do badań wybrano rejon Karviny, stąd analizy otrzymanych wyników dotyczą tego właśnie obszaru.