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SEISMIC PROFILES FOR ATTENUATION ACCELERATION MEASUREMENT

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ABSTRACT
The information about new seismic profiles is given. The Profile I was built near the N-S direction and it links the seismic source zone in Vienna basin and mining induced seismic events zone Lubin. The seismographs dislocated along this Profile had operated since July 2003. The Profile II has approximately the NW-SE direction and it links the Vienna basin source zone and the Vogtland zone of earthquake swarms. The main purpose of both profiles is to collect seismograms of events originating in mentioned zones and to derive authentic acceleration attenuation relations for seismic waves, propagating through the Bohemian massif. These relations are necessary input data for earthquake hazard assessment.

KEYWORDS: seismic profile, source zone, acceleration, attenuation, response spectra

INTRODUCTION

At present, there are two nuclear power plants (NPP) (Dukovany and Temelín) on the territory of the Czech Republic, whose seismic hazard has to be re-evaluated based on international NPP standards (IAEA 50-SG-D15, 1992, IAEA - TECDOC-724, 1993) issued by the International Atomic Energy Agency (IAEA). Similar standards for evaluating seismic hazard also refer to places of future depositories of radioactive and or toxic waste. Besides this, evaluation of seismic hazard is also required for vulnerable technical and engineering facilities such as underground gas reservoirs, chemical plants and constructions subject to a high degree of risk.

From the point of view of seismic activity, the Bohemian Massif belongs to regions with moderate seismic activity. Natural seismic activity in the Bohemian Massif is concentrated primarily in the border areas of the state. Among the most active areas is the West Bohemian earthquake-swarm region, the Opava region and the region of the Hronov-Poříčí fault. The magnitude of the strongest earthquakes in these regions quite exceptionally attains the value of 4.5. Higher seismic activity is to be expected also in regions of mining induced activity (Ostrava, Pribram) and in the close vicinity of technical seismic sources (blasting of large extent).

As regards the seismic hazard to localities on the Czech territory, seismic activity has to be considered in several outer seismically active zones, which are located within 300 km of the locality, in question. Among these earthquake source zones is primarily the Vienna Basin, Slovenia, Friuli – Villach, the Swabian Jurassic and the areas, where induced seismic events occur (Lubin, Lower Silesian coal basin).

The determination of seismic hazard consists of several steps, which can be divided into the following groups:

a) Determination of seismic source zones, and their geographical and depth coordinates;
b) Determination of the seismic activity in the individual zones, i.e. mainly determining the magnitude-frequency distribution;
c) Determination of the attenuation of seismic waves along the path between the source and the locality in question;
d) Computation of the occurrence probability of severe events within a given time interval;
e) Estimation of the maximum seismic effects (maximum acceleration of ground motion oscillations, spectral content and spectral amplitude, duration of maximum amplitudes) at the locality.

The inaccuracy in determining the attenuation, which can cause an error of as much as an order of magnitude in estimating the acceleration of seismic oscillations for distant sources. Not only peak acceleration, but also the frequency content and duration of the seismic event is important for the stability of engineering and geologic structures. These parameters differ greatly for various sources of

Table 1 Coordinates of seismic stations - Profile I

Seismic station	Code	Latitude [^{o}N]	Longitude [^{o}E]
Broumov - Šonov	SON	50.614	16.396
Potštejn	POT	50.079	16.306
Skalka	SKA	49.445	16.277
Znojmo - Konice	KON	48.834	16.021

seismic hazard; the therefore monitoring and processsing of the seismic data have to include all these parameters.

The attenuation of seismic waves is determined on the basis of instrumental data, i.e. seismograms. To avoid errors, which are generated if the unconsolidated Quaternary surface layer, records of only stations built on a solid rock foundation, area considered.

The purpose of this report is to inform on newly constructed seismic profiles for the experimental determination of the decrease of acceleration amplitude of seismic oscillations and the design spectrum in dependence on the distance and magnitude of the seismic source.

SEISMIC PROFILE I (NS)

Seismic Profile I was established on 20.7.2003. It links the zone of tectonic earthquakes (Vienna Basin) and the zone of strong induced mine events (the Cuprum and Lubin mines, Poland)

Numerous seismic events, which contribute to the seismic hazard on Czech territory and are suitable for studying subsidence regularities, are generated in both these zones.

The profile consists of four seismic stations, the co-ordinates of which are given in the following Table 1.

Seismic pillars were built at all stations, which have been fed from electric mains, and the appropriate protection of instruments has been installed. Seismic noise has been measured at all sites and, with a view to its level, the sites for the seismic pillar were chosen. It was measured in a broad dynamic range by a Lennartz – Mars seismic apparatus. The maxima of seismic noise occur in the frequency range of 1 – 15 Hz. The maximum amplitudes of velocity reach values of 0.1 $\mu m.s^{-1}$ at the most at stations KON and POT. At stations SON and SKA the level of permanent noise is 0.25 $\mu m.s^{-1}$. These velocity values were converted by numerical differentiation to acceleration amplitudes and resulting values are 6.3 and 15 $\mu m.s^{-2}$, respectively. Since the seismic events to be analyzed and used in constructing the subsidence relation and in determining the response spectra display amplitudes at least 100 times larger, the level of noise is negligible.

All stations are located on a rock base, which enables the observed values to be compared without applying corrections of the transfer function of the sedimentary subsoil. Locating all the seismic stations on a rock outcrop minimizes the local seismic noise and the effect of sediments, stratification, etc. on the one hand, and corresponds to the present conditions for sitting nuclear facilities (power plants, as well as future radioactive waste depositories) in granite rocks, on the other.

Three-component sensors of the oscillation velocity by the Swiss firm Syscom, model MR 2003, with an MR 2002 recording unit have been installed at all stations. The sensors are placed in an aluminum cover, 12 by 12 by 8 cm in size, which is equipped with leveling screws. Their total weight is 1.55 kg. The MR 2002 recording unit is protected by an aluminum cover, 20 by 23 by 11 cm in size, and its total weight is 7.2 kg. The cover is watertight (the device is able to operate at 100% humidity) and the permitted range of ambient temperature is –20^{o}C to +50^{o}C. The manufacturer increased the sensitivity of the apparatus 50 times as compared with standard models, which makes it possible to record weaker seismic events. The device's dynamics is 16 bits, range ± 114 $mm.s^{-1}$, and sampling frequency 200 samples/s/channel. It can be fed from the mains (220 V, 50 Hz) or autonomously (12 V). The time data are derived from the system clock of the station's recording unit. In 2005 all the apparatuses along Profile I NS will be equipped with a record of the system time based on receiving DCF time signals. This unified time system will, moreover, enable the monitoring of long-term variations of the velocities of seismic waves in the Bohemian Massif. The apparatus is triggered once the signal amplitude exceeds the triggering level. The triggering level has been set with a view to the level of the local seismic noise. The data are stored on a disc and the RS-232 port realizes their transfer to the processing unit.

The records are processed in the Central Laboratory of the Institute of Rock Structure and Mechanics (IRSM) using the VIEW 2002 software, version 3.0 (of 22.5.2003). Seismic signals (velocities, displacements, acceleration of individual components and the total vector) are processed within the frequency range of 1 – 40 HZ. Fourier and power spectra and the particles motion in planes XY, XZ and YZ are determined of the whole record, as well as of selected parts.

Table 2 Coordinates of seismic stations - Profile II

Seismic station	Code	Seismometers	Latitude [°N]	Longitude [°E]
Komorní hůrka	KOH	GURALP CMG – 40 T	50.600	12.336
Krásno	KRA	GURALP CMG – 40 T	50.111	12.783
Nečtiny	NEC	GURALP CMG – 40 T	49.977	13.170
Háje	HAJ	GURALP CMG – 40 T	49.675	14.049
Tábor	TBR	GURALP CMG – 40 T	49.413	14.648
Mrákotín	MRA	Syscom, MR 2003	49.187	15.379
Znojmo – Konice	KON	Syscom, MR 2003	48.834	16.021

A seismograph for recording the rotational component of seismic oscillations, manufactured by the Institute of Geophysics of the Polish Academy of Sciences, which also interprets the records, was installed at station SON in January 2004.

A newly developed apparatus for recording the rotational motion of seismic oscillations will be installed at station SON with sensitivity of the order of micro-radians per second (Buben and Rudajev, 2004a). This apparatus is suitable for recording rotational oscillations close to seismic foci and the rotational response of structures to seismic excitation. Strong quarry blasts with charges of several tones of explosives at distances of 1 – 10 km may also be the source of these oscillations. Quarries Rožmitál and Litice, where such blasts are carried out, are located in the neighborhood of station SON.

SEISMIC PROFILE II NW – SE

Seismic Profile II was established along the line between the Voigtland region, where earthquake swarms occur, and the region where tectonic earthquakes occur in the Vienna Basin. This profile runs close to the localities of the nuclear power plant Temelín and close to the locality of the Příbram – Háje gas reservoir. A detailed check of the formula for the decrease of oscillation amplitudes is thus also of practical importance for obtaining a more accurate value of the seismic hazard of these structures, which is in accord with the recommendations of the IAEA.

There are seven seismic stations along Profile II, the names and co-ordinates of which are given in the following Table 2.

All stations are located on rock base, which enables the results between both profiles to be compared without correction for a sedimentary base. The seismometers have been installed on seismic pillars, and the stations are connected to electrical mains.

The frequency of continual quasi-stationary seismic noise displays values within the range of 4 – 5 Hz, which is characteristic for the Bohemian Massif. Amplitudes of rare temporary disturbances of technical origin do not exceed the value of 1 $\mu m.s^{-1}$.

Broadband GURALP CMG – 40 T seismometers have been installed at stations KOH, KRA, NEC, HAJ and TBR. Electronic circuits with a frequency-dependent feedback set the natural frequency of these systems. The broadband frequency characteristic is practically constant within the frequency range of 0.03 – 30 Hz. The adjustable amplification is practically restricted only by the level of the permanent noise. The sampling frequency of the digital recording device is 100 samples/s/channel. The dynamic range is at least 110 dB. The recording device operates in the triggering mode. The triggering criterion is the ratio LTA:STA. All stations receive the GPS time signal.

The recorded data are transferred to the processing center by removable hard-disc memories. The data are collected and the operation of the apparatuses is checked at intervals of one month. Unexpected faults in the operation of the apparatuses are immediately identified telemetrically using USW links. The acceleration is determined by numerical differentiation of the velocity records with the appropriate low-pass and high-pass filtration of the fourth order with limiting frequencies of 0.3 and 30 Hz.

Stations MRA and KON are equipped with Syscom instruments, whose technical data are given in above.

Both the profiles described are depicted in Fig. 1.

PROCESSED DATA

The relations for the attenuation of velocity and acceleration amplitudes are expressed in terms of magnitude, focal distance and generally in seismic transmission functions of the station subsoil. All stations along the said profiles are located on rock outcrop and, therefore, the effect of different transmission properties need not be considered.

The seismic stations along the profiles provide seismic records, whereas the data on magnitudes and focal distances are adopted from the following bulletins:

- Bulletin of the Geophysical Institute of the Academy of Sciences of the Czech Republic stations Průhonice and Kašperské Hory);
- Seismic Service station of the Cuprum-Lubin mine, where a local seismic network is in operation.

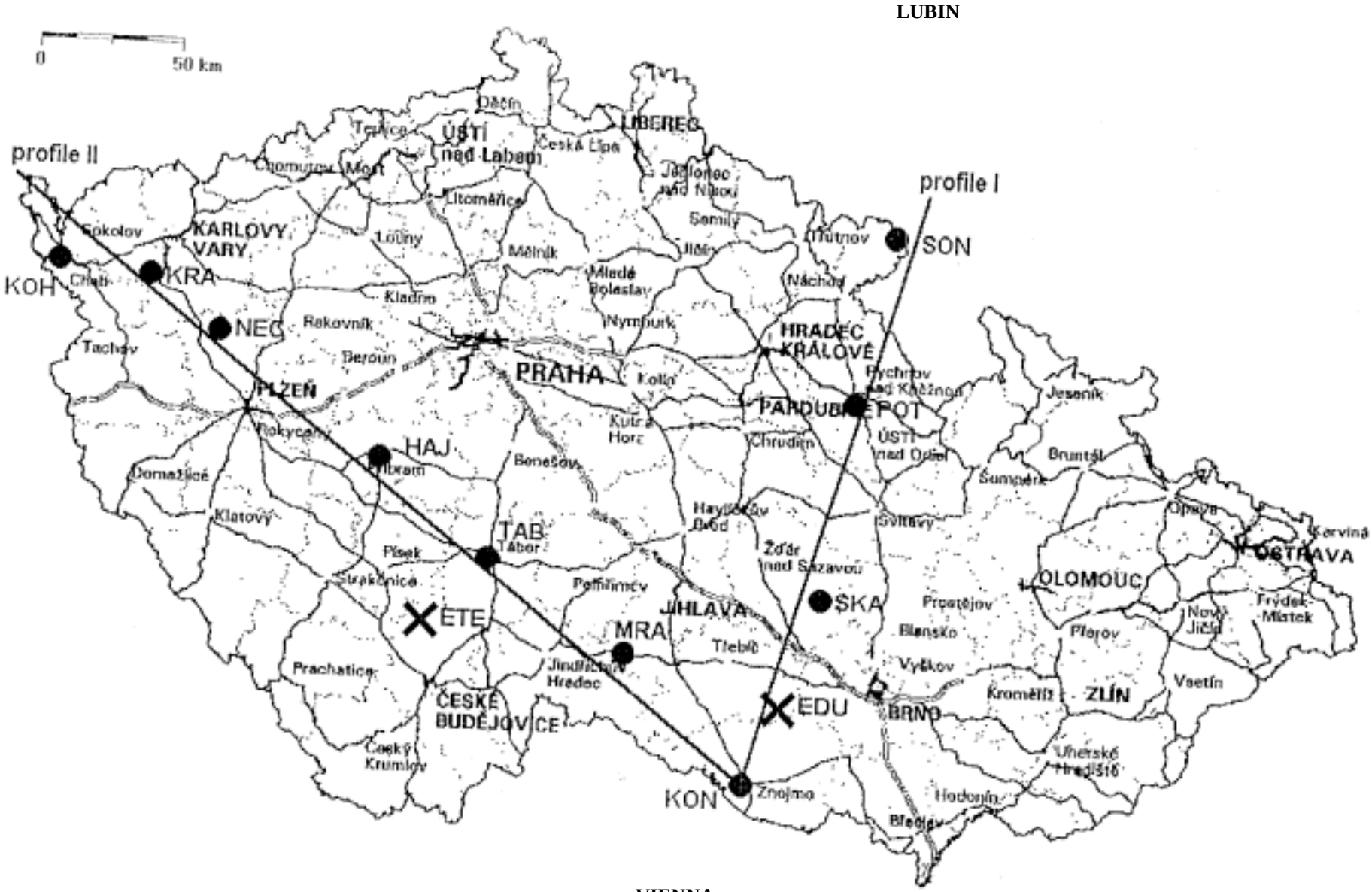

Fig. 1 Layout of seismic profile I and profile II and positions of source zones Lubin Vienna and Vogtland

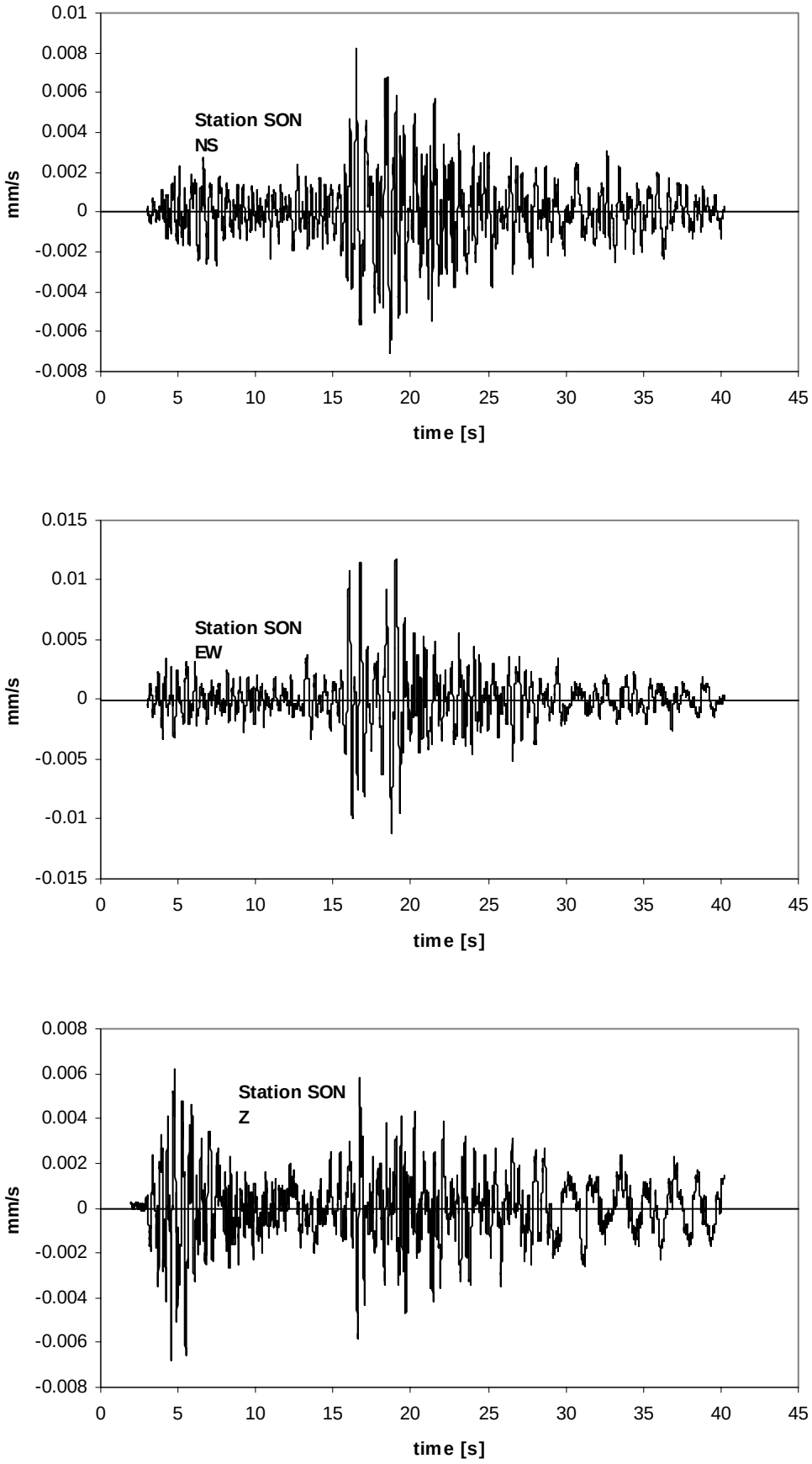

Fig. 2A Wave trains of ground motion velocity in channels NS, EW and Z of Lubin rockburst (10. 2. 2004, M_L = 3.6) recorded by stations SON.

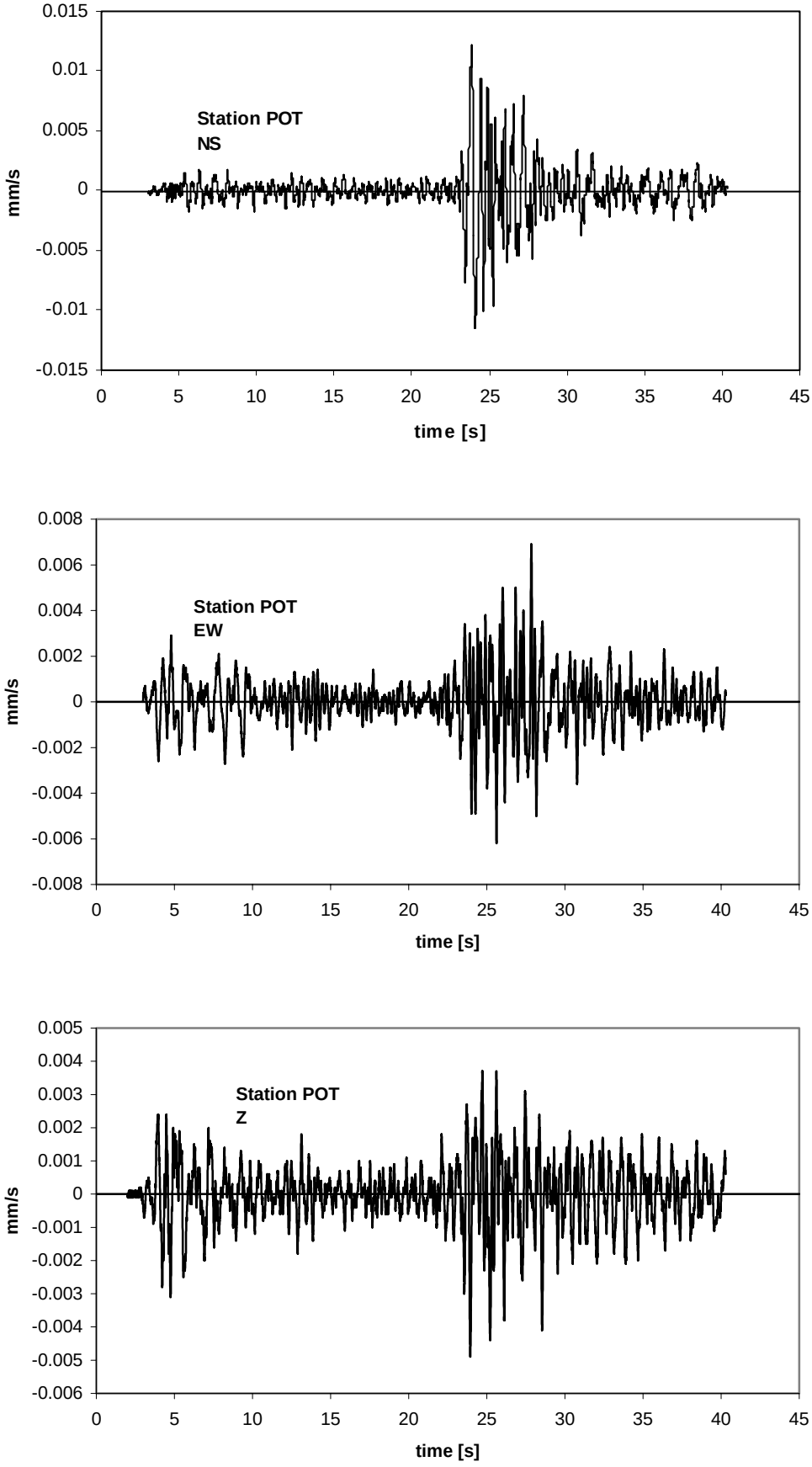

Fig. 2B Wave trains of ground motion velocity in channels NS, EW and Z of Lubin rockburst (10. 2. 2004, $M_L = 3.6$) recorded by stations POT.

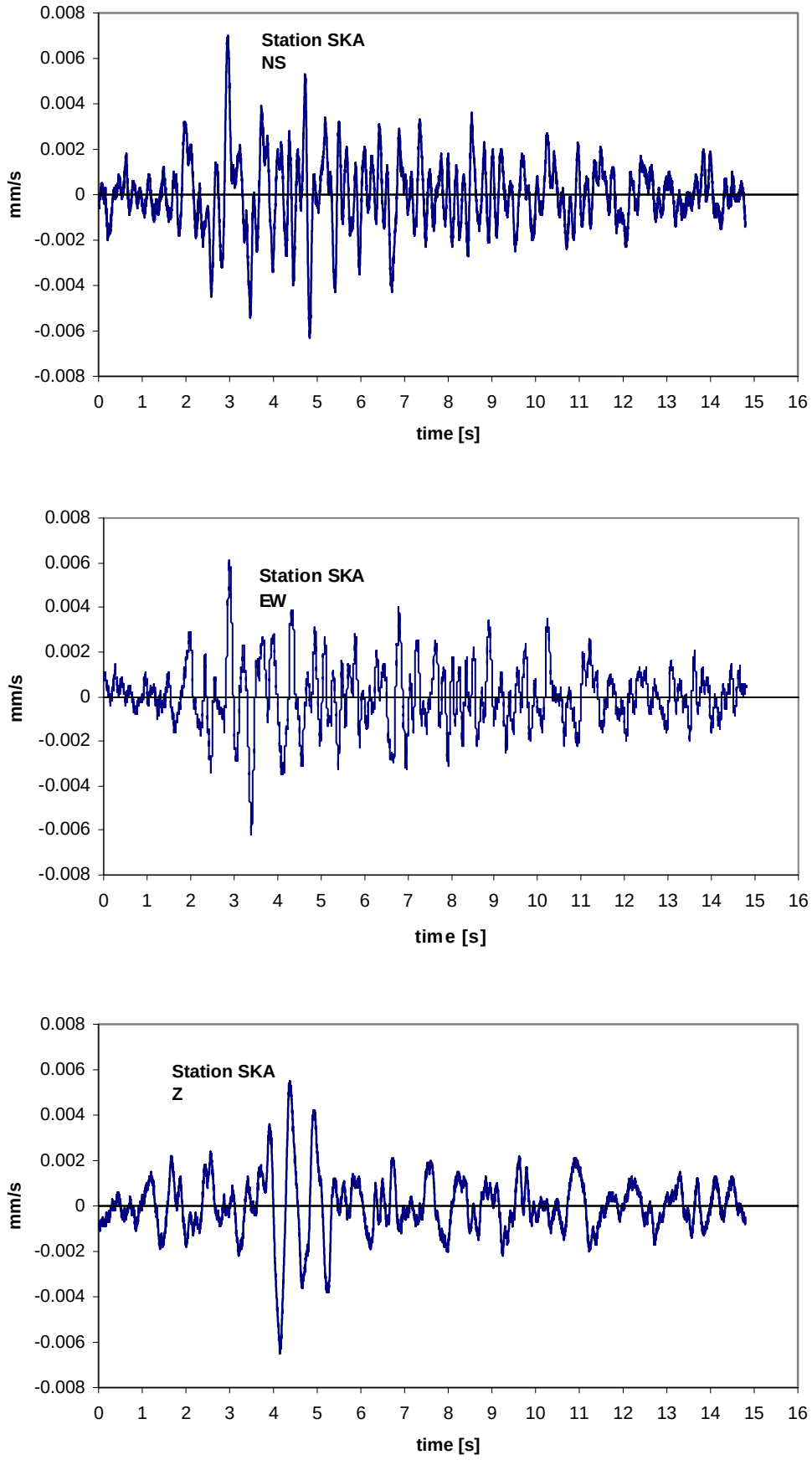

Fig. 2C Wave trains of ground motion velocity in channels NS, EW and Z of Lubin rockburst (10.2. 2004, M_L = 3.6) recorded by stations SKA.

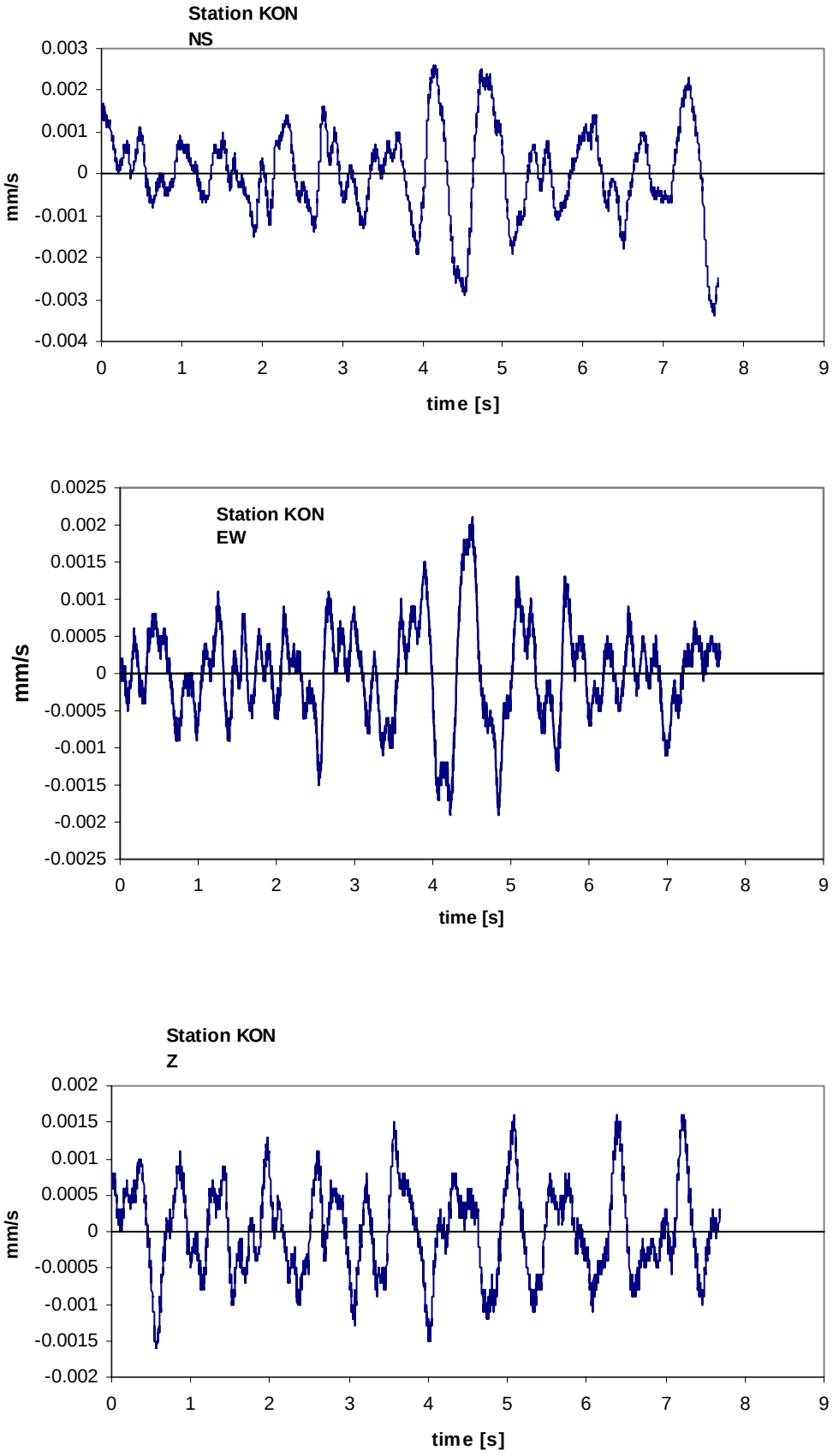

Fig. 2D Wave trains of ground motion velocity in channels NS, EW and Z of Lubin rockburst (10.2. 2004, $M_L = 3.6$) recorded by stations KON.

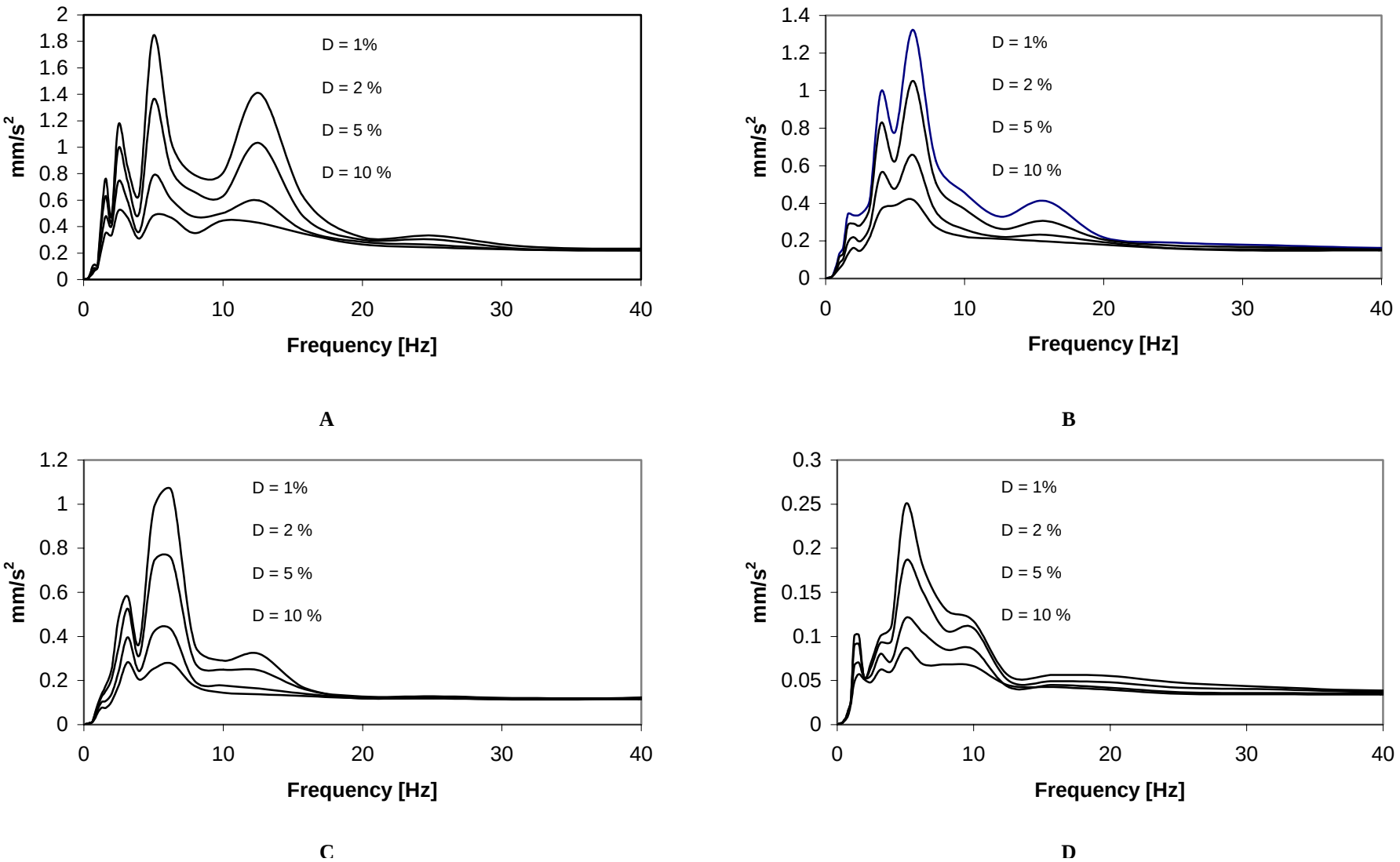

Fig. 3 The courses of acceleration response spectra (damping 1, 2, 5, and 10 %) of EW components of Lubin rockburst (10. 2. 2004, M_L = 3.6). Stations SON (A), POT (B), SKA (C) and KON (D).

During the period 2003 July 7th - 2004 June 30th the stations along Profile I recorded 63 seismic events from the Lubin source zone. The magnitudes of the recorded earthquakes M_L ranged from 2.7 to 3.8. From this number, 41 events were recorded together by stations SON and POT. On three stations, SON, POT and SKA, 9 events were recorded and on all four stations were recorded 4 events, with magnitude M_L greater than 3.5.

From the Vienna basin source zone 5 earthquakes with magnitude 3.0 – 4.5 were recorded. In addition to these events, some earthquakes from Northern Italy, Austria and Poland were recorded.

Fig. 2 shows the velocity wave train for NS, EW and Z components for rockbursts in Lubin with magnitude M_L = 3.6, recorded by stations SON (2A), POT (2B), SKA (2C) and KON (2D). The courses of acceleration response spectra (damping 1, 2, 5, and 10 %) of this event for the EW component, e.g. greater of horizontal components and for separate stations are shown in Fig. 3 (Fig, 3A, B, C, D).

The values of peak ground motion velocity were calculated using relation V1 (Atkinson and Hanks, 1995). This relation was recommended in the first approximation for the Bohemian Massif (Buben and Rudajev, 2002). The calculated values are 3 times higher than recorded ones for short focal distances (about 100 km) and 2 times greater for distances above 150km. The comparison of the observed and calculated values indicates that the new authentic formula should be developed for the attenuation of seismic waves in the Bohemian Massif.

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