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RESULTS OF SEISMIC MEASUREMENT IN TUNNELS ON THE RAILWAY CORRIDOR IV.

VÝSLEDKY SEIZMICKÝCH MĚŘENÍ NA TUNELECH IV. ŽELEZNIČNÍHO KORIDORU

Abstract

In the Railway Corridor IV tunnels were realised several unique experimental measurements of blasting operation seismic response. These blasts were performed during tunnels' driving in frame of the Votice-Benešov u Prahy rail track modernization on the National Railway Corridor IV. seismic experiments were concentrated on vibration effect in near zone, i.e. first tens of meters. Sensors were placed on bottom of tunnel and on the surface. The nearest sensor was located in distance 4.5 m from source of vibrations. This paper presents selected results of experimental measurements and their interpretation, especially relation between distances and maximal velocity amplitudes.

Keywords

Tunnel, blasting operation, seismic measurements, near zone.

Abstrakt

Na tunelech IV. železničního koridoru bylo realizováno několik unikátních experimentálních měření seizmické odezvy trhací práce. Tyto trhací práce byly prováděny během ražby tunelů v rámci modernizace úseku trati Votice-Benešov u Prahy, ležícím na IV. národním železničním koridoru. Seizmické experimenty byly soustředěny na vibrační efekt v blízké zóně, tzn. první desítky metrů. Senzory byly umístěny na počvě tunelu a na povrchu. Nejbližší senzor byl umístěn ve vzdálenosti 4,5 m od zdroje vibrací. Tento příspěvek prezentuje výsledky experimentálních měření a jejich interpretaci, zejména pak závislost mezi vzdáleností a maximální amplitudou rychlosti kmitání.

Klíčová slova

Tunel, trhací práce, seizmické měření, blízká zóna.

1 INTRODUCTION

The tunnels of the 4th railway corridor are part of the Trans-European E55 main railway line delimited by the Děčín state border – Prague – České Budějovice – Horní Dvořiště state border railway route on our territory. The Votice – Benešov u Prahy section of the route belonging to the Railway Corridor 4, was built round 1870 as a single-track line. After the establishment of Czechoslovakia, some work was done between Votice and Benešov, the purpose of which was to build a double-track railway in this section of the route, however, it was not completed and the route there remained as the single-line railway only. In this section, which is 18.3 km long, five tunnels are planned to be built within the framework of Modernization of Votice – Benešov u Prahy track line: the excavated Votický tunnel (590 m) and four driven ones, namely the Olbramovický (480 m), Zahradnický (1044 m), Tomice I (324 m) and Tomice II (252 m) tunnels. All tunnels are designed

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as double-track with the designed speed of 150 km/hr, or 160 km/hr. Due to the length of the Zahradnický tunnel, it is equipped with an escape corridor and a shaft. The construction started in August 2009, the termination date is scheduled for December 2013. The entire area of interest belongs to the South Bohemian geomorphological system, to the Benešov upland. The territory is found at the south-east edge of the Central Bohemian plutonic complex in the vicinity of the moldanubic headland and is built namely by paleozoic eruptive rocks, deep-seated and venous. The rocks are generally very variable and they are characteristic by their petrographic diversity. The dominant rock types in the area of interest are small-grained granites and aplites, in a part of the territory also porhyric, medium-grained, amphibol-biotitic granites and porphyric, medium-grained biolitic granites with amphibolite of Sedlčany type. Locally, contact metamorphites represented by cordieritic gneisses and migmatites occur there. Fracturing of rocks is considerable, very large and large density of discontinuities is predominant there, medium density of discontinuities was detected there only exceptionally. The fractures are usually omnidirectional, discontinuous and enclosed or filled with vein quartz. The rocks in the surrounding of tectonic lines and fracture zones are heavily altered and usually crushed. The quarternary capping is represented by deluvial and fluvial deposits, the thickness of which varies between 0.5 to 10 m. In light of hydrogeology, the granitic rocks, as a whole, are relatively little leaky and have just a limited fissure penetrability. Doping of water into the water-bearing rock is secured solely by infiltration of precipitation into the hydrogeological basin, the drainage occurs in morphological depressions into local water courses. [1, 2]

Experimental seismic measurements were carried out in Olbramovice, Tomice I and Tomice II tunnels. These railway tunnels are built by means of the New Austrian Tunneling Method, the part of which is also soil cutting by means of blasting operations.

All the measurements were implemented by Gaia2T seismic apparatus with ViGeo2 sensors (both are made by Vistec Praha). The Gaia2T apparatus is a three-channel seismic station with options of triggered and continuous registration of digital data. The advantage of the sensors is their frequency response reaching higher frequencies, i.e. from their natural frequency of 2 Hz up to 200 Hz, and their greater weight, which provides more stable mounting. Horizontal axes of the sensors were directed along and across the tunnel direction, the third axis was vertical. Record parameters for these measurements were set to the maximum sampling rate - 500 Hz/channel.

In order to process the entire data set, the methodology during which maximum amplitude values of oscillations at individual components (vertical, horizontal-radial and horizontal transversal) was selected and the spatial component is subsequently computed according to the following equation:

$$v = (v_x^2 + v_y^2 + v_z^2)^{0,5} \tag{1}$$

This value is used for the subsequent calculation of the attenuation coefficient "K" and corresponding relations. The well-known Langefors's relationship [e.g. 4, 5, 6, and 7] was used for graphical representation.

The study of waveform records in the frequency area using Fourier's transformation (FFT spectra) is the integral part of interpretation of the measured data.

Partial results are also presented Din the paper Examples of law of seismic wave attenuation by composite author Kaláb, Pandula, Stolárik, Kondela, sent to the Tunnelling and Underground Space Technology journal.

2 EXPERIMENTAL SEISMIC MEASUREMENTS IN OLBRAMOVICE TUNNEL

The experimental seismic measurement was carried out during blasting operations carried out on the core between 220.0 a 245.0 stationing as far as 265.0 stationing. 12 measurements altogether were implemented on the upper bench of the driven tunnel ranging from 6.5 m to 35 m apart from the face (or 4.5 m to 33 m from the base of the drill holes). In all case, there were blasting operations

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with a total charge up to 25 kg and a 3 kg limit charge for one time step. The boreholes were drilled in the axial direction of the working and the coverage was 2 m.

The example of a waveform record measured in the tunnel is in Figure 1. This figure illustrates vertical component /Z/ displayed down from top, followed by horizontal-radial /N/ and transversal /E/ components; the horizontal axis indicates time in seconds (the axes are represented in the same amplitude and time scales). The processing SW does not make it possible to convert the amplitudes of oscillations into physical units [mm.s^{-1}] and that is why the vertical axes in the figures are plotted in quantization levels [Mcnt]. It is clearly seen in the record, on all of the three axes, timing of blasting operations in their individual time steps, the induced vibrations after shots of individual steps are almost damped, and therefore, the summation of seismic effects of the consecutive time steps does not occur. The length of the entire record corresponds with the time range of the performed blasting and it is approx. 5 s.

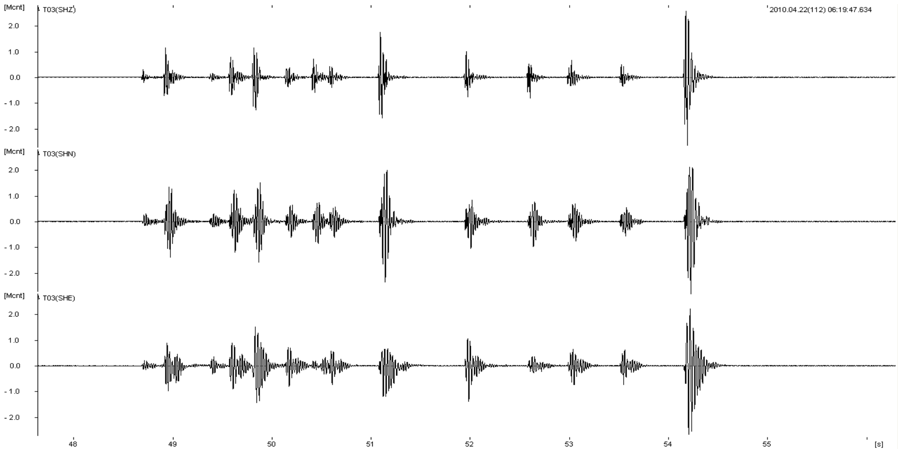


Fig. 1: Example of the waveform record of blasting carried out in the Olbramovice tunnel

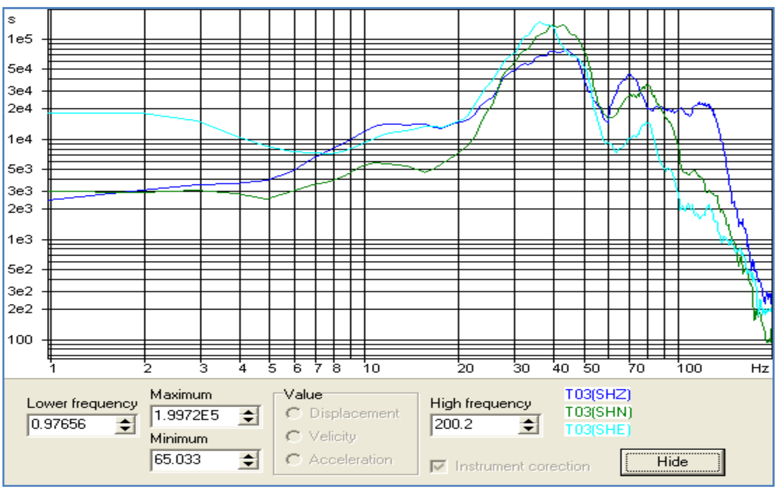
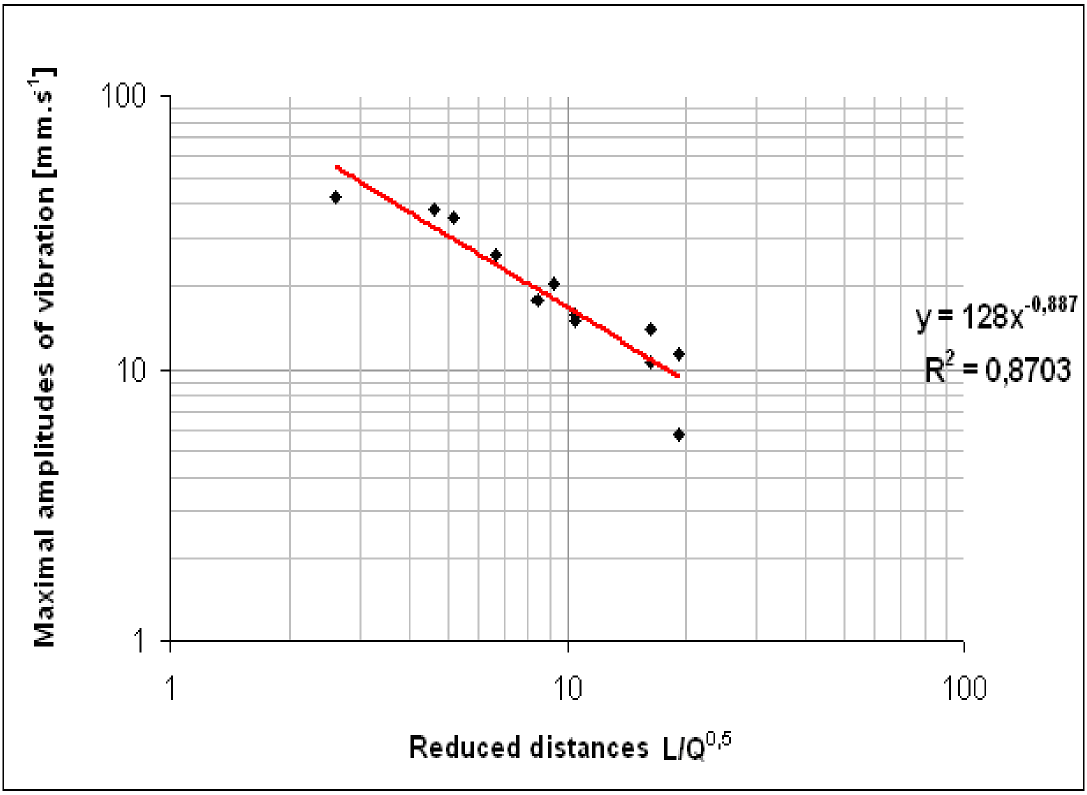


Fig. 2: Example of the frequency spectrum record of blasting carried out in the Olbramovice tunnel

Example of the frequency spectrum to the given record is illustrated in the following Figure 2. The dominant frequencies in the records are found within the range of 30 - 50 Hz in all spectra. It is possible to identify wide distinct peaks with the indicated range in the spectra. Less distinct peaks on higher frequencies, i.e. 60 – 70 Hz, can also be observed, especially in the record of the vertical component.

The records obtained from individual rock blasts are similar to one another, namely in the time and spectrum areas. It implies that the data from implemented measurements can be used for presentation of Langefors's empirical equation in a graphical functionality. Distinct changes in the registered data would evidently indicate significant changes in local geology or the registration of various types of wave.

The acquired dependability of maximum spatial components of oscillation on reduced distances is represented in Graph 1. Here, it is seen that the relation in this representation is very close (correlation coefficient R^2 for the displayed data is 0.87). This fact is evidently the result of a monotonous geological structure (in light of propagation of seismic waves through the massif) in the measurement location. The exceptionality of this acquired relationship is in the fact that the curve starts at the value of reduced distance of 2.6 $m.kg^{-0,5}$ (this makes it possible to measure the seismic effects at a very small distance from the "gravity centre of blasting").



Graph 1: Empirical dependency of the reduced distance and maximum amplitudes of oscillation velocity obtained for the Olbramovice tunnel

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3 EXPERIMENTAL SEISMIC MEASUREMENTS IN TOMICE I TUNNEL

The experimental seismic measurements were carried out during blasting operations carried out on the calotte between 215.0 and 225.0 stationing. On the whole, 12 measurements 12 m up to 55 m apart from the face were implemented on the driven tunnel footwall. In all cases, there were blasting operations with a total charge up to 72 kg and a 7.2 kg limit charge for one time step. The boreholes were drilled in the axial direction of the working and the coverage was 3 m.

The example of a waveform record measured in the tunnel is in Figure 3. The length of the entire record corresponds with the time range of the blasting operations implemented and it is approx. 8 s. An example of the frequency spectrum to the given record is in the following Figure 4. The dominant frequencies in the records are found within the range of 45 - 70 Hz in all horizontal component spectra. In the vertical component spectrum 45 – 120 Hz.

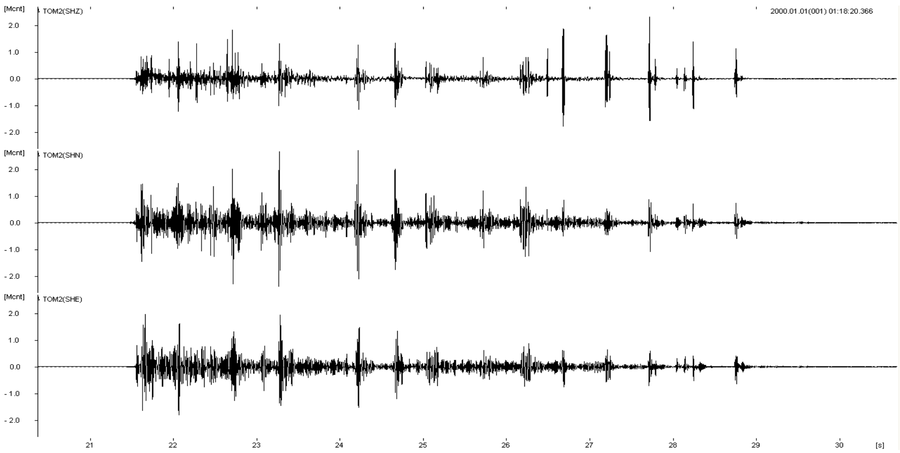


Fig. 3: Example of the waveform record of blasting carried out in the Tomice I tunnel

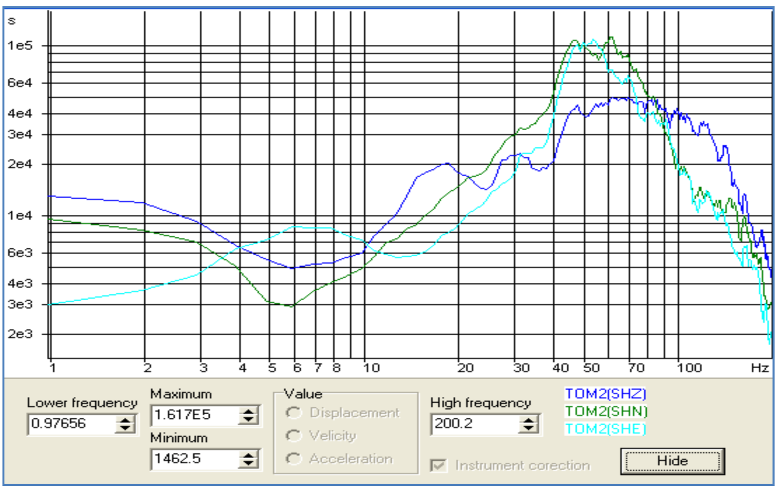
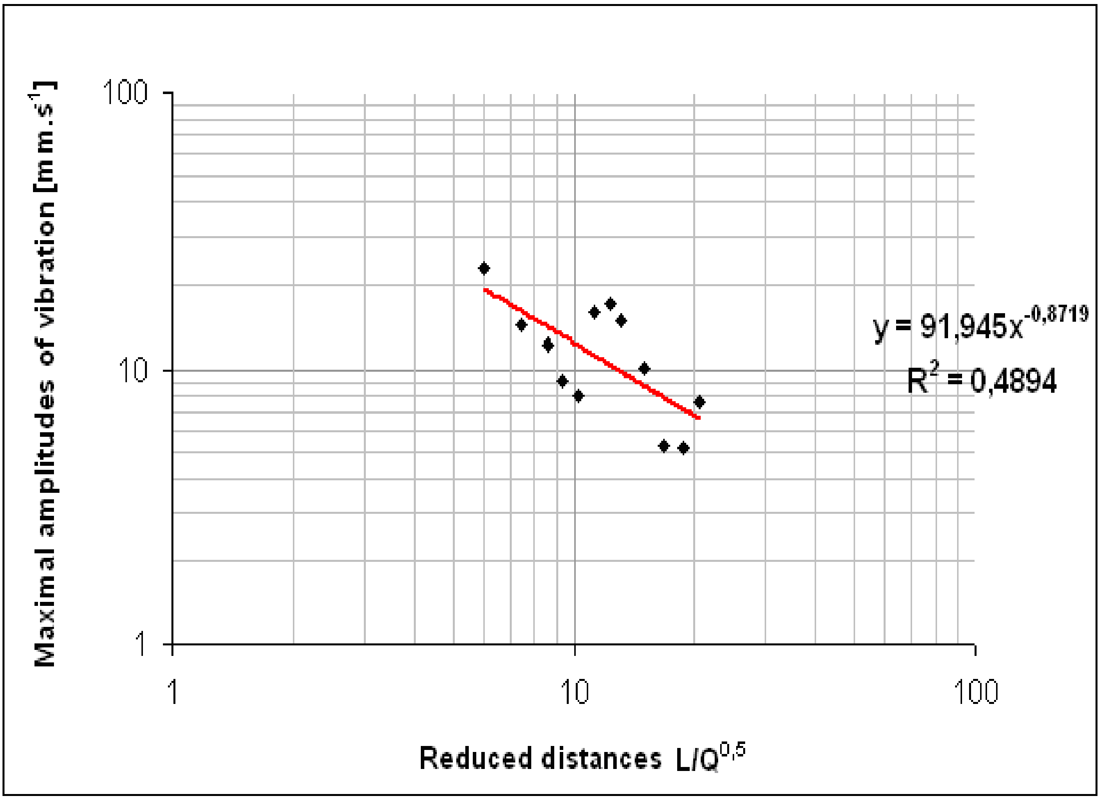


Fig. 4: Example of frequency spectrum in the blasting operation record in the Tomice I tunnel

The data from the implemented measurements were again used for representation of Langefors's empirical equation in a graphical functionality. The acquired dependability of maximum spatial components of oscillation on reduced distances is represented in Graph 2. The correlation coefficient R^2 for the data displayed is 0.49.



Graph 2: Empirical dependency of the reduced distance and maximum amplitude of oscillation velocity obtained for the Tomice I tunnel

4 EXPERIMENTAL SEISMIC MEASUREMENTS IN TOMICE II TUNNEL

The experimental seismic measurements were carried out during blasting operations carried out on the calotte between 168.2 and 175.7 stationing. On the whole, 27 measurements 13.5 m up to 50 m apart from the face were implemented on the surface above the tunnel tube. In all cases, there were blasting operations with a total charge up to 82 kg and a 4.8 kg limit charge for one time step. The boreholes were drilled in the axial direction of the working and the coverage was 1.5 m.

An example of a waveform record measured on surface is in Figure 5. The length of the entire record corresponds with the time range of the blasting operations implemented and it is approx. 10 s. An example of the frequency spectrum to the given record is in Figure 6. The distinct peak in the spectre of the vertical component is on frequency of 20 Hz, the less distinct one is on frequencies of 60 and 110 Hz. The dominant frequency in the spectrum of horizontal radial component is within the range of 20 – 60 Hz and in the spectrum of horizontal transversal component within the range of 40 – 70 Hz.

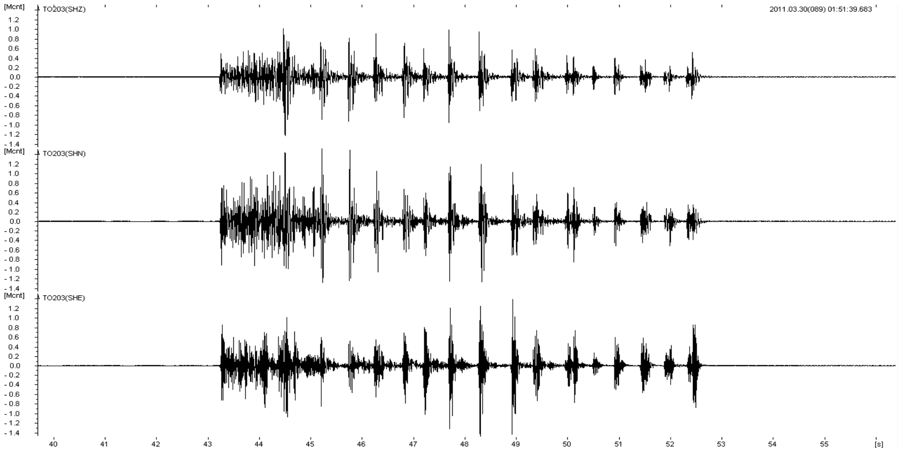


Fig. 5: Example of the waveform in the record of blasting in the Tomice II tunnel

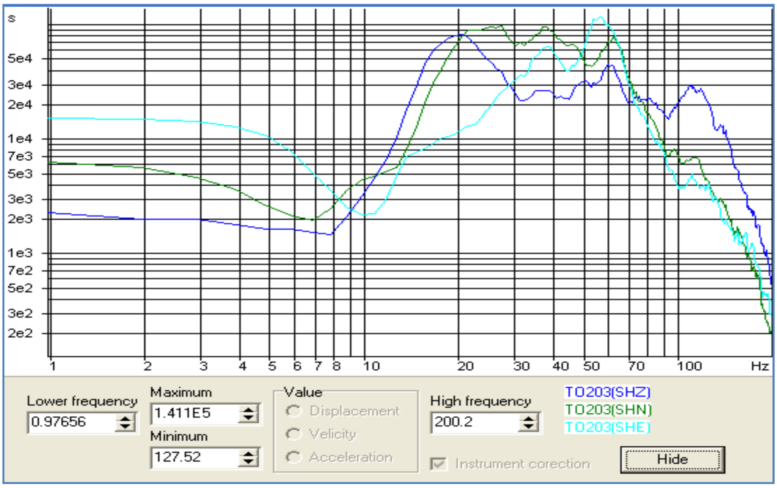
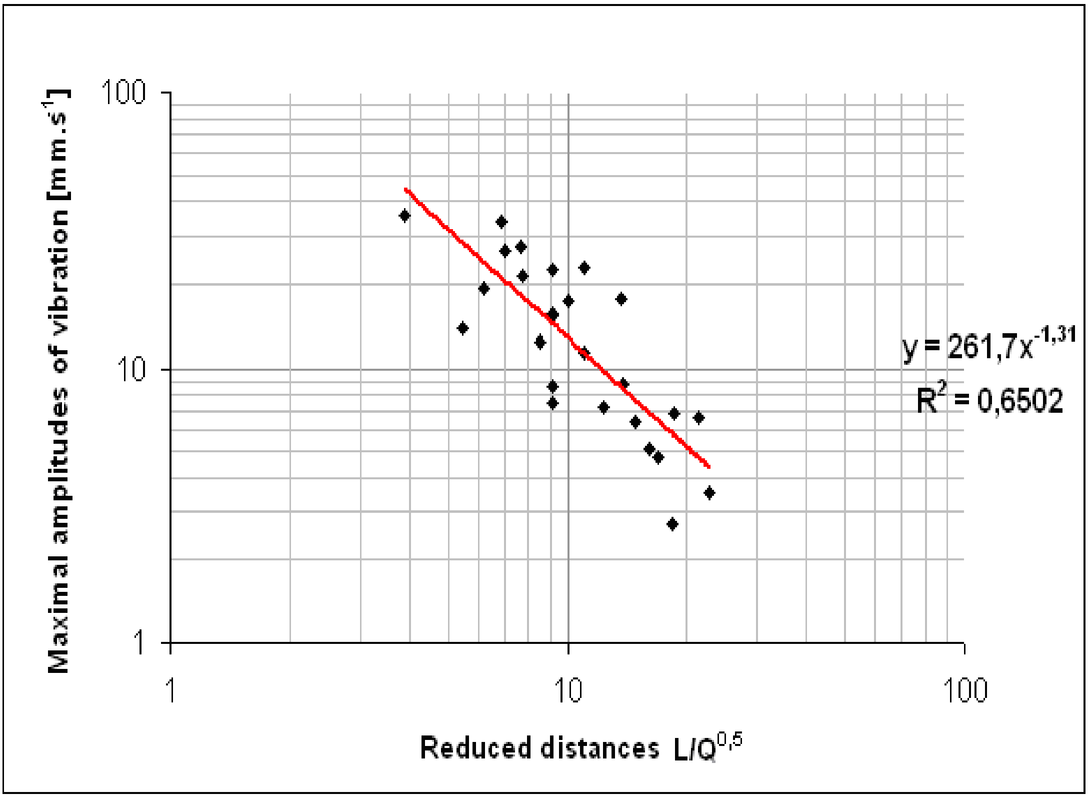


Fig. 6: Example of frequency spectrum in the blasting operation record in the Tomice II tunnel

The data from the implemented measurements were used for representation of Langefors's empirical equation in a graphical functionality as in the two previous cases from underground. The acquired relation is presented in Graph 3. The correlation coefficient R^2 for the data displayed is 0.65.



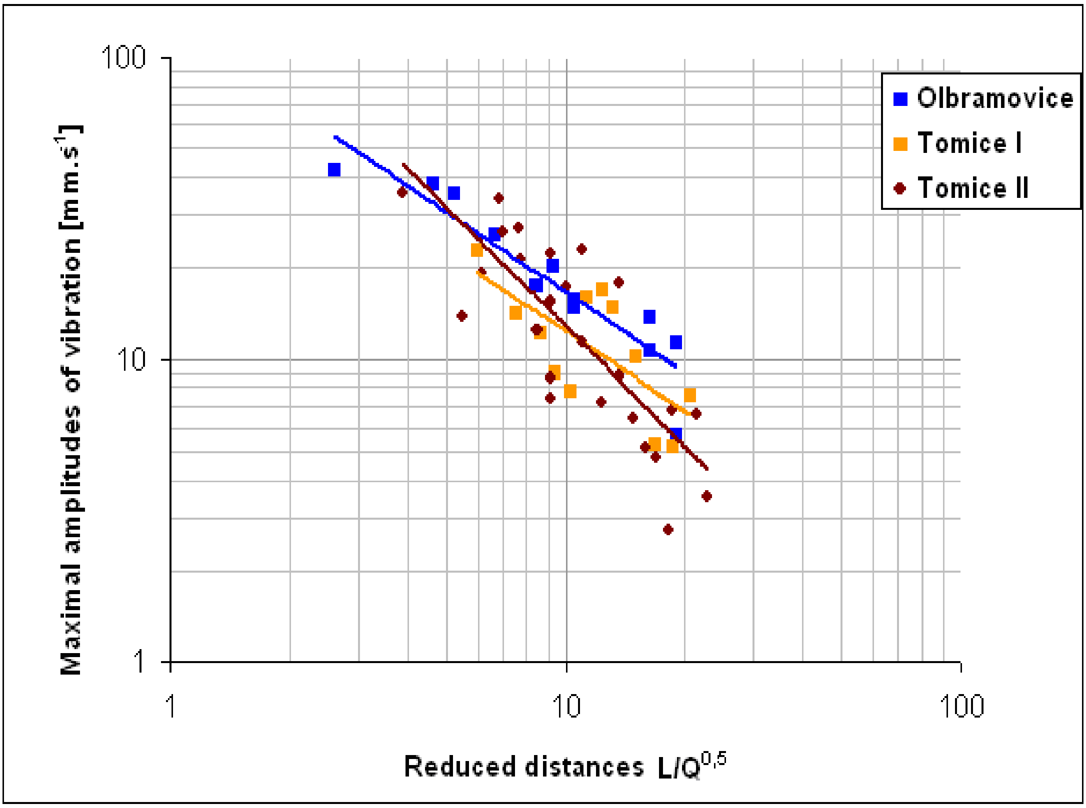
Graph 3: Empirical dependency of the reduced distance and maximum amplitudes of oscillation velocity obtained for the Tomice II tunnel

5 CONCLUSION

The paper presents the results of seismic measurements in three tunnels built on the territory of the Czech Republic by the New Austrian Tunnelling Method. In two cases, it was an experimental measurement of response to blasting in the near zone right in the driven tunnel on footwall. In the third case, on the surface over the driven tunnel. The data acquired from the measurements were used for representation of Langefors's empirical equation in a graphical functionality (Graph 4) and for computation of the transmission constants K given by this relation.

	Olbramovice		Tomice I		Tomice II	
	K1	K2	K1	K2	K1	K2
	109,92	216,06	137,69	157,03	137,91	80,06
v_{max} [mm.s^{-1}]	42,31	11,34	23,09	7,66	35,55	3,51
L [m]	4,5	33	16	55	8,5	50
Q [kg]	3		7,2		4,8	

Tab. 1: Summary of extreme values of the transmission constant K for monitored tunnels



Graph 4: Empirical dependencies on reduced distances and maximum amplitudes of oscillation velocity obtained for three monitored tunnels

For the Olbramovice tunnel, the dependency was tight with a correlation coefficient $R^2 = 0.87$. For the Tomice I and Tomice II tunnels, we obtained a slightly looser dependency with correlation coefficients $R^2 = 0.49$ or $R^2 = 0.65$.

From the previous relation, two values of transmission constant K were defined namely for the smallest ($K1$) and the largest ($K2$) reduced distance (given by the distance from the source of vibrations L and the limit charge Q) at the maximum amplitude of oscillation velocity in the given reduced distance (Tab. 1).

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