Abstract

The conduction of the seismological observation is still related to recording the signals of the translational motions, which provide the analysis and research of the natural and induced seismicity. Apart from translational motions, the rotational motion is observed and recorded as a consequence of the natural (Igel et al. 2006; Igel et al. 2007; Liu et al. 2009; Schreiber et al. 2009; Wu et al. 2009; Igel et al. 2011; Brokešová & Málek, 2013; Brokešová & Málek, 2015; Salvermoser et al., 2017; Sbaa et al. 2017; Ringler et al. 2018, Perron et al. 2018) and induced seismicity (Kalab & Knejzlik, 2012; Kalab et al., 2013; Zembaty et al. 2017; Fuławka et al. 2020; Mutke et al. 2020, Nawrocki et al. 2024). However, the unequivocal mechanism of its generation is still unknown (Kozák, 2009). So far, the researches were performed by using empirical and synthetic data sets, and their target was connected with engineering and spectral aspects (Trifunac 2008; Falamarz-Sheikhabadi & Ghafory-Ashtiany, 2012 Basu et al. 2015; Falamarz-Sheikhabadi & Ghafory-Ashtiany 2015; Bońkowski et al. 2018; Bońkowski et al. 2019; Bońkowski et al. 2020; Guéguen et al. 2021; Guéguen & Astroga, 2021), the next step of the surveys should be investigating the soil-structure interactions. The site effect, defined by the amplification factor and resonance frequency, is connected with the mentioned soil-structure interaction and plays an important role in the amplitude of the motion amplifications (Finn Et al. 2004). The most known method of the parameters of the site effect estimation is the horizontal-to-vertical spectral ratio (HVSR) (Nakamura, 1989) method, named H/V, which is based on the estimation of the spectral ratio between horizontal and vertical components of the records. Applicability of such a method to estimate the site effect parameters of the rotational motion is possible, however, for the inversed ratio of the HVSR. In light of studies presented by Nawrocki et al. (2021), the approach's motivation is related to the direction of the propagation rotational components. Therefore, torsion, which is the vertical component of the rotation, refers to the horizontal components of the translations, while rocking, which describes the horizontal components of the rotation, refers to the vertical direction of the translational motions (Zembaty, 2006). Consequently, the new method is defined as torsion-to-rocking spectral ratio (TRSR) (Nawrocki et al., 2021). The wave part of the registered signals used in the HVSR and TRSR analysis should encompass only the S-wave part (Nakamura, 2000; Nakamura, 2019). The motivation for using the TRSR approach in the estimation rotational site effect is connected with the double-couple source mechanism, in which the rotational vibration's radiation pattern is similar to a shear wave (Suryanto, 2006). The double-couple focal mechanism is the necessary conditions, which allow to use of the mentioned approach of

the rotational site effect estimation. Mainly, sources of the registered seismic events as an effect of the hard coal exploitations at the Uppear Silesian Coal Basin are characterized by a double-couple focal mechanism (Stec, 2006), which, after detailed analysis, allows for the estimation of the TRSR.

In the following dissertation, the 210 seismic events, which were localized in the USCB region, were analyzed to find: **Relations of the H/V spectrum of the rotational and translational motion with the subsurface geological conditions.**

The first step of the research was the estimation of the amplification spectrum for a rotational and translational motion for two seismic stations. For the first station, the conducted researchers obtained similar values of the resonance frequency for both motions, but for the second station, the results differed by 1.40 Hz. Explanation of that observation was thought that the strong fracturing presence at defined depth caused resonance of the rotational motion shallower than in case of the translational motions. Application of the estimated values of the amplification to estimate the models of the scaling relations shows that correction by the amplification reduces the value of the SH waves' phase velocity and gets closer to the values obtained from different geophysical surveys.

The next stage examined the differences between the H/V obtained using the Fourier Amplitude Spectrum (FAS) and response spectrum acceleration (RSA) method. A comparison of both approaches presented that the RSA method produced a lower amount of amplification peaks, but the comparison between rotational and translational results presented that the dimensions of the foundation where the sensors are mounted significantly influenced the torsion component, causing damping the amplitudes and precluding the TRSR estimation.

In the last step, the rotation of the time histories of the horizontal components of the rotational and translational motions and re-estimation of the amplification spectrum for each case of the rotation signals were carried out. The radar plots of the amplification variation presented circular and ellipsoidal path trajectory. Ellipsoidal path trajectory suggest local anisotropy of the surface geological layer occurrence and directional amplification effect; however, the circumstances' circular emptiness exists. The circular path trajectory were obtained for the first peak of the rotational amplification. In contrast, the ellipsoidal was noticed for the translations' first amplification peak and the rotations' second peak. The difference in the resonance frequency values between them reaches 3.00 Hz. Consequently, such a thesis can be put forward: the different geophysical layers may be responsible for rotational and

translational resonance, but it couldn't be excluded that defined geophysical layers can produce different levels of resonance for rotational and translational motions.

The results of the surveys which were carried out prove that rotational motion is affected by site effect, and obtained values of the parameters are different in comparison to the translational motions, which gives the motivation to conclude that the site effect of the rotational and translational motion is producing by geological layers, which occur on different depth levels.

The following conclusions were formulated during the research connected with that dissertation:

1. Different values of the resonance frequency of rotational and translational motions can affect the local anisotropy occurrence such as fractures and faults.
2. Differences in resonance frequency values do not have to be related to different depth levels of the layers, which are responsible for resonance generation.
3. The tendency to obtain different parameters of the site effect by rotational and translational motions does not exclude the generation of the resonance by the same geophysical layer.
4. The response spectrum method application allows for precise which of the amplification peaks is dominant.
5. The fundamental limitation of the amplification spectrum estimation of the rotational motion is the damping of the torsion component, which is related to the dimension of the foundation.
6. Estimating the scaling relations for the peak values corrected by an amplification effect allows for a more reliable estimation of the phase velocity value of the SH wave group in the subsurface layers.
7. The scaling relations, which assume a zero value of the b- component, allow to determine the model more accurately than in the opposite situation.
8. Analysis of the scaling relations presented an impact of the circumstances connected with the epicentral distance, seismic energy and damping on the measured peak rotational values. Consequently, the analysis should be performed separately for each station despite the similar values of the parameter.

The obtained results of the research constitute a multi-faceted contribution to the theoretical and practical knowledge, connected with the estimation of the site effect parameters of the rotational motion by using the TRSR method, dependencies between parameters values of the site effect of both motions or impact of the spectrum method estimation on the HVSR and TRSR results.

However, the presentation about the mechanism, which influenced the site effect parameter values of the rotational motions and an indication of the scaling relation model, which includes correction of the amplification, provides a starting point for subsequent scientific research consistent with the current work.