Comparing Acceleration and Velocity Horizontal-To-Vertical Spectral Ratios at South Korean Sites

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1. Introduction

The 2016 Gyeongju and 2017 Pohang earthquakes in South Korea caused extreme concern amongst the local population as well as industry due to the epicentral proximity to several nuclear power plant complexes. This situation is shown in Figure 1. Media also showed the effects of strong ground shaking at urban areas and the worries of the local populations.

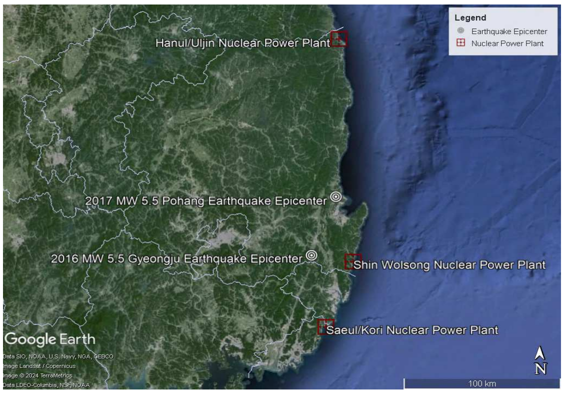

Fig. 1. Epicenters of the 2017 Gyeongju and 2018 Pohang earthquakes. Local nearby nuclear power plant complexes are also shown in the map.

The state-of-practice to properly account for the effects of strong ground shaking from earthquakes, is probabilistic seismic hazard analysis. Probabilistic seismic hazard analysis is commonly considered by all nuclear regulatory agencies and is generally composed of multiple models describing the factors that affect ground shaking. However, nuclear regulatory agencies require site-specific analyses, which in turn require some parameterization of site-specific properties relative to earthquake ground motion behavior.

The shear wave velocity of the upper 30 m of earth materials, V_{S30}, is a common parameter in understanding site-specific properties. This parameter is used in a variety of earthquake risk and seismological studies [3]. One approach used to help estimate the shear wave velocity is the horizontal-to-vertical spectral ratio, HVSR, method [4-5]. This method compares the ratio of vertical and horizontal response spectra to response spectra frequency. If there is a peak frequency, it is used to estimate a shear wave velocity for the site-specific materials. Typically, acceleration response spectra is used in this method. However, sometimes a peak cannot be identified and there is some curiosity as to whether using velocity response spectra may be a better as it would imply a velocity-to-velocity comparison. Therefore, this study attempts to ascertain if there is a difference in deriving V_{S30} from velocity data in place of acceleration data.

2. Methods and Results

For this study, horizontal-to-vertical velocity and acceleration spectral ratios are estimated using several South Korean earthquake ground motions recorded by the Korea Institute of Geoscience and Mineral Resources. These events were taken from the online database system provided by Korea Meteorological Administration and the International Seismological Centre. Figure 2 shows the epicenters of these events.

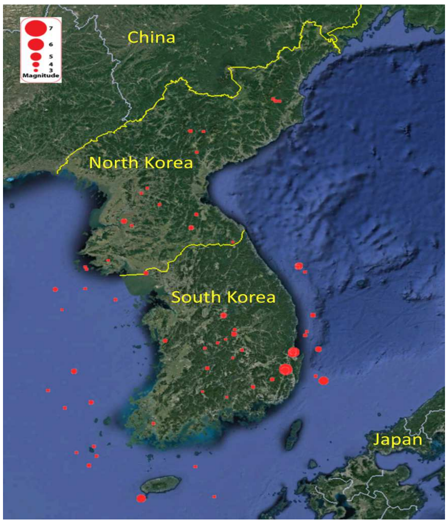

Fig. 2. Epicenters of events with recorded waveforms.

The raw ground motion recorded from KIGAM were downloaded through the International Federation of Digital Seismograph Networks. Subsequently, these records underwent a series of post-processing steps to obtain corrected acceleration-time histories. These acceleration-time histories were then employed to compute the acceleration and velocity response spectrum, SA and SV, respectively. HVSRs for SA and

SV were independently computed. The entire process was executed using the Python-based seismic research module called Obspy. It should be noted this work is not using pseudo-SA or pseudo-SV, which are both related by a constant of $2\pi/T_n$, where T_n is the natural period of the system. Therefore, the SA and SV derived HVSRs should not be exactly the same, but are similar as shown in Figure 3.

It should be noted not all earthquakes had a recorded waveform per seismic observation station because either the station was installed after the earthquake, the station was nonoperational, or the event did not trigger the recording mechanism. These response spectra were used to calculate horizontal-to-vertical spectral ratios. When these ratios are plotted against frequency, there may be a peak. This peak is called peak frequency, f_p. The general idea is that as f_p increases, so will V_{S30}. For example, Figure 3 shows the average horizontal-to-vertical spectral ratio for seismic observation station BBK. The figure shows that both velocity and acceleration derived spectral ratios show a clear peak at f_p = 2.5 Hz.

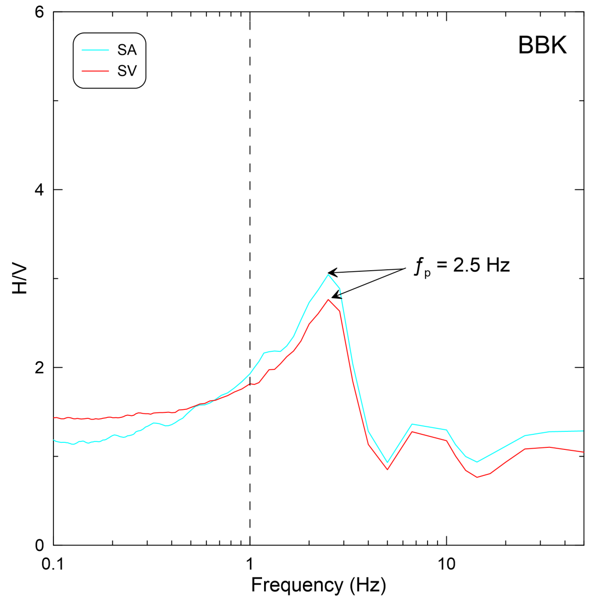

Fig. 3. Velocity and acceleration derived horizontal-to-vertical spectral ratios. The peak at 2.5 Hz is shown for comparison.

Additionally, site data was also compiled from Korea Institute of Geoscience and Mineral Resources, however not all seismic observation stations had a measured V_{S30}. Results show that there is a lack of local site-specific shear wave velocity data. For the available data, a plot of the seismic observation station peak frequencies and their measured V_{S30}s is shown in Figure 4. Nonetheless, of the sites with both shear wave velocity and ground motion data, there did not appear to be a significant difference when acceleration or velocity response spectra were applied for a majority of the sites. An interesting observation was that for sites with similar shear wave velocities, the actual value of the horizontal-to-vertical spectral ratios were not the same in an absolute sense, but did produce peaks at similar frequencies.

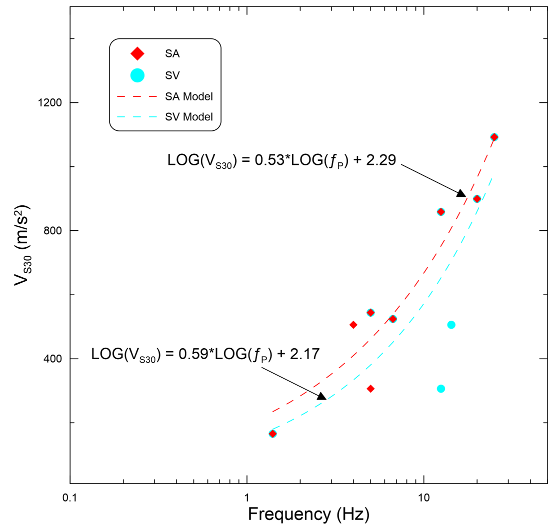

Fig. 4. Plot of f_p and V_{S30} for acceleration and velocity based response spectra. Generic models are made for acceleration and velocity derived V_{S30} to better show the differences.

3. Conclusions

This study attempted to ascertain if there is a difference in horizontal-to-vertical spectral ratios when the underlying spectra is either acceleration or velocity. Overall, the difference is small as the peak frequencies tend to be similar.

Acknowledgement

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